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RESD

Renewable Energy and Sustainable Development (RESD) is a biannual international peer-reviewed journal which presents a global forum for dissemination of research articles, case studies and reviews focusing on all aspects of renewable energy and its role in sustainable development. The topics of focal interest to RESD include, but are not limited to, all aspects of wind energy, wave/tidal energy, solar energy, as well as energy from biomass and biofuel. The integration of renewable energy technologies in electrical power networks and smart grids is another topic of interest to RESD. Experimental, computational and theoretical studies are all welcomed to RESD.

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International Conference on New Trends for Sustainable Energy

The (First International Conference on New Trends for Sustainable Energy) was held in October 1-3, 2016 at Pharos University, Alexandria, Egypt. with the cooperation of the KTH (Royal Institute of Technology) of Sweden under the auspices of the Minister of Electricity and Renewable Energy and the auspices of the Minister of Higher Education and Scientific Research.

The Conference discussed the general new Trends in Sustainable Energy development through distinguished keynotes speakers from Sweden and Egypt. The steering committee managed the peer reviewing process to the submitted papers and selected accepted papers is published in this special issue of the RESD in Volume 3, No.1.

The conference was specifically designed to focus on the issues related to energy and energy conservation. Industry leaders, engineers and academics will discuss in this conference the latest developments in the use and production of renewable energy and ways of energy conservation focusing on six main topics:

1. **Power Engineering**
2. **Energy Conservation**
3. **Solar Energy**
4. **Saving Energy In Building**
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Simulation of Distance Relay for Load Encroachment Alleviation with Agent Based Supervision of Zone-3

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***Abstract* -** Cascaded tripping of power lines due to mal-operation of zone-3 distance relays has been one of the main causes of many previous blackouts worldwide. Encroachment of load into zone-3 characteristics during stressed system operation conditions is a basic factor for such mal-operation of the relays. By improving the operation of zone-3, it is possible to prevent mal-operations so that cascaded line tripping can be avoided.For proper study of the behavior of distance relay during faults and load encroachment phenomenon, we must build a model of distance relay, soin this paper a modeling study of distance relay is implemented using MATLAB/Simulink program.However, this model is distinguished from previous modelsthat, examines in detail the third zone of distance relay. Many cases are simulated with changing line loading and fault location to ensure the capability of the relay to detect the fault and thus the maximum loadability limit of distance relay is obtained.In order to prevent cascading events caused by hidden failures in zone-3 relays, agent based relay architectures have been suggested in the recent past. In such architectures each zone-3 relay contains agents that require communication with other agents at various relevant relays in order to distinguish a real zone-3 event from a temporary overload. In this paper, a local master agent is consulted by all zone-3 agents before a tripping decision is made. The master agent maintains a rule base which is updated based on the local topology of the network and real time monitoring of the status of other relays and circuit breakers. Cisco Packet Tracer program is used for running communication network simulations. The result of the simulation indicate that the time estimated to send and receive a packet data unit (PDU) message between one relay to anther can satisfy the communication requirement for the proposed scheme with fiber media.

***Keywords* -** Distance Relay, Load Encroachment, Hidden Failure, Cascading Blackouts, Agents, Communication, TCP/IP.

I. INTRODUCTION

Transmission lines are usually protected by distance relays. The main objective of the distance relaying protection scheme is to isolate a faulted line out of service as soon as possible to minimize the negative effect of the fault on the power grid. The secondary objective of the fault isolation is to minimize the amount of load shedding as a result of the disconnection of lines by distance relay. Distance relays are classified as local primary (zone-1) relays, secondary (zone-2) relays and remote back up (zone-3) relays [1]. By comparing primary relays with remote backup relays, remote backup relays require longer fault clearing time and also its operation to remove a fault may lead to larger area of load shedding. Therefore the distance relaying protection schemes are designed in such a way that the remote back up relays do not operate unless it is certainly necessary i.e. when both the zone-1 and zone-2 relays fail to clear the fault.Worldwide analysis of recent wide area cascading failures has shown that very often these failures were mainly caused by the mis-operation of the third zone of a distance protection relay [2]. The hidden failure, load encroachment and power swing phenomena are the most common problems to solve when dealing with the third zone of distance protection [2]. It is well reported that the majority of blackouts along with their consequences could have been eliminated if the mal operation of distance relays could have been avoided. Zone-3 is especially exposed to load encroachment and power swing, where all these situations can lead to the measured impedance encroachment into the zone-3 area. This results in relay mal-operation and can be a leading factor to a large scale blackout occurrence. Despite the fact of zone-3 setting encroachment, the system operational conditions may not be dangerous and in case of load encroachment the load may be permissible due to the transmission lines temporary load ability. In case of stable power swing, after some time the system recovers to its normal operation conditions. The important issue is to distinguish whether the third zone area encroachment is a result of fault and the relay should operate, or it is one from abovementioned situations and the relay decision about tripping should be restrained [3].

Modern study discussed and modeled the characteristics of the Mho relay. In this paper we established a model of distance relaying protection using MATLAB program. In [4] PSCAD/EMTDC Software is used to study the performance of the relay characteristics with different type of faults (L-G, L-L, L-L-G etc.) at different locations. That work presented only the simulation of distance relay during faults. But in our model, we take into account the problems that faced the distance relays during faults and normal operations like the effect of ground resistance during ground faults and the problem of load encroachment respectively. We study the effect of ground resistance by changing the value of ground resistance and studying the effect of it on the impedance of distance relay. Also, we study the problem of load encroachment in our model by increasing the value of load gradually till reach to the maximum loadability limit of distance relay.

A hidden failure is a defect (incorrect relay setting or software or hardware error) in a relay which may go unidentified for a long time and gets excited by another event leading to erroneous removal of circuit elements [5]. Because of hidden failures, zone-3 relays may be extra sensitive to temporary line overloading due to transients, results in unreal fault as a fault in a line and mis-trip even though it is not recognized as a faulty condition by zone-1 or zone-2 relay. At this instance, if power system is operating under stressed conditions, the hidden failure induced zone-3 relay mis-trip may initiate other line trips leading to catastrophic failures like blackouts.

According to the analysis of historical blackouts such as the 1965 Great North-east blackout, the 1977 New York blackout and the 1996 western blackout, North American Electric Reliability Council (NERC) concluded that the mis-operation of zone-3 relays is one of the major causes of cascading outages leading to blackout events [2], [10]. Therefore, Horowitz and Phadke[6] reviewed the distance relaying protection scheme to judge the necessity of the remote back up relays but concluded that the zone-3 relays cannot be omitted as its elimination will put the power system at risk . Also, according to a report from the latest 2003 blackout in the US [7], many of zone-3 distance relays operated under the overload situation, which further stressed the system thereby causing the cascading blackout in the end. This kind of relay mal-operation may further weaken the system. Zone-3 relays can incorrectly trip a line due to hidden failures [8], [9].

One of the main objectives of smart grid is to prevent these types of mis-operations of power system protection components, by establishing communication between its components. This paper concerns on zone-3 relay mis-operation. In [11] a distributed agent based supervisory scheme is proposed to make zone-3 relays able to withstand hidden failure induced tripping, facilitated by communication network. In their approach the entire power grid is populated with software components called agents at every relay. Communication architecture is established between hierarchically distinguished master and slave relay agents to help making critical decisions. In order to aid the zone-3 relays to distinguish between a real fault and an unreal fault (due to unexpected loading conditions), in this paper we establish a simple model of communications between relays using TCP/IP protocol to help the distance relaying scheme reducing the zone-3 mis-operation further reducing the cascading outages.

The rest of this paper is organized as follows: section II presents the implementation of distance relays model using MATLAB software. The load encroachment phenomena and loadability limits of distance relays are explained briefly in section III. Section IV describes the agents rules of zone-3 to avoid mis-operation of distance relay, also presents the established model in Cisco Packet Tracer program. Section V concludes the paper.

II. MODELING AND SIMULATION OF DISTANCE RELAY

Fig. 1 shows the basic distance protection scheme of a transmission line. The impedance measurement inputs are the values of three phase current and voltage signals taken from the current transformer

(CT) and potential transformer (PT) respectively. Three phase current and voltage waveforms must be filtered first to eliminate the harmonic contents which may present due to arcing of the fault. The filtered waveforms are then sampled at a selected sampling frequency before being used digitally inside distance relay. The relays compare the setting impedance with the measured impedance to determine if the fault is inside or outside the protected zone.

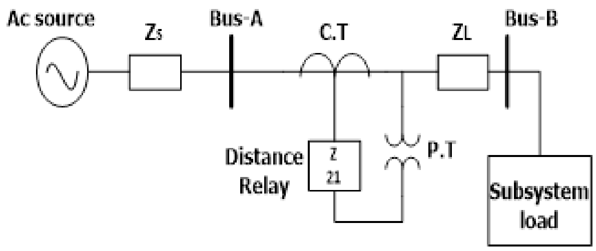

Fig .1. One-line diagram of simulation system

Distance relays are also named impedance relays [12]. They are used to calculate line impedance by measurement of voltages and currents at one single end. For example, as shown in Fig. 2 Mho type distance relays, by comparing the setting value and the measured value the relay can determine if there is a fault or not .Distance relays immediately release a trip signal when the impedance value is inside the zone-1 impedance circle of distance relay. For security protection consideration, the confirmation of a fault occurrence will not be made until successive trip signals are released in one season (faulted section).

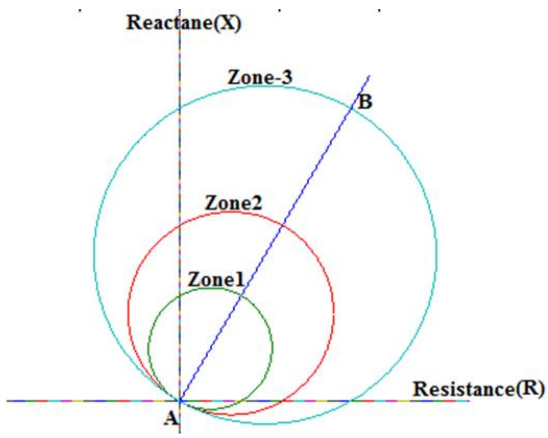

Fig .2. Distance relay of mho characteristic type

Different formulas should be adopted when calculating the fault impedance due to different fault types. Table 1 indicates calculation formula for all of the fault types. [13].

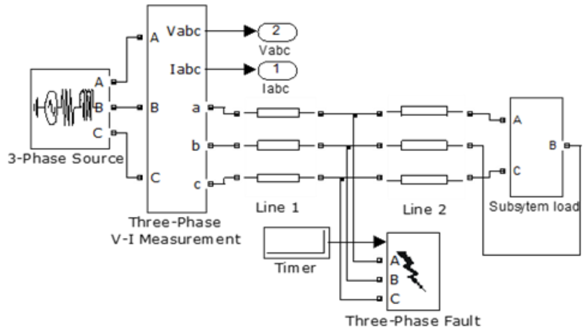

Fig .3. Snapshot of the transmission line and load model

Table 1. Fault impedance formula for different faults

Fault Type	Formula
Phase A to G	$V_A/(I_A+3K_0I_0)$
Phase B to G	$V_B/(I_B+3K_0I_0)$
Phase C to G	$V_C/(I_C+3K_0I_0)$
Phase A to Phase B	$V_{AB}/(I_A-I_B)$
Phase B to Phase C	$V_{BC}/(I_B-I_C)$
Phase C to Phase A	$V_{CA}/(I_C-I_A)$

where,
A, B and C indicate faulty phases, G indicates ground line, VA, VB and VC indicate voltage phasors, IA, IB and IC indicate current phasors, I0 is zero-sequence current, K0= residual compensation factor where K0 = (Z0-Z1)/3Z, where Z0 = line zero-sequence impedance, Z1 = line positive-sequence impedance.

In this paper in order to get exact simulation results, we must establish accurate network model. Simulink/PSB (power system blockset) is used to create power system model for simulation. Fig. 3 shows the developed model of transmission line and load in MATLAB/Simulink. From this figure, it can be seen that the transmission line is separated into two equal lines. The reason is to simulate a fault at a point along the transmission line where the first line simulates the fault distance from the substation terminal until fault point while the second line simulates the remaining distance from fault point until the end of the transmission line.

When power systems faults occur, the signals may contain high frequency components. As shown in Fig.4, these higher frequency components must be eliminated, so we adopt analogue low pass filters in the simulated systems. After filtration, the only remained fundamental voltage and current waveforms will be passed to FFT blockset. The function of FFT blockset is to extract the magnitudes and phase angles of fundamental three phase current and voltage phasors. The FFT blockset performs a Fourier analysis of the input signal over a running window of one cycle of the fundamental frequency of the signal. These magnitudes and phase angles are then used by the fault calculation algorithmblockset to calculate the impedance of the faulted phase.

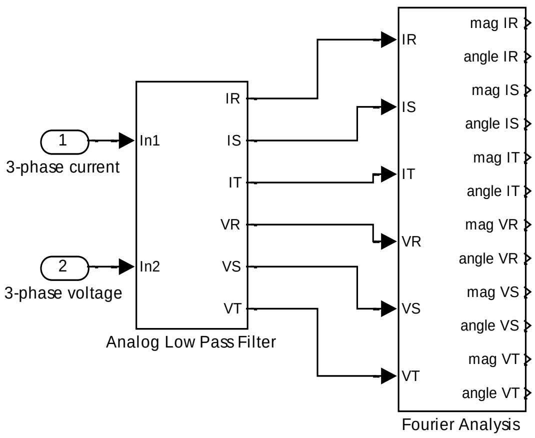

Fig .4. Snapshot of the analysis of 3 phase faulted current and voltage

The parameters of the simulated transmission system are [13]:

Voltage Rating: 132 kV at 50 Hz
Length of Transmission Line: 50km
Line Impedance:
Z_{1line} = 6.8432Ω
Z_1=0.01239+ j0.13630113 Ω/km
Z_0=0.1239+j0.4089 Ω/km

Fig. 5 shows R-X diagram for the simulation of LG fault at 30 km from the relay location at fault resistance (0.1 Ω) and maximum torque angle (MTA) of 60 °. From the figure the fault location is found to be at zone-1, where zone-1 setting = 90% of Z_{line}.

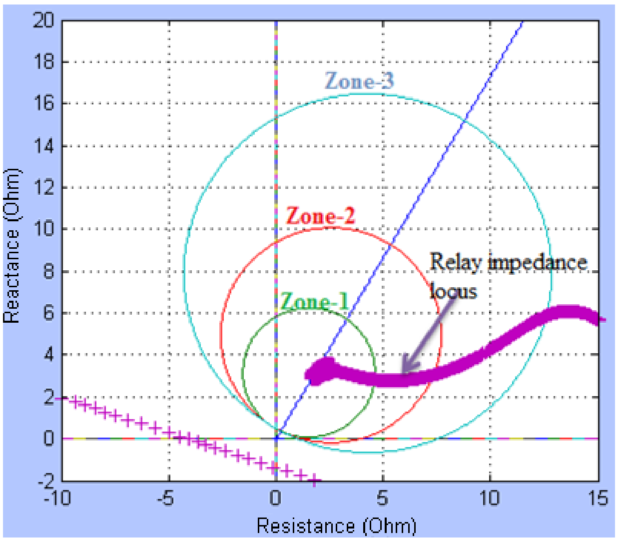

Fig .5. L-G Fault at 30 km from Bus-A, Zone-1

Fig. 6 shows R-X diagram for the simulation of LG fault at 125 km from the relay location. From the figure the fault is found to be at zone-3, where zone-3 = 100 % of protected line + 150 % of the next protected line. This figure also shows that there is a variation in the relay impedance locus, where this variation existed only in the beginning of simulation until the relay impedance locus reaches the final locus

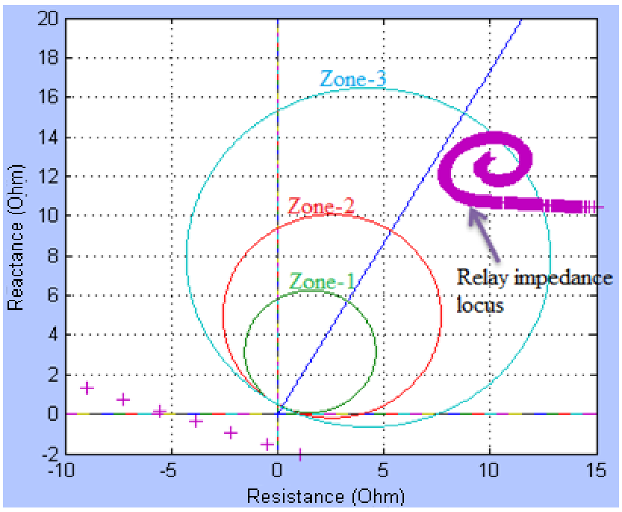

Fig .6. L-G Fault at 125km from Bus-A, Zone-3

The reach of the Mho relay is affected the presence of fault resistance as shown in the Fig. 7. AB is the line to be protected, due to fault resistance BC. The impedance seen by the relay getting out of the zone.Therefore Mho relay under reaches because of fault resistance [14].

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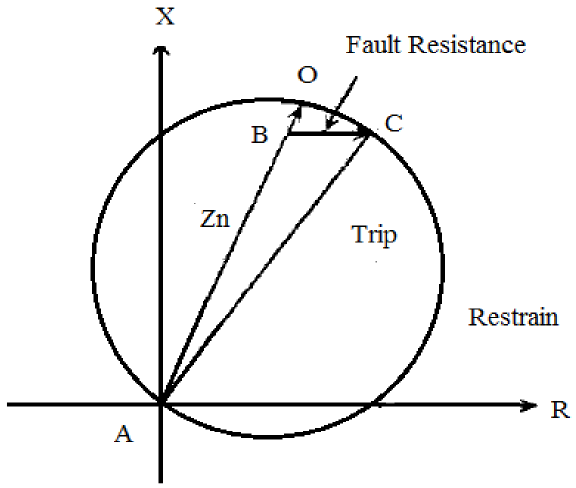

Fig .7. Effect of fault resistance on reach of the relay

Fig. 8 shows R-X diagram for the simulation of LG fault at 30 km from the relay location. By comparing fig. 5 and fig. 8 it can be noted that the fault resistance has deviated the final point of fault impedance locus far away from zone-1 reach.

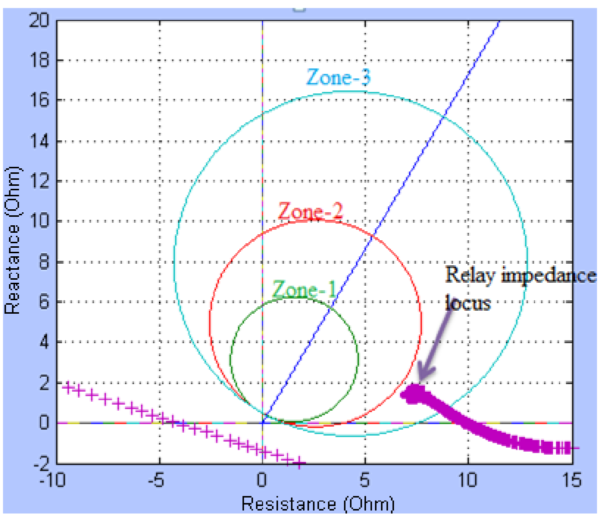

Fig .8. L-G Fault at 30km from Bus-A with Rf = 10 Ω

III. LOAD ENCROACHMENT AND LOADABILITY LIMITS OF DISTANCE RELAYS

The relay impedances zones of protection must be selected carefully in order to avoid load encroachment problems. The zone of protection with greater risk is zone-3, since it is the Mho circle with the greatest area and closest proximity to the load impedance. Zone-3 settings are certainly vulnerable to load encroachment conditions during high load and power swings conditions, which can cause the load impedance to travel towards the boundaries of the zone-3 mho circle and cause an undesired trip. Fig. 9 shows the apparent impedance of the load with respect to a distance relay with a forward reaching mho characteristic.

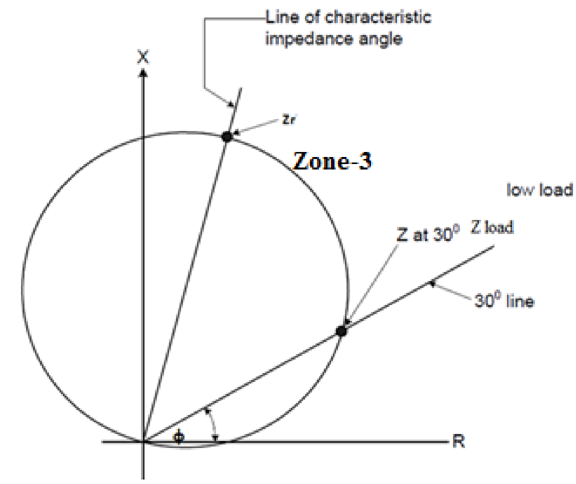

Fig .9. The apparent load impedance w.r.t mho relay

For Mho relay impedance settings, minimum trip MVA is often calculated in accordance with the following formula [15]:

$$MVA_T = \frac{(0.85\times V_{LL})^2}{Z_r \times cos(MTA-\boldsymbol{\varphi})} \qquad (1)$$

where,
MVAT = minimum MVA required to trip
V_{LL} = nominal line voltage in kV depressed to 85% of normal
MTA = maximum torque angle of relay (characteristic impedance angle)
Z_r = relay reach in primary Ohms at MTA
φ = maximum anticipated phase angle of load.

When using the above calculated loadability limits for planning or operating purposes, it is important that the user be advised whether the limits include any margins [16]. By MVA_TEqu. (1), the minimum MVA required to trip in the proposed model is 618 MVA. Fig. 10 shows the R-X diagram where the load impedance increased to 618 MVA under the normal operating condition. It may be noted that the relay impedance located in the circle of zone-3 so, the relay will see the increasing of load as a fault and the relay will trip the circuit breaker. By comparing with the value of the calculated minimum MVA required to trip, we will conclude that 618 MVA is approximately the minimum value for the occurrence of the load encroachment phenomenon for this relay.

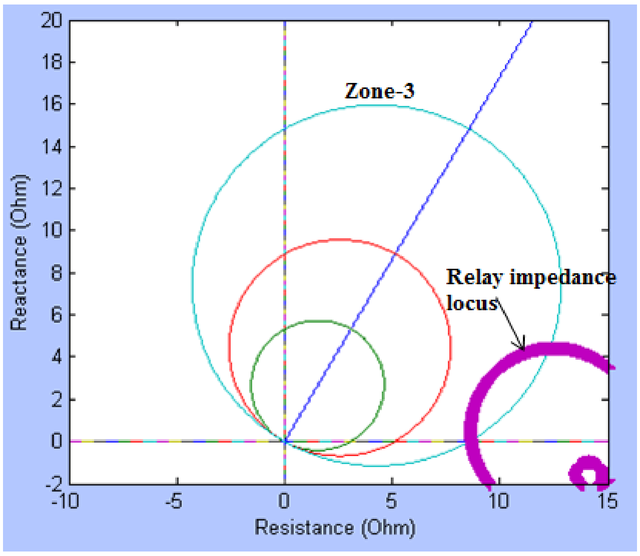

Fig .10. Normal operation at 618 MVA

For distance elements, such as "Mho" characteristic, the susceptibility of the zone to pickup on load generally increases as the reach (impedance setting) is increased. The mho characteristic is most likely to respond to system transient load changes, but may also detect steady-state load - especially when it is heavy and inductive in nature. Alterations in zone characteristics can be made which will reduce the susceptibility of distance zone responding undesirably to a load condition; some of them are outlined as following [16]:

1. Increase of the torque angle.
2. Adoption of a lens characteristic.
3. Use of blinders.
4. Use of load encroachment characteristic.

Options 1, 2, and 3 above, reduce the susceptibility of the relay response to heavy load conditions but reduce the coverage of resistive faults. Option 4 presents the most effective and reliable method of discriminating system faults from heavy load conditions. The load encroachment is a protection feature available in modern line relay packages (for example: [17], [18]) that enables the protection engineer to define custom load regions in forward and reverse direction. Modern study like [19] improves the operation of the distance protection relay by introducing a new blocking algorithm using Dynamic Thermal Line Rating (DTLR) to restrain relay from tripping when conditions in electrical power system allow for it. This reference focused on the possibility of Dynamic Thermal Line Rating usage to prevent distance protection relay from tripping in situations of extreme load conditions and power swing by introducing an additional blocking signal into the distance relay. The blocking signal is based on the DTLR technique monitoring weather conditions and calculating the overhead conductor temperature and actual for ambient weather conditions conductor current limit and the author [19] analyzed this technique by using MATAB/Simulink.

In the implemented model, different values of maximum torque angle for example (60°, 75°, and 90°) are applied. As shown in Fig. 11, the simulation results show that,to increase line loading (greater than minimum MVA required to trip), the MTA angle can be adjusted on some relays up to 90 degrees. As indicated, such adjustments can increase line loadability as measured along the load apparent impedance line. If the applied relay has the capability of increasing MTA, this method maintains trip dependability while increasing loadability security with minimum cost implications.

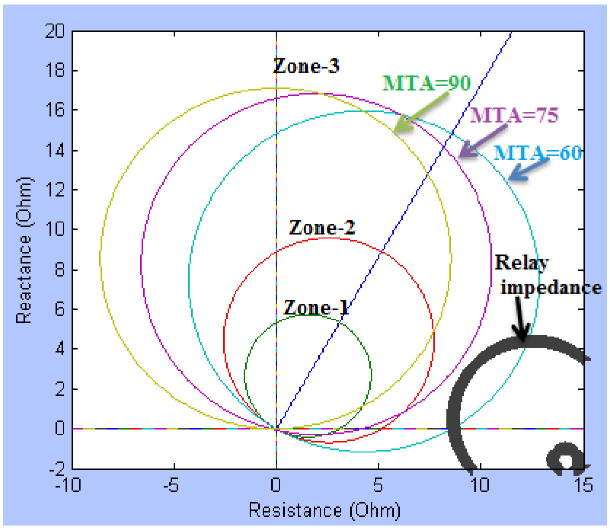

Fig .11. Mho circle torque angle adjustment

IV. AGENT RULES OF ZONE 3 DISTANCE RELAYS TO PREVENT HIDDEN FAILURES AND BLACKOUTS

A. Model

Further studies suggested that incorrect operation performed by zone-3 back up protection relays is due to the presence of hidden failures that may trip a healthy line instead of a faulty line. Such false trips may lead to a sequence of trips resulting in a catastrophic failure like blackout [8].

In this paper, a distributed agent based supervisory model is suggested to make zone-3 relays able to distinguish between real faults and false faults specially hidden failures induced tripping, facilitated by the communication network to become an integral parts of the smart grid. Zone-3 relays are often overly sensitive to remote line overloading, and are known to cause mis-trips during cascading failure scenarios. Therefore, providing robustness to zone-3 relays to minimize the risk of erroneous trips, especially when hidden failuresare existed [8], is an important problem. In the proposed schemes, a grid is populated with agents at each relay, and an agent hierarchy is maintained in master/slave relationship. The communication established between relay agents decreases the probability of erroneous zone-3 trips thereby preventing them from annoying cascading failure scenarios, and reducing the probability of cascading blackouts. Many studies [20], [21] discussed this issue and presented different approaches and schemes for communications between agents.

It is possible that a fault in a single transmission line can be sensed at least by six relays i.e. zone-1, zone-2 and zone-3 from both ends of the transmission line. Therefore in order to classify a sensed fault as a real fault or an unreal fault, agent of the faulted zone (relay that sense fault) has to communicate with at least five other agents. This can result in huge communication overhead and longer response times. If the total response time is greater than the relay fault clearing times, agent based relay supervision scheme does not serve the intended purpose. Therefore, in order to reduce the response times, agents are hierarchically distinguished as slave agents and master agents. A slave agent associated with a relay is called as "slave agent" and a master agent associated with a relay is called as "master agent".

A slave agent relay records the fault status of its associated relay and reports it to the master agent. Master agent is endowed with high privileges and responsibilities. At any given time, a master agent has the fault status information of all the slave agents reporting to it. Therefore whenever a relay senses a fault, its associated slave relay agent records it and queries the master agent, master agent compares the queried slave relay agent's fault status with the fault statuses of other slave agent relays protecting the same transmission line to classify the fault as a real fault or an unreal fault and respectively acknowledges the queried slave relay agent to trip or not to trip the line out of service [21].

In proposed scheme as shown in Fig. 12, each relay is associated with an agent that has the ability to communicate with other agents in the network. Whenever a relay senses a fault in the transmission line protected by it, its associated agent records it and communicates with other agents protecting the same transmission line in the network to find out if the perceived fault is real fault or unreal fault. If the majority of other relays protecting the same transmission line also sense a fault, classifying it as a faulty condition, master agent can advise its associated relay to trip. On the other hand if the majority of the other relays protecting the same transmission line do not sense a fault, categorizing it as a fault-free condition,master agent advises the relay not to trip. This is because the relay might have sensed a fault due to temporary loading conditions and it is not required for the relay to trip.

In this paper we focus only on the communication between relay agents and estimate the sending and receiving time, and we do not take into account the setting of agents. In this work, to gain better evaluation of communication for the zone-3 supervision scheme we use Cisco Packet Tracer program as a communication tools.

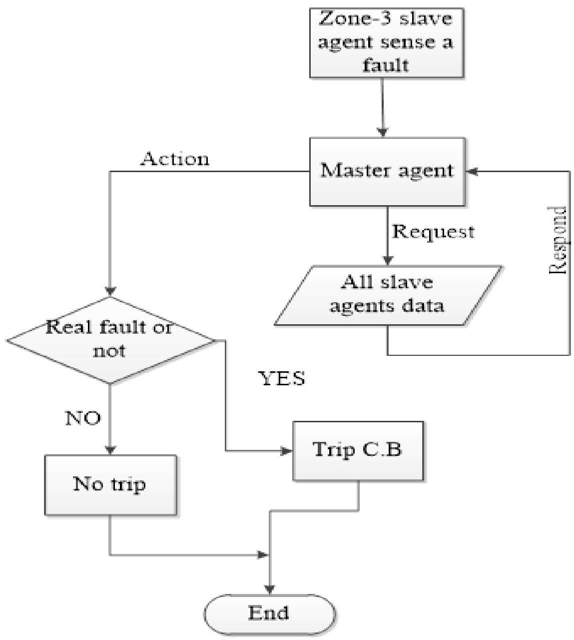

Fig .12. Flow chart of the proposed scheme of agent rules

The master agent has the topology of transmission system within its domain, including the relays and breakers. All other agents in the domain are considered as slave agents. In the proposed scheme, as shown in Fig. 13, whenever a zone-3 relay senses a fault in its zone as a reduction in impedance, it queries the domain master agent if any other slave agents associated with the associated set of zone-1 and zone-2 relays reported any abnormality. The master agent then requests the status of the remaining slave relay agents. Based on the response of the other relays, the master agent can decide if zone-1 or 2 could not clear a fault that zone-3 must act upon. If not, the zone-3 will periodically query master agent until the faulty condition is either cleared or the master agent instructs the zone-3 relay to continue with its trip timer. This will reduce the probability of false trips by zone-3 relays. The request, response delays of communication must be within the time allowed for zone-3 relays to wait before tripping. The choice of the networking topology, the communication protocol, and the physical media of the network will affect these delays. Also, whether to use the Internet or any other type of networks will also have to be decided.

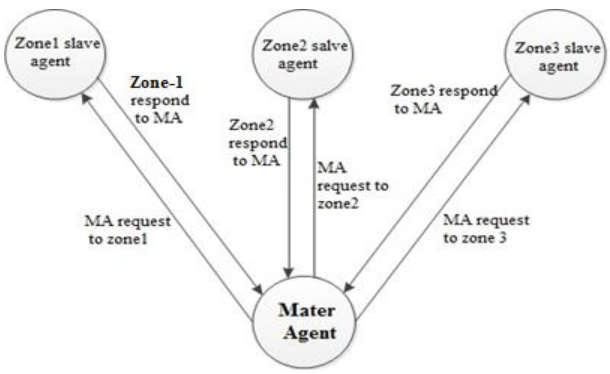

Fig .13. Communications in the proposed scheme

As an illustration, consider a part of the IEEE 14 bus system, as shown in Fig. 14. Consider a fault on the transmission line between buses 10 and 11 in the vicinity of bus 11, the relays that will sense this fault are, zone-3 of relays R(9,15), R(12,12) and R(13,20) sense this fault. Ideally the zone-1 of relays R(10,17) and R(11,17), zone-2 of relay R(6,11) and zone-3 of relays R(9,15), R(12,12), R(13,20) should see the fault. Based on the response of the relays, the master agent would locate the fault and would allow the zone-3 timers of relays R(9,15), R(12,12), R(13,20) to continue, whereas it would block the zone 3 timer of all other relays ((14,16) in this case). If there is any zone-1 or zone-2 relay operation and subsequent circuit breaker operation, resulting in a successful clearing of the fault, the master agent would silence all the zone-3 timers. Thus the operation of zone-3 is under the supervision of the master agent. One other expected benefit of this scheme is the identification of hidden failures in these relays. For example, in the above scenario if any of the listed relay pick-ups is not observed or other relays (like (14,16)) respond, it is an indication of a hidden failure in the relay that has not responded or responded wrongly, in sensing the fault.

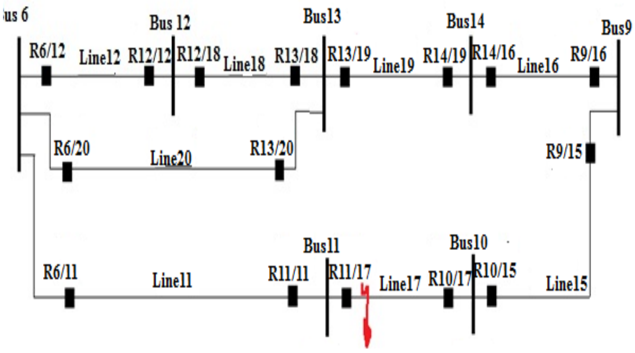

Fig .14. Part of IEEE-14 bus system

Many studies [11], [20] presented different types of communications and response time. In [11] the study was experimented with various communication topologies, protocols, and media to figure out which topology, media, and protocol would make the presented scheme feasible. It is clear that with fiber media, all possible protocols, and topologies will allow enough slack in latency for the studied scheme to work. In [20]three different network topologies and physical media of communication were evaluated to find out the most suitable network topology and physical media that meets the time constraints of zone-3 relay supervision scheme. The networking and optimization simulation results indicate that the proposed scheme can reduce the undesirable zone-3 tripping and thus reduce the probability of occurrence of blackouts. In this paper a model is implemented as follows in the next section to study the time of response between mater agent and slave agents. The results of this model give better response, where the time of response is less that the time gained before in the previous studies.

B. Simulated example:

We assume each protection relay to be an agent which can communicate with master agent directly. In this way, relays near a bus/substation compose a local area network (LAN) which uses Ethernet as link layer protocol. Then relays can send message from this LAN to other LANs or master agent through routers. The links between LANs are fibers media. This simulation actually simulates various TCP/IP based protocols for communication.

We use Cisco Packet Tracer program tool for running communication network simulations. We apply our simulation on 7 buses of IEEE-14 bus system. In this simulation we put a router at each bus and we connect between buses by fiber cables and each router has IP address as shown in Fig. 15. Table 2 shows IP addresses of any cable at the start bus or router to end bus or router.

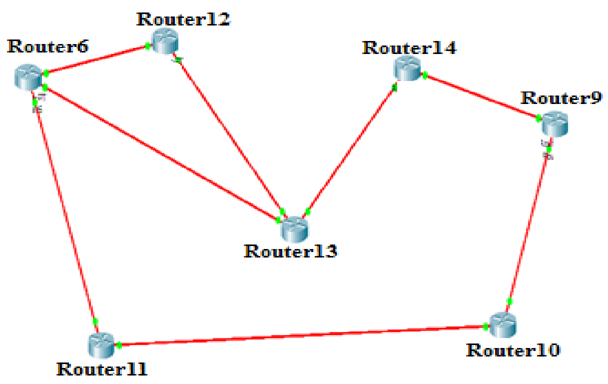

Fig .15. 7 Buses of 14 IEEE bus system in Cisco Packet Tracer program

Table 2. IP addresses for fiber cables

Bus to bus (router to router)	Start Bus (Router) IP Address	End Bus (Router) IP Address
Router 6-To-Router 11	16.0.0.1	16.0.0.2
Router 6-To-Router 12	10.0.0.1	10.0.0.2
Router 6-To-Router 13	17.0.0.1	17.0.0.2
Router 12-To-Router 13	11.0.0.1	10.0.0.2
Router 13-To-Router 14	12.0.0.1	12.0.0.2
Router 14-To-Router 9	13.0.0.1	13.0.0.2
Router 11-To-Router 10	15.0.0.2	15.0.0.1
Router 10-To-Router 9	14.0.0.2	14.0.0.1

A master agent at any given instance has the complete knowledge of all relays and breaker status in its region. A slave agent, whenever it senses a fault, sends the fault status of its relay to the master agent. Thus master agent has up-to-date information of all relays/breaker status. At any given time, slave agent has the ability to contact master agent for any required information like fault status of other relays. A zone-3 slave relay agent queries the master agent for the fault status of all relevant relays as soon as it senses a fault due to a drop in impedance of the transmission line it is protecting. Master agent acknowledges by providing the fault status of the respective set of relays. In order to achieve this, master agent needs to have a set of rules of which relays fault status along with its zones of protection, it has to provide for a particular zone-3 slave agent request.

C. Results:

Table 3 shows the time required to send a packet data unit (PDU) message between one relay to anther after running the model built in Cisco Packet Tracer program.

Table 3. Time estimated to send a PDU between relays

Bus to Bus	Time (msec)	Bus to Bus	Time (msec)
Bus 6 to Bus 12	1	**Bus 12 to Bus 6**	2
Bus 6 to Bus 13	1	**Bus 13 to Bus 6**	2
Bus 6 to Bus 11	1	**Bus 11 to Bus 6**	2
Bus 12 to Bus 13	1	**Bus 13 to Bus 12**	2
Bus 13 to Bus 14	1	**Bus 14 to Bus 13**	2
Bus 9 to Bus 14	1	**Bus 14 to Bus 9**	2
Bus 9 to Bus 10	1	**Bus 10 to Bus 9**	2
Bus 10 to Bus 11	1	**Bus 11 to Bus 10**	2

These results indicate that the delays can satisfy the communication requirement for our scheme with Fiber media.

V. CONCLUSION

This paper presents undesired operation of distance relay third zone due to load encroachment and hidden failures in power system networks. In this paper a model of distance relay is built using MATLAB/Simulink package, inside the modeling single line to ground fault is chosen to be the fault type and Mho characteristics is chosen to be as the protection scheme. A graphical user interface (GUI) is created using GUI package inside MATLAB for the developed model. The phenomenon of load encroachment is simulated in the established model by changing the value of load until reach the value of zone-3 setting. Also the value of maximum load ability limit of distance relay is calculated and simulated using the established model in MATLAB. The problem of cascading events caused by hidden failures in zone-3 is also presented in this paper.We proposed a hierarchically distributed agent based distance relaying protection scheme and use communications between each relay by using IP protocols for communication to reduce the cascading outages like blackouts due to zone-3 relay undesirable trips. This technique is very helpful to distinguish between real faults and unreal faults.

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Optimal PMUs Placement Due to Several Stages for Achieving Full System Observability

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***Abstract* -** The new measurement devices such as phasor measurement units (PMUs), is considered to be an essential component in implementing future power network systems. The problem of optimal placement of PMUs (OPP) requires finding a minimum numbers of PMUs that must be installed to provide full system observability. Due to the large number of the PMUs required and their relatively high cost, it is important to partition the installation of PMUs placement into several stages to overcome this problem. A new proposal depends on limiting the number of installed PMUs at each stage and maximizing system observability will be illustrated in this paper. The proposed method will be implemented on IEEE-14 bus system and IEEE-30 bus system.

I. INTRODUCTION

Operation of the power system is becoming very complicated and facing many challenges every time due to the expanding of the power generation and transmission utilities. The power systems have also become so interdependent that the events in one area can cascade and have significant impact on other remote areas. This change in the industry is putting pressure for the development of new tools to monitor system stability and reliability.

Until recently, available measurement sets did not contain phase angle measurements due to the technical difficulties associated with the synchronization of measurements at remote locations. Global positioning satellite (GPS) technology alleviated these difficulties and lead to the development of phasor measurement units (PMUs).

Synchronized Phase Measurement Unit (PMU) is a monitoring device, which was first introduced in mid-1980s. Phasor measurement units (PMU) are devices, which use synchronization signals from the global positioning system (GPS) satellites and provide the phasors of voltage and currents measured at a given substation. As the PMUs become more and more affordable, their utilization will increase not only for substation applications but also at the control centers for the EMS applications [1].

All Synchrophasor measurements are time tagged with the Coordinated Universal Time, via GPS. All GPS receivers generate a very accurate pulse, which is used by PMUs to generate very precise sampling pulses. PMUs provide a more exact view of the system because samples are taken and time stamped in a microsecond sampling window and although data from multiple units can only be available and time aligned in the order of milliseconds the time stamp included with the measurements eliminates the errors introduced in the state estimator by the size of the scanning window.

Different methods which are used to compute the minimum required numbers of PMUs for full system observability will be described in part II.
Importance of PMU in wide area monitoring system, and PMUs placement based on system decomposition will be illustrated in part III.
Different methods which are used for multi-stage of PMUs placement in power system will be described in part IV. Implementation of optimal multi-stage PMUs placement will be carried out on IEEE-14 bus and IEEE-30 bus systems, part V.

II. OPTIMAL PMUS PLACEMENT FOR FULL POWER SYSTEM OBSERVABILITY

The main objective from this section is to explain different methods which are used for optimal PMUs placement to make the system fully observable. An integer linear programming (ILP) approach is used to determine the optimal number and locations of PMUs. PMUs placement guarantees the system observability during normal operating conditions as well as single branch outages or single PMU outages. The proposed scheme is applied to the IEEE-14 bus and IEEE-30 bus systems.

A. OBSERVABILITY RULES FOR PMUS PLACEMENT

A PMU is able to measure the voltage phasor of the installed bus and the current phasors of some or all the lines connected to that bus. The following rules can be used for PMUs placement:
Rule 1; assign one voltage measurement to a bus where a PMU is placed, including one current measurement to each branch connected to the bus itself.

Rule 2; assign one voltage pseudo-measurement to each node Reached by another equipped with a PMU.

Rule 3; assign one current pseudo-measurement to each branch connecting two buses where voltages are known. This allows interconnecting observed zones.

Rule 4; assign one current pseudo-measurement to each Branch where current can be indirectly calculated by the Kirchhoff current law (KCL). This rule applies when the current balance at a node is known [2].

B. INTEGER LINEAR PROGRAMMING(ILP) FOR PMUS

A PMU placed at bus i will measure the voltage phasor of bus i and a predetermined number of phasor currents of outgoing branches of that bus. The number of the measured current phasors depends on the number of PMU channels made available.

It is assumed that a PMU placed at bus i will measure all current phasors of the branches connected to that bus, in addition to the voltage phasor of bus i. Therefore, with the absence of any conventional measurements in the system, bus i will be observable if at least one PMU is placed within the set formed by bus i and all buses incident to it. The zero injection bus, single PMU outage and transmission line failure will be considered.
Therefore, the objective of optimal PMU placement problem is to determine the minimum number of PMUs so as to preserve the system Observability [3]. This objective can be formulated as:

$$\min \sum_{i \in I} xi \qquad (1)$$

$$fi = \sum_{j \in I} a_{ij} xi \qquad \forall i \in I \qquad (2)$$

$$fi \geq 1 \qquad \forall i \in I \qquad (3)$$

$$aij = \begin{cases} 1 & if\, i = j \\ 1 & if\, buses\, i\, and\, j\, are\, connected \\ 0 & otherwise \end{cases}$$

Where:
Xi is a binary decision variable associated with bus i
I is the set of buses;
fi is the observability function related to bus i;
aij is a binary decision variable associated with bus i and j

Table 1. Results of OPP for IEEE-14 bus system

Scenario	Min No of PMUs	Optimal locations
Normal topology	4	2, 6, 7, 9
Modeling of ZI	3	2, 6, 9
Single PMU outage with modeling of ZI	7	2, 6, 9, 4, 5, 10, 13

III. PMUS PLACEMENT BASED ON SYSTEM DECOMPOSITION [4]

Due to the large required number from PMUs to fulfill power system observability it is considered economically infeasible to install all these PMUs in one shot. The optimal PMUs placement (OPP) is divided into muti-stage installation. This means solving the OPP in incremental placement strategy. Area system decomposition by using the spanning tree method will be illustrated. The optimal number of PMUs for each area will be determined taking into consideration the effect of the internal and boundary buses, using these properties to minimize the total number of PMUs for full power system observability.
In this section an approach used for finding the initial partitioning between the buses of the power system will be overviewed. This approach was firstly proposed by Branes [5]. The approach partition the network into many blocks (m) or sub-networks then, it creates a formulation for that partitioning by using

ILP. The main principle for this approach is to find the minimum spanning tree for the network after that, the system is partitioned using equi-partitioning, multi-partitioning algorithm [6] and Kruskal algorithm [7]. Consider a power system with n buses and partitions. Partitions are separated by tie-lines whose terminal buses are assigned to both the connecting blocks. Thus, after decomposition, each bus will belong to anyone of these two categories:

- Internal bus (XI), if its neighbors belong to block-i. (The bus inside area and is not connected to buses of any other areas.)
- Boundary bus (Xb), if its neighbors are internal buses of block-i and at least one boundary bus from another block. (The bus inside area but connected to buses of external area)

Based on these two categories, six bus vectors are defined as follow:

- XiI - set of internal buses of block-i.
- Xib - set of boundary buses of block-i.
- XiTb - set of total boundary buses (including buses of blocks adjacent to block-i) associated with block-i.
- X= {XiI; Xib} - set of total buses in block-i.
- XT= {XiI; XiTb} - set of buses of block-i including neighboring boundary buses also.
- XB - set of boundary buses to be excluded from block-i its constraint function.

The optimal PMU placement has been formulated as an Integer Linear Programming problem in order to minimize the total cost of PMU installation and the constraints are formulated using phasor measurements from PMUs along with the pseudo-measurements. Pseudo-measurements are obtained using Ohm's and Kirchhoff's laws. [8].

The following steps have been used to optimally place the PMUs in the sub-networks.

1. Sort the blocks in descending order of their size
2. Start block counter, i = 1.
3. Identify all set of buses for the block-i i.e. XiI, Xib, XiTb, X= {XiI; Xib}, XT= {XiI; XiTb}.
4. Formulate ILP problem for block-i as,

$$Min \sum C_j x_j \qquad x_{j \in X}$$

Subject to

$$f_j\ (x_{iI}, x_{iTb}, x_B)\ \geq 1$$

$$x_j = (0 \text{ or } 1)\ \text{bir}$$

where

- Cj is the cost of PMU installation at bus. Assume that, cost of installation of each PMU has assumed to be equal and considered as 1 p.u. Thus, in (1) Cj = 1.
- f is constraint set; constraint at any bus-j is formulated in such a way that it becomes observable either through direct phasor measurement or phasor pseudo-measurement. This is achieved either by directly placing the PMU at the bus-j or at any one of the buses directly connected to the bus-j.
- XB is the set of boundary buses to be excluded while formulating constraint set of block. This is an essential step; otherwise, each boundary bus would be considered twice for the constraint formulation and would lead to increased optimal PMU solution. Thus, when a boundary bus is once considered for the constraint formulation, it should be added in the XB set so that it cannot be considered again. Clearly, for i = 1 the first block, XB would be a null vector and after each iteration it has to be updated.

5. Update XB = {XB; Xib}.
6. If i = k, then Stop, else i = i+1 and go to step 3.

The results of the portioning of IEEE-14 bus system are shown in figure (1)

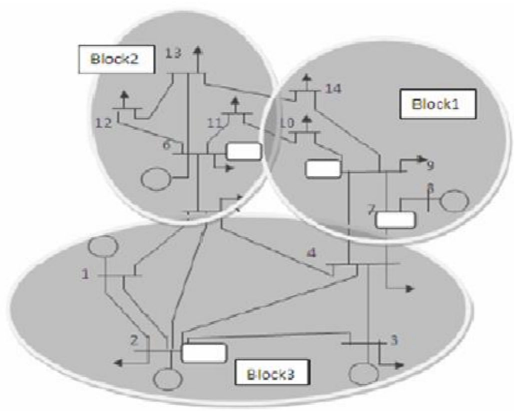

Fig .1. OPP result for IEEE14 bus system after system decomposition [4]

Table 2. optimal PMU placement results for IEEE-14 bus system

System	Number of partitions	Number of buses	Number of zero injection	Optimal PMUs
IEEE 14	3	5,5,4	0	4

IV. PROPOSED METHOD FOR OPTIMAL MULTI-STAGE OF PMUS PLACEMENT FOR FULL SYSTEM OBSERVABILITY

In this section the main principle of the proposed algorithm will be explained. The simulation results will be illustrated. The proposed utilizing model depends on maximizing the system observability taking into consideration installing limited number of PMUs at each stage as constraints. The model will be implemented on IEEE-14 bus and IEEE-30 bus systems.

The main principle of the present algorithm is maximizing the observability of the power system subject to a limited number of PMUs at each stage.
By this way a direct relationship between the PMUs placement at each stage and the cost or the available budget during that stage will be considered. The main objective function is to maximize the observability.

Max O *(4)*

Subject to

No PMU ≤ M *(5)*

Where M is the number of PMUs at each stage determined based on allocated budget for the particular stage.

The steps of the proposed algorithm are illustrated as follows:

1. Determine the minimum number of PMUs required for full system observability N, taking into consideration the zero injection buses and the probability of PMU loss or transmission line failure.

2. Determine the number of combinations of choosing M PMUs in our system out of N.

$$C_M^N = \frac{N!}{M!(N-M)!} \qquad (6)$$

3. Determine observability index for each combination included in M.

4. Select the particular combination of M, which will achieve maximum system observability, and install the M PMUs at those buses at first stage.

5. At the second stage selected M buses at the previous stage will be eliminated.

6. Calculate the number of combinations of choosing M buses from the remaining possibilities or combinations out of (N-M).

7. Determine the observability index for each combination, choose the combination which will achieve maximum Observability for the system and install PMUs at those buses at second stage.

8. If there are many combinations achieve the same observability for the system, the one which achieves maximum number of new observable buses which are not observable at the previous stages will be considered where the remaining buses are neglected.

9. At the next stages the three above steps (5-6-7) will be repeated.

10. If all N buses have been taken at previous stages, then all PMUs have been installed at the system.

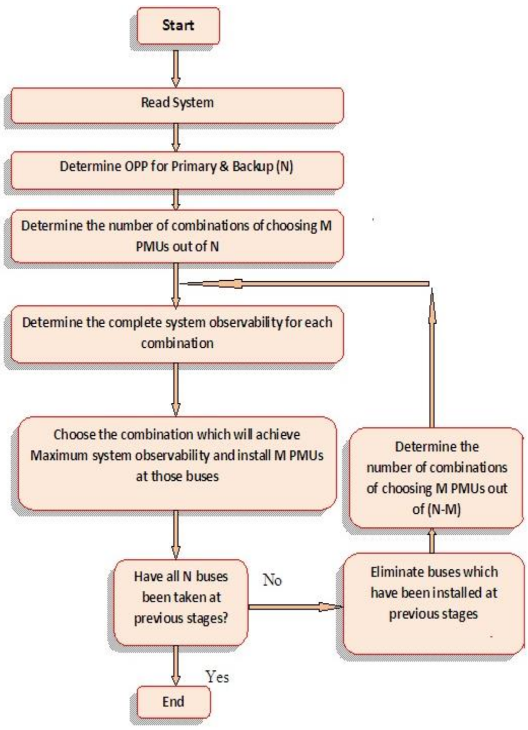

Fig .2. Flowchart of proposed algorithm for carrying out multistage of PMUs placement

V. CASE STUDY

In this study the above steps will be implemented. For simplifying it can be assumed that the number of PMUs which will be installed at each stage M = 2. The implementation will be carried out for the IEEE-14 bus system and IEEE-30 bus system.

A. IEEE-14 bus system

From section II, the minimum number of PMUs placement for full power system observability (OPP) of IEEE-14 bus system is seven PMUs as follow:
The OPP = [2 6 9 4 5 10 13]
By implementing the above steps in section IV on IEEE-14 bus system, the results are shown in table (3). The combination numbers of choosing 2 PMUs from 7 are 21 as shown in the below equation.

$$C_2^7 = \frac{7!}{2!\,5!} = 21 \qquad (7)$$

From the simulation results, it is found that, there are three combinations that will achieve same system observability, ten buses will be observable at each one. These combinations are (6, 9), (6, 4), (4, 13). To define which one must be installed at the first stage from the above three Combinations, the maximum number of new observable buses at the second stage which are not observable at first stage for each combination must be defined. After that start with the combination number which achieve maximum number of new observable buses at second stage. from the simulation results it can be concluded that, all three combinations will achieve three new observable buses at second stage. the combination of (6,9) will achieve these three buses four times while the other two combinations will achieve these three buses two times only.

So at first stage it is recommended to install two PMUs at buses (6, 9). After the first stage the following buses are observable [4 5 11 12 13 7 10 14 6 9]. After completing that stage the system observability will be 0.7143, as shown in table (3).

At second stage, to define the location of the PMUs which will be installed at the second stage, we should carry out the followings:

Table 3. OMPP for IEEE-14 bus system results

Stages	1	2	3	4
Location of PMUs	6,9	2, 13	4, 5	10
Number of observable buses at system	10	13	13	13
New observable buses	Non	1 2 3	Non	Non
Observable buses status	4 5 11 12 13 7 10 14 6 9	1 2 3 4 5 11 12 13 7 10 14 6 9	1 2 3 4 5 11 12 13 7 10 14 6 9	1 2 3 4 5 11 12 13 7 10 14 6 9
Observability Function	0.7143	0.9285	0.9285	0.9285

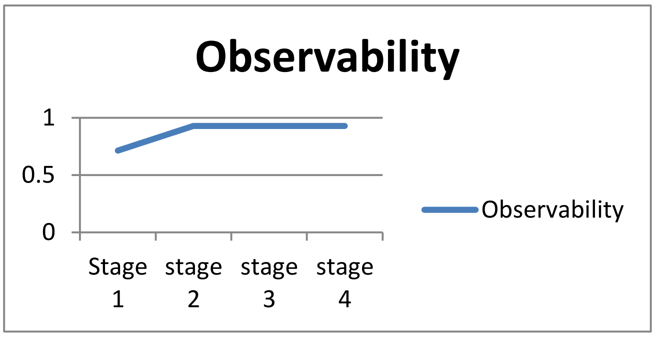

Fig .3. Observability function toward multi-stages of PMUs.

B. IEEE-30 bus system

The minimum numbers of PMUs placement for full power system observability are 16 PMUs. The optimal PMUs placement is (OPP)
OPP = [1 3 5 7 9 10 12 13 15 17 19 20 22 24 27 29].
The combinations or possibilities of choosing 2 buses from 16 are 120 as follow:

$$C_2^{16} = \frac{16!}{2!\,14!} = 120 \qquad (8)$$

From the results found that, there are one combination (10, 12), will achieve maximum system observability, ten buses buses. So at the first stage two PMUs will be installed at buses (10,12). After that stage the observable buses are [4 6 9 17 20 21 22 13 14 15 16 10 12].
To define the location of the PMUs which will be installed at the second stage, the following steps must be carried out:

1. Eliminate any combination which contains bus 10 or bus 12.

2. Determine the remaining possibilities or combinations of choosing 2 from 14 as follow:

$$C_2^{14} = \frac{14!}{2!\,12!} = 91 \qquad (9)$$

For each combination, we should determine the new observable buses which are not observable in the first stage. From the results it can be concluded that, there are two combinations will achieve the maximum number of new observable buses (8 buses), which are not observable at first stage these combination are (1, 27) & (5, 27). To define which one must be installed at the second stage, the number of buses which are not observable at the second stage for each one must be calculated. The combination which will achieve the maximum number of new observable buses will be taken. From the results it can be concluded that, it is no difference between the two combination (1, 27) & (5, 27), as if two PMUs are installed at buses (1,27) or at (5,27), four new buses will be observable at the third stage which are not observable at the second stage. So at the second stage two PMUs can be installed at buses (1, 27) or (5, 27). It can be assumed that, at the second stage two PMUs will be installed at buses (1, 27).

At the next stages same concept will be implemented. The final results are shown in table (4).

Table 4. Conclusion results of proposed method for OMPP for IEEE-30 bus system

Stage number	PMUs location	New observable buses which are not observable at previous stage	Observable buses at the system	Number of Observable buses	System Observability function
1	10.12	None	4, 6, 9, 17. 20, 21, 22, 13, 14, 15, 16, 10, 12	13	0.433
2	1,27	2, 3, 25, 28, 30, 29, 1, 27	4, 6, 9, 17. 20, 21, 22, 13, 14, 15. 16, 10, 12, 2, 3, 25, 28, 30, 29, 1, 27	21	0.700
3	19.22	18, 19, 24	4, 6, 9, 17. 20, 21, 22, 13, 14, 15. 16, 10, 12, 2, 3, 25, 28, 30, 29, 1, 27, 18, 19, 24	24	0.800
4	7.9	5, 11, 7	4, 6, 9, 17. 20, 21, 22, 13, 14, 15. 16, 10, 12, 2. 3. 25. 28. 30. 29. 1. 27, 18, 19, 24, 5, 11, 7	27	0.900
5	3,15	23	4, 6, 9, 17. 20, 21, 22, 13, 14, 15. 16, 10, 12, 2, 3, 25, 28, 30, 29, 1, 27, 18, 19, 24, 5, 11, 7, 23	28	0.933
6	5,13	None	4, 6, 9, 17. 20, 21, 22, 13, 14, 15. 16, 10, 12, 2, 3, 25, 28, 30, 29, 1, 27, 18, 19, 24, 5, 11, 7, 23	28	0.933
7	17,20	None	4, 6, 9, 17. 20, 21, 22, 13, 14, 15. 16, 10, 12, 2, 3, 25, 28, 30, 29, 1, 27, 18, 19, 24, 5, 11, 7, 23	28	0.933
8	24,29	None	4, 6, 9, 17. 20, 21, 22, 13, 14, 15. 16, 10, 12, 2, 3, 25, 28, 30, 29, 1, 27, 18, 19, 24, 5, 11, 7, 23	28	0.933

From the above simulation results on the two systems it can be concluded that, the complete system observability is achieved much before the last stage of installation of PMUs. Also all the tie lines become observed well before the last stage of PMUs placement. Since the PMUs placement is robust against a PMU failure or single line outage.

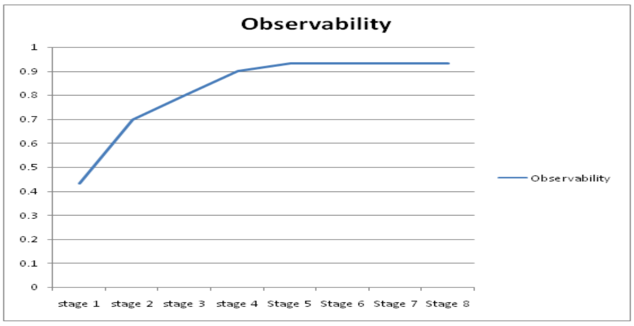

Fig .4. Observability function belongs to number of stages for IEEE-30 bus system.

VI. CONCLUSION

Improvements in power system control and protection is achieved by utilizing real time synchronized phasor measurements PMUs. The trend in recent years is the steady increase of Phasor Measurement Units (PMUs) installations worldwide for various applications. Placement of phasor measurement units (PMUs) in power systems has often been formulated for achieving total network observability. In practice, however, the installation process is not implemented at once, but at several stages, because the number of available PMUs at each time period is restricted due to financial problems.

Full system observability will be achieved by installing PMU at each bus, but the PMUs are expensive devices. So it very important to minimize the numbers of PMUs in power system. So different methods are used to compute the minimum required numbers from PMUs in order to fulfill the system observability even PMUs failure or transmission line loss.

An Integer linear programming method had been implemented. The optimal PMUs placement (OPP) will be extended to multi-stages installation. This means that instead of solving OPP in one shot, it will be divided into many stages. New method will be overviewed. That method depends on the decomposition of the power system into sub-networks and computes the optimal PMUs placement (OPP) for each sub-network.

Because of the power system with considerable size will require a huge numbers of phasor measurement units (PMUs) for full system observability and also due to high cost of PMUs it is very important to find methods for multi-stages of PMUs placement installation.

A new proposed method had been explained. This method is depending on installing a definite number of PMU at each stage. The study case and simulation had been implemented on the IEEE-14 bus system and IEEE-30 bus system.

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Development of Reliability Indices for Electric Distribution Network in Egypt

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***Abstract* -** Reliability indices (RIs) are the elemental benchmark used by Egyptian Electricity Holding Company (EEHC), and the Electric Utility and Consumer Protection Regulatory Agency (Egypt ERA) to evaluate the continuity and compliance of supply, which surpasses the customer's requirements and satisfaction.

The power system is very complex, mixing huge different types of generating resources and clusters to supply electric power through transmission and distribution system to a number of customers with varying requirements.

The main function of electric system is to supply customers with electric energy that has an acceptable degree of reliability and quality. The power system continuity of supply level is controlled through system indices. The most widely used reliability indices are SAIFI, SAIDI and CAIDI (IEEE std. 1366-2000).

Historical electrical indices, reliability indices threshold and satisfaction index are used as guide for electric network performance, which measure the adequate and secure power supply.

The paper presents the reliability indices, relation between indices and satisfaction area to highlight the appropriate guideline values for electric systems, also presents the development of indices since 2011 to now for distribution network in Egypt.

***Keywords* -** Reliability; Power System; Benchmark; Continuity; Indicators.

I. INTRODUCTION

The Egyptian Electricity Holding Company (EEHC) mission towards the society is to supply electricity to all types of consumers according to international performance standards taking into consideration all environmental, social and economic determinates and also the terms and conditions set by The Egyptian Electric Utility and Consumer Protection Regulatory Agency (EGYPTERA).

EEHC has sixteen affiliated companies as shown in "Fig. 1" (six generations (EPC), nine distributions and the Egyptian Electricity Transmission Company (ETC)).

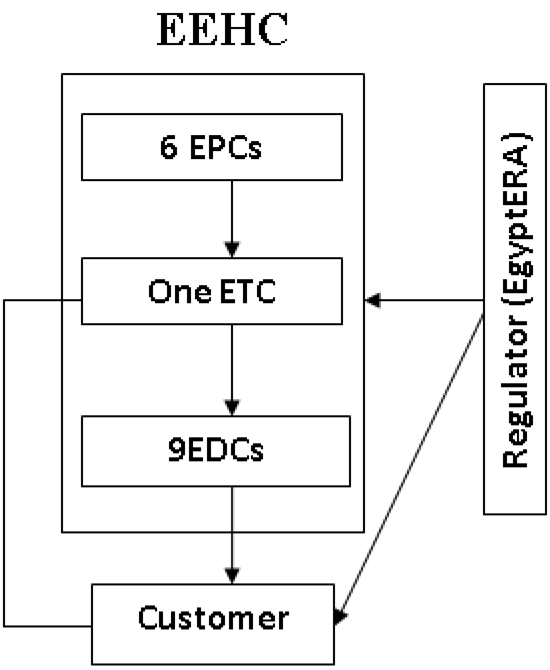

Fig. 1. the relation between EEHC and Egypt ERA

The main objectives of electricity Distribution Company
(EDC) are:

- Distributing and selling to consumers on medium and low voltages.
- Managing, operating and maintaining medium and low voltages grids in the company.
- Ensuring high level of quality, availability and continuity of supply to distribution customers.

- The following procedures have been taken to improve
- Continuity of supply indices:
- Analysis of the causes in case of increased unplanned interruptions and relate it to network renovation and Rehabilitation plans.
- Follow up the implementation of maintenance programs to insure optimizations of interruption of supply time and at the same time implementation of the maintenance procedures with high quality.
- Intensive field inspections and data collection for interruptions.

Each EDC consists of number of geographical sectors, Have number of districts. The district network consists of MV distributors, distribution transformers (MV/LV), and MV, LV lines, as shown in “Fig.2”.

EEHC and EGYPTERA use RIs to trace the Performance of EDCs. EGYPTERA most commonly uses KPIs: SAIFI, SAIDI, CAIDI, ENS and CENS.

II. PERFORMANCE INDICES (PIS)

Recommended interruption indices or key performance indices (PIs) are those defined in both IEEE 1366[1] and the CIGRE study committee C2 [2]:

- SAIFI (System Average Interruption Frequency Index): the average number of sustained interruptions per customer during the year.
- SAIDI (System Average Interruption Duration Index): the average time for which customers power supply is interrupted in a year.
- CAIDI (Customer Average Interruption Duration Index): the average time required to restore service to the average customer per sustained interruption.
- ENS (Energy Not Supplied): the summation of energy not supplied due to supply interruptions over a year Period. Its cost is CENS (cost of energy not supplied).

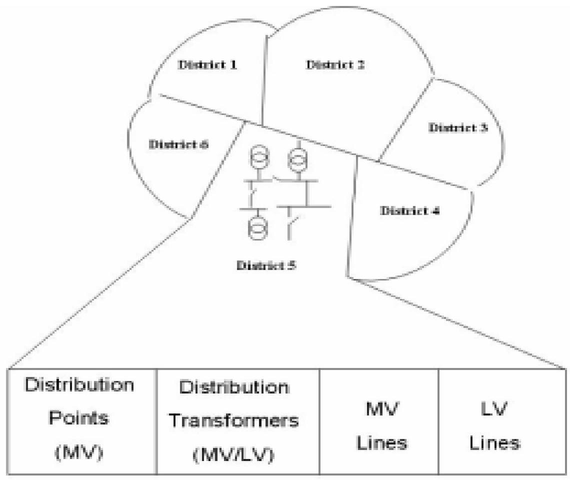

Fig. 2. Part of geographical area of an EDC

III. SYSTEM RELIABILITY INDICES (RIS)

A. System Average Interruption Frequency Index (SAIFI)

It measures the average number of interruptions experienced by each customer. All planned and unplanned interruptions are used in calculating the index. SAIFI can be calculated as follows:
SAIFI = (No. of interruptions during one year)/ (No. of customers).

B. System Average Interruption Duration Index (SAIDI)

It measures the yearly average interruptions duration per customer. It can be calculated as follows:
SAIDI = (Σduration of interruption in min)/ (No. of customers).

C. Customer Average Interruption Duration Index (CAIDI)

It measures the average time required to restore service to the average customer per interruption. The following formula is employed for calculating CAIDI:
CAIDI = (SAIDI)/ (SAIFI). [4], [5]

IV. CONTINUITY OF POWER SUPPLY

The main aspects of quality for electric network operation are continuity of supply, safety, technical quality of the commodity, end user service and environmental impact. Continuity of supply measures the electric networks ability to supply the end users with electricity. It is generally characterized as the frequency and duration of interruptions in supply.

- Continuity of power supply or sustained outage – an outage that lasts longer than a specified amount of time .SAIDI, SAIFI and CAIDI are all based on sustained outage .The duration of a sustained outage varies from state to state. IEEE -1366 defines the duration of sustained outage to be 5 minutes.

- Power quality – measure of the purity of the electric waveform on power lines. A power quality event, which is not the same as an outage, occurs when one of the waveforms differs from a pure sinusoidal waveform or one or two phases of power are lost. [10]

Measurements that can quantify power quality are harmonic distortion and peak to peak voltage. Power quality events can last from few cycles to a few seconds and can be caused by lightning strikes, falling trees, utility operations and operations from other customers such as disturbances from starting a large motor.

A. International example

A review of some countries revealed the SAIDI and SAIFI performance shown in "Table I". These countries also put greater emphasis on power quality [3], [11]

B. Variables affecting reliability indices

1. Longer circuits lead to more interruptions. It is easier to provide higher reliability in urban areas; line lengths are shorter.

2. The distribution supply configuration greatly impacts reliability. Long radial lines provide the poorest service; grid networks are exceptionally reliable.

3. Higher primary voltages tend to be more unreliable, mainly because of longer lines.

Table 1. EUROPEAN RELIABILITY PERFORMANCE, WITH MAJOR EVENTS

Country	SAIDI	SAIFI
Austria	72	0.9
Denmark	24	0.5
France	62	1.0
Germany	23	0.5
Italy	58	2.2
Northlands	33	0.3
Spain	104	2.2
UK	90	0.8

*Source: council of European energy regulator ASBL (2008) 4th benchmarking report on the quality of electricity supply .Brussel CEER.

Faults and interruptions have significant year-to-year variation because weather conditions vary significantly, age of electrical equipment, or performance of protective systems. These factor variations are translated into variations in the number of faults and in reliability indices.

C. Relation between SAIFI & CAIDI

The envelope of "acceptable supply" for relation between frequency of interruptions and longest duration per interruption is shown in "Fig.3".

- Find optimum and customer satisfied: "A" area, represents the area of biggest reliability, move towards the origin, the performance will be better.

- Customer dissatisfied: Balanced area represents the lower reliability, divided to:

- Region "B" indicates for the excess number of interruptions but for short time durations.

- Region "C" indicates for little number of interruptions but for long time durations.

- Vertical axis "X" and horizontal axis "Y" give the reliability indices threshold.

D. Performance indicators for EDC

"Table 2" and "Table 3" represent the development of SAIFI and CAIDI during 2011:2014 for EDCs. If indicators through the three years are abnormal, (as CAIDI for EDC3 & EDC5), the stray number must be dropped out.

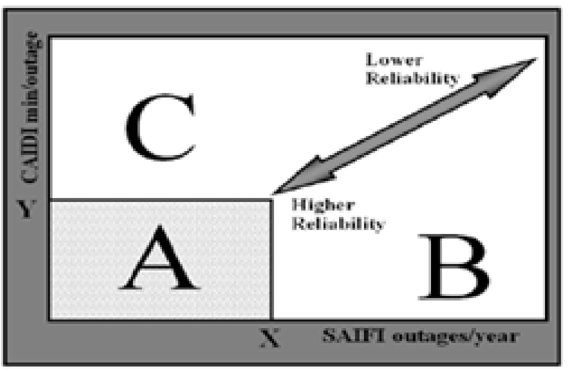

Fig.3. Relation between SAIFI and CAIDI

Table 2. DEVELOPMENT OF CAIDI FOR EDCS

CAIDI					
Company	**2011**	**2012**	**2013**	**2014**	**average**
EDC1	102.4	117.761	107.852	97.062	106.269
EDC2	31.768	27.12	24.118	21.758	26.191
EDC3	54.851	18.483	18.906	9.509	25.437
EDC4	143.577	2.094	7.576	67.048	55.074
EDC5	40.071	40.416	41.76	36.177	39.606
EDC6	67.841	48.567	27.377	28.104	42.972
EDC7	23.879	24.474	88.877	106.13	60.84
EDC8	152.413	106.931	103.703	108.7	117.937
EDC9	77.801	83.167	130.727	171.301	115.749

Table 3. DEVELOPMENT OF SAIFI FOR EDCS

SAIFI					
Company	**2011**	**2012**	**2013**	**2014**	**average**
EDC1	0.435	0.495	0.423	0.341	0.4235
EDC2	0.192	0.169	0.134	0.131	0.1565
EDC3	0.149	0.934	0.958	0.764	0.70125
EDC4	0.452	0.405	0.442	0.445	0.436
EDC5	0.66	0.533	1.01	1.009	0.803
EDC6	3.01	2.145	0.095	0.081	1.3328
EDC7	0.121	0.117	1.388	0.559	0.5463
EDC8	0.289	0.169	0.464	0.225	0.287
EDC9	1.59	2.237	0.221	0.179	1.0568

The relation between SAIFI and CAIDI for 9 EDCs during 2011:2014 is presented in “fig. 4”.

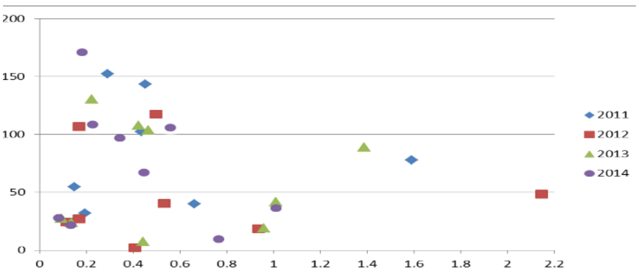

Fig.4. relation between SAIFI&CAIDI for EDCs (data 2011-2012-2013-2014)

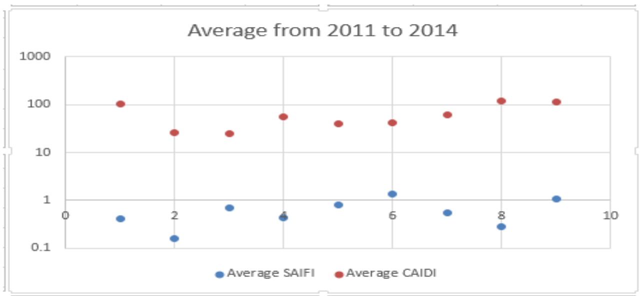

Fig.5 Relation between SAIFI and CAIDI fir EDCs in 2014

“Fig.5” represents the envelope of “acceptable supply “for relation between SAIFI and CAIDI for EDCs in 2014.

According to IEEE1366, 2001 the target of SAIFI and CAIDI are 1.0 and 90 minute respectively, they are close to the calculated threshold values

Notes:

1. SAIFI and CAIDI are improved in 2014 for most EDCs.
2. EDC2 and EDC3 are in optimum area

V. CONCLUSION

There is increasing demand from consumers for more reliable and economical electric power. Many factors share to evaluate the reliability of a power network: design, planning, operation and maintenance and faults; which have their contributed input to all power network reliability.

The main measures to improve reliability: adequate maintenance, adoption of preventive maintenance rather than break down maintenance, improving power quality and ensuring coordination protection settings.

The reliability indicators for electric network in Egypt are used by EEHC and Egypt Era to benchmark performance and scenariotize investments in generation, transmission and distribution network, to improve performance. Also, these indicators are used by system planners and operators as a channel to improve the level of customer service.
Reliability level for its delivery facilities and, where appropriate to improve performance.
The results are the reliability performance objectives for EDCs, ETC, and EPCs shall have threshold objective designed to help maintain the acceptable envelop.

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Reliability Improvement of Power Distribution Systems using Advanced Distribution Automation

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***Abstract* -** Towards the complete vision of smarter distribution grid, advanced distribution automation system (ADAS) is one of the major players in this area. In this scope, this paper introduces a generic strategy for cost-effective implementation and evaluation of ADAS. Along with the same line, fault location, isolation and service restoration (FLISR) is one of the most beneficial and desirable applications of ADAS for self-healing and reliability improvement. Therefore, a local-centralized-based FLISR (LC-FLISR) architecture is implemented on a real, urban, underground medium voltage distribution network. For the investigated network, the complete procedure and structure of the LC-FLISR are presented. Finally, the level of reliability improvement and customers' satisfaction enhancement are evaluated. The results are presented in the form of a comparative study between the proposed automated and non-automated distribution networks. The results show that the automated network with proposed ADAS has a considerable benefit through a significant reduction in reliability indices. In addition, it has remarkable benefits observed from increasing customers' satisfaction and reducing penalties from industry regulators.

***Keywords* -** Advanced distribution automation system, Fault location, isolation and service restoration, Self-healing grid, Relaibilty assessment study.

I. INTRODUCTION

In the contemporary world, the electrical distribution system is the backbone of the smart grid environment. However, most of customer outages are a result of the distribution networks, where 80% of customer interruptions attribute to faults and component failure at the feeder level [1]. Conventional distribution systems do not involve much automation i.e. rely mainly on manual operations, and do not have any communication or information exchange i.e. blind system. During system events, the absence of monitoring and lack of information with increasing failure rate would dramatically increase the duration and number of customers affected by specific outage. The technical impact will appear in decreasing the reliability level of the network and the quality of supply. The significant economic impact of this would be observed in increasing the outages cost of utility and their customers. For these reasons, improving system reliability and power quality becomes an important issue.

Keeping the above problems in mind, distribution automation (DA) is the key answer to many challenges facing electrical distribution networks. Referring to electrical power research institute (EPRI), advanced distribution automation system (ADAS) has been defined as "a fully controllable and flexible distribution system that will facilities the exchange of electrical energy and information between participants and system components" [2], [3]. The expected results of applying DA on medium voltage (MV) distribution networks include, for example, reliable, resilience, self-healing, fully controllable and efficient distribution system for energy delivery to end users in customers' domain. Much of efforts that depend upon modernizing the distribution network are accomplished and many utilities around the world started distribution automation projects [4]-[9]. ADAS combines different applications that have been discussed in [10] and summarized as follows:

- Fault location, isolation, and service restoration
- Volt/Var control and optimization
- Distributed generation resources management
- Adaptive distribution feeder protection coordination
- Optimal feeder reconfiguration
- Automatic meter reading
- Demand side management

Fault location, isolation and service restoration (FLISR) is defined as the most beneficial, attractive application among all applications of ADAS in order to getting self-healing grid, enhancing the reliability level of distribution networks, reducing operation and maintenance cost and increasing customers satisfaction. This is achieved by means of reducing the outage time from several hours to few minutes [11]. There are different architectures for FLISR implementation based on where the decision is made: fully-centralized (FC-FLISR) [6],[7], fully-decentralized (FD-FLISR) [8],[9] and local-centralized (LC-FLISR) architectures. In fully centralized architecture, the FLISR algorithms are implemented in DMS/SCADA system located at the control centre (CC) in so far area. In the decentralized architecture, the FLISR uses an intelligent local controller, integrated with the multiple switches distributed along feeder nodes.

The scope of this paper is to evaluate the effective utilization of ADAS within power distribution systems. In the context of ADAS implementation, to avoid the huge investment and maximize the benefits towards a complete vision for the smart distribution grid, a generic strategy for ADAS is developed in this paper. Also, a local-centralized architecture is presented as the most appropriate architecture for FLISR implementation within the investigated distribution network. The reasons and encouragements for this choice are discussed in the next sections. In addition, the structure and procedure of FLISR system are presented. Finally, The reliability assessment study is performed using analytical technique. The results are presented in the form of a comparative study between the proposed automated and non-automated distribution networks. The results show that the automated network with proposed ADAS is able to achieve a significant and considerable improvement in reliability level of the distribution network.

II. DESCRIPTION AND OPERATION OF THE DISTRIBUTION NETWORK UNDER STUDY

A. Description of the investigated distribution network

To prove the validity of the proposed study, it will be performed on a real distribution network as a case study. This distribution network is an actual, urban, underground, 11 kV rated distribution network with open-ring configuration. As demonstrated in Fig. 1, the investigated network consists of an 11 kV distribution substation fed from a 22 kV distribution system, which has a 750 MVA short circuit capacity. This distribution substation supplies four outgoing feeders. Each is protected by and intelligent electronic devices (IED) at the beginning of the feeder. The lengths of these feeders are 5.485 km, 1.750 km, 3.725 km, and 6.725 km, respectively. The distribution network contains thirty-five 11 kV compact secondary substations (CSSs), which are installed over the four feeders. Each CSS is a fully equipped package substation divided into three main compartments: incoming MV compartment, transformer (XFMR) compartment and low voltage feeder panel (LVFP) compartment as illustrated in
Fig. 2.

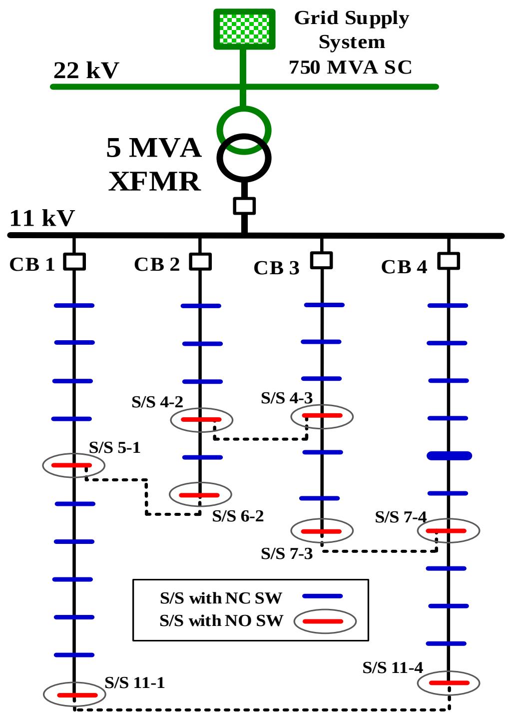


Fig .1. 11 kV Underground distribution network

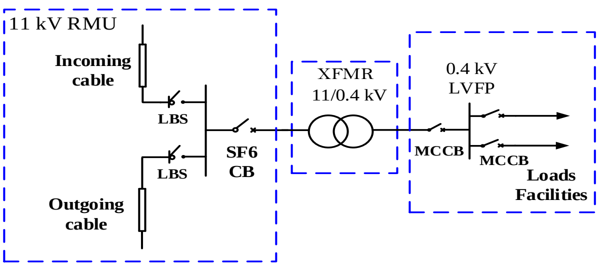


Fig .2. Compact secondary substation compartments

B. *Operation mode of the investigated distribution network*

The existing MV distribution network is a conventional network and have not involved much automation i.e. rely mainly on manual operations. Traditional FLISR still exhibits long time and stressful efforts as follows:

- The fault is detected via the outage reports received from the outage customers.
- Afterwards, investigation process for fault localization to determine the faulty section is started. This process necessitates the patrolling of the entire network.
- For successful isolation of the faulty section, manual-switching actions are completely accomplished by human intervention.
- Finally, other manual switching actions are executed to restore the service to healthy customers.

Briefly, FLISR is performed manually via human intervention and hence, the network operator is facing some of technical and financial issues that are defined and represented by increasing the outages time and outages costs, especially with the presence of the underground cables spread over long distances. Consequently, it is suffered from low level of service reliability and low customers' satisfaction.

III. THE PROPSED ADVANCED DISTRIBUTION AUTOMATION SYSTEM

Motivated by the earlier mentioned issues in the previous section, ADAS is an imperative solution in order to strengthen the operation of MV distribution networks. This following section attempt to discuss some issues related to ADAS implementation from different points of view, e.g. ADAS strategy of implementation, selection of the most appropriate architecture. Finally, the structure and requirements of the proposed automation system is introduced.

A. *Implemented strategy of ADAS*

Although it may be not possible to describe a successful ADAS strategy, rapid deployments worldwide have thought some lessons [11], [12] that help to construct the proposed implemented strategy for the existing distribution network, as illustrated in Fig. 3. The target of the proposed ADAS strategy is to determine the main requirements of ADAS including selection of the most appropriate architecture or approach for ADAS, defining of automation degree and complete structure of ADAS. The detailed explanation of the proposed ADAS strategy will be presented as follows:

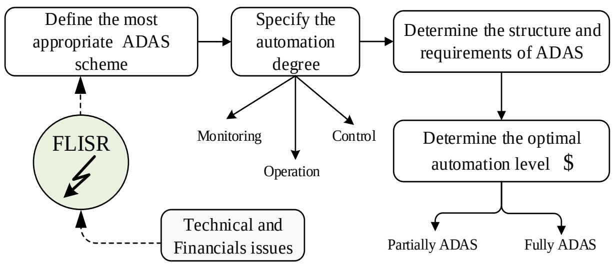


Fig .3. General Strategy for distribution automation implementation

The proposed strategy starts with selection of the most significant and beneficial application that is currently needed for the system. This application will be the first phase of the smart distribution network and will be defined according to the existing technical and financial issues facing the distribution network e.g. for the existing distribution network, which is presented as a case study, FLISR is defined. The second step is to define the most appropriate architecture for ADAS. The ADAS scheme is refer to where the decision is made. Three different scheme are introduced in section I. The selection criteria are based on the requirements of the defined application, the nature of the existing control strategy of the network, network size and configuration, as well as economic resources.

The next step is the specification of the automation degree. The automation degree is categorized into three categories; monitoring, control, and operation or any combination of them. This is based on the network operator target and requirements. After that, utility have to determine the copmlete structure and requirements of the ADAS. In general, the main structure and requirements of ADAS include: flexible electrical hardware facilities, modern communication technologies and intelligent software applications [11]. Finally, for for reasonable degree of improvement in system performance and economic justification and profitability, cost/benefit analysis is performed to determine the optimal automation level of the distribution network. The automation level of MV distribution network is considered to be percentage of automated points in the network. For underground networks, the automated points are the number of secondary substations (S/Ss) retrofitted with smart devices such as feeder remote terminal units and fault indicators.

B. Proposed Local-centralized FLISR

Nowadays, the great evolution of smart sensors, advanced communication technologies and utilization growing of SCADA/DMS, accelerates the transformation of the traditional distribution networks into automated systems. Following the proposed strategy for ADAS, FLISR application is defined as the most appropriate solution among all applications of ADAS to achieve self-healing grid and to improve the reliability level of distribution network. FLISR is implemented on the existing MV distribution network based on local-centralized architecture, called (LC-FLISR). The information is acquired and analysed in primary substation. Then, the control decision is executed automatically on real network or after confirmed by the operator using the SCADA interface. The idea behind FLISR is to achieve the self-healing grid, where the service for all customers is restored automatically after few minutes (< 5 minutes) from fault from fault occurrence [11]. The main objectives of the LC-FLISR are illustrated in Fig. 4. So, As shown in Fig. 5, the proposed structure of ADAS consists of:

Therefore, this paper aims to present a simple and more efficient CBPWM technique to control three to five-phase matrix converters, which can be used to supply a five-phase induction motor drive system that delivers some advantageous features for industrial applications. The basic concept of the proposed technique is already published in [27]. Thanks to its simplicity, the proposed technique will be based on the indirect modulation of the 3×5 MC which control the converter as a double stage converter. Therefore, the carrier based PWM methods are applied for each stage independently. The proposed modulation will maximize the converter VTR by operating the converter in the overmodulation mode as well as in the linear modulation mode. It also controls the input power factor by controlling the input current displacement angle. The proposed modulation technique is verified using simulation and experimental results based on a laboratory prototype and the dSPACE-DS1104 controller platform and the results are compared by the existing SVM technique.

- Master unit controller (called MU) as the "decision support system" of the ADAS. The information is acquired and analysed by MU. Then, the control decision is executed automatically on real network or after confirmed by the operator using the SCADA interface

- Intelligent software applications (FLISR algorithms); as this paper focus on FLISR application. Thereby, there are two main intelligent algorithms are needed to be integrated with ADAS: "fault location" and "service restoration" algorithms.

- Modern communication technologies as the heart of ADAS. The core mission of the network communications is to provide information exchange facilities between field devices dispersed geographically along the distribution grid and master unit located at primary substation.

- Flexible electrical hardware facilities (field devices).

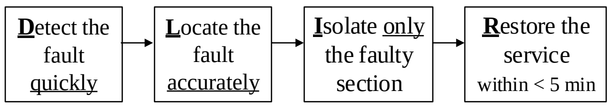


Fig .4. FLISR Objectives

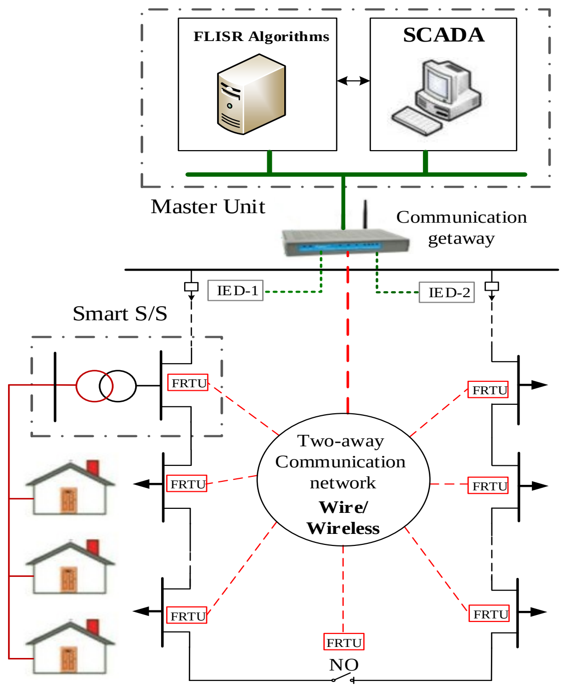


Fig .5. Over view of local-centralized ADAS structure

Regardin to field devices, the secondary substations play a vital role in the evolution toward the self-healing grid. Therefore, the retrofitting of the existing traditional S/Ss with smart equipment suitable for ADAS. A typical configuratuon of smart S/S is presented in Fig. 6, where the figure is taken from [13]. However, the smart devices that are suitable for the propsed ADAS are only highlighed. So, the smart S/S is consists of: smart RMU equipped with motorized LBSs, motorized CB, fault indicators (FIs), voltage indicators (VIs), and uninterruptible power supply (UPS). Also, the smart S/S is supported with feeder remote terminal unit (FRTU) acts as a local controller for field devices. In addition, FRTU acts as a gateway between field devices and MU. From the literature [14], the communication between MU and FRTUs in this paper will take place through public GPRS communication based on IEC 60870-5-101 protocols as a cost-effective solution [5]. On the other hand, connection with field devices will be wired (serial RS-232/RS-458) using conventional IEC 60870-1-104 or Modbus RTU protocols supported by field devices. On the way to realise a high level of reliability, reducing outage time and outage cost, increasing customer satisfaction, a fully automated system is implemented. So, all S/Ss would be retrofitted with smart equipment that are suitable for DAS.

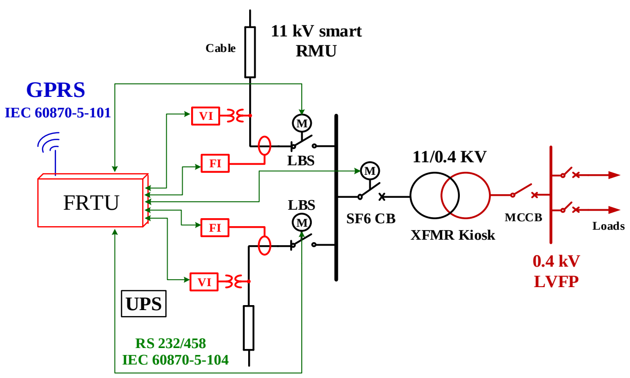


Fig.6. Typical configuration of smart S/S with ADAS equipment

C. *Proposed ADAS architecture:*

In this paper LC-FLISR architecture is selected as the most appropriate solution due to the following reasons:

The choice of a LC-FLISR architecture to be implemented in this paper is judged by the following reasons:

- Compared to fully centralized architecture, there is no need for huge investment that is required for FC-FLISR scheme including SCADA/DMS hardware and software. The decision is taken from MU located at the primary substation within the same graphical area of the entire network. The results, the communication is over relatively short distances. Hence, high-speed data transfer is achieved and the service restoration time is lower. The significant economic impact of would be observed in decreasing the customer outages cost of utility and their customers.
- Compared to distributed architecture that has limited functionality, in LC-FLISR, the structure of constructed algorithm located in primary substation is easy to be modified and expanded to accommodate the upcoming extensions in the network. Also, because of the communication network between MU and RFTUs are already used in the system e.g. GPRS network, a few costs are required with adding more ADAS application such as volt/var control and Distributed generation resources management

D. *LC-FLISR procedur*

In this subsection, the steps of LC-FLISR procedure are discussed as follows:

- Firstly, with permanent fault occurrence the IEDs at the beginning of each feeder will detect and initiate the corrective action as quickly as possible for the corresponding feeder CB.
- With the help of the FPIs installed in each smart S/Ss, the faulty section well-known between the last flashed FI and first unflashed FI.
- The next is to isolate only the faulty section. So, a control commands are automatically issued by MU in order to open the proper LBSs surrounding the fault.
- After the faulty section is isolated successfully, the LC- FLISR algorithms are triggered swiftly through SCADA inputs such as LBSs and FPIs statuses. With fault location capability integrated with the proposed ADAS system. The probable location of the faulty point will be estimated, [15] rather than determining the faulty section. Consequently, the fault damage inspection and repairing time and money can be saved.

- Finally, the service can be restored again for the customers of remaining healthy sections by the help of the service restoration algorithm implemented in MU. the service restoration algorithm is responsible for generating a suitable restoration-switching plane to the proper LBSs in the system to achieve the goal [16]. As a result, it will improve the service reliability and increases the operational efficiency of the network.

IV. RELIABILITY ASSESSMENT STUDY

A. Reliability indices and technique

In order to quantify and evaluate the benefit of ADAS implementation, reliability assessment study is performed. System reliability refers to the capability of the system to perform its specified task correctly for certain duration of time. The system reliability is represented using two terms “system adequacy” and system security”. There are two categories of indices that used to define the reliability level of the distribution system; load point reliability indices and system reliability indices. The load point indices include; average failure rate, λi (f/yr), expected outage duration, ri (hr), and unavailability, Ui (hr/yr) for load point “i” [17]. Also, the expected energy not supplied index at each load point, EENSi (MWhr/yr) can be used to assess the performance of the system. From theses load point indices, the system reliability indices such as SAIDI, SAIFI, CAIDI and EENS can be then calculated for the whole system [17]. Theses indices can be calculated according to references, [18], [19] as follows:

$$\lambda_i = \lambda_1 + \lambda_2 + \cdots \lambda_M = \quad (f/yr) \qquad (1)$$

$$U_i = \lambda_1 r_1 + \lambda_2 r_2 + \cdots \lambda_M r_M = \sum_{x=1}^{M} \lambda_x r_x \quad (hr/yr) \qquad (2)$$

$$r_i = \frac{U_i}{\lambda_i} = \frac{\sum_{x=1}^{M} \lambda_x r_x}{\sum_{x=1}^{M} \lambda_x} \quad (hr) \qquad (3)$$

$$EENS_i = P_i\, U_i \quad (MWhr/yr) \qquad (4)$$

$$SAIDI = \frac{\sum_{i=1}^{N_T} U_i N_i}{N_T} \quad (hr/yr) \qquad (5)$$

$$SAIFI == \frac{\sum_{i=1}^{N_T} \lambda_i N_i}{N_T} \quad (int/yr) \qquad (6)$$

$$CAIDI = \frac{SAIDI}{SAIFI} \quad (hr/int) \qquad (7)$$

$$EENS = \sum_{i=1}^{N_T} P_i U_i \quad (MWhr/yr) \qquad (8)$$

where: λ_j is failure rate of component j (f/yr), M is the number of components that affect the load point “i”, rj "is" the restoration time of load point “i” after failure of component “x” (hr), P_i is the total demand at load point “i” and N_T is the total number of customers served (MW).

The reliability level of the distribution system depends mainly on the overall time of the FLISR procedure after fault event. This time is estimated according to the operating strategy non-automated and automated distribution network. In this paper, the reliability study is performed using analytical technique based on failure mode effect analysis (FMEA) [20]. The basic procedure used in the analytical technique is shown in Fig. 7.

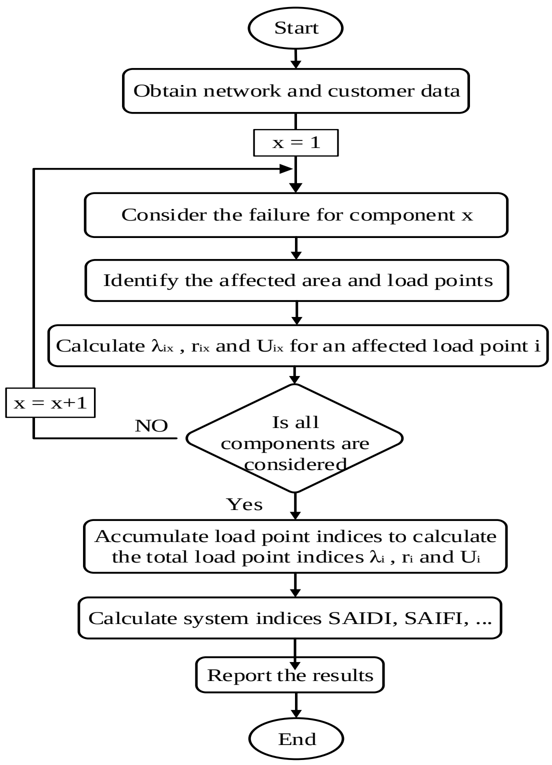


Fig. 7. Procedure of the analytical technique for reliability assessment

B. Simulation results

The structure and configuration of the investigated 11 kV distribution network is presented in section II-A. The reliability indices of the distribution network are evaluated with two operating philosophy: non-automated distribution network strategy e and automated distribution network. Then, the results are compared in order to ensure the achievement of improving the reliability indices using ADAS. The network reliability data are taken from IEEE Standard 493-2007 (Golden book) [19], and given in Table. 1.

Table 1. NETWORK RELIABILITY DATA

Equipment category	Failure rate (failure/year)	Repair time (h/failure)	Unavailability (h/year)	Comments
LV CB	0.0027	4	0.0108	
MV CB	0.0036	2.1	0.0076	
LV Cable	0.00141	10.5	0.0148	1000 circuit ft.
MV Cable	0.00613	26.5	0.1642	1000 circuit ft.
Disc. Switch	0.0061	3.6	0.022	
MV Transf.	0.003	130	1.026	Replace by spare
LV SWGR	0.0024	24	0.0576	
MV SWGR	0.0102	26.8	0.2733	

The reliability study is performed under the following assumption: normally, the distribution network operates in open-ring configuration, but some of the network feeders can be connected to each other through the normally open tie switch and the average restoration time for the healthy customers defined to be under 5 minutes with automated network and two hours with non-automated one. Also all the CBs and LBSs are assumed to be 100% reliable and all failures are statistically independent.

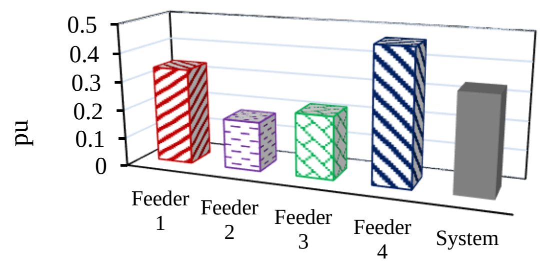
The load point reliability indices such as λ, r, U and EENSI are calculated using FMEA method with the help ETAP®12.60 software package and the results are presented in Table 2 for comparative study purpose between non-automated and automated network. In addition, the system reliability indices such as SAIDI, SAIFI, and EENS are also calculated for each of four feeders and whole system and given in Table 3. The results indicate clearly that the load point indices are improved significantly for all load points in the investigated distribution network by implementing the proposed ADAS. In addition, there are a clear reduction in system indices, i.e. SAIDI and EENS, for all system feeders and whole system. For the whole system, there is a reduction in both SAIDI and EENS by 34 % and 32 % respectively by using ADAS as shown in Fig. 8. This is observed through the reduction in reliability indices. So, this will directly lead to the improvement of the reliability level of the investigated distribution network, increase customer satisfaction, reducing system interruption cost for various load categories (residential, commercial, industrial and so on) by quick restoration of service and reducing penalties and achieve incentives offered by regulators.

Table 2. Results summary of load point indices for non-automated and automated distribution network

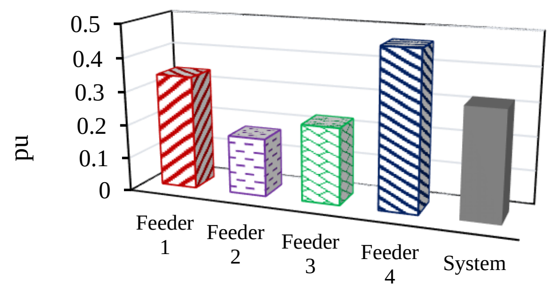
LP	Feeder	Non-automated			Automated		
		r (hr)	U (hr/yr)	EENSI (MWhr/yr)	r (hr)	U (hr/yr)	EENSI (MWhr/yr)
1	#1	4.744	1.108	0.148	3.029	0.707	0.094
2	#1	4.916	1.157	0.284	3.214	0.757	0.186
3	#1	4.826	1.131	0.303	3.117	0.731	0.196
4	#1	5.023	1.188	0.172	3.330	0.788	0.114
5	#1	4.934	1.162	0.081	3.234	0.762	0.053
6	#1	6.035	1.500	0.045	4.424	1.100	0.033
7	#1	4.726	1.131	0.056	3.009	0.702	0.035
8	#1	4.826	1.188	0.101	3.117	0.731	0.065
9	#1	5.023	1.167	0.083	3.330	0.788	0.055
10	#1	4.735	1.105	0.077	3.019	0.705	0.049
11	#1	5.049	1.196	0.153	3.359	0.796	0.102
12	#1	5.995	1.487	0.156	4.381	1.087	0.114
13	#1	4.853	1.139	0.186	3.146	0.738	0.121
14	#2	7.934	0.860	0.292	6.491	0.704	0.239
15	#2	8.213	0.904	0.360	6.792	0.748	0.298
16	#2	8.196	0.902	0.252	6.775	0.745	0.208
17	#2	8.309	0.920	0.047	6.896	0.763	0.039
18	#2	8.530	0.956	0.227	7.135	0.800	0.190
19	#2	8.180	0.899	0.355	6.757	0.743	0.293
20	#2	8.066	0.881	0.095	6.634	0.724	0.078
21	#2	8.196	0.902	0.230	6.775	0.745	0.190
22	#3	5.875	0.961	0.211	4.257	0.696	0.153
23	#3	5.998	0.987	0.073	4.389	0.722	0.053
24	#3	6.309	1.054	0.135	4.725	0.790	0.101
25	#3	6.438	1.083	0.048	4.864	0.818	0.036
26	#3	7.013	1.215	0.389	5.486	0.951	0.304
27	#3	7.013	1.215	0.112	5.486	0.951	0.087
28	#3	6.610	1.122	0.103	5.051	0.857	0.079
29	#3	5.924	0.971	0.618	4.310	0.706	0.449
30	#3	6.747	1.153	0.101	5.198	0.888	0.078
31	#3	6.022	0.992	0.045	4.415	0.727	0.033
32	#3	8.204	1.517	0.194	6.773	1.252	0.160
33	#3	10.35	2.177	0.279	9.09	1.913	0.245
34	#4	5.403	1.444	0.252	2.914	0.779	0.136
35	#4	5.169	1.366	0.190	2.652	0.701	0.098
36	#4	5.326	1.418	0.238	2.828	0.753	0.127
37	#4	5.224	1.384	0.145	2.714	0.719	0.075
38	#4	5.232	1.387	0.371	2.723	0.722	0.193
39	#4	5.380	1.436	0.460	2.888	0.771	0.247
40	#4	5.224	1.384	0.169	2.714	0.719	0.088
41	#4	5.411	1.447	0.296	2.923	0.782	0.160
42	#4	5.240	1.390	0.193	2.732	0.724	0.101
43	#4	4.405	1.165	0.149	2.661	0.704	0.090
44	#4	5.326	1.418	0.149	2.828	0.753	0.079
45	#4	5.341	1.423	0.198	2.845	0.758	0.106
46	#4	5.318	1.416	0.085	2.819	0.750	0.045
47	#4	5.310	1.413	0.091	2.810	0.748	0.048
48	#4	5.310	1.413	0.197	2.810	0.748	0.104

Table 3. Comparison between system reliability indices for non-automated and automated distribution network

Operating philosophy	Feeder	SAIDI (hr/yr)	SAIFI (int/yr)	CAIDI (hr/int)	EENS (MWh r/yr)
Non-automated	Feeder 1	1.20	0.24	5.08	1.85
	Feeder 2	0.91	0.11	8.23	1.86
	Feeder 3	1.22	0.17	7.04	2.31
	Feeder 4	1.40	0.26	5.37	3.18
	System	1.20	0.21	5.86	9.19
Automated	Feeder 1	0.80	0.24	3.37	1.22
	Feeder 2	0.75	0.11	6.81	1.53
	Feeder 3	0.96	0.17	5.52	1.78
	Feeder 4	0.75	0.26	2.86	1.7
	System	0.79	0.21	3.87	6.23



(a) Effect of distribution automation on SAIDI



(b) Effect of distribution automation on EENS

Fig. 8. Reduction in SAIDI and EENS with ADAS

V. CONCLUSIONS

The growing importance of ADAS and its expected benefits on the operation of distribution systems encourage the investigation of this subject. The results show that the determination of the generic strategy for ADAS will avoid the huge investment toward a complete vision of smarter distribution systems. Following the proposed implemented ADAS strategy, FLISR application has been implemented on real, urban, underground 11 kV distribution network based on local-centralized architecture. From the investigation, the presented architecture is defined as a cost-effective solution with the existing network. The results of reliability analysis for both automated and non-automated distribution network are evaluated and compared. It is concluded that the automated network with the proposed ADAS has a tangible benefit through considerable reduction in load point indices. Along with the same line, the system indices such as SAIDI and EENS exhibit a significant reduction by 34 % and 32 %, respectively. In addition, the proposed ADAS provides an intangible benefits observed by grater customer satisfaction and reduced penalties by industry regulators through the reduction of the outage time and outage cost.

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DG- Allocation Based on Reliability, Losses, and Voltage Sag Considerations – An Expert System Approach

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Abstract - Expert System (ES) as a branch of Artificial Intelligence (AI) methodology can potentially help in solving complicated power system problems. This may be more appropriate methodology than conventional optimization techniques when contradiction between objectives appears in reaching the optimum solution. When this contradiction is the hindrance in reaching the required system operation through the application of traditional methods ES can give a hand in such case.

In this paper, the knowledge- based ES technique is proposed to reach near-optimum solution which is further directed to the optimum solution through particle swarm optimization (PSO) technique. This idea is known as Hybrid-Expert-System (HES). The proposed idea is used in getting the optimum allocation of a number of distributed generation (DG) units on Distribution System (DS) busbars taking into consideration three issues; reliability, voltage sag, and line losses. Optimality is assessed on the economic basis by calculating money benefits (or losses) resulting from DG addition considering the three aforementioned issues. The effectiveness of the proposed technique is ascertained through example.

Keywords – Expert system; Artificial Intelligence; particle swarm optimizatiom; Hybrid Expert System; Disteributed generation; reliability; voltage sag.

I. INTRODUCTION

The problem of optimum allocation of DG units is one of the most challenging problems emerged since the advent of DG technology in DS. This is due to the inherent characteristics of the electric power systems with their contradicting behavior. As an example, raising the generating capacity of the grid may lead to improving voltage sag phenomenon at some busbars and -at the same time- impairing this phenomenon at other busbars. Another example is the case when seeking at getting the optimum placing of a number of DG units which minimizes the overall transmission losses. This placing may not achieve the required reliability level, or, at least does not verify the best possible reliability indices. Many other contradictions are found among grid operation, control, and protection. Although most of literature about the problem of DG allocation deal with radial systems which are relatively simple [1-5]. The problem is still complex and needs some assumptions to simplify the solution. In many cases these assumptions limit the usability of the suggested methods and the benefit gained from them. On the other hand few authors consider ring and interconnected systems which add more complexity to the problem [6].

It becomes an agreement among all authors that the Artificial Intelligence (AI) techniques are the only suitable methods for solving the problem of optimum DG allocation. Conventional optimization techniques cannot be applied because of the non-convexity of the objective function and the different nature of the problem variables which contain electrical, statistical, and economical variables. However the common drawback in most of the AI optimization methods is that these methods do not have a robust algorithm which assures that the solution is the absolute minimum (the least value) in case of minimization problem. This is similar to the case of nonconvex objective function in conventional optimization.

This paper suggests utilizing Hybrid Expert System (HES) for improving and accelerating the solution of optimum DG allocation either by conventional optimization methods or by AI techniques. ES is not an optimization technique rather than it helps in getting adequate and quick pragmatic answers for problems that defy effective solution. In the present work a rule chain containing heuristic rules is adopted to help in getting a “near optimum” DG allocation.

This solution can be used as a starting population in the PSO methods which helps in reducing number of iterations and gives better results.

II. NOMENCLATURE

NS: Total number of busbars in the grid.
ND: Number of DG units.
TLL: Total power losses in grid lines, in p.u. kW.
CK: Cost of p.u. kWh loss in grid lines.
8760: Average number of hours per year.
CL: Total annual line loss cost of the grid, $.
CVS(j-k): Voltage of busbar #j when S.C. occurs on busbar #k.
NV(k): Estimated number of S.C. on bus #k, per year.
F(j): Loss cost from load isolation resulting from voltage sag or from forced outage at bus #j in p.u. kW.
R(k): Availability of busbar k.
VC(j): Critical trip voltage at busbar #j due to voltage sag.
VS(j): Voltage at busbar #j during S.C..
CS: Total annual loss cost due to voltage sags, $.
CT: Total annual cost in the grid due to line losses and voltage sags, $.
V_i, V_j: Voltages of busbars #i, j resulting from load flow solution.
V_i*, Vj* Conjugates of , respectively.
y_i: Series admittance of line between busbars i and j.
yij: Shunt admittance of line between busbars i and j.
R, X: Series resistance and reactance of line respectively, in p.u..
P_i, Q_i: Active and reactive net injected power at busbar #i, in p.u.
P_{ij}: Real power transmitted by line i-j.

III. PROBLEM FORMULATION

The problem can be stated as follows: "It is required to get the best possible allocation of a number of DG units at busbars of a DS taking into consideration three factors; line power losses, voltage sag and reliability".
As a common practice, the objective function of the problem is derived on the form of cost function of loss costs of the followings:

1. Loss cost due to transmission power loss (CL). This cost reduces by reducing transmission line power loss.

2. Loss cost due to load isolation by undervoltage protection resulting from S.C. occurring somewhere at any busbar in the DS (CV). This cost may be reduced by minimizing the effect of S.C. occurring at one busbar on the transient voltage drops at other DS busbars.

3. Loss cost due to load interruption (CR). This can be minimized by maximizing the reliability indices at the grid loads.

Mathematically, the problem can be written as:

$$\text{Minimize } CT = CL + CS + CR \tag{1}$$

Subject to

$$V_{i\min} \le V_i \le V_{i\max} \ \ where;\ i \forall NS \tag{2}$$

$$P_{ij} \le P_{ij\max} \ \ where;\ i, j \forall NS \tag{3}$$

Conceptually, the calculation of CT is based on the following functions:

4. Load flow: this function uses any traditional method such as Newton-Raphson and Gauss-Seidel methods from which TLL is calculated. DG are modelled as PQ busses. Hence, the first part of equation (1) is calculated as follows;

$$CL = (TLL) \bullet (Ck) \bullet 8760 \tag{4}$$

5. Voltage sag: this function determines the grid buses which will be tripped by undervoltage relays when a three-phase S.C. occurs on one bus in the grid. This is calculated for S.C. on all buses, one at a time. Expected loss cost due to voltage sags is calculated as:

$$CS = \sum_{k=1}^{NS} \sum_{j=1}^{NS} CVS(j-k) \tag{5}$$

$$CVS(j-k) = NS(k) \bullet A(j) \tag{6}$$

Where;

$$\begin{aligned} A(j) &= F(j) \bullet PL(j) \quad && if\ VS(j) \le VC(j) \\ A(j) &= 0 && if\ VS(j) > VC(j) \end{aligned} \tag{7}$$

6. Reliability; Reliability assessment in radial DS is relavively simple as load connected to any bus requires that all components from the supply point be avaliable. However, this concept cannot be applied to the case when both main substation and DG feed the grid at the same time as the grid becomes no longer radial. For this reason, most of researchers assume one DG only for reliability assement and allows the DG operate independently (island) where the main power is not present [7,8].

However, two issues have to be considered in order to simulate practical requirements. These are:

1. Some distribution grids are fed from more than one point. This makes the grid as ring or even interconnected configuration.

2. It is essential to evaluate the reliability indices at load points considering both DG units and main supply feeding the grid at the same time. This represents most of practical applications.

The two aforementioned issues violate the condition of series reliability and draw attention to the importance of reliability evaluation of ring and interconnected systems. In the present work, reliability of ring and interconnected network is calculated following the method suggested in [9]. Cost of load interruptions resulting from forced outage of any component in the DS is calculated as

$$CR = \sum_{k=1}^{k=N} \{(1 - R(k)) \bullet PL(k) \bullet F(k) \qquad (8)$$

IV. HYBRID EXPERT SYSTEM

Rule-Based Expert System is a branch of Artificial Intelligent system created to solve problems in a particular domain. It has been developed to assist in finding pragmatic answers for problems that defy effective solution [10]. All knowledge in an ES is provided by people who are experts in that domain. ES may contain heuristic rules which differ from other rules in that, they are not formulated as a result of ordinary accepted knowledge but are rules that only an expert would know. In general, to create an ES a team consisting of expert and knowledge engineer gathers the facts, rules and heuristic rules for a domain and organizes them into an AI program. The same problem may find different solutions according to the ES used in this program [11].

As a matter of fact, not all problems can be or should be solved by mean of an ES. Further, even among those solution by ES is appropriate, the results found may be marginally accepted. In this paper we suggest HES to improve results and reduce the calculation effort. The proposed methodology utilizes ES first to get- near optimum- solution to the problem under study, then this solution is considered as the initial population for the PSO method. In this work, a rule chain containing three heuristic rules is adopted to help in getting near-optimum solution for the DG units allocation which can be taken as starting populations in the PSO technique. These are:

Rule #1

IF	Node has high load and it is connected with high resistance lines.
THEN	Begin with this node for DG installation for loss minimization.

Rule #2

IF	The cost of load tripping at the node is high and the load is critical.
THEN	Installation of DG at this node has the second preference.

Rule #3

IF	The grid is highly interconnected.
THEN	The issue of reliability has less importance in DG allocation.

V. PARTICLE SWARM OPTIMIZATION

PSO is a branch of AI systems emerged in the last three decades as an efficient method of optimization [12]. It is characterized as a population of random space. A particle's location in the multidimensional problem space represents one solution for the problem. When a particle moves to a new location, a different problem solution is generated. This solution is evaluated by fitness function that provides a quantitative value for the solution's utility.

The velocity and direction of each particle moving along each dimension of the problem space will be altered with each generation of movement. In combination, the particle's personal experience and its neighbors' experience influence the movement of each particle through a problem [13].

VI. CASE STUDY

The proposed problem structure was tested on the IEEE 14-bus system given in [14]. Table I contains the system lines and loads raw data

Table 1. system raw data

Line	R	X	Line Avaliability	Node	PLoad	QLoad	Node Avaliability
1-2	0.01938	0.05917	0.951	1	0	0	1
1-5	0.05403	0.22304	0.98	2	0	0	1
2-3	0.04699	0.19797	0.94	3	-0.942	0	0.945
2-4	0.05811	0.17632	0.98	4	-0.478	0.039	0.986
2-5	0.05695	0.17388	0.99	5	-0.076	-0.016	0.991
3-4	0.06701	0.17103	0.99	6	-0.112	0	0.999
4-5	0.01335	0.04211	0.995	7	0	0	0.982
4-7	0	0.20912	0.98	8	0	0	0.963
4-9	0	0.55618	0.98	9	-0.295	0.046	0.963
5-6	0	0.25202	0.995	10	-0.09	-0.058	0.962
6-11	0.09498	0.19890	0.98	11	-0.035	-0.018	0.999
6-12	0.12241	0.25581	0.995	12	-0.061	-0.016	0.999
6-13	0.06615	0.13027	0.995	13	-0.135	-0.058	0.998
7-8	0	0.17615	0.98	14	-0.149	-0.05	0.963
7-9	0	0.11001	0.98				
9-10	0.03138	0.08450	0.99				
9-14	0.12711	0.27038	0.995				
10-11	0.08205	0.19207	0.99				
12-13	0.22092	0.19988	0.94				
13-14	0.17093	0.34802	0.98				

The system contains five generators. The first one which is the slack generator is connected on busbar 1. The second one is fixed on busbar 2. We are seeking at getting the optimum allocation for 3 DG units (G3, G4 & G5) each of 0.1 p.u. power output and 0.1 p.u. reactance, on three busbars of the grid which minimizes the value of CT. Table II shows the DGs data in p.u.

Table 2. Generators data

	G1 (Slack)	G2	G3	G4	G5
Voltage Magnitude	1.06	1.04	1.01	1.07	1.09
Rated Power	-	0.183	0.1	0.1	0.1
Reactance	0+0.02i	0+0.1i	0+0.1i	0+0.1i	0+0.1i

Data needed for the problem solution are as follows;

$NS = 14$, $ND = 3$, $Ck = \$0.5$, $VC(j) = 0.8\ p.u.$

for all buses. Values of F(i) and NS(i) are given in table 3.

Table 3. Values of F(i) and Ns(i)

Busbars #i	NS(i)	F(i)
1	0.03	75000
2	0.09	12000
3	0.05	12000
4	0.09	60000
5	0.09	60000
6	0.9	75000
7	0.06	12000
8	0.7	12000
9	0.09	50000
10	0.08	60000
11	0.09	50000
12	0.09	12000
13	0.09	50000
14	0.03	75000

Following the steps of solution described in section III and applying the PSO method described in section IV results given in table III are obtained. The starting random allocation of DG units consists of busbars 12, 13, and 14. Solution can be accelerated when the three heuristic rules of the ES is applied. Rule #1 recommends starting with node #8, rule #2 recommends node #8 hence node #12 followed by node 14. Rule #3 recommends node #9. Combining the three ES rules suggests starting population consisting of nodes 8, 9, and 12 which reduces the number of PSO iterations from 34 to 9 iterations only.

Table 4. Results of the case study

Iteration Number	Generators Distribution					Line Losses
	G1	G2	G3	G4	G5	
1	1	2	12	13	14	0.13451+0.44637i
2	1	2	11	12	13	0.12426+0.43931i
3	1	2	9	10	14	0.13739+0.48425i
4	1	2	10	12	13	0.11837+0.42714i
5	1	2	11	12	14	0.11911+0.42988i
6	1	2	8	12	13	0.11427+0.42553i
7	1	2	9	10	12	0.12897+0.46042i
8	1	2	10	11	12	0.11876+0.42963i
9	1	2	9	10	11	0.12804+0.46105i
10	1	2	8	11	12	0.11099+0.41879i
11	1	2	10	11	13	0.11797+0.43456i
12	1	2	11	13	14	0.11838+0.42846i
13	1	2	9	10	13	0.12768+0.46575i
14	1	2	9	12	14	0.12116+0.43572i
15	1	2	9	12	13	0.11859+0.42843i
16	1	2	10	11	14	0.12326+0.44395i
17	1	2	8	11	13	0.10912+0.42089i
18	1	2	10	12	14	0.11741+0.42666i
19	1	2	9	13	14	0.11975+0.43336i
20	1	2	8	10	12	0.10918+0.42021i
21	1	2	9	11	12	0.11654+0.42447i
22	1	2	8	12	14	0.11002+0.4198i
23	1	2	10	13	14	0.11619+0.42454i
24	1	2	9	11	14	0.12445+0.44704i
25	1	2	8	10	11	0.11035+0.42422i
26	1	2	8	9	12	0.10749+0.4245i
27	1	2	8	10	13	0.10697+0.42107i
28	1	2	9	11	13	0.11595+0.43049i
29	1	2	8	11	14	0.1092+0.4212i
30	1	2	8	9	10	0.10954+0.43193i
31	1	2	8	9	11	0.10805+0.42773i
32	1	2	8	10	14	0.10774+0.42167i
33	1	2	8	9	13	0.10574+0.42463i
34	1	2	8	9	14	0.10686+0.42443i

Table 5. Costs of the case study

Iteration Number	Line Losses Cost	Voltage Sag Cost	Unavailability Cost	Total Cost
1	589.1321	116.522	3.005	708.6591
2	544.2604	126.2712	2.734	673.2656
3	601.7814	49.872	4.166	655.8194
4	518.477	116.0267	3.005	637.5087
5	521.6899	112.7459	3.101	637.5368
6	500.4813	132.9739	2.266	635.6142
7	564.8807	61.4675	4.088	630.4362
8	520.1535	105.9278	3.334	629.4153
9	560.8087	64.6447	4.954	630.4074
10	486.1372	134.815	2.232	623.1842
11	516.729	99.2065	3.678	619.6135
12	518.513	96.9881	3.606	619.1072
13	559.2217	55.1854	4.133	618.5401
14	530.7001	82.372	4.000	617.0727
15	519.4398	91.4309	3.824	614.6947
16	539.8922	66.5135	5.000	611.4057
17	477.9535	128.2474	2.629	608.8299
18	514.2624	91.4699	3.023	608.7553
19	524.4897	78.9075	3.998	607.3952
20	478.1931	121.2071	2.999	602.3992
21	510.4279	88.8656	3.862	603.1555
22	481.8692	116.8675	3.988	602.7247
23	508.9287	87.0806	3.988	599.9972
24	545.1025	49.8114	4.135	599.0489
25	483.3392	108.0512	3.001	594.3914
26	470.8275	96.8246	3.023	570.6751
27	468.5132	98.0881	3.201	569.8024
28	507.882	56.3075	4.097	568.2866
29	478.29	74.1125	4.001	556.4035
30	479.7864	65.5598	4.999	550.3451
31	473.2767	67.4876	4.001	544.7653
32	471.8799	68.2468	4.000	544.1267
33	463.1405	64.987	4.923	533.0505
34	468.0572	59.3839	4.096	531.5371

VII. DISSCUSSION

This paper is based mainly on economical consideration when dealing with DG allocation on DS busbars. The main conclusions which can be extracted from the present work are:

- Cost of line losses has the maximum value among the three costs (line losses- voltage sag-unavailability).
- Cost of load isolation due to voltage sag has tangible value and should not be ignored in economic studies.
- Cost of loss of supply to loads due to forced outage of network component has minor effect in case of ring and interconnected distribution networks. However this cost cannot be ignored in case of radial systems.
- HES can greatly reduce the number of iterations and calculation effort in PSO application.
- Generally, there is an inverse trend between line loss and voltage sag costs.

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Harmonics Monitoring Survey on LED Lamps

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Abstract - Light Emitting Diode (LED) lamps are being increasingly used in many applications. These LED lamps operate using a driver, which is a switching device. Hence, LED lamps will be a source of harmonics in the power system. These harmonics if not well treated, may cause severe performance and operational problems. In this paper, harmonics (amplitude and phase angles) generated by both LED lamps and conventional fluorescent lamps will be studied practically. Then they will be analyzed and evaluated. Compared to each other harmonics generated by both LED and conventional florescent lamps, self mitigation may occur based on the phase angle of these harmonics. All data will be measured using power analyzer and will be done on a sample of actual lamps.

Keywords — LED lighting; harmonics; power quality; conventional lighting;

I. INTRODUCTION

Recently, the LED technology is being applied in modern light sources which are now widely used in the lighting industry. They replace traditional bulbs, halogens, and fluorescent light sources for indoor lighting [1]. They are also used for outdoor lighting, building decoration, and vehicles applications. The main purpose of using LED lamps is energy saving because of their low energy consumption and overall efficiency augmentation [2].

Energy saving lamps due to their non-linear characteristics, inject harmonic currents into the network [3]. This may be a problem because, for a very high penetration level of these types of lamps, the overall voltage harmonic distortion may increase considerably [4]. LED lamps are modern technology hence; they may replace conventional light lamps for reasons of power quality improving [5]. In [6], a power quality (PQ) study on various number of LED lamps showed that they could damp the overall harmonics injected in the distribution network. Compared to other light sources a better improved THD could be achieved by mixing various light sources. Since LED lamps could mitigate each other harmonics, various types of light sources could also do the same.

In this paper, different types of lamps will be studied and their power quality will be analyzed. In section two, a LED lamps advantages and disadvantages will be illustrated. While, in section three, power quality was defined. Practical PQ results for different types of lamps were presented in section four. Finally, the conclusions and future work.

II. LED LAMPS

LED lamps have the potential to play a major role in developing commercial, residential, and public buildings just as compact fluorescent lamps (CFLs) did three decades ago. That's because LED lamps obviously offer great energy saving potential. For some LED lamps, their efficacies already exceed 100 lumens per watt.

LED lamps are much more complex than incandescent lamps. The main difference between both lamps is that LEDs requires direct current (DC) in order to operate which is supplied through power electronics driver, rather than the resistive incandescent filament which is a different type of load that operates on alternating current (AC). The LEDs' driver must convert AC to DC and decrease the voltage to more adequate level. There is also a phenomenon called "latency" which represents another difference between both LED and incandescent lamps. For the incandescent lamps, light is maintained for some period of time after the feed-in current is being cut. That's because the incandescent filaments do not cool down instantly. On the other hand, LEDs react very quickly to even small variations in current, also phosphor-converted or remote phosphor LEDs tend to have very small latency.

A. Advantages of LED Lighting

- LED lamps can be finely tuned to produce a wide range of color temperatures by mixing different colored LED chips in the same array. Incandescent and halogen lamps typically provide light with a color temperature in the range from 2600k to 3000k (2700k is the most common) while, LEDs generally have color temperature ranging from 2700k up to 6000k or higher.
- LEDs efficacy is being improved quickly.
- Dimmers are being used in the majority of LED bulbs.
- While, incandescent lamps have an average lifetime between 1000 and 2000 hours, most of LED Lamps have an average lifetime of over 35000 hours and a warranty of 5 years.
- LEDs do not tend to fail suddenly (as an incandescent lamp does), but instead their light output slowly decrease.
- Many LED lamps have almost no warm-up delay, while most of them turn on instantly at full brightness. This advantage is in corresponding to particular lamps such as fluorescent high intensity discharge, and high pressure sodium, which in order to reach full brightness consume time from a few seconds to several minutes.
- LED illumination has small amount of infrared and almost no ultraviolet emissions.
- LED lights can be dimmed which offers a flexible control, color, and distribution.
- LED lights can be switched on and off frequently without negatively affecting their lifetime of light emission.
- LED lights are still more expensive than CFL lights, but they are far less expensive than they were year ago.
- LEDs operate silently with no annoying flickering noises.
- LEDs provide a range of various colors for different applications and purposes.

The major and mandatory advantage of LEDs is the huge reduction in energy consumption they offer when replacing traditional lighting.

B. Disadvantages of LED Lighting

- LEDs do not concentrate a “point source” of light, hence they cannot be used in applications that requires highly collimated beam.
- On an initial capital cost basis, LEDs are currently more expensive than conventional lighting technologies.
- LEDs must be supplied with certain current value which requires applying series resistors or current-regulated power supplies.

III. POWER QUALITY ANALYSIS

A power quality (PQ) analysis has been performed by comparing the different luminaries' performance. According to [7] and [8]:

Current harmonic distortion is a phenomenon arising from the operation of non-linear loads, which is caused by non-sinusoidal waveforms accompanied to sinusoidal wave with frequencies of integral multiples of the source frequency
The total harmonic distortion (THD) is a measurement of the harmonic distortion value and it is defined as the ratio of the sum of all harmonic components' powers to the fundamental's power. and it is defined for current and voltage respectively as follow [9]:

$$THD_i = \sqrt{\sum_{h=2}^{h=H} \left(\frac{I_h}{I_1}\right)^2} \qquad (1)$$

$$THD_u = \sqrt{\sum_{h=2}^{h=H} \left(\frac{U_h}{U_1}\right)^2} \qquad (2)$$

Where:

I_h = individual harmonic current
U_h = individual harmonic voltage

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I_1 = Fundamental current
U_1 = Fundamental voltage
h = order of harmonics

Power factor (PF) represents the ratio of the average power converted by the device -real power- and the maximum average power that may be converted -apparent power- considering the same rms values of current and voltage. PF could be considered an indicator for the quality of the energy conversion.

A. Harmonics Emission Standard

Harmonic emission of individual lamps is restricted by the standard IEC 61000-3-2 [7]. Limitation are classified into two categories:

- Lamps with an active input ≤ 25 w
- Lamps with an active input > 25 w

Lamps with an active power ≤ 25 w have a higher margin for harmonic current in percentage. It is assumed that a large number of smaller lamps will emit less harmonic currents than a small number of bigger lamps. Table (1) shows the limited harmonic current of lighting equipments according to the mentioned standard (for P > 25 w).

B. *Recommended values for displacement factor*

The recommended values for displacement PF is presented by the standard IEC 62612-2013 [8]. Table (2) summarizes these values.

Table 1. LIMITS OF HARMONIC CURRENT OF LIGHTING EQUIPMENT ACCORDING TO IEC61000-3-2

Harmonic order (h)	Maximum harmonic current permitted (calculated in % compared to fundamental magnitude)
2	2
3	30*(power factor)
5	10
7	7
9	5
11< h≤ 39 (odd only)	3

Table 2. LED LAMP POWER FACTOR FOR LAMPS WITH INTEGRATED CONTROL GEAR

Power	Power Factor (PF)
P ≤ 2 w	No requirement
2 w < P ≤ 5 w	≥ 0.4
5 w < P ≤ 25 w	≥ 0.7
P > 25 w	≥ 0.9

IV. EXPERIMENTAL TESTS ON LED LIGHTS

Luminaries are generally nonlinear loads connected to the low voltage AC distribution network. Some kind of light sources, like fluorescent lamps and LEDs, require a power supply system (ballast or driver) to interface them with the electric network. Generally, the current waveform contains some amount of distortion, depending on the luminaries' technology.

A. Case Study (A)

The experimental tests, carried by the energy analyzer, have been performed on different kinds of indoor luminaries:

- LED bulbs
- LED Tubes
- LED Panels

The results of the power quality (PQ) analysis for the previous three types of lamps are presented in tables (3), (4), (5), and (6) respectively. Tables (3) and (4) shows the results of studying 12 samples of light bulbs.

Table 3. PQ ANALYSIS FOR LED BULBS (1)

Sample No.	1	2	3	4	5	6
Rated Power (w)	12	10	9	9	9	9
Measured Power (w)	11.5	9.1	10	7.9	8.9	9.2
PF	0.567	0.927	0.937	0.954	0.979	0.932
V_{rms} (V)	219.9	219.8	220	220.1	220	220
THD_V (%)	2	2.4	1.1	1.4	2.1	2.1
I_{rms} (A)	0.093	0.045	0.048	0.038	0.041	0.045
THD_I (%)	122.5	22.6	21.9	18.0	15.1	22.7
I_3 %	81.6	17.1	16.4	15.6	6.5	15.4
I_5 %	55.9	11.1	8.8	3.1	10.7	11.6
I_7 %	39	6.4	8.5	4.2	6.1	7.8
I_9 %	34.5	2.9	5.2	3.1	3.7	4.8
I_{11} %	30.5	4.0	3.1	4.0	1.7	1.9

Table 4. PQ ANALYSIS FOR LED BULBS (2)

Sample No.	7	8	9	10	11	12
Rated Power (w)	9	6	6	5	4	3
Measured Power (w)	8.9	6.3	5.9	5.1	4.0	1.6
PF	0.955	0.917	0.663	0.437	0.541	0.109
V_{rms} (V)	220.1	220.9	218.9	220	220.2	220.2
THD_V (%)	2.2	1.3	1.4	1.2	0.7	1.3
I_{rms} (A)	0.042	0.031	0.041	0.053	0.033	0.067
THD_I (%)	20.5	24.5	60.8	63.0	137.7	19.3
I_3 %	18.2	18.3	50.1	44.2	87.3	10.3
I_5 %	5	10.8	25.1	27.6	73.3	7.8
I_7 %	2	9.3	15.2	20.2	54.9	8.5
I_9 %	2.5	3.9	10.7	13.2	38.4	1.8
I_{11} %	2.8	3.2	10.1	3.5	25.1	4.1

Table 5. PQ ANALYSIS FOR LED TUBES

Sample No.	1 (120 cm)	2 (120 cm)	3 (60 cm)	4 (60 cm)
Rated Power (w)	18	18	10	9
Measured Power (w)	18	16.8	9.9	8.8
PF	0.947	0.906	0.927	0.966
V_{rms} (V)	220.1	220	220.2	220.2
THD_V (%)	2.1	1.2	2.3	1.2
I_{rms} (A)	0.086	0.084	0.048	0.041
THD_I (%)	20.2	43.6	22.1	16.1
I_3 %	14.6	19.8	14.0	8.8
I_5 %	9.6	11.3	11.1	7.5
I_7 %	8.2	31.7	10.6	6.4
I_9 %	4.1	10.5	3.6	5.6
I_{11} %	2.6	7.0	2.1	3.4

Table 6. PQ ANALYSIS FOR LED PANELS (60×60)

Sample No.	1	2	3	4
Rated Power (w)	42	42	32	32
Measured Power (w)	43.3	41.3	31.4	31.6
PF	0.953	0.973	0.927	0.929
V_{rms} (V)	220.3	220.9	220.2	220.6
THD_V (%)	1.3	1.2	3.1	1.1
I_{rms} (A)	0.208	0.192	0.154	0.153
THD_I (%)	15.9	11.8	12	10.5
I_3 %	14.5	10.8	8.5	8.1
I_5 %	3.6	3.4	5.8	3.9
I_7 %	1.1	1.4	1.1	1.3
I_9 %	2.2	1.8	3.6	3.5
I_{11} %	2.1	1.1	2.4	1.9

From Tables (3), (4), (5), and (6) the PQ analysis has led to these considerations:

1. The THDV is only related to the harmonic background already existing into the grid. All values are in complying with IEC standard limits (< 5%).

2. Most of PF values are almost close to the unit value, which means that fundamental voltage and current have a small phase shift. Hence, current harmonics do not have a strong impact on the quality of the energy conversion [2].

3. PF in samples 1 & 12 -in Tables (3), (4) - are not accepted according to IEC standard limits. Shown in Figs. (1), (2)

4. In samples 1 & 11 -in Tables (3), (4) - the current waveforms are affected by distortion, while voltage is almost sinusoidal, as indicated by THD indices and waveforms in Figs. (1), (3).

5. Fig. (4), (5) for waveforms of sample 4 & 2 in Table (5) & Fig. (6) for sample 3 in Table (6), they all contain current harmonics.

6. Individual current harmonics I3, I5, I7, I9, I11 are dominated.

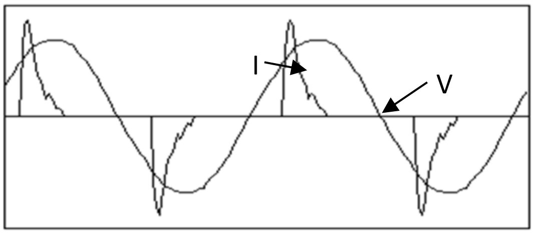

Fig .1. LED bulb 12 w

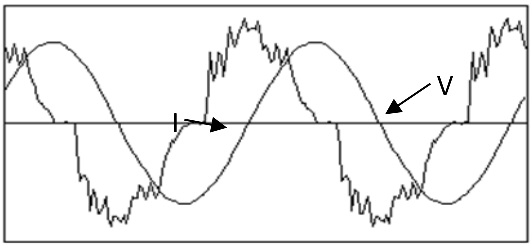

Fig .2. LED candle 3 w

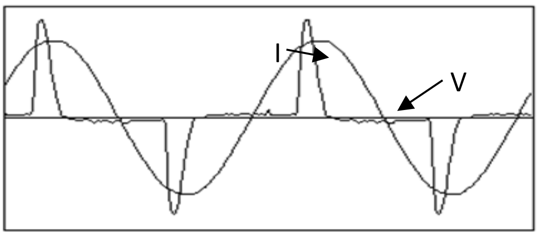

Fig .3. LED candle 4 w

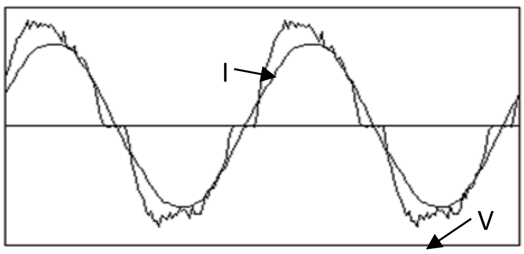

Fig .4. LED tube 9 w

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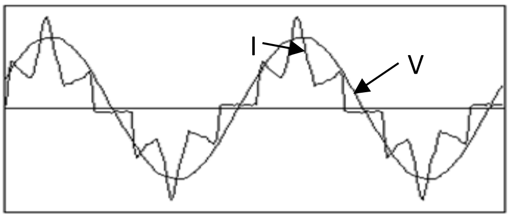

Fig .5. LED tube 18 w

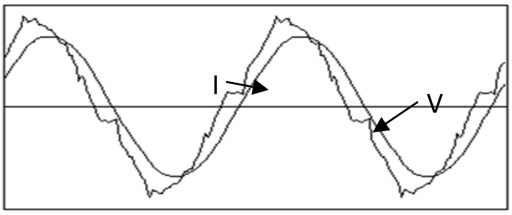

Fig .6. LED panel (60×60) 32 w

B. *Case Study(B)*

Power quality analyzer model HIOKI 3196 has been used in this step of testing in order to measure both magnitude and angle for each harmonic order. It is anticipated that if the same harmonic order generated by various electric equipments has different phase angle, it may be self mitigated. Hence, various types of lamps were tested in order to prove this hypothesis. The lamps' samples that have been tested were as follow:

- LED 18w Tube 120 cm
- 40w fluorescent lamp with electronic ballast
- 40w fluorescent lamp with magnetic ballast
- LED bulb 9w
- CFL 26w

In Table (7) PQ test results for these 5 samples are shown.

The following figures show the magnitude and angle for each harmonic order tabulated in complex form for all the samples. In Fig. (7) the 3rd harmonic for 4 samples is shown and because CFL 26w lamp has the largest level of harmonics it was excluded from the charts in order to give adequate space for the other samples to be shown clearly. In Fig. (8) the 5th harmonic for 4 samples are shown. For Figs. (9), (10), and (11) there are not homogenous distribution for the five samples although in Fig. (11), the 11th harmonic of both magnetic and electronic ballast will mitigate each other.

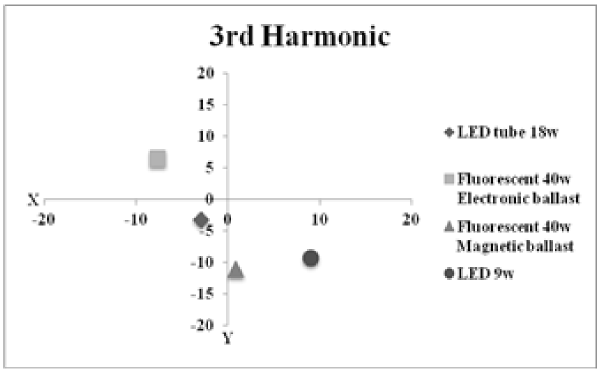

Fig .7. 3rd Harmonic of Current

Table 7. PQ ANALYSIS FOR VARIOUS LAMPS

Sample No.	1	2	3	4	5
Rated Power (w)	18	40	40	9	26
Measured Power (w)	18	36.00	49.5	8.10	11
PF	-0.95	-	-	-0.76	-0.59
V_{rms} (V)	225.23 0	224.48	225.72	211.28	211.15
THD_V (%)	2.720	2.78	2.02	2.73	2.73
I_{rms} (A)	0.082	0.16	0.22	0.05	0.09
THD_I (%)	13.640	14.66	11.18	16.88	116.08
I_3 %	4.42	9.68	11.03	13.00	73.64
Phase I_3	- 132.23	141.76	-85.3	-45.74	- 152.58
I_5 %	8.23	5.88	0.94	6.52	42.63
Phase I_5	56.82	66.55	69.71	120.44	-52.41
I_7 %	7.28	6.68	0.7	2.18	37.01
Phase I_7	120.85	125.73	43.37	125.90	-9.84
I_9 %	4.78	4.47	0.33	3.78	40.22
Phase I_9	13.03	-32.96	131.86	52.30	67.83
I_{11} %	1.30	2.88	0.29	2.02	33.05
Phase I_{11}	-95.06	79.39	-52.61	- 104.38	166.57

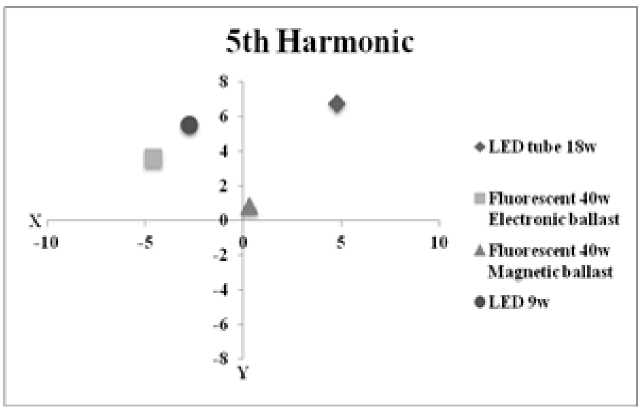

Fig .8. 5th Harmonic of Current

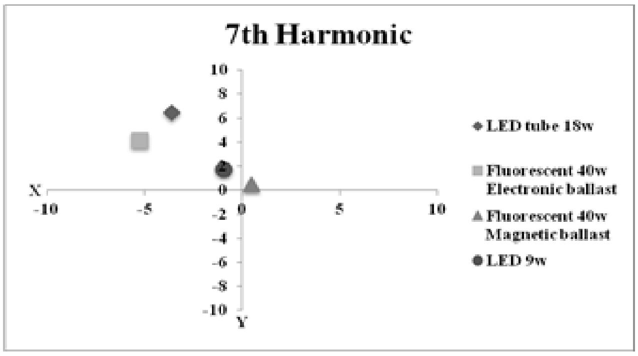

Fig .9. 7th Harmonic of Current

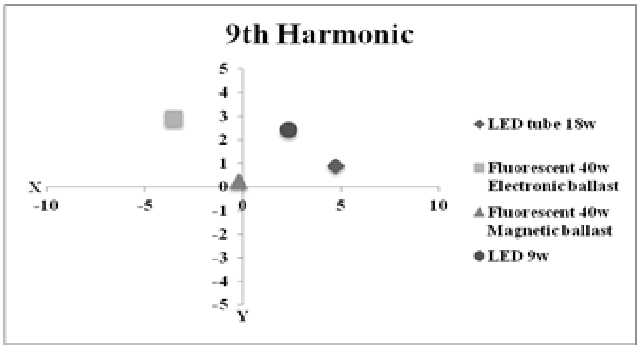

Fig .10. 9th Harmonic of Current

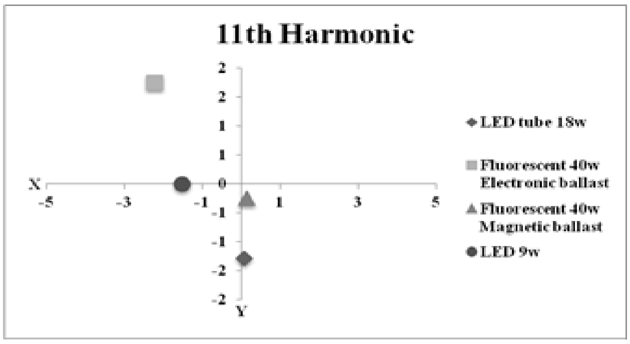

Fig .11. 11th Harmonic of Current

From previous figures, I3 for fluorescent lamp with electronic ballast and for LED 9W are in opposite directions. For the other harmonic orders which could not be mitigated completely, various devices could reduce THD in current waveform generated by each other, if they are not pure opposite to each other.

V. CONCLUSION

Harmonics generated by various loads could be a serious problem if not well treated. In this paper an analysis study for different kinds of lamps such as LED, CFL, and fluorescent showed the power quality performance for each type. If the harmonic order of certain types of lamps could be controlled in order to stand up to the one generated from its alternatives, this will certainly reduce the size of the problem. As a future work, these studies could be repeated for a group of lamps in order to investigate the effectiveness of the results of this research.

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Harmonic Analysis of Radial Distribution Systems Embedded Shunt Capacitors

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***Abstract* -** Harmonic analysis is an important application for analysis and design of distribution systems. It is used to quantify the distortion in voltage and current waveforms at various buses for a distribution system. However such analysis has become more and more important since the presence of harmonic-producing equipment is increasing. As harmonics propagate through a system, they result in increased power losses and possible equipment loss-of-life. Further equipments might be damaged by overloads resulting from resonant amplifications. There are a large number of harmonic analysis methods that are in widespread use. The most popular of these are frequency scans, harmonic penetration and harmonic power flow. Current source (or current injection) methods are the most popular forms of such harmonic analyses. These methods make use of the admittance matrix inverse which computationally demand and may be a singular in some cases of radial distributors. Therefore, in this paper, a new fast harmonic load flow method is introduced. The introduced method is designed to save computational time required for the admittance matrix formation used in current injection methods. Also, the introduced method can overcome the singularity problems that appear in the conventional methods. Applying the introduced harmonic load flow method to harmonic polluted distribution systems embedded shunt capacitors which commonly used for losses minimization and voltage enhancement, it is found that the shunt capacitor can maximize or minimize system total harmonic distortion (THD) according to its size and connection point. Therefore, in this paper, a new proposed multi-objective particle swarm optimization "MOPSO" for optimal capacitors placement on harmonic polluted distribution systems has been introduced. The obtained results verify the effectiveness of the introduced MOPSO algorithm for voltage THD minimization, power losses minimization and voltage enhancement of radial distribution systems.

***Keywords* -** Total harmonic distortion, Power losses, Radial distribution systems, Particle swarm optimization, Harmonic load flow and Frequency scan.

I. INTRODUCTION

Harmonic analysis is an important application for distribution systems analysis and design. It is used to quantify the distortion in voltage and current waveforms, which are caused by nonlinear loads, electronically switched loads and converters etc., at various buses for a distribution system, and to determine whether dangerous resonant problem exists and how they might be mitigated. However such analysis has become more and more important since the presence of harmonic-producing equipment is increasing. As harmonics propagate through a system, they result in increased power losses and possible equipment loss-of-life. Further equipments might be damaged by overloads resulting from resonant amplifications [1]-[3].

Distortion in AC voltage and current waveforms can be studied by expressing the harmonic sources of the waveforms as a Fourier series with the fundamental frequency equal to the power frequency. Then, utilizing the harmonic analysis it can investigate the generation and propagation of these components throughout a given distribution systems. Research in this area has led to the availability of fairly general techniques and softwares for the formulations and solutions of harmonic propagation problem. The techniques vary in terms of data requirements, modeling complexity, problem formulation and solution algorithm. In [4]-[6] the frequency-domain was presented to calculate the frequency response of a system. In [7], it was presented a time-domain based transient-state analysis that utilize the EMPT program for harmonic analysis. However, one of the main disadvantages of the time-domain-based method is that the lack of the load flow constraints (such as, constant power specification at load buses) at the fundamental frequency. Recently, the idea of Wavelet Transform is integrated into the harmonic analysis [8], [9], for which system components and power devices need to be derived first and then the harmonic analysis is applied, and hence more computational time is needed.

The conventional harmonic load flow methods use load flow programs, and employing the frequency-based component model, for updating admittance matrix and then rerun the load flow program for each harmonic order. However, the decomposition of the admittance matrix is a time-consuming procedure and it makes the conventional methods difficult for real-time analysis. Furthermore, determination of the buses voltage values needs admittance matrix inverse computation, which in some cases of radial distribution systems is singular. In this paper, fast harmonic load flow method for radial distribution systems, which can overcome the singularity problems without excessive computation time need, is presented. Applying the introduced harmonic load flow method to harmonic polluted distribution systems embedded shunt capacitors which commonly used for losses minimization and voltage enhancement, it is found that the shunt capacitor can maximize or minimize system total harmonic distortion (THD) according to its size and connection point. Therefore, in this paper, a new proposed multi-objective particle swarm optimization "MOPSO" for optimal capacitor placement on harmonic polluted distribution systems, based on a modified Non-Dominated Sorting algorithm, has been introduced. The obtained results verify the effectiveness of the introduced MOPSO algorithm for voltage THD minimization, power losses minimization and voltage enhancement of radial distribution systems.

II. HARMONIC LOAD FLOW OF RADIAL DISTRIBUTION SYSTEMS

The Harmonic Load Flow (HLF) is one of the most important tools for distribution system analysis and design. It can be used to quantify the harmonic distortion in voltage and current waveforms at various buses for a given power system, and also to determine whether the dangerous resonant problems may exist and how they might be mitigated. Such analysis has become more important since the presence of harmonic-producing equipment is increasing. In this section a new introduced harmonic load flow technique for radial distribution systems is introduced. The introduced technique can overcome the difficulties faced by the conventional harmonic load flow methods, such as the needed computation time, the admittance matrix reformation for each considered harmonic order, and the admittance matrix singularity problem.

The introduced technique employs the equivalent current injection transformation and the BIBC and BCBV matrices, which can be constructed as mentioned in Ref. [10]. The computation steps of the introduced HLF technique can be summarized as follows.

1. Fundamental load flow

The fundamental load flow is carried out by the iterative solution of the following three equations, from which the buses voltage and load current can be obtained [10].

$$I_i^m = \left(\frac{P_i + jQ_i}{(V_i)^m} \right)^*$$
$$\left[\Delta V^{m+1}\right] = \left[BCBV\right]\left[BIBC\right].\left[I^m\right]$$
$$\left[V^{m+1}\right] = \left[V_s^0\right] - \left[\Delta V^{m+1}\right] \qquad (1)$$

where P_i and Q_i are the specified active and reactive powers at the i^{th} bus, and V_i is the voltage at that bus.

2. Branches and harmonic sources injected currents relationship

In order to clear the branches and the harmonic sources currents relationship, let us consider the simple distribution system shown in Fig. 1, in which the harmonic injected currents are expressed as I2h, I4h, and I5h, while the distributor branch currents are expressed as Ib1h, Ib2h, ... and Ib6h. Firstly, the harmonic sources injected current, for each harmonic order, are calculated as a percentage of the obtained load fundamental current. Then the branch currents, for each harmonic order, can be obtained as,

$$\left[Ib^h\right]_{n\ell \times 1} = \left[BIBC\right]_{n\ell \times (nb-1)} . \left[I^h\right]_{(nb-1) \times 1} \qquad (2)$$

For the assumed simple distribution system shown in Fig. 1, the branches current can be simplified and

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obtained as follow,

$$\begin{bmatrix} Ib_1^h \\ Ib_2^h \\ Ib_3^h \\ Ib_4^h \\ Ib_5^h \\ Ib_6^h \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} -I_2^h \\ -I_4^h \\ -I_5^h \end{bmatrix} \qquad (3)$$

3. Distributor buses voltage computation

Referring to Fig. 1, the buses voltage for hth harmonic order can be computed as follow,

$$\left[V^h\right] = \left[V_{S/S}^h\right] - \left[BCBV^h\right].\left[Ib^h\right] \qquad (4)$$

where $[V^h]$ is the vector of buses voltage except the substation, $V^h_{S/S}$ is the substation harmonic order voltage vector, and $BCBV^h$ is the Branch-Current to Bus-Voltage matrix and it is given for the considered system in the form,

$$\left[BCBV^h\right] = \begin{bmatrix} Z_{12}^h & 0 & 0 & 0 & 0 & 0 \\ Z_{12}^h & Z_{23}^h & 0 & 0 & 0 & 0 \\ Z_{12}^h & Z_{23}^h & Z_{34}^h & 0 & 0 & 0 \\ Z_{12}^h & 0 & 0 & Z_{25}^h & 0 & 0 \\ Z_{12}^h & 0 & 0 & Z_{25}^h & Z_{56}^h & 0 \\ Z_{12}^h & Z_{23}^h & 0 & 0 & 0 & Z_{37}^h \end{bmatrix} \qquad (5)$$

It is to be noted that when a shunt capacitors are connected at a buses of a given distribution system to which a number of nonlinear loads are connected, it cannot determine the connected capacitor current for any considered harmonic order. This is because the harmonic voltage across its terminal is not known. Hence Eq. 2 cannot be applied to obtain the branches currents and the introduced harmonic load flow algorithm fails to be completed. However, using the repetitive load flow algorithm, the required capacitor harmonic current can be determined at each harmonic order but larger computation time values are needed.
Assuming shunt capacitors to be connected to the distribution system then the distributor branches currents can be obtained from the general form,

$$\left[Ib^h\right]_{n\ell x1} = \left[DBIBC\right]_{n\ell\ x\ 2(nb-1)} \cdot \left[Ihs^h\right]_{2(nb-1)x\,1} \qquad (6)$$

where the DBIBC matrix is formed by placing two BIBC matrix side by side. Ihsh is the current vector of the harmonic source injected currents and shunt capacitors currents.

Considering capacitors connection at buses 3 and 6 of the simple assumed system as shown in Fig. 2, the branches currents are obtained in simplified form as follow,

$$\begin{bmatrix} Ib_1^h \\ Ib_2^h \\ Ib_3^h \\ Ib_4^h \\ Ib_5^h \\ Ib_6^h \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} -Ih_2^h \\ -Ih_4^h \\ -Ih_5^h \\ +Is_3^h \\ +Is_6^h \end{bmatrix} \qquad (7)$$

Applying Eq. (4), considering the substation harmonic voltage equals zero, the distributor buses voltage can be calculated from the equation,

$$\begin{bmatrix} V_2^h \\ V_3^h \\ V_4^h \\ V_5^h \\ V_6^h \\ V_7^h \end{bmatrix} = -\begin{bmatrix} (Z_{12}^h) & (Z_{12}^h) & (Z_{12}^h) & (Z_{12}^h) & (Z_{12}^h) \\ (Z_{12}^h) & (Z_{12}^h + Z_{23}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{23}^h) & (Z_{12}^h) \\ (Z_{12}^h) & (Z_{12}^h + Z_{23}^h + Z_{34}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{23}^h) & (Z_{12}^h) \\ (Z_{12}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{25}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{25}^h) \\ (Z_{12}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{25}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{25}^h + Z_{56}^h) \\ (Z_{12}^h) & (Z_{12}^h + Z_{23}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{23}^h) & (Z_{12}^h) \end{bmatrix} \begin{bmatrix} -Ih_2^h \\ -Ih_4^h \\ -Ih_5^h \\ +Is_3^h \\ +Is_6^h \end{bmatrix} \qquad (8)$$

From Eq. (8), for the assumed distribution system, the voltage at the capacitor connected buses can be written as,

$$\begin{bmatrix} Vb_3^h \\ Vb_6^h \end{bmatrix} = -\begin{bmatrix} (Z_{12}^h) & (Z_{12}^h + Z_{23}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{23}^h) & (Z_{12}^h) \\ (Z_{12}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{25}^h) & (Z_{12}^h) & (Z_{12}^h + Z_{25}^h + Z_{56}^h) \end{bmatrix} \begin{bmatrix} -Ih_2^h \\ -Ih_4^h \\ -Ih_5^h \\ +Is_3^h \\ +Is_6^h \end{bmatrix} \qquad (9)$$

Also, the voltage at the shunt capacitor can be given as a function of it impedance at h^{th} harmonic and the capacitor current as,

$$\begin{bmatrix} Vb_3^h \\ Vb_6^h \end{bmatrix} = \begin{bmatrix} ZC_3^h \ x\ Is_3^h \\ ZC_6^h \ x\ Is_6^h \end{bmatrix} \qquad (10)$$

Substituting from Eq. (10) into Eq. (9),

$$\begin{bmatrix} ZC_3^h & 0 \\ 0 & ZC_6^h \end{bmatrix}\begin{bmatrix} Is_3^h \\ Is_6^h \end{bmatrix} = \begin{bmatrix} (Z_{12}^h) & \begin{pmatrix} Z_{12}^h \\ +Z_{23}^h \end{pmatrix} & (Z_{12}^h) \\ (Z_{12}^h) & (Z_{12}^h) & \begin{pmatrix} Z_{12}^h \\ +Z_{25}^h \end{pmatrix} \end{bmatrix}\begin{bmatrix} -Ih_2^h \\ -Ih_4^h \\ -Ih_5^h \end{bmatrix} + \begin{bmatrix} \begin{pmatrix} Z_{12}^h \\ +Z_{23}^h \end{pmatrix} & (Z_{12}^h) \\ (Z_{12}^h) & \begin{pmatrix} Z_{12}^h + Z_{25}^h \\ +Z_{56}^h \end{pmatrix} \end{bmatrix}\begin{bmatrix} +Is_3^h \\ +Is_6^h \end{bmatrix} \quad (11)$$

Solving Eq. (11), the shunt capacitor current can be obtained depending on the value of the known harmonic sources injected currents and given shunt capacitors and branches impedance. Note that Eqs. (8, 9 and 11) are written for the special case shown in Fig. 2.

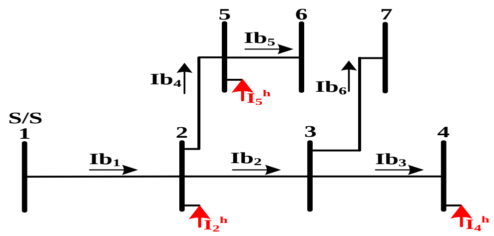

Fig. 1. Harmonic polluted simple distribution system

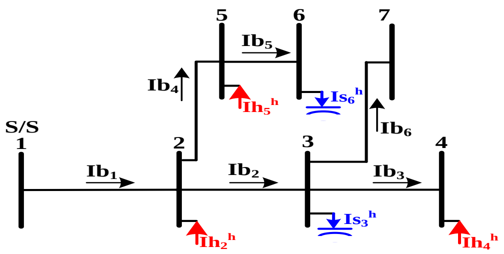

Fig. 2. Harmonic polluted distribution system with embedded shunt capacitors

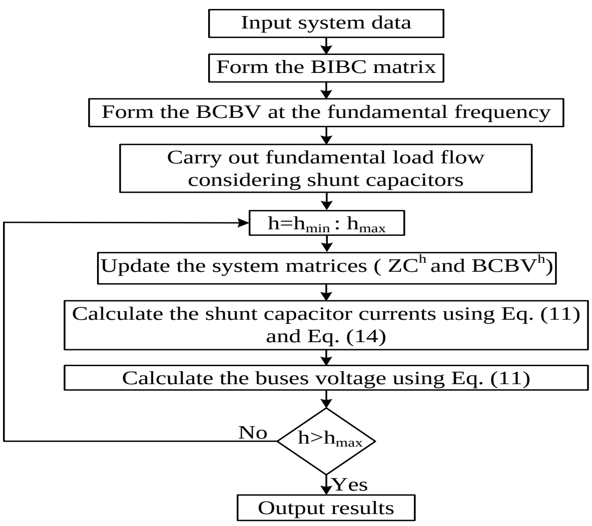

Fig. 3. Flowchart of harmonic load flow procedure

From the previous derivation, the harmonic load flow considering the connection of shunt capacitors can be obtained following the flowchart shown in Fig. 3,

A. Harmonic Load Flow Computation Results Considering the Shunt Capacitors Connection to the 11-Bus Test System

In this section the introduced harmonic load flow technique has been tested on the 11-bus test system, shown in Fig. 4, which introduced in Ref. [11]. Table 1 lists the 11-bus impedances of distribution feeders. The load demand at each bus has been recorded in Table-2.

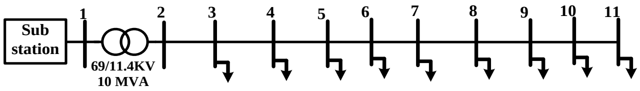

Fig. 4. Single line diagram of the 11-bus test system

Table 1. SYSTEM IMPEDANCE OF THE 11-BUS DISTRIBUTION FEEDERS

Bus		Impedance (p.u.)	
From	To	R	X
2	3	0.0932	0.2121
3	4	0.0106	0.1575
4	5	0.0643	0.4112
5	6	0.0523	0.4612
6	7	0.0531	0.2063
7	8	0.0845	0.4963
8	9	0.0554	0.3832
9	10	0.0491	0.4612
10	11	0.0554	0.4353

Table 2. LOADS DEMAND OF THE 11-BUS DISTRIBUTION SYSTEM

Bus	P (KW)	Q(Kvar)
2	0	0
3	427	140
4	684	224.8
5	534	400.5
6	534	544.8
7	1048	786
8	406	196.6
9	972	857.2
10	408	416.2
11	1487	921.6
Total	6610	5340

Table 3. HARMONIC CURRENT GENERATED AT EACH BUS [11]

Harmonic order	Harmonic current (%)								
	Bus 3	Bus 4	Bus 5	Bus 6	Bus 7	Bus 8	Bus 9	Bus 10	Bus 11
2	1.80	2.14	1.61	1.33	1.46	2.18	1.25	1.88	1.87
4	1.50	1.39	1.02	0.82	0.94	1.42	0.80	1.22	1.17
5	3.11	3.16	3.50	3.40	1.44	2.96	4.36	3.61	4.01
7	2.19	2.23	2.46	2.38	2.90	2.08	3.08	2.55	2.84
8	0.64	0.61	0.52	0.48	0.48	0.63	0.43	0.56	0.53
10	0.62	0.53	0.34	0.21	0.32	0.56	0.25	0.47	0.46
11	1.15	1.15	1.28	1.19	1.60	1.05	1.72	1.37	1.59
13	1.04	1.04	1.09	0.98	1.36	0.95	1.44	1.20	1.38
14	0.39	0.34	0.17	0.06	0.16	0.34	0.11	0.28	0.27
16	0.26	0.24	0.18	0.15	0.16	0.24	0.14	0.21	0.20
17	0.82	0.82	0.87	0.80	1.08	0.75	1.14	0.95	1.09
19	0.81	0.79	0.80	0.71	0.98	0.72	1.03	0.89	1.01
20	0.41	0.36	0.20	0.10	0.19	0.36	0.13	0.30	0.29
22	0.43	0.39	0.26	0.18	0.24	0.39	0.19	0.33	0.32
23	0.35	0.39	0.55	0.57	0.70	0.34	0.78	0.53	0.62
25	0.48	0.50	0.60	0.60	0.72	0.46	0.77	0.60	0.68

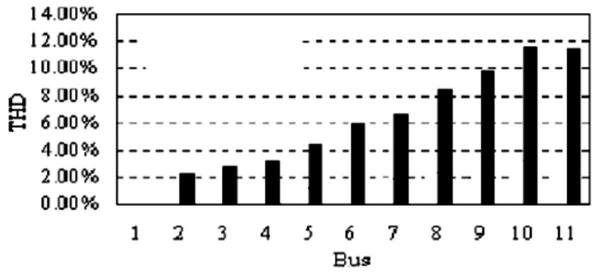

Fig. 5 Voltage THD of each bus of the 11-bus test system [11]

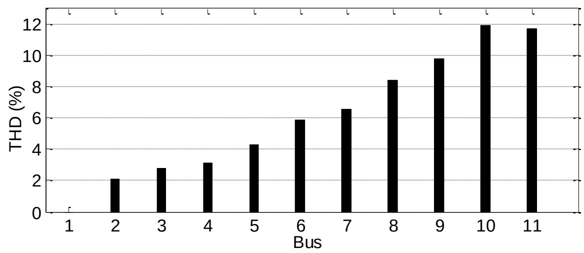

Fig. 6 Voltage THD of each bus of the 11-bus test system using the introduced method

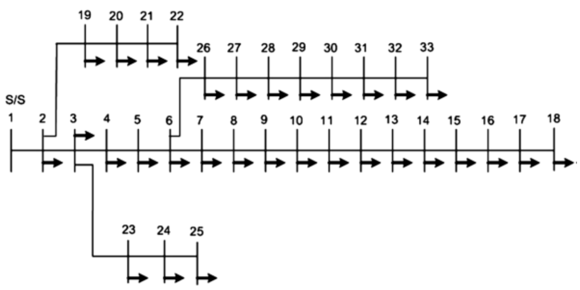

Fig. 7 Single line diagram of the 33-bus distribution test system

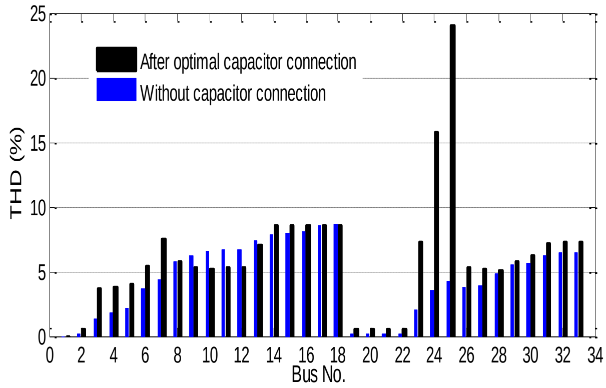

Fig. 8 Voltage THD of each bus of the 33-bus system with and without connection of optimal capacitors

The injected harmonic current values to the considered distribution system are given in Table III. Also, it is assumed that a capacitor banks with total capacity of 1500 kvar is connected to the distribution system at Bus 10 to provide the reactive power compensation for the feeder [11]. Fig. 5 shows the THD at each bus given in Ref. [11] while the THD value obtained from the introduced harmonic load flow method is given in Fig. 6. The obtained results verify the effectiveness of the introduced HLF method.

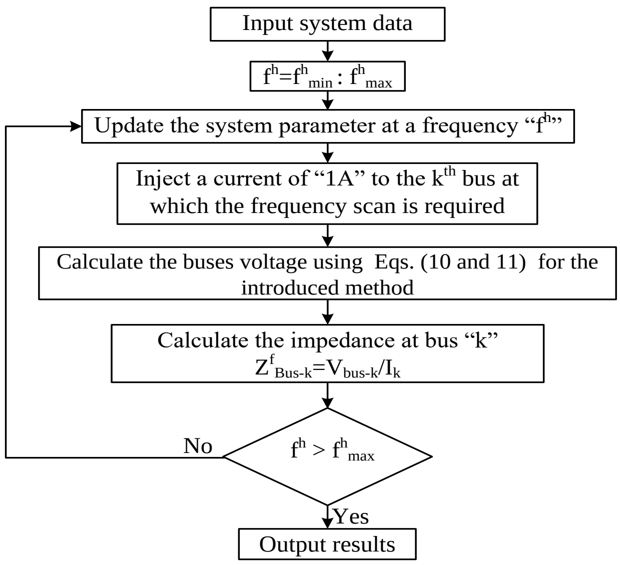

Fig. 9 Flowchart of the impedance scan algorithm

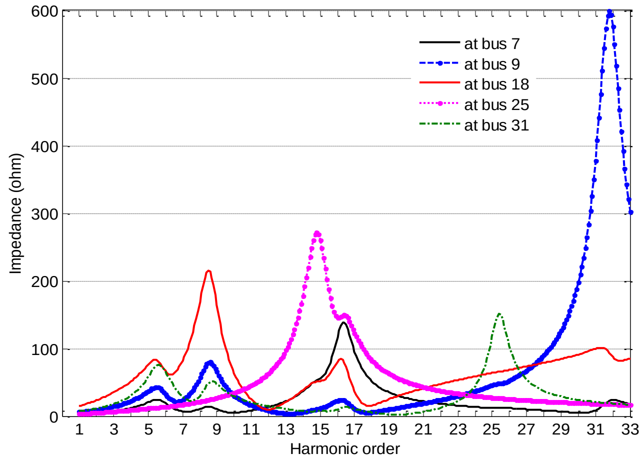

Fig. 10 Impedance scan at some buses of the 33-bus distribution system

B. Harmonic Load Flow Computation Results Considering the Shunt Capacitors Connection to the 33-Bus Test System

In this section, the harmonic load flow computations for the 33-bus distribution system, shown in Fig. 7 with the branches and loads data given in Ref. [12], are carried out considering the connection of shunt capacitors given in Ref [13]. The obtained capacitors sizes and connection point in Ref [13] represent the optimum values for loss minimization and voltage enhancement. Ref [13] obtains the optimal capacitors sizes at the fundamental frequency, not considering harmonic effect. The capacitors size are 600, 150, 300, 350, 600 and 450 Kvar and connected at buses 7, 9, 14, 25, 30 and 31, respectively. After carrying out the harmonic load flow computations considering the harmonic current injection of orders 5, 7, 11, 13, 15, 17, 23 and 25 with a ratio of 1/n from the fundamental load current value, where "n" is the harmonic order. The nonlinear loads are considered to be at buses 4, 8, 14, 18, 24, 29 and 32. Fig. 8 shows the computed THD at each bus with and without optimal capacitor connection, from which it is clear that the THD value at bus 25 after capacitor connection reaches a value about 25%, which unacceptable value according to [14]. The impedance scan at this bus, See Section III, shows that this bus is subjected to parallel resonance at the 13th harmonic order with the connection of previous optimal capacitors. Also, although, the connection of a capacitor at bus 9, the THD at buses 9, 10, 11 and 12 is less than that before optimal capacitor connection. Therefore, from the obtained results it can be said that the capacitor optimal size and location at fundamental frequency may lead to unacceptable THD at distribution system buses. On the other hand shunt capacitor connection to distribution systems can be used for THD minimization besides voltage enhancement and losses minimization if they properly sized and located.

III. FREQUENCY (IMPEDANCE) SCAN

A frequency or impedance scan refers to a plot showing the magnitude and phase angle of the driving point impedance (of the linear network) at an interested bus versus the frequency, and it can provide some useful, and sometimes qualitative, insight into the system performance under harmonic pollution. The term “scan” arises from the systematic variation of frequency from an initial value fmin to a final value fmax. The impedance scan computation steps can be summarized by the following flowchart shown in Fig. 9.

Now, considering the connection of the capacitors listed in Section II-B, and carrying out the impedance scan of the 33-bus system, the impedance scan at some buses are shown in Fig. 10, from which it is clear that bus 25 is subjected to parallel resonance at 15th harmonic order which prove the larger obtained THD value given in Fig. 8. Although a parallel resonance occurrence at bus 9 near 31th harmonic order, the THD at this bus with capacitor connection is smaller than its value without capacitor connection, see Fig. 8. The reason is the absence of injected harmonic current at this higher harmonic order. Also, although a parallel resonance occurrence at bus 18 as shown in Fig. 10, the THD at this bus, shown in Fig. 8 is the same for the cases with or without capacitor connection. The reason is the occurrences of parallel resonance at 9th harmonic order which not existing.

IV. CAPACITOR OPTIMAL PLACEMENT ON HARMONIC POLLUTED DISTRIBUTION SYSTEMS

It is found in Sections. II-B and III that considering only the fundamental frequency the optimal sizes and connection points for the connected capacitors with a given harmonic polluted distribution system may lead to an occurrence of a parallel resonance and larger THD values for the buses voltage. Therefore, in this section, it is introduced a Multi-Objective Particle Swarm Optimization (MOPSO) algorithm for the optimal capacitor sizes and locations on a harmonic polluted distribution system. The buses voltage THD minimization, total power losses minimization and voltage enhancement are the considered objective functions. A modified Non-Dominated Sorting algorithm [15] has been used with PSO technique for achieving the optimum solution. The computation steps for the introduced MOPSO algorithm are given in the flowchart, shown in Fig. 11.

Applying the introduced MOPSO algorithm, the capacitor optimal placement on the 33-bus distribution system is carried out. Assuming that the loads connected to buses 5, 7, 8, 10, 11, 14, 15, 17, 24, 2, 27, 29, 30, 31 and 32 to be nonlinear loads, and each of them inject the harmonic orders 5, 7, 11, 13, 15, 17, 23 and 25 with the amplitude 1/n from the load fundamental current value, where "n" is the harmonic order. The assumed number of the connected capacitor, in this case, is five capacitors. The optimal capacitors sizes and connection point for the introduced MOPSO and individual objective functions are listed in Table 4. Fig. 12, and Fig. 13 show the buses voltage THD and the buses voltage values of the 33-bus system after optimal capacitor connection mentioned in Table 4.
Fig. 14 shows the impedance scan at bus 18 of the 33-bus distribution system with the connection of the obtained optimal capacitor given in Table IV. Case a, b, c and d, shown in Fig. 14, represent the frequency scan after the connection of the optimal capacitor obtained applying the MOPSO, f1 only, f2 only and f3 only, respectively.

Fig. 15 shows the convergence of the global best solution for the case of the multi-objective.

V. CONCLUSIONS

Harmonic analysis is an important application for distribution systems analysis and design. In this paper, a new fast harmonic load flow method has been introduced to overcome the shortage of the conventional HLF methods. The introduced method can overcome the singularity problems that appear in the conventional methods without excessive computational time required for the admittance matrix formation used in conventional harmonic load flow methods. The obtained results verify the effectiveness of the introduced HLF method.

Applying the introduced harmonic load flow method to harmonic polluted distribution systems embedded shunt capacitors which commonly used for losses minimization and voltage enhancement, it is found that the shunt capacitor can maximize or minimize buses voltage THD of distribution systems according to its size and connection point. Therefore, in this paper, a new proposed MOPSO algorithm for optimal capacitors placement on harmonic polluted distribution systems has been introduced based on a modified Non-Dominated Sorting algorithm. The obtained results verify the effectiveness of the introduced MOPSO algorithm for voltage THD minimization, power losses minimization and voltage enhancement of radial distribution systems.

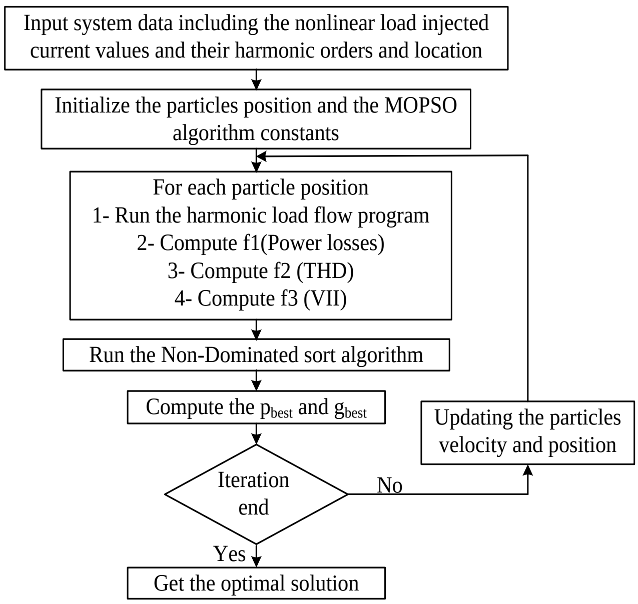

Fig. 11 Flowchart of the introduced multi-objective PSO algorithm

Table 4. Optimal capacitor placement on the 33-bus distribution system

Objective function	**Optimal size and connection point**						**Losses (KW)**
Multi-objective	Bus	16	14	32	33	33	200.74
	Size (Kvar)	582.8	510.4	513.4	648.4	665.7	
Ploss minimization only (f1)	Bus	7	17	29	30	3	185.86
	Size (Kvar)	624.2	348.1	356.2	220.1	680.8	
THD minimization only (f2)	Bus	18	31	9	14	20	228.45
	Size (Kvar)	540.3	635.0	470.2	566.6	363.9	
Voltage enhancement only (f3)	Bus	18	31	9	14	20	208.87
	Size (Kvar)	468.2	550.3	407.5	491.1	315.4	208.87
Without capacitors							**228.5**

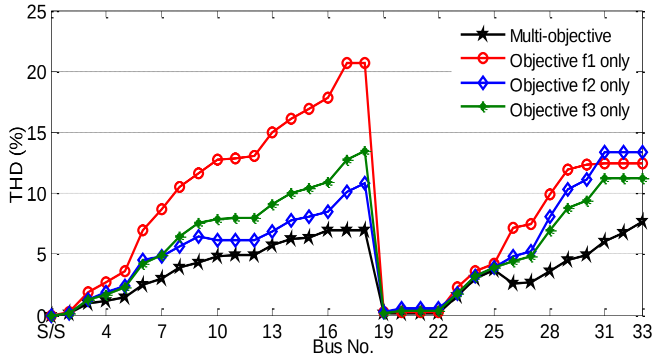

Fig. 12 Buses voltage THD of the 33-bus system

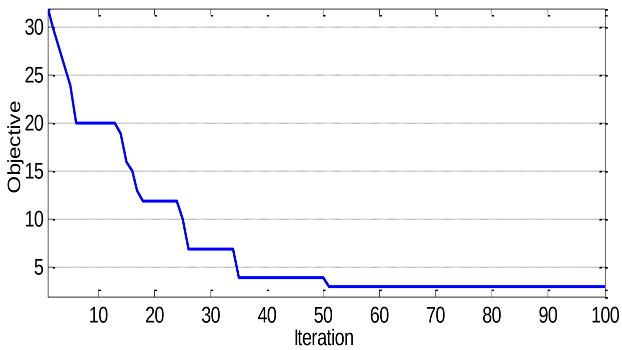

Fig. 15 Convergence of the objective function

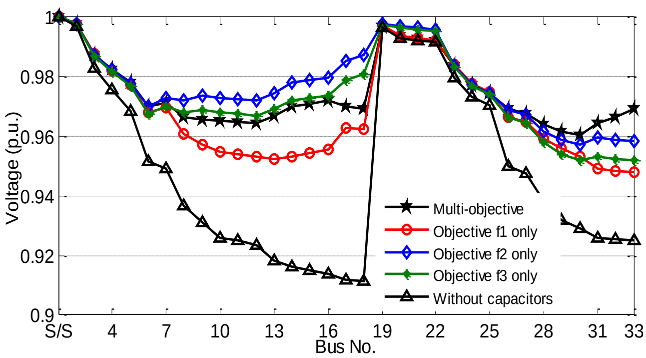

Fig. 13 Buses voltage of the 33-bus system

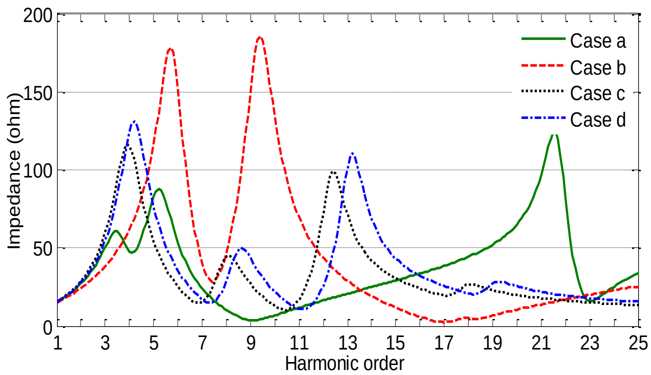

Fig. 14 Impedance scan at bus 18 of the 33-bus system

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Application of DSTATCOM coupled with FESS for Power Quality Enhancement and Fault Mitigation

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***Abstract* -** In power systems, the use of renewable energy, especially Wind power generation is steadily increasing around the world. However, this incorporation and the lack of controllability over the wind, and the type of generation used cause problems in the power quality and in the dynamics of the system. In this work, the use of a Distribution Static Synchronous Compensator (DSTATCOM) coupled with a Flywheel Energy Storage System (FESS) is proposed to mitigate problems introduced by the intermittency of wind power generation. A dynamic model of the DSTATCOM/FESS device is briefly presented and a multi-level control technique is proposed. The proposed control technique has one control mode for active power, and two control modes to choose between, for reactive power and voltage control. The above technique has been used here to enhance not only the steady state operation but also to mitigate sudden load changes. The control system under consideration, with the DSTATCOM/FESS, and its controls are analyzed also, under the conditions of different faults which may happen in the system. Simulation tests of the device are analyzed when it is combined with wind generation in the electric system. The results demonstrate satisfactory performance of the proposed control techniques, as well as a high effectiveness of the control system to mitigate problems introduced by wind power generation.

***Keywords* -** Distribution Static Synchronous Compensator (DSTATCOM), Flywheel Energy Storage System (FESS), power quality, Wind Power, fault.

I. INTRODUCTION

Due to the increase in population and industrialization, demand of electricity is increased too. So, integration of renewable energy in power networks becomes very important in the generation of power now a day [1].

The generated power from the wind energy is considered to be the most economical alternative within the renewable energy resources; due to its main advantages such as the large number of potential sites for planting installation and a rapidly evolving technology, with many suppliers offering from individual turbine sets to turnkey projects. However, due to the lack of controllability over the wind and the type of generation system used, problems arise in the electrical systems. One of the major problems of wind conversion systems is the variations of the output power produced by short-term wind fluctuations, which affect the power quality and may lead to system instability [2]. In order to mitigate the variation in power quality, and enhance the during-fault performance of the system, which may occur due to wind variations, load step changes, which can last for seconds or minutes or even longer, a scheme of Distributed Static Synchronous Compensator (DSTATCOM) connected at a point of common coupling with flywheel (FESS) is suggested [3].

A DSTATCOM is one of the main shunt controllers to be used in distribution systems. It is suitable for its fast-response. Its solid-state power controller provides flexible voltage control at the point of common coupling with the utility grid, a matter which leads to power quality improvements. This device can exchange active and reactive powers with the wind energy resource, if an energy storage system, in this case a flywheel system, is included with it into the DC bus [4].

A FESS stores kinetic energy in its rotating mass. In this paper, the flywheel system has been used as a short-term energy storage device. Flywheel systems can be classified as low-speed flywheel (LS-FESS) and high-speed flywheel (HS-FESS) devices. However, HS-FESS represents a newer technology than LS-FESS. In fact, HS-FESS provides better speeds of response, cycling characteristics and electric efficiencies. As the HS-FESS will be the only type used here, it will be referred to as FESS from now. It works as a motor while charging, and as a generator while discharging. It has several advantages over other energy storage systems due to its simple structure with the very high efficiency, higher power, energy density with high dynamics and fast response, and longer lifetime with low maintenance requirements. FESS merely consists of a flywheel, electric machine, power conversion system and bearings [5].

From the foregoing discussion, it is obvious that a DSTATCOM/FESS supporting system is able to correct the active and reactive power fluctuations of a wind power system.

In this paper, a detailed model and a multi-level control of a DSTATCOM controller coupled with FESS, meant to improve the integration of wind generators (WGs) into a power system, and to mitigate wind power fluctuations are presented in details. It can be also, helpful, and efficient in the mitigation of the effects of some different types of faults. A validation of a DSTATCOM/FESS device and control schemes are carried out through MATLAB/Simulink. Results are obtained, and presented in the paper. Moreover, the complete control design for DSTATCOM/FESS is presented which includes three modes of operation, namely, voltage control, power factor correction, and active power control. This control scheme implements a new approach depending on multi-level control technique.

II. DSTATCOM/FESS GENERAL MODEL

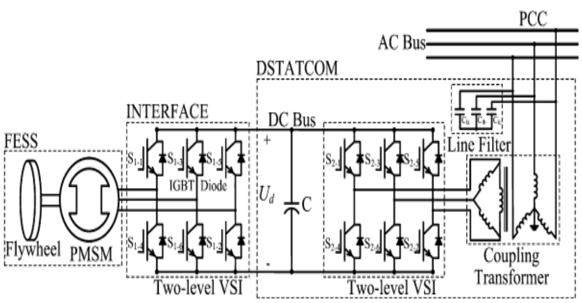

Fig.1. DSTATCOM/FESS controller

For studying the dynamic performance of the DSTATCOM/FESS controller, a detailed model of the combined system is presented. It mainly consists of the DSTATCOM controller, the Interface converter and the FESS, as shown in Fig.1.

The DSTATCOM and the interface use a voltage-source inverter (VSI), in which the valves used are: Insulated Gate Bipolar Transistors (IGBT) with anti-parallel diodes. The VSI is modeled by detailed blocks, and is presented into the simulation program. Other components are the coupling transformer, the line filter and the DC bus capacitor. They are all represented in the model

The stored energy of the FESS device is computed by:

$$\Delta E = \frac{J(\omega_{max}^2 - \omega_{min}^2)}{2} \qquad (1)$$

Where ΔE is the available stored energy by the flywheel, J is the flywheel moment of inertia, ω_{max}, ω_{min} are the maximum and minimum flywheel operational speed, respectively.

A permanent magnet synchronous machine (PMSM) is used to allow the exchange of power between the flywheel and the Interface. The PMSM is worked at high speeds as its type of rotor is brushless, and there is no rotor winding. It is also modeled in the simulation program with a detailed block. The flywheel itself is modeled as an additional mass connected to the rotor shaft of the PMSM [6].

III. DSTATCOM/FESS CONTROL

The control system presented here for the DSTATCOM/FESS device is divided into two parts, the DSTATCOM control, and the FESS control. To avoid system complexity, each one of the two parts is divided into multi-level control schemes. Similarly, each scheme has its own control objectives. In this way the system control will be simpler in design [7].

For each part, i.e., the DSTATCOM and the FESS, three distinct control levels are done: external, middle and internal level, as shown in Fig. 2

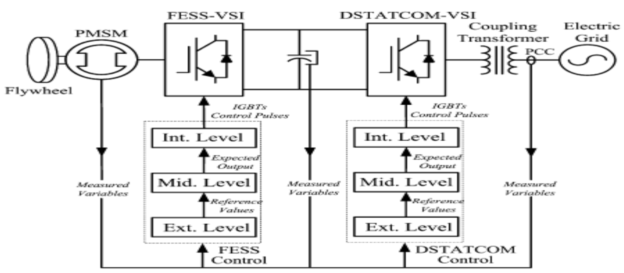

Fig.2. DSTATCOM/FESS multi-level contro

A. DSTATCOM CONTROL

Each control level of the DSTATCOM has functions to be fulfilled. By the external level, active and reactive power exchange between the DSTATCOM and the utility system can be

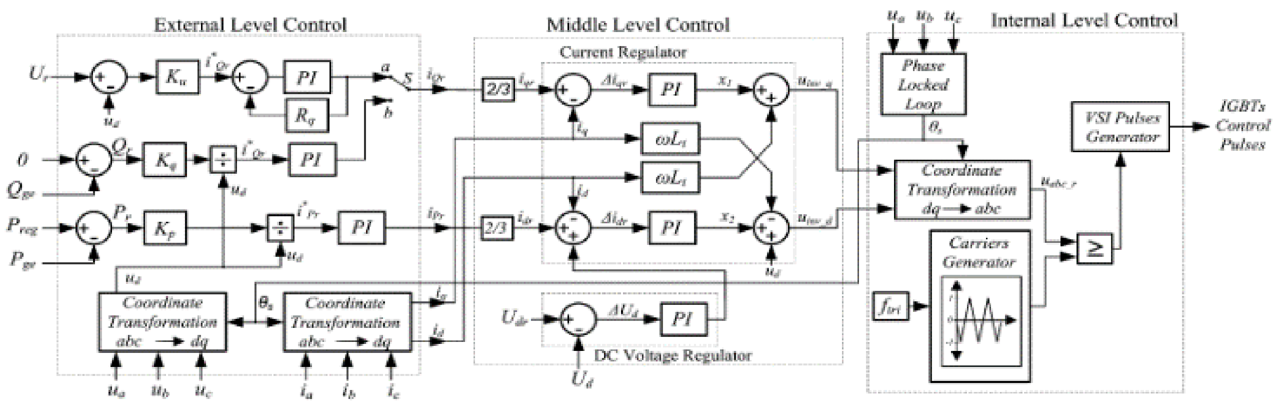

Fig.3. three-level control of DSTATCOM

determined. The external control level is designed for performing active power control mode (APCM), power factor control mode (PFCM) and voltage control mode (VCM). By the middle level, the expected output is dynamically tracked to the reference values set by the external level. This block has two main parts, the current regulator and the DC voltage regulator. By the internal level, firing signals are generated for the switching valves of the VSI of the DSTATCOM. The internal level is mainly composed of a line synchronization module and a three-phase pulse-width modulation firing pulses generator [8]. The three control levels of the DSTATCOM with all parts given in details are shown in Fig. 3.

B. FESS CONTROL

The control of the FESS is done through the control of the Interface -VSI. For a three-phase voltage of controllable amplitude and phase with the VSI, the PMSM can work as a motor storing energy or as generator delivering energy. Like the DSTATCOM control, by the external level, power exchange between the DC bus of the DSTATCOM and the FESS can be determined so as to fulfill the required power imposed by the DSTATCOM as shown in Fig. 4. The maximum efficiency of the PMSM is obtained by computing the reference current i_{qmr} from the torque of the PMSM by using Eq. (2), and the reference current i_{dmr} is set to zero [9].

$$T_{e\_r} = \frac{3}{2} p\, \psi_m i_{qmr} \qquad (2)$$

Where, T_{e_r} is the electromagnetic reference torque of the machine, p is the number of pairs of poles, and ψ_m is the magnetic flux.

The reference torque is calculated through a speed regulator which adjusts the actual speed of the machine (ω_m) to the reference speed of the machine (ω_{mr}) .The reference speed is computed from the reference power of the

machine, P_{mac_r}, which is the power, to be stored or delivered by the flywheel, which can be expressed using Eq. (3).

$$P_{mac\_r} = d/dt \left(\frac{1}{2} J\, \omega^2_{mr} \right) \qquad (3)$$

The reference power of the machine is calculated by summing up the reference power of the DSTATCOM/FESS (P_r) and the power losses of the machine (P_{loss}), which denotes the sum of the copper losses (P_{Cu}), the iron losses (P_{Fe}), and the mechanical losses (P_{mec}) [10].

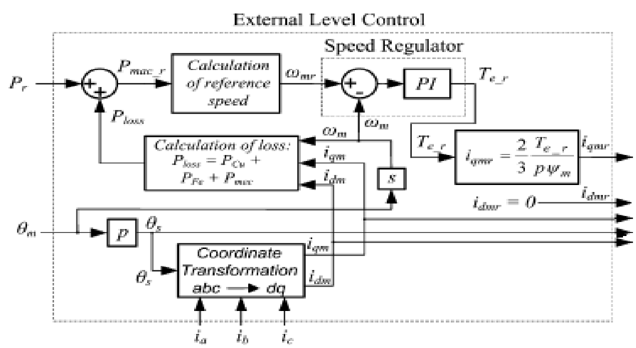

Fig.4. the external -level control of FESS

The middle level has the same functions as the middle level of the DSTATCOM, except that the angle of synchronism for making the coordinate transformation, θ_s, is computed in a different way. Here, the angle is obtained by measuring the position angle of the machine (θ_m) and multiplying this angle by the number of pair poles.

The internal control level is also similar to that of the DSTATCOM except that it does not have the phase locked loop block (PLL) as the angle θ_s is obtained by the measurement as mentioned before.

IV. TEST MODEL

To study the dynamic performance of the DSTATCOM/FESS device, the test power system shown in Fig. 5, as a single line diagram, is used. This sub-transmission system works at 13.8 kV, and 50Hz, and implements a dynamically modeled wind generator linked to a bulk power system, represented by an infinite bus type.

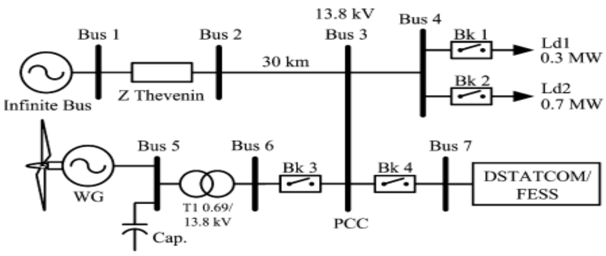

Fig.5. sub-transmission power system network

The WG used is an induction generator with a squirrel-cage rotor and of rated power 750 kW.

It is connected to the grid through a transformer of star-triangle winding. The demand of the reactive power for the WG is supplied by capacitors in order to reach approximately unity power factor. WG is modeled with blocks of a wind turbine of induction generator type which are available in the library of the simulation program and with parameters taken from [11]. The sub-transmission line is modeled by using lumped parameters. All loads are modeled by constant impedances and are connected at bus 4 in which Ld1 has a power 0.3 MW and Ld2 has power 0.7MW. The DSTATCOM/FESS proposed is connected to bus 3 (the main bus). The DSTATCOM has DC voltage of 750 V and the used capacitor is of 1000 μF. The DSTATCOM-VSI works with a frequency of 8 kHz, whereas the Interface-VSI works at 20 kHz. The parameters of the FESS (PMSM and flywheel) are obtained from [11].

The analysis and validation of the models and control algorithms, suggested for the DSTATCOM/FESS controller, are done through simple tests that impose high demands upon the dynamic response of the device. For this purpose, a variable profile of wind speed is applied to the WG, so that the DSTATCOM/FESS may work in both ways, by storing and delivering energy. In addition, external disturbances, such as sudden load change and different fault types are imposed, and the behavior of the device in the different modes of control is observed.

V. SIMULATION RESULTS

The test model shown in Fig. 5 is used to verify the suggested control scheme. A wind speed variation of the form shown in Fig. 6 is applied.

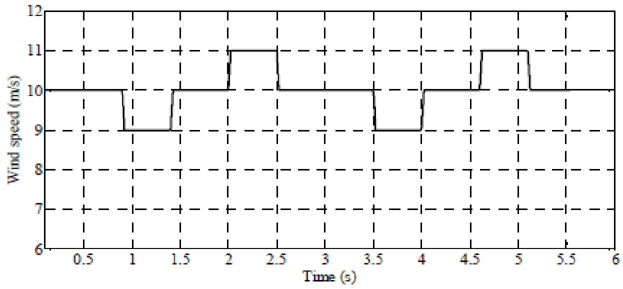

Fig.6. variation of the wind speed

The wind speed variations applied cause fluctuations in the active and reactive power injected by the WG. A capacitor bank is used to compensate the reactive power of the WG, when it operates at a mean wind speed of 10 m/s.

1. SUDDEN LOAD VARIATION

At bus 4 of Fig.5, a load Ld1= 0.3MW is first connected (t = 0 sec.) and then, load Ld2 = 0.7MW is added (t = 3 sec.). The behavior of the system is analyzed in both cases i.e. when the DSTATCOM/FESS is disconnected and when it is connected. The variations in active power, injected into the system for both cases are shown in Fig. 7.

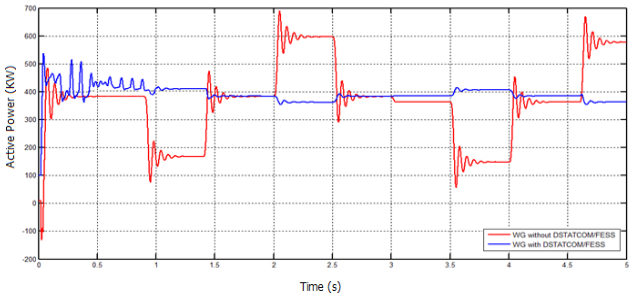

Fig.7. the active power of the WG-DSTATCOM/FESS.

It is obvious that when the DSTATCOM/FESS device is connected, the variations of power injected from the WG into the system, are reduced, indicating that the active power is approximately constant.

For the reactive power control, three different cases are observed: DSTATCOM/FESS disconnected, DSTATCOM/FESS connected working in Power Factor Control Mode (PFCM) and DSTATCOM/FESS connected working in Voltage Control Mode (VCM) as shown in Fig.8.

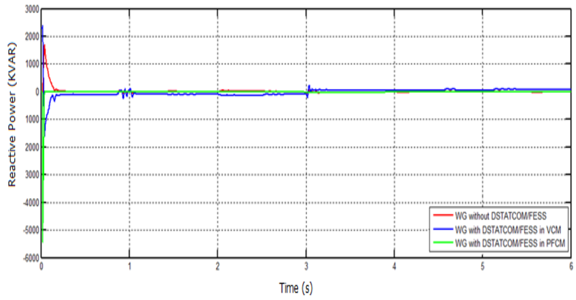

Fig.8. the reactive power of the WG-DSTATCOM/FESS.

When the DSTATCOM/FESS-connected working in PFCM, it is observed that the reactive power injected is zero. So, the device proposed has satisfactorily compensated the reactive power variations of the WG. When the DSTATCOM/FESS-connected working in VCM, the reactive power variations from the WG are also compensated in order to make the voltage at bus 4 equal to 1 pu.

The voltage at bus 4 can also be observed as shown in Figs. 9, 10, 11, 12, 13 and 14. When the DSTATCOM/FESS is disconnected, significant variations in voltage happen. This is due to both the variations of power from the WG and those of the load. When the DSTATCOM/FESS device is connected in PFCM, there are no voltage variations due to the variations in the wind power. However, in this mode, the voltage has a value different from 1 pu due to the load variation. When the DSTATCOM/FESS device is connected in VCM, the voltage is approximately maintained at 1 PU and does not change due to the variations in wind power or the variations of the load. So this control mode solves, in quite an effective way, the problem caused by the PFCM. Thus, the VCM is the most convenient mode when the connection point of the WG has no other device that controls the voltage.

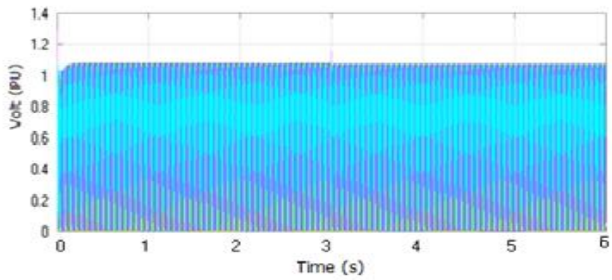

Fig.9. voltage at bus 4 without DSTATCOM/FESS connected.

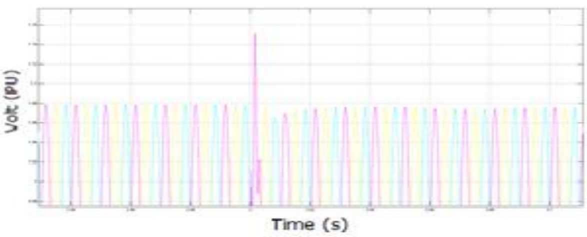

Fig.10. Expanded scale of voltage at bus 4 without DSTATCOM/FESS connected at time = 3 sec

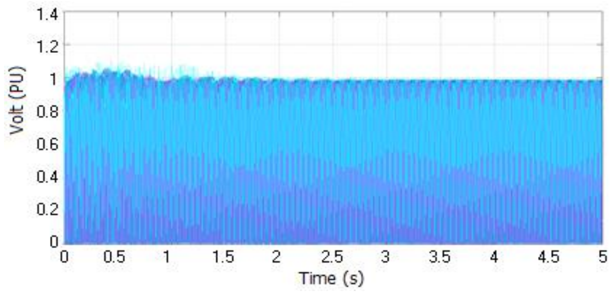

Fig.11. voltage at bus 4 with DSTATCOM/FESS connected in VCM.

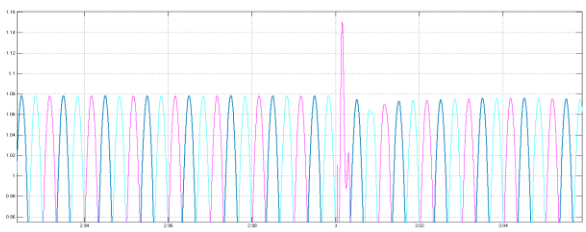

Fig.12. Expanded scale of voltage at bus 4 with DSTATCOM/FESS connected in VCM at time = 3 sec

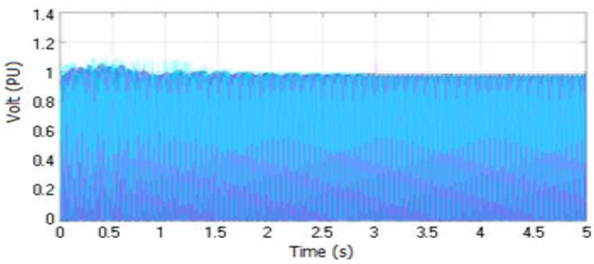

Fig.13. voltage at bus 4 with DSTATCOM/FESS connected in

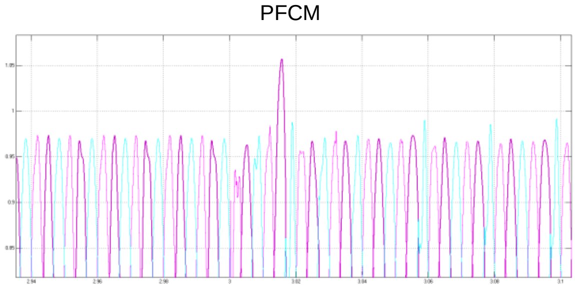

Fig.14. Expanded scale of voltage at bus 4 with DSTATCOM/FESS connected in PFCM at time = 3 sec.

2. OPERATION UNDER DIFFERENT TYPES OF FAULTS

For the system of Fig. 5, different types of faults are applied at bus 4; such as line to ground fault, line to line fault, line to line to ground fault, three lines to ground fault, and the system is studied under each case of them in details. In the following the simulation results of the foregoing types of faults are given

A. LINE TO GROUND FAULT

For line to ground fault, assumed to happen at t = 3 sec., and then be removed after 0.5 sec., three cases are observed: in the case when the DSTATCOM/FESS is disconnected, significant variations in voltage happen. These are shown in Fig. 15.When the DSTATCOM/FESS is connected, and working in VCM, the variation in voltage is mitigated as shown in Fig. 16. When the DSTATCOM/FESS is connected; working in PFCM, as shown in Fig. 17, voltage variation is mitigated, as well. In all cases when the DSTATCOM/FESS operates in VCM mode the dynamic performance of the system is best.

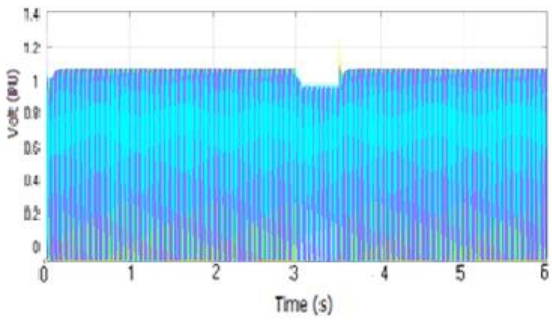

Fig.15. voltage at bus 4 without DSTATCOM/FESS connected of line to ground fault.

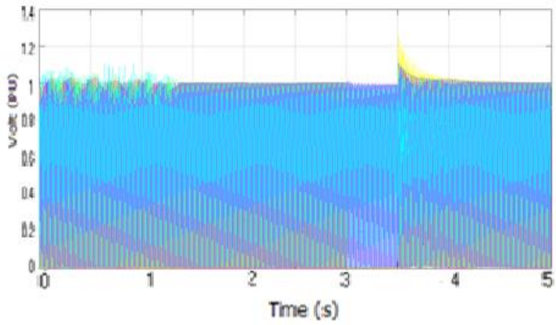

Fig.16. voltage at bus 4 with DSTATCOM/FESS connected.in VCM of line to ground fault.

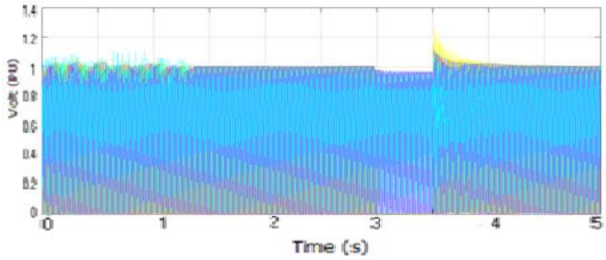

Fig.17. voltage at bus 4 with DSTATCOM/FESS connected.in PFCM of line to ground fault.

B. LINE TO LINE FAULT

For line to line fault, assumed to happen at t = 3 sec., and then be removed after 0.5 sec., three cases are observed: in the case when the DSTATCOM/FESS is disconnected, significant variations in voltage happen. These are shown in Fig. 18.When the DSTATCOM/FESS is connected, and working in VCM, the variation in voltage is mitigated. In addition, the time taken by the system to return to stability decreased as shown in Fig. 19. When the DSTATCOM/FESS is connected; working in PFCM, as shown in Fig. 20, voltage variation is mitigated and the time taken to regain stability decreased as well. In all cases when the DSTATCOM/FESS operates in VCM mode the dynamic performance of the system is best.

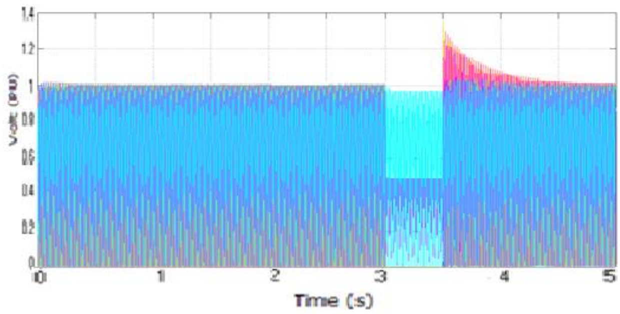

Fig.18. voltage at bus 4 without DSTATCOM/FESS connected of line to line fault.

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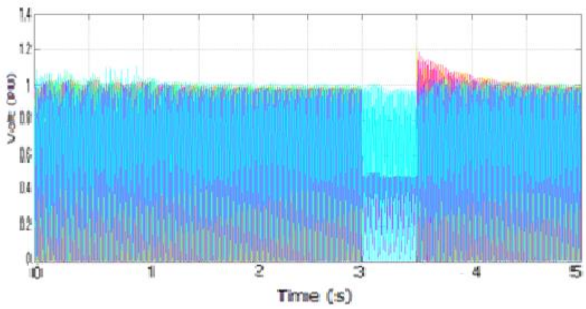

Fig.19. voltage at bus 4 with DSTATCOM/FESS connected.in VCM of line to line fault.

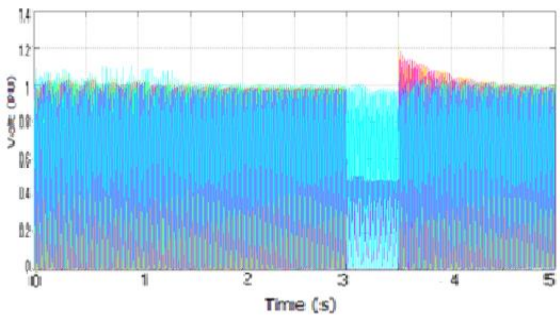

Fig.20. voltage at bus 4 with DSTATCOM/FESS connected.in PFCM of line to ground fault

C. LINE TO LINE TO GROUND FAULT

For line to line to ground fault, assumed to happen at t = 3 sec., and then be removed after 0.5 sec., three cases are observed: in the case when the DSTATCOM/FESS is disconnected, significant variations in voltage happen. These are shown in Fig. 21.When the DSTATCOM/FESS is connected, and working in VCM, the amplitude of faulty voltage increased as shown in Fig. 22. When the DSTATCOM/FESS is connected; working in PFCM, as shown in Fig.23, the amplitude of faulty voltage increased, as well. In all cases when line to line fault happen it is better to disconnect the DSTATCOM/FESS.

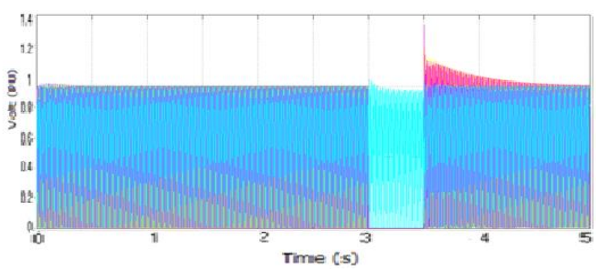

Fig.21. voltage at bus 4 without DSTATCOM/FESS connected of line to line to ground fault.

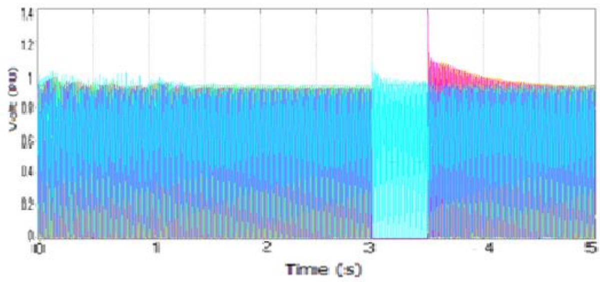

Fig.22. voltage at bus 4 with DSTATCOM/FESS connected.in VCM of line to line to ground fault.

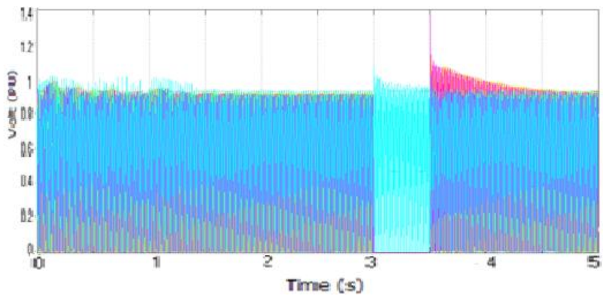

Fig.23. voltage at bus 4 with DSTATCOM/FESS connected.in PFCM of line to line to ground fault.

D. THREE LINES TO GROUND FAULT

For three lines to ground fault, assumed to happen at t = 3 sec., and then be removed after 0.5 sec., three cases are observed: in the case when the DSTATCOM/FESS is disconnected, significant variations in voltage happen and at the time of fault the voltage reach zero, as shown in Fig. 24.When the DSTATCOM/FESS is connected, and working in VCM, the variation in voltage is increased as shown in Fig. 25. When the DSTATCOM/FESS is connected; working in PFCM, as shown in Fig. 26, voltage variation is increased, as well. In all cases when three lines to ground fault happen, it is better to disconnect the DSTATCOM/FESS

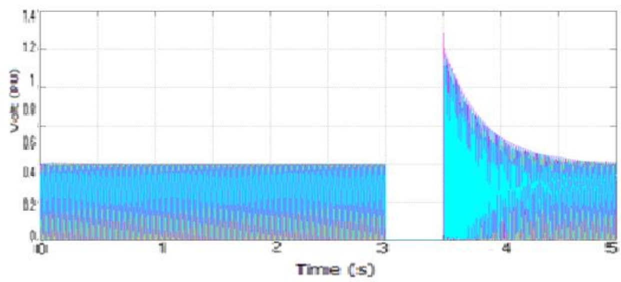

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Fig.24. voltage at bus 4 without DSTATCOM/FESS connected of three lines to ground fault.

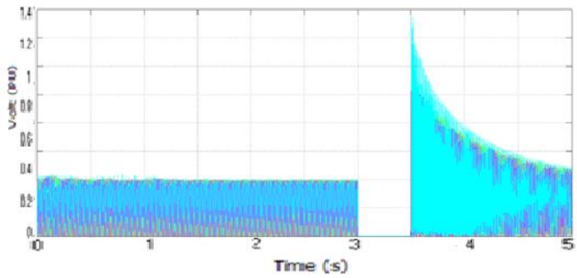

Fig.25. voltage at bus 4 with DSTATCOM/FESS connected.in VCM of three lines to ground fault

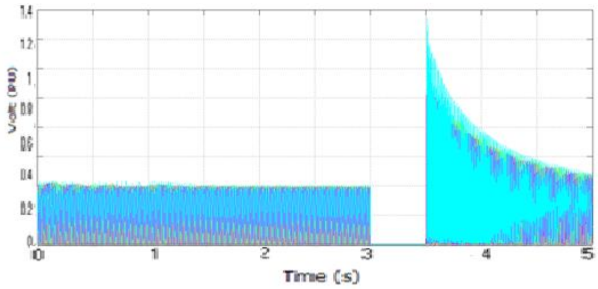

Fig.26. voltage at bus 4 with DSTATCOM/FESS connected.in PFCM of three lines to ground fault.

VI. CONCLUSIONS

This paper presents the control algorithms of a DSTATCOM controller coupled with a FESS System. A proposal is made of a fully detailed model with multilevel control algorithm based on the synchronous rotating d-q reference frame. The incorporation of the DSTATCOM/FESS with wind generation in the electric system was studied, and its behavior is analyzed in different control modes.

From the results obtained, it is concluded that with the proposed device, the power fluctuations coming from a WG are effectively mitigated. It was shown that the WG-DSTATCOM/FESS system can deliver an approximately constant active power in a time range of seconds or more. For the reactive power control, it was shown that the system is able to provide an approximately unity power factor or to maintain the voltage in the connection point. The voltage control operates satisfactorily in case of power disturbances in the WG and also for fluctuations in the system. The WG-DSTATCOM/FESS system is also studied under different types of faults, the results show that DSTATCOM/FESS is better to be connected during line to ground and line to line fault, while during line to line to ground and three lines to ground fault, disconnection of it is better. Therefore, the incorporation of DSTATCOM/FESS has shown that it can improve the power quality in wind systems, as well as, during some types of faults

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Assessment of Energy Conservation in Egypt's Electric System

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Abstract - This paper proposes a simple carrier-based PWM (CBPWM) technique to control the three- to five-phase Direct Matrix Converter (3×5 DMC). The proposed technique uses the indirect modulation approach to control the 3×5 DMC such as a three-phase bidirectional rectifier followed by five-phase voltage source inverter (VSI). Based on this approach, it is possible to synthesize the desired five-phase output voltages with sinusoidal three-phase input currents and unity input power factor. A CBPWM method is suggested for each stage independently including both linear and overmodulation operating modes. By the proposed technique, in both operating modes, the maximum possible overall Voltage Transfer Ratio (VTR) is achieved. Moreover, this technique allows the input power factor to be controlled by controlling the input current displacement angle. The feasibility of the proposed technique has been verified by a series of simulation and experimental results based on Matlab/Simulink and dSPACE-DS1104 platform. The results show that a sinusoidal output and input waveforms can be achieved with a maximum possible VTR in the linear region. However, in the overmodulation region, a maximum possible VTR is achieved at the cost of some distortion of output and input waveforms. Therefore, this technique can be used for the application where a higher VTR is essential.

I. INTRODUCTION

In the last few years Egyptian electrical system has been encountered by many challenges for instance shortage of primary source of energy which needed for generating electricity from power plants, continues increase in load demand, high value of peak load, great sum of energy subsides and high cost of investments for production, transmission and distribution of power.

Egypt`s electrical system is characterized by fuel fired electric generating power plants. Thermal electrical power plants combined of thermal, gas and combined cycle power stations have the major share of production which represents approximately 89% of electric power generation. Hydroelectric power is 9%, in addition to 2% for renewable and zero nuclear power plant is included. The major contribution of fuel fired power plants is distinguished highly. Fossil fuel is the corner stone of the electric production system, green renewable energies solar and wind is very limited with no other renewable. Diversity of primary sources isn't wide. This splitting up situation confirms that thermal electric power generation represents the dominant part of the nation electric system. Although there are many considerations against consequences of burning fossil fuel upon the environment due to emission of harmful gasses, fuel fired power plants have several advantages of relatively rational cost of installations, reasonable cost of generating energy per KWH, simple operation & maintenance conditions and long life time. Fig (1) illustrates share of electrical power plants in Egypt`s electric system EES-2014.

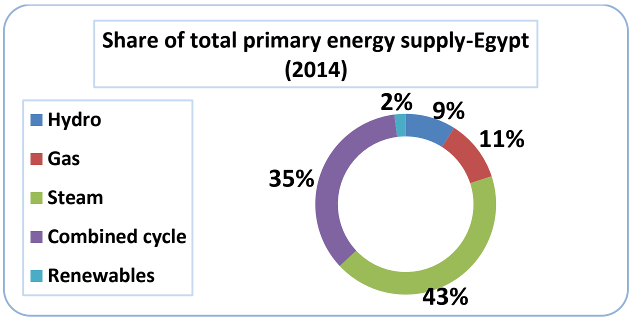

Fig .1. Egypt`s electric generation by type

Egypt`s electric system has ratios of primary electric generation by type very close to that of worldwide electric system. It means thermal power plants are the dominants (global generation: 88% thermal, 1-3 green renewable). Fig (2) shows prime electric generation by type in universal electric system (2010).

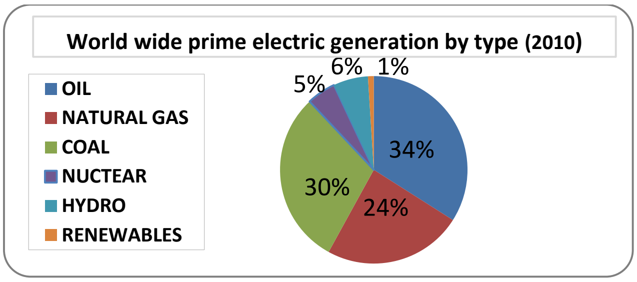

Fig .2. illustrates share of electric generation in worldwide electric power system

II. BACK GROUND

Primary sources of energy for Electricity generation in Egypt are basically oil and natural gas. Their production and consumption pass through three phases; first, from mid 70`S till mid 90s` increase in production was greater than consumption. Second, Oil production declined simultaneously with increase in consumption in local market till year 2005. Natural gas was substituted for oil in electricity generation. At fine, oil and natural gas productions were reduced dramatically with high increase in local consumption. A big gap between (oil & natural gas) production and consumption is created and it has been continued till now. Therefore, electricity generation is certainly affected by deficiency of fuel [1] Fig (3) shows oil productions and consumptions during last four decades in Egypt.

Source: \\ peak oil production

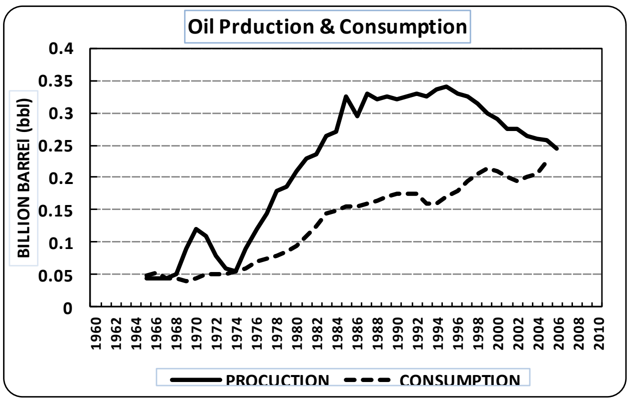

Fig .3. oil productions and consumptions in last four decades in Egypt

Assured remaining reserves for oil & natural gas in Egypt are very limited and they decrease annually in regular bases as shown in fig (4). I n year 2030 Oil and N.G will decay almost to one third of their reserves; at then no consumption of Oil & N.G will be admitted [5].

Source: http:// www.iea.org/statist/index.htm

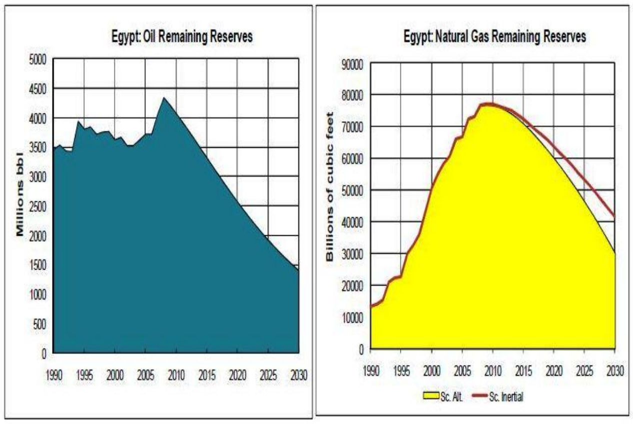

Fig .4. Remaining reserves for oil & natural gas in Egypt

III. EGYPT`S ELECTRIC SYSTEM CHALLENGES

- Declining of oil & gas productions simultaneously with raise in consumptions.
- increase in electric load demand by about 4.5% annually
- High daily peak power demand (worsen the system overall efficiency and increases energy price.
- Significant technical and un technical losses.
- Limited contribution and utilization of renewable energies.
- Lack of finance resources in energy sectors and huge budget of subsides for fuel and electricity.
- Maintenances along the network are somehow lower than recommended.
- Weakness of energy saving policies and programs in different activities.

IV. MAJOR PILLARS FOR SOLUTION

A new energy policy for solution of Egypt`s` electric system difficulties has been put into actions by the system planners and decision makers; it mainly depends upon three pillars given as:

1. Improve overall efficiency of existing electric system.

2. Maximize contributions (production & use) of available types of renewable energies (RE).

3. Initiate\ promote an impressive energy saving program and apply strategic plan for improve energy efficiency.

Suggested points of solution are the main areas of implementation; they are already put in the pathway. Extra factors have also been included.

Actions have been taken for solution points 1 & 2 in power supply side have led to increase System overall efficiency to higher than 0.44, increase availability of generating units up to 87%, reduction in fuel consumption to (0.209) gm oil equivalent/KWH and reduction in System losses almost to 11%[6] .

Point 3 of solution can be verified by bilateral cooperation between power provider and end users to achieve the goal of energy saving.

V. ENERGY CONSERVATION AND IMPROVE ENERGY EFFICIENCY.

Energy saving is defined as two terms energy conservation EC and energy efficiency improvement EEI, first, energy conservation means less input power for lower output; for example air conditions and lighting with lower operating hours, switch off lights of unoccupied areas and stop unloaded motors ..Etc. Second, energy efficiency improvement means less input power for the same output; for example use high efficient electrical and electronic appliances and devices.

Factors influence applications of energy saving procedures are given in Fig (6).

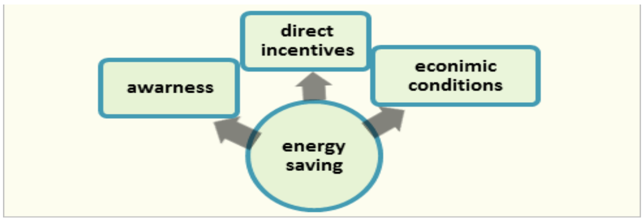

Fig .5. factors affect applications of energy saving techniques

Better use of electric energy is achieved by energy conservation, modifying efficiencies of equipment and customer behavior against use and consumption of energy as well.

VI. ENERGY SAVING FROM ECONOMIC AND ENVIRONMENTAL PERSPECTIVE

Meeting the ever increasing in electric load demand coincides with high reliability and availability and in presence of a gap between oil and gas production; energy saving is a must.

Multiple advantages of energy savings are achieved for both power providers (electric utilities) and end users since energy saving is regarded as an additional source of power with low cost price for the reason that cost of saving energy is lower than cost of generating it.

A. Benefits of Energy Saving for Electric System

- Improve electric system overall efficiency.
- Reduce system losses and boost up voltage levels
- Perform better load profile & lower peak demand
- Decrease fuel needed for electricity Production.
- Downsizing capacities of electrical generating units & lengthen their expected life times.
- Declining energy costs especially at periods of peak demands.
- Reduce air pollutions and guarantee environmental safety.

B. Benefits of Energy Saving for customer

- Reduce customer electric energy bills.
- Increase customer system capacity for the same ratings of components.
- Possible extend in loads for the same contracted power.
- Lower losses and improved voltage drop.
- Higher customer system power quality.

VII. PROGRAMS OF ENERGY CONSERVATION IN EGYPT

Several programs of energy Conservation have been conducted since mid1990`s up to date, Alexandria electricity distribution company (AEDC) has participated in several programs such as:

- Energy conservation and urban environment in Mediterranean countries (95-96), the program was sponsored by European commission, it has been planned to customer awareness of compact fluorescent lamps (CFL) and Primary studies in cogeneration techniques.

- USAID energy conservation and environmental project (DSM). The objectives were designed to, first develop and launch demand side management unit at AEDC. Second, test potential impacts of industrial DSM (96-97).

- Energy and environmental auditing in small & medium enterprises (SME`S) in Alexandria network, it intended to identify and evaluate opportunities for energy conservation and environmental protection for SME`S. Energy efficiency improvement & green house gas reduction (EEIGGR) was sponsored by developing program of United Nations and in cooperation with (EEHC) Egypt`s electricity holding company (99-2002).

- Energy conservation in governmental buildings in collaboration with (EEHC) and Alexandria governorate (2006-2007).

- Energy efficiency improvement for small industrial enterprises in cooperation with (IMC) industrial modernization center (2007-2010).

- Energy efficiency improvement in public lighting in collaboration with (EEHC) and ministries of industry & trade, finance and social developments (2009).

- Energy conservation in worship houses mosques, cathedrals and churches in collaboration with (EEHC) (2010-2011).

- Energy efficiency improvement for small industrial enterprises in cooperation with (IMC) industrial modernization center (2015-2016).

VIII. CASE STUDY

In a program of energy conservation, a variety of medium scale end user utilities are selected to implement energy audit / survey to identify potentials of no cost/ low cost energy saving opportunities in administrative, commercial, industrial, worship houses and governmental facilities. Numbers of 50 utilities were included in the survey. Energy saving opportunities for electricity fuel and water were identified; reduction in emitted co2 was evaluated.
ost of investments and pay back periods for options were estimated.
High cost opportunities for energy savings are avoided and utility doesn't have the suitable demonstration project is excluded from the program.

IX. SEQUENCE OF PROGRAM EXECUTION

Steps of completing the survey and reported the results are conducted according to the sequence given in Fig (6).

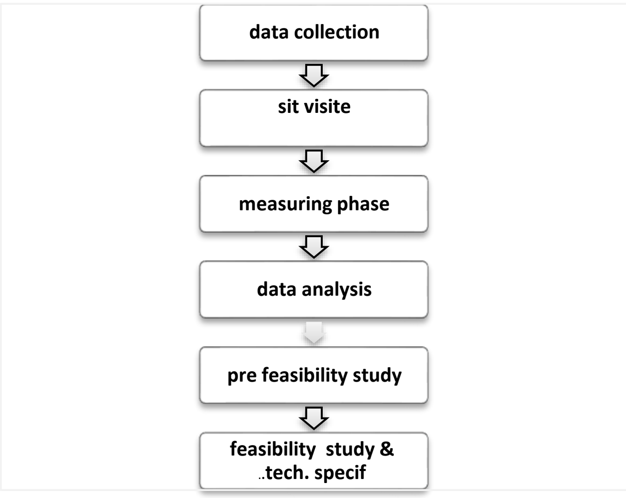

Fig .6. flow chart of energy saving reported program

X. MEASURING PARAMETERS AND DEVICES

Electrical measurements are executed by energy analyzer device at low voltage side of .a Customer plant. It is a robust device with ability to store an enormous amount of data in a memory box. Recorded data are transmitted to computers by interface unit and converted to graphs. Measuring parameters are volt (V), current (I), active & reactive power (P&Q), power factor (PF), harmonic total and individuals (THDV%, V n% THDI%, I n %). Measuring Period is a daylong or more to record variables during complete load cycle. Luxmeter is a device for measuring lighting intensity.

Thermal parameters are measured by gas analyzer device to measure exhaust (flue) gases as o2, co2, & co. Ultrasonic microphone to measure leakage in steam/ compressed air. Temperature sensor and barometer are also used.

XI. ENERGY SAVING PROGRAM DATA

The program included 50 utilities represent groups of activities such as commercial buildings, hotels, cinema, conference centers, hospitals, worship houses, educational and governmental buildings, sports club,..Etc. Table (1) gives group No., activity types and % weight of each.

Table 1. activities types and numbers of categories

Group No.	Activity type	Utilities no.	% weight
1	Commercial building	5	10
2	hotel	6	12
3	Conference center	2	4
4	Sport club	1	2
5	hospital	4	8
6	Resort & tourist village	3	6
7	Worship house	2	4
8	Educational building	1	2
9	Governmental building	1	2
10	industrial facility	25	50
TOTAL		50	100

Several energy saving opportunities were achieved for facilities included in the survey. They are summarized as follows:

- Power factor improvement.
- Lighting system upgrade.
- Air condition & heat ventilation system improvement.
- Boiler fuel consumption improvement.
- Steam distribution system efficiency improvement.
- Automatic control of steam feeding.
- Cogenerations & waste heat recovery.
- Load management (demand control).
- Boiler blow down rate.
- Steam traps replacement and maintenances.
- Steam condensate system install & maintenance.
- PV solar power and /or solar heating systems.
- Steam & compressed air leakage minimize.

Results of survey show that most utilities use more than one type of energy source like electricity, fuel, steam and compressed air. Any utility almost has at least one opportunity for energy saving and improve lighting system is a common option for all individuals. Many electrical, thermal and environmental options were achieved; they are classified as Reduction in power peak demand in megawatt (MW), saving in electrical energy consumptions in mega watt hour (MWH), fuel use reduction in tones and water use in cubic meter (m3) are evaluated. Corresponding reduction in energy cost in Pounds (LE) are estimated. Environmental impact due to saving in co2 in tones was computed. Cost of equipments in LE and pay back periods in years were calculated. Results are shown in tables (2) and (3).

Table 2. energy audits for 50 AEDC end user`s sites & energy savings

Activity type	Saving options	saving		Water (1000 m3)	Fuel oil#6 (1000 tone)	Penalties (1000L)
		MW	MWH			
Commercial building	2 , 3 &12	0	397.55	0	0	0
Hotels	1, 2, 3 8 & 9	0.312	1457.81	2.64	0.11	85.50
Conference center	1 & 2	0	380.53	0	0	28.83
Sport club	1 & 2	0	19.98	0	0	4.82
hospitals	1, 2, 5 11&13	0.342	1404.79	1	0.039	133.99
Resort & tourist village	1 & 2	0	688.96	0	0	9
Worship houses	2 & 3	0	11.79	0	0	0
Educational building	2	0	20.41	0	0	0
Governmental building	2 & 3	0	63.11	0	0	0
industrial company	1, 2, 3, 4 5, 6, 7, 8 9, 10, 11 12 & 13	2.48	7527.88	249.02	235.37	708.38
Total saving		3.14	11972.8	252.67	235.52	970.52

Table 3. results of energy saving s and environment impact

Activity type	Saving co2 (1000 tone)	Total saving (1000L.E)	Invested Cost (1000 L.E)	Payback period (year)
Commercial building	0.34	95.97	132.08	1.38
Hotels	1.43	364.73	448. 25	1.23
Conference center	0.29	98.65	144.95	2.8
Sport club	0.15	13.81	70.24	5.1
Hospitals	0.66	412.32	454.48	1.1
Resorts & tourist villages	0.52	128.70	74.54	0.58
Worship houses	0.01	1.80	5.19	6.6
Educational building	0.014	3.67	4.15	1.1
Governmental building	0.048	11.68	6.70	0.57
Industrial companies	71.47	6008.33	6129.50	1.02
TOTAL	74.94	7139.67	7469.92	1.05

Calculations are based upon prices of all types of energies and costs of materials. Irrespective electricity tariff, prices of fuels and cost of materials are often unfixed; that don't change the ending results anyway. Calculations are performed based upon fuel consumption is 0.209 grams of oil equivalent per KWH and emission of warming gas co2 is 3.082/kg fuel.

Results obtained from a medium scale energy saving program implemented to 50 utilities represent different load categories such as commercial, educational, governmental buildings, hotels, sports clubs, conference centers, worship houses and industrial utilities evaluate and assess the benefits gained from energy conservation program applied to a random sample of loads.

Tables (1) & (2) and (3) illustrate the results, it show that:

- Most savings are achieved in group (10) presented in table (1). It`s weight% is 50% but it provides savings between 0.63 to 0.99 of total savings, i.e. potentials of energy savings are considerable in industrial sector.
- Savings are remarkable in electrical energy consumption in groups (4, 7) despite cost of investments for each need relative long payback period.
- Total reduction is 3.14 M.W in peak load demand .Yearly Savings are 11972.8 MWH in electric energy, 252.67 *1000 (m3) in water and 235.52 *103 (tone) in fuel.
- Total cost saving is 7139.67*103 L.E, estimated cost of investments is 7469.92*103 L.E; overall payback period is 1.05 year.
- Good environment impact; reduction equals 74.94*103 tone of emitted gas co2 is accomplished

Investigation of results show that in any organization energy is often consumed somehow in an inefficient manner, excess consumptions in electricity, fuel and water are observed, therefore, energy conservation programs could be implemented upon any class of business. Results are significant. Procedures of improvements are almost simple and easily Applied, Invested cost isn`t highly sound, payback periods are very limited and positive effect upon environment is extremely attained.

XII. CONCLUSIONS

Since Egypt`s electric system encounters several challenges that seriously affect its performance from view points of continuity, adequacy and quality that may reflect negatively upon satisfaction of consumers and detrimentally have an effect on economic situation; this has push decision makers and system planners to establish a strategic plan for solution depends on three supports including; efficiency improvement of present electric system, scale up contributions and use of all available types of renewable energies and promote/encourage energy saving programs, adding to installation of coal fired electric power plants and nuclear power stations.

Shortage in natural resources of prime energies oil & natural gas , volatile in petroleum prices in world markets and guarantee safety of environment as a result of fossil fuel fired power plants make the challenges are great. Although increase contribution of renewable energies in Egypt`s electric system is suitable solution in long run, it also controlled by extremely large invested cost needed by local or foreign financiers. As will as setting up power plants certainly require few years till electricity begins to generate.

Energy saving seems to be the key factor for assurance of adequacy, continuity and quality of power supply. Electric utilities especially distribution companies are in the heart of events, they have a big role in involving the end users participation in energy saving programs, the customer `s awareness, guidance and support will lead to wonderful results. Media and social organizations have also a great responsibility in drive the individuals towards energy savings.

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ICT for Community Energy

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Abstract - Community energy initiatives are becoming more and more widespread. For them to be successful and flourish, engagement from people in the community is a prerequisite. ICT can provide the means to support engagement, by helping people to assess the impact and benefits of a CE project and by capturing and disseminating the benefits. Also, ICT can support with the design and management of a CE project; and lastly ICT can support research on the topic.

***Keywords* -** Community energy, ICT, engagement, participation, CIVIS.

I. INTRODUCTION

Due to changing dynamics in social structures, technology, economics and politics, the traditional role division between citizens and government has started to shift. This shift is often referred to as a transition: "a gradual, continuous process of societal change where the structural character of society (or a complex sub-system of society) transforms" [1]. A result of this transition is the fact that community-led initiatives arise more and more, of which specifically the number of communities that generate their own energy is notably growing [2]. Also known as 'community energy' (CE), this refers to initiatives where communities exhibit a high degree of ownership and control of an energy project, as well as benefitting collectively from the outcomes [3]. Although often characterised by a high degree of motivation from the people involved, we propose that for these initiatives to flourish in practice, information- and communication technologies (ICT) can support community engagement; a crucial prerequisite for a successful initiative. This topic is part of the FP7 CIVIS project, that explores the potential of social networks and communities to significantly reduce energy use and carbon emission.

II. ICT FOR COMMUNITY ENERGY

For a CE initiative to become more than a daydream of a few, engagement is needed from the broader population. CE projects can address both the supply and demand of energy, for example realising a communal windmill or collective buying of energy. Engagement in turn means that people have to understand the goal of the initiative, feel connected to it, and are willing to take action to reach this communal goal. Engagement is therefore the result of the weighing of impacts and benefits, and is thus very much coloured by people's values [4]. Values are what people find important; they can range from individual and collective accomplishments, competence or autonomy, to community spirit and environmental protection. For people to make a well-informed assessment of a CE initiative, thereby addressing the values people hold, we propose that ICT can service as a supporting tool in CE initiatives.

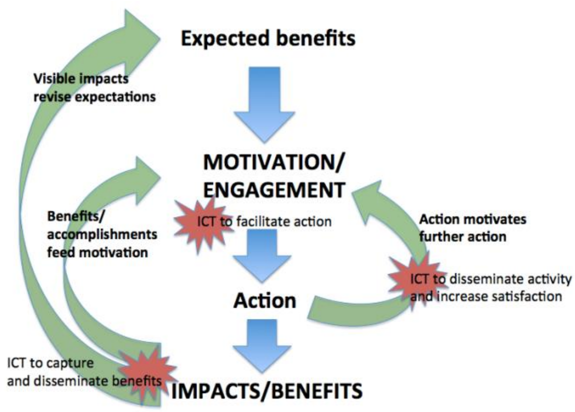

Fig .1. Possible intervention points for ICT to support engagement.

The range of potential roles for ICT in relation to maximizing engagement for CE may be grouped into three categories: ICT to support engagement (as depicted in Figure 1 above); ICT to support project design/management; and ICT to support research. The three categories, and how ICT can specifically support, are briefly explained here:

III. ICT TO SUPPORT ENGAGEMENT

- Remove specific barriers (e.g. crowdfunding for financing project or sourcing volunteers);
- Facilitate action and participation (e.g. providing practical information, awareness-raising);
- Support sharing info/ advice/experiences (knowledge-sharing) (e.g. online forum facility including video, audio and interactive media for user-generated content);
- Create opportunities for interaction between citizens and enhancing experiences of social gratification from collective activities (e.g. gamification and social gaming element to maximize social presence, trust, reciprocity, fairness etc.);
- Give feedback to participants/citizens others' participation and activity including the enjoyable aspects of participation in collective action (e.g. Content posted on the platform by participants);
- Give feedback to participants/citizens about the positive impacts, accomplishments and benefits (broadly defined) of the CE initiative (e.g. Content posted on the platform by project , e.g. to promote pro-social values by broadening the usual discourse about benefits beyond financial ones);
- Improve the measurement and assessment of impacts and benefits of all kinds and collating an evidence base and disseminating this (e.g. using digital media of various kinds. This could also spur other communities/actors to follow suit);
- Disseminate benefits, accomplishments and activity more widely beyond the community and to other stakeholders (e.g. this could include supporting and disseminating user-generated content (UGC), i.e. first-hand accounts about project benefits/impacts or experiences of participation.

IV. ICT TO SUPPORT DESIGN

ICT can support design and management of projects/initiatives (e.g. feedback from users/citizens to project designers/leaders/coordinators to support consensus-building, decision-making and data collection). Applying the feedback in turn can lead to more engagement if people see that their input is used.

V. ICT TO SUPPORT RESEARCH

ICT can support research and data collection/sharing (e.g. platform functionality to allow/facilitate research activity and data collection on engagement, attitudes and user experience such as discussions, polls and making data available to other projects/researchers). This would also help in the accumulation of an evidence base. Applying the data in turn can lead to more engagement by making the value of the initiative more explicit.

VI. CONCLUSION

We argue that perceived benefits and impacts from a CE initiative can play an important role in supporting engagement and that ICT can play an important role in both addressing the evidence for assessment of impacts and in capturing and representing these to increase participants' awareness of these impacts/benefits. Furthermore, ICT can be used as a supporting tool for the design and management of an CE project itself, and for broadening the evidence base for research purposes.

VII. ACKNOWLEDGEMENTS

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Performance Improvement of Roof Transparent Solar Still Coupled With Agriculture Greenhouse

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***Abstract* -** In Egyptian desert, growing plants is difficult due to harsh climate (hot at the daytime and cold at the night), infertile soil, low average rainfall and lack of fresh water for irrigation purposes. A set of simple transparent solar stills are integrated with a new solar driven agriculture greenhouse (GH). The stills are placed at the GH roof to use the extra solar radiation (above that required for plant photosynthesis process) for water desalination. In addition to water desalination concept the solar still units even reduce the cooling load during the daytime. A net of aluminum metal coated with black colour is placed on the base of the solar still units to raise the water temperature (enhance desalination process) and provide partially shading for the GH. Using aluminum net decreases also the number of solar still units required to produce the required amount of GH fresh water leading to a significant cost reduction.. Therefore, this technique can be used for the application where a higher VTR is essential.

The main objectives of this work are sizing of the aluminum net, spacing between solar still units to obtain the threshold of plant requirements. Also fresh water production and greenhouse climatic conditions that plant needs (temperature, relative humidity, air velocity and amount of oxygen) are simulated.

Numerical simulation was carried out for the hottest day of Borg Elarab, Alexandria (Egypt).

***Keywords* -** renewable energy; solar energy; water desalination; agriculture greenhouse; solar stills

I. INTRODUCTION

Water, suitable soil, solar radiation and suitable climate are the major parameters for high quality and quantity plants production. Most of Egypt deserts are not used because of water shortage and harsh climatic conditions.

The threshold of solar radiation plant needs for photosynthesis process is 8.46 MJ/m2.day (2.35 kW.hr/m2.day) [1]. Plants often need a temperature in the range of 10 – 30 oC and a relative humidity in the range of 60 – 90 % [2]. Where the temperature should not be high to avoid water stress resulting from water losses through the plant leaves. Also, low humidity increases the water loss as a result of transpiration. On the other hand high humidity severely limits evaporation rates, so water is not being transported from the root zone and neither are any nutrients [3]. Therefore, solar radiation, temperature and relative humidity should be controlled to produce a proper environment for plant growth. GH can present an agriculture solution as the main environmental factors can be controlled as temperature, relative humidity, and photosynthetic photon flux.

Parameter	Nomenclature
A_{gr}	Area of the greenhouse floor
B_c	Breadth of the channel
$C_{p,g}$	Specific heat of glass
$C_{p,p}$	Specific heat of the plants
$C_{p,al}$	Specific heat of aluminum
H_b	Heat transfer coefficient to soil
h_w	Height of water in the solar still
L	Length of the GH
LAI	Leaf area index
L_b	Base length of solar still
lp	Characteristic length of a leaf
M_p	Mass of the plants
$\dot{m}_{air}$	Mass flow rate of mixed air
$N_{SS,r}$	No. of solar still units in vertical riser
$N_{SS,h}$	No. of solar still units in horizontal riser
ra	Plant aerodynamic resistance
rs	Plant stomatal resistance
Tco	Cooling water temperature
T_o	Temperature of soil at larger depth
t_{net}	The thickness of the metal net
W	Width of the GH into paper
α_{al}	Absorptivity of aluminum
α_p	Absorptivity of the plants
α_g	Absorptivity of glass
α_{gr}	Absorptivity of the GH floor
α_w	Absorptivity of water
□	Angle of the solar still cover
ε_g	Emissivity of glass
ε_{gr}	Emissivity of the GH floor
ε_p	Emissivity of the plants
ε_w	Emissivity of water
ρ_{Al}	Density of aluminum
ρ_g	Density of glass
ρ_w	Density of water
τ_g	Transmissivity of glass
τ_w	Transmissivity of water
ΔTapp	Approach temperature

A new GH design of inside controlled climate, solar driven and self-sufficient of water production agriculture greenhouse system is developed to overcome these problems [2-4] where a roof solar stills are placed on the GH roof.

In this paper, a net of aluminum coated by black color is placed over the base of solar still units to enhance the desalination process. A mathematical model based on mass and heat transfer for each greenhouse component has been modified to predict the inside climate conditions and calculate the water production of the system. The simulation is carried out for the hottest day of Borg Elarab, Egypt.

II. SYSTEM DESCRIPTION

Figure 1 clarifies the Conceptual Configuration of the on-roof transparent solar still coupled with agriculture greenhouse system. The system consists of a greenhouse cavity covered with transparent cover, a condenser at exit of greenhouse cavity, vertical and inclined risers, down comer channel, short chimney, a set of simple transparent solar still units placed in vertical and inclined risers.

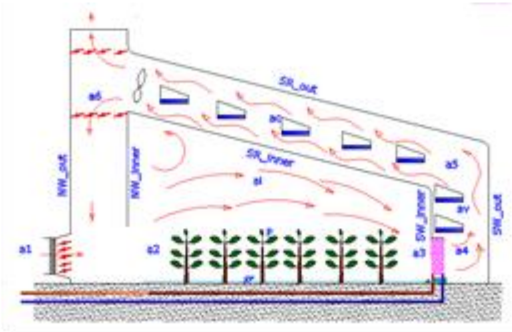

Fig .1. Conceptual Configuration of the GH Integrated With Roof Solar Stills

Figure 2 clarifies the Solar Still Configuration. A net of aluminum metal coated with black colour is placed on the base of the solar still units.

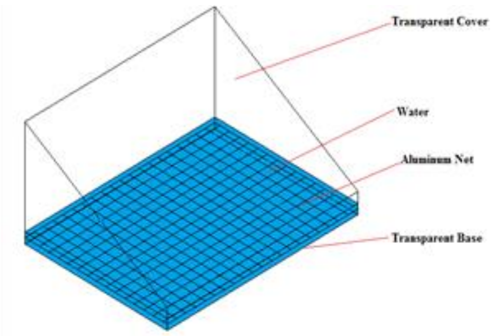

Fig .2. Conceptual Configuration of the Solar Still Unit

Part of the solar radiation is transmitted for plant photosynthesis process and the main part is absorbed by the solar still units for saline water desalination. The rest of solar energy is absorbed by transparent covers of the greenhouse and solar still units and get heated to enhance the air natural circulation.

The circulating air (coming from the GH down comer channel) is mixed with fresh ambient air to adjust its temperature and relative humidity to be suitable with plant requirements, Figure (1). The mixed air passes through GH cavity and entrain the water vapor produced by plant inspiration. Then, part of this humid air passes through a chilled water condenser to condense as fresh water while the other part is bypassed. After that air is mixed and passes through vertical and inclined risers to cool the solar still units and get heated causing natural draft.

III. MATHEMATICAL MODEL

Mathematical model is developed to calculate the hourly transmitted and absorbed solar radiation for each GH surface based on clear sky day model [5] and quantify the GH performance based on mass and energy balance for each GH component where the following assumptions were taken in the consideration: a) uniform distribution for circulating air temperature and relative humidity; b) The temperature at deep ground is constant and evaporation from the greenhouse floor is negligible; c) lumped system is considered for each GH component; d) Thermal properties of the plants are same as those of water; f) One dimensional model.

IV. RESULTS AND DISCUSSIONS

The thermal performance of the system is illustrated based on developed model calculations for environmental conditions of the hottest day (the 11th of July) which represents summer season of Borg Elarab, Egypt. Design and operational parameters that have been used as input parameters for the developed mathematical model are given in Table 1.

Table 1. Input parameters

Geometrical parameters		**Operational parameters**	
A_{gr}	*160 m²*	$\dot{m}_{air}$	*0.5 kg/s*
B_c	*1.5 m*	M_p	*1600 kg*
$N_{SS,r}$	*60*	ΔT_{app}	*5 °C*
$N_{SS,h}$	*120*	T_{co}	*10 °C*
W	*20 m*	**Plant parameters**	
L	8 m	l_p	*0.03* [6]
W_b	1 m	LAI	*3* [6]
L_b	0.75 m	r_a	*50 (day) to 5000 (night) S/m* [7]
h_w	0.01 m		
β	30°	r_s	*250 S/m* [7]
t_{net}	0.005 m		
Thermal and optical parameters			
α_p	*0.4* [8]	ρ_w	*1000 kg/m³*
α_g	*0.06* [9]	ρ_{Al}	*2712 kg/m3*
α_{gr}	*0.4* [10]	τ_g	*0.9* [12]
α_{al}	*0.92*	τ_w	*0.7*
α_w	*0.89*	$C_{p,g}$	*4190 J/kg k* [11]
ε_g	*0.92*	$C_{p,p}$	*4190 J/kg k* [13]
ε_{gr}	*0.93*	$C_{p,al}$	*921.096*
ε_p	*0.92*	H_b	*1 w/m² °C* [14]
ε_w	*0.4733*	T_o	*17 °C* [14]
ρ_g	*2500 kg/m³* [11]		

The ambient temperature and relative humidity is shown in Figure 3. The ambient temperature varies from 23.5 to 31 oC and the ambient relative humidity varies from 55 to 91%.

Figures 4 and 5 show the effect of using AL-metal with area ratio between the metal net and the base of 20% on the performance of climate inside the greenhouse. It is seen that changing the area ratio did not cause any change in the inside microclimate conditions.

Figure 6 and 7 show the effect of using AL-metal on the GH fresh water production and the transmitted solar radiation respectively.

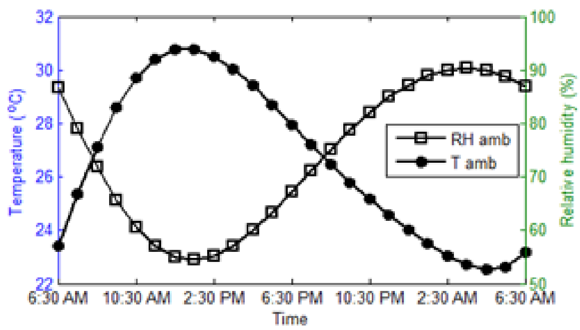

Fig .3. Ambient conditions (temperature and relative humidity)

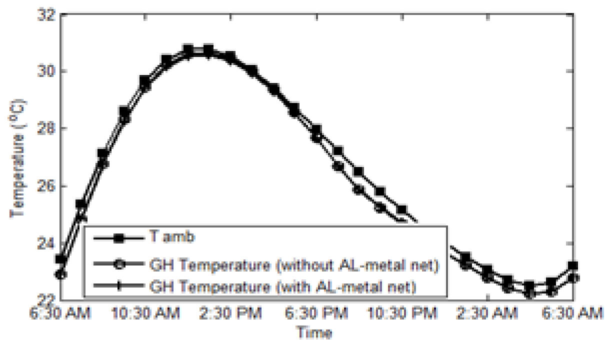

Fig .4. Effect of using AL-metal net on GH temperature.

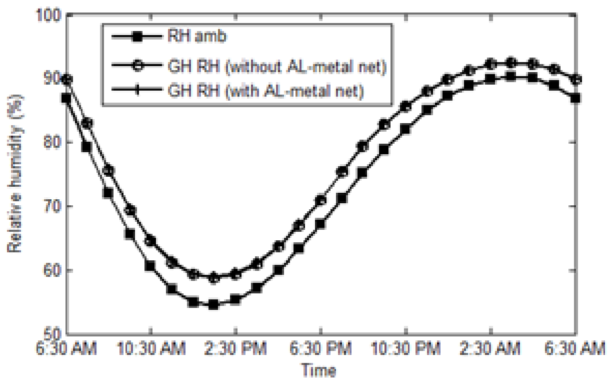

Fig .5. Effect of using AL-metal net on GH RH.

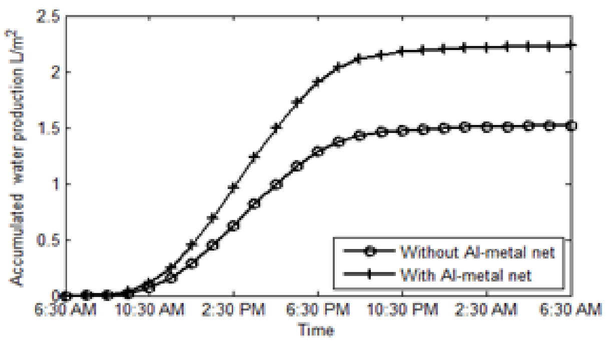

Fig .6. Effect of using AL-metal net on water production.

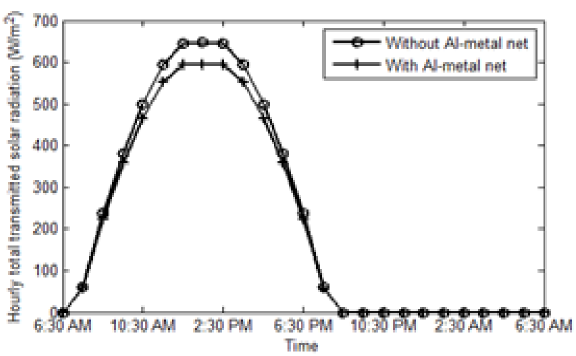

Fig .7. Effect of using AL-metal net on solar radiation transmittance.

V. CONCLUSIONS

It is concluded that the developed GH-Still integrated system can produce its needs of water for irrigation purposes. Using AL-metal net with area of 20% of the solar still base area increases the water production by 50%. The transmitted solar radiation slightly affected by the metal net, but the internal performance of the greenhouse was not affected.

VI. ACKNOWLEDGMENT

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Role of Dyestuff in Improving Dye-Sensitized Solar Cell Performance

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Abstract - Dye-sensitized solar cells DSSCs have attracted great attention for their simple fabrication process, low production costs, relatively high conversion efficiency, and being environmental friendly.

DSSC are a combination of materials, consisting of a transparent electrode coated with a dye-sensitized mesoporous film of nanocrystalline particles of TiO2, an electrolyte containing a suitable redox-couple and a electrode.

DSSCs use organic dye assist to produce electricity in a wide range of light conditions, indoors and outdoors. The dye in the solar cell is the key element since it is responsible for light harvesting ability, photoelectron generation (the creation of free charges after injection of electrons into the nanostructured semi-conducting oxide) and electron transfer.

For this reason, this paper gives a background of dyestuff, types and limitations. The motivation of this work is to design a simple, easy and prepare an efficient organic dye sensitizer.
Also, this paper investigates the important criteria which are considered for selecting dye to enhance DSSC efficiency.

Keywords - dye-sensitized solar cells, DSSC performance, dye, poto sensitizers, organic dye sensitizer.

I. INTRODUCTION

Solar energy provides a clean, renewable and cheaper energy source for human race, while serving as a primary energy source for another type of energy sources, namely; wind energy, water, bio-energy and fossil fuel. The solar cells used in harvesting the solar power are commonly categorized into different types in respect to the composition of their material e.g. organic dye solar cells, non-crystal, multiple crystal, and single crystal silicon solar cells. A solar cell usually signifies the cell that is made from silicon crystal material. Nevertheless, the production cost of the solar cells based on silicon crystal material compared to the Dye-Sensitized Solar Cells (DSSCs) is high. DSSCs are devices that convert solar to electric energy by light sensitization established on wide energy band semiconductor [1]. DSSC shows a very promising future in the field of photovoltaic cells. DSSC also known as Grätzel cell is a new type of solar cell [2], and have attracted a great interest due to their minimal production cost, and environmental friendliness

DSSC considered as third generation solar cells of high efficiency with low production costs. Although present-day DSSCs provide light-to-electricity conversion of less than 12%, further condensed investigations daily done for improvement this ratio by modifying not only each single component's function of the cell but also optimizing their compilation for easier and efficient communication between them to produce maximum benefits.

In addition, DSSC devices can be manufactured to be semi-transparent to harvest light from any direction in order to be used as photovoltaic windows in buildings or small devices.

The dyestuffs which are the backbone of the DSSC or photo-electro-chemical-voltaic cells are common issue in many research centers interested in developing photovoltaic cells.

This review article presents what we know and what we need to know about role of dye in DSSC in order to formulate basic guidelines and strategies for improving of dye-sensitized solar cells.

Also, in this perspective article, some important points will be recommended for further increase of DSSC efficiency.

In order to be familiar with the function or dyestuff in the DSSC a concise overview will be summarized about different types of dyestuff, its role in DSSC, relation with colors and light, classification according to application and structure , synthesis and what factors affecting its quality.

II. DYE SOLAR SENSITIZED CELLS (DSSC) CONSTRUCTION

DSSC comprises of a nano-crystalline porous semiconductor electrode-absorbed dye as a power electrode and counter electrode, an electrolyte containing iodide and triiodide ions, and shown in Figure (1).

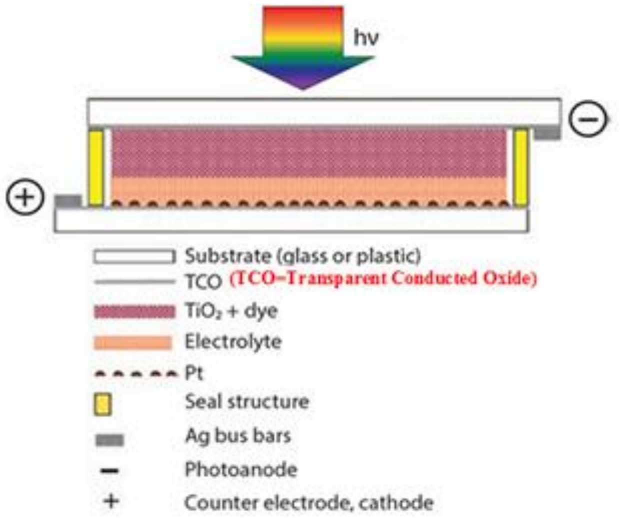

Fig .1. Construction of DSSC

III. SIMILARITIES OF DSSCS AND PHOTOSYNTHESIS

Both DSSCs and plants both harvest energy from sunlight. Photovoltaic solar cells collect sunlight and change it to electricity. Plant leaves gather sunlight and convert it into stored chemical energy. Both DSSCs and plants are utilizing dye to convert light energy into another sorts of energy, but they do it in different ways.

Photosynthesis, the effectiveness of the light conversion in plant's leaves in which chlorophyll acts as the dye corresponds to the sensitizer dye in DSSC as shown in Figure (2).

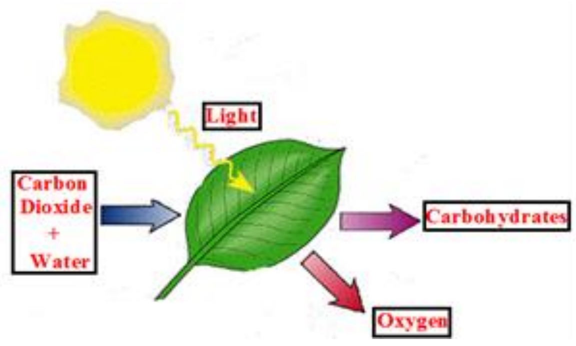

Fig .2.

Light energy transfers (in plant) into chemical reaction forming formal dehyde(from CO2+H2O+hv = HCHO +O2) which polymerized to glucose (6HCHO = C6H12O6)then starch (C6H10O5)n or cellulose polymers, while Light energy converted to electric current in DSSC.

So, the DSSC is designed based on photosynthesis phenomena.

IV. DYE AS PHOTO SENSITIZER

In spite of several elements combining the DSSC (2 electrodes, dye, electrolyte, sealing),

The dye which acts as sensitizers in DSSCs plays an essential task in absorption and conversion of incident light ray into electricity.

Dye is considered as a promising element for getting more performance to DSSC.

V. WHAT IS DYE

By definition Dyes can be said to be colored, ionising and aromatic organic compounds which shows an affinity towards the substrate to which it is being applied. It is generally applied in a solution that is aqueous. Dyes may also require a mordant for better fastness on the material on which it is applied.

Dyes are applied to numerous substrates for example to textiles, leather, plastic, paper etc. in liquid form. One characteristic of dye is that the dyes must get completely or at least partially soluble in which it is being put to. The rule that we apply to other chemicals is similarly applicable to dyes also. Precautions should be taken upon handling of dyes For example certain kind of dyes can be toxic, carcinogenic and can pose as a hazard to health.

VI. CLASSIFICATION OF DYES

There are several ways for classification of dyes. It should be noted that each class of dye has a very unique chemical structure and particular way of bonding. While some dyes can react chemically with the substrates forming strong bonds in the process, others can be held by physical forces. One of the prominent ways of several classifications which is more effective to our application is Chemical classification- Based on the nature of chemical structure.

VII. WHY DYES ARE COLORED

Dyes possess color because they

1. Absorb light in the visible spectrum (400–700 nm),
2. Have at least one chromophore (color-bearing chemical group),.
3. Have a conjugated system, i.e. a structure with alternating double and single bonds, and
4. Exhibit resonance of electrons, which is a stabilizing force in organic compounds.

When any one of these features is lacking from the molecular structure the color is lost.

In addition to chromophores, most dyes also contain groups known as auxochromes (color developers), examples of which are carboxylic acid, sulfonic acid, amino, Nitro, and hydroxyl groups. While these are not responsible for color, their presence can shift the color of a colorant and they are most often used to influence dye solubility.

Table 1 shows the relationships between wavelength of visible (observed) color and absorbed color (Complementary colors).

Table 1. Wavelength of light absorption versus color in organic dyes

Wavelength Absorbed (nm)	Color Observed	Color Absorbed
400-435	Yellow- Green	Violet
435-480	Yellow	Blue
480-490	Orange	Green-Blue
490-500	Red	Blue-Green
500-560	Purple	Green
560-580	Violet	Yellow- Green
580-595	Blue	Yellow
595-605	Green-Blue	Orange
605-700	Blue-Green	Red

VIII. THE IMPORTANT FACTORS TO BE CONSIDERED WHEN DESIGNING A DYE.

When designing a dye for DSSC application, there are many important factors that need to be taken into consideration.

1. The dye should have a broad absorption spectrum, preferably all the way into the near-IR in order to harvest as many incident photons as possible.

When we talk about light and dye we concentrate on 600 nm out of 1014 nm wave length or 103 Hz frequency out of 1014 Hz. As it shown in Figure (3) by part of UV, all visible light and near Infra-red (NIR) range.

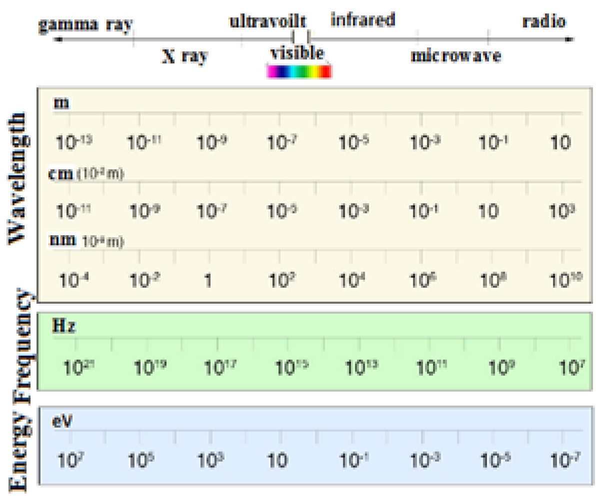

Fig .3. The Electromagnetic Spectrum

2. A high extinction coefficient will enable the use of thinner semiconductor films and still keep a high degree of absorbed photons as shown in Figure(4).

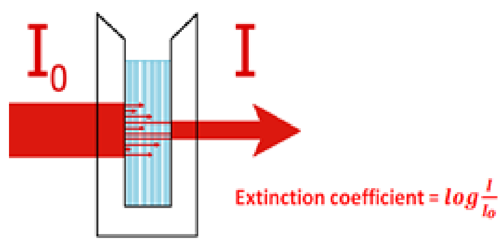

Fig .4.

3. It must bind strongly to the semiconductor surface for long term stability.
4. The energy levels should match the conduction band of the semiconductor and the redox potential of the hole-conductor, as shown in Figure (5).

5. Easy and straightforward synthesis for future large scale production.
6. Low toxicity and possibility to recycle.
7. High photo-stability to sustain at least 20 years of use.
8. Achieve a long lifetime of the injected electrons by blocking the recombination pathways.

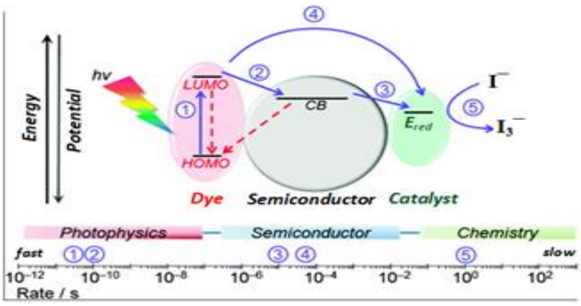

Fig .5.

The properties of the organic sensitizers can be modified by incorporating different groups into the molecule.

By choosing the right design, the sensitizer can be tuned in order to increase the long wavelength absorption, achieve a high extinction coefficient, and shift the energy levels to improve the performance of the solar cell.

The positions of the energy levels in the sensitizer are of great importance.

A small gap between the levels gives the possibility to harvest more low energy photons.

If the energy exceeds the band gap of the semiconductor, the photon can be absorbed and an electron will be excited from the valence band to the conduction band. Electrons in the conduction band can move, which allows for electric current, as shown in Figure (6). The difference between the photon energy and the band gap will end up as heat.

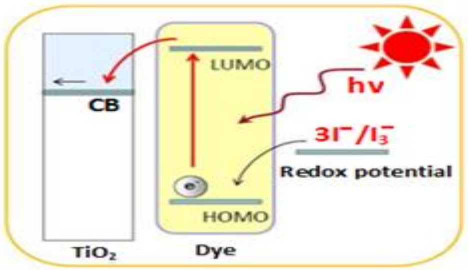

Fig .6.

A common way of designing organic dyes is the D-π-A strategy [4], where the molecule is built up of an electron donor, a conjugated linker, and an electron acceptor, as illustrated in Figure (7). This structure will yield an intramolecular charge separation upon excitation which is desired for DSSCs.

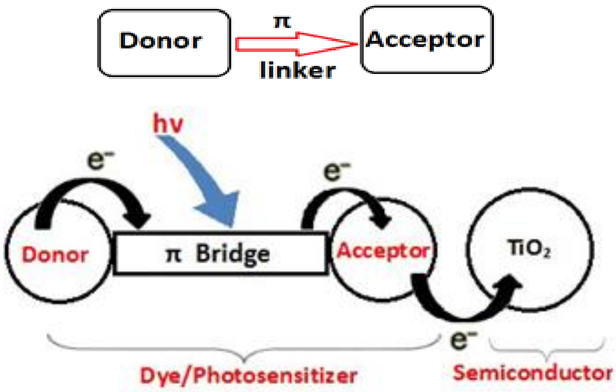

Fig .7.

IX. CONCLUSION

This review article presents what we know and what we need to know about role of dye in DSSC in order to formulate basic guidelines and strategies for improving of dye-sensitized solar cells.

Also, this paper investigates the important criteria which are considered for selecting dye to enhance DSSC efficiency, and it has been shown that, there are a great number of factors that need to be kept in mind.

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Factors Affect Dye Sensitized Solar Cells performance

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Abstract **-** Recently, dye-sensitized solar cells (DSSCs) have received great attention for their simple fabrication process, low production costs and, relatively high conversion efficiency.

DSSC are a combination of materials, consisting of a transparent electrode coated with a dye-sensitized mesoporous film of nanocrystalline particles of TiO2, an electrolyte containing a suitable redox couple and an electrode. In order to optimize DSSC performance, it is important to fully understand the factors which affect the key features of DSSC characteristics.

This paper presents an overview of the construction of a dye-sensitized solar cell, operating principle of DSSC, DSSC performance and, investigates the most important parameters which affect Dye-Sensitized Solar Cells performance.

Keywords **-** dye-sensitized solar cells, DSSC performance, dye, Factors improve DSSC efficiency

I. INTRODUCTION

Traditional energy sources (fossil full) face a number of challenges such as:

- Increasing energy demand;
- Fuel depletion.
- Climate change; and
- Pollution and public-health hazards.

From an environmental perspective, renewable energy source is an alternative source to the conventional energy sources.

Solar energy sources are considered one of the most promising renewable sources [1-6], since solar energy sources are clean, inexhaustible, environment friendly, plentiful and easy to utilize. Also, solar energy sources can provide electricity in remote areas where electricity is not available.

Solar cells give us the easier way to utilize the enormous source of renewable energy. Solar cells are considered a best choice of solar energy since it cuts-down electricity bill, needs low maintenance, produces no pollution, no emission and no noise.

Solar cells are usually divided into three main categories called generations [7]. As shown in Figure (1), first generation solar cells are mainly based on silicon wafers and its efficiency is about 15-25 %.These types of solar cells dominate the market. The benefits of this solar cell technology lie in their good performance, as well as their high stability. However, they are rigid, relatively expensive to produce, have a low efficiency, and are more at risk to lose some of their efficiency at higher temperatures.

Second generation solar cells is used to produce a cheaper solar cell by applying thin-film technology. These solar cells use less material and lower cost manufacturing processes compared to the first generation solar cells. However the 2nd generation solar cells have significant limitations, including lower overall efficiency compared to 1st generation and the toxicity of the component materials used.
The goal of third generation technologies is to enhance poor electrical performance of second generation (thin-film technologies) while maintaining very low production costs.

3rd generation solar cells, are based on nanostructured materials and they are made of purely organic or a mixture of organic and inorganic components, thus allowing for a vast and inexhaustible choice of materials.

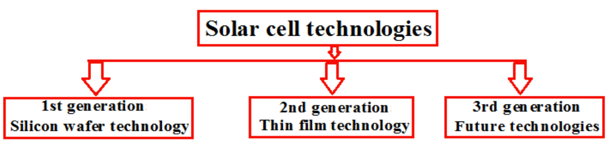

Fig. 1. Solar cells technologies

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There are four types of third-generation PV technologies:

- Nanocrystal solar cells
- Polymer solar cells
- Dye sensitized solar cells
- Concentrated solar cells

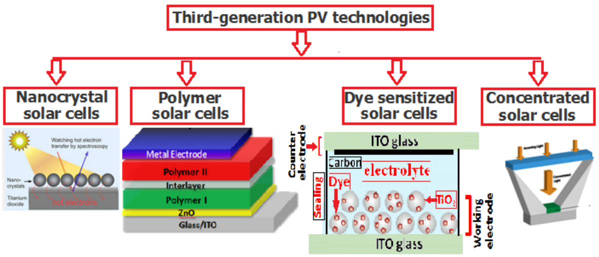

Fig. 2. Third-generation PV technologies

Among the different possibilities of 3rd generation solar cells, Dye sensitized solar cells (DSSCs) have the most promising prospect.

Manufacturing of DSSC is simple, mostly low cost, and incorporate environmentally friendly materials. DSSC uses an organic dye to produce electricity in a wide range of light conditions, indoors and outdoors.

However, a major drawback is the temperature sensitivity of the liquid electrolyte. Hence a lot of research is going on to improve the electrolyte's performance and cell stability.

This paper presents an overview of

- Construction of a dye-sensitized solar cell ,
- Operating principle of DSSC,
- DSSC performance
- The factors affect performance of Dye Solar Cells.

II. CONSTRUCTION OF A DYE-SENSITIZED SOLAR CELL

DSSC has 3 primary parts, anode, counter electrode and iodide electrolyte. With a few simple materials, you can create a working solar cell that mimics the process of photosynthesis. Indium Transparent conductive oxide ITO

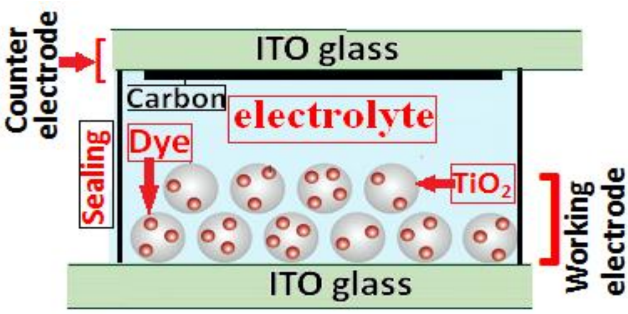

Fig. 3. Construction of a dye-sensitized solar cell

Figure (3) shows the four parts of DSSC which are:

- The electrode film layer (TiO2), covered by a dye molecules, that absorbs solar energy;
- Indium tin oxide (ITO) layer is used to facilitate charge transfer from the electrode layer;
- The counter electrode layer made of C;
- Iodide electrolyte it used to supply electrons to dye to replace the ones being extracted by TiO2.

III. OPERATING PRINCIPLE OF A DYE-SENSITIZED SOLAR CELL (DSSC)

With aid of Figure (4), the operating principle of a dye-sensitized solar cell (DSSC) is explained as follows:

- Light strikes the dye molecules.
- If the photon has enough energy, it will excite an electron from the dye, which is transmitted into the conduction band of the TiO2.
- The electrons will be collected by front electrode and supplied to external circuit to the counter electrode.
- The counter electrode returns electrons from the external circuit back to the cycling current in the cell.
- The original state of the dye is subsequently restored by electron transferred from the redox electrolyte.
- The electrolyte itself is restored to its original state by an electron coming from counter electrode.

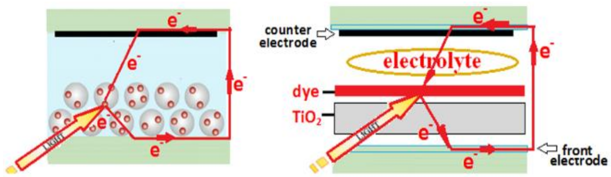

Fig. 4. Working principle of DSSC

Generation of electrical power under illumination is achieved by the capability of DSSC to produce voltage over an external load and current through the load at the same time. DSSC is characterized by current-voltage (J-V) curve and (P-V) curve of the cell as shown in figure (5) [8]:

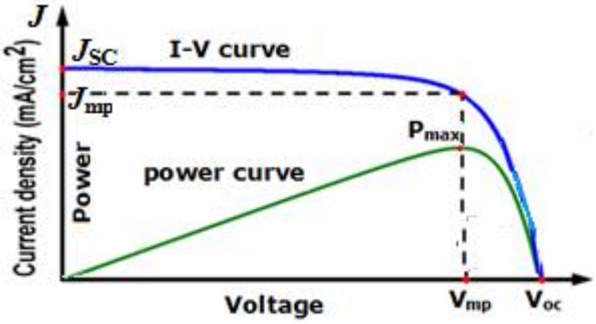

Fig. 5. Current-voltage (J-V) curve and (P-V) curve of the cell

In this Figure, When the cell is short circuited under illumination, the maximum current (short circuit ISC) or short circuit current density (JSC) is generated, while under open circuit conditions no current can flow and the voltage (open circuit voltage, VOC) is at its maximum .

Also in this figure, DSSC output power increases with increase in value of voltage /current density, reaches a maximum value at optimum value of voltage /current density and then starts decreasing, reaches zero value at open circuit voltage/short circuit current. The maximum power point can be obtained by determining the maxima of output power (Pmax) where Pmax is equal to

$P_{max} = V_{mp} I_{mp} = V_{mp} J_{mp} A_{cell}$

Where:

I_{mp} = the current at the maximum power output

J_{mp}= the current density at the maximum power output

V_{mp} = the voltage at the maximum power output

A_{cell} = the illuminated cell area

The value of conversion efficiency of prepared dye sensitized solar cells was measured from Eq. (1), were η is overall conversion efficiency and VOC, ISC, FF, Pin are the open-circuit voltage, short-circuit current density, fill factor and the intensity of incident light, respectively.

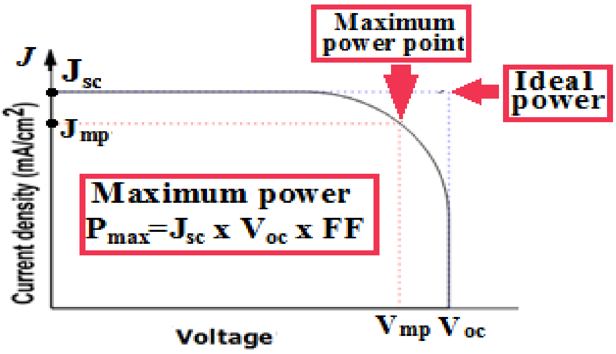

Fig. 6. Performance of DSSC

Figure (6) illustrates the performance of DSSCs, and the solar power (P) can be calculated by the equation: P=IV

The energy conversion efficiency of DSSCs is described by the ratio of the maximum electrical power output P_{max} to the solar energy input Pin. The maximum electrical power output P_{max} is calculated by the maximum current J_{mp} and the maximum voltage V_{mp}:

$P_{max} = J_{mp} \times V_{mp}$

The solar power input is taken as the product of the irradiance of the incident light that is measured in W/m2:

$$\eta = \frac{P_{max}}{P_{in}} \times 100 = \frac{J_{mp} \cdot V_{mp}}{P_{in}} \times 100 \quad (1)$$

The fill factor FF is index of loss electric generation or a measure of the quality of the solar cell, and it can be calculated by comparing the maximum short-circuit current Jsc and maximum open-circuit voltage Voc to the maximum current Jmp and maximum voltage Vmp:

$$FF = \frac{P_{max}}{J_{sc} \cdot V_{oc}} = \frac{J_{mp} \cdot V_{mp}}{J_{sc} \cdot V_{oc}} \quad (2)$$

By subsuming Eq. (2) into Eq. (1),

$$\eta = \frac{J_{sc} . V_{oc} . FF}{P_{in}} \times 100 \quad (3)$$

The ideal power density of DSSCs is the product of Jsc and Voc . The maximum power density is the product of Jmp and Vmp , and the difference between the two comes from the resistances of the cell, electrolyte, electrode, and other components. The energy conversion efficiency of DSSCs is related to the ideal power density and maximum power density as shown in Figure (6). When the fill factor is equal to 1, Jsc and Voc are the same as Jmp and Vmp . The series resistance Rs includes the cell, electrolyte, electrode, and interface resistance.

IV. FACTORS IMPROVE DSSC EFFICIENCY

The DSSC contains several different components: A conducting glass substrate, a mesoporous semiconductor film, a sensitizer, an electrolyte with a redox couple and a counter electrode. The optimization of each of them is of great importance in order to improve the overall efficiency.

Figure (7) presents best properties of each of the materials which constitute the DSSC of the overall process for energy conversion.

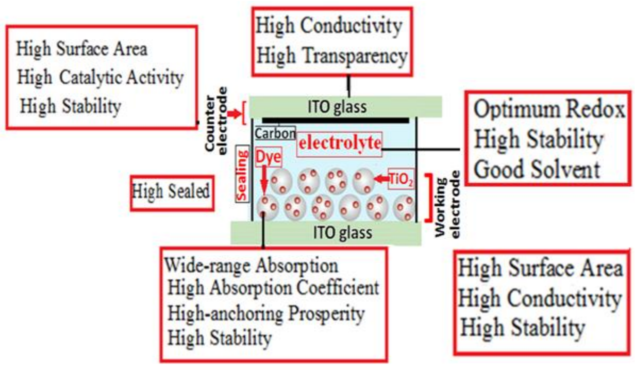

Fig. 7. The property of each DSSC components

A lot of researchers do all affords to satisfy the requirement properties of each DSSC's components [9]. Unfortunately, the researchers affords don't give a significant increase. But from my view if a cooroperation between Electrical, Chemical and Mechanical departments is done a good result is expected.

V. CONCLUSIONS

The potential for improvement in the power conversion efficiency of DSSC is regarded as a highly promising method for efficient and economical conversion of light in to electrical energy.
The DSSC contains several different components; the optimization of each of these components is of great importance to improve the overall efficiency.

The key requirements for efficient sensitization needs examination of numerous dyes of different chemical structure and functional groups.

Determination of the absorption spectrum of the dye and its stability are most important components influencing solar cell performance.

Investigations of Influence of physical factors affected DSSC performance require co working between scientific branches (Electrical, Chemical and Mechanical).

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Highlight of Grid-connected PV systems in administrative buildings in Egypt

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Abstract - Solar energy applications are becoming increasingly common in Egypt. The abundant sunshine in Egypt, as well as the increasing competitiveness of solar energy systems including- but not limited to photovoltaic (PV), – predicts that these technologies could be weighed to be raised in Egypt.

PV systems are installed on roof tiles or other parts of building structures to supplement grid utility, reduce electric bills, and provide emergency back–up energy. Moreover, they simultaneously reduce significant amounts of CO2 emissions. It is foreseen, a number of residential and public buildings in Egypt are using solar power to cut electric utility bills significantly. The approximately payback period to recover the investment costs for PV systems is up to about 5 years. In addition, it is more economical to use PV system than grid utility systems. The two components that determine the total initial price of a grid-connected PV system are the modules and the balance of systems (BOS). The BOS includes different components such as mounting frames, inverters and site- specific installation hardware.

The Government of Egypt (GOE) has endorsed the deployment of PV systems through three approaches. It started with a prime minister decree to install PV projects on one-thousand of the governmental buildings. This was followed by as an initiative called "Shamsk ya Masr", and finally the Feed-in Tariff (FiT) projects.

Following the prime minster decree the Egyptian Electricity Holding Company (EEHC) and its affiliated companies took the lead to install PV systems at the top roof of their administrative buildings and interconnect these systems to the electricity network where the suitable locations have been selected for mounting them. About 90 PV systems have been already mounted with about a capacity of 9 MW. On the other hand, "Shamsk ya Masr" has considered energy efficiency (EE) so as to complement the PV systems, which will be installed on administrative buildings. Cost- effective EE measures should be implemented prior to or at the same time as implemented PV program. The amount of electricity that a PV system produces depends on the system type, orientation and the available solar resource. In 2014, the GOE issued the Feed-in Tariff program to further promote RE technologies in general and PV in particular. Egyptian Electric Utility and Consumer Protection Regulatory Authority (Egypt ERA) has set the regulations, promotion and awareness for PVs. This approach has been applied for administrative buildings as well.

The paper highlights the impact of the previously mentioned mechanisms in deploying PV technologies through small scale projects. It also represents a cost-benefit analysis for the installed systems taking into account the measured value for PV parameters (kWh/kWp, PSH) and daily load profiles of the selected administrative buildings.

Keywords - photovoltaic (PV), emissions, Feed-in Tariff (FiT), cost- benefit, peak sun hours,grid- tied.

I. INTRODUCTION

The Egyptian Electricity Holding Company (EEHC) has sixteen affiliated companies six generation companies (EPCs), nine distribution companies (EDCs) and the Egyptian Electricity Transmission Company (EETC).

Both the Solar Radiation Atlas and the German Aerospace Center estimate Egypt's economically viable solar potential in the range of 74 billion MWh/year, or many times Egypt's current electricity production. The Energy Research Center at Cairo University's Faculty of Engineering estimate that 6 MW of solar PV are currently installed in Egypt. In addition, a 150 MW integrated-solar combined-cycle power plant is in Kureimat, with a solar component of 20 MW is already under operation.

II. PV SYSTEMS

Solar panels generate free power from the sun by converting sunlight to electric power with no moving parts, no emissions, and no maintenance. The PV system structure is very flexible. PV modules are the main building blocks, these can be arranged into array to increase electric energy production. Normally additional equipment is necessary in order to transform energy into a useful form or store energy for future use. The resulting system will therefore be determined by the energy needs, or loads, in a particular application.

Solar PV is one of the world's fastest growing renewable energy technologies. This is due to its flexibility in both size and location, ease of installation to both new and retrofit buildings and low operation and maintenance costs. For the PV system to be located on the roof of a building, roof structure must be deigned to accommodate the additional dead loads (static load) of the PV system. The solar panels and racking will add approximately 3 pounds for each square foot of collector area [1].

A. Advantages of solar PV :

- PV panels provide clean-green energy. During electric production with PV, there is no harmful greenhouse gas emissions, thus PV is environmentally friendly.
- PV panels via photoelectric phenomenon, generate electricity in a direct electricity generation way.
- PV panels have no moving parts, except in case of sun-tracking mechanical bases.
- PV panels are totally silent, producing no noise at all.
- PV panels are easy to install on rooftops.
- Solar energy is energy supplied by nature –it is free and abundant.
- Solar energy can be made available anywhere there is sunlight.
- Solar panels cost is currently on a fast reducing track and expected to continue reducing for the next years.
- Operation and maintenance cost for PV panels are considered to be low, almost negligible.

B. *Disadvatnges of solar PV :*

- Solar panels efficiency levels are relatively low.
- PV panels require relatively large areas.
- Solar energy panels require additional equipment (inverters) to convert DC to AC in order to be used on the power network.
- Solar energy has intermittency issues, not shining at night but also during daytime there may be cloudy or rainy weather.
- Consequently, intermittency and unpredictability of solar energy makes solar energy panels less reliable a solution.

III. PV PLANTS PROBLEMS IN EGYPT [2]

Egypt lies in dusty and very dry weather with limited rainfall (<10mm), the results on the PV test park in Cairo:

- Two months dusty module has an energy reduction of 25%.
- One year dusty module has an energy reduction of 35%.

IV. GRID- TIED

These systems are directly coupled to the electric distribution network and do not require battery storage. Electric energy is either sold or bought from the local electric utility depending on the local energy load patterns and the solar resource variation during the day, this operation mode requires an inverter to convert DC to AC currents. There are many benefits that could be obtained from using grid-tied PV system instead of the traditional stand-alone schemes. These benefits are:

1. Smaller PV arrays can supply the same load reliably.
2. Takes advantage of the existing electrical infrastructure.
3. Less balance of system (BoS) component are needed
4. Eliminates the need for energy storage
5. Lower capital cost.

- **Solar Atlas of Egypt**

Egypt is one of the world's most attractive sites for solar energy thanks to both ample sunlight and proximity to existing and potential energy grids. Solar power uses direct sunlight and must be located in regions with high direct solar radiation. Among the most promising areas of the world are: the South-Western United States, Central and South America, Northern and Southern Africa, the Mediterranean countries of Europe, the Middle east and Iran [3].

High intensity of direct solar radiation ranging between 2000 – 3200 kWh/m2/year from North to South. The sun shine duration ranges between 9-11 h/day from North to South, with very few cloudy days.

Fig .1. represents the map of Egypt's annual average of direct solar radiation.

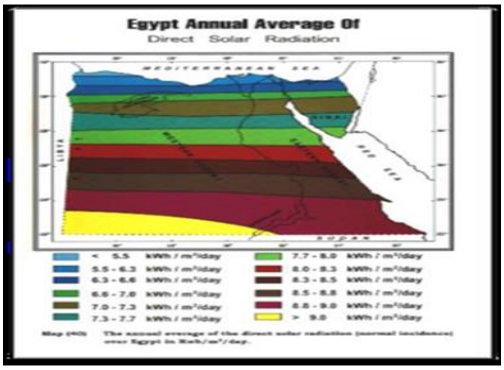

Fig .1. map of Egypt's annual average of direct solar radiation.

Table 1. shows the comparison between direct, diffuse radiation (kWh/m2.a) in Berlin and Cairo. Horizontal plane radiation in Berlin and Cairo are 1000 and 2000 kWh/m2.a respectively.

Table 1. Comparison between direct, diffuse radiation (kWh/m2.a) in Berlin and Cairo

Month	Berlin		Cairo	
	Direct	Diffuse	Direct	Diffuse
Jan	6	13	67	33
Feb	12	22	75	40
Mar	30	41	103	61
Apr	42	65	120	72
May	60	90	143	80
Jun	64	94	161	71
Jul	67	89	163	70
Aug	64	70	147	68
Sep	40	49	124	57
Oct	21	30	99	50
Nov	9	13	64	43
Dec	3	10	55	36
%	42 %	58%	66 %	34%

Table 2. represents the total monthly solar irradiation [kWh/m²], for this table:

- Horizz.Global solar radiation on horizontal surface in kWh/m2/day
- Best incline: Solar energy density on south facing flat plate tilted by the latitude angle of the site in kWh/m2/day
- South: Solar energy density on N-S polar axis and E-W tracking in kWh/m2/day
- East / west: Solar energy density on E-W polar axis and N-S tracking in kWh/m2/day

Table 2. Total monthly solar irradiation [kWh/m^2]
"in Marsa - Matroh (Egypt-North)"

Orientation	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Horizz.	3.1	3.97	5.33	6.61	7.37	8.01	7.98	7.37	6.3	4.73	3.51	2.92
South	5.27	6.32	7.17	8.41	8.89	9.27	9.33	9.08	8.16	6.69	5.34	4.7
East/West	4.9	5.49	5.89	6.81	7.35	7.81	7.73	7.13	6.34	5.56	4.84	4.46
Best incline	4.54	5.3	5.83	6.54	6.54	6.52	6.6	6.63	6.29	5.45	4.54	4.08

V. MONTIROING SYSTEM

A monitoring system is a common component in PV systems. Monitoring allows tracking of solar system performance over the life of the system and makes it easy to identify systems that perform below expectation and may be in need maintenance. Monitoring systems requires an internet connection in the room that contains the inverter.

The monitoring system was designed to meet guideline of standard IEC 61724 and within the framework of the International Energy Agency Photovoltaic Power System (IEA PVPS) Program. For the general data acquisition, a multi- function increasing device measures the different parameters, such as: KWP /month, kWh/day, kWh/month , …etc.
Egypt's geographic location provides a generous solar resource that should be exploited to its maximum potential. The use of PV technology could allow the local community to take advantage of this resource without sacrificing land resources by using the building rooftops as energy collection fields. Using roof areas is more economical.

VI. PERFORMANCE INDICES OF PV SYSTEMS

There are many indices for assessing PV systems performance

1. Peak Sun Hours (PSH)

This is the equivalent number of hours per day when solar irradiance average 1000 W/m2, or it refers to the solar irradiance which a particular location would receive if the sun was shining at its maximum value for a certain number of hours. Fig .2. represents this definition.

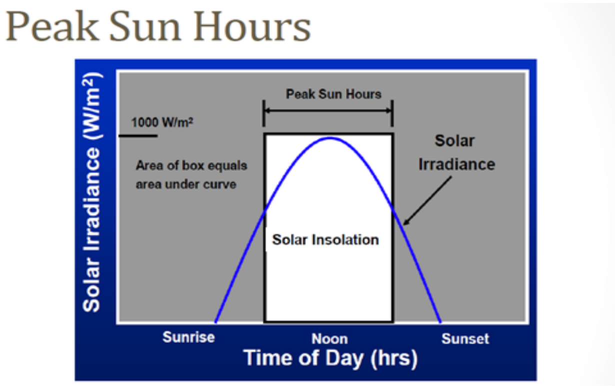

Fig .2. Definition of PHS

PHS is calculated based on the following equation:

$$\text{PHS}\left(\frac{hrs}{day}\right) = \frac{Avg.Daily\ Irradiation\ (kWh/m^2.day)}{Peak\ Sun\ (1\frac{kW}{m^2})} \quad (1)$$

By using the monitoring data for 90 PV systems related to EDCs according to geographical location for each EDC. The calculation of PHS were carried out and presented in Table (3).

The result is: av. PHS for 90 PV located in different locations in Egypt, are between 4 and 7.7 hr/d.

Table 3. The PSH for EDCs

Company	Range of PSH (hr/d)	Av. PSH (hr/d)
EDC 1	3.9 – 7.2	5.3
EDC 2	4	4
EDC 3	2.7 – 12.4	5.1
EDC 4	5.5 – 6.4	4.1
EDC 5	3.6 – 7.1	5.1
EDC 6	2.9 – 7.1	4.4
EDC 7	3.9 – 6.2	4.7
EDC 8	3.7 – 6.8	7.7
EDC 9	3.9 – 6.5	5.2

2. Performance ratio (PR)

The PR is the ratio of PV energy actually used to the energy theoretically available. PR is calculated based on the following equation

PR = Yf / Yr

Where:

Yf is final system yield = Epv / Po
in (kWh/KWp.d) or (hr/d)

Yr is reference yield = Hi/GSTC
in (kWh/KWp.d) or (hr/d)

Table 4. The PR values for PV systems in Egypt

Company	Yr Range of global solar radiation (kWh/m2.d) (Hi)	Yf (av.) kWh/kWp.d	PR
EDC 1	< 5.4	5.3	0.98
EDC 2	5.4 – 5.8	4	0.72 – 0.74
EDC 3	5.6 – 5.8	5.1	0.88 – 0.91
EDC 4	5.4 – 5.6	4.1	0.73 – 0.76
EDC 5	5.8 – 6.0	5.1	0.85 – 0.9
EDC 6	5.8 – 6.0	4.4	0.73 – 0.76
EDC 7	5.8 – 6.0	4.7	0.81 – 0.84
EDC 8	6.4 – 6.6	4.7	0.71 – 0.73
EDC 9	6.8 – 7.1	5.2	0.73 – 0.77

Table 4. shows the PR values for some PV system according to their locations indicated by each DC.

Previously, companies used to guarantee the specific yield of a PV plant

- Typically required by uninformed clients.
- Not possible due to fluctuations in weather conditions.
- Ends in very conservative calculations to minimize risk.

Nowadays, PV clients are more informed

- Request PR guarantees
  Typical PR ranges 70 - 85 %
  Independent testing body typically conducts audits.

- **Factors affecting PR:**

- Irradiance losses.
  Modules are rated at STC.
- Temperature losses.
  Modules 25 degrees Celsius.
- Module mismatch.
  Due to + or – tolerance range in module rating.
- Cabling losses.
- Transformer losses.
- Inverter losses.
- Soiling losses.
- Shading losses.

VII. BENEFIT- COST ANALYSIS

1. Benefit-cost analysis:

When the benefits of a project can be valued, they are discounted and aggregated, and compared with the associated aggregate costs over the lifetime of a project. Comparison between project costs and benefits can be conducted in the following ways:

- Benefit-cost ratio: compares the total discounted benefits of electrification with total discounted costs, as a ratio, and provides an indication of the scale of return on the investment. This is done by examining the ratio of the present value of benefits to the present value of costs. If the ratio of benefits to costs is greater than one, the project can be viewed as desirable from an economic point of view.

2. Economic Benefits and Costs:

Investment evaluations of energy systems generally include an assessment of the projected benefits compared to the estimated costs of the system. The direct financial benefit of a BIPV system is primarily the value of energy generated.

These benefits and the direct economic costs of a BIPV may be viewed as:

- Projected Benefits = Value of Electricity Generated

- Estimated Costs =

Capital Costs + Periodic Costs + Replacement Costs

Quantitative analysis is a tool that facilitates ranking and choosing among investment alternatives. As such, quantitative procedures appear to be straightforward. However, numerous factors influence comparative evaluations. A building owner's economic expectations about future interest rates, inflation, and fuel costs directly affect investment decisions, as can utility interface requirements, environmental regulations, and tax incentives.

The Egyptian government started installing PV projects on one-thousand of the governmental buildings, which was followed by as an initiative called "Shamsk ya Masr", then the Feed-in Tariff (FiT) projects were launched.

VIII. FIT

Egypt faces a major challenge in generating electricity from its primary energy resources, especially oil and natural gas that contribute to 97% of the total energy resources. Studies show that even though Egypt has reasonable reserve of gas and oil, it is likely that it will face severe shortage in satisfying its electricity demand due to rapid growth in demand and the increase of oil and gas extraction costs [4]. Noticing this problem, Egypt has consequently pursued several mechanisms for deploying Renewable Energy (RE) technologies and integrating them to the Egyptian electricity systems.

Unfortunately, lots of barriers have impeded Egypt from achieving any of its electricity generation targets; particularly financial and regulatory barriers. Feed-in tariff (FiT) is one of the mechanisms that has been adequately studied but was never recognized as a possible solution to the deployment of RE due to existing electricity tariff subsidies. Moreover, the huge political transition that started in 2011 has led to deteriorating the economic and financial position of the country. The global economic slowdown, started in 2008, caused a decline in Foreign Direct Investment, the international reserves also fell sharply by that time, and its creditworthiness has been undermined as reflected by lowering of the international ratings assigned to Egypt. Certainly, this is considered a typical unhealthy environment to attract investments or even to maintain the existing ones. Recently, the government of Egypt (GoE) has launched several national programs in order to regain its economic health.

On September 2014, Egypt has announced its ambitious FiT program for deploying 4300 MW of wind and solar energy in a 2-years' time. It is believed that the program as designed in this way would overcome most of the barriers that have hindered the RE market in Egypt.

FiT planning program for Egypt includes the early provision for setting the RE target for Egypt at larger and the capacity cap for the FiT program in particular.

1. RE-FiT Policy Making

Several studies were conducted to assess the energy situation in Egypt. These studies have indicated that retaining balance between oil and natural gas production and their usage within three (3) years can be achieved after overcoming the economic challenges facing the oil and natural gas sector. However, it is expected that Egypt will be a net importer of oil and natural gas within ten (10) years from the start of the third decade of this century. This situation represents an additional challenge for the Egyptian economy which will become more vulnerable to the price fluctuations in the international energy markets, which can't be predicted or controlled. Therefore, there has to be diversity in the energy resources so as to maximize the benefits of using local RE resources which are characterized by sustainability and stable prices. [5]

A. Setting the Target

The starting point for RE policy making is usually the definition of targets in terms of installed capacity or minimum shares in the country's electricity production. In Feb. 2008, the Supreme Council of Energy has set a target to have a 20% of the total generated electricity to be from RE resources by the 2020. Wind energy was been given the priority such that it would represent 12% of the total target (equivalent to 7200 MW). Hydro power will provide 6% and the remaining 2% will come from other RE resources including solar and biomass energies. In July 2012, the Cabinet approved the Egyptian Solar Energy target with a total installed capacity of 3500 MW by the year 2027. It includes 2800 MW from Concentrated Solar Power (CSP); in addition to 700 MW from Photovoltaic (PV). The private sector should participate with 67% of the mentioned capacities, while the governmental projects share, represented by New and Renewable Energy Authority (NREA), will be 33%.[6]

B. Defining the Mechanisms

Once targets have been defined the choice of appropriate policy instruments/mechanisms should realize their achievement. They considerably vary in their design and conception. Some of them stimulate the supply of renewable electricity, while others directly affect the demand. Furthermore, support schemes can be distinguished according to the chosen instrument.

All of the above mentioned mechanisms are currently in place in Egypt. State owned projects which are carried out by NREA, the BOO projects which are carried out by the Egyptian Electric Transmission Company (EETC) through tendering process, and the bilateral market of RE where Power Producers (PPs) that get into bilateral contracts with their own customers, are all mechanisms that Egypt has undertaken for quite long time. However, the achievements that were expected from these mechanisms have never been satisfied. A deep insight into the reasons behind such shortcomings is due to (but not limited to); the GoE could hardly manage the sovereign risks causing prolonged delay in the first 250 MW BOO wind projects, the heavily subsided tariffs and absence of quota system hurdles the bilateral market of RE so that PPs to could hardly get into contracts with direct customers, and last but not least, failure to realize the RE Fund. Accordingly, a concrete design for a FiT system taking into consideration the current economic, financial, regulatory and legal barriers became essential. [7]

C. Design of Feed-in tariff program

In October 2014, the FiT program for (PV - Wind) projects has been announced according to a prime minister decree. A total capacity cap of 4300 MW is to be achieved over the first regulatory period of applying the FiT. This target includes 300 MW for small PV projects below 500 kW, 2000 MW for medium size PV projects which range from 500 kW up to 50 MW and the remaining 2000 MW is from wind projects with capacities ranging from 20 MW up to 50 MW. The first regulatory period starts from the day of announcing the FiT (i.e. October 2014) and ends if either the capacity cap is reached or a two years period is passed, whichever happens first. The EETC or the electricity distribution companies are committed to purchase the produced electricity from RE power plants at the prices announced by the Cabinet over the duration of the PPAs which is 20 years for wind and 25 years for PV.

Four basic pillars should be in place to support the design of the FiT program. These are the legal, regulatory, contractual frameworks and the tariff structure. Each of these four pillars will be discussed in this section. [8]

IX. CONCLUSION

Within Egypt power Strategic plan, the power sector strategy is depending on the diversification and expansion of energy resources, and rational use of conventional energy resources.

Moreover the solar Atlas indicates that Egypt is one of the sun belt countries endowed with high intensity of direct solar radiation ranging between 2000-3200 kWh/m2/year and sunshine duration from 9-11 hours per day which offers opportunities of investing in Solar energy projects.

The Egyptian Electricity Holding Company is cooperating with the New and Renewable Energy authority through the following:

- Generation planning taking into consideration the contribution of the renewable energy.
- Network planning to ensure safe evacuation of the generated energy from the renewable energy projects.
- The Egyptian Electricity Transmission Company is tendering competitive biddings for the construction of renewable energy power plants through BOO (Build, Own and operate) model at predetermined sites.

The endowment of Egypt with these renewable resources is offering a great opportunity to exchange "Clean Energy" through the electrical interconnection with neighboring countries.

The Egyptian Electricity Holding Company and its affiliated companies have taken the initiative to install solar Photo Voltaic (PV) systems at the top roof of their administrative buildings and interconnect these systems to the Unified Power System where the suitable locations have been selected for mounting them 90% solar PV systems have been contracted with a total capacity of 9 MW.

The Monitoring systems are good tools to evaluate the performance for the PV plants.
The results are:

- av. PSH in range 4: 7.7 hr/d
- PR in range 0.71: 0.98 which is in the recommended range.

FiT is considered a solution to major challenges hindering the development of RE market in Egypt, although being a challenge in itself. The learning process that preceded the design of the FiT program, started at a time when this approach was not foreseen at any level of decision making in the GoE.

However it was essential to gain the adequate knowledge of FiT design at large, and for the Egyptian case in specific. For solar energy, the tariff was categorized between different sizes of projects in order to match with the different categories of customers (individuals, commercial and large investors). Also, the GoE has provided soft loans for individuals and small customers. When it came to implementation, the design was accurately fine-tuned; first to the economic updates, second to overcome various barriers which have been ingrained in the existing corporate's culture. Moreover, the GoE has mandated the electricity companies to carry out the required procedures on behalf of the small customers in order to facilitate the process of acquiring the loans. Also, a one-stop-shop entity to facilitate the overwhelming official procedures was established.

Finally, it is worth mentioning that lack of interest in a FiT program from the GOE has stopped it for years, nevertheless the commitments which GoE has recently declared were the backbone for supporting the FiT today. These include; issuance of the RE law that among its articles has approved the quota system that reduces the financial burden on the electricity sector due to the feed-in tariff, availing state lands for investors, providing sovereign guarantees for large projects, offering low interest loans for small projects, and providing finance for upgrading the transmission and distribution infrastructure.

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Opportunities of energy saving in lighting systems for public buildings

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Abstract - The lighting system provides many options for cost-effective energy saving with low or no inconvenience. Lighting improvements are excellent investments in most public buildings, it is usually cost-effective to address because lighting improvements are often easier to make than many process upgrades.
For public buildings, the easy no and low cost options to help save money and improve the energy performance are:

- Understand energy use.
- Identify options
- Prioritize actions

Make the changes and measure the savings.
Continue managing energy efficiency.
The challenge is to retrofit traditional lamps with LED lamps of good quality. The benefits of LED light bulbs are long-lasting, durable, cool, mercury free, more efficient, and cost effective.

The light Emitting Diode (LED) bulb uses a semiconductor as its light source, and is currently one of the most energy efficient and quickly developing types of bulbs for lighting. LEDs increasingly are being purchased to replace traditional bulbs. LEDs are relatively more expensive than other types of bulbs, but are very cost-effective because they use only a fraction of electricity of traditional lighting methods nd can last for longer.

Benchmarking guides decision makers to policies aimed at the energy sector through better understanding of energy consumption trends nationwide, e.g.: energy price, moderating, peak demand, and encouraging sectors, low energy expansions.

The "Improving Energy Efficiency Project of Lighting and Appliances" carried out energy audits and implemented opportunities of energy saving in lighting for different type of public buildings.

To rationalize the use of energy by giving guidelines to consumers, the IEEL&A project prepared some brochures.

This paper leads with the results of case studies as energy audits, opportunities in lighting systems, energy saving and CO2 reduction.

I. INTRODUCTION

Improving Energy Efficiency of Lighting and Building Appliances (IEEL&A) project was initiated by the Global Environmental Facility and the United Nations Developmental Program (GEF-UNDP), in conjunction with the Ministry of Electricity and Renewable Energy (MOERE), intends to publish the use of energy efficient lighting by making energy audits for public buildings and increase the awareness on the benefits of using new lighting technologies as LED.

Lighting consumes a considerable share of the total electricity consumption in Egypt, and it was identified as one of the main factors of the system peak consumption. In response, the Egyptian Ministry of Electricity and Renewable Energy (MOERE) has encouraged the use of LED on the domestic, commercial and industrial levels, as energy saving lamps, to reduce lighting consumption. LEDs are energy efficient as they consume 85% less electricity than the incandescent lamps, which are widely used in Egypt.

Lighting systems provide many options for cost-effective energy saving with no or low inconvenience.

Lighting improvements are excellent investments in most of public buildings which make very good savings in electricity consumption.

The challenge is to retrofit traditional lamps with LED lamps of good quality.

II. LED LIGHTING

The Light-Emitting Diode (LED) is one of today's most energy-efficient and rapidly developing lighting technologies. Quality LED light bulbs last longer, are more durable and offer comparable or better light quality than other types of lighting, also LEDs are safe on environment as they don't contain mercury in its components.

The Light-Emitting Diode (LED) is an electronic component made from semiconductors and emits light without lost energy in heat. It is a highly energy efficient lighting technology, as it uses at least 75% less energy than traditional lamps, and lasts 25 times longer than incandescent lighting lamps. It is very different from other lighting sources such as incandescent bulbs and Compact Fluorescent Lamps (CFLs), because of many key differences include the following:

- Long lifetime - LED s' can last up to 50,000 hours.
- Rugged – LED's are also called (Solid State Lighting "SSL") as they are made of solid material with no filament or tube or bulb to break.
- No warm-up period - LED's light instantly – in nanoseconds.
- Directional – with LED's you can direct the light where you want, thus no light is wasted.
- Excellent Color Rendering - LED's do not wash out colors like other light sources such as fluorescents, making them perfect for displays and retail applications.
- Environmentally friendly - LED's contain no mercury or other hazardous substances.
- Controllable - LED's can be controlled for brightness and color using dimmers.

Table (1): Summarizes features for LEDs, incandescent and CFL lamps.

Table (2): Represents wattage comparison between LEDs, incandescent and CFL lamps.

Table (3): Represents the comparison between LEDs, incandescent and CFL lamps for efficiency and Color Rendering Index (CRI).

Table 1. Features for different types of lamps

Feature	Light Emitting Diodes (LEDs)	Incandescent Light Bulbs	Compact Fluorescents (CFLs)
Life Span (Hours)	Typically above 50,000	1,000 – 2,000	8,000 – 10,000
Wattage (equivalent to 60 W Incandescent bulb)	6 – 8 W	60 W	13 – 15 W
Temperature Sensitivity	None	Yes, Somewhat	Yes
Sensitive to humidity	No	Yes, Somewhat	Yes
Switching On/Off Quickly	No Effect	Yes, Somewhat	Yes – lifespan can reduce drastically
Turns on instantly	Yes	Yes	No – takes time to warm up
Durability	Durable – can handle jarring and bumping	Glass or filament are fragile	Glass can break easily
Toxic Mercury	No	No	Yes

Table 2. Wattage comparison between incandescent, CFL and LED lamps

Incandescent / Halogen	CFLs	LEDs
40-60	12-15	5-8
60-75	15-18	7-10
75-100	18-23	10-15
100-150	23-35	15-20
150-200	35-45	20-25
200-250	45-60	25-30

Table 3. Comparison between incandescent/Halogen, CFL and LED lamps in regards to efficacy and CRI

Incandescent / Halogen	CFLs	LEDs
Efficacy: 15-25 Lm/W	Efficacy: 40-70 Lm/W	Efficacy: 60-140 Lm/W
CRI: 98-100	CRI: 60-90	70-95

A. DISADVANTAGES OF LED

LED's are currently more expensive on the initial capital cost basis than other conventional lighting technologies.

LED performance largely depends on correctly engineering the fixture to manage the heat generated by the LED. Over-driving the LED or not engineering the product to manage heat in high temperatures may result in overheating of the LED package, eventually leading to device failure. Heat sinking is required to maintain long life.

III. ENERGY AUDIT

The energy audit is the first and fundamental step for any organization, irrespective of type (Public Administration, Private company), size (SME, large organization) and sectors (commercial, industrial, residential), striving to reduce energy consumption and improve its energy efficiency. The implementation of the actions identified in the energy audit will generate values to the Customer (cost saving) and related environmental benefits. Fig (1) Describes the steps of an energy audit process.

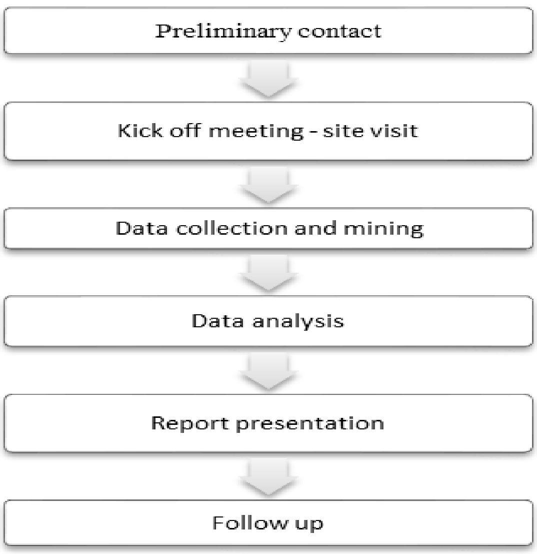

Fig .1. STEPS OF ENERGY AUDIT PROCESS

1. Final Report of energy audits:

The final report of the energy audit has to include all the key elements of the energy audit as below:

- Executive summary.
- Aim, scope and boundaries of the audited object.
- Baseline energy flow and adjustment factors.
- Criteria for ranking the improving energy efficiency opportunities.
- Assumptions made
- Proposed recommendations and action plan.
- Expected benefits.
- Technical, economic and financial analysis.
- The measurement and verification method.

2. BENCHMARKING AS THE BELOW IMPORTANT FACTORS

- Building Energy Index (BEI) (in Kwh/m2/year)
- Load factor
- Power factor
- Lighting Power Density (LPD) (in W/m2)

Depending on the values of those factors, the energy conservation potential is determined

IV. CASE STUDY

“Improving Energy Efficiency Project” has intended to provide technical aid as energy audits by qualified electrical engineers for more than 60 project and financial participation of replacing all the lighting systems for 17 buildings to the LED lighting technology systems.

Due to the success of those projects and the savings were recorded and notable, there are more cooperation with other parties to implement a set of pilot projects in different sectors and below is a detailed table of pilot projects that have been already implemented by the project:

Table 3. RESULTS OF CASE STUDIES

Places have been totally changed to LED	Number of LED lamps	Initial investment (EGP)	Yearly energy saving (kwh)	Lighting energy saving (%)	Yearly energy saving (EGP)	Payback period (year)
Public Building (1)	1,740	183,460	158,755	75%	57,946	3.2
Public Building (2)	1,018	91,351	109,433	75%	40,052	2.3
Public Building (3)	2,540	133,215	116,312	75%	42,570	3.1
Hotel (1)	8,312	942,181	1,804,998	81%	828,609	1.2
Hotel (2)	24,304	3,378,948	4,769,556	80%	2,527,865	1.3
Public Building (4)	1,753	346,000	229,520	90%	119,307	3
Public Building (5)	3,600	213,905	231,922	77%	70,672	3.4
Public Building (6)	2,295	134,930	128,824	66%	47,149	3
Public Building (7)	474	31,224	27,358	80%	10,013	2.2
Public Building (8)	9,477	528,011	364,984	65%	195,432	3
Public Building (9)	3,328	252,446	325,339	80%	119,074	2
Bank (1)	5,280	231,792	73,333	82%	627,216	0.4
Bank (2)	1,601	235,251	312,136	77%	206,010	1.1
Commercial Store	3,940	289,322	396,617	72%	187,698	1.5
Public Building (10)	100	275,220	48,904	76%	26,897	3
Public Building (11)	2,991	328,669	693,636	80%	457,800	0.7
Public Building (1)	3,290	781,631	635,543	75%	400,681	2
Total	76,043	8,377,556	10,427,170		5,964,991	

V. CONCLUSION

The Egyptian market is shifting toward energy-saving lighting projects and many pilot projects were implemented by "Improving Energy Efficiency Project" and supported by the Ministry of Electricity and Renewable Energy. The project intended to provide technical aid as energy audits by qualified electrical engineers for more than 60 project and financial participation of replacing all the lighting systems for 17 buildings to the LED lighting technology systems with a total number of 76,043 changed bulbs of different types and capabilities to the LED bulbs with a total investment 8.3 million Egyptian Pounds worth of energy savings of 10 million Kilowatt hours per year with a value of saving about 5 million pounds per year.

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Energy efficiency opportunities in Hotels

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Abstract - According to the statistics in Egypt (2013), the number of hotels is 1193, about 407 of them have contracted power greater than 500 kW.

Air conditioning, lighting, water heating and refrigeration represent the main activities demanding electrical energy in hotel business.

The energy consumption per night spend changes a lot, depending on various factors; facilities provided, category of hotel, occupancy , geographical situation, weather conditions, nationality of clients, design and control of the installations.

Energy benchmarking is an internal management tool designed to provide ongoing, reliable and verifiable tracking on the hotels performance. The most useful performance indicator (or Energy Efficiency Benchmarking) of hotels are: Lighting Power Density (LPD) in W (for lighting)/m2, and energy intensity (kWh/m2/ y).

There are multiple benefits for improving energy in hotel business; reduces the hotel's operating cost, reduces climate change risks and promotes green tourism.

Energy efficiency opportunities are low-cost measures and cost- effective investments.

There are many energy saving opportunities for lighting in hotel's guest rooms as well as the more obvious savings in lobbies and exterior lighting areas. Behavior campaigns can yield substantial energy savings, both through the guests and housekeeper behavior. Encouraging housekeepers to use natural light during room cleaning is a simple first step to implement energy saving program.

This paper presents the energy efficiency guidelines and energy benchmarking for hotels. Also a case study showing how the energy efficiency program implemented is presented.

I. OVERVIEW OF ENERGY CONSUMING ACTIVITIES IN A HOTEL

The main energy consuming activities in a hotel are:

- Heating rooms.
- Cooling rooms.
- Lighting.

- Hot water use and other energy consuming activities by guests.
- Preparing meals.
- Swimming pools.
- Others.

Table (1) represents consumption structure of a hotel.

Table 1. ENERGY CONSUMPTION STRUCTURE OF A HOTEL [6]

Type of load	Energy consumption (%)
Cooling source	14.2 %
Heating source	10.7 %
Fan	15.7 %
Water	2.9 %
Hot water supply	9.9 %
Lighting	14.7 %
Outlet	7.7 %
Others	24.2 %

II. ENERGY EFFICIENCY

- uses less energy to perform the same tasks and functions
- saves energy.
- lowers operational costs.
- reduces carbon emissions/foot print.
- increases competitiveness.

Table (2) classified use to EE

Table 2. CLASSIFICATION USED TO EE

Item	Classification
Energy management	- assess energy profile. - draws up a simple energy policy. - adopts good housekeeping practices. - ensures periodic serving and maintenance of equipment and device. - provide information to staff and guests.
Reduction of the Hotels' heating and cooling needs	- improves the thermal insulation of the building - avoids uncontrolled air infiltration. - protects the building from the summer heat.
Equipment efficiency	- improves Lighting efficiency - improves ventilation efficiency. - improves space cooling efficiency. - improves heating efficiency. - better operational use of current equipment.

III. ENERGY EFFICIENCY OPPORTUNITIES

EE provides hotel owners and operators cost savings. Efficiency also improves the service of capital equipment, enhances guest comfort, and demonstrates a commitment to climate stewardship.

In a typical hotel, lighting, air conditioning and water heating represent up to 70 % of total energy consumption. Laundry is considered as one of the largest consumption segment of electrical power in hotels.

The following shows a guide on how to reduce energy consumption with low cost procedures or no cost at all sometimes.

A. Laundry EE opportunities

- Washing machines shouldn't be during peak hours and it is best to operate them only when in full loads.
- Use high efficiency appliances (such as washing machines, dryers, steam irons etc.) and other high-efficiency equipment to minimize electricity consumption.
- Reduce the temperature of water used for laundry from 85°C to 60°C, or use cold water washing when possible. It will save energy and cut down on costs.
- Make sure that washing machines and dryers are kept clean and have no scale.
- Turn off lights, ventilation and air conditioning when the area is not being used.

B. Lobby and other hotel areas EE opportunities

- Install LEDs in the lobby area and around the hotel.
- Set the temperature in busy areas of the hotel at 24°C.
- Switch off or dim lights in areas that receive natural sunlight during the day.
- All light fittings in the hotel should be cleaned on a regular basis.
- Install occupancy sensors for lighting in areas such as rooms that are not regularly used such as meeting rooms or storage areas, or walkways/corridors.
- Some elevators can be programmed to stay stationary on the floor they exit at instead of all elevators returning to the lobby.
- During off-peak periods shut down one or two of your elevators to help save energy.
- Heating of pools can be quite costly. Try to maintain the temperature of the pool to 25.5°C
- Install Light Emitting Diodes (LED) in areas where the lighting is on continuously or for long periods, e.g. exit signs, other signs, stairwells, front desk etc.
- Install electricity meters in each department to monitor consumption.
- Operate garden and exterior lights only when there isn't enough natural light.
- Turn off exterior decorative lights in the middle of the night when most guests are asleep.
- At the end of the workday, make sure that lights, air conditioning and office equipment is switched off in the hotel's back-of-house areas.

- Make sure equipment is used efficiently in the hotel's office areas. E.g. Copiers, fax machines, computers, printers etc.

C. KITCHENS / RESTAURANTS / COFFEE SHOPS EE opportunities

- Use gas ovens rather than electrical ones if possible.
- Lights in areas such as coffee shops and restaurants should have flexible or separate switches so that part of the lighting system can be switched off if that area is not being used. Another good idea is to install dimmers.
- Keep the walls and ceilings of the restaurants clean for better light reflection.
- Use high efficiency appliances (such as fridges, freezers, dishwashers, etc.) and other high-efficiency equipment to minimize electricity consumption.
- Switch off and unplug all appliances after their use (coffee makers, mixers, blenders, grills, fryers, plate warmers, stoves etc.). Electricity to power appliances and electronics are still consumed while the devices are turned off, so make sure they are unplugged.
- Make sure all kitchen equipment and appliances are cleaned and checked daily.
- Turn off exhaust fans and lights when the kitchen is not being used.
- Keep the refrigerator full if possible.
- Do not put items right in front of the refrigerant coils or fans in a way that would restrict air circulation.
- Try using minimum number of electrical appliances; avoid using them all simultaneously, especially during peak hours.

D. Guest rooms EE Opportunities

- Install efficient air conditioning units.
- Set room temperature to 24°C.
- Set unused room temperature to 28°C or switch them off completely.
- Install lighting emitting diodes (LEDs) in all rooms; LEDs use about 10-15 % of the energy and last up to 25 times longer than regular incandescent bulbs.
- Install master key-tag switches at the entrance of each guest room, which is activated by a room key tag/card. When guests leave the room and remove the key tag from the holder (master switch), lighting, heating, ACs, radio and television are automatically switched off. Energy management systems such as this can reduce the electricity consumption of guest rooms by 15 to 30%.
- Close the blinds or drapes in unoccupied rooms.
- Make sure windows are tightly shut to minimize air escaping.
- Clean lamps and lamp shades regularly.
- Set the temperature of water heaters between 49 and 55°C.
- Avoid keeping equipment such as televisions, hair dryers, and lamps close to A/C thermostats. The heat from these appliances can affect the thermostat readings and increase energy consumption.
- Provide regular preventive maintenance to all appliances, boilers, piping and other equipment.

IV. PILOT PROJECT ("Z" HOTEL)

Before energy use can be reduced in the hotel, it is necessary to understand how energy is being consumed. It is also helpful to compare the hotel's energy consumption to other similar hotels. It's very important to know how efficient is the hotel in terms of energy and where potential energy saving could be made through energy conservation.

"Z" hotel building mainly consumes its energy on water heating, space heating, refrigeration, space cooling, cooking, lighting and other building services.

The Z-hotel has166 normal guest rooms, 7 suite rooms and 4 conference rooms. The annual energy consumption for the year 2012 is equal to 573,000 KWh

Table (3) Shows electric loads in hotel as result of energy audit.

Table 3. KW FOR APPLIANCES IN HOTEL

Place	Power for appliances (kW)
Guest rooms	1.764/ guest room
Suite rooms	1.963/ suite room
4 Conference rooms	12.97
Bazar	0.125
Laundry	33.476
Kitchen	22.98
Restaurant	2.36

The appliances (electrical loads) are: lamps, TV, mini bars, hair dryers, washing machines, dryers, irons, fans, ACs, refrigerators and kitchen machines (coffee maker, meat blinder, toaster, …).

V. TYPES OF LAMPS AND RATING

Different rating and type of lamps are used. Table (4) shows the result of audit

Table 4. TYPE AND RATING OF LAMPS

Type of Lamp	Rating (W)
CFLs	11 & 22
Fluorescent lamp (T12)	20 & 40
Incandescent lamps	40 & 60 & 100
Halogen lamp	25
LED lamp	3 & 6

Energy performance benchmarking is an internal management tool designed to provide ongoing, reliable and verifiable tracking on the hotels performance. The most useful performance indicator (or Energy Efficiency Benchmarking) of hotels is: Lighting Power Density (LPD) in W (for lighting)/m2.

Table (5) shows the calculated LPD for different places in hotel, and LPD according to ASHRAE/ IENSA standard [1].

From Table (5) it is noticeable that the LPD for conference rooms, laundry, kitchen and restaurant is exceeding the standard value. Then a use of high efficiency fluorescent lamps and electronic ballasts in such area, which is used for long hours, would greatly improve both efficacy and LPD.

Table 5. EE BENCHMARKING FOR DIFFERENT PLACE IN HOTEL.

Place	Calculated LPD (w/ m2)	ASHRAE/IENSA(1) LPD (w/ m2)
Guest room	4.125	11
Suite room	4.95	11
Conference room	27.59	13
Bazar	13.44	14
Laundry	22.625	5
Kitchen	24	12
Restaurant	14.15	13

According to [5] the guest room energy benchmark figures are represented in Table (6).

Table 6. KWH PER OCCUPIED GUEST ROOM PER YEAR

EE rating	Good	Fair	Poor
Electricity kWh/room	< 1825	1825-2550	>2550

The guest room energy benchmark for " Z" hotel is 3312 kWh/room/y.

VI. CONCLUSION

Energy is essential to maintain comfort standards in a hotel; however it is important that this energy is used efficiently. Reducing the energy consumption in hotels helps in environmental protection by reducing greenhouse gas emissions.

EE in hotel is a valuable resource that creates a win-win solution on multiple fronts. It saves energy consumers, money, increases comfort, protects the environment and enhances the economy. When EE is mixed with smart energy practices, like turning off lights, air conditioners, and TVs that are not in use, all of the benefits above are compounded. Providing training to all hotel staff on EE is important to motivate for energy saving.

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Sustainability and Conserved Energy Value of Heritage Buildings

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***Abstract* -** Conservation and sustainability have long shared fundamental goals. Heritage buildings are basically sustainable and will continue to be if their sound construction and superior materials are conserved properly. Despite this fact, heritage buildings have gained a reputation for being inefficient and therefore unsustainable in the face of modern, energy-efficient structures. As a result, models which are measured embodied energy arose to advocate the retention of heritage structures over new constructions. The initial need to measure energy capital in buildings started due to rising needs to save energy and address global sustainability goals. Both responses measure overall energy efficiency of heritage buildings by attempting to account for the "energy capital." The life cycle assessment/avoided-impacts model is another model that acts as a response to the evolving metrics and currency of sustainability. The Conservation Green Lab has further developed the capabilities of the life cycle assessment/ avoided impacts model in 2012 in its innovative report: “The Greenest Building: Quantifying the Environmental Value of Building Reuse”. With this aim, the study applies energy software models supported by guidelines laid out by LEED, and are consistent with judicious conservation practice on a case study heritage building in Alexandria. The outcome revealed proves that heritage buildings can be both sustainable and energy efficient while maintaining their historic integrity, when dealt with properly.

***Keywords* -** Sustainability, Embodied energy, Heritage Conservation, LEED, Life Cycle Assessment, Energy value.

I. INTRODUCTION

Heritage conservation has evolved from the aspiration to preserve sites linked to specific identities. The conservation field has also responded to a raise in energy prices, and deficiency of energy sources with a number of initiatives. These initiatives have laid the basis for the embodied energy dispute of the preservation of existing buildings with their locked-up energy rather than substitution with new more energy efficient buildings. Nevertheless, traditionally, sustainability, when dealing with the built environment, has relied heavily on “green technology” and new high performance construction in contrast with conservation projects. The arguments for retention of heritage buildings from an energy value perspective have evolved around the focus of the energy capital embodied within constructions. Additionally, the environmental avoided impacts approach looks at the environmental impacts that are avoided by rehabilitating an existing heritage structure compared to demolition and novel construction.

Continually, the conservation field is faced with the challenge of bridging the gap between operational energy and embodied energy when comparing the efficiency of energy in historic versus new buildings. Operational energy is defined as the energy used within a building to heat, cool and illuminate, as it operates over a typical meteorological year. Operating energy is a vital component when measuring the energy used up in a building; the ability to integrate and mature the operating energy component into the assessment of the “energy capital” of a building will develop the argument for the conservation field. The embodied energy format measured “energy capital” by what had been invested, while the life cycle assessment/avoided impacts scheme measures “energy capital” by what is required to be spent in the future to improve operating efficiency of an existing building [1]. In both cases the “energy capital” of the heritage building is compared to the “energy capital” of a new building.

The methodology of this research consists of an outline of the relationship between sustainability and conservation; an in-depth evaluation of the embodied energy model and the life cycle assessment/avoided impacts model, followed by the examination of a case study. Utilization of models is explained and explores potential options for the conservation field to proceed, and to continue to be relevant rather than to indicate these past claims and advances. Embodied energy for the case study building was assessed using the survey method. Environmental consequences, or the avoided impacts, were measured as well as using the Athena Eco-Calculator provided by the Athena Sustainable Materials Institute in Canada. The investigation of a case study was used to draw conclusions about how to better lever conversation sustainability, specifically as those conclusions relate to energy value in heritage structures.

II. LITERATURE REVIEW

A. Conservation, Sustainability and Energy

Sustainable development is defined as "the means to providing the basic necessities of life... to meet our needs today while enabling future generations to meet their needs" [2]. Conservation equals a commitment to sustainable practices. Certainly there is a common sense notion that reusing existing buildings is better than demolishing and replacing them. The fact is that reducing waste, rather than accepting and managing it, has become a critical priority. Reference [3] points out the essential coincidence between conservation and sustainability in the '3 Rs' i.e. reduce, reuse and recycle of non-renewable resources [3]. Reference [4] defines the embodied energy as "the quantity of energy required by all activities associated with a production process" [4].Additionally, reference [5],in his speech at the National Trust annual conference, explains the term "embodied energy" as "the total expenditure of energy involved in the creation of the building and its constituent materials" [5]. Besides, Ashworth explains that historic buildings are often viewed as containers of stored value of embodied energy, and a sort of frozen employment [6]and [7]. Reference [8]gives an example: a heritage building with approximately 308,000 exterior bricks, each with an embodied energy value of 14,300 Thermal Units (BTU), represents 4.4 million BTUs of energy expended in the original construction of the building, or 1.3 million kilowatt hours of electricity [8]. Reference [9]points out that conservation and adaptive reuse cause much less destruction to our natural resources than new construction. Interestingly, about 85 percent of the total embodied energy in materials is used in their production and transportation [9]. Unmasking these costs can provide strong incentives for a transition to more sustainable energy use, less profligate use of new materials, and greater use of existing building stock [10](see figure 1).

Existence of heritage structure is a testament to their sustainability because they have remained useful spaces.

A building and its components is a major tenet of sustainable design. Heritage structures are also sustainable for the types of architectural elements they employ. Because most of these buildings were built before the advent of air-conditioning, they utilize the earth's natural energies, such as sunlight and wind. This consideration is crucial to "greening" a heritage building because the original materials have largely performed admirably over decades and even centuries. Removing the heritage fabric or damaging it to the point of necessitating its removal would thus create a less sustainable structure, even if the replacement was considered more efficient.

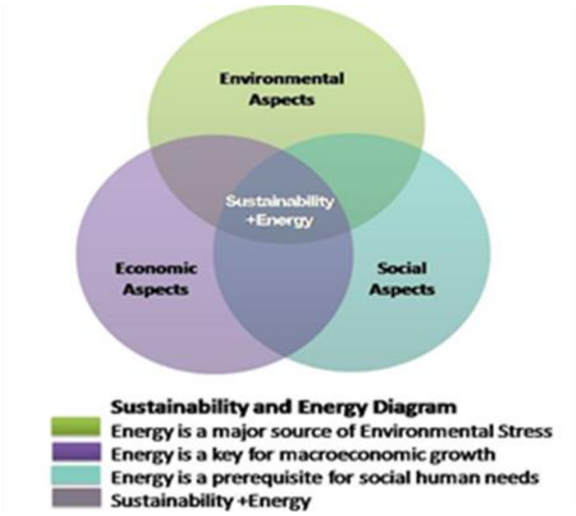

Fig .1. Sustainability and Energy Diagram (Source: Author).

Reference [11] identifies the role buildings play from an energy usage perspective, and it is believed that the future energy adaptive qualities and design buildings will have to incorporate with their concepts [11]. It has been concluded that conservation of energy within buildings has an integral role in the effort to cut down on energy consumption. Furthermore, reference [12] recognizes the benefits associated with reusing heritage structures versus building new ones. He explains the benefits of intensifying the discussion to encompass environmental benefits, including the issue of embodied energy [12].

Moreover, the Advisory Council on Historic Preservation commissioned a study regarding energy conservation and heritage structures. The aim was to provide a tool for determining the energy value of heritage structures. The methodology related to embodied energy used by the Advisory Council for Historic Preservation (ACHP) measured the embodied energy of materials and construction for existing, rehabilitated and new construction. It also measured the demolition energy for existing buildings; including the energy to demolish, load and drag away building materials [13]. Besides, Carter overviews the importance of the study produced by the ACHP, Assessing the Energy Conservation Benefits of Historic Preservation: Methods and Examples, and affirms that it must extremely influence the conservation movement and perhaps transform the way effects on the built environment are evaluated [14].

B. Resource Conservation and Adaptive Reuse

In 1993, the U.S. Green Building Council was established with a mission to support sustainability in the industry of building and construction. Additionally, the U.S. Green Building Council delivered the green rating system, LEED. LEED is therefore defined as: “The most widely recognized and widely used green building program across the globe. LEED is certifying 1.6 million square feet of building space each day in more than 130 countries. LEED is a certification program for buildings, homes and communities that helps guide the design, construction, operations and maintenance. Today, nearly 50,000 projects are currently participating in LEED, comprising more than 8.9 billion square feet of construction space.” [15]. LEED has provided the basis for the building business to begin designing with sustainable incentives. This has raised the question: How would heritage structures be compatible in a world with limited resources?

Responsiveness of the need to decrease greenhouse gas emissions has transferred the sustainability initiative from an energy crisis to a climate of alleviation. Over the last years, buildings have continually been noticed as the largest energy use sector over transportation and industry. As energy use by buildings continues to be a growing anxiety, the conservation community can gain traction on the dispute of heritage buildings adaptive reuse. Reference [16] has declared that the greenest building is the one that is already built [16]. Reference [16] viewpoint has become the framework for a dispute for many to defend the value of energy embodied in heritage buildings.

Fig. 13 shows a photograph of the complete experimental setup. In this figure, the host PC including the dSPACE controller, which is used to control and monitor the system variables by using the connector pins interface, is shown. Also, the power and interface circuits of the laboratory prototype of the proposed multi-phase MC are shown.

Reference [17], the former President of the Athena Sustainable Materials Institute, discusses the environmental gains in renovation versus new constructions. This is considered the benchmarking approach of comparing demolition versus new construction and estimating the environmental impacts that are avoided by saving an existing building [17]. Reference [17] looks at two scenarios, the first is the minimum avoided impact case, which entails saving only the structural system of a building, while the rest is demolished or replaced. The second scenario is the maximum avoided impact case, which involves saving the wrapping as well as the structure. A well known researcher concluded that life cycle assessment should be used for renovation projects as a decision support methodology, if the appropriate data and tools are accessible [17].

The Athena Sustainable Materials Institute has examined the life cycle analysis, and whole building energy simulation, in evaluating the material and operational environmental effects of rehabilitating an existing building compared to new construction [18]. Furthermore, renewed heritage buildings can function comparably to new buildings using common environmental measures such as energy power and global warming contributions [19]. Finally, in 2012, the Preservation Green Lab has released its prominent study results which conclude that building reuse constantly offers environmental savings over demolition and new construction. Moreover, it can take between 10 and 80 years for a new, energy-efficient building to surmount, through more efficient operations, the negative climate change impacts that were formed during the construction process [20].

C. Embodied Energy and the ACHP Model

The Advisory Council for Historic Preservation in their report, defines embodied energy as the energy which is measured in fossil fuels, and that was consumed to make any product, bring it to market, put it to use, and then to dispose of the product at the end of its useful life [13]. The First and Second Law of Thermodynamics provide the basis for exploring embodied energy in resources. Therefore, the quality of a resource will determine and influence its utility and value within a system, by raising the quality of a resource, and it will enforce its own set of environmental demands. Stein displays this law through the life cycle of a brick [21]. The brick has the same amount of material as an equivalent chunk of clay in the ground. However, the brick in the brick wall has considerably more value than the unprocessed soil. In order for the clay in the ground to become a brick, it has to go through a number of processes including: extraction of the raw clay, transportation, crashing and separation of the clay, shaping, firing in the furnace, transportation to the job site and assembly in the wall [21]. As a result, the brick has higher environmental demands. In order to raise the quality of the clay to that of a brick, energy has been added. As the brick weathers or declines by natural processes, or when it is demolished, the resources and energy that have been added to the material will be vanished. Decline of materials and assemblies as a building witness the passage of time is a predictable consequence of the Second Law of Thermodynamics. Buildings begin deteriorating at the point of finishing construction, slowly at first, and then accelerating the pace of deterioration before slowing once again. Building owners slow deterioration rate by preventative maintenance, or compensate deterioration with repairs and replacements, incrementally increasing the embodied energy, ultimately approaching the original values.

In view of that, the Advisory Council on Historic Preservation has reached a model whichprovides another tool for determining the total worth of threatened properties, and, in specific cases, whether retention and continued use are in the public interest. The Advisory Council of Historic Preservation has developed tools for assessing the potential energy conservation value that preservation provides. The following are outlined tools [13]. Firstly, the embodied energy of materials and construction for existing, rehabilitated, and new construction is the amount of energy required to process and put materials of construction in place. Embodied energy increases with the amount of processing and is not recoverable.

Secondly, demolition energy for existing buildings is the amount of energy required to raze, load, and haul away building construction materials. The annual operational energy for existing, rehabilitated and new construction is the amount of energy required to operate the facility where the operational energy depends upon climate; occupancy characteristics; and physical design of the building [13].

The methodology of the mentioned report looks at embodied energy of materials and construction for existing, rehabilitated and new construction [13]. The embodied energy calculation includes the amount of energy to process and put materials of construction into place. The first model presented is the building concept model. The report states that “results are generally correct but not precise,” [21] (Booz, 1979, p.19). This model states that embodied energy is measured by assessing the building type and gross square footage [23]. The concept model as a formula is expressed as:
Embodied Energy Investment = {Gross floor area of heritage building x invested energy per square foot specific to the building type from Exhibit 1}.

The second model is the building survey model, and it is considered to be the most useful [13]. Hence, embodied energy is determined using a rough survey of primary material quantities, and applying their relevant energy values.

An evaluation of the data inputs for the above methods is further investigated to identify the justification behind the embodied investment dispute. The variance for heritage structures may be noticeable because structures were originally built in varying centuries with varying building technologies that had utilized varying energy yields. Hence, it is important to recognize the basis and origins of the data and numeric quantities. The U.S. Department of Energy provides a study of patterns of embodied energy through diverse construction industries [23]. The embodied energy total includes the embodied energy of the materials plus the direct energy of construction used at the site. The breakdown of the forty-nine categories is: seventeen are new building; five are building maintenance, repair and alteration; and the remaining twenty-seven are non-building construction and repair. The Department of Energy report stresses that 70 percent of embodied energy in new construction is attributed to fabrication of basic construction and components; the remaining 30 percent is due to delivery and setting up, including direct fuel purchases, administration, and transportation of materials, furnishings and construction equipment [23].

The Advisory Council on Historic Preservation report has become an embedded dispute within the field as a link to the sustainability conservation. The ACHP report has laid the basis for quantifying the energy value of conserving heritage structures. The ACHP model was innovative at the time of its release. However, at what position does the industry respond to the new wave of energy efficiency and green building design solutions? The answer to this question may be evident within the Preservation Green Lab, National Trust for Historic Preservation's recent study [24]. To express what embodied energy is basically accounting for a formula which can be articulated starting with the original capital investment, minus the losses due to decline, plus the added investment while ownership is maintained, equals the residual current value of investment (see figure 2). Consequently, the embodied energy method does not account for predictable processes that occur to every building such as deterioration and maintenance, therefore not accounting for the true current capital value of the building.

Embodied Energy	Minus (-)	Value of Embodied Energy Lost to Deterioration	Plus (+)	Embodied Energy Repairs/ Maintenance	equals (=)	Net Residual Energy Embodied in Building

Fig .2. Formula to Express Embodied Energy (Source: Author based on Booz, 1979).

D. Life Cycle Assessment of Heritage Structures

While conservation is not the sole resolution to sustainability, it can be an integral part of it. The Whole Building Design Guide, in its 2012 article "Sustainable Historic Preservation," endorses the notion that "preserving a building is often called the ultimate recycling project" [25]. It goes on to detail intrinsic sustainable features within heritage structures such as sustainable sites, water efficiency, energy and atmosphere, on-site renewable energy, green power, materials and resources and indoor environmental quality [25]. The reality is that these features emphasize the similarities and common characteristics in sustainability goals and conservation.

The Whole Building Design Guide refers to Life Cycle Assessment (LCA) which is defined by the United States Environmental Protection Agency as a technique to assess the environmental aspects, and potential impacts associated with a product, process, or service by compiling an inventory of relevant energy and material inputs and environmental releases; evaluating the potential environmental impacts associated with identified inputs and releases, in addition to interpreting the results to help you make a more informed decision [26]. LCA is also appropriate to heritage conservation as it can be utilized to assess the environmental values and benefits associated with reusing a building. This approach to investigating existing structures shifts the focus from solely embodied energy, which makes up a fraction of an LCA, to a whole building approach, and brings to the front position a range of environmental values [17]. The LCA assessment tool would be used to compare rehabilitation and new construction, in addition to comparing various rehabilitation options.

Furthermore, the Greenest Building: Quantifying the Environmental Value of Building Reuse study has explored the environmental impact reduction when rehabilitated buildings are compared to demolition and new construction. This LCA framework enables the conservation industry to look at key variables such as building life span and the efficiency of operation energy that may affect the decision to reuse buildings in opposition to building a new one [20]. Three key findings from the study are: firstly, building reuse almost always yields fewer environmental impacts than new construction when comparing buildings of similar size and functionality; secondly, reuse of buildings with an average level of energy performance consistently offers immediate climate change impact reductions compared to more energy efficient new construction; and thirdly, materials matter i.e. the quantity and type of materials used in building renovation can reduce, or even negate, the benefits of reuse [20].

E. Athena Sustainable Materials Institute and Life Cycle Assessment Measures

Several attempts were made to build up spreadsheets calculating environmental impacts of heritage buildings retention. Spreadsheets were therefore developed into software [27]. In 2002, it was released under the name Environmental Impact Estimator (and is currently called the Athena Impact Estimator for Buildings). A second tool, the Athena EcoCalculator for Assemblies, was developed in 2007. The Athena Institute is still a reliable source providing software, research and valuable information in the form of life cycle assessments for the construction industry. Examining the environmental impacts that are avoided by recycling a building opposed to demolition amplifies the dispute for conservation. Accounting for the energy, in the future, closes the gap that exists between the energy that was spent at initial construction, and the energy added for a replacement building. Therefore, the life cycle assessment/avoided impacts model is in alignment with the sustainability goals. The method used was novel and exemplary in the response to provide the conservation field the tools.

III. METHODOLOGY

A. Heritage Conservation and Energy Sustainability in the International Context

Heritage preservation groups around the world have begun not only informing others about the role of conservation in sustainability, but also utilizing sustainable practices in their own preservation projects. The U.S National Park Service, which oversees the Secretary of the Interior's Standards, has released standards to provide general goals for preservation projects at the international level, as well as guidelines for specific aspects of heritage construction. In fact, within the Secretary of the Interior's Standards for Rehabilitation, there are "special requirements for energy efficiency" that fall into their guidelines [28].

In addition, the National Trust for Historic Preservation is a national, private non-profit organization in U.S. that seeks to "save historic places and revitalize America's communities." [24]. The National Trust has partnered with LEED, or Leadership in Energy and Environmental Design, for several of their preservation projects, showing their dedication to increasing efficiency and sustainability even further in historic structures [29]. The Trust utilizes LEED certifications because their standards focus largely on the reuse of materials and resources in any construction project, whether it is a new or existing building. The National Trust has taken on even more involvement to partner with several U.S. national groups to create the Sustainable Preservation Coalition, which has made the goal of meeting with the U.S Green Building Council to improve LEED standards. The coalition's goal is to improve certain aspects of the LEED certification system, primarily because the current versions that "overlook the impact of projects of cultural value, do not effectively consider the performance…and embodied energy of historic materials and assemblies; and are overly focused on current or future technologies, neglecting the advantages of many traditional building practices." [29]. A heritage construction is inherently sustainable because it is extremely durable and often utilizes natural energies, and LEED standards should reflect this reality. However, even though there are many ways for the LEED certification process to improve, it is still possible for heritage buildings to be LEED certified, or even gain higher recognition in silver, gold or platinum LEED ratings.

Furthermore, English Heritage, officially known as the Historic Buildings and Monuments Commission of England, most recent efforts towards sustainability have culminated in a document aptly titled "Building Regulations and Historic Buildings: Balancing the needs for energy conservation with those of building conservation." [30]. The guide is meant to be an application of the country's regulation, which deals with energy conservation in new, existing, and heritage properties in order to reduce CO2 emissions and protect the building from negative impacts related to irreversibility.

B. Energy Sustainability of Heritage Buildings: The Egyptian Status Quo

The site of the Egyptian Ministry of Electricity and Renewable Energy was explored to look into Egyptian efforts towards energy sustainability of heritage buildings. Unfortunately, no information was available regarding this issue [31]. Since Egypt has been lacking a national program for this subject, it therefore has much to learn from efforts investigated abroad. This is the reason for investigating international literature and applying its experiences in this research. The Egyptian government and Egyptian governorates should coordinate to better inform the public about energy sustainability guidelines and their implementation benefits for heritage structures.

C. Heritage Reuse in Alexandria, Egypt

The practice of rehabilitating old buildings to extend their use, or recycling them for a new purpose is a well- established practice in many parts of the world. Generally speaking, the stock of potential reusable buildings in Alexandria is in Sharq district, in addition to the central urban area district (see figure 3). One can point out that Alexandria has maintained its downtown with architectural continuity to a certain extent. Likewise, there is a vast number of buildings in Alexandria that are candidates for continued adaptive reuse; thus adding up to those in the city centre. Some are outstanding examples of architecture and craftsmanship.

D. Case Study Selection

There is a tremendous impact to the environment when we construct something new, so avoiding new construction may be the most eco-conscious approach to our environment." [27]. Consequently, several heritage buildings were examined to select the case study taking into consideration accessibility to available needed information. The selected case study is a house which lies at Sharq district in Alexandria. It is registered as a villa no. 891 within Alexandria Heritage Report (see figure 4).

It lies at 24KafrAbdou Street in Alexandria [32] (Alexandria Heritage Report, 2007, Map no. 17).

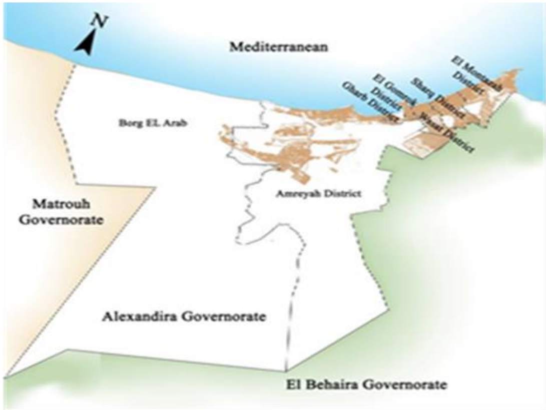

Fig .3. Alexandria Districts, with Sharq District

It is one of 463 listed buildings in Sharq district. It is categorized as important at the local level, the Architectural style is the English style. This style refers to buildings created under English influence or by English architects in parts of the world other than Britain, particularly in the later British colonies and Empire. The house has utilized the whites of splashes in the façade and windows of wood. The building roof is formed of wood and brick veneers. The height of the ground floor is 4 meters and the height of first and second floors are 3.5 meters.

Fig .4.KafrAbdou villa (Source: author.)
From Left: Arial Photo for villa in 2016. Middle: Villa before Rehabilitation. Right: Villa after Rehabilitation

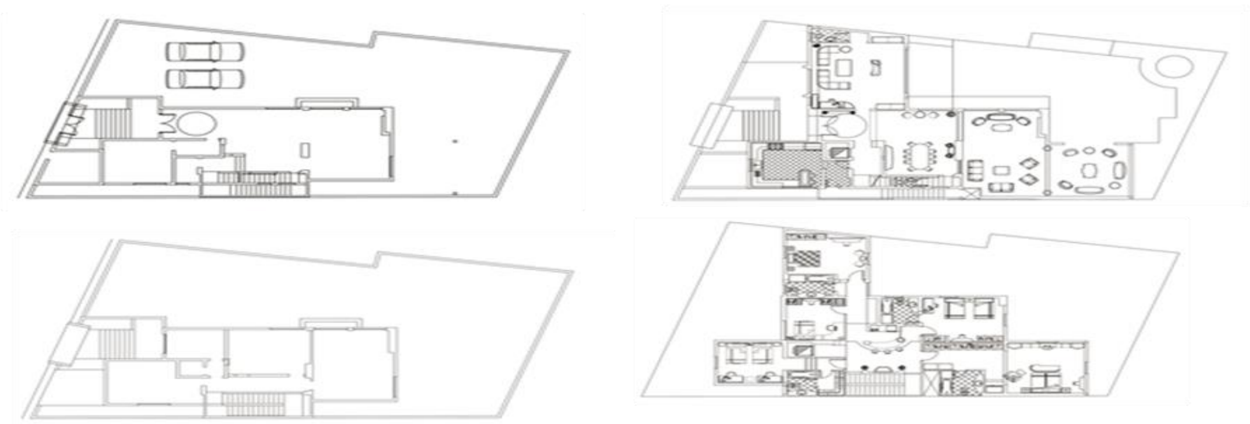

Fig .5.KafrAbdou villa (Source: Rehabilitation project consultant)
Up Left: Ground floor plan before rehabilitation
Down left: First floor plan before rehabilitation
Up Right: Ground floor plan after rehabilitation
Down Right: First floor plan after rehabilitation

- Case Study Original Form

The house consists initially of a building with an area of 175 square meters per floor (2 floors = 3767 sq. ft.) within a whole land parcel area of 470 square meters. The house originally composed of two floors only. The ground floor included the reception and a kitchen. The upper floor comprised 4 bedrooms and a living room.

- Current Form after Development

During the rehabilitation process, a mass of a 45 square meters area was added to both ground and first floors. An additional staircase was added leading to the second floor to meet the needs of the owner and access the second additional floor. An elevator was added as well. An additional basement of 90 square meters was supplemented below the building to accommodate four car parking spaces. The ground floor still comprises The second newly added floor is totally furnished and equipped as a private flat for the owner's son. It currently consists of three bedrooms, a living room and a kitchen.

- Building structure and details

The Structural system is Skeleton (i.e. beams and columns). Research focus is on material quantities of the original building to be able to calculate its contained energy. The original structure of the building includes 123 cubic meters of reinforced concrete columns and beams. The house foundation consists of additional 170 cubic meters. The foundation also includes 170 square meters of plain concrete.

- Openings

The house includes 12 windows openings of three different surface areas which comprise about 32 square meters.

- Brick exterior and interior walls

The total quantity of originally kept internal and external bricks is about 70 cubic meters of bricks (70*35=2450 cf).

- Wood Works

Wood flooring of Swedish wood, and wood parquet totals 245 square meters (using 2inch thickness * 4inch width * 2450 length = 1633 BF) are successfully kept.

- Asphalt pavement

Asphalt street outside is kept and it comprises 108 square meters of asphalt.

- Iron Works

Several iron works were kept such as iron doors and fences which have a quantity of 16 square meters (16*300*2.2=10560 lb).

- Nonferrous Products

These materials may include mortar, sand beneath wood installations 22 tons approximately (22*1000*2.2=48400 lb.)

- Infrastructure Works

All electric connections and sanitary works have been completed to accommodate and comprise current owner requirements.

E. Research Procedure and Results

The data gathered from the site includes a basic site visit to assemble building information, building dimensions, detection of observable materials, and applicable material quantities. The current function is residential. Interior access was not permissible. Architectural Drawings including detailed plans dimensions before and after restoration, sections and elevations, were received from the consultant architect who achieved the rehabilitation process [33]

The survey level methodology for the embodied energy analysis (ACHP) was applied for this case study. The survey method calculator is accessed through [22] www.thegreenestbuilding.org website.

The survey method examines major material components of the structure, and calculates the embodied energy of each individual element for calculation [22] (thegreenestbuilding.org website) (Table 1). The data sets comprise extraction of raw material, manufacturing, transportation and physical construction (see figure 6).

Several assumptions were necessary for structural materials that were not visible. The green building association generates British thermal unit (BTUs) results based on the square footage of materials used in original construction. For this reason, all dimensions were changed from available French Metric units used in Egypt to British Metric units to be able to apply the Greenest Building calculations per square footage.

Energy Used in Construction					
Residential - Single Family		3767	sq. ft.		
Material Category					
Wood Products		Brick		Concrete	
1633	BDFT	2450	cf	16205	cf
14697000	BTU	980000000	BTU	1555680000	BTU
Paint		Glass: windows		Glass: plate	
quantity (450 sf/gal.)	sq. ft.	344	sq. ft.		sq. ft.
0	BTU	5160000	BTU	0	BTU
Asphalt		Iron & Steel		Non-Ferrous Products	
1162	sq. ft.	10560	lbs.	48400	lbs.
2324000	BTU	264000000	BTU	4598000000	BTU
Calculate	Clear	10726835	MBTU Embodied Energy Investment*		

Fig.6. Survey method of energy calculations used in construction.[22] (Application Template :www.thegreenestbuilding.org).

The results from the survey method yield 10726835 MBTU Embodied Energy Investment. The result from calculations is of 10,726,835 BTUs put into the Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator 10,726,835 BTUs is equivalent to 770.3 metric tons of CO2 or CO2 equivalent. To humanize these results further: that is equivalent to the CO2 emissions from the energy use of 42.6 equivalent area homes for one year. This number is relevant when comparing it to the results from the LCA approach.

Limitations related with the embodied energy approach to quantifying value in heritage structures are first the handling. While the embodied energy calculator is accessible for free via the Internet, it is not a downloadable interactive document. An extra paper and pencil calculation to get BTUs is necessary. Time intensity for this approach is low. For the gross square footage calculation, it took approximately two hours to perform take offs of existing plans.

Besides, Athena EcoCalculator is a structured excel spreadsheet workbook, with tabs for various construction assemblies on each; individual worksheet with specific assembly information is included. All life cycle stages are taken into account: resource extraction and processing; product manufacturing; on-site construction of assemblies; all related transportation; maintenance and replacement cycles over an assumed building service life of 60 years; and the demolition and transportation of non-metal materials to landfill [27] (Athena Ecocalculator website).

Designed to be readily-applied, the EcoCalculator template can be used without outside consulting or help of any specialty, and the results are considered to be reasonable approximations as opposed to accurate estimates. The use of the Athena EcoCalculator is to estimate embodied environmental impacts, and global warming potential measured in terms of CO2 equivalence. Estimated avoided impacts associated with demolition of the existing building and construction of new buildings of essentially the same size is designed to serve the functions currently being utilized by the renewed buildings.

Hence, the EcoCalculator provides results for seven indicators of climate change impacts the classification of those seven impact categories are fossil fuel consumption (MJ), global warming potential (GWP) in tones CO2 e.g., acidification potential, human health criteria, eutrophication potential, ozone depletion potential and smog potential. These impact measures can be assessed to determine which assemblies provide the lowest negative impact by entering the square footage of materials into different assemblies. The summary of the results from the EcoCalculator is accounted for across the eight climate change indicators (see figures 7, 8 and 9).

The total avoided impacts for global warming potential (GWP) were compiled and the inclusion of calculating the global warming potential for whole building demolition was added on as an avoided impact in case of the reuse of an existing building (see figure 7). The assembly groups are also represented by the percentage contribution from each assembly to the seven climate change indicators (see figure 9).

Athena EcoCalculator
for Residential Assemblies

Version 1.21
Location: Toronto
ASHRAE climate zone 6

ENVIRONMENTAL IMPACT SUMMARY

ASSEMBLY	Total area	Fossil Fuel Consumption (MJ) TOTAL	GWP (tonnes CO2eq) TOTAL	Acidification Potential (moles of H+ eq) TOTAL	Human Health Criteria (kg PM10 eq) TOTAL	Eutrophication Potential (g N eq) TOTAL	Ozone Depletion Potential (mg CFC-11 eq) TOTAL	Smog Potential (kg O3 eq) TOTAL
Foundations & Footings	3,175	91,059	10	2,537	42	1,939	61	536
Columns & Beams	58	82,540	9	2,086	32	1,510	52	417
Intermediate Floors	1,445	140,892	10	2,322	28	5,115	0	291
Exterior Walls	861	98,342	8	2,728	29	1,481	28	405
Windows	244	78,971	8	5,059	148	2,038	28	753
Interior Walls	800	48,932	4	1,117	27	1,004	22	194
Roof	1,130	204,967	14	4,030	61	5,296	2	315
TOTALS		745,704	62	19,879	368	18,382	194	2,911

Fig .7. Athena EcoCalculator Results on Spreadsheet. (Application Template:www.athenasmi.org).

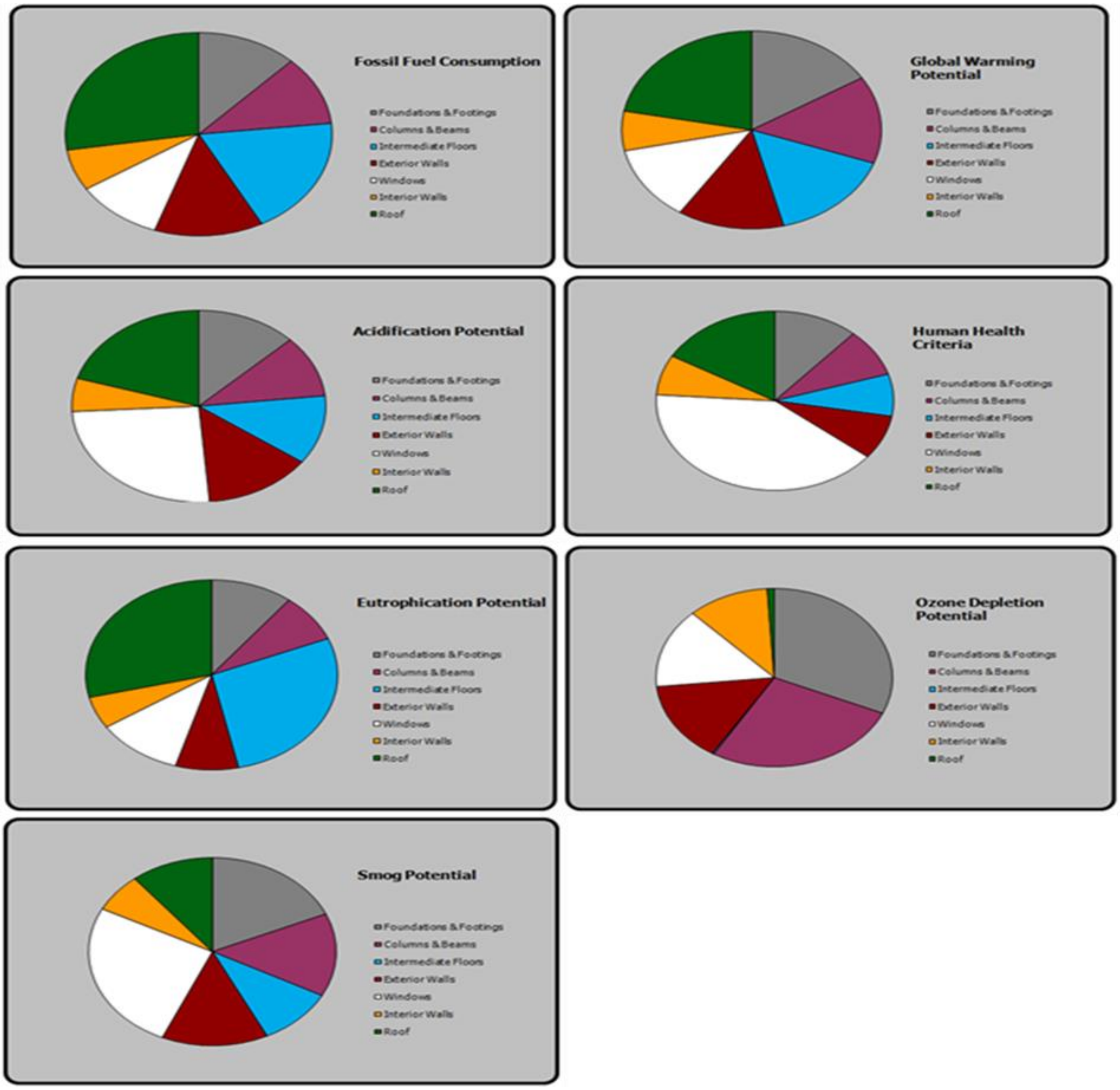

Fig.8. Athena EcoCalculator Results in the form of Pie charts (Application Template: www.athenasmi.org).

Percentages by assembly groups
(these results are shown in the pie charts below)

Fossil Fuel Consumption	Global Warming Potential	Acidification Potential	Human Health Criteria	Eutrophication Potential	Ozone Depletion Potential	Smog Potential
12%	16%	13%	11%	11%	32%	18%
11%	14%	10%	9%	8%	27%	14%
19%	16%	12%	8%	28%	0%	10%
13%	13%	14%	8%	8%	15%	14%
11%	12%	25%	40%	11%	14%	26%
7%	6%	6%	7%	5%	11%	7%
27%	22%	20%	17%	29%	1%	11%

Fig.9. .Athena EcoCalculator Percentages on Spreadsheet. (Application Template: www.athenasmi.org).

Out of the eight climate change indicators, global warming potential is the indicator that can be translated into a carbon dioxide equivalent. Global warming potential (GWP), as defined by the Environmental Protection Agency, was developed to compare the ability of each greenhouse gas to catch heat in the atmosphere relative to another gas. The definition of a GWP for a particular greenhouse gas is the ratio of heat trapped by one unit mass to the greenhouse gas to that of one unit mass CO2 over a specified time period [26] (U.S. environmental Protection Agency website). The avoided GWP impact of case study house is equivalent to emissions from the electricity use of 16equivalent area homes for one year, or CO2 emissions from the energy use of equivalent area of 5.2 homes for one year.

As it is the case with any model, there are particular limitations in the system. When calculating the square footage for the Exterior Walls assembly, there is a built-in 20 percent window to wall ratio. The model automatically accounts for the 20 percent ratio. Time and user building construction knowledge is the second limitation. While this template is accessible, it does require the user to have some basic architectural building construction knowledge to choose appropriate building assemblies.

I. DISCUSSION

Historically, the conservation field has relied on the embodied energy outputs of BTUs when discussing the energy capital in existing structures [13]. However, with the development of the LCA/avoided impacts approach, outputs in the form of GWP or carbon dioxide equivalent emissions can be utilized to still maintain the gallons of gas comparison [26]. The environmental avoided impacts model provides a currency that is interdisciplinary. The environmental avoided impact incorporates not just emissions from CO2, but also human health, acidification, water, etc… [27].

This case study identifies and applies two ways to approach quantifying the energy capital in heritage structures. Both provide quantitative results, but with different units of measurements. The EcoCalculator Life Cycle Assessment measured the energy capital in terms of eight climate change indicators, and focused on global warming potential [27], while the Advisory Council for Historic Preservation embodied energy ACHP model measured the energy capital in BTUs. Both approaches have developed results that represent a currency that has the potential to be communicable across the sustainability community. When measuring embodied energy, capital energy is viewed retrospectively. We value a building currently in terms of energy that has been expended historically, not taking into account that a building declines over the years. The LCA/avoided environmental impacts approach looks at what total replacement with a comparable new building would require and accounts for the building declining over the years.

The role that heritage conservation plays within sustainability and the goal to reduce greenhouse gas emissions is already on its way to adapting to modern sustainability goals and policies. Examining the resulting unit of measurement indicates the embodied energy model, and produces results that are measured in BTUs, and they are commonly translated to gallons of gas. The life cycle assessment/avoided impacts model produces results in a metric of CO2 and GWP. In terms of the conservation field utilizing a common currency to communicate with experts driving sustainability the life cycle assessment/avoided impacts model provides these communicable measurements.

II. CONCLUSION

The role of the conservation field within energy sustainability will continue to expand and adjust since sustainable strategies and goals are continually developing. This research has highlighted the importance of the conservation field to stay side by side with the saved energy that is associated with sustainability. It is important for the conservation field to approach the ability to employ environmental avoided impact methods when discussing and assessing heritage structures.

The core aim of sustainability is to safeguard the eco-system for future generations. Conservation professionals should adapt to this role, as they have taken on the role of safeguarding structures, landscapes and cultures for years. The ability to reinforce the relationship between conservation, sustainability and energy should be the responsibility of the conservation field. Communicating in a common energy value and avoiding work in a silo will allow professionals to be successful at the reuse of heritage structures.

With trained professionals, heritage buildings can be better protected during retrofits, as well as becoming more efficient with less impact on the environment over time. With this understanding of the broader movement for sustainability and preservation internationally, we can begin to focus on and support such initiatives to be performed in Egypt.

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Dynamic Facades
Environmental Control Systems for Sustainable Design

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Abstract - Façades are the most strategic and visible part of the building which leads to an improvement in appearance and environmental performances in buildings. Facades play a significant role in the quality of a building. It forms the barrier between the internal space and the outside climate. This means that the façade is the medium through which the interaction takes place between the activities, inside and outside. The image of a building, and therefore for the users, is reflected through the design of the façade.

In recent practices, architects and engineers are strategically designing and installing dynamic facades not only for their aesthetic values, but also for improving the buildings' energy performance. The high integration of these strategies for dynamic facades increases their durability and suitability, with current building demands, which targets for energy efficiency and thermal comfort level.

In the meantime, recent studies show that the majority of people spend up to 90% of their time indoors especially in hot climates. This trend has had a high impact on the requirements of the indoor environment, consequently turning the buildings into complex devices that ensure the wellbeing of the people who use them. Therefore, users are starting to look for new products for the façade design that comply with the requirements of energy. This poses an important question, is there anything to be done to this specific part of the building in order to positively influence the overall energy need of the building?

The paper will discuss the concept and the importance of dynamic facades according to their design and types, implementations, current challenges and climate impacts. It will highlight the history of these facades and the essential parameters which make the building sustainable through its facades. Moreover, the paper will analyze two examples of buildings with dynamic facades with automated control systems and its effect on the building environment. At the end, the paper tries to demonstrate if these facade systems and strategies could be applicable on the buildings in Egypt.
Finally, the paper aims at integrating the dynamic facades in buildings as an environmental control system to achieve a sustainable design to reach good energy performance in buildings.

Keywords - dynamic facades; sustaianble design; energy efficiency; environemtal control.

I. INTRODUCTION

In recent years, contemporary architecture has been deeply influenced by the urgent need for reducing harmful emissions of carbon dioxide in the atmosphere. The building sector constitutes in fact one of the most energy consuming sectors of the world economy. However, buildings are also potentials and powerful agents able to carry out with effectiveness and relatively rapid's time actions to minimize emissions, through the drastic reduction of their energy consumption. With regard to energy consumption, sustainable building is often directed at energy-efficient use of fossil fuels and the generation of renewable energy through technical appliances. These measures may be considered adjustments to a furthermore traditional way of building, ignoring the fact that the building itself can be innovated to an intelligent, responsive or even proactive device.
From this perception, the building is to be fire-tuned to its environments and interact intelligently with local characteristics such as: climate, type of soil and surroundings. This interaction is most logically performed by the building skin: the roof, the ground floor and the façade, where in changeable climates the use of building mass of the thermally subsoil is an effective means to smooth big temperature differences.

In this paper, the concept of dynamic facades will be explored. Also, the importance of active facades according to their design and types will be discussed. The paper will present the role of building facades particularly “dynamic facades” as an innovative solution that makes buildings sustainable to different conditions and responsive to different environmental needs. In addition, the paper analyzes two applications in different regions with different climates that deal with technological and environmental aspects in sustainable building skins and their role in fulfilling the environmental demands.

Finally, the paper ends up with a comparison between the two applications to reach different solutions to be applied on the Egyptian building facades which could control the surrounding environment and be sustainable.

II. THE BUILDING SKIN AS A SEPRATING AND A LINKING ELEMENT BETWEEN INSIDE AND OUSIDE

Despite changed cultural, economic, building technological and energetic parameters, the principal task of architecture is still to create a comfortable “shelter”. In other words, the fundamental aim of a building is to protect people from the external climate conditions, such as intensive solar radiation, extreme temperatures, precipitation and wind. In construction, the building skin is the primary subsystem through which prevailing external conditions can be influenced and regulated to meet the comfort requirements of the user inside the building. Like the skin and clothing of humans, this raiment, too, fulfills the tasks demand of it by performing a number of functions made possible by means of the appropriate design and construction.

The building skin is the dominant system in all subsystems of a building-the load bearing structure, mechanical services and spatial framework-not only in terms of design, but also fulfill a multitude of vital functions and is a principal factor in the energy consumption of a building [1].

III. CONCEPT OF DYNAMIC FACADES

The façade is a strategic element because it is the most visible part of the building. This leads to an improvement in environmental and appearance performances of a building. The façade also exchanges energy with the external environment, this increases energy performance. The façade protects structures and interiors of the building and this contributes to the extension of the life of the building [2].Thus, the building’s façade should function as a mediator between the external and internal environments which can be entrusted with multiple vital functions that dictate the building’s energy consumption and which determine the indoor environmental quality [3]. Dynamic facades are “facades with the ability to respond to their environment by either typological change of material properties that alter the overall form or local alteration by regulating their energy consumption to reflect the environmental conditions that surrounds it”.

Traditionally, the design of a building’s façade is “static”, where the external environmental boundary conditions are designed to be constantly changing. As a result, traditional facades are not capable of adapting and responding to various changes that they are exposed to. According to a recently completed project of the International Agency – Energy Conservation in Buildings and Community Systems Programme, the development, application and the implementation of dynamic facades provide a necessary step towards creating improvements for energy efficiency within building environments. However, through the use of dynamic facades, the buildings have the ability to react to these conditions with improved energy efficiency in the building [2].Facades that respond to the environment are considered as part of the building’s envelope in a primarily different way. Dynamic facades actively adapt to their behavior over time in response to changing environmental conditions and performance requirements. The term “dynamic” in architecture has been described as the ability of artificial and natural systems to adapt to varying environmental conditions. Also, this term is used to describe the interaction between external environmental conditions and the façade systems. Thus, environmental conditions can encompass a range of different elements such as daylight, wind and heat. However, the term “environmental conditions” are associated with solar radiation, daylight and heat [3].

IV. HISTORY OF DYNAMIC FACADES

Within the scope of the technologies of their time, traditional farmhouses had already made optimum use of energy-saving potentials. The heat generated by the livestock was used for heating the building, and straw and hay were not merely bedding and feed but provided insulation. Energy consumption caused by burning firewood was kept to a minimum. Windows had folding shutters that created a thermal buffer between the glass and the shutter at night, very much like a double-skin façade today. Double skin structures make up one of the most widely employed functional principles used to protect against exterior environmental influences through the façade envelope. Prior to the development of insulated glass, a second window was insulated to utilize the area between the two windows as a thermal buffer. The combination of two single glass panes generated higher insulation values and adapted to the prevailing weather conditions. During winter both windows remained closed, whereas during summer, the exterior windows opened to promote ventilation [4].

In modern times, glass has been used more frequently, however, this has increased the issue of excessive cool down in winter and overheating in summer.

As early as 1929, the integration of the building skin and the building mechanics was of vital importance in the goal to successfully translate and realize innovative façade concepts. Le Corbusier formulated a concept for a building envelope with positive impacts on the indoor climate in Precisions: On the Present State of Architecture and City Planning. He talked about the “Mur-rneutralisant”: ‘We have seen that these neutralizing walls are in glass, in stone, or in both. They are made up of two membranes with a space of few centimeters between them…A circuit in that narrow interval between membranes, hot air is pushed if in Moscow, cold air if at Dakar. The result: one has regulated in such a way that the inside face, the inside membrane, stays at a temperature of 18 degrees”.

Le Corbusier’s thoughts were never conveyed into a satisfactory result. His ideas were far ahead of his time. Today his “Mur-neutralisant” can be seen as the predecessor of the exhaust-air façade. This type of façade allows regulating the environment of the usable spaces individually independent on the exterior environment by employing a combination of a double-skin structure and an air-conditioning unit. Whereas Le Corbusier aimed to moderate the room adjacent to the façade with an artificial environment in the building envelope, modern environmental concepts used the gap between the façade layers to create a buffer. Thus, the façade space creates an intermediate environment between the interior and the exterior [4].

In other words, the regulation and the adaptability of skin were achieved with control system that is intelligently planned and easy to operate.

V. THE RELATIONSHIP BETWEEN INDOOR THERMAL COMFORT AND BUILDING FACADE

In general, facades are designed to respond to many scenarios and perform functions that can be contradictory to each other: daylighting versus energy efficiency, ventilation versus views and energy generation. Since a wide range of environmental parameters can affect the quality of indoor spaces and user’s satisfaction. Numerous studies have been conducted by researchers and architects in order to establish design strategies to create acceptable indoor environments in accordance with the behavior of users and locality of the buildings. Hence, in view of the indoor environmental quality, most of the researchers concentrate on the thermal aspects of environments and the condition of human thermal comfort inside the building.

Facades are the main constitute of the building envelope and a boundary between external and internal environments, considerably impact the environmental conditions of indoor spaces, the thermal performance of buildings and subsequently the user’s satisfaction. Hence, thermal comfort conditions depend not only on the external environmental factors (i.e. air temperature, air movement, solar radiation) but also mainly on the architectural parameters and design elements such as the position and orientation of building, façade materials, shading devices, type and location of windows and roof shapes. Thence, design and selection of facades during the design process of building should be considered as one of the major tasks in order to support the quality of visual and thermal sensations in indoor environments [5].

VI. PARAMETERS FOR DESIGNING DYNAMIC FAÇADE

The concept of dynamic facades is not new, however, it is only during the last few years that architects and engineers have started to trust these systems and use them in building. Facades focus on feasibility systems for developing the quality and economy of this technology to be sustainable in the future [6].There are several parameters that should be included when designing building facades. Each has the potential to define the character and affect the overall perception of a building.

- Sun ccontrol

Thermal and visual comforts are dependent on controlling the light entering a building through its façade. The amount of light admitted to a building correlates directly with an increase in interior temperatures, affecting the comfort level of the users within. Blinds can provide a simple way to restrict sunlight subtly without affecting the overall appearance of the building. Alternatively, shading elements can be highlighted by integrating the solar strategy into the façade.

- Natural ventilation

The building skin plays an important role in terms of the natural air exchange in buildings. Ventilation strategies can also give a strong character to the elements of a façade. They can be simple, small, repetitive louvers that allow for localized air circulation, or involved mechanical systems that direct fresh air throughout the building.

- Daylighting

The use of natural daylight is important, both in terms of the comfort and contentment of the users and with regard to reducing the requirements for artificial light. Daylight systems can be achieved mainly through passive measures. A simple movable light shelf can bounce light deep into the space, illuminating the interior by taking advantage of the reflectivity of the ceiling. Daylight levels are known to affect the mental health of the users.

- Connection to outdoors

Connection to the outdoors is another sustainability feature that is physiological in nature, like daylighting. This could be achieved by applying glass protected by a vegetated screen that serves as a visual connection to the outdoors. Sometimes, the walls can open, connecting the interior of the building directly with the outdoors. The aim is to blur the boundary between the interior and exterior space, enhancing the feeling of building in nature.

- Thermal insulation

Thermal insulation systems employ materials and components capable of reducing heat loss through transmittance, convection or radiation. The invisible insulation in walls has a huge potential to impact the thermal performance of a building. A particular insulation's make up and placement within the layering of the building skin can have large consequences that are observable in the thermal performance and aesthetics of the building skin [7].

- Moisture control

Bitumen, a natural substance consisting mainly of hydrocarbons, is frequently used to create moisture barriers in buildings. It is often thought of the outer most skin as the water barrier, but more frequently it is as a rainscreen. There are two kinds of moisture to contend with when trying to keep the building dry: rain and condensation. When large temperature differentials occur between the interior space and the exterior, condensation forms on the colder surface. Protection is necessary to prevent this moisture from seeping into the building. The rainscreen and moisture barrier work together to prevent the unwanted rain and condensation from entering the building.

- Structural efficiency

It is important to integrate structure into the building skin. High-rise construction is primarily concerned with carrying lateral loads, so the diagonal lateral bracing of the building often called the "Gherkin" is expressed as part of the skin, helping to define the character of the building.

- Material choices

Materials can give a very distinctive character to a building. Although they are often overlooked by professionals early in the design process, materials are seminal because their texture and appearance define the experience of the building. Materials also play a primary technological role and have a tremendous effect on the comfort of the building.

- Possibility of energy generation

There is also the possibility for a building's skin to become an energy source. Photovoltaics or flexible solar thin films can be integrated into facades to simultaneously generate power and shade a building [7]. To advance the issue of the building skin with a view to creating truly sustainable and enduring architecture, planning must be goal-oriented, responsible and sensible. Also, a high degree of technical and creative ability is essential. The enormous potential of the building skin must be realized from structural, functional, aesthetic and ecological perspectives to promote advances in the development of architecture that is oriented towards sustainable future [1]

VII. TYPES OF DYNAMIC FACADES

The environment is the key factor that impacts the design of facades, the amount of layering and the material choice, all is dependent on these external forces. So, there are several types of dynamic facades which could be put in category according to the previous parameters.

A. User Control Dynamic Façade

The user control system is an automated system that provides solutions for some time to convey the actuated and responsive reactions to passive processes. Applying such a technology to a building's façade and integrate it with intelligent features will develop an adaptive system that will transmit a higher level of performance while reducing the negative impact of the environmental conditions and the consumption of resources. As a consequence, designing any façade system should take advantage of all the surrounding conditions and resources to develop intelligent techniques that observe occupants' behavior and thus control the façade and achieve a performative envelope that enhances energy efficiency, adaptivity and aesthetics.In general, dynamic and adaptive façade implies that the intelligent objects and components will be featured with enhanced abilities to communicate and interact with environmental conditions and user behavior and respond to changes in external climatic circumstances. Therefore, the situational information can provide the users with complete control through applications to accomplish its process and adjust its functions [8].The following example illustrates this type of dynamic façade. Kiefer Technic Showroom designed by Ernst Giselbrecht + Partner (2007) located in Steiermark, Austria. It is an office building and an exhibition space with a dynamic façade "Fig.1". In this building, the façade changes continuously, each day, each hour which shows a new "face" that turns into a dynamic sculpture. It changes according to the outdoor conditions to optimize internal climate while allowing users to personalize their own spaces with user controls. The façade exterior insulation and finishing system (EIFS) in white plaster operates automatically and can be controlled by users. The façade shading not only can give the flexibility in controlling the outdoor conditions, but also can lend variable forms to the façade design [9].

Fig .1. The dynamic façade of Kiefer Technic Showroom

B. Light Control Dynamic Façade

In this type of façade, automated shading and daylighting control systems are integrated and operate appropriately for all environmental conditions. A notable example is the Arab Institute in Paris designed by Jean Nouvel in 1988. The façade of the building showed continuous considerations for the surface that can actively respond to changes in environmental conditions "Fig.2 and 3". The south of the facades is composed of a 20x10 grid square bays that consist of a central circular shutter that was set within a small grid of shutters – the design was adopted from the geometry of traditional Arab screens. These screens operate like a series of camera lenses, shrinking and widening in response to sensors to control the penetration of sunlight into the building.

Fig .2. The façade of Arab Institute (Paris)

Fig .3. The dynamic circular shutter adopted from the traditional mashrabiya

A similar pattern of design was adopted by AEDAS in Abu Dhabi in Al Bahr Towers (2012). The building consists of a membrane clad dynamic façade with a similar hexagonal pattern in the construction of the active surfaces "Fig.4 and 5". The design of the dynamic "mashrabiya" adopted a similar concept by Nouval to create a responsive façade. The dynamic mashrabiya includes 1,049 units for the west and east side of the building, which claims to be the world's largest, computerized façade built today for 150 metres high towers. The facades create a folding and unfolding movement, which adapts to the sun and the changing environmental conditions [4].This system is predicted to reduce the solar energy entering the building by 20%. Also, it is claimed that the design has resulted in 40% saving in carbon dioxide emissions.

Fig .4. Al Bahr dynamic facades

Fig .5. The folding and unfolding movement of the facade

C. Energy Control Dynamic Façade

Another application for dynamic facades is saving energy in buildings and controlling energy performance in buildings. Energy conscious facades is where the envelope has construction functions such as strength and rigidity, stability and durability, control of heat, air and moisture vapor flows, control of liquid water movement cost-effectiveness and fire resistance. The envelope is responsible for the building energy performance [10].

This is illustrated in Henning Larsen's University Building in Kolding, Denmark that moves in response to changing heat and light "Fig. 6". The daylight changes and varies during the course of the day and year. Thus, Kolding Campus is fitted with dynamic solar shading, which adjusts to the specific climate conditions and user patterns and provides optimal daylight and a comfortable indoor climate spaces along the façade. The solar shading systems consist of approximately 1,600 triangular shutters of perforated steel. They are mounted on the façade in a way which allows them to adjust to the changing daylight and the desired inflow of light. When the shutters are closed, they lie flat along the façade, while they produce from the façade when half-open of entirely open and provide the building with a very expressive appearance. The solar shading system is fitted with sensors which continuously measure light and heat levels and regulate the shutters mechanically by means of a small motor [11].

Fig .6. The dynamic patterns in the façade of Henning Larsen's University Building

D. Wind Responsive Dynamic Façade

Wind as a natural element itself is strong enough to provide a dynamic pattern of motion without wasting any energy. Brisbine domestic Terminal Carpark in Australia (2011) has installed 250,000 aluminum plates to create this wind-powered façade. The car park's entire eastern side appeared to ripple fluidity as the wind activates 250,000 suspended aluminum panels. As it responds to the ever-changing patterns of the wind, the façade created a direct interface between the built and the natural environments. The façade itself constantly stays in moving motion as the wind blows.

E. Façades Designed to Manage Water

A fundamental role for high-performance buildings is the management of water. It is imperative that roofs and facades effectively manage rainfall through material selection and articulated detailing from top to bottom. Rainscreens are innovative solution to manage rain and vapor migration. As buildings embrace a greater set of sustainability challenges, they also need to collect rainwater. There is a decline in sources of fresh water and increase of storm runoff challenges. The importance of designing building to catch and store water is of growing importance.

VIII. APPLICATIONS ON DYNAMIC FACADES

A. Masdar Institute for Science and Technology (Abu Dahabi, United Arab Emirates)

Masdar Institute for Science and Technology (2007-2010) is located in Masdar City under the supervision of Masdar Initiative. It is designed by Foster + Partners "Fig. 7". Abu Dhabi's climate is considered to be subtropical climate, with temperatures that very from warm in winter months to hot in summer with sunny blue skies prevail throughout the year and rainfall is infrequent which affect the building architecture design to fulfill the environmental and climatic conditions.

Fig .7. Masdar Institute for Science and Technology (Abu Dhabi-U.A.E)

- Sun control

Windows that are not already shaded by adjacent buildings have louvers vertical to block morning and afternoon and horizontal to block mid-day sun-set to prevent direct sunlight from shining into the building.

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- Natural ventilation

There is a contemporary re-interpretation of the traditional Arabic wind tower which brings cooling breezes to the courtyard. Rising 45 meters above the podium, this modern interpretation will be a landmark for Masdar city. Sensors at the top of the steel structure operate high level louvers to open in the direction of the prevailing winds and to close in other directions to divert wind down the tower. A PTFE (non-stick brand Teflon) membrane carry the wind downward while mist generators at the top add additional cooling to the air. Combinations of evaporative cooling and air movement techniques help to moderate perceived air temperatures, thereby improving users' comfort.

- Moisture control

Behind the foil is a highly insulating and highlysealed panel. Aside from the rest of the façade, are highly sealed, insulated and wrapped 90% windows, recycled aluminum sheeting and rose-red color.

- Material

Facades at Masdar city incorporate a variety of technologies and materials to address sustainable building. Laboratory buildings are characterized by air-filled ETFE cushions (30 cm thick) that ensure almost no solar gain on the structure and limit the heat re-radiated to the street. A reflective foil-clad inner layer behind the cushions send light to the pedestrian street below.

- Energy generation

There are over 5,000 square meter roof dynamic photovoltaic panels which provide power and further protection from the direct sun. The photovoltaic array above the building helps to provide 30% of the electrical load of the city [12].

B. Pearl River Tower (Guangzhou, China)

Pearl River Tower is located in Guangzhou, China. It was constructed under the supervision of CNTC Guangzhou Tobacco Company. It was designed and constructed by Skidmore Owings & Merill with partner Adrian Smith and Gordon Gill during the period 2006 – 2010 and it had been awarded in 2008 for Green, Carbon Lowering and Environmental Category: Gold Award "Fig. 8".Guangzhou is in south eastern China which is characterized by its hot humid, heavy rain climate with predictable prevailing north, south and south west winds. Summer season is long, wet, hot and humid, where winter is mild, dry and free of snow with average mean temperature. These climatic conditions played an immense role in terms of different design and sustainability integrated either on the building scale or façade scale.

Fig .7. The dynamic façade of Pearl River Tower (China)

- Sun control

Pearl River Tower integrates various technologies in building skin design as follows:
Double glazed wall system:
The north and south façade are double layer curtain wall system which offers insulation that reduces heat gain and leads to less demand on HVAC systems.

Exterior glazing material:
Exterior glazing is insulated, tempered glass with low-coating. The inner layer is operable clear glass on the building south face where low-emittance glass is coated with microscopically thin, virtually invisible metal layer that reduces thermal conductivity.
Triple glazed façade:

East and west facades are associated with external shades and automated blinds within the facades cavity. A photovoltaic system is integrated into the building's external shading system and glass outer skin.

- Ventilation

The most innovative of Pearl River's element are the vertical axis integrated wind turbines that are used for catching the prevailing winds from the south and the notrth with minimum loss.

- Shading

As all the facades of Pearl River Tower are double glazed facades, then shading blinds are placed within their cavities where motorized venetian blinds is in the east and west double façade. The blind position is determined by a photocell that tracks the sun position to ensure occupancy comfort from both solar gains and glare.

- Energy generation

There are photovoltaic panels which are integrated into the facades to transform the sun's energy to usable AC current where the use of PV cells could be productive if it is used on certain portions on the building envelope.

Also, Pearl River Tower is planned to utilize hydrogen fuel cells in the building façade to store excess generated energy and convert gas into electricity with more than 50% energy efficiency which could be used as power energy for cooling and ventilation [10].

Table 1. Comparison between the parameters of the two applications

Parameter	Applications	
	MIST (Masdar City, U.A.E.)	Pearl River Tower (Guangzhou, China
1. Sun control	Vertical louvers to prevent direct sunlight	Facades are associated with external shades and interior automated blinds
2. Natural ventilation	Re-interpreation of the traditional Arabic wind tower	Consists of a double glazed façade with integral spandrel panels and cavity space for air cooling
3. Daylighting	N/A	Integrated glass façade to provide visual transmissions, enhancing daylight and reduce artificial lighting
4. Connection to outdoors	N/A	N/A
5. Thermal insulation	N/A	N/A
6. Moisture control	High insulated panels	N/A
7. Structural efficiency	N/A	N/A
8. Material choices	air-filled ETFE cushions with reflective fiol cladding	N/A
9. Energy genration	Energy is 60% less using photvoltaic panels	Energy is 44% less using photvoltaic cells and hydrogen fuel cells

IX. TRANSFORMING TRADITIONAL FACADES INTO DYNAMIC FACADES IN EGYPT

So, the question now, after studying the parameters of dynamic facades, could these facades be applied in buildings in the Egyptian context?

The answer is yes, however there are some criteria concerning the climate of the region, the materials used and the availability of technologies. Also, design of facades should take the surrounding environment of the country, the sun path, wind and humidity and the use of energy consumed in consideration.

This can be achieved through the delicate traditional mashrabiya which has offered effective protection against intense sunlight in Egypt for several centuries. However, nowadays this traditional Islamic window element, with its characteristic lattice-work, is used to cover entire buildings as an oriental ornament providing local identity and a sun-shading device for cooling.

In fact, designers have transformed this vernacular wooden structure into high-tech responsive daylight system according to the external conditions.

The ancient mashrabiya merges cultural, visual and technical aspects. Therefore, this window screen is often found towards the street to enable discretion and allow cool air to pass through the façade. Several newer buildings in Egypt have transformed the oriental window technique into dynamic facades to reduce the cooling loads for the interior.

Also, the malqaf is another façade element which could be used in a dynamic way. It is a suitable source for natural ventilation in buildings especially in hot arid regions. It is a device or a shaft rising high above the building where it is cooler and stronger and the wind channels down into the interior of the building.

The malqaf could be adapted to move dynamically according to the direction of the prevailing winds of the city/country which creates air movement and consequently natural ventilation . The following table (Table 2) proposes some ways for improving the façade systems in Egypt. These recommended ways could increase comfort and reduce energy consumption and improve daylighting inside buildings.

Table 1. Recommended ways for improving façade systems in Egypt

Design	Materials	Systems	Performance
- Automation - Daylighting - Design for adaptability - Design for intelligence - Design tools - Modular coordination - Natural ventilation	- Advanced materials - Advanced insulation - Air/Vapor barriers - Intelligent materials - Resource-efficient materials	- Advanced foundations - Double enevelope - Intelligent envelope sysstems - energy services - rainscreen	- Modeling - Monitoring - Testing - Rating criteria

X. CONCLUSION

The paper has situated the main objectives for an efficient sustainable building façade taking into account the environmental sustainability aspect, where it has introduced the main parameters for developing building façade concept. Also, it has focused on the different façade techniques in terms of natural ventilation, shading techniques and energy conservation and its role in enhancing the internal environment.

According to the applications and examples reported in this paper, building facades play an immense role in building energy efficiency and building energy performance where:

- Dynamic facades are more widely used to permit natural light, it is considered also an efficient innovative ventilation system if properly designed.
- The most advantageous shading schemes have proved to be external shading device and movable overhangs installed on building façade, considering also other benefits of external shading as it could be suggested as a very effective design solution against overheating.
- The most effective shading system is the adjustable exterior shading louvers, where it is considered to be the most effective shading devices as it has a variety of colors and materials.

XI. RECOMMNEDATIONS

In this section, some recommendations about the appliance of sustainable building façades technologies in Egypt will be presented taking into account the environmental, economic and climatic conditions. Egypt lies within the North African desert, this geographical location gives the Egyptian climate some characteristics which affect the design of nay building especially the facades. The Egyptian climate is arid and characterized by hot dry summers, moderate winters and very little rain fall which will encourage designers to design dynamic facades which will be able to provide natural ventilation, shading and reduce energy consumption. There are some recommendations for architects and governments in order to enhance the application of sustainable dynamic facades strategies.

A. *Responsibilites for Architects:*

Designers should consider important issues for efficient dynamic facades. These issues affect the technologies applied into building façade taking into account its costs and how appropriate it is for building requirements and thus, energy saving. So designers should:

- Properly select site for the building, as the design features change with site climatic characteristics.
- Properly decide the best façade technology that serves the target of the building.
- Choose appropriate ventilation strategies that are suitable for the building usage.
- Architects must carefully study the complex issue of material and energy exchange, moreover they must know how to apply the information just thus gained to planning and construction and consult specialized engineers.
- Be updated to all computer modeling that can lead the designer to exact performance of the chosen perfect façade strategies.

B. *Responsibilites for Governments:*

Governments own and maintain a wide range of buildings and facilities where there are a variety of tools that could help the government develop and operate building resources for applying efficient passive cooling strategies in a sustainable manner:

- It could create community boards and commissions to study local sustainable issues and provide economic motivation for sustainable design building development.
- It should permit training and education programs that focus attention on building sustainable development.
- New government buildings should in corporate and promote energy efficient facades that harmonize with the Egyptian climate.

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Low-Carbon Communities between Vision and Implementation The Case of Borg Al Arab

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***Abstract* -** Several cities are facing the problem of running-out of fossil fuels and are contributed to an estimated 70% of the world's energy-related greenhouse gases (GHGs). Consequently, there is a tremendous need for low-carbon communities which will lead to more livable, efficient and ultimately sustainable cities. Furthermore, well-planned and designed communities can effectively provide the basic human needs and reduce reliance on fossil fuels. Some communities have developed strategies to reach net zero-carbon future by reducing demands for energy and supplying the remaining demands with renewable resources.

In the meantime, Egyptian cities face the problem of greenhouse gases and the lack of energy and water. Therefore, passive, energy efficient and energy offset design are needed. This can be achieved through sustainable transportation systems and the shift to efficient management of water and waste.

The paper discusses the problem of climate change and its relation with communities. It investigates examples of communities that have focused on reducing their carbon emissions in different parts of the world. Also, it examines some of the most important aspects of design strategies that help to implement low-carbon communities and how could they be achieved in the Egyptian context (Borg Al Arab-Alexandria).

The aim of the paper is to highlight certain cities that demonstrate a deeper understanding of what a low-carbon community is and how to achieve it through reducing energy demand and providing the best options for passive design and renewable energy supply in the Egyptian communities to become self-contained in terms of energy.

***Keywords* -** energy-efficient; grenhouse gases; low-carbon communties; renwable energy sustaianbilty

I. INTRODUCTION

The tremendous increase in energy use in Egypt has caused many environmental problems and lack of resources. These problems can be solved through planning low-carbon communities in the urban extensions of cities. Presented here is a methodology for generating appropriate energy design guidelines for these new communities through analyzing different examples that have adopted these strategies in their urban planning to achieve low-carbon goals. The study starts by discussing the problem of climate change in cities and the need for low-carbon communities. Also, it presents the history and evolution of low-carbon communities and their different concepts. Then, the study tackles different low-carbon urban strategies through passive, energy efficient and offset design. A future model for Borg Al Arab (Alexandria) is proposed through the main guidelines for planning of low-carbon communities. Finally, the paper ends up with a SWOT analysis for the design of low-carbon communities to compare points of strengths and weaknesses of low-carbon concept. The paper proposes different low-carbon strategies and aspects to be applied in the Egyptian context and across the developing world.

II. CITIES AND CLIMATE CHANGE

Cities and climate change have a dual relationship. Cities, as major emitters of greenhouse gases, contribute to climate change. The changing climate would cause severe impacts on cities, as they have the increasing majority of the population and productive assets. Nevertheless, globally, city planners are now increasingly paying attention to climate change for three key reasons. First, the participation of cities is vital in achieving national environment and development goals. Second, since cities hold most of the financial, institutional and intellectual capitals, their attractive participation is essential in formulating and implementing national climate change mitigation and adaptation policies. Finally, cities are sizable co-benefits of climate change, such as improvements in air quality, traffic congestion and reduction of heat island effects, which would accrue by aligning climate change and development policies [1].

Thus, the activities of urban settlements are key contributors to climate change factors. Climate change is characterized by the irreversible build-up of greenhouse gases (GHGs) and global warming at a potentially huge cost to the economy and the society worldwide. Much of the greenhouse gases in the atmosphere are driven by human activity which is already affecting the global climate. Emissions of carbon dioxide (the principle greenhouse gas) have risen more than ten-fold since the start of the industrial revolution. Also, the atmospheric concentrations of carbon dioxide have risen more than 30% and are projected to reach twice the pre-industrial level by the middle of this century [2].

World GHG emissions have roughly doubled since the 1970s and on current policies could rise by over 70% during 2008-2050. Historically, energy-related GHG emissions were predominantly from richer developed countries. However, today two-thirds of the flow of new emissions into the atmosphere is accounted for the developing countries [3].

At present, growth rates of developing countries' emissions are expected to surpass those of developed countries within a matter of decades due to the rise of populations, low income levels and the extreme of energy use. In the meantime, it is estimated that the costs of inaction on climate change will be large particularly in many developing countries such as the rise of sea levels, the intense of heat waves and the decline of agricultural yields in rural areas. Even more, each degree in global warming increases irreversible damage worldwide [2].

To address the threat of climate change, GHG emissions are to be solved, stopped and reversed. Meeting the challenge will require dramatic advances in technologies and a shift in how the world economy generates and uses energy [4].

Thus, all instruments are being mobilized to reduce net emissions to zero and to adopt the existing emissions according to a climate change policy. It is required to change the way in which the buildings are spatially configured and served and the way in which communities are planned to reach low-carbon communities that would contribute to climate change protection.

III. THE EVOLUTION OF LOW-CARBON COMMUNITIES

The planning and design of traditional settlements saves much energy through the pattern and structure of buildings which aimed to minimize the use of energy consumed in travelling between essential activities and also in the operation of buildings. It also assumes high degrees of self-sufficiency at levels of settlement structure. There are common structural and physical features in the layout in most of the desert cities. The complicated and interrelated factors that have shaped historic architecture and urban form in desert regions are mostly affected by climatic characteristics.

The urban form of traditional Arab cities is highly centralized or inward looking "Figs.1 and 2". Certainly, the orientation and relation to the environment have been of high importance in the planning of city. The particular climatic problems caused the people of the hot arid zone to find solutions to their settlements' architecture. The high radiation and temperature in the summer, diurnal variations of temperature, seasonal variations from dry hot summer to cold dry winter, low humidity, limited water supplies and the dusty winds are the most important factors in forming the urban structure of such settlements [5].

Fig .1. The concentrated urban form of old cities

Fig .2. Compact buildings in Old Algeria

The arrangement of buildings appears to be compact in layout. This is ecologically held up as a model for city planning to minimize the heat flow into the buildings, thus applying human comfort. It is also characterized by uniformity in urbanization. These settlements promote walking and cycling as the main modes of movement. The main objective of a traditional city planning is to establish the optimum orientation of buildings with regard to the sun and the prevailing winds.

The layout of almost all traditional cities in hot arid regions is characterized by some features such as narrow widening streets, large open courtyards and internal gardens. This design reduces the cooling load transmitted through the building shell and makes natural ventilation more desirable and effective. Based on these examples, Hassan Fathy introduced the traditional planning of cities “Fig.3”. He employed narrow streets and introverted houses with inner courtyards in his design of the village of New Bariz [6].

Fig. 3. New Bariz village by Hassan Fathy

IV. CONCEPT OF LOW-CARBON COMMUNITIES

Low-carbon communities are more realistic and could address the emergence of urban scale that would generate renewable energy systems. A low-carbon community is “one that has greatly reduced energy needs through efficiency gains such that the balance of energy for vehicles, thermal and electrical energy within the community is met by renewable energy” [7]. This means that, it minimizes the energy demand within the boundaries through promoting energy efficiency and balancing the energy consumption and the facilitation of renewable energy.

The energy performance of a low-carbon community or a net-zero community can be accounted for in several ways. The definitions listed below are based on those by Torcellini (2006):

A. Net-Zero Site Energy

A net zero site energy produces at least as much renewable energy as it uses over the course of a year when accounted for at the site. The net zero site energy concept measures the building’s site, ignoring whether the utility source is coal or wind.

B. Net-Zero Source Energy

A net source zero energy building (ZEB) produces at least as much renewable energy as it uses over the course of a year when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site.

C. Net-Zero Energy Costs

In a cost ZEB, the amount of money the utility pays the building owners and the community (for renewable energy generated on all residential and community buildings and infrastructure) for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year. If transportation is included, the cost of the fossil-based fuels is offset by fuel generated from renewable resources.

D. Net-Zero Energy Emissions

A net-zero emissions community produces and uses at least as much emissions-free renewable energy as it uses from emissions-producing energy sources annually.

A community may be designed to achieve one or more of the above definitions but may not achieve it in actual operations every year. If the community produces at least 75% of its required energy through the use of on-site renewable energy, it is considered a near-zero or low-carbon community [7].

V. LOW-CARBON COMMUNITIES DESIGN STRATEGIES

Low-energy design has probably the greatest direct impact on the nature of cities and communities' life. However, urban design and fundamental principles of how to shape the communities have so far barely featured in the greenhouse debate. The movement towards low-energy design in urban planning may result from the influence of a variety of inter-connected factors including the design and technological advancements, ethical considerations, economic costs and opportunities, risk management and marketability. The challenge is to design a community where people live, while also have the flexibility to evolve and work well environmentally, socially and economically, both now and for the future [8].

It is necessary for architects and design professionals to understand low-energy drivers and to consider them at the beginning of the design stages and to continue throughout the construction phase (Table 1). This section provides an overview of low-carbon deign strategies and guidelines which discuss various aspects and scales of interventions for energy efficient urban planning structured according to the following categories:

Table 1. Low-carbon communities' design strategies

Design at Building Level	Design at Urban Level	
Passive Design	Energy Efficient Design	Offset Design
- Building massing - Building type - Architural elements - Sustaianble building materials	- Green and pedestrian spaces - Mobility and Accessability (sustainable transport) Sustainable food	- Energy Management technologies - Water management - Waste management

A. Passive Design

- Building massing

The configuration of building mass is related to specific climate type and the influence indoor and outdoor comfort. Certain building typologies increase shading and ventilation, which can reduce the cooling load. The recommended elements of the urban form in hot-dry climates are low-rise, high-density and narrow streets to achieve optimal energy efficiency where buildings can provide shade on each other, and thus lower cooling loads. The shading of streets is maximized, to create a more comfortable micro-climate for pedestrians. [9].

This climate-sensitive urban form is seen in Hashtgerd New Town (Iran) which is based on passive design "Fig.4". It bears considerable mitigation and adaptation potentials by reducing energy consumption especially for cooling and heating without losing thermal comfort. The 35 hectares area exploits this potential by referring to the traditional Iranian city whose characteristics are translated into a dense and compact urban form with a clear hierarchy of public, semi-private and private spaces and access systems in a low-rise-high density design. The proposed twenty-nine compact neighborhood clusters are organized in four rows, stretching from north to south and are located on the ridges of the hills on the site allowing the main and hot winds from west and northwest to channel through the site "Fig.4 and 5". Every cluster (approximately 15x30m) and four building groups are arranged around it.

The clusters are accessible by foot and bike via a narrow 6m wide path in the north-south direction. All clusters are connected through these paths which allow for a compact urban fabric and a reduction for traffic areas. The organization of each housing group supports the compact form since it is considered as a major need for achieving this low-carbon city. This compactness contributes to the reduction of direct solar radiation and thermal loss. The orientation of buildings in Hashtgerd is another major aspect for energy efficiency. The predominant north-south orientation of the buildings reduces the cooling demand by up to 23% and the heating demand by up to 16%. Also, the low skyline follows the topography of the site allows for free movement of air above the city [10].

Fig .4. Hashtgerd New Town (Iran)

Fig .5. The dense and compact urban form of the 35ha area

- Building type

Building typology, form and design can cater to various aspects of passive cooling for a comfortable indoor climate and reduce the cooling loads of buildings. Passive design strategies (for sun and wind), guide urban fabric development for low-carbon communities at the building level and improve the micro-climate through reduced solar gain. On one hand, the architectural concept is addressed through optimal use or protection from the solar radiation, for both building and outdoor space. Building envelopes should be oriented along the east-west axis. The south facing facades are designed to have small openings and horizontal shading. On the other hand, buildings are oriented in such a way that the prevailing winds can be used for most optimal natural ventilation [9].

- Building architectural elements

Building envelope designs are created through the optimization of window-wall ratios, allowing sufficient daylight, while minimizing the openings that provide heat gain. Window shading concepts are used in order to match the climatic conditions, maximize natural light and ventilation. Green roofs are to be promoted, as they improve the shading and thermal capacity of the building envelope and reduce the solar heat gain [9].

- Sustainable building materials

The design process offers greater opportunities for reducing environmental impacts through material selection. One of the primary concerns in selecting building materials is to avoid negative impacts on health and provide safety and comfort for building users. Also, identification of materials and products that contribute to energy efficiency is one of the primary selection criteria [11]. Natural building materials such as stone, brick and wood require minimal processing and energy inputs. They are characterized by their durability, adaptability and low construction impact. Also, the use of local and regional materials enables energy savings in transport and compatibility with local building traditions which support the local economy [12].

B. Energy Efficient Design:

Energy efficient urban design may require the use of new designs and technologies.

- Green and pedestrian spaces

Communities are principally made up of buildings and infrastructure. However, they contain a significant proportion of open spaces. On one hand, green open spaces such as parks, protected green spaces, gardens, street trees and landscaping provide a high quality of life and a number of vital ecosystem services, acting as “green lungs” which absorb and filter air pollution. They also provide a habitat for wildlife and offer recreational benefits for the community residents [13].

Also, to support the short distances and mix of uses, pedestrian networks need comfortable micro-climatic conditions in order to access services and amenities easily without depending on private automobiles. A comfortable outdoor pedestrian space is created through the use of porous, light colored-materials for outdoor public spaces and surfaces. It leads to the reduction of urban heat island effect and thereby lowering the outdoor ambient temperature and the reduction of cooling loads of adjacent buildings. Native vegetation uses less water and provides dust protection which enhances natural ventilation for public outdoors and buildings and reduces the reflective humidity supporting a more comfortable outdoor space [9].

This strategy is applied in Xeritown (Dubai-U.A.E.), where there is a boulevard which ties together the urban public elements of cafes, restaurants, lobbies and retail shops. They are all shaded by deep arcades on one side of the promenade and landscape on the other. The most public part of the development is framed by the urban sun shading (an ornamental roof structure composed of photovoltaic panels providing low-voltage direct current electricity) which turns the promenade into a place for strolling, sitting and watching or waiting for the bus “Figs.6 and 7”. The landscape can be explored by walking or via jogging or cycling track which runs through it. Xeritown thus, encourages a public life outdoors at least in winter months [14].

Fig .6. Sun shading with photovoltaic panels in the streets of Xeritown

Fig .7. Public outdoor spaces in Xeritown

- Mobility and accessibility (sustainable transport)

Current transport patterns are based primarily on motorized vehicles which generate many social and environmental problems and economic costs. They represent a significant source of greenhouse gas emissions and can affect the community and urban planning in a direct way. These unsustainable patterns of transport are expected to worsen under the conditions of rapid trend of motorization [15]. The approach of low-carbon transportation reduces greenhouse gas emissions and can be maintained through the high shares of low-carbon modes of transport and at the same time shifting to environmentally-friendly technologies and enabling a less car dependent mobility [16].

In order to ensure efficient ways of transporting people and goods, new communities need to be planned including easy access to various types of mobility such as bicycles, bus (light rail), shared taxi or car pooling within short distances. Within the community site itself, cycling can be encouraged by providing accessible, secure and covered bicycle storage [8].

Also, low-carbon communities need to be designed to use sustainable transport by offering walkable transit oriented options, often supplemented by vehicles powered by renewable energy “Fig.8 and 9”. Communities with sustainable transport systems are able to reduce their ecological footprints from their reduced use of fossil fuels as well as their reduced dependence upon car-based infrastructure [17].

Fig .8. Electric powered vehicle

Fig .9. The vehicular streets in Xeritown are limited to two lanes

This strategy is achieved in Xeritown (Dubai, U.A.E.) where it is considered mainly as a pedestrian neighborhood.

The design of Xeritown reduces pollution, encourages pedestrian movements and represents a compromise solution with vehicular streets limited to two lanes. Consequently, this arrangement discourages driving, encourages public transportation and reduces private vehicular transportation to a minimum. The city’s extensive shaded and well-ventilated pedestrian and cycling networks, together with the proposed public transport network, all work together to reduce the carbon emissions emitted by the city's transportation systems.

- Sustainable local food

Food has significant impacts on the green credentials, especially if one takes into account the energy use generated by transporting food from remote locations to urban places. Reducing the environmental problems associated with food consumption involves changing the current food culture. Locally produced food reduce carbon dioxide emissions from present approximately one-tenth of the energy consumption of conventional housing. Energy systems include heat pumps, a heat recovery system, solar hot water collectors and photovoltaics. Each house has its own photovoltaic system to generate electricity "Figs.10 and 11". Based on the size and needs of the housing unit, the photovoltiac systems have outputs that vary from 3.0 to 12.0 KW [19].

Fig .10. Solarsiedlung am Schlierberg complex (Germany)

Fig .11. Each house has its own photovoltaic system to generate electricity

- Water management

In many areas of the world, especially in hot arid urban regions, demand for water exceeds supply and is seriously straining available water resources. Excessive water usage can degrade local water resources, threatening the availability of water for local future needs [11].

Water management is considered as one of the main elements to achieve low-carbon communities. This can be achieved through a number of conservation measures which can be used in communities. Also, water reduction measures can conserve and protect local water resources upon which the local community depend. In the meantime, preserving the quality of local water resources can eliminate the need for costly drinking water treatment processes. Reduction of water use requires the implementation of strategies at both the building and site scale. The consumption of primary water can be reduced to less than half the current use through applying water efficiency strategies such as low-flush fixtures, automatic controls and water-saving devices for kitchens and bathrooms, as they reduce the flow of water by 50% without affecting the comfort level of the user.
Also, it is important to use the roofs of buildings to collect rainwater instead of allowing all water landing on the building's roof to run into stormwater drains. Water is captured, stored and prepared for future uses. Designing the roofs and angling them properly can result in a maximum intake of rainwater [12]. Furthermore, water reuse and recycling technologies can be economical and efficient to reduce a building's overall water consumption by directing appropriate wastewater to other uses such as irrigation [18].

This wastewater concept is introduced in Hammarby Sojostad (Stockholm) which initiated the first step to water supply in a sustainable approach. The reduction of water is achieved by installing low-flush toilets and fixtures in all housing units. Hammarby Sojostad's wastewater (sewage) is treated at Stockholm's Henriksdal's plant. A new experimental treatment plant is testing innovative alternative system for stormwater that it would be treated as a landscape feature. Stormwater from buildings and courtyards is detained in a stormwater bio-swale canal and in paved gutters before being released into Lake Hammarby. The goal for street-water runoff is that it would be collected on-site in setting tanks and filtered. In this way, all rainwater and snowmelt from streets is drained into holding basins and then into settling tanks [20] "Figs.12".

Fig .12. Storm water retention in Hammarby Sojostad (Stockholm)

Fig .13. Detail of the south-facing photovoltaic array

- Waste management

Buildings produce large quantities of waste (solid and liquid). In many cases, this waste is collected in badly designed damps, discarded directly in rivers or simply damped in areas out of site [10]. However, low-carbon communities have demonstrated considerable resilience in finding green solutions that reduce the overall waste, increase recycling and finding new forms of environmentally friendly treatment of unavoidable waste [13].

Waste management begins by reviewing the types and quantities of waste produced and the current disposal methods and costs [21]. Waste reduction means minimizing the quantity of waste that is going to disposal. Also, reuse and recycling are necessary to prerequisite the provision of easily accessible and well served areas for separate collection of glass, paper, plastics and metal with local recycling possibilities [12].

Also, composting solid waste technology generates a small amount of energy from a given quantity of waste and it requires a large amount of waste to become viable. Advanced thermal treatments turn waste into energy rich fuels through heating the waste under controlled conditions. Such approaches to generate energy from waste require new technologies and management systems that integrate public health and environmental engineering with ecological planning [21].

In Hammarby Sojostad (Stockholm), waste is recycled into natural gas which is used as an energy source for the neighborhood. Heat produced through the purification process is recycled for use at a district heating unit. Also, Hammarby Sojostad has its own pilot sewage treatment center where nutrients are recycled from sewage for use on agricultural land. Any combustible waste produced is recycled into heat energy for use in the apartments. Each apartment block has recycling facilities and biodegradable waste is composted nearby.

Eliminating the concept of waste is the most comprehensive approach to waste removal, however, reducing the initial flow of waste is an important step. Hammarby Sojostad sets the goal of reducing solid wastes by 15% and, further, has taken the most the remaining flows [20].

VI. LOW-CARBON COMMUNITIES IN EGYPT (A FUTURE MODEL IN BORG AL ARAB ALEXANDRIA)

The governorate of Alexandria consists of three individual cities which are Alexandria, Borg Al Arab city center and New Borg Al Arab. Borg Al Arab is located about 45 km south-west Alexandria city center and seven kilometers from the Mediterranean coast. North of Borg Al Arab city is King Mariout and Mariout Lake. It is surrounded on all sides by a green belt with a surface area of 18,000 feddans. The city has an airport that serves nearly 250,000 passengers every year and also has the biggest stadium in Egypt. Borg Al Arab is seen as the natural extension for Alexandria city yet suffers a continuous environmental abuse from man-made viloations. It has been subjected to unplanned urbanization as well as discharge of heavy industrial pollutants. Thus, the city of Borg Al Arab faces several problems which can be summarized as follows:

- Urban structure:

Deteriorated conditions of services and the inability and imbalanced urban growth (industry vs. housing).

- Residential housing:

Low settlement rate due to the lack of housing for factory workers and hierarchy of centers.

- Industrial factories:

They are causing air and noise pollution due to heavy traffic of transporting factory material at the entrance of the city and industrial zones.

- Transportation:

Lack of public transport and mass transit modes that connect Borg Al Arab with Alexandria city center.

- Traffic:

High traffic volume at northen and southern city centers.

- Utilities and infrastructure:

High voltage power lines inside the city and low water pressure in some districts.

- Environment:

Common drainage network is used for both industrial and domestic wastewater, lack of industrial solid waste collection and disposal systems, lack of building and agricultural solid waste collection systems.

- The governance system:

There is no single authority managing the city and the residents of the area do not participate in the decision of uses in the area [22].

VII. GUIDELINE FOR TRANSFORMING BORGAL ARAB TO A LOW-CARBON CMMUNITIY

The development plan for Borg El Arab aims at optimizing the utilization of natural resources without causing any ecological disequilibrium in this vital and important zone of the city of Alexandria. Also, it aims to improve and transform the current city and change it to a low-carbon community. This will ensure equal opportunities for generations to come. Within the next ten years, Borg Al Arab would be an investment magnet, a job creator, a visitors' attraction spot within the city of Alexandria. The broad aim is to create a socio-economic, environmental, urban and infrastructure foundation that would initiate a successful low-carbon development.

Borg Al Arab is found to have great potentials to be transformed to a low-carbon community and thus helps in the reduction of carbon emissions and the negative effects in the area. After analyzing the previous examples of zero-energy communities and explaining their strategies and guidelines that can be applied to reach a low-carbon community, it is found that Borg Al Arab should undergo some changes in order to be transformed.

The proposed transformation guidelines are divided into immediate, medium and long-term action plans. The sustainable, low-carbon vision of Borg El Arab can be displayed in a set of objectives as follows:

A. Passive Design:

- Building massing

The most cost-effective step towards a reduction in a building's energy consumption is the form of buildings. Thus, it is proposed to create low-rise, high-density buildings with a proper network of narrow streets in between to achieve optimal energy efficiency and solve the problem of urban structure.

- Building types, features and materials

It is important that buildings should be oriented north-south to get the optimal benefit from the prevailing winds and achieve natural ventilation. Buildings should be constructed from local building materials found in the surrounding context. These materials should be of a high quality, durable and flexible. This will lead to find a solution for the residential housing problem [22].

B. Energy-Efficient Design:

- Green and pedestrian spaces

It is important to enhance the area of Borg Al Arab with attractive uses, high quality public spaces. Parks and open spaces are necessary to a vital urban extension like Borg Al Arab. Moreover, it is proposed to extend high quality public facilities by linked green areas which provide a central focus for Borg Al Arab.

- Mobility and accessibility (sustainable transport)

It is encouraged to use clean and economic forms of transportation such as bicycles and public transit, ……etc. The city should be easily accessed due to its regional location which enhances its competiveness and makes it easy to access Borg Al Arab via the airport and the Alexandria marine port. Also, the area is connected to the international and coastal roads. It is recommended to enhance the existing network of transport by increasing the capacity and quality and redistribute the nodes geographically in the area as well as developing new connections to Borg Al Arab.

- Sustainable local food

It is proposed to implement and create vast areas suitable for agriculture to be able to grow local food which provides the residents with healthy and fresh resources. Also, it will help to reduce carbon dioxide emissions from transport and it will help strengthen the local agriculture economy. Also, it is proposed to create small gardens or exploit roof tops for growing food.

C. Energy Offset Design:

- Energy Management technologies

It is proposed to use renewable energy solutions through future plans for establishing solar-operated electric plants to generate the electricity needed in the area. This can be achieved through creating a field of photovoltaic cells (PVs) which can be placed in a land near Borg Al Arab. Also, it is proposed to create large wind turbine farms to supply the area with the energy needed. In this way, the problem of energy will be solved substantially.

- Water management:

People should learn how to use water and this might need to increase the awareness for water preservation. It is proposed to reduce the environmental degradation of water, increase the capacity and quality of existing sewerage and water systems and enhance wastewater treatment. Also, it is proposed to serve all residential areas with potable water and to incorporate smart water appliances in the buildings. Furthermore, it is encouraged to use treated recycled water in irrigation and other non-potable services.

- Waste management:

There is a real need for industrial and agriculture solid-waste collection and creating disposal systems. It is proposed to sort and separate wastes at source into four individual basins, each one is used for a specific material, for example, one basin for plastics, metal, glass and paper. Trained workers should collect the wastes and recycle them to be used again in the area.

Thus, Alexandria's environmental and comprehensive development strategy plan aims at solving the problems found in Borg Al Arab and at improving the quality of life and citizens' comfort. Also, it puts into act projects that would ensure the city's sustainable development based on low-carbon design tools .

VIII. LOW-CARBON COMMUNTIES BWTWEEN VISION AND IMPLEMENTATION

In order to keep the communities alert to staying green and sustainable and achieving the low-carbon applications in Borg Al Arab, it is important to learn how to be sustainable and have the knowledge needed for that to maintain the qualities given by that way of life. In the meantime, it is important to make SWOT analysis (Table 2) for the points of strengths, opportunities, points of weakness and threats for the design and planning of low-carbon communities to know if it can be implemented and achieved or not.

Table 1. SWOT analysis for low carbon communities

POSITIVE FACTORS	**Strengths**	**Weaknesses**	NEGTIVE FACTORS
	1. Reducing carbon footprint and minimizing emissions of greenhouses gases (GHGs)	1. Requiring certain restrictions and qualifications	
	2. Minimizing energy consumption	2. High costs of technologies	
	3. Energy conservation strategies	3. Difficulty in changing people's behavior	
	4. The use of energy-efficient technologies	4. Require large site areas	
	5. Making people aware of the carbon impact	5. Difficulty of governmental regulations	
	Opportunities	Threats	
	1. Self-sustaining in terms of energy needs	1. Funding low-carbon designs require massive amounts of energy, water and land.	
	2. Encouraging passive, energy efficient and offset design and planning strategies	2. Funding low-carbon projects comes from unsustainable means	
	3. Economic advantages		

IX. CONCLUSION

The paper shed light on an important community in the city of Alexandria (Borg Al Arab) which is rich because of its location and potentials. A land use strategic vision has been proposed providing a way forward to a sustainable low-carbon community which achieves low-energy goals preserving the natural, socio-cultural and economical dimensions of sustainability.

This system of criteria and indicators for a low-carbon community is meant to function as an aspiration for decision-makers, organizations, planners and interested citizens. It has to be underlined that a part of the process towards low-carbon developments and the use of criteria and strategies are crucial because it is all about quality of life and concrete impact and lasting solutions. Low-carbon urban strategies serve as guidance for all actions, small and big, individual and collective. Therefore, it is necessary to define strategies and guidelines for each community development “Fig.13”.

X. GENERAL FINDINGS AND OUTCOMES

Leading a community towards low carbon strategies is ambitious and necessary. Fortunately, many cities have begun this innovative kind of future-oriented process. Based on the experience of low-carbon developments in many Arab and European countries, it is of the utmost importance to improve, innovate and modernize policy and management activities towards low-carbon design. Therefore, in case of Egypt (Borg El Arab-Alexandria), it is important to achieve this type of communities to reduce energy demands and provide the best options for passive design, energy-efficient and offset deign through the use of renewable energy supply to be self-contained in terms of energy and decrease the effect of climate change and global warming. The achievement of a low-carbon community in Borg Al Arab will be able to substantially improve energy efficiency, conserve non-renewable energy, with various economic advantages. Also, the first and crucial step towards low-carbon is to promote passive design techniques as much as possible, not only for community scale, but also for building scale.

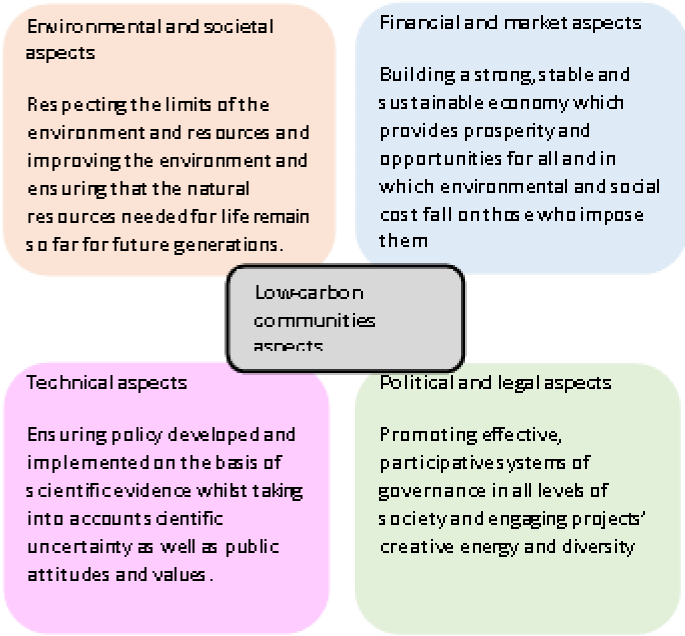

Fig. 14: Aspects of low-carbon communities

XI. RECOMMENDATIONS

Based on the conclusions discussed before, the following recommendations are madeble:

- Low-carbon communities should be new and distinct from the rest of the cities in order to be a magnet for residents to live and work in it through applying sustainable low-energy urban strategies in the planning process of these communities.
- Support life-styles that move towards low-carbon and zero-carbon energy strategies.
- Increase public’s environmental awareness for future challenges to face the environmental issues in Egypt and understand the concept of low-carbon communities in order to promote the development of zero-carbon developments.
- Public participation through encouraging people to participate in building communities with the new techniques to understand the requirements of buildings and sites.
- Government should lead in reducing carbon emissions through new ideas and project developments.
- The current situation in Borg Al Arab should be identified with its major challenges on the local

level, and tools should be utilized like SWOT-analysis and sustainability reporting in order to put hand on the real problems and find solutions to it.

- It is important to eliminate the economic problems of the area of Borg Al Arab through dealing with this kind of communities as an important and significant pole in the country by searching the properties of the city which distinguish it from other cities in the same region.

- It is important to address the social problems of Borg Al Arab so as social levels may begin to move to these new communities and create a kind of balanced life which is not limited on the poor and unskilled labor.

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Exploring the Importance of Employing Bio and Nano-Materials for Energy Efficient Buildings Construction

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***Abstract* -** The continued and increasing use of ordinary building materials to house the ever-growing world population ensures growing contributions of carbon (C) to the active carbon cycle through carbon dioxide (C02) emissions from combustion and chemical reactions in the raw material to the atmosphere. To minimize this, materials should be conserved, reduce their unnecessary use, produce them more benignly and make them last longer, recycle and reuse materials. Thus, paper will focus on exploring alternative building materials and systems that can be developed in order to balance atmospheric carbon dioxide. It also presents the Bio-inspired architecture approach that embraces the eco-friendly practices of using Biomaterials and Nano-materials for sustainable dwelling construction through a number of examples that shows how a building can be strongly related to its site.

***Keywords* -** Bio-Nano Material, Sustainable Dwelling Construction, Cradle To Cradle Materials, Energy Efficient Building Materilas.

I. INTRODUCTION

Building materials are literally part of the air human breath. Compared to most other materials in the living world, they are also much longer-lived, with a much longer use phase. Unfortunately, Current use of materials for building construction especially for the housing sector is running down natural systems, destroying community and biodiversity, debasing work, and suppressing all kinds of possibilities for real development. With the exception of wood, sand, gravel, and natural stone, the manufacture of the greater part of most conventional building materials used today is based on the use of hydraulic cement, lime, fired brick, steel, aluminum, and plastic which are fossil-fuel intensive in their manufacture. Following the philosophical principles of Cradle to Cradle “waste equals food” will also help in creating a healthy regenerative built environment which will benefit people and other living creatures as well as safeguarding the biodiversity.

II. SUSTAINABLE MATERIALS FOR BUILDING SKINS:

An essential dimension of detoxifying production and achieving regenerative sustainable design is increasing the use of renewable and bio-based materials that can be more safely reabsorbed by natural systems. As well as using materials that help preserve the biodiversity of the place. [2] To connect buildings to place; architects should start by making the interface of buildings better suited to its environment. This interface occurs in a building’s first line of defense to the environment, the building Skin, which includes the exterior walls, roof, and exterior openings. However, current envelopes are seen as barriers from the outside world, instead of filters like a natural skin. Thus, to make improvements in the building skin’s efficiency and construction it is necessary to look on how a sustainable regenerative building skin should function.

These are as follows: [1]

1. Protection from the natural elements.
2. Environmentally-friendly manufacturing as well as adding positive contribution.
3. Not be harmful to the natural environment at the end of its life
4. Integrate multiple systems within thin membrane.
5. Regulate transfer of heat, air, water and energy efficiently.

6. Be adaptable to its local environment and respond accordingly.
7. Be beautiful.

III. EXAMPLES OF NATURAL AND BIOMATERIALS

A. Hempcrete

Two materials are produced from the hemp plant stem, fiber from the outer bark and wood chips from the core. Every part of the hemp plant can be used for applications like building materials (Hempcrete , fibreboard and insulation). Hemp wood chips or hurds are mixed with lime-based binders and water to create a bio-composite breathable masonry material termed hempcrete. The lime is typically combined with a small amount of cement to reduce the curing time.

Fig.1. Shows Hemp wood chips are mixed with lime to create hempcrete Bricks and insulation sheets

Source:http://internationalhempbuilding.org, retrieved 1-5-2013

The common application of hempcrete in buildings is to be used as infill in timber frame walls. It is also used to build monolithic walls and floors and to fill roof cavities. This method has been used in France since the early 1990's to construct non-weight bearing insulating infill walls supported by a timber frame.

Fig.2. Shows that hempcrete can be cast manually around a timber frame using a shuttering system,

Source: http://internationalhempbuilding.org, retrieved 1-5-2013

Hempcrete bricks have the capability of being self-supporting removing the need for a timber frame. Local style of vernacular buildings can be easily built with hempcrete bricks.

Hempecrete has many sustainable advantages such as: [3]

1. Hemp is a rapidly growing, annually renewable plant.

It takes one hectare of land to grow, in approximately four months, sufficient hemp to build a three-bedroom house. This estimated production amounts to four tones of material per acre per year.

2. Hempcrete is carbon negative.

Buildings built with hempcrete achieve a low carbon footprint as hemp absorbs nearly twice its dry weight in CO2 during growth, providing a lower carbon footprint to all materials it is used to create. The carbon trapped in the hemp offsets the carbon not only of the hemp production but also the residual carbon from the lime binder production after re-absorption of carbon as the lime cures. A 300mm hemcrete wall absorbs in its construction 40kg per m2 CO2. A typical brick and block wall emits 100kg giving a net benefit of 140kg. [2]

3. Hemp does not require agrochemicals in its cultivation.

Providing a clean air and clean soil as well as clean water

4. Hempcrete is also recyclable at the eventual end of the life of the building.

5. The walls are breathable

This controls moisture and condensation and improves internal air quality. Hempcrete regulates the temperature and humidity of a building; in some cases completely eliminating the need for heating and cooling systems, resulting in huge energy savings.

6. Hempcrete does not rot

[when used above ground due to presence of lime] and is mostly biodegradable. [3]

B. Rammed Earth Construction and compressed Earth blocks

Unfired clay bricks and rammed earth are two more ancient technologies that are finding increasing use in modern sustainable buildings. Clay and sand are mixed with water and then placed in formwork to form bricks, walls or columns. Often soil from the building site is used, resulting in an extremely low embodied energy structural element with high thermal mass. Conventional fired clay bricks require large amounts of energy for their production and result in the release of large amounts of carbon dioxide (MacDougall 2007). Compressed Earth Blocks (CEB's) are energy-efficient, comfortable, durable and cost-effective. In addition, they are insect-proof, bullet-proof, earthquake-resistant and fire-proof. The thermal insulation capacity of CEB buildings are up to 10 times more efficient than concrete block building, meaning cool housing in summer and less heating required in winter. Unlike modern adobe blocks, the CEB's are entirely natural and they don't use asphalt or other potentially toxic additives. Workers employing hand presses can make up to 500 blocks a day, and all the bricks necessary for a modest house in a week. Hydraulic machines can make all the blocks for a large house in a day. CEB construction has been employed around the world, from Latin America to Africa to India and the Middle East. CEBs are stronger in compression than regular adobe blocks. [4] Unfired clay and rammed earth must be protected from exposure to the elements. To completely waterproof the unit with the more expensive option is to wrap the walls in chicken wire and plaster the whole unit, or else special sealant coats are available such as Earth Cote elastomeric polymer coating developed in South Africa which can be painted on in two coats – primer and finishing coat. [3]

- Soil Selection and quality control:

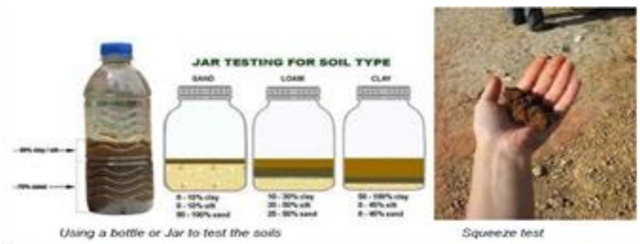

Fig.3. Shows the two types of soil selection tests to form compressed earth block,

Source: http://use-it.co.za/, Retrieved 4-5-2013

There are a number of tests used to select the right soils and ensure that the blocks produced will make strong blocks. One of them is the squeeze test and the other one is the jar or bottle test. Soil with a clay content of between 10 and 50% is the better selection. The strength of the blocks will vary depending on the clay content and type. Once the right soils have been tested and sourced – transport these to the production site (keep it close to the source) and prepare soils for production. They should be dried to ambient moisture conditions (<12%) in the sun and then blended through the soils blender (adding stabilizer of lime or cement at 5% to ensure greater stability and to waterproof the blocks) and then fed through to the block production system. Although clay is essential in earth block construction, blocks that contain too much clay may crack. In some parts of the world builders use Portland cement to stabilize the clay – stabilisation is only required for the lower course of blocks for waterproofing. Lime is a good stabilizing ingredient for the CEB blocks if it can be sourced locally as it is cheaper than cement and also a more natural ingredient. The exact recipe used to manufacture CEBs will depend on the soil composition of the region. [8]

- Block production:

Blended and sifted soils are loaded into the block press machine. Several adjustments are required to set the thickness of the blocks to the desired size, and then the sensor system takes over for mass production. Fuel is saved because each hydraulic ram machine consumes only about 10 gallons or 38 litres of diesel a day. A "set" of CEB equipment, when fully functioning, will employ in excess of 50 employees. This will include soil selection, soil preparation, equipment operators, block handlers, house builders, roofers, electricians, plumbers, glazers, finishers, security individuals, managers, truck drivers and inspectors. . [8]

Fig.4. Shows using of earth construction in the three systems Villa, by Adel Fahmy, Giza, Egypt. Source: Photo taken by Architect Ahmed abd el Gawad

C. Solar-generated Building Material from Seawater (SBM):

Solar-generated Building Material from Seawater (SBM) is an alternative building material and system that has been developed in order to balance atmospheric carbon dioxide. Using electricity from renewable sources, limestone-storing carbon can be precipitated from seawater with simultaneous production of hydrogen, oxygen, and chlorine gas. These installations could also produce SBM for use elsewhere, replacing building materials made with hydraulic cement like concrete blocks, walls, and slabs, even foundations. SBM can substitute for bricks made of fossil-fuel fired lime and clay, not only reducing CO2 emissions, but subtracting carbon from the carbon cycle. [11]

Wolf Hilbertz, German architect and inventor is the father of sea-creation, had mimicked the electrolytic deposition of sea-shell-like minerals from seawater and had found a way to use sunlight to turn the minerals in seawater into limestone for underwater and dry land constructions. The limestone structures in the sea will facilitate the growth of corals and provide habitat for fish and other coral reef species; Coral reefs are one of the most complex marine ecosystems, important to sea life and protective of shorelines from erosion. The method is sustainable, environmentally safe, and economically and biologically feasible. [11]

Fig.5. Autopia, ocean settlement with membrance construction. Photo: W.H. Hilbertz. Source: www.globalcoral.org Retrieved 9-5-2013

This idea is derived from Coral blocks, which have been utilized for centuries as a dependable and lasting building material for structures and roads.

- Calcium Carbonate as a Building Material:

Nature uses controlled and uncontrolled bio-mineralization processes to build a variety of structures. They produce about 60 different minerals [9]. CaCO3 is one of the more abundant minerals involved in the processes which are often on such a scale that they affect ocean/atmosphere chemistry and form major parts of sedimentary rocks. When one molecule CaCO2 is precipitated from seawater, charge balance requires the formation of one molecule of carbonic acid and super saturation of carbonic dioxide. If this escapes to the atmosphere, carbon is removed from the hydrosphere, but CO2 added to the atmosphere. Therefore, deposition of CaCO3 is often seen as a source of atmospheric CO2, SBM is a sink for carbon although its direct effect on the atmosphere has to be treated as controversial. To fully assess the role of SBM in the global atmospheric balance the net effect of all electrolytic and biogenic reactions needs to be measured experimentally. At the same time, as a result, global warming would be mitigated. A note of caution needs to be taken in equating carbon removal from the ocean with carbon removal from the atmosphere. [11]

Fig 6. Examples of the application of bamboo structural material in the building industry

Source: http://www.inspirationgreen.com/bamboo-buildings.html, Retrieved 4-6-2013

D. Bambo:

Bamboo is a grass native which has been used as a building material dating back to 3500 BC (Kennedy, J.F., 2002:125-131).It is the fastest growing woody plant on the planet. Most species produce mature fiber in about three years, much more rapidly than any tree species. Some species grow by up to one meter a day, and the majority reaches a height of 30 meters or more. It is adaptable to most climatic conditions and soil types, acts as an effective carbon sink and helps counter the greenhouse effect. According to the Zero Emissions Research Institute (ZERI), a bamboo forest can sequester 17 times as much carbon as a typical tree forest. Some species grow as much as 39 inches in a day. Also, due to bamboo's high nitrogen consumption, bamboo helps mitigate water pollution, as it takes in and transforms nutrient wastes when planted alongside manufacturing zones, intensive livestock farming, and sewage treatment facilities. It can also desalinate seawater. It is being used increasingly in land stabilization to check erosion and conserve soil. It can be grown quickly and easily, even on degraded land, and harvested sustainably on three- to five-year rotation. Bamboo is a truly renewable, environmentally friendly material. [8]

In building construction, Bambo is used as framing, roofing, flooring, wall matting, ceilings, scaffolding, boards and panels, plywood, concrete reinforcement, connecting stakes, and more. Bamboo in buildings can help reduce the amount of wood, steel and concrete needed. As a substitute for wood, it can take great pressure off forests, and contribute to local self-reliance, since great quantities can be produced in small areas. It has great compressive and tensile strength, and has shown great resistance to earthquakes. [2]

Possibly the major factor contributing to the view of bamboo as a temporary material is its lack of natural durability. It is susceptible to attack by insects and fungi. It deteriorates rapidly in contact with moisture. Its service life may be as low as one year when in ground contact. However, the durability of bamboo can be greatly enhanced by appropriate specification and design and by careful use of safe and environmentally friendly preservatives such as boron. [8]

E. Timber from sustainably managed forests:

Cutting down trees to make buildings does not immediately sound eco-friendly either, but if sourced from sustainably managed forests (like those in Europe and North America), it can be more environmentally sensitive.

A sustainable forest is a forest that is carefully managed so that when mature trees are felled they are replaced with seedlings that eventually grow into mature trees. In this way the forest is constantly renewed and will continue to exist providing natural materials for all generation. The forest is a working environment, producing wood products such as wood pulp for the paper / card industry and wood based materials for furniture manufacture and the construction industry.

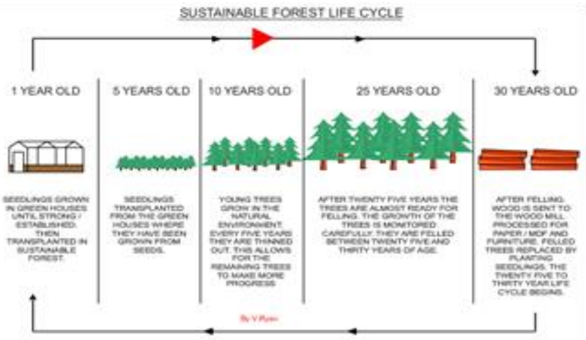

Fig.7. Shows the life cycle of trees in a sustainable forest, Source:

http://www.technologystudent.com/prddes1/susenv1.html, Retrieved 12-5-2013

Green says that the modern wood materials have been used for around 20 years, but until recently they have been quite niche or used only in low-rise buildings. What has changed is the way in which architects and builders are thinking about using wood. Swapping cement and steel for timber is the vision of a number of environmentally minded architects who are planning high-rise buildings across the world. Wood buildings lock in carbon dioxide for the life cycle of a structure, while the manufacture of steel and concrete produces large amounts of CO2 -- the International Energy Agency (IEA) estimated that for every 10 kilos of cement created; six to nine kilos of CO2 are produced. [17]

- Example Of High Rise Wooden Building:

The Stadthaus, Murray Grove is one of the highest modern wooden buildings in London, Completed in 2009. It’s a nine-story residential building with height of 30 meters. It is the tallest building in Europe structured entirely of wood. Even the lift shafts and stairwells are made from wood. It illustrates a groundbreaking approach of building material selection that can help achieve carbon-neutral (or even carbon-negative) buildings with current technology. It is built of solid slabs of timber, used for floors and walls, with no other structural framework. Much like plywood, but on a larger scale, the slabs are made of layers of solid 1” thick boards, cross-laminated into large slabs up to 30 ft. long.

Fig.8. Shows the wood structure of the 9 stores Stadthaus, Murray Grove residential building.

Source http://www.nytimes.com/interactive/2012/06/05/science/0605-timber.html?_r=0, retrieved 13-7-2016

cross-laminated timber used on the Stadthaus is classified as air-tight, making it one of London's most energy efficient buildings. These are quite strong, resilient, and the solid construction offers excellent fire-resistance and acoustic separation properties, compared to more typical hollow “stud” walls. [12]

Wood is a renewable resource and all of the adhesives and chemicals used in the manufacture of this system are non-toxic. Compared to conventional steel and concrete construction, embodied energy was reduced an equivalent of 340 tons of carbon emissions. This calculation allows for the fact that the panels were manufactured in Austria and transported to the project site in England. Unfortunately, there is not yet any manufacturing source in the United Kingdom. Ideally, the building would be made of lumber from Scotland, reducing transportation and further reducing the embodied energy. In addition, approximately 200 tons of carbon are “locked in” the wood material, which alone is equivalent to the energy that will be used to heat, cool and operate the building for twenty years. Thus, the building will have a negative carbon footprint until almost 2030. Wood is biodegradable, the wood slabs will easily disassembled for some re-use when the day comes for its demolition, following the concept of “cradle-to-cradle”. The exterior cladding of the building consists of fiber-cement panels, made from 70% wood-waste products. [12]

IV. EXAMPLES OF NANO-MATERIALS FOR GLASS WINDOW AND CURTAIN WALLS

Glass is a sustainable, fully recyclable material and a resource efficient material which is made of abundant natural raw material such as sand and glass waste which provides great environmental benefits such as contributing to mitigating climate change and saving precious natural resources. It is also used to generate renewable energy through solar-thermal and photovoltaic applications as well as contributing in safeguarding people’s health and well-being. Window glass is completely different than traditional glass bottles, which are the most recyclable items. By contrast, it is nearly impossible to recycle window glass. Though the two products may seem virtually the same, there are actually some notable differences. Bottle glass has a different chemical composition and melting temperature than window glass, meaning the two products can’t be recycled together. Window glass is a trickier proposition. Most windows come attached to metal or wooden frames and have to be disassembled, which is labor intensive and expensive. Picking out the different types of window glass poses a bit more of a challenge. Is the glass tinted or not? Is it safety glass or tempered glass? Different glass products have a different melting point from container glass. All these different subsets of window glass also cannot be combined to create a new product. However, there are still nontraditional ways to properly recycle it. Creative industry professionals are finding other uses for old windows. The glass can be melted and remanufactured into Fiberglas. Ground glass can be incorporated into glassphalt, a glass and asphalt blend. Broken glass is combined with concrete to create terrazzo flooring and countertops. Old windows can also be reused as is or use them to construct greenhouses or cold frames for the garden. However, there are great efforts to create more innovative bio-regenerative glass materials by following the Biomimetics approach

A. Sunclean, Self Cleaning Glass

The advanced architectural glasses, such as Sunclean, Self cleaning glass, Solarban solar control, low-e glasses and Oceans of Color spectrally selective tinted glasses can contribute to green building projects through their ability to transmit light and block solar heat, which can minimize reliance on artificial lighting and air conditioning.[13]

Fig.9.Hydrophobic surface allows self-cleaning: sacred lotus ,

Source: http://www.asknature.org/strategy/714e970954253ace485abf1cee376ad8, Retrieved 4-5-2013

SunClean glass is inspired by self-cleaning mechanism of lotus plants, the glass self-cleaning is formulated with a proprietary coating that becomes “photocatalytic” and “hydrophilic” after prolonged exposure to sunlight as it reacts with UV rays to disintegrate organic deposits and repel dust during rain.

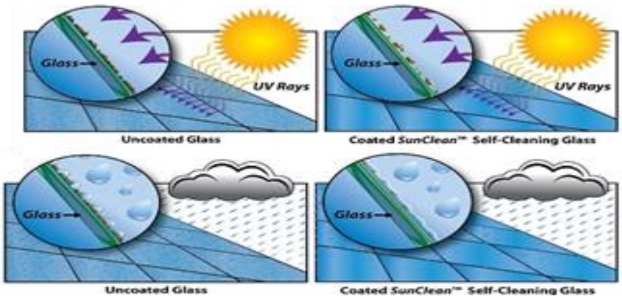

Fig.10. Diagram shows the difference between conventional uncoated glass & innovative coated sun-clean, self-cleaning glass,

Source: http://www.ppg.com/corporate/ideascapes/glass/products/suncl ean/Pages/suncleanglass.aspx, Retrieved 18-5-2013

Photocatalysis enables the coating to gradually break down organic materials that land on its surface when exposed to UV light.

Hydrophilicity causes water to sheet when it strikes the coating so that decomposed materials are naturally rinsed away when it rains. Some types of the self cleaning glass are also Cradle-to-Cradle Certified which make them more sustainable and environmental stewardship. [14]

B. Dye Solar Cell Technology:

Dye solar cell is described as “artificial Photosynthesis” using an electrolyte, a layer of titania and ruthenium dye sandwiched between glass. [16]

The main difference from a traditional solar cell is that Dye solar cell does not require high-energy consuming silicon, but is instead made of titanium dioxide, used in white paint and toothpaste.

Fig.11. Dye solar cell inspired from the Photosynthesis of tree leaves,
Source: http://www.asknature.org/product/b57e64dd3a2a1a9d36a92a5a51ef7293, retrieved 4-5-2013

The dye in cells absorbs light just like chlorophyll in photosynthesis, releasing an electron that is conducted by the chemical electrolyte in the cell. Light striking the dye excites electrons which are absorbed by the titania to become an electric current many times stronger than found in natural photosynthesis in plants. [16]

It also can be directly incorporated into buildings by replacing conventional glass panels rather than taking up roof or extra land area.

Compared to conventional silicon based photovoltaic technology, Dye solar cell technology has lower cost and embodied energy in manufacture, and it produces electricity more efficiently even in low light conditions and regardless of the panel's orientation. [16]

V. CRADLE TO CRADLE CONCEPT

Cradle-to cradle design raises an entirely different agenda. Rather than seeing materials as a waste management problem as in the cradle-to grave system, cradle-to-cradle design is based on the closed-loop nutrient cycles of nature, in which there is no waste. By modeling human designs on these regenerative cycles, cradle-to-cradle design seeks, from the start, to create buildings, communities and systems that generate wholly positive effects on human and environmental health. Not less waste and fewer negative effects, but more positive effects, buildings that make oxygen, sequester carbon, fix nitrogen, distill water, provide habitat for thousands of species, accrue solar energy as fuel, build soil, create microclimate, change with the seasons, belong to the place and are beautiful.

The milestone of the cradle to cradle certification is based on the principle that **WASTE=FOOD**; that everything should be designed so that its components are either **biological nutrients**, food for natural systems capable of being composted and returned to the earth as food for more plants and animals, or **technical nutrients**, food for industry capable of being easily separated and properly recycled. In the natural world, everything is conceived of and designed to be food. When everything (every material, manufacturing process and emission) is food for one system or the other, then humanity will be indeed benefitting the environment. So that building should act like a tree and cites like a forest. A tree, for example, is not "zero-emitting." It emits oxygen and nutrients for soil, while purifying water and providing habitat for multiple species. This total quality framework has been designed to support companies in creating products that are "good" rather than simply "Less bad." [6]

A. The C2C philosophical principles:

McDonough and Braungart had investigated three key concepts for any environmental design for new products as well as for buildings design, which are: All Materials in Continues cycle, Use Renewable energy only and respect diversity. Despite the publication of the manifesto "c2c in Architecture" in 2009 as well as the "cradle to cradle criteria for the built environment" by Douglas Mulhall and Michael Braungrat in 2010, in which issues such as the C2C design principles were clarified in building sector, there is still an insufficiently detailed handbook for the realization and evaluation of the C2C building project. The C2C building projects provide their own interpretation by combining elements from C2C philosophy with elements from "sustainable building", "energy-efficient building", "Bio-eco logical building" and others. [7]

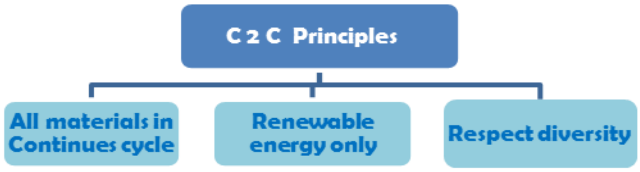

Fig.12. Diagram shows the Cradle to Cradle Principles

A. All Materials in Continues Cycle:

"Waste Equal Food" it is the conceptual basis for the C2C philosophy. All products should be made using materials that can be recycled with minimal environmental impact to be reused as biological or technological nutrients.

B. Use Renewable Energy only:

"Current Solar Income" McDonough and Braungart use this phrase to argue that manufacturing processes should use energy from the sun or other renewable sources instead of fossil fuels which are earth's stored solar energy reserve.

C. Respecting Diversity:

It is about evaluating the impact of industrial processes on all plant and animal life or as McDonough and Braungart say: *"All the children of all species for all time*". [5]

VI. CONCLUSION

Looking back to learn from nature as well as using natural materials in building structure will help in creating more energy efficient buildings. It is highly recommended to create a community that appreciate this concept and to be aware about the benefit that will touch their quality of life by creating an energy efficient environment.

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Towards a zero carbon Alexandria

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***Abstract* -** Today, the world faces an unprecedented environmental crisis. Since the Industrial Revolution, the accelerated climate change is believed to be a result of human activities; that increase the concentration of greenhouse gases (GHG) in the atmosphere – to which carbon dioxide is the largest contributor. It made a must beginning to reverse the damage inflicted on the planet. Egypt is exerting great efforts to reduce the emissions of Green House Gases and mitigate the negative impacts of climate change and deal with the main challenges that affect sustainable development.

Based on an empirical analytical study, the paper examines all of the environmental factors and its effect on carbon dioxide concentration taking into consideration the characteristic of the urban fabric and conditions of Alexandria one of the biggest cities in Egypt as an applied case study of a big willing costal city. The paper simultaneously aims the management of the carbon dioxide emissions through several recommendations based on the stated study, while creating a vibrant urban environment.

***Keywords* -** Environment; climate change; carbon dioxide; Sustainable Development; management.

I. INTRODUCTION

Human industrial activities and technological revolution have led to increased rates and concentrations of greenhouse gases GHG emissions in the atmosphere; causing climate change. (1) Atmosphere has some variable components including water vapor, dust particles, and ozone. Although these are found in small amounts, they can have significant effects on greenhouse gases and climate. (2) These are not considered sources of air pollution but it has been influential on the global warming phenomenon. Carbon dioxide is one of the main gases which has a large contribution of this phenomenon. (1)Therefore, the industrial applications of this type of converter are limited [1].

It is well known that GHG and climate change is a global phenomenon but its effects would vary from one place to another on earth. Egypt is expected to be largely vulnerable to number of risks and threats such as sea level rise, high temperatures, followed by shortages in water resources, impacts on agricultural productivity and difficulty on cultivating some types of crops; as well as impacts on touristic areas, public health and infrastructure that would affect energy, industry, food safety and national economy sectors. (1) Thus it became a significant matter analyzing the causes of carbon dioxide emissions and the mainly environmental factors that affect its concentration in atmosphere which differ from one place to another at the different time intervals.

Through studying two main axises of Alexandria city, different devices had been used to measure the values of carbon dioxide and several environmental factors in the atmosphere at different points. The collected data was analyzed comparing the effect of the environmental factors on the carbon dioxide concentration in the atmosphere for the same selected points. through this analysis a conclusion was made with some recommendations on how to control the carbon dioxide emissions, aiming to reduce greenhouse gases to make Alexandria a zero carbon city.

II. EGYPT'S STAT E OF CARBON DIOXIDE EMISSION

The table below shows the GHG emissions in Egypt in 2000 (co2.mt.eq) according to Egypt second national communication report, also shows the calculated emissions in 2009.

Table 1. GHG EMISSIONS IN EGYPT

Year	Egypt's amount of GHG emissions (co2eq Mt)	Egypt's share of the global GHG emissions (%)
2000	193,267	0,64
2009	305,1	0,71

Egypt's CO2 emissions were fairly stable during the past decades as shown in the below figure 1. As compared to industrialized countries, Egypt's CO2 emissions are still considered low, and are marginal on a global level. Although the CO2 emissions level increased (from 116.6 Mt CO2 equivalent to reach 226.6Mt CO2 equivalent In 2007, i.e. about 93% increase), the greenhouse gases in Egypt still represents a very small percentage of the global yearly emissions (about 0.96%). (3)

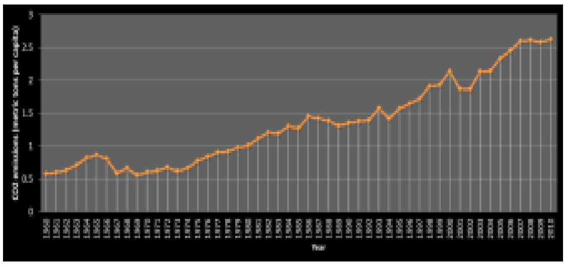


Fig .1. Egypt's CO2 emissions (metric tons per capita) from 1960 till 2010.

The below figure shows the different activities which contribute the carbon dioxide emission in Egypt. It is clearly noticed that fuel combustion in the energy sector has the major contribution in the carbon dioxide emission followed by the industrial activities

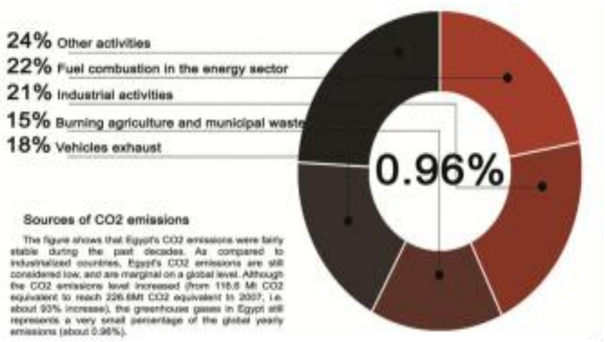


Fig .2. Sources of Co2 emissions in Egypt.

III. ALEXANDRIA AS A CASE STUDY

Alexandria, with a population approximately 3.9 million inhabitants, is Egypt's second largest city situated on the Mediterranean Sea. Its borders extend along a 70 km coastline north-west of the Nile delta. It is also the largest city lying directly on the Mediterranean coast. (4)

Fig .3. A recent map of Alexandria showing the linear form of the city.

A. Empirical Study

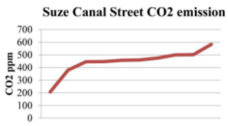
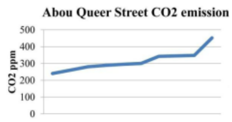
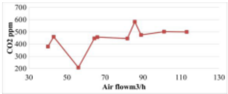
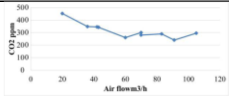
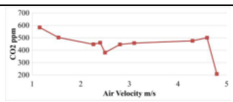
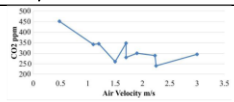
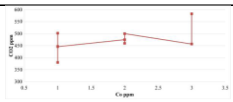
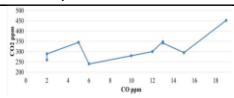
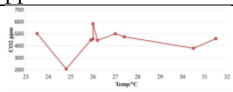
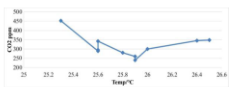
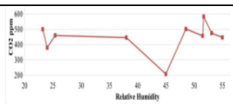
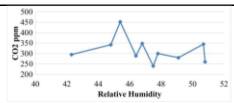
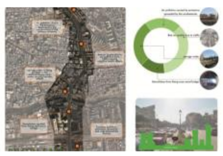
Six environmental factors had been investigated to observe their effect on the amount of carbon dioxide concentration in the atmosphere at different selected points. These environmental factors that had been investigated are air flow, air velocity, carbon monoxide, temperature, relative humidity and the urban fabric. The air velocity and airflow were measured using the Multifunctional AMI300 device. The carbon dioxide was measured using 2 devices; Air Quality data logger and Multifunctional AMI300. The carbon monoxide, temperature and relative humidity were measured using Air Quality data logger.

As shown in the below figure the first urban fabric is the suez canal street which is a main road axis perpendicular to the sea shore line and the second one is Abou Queer street which is a main road axis parallel to the sea shore line.

Fig .4. A map showing the two investigated road axis.

The table below sums up the different environmental factors measures versus the carbon dioxide emission in the form of charts in two different urban fabrics.

Table. 2. MATRIX OF CARBON DIOXIDE EMISSION VERSUS THE DIFFERENT ENVIRONMENTAL FACTORS

Points of comparison	**Carbon dioxide emission**	
	Suez Canal Street	Abou Queer Street
	 The average CO2 emission is 445 ppm	 The average CO2 emission is 315 ppm
Air Flow	 The average air flow 74 m3/h	 The average air flow 60 m3/h
Air Velocity	 The average air velocity is 2.9m/s	 The average air velocity is 1.7 m/s
Carbon monoxide	 The average carbon is 1.6 ppm	 The average carbon is 9.7 ppm
Temperature	 The average Temperature is 27 °C	 The average Temperature is 26 °C
Relative Humidity	 The average relative humidity is 41%	 The average relative humidity is 47%
Urban Fabric	 Figure I. Suez canal street Urban pattern. **Grid Pattern:** While the Suez canal road is perpendicular on the sea shore line; the sub-Streets have been aligned parallel to sea shore which had blocked the cooling breeze of the sea. It causes difficulty in getting out the produced carbon dioxide at once.	 Figure II. Abou queer street Urban pattern. **Grid Pattern:** While the Abou Queer road is parallel to the sea shore line; the sub-Streets have been aligned perpendicularly on sea shore line to take advantage of the cooling breeze of the sea. It also helps getting out the produced carbon dioxide at once.

B. Analytical Study

By studying and analyzing the above collected data it was found that the carbon dioxide emission is higher in the Suez Canal street with average 445 ppm than Abou Queer street with average 315 ppm but both are mostly still below the normal limit which is 450 ppm as shown in the below chart. This slight difference in CO_2 emission showed a slight increase in the average temperature of in suez canal road with average 27°C than Abou Queer road with average 26°C.

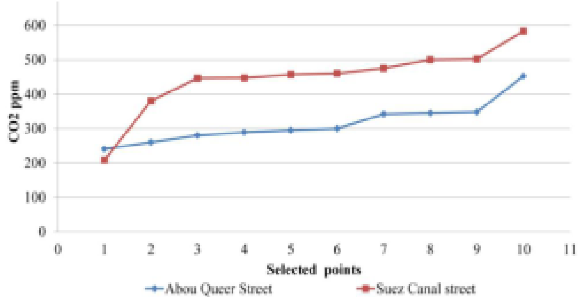


Fig.7. A chart showing the carbon dioxide readings of both road axises at 10 selected points.

As for the air velocity factor it was found that with the increase of the air velocity there is clear decrease in the CO_2 concentration in the atmosphere that could be noticed in both road axises. The Air flow showed a steady concentration of CO_2 as the air flow increases at the Suez canal Street, while it showed a slight decrease in CO_2 concentration as the air flow increases at Abou Queer street.

The average relative humidity of both road axes were almost close; Abou queer street 47% and Suez Canal 41% were both showed a steady concentration of CO_2 with the increase of relative humidity. The carbon monoxide showed an average higher reading in Abou Queer street 9.7 ppm than Suez Canal street 1.6 ppm without a noticeable effect on the CO_2 concentration.

Finally the urban fabric which mainly could be noticed of having an effect on the air velocity and airflow which showed higher reading is the ax perpendicular to the sea shore (suez canal road) than in the ax parallel to the sea shore (Abou Queer road).

Table. 3. SWOT ANALYSIS OF STUDY AREA

Strengths	Weaknesses
• CDM Projects, which had been approved during 2008, reduce greenhouse gases emissions by up to about 0.9 million tons of carbon dioxide equivalent. • They have also an investment cost up to $ 66 million USD. • The good urban fabric around Abou Queer street allows the immediate disposal of produced carbon emissions from automobile exhausts which decrease the concentration of carbon dioxide. • Heritage buildings along Abou Queer Street feature strong opportunities for natural ventilation and daylight because of strong thermal mass for heat absorption.	• Many of heritage buildings in the city haven't benefited optimally from changes to building systems over the years which prevent these buildings from receiving the benefits of full sustainable upgrades. • limited energy code requirement for existing buildings • lack of corporate support and business community engagement • Mechanical systems sizes are driven by the internal loads on the building (heat from people, lights and equipment) as well as the external envelope loads. There for, the mechanical system efficiency is ultimately dependent on the architectural design of the building and its use.
Opportunities	**Threats**
• Ratification of the UN Framework Convention on Climate Change (UNFCCC) and Kyoto protocol and is committed to any obligation • Institutional formation of a National Committee of Climate Changes to manage all issues related to climate changes. • Make use of the three mechanisms of the Kyoto protocol for the reduction of GHG emissions: the Clean Development Mechanism (CDM), Joint Implementation and Emissions Trading.	• There are some factories along Suez canal street that emit massive amounts of greenhouse gases such as carbon dioxide and methane. • Retrofitting buildings is critical for the overall carbon emissions for the city

IV. CONCLUSION

According to the data collected and analysed it was found that the carbon dioxide concentration is inversely proportional with the air velocity, as when the air velocity increased, the carbon dioxide decreased in both road axis. This shows that the carbon dioxide concentration is affected with the air velocity which in turn is affected by the different urban fabric. Accordingly it can be concluded that urban fabric with perpendicular grid to the sea shore line has higher air velocity and airflow.

V. RECOMMENDATIONS

- Promoting Good environmental design solutions that benefit the community as a whole on both scales of buildings or urban planning.
- Using the open spaces along the Mahmoudya canal as an entertainment zones with landscape and green areas to create a strong Green corridor that can improve livability and reduce the heat island effect.
- Increasing the landscape elements and greenery in the residential zone and along the Suez Canal artery to help absorb the vehicle emissions.
- Creating a green axis as a spine that links a series of smaller green plazas to improve transportation, amenities and livability and also offer a way of respite for residents, commuters and visitors.
- Reducing key sources of carbon dioxide through policies and investments supporting cleaner transport, energy-efficient housing, power generation, industry and better municipal waste management.
- Updating to new, more efficient equipment, technologies and infrastructure for rail, bus and taxis, to realize significant carbon savings.
- Improving pedestrian and bicycle amenities will also decrease automobile use.
- Adding new transit options such as one-way car/scooter/bicycle programs will further reduce the need for private car ownership, reducing carbon emissions.
- Charging vehicles based on their emissions and the rush-hour congestion of certain roads
- Creating an energy code requirement for existing buildings.
- Increasing corporate support and business community engagement.
- Managing the vehicular use carefully adjacent to buildings and in vocational programs.

VI. ACKNOWLEDGMENT

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Green Building between Tradition and Modernity

Study Comparative Analysis between Conventional Methods and Updated Styles of Design and Architecture Processors

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Assistant Lecture, Architectural Engineering Department, Pharos University, Alexandria, Egypt

***Abstract* -** Green house concept appeared from the ancient to the modern age ages and there is a tendency to use a traditional architecture with a pristine ecological environment areas and through sophisticated systems arrived to modern systems of the upgraded systems by Treatment architectural achieve environmental sustainability in recent years, sustainability concept has become the common interest of numerous disciplines. The reason for this popularity is to perform the sustainable development. The Concept of Green Architecture, also known as "sustainable architecture" or "green house," is the theory, science and style of buildings designed and constructed in accordance with environmentally friendly principles. Green house strives to minimize the number of resources consumed in the building's construction, use and operation, as well as curtailing the harm done to the environment through the emission, pollution and waste of its components.

To design, construct, operate and maintain buildings energy, water and new materials are utilized as well as amounts of waste causing negative effects to health and environment is generated. In order to limit these effects and design environmentally sound and resource efficient buildings; "green building systems" must be introduced, clarified, understood and practiced.

This paper aims at highlighting these difficult and complex issues of sustainability which encompass the scope of almost every aspect of human life.

***Keywords* -** Greenhouse; sustainable buildings; natural buildings; living architecture; renewable resources-eco-design; eco-friendly architecture; earth-friendly architecture; environmental architecture; natural architecture.

I. INTRODUCTION

Sustainability is comprehensive therefore a complex subject. It is of vital importance to all because it deals with the survival of human species and almost every living creature on the planet. Sustainable and eco-friendly architecture is one of the main aims thans for creating a better life have made as the ultimate model for all their activities. For this reason, moving towards a greener architecture is well-thought-out the main goal of the present architecture of our time [1]

At the rate the development needs of this world is using the scarce and limited resources found on the earth, it is becoming obvious that unless there are major changes to Man's thinking and behavior, the future of civilization as known today is dubious. This complex subject has no straight forward solution, especially considering that sustainability is a goal for all to reach as they continually strive to reach towards it. Green architecture produces environmental, social and economic benefits. Environmentally, green architecture helps reduce pollution, conserve natural resources and prevent environmental degradation. Economically, it reduces the amount of money that the building's operators have to spend on water and energy and improves the productivity of those using the facility [2]

And, socially, green buildings are meant to be beautiful and cause only minimal strain on the local infrastructure.

The buildings in which we live, work, and play protect us from nature's extremes, yet they also affect our health and environment in countless ways. As the environmental impact of buildings becomes more apparent, a new field called "green building" is gaining momentum. Green, or sustainable, building is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition [3].

II. PROPLEM STATEMENT

There is no clear approach to design the green architecture

III. 2. AIM OF STUDY

Access to appropriate methodology for Egypt correspond to different levels of design in terms of ecological techniques to advanced one

IV. METHODOLOGY

In order to achieve the stipulated aim, the study presented in this paper, traces the following steps:

1. General overview on applying “Green Architecture“ as A concept of sustainability.
2. Analytical Study to ecological project (Adrar Amlal)
3. Analytical Study to advanced project (Tenth of Ramadan City)

V. GENERAL OVERVIEW ON APPLYING “GREEN ARCHITECTURE “AS A CONCEPT OF SUSTAINABILITY

A. Green Architecture

Green architecture, or green design, is an approach to building that minimizes harmful effects on human health and the environment. The "green" architect or designer attempts to safeguard air, water, and earth by choosing eco-friendly building materials and construction practices [3].

B. Green Architecture and Green Design

Green architecture defines an understanding of environment-friendly architecture under all classifications, and contains some universal consent [4]; it may have many of these characteristics:

- Ventilation systems designed for efficient heating and cooling
- Energy-efficient lighting and appliances
- Water-saving plumbing fixtures
- Landscapes planned to maximize passive solar energy
- Minimal harm to the natural habitat
- Alternate power sources such as solar power or wind power
- Non-synthetic, non-toxic materials
- Locally-obtained woods and stone
- Responsibly-harvested woods
- Adaptive reuse of older buildings
- Use of recycled architectural salvage
- Efficient use of space

While most green buildings do not have all of these features, the highest goal of green architecture is to be fully sustainable.

Also Known As: Sustainable development, eco-design, eco-friendly architecture, earth-friendly architecture, environmental architecture, natural architecture [5].

C. Consideration for Green Building

Green building involves consideration in four main areas: site development, material selection and minimization, energy efficiency, and indoor air quality

- Consider site development to reduce the impact of development on the natural environment. For example, orient the buildings to take advantage of solar access, shading and wind patterns that will lessen heating and cooling loads.

- Carefully select materials that are durable, contain recycled content, and are locally manufactured to reduce negative environmental impacts. A growing market exists of quality recycled products at affordable prices.

- Incorporate energy-efficient design into buildings to create an efficient and comfortable environment. Take advantage of the natural elements and technologies to conserve resources and increase occupant comfort/productivity while lowering long-term operational costs and pollutants [6].

- Design for high indoor air quality to promote occupant health and productivity.

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- Minimize the waste in construction and demolition processes by recovering materials and reusing or recycling those [7].

D. THE PRINCIPLES OF GREEN BUILDING DESIGN

The green building design process begins with an intimate understanding of the site in all its beauties and complexities. An ecological approach to design aims to integrate the systems being introduced with the existing on-site ecological functions performed by Mother Nature.

These ecological functions provide habitat, respond to the movements of the sun, purify the air as well as catch, filter and store water. Designers can create features in their buildings that mimic the functions of particular eco-systems. Species that thrive in natural ecosystems may also utilize habitats created in man-made structures. Creating new habitat on structures in urbanized areas is especially important to support bio-diversity and a healthy ecosystem [2].

The following points summarize key principles, strategies and technologies which are associated with the five major
Elements of green building design which are: Sustainable Site Design; Water Conservation and Quality; Energy and Environment; Indoor Environmental Quality; and Conservation of Materials and Resources. This information supports of the use of the USGBC LEED Green Building Rating System, but focuses on principles and strategies rather than specific solutions or technologies, which are often site specific and will vary from project to project (USGBC).

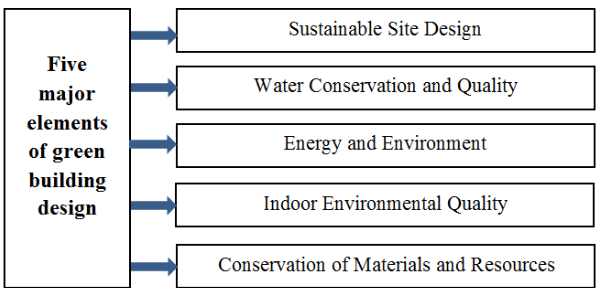

Fig. 1. Elements of green building design by author (USGBC).

E. GREEN BUILDING BENEFITS

Green building is not a simple development trend; it is an approach to building suited to the demands of its time, whose relevance and importance will only continue to increase (USGBC)

- Comfort. Because a well-designed passive solar home or building is highly energy efficient, it is free of drafts. Extra sunlight from the south windows makes it more cheerful and pleasant in the winter than a conventional house [8].

- Economy. If addressed at the design stage, passive solar construction doesn’t have to cost more than conventional construction, and it can save money on fuel bills [9].

- Aesthetics. Passive solar buildings can have a conventional appearance on the outside, and the passive solar features make them bright and pleasant inside.

- Environmentally responsible. Passive solar homes can significantly cut use of heating fuel and electricity used for lighting. If passive cooling strategies are used in the design, summer air conditioning costs can be reduced as well [10].

VI. ANALYTICAL STUDY TO ECOLOGICAL PROJECT (ADRAR AMLAL)

An applied analytical study on a project of "Adrar Amlal" hotel in "Gaafar oasis"at Siwa in Egypt.

The mechanism of choosing the construction system is considered as an important stage in urban projects due to its relation with a group of limits forming the building technology, the mechanism of choice is related to the engineering method of decision support system used in construction system through building technical analysis and its application limits which passThrough a group of consecutive stages related to the project nature and the surrounding environment especially in the distinguished sites environmentally to assure the environmental resource conservation for humanity secure in his environment which needs from him to know the Ecological dimensions (capacity-dependence-recycling).

The research aims to achieve a group of goals, the most important of them is to reach a mechanism to choose the suitable construction system matching with sustainable development forming harmony between the design and the construction system and the sustainable development to reach the best economic efficiency of the project encouraging the environment sustainability as one of affecting sustains for a balanced environmental urbanism.

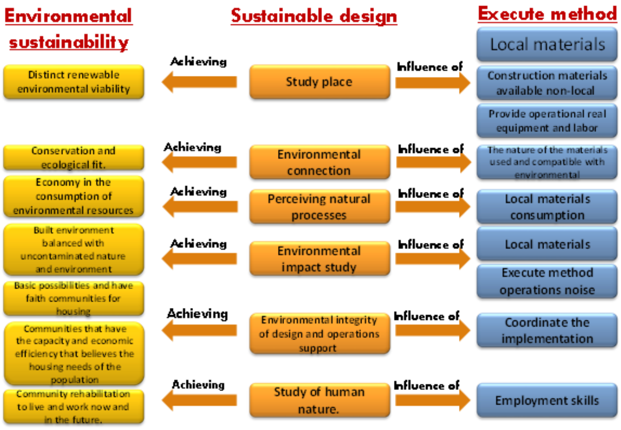

Fig. 2. Run harmonic reciprocal approach on the study

A. The research is sequenced as follows

- A study and analysis of the decision support system stages to choose the architectural project construction system as a primary stage.
- A study of factors and limits fuming the sustainable development and confirming it in an activated developed way.
- A study of the harmony relation between the construction system and the sustainable development and the exchangeable effects between them.
- A comparison and ordering the construction system priorities' and sustainable development priorities'.
- Concluding a mechanism of choosing the best construction system in harmony with the sustainable development.

The "Adrar Amlal" hotel in "Gaafar oasis"at Siwa in Egypt is considered the best example of applying the mechanism of choosing the construction system in harmony with sustainable development, the Oasis is a distinguished site environmentally at Siwa ,it is centralized around (the White mountain),the project criteria is there use of the old oasis method of construction again to build environmental houses of a new view using building technology by using building materials which are suitable for Siwa environment such as (Karsheef (salted masses)-clay-cured palm cores)

Fig .3. Siwa site for a map of natural reserves [11].

Fig.4.Natural determinants of the problem of site [12].

Fig.5.Architectural character of the Siwa Oasis [13].

B. *The research conclusions*

First: The choice of the best construction system suitable for the project environment is the first step to achieve sustainable development.

Second: The abundance of the environmental building materials is the most important factor to choose the environmental construction system.

Third: To make a relation between construction rates and "replacement and exchange "rates of projects in site to achieve the environmental sustainable development.

Fourth: Studying and developing the traditional construction systems of projects in sustainable sites which helps to make the project more economic efficient and in harmony with environmental sustainability

Fifth: The architectural integration together with knowledge between different stages in study and construction helps to achieve the environmental sustainability for the built environment

VII. ANALYTICAL STUDY TO ADVANCED PROJECT (TENTH OF RAMADAN CITY)

This part has concentrated on the neighborhood sustainability evaluation and its efficiency in improving the decision-making for sustainable development, it plans to provide a better understanding of the sustainability assessment at the neighborhood level and provide a critical analysis of both the theory and practice of neighborhood sustainability evaluation.

This project aim to introduce a case study for new application of the microclimate of urban open spaces is affected by several factors such as the urban form and geometry, urban density, the vegetation, the water levels and the properties of surfaces. Both climatic and physical factors are combined in order to attain sustainable human thermal comfort conditions.

A. MATERIALS & METHOD

To design the form of a village, town or city, we should understand the outline design principles of the urban form.

- The concept of sustainability in urban design to residential communities and housing.

Several design concepts related to sustainable urban forms	Principles sustainable neighborhood planning:
1. Compactness 2. Sustainable transport 3. Density 4. Mixed land uses 5. Diversity 6. Passive solar design 7. Greening.	1. Suitable space for streets and an efficient street network 2. High density 3. Mixed land-use 4. Social mix. 5. Limited land-use specialization.

- Urban Microclimate

The main purpose of climatic design, on a macro (Settlement) and micro (building) scale, is to reduce uncomfortable conditions created by an excess of heat and dryness. Buildings must be adapted to extreme summer and Winter, day and night conditions to achieve a well-balanced indoor climate. Not only cooling is required; passive heating may also be required in winter and during cold nights. Protection is required from the intense radiation from the sun, ground and surrounding buildings, from dust, sandstorms and insects (flies). Glare has to be reduced and dust penetration prevented. Settlements and buildings, therefore, have to be compact, providing shade and controllable ventilation.

The urban microclimate plays an important role in building energy consumption and thermal comfort in outdoor spaces. Nowadays, cities need to increase energy efficiency, reduce pollutant emissions and mitigate the evident lack of sustainability [14].

- Human Comfort

Thermal comfort is the most important factor that Human comfort depends on. Thermal comfort is affected by six major factors which can be classified into two categories: personal factors - because they are characteristics of the occupants and environmental factors - that are related to the conditions of the thermal environment. The former consisting of clothing level and metabolic rate, while the latter is mean radiant temperature, air temperature , air speed and humidity. Even if all of these factors may change with time, standards usually refer to a steady state to study thermal comfort, just allowing a change in temperature by small scale. Air temperature is also governed by solar radiation.

B. URBAN DESIGN IMPROVEMENT METHODS FOR THERMAL COMFORT

There are a lot of urban microclimate moderation approaches Parameters like air temperature, relative humidity, mean radiant temperature, and wind velocity can be modified by the effect of urban interventions, which may improve the outdoor thermal comfort conditions [15].

- Cool Reflective Materials
- Water Surfaces
- Green Spaces and Vegetation
- Building Arrangements with Wind Movement

C. *SIMULATION TOOLS IN URBAN DESIGN DECISIONS*

There are a Few studies have indicated that a good neighborhood Sustainability Assessment Frameworks and Tools should have the following characteristics Sustainability coverage—consideration of the major themes of sustainability of neighborhoods based on which their performance to be measured in a comprehensive and integrated way [16].

Several simulation tools related to urban design such as Ecotect, Urbanism, GIS, Envi-met and others. Each simulation tool deals with a specific area for instance. Urbanism is concerned with transportation, environmental planning, and metropolitan land use; While Envi-met is concerned with surface-plant-air interaction inside urban environments. All simulation tools have an unlimited number of points from the model that can be analyzed, whereas, in a measurement study, only the results derived from the measured spots are reliable.

On the other hand ECOTECT software is designed to improve the analysis, simulation, and optimization of high- performance buildings and systems. By using this software architects and engineers can test, evaluate and respond to a variety of strategies because it has a special use in the design and delivery of sustainable 'green' projects. 3D spatial models are one of the most advantages of the design and performance analysis tools because of the property of cutting edge that helps users to visualize simulation output, smoothing the translation of simulation results into the project design. Using simulation software, design professionals are able to continuously study and predict how decisions will impact the performance of the building from the early phases of design through occupancy without significant investment in mockups or manual calculations. Simulation tools such as ECOTECT and other similar software can improve the building industry by giving architects and engineers the power to use performance-based criteria in the design of projects.

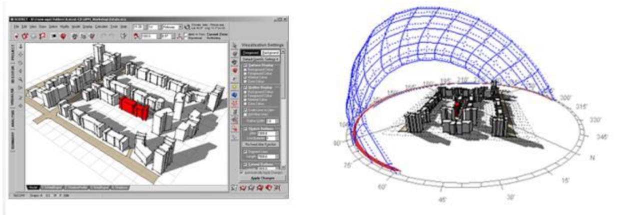

Fig. 6. ECOTECT (Building Performance Simulation Software)

(http://www.zigersnead.com/current/blog/post/ecotect-building-performance-simulation-software)

D. *Tenth of Ramadan City (case study)*

El Asher City or Tenth of Ramadan City is located in the Sharqia governorate of Egypt close to the city of Cairo and follows the Urban Communities Authority. It is one of the first generation cities in Egypt, and also one of the largest new industrial cities. It was constructed to provide job opportunities for youths as well as to attract the population increase to the outside of Cairo and the narrow valley, its climate classified as hot desert as the rest of Egypt.

1. Design Concept of the project

Design Concept of project (Figure 7) based on meeting the determinants architectural device “El Asher City or Tenth of Ramadan City” functional requirements in line with the Principles sustainable neighborhood planning to (Figures 8, 9):

- Achieve the functional requirements of the project according to the structural and architectural determinants.

- Reduce waste entrances of apartment buildings in the movement areas (roads) role habitation and what reduces the cost of the housing unit.

- Designed Muscat approved symmetric to afflict balance in marketing and reduce differences to distinguish between the blanks in order to achieve special layers housing average and exterior distribution quality takes into account the non-typical after the concept of housing People's abhorrent to rush to

- The Building was used major traffic battery different their positions to ensure optimal routing and compatibility with the gradient vacuum spaces planning (Figures 10, 11).

- The idea of assembling buildings to reduce the blanks rely on among themselves to provide spaces of the inner shadows.

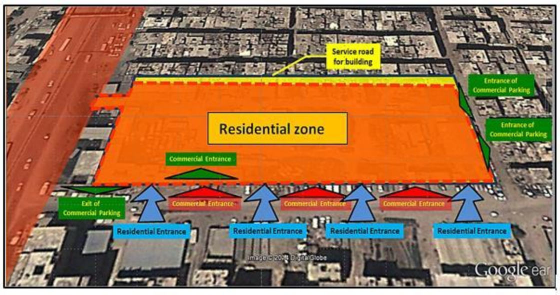

Fig. 7. Design Concept of the project

Fig. 8. Residential Neighborhood Layout

Fig. 9. Site Perspective

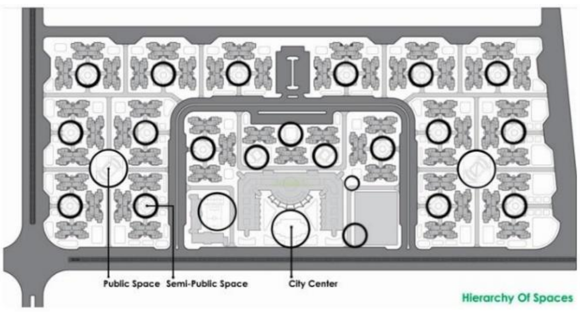

Fig. 10. Hierarchy of Spaces

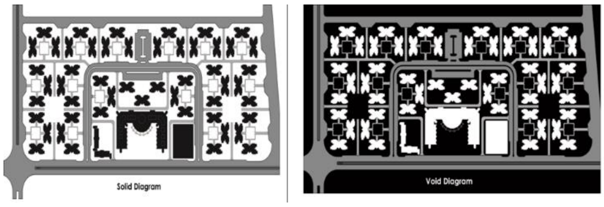

Fig. 11. Solid and Void Diagram

E. Case study evaluation

The simulation was run on Neighboring residential in Tenth of Ramadan City In order to investigate the local microclimate (Solar Radiation, air temperature, Relative humidity) in the climate of Egypt, Egypt as a proposed area. Readings of the Microclimatic parameters were run consecutively currently, expected and proposed then compared on each indicator.(Figures 12, 13, 14 and 15).

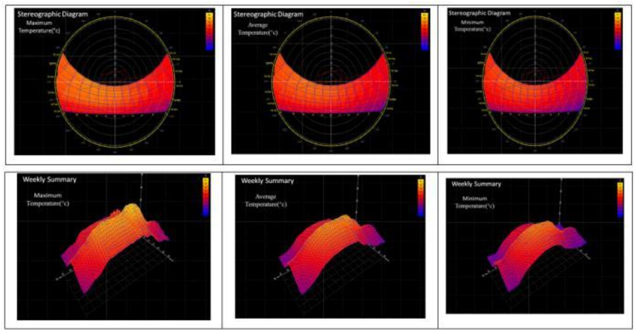

Fig. 12. The Stereographic Diagrams represent the range of Maximum Temperature in between (40-45) °c on June and observed that the highest day temperature is on 7 July.

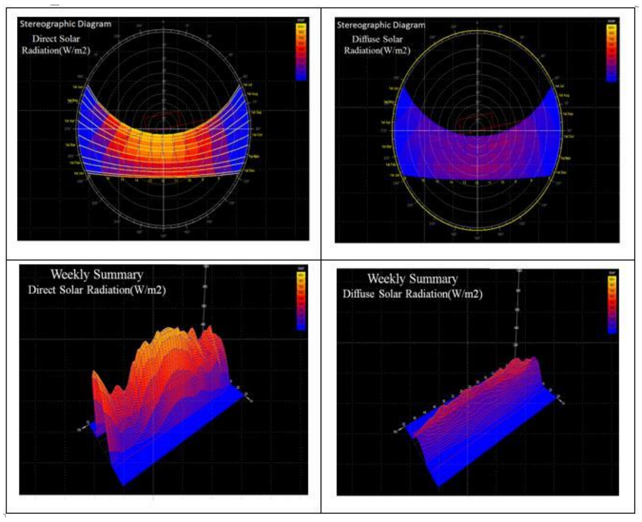

Fig .13. The Stereographic Diagrams represent the Direct Solar Radiation (W/m2) & Diffuse Solar Radiation (W/m2).

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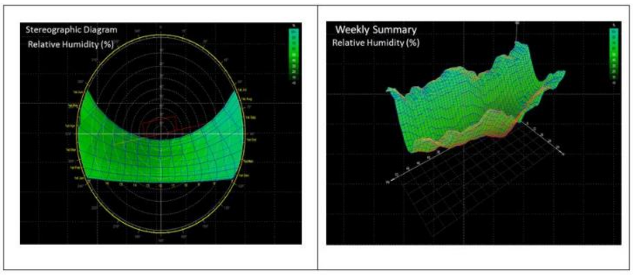

Fig .14. the Stereographic Diagrams represent the Relative Humidity.

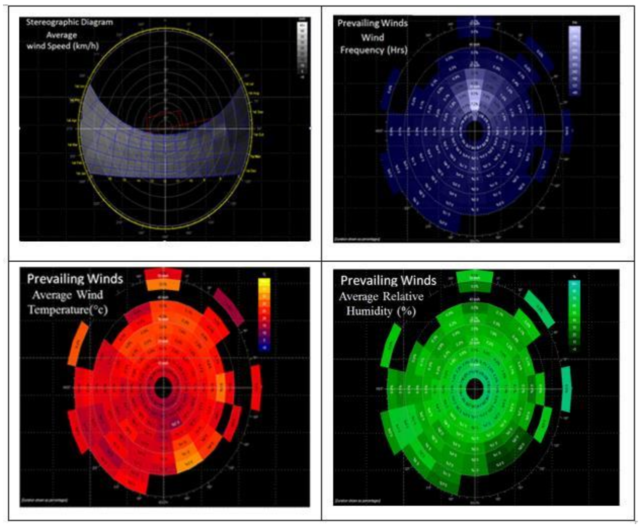

Fig .15. The Stereographic Diagrams represent the Prevailing Winds.

VIII. CONCLUSION

This paper presents a review on urban sustainability with the aim of Understanding key technical principles to be considered while planning for new neighborhoods. Sustainable neighborhoods evolution and initiatives are described, several design concepts related to sustainable urban forms are defined and their sustainability characteristics investigated. (Focusing on sustainability concepts under the triple bottom line of environmental, economic, and social dimensions) and practitioners.

Rapid urbanization has brought environmentally, socially, and economically great challenges to cities and societies. To build a sustainable neighborhood, these challenges need to be faced efficiently and successfully. In this regard, the first step of action is to determine the sustainability levels of neighborhoods. From this perspective, the literature points to a number of NSA tools. However, as the critique of these tools suggests they have limitations in their indicator systems and adaptation in the developing country context is challenging.

There are many approaches that aim to achieve sustainable urban forms. Different approaches use different scales
of concepts, as well as emphasizing some concepts over others. In practice, many local governments, planning consultants, landscape architects, and so on are grappling much more specifically with aspects of sustainable urban form through a variety of planning and design approaches and policies.

Different urban forms give differently to sustainability. Moreover, different planners and scholars may develop different combinations of design concepts to achieve sustainable development goals. They might come with different forms, where each form emphasizes different concepts. However, all should be forms that environmentally contribute beneficially to the planet for the present and future generations.

The ideal sustainable urban form according to the design concepts of sustainable urban form is that which has a high density and adequate diversity, compact with mixed land uses, and its design is based on sustainable transportation, greening, and passive solar energy. Ultimately, sustainable urban forms aim to achieve different objectives. The most prominent among them are decreased energy use, reduced waste and pollution, reduced automobile use, preservation of open space and sensitive ecosystems, and livable and community-oriented human environments.

The Five Principles are highly interrelated and support each other. High density provides the population and activity basis for a sustainable neighborhood; adequate street density is the material basis; mixed land-use and social mix shape the land use and social life in the neighborhood, and limited land use specialization is the first step towards mixed neighborhoods.

The Five Principles balance population growth, economic growth, rapid urbanization, sustainable urban development and other factors, and try to establish a new urban system. In this system, population and urban infrastructure accomplish economies of scale; diversified social networks and the diversity of land uses to support each other and develop together and urban space and urban dwellers live and develop in harmony.

Besides good planning and design decisions, the application of these principles also requires supporting legal frameworks, an analysis of the local society and economy, appropriate infrastructure technology and capacity, and the institutional capacity to enforce decisions.

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Hydrogen Through Water Electrolysis and Biomass Gasification for Application in Fuel Cells

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***Abstract* -** Hydrogen is considered to be one of the most promising green energy carrier in the energy storage and conversion scenario. Although it is abundant on Earth in the form of compounds, its occurrence in free form is extremely low. Thus, it has to be produced by reforming processes, steam reforming (SR), partial oxidation (POX) and auto-thermal reforming (ATR) mainly from fossil fuels for high throughput with high energy requirements, pyrolysis of biomass and electrolysis. Electrolysis is brought about by passing electric current though two electrodes to evolve water into its constituent parts, viz. hydrogen and oxygen, respectively. Hydrogen produced by non-noble metal catalysts for both anode and cathode is therefore cost-effective and can be integrated into fuel cells for direct chemical energy conversion into electrical energy electricity, thus meeting the sustainable and renewable use with low carbon footprint.

I. INTRODUCTION

Environmentally benign fuels, which can replace today's fossil based fuels, such as gasoline, oil and coal for combustion either in stationary or mobile applications is of utmost importance. One such fuel is hydrogen, which is considered to be the fuel of the future. Hydrogen is an energy carrier maintaining potential applications in many industrial processes such as fertilizers, petroleum refineries, food processing, bulk and specialty chemicals as well as power generation. Hydrogen plays an important role as a potential fuel for aviation, vehicles and domestic heating requirements either by direct combustion or in the so-called "cold combustion" as in fuel cells. Large scale introduction of hydrogen would mean a paradigm shift as a renewable energy carrier, leading to a substantial decrease of the greenhouse gases. Owing to its abundance in the form of compounds and complexes, it is estimated that over 75% of the mass of the universe is primarily hydrogen (1). The combustion product of hydrogen practically being water makes it to be highly important for clean and sustainable energy production. Since hydrogen is energy rich on weight basis (120 MJ/kg) compared to gasoline (44.4 MJ/kg) but poor on volumetric basis, large volumes of hydrogen has to be stored, handled and transported for application for example in vehicles with internal combustion engines or fuel cells. Therefore one of the daunting challenges for the introduction of hydrogen as a fuel is to find a safe method with high storage capacity and facile generation of the fuel, providing high energy efficiency, light weight and volume, predictable performance, fuel purity and economy.

II. HYDROGEN PRODUCTION

Global hydrogen production is estimated to be 50 million tons annually (2,3), where the main feedstock are fossil fuels, such as natural gas, hydrocarbons and coal. These processes are highly endothermic, implying high temperatures (>800 oC) and moderate pressures (20-30 bar), where a set of reaction steps such as desulfurization, high and low temperature shift reactions, methanation and adsorption are required for high purity hydrogen. Due to the carbon content contained in the fossil fuels, there is a stoichiometric emission of carbon and thereby increasing the concentration of greenhouse gases (GHG) to the atmosphere. Thus, electrochemical process of water splitting (electrolysis), where hydrogen in the cathode and oxygen in the anode are released is a sustainable solution, if electricity is generated from renewable energy resources.

The benefit of finding robust, stable and active electrocatalysts instead of the noble metals, which are scarce and highly expensive is a challenge for the production of hydrogen as a "green energy" source for application in industrial processes and fuel cells. Demand and supply constraints of Ru, Ir and Pt and platinum group metal alloys for application in large-scale electrolyzers would mean a decrease of the loadings by several factors and keeping intact the catalytic activity. Thus, there is a growing interest in replacing these electrocatalysts by non-precious and ample reserves of the transition metals. Herein we report the sponge-like and highly porous with significant surface area of the Ni-Al alloys leached out by KOH for this purpose. Two different electrochemical reactions for cathodic (hydrogen evolution) and anodic (oxygen evolution) configurations were studied by applying alloys of Raney-Ni catalysts, albeit with different compositions and doped with other metallic species. The gas diffusion electrodes (GDE), wet-proofed by PTFE were prepared by the rolling method in thicknesses of 0.5-07 mm and then tested in 6M KOH at 60-80 oC, where their polarization curves were assessed in durability tests. The role of catalyst additives is significant for lowering the overpotentials and the intrinsic activities of the respective electrodes to be able to serve for prolonged performances in alkaline electrolyzers.

III. FUEL CELLS FOR ELECTRIC GENERATION

The high efficiency, high power density, flexibility in size and installation area as well as environmentally friendliness of the fuel cells make them an attractive and alternative power sources for tractionary, portable, hybrid and stationary applications. There are five main types of fuel cells, which have the common advantages but yet are contending in cost, access in materials, performance and stability. Although the pros and cons of each type of fuel cell are to a large extent specific to the materials, electrolyte, operation temperature, purity or impurity of the oxidant, there are however, major distinguishing marks among them. Common to all fuel cells is, however the electrochemical oxidation of hydrogen at the anode and reduction of oxygen at the cathode resulting in the in the generation of electricity and heat as well as water.

The low temperature fuel cells, especially polymer membrane electrolyte fuel cell (PEMFC) and alkaline fuel cell (AFC) have both a relatively fast start-ups mainly due to the temperature regime in which they operate. PEMFC has shown high current densities and small weight and compact stacks due to the incorporation of the electrolyte in the polymer matrix. Not excepting that the noble metal price is high and less accessible for mass application in fuel cells, the loss of the activity is ascribed to the agglomeration and corrosion of the catalyst particles and hence decrease of the surface areas. The phosphoric acid (PAFC) as an intermediate temperature fuel cell was a frontrunner during the 80s and 90s but due to high loadings of platinum group metals as catalyst, this fuel cell has been phased out. The molten carbon fuel cell (MCFC) and solid oxide fuel cell (SOFC) operate at 500-600 oC and 900-1000 oC, respectively, both requiring robust materials and thermal stability.

Previous work (4) with wood charcoal and agro-residues of a producer gas integrated with fuel processing and gas clean-up laboratory demonstration unit (LDU) showed a successful production of hydrogen for operation in a 250 W AFC system. The integrated system was composed of a gasifier to generate producer gas, hydrogen enrichment through high temperature and low temperature shift reactors, gas cleaning units (sulfur, carbon dioxide and oxygen) and preferential oxidation of carbon monoxide. The hydrogen produced after the gasifier, having 3-6% vol.% after these steps increased to 20-30 vol.% to be fed to the fuel cell. Electrical efficiency from material and energy balances for the system producer gas to the AFC generator, based on lower heating value of wood to direct current was found to be 29% . Thus, the study showed that biomass gasification/pyrolysis can be integrated for production of electricity both in decentralized or as stand-alone fuel cell power generators.

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Application of the Fuzzy Computational Intelligence in Power Quality Data Management

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Abstract - In Electrical Power Distribution System the sustained availability and quality of electric power are the main challenge they need to satisfy so overcoming the power quality (PQ) degradation became an asset. This Paper addresses the perfect load management using the computational techniques by analyzing the data of the system taking into account the density of the feeding nodes and its distribution also the classification of major Power quality degradations such as power factor and harmonics in the System and The methodology will be illustrated, simulated and evaluated using the fuzzy technique clustering the data and on an Artificial Neural Network (ANN) to achieve the optimum utilization of the energy loads and perfect load management and optimization. Simulation results demonstrate the effectiveness of the proposed algorithm in reducing the power and energy losses, improving the quality of the electric power system.

Keywords - Power Quality Degradaion; fuzzy technique; Artificial Neural Network.

I. INTRODUCTION

The power quality is an important issue to maintain the stability of the Electric Power Distribution System (EPDS) and its instability due to any kind of disturbance leads to malfunction of the end user devices or the complete outage in the Energy distribution system.

The degradation in quality of power is mainly caused by disturbances such as voltage swell, voltage sag, notch, transients, and harmonic distortions and mainly the non-linear loads that draw harmonic currents, and as a consequence, harmonic voltages are generated whenever the harmonic current flows through the impedance of the system which are the main cause of power quality (PQ) degradation leading not only to the (PQ) degradations or temporary interruption but also to ultimately complete outage of EPDS[1].

The power quality became more important to maintain the power system and so the exact and fast detection of the disturbances created the need to have a precise system that detect the time and duration of the occurrence of the disturbance analyzing the data of the PQ field and classifying them according to the rate of occurrence and their effect on the Quality of the network.

Soft computing techniques like the fuzzy logic, neural networks or combination of them are used to design an intelligence system. The fuzzy logic used for reasoning while neural networks provide algorithms for learning, classification, and optimization [2], although there are substantial areas of overlap between neural networks, FL, and probabilistic reasoning.

Modern spectral and harmonic analysis is based on Fourier based transforms. However, these techniques are less efficient in tracking the signal dynamics for transient disturbances. Consequently, The wavelet transform has been introduced as an adaptable technique for non-stationary signal analysis. Different power quality disturbances are classified by a unique energy distribution pattern based on the difference of the discrete wavelet coefficients of the analyzed signal and a pure sine wave. [4]. Also the S-transform algorithm and continuous wavelet transform (CWT) are time frequency algorithms powerful in detection and classification of PQ disturbances as in [5] comparing the effect of each on different categories of disturbances. As proposed in [6] the power quality disturbance recognition system contain three main components which are a simulator to generate the power quality disturbances and the detector which used the DWT to detect the power signal disturbances and the neural network architecture to classify the disturbances with increases the accuracy of detection.

In this paper we propose a technique that analyzes the PQ data of the system under consideration Taking into account the Power factor and peak hour table in EPDS to predict the undesired PQ disturbance in the system. This will provides power system engineers to formulate intelligent strategy for efficient power system operations. The proposed algorithm incorporates multi-band wavelet transformation and the modern computation intelligent approaches like fuzzy technique and the artificial neural network.

This paper is organized as follows In the first section we present a review of related work, In Section 2 we clarify different sources of major power degradations like the power factor and the harmonics and their classification, In Section 3 presents some fundamental Techniques used in our algorithm like the fuzzy technique . Section 4,we describe the proposed algorithms for the power quality disturbance detection. Section 5, we report the effectiveness of our method and compare results of each algorithm used; At last conclusion of this paper will be drawn in Section 6.

II. CLASSIFICATION OF MAJOR POWER QUALITY DEGRADATION

The power quality term PQ can be defined as voltage quality with reference to slow variation in voltage magnitude and to indicate the existence of an adequate and secure power supply.

The patterns of voltage or PQ disturbances need to be identified for preventive action in order to avoid the problem in the electrical system and the cause of any deviation from the ideal waveform. PQ disturbances/events cover a broad frequency range with significantly different magnitude variations and can be non-stationary, thus, accurate techniques are required to identify and classify these disturbances [3].

- Most of the PQ problems fall into those two basic categories:-

A. Non steady state variation

which is the abnormality in the voltage or the current Transient voltages may be detected when the peak magnitude exceeds a specified threshold. RMS voltage variations (e.g., sags or interruptions) may be detected when it exceeds a specified level. This is classified according to the nature of the waveform distortion. For non steady state disturbances, other attributes such as rate of rise, rate of occurrence and energy potential are useful.

B. Steady-State Variations

Steady state variation is basically a measure of the magnitude by which the voltage or current may vary from the nominal value, plus distortion and the degree of unbalance between the three phases. These include normal rms voltage variations, and harmonic and distortion. For steady-state disturbances, the amplitude, frequency, spectrum, modulation, source impedance, notch depth and notch area attributes can be utilized.

- Power factor

The power factor is (P.F) is a relation between the actual power and the apparent power as given by equation (1)

$$P.F = \cos \Phi \qquad (1)$$

The voltage unbalance contributes to poor power factor in EPDS with the increase of non-linear loads also as a result of the voltage unbalance between the three phases.

As most of the distribution companies impose a penalty to its customers if **THEIR** loads contributes towards poor power factor so we need to monitor the power factor at the industrial customers to force them to take all adequate steps to maintain their power factor close to unity.

- Harmonics

Harmonic distortion is in the voltage and the current waveforms in power distribution networks as in equations 2 and 3 where Vh and Ih are the amplitude of the voltage and the current at the harmonic component and Vrms and Irms are the root mean square values of voltages and currents for the non-sinusoidal waveforms [9]

$$V_{rms} = \sqrt{\sum_{h=1}^{h_{max}} \left(\frac{1}{\sqrt{2}} V_h\right)^2} = \frac{1}{\sqrt{2}} \sqrt{(V_1^2 + V_2^2 + V_3^2 + .. + V_{h_{max}}^2} \quad (2)$$

$$I_{rms} = \sqrt{\sum_{h=1}^{h_{max}} \left(\frac{1}{\sqrt{2}} I_h\right)^2} = \frac{1}{\sqrt{2}} \sqrt{(I_1^2 + I_2^2 + I_3^2 + .. + I_{h_m}^2} \quad (3)$$

The total harmonic distortion (THD) is a measure of the harmonic equipment in a distorted wave as in equation 4.

$$THD = \frac{\sqrt{\sum_{h>1}^{h_{max}} (M_h)^2}}{M_1} \quad (4)$$

Where M_h is the root mean square value of the harmonic component.

The power Distribution network is ideally designed to tackle sinusoidal voltage and current waveforms and the existing power distribution network design is only capable of absorbing harmonic distortion to a certain limit. [10] And the extensive use of the non-linear loads that the conventional power system not designed to accept it that increases the power quality disturbances so we need fast and intelligent methods to detect theses disturbances like the methods will be mentioned later.

III. FUZZY LOGIC SYSTEM

The Fuzzy logic poses the ability to mimic the human mind to effectively employ modes of reasoning that are approximately rather than exact especially in decisions or action that are based on precision and certainty [7] .

Zadeh [11] introduced the term fuzzy logic which described the mathematics of fuzzy set theory (1965) indicating that there was a third region beyond True and False by declaring the fuzzy set that allows partial membership which is an extension of a crisp set that allows only full membership or no membership at all.

In designing the fuzzy inference system, membership function is essentially the curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. Various types of membership functions are used, including triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions and the fuzzy inference systems consist of if–then rules that specify a relationship between the input and the output fuzzy sets .

As shown in Figure 1 the fuzzy inference system (FIS) essentially defines a nonlinear mapping of the input data vector into a scalar output, using fuzzy rules. The mapping process involves input/output membership functions, FL operators, fuzzy if–then rules, aggregation of output sets and defuzzification.

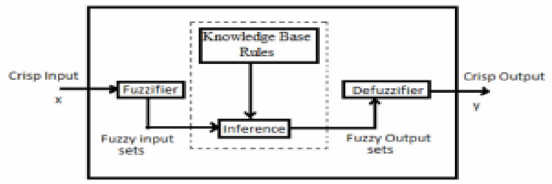

Fig.1. Block Diagram of the Fuzzy Inference system

IV. THE PROPOSED ALGORITHM

To minimize power quality disturbances and to devise suitable corrective and preventive measures, efficient detection and classification techniques are required in the emerging power systems. As the recent development in the technologies of the signal processing and the artificial intelligence we were able to develop more accurate system based on these new techniques.

The First step is to develop or pick a suitable method for the detection of the PQ Degradations which is the wavelet transforms based on the norm-entropy based feature extraction which is an ideal tool for non-stationary signals and the classification of theses degradations such as the interruption, the waveform distortions, harmonics, sags, swells, then clustering these data into our system with the power factor measurements and the peak hour table and major power quality degradation like the harmonics using the fuzzy technique and the artificial neural network specifying the rules that enable us to detect the disturbances and hence the perfect optimization of the energy loads.

A. Feature Extraction and Detection of (PQ) Disturbances using DWT

The Wavelet domain is a promising domain as it is a frequency domain technique. DWT is more preferable for detection of time-frequency variations as it employs a short window for high frequency components and long window for low frequency components which provides the best time frequency resolution to detect the all Power quality disturbances.

The Wavelet transform uses wavelet function as the

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basis function which scales itself according to the frequency under analysis. As it uses the mother wavelet function ψ which will generate the high frequency components (detail) and scaling function ϕ which will generate the low frequency components (approximation) to perform simultaneously the multi resolution analysis decomposition and later the reconstruction of the signal.

The wavelet function is defined as follows:

$$f(x) = \sum_{i,j} c_{i,j} \Psi_{i,j}(x) \tag{5}$$

Where ψi,j(x) are the wavelet expansion function and the two parameter expansion coefficients ci,j are the discrete wavelet transform coefficients of f(x) where j is the translation and i is the dilation parameter

$$C_{i,j} = \int_{-\infty}^{\infty} f(x)\psi_{i,j}(x)$$

(6)

The mother wavelet is related to the scaling function as follows:

$$\Psi(x) = \sqrt{2}\sum g(k)\ \phi(2x-k)$$

(7)

And

$$g(k) = (-1)k\ h(1-k)$$

(8)

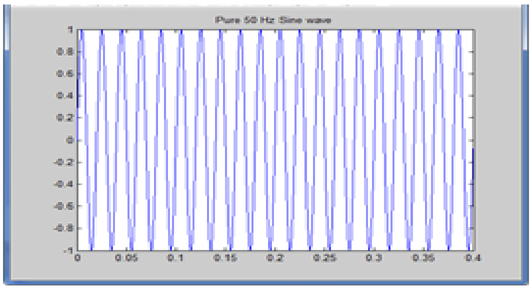
where g and h are the filter coefficients of half- band low-pass and high-pass filters.

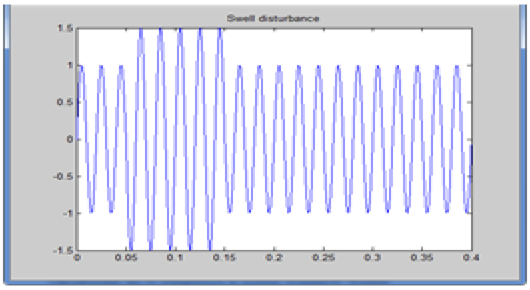
As the wavelet transform uses a time- window function that changes in frequency as the mother wavelet is scaled and translated to provide information in the frequency and the time domain not like the STFT where the window function is fixed.

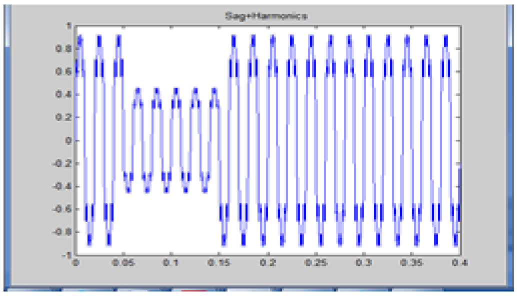
Using the sub band coding in the WT the signal is decomposed into different frequency levels and presented as wavelet coefficients. Depending on the types of signal, continuous wavelet transforms (CWT) or discrete wavelet transform (DWT) are employed.

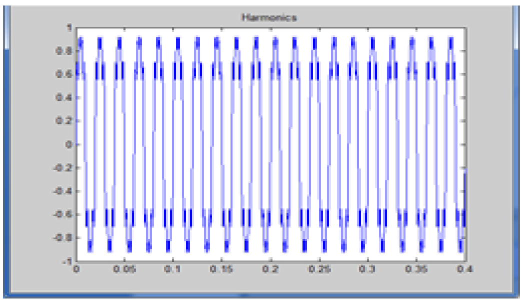
The waveforms in fig 2 generated using the MATLAB indicating 6 types of disturbances which are sag, swell, interruption, harmonics, sag-harmonics, swell -harmonics.

The statistical parameters used for Power quality disturbance detection are the sample mean and variance and wavelet entropy so comparing the original power signal without disturbance and signal with disturbance the disturbance type can be detected.









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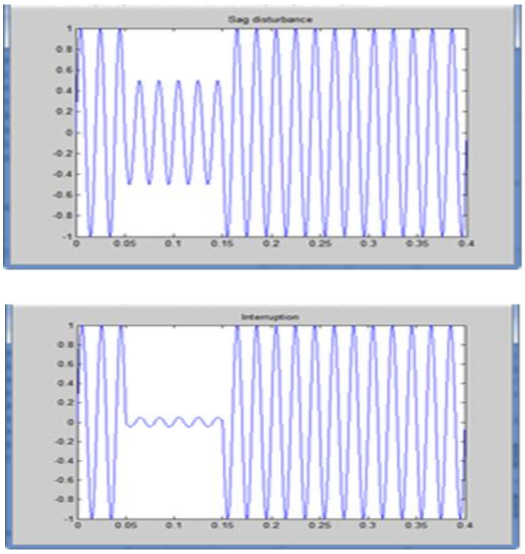
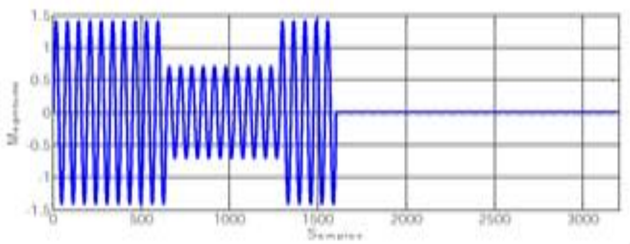
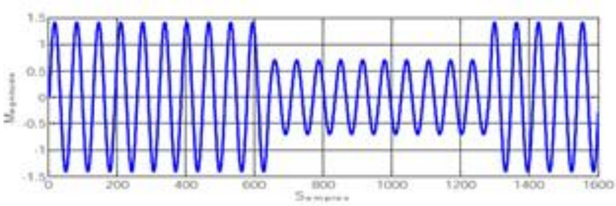


Fig .2. Different Types of PQ Disturbances

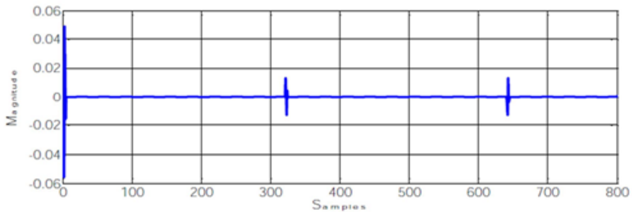
Multiresolution analysis leads to a hierarchical and fast schema and this can be implemented by a set of successive filter banks until the fourth level of decomposition and then reconstruction of the signal as we have done here in this algorithm. One approximation level which contains the fundamental frequency component and 4 detail levels that is the high frequency component which shows the abrupt change it the discontinuities to show the start and the end point of the disturbance as shown in fig.3 for a sample of disturbance "voltage sag disturbance".



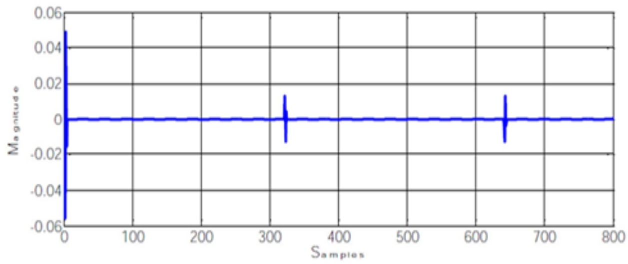
Decomposed voltage sag level 1 using WT



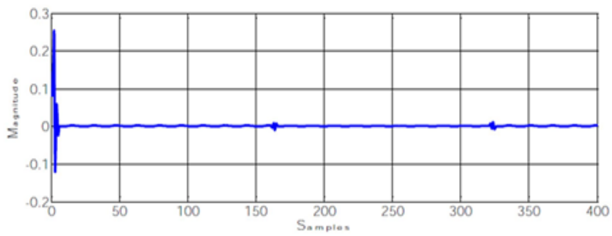
Approximate Signal level 1



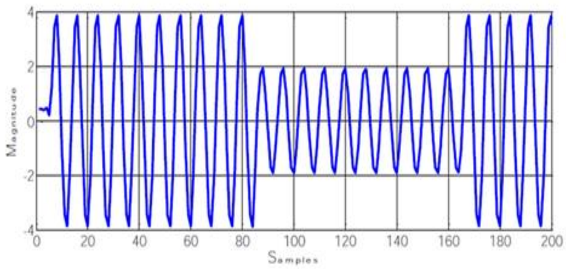
Detail Signal level 1



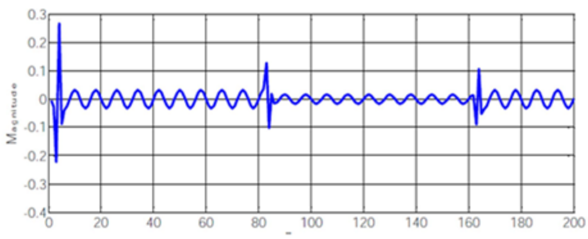
Detail Signal level 2



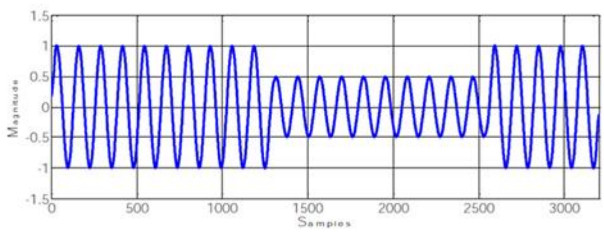
Detail signal level 3



Approximate signal level 4



Detail signal level 4



Reconstructed approximate signal

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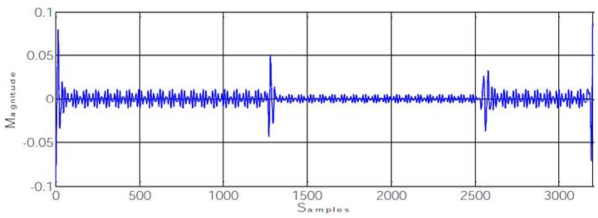

Reconstructed detail signal

Fig. 3. Feature Detection of a disturbance using the wavelet transform for the voltage sag

The norm–entropy based feature extraction based on the measure of the irregularities of states such as the uncertainty or the irregularity of the signal.

The norm entropy values for detail and approximation coefficients in each decomposition level from wavelet transform for different disturbances calculated as follows:

$$W_d = \frac{1}{N_j}\sum_n |d_j[n]|^P \quad , \quad W_{aj} = \frac{1}{N_j}\sum_n |a_j[n]|^P$$

(j=1,2,….,j) *(9)*

The wavelet Entropy Wsignal is a positive real number ,j is the number of resolution levels. And the pure signal is used as a reference to distinguish disturbances from each other so we subtract the wavelet entropy of the pure sine of the wavelet entropy of the disturbance and as declared in fig.

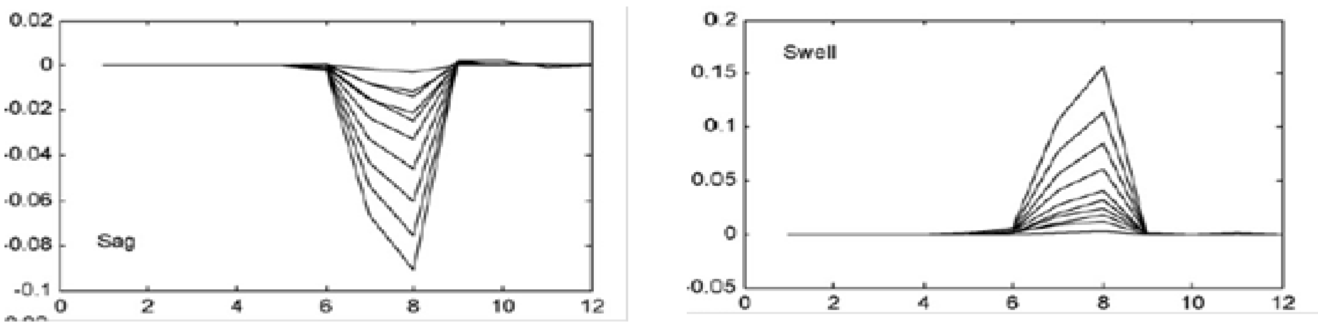

Fig .4. The norm Entropy for some PQ disturbances

$\Delta W = W_{\text{disturbed}}$ signal $- W_{\text{pure signal}}$ *(10)*

DWT based decomposition is applied in for different PQ disturbances such as Sag, Swell, Interruption, Sag with harmonics and Swell with harmonics are generated using MATLAB and then decomposed using decomposition algorithm of WT and type of disturbance is detected.

B. Classification using the fuzzy clustering technique

The fuzzy clustering technique is based on two main blocks the first one is the wavelet feature extraction which work by extracting the different feature through the wavelet transform as declared in the previous section then the second block which the fuzzy inference system that maximize the accuracy of the detection and classifying the PQ disturbances into clusters as the decision boundaries of disturbances may overlap we need to detect and classify the events overlap by the setting the fuzzy rules. Identifying the features of the membership function that used to identify the disturbances using the least number of features achieving the effective classification of PQ events.

The rule of the artificial intelligence technique (Fuzzy Logic) is a measure of the degree of similarity of PQ disturbances and the total distorted signal energy of the signal is compared to the corresponding pure signal. As mentioned above the Fuzzy logic block consists of the fuzzy inputs which are the feature extracted with the wavelet transform which are the norm entropy and the power factor and the Peak hour table and forming the fuzzy rules as follows :-

Considering the range for Power factor is from 0 to 1 and the values are high, medium and low, Rush hour

values are Peak as P or moderate M or low L.

Rule 1:- if norm entropy is medium and Power factor is high and Rush hour is L Then the PQ disturbance is Normal pure signal

Rule 2:- if norm entropy is low and Power factor is high and Rush hour is L Then the PQ disturbance is sag.

Rule 3:- if norm entropy is high and Power factor is high and Rush hour is H Then the PQ disturbance is swell.

Rule 4:- if norm entropy is medium and Power factor is medium and Rush hour is H Then the PQ disturbance is harmonic.

Rule 5:- if norm entropy is low and Power factor is medium and Rush hour is L Then the PQ disturbance is sag + harmonics.

Rule 6:- if norm entropy is high and Power factor is medium and Rush hour is H Then the PQ disturbance is swell + harmonics.

Rule 7:- if norm entropy is low and Power factor is low and Rush hour is H Then the PQ disturbance is Interrupt.

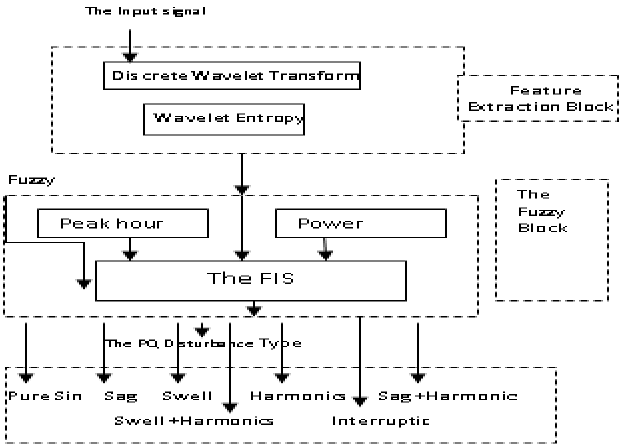

Fig. 5. The structure of PQ Disturbance Classification based on the WT and the fuzzy Logic

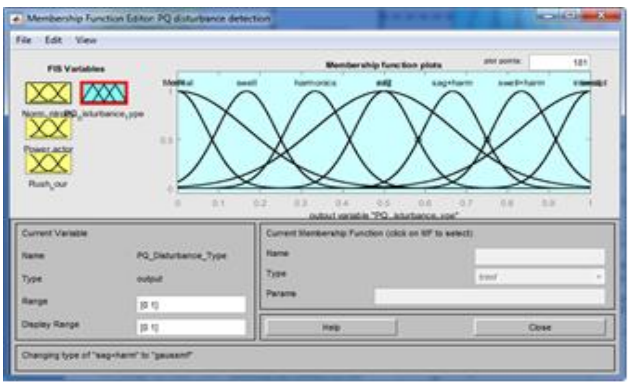

Fig .6. The FIS For the membership functions of the PQ disturbance detection

In the FL algorithm we used 100 signal for detection and classification and the classification result is shown in table 1 using the parameters of the power factor and the peak hour table so the fuzzy logic is able to detect and classify the power quality disturbance accurately.

C. Classification through Multilayer Feed forward Neural Network (MFNN)

Neural networks are simplified model of the biological nervous system as it's a highly interconnected network of a large number of processing elements (PEs) called neurons that composes the topology of the Artificial Neural Network (ANN) and the learning process is done by being trained on some examples by giving data to acquire knowledge about the problem, the neural networks adopt various learning mechanisms of supervised and unsupervised learning [8].

Artificial Neural Network are characterized by the number of
interconnections and the node characteristics that are classified by the kind of learning rules has been employed and the type of non-linear elements has been used.

Artificial Neural Networks (ANN) approaches have been developed to solve problems in power plants and power systems using the process identification, sensor validation, monitoring and fault diagnosis, in power plants, and security assessment, load identification, load modeling, forecasting and fault diagnosis, in power systems.

As in our algorithm using the wavelet and neural network combine the aspects of the wavelet transformation which works on the frequency domain for the purpose of feature extraction and selection and the characteristic decision capabilities of neural network approaches.

Probabilistic Neural Network for classification of PQ events based on the features extracted from the detail coefficients through decompositions.

We used an artificial neural network with 3 layers as the inputs are the feature extracted using the wavelet transform (feature extraction block) and the output specifies the class of disturbance using multiple instances of the original waveform signal as a test pattern and multiple instances of the various types of disturbances as a training set for the neural networks.

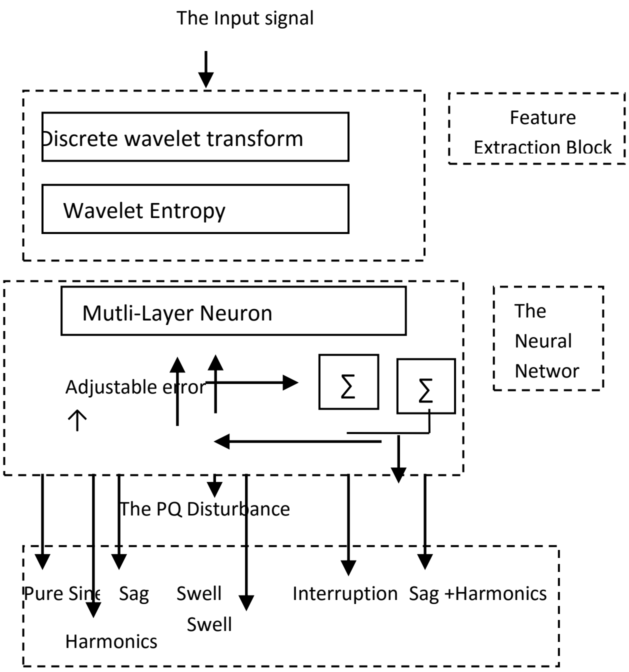

Fig. 7.Architecture of the PQ Disturbance Classification Using WT and ANN

The structure of the network is a 3- layered neural ne network architecture with sigmoid activation function and error back propagation for supervised learning as the inputs are the features extracted from wavelet transform and other factors feed like the density of the feeding nodes and its distribution also the power factor and the peak hour table and the 7 classes of power quality disturbances as the output of the NN and 100 signal is used for training the network to be adjusted according to its error and another 100 for testing the algorithm to measure the network performance after training.

V. SIMULATION RESULTS AND EVALUATION

The classification was done with power quality disturbance signals simulated by MATLAB version R2015a. The classes include the voltage sag, voltage swell, harmonics, sag with harmonics, swell with harmonics and the interrupt.

Table 1. CLASSIFICATION RESULT

CLASS	CLASSIFICATION %	
	FUZZY LOGIC	ARTIFICIAL NEURAL NETWORK SUBHEAD
SAG DISTURBANCE	98	97
SWELL DISTURBANCE	97	96
HARMONIC DISTURBANCE	94	95
HARMONIC+ SAG	95	96
HARMONIC+ SWELL	94	95
INTERRUPT	98	97

The results proved that the two systems are effective in detecting the PQ disturbances but in the neural network algorithm there is no rule to determine the data required for the training of each disturbance types and if more data available for training it will give better accuracy but will increase time to train the network And the rules of the fuzzy technique not adaptable according to the variation in data.

VI. CONCLUSION

In this paper we proposed two algorithms for the fast and accurate detection of the power quality disturbance detection based on the intelligent computing techniques and the Multi-resolution analysis. The algorithms are the fuzzy logic and the neural network and both of them depends mainly on detecting the features using the wavelet transform.

Fuzzy logic system has strong inference capabilities of expert system as well as power of natural knowledge representation. But the rules are based on the human experience and expertise. A membership function provides a measure of the degree of similarity of an element in the fuzzy subset. And we can't modify the membership function. So The rules of the fuzzy algorithm should be updated and weighting factors in the fuzzy sets should be refined by using the Neural networks.

In the artificial neural network the classification accuracy increases by increasing the number of inputs applied to it but as the architecture of the neural network is getting more complex the computational complexity increases too.

We might think of using a hybrid system incorporating the learning capabilities of ANN and excellent knowledge representation and inference capabilities of fuzzy logic that have the ability to self modify their membership function to achieve the desired performance.

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Modified Open Loop Control of a Matrix Converter Connected to Wind Energy System

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***Abstract* -** wind energy conversion system (WECS) is bit by bit gaining interest as a suitable source of renewable energy. In this paper a direct AC-AC matrix converter is utilized to interface an isolated static load fed from WECS. A self-excited induction generator is utilized as it has many advantages in terms of ease of maintenance, self-protection against short circuits. This paper proposes a modified open loop control of matrix converter with indirect space vector modulation. The modified open loop provides constant output voltage and constant frequency even if the wind speed changed. Matrix converter (MC) is used rather than AC-DC-AC converter as it eliminates the bulky capacitors. Finally, simulation results for different operating points are displayed which are consistent with the expected results.

I. INTRODUCTION

Due to the continuous demand on electrical energy and environmental concerns, a lot of exertion is being made to create power from renewable sources of energy. The advantage of using renewable sources is absence of harmful emissions. Wind generators have been generally utilized in autonomous systems for feeding loads which fall outside the scope of the electrical network. There are two types of WT horizontal axis configuration or vertical axis configuration [1].As a result of the numerous advantages of using a self-excited induction generator in converting the captured mechanical energy from WT made it suitable for use in small and medium size WECS. Due to the low cost of SCIG compared to other types of electric machines make it suitable for isolated load application of WECS. SCIG also have the ability of self –protection against short circuits and doesn’t require routine maintenance . AC can be directly converted to AC with different voltage rms value and different frequency by using a MC without using any DC link[2,3]. And this is the bold feature of MC over rectifier-inverter converter, so MC can be considered an emerging alternative to the conventional rectifier- inverter converter [4-7]. Independent control on the output voltage magnitude and frequency can be provided by utilizing a MC. In addition to control the phase angle between input voltage and input current and unity input displacement factor can be achieved. Due to MC has a faster dynamic response, MC –based on WECSs has higher efficiency than conventional one. This paper introduces a static R-L load controlled by using a MC fed from WECS as shown in Fig. 1.This paper proposes a modified open loop control to provide constant output voltage and constant frequency even if the wind speed changed. First, a short description of WT is introduced, in addition to demonstrate how the wind energy can be ideally caught and changed over to electric energy. Secondly, a short description on operation of a SCIG is introduced. Third, indirect space vector control of matrix converter is presented. MC is used to control load voltage and frequency. Fourth modified open loop control of matrix converter is introduced. Finally, simulation results for different operating points are displayed.

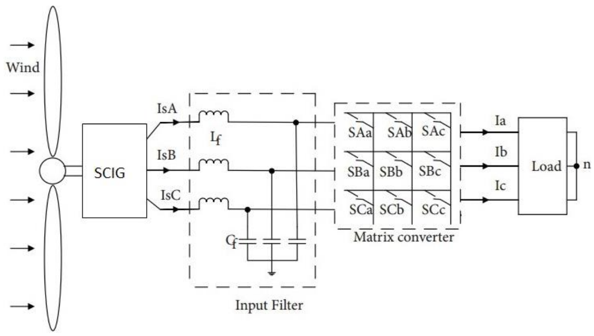


Fig. 1. matrix converter fed from wind turbine

II. WIND TURBINE

The produced mechanical power from turbine is given by (1).

$$P_m = \frac{1}{2}\rho c_p A_r v_w^3 \qquad (1)$$

$$c_p(\lambda,\theta) = 0.73\left(\frac{151}{\lambda_i} - 0.58\theta - 0.002\theta^{2.14} - 13.2\right)e^{\frac{-18.4}{\lambda_i}} \quad (2)$$

$$\lambda_i = \frac{1}{\frac{1}{\lambda-0.02\theta} - \frac{0.003}{\theta^3+1}} \quad (3)$$

$$\lambda = \frac{\omega_r R_r}{v_w} \quad (4)$$

Where P_m represents the generated power, v_w is the wind speed in m/s, ρ is the air density in g/m^3, A_r the turbine rotor area in m^2, ($A_r = \pi R_r^2$, where R_r is the rotor blade radius) and, c_p a power coefficient. The power coefficient can be calculated as a function of tip speed ratio and rotor blade pitch angle θ according to (2) ω_r is the angular speed of the turbine shaft in rad/s. In this paper assumes a fixed rotor pitch angle (θ=0). The previous four equation give, the generated mechanical power by the wind turbine at a given wind velocity is a function of the shaft speed. Figure 2 demonstrates the generated mechanical power with turbine speed at various wind velocity [1].

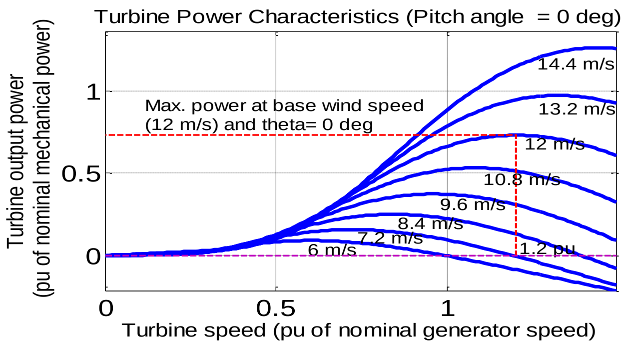


Fig. 2 mechanical power with turbine spee

III. INDUCTION GENERATOR

Induction machine can be utilized as an induction generator as well as induction motor without making any internal modification. Reactive power required for induction generator can be achieved by connecting a capacitor bank across the stator terminals. When the rotor is rotated by a speed greater than synchronous speed, a little voltage is produced over the stator terminals because of residual magnetism. A capacitor current will be produced due to this small generated voltage, and reactive power which required for magnetization will increase. Induction generators are suitable in wind turbines as they produce valuable power even at different rotor speeds. Neither commutator nor brush arrangement is required for Induction generators compared to synchronous generators. Figure 3 shows the equivalent circuit of induction generator [1].

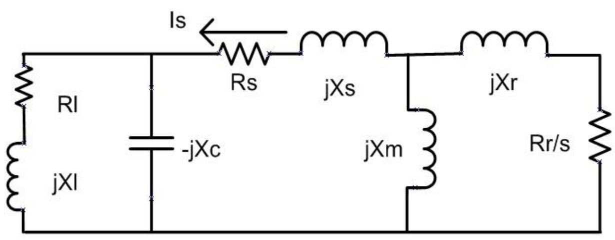


Fig. 3 one phase equivalent circuit of induction generator

$$\begin{Bmatrix} V_s^{abc} \\ 0^{abc} \end{Bmatrix} = \begin{bmatrix} r_s^{abc} & 0 \\ 0 & r_r^{abc} \end{bmatrix} \begin{Bmatrix} i_s^{abc} \\ i_r^{abc} \end{Bmatrix} + \frac{d}{dt}\begin{Bmatrix} \lambda_s^{abc} \\ \lambda_r^{abc} \end{Bmatrix}$$

$$V_s^{abc} = \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix}, \quad V_r^{abc} = \begin{bmatrix} v_{ra} \\ v_{rb} \\ v_{rc} \end{bmatrix}, \quad i_s^{abc} = \begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix}, \quad i_r^{abc} = \begin{bmatrix} i_{ra} \\ i_{rb} \\ i_{rc} \end{bmatrix}$$

$$r_s^{abc} = \begin{bmatrix} r_s & 0 & 0 \\ 0 & r_s & 0 \\ 0 & 0 & r_s \end{bmatrix}, \quad r_r^{abc} = \begin{bmatrix} r_r & 0 & 0 \\ 0 & r_r & 0 \\ 0 & 0 & r_r \end{bmatrix}$$

$$L_{ss}^{abc} = \begin{bmatrix} L_{ss}+L_{ls} & L_{sm} & L_{sm} \\ L_{sm} & L_{ss}+L_{ls} & L_{sm} \\ L_{sm} & L_{sm} & L_{ss}+L_{ls} \end{bmatrix},$$

$$L_{rr}^{abc} = \begin{bmatrix} L_{rr}+L_{lr} & L_{rm} & L_{rm} \\ L_{rm} & L_{rr}+L_{lr} & L_{rm} \\ L_{rm} & L_{rm} & L_{rr}+L_{lr} \end{bmatrix}$$

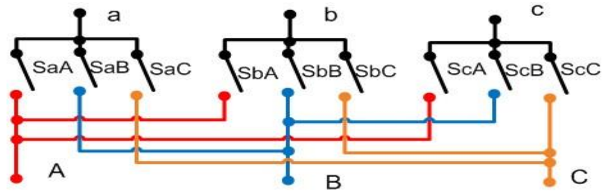
$$L_{sr}^{abc} = \{L_{rs}^{abc}\}^t =$$

$$L_{sr}\begin{bmatrix} \cos\theta_r & \cos(\theta_r + \frac{2\pi}{3}) & \cos(\theta_r - \frac{2\pi}{3}) \\ \cos(\theta_r - \frac{2\pi}{3}) & \cos\theta_r & \cos(\theta_r + \frac{2\pi}{3}) \\ \cos(\theta_r + \frac{2\pi}{3}) & \cos(\theta_r - \frac{2\pi}{3}) & \cos\theta_r \end{bmatrix} \quad (5)$$

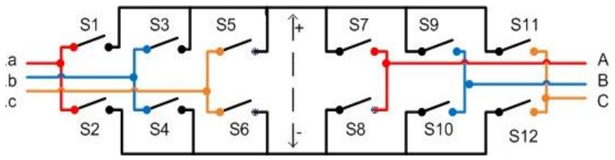
Where, r_s: resistance of the stator winding, r_r: resistance of the rotor winding , L_{ss}: self-inductance of the stator winding, L_{sm}: Mutual inductance between stator winding, L_{rr}: self-inductance of the rotor winding, L_{rm}: Mutual inductance between rotor winding, L_{sr}: Maximum value of Mutual inductance between stator and rotor winding, L_{ls}: Leakage inductance of stator winding, The required capacitance value for exciting SCIG was calculated as in [8,9].

IV. MATRIX CONVERTER

MC consists of a nine bidirectional switches which provide a direct connection between the three phase input voltage to the load without utilizing any dc link so MC can be manufactured in a simple and a compact form as shown on Fig. (4.a). . In 1976 Gigi and Pelly introduce the first principle of a MC.The first mathematical form of MC was introduced in 1980 by Venturini and switches are the primary disadvantage of this converter [10-15].



(a)



(b)

Fig .4: (a) Direct MC , (b) Indirect virtual DC-link MC

A. MATRIX CONVERTER CONTROL

This paper use indirect space vector control to control MC. MC consists of nine bidirectional switches which allow connection all input lines to all output lines. Indirect space vector control deals with MC as a rectifier-inverter with virtual DC link as in Fig. (4.b) which consists of two stages first is rectifier based on switches S1-S6, second is Inverter which has a three phases voltage source topology based on six switches S7–S12 [16].

$$V_{DC} = E * V_{abc}\,,\, V_{ABC} = N * V_{DC}$$

$$V_{ABC} = \mathrm{N} * \mathrm{E} * V_{abc}\,,\ \mathrm{K} = \mathrm{N} * \mathrm{E} \tag{6}$$

$$E = \begin{bmatrix} S_1 & S_3 & S_5 \\ S_2 & S_4 & S_6 \end{bmatrix}, \quad N = \begin{bmatrix} S_7 & S_8 \\ S_9 & S_{10} \\ S_{11} & S_{12} \end{bmatrix},$$

$$K = \begin{bmatrix} S_{aA} & S_{bA} & S_{cA} \\ S_{aB} & S_{bB} & S_{cB} \\ S_{aC} & S_{bC} & S_{cC} \end{bmatrix} \tag{7}$$

$$\begin{bmatrix} S_{aA} & S_{bA} & S_{cA} \\ S_{aB} & S_{bB} & S_{cB} \\ S_{aC} & S_{bC} & S_{cC} \end{bmatrix} = \begin{bmatrix} S_7 & S_8 \\ S_9 & S_{10} \\ S_{11} & S_{12} \end{bmatrix} \begin{bmatrix} S_1 & S_3 & S_5 \\ S_2 & S_4 & S_6 \end{bmatrix} \tag{8}$$

Where N, E and K represent inverter, rectifier and MC transfer function respectively. This strategy deal with MC as a rectifier-inverter converter so space vector of the inverter output voltage and space vector of rectifier input current can be decoupled to control direct MC[17]. As shown in (4) the output phases can be compounded by the product and sum of input phases through rectifier and inverter switches $S_1 - S_6$ and $S_7 - S_{12}$ respectively. The first row of the matrix in (10) show how to obtain output phase A from input phases a, b and c for direct MC using ISVM [18].

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \begin{bmatrix} S_7 & S_8 \\ S_9 & S_{10} \\ S_{11} & S_{12} \end{bmatrix} \begin{bmatrix} S_1 & S_3 & S_5 \\ S_2 & S_4 & S_6 \end{bmatrix} \begin{bmatrix} \mathrm{V_a} \\ \mathrm{V_b} \\ \mathrm{V_c} \end{bmatrix} \tag{9}$$

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \begin{bmatrix} S_7S_1 + S_8S_2 & S_7S_3 + S_8S_4 & S_7S_5 + S_8S_6 \\ S_9S_1 + S_{10}S_2 & S_9S_3 + S_{10}S_4 & S_9S_5 + S_{10}S_6 \\ S_{11}S_1 + S_{12}S_2 & S_{11}S_3 + S_{12}S_4 & S_{11}S_5 + S_{12}S_6 \end{bmatrix} * \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \tag{10}$$

The switches of inverter can have only eight allowed combinations, to avoid short circuit on DC link. These eight permitted combinations is classified into six active nonzero output voltage vectors $V_1 - V_6$ two zero output voltage vectors V_0 as in Fig. 5(a). For virtual rectifier there are allowed nine switching combinations to avoid an open circuit in rectifier. These nine combinations are divided into six active nonzero input current vectors $I_1 - I_6$ and three zero input current vectors I_0 as shown in (Fig. 5(b)). The duty cycles d_α and d_β of active vectors V_α and V_β respectively for the reference voltage vector V_O^* within a sector of the voltage hexagon can be derived from Fig. (6.a) [19].

$$V_o^* = d_\alpha V_\alpha + d_\beta V_\beta + d_z \mathrm{V_z} \tag{11}$$

$$d_\alpha = \frac{T_\alpha}{T_s} = m_v . \sin\left(\frac{\pi}{3} - \theta_v\right) \tag{12}$$

$$d_\beta = \frac{T_\beta}{T_s} = m_v . \sin(\theta_\mathrm{v}) \tag{13}$$

$$d_z = \frac{T_z}{T_s} = 1 - (\ d_\alpha + d_\beta) \tag{14}$$

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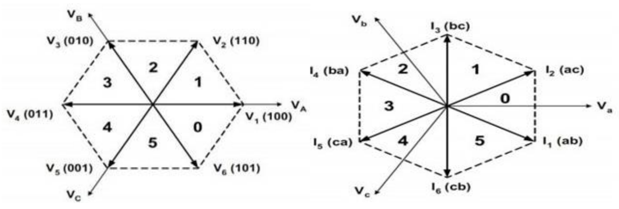
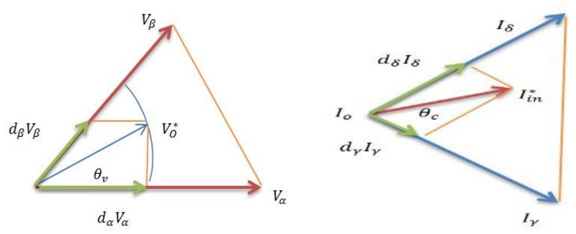


(a) (b)

Fig.5. Hexagon of (a) the inverter, (b) the Rectifier



(a) (b)

Fig. 6. Composition of reference: (a) output voltage vector (b) input current vector

Where, T_α, T_β *and* T_z are the total duration times of the vectors V_α, V_β *and* V_z. The I_{IN}^* can be obtained by impressing the adjacent active vectors I_γ and I_δ with the duty cycles d_γ *and* d_δ respectively as shown in Fig. (6.b). [1,2]

$$I_{IN}^* = d_\gamma I_\gamma + d_\delta I_\delta + d_{oc} I_0 \qquad (15)$$

$$d_\gamma = m_c.\sin\left(\frac{\pi}{3} - \theta_c\right) \qquad (16)$$

$$d_\delta = m_c.\sin(\theta_c) \qquad (17)$$

$$d_{0c} = 1 - (\ d_\gamma + d_\delta) \qquad (18)$$

B. MODIFIED OPEN LOOP CONTROL OF MATRIX CONVERTER

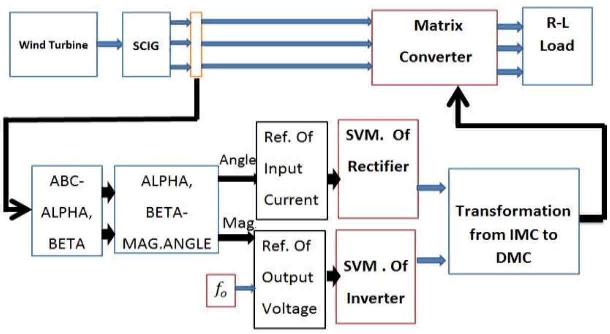
MC can control the rms value of the output voltage and frequency. But the output voltage of matrix converter in case of open loop control is a percent of the input voltage. If q is the ratio between output voltage and input voltage, if q=0.4 in open loop control, input voltage =100V, the output voltage will be 40 V but with the required frequency. If the input voltage changes from 100V to 50 V the output voltage will be 20 V. If we need to obtain constant output voltage the q ratio must be changed from 0.4 to 0.8 so the q ratio must be depend on the input voltage and this can be achieved by modified open loop control. Modified open loop control takes a signal from three-phase input voltage and q ratio can be calculated as in (19).

From table 1 and Eq. (19) the ratio q in case ofmodified open loop control depend on the input voltage where if the input voltage decreased the ratio q increased so that obtain a constant output voltage.Figure7.a shows the proposed modified open loop control of indirect space vector modulation. Figure7.b shows Matlab Simulink modification in the proposed modified open loop control of indirect space vector modulation

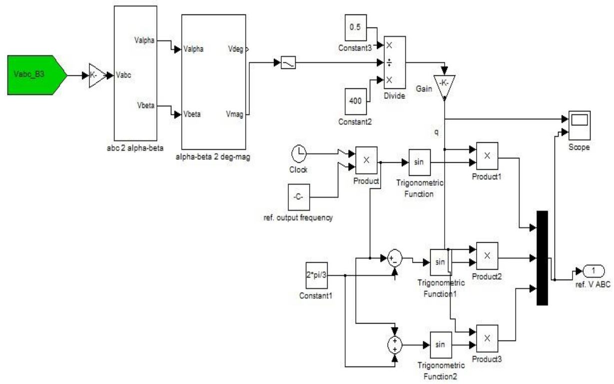
$$q = \frac{V_{out}^*}{V_{IN}} \qquad (19)$$

Table 1. Modified open loop control and open loop control

V_{IN}	Open Loop Control		Modified open Loop Control	
	q	V_{out}	q	V_{out}
100	0.4	40	0.4	40
50	0.4	20	0.8	40



(a) block diagram of model



(b) Simulink of modification in the Model

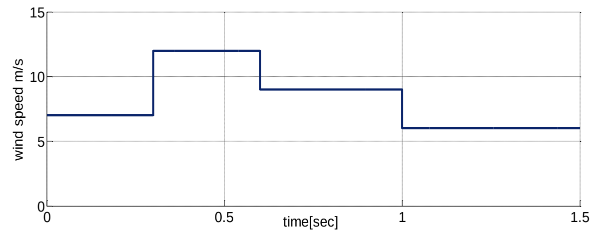
Fig. 7. Modified open loop control

V. SIMULATION RESULTS

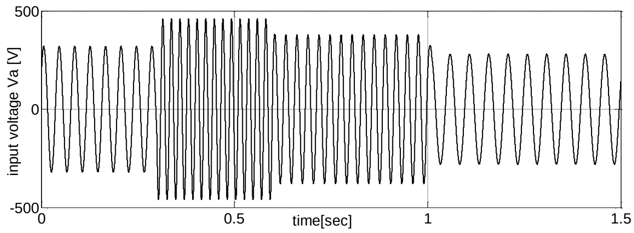
Simulations were done using MATLAB/Simulink software package. The simulation results for a MC interfaced wind energy conversion system for an isolated R-L load(R=2Ω, L=1mH) will be presented. The bidirectional switch used here is MOSFET and four ultra-fast diodes. The output filter used is LC filter with value of L=2.3 mH, C=100 µf [20]. To obtain the desired output voltage and frequency, the matrix converter is controlled by using indirect space vector modulation with modified open loop control. Figure 8shows simulation results at different wind speed with open loop control. Figure 9 shows simulation results at different wind speeds with modified open loop control, In case of a modified open loop control the output voltage and frequency remain constant to the desired value 220 V, 50 Hz output even if the wind speed changed. In case of open loop control the output voltage is a ratio of input voltage so if the output voltage changed with speed as shown in fig.8. Table 2 gives the magnitude of voltages and frequency with variation of wind speeds. Figure (8.a, 9.a) shows wind velocity with time, where the speed of wind changed from 7 m/s to 12 m/s at t=0.3 sec, from 12 m/s to 9 m/s at t= 0.6 sec, from 9 m/s to 6 m/s at t= 1 sec. Figure 8.b shows input voltage to MC (generated voltage), Fig.8.c shows simulation results of output voltage of 50 Hz with open loop control. It's clear from fig.8.c that the magnitude of the output voltage isn't constant; Fig.8.d shows simulation results of output current of 50 Hz with open loop. Figure 9.b shows input voltage to MC (generated voltage), where for t=0:0.3 sec the generated voltage is 320 V, 25 Hz, where for t=0.3:0.6 sec the generated voltage is 460 V, 46 Hz, where for t=0.6:1 sec the generated voltage is 380 V, 34Hz, where for t=1:1.5 sec the generated voltage is 280 V, 21Hz. Fig.9.c shows simulation results for the desired output voltage of 220 V, 50 Hz with modified open loop control. It's clear from fig.10.c that the magnitude of the output voltage is constant and equal to the reference value =220 V; Fig.9.d shows simulation results of output current of 50 Hz with modified open loop control.

Table 2. Variation of generated voltage and frequency with wind velocity

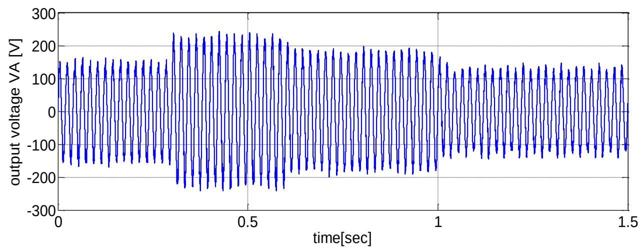
Wind velocity m/s	Voltage (V)	Frequency (Hz)
6	280	21
7	320	25
9	380	34
12	460	46



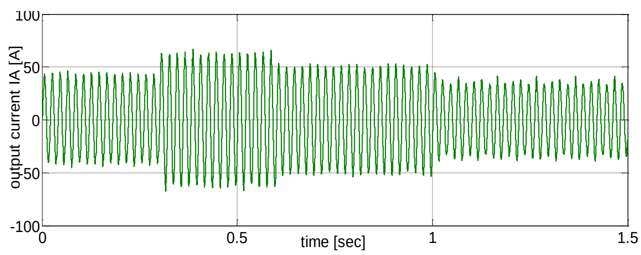
(a) Dynamic response of wind speed



(b) Input voltage V_a at different wind speeds

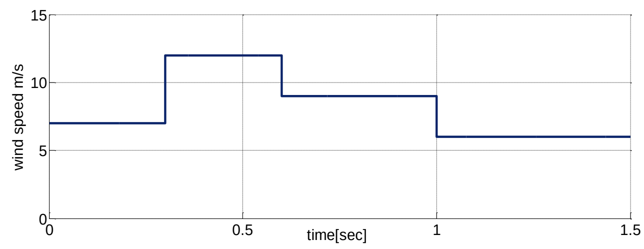


(c) Output voltage V_A 50 Hz

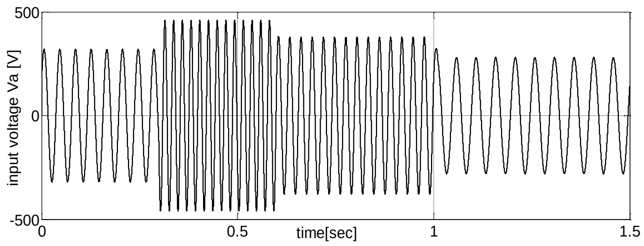


(d) Output current I_A 50 Hz

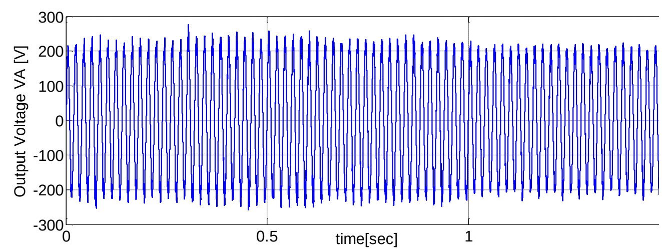
Fig. 8. Simulation results for open loop control of a matrix converter



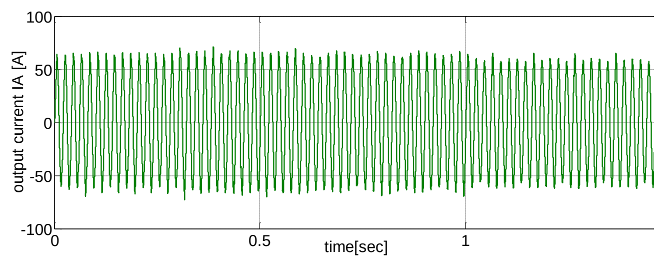
(a) Dynamic response of wind speed



(b) Input voltage V_a at different wind speeds



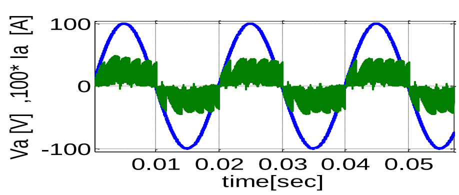
(c) Output voltage V_A 50 Hz



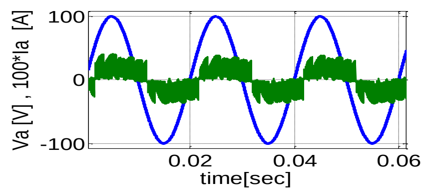
(d) Output current I_A 50 Hz

Fig. 9. Simulation results for modified open loop control of a matrix converter

Figure 10 show input displacement factor control, Fig.10-a shows unity input displacement factor, Fig.10-b show input displacement factor with displacement factor angle equal to 20^{o}.



(a) Unity input displacement factor

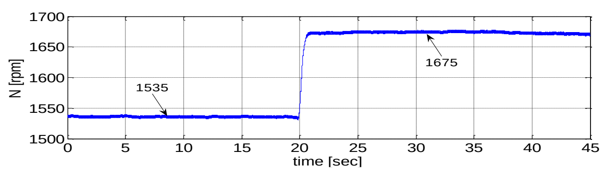


(b) Displacement factor of angle 20^{o}

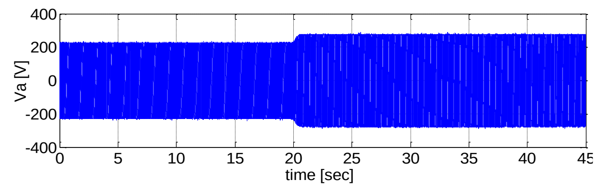
Fig.10. control of displacement factor

VI. EXPERIMENTAL RESULTS

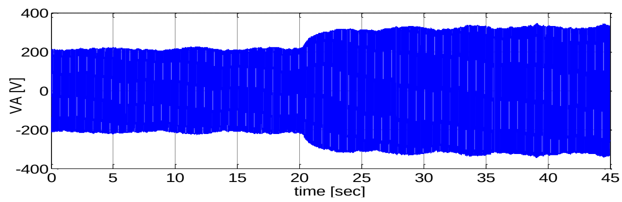
Experimental results were performed using DSP1104, with an isolated static load of (R=20Ω, L=40mH).The field and armature voltage of DC motor is controlled to control its speed to simulate wind turbine. Figure 11 show Experimental results for change in speed at a time 20 sec in case of open loop control with 50 Hz output frequency, wherefig.11-a shows the change in speed where speed changes from 1535 rpm to 1675 rpm by increasing the armature voltage. Figure 11-b shows the input voltage where the rms value and frequency of the input voltage increase with the increase in speed. Figure 11-c shows output voltage in case of open loop control .The rms value of the output voltage is a precent of the input voltage so the rms value of the output voltage changes with change in input voltage.



(a) Speed response

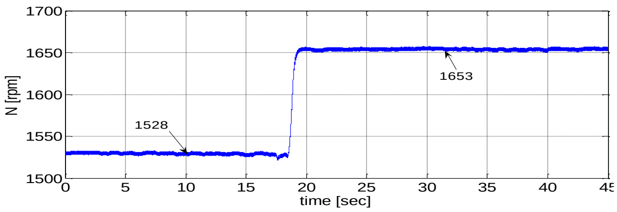


(b) Input voltage V_a

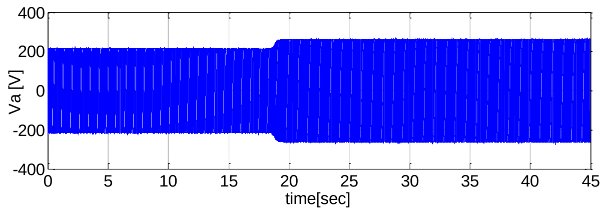


(c) Output voltage V_A

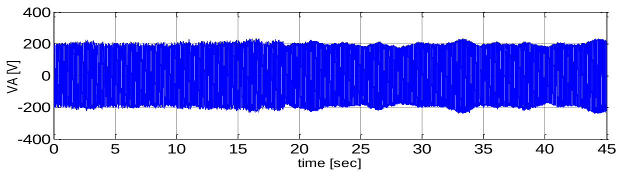
Fig. 11. Experimental results with open loop control & output frequency 50 Hz



(a) Speed response



(b) Input voltage V_a



(c) Output voltage V_A

Fig .12. Experimental results with modified open loop control & output frequency 50 Hz

Figure 12 shows experimental results for change in speed at a time 18.5 sec in case of modified open loop control with 50Hz output frequency, where Figure 12-a shows the change in speed where speed changes from 1528 rpm to 1653 rpm by increasing the armature voltage. Figure 12-b shows the input voltage where the rms value and frequency of the input voltage increase with the increase in speed the input frequency increases from 30 Hz to 33.5 Hz approximately. Figure 12-c shows output voltage in case of modified open loop control .The output frequency doesn't change even if the input frequency changes.

VII. CONCLUSIONS

In this paper, a modified open control of the indirect space vector modulation was introduced which improve the performance of matrix converter with variable speed operation of the wind turbine. The voltage and frequency of a static R-L load can be controlled by using a MC fed from wind energy conversion system. The angle between input voltage and input current of MC can be controlled and unity input displacement factor can be achieved. The analysis of indirect space vector modulation was introduced, in addition to introducing how to transform from indirect MC to direct one. Model produces a very good wave form on output side. The simulation and experimental set up results are consistent with the expected results, where the direct converters have the ability to provide sinusoidal wave forms.

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