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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.

Sustainable development is a multidisciplinary advancing to the center of energy research with the declaration of UN millennium development goals for the first time in 2000, and continued to constitute a challenge in energy technologies in the past decade. RESD is mainly interested in case studies of sustainable development and its relation to transition economies in the Middle East, Africa, Asia and Oceania.

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Peer review is an objective process at the heart of good scholarly publishing and is carried out on all reputable scientific journals. Our referees therefore play a vital role in maintaining the high standards of Renewable Energy and Sustainable Development (RESD) and all manuscripts are peer reviewed following the procedure outlined below.

Overall process for publishing a paper will be taken approximately 4 months after initial submission. Reviewing process will take about 2 months, and then publishing process will not exceed 2 months.

1. Initial manuscript evaluation

The Editor first evaluates all manuscripts. It is rare, but it is entirely feasible for an exceptional manuscript to be accepted at this stage. Those rejected at this stage are insufficiently original, have serious scientific flaws, have poor grammar or English language, or are outside the aims and scope of the journal. Those that meet the minimum criteria are passed on to at least 2 experts for review.

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Energy and the city

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Spatial planning should have a key role in creating urban environments that support less energy-intense lifestyles. A wise consideration of energy in urban land use policies should play an important role considering that, in spite of having a land occupation of 2% and accommodating 50% of the world population, cities produce 80% of GHG emissions and consume 80 % of the world's resources.

In the building industry, the green economy is already part of the designers' approach. This has already produced several energy efficient buildings that also feature high architectural quality. Now is the turn of cities to take the same direction in developing the capacity of formulating sounded urban policies. This will contribute to develop adequate new tools for achieving the energy efficiency goal.

Climate change concern, the dominating environmental paradigm, is permeating the political scenario worldwide, producing a plethora of formal documents. The most recent one is the COP21 agreed in Paris in December 2015, after the failure of the Copenhagen summit in 2009, and formally signed in April 2016 in New York. The challenge for land use planning now is to translate these general commitments into actions that modify planning practices at all levels, from cities to regions.

In this field, the current situation is extremely varied. EU has issued several documents focussed mainly at building level but also sustainable transports are considered a key issue. However, a further step is needed in order to increase the level of integration among all land use approaches, including the idea of green infrastructure as a key component of any human settlement. (European Commission, 2013).

The relationship between urbanisation and climate change has become key worldwide but looking at it from a Mediterranean perspective arises some specificities, considering also the political strain that this part of the world is facing. Both Southern Europe and Middle East and North Africa (MENA) countries will face stronger heat waves in the near future (Fischer and Schär, 2001). Their cities, often poorly planned for decades, will be considerably affected by these temperature upsurges.

A further complexity arises from the fact that the energy approach in land use plans is not direct. Including energy considerations in urban and regional planning is hardly a technological issue. On the contrary, it requires a deep change in the mind-set of urban planners that have to think at the whole city structure wearing the new "energy glasses".

It is possible to trace the energy issue in land use planning back to its history. Spatial planning has a long lasting tradition in defining the shape of urban fabric and the layout of buildings, taking into account the role of the sun and the wind. This tradition has evolved from the seminal experiences of modernist planning to the new sustainable districts, recently developed in several countries like Germany, the Netherlands, France and Sweden, including the ones described by Peter Hall (2014) in his last book.

But Mediterranean countries have an even longer tradition in building cities and houses that were capable of facing hot temperatures, without any of the electric appliances that are consuming now a considerable share of energy. As part of this long-established tradition, it is worth remembering the inspiring contribution of the Egyptian architect Hassan Fathy. Looking back at the city history is not a mere exercise based on nostalgia. Making greener Mediterranean cities, as they were up to a recent past, is a complex task but it will become unavoidable in order to guarantee forms of sustainable cooling.

This is especially true in those cities that have grown considerably in the second half of the 20th century, according to high-density models.

Urban planning has been also concerned with defining the proper mix of land uses, taking into account the key role of transports. Compact and walkable cites, rich of activities, are naturally energy efficient. The lesson taught by Jane Jacobs in her seminal book *Death and Life of Great American Cities* remains relevant also assuming the energy approach. More recently, emerging planning themes are including the containment and retrofitting of urban sprawl by integrating transport and land use planning. Applying Transit Oriented Development (Tod) principles can induce a change in mobility choices of inhabitants of this unsustainable form of urban settlement, by giving them more mobility opportunities.

Land use planning will also play a relevant role in accommodating new forms of distributed sustainable energy production in the urban fabric. The recent 2015 Snapshot of Global Photovoltaic Markets, by the International Energy Agency, confirms that economic incentives, like feed-in tariffs, are not enough to guarantee a stable diffusion of this type of energy production. After the phasing out of this incentives there diffusion of PV, reduces considerably. This is case of Italy that installed only 300 MW of PV systems in 2014, compared to 9,3 GW in 2011, 3,6 GW in 2012 and 1,6 GW in 2013. Integrating energy production in the city as part of urban design will increase the opportunity of making sustainable energy production an inherent feature of the city design, including energy production devices in the city realm and using them for retrofitting poor quality buildings.

In addition, planning tools have to incorporate incentives aimed at favouring higher energy standards, both for new and existing buildings. The costs of these actions should be covered by planning normative tools. Several techniques, like the Carbon Offset Fund in Great Britain, have been tested but there is a great need of new research in this field, at national and local level, since these tools are not easy to implement without taking into account site-specific norms and approaches. In addition, the exclusive use of the market leverage risks to confine these tools to wealthy communities, excluding the poor ones.

These new attitudes require not only new planning tools but also a great capacity of devising urban policies capable of involving communities with different cultural backgrounds and planning traditions. A wise mixture of tradition and innovation is central to innovate the urban planning discipline in the direction of sustainability. A lot of *mental energy* has to be devoted to the difficult but stimulating objective of improving the energy awareness of our cities.

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About Francesco Martinico

Associate Professor in Town and Regional Planning at the University of Catania, School of Architecture, since October 2005, Deputy President of the School of Architecture. He has been Faculty Coordinator of the PhD Program in "Environmental Planning and Design" at University of Catania. In 1987 he graduated in Civil Engineering at the University of Catania. He received his PhD in Urban and Regional planning in 1998. He attended courses at INSEAD, Fontainebleau, and at University of Surrey. His main fields of interests includes regional and landscape planning, management issues related to land use, the use of GIS and planning of industrial estates. He has been part of research teams of several plans and research programs including the following: Land Use Master Plan of Catania, Landscape protection Plan in Sicily, GRaBS (Green and Blue Space Adaptation for Urban Areas and Eco Towns, a program funded by EU - INTERREG IVC), SPECIAL (Spatial Planning and Energy for Communities in All Landscapes, a project funded by Intelligent Energy Europe). He is author co-author and editor of over 80 publications (books, book chapters and research papers).

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Efficient Use of Energy….. as a Life Style

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Since the Early Eighties of the last Century, the Egyptian Government considered Energy Conservation as one of the main pillars of Energy Planning in Egypt, based on the fact that investing in Energy Efficiency is more cost effective than in constructing new Power Plants.

Energy Efficiency (EE) Programs financed by International Financing Institutions focused at that time, on Energy Audits in Industrial Buildings, Power Plants, Electricity Transmission and in some other Governmental Buildings. Recommendations for Efficient Use of Energy and reducing energy consumption at those entities were implemented by the Use of Efficient Lamps, Improving Power Factor, Waste Heat Recovery, Thermal Insulation, Efficient Firing in Boilers…. Consequently, High Quality Energy Efficient Products were competing in the market with others not having the same advantage.

Although the above mentioned EE Programs included Awareness Campaigns for all sectors but the consumption in **Residential Sector** remained high and increased more and more ,exceeding even the consumption in Industrial Sector specially that the prices of electricity were highly subsidized.

For that reason, more awareness campaigns (Lectures, Brochures, Audio and visual advertisement) and more incentives were offered by Ministry of Electricity and Renewable Energy (MoERE) to consumers in the Residential Sector. Meanwhile, a Program to reduce gradually subsidies on electricity prices started aiming to push consumers to follow energy efficiency instructions and buy efficient appliances especially while they were suffering from electricity cut for about two years.

To prepare for Market Transformation to efficient appliances the Government, issued the Standard Specifications and Labeling for Energy Efficient Appliances (lamps, refrigerators, freezers, washing machines, air conditioners, dish washers and others). Meanwhile, these Standards are supported with Accredited Testing Labs in National Entities (NREA,EOS,…). In addition, Ministerial decisions and resolutions were issued to enforce the standards and labeling and to monitor the industry and the market as well.

At the Regional Level the League of Arab States issued the “Arab Framework for Energy Efficiency for End-User” supported by the Regional Center for Renewable Energy and Energy Efficiency(RCREEE) acting as technical arm.

In 2012, MoERE applied this Framework to develop its National Plan which has been endorsed by the cabinet in the same year. This Plan included EE projects to be implemented by the Ministry as well as Measures for Energy Efficiency Improvement expected as a result of implementing these projects.

Efficient Use of Energy is a Life Style and Culture that should be taught to children in Schools and at Home.

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About Eng. Omneya Sabry

Qualification:
B.Sc. Telecommunication Engineering, Faculty of Engineering, Ain Shams University, 1978

Present Post:
Chairperson of Executive Committee, Regional of Renewable Energy and Energy Efficiency

Employment Record:

2013- 2015:	Vice Chairman for Studies and Technical Affairs, New and Renewable Energy Authority
2007- 2013:	Undersecretary of State for International Cooperation, Ministry of Electricity and Energy
2001- 2007:	General Manager of Testing Department, New and Renewable Energy Authority
1986-2001:	Database Developer then Computer Network Manager at IT Department, New and Renewable Energy Authority
1979- 1986:	Maintenance Engineer, Arab Organization for Industrialization

Practical skills and Experience were acquired in the field of renewable energy and energy efficiency by participating in several activities including:

- Wind and solar projects
- Wind, solar and biomass studies
- Solar and biomass testing process
- Quality Management System in Testing Facilities (Solar, Biomass and Energy Efficiency)
- Standard Specifications of Solar Water heaters and PV systems
- Setting plans and securing finance for developing solar and wind systems or plants in Egypt
- National Energy Efficiency Plan for Electricity Sector, Energy Strategy of Egypt 2035.
- Research Projects in solar and biomass
- Publications in Solar, Biomass, Energy Efficiency and Leadership Development.

In addition to Three Awards of Excellence received from Minister of Electricity and Energy

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How the HBRC contributes to the Sustainability in Egypt

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Housing & Building National Research Center, HBRC, is a governmental institute subordinate to the Ministry of Housing, Utilities and Urban Communities which started in 1954 by 12 employees. HBRC now has more than 1100 employees, 300 of which are M.Sc., and/or Ph.D. holders.

HBRC is the sole entity nationwide responsible for issuing the Egyptian Codes (30) as well as technical specifications (21), in addition to providing periodical training for these codes and specifications. Training also extends to a variety of engineering subjects and it serves both public and private sectors.

HBRC is involved in several national scientific research plans as well as researches leading to academic degrees.

One of the main activities of HBRC is serving the community through the assessment of mal-functioning structures nationwide, as well as technically refereeing disputes between different parties. Moreover, HBRC is taking a substantial role in the quality control and construction supervision of the national projects.

It is worth mentioning that all HBRC labs are ISO 17025 accredited by the International Accreditation Services, IAS.

Moreover, HBRC hosts the Egyptian Green Building Council, originated back in 2009 by a ministerial decree. Several rating systems exist worldwide, .e.g., LEED, BREEAM, CASBEE, etc. In this capacity, a rating system for new buildings, termed Green Pyramid Rating System (GPRS) has been developed. It has been issued back in December 2010. Other rating systems have followed since then, including GPRS for banks, communities, etc. These rating systems have been applied to several structures / compounds, e.g., the first governmental green building has been designed at HBRC; compounds, club houses and banks have been assessed according to the appropriate GPRS.

HBRC has carried out some tangible steps towards the application of the green building concept in Egypt. The use of traditional construction systems has to be developed so as to coop with the green building concepts. This started back in 2010 when a research team from HBRC visited several countries so as to carry out smooth technology transfer after making the necessary adaptations for the used systems in order to suit the Egyptian climate, habits, etc. A sustainable park subordinate to HBRC has been initiated at the city of 6 October in which full scale models have been constructed with non-traditional systems and/or materials of construction. This can be summarized briefly as follows:

- Sandwich panel system in which polystyrene panels are used with wire mesh attached to both sides and covered with shotcrete. This is used for both walls and ceiling.
- Glass reinforced concrete panels (GRC) are also used for both walls and ceiling.

- Cold formed steel is used for both walls and ceiling.
- Sand sacs, in which sacs are filled with sand or silty sand and stacked together to form the walls of the structure. Ceilings can also be built in the same manner with special technique in construction.
- Rammed earth in which soil is mixed with a very low percentage of cement (about 4 to 5%) and the mixture is manually rammed with a hammer to build the walls of the structure.

Alternatively, the mixture can be used to form blocks with different shapes using a hand operated simple machine which produces several blocks at a time. The blocks are then sprayed with water and treated for 28 days, after which these blocks can be used to construct both the walls and ceiling of the structure. A full scale model is built as such at the premises of the headquarters of HBRC at Dokki.

All the previously shown methods of construction have a common factor which is that they are all eco buildings, i.e., environmentally friendly structures which help minimize their life time running cost, help in the reduction of harmful emissions, thus supporting the environment, etc. In short, these types of systems can be considered among the future systems to be used rather than the traditional methods which are becoming more expensive and more important some of the constituents of the conventional methods are getting depleted.

Part of the vision of HBRC is to help create a green environment.

About Prof. Khalid Mohamed El Zahaby

Prof. El Zahaby is currently the Chairman of the Housing & Building National Research Center (HBRC) subordinate to the Ministry of Housing, Utilities & Urban Communities. He is also the chairman of the Metropolis® regional branch as well the Chairman of Urban Training institute (UTI). He is the Vice-Chairman of the Egyptian Green Building council. He started as a research assistant and progressed to be a professor of geotechnical engineering then Vice Chairman of HBRC before being nominated for the post of the Chairman. He obtained his B.Sc. and M.Sc. from Cairo University, Egypt and his Ph.D. from North Carolina State University, USA.

He authored and co-authored 36 research papers published in national and international journals and/or conferences. He chaired several international conferences and presented invited keynote lectures in several countries. Moreover, Prof. El Zahaby supervised tens of theses and refereed tens of M.Sc, Ph.D. and scientific papers. He is also a member on several regional and international organizations.

In his capacity as a researcher at HBRC or being a geotechnical consultant, Prof. El Zahaby prepared more than 2000 geotechnical studies in Egypt and some Arab countries including geotechnical reports, side supporting systems, dewatering, etc.

It is worth mentioning that Prof. El Zahaby is a member on several standing committees as well as a variety of Code committees.

Prof. El Zahaby is the recipient of several awards, among which are the ICC Global Award, USA, 2013; the award given by His Highness, Prince Mansur Ibn Metaab, KSA, 2013.

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Production of Biodiesel from Locally Available Spent Vegetable Oils

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***Abstract* -** The depletion of fossil fuels prompted considerable research targeting the development of alternative fuel sources. Biodiesel production has acquired increasing importance owing to its renewable nature and milder environmental impacts. To this end, alternative sources of feedstock have been sought and studies aiming at the optimization of the production procedure have been carried out. Millions of liters of waste frying oil are produced from local restaurants and houses every year, most are discarded into sewage systems damaging networks and complicating the treatment process. This study is intended to consider aspects related to the feasibility of the production of biodiesel from waste frying oils in order to alleviate the waste frying oil pollution problems as well as to reduce the cost of biodiesel production. Locally available spent vegetable oils have been collected from different sources and accordingly have somewhat different chemical compositions. The conducted experiments involved the production of biodiesel from the different feed stocks using the base catalyzed trans-esterification process. The quality of the produced biodiesel is compared to petro-diesel in terms of established standard specifications.

I. INTRODUCTION

Increase of energy usage in the industrialized world entails rapid depletion of nonrenewable fossil fuels and is associated with pollution problems [1]. Renewable resources of energy include solar energy, wind energy, geothermal energy, tidal energy, ocean thermal energy, hydropower, and alternative combustible fuels [2]. Production of alternative fuels should be technically feasible, economically competitive, environmentally acceptable, and readily available [1]. Diesel engines are the main engines used in industrial, transport and agricultural applications due to their high efficiency and reliability [3]. Diesel engines operate via compression ignition where the fuel is injected in the engine's cylinder with compressed air at high pressure and temperature. The fuel self-ignites and burns rapidly when it enters the cylinder forcing the piston back down and converting the chemical energy in the fuel into mechanical energy. The fuel used in the first diesel engine, developed by Dr. Diesel in 1895, was vegetable oil. This, however, poses socio-economic arguments arising from the conflict between food shortage and the demand for energy. Due to the availability and low cost of petroleum diesel fuel, vegetable oil-based fuels are not used widely except in times of high oil prices and shortages as in World War II and the oil crisis of the 1970's. At present, vegetable oils are not directly used as alternative fuels due to their high viscosity, incomplete combustion, injection and ring coking and may ultimately cause engine failure [4, 5]. Vegetable oils, as a source of biodiesel production, include sunflower, safflower, soybean, cottonseed, rapeseed, and peanut oils. Vegetable oil based fuels are the attractive alternative for diesel fuel due to their renewable nature, better ignition quality, comparable energy content, high density, higher flash point, nontoxic emissions, cleaner burning, nearly zero sulfur content, high cetane number and high calorific value close to diesel fuel [6, 7].

There are many reasons that encourage search for alternative compression ignition engine fuels. Conventional diesel engine fuels are associated with smoke and nitric oxide (NOx) emissions. More stringent governmental regulations targeting cleaner combustion have been imposed to reduce diesel engine emissions. This can be done by engine development with fuel reformulation and use of alternative fuels [3]. The alternative sources considered include oils of plant origin [1]. Bio-fuel, namely biodiesel and ethanol, is predicted to replace petroleum diesel fuel [8]. The ethanol is used for gasoline engines and biodiesel for compression ignition engines [9]. Many countries such as Brazil, the United States, Germany, Australia, Italy and Austria are currently using bio-fuel; however, its economic feasibility should be improved before it could be widely used. In most countries, the governments support biodiesel usage by reducing its cost through tax rebates [10]. According to the American Society for Testing and Materials (ASTM), biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils and animal fats. "Bio" represents its biological and renewable source, and "diesel" implies its use as a fuel on diesel engines [11]. Biodiesel is derived from renewable biomass sources thus it represents a closed carbon dioxide cycle (approximately 78%) [12].

The chemical structure of methyl esters depends on the length and degree of un-saturation of the fatty acid alkyl chains. The degree of un-saturation of methyl esters affects the carbon to hydrogen ratio which is slightly different from conventional diesel fuel. The oxygen content is the important difference between conventional diesel fuel and biodiesel because biodiesel contains 10-12 wt% oxygen [13, 14, 15]. The burning efficiency of biodiesel is improved due to its high oxygen content; thus, it corresponds to lower particulate matter (PM), carbon monoxide (CO), and hydrocarbon (HC) emissions, however, and it produces higher NOx emissions [16].

The purpose of this work is to conduct a laboratory scale study for production of biodiesel using locally gathered waste vegetable oils from different origins. The processing requirements for the different feed stocks are to be compared. The final product specifications are to be also compared with those of petro diesel.

II. EXPERIMENTAL CONDITIONS

Trans-esterification reactions have to be carried out under vigorous mixing conditions owing to the immiscibility of the oil and methanol phases. Since trans-esterification is a relatively slow process, intense mixing is required both because of the relatively high oil viscosity and in order to ensure sufficient interfacial area between the two reactants present in different phases. The optimum operating temperature for this reaction is 65°C, which is slightly above the boiling point of methanol (64.7°C)[17]. When the reaction temperature exceeds the boiling point of methanol, the methanol will vaporize and form a large number of bubbles which may inhibit the reaction. The experimental conditions for the different feed stocks have been fixed at an agitation rate of 400 rpm and at a temperature of 65°C.

III. MATERIALS AND METHODS:

Waste oil was collected from three different sources: (1) waste frying palm oil (WPO) from a local fast food restaurant, (2) mixed waste home frying oil used only once or twice (WHO), (3) waste mixed oils, sunflower, palm oil and soya oil (WTO) collected after 48 working hours from a controlled food court. The chemicals used in the experiments were: methanol procured from El-Nasr Pharmaceutical Chemicals Co. (ADWIC) with a molecular weight of 32.04 and an assay of 99.8%, KOH purified pellets from Thann-Fransu, analar grade isopropyl alcohol, and phenolphthalein.

A small-scale laboratory setup was used for pretreatment and trans-esterification experiments. The waste oil is first heated to 60°C in a water bath to ensure complete melting. It is then filtered using a standard Buchner funnel connected to a vacuum pump in order to ensure complete solids removal. The filtrate is then heated in a water bath up to 110°C to ensure vaporization of any residual water since the presence of water negatively affects the reaction by promoting saponification and increasing the viscosity. Trans-esterification experiments were conducted in triplicate using 100g of used frying oil. Methanol and KOH catalyst were poured into a clean reaction flask provided with a magnetic stirrer and a reflux condenser. The oil, methanol, and KOH mixture was stirred for 120 min at 60-70°C and 400 rpm. The trans-esterification reaction was carried out for different ratios of oil to methanol (10, 15, 20, 30, and 40g). The amount of catalyst had a pronounced influence on the conversion to esters. Various amounts (0.75g, 1g, and 1.5g) of KOH catalyst were used in the experiments: After the trans-esterification reaction, the biodiesel was separated from glycerol using a separating funnel where the reaction mixture was allowed to cool. Clear separation was observed after 12-24 hours of settling. The ester was then washed three times with warm distilled water. The product was then dried by heating at 110°C for 30 min to remove the moisture content and the methyl ester is filtered to remove any residual soap.

The effects of catalyst content, methanol to oil molar ratio, and reaction time were determined. It is recognized that the production of waste cooking oil will be a function of the frying temperature and length of use as well as the material used for frying.
The free fatty acid (FFA) analysis for the raw oil

should be lower than 0.5%. The oil has been treated and the FFA content was determined by standard titration while the fatty acid composition was determined using chromatographic analysis (GC).

IV. RESULTS AND DISCUSSION:

- **Yield and Conversion**

The effect of base-catalyzed trans-esterification process variables on biodiesel yield from the different waste frying oils was investigated by changing the (KOH) catalyst to oil ratios (% w/w) and the methanol to oil ratios (% w/w).

Table 1.Yield and Conversion of Trans-esterification Reaction of all Waste Frying Oils

Run#	KOH (g)	Meth. (g)	Yield %			Conversion %		
			WPO	WTO	WHO	WPO	WTO	WHO
1	0.75	10			63.69			32.41
2	0.75	15	81.41	67.25	78.22	76.92	55.56	61.38
3	0.75	20	76.21	86.35	87.71	61.54	55.56	61.03
4	0.75	30	87.05	75.73	85.14	76.92	77.78	62.07
5	0.75	40	90.26	88.06	87.25	76.92	66.67	31.72
6	1	10	34.53		71.18	69.23		60.34
7	1	15	77.53	54.2	91.06	61.54	55.56	42.07
8	1	20	87.18	80.04	91.41	69.23	55.56	80.69
9	1	30	84.66	83.27	88.01	84.62	77.78	42.76
10	1	40	88.26	84.08	68.96	84.62	55.56	42.17
11	1.5	10	45.9			69.23		
12	1.5	15	70.66	73	83.89	38.46	55.56	50.35
13	1.5	20	78.19	79.4	72.37	61.54	66.67	42.41
14	1.5	30	88.59	77.12	67.85	76.92	77.78	60.21
15	1.5	40	81.64	89.6	54.48	53.85	83.33	42.05

Table 1 presents the calculated yield and conversion obtained from the experimental data for the different waste frying oils under different reaction conditions.

Previous results reported in the literature [17] on the effect of catalyst and methanol to oil ratio on biodiesel production suggest that biodiesel with the best properties was obtained using 1 % KOH by weight as the catalyst. Methanolysis with this catalyst produced the best yields and viscosities of the resulting esters. A. B. Chhetri et al. [12] used 0.4%, 0.6%, 0.8%, 1.0% and 1.2% sodium hydroxide as a catalyst and observed that no reaction took place with the 0.4% NaOH. With catalyst concentrations of 0.6%, 0.8% and 1.0%, ester yields were approximately 50%, 94% and 40%, respectively. It was also observed that the ester yield decreased with the increase in NaOH concentration. With 1.2% catalyst concentration, soap formation was pronounced. Increased soap formation caused the ester to dissolve into the glycerol layer.

The findings obtained in the present work may be compared with the above literature data by considering the experimental results presented in Figures (1-3) below. Figure (1) presents the yields obtained for WPO, WHO, and WTO respectively for different amounts of CH_3OH and KOH.

It is seen that the highest yield for WPO ranged between 87.05% to 90.26% (runs 4, 5, 8, 10, and 14). In these runs, the dominant catalyst amount ranged between (0.75 – 1g) except for run 14 which used 1.5g KOH. Two runs (runs 6, 11) gave a very low yield (34.53%, 45.9%) and no yield was obtained for run (1). All of these runs were carried out using 10g CH_3OH, and as such the amount of methanol is not sufficiently in excess to increase the rate of the forward reaction towards ester production.

The maximum yield for (WHO) was found in runs (7, 8, 9) where the amount of catalyst was (1g) and the amount of methanol was (20, 15, 30g), respectively. No yield was obtained from run number (11) while the lowest yield was obtained in runs (1, 10, 14, and 15), where the high amount of KOH (1.5g) reduced the yield due to saponification (runs 14, 15) and the low amount of methanol caused incomplete reaction (run 1). Also the increase of methanol reduced the yield because it diluted the reaction mixture (runs 10, 14 and 15).Thus the optimum trans-esterification reaction conditions for (WHO) were 1g KOH and 20g methanol.

The maximum yield for (WTO) was in runs (3, 5, 9, 10, and 15) with KOH ranging between 0.75g and 1g except for run 15 which used 1.5g KOH. The lowest yield was in runs (2, 7) and no reaction took place in runs (1, 6, and 11). All of these runs were carried out with methanol ranging between (10 – 15g), and this means that the amount of CH_3OH should not be lower than (20g) to push the reaction in the forward direction. Thus, in the case of using (WTO) the optimum amount of CH_3OH required to achieve a high yield is (20g).

Comparison of the yields of the three types of oil showed that the highest yield was obtained for (WHO) in runs (8, 7) reaching 91.41% and 91.06%, respectively. This is attributable to that (WHO) had the lowest FFA content and thus it gave higher yields under the same conditions. The second highest yield was obtained in run (5) for (WPO). Yields for both (WPO) and (WTO), at low amounts of CH_3OH (10 – 15g), were very low and sometimes no reaction occurred.

The highest conversion of 84.62% was obtained for (WPO). The second highest conversion of 83.33% was for (WTO) while the highest conversion using (WHO) was 80.69%.

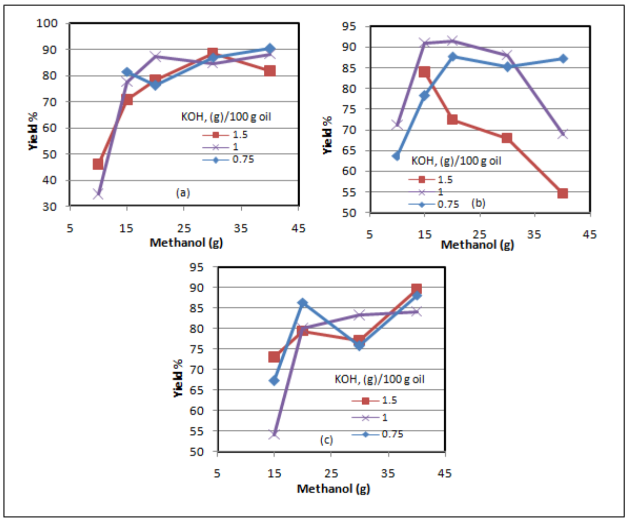

Fig .1. Effect of catalyst content on yield (a) WPO, (b) WHO and (c) WTO

- **Density and Viscosity**

Table 2 presents the density and viscosity of the produced Fatty Acid Methyl Ester (FAME) from WPO, WHO, and WTO respectively for different amounts of KOH and CH_3OH. The FAME density should lie between 0.86 and 0.9 kg/m^3 [11]. All the (WPO) densities were within the above specified range except for run (10) which gave a lower density (0.849 kg/m^3). All the measured (WTO) and (WHO) densities were equal to or higher than the upper limit of the specification. Figure (2) displays the measured kinematic viscosities (KV) for the FAME produced from WPO, WHO, and WTO, respectively. The range for biodiesel kinematic viscosity is (1.9 – 6 mm^2/s) according to ASTMD 6751 standard and (3.5 – 5 mm^2/s) accords to EN14214 standard. The measured (KV) at 40°C for (WPO) was 52.9 mm^2/s, for (WHO) was 33.5 mm^2/s, and for (WTO) was 52.1 mm^2/s. Most of the produced FAME was within the ASTM range except for run (1) for (WHO) and runs (2, 3, 7, and 12) for (WTO). In these runs, low amounts of methanol were used and as such (WTO) require more methanol to improve FAME characteristics. For (WPO) the out of specification runs were (2, 6, 7, 11, and 12). All of these runs were carried out using low amounts of methanol and, accordingly, their viscosities were higher than the standards. Palmitic acid was the major saturated fatty acid found in this waste oil which is the major factor that determines the viscosity of biodiesel. Finally, the recorded decrease in density and viscosity after trans-esterification indicates that good trans-esterification has been achieved under appropriate experimental conditions.

Table 2.Density and Viscosity of FAME from all Waste Frying Oils

Run#	KOH (g)	Meth. (g)	Density kg/m^3			Viscosity mm^2/s		
			WPO	WTO	WHO	WPO	WTO	WHO
1	0.75	10			0.91			6.6
2	0.75	15	0.889	0.92	0.91	6.14	9.2	5.6
3	0.75	20	0.8924	0.91	0.91	5.63	6.7	4.8
4	0.75	30	0.8856	0.90	0.90	4.88	5.2	4.6
5	0.75	40	0.8844	0.90	0.90	5.05	4.9	4.5
6	1	10	0.899		0.90	8.31		5.1
7	1	15	0.891	0.91	0.91	6.11	8.7	4.9
8	1	20	0.8818	0.90	0.90	5.08	4.9	4.4
9	1	30	0.885	0.90	0.90	4.53	4.9	4.2
10	1	40	0.849	0.90	0.91	4.88	5.1	4.7
11	1.5	10	0.896			7.37		
12	1.5	15	0.894	0.90	0.91	6.4	6.6	4.7
13	1.5	20	0.8832	0.90	0.91	4.84	4.9	5.7
14	1.5	30	0.8838	0.90	0.89	4.74	5.1	5.2
15	1.5	40	0.891	0.91	0.90	4.62	5	5

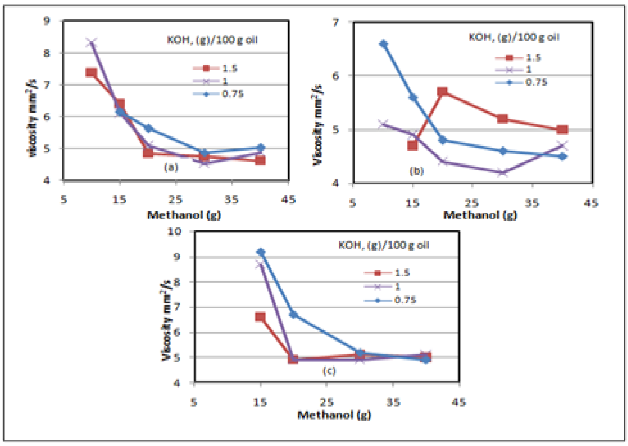

Fig .2. Viscosity of FAME at 40°C, (a) WPO, (b) WHO and (c) WTO

- **Cloud Point and Pour Point**

Figure (3) reveals that the cloud point for (WHO) ranged between (-2 – 2.5°C), for (WTO) between (-1.75–5°C) and for (WPO) between (15–25°C). The Pour point results presented in Figure (4) revealed that it ranged between (-8 – -3°C) for (WHO), between (-5.5– -0.5°C) for (WTO) and between (4–14°C) for (WPO). It may be concluded that (WPO) is solid at room temperature because its main constituent is Palmitic acid. The FAME produced from (WPO) would not be suitable for cold weather as it will block vehicles' hoses and pipes. The cloud point and pour point limits of Egyptian petro-diesel are 9°C and 6°C, respectively. Thus most esters produced from WHO and WTO would conform to the Egyptian specifications, however all esters produced from WPO would not be suitable for local use in cold conditions.

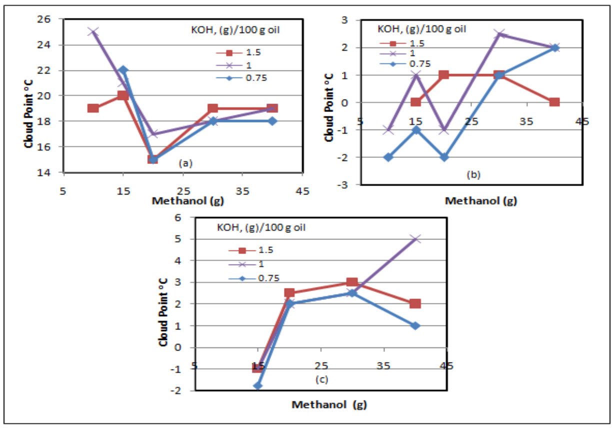

Fig .3. Cloud Point of FAME, (a) WPO, (b) WHO and (c) WTO

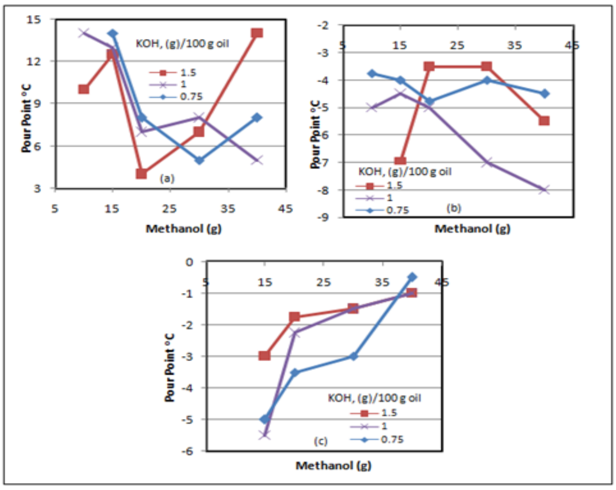

Fig .4. Pour Point of FAME, (a) WPO, (b) WHO and (c) WTO

V. SAPONIFICATION VALUE:

The saponification value is defined as the milligrams of KOH required to saponify one gram of oil. The obtained saponification value for biodiesel produced from all the tested waste frying oils (WFO) was higher than that of the WFO feed. This is not the case when virgin vegetable oil is used for biodiesel production. This is attributable to the chemical degradation during frying when reactions such as cyclization and polymerization take place. The saponification value of WPO was160.78 mg KOH/g oil, while that of its esters ranged between 162.69 and 201.96mg KOH/g oil. The saponification value of WHO was150.66mg KOH/g oil, while that of its esters ranged between140.25 and 252.45mg KOH/g oil. The saponification value of WTO was135.25mg KOH/g oil, while that for its esters ranged between145.86 and 238.43mg KOH/g oil. The obtained saponification values for the different oils are presented in Figure (5).

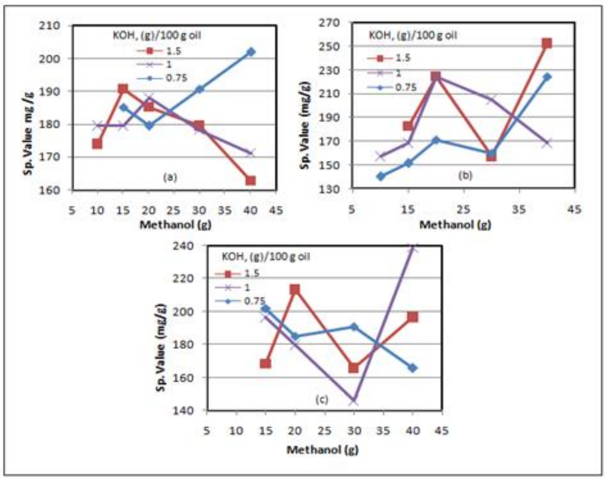

Fig .5. Saponification Value of FAME, (a) WPO, (b) WHO and (c) WTO

I. GAS CHROMATOGRAPHY (GC) ANALYSIS:

Table (3) presents the results of the GC analysis of the produced FAME from WPO. The fatty acid content is the major factor affecting the properties of biodiesel. The biodiesel derived from the sample of waste cooking oil subjected to GC contained palmitic acid, stearic acid, oleic acid, and linoleic acid. The saturated fatty acid content of the waste cooking oil was approximately 60% corresponding to a Cold Filter Plugging Point (CFPP) of (6-14 °C).

Table 3. GC Results of FAME Produced from WPO

KOH (g)	CH_3OH (g)	A Palmitate	B Linoleate	C Oleate	D Stearate	Saturated	Unsaturated
0.75	20	49	5.939	38.8	6.202	55.241	44.758
0.75	30	52.7	4.687	36.6	6.008	58.677	41.323
0.75	40	53.2	5.123	35.8	5.878	59.042	40.958
1	20	50	5.913	38.3	5.787	55.745	44.256
1	30	51.8	5.427	37.1	5.744	57.5	42.501
1	40	52.9	5.333	35.8	5.928	58.84	41.161
1.25	20	47.7	6.058	40.2	6.073	53.737	46.264
1.25	30	64.8	4.152	26.6	4.432	69.226	30.775
1.25	40	53	5.232	35.8	6.024	58.982	41.018
1.5	20	57.1	4.854	32.1	5.857	62.996	37.003
1.5	30	53.4	5.31	35.4	5.915	59.294	40.706

II. CONCLUSION

Laboratory trans-esterification experiments have been carried out to determine the effect of the amount of catalyst and methanol on the FAME yield produced from different waste frying oils at a reaction temperature of 60 -70ºC), a reaction time of 120 min and at an agitation speed of 400 rpm. Since the feedstock has been collected from different sources, there was a significant difference in the chemical and physical properties of the produced biodiesel.

The yield, conversion, density, viscosity, cloud point, pour point and saponification value of the produced FAME have been experimentally determined for different KOH and methanol to oil ratios. The optimum amount of catalyst and methanol for the three types of waste oils investigated are respectively(1g KOH – 40g methanol) for (WPO), (1.5g KOH – 40g methanol) for (WTO), and (1g KOH – 20g methanol)for (WHO). The highest yield was obtained from (WHO) due to its relatively low FFA content.

The densities and viscosities of the biodiesel produced from the three waste cooking oils lie within the ASTM standard except for the runs using low amounts of methanol. The cold flow properties of the (WTO) and (WHO) conform to the Egyptian specifications; however, all the esters produced from WPO were not suitable for use in cold conditions. The best biodiesel properties were obtained from (WHO), followed by that obtained from (WTO) and then (WPO) owing to its high palmitic acid content.

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THREE NEW DC-TO-DC SINGLE-SWITCH CONVERTERS

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Abstract - This paper presents a new family of three previously unidentified dc-to-dc converters, buck, boost, and buck-boost voltage-transfer-function topologies, which offer advantageous transformer coupling features and low capacitor dc voltage stressing. The three single-switch, single-diode, converters offer the same features as basic dc-to-dc converters, such as the buck function with continuous output current and the boost function with continuous input current. Converter time-domain simulations and experimental results (including transformer coupling) support and extol the dc-to-dc converter concepts and analysis presented.

Keywords - dc-to-dc converters, switch mode power supplies, dc-to-dc power conversion

I. INTRODUCTION

Applications for dc-to-dc converters include dc power supplies for electronic systems, hand-held electronics, portable electronics, electric vehicles, battery chargers [1], [2], systems for the utilization of fuel cell [3]-[5], solar [6]-[8], and wind energy [9], which incorporate super-capacitors [3], smart grids and distributed generation [10]-[13], electronic ballast [14], energy harvesting [15], power factor correction, and dc motor drives. Additionally, these converters form the basic building blocks for other power converter types, plus interleaved or multiphase converters [16]-[19], bidirectional dc-to-dc converters [20]-[23] multiple input converters [24], cascaded output converters [25], [26] and high voltage supplies. Similar to basic dc-to-dc converter analysis [27], with snubbers [28], converters can be controlled in a voltage mode or a current mode [29], [30].

Additional to the basic three converters, viz., buck, boost, and buck-boost converters, there are 27 other (plus three new converters here within) identified single-switch, single-diode transformer-less dc-to-dc converters. In all cases, continuous conduction operation is possible at light loads with two switch/diode combinations, which allow bidirectional inductor current, [2], [20]-[23].

Also, in addition to a switch and diode, the three new dc-to-dc converters incorporate two inductors and two capacitors (as with the Cuk, zeta, -ve Lou, and sepic converters) from which a voltage sourcing output is derived.Operational concepts of three new dc-to-dc converter topologies (with buck, boost, and buck-boost transfer functions) are presented, along with component ratings and specifications, circuit simulations, and practical results. For reference purposes, performance and features of the three new converters are compared with the three basic (buck, boost and buck-boost) converters. Experimental results for a transformer coupled version of the new buck-boost topology culminate the paper.

II. THREE NEW DC-TO-DC CONVERTER TOPOLOGIES

The three new converter topologies, termed P#1, P#2, and P#5, are shown in figure 1 row cct P. The buck-boost topology P#5 is derived by an alternative alteration rearrangement of the elements common to the Cuk, sepic, and zeta converters. The buck converter P#1 has a current source output, being sourced by two inductors L_i and L_o, converted to a voltage source output by the addition of load ac current shunt capacitor C_o as shown in figure 1P(a). The boost converter P#2 in figure 1P(b) has continuous input current properties since the input paths comprises two inductors L_i and L_o. The buck-boost converter P#5 in figure 1P(c) has discontinuous input and output currents, since a series switching device switches between the input and output circuits. These properties are the same features possessed by the basic three dc-to-dc converters, termed A1 - buck, A2 - boost, and A5 – buck-boost converters in figure 1 row cct A [31], in which all have one inductor less (one rather than two inductors) and no energy transfer capacitor. All converters use shunt output filter capacitor C_o to create a voltage sourcing output.

Figure 1 row cct P′ shows the two states created by operation of the switch T, namely the current loops when the switch T is on, ton and when T is off, toff, (such that ton+toff = τ = 1/fs where fs is the switching frequency). Energy transfer (voltage and current transfer function) analysis is based on the capacitor C voltage ripple Δvc, specifically C×Δvc = ∫ic dt, (eqn 1 in figure 1), assuming continuous but not necessarily constant current in the two circuit inductors Li and Lo (continuous conduction mode, CCM). Three basic converter transfer functions result, viz., buck, boost, and buck-boost, which are only switch on-state duty cycle ton /τ = δ dependent, as shown by eqn 2 in figure 1.

All three new topologies are characterized by a central Kirchhoff voltage loop involving only a capacitor C and two inductors Li and Lo. By Kirchhoff's voltage law, the average capacitor voltage is zero, since each of the two inductors has an average voltage of zero. This zero average capacitor voltage is fulfilled by alternating balanced positive and negative charging (positive and negative voltages). Kirchhoff's voltage and current laws can be used to derive the average voltage and current ratings of the various circuit elements, which are summarised in Table I. In Table I the steady-state characterization (for sake of consistency) process makes extensive use of the fact that, in steady state, average inductor voltage [iL(0)=iL(τ)] and average capacitor current [vc(0)=vc(τ)] are both zero.

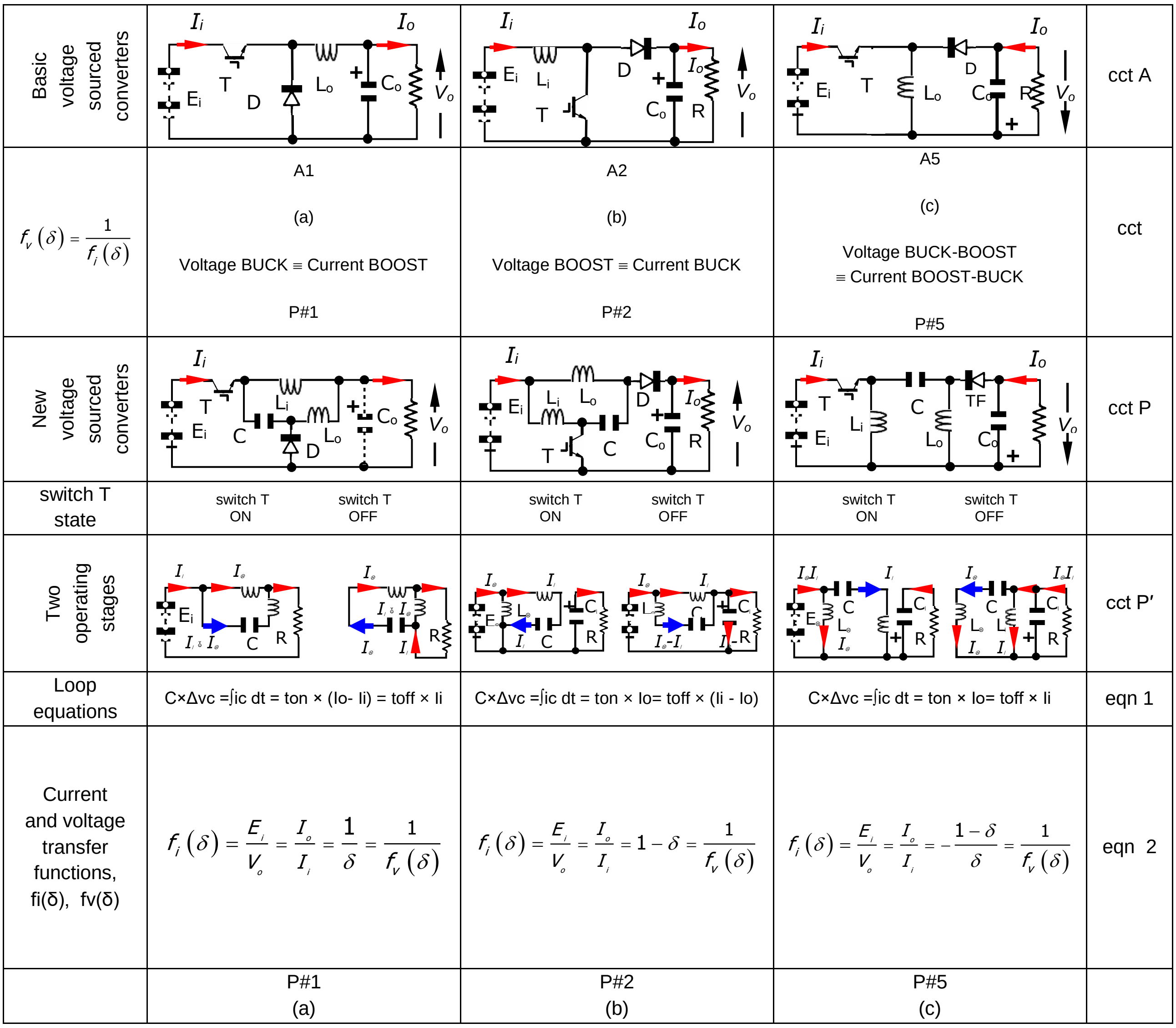

Fig .1. DC-to-dc voltage-sourced topologies, operating stages, and transfer functions.

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Table 1. DC-to-dc converter normalized component ratings

voltage				Buck	boost	buck-boost
Figure 1 / cct				A (a)	A (b)	A (c)
topology				P#1	P#2	P#5
transfer function	Voltage	TF_v	V_o / E_i	δ	$\frac{1}{1-\delta}$	$\frac{-\delta}{1-\delta}$
transfer function	Current	TF_i	I_o / I_i	$1/\delta$	1-δ	$\frac{1-\delta}{-\delta}$
Switch T	T (ave)	voltage	V_T / E_i	1-δ	1	1
Switch T	T (ave)	current	I_T / I_o	δ^2	δ^2	$\frac{\delta}{1-\delta}$
Switch T	T (max)	voltage	V_T / E_i	1	$\frac{1}{1-\delta}$	$\frac{1}{1-\delta}$
Switch T	T (max)	current	I_T / I_o	1	$\frac{1}{1-\delta}$	$\frac{1}{1-\delta}$
Diode D	D (ave)	voltage	V_D / E_i	δ	$\frac{\delta}{1-\delta}$	$\frac{\delta}{1-\delta}$
Diode D	D (ave)	current	I_D / I_o	$\delta(1-\delta)$	1	1
Diode D	D (max)	voltage	V_D / E_i	1	$\frac{1}{1-\delta}$	$\frac{1}{1-\delta}$
Diode D	D (max)	current	I_D / I_o	1	$\frac{1}{1-\delta}$	$\frac{1}{1-\delta}$
Capacitor C	current	t_{on}	I_C / I_o	1-δ	1	1
Capacitor C	current	τ - t_{on}	I_C / I_o	δ	δ	$\frac{\delta}{1-\delta}$
Capacitor C	voltage	average	V_C / E_i	0	0	0
Capacitor C	voltage	ripple	$C\Delta v_C / \tau I_o$ $C\Delta v_C / \tau I_i$	$\delta(1-\delta)$ $1-\delta$	δ $\delta(1-\delta)$	δ $1-\delta$
Inductor current I_L	average current	L_i	I_{Li} / I_o I_{Li} / I_i	δ 1	$\frac{\delta}{1-\delta}$ δ	$\frac{\delta}{1-\delta}$ 1
Inductor current I_L	average current	L_o	I_{Lo} / I_o I_{Lo} / I_i	$1-\delta$ $\frac{1-\delta}{\delta}$	1 $1-\delta$	1 $\frac{1-\delta}{\delta}$
Inductor current I_L	dc losses	$PL_i + PL_o$ $L_i = L_o$	$\frac{I_{Li}^2 + I_{Lo}^2}{I_i^2}$	$\frac{2\delta^2 - 2\delta + 1}{\delta^2}$	$2\delta^2 - 2\delta + 1$	$\frac{2\delta^2 - 2\delta + 1}{\delta^2}$
Inductor current I_L	ripple current	L_i	$L_i \Delta I_{Li} / \tau E_i$	$\delta(1-\delta)$	δ	δ
Inductor current I_L	ripple current	L_o	$L_o \Delta I_{Lo} / \tau E_i$	$\delta(1-\delta)$	δ	≈ δ
input/output ripple current	input	I_i	$L_i \Delta I_i$	discontinuous 0, I_o	continuous 2δτE_i	discontinuous 0, I_o/(1-δ)
input/output ripple current	output	into C_o // R	$L_o \Delta I_o$	continuous 2(1-δ)τV_o	discontinuous 0, I_o/(1-δ)	discontinuous 0, I_o/(1-δ)

AC wise, C is a short circuit resulting in Li and Lo being parallel connected such that each topology in figure 1 cct P reverts (degenerates), for analysis purposes, to the corresponding basic dc-to-dc converter in Figure 1 cct A. This paper specifically exploits the benefits gained from zero average capacitor voltage, which are not available with the degenerate basic converters circuits.

From Table I, the average inductor currents ILi and ILo are related to the input and output currents Ii and Io, and the duty cycle δ. Thus as the load current decreases, the input current decreases, whence the average current of both inductors decreases. As the transferred energy decreases (average input current decreases), the capacitor ripple voltage (eqn 1 in figure 1) which is proportional to output current (energy transfer) decreases. Eventually, with decreasing load current, discontinuous conduction occurs in C, characterized by continuous zero capacitor voltage regions at the end of each switching period.

III. SIMULATION AND EXPERIMENTAL RESULTS: THREE

The functionality operation aspects can be initially established by time domain transient analysis. Additionally, component voltage and current stresses can also be assessed, confirming the circuit analysis used to derive the component ratings given in Table I. Table IIA shows the component values and ratings used for both the simulations and the experimentation, although some ideal components (losses capacitors and inductors, no switch and diode switching losses) are assumed in the simulations so as to confirm the theoretical circuit analysis performance values in Table I. Transient analysis simulations were performed using National Instruments, Multisim Power Pro 11.0.1, with user defined initial conditions as shown in Table IIB.

Table 2.A Component values

Ei	20V		T, mosfet	200V, 54mΩ
Lo	1.0mH, 74mΩ, 10A		D, SiC	600V, 10A
Li	1.0mH, 74mΩ, 10A		ton , toff	15μs, 5μs
C	10μF		δ	75%
Co	1000μF		f	50kHz

Table 2.B Circuit initial conditions

Simulation initial values and results				
converter	Buck	boost	buck-boost	
	P#1	P#2	P#5	
Ro	2.8125	80	45	Ω
Co	0.01	100	100	μF
IEi	0, 5.40, 5.26	4 ± 150m	0, 5.66, 5.06	A
ILi	4 ± 37.5m	3 ± 150m	4 ± 150m	A
ILo	1.33 ± 37.5m	1 ± 150m	1.33 ± 150m	A
Vc	0 ± 1	0 ± ¾	0 ± 1	V
Vo	14.99 ± 0.1	79.95 ± 75m	59.96 ± 0.1	V
Io	5.33 ± 36m	1 ± 1m	1.33 ± 2m	A

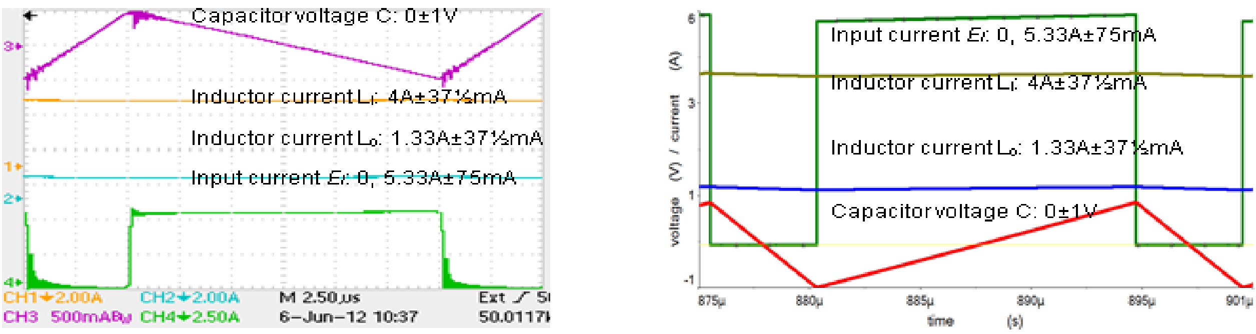
The six plots of figure 2 show the simulation and experimental time domain results for each of the three converters, operating under the same frequency (fs=50kHz), duty cycle (δ = ¾), and input conditions (Ei = 20V and Ii = 4A average, sourcing 80W). The same electrical components, rearranged, are used in each case.

Basically, in simulation and experimentally, the currents in both inductors and the supply input agree, as does the capacitor voltage ripple, all of which are predicted by the appropriate equations in Table I. Figure 2 also shows that the corresponding simulation and experimental current values agree with awing accurately. That is, the current regulation is good, unlike the voltage regulation which is significantly poorer and deteriorates with increasing input current. These converter regulation features are considered further in the next section.

IV. FURTHER EXPERIMENTAL RESULTS: THREE NEW CONVERTER TOPOLOGIES

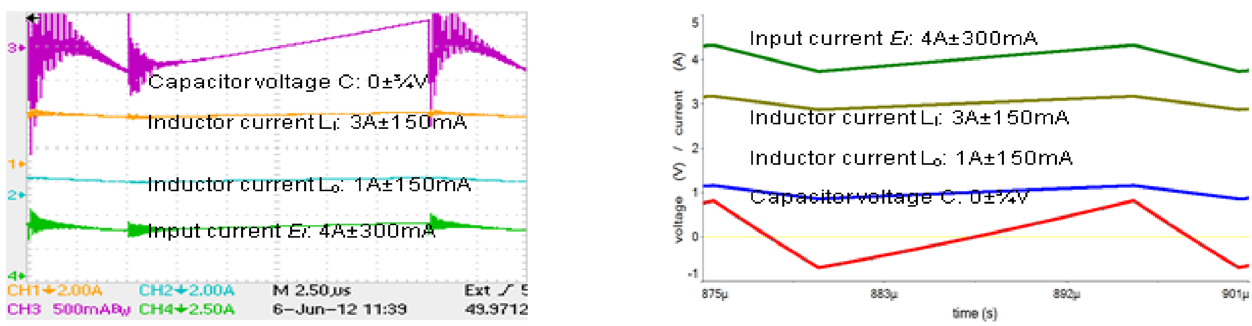
Figure 3 shows the open loop dependence of efficiency, voltage regulation (droop), inductor ripple currents, capacitor voltage and ripple, and output current regulation (droop), on input current average magnitude Ii. The experimental circuit component values are as shown in Table IIA. Generally, these graphs show that efficiency and voltage regulation deteriorate (near linearly) with increased load/input current. In confirming the inductor ripple current equations in Table I, the ripple current of the inductors is independent of load current – figure 3b. The effects of inductor saturation are observed first in the buck-boost and buck converters, before the boost converter, as input current increases, since the buck converter decreases the voltage and increases the output current (hence inductor current) for a given input voltage and current (cf. figure 4b). Figure 3a shows that the boost converter P#2 is the most efficiency hence has the best output voltage regulation, whilst the buck-boost converter P#5 has the lowest efficiency, whence the poorest output voltage regulation. Figure 3b shows that the buck converter P#1 has the lowest inductor ripple currents, which is due to the fact that buck circuit voltages are lower than the boost and buck-boost circuit voltages, for a given input voltage Ei (cf v=Ldi/dt). Also in accordance with the theory and eqn 1 in figure 1 and table I, the capacitor ripple voltage Δvc in figure 3c increases linearly with increased load current (for a given δ, etc.). Due to Lo - Li - C circuit loop losses, specifically the unequal inductor resistive component voltages, thus not included in the theory, the capacitor has a dc bias, which is duty cycle dependant, and increases with load current, as shown in figure 3c. Important to CCM operation, figure 3c also shows that the offset voltage tends to zero as the input current, hence output current, approaches zero (that is, no load). (This bias is not explicitly shown in the Ii = 4A experimental time domain ac coupled waveforms in figure 2.) Figure 3b shows that if the inductances are equal (Li = Lo), the ripple current magnitudes are equal, whence the two inductors can be wound on a common core (as with the Cuk, sepic and zeta converters) but with ripple current addition (not cancellation), resulting in an accumulated dc flux biases. From Table I, the relative current magnitudes in the two inductor windings, change-over at δ=½ (the buck to boost boundary).

In contrast to the output voltage regulation, the three converters exhibit good output current regulation characteristics, as shown in figure 3d. The voltage regulation in figure 3a deteriorates because semiconductor voltages and IR drops detract from the effective input voltage. On the other hand, the current transfer ratio is largely unaffected by voltage components; it is purely a relation between the input and output currents, independent of the input voltage. Hence at the modest input voltage of 20V, the current regulation is an order of magnitude better than the voltage regulation. Such a regulation feature is common to all dc-to-dc converters.

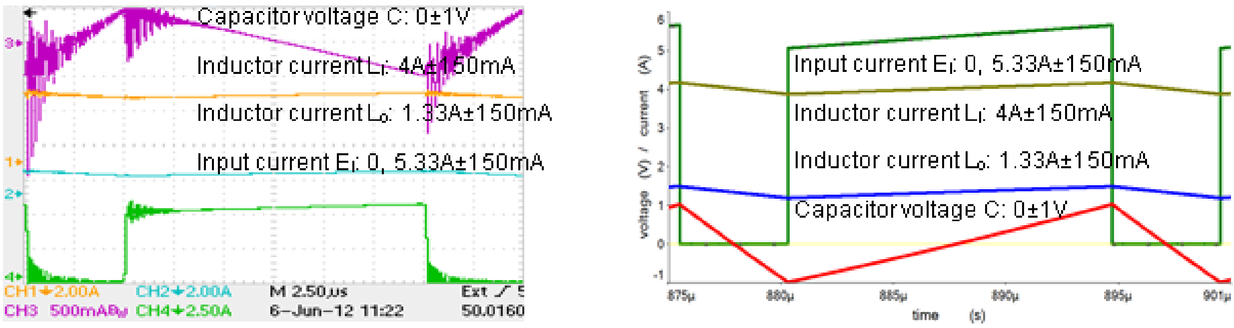


(a) Experimental and simulation buck converter P#1 waveforms:

inductor and input currents and capacitor voltage for Vo = 13.8V, Io = 5.36A, η = 92.5%.



(b) Experimental and simulation boost converter P#2 waveforms:
inductor and input currents and capacitor voltage for Vo = 76.4V, Io = 0.99A, η = 94.5%.



(c) Experimental and simulation buck-boost converter P#5 waveforms:
inductor and input currents and capacitor voltage for Vo = 55.1V, Io = 1.32A, η = 90.9%.

Fig .2. Experimental and simulation results at 50kHz, δ = 75%, Ei = 20V and Ii = 4A (ave): 80W for:
(a) buck-P#1, (b) boost-P#2, and (c) buck-boost-P#5 converters.

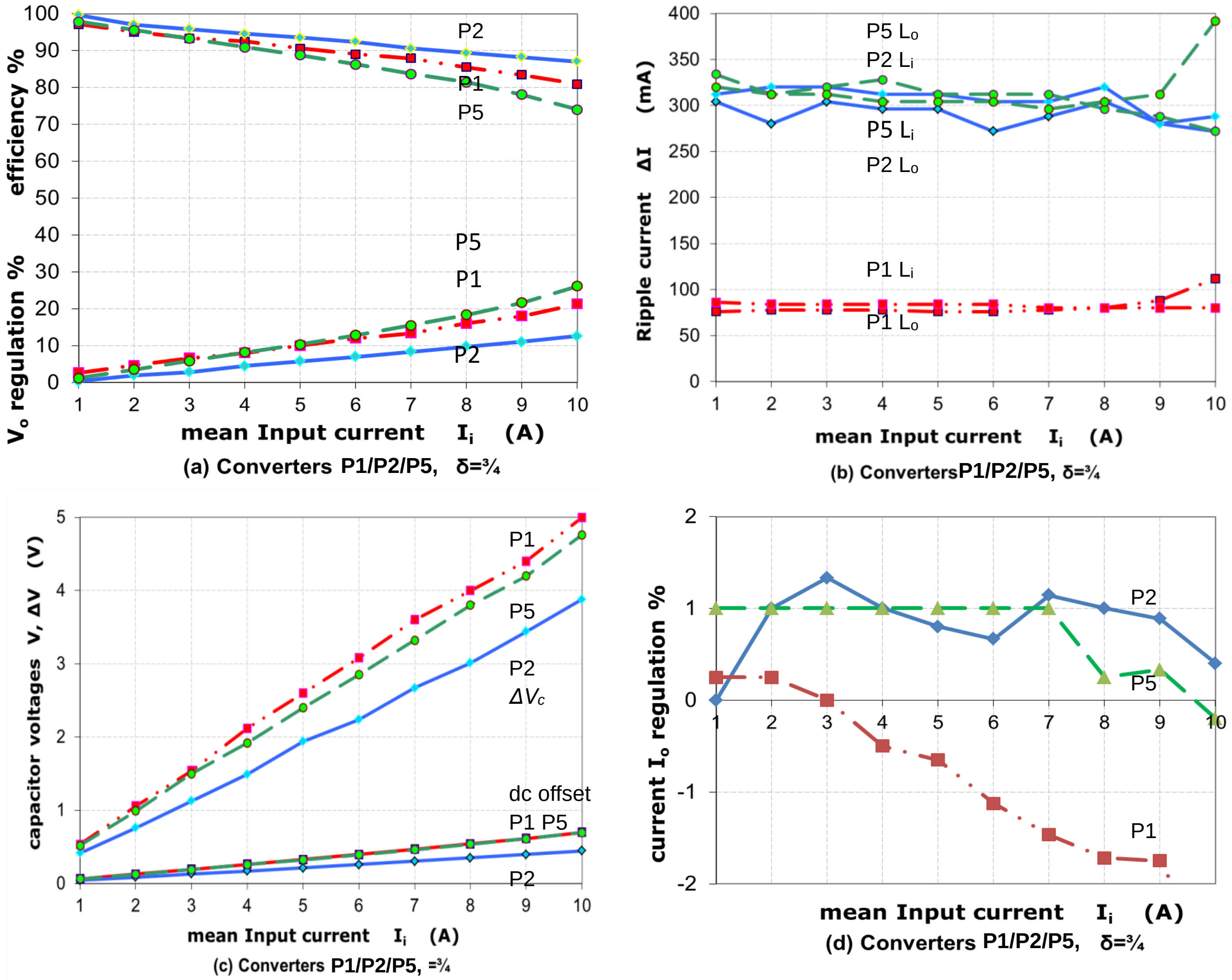


Fig .3. Experimental results at 50kHz, δ=75%, Ei = 20V and varied average input current, for the three new dc-to-dc converters
(P#1≡buck, P#2≡boost, P#5≡buck-boost): (a) output voltage regulation (droop) and efficiency,
(b) inductor ripple currents, (c) capacitor voltages, and (d) output current regulation (droop).

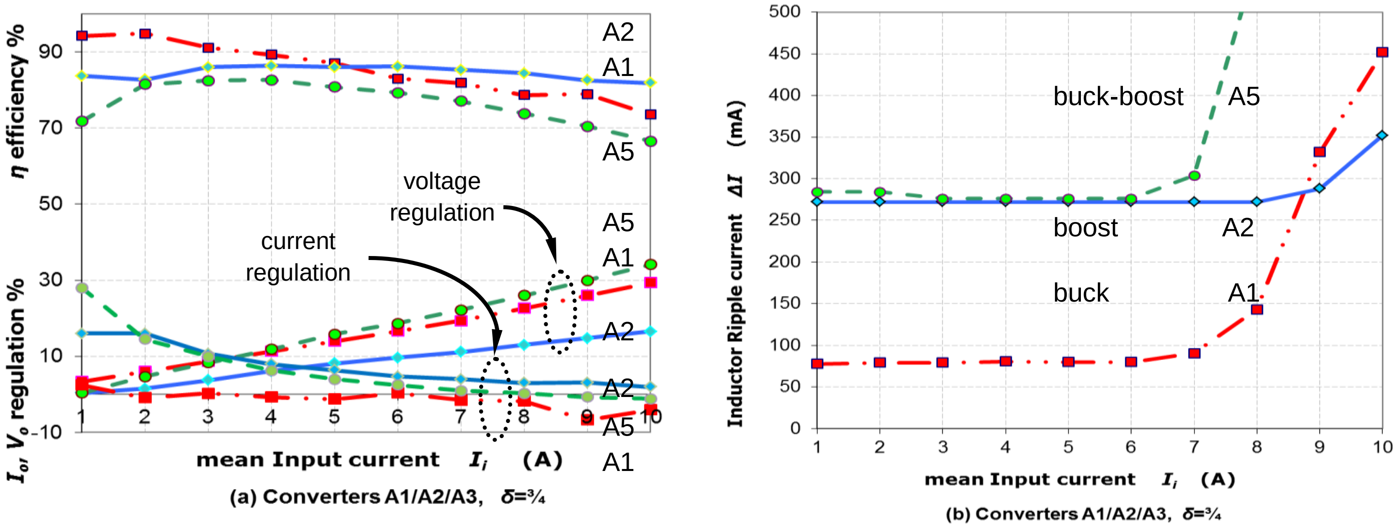


Fig .4. Experimental result for basic single-inductor dc-to-dc converters, A1, A2, and A5: (a) voltage and current regulation (droop) and efficiency and (b) inductor ripple current.

In the three basic dc-to-dc converters, A1, A2, and A5, inductor ripple current is an indication of minimum load current before loss of CCM operation. In the buck converter P#1 waveforms (simulation and experimental) in figure 2a, the ripple current is a constant ±37½mA (which is the same as for P#1 in figure 3b and A1 in figure 4b), which for the basic buck converter A1 represents a minimum load current of 37½mA, for CCM. In a light-load case for the new buck converter P#1, at 100mA (0.01pu) input current, the efficiency is 96.9%, and importantly the output voltage is 14.9V, representing voltage and current regulation droops of 2.5% and 0.7% respectively.

In the case of the buck-boost converter, rearrangement of the basic components, giving the Cuk, sepic and zeta converters, results in similar performance characteristics of efficiency and regulation, as well as ac closed loop performance. The main component difference between the four buck-boost converters is the capacitor dc bias.

V. EXPERIMENTAL COMPARISON WITH THE THREE BASIC CONVERTER TOPOLOGIES

The experimental performance characteristics of efficiency, voltage and current regulation and ripple current of the three basic (buck – A1, boost – A2 and buck-boost – A5) [31] converters are shown in figure 4. The three basic converters have a single energy transfer storage element, namely an inductor; regulation would be expected to be poorer than that for the new converters which (like the Cuk, sepic and zeta converters) have more storage elements. Figure 5 compares the characteristics of the basic converters A1, A2, and A5 with the three new converters, P#1, P#2, and P#5. The boost converter has the best output voltage regulation, whilst the buck-boost converter has the poorest output voltage regulation. The buck converter output current regulation is similar for both buck converters (A1 and P#1) since the basic buck converter also has inductance in the output, which maintains current regulation. The basic boost and buck-boost converters have poor current regulation because the only inductor is not solely in the output (that is, the inductor is switched between the input and output circuits). Figure 4b shows that the inductor current ripple of the three basic converters is similar to the ripple in the new converters, shown in figure 3b. Inductor saturation at just under 10A input is shown in figure 4b, for the three basic converters. In the boost converter A2, the inductor is in series with the input, hence its current is the input current. The buck and buck-boost converters saturate at less than 10A input current, because the inductor average current is not the average input current, but is dependent on duty cycle. Specifically, the basic buck converter inductor current is the output current, which is given by Ii /δ, which is always greater than the input current. The same expression applies to the buck-boost converter, thus saturation is seen to occur at δxIi (¾×10A=7½A) in figure 4b, for both A1 and A5.

The three new converters are correspondingly more efficient, independent of ripple current. For example, the ripple current of the two buck versions (A1 and P#1) is 75mA in each case, yet for the same input power conditions, the new buck converter P#1 is more efficient. The improved efficiency is related to the fact that the effective inductor dc current component is split between two inductors, which significantly decreases the total I2R loss. Specifically for the buck converter P#1 in figure 2a, at 4A average input current, which gives 5⅓A output current at δ=¾, inductor copper losses are 42×74mΩ + 1⅓2×74mΩ = 1.3W as opposed to 5⅓2x74mΩ = 2.1W with the single inductor buck converter A1.

Figure 5 shows that the new converters have better performance indicators (efficiency and open loop regulation) than the corresponding basic converters, but inductor ripple current is the same. This performance improvement with the new converters would be expected since the new converters (like the Cuk, sepic and zeta converters) have more energy storage components. From figure 5c, when comparing the basic and new converters, generally voltage regulation becomes poorer with increasing current. The current regulation for the new converters is near independent of current magnitude, while the current regulation is poorer for the basic boost and buck-boost converters A1 and A5 as the input current decreases.

These comparative performance results, based on figures 3 and 4, and collated in figure 5, are summarized in table 3.

The closed loop design criteria are the same as for the Cuk, sepic and zeta converters, all of which employ two inductors and a capacitor, rearranged. This is because all these topologies have the same ac equivalent circuit.

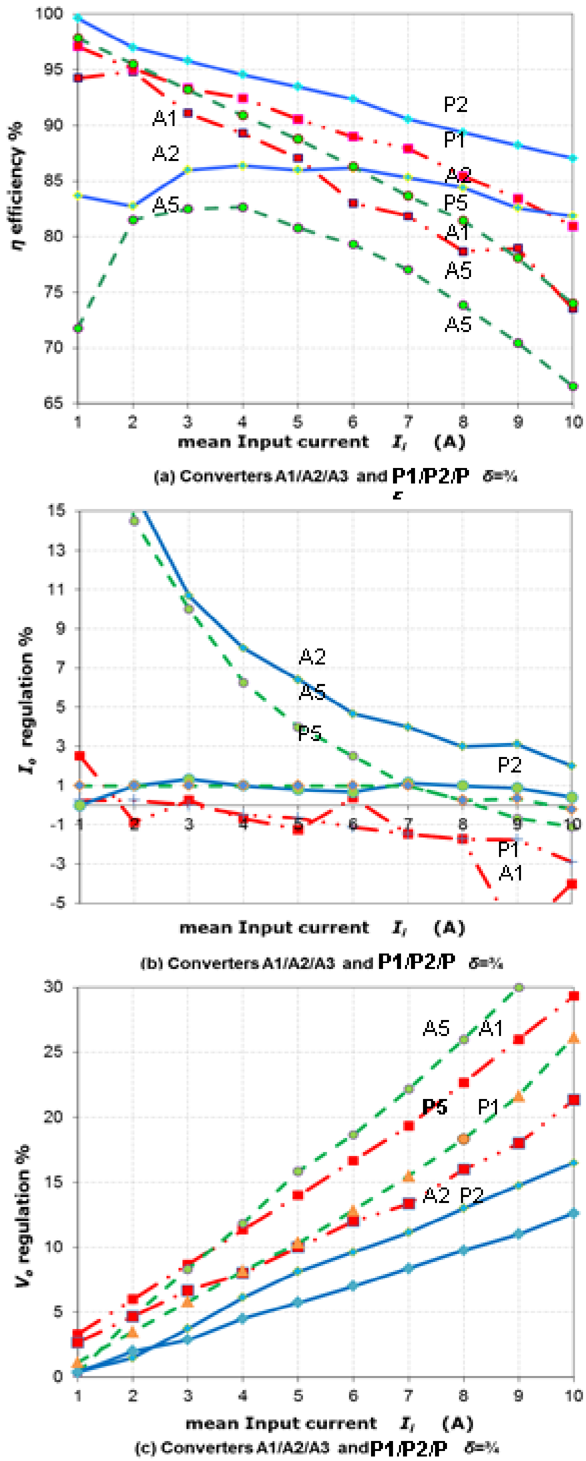


Fig .5. Experimental result comparing three basic (A1, A2, A5) and three new dc-to-dc converters (P#1, P#2, P#5):

(a) efficiency, (b) output current regulation (droop), and (c) output voltage regulation (droop).

Table 3. Comparison of operational properties and characteristics (at δ=¾).

	CONVERTERS					
	Basic converters (one inductor)			New converters (two inductors and one capacitor)		
transfer function	buck	boost	buck-boost	buck	boost	buck-boost
classification	**A1**	**A2**	**A5**	**P#1**	**P#2**	**P#5**
efficiency	Less than P1 Better than A5	Less than P2 Better than A5	Less than P5 Poorer than A1 and A5	Better than A1 Better than P5	Better than A2 Better than P1 and P5	Better than A5 Poorer than P1 and P5
output voltage regulation	Better than A5 Poorer than P1, P2, and P5	Better than A1 and A5 Better than P1 and P5	Worse than A1 and A2 Poorer than P1, P2, and P5	Better than P5 Better than A1 and A5	Better than P1 and P5 Better than A1, A2 and A5	Worse than P1 and P2 Better than A1 and A5
output current regulation	Similar to P1 Better than A1 and A2	Poorer than P2 poorer than A1 and A5	Poorer than P5 Poorer than A1	Similar to A1 Similar to P2 and P5	Better than A2 Slightly better than P1	Better than A5 Slightly better than P1
ripple current	Same as P1 Less than A2 and A5	Similar to P2 Similar to A2 and A5	Similar to P5 Similar to A2 and A5	Same as A1 Less than P2 and P5	Similar to A2 Similar to P5	Similar to A5 Similar to P2

VI. TRANSFORMER ISOLATED BUCK-BOOST CONVERTER

The basic buck-boost converter A3 output can be isolated via a coupled magnetic circuit. Additional features to isolation are voltage matching and better semiconductor utilization, but the limitation is that energy is temporarily stored in the magnetic coupled circuit core. Thus for a given magnetic material, maximum energy transfer is limited by core volume, viz. ½BH×Volume. The core volume is utilized differently if magnetic energy transfer is through transformer action (as with the Cuk converter variation) rather than intermediate energy storage (as for the basic buck-boost converter variation).

If energy is transferred from the source to the load via ripple current through a series capacitor, then that capacitor can be split so as to facilitate an interposed high magnetizing inductance shunt transformer as shown in figure 6. If electrical equivalence is maintained, each capacitor has the same capacitance as the original capacitor, if the transformer turns ratio is 1:1. This is the process used for the transformer isolated Cuk converter, with a buck-boost voltage transfer function, which fulfills the series energy transfer capacitor requirement. The transformer acts in a current controlled mode where the voltage adjusts to meet the corresponding voltage requirement associated with the transformer equation ($I_{in} / I_{out} = V_{out} / V_{in} = N_{out} / N_{in}$) together with the converter current/voltage transfer function ($I_i / I_o = V_o / E_i = -\delta / 1-\delta$), both enforced since both equations must comply with instantaneous energy conservation. This operation is not to be confused with the problematic so called 'verge of coupled circuit and transformer operation'. In the Cuk converter case the split capacitor pair must also fulfill the important function of blocking a dc voltage component (E_i on the primary, V_o on the secondary) from the magnetic coupling circuit, which is catered for, blocked, by using large capacitance. The new buck-boost converter P#5 theoretically develops no dc voltage component on the primary or the secondary, because each is in parallel with inductance, which has zero average voltage. In practice, any dc voltage bias is modified (increased) due to component voltage drops, including inductor and transformer winding resistance associated voltages.

The energy transferred is the load power Vo Io over the switching cycle period τ, which is related to the change in energy in the primary and secondary capacitors Cp and Cs. From eqn 1 in figure 1, for the buck-boost converter, the capacitor ripple voltage is given by

$$\Delta V_c = \frac{t_{on} \times I_o}{C} = \frac{(\tau - t_{on}) \times I_i}{C}$$
$$= \delta \frac{I_o \tau}{C} = (1-\delta)\frac{I_i \tau}{C}$$

Therefore the capacitor dv/dt requirement is

$$\frac{\Delta V_c}{\Delta t_{on}} = \frac{I_o}{C} \qquad \frac{\Delta V_c}{\Delta t_{off}} = \frac{I_i}{C}$$

Energy is transferred in a single direction through the transformer: the voltage polarities change depending on whether the capacitors are charging or discharging, but with zero average current. Since the capacitors in P#5 have a zero average-voltage requirement, that is, do not need significant dc blocking capability, the capacitance is dimensioned based on dv/dt restrictions (as opposed to average voltage values in addition to superimposed dv/dt limitations as with the Cuk, sepic and zeta converters). Capacitance transfers transformer sides in the turns ratio, inverse squared (Xcα1/C).

results yield 80.5% efficiency at 80W input, falling to 70% efficiency at rated (200W) 10A input, for the given duty cycle, δ=¾. The capacitor dc offset of 380mV at 4A and 1.2V at 10A, implies Joule losses consistent with 110mΩ resistance in the transformer (primary and secondary) and inductor (74mΩ), plus switch (54mΩ) loops. An RCD snubber or a transient surge suppressor (<1W for 20V, 10A input) is essential to preventing excessive switch voltages at turn-off due to transformer leakage inductance (≈200nH) related trapped magnetic energy. Differences between the experimental and simulation results are due to the simulation models not accounting for switching losses, capacitor tan δ, and transformer leakage inductance losses and effects.

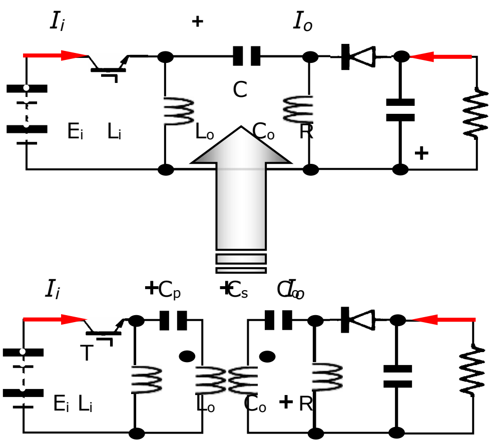


Fig .6. New dc-to-dc buck-boost converter P#5 conversion to transformer coupled version.

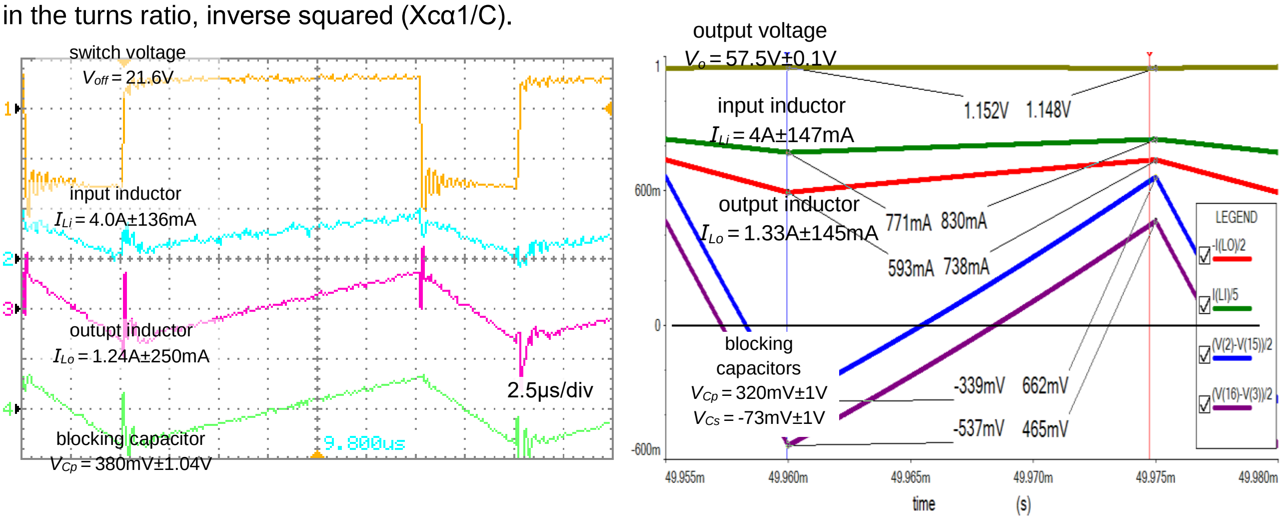


Figure 7. Simulation and experimental results for the transformer coupled buck-boost converter P#5,
at 20Vdc, 4A ave (80W) input, η=80.5% (output 51.9Vdc, 1.24A).

Figure 7 shows time domain simulation and practical results, which confirm the mechanisms proposed, when the component values are as used for assessment of the three converters, in table IIA. The series energy transfer capacitors are both 10μF and the transformer has a 1:1 turns ratio. The practical

VII. CONCLUSIONS

Three new dc-to-dc converters (buck – P#1, boost – P#2, and buck-boost – P#5) have been presented. Like the Cuk, sepic, Luo and zeta converters, the disadvantage of the three new converters is that an extra capacitor and inductor are needed, compared to the three basic dc-to-dc converters (A1, A2, and A5). The advantages gained by the extra passive energy storage components, as with the Cuk, sepic and zeta converters, are better efficiency and output voltage and current regulation.

Analysis wise, the new circuit topologies degenerate to the equivalent basic converter with the same voltage transfer function (A1, A2, and A5). The interesting features of the new converters are associated with the fact that the three topologies have zero average capacitor voltage. Unlike the Cuk, sepic and zeta converters, capacitor stressing is solely limited to dv/dt stressing, without a dc component. This property is best exploited in a transformer isolated version with a buck-boost transfer function, P#5, where the split capacitors have zero average voltage, that is, zero dc blocking voltage requirements, unlike the split capacitor transformer isolated Cuk converter. This new topology has been validated by simulation and 20V, 200W experimentation, and is suitable for fuel cell, battery, and PV module isolated interfacing.

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Renewables within the German Electricity System Experiences and Needs

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***Abstract* -** During the last two decades renewable sources of energy as an environmentally friendly alternative to fossil fuel energy have gained greater importance within the German electricity system. Their share has increased from less than 4 % to roughly one third of the gross electricity production in the last 25 years. Against this background, the goal of this paper is to present briefly the current status of the use of renewables within the German electricity system, to assess selected developments taking place during this development process and to identify given challenges and needs as well as the necessary actions to pave the road for a further use of renewable sources of energy. The political driver for the latter is the overarching goal to reduce Greenhouse Gas (GHG) emissions which have been confirmed within the Paris agreement signed by the end of 2015.

I. INTRODUCTION

As one consequence of the Kyoto Protocol, the European Union (EU) has implemented binding Greenhouse Gas (GHG) reduction targets. Following this overall goal also Germany has to reduce energy related GHG emissions substantially. Thus, a broad variety of policy measures have been implemented within the last decades among others to bring renewable sources of energy closer to the market and to exploit their possible contribution to this overarching political goal. Within the electricity sector the most important policy instrument implemented by the government has been and still is an act on the use of renewable sources of energy for electricity generation, i.e. the Erneuerbare-Energien-Gesetz (EEG; electricity-feed-in law). Initially, within this act fixed reimbursement rates for different electricity generation options from renewable sources of energy have been defined. These fixed feed-in rates for "green" electricity are guaranteed by the government for 20 years and electricity from renewable sources is granted priority access to the public electricity grid independent from the actually given demand for electrical energy within the electrical distribution system. The remuneration of the fixed and guaranteed reimbursement for "green" electricity is financed by a surcharge to be paid by all electricity consumers except for an increasing number of large scale industrial consumers that face strong competition on international markets or whose expenditures amounts to a high share of their gross value added.

Based on such measures the share of renewables within the electricity supply system has increased significantly in Germany (Figure 1) from less than 4 % in 1990 to roughly on third in 2015; within the last year all over close to 200 TWh (2015) of electricity has been produced from renewables and the overall German electricity consumption has been roughly 600 TWh (2015). Wind energy (i.e. onshore and offshore use) contributes with close to 45 %, biomass (i.e. solid biofuels, biogas) with 26 %, photovoltaics with ca. 20 % and hydropower with less than 10 %. The avoided GHG emissions due to this renewable electricity generation have been summed up to more than 167.5 Mill t (2015). Related to the overall energy related GHG emissions of close to 900 Mill t (2015) and this represents a share between 18 and 19 %.

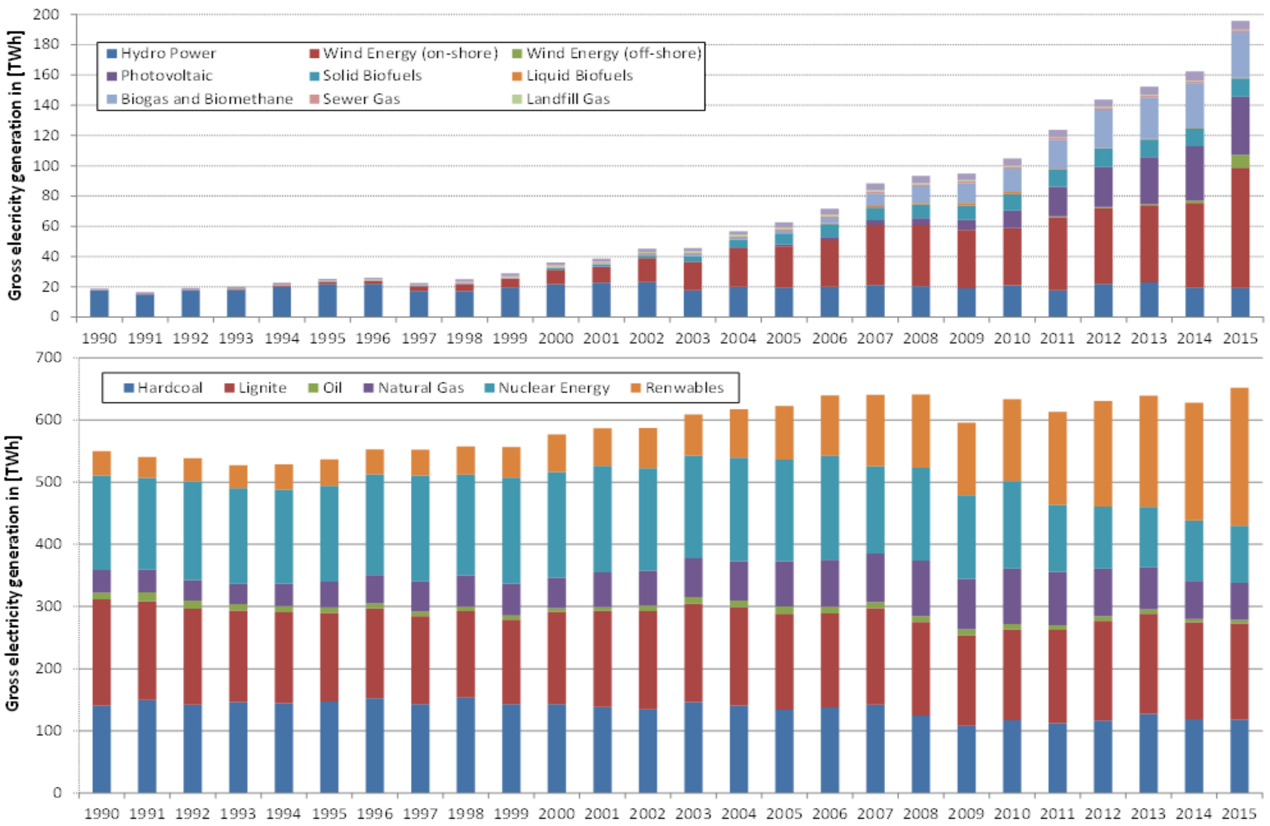

Fig .1. Gross electricity generation in Germany (lower chart: overall development, upper chart: electricity generation from renewables) (data according to [1, 2])

II. EXPERIENCES AND LESSONS LEARNED

Wind energy. As a consequence of the promising feed-in tariffs and the stable long term conditions guaranteed by the legal framework, electricity generation from wind energy has steadily expanded from basically zero around the year 1990 to 79.3 TWh (only onshore installed wind mills) in 2015. This increase in power generation has taken place in parallel with a strong and impressive technological development of the wind mill technology. Thus during the 25 years between 1990 and 2015 wind mill technology has been characterized by a strong increase in the installed electrical power per unit from roughly 100 to 250 kW in the late 1980s / early 1990s to more than 5 to 6 MW today. This power increase throughout these roughly 25 years has been accompanied by clear reductions in specific market prices as well as continuously increasing overall efficiencies and reliabilities. Beside this, wind mills become more environmentally sound, their operation much more reliable, their safety features more advanced, and their interaction with the electricity grid more system compatible. In parallel, wind mill manufacturing in Germany has been developed to a fast growing large scale innovative industry sector with high technological standards and a strong export orientation during this quarter of a century due to globally strongly growing markets. This impressive development has been supported and accompanied by the development and implementation of binding and non-binding guidelines and standards defining various side aspects for the increasingly larger wind mills (e.g. noise, safety and environmental standards); i.e. a process has been takening place to develop the wind mill industry to industry branch fully integrated within the German overall economy. The wind mills currently available on global markets from the German manufacturers present a fully marketable technology easily adaptable to locations with a different wind supply, which can even support grid stability.

This development has been accompanied by considerable and controversial as well as very emotional discussions related to the visual impact of wind mills on the landscape due to their over time strongly increasing dimensions as well as the rotor rotation putting movements into a formerly more or less static landscape. Thus, with an ongoing expansion of the installed wind mills and thus an increased use of this technology the acceptance by the local population as well as promising wind mill sites with high average wind speeds continuously decreased. Especially in areas where many wind mills have been installed due to favorable wind conditions (e.g. in areas close to the North Sea coast) citizens' initiatives became more active and hindered or even prohibited further installations. To alleviate this obstacle, the German government promoted the installation of offshore wind farms in the North Sea as well as the Baltic Sea. Advantages of this approach to go offshore are significantly higher electricity yields at a certain spot due to considerable higher wind speeds compared to most onshore locations and a much better acceptance by the public. Severe technological challenges clearly higher specific electricity generation costs and still hard to fulfill legal conditions for the protection of the fragile offshore ecosystems present strong disadvantages of this approach. To overcome the challenging environmental, economic and site-specific conditions given at locations more than 50 km off the North Sea coast in water depths of 30 m plus hindering an increased wind energy use, the existing political framework has been adjusted to set appropriate conditions to foster offshore wind energy utilization; i.e. the feed-in tariffs have been increased several time to compensate the given technical risks and the high costs necessary to master the challenging conditions regarding location as well as to fulfill the environmental protection requirements controlled by the local authorities. Even due to these challenge in 2015 already 8.7 TWh provided from offshore located wind mills have been feed into the German electricity grid in addition to several additional offshore wind parks which are under construction. In parallel great effort is put into the development of advanced wind mill technologies operating reliable even under the rough and challenging environmental conditions offshore as well as the necessary foundations to fix the mills securely on the sea ground; experiences available so far have shown that there is indeed a huge demand to adjust the wind mill technology to face successfully the significantly different environmental conditions given at a certain offshore location. The developments in the years to come will show if the cost reductions to be expected with an increasing installation of offshore wind parks combined with a much better wind supply within these locations will offset the additional investment and maintenance costs of offshore installations. If this turns out to be the case, this option offers huge electricity generation potentials as well as immense markets for equipment and services globally. Besides, on the longer term a significant share of the electricity needed by the German population might come from offshore wind parks due to the huge potentials as well as the relatively high wind speed.

Photovoltaic (PV). The support scheme implemented by the German feed-in law has originally been designed to support electricity generation systems based on renewable sources of energy to become marginal profitable by the owner / operator. Beside climate protection as the main driver the intention was to help these technologies to become market mature (i.e. to overcome the market entrance barriers) and in parallel to treat the electricity customer / the payer of this additional financial burden with care with respect to the resulting costs (i.e. to minimize the additional costs for the final user of the electricity). This has been especially true for PV systems, which were politically intended to be operated by individuals in the one digit kW-range and to be installed on dwelling houses without additional land use to increase acceptance; the original politically intended long term vision was to upgrade each dwelling house to a small power plant. These circumstances combined with the still relatively high costs and limited return on investment some 10 years ago, the share of PV within the German electricity system was almost negligible till 2006/07. In the following years, prices of PV modules dropped fast and significantly due to a strong development of the respective production capacities especially in China among others due to the incentives granted by the Chinese government. These strong decreases in module prices in these days, combined with the now relatively high reimbursement rates guaranteed and continuously confirmed by law resulted in a rapid development of small and especially large scale PV systems operated by individuals as well as financially strong market participants (e.g. investment funds, utilities, pension funds). And this relative profitability during these days increased on a daily basis because the feed-in tariffs defined within the German feed-in law have not been adapted adequately in parallel; i.e. it has been very profitable to invest in PV systems for financially strong investors as well as private market participants. This development shows clearly the disadvantage of fixed reimbursement rates with an unlimited expansion option as it has been realized within the German feed-in law these days. If market prices change rapidly due to new production facilities and/or a strong expansion of the market volumes the reimbursement rates could not be adjusted fast enough due to the time consuming administrative procedures necessary to amend an existing law.

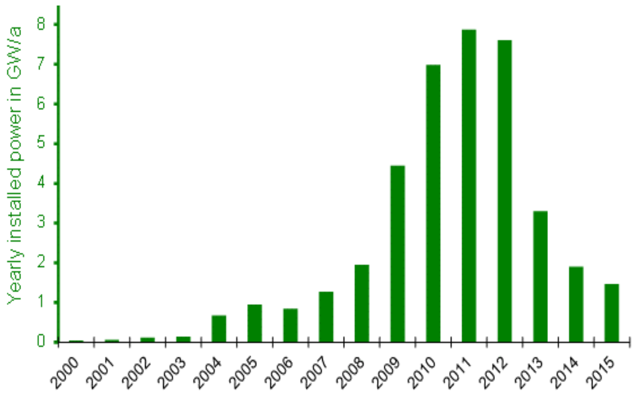

Fig .2. Yearly installed PV capacity in Germany (data according to [7]).

This development results in an installation of roughly 7 to 8 GW/a in PV systems in the years 2010, 2011 and 2012 (i.e. 22.5 GW within these three years, Figure 2). During the beginning of this time period roughly half of the global PV module production has been installed only in Germany, this share decreased then to about one third in 2012. Thus, the (subsidized) German market helped significantly to pass through the learning curve, to overcome the market entrance barriers, and therefore to bring the prices for PV modules globally down. As a consequence the foundation of the worldwide market break-through of PV systems has been set these days based on the money of the German electricity consumer. As a result of this impressive development, the surcharge to be paid by electricity consumers in Germany has reached roughly 10 Bill €/a, which corresponds to 0.0263 €/kWh to be paid according to the legal frame work with the monthly electricity bill mainly by the household and other small customer of electrical energy (some large scale industrial consumers of electricity do not have to pay this fee due to the legal situation in Germany). In total, the overall capacity of the installed PV modules reached 39.7 GW in 2015, providing 38.4 TWh (2015) of electricity.

To limit the significant cost increase and to meet the instructions from the European Union (EU), the legal support scheme for renewables in general and PV in particular has been changed completely in recent years. A bidding system with a clearly defined cap (i.e. a maximum amount of electrical capacity to be installed each year) has been introduced. The very limited practice with this support scheme has shown so far that the aspired goal of 1.5 GW/a of PV capacity to be installed have not been reached due to numerous reasons related to the design of this support concept as well as a strongly changing environment within the electricity market.

Solid biofuels. The electricity-feed-in law has also triggered a significant and unexpected increase in electricity production based on solid biomass. In 2015, ca. 18.2 TWh of electricity and 19.3 TWh of heat have been produced by co-generation (CHP) from solid organic matter. The technical maturity of an energy generation from solid biomass based on CHP-systems under operation within the wood processing industry already since generations resulted in a rapid market increase in 2000 as soon as the feed-in law was opened up to electricity generation from such fuels (Figure 1). These existing plants operated by industry are needed to produce electrical energy for the various wood processing facilities, to provide heat for drying the manufactured wood products, and to get rid-off the wood waste piled up during wood processing. After the implementation of this option within the feed-in law new plants have been erected by investment companies as well as various utilities using contaminated wood waste. Thus, this legally pushed increase of energy generation from solid biomass has been taken off on decades of experiences available already within industry from the construction as well as the operation side. Therefore an immediate roll-out of this technology has been possible and has been realized successfully. However in argumentum e contrario basically no major new technological advancements have taken place. Thi has also been one of the main original goals of the feed-in law; i.e. only state-of-the-art technology has been installed within the growth process and thus for example no gasification facility promising higher electrical efficiencies has been realized due to potentially too high technological and thus economic risks.

All over Germany started to use on large scale demolition wood as a fuel for electricity generation and/or for combined heat and power (CHP) starting roughly in the years around 2000. Independently from this, since the 1990s this fuel has been used extensively for power and/or heat generation in such

European countries where a CO2-tax has been implemented and/or low emission standards have been valid; i.e. during these days demolition wood incurred in Germany have been exported e.g. to Italy and to Sweden. However, with the implementation of the feed-in law in Germany this development has come to a stop. Subsidizing electricity from (contaminated and non-contaminated) wood (waste) and thus developing own wood-fired power plants in Germany has induced not foreseen market and thus price effects within the markets for such solid biofuels. Prices for fuel wood / demolition wood / waste wood have increased significantly and waste wood has changed from being considered waste bringing money(i.e. the institution producing the waste wood has to pay deposing fee to the waste management company to get rid of this waste) to a valuable energy carrier with a market price defined by the average heating value; (i.e. power plant operators formerly received wood waste disposal fees and now they have to pay for the waste wood according to the average heating value). The increased demand for fuel wood due to an over-expansion of the amount of the respective power plants furthermore resulted in an overall price increase for all types of fuel wood / waste wood for industrial/ energetic purpose Thus, potential economic profits to be exploited by the owner of a power plant using waste are not possible any more. But, still the producer of the waste wood has to pay to get rid of this material. The economic margin in between has been exploited by fuel wood / waste wood traders. Due to these effects the profitability of power plants fueled by waste wood have been lowered considerably. This development has increased the economic pressure on power plant operators / owners dependent economically on disposal fees or very low fuel prices. Resulting effects have been the shut-down of some of these newly build power plant facilities and/or the conversion of a wood fired power plant to a coal fired facility.

Besides, also the prices for virgin wood fuels have increased. This price increase have also had a strong influence on the market prices for wood as a raw material and thus on the feedstock used by the wood processing industry. This development has been very much appreciated by most of the producers (i.e. the forest owner) but not at all by the wood processing industry interested in low feedstock prices. This was the reason why the German wood processing industry has been strongly opposed to this part of the feed-in law and thus has campaigned heavily against an electricity generation from wood even due the fact that an electricity generation from wood waste piling up during wood processing has been and still is realized to a large extend within their own factories. The consequence of these political activities of the various responsible associations has been a strong cut of the reimbursement rates preventing economically the use of virgin wood within large scale power plants as well as large CHP-plants.

Additionally, nowadays basically the overall available amount of demolition and other wood waste that is not useable as a raw material for producing recycled wood products (e.g. chip board, oriented structural board) is used energetically. Thus the installation of new wood waste fired power or CHP plants has come to an abrupt stop when the fuel wood demand of the existing plants exceeded available potentials of demolition wood / waste wood in Germany. This development is supported by the fact that reimbursement rates are too low resp. the prices for fresh wood are too high to allow the use of significant amounts of virgin wood material within the large scale energy market. As a consequence, electricity generation from solid biofuels has been more or less stable in recent years because the yearly incurred demolition wood / waste wood is more or less constant in Germany and an increased import is not possible due to economic constraints.

Biogas. Also biogas production and a subsequent electricity provision have shown a remarkable development in recent years in Germany. Starting basically from a plant inventory of some 100 "homemade" biogas plants some 25 years ago the technology has become technically mature with highly efficient, easy to operate, reliable and environmental sound plants. In 2015, close to 9,000 biogas plants (Figure 3) have been in operation primarily within the agricultural sector. These plants produced roughly 31.8 TWh of electricity and in parallel 16.8 TWh heat in 2015.

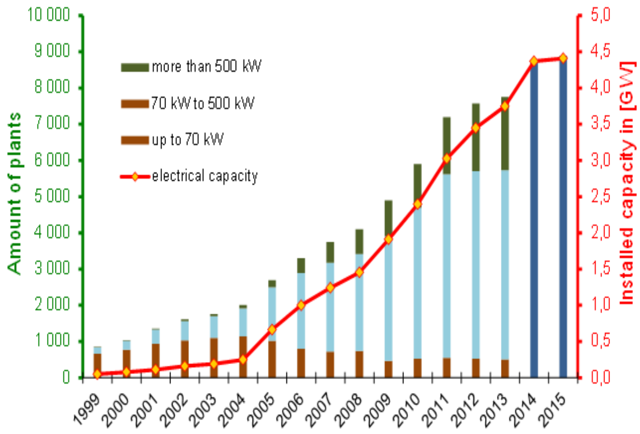

Fig .3. Development of the installed capacity in biogas plants in Germany (2014 and 2015: preliminary data; data according to [7]).

This biogas production is based on two different types of feedstock: organic residues and wastes as well as energy crops. Both material streams are a priori limited.

- Organic residues and wastes suitable for biogas production, e.g. animal manure, organic urban waste fraction from household waste, organic waste from the food processing industry, need to be collected and transported. But, such organic material is characterized by high water content typically contained within such organic material streams and a low energy yield. Thus, this material cannot be transported over long distances due to economic reasons (i.e. mainly water is transported). In contrast, due to "economy of scale"-effects, biogas plants become specifically clearly cheaper with increasing capacity and very small biogas plants are typically specifically extremely expensive. Due to this dilemma only a (small) part of the overall available organic residues and wastes are used so far, even considering the fact that the subsidizing scheme supports the use of such organic matter in small scale biogas systems with a bonus, which is however too low to fully exploit the existing technical potentials. Thus the debate on how the existing agricultural and non-agricultural waste and residue streams could be utilized in the most efficient manner related to technical, economic and environmental aspects taking also acceptance aspects into consideration is still ongoing. It is not expected that this discussion will come to an end in the months to come.
- Fertile agricultural land is limited and cannot be expanded at least in Germany. However, in recent years, slightly increasing yields of roughly 1 to 2 %/al- together with a stable population with more or less a constant food pattern resulted in an ongoing reduction of the demanded agricultural land for food production. Thus during the last decades an increasing amount of agricultural land has not been needed any more to produce food and feed for the domestic market. This development will most likely be ongoing and even accelerate in the years to come because the German population will probably decline in the future due to low birthrates; this is supported by an ongoing trend towards a higher share of vegetarian food. To keep this "surplus" land fertile energy crops can be produced on this agricultural land which is basically not needed for food and fodder production any more – if these land resources will not be used to produce food for an increasing export of food "Made in Germany" and/or set aside based on public money e.g. due to ecological considerations (e.g. increase in biodiversity). Additionally, the availability of fertile agricultural land is also very much influenced by other regulations, e.g. the Common Agricultural Policy (CAP) of the EC, land requirements for other energy crops, e.g. rape for Biodiesel production, the need for biomass as a raw material, e.g. for the chemical industry, as well as the agricultural production intensity in Germany. Taking these influencing parameters into account, the potential of producing energy crops is already used to a considerable extend (currently substrates for biogas plants are grown on ca. 1.4 Mill ha and the overall agricultural land in Germany is 11.8 Mill ha). Additionally public acceptance of growing energy crops is limited and some NGO's are working hard to reduce the amount of land used for this purpose due to ethical and/or environmental objections. Beside this, agricultural feedstock production for biogas plants is expensive and thereby contributes to high electricity generation costs. Thus, also discussions on the energy provision costs of biogas are on the political agenda. Thus it is not expected that the amount of land used for the production of biogas feedstock will expanded significantly in the years to come.

Consequently, a further expansion of biogas production will reach sooner or later its limit in Germany. This is independent from the fact that biogas production is anyway controlled by the reimbursement rate granted by the feed-in law which has been step by step reduced in recent years. Thus, after the end of the boom phase in recent years the industry producing and constructing biogas plants urgently need to find new and/or additional markets for their products nationally and in particular internationally if they want to survive and thus stay in business in the longer term. In this respect the food processing industry seems to be a promising commercial market for biogas plants. Companies providing food products produce necessarily organic waste streams to be treated and/or utilized in one way or another in most countries globally due to environmental reasons.

Additionally these companies always need energy, i.e. heat and electricity, to process the food biomass to a marketable food product meeting the needs of the customer. The use of these organic waste streams – together with waste water polluted with organics typically provided necessarily in parallel – to provide biogas could contribute significantly to solving both challenges. This is a reason why some countries have already started to force the food processing industry to install biogas plants as an adequate measure for the management of the produced organic waste streams, for environmental protection, for "green" energy provision and for cost reasons as well as for a better acceptance within the local population. These arguments and developments are some reasons why in Germany there is currently a tendency to reroute the developments within the biogas sector towards the use of organic waste streams from commerce and industry as well as from households instead of expanding the production of biogas from energy crops to be produced on fertile agricultural land. The fact that the increasingly more local waste management companies start to collect organic household waste separately adds up to this.

Geothermal energy. The feed-in law grants also feed-in revenues for electricity from geothermal energy. Due to the less promising (i.e. average to below average) geological conditions in Germany compared, for example, e.g. to New Zealand, the Philippines, and Iceland, the reimbursement rate has been defined generous according to the status of knowledge more than 15 years ago when geothermal electricity generation has been included within the legal subsidizing scheme. Based on this a gold rush mentality developed visible in popping up of lots of different companies with basically no relevant experience promising very high revenues to public and private investors. Some of these companies have been successful in convincing communities to invest in geothermal CHP plants. But none of these projects have been completed in time achieving the aspired performance figures. Some of these projects have even been terminated in the design phase already. Others have not been successful in finding enough hot water to meet the necessary design criteria (i.e. temperature level, specific production rate and water quality) within the unlocked reservoir. Some projects even failed in unlocking the geothermal reservoir due to severe technical problems during the drilling process.

This invidious situation has also been recognized by the German government. To give the emerging geothermal industry a chance to develop towards a reputable industry branch yearly several 10 Mill. € of public money for research and demonstration activities have been provided to support at least two or three geothermal CHP plants to go successfully into operation. Besids, the reimbursement rate has been increased several times to improve the economic incentive to bring such geothermal plants closer to the market. In parallel, subsidies have been made available by the state-owned KfW-bank to develop also heat distribution infrastructure to allow the sale of "green" geothermal heat provided in parallel to geothermal electricity within the geothermal CHP units.

After the first geothermal energy systems have gone successfully into operation with some years of delay several new projects have been initiated. Most of them failed; but roughly a handful has been realized. Thus, due to these administrative measures so far 8 geothermal power resp. CHP plants are under operation in Germany with an overall installed electrical capacity of roughly 33 MW. These plants provide 0.13 TWh of electricity and in parallel 1.2 PJ of heat (2015).

The experiences gathered during the operation of these plants have been very much mixed. One plant initiated a weak seismic incident. Due to the resulting fear of additional earth shattering and the respective disapproval of the local people this plant is only allowed to operate in part load to avoid or at least to minimize further seismic effects. Other plants do have significant economic problems among others due to expensive maintenance efforts especially with the submersible pump transporting the geothermal fluid from the underground to the above ground. These are some of the reasons why there is basically no visible development in this field so far. The only exemption is the area around Munich where the Molasse Basin shows relative stable geological conditions allowing for a reliable CHP-operation. Additionally in Munich a big district heating system has been installed during recent decades which can distribute geothermal heat on a large scale to the final customer, but even there the available potential does not exceed a couple of plants.

III. FINAL CONSIDERATIONS

Renewable sources of energy have gained more importance within the German electricity system. Important aspects can be summarized as follows (see also [3-11]).

- The use of renewable sources of energy can be expanded significantly within the electricity system by administrative measures; the development in Germany during the last 25 years has proven that such a political strategy can be successful (even to due the fact that not all implemented measures and each renewables source of energy getting financial support have proven to be a success story). With a share of roughly one third of the electricity generation coming from renewables in 2015 two main political goals of this legally controlled development has been achieved: the amount of greenhouse gas (GHG) emissions has been significantly reduced and the share of domestic energy carrier within the electricity system has been noticeable increased.

- If the legal frame work is set adequately and the overall goal of such a politically intended development is clearly defined and widely accepted by the majority of the population (as it is still the case in Germany) such a strategy can push the technological development and thus create additional benefits for the overall society, e.g. availability of new jobs, creation of value in rural areas, and set-up of export oriented industry branches. From a purely technological point of view the following experiences could be observed.

A. If a conversion technology has already been available on the market and a significant growth potential is given the legal frame could trigger an impressive und unforeseeable technological development; in Germany this has been especially true for wind mill technology and photovoltaic systems as well as for biogas plants. New and not market mature technologies as well as options with a limited expansion potential have not or to a very limited extent, been further developed (e.g. electricity generation from solid biofuels). Other electricity provision options characterized by too much uncontrollable risks related to the potential return on investment together with insufficient and error-prone technological solutions failed respectively and showed only a very limited development (e.g. geothermal electricity generation).

B. Due to the market introduction of conversion technologies using renewable sources of energy based on administrative measures considerably more efficient – and thus theoretically cheaper – conversion plants have been developed throughout recent years; the development of completely new industry branches has been a consequence. This development has been supported by yearly decreasing reimbursement rates to force industry to come increasingly closer to electricity generation costs competitive on global energy markets. In parallel, technological, economic and environmental as well as societal and safety demands to be fulfilled by these plants have increased also due to local demands promoted especially by environmental NGO's. To fulfill these numerous and partly contradicting demands from various sides the respective costs have increased. Hence, the achieved cost reduction due to improved technological solutions was compensated respectively. overcompensated by higher technological, safety and environmental as well as societal standards. Thus as a consequence of this development, conversion systems based on renewables have become more efficient and technologically more mature over time but not necessarily specifically cheaper.

- To initiate and control such a transformation process towards an increased use of renewables, public money as well as a reliable and stable long term strategy implemented by the government is absolutely needed; if such a strategy is designed well the benefit for the overall economy could (and should) overcompensate this necessary initial investment based on public money. For Germany this has only been partly successful. Within the wind sector a strong industry for manufacturing wind mills has been developed creating value also in rural and economically less developed areas. This has not been the case for photovoltaic systems. Here, other countries have been much more successful in building up a prospering industrial infrastructure and German companies producing PV modules have gone bankrupt to a large extent.

- So far, the German legal framework has supported electricity generation from renewable sources of energy. This has been realized with a broad approach to give all options a realistic chance at the market. However, with an increasing use of these options within the overall electricity system cost aspects gain more importance. The consequence is that the public and political discussion moves more in the direction of recommending a further financial support only for the most cost efficient options characterized by huge unexploited potentials and a high public acceptance. According to current knowledge and based on today's technology, these are wind mills and photovoltaic systems. These electricity generation options show a strong fluctuating electricity production characteristic. Thus the next move is to find concepts as well as technologies to integrate significantly higher shares of such generation plants within the electricity supply system by guaranteeing an ongoing high security of supply throughout the overall year. Thus the current discussion focuses on the identification of technologically efficient, environmentally sound and economic viable as well as socially acceptable solutions.

Altogether, the German example has shown that a strategy to use renewables more intensively within the overall energy system is possible and could be successful in terms of an increased energy provision as well as a significant reduction in greenhouse gas emissions.

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ARTIFICIAL NEURAL NETWORK BASED MODEL OF PHOTOVOLTAIC CELL

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Abstract **-** This work concerns the modeling of a photovoltaic cell and the prediction of the sensitivity of electrical parameters (current, power) of the six types of photovoltaic cells based on voltage applied between terminals using one of the best-known artificial intelligence technique, which is the Artificial Neural Networks. The results of the modeling and prediction have been shown and then compared between them. NEWFF learning algorithm was used with specified number of iteration that gave the best results. The error was calculated in all cases to check the accuracy of the used method.

Keywords –

PV: Photovoltaic
I-V: current-voltage
P-V: power-voltage
NEWFF: Feed Forward Multilayer Perceptron Network
L3P: Lumped, one mechanism, Three Parameters
L4P: Lumped, one mechanism, Four Parameters
L5P: Lumped, one mechanism, Five Parameters
2M5P: Two Mechanisms, Five Parameters
2M6P: Two Mechanisms, Six parameters
2M7P: Two Mechanisms, Seven Parameters
I_{ph}[A]: the current generated by the incident light
I_s [A]: the diode reverse bias saturation current
I_{sh} [A]: the shunt resistance current
I_{sc}[A]: short circuit current of the PV cell
Isc_0: short circuit current of the PV cell under standard conditions
I_{pv}[A]: the output current
V_{pv}[V]: the terminal voltage
V_{ph}[V]: the photovoltaic voltage
V_{oc} [V]: open circuit voltage
q: the electron charge
k: the Boltzmann constant
T [K]: the temperature of the PN junction
T_0: standard temperature
Eg: energy gap
E[W/m^2]: the irradiation
E_0: standard irradiation
R_s[Ω]: series resistance
R_{sh}[Ω]: shunt resistance
n: the ideality factor of the diode
I_{s1} [A]: the first diode reverse bias saturation current
I_{s2} [A]: the second diode reverse bias saturation current
I_{sh} [A]: the shunt resistance current
I_d[A]: the diode current
I_{d1}[A]: the first diode current
I_{d2}[A]: the second diode current
m_1: the ideality factor of the first diode
m_2: the ideality factor of the second diode
$V_t = \frac{KT_c}{q}$: thermodynamic potential
T_c: the actual temperature of the cell temperature
$T_{c_{ref}}$: the cell temperature at reference conditions
I_{sref} [A]: the saturation current at reference conditions
k1, k2: constants
s_j: weighted amount to the input of neuron j of the layer (l)
N^l: number of the neuron of the layer (l)
u_j^l: output of the neuron j of the layer (l)
w_{ji}^l: weight that connects neuron i of the layer (l-1) with the neuron j of the layer (l)
L: number of layers in the network. Layer (0) corresponds to the input nodes
f (.): activation function.
ErI: current error
ErP: power error

I. INTRODUCTION

Artificial neural networks have attracted the attention of a large number of researchers in the field of renewable energies, and in particular for the modeling of photovoltaic cells [1].

Indeed, much research has proved the ability of neural networks to model PV cells. They have shown that they are more appropriate, and give better results compared to the conventional approximation methods proposed by other researchers, for the modeling of PV cells [2].

The purpose of this paper is to find the most precise mathematical models in order to obtain an optimal dimensioning of the PV cells using artificial neural networks [3]. The work was organized in three parts:

- In the first part, we discussed the six different models of a solar cell.
- The second part presents a definition of artificial neural networks with their mathematical equations.
- The third part is devoted to modeling and thus predicting a photovoltaic cell by artificial neural networks then validating the results by calculating the error.

II. MODELING OF SOLAR CELL

A photovoltaic cell can be described simply as an ideal source of courant which produces a current Iph proportional to the incident light power after being exposed to solar radiation. The equivalent circuit diagrams of the PV cell for the different models of PV cell are represented in the following figure [1][2].

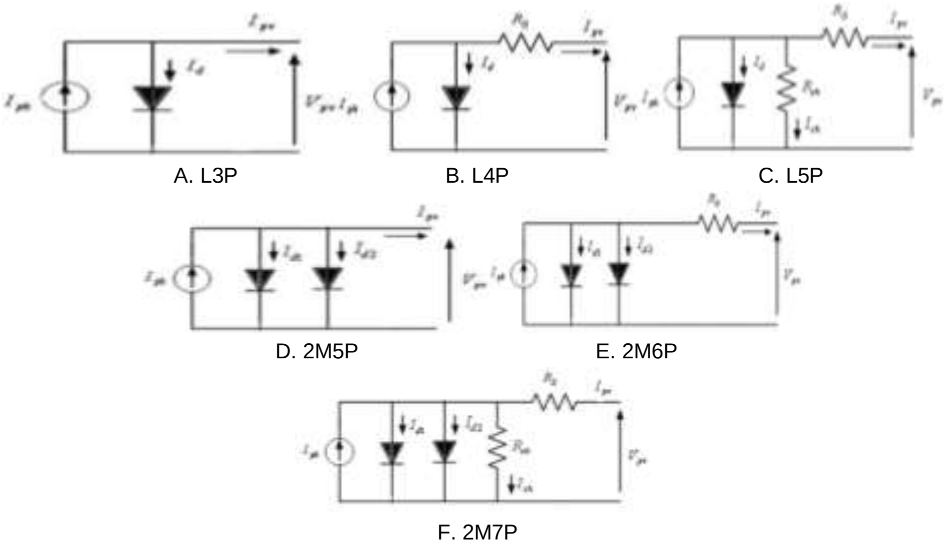


Fig.1. Equivalent diagram of the different models of a solar cell

The characteristic equation is derived in a straightforward manner from the law of kirchhoff:

$$I_{pv} = I_{ph} - I_d \qquad (1)$$

The diode is a nonlinear element; the IV characteristic is given by the relation:

$$I_d = I_s\left(\exp\left(\frac{V_d}{V_t}\right) - 1\right) \qquad (2)$$

The debited current is equivalent to:

$$I_{pv} = I_{ph} - I_s\left(\exp\left(\frac{V_{pv}}{V_t.n}\right) - 1\right) \qquad (3)$$

The saturation current of the diode is assumed to vary with temperature according to the expression:

$$I_s = I_{s\_ref}.\left(\frac{T_c}{T_{c\_ref}}\right)^3 \exp\left(\left(\frac{q.E_{gap}}{n.k}\right).\left(\frac{1}{T_{c\_ref}}\right) - \left(\frac{1}{T_c}\right)\right) \qquad (4)$$

a) Short-circuit I current I_{CC}

It is the current for which the voltage across the PV cell is zero (V_{pv}=0).

$$I_{CC} = I_{pv} = I_{ph} \qquad (5)$$

b) Open circuit voltage V_{co}

This is the voltage at which the debited current by the PV cell is zero expression. Its expression is derived from equation (3) by canceling the current (I_{pv}=0)

$$V_{pv} = V_{co} = V_t . n . \ln\left(1 + \frac{I_{CC}}{I_s}\right) \quad (6)$$

The electric power P (W) provided to the terminals of a PV cell is equal

$$P = V_{pv}\left[I_{CC} - I_s\left(\exp\left(\frac{V_{pv}}{n. V_t}\right) - 1\right)\right] \quad (7)$$

The L4P model treats the photovoltaic cell as a dependent current source of illumination, connected in parallel with a diode and in series with a series resistance Rs. Electric current produced by the cell is then given by the following expression [3]:

$$I_{pv} = I_{ph} - I_s\left(\exp\left(\frac{V_{pv} + I_{pv}. R_s}{n. V_t}\right) - 1\right) \quad (8)$$

In the case of L5P, losses are modeled by two resistances, shunt resistance and the series resistance. The model thus involves the following five unknown parameters: n, Iph, Rs, Rsh and Is [4].

The characteristic equation is derived in a straightforward manner from the law of Kirchhoff

$$I_{pv} = I_{ph} - I_d - I_{sh} \quad (9)$$

The electric current produced by the cell is:

$$I_{pv} = I_{ph} - I_s\left(\exp\left(\frac{V_{pv}+I_{pv}.R_s}{n.V_t}\right) - 1\right) - \left(\frac{V_{pv}+I_{pv}.R_s}{R_{sh}}\right) \quad (10)$$

The operation of a solar cell can be modeled by considering the parallel connection of two diodes having saturation currents Is1 and Is2, the diode factors n1 and n2, a current source generating a photocurrent Iph, which depends on solar irradiation [5][6].

The characteristic equation is derived in a straightforward manner from the law of kirchhoff:

$$I_{pv} = I_{ph} - I_{d1} - I_{d2} - I_{sh} \quad (11)$$

The diode is a nonlinear element, the IV characteristic is given by equation:

$$I_{d1} = I_{s1}\left(\exp\left(\frac{V_d}{n_1.V_t}\right) - 1\right) \quad (12)$$

$$I_{d2} = I_{s2}\left(\exp\left(\frac{V_d}{n_2.V_t}\right) - 1\right) \quad (13)$$

$$I_{sh} = \frac{V_{pv}+I_{pv}.R_s}{R_{sh}} \quad (14)$$

The electric current produced by the 2M5P cell is then given by the following expression:

$$I_{pv} = I_{ph} - I_{s1}\left(\exp\left(\frac{V_{pv}+I_{pv}.R_s}{n_1.V_t}\right) - 1\right) - I_{s2}\left(\exp\left(\frac{V_{pv}+I_{pv}.R_s}{n_2.V_t}\right) - 1\right) - \left(\frac{V_{pv}+I_{pv}.R_s}{R_{sh}}\right) \quad (15)$$

It involves the mathematical description of a circuit realized by the parallel connection of two diodes having the saturation currents I_{S1} and I_{S2}, diodes factors n_1 and n_2, a current source generating a photocurrent Iph that is dependent on the solar irradiance and RS series resistance [7][8].

It The characteristic equation is derived in a straightforward manner from the law of Kirchhoff:

$$I_{pv} = I_{ph} - I_{d1} - I_{d2} \quad (16)$$

The electric current produced by the 2M6P cell is then given by the following expression

$$I_{pv} = I_{ph} - I_{s1}\left(\exp\left(\frac{V_{pv}+I_{pv}.R_s}{n_1.V_t}\right) - 1\right) - I_{s2}\left(\exp\left(\frac{V_{pv}+I_{pv}.R_s}{n_2.V_t}\right) - 1\right) \quad (17)$$

The equivalent circuit model 2M5P is obtained using the simplified circuit model which has six parameters (Lumped, 2 Mechanism model with 5 parameters) [9][10]. It is achieved by mathematical description in parallel connection of two diodes having its saturation current IS1 and IS2, the diode factors n1 and n2, a current source generating a photocurrent Iph that depends on the solar irradiance and temperature [16]. The characteristic equation is derived in a straightforward manner from the law of Kirchhoff [18][19] :

$$I_{pv} = I_{ph} - I_{d1} - I_{d2} \quad (18)$$

The electric current produced by the cell is then given by the following expression:

$$I_{pv} = I_{ph} - I_{s1}\left(\exp\left(\frac{V_{pv}}{n_1.V_t}\right) - 1\right) - I_{s2}\left(\exp\left(\frac{V_{pv}}{n_2.V_t}\right) - 1\right) \quad (19)$$

III. ARTIFICIAL NEURAL NETWORK

Artificial neurons are the artificial intelligence technique most commonly used in the field of modeling and control methods. They consist of a precise number of neurons that are arranged in layers. Neurons of two adjacent layers are interconnected by weight, using the NEWFF algorithm with variable number of iterations, after many experiences we found that the number of 150 iterations gave the most appropriated results[11] [12]. The figure (2) shows an example of artificial neural network.

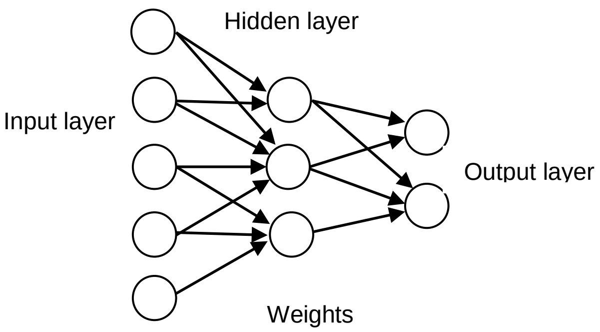


Fig.2. Architecture of the ANN

The multilayer perceptron is probably the simplest and most well-known neural network. It consists of several

connected layers of neurons. The activation function is mainly used sigmoid function.

Consider the neural network MLP "Multi-Layer Perceptron" L layer P inputs and q outputs. The input layer contains the components of the input vector (x_i) $0 \le i \le p$.

The calculations are made layer by layer from the input to the output.

The output of the neuron j of the layer l ($0 < l \le L$) is given by:

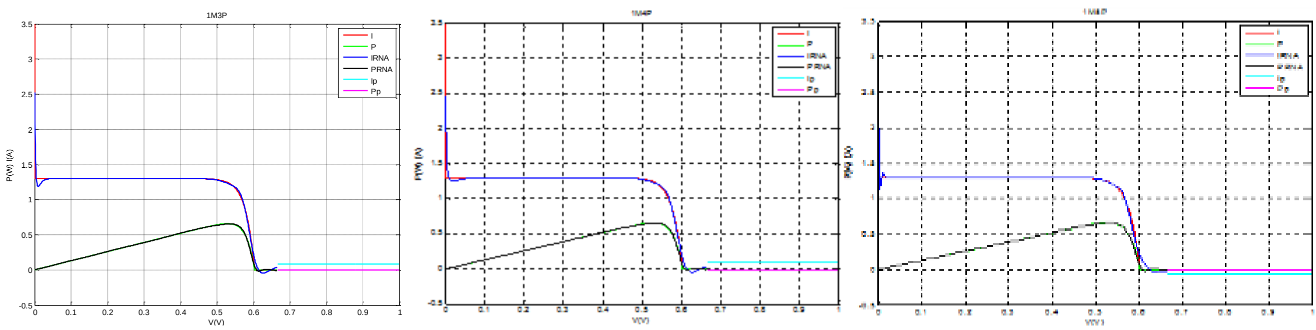
$$s_j^l = \sum_{i=0}^{N^{l-1}} w_{ji}^l . u_i^{l-1} \quad (20)$$

$$u_j^l = f\left(s_j^l\right) \quad (21)$$

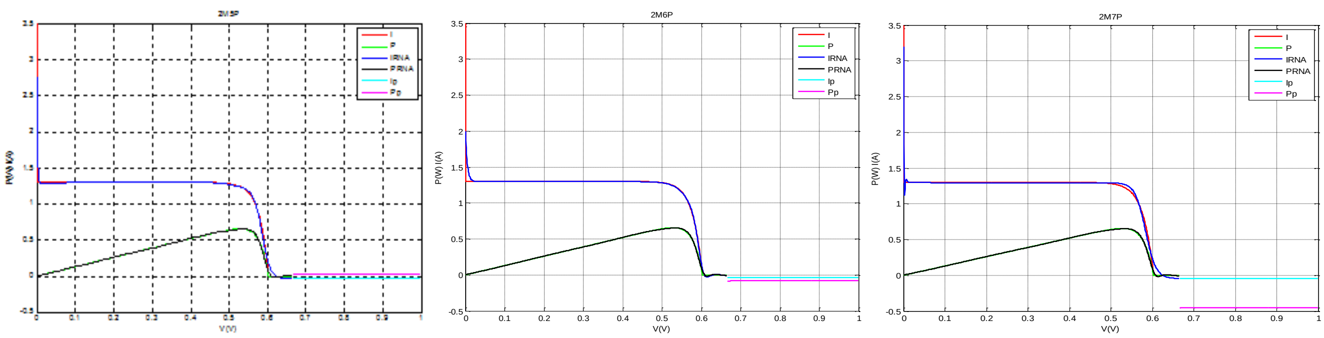
It is noted that the first element of each vector $u^l(1=0,1,\ldots L\text{-}1)$ is set at one (i.e.,u_0^l=1) and the product ($w_{j0}^l * u_0^{l-1}$) represents the value of the internal threshold of the neuron j in the layer [15][17]

IV. MODELING AND PREDICTION OF THE PV CELL POWER

The experimental data of current and power versus the voltage was loaded on Matlab to be compared to the obtained results. Each time the neural network is trained. In Fig.3 the model and the prediction follow the curves of experimental data with a minimum error for different models. The error increases in case of prediction.



a. Single diode cell



b. Double diode cell

Fig.3. Modeling and prediction of current and the power

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V. COMPARING THE PERFORMANCE OF PV CELLS

The following table shows that current errors are almost zero, and the L4P model is better because the error is close to zero, but in the prediction there is a remarkable difference. Power errors are zero even in prediction. These of the two models 1M4P and L3P are zero white the error the L5P model increases.

When we compare the results of double diode models. The 2M7P model is the best one. In the prediction, there is a remarkable difference; we note that errors of the two models 2M5P and 2M6P are zero against the error of the 2M7P model which increases.

The current errors are larger than those of the models with double diode. The 2M7P model is the best, and in the prediction, there is a remarkable distance. We note also that the power errors are zero even in prediction. Errors of the two models 2M5P and 2M6P are zero against the error of the 2M7P model which increases.

	Model	Error	ErI	ErP
Single diode	L3P	Min	3.1769e-011	2.9098e-011
		Max	0.0046	7.7701e-004
		Moy	1.1375e-004	1.1035e-005
	L4P	Min	2.1260e-010	1.0895e-011
		Max	0.0959	4.0899e-004
		Moy	2.9477e-004	5.3479e-006
	L5P	Min	5.1622e-010	1.2892e-011
		Max	0.7242	7.0896e-004
		Moy	0.0011	9.0903e-006
Double diode	2M5P	Min	7.2114e-011	4.8659e-012
		Max	0.0664	5.1830e-004
		Moy	1.8160e-004	7.0947e-006
	2M6P	Min	1.6538e-011	7.4209e-013
		Max	0.7241	4.5467e-004
		Moy	0.0011	6.4361e-006
	2M7P	Min	6.1825e-012	8.1567e-012
		Max	0.0124	4.0753e-004
		Moy	5.4083e-005	5.4244e-006

Table. 1. Current and power errors of PV single and double diode cell

VI. CONCLUSION

This work presents the modeling of the problem of six photovoltaic modules using artificial neural networks. Also one presented the basic electrical characteristics of a photovoltaic cell and the equivalent circuits were described.

The comparison results of the performance of PV cells with a single diode and two diodes indicates that the prediction error increases when adding the shunt resistor i.e. in case of the two models L3P and 2M7P. On the other hand, the current error is generally greater than the power error in all the models. These results confirm the ability of artificial neural networks to modeling of photovoltaic cells.

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A New Controller to Enhance PV System Performance Based on Neural Network

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***Abstract* -** In recent years, a radical increase of photovoltaic (PV) power generators installation has taken place because of the increased efficiency of solar cells, the growth of manufacturing technology of solar panels, in addition to the government support policy. This paper shows the operation and modeling of photovoltaic systems, particularly designing neural controller to control the system. Neural controller is optimized using particle swarm optimization (PSO), which leads to getting the best performance of the designed PV system. By using neural network, the maximum overshoot and rise time obtained become 0.00001% and 0.1798 seconds, respectively. Also, this paper strikes a comparison between some kinds of controller for the PV system.

***Keywords* -** Particle Swarm Optimization, neural network and photovoltaic.

I. INTRODUCTION

The study of renewable energy sources has been an inclusive concern to the world, and has drawn the attention of many institutions, like the European Commission and others. Renewable energy is a clean energy system that has no effect during or after generation on the environment and this has grabbed the attention of researchers to make continuous improvement in solar energy. Renewable energy is numerous, abundant, sustainable, and can be utilized from different origins such as wind, solar, tidal, hydro, geothermal and biomass.

Solar energy could be one of the important sources as substitution energy for the hereafter. There are two kinds of technology that has anticipated solar energy, solar thermal and solar PV. A PV cell (solar cell) transforms sunlight into electrical energy by the photovoltaic effect.

The solar PV system exhibits various advantages, such as, it needs little maintenance and produces no environmental pollution. PV module presents the fundamental power conversion unit of a PV generator system.

II. LITERATURE REVIEW

Many papers have presented different simulations of PV system. In [1], a procedure for the simulation of photovoltaic modules with MATLAB/Simulink is presented. One-diode equivalent circuit is employed in order to investigate I-V and P-V characteristics of solar module. The final model takes irradiation, operating temperature in Celsius and module voltage as input and gives the output current Ipv and output voltage Vpv. Also, in [2], a one-diode equivalent circuit-based versatile simulation model in the form of the masked block PV module is proposed. By using the model, it is allowed to estimate the behavior of PV module with respect to changes in irradiance intensity, ambient temperature and parameters of the PV module. In another study [3], a fractional-order PID (FOPID) controller [4-6] is designed to control a DC-DC boost converter in a PV-system. In order to obtain the best system performance, parameters of the proposed controller are tuned by using Particle Swarm Optimization (PSO) algorithm. In another paper [7], the effect of uniform and non-uniform irradiance on a series of connected solar PV array is presented in detail under MATLAB-Simulink environment. The proposed simulation model helps the researchers to investigate the characteristics of a PV array under different irradiance and temperature conditions [7].

This paper is framed around three major parts. First, an overview of mathematical model of the PV system is summed up. Second, a neural controller is designed to enhance the performance of the system. Finally, in order to obtain the best system performance, neural network of the proposed controller is optimized using the PSO. The system response is tested under various solar irradiation and constant temperature. Percentage overshoot (Mp) and rise time (Tr) are measured and compared with

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other papers. The comparison shows that the system with the neural controller performs better than other systems with different kinds of controller.

III. MATHEMATICAL MODEL OF THE PV SYSTEM

1. Mathematical Model of PV Panel

The first part of the system is the solar cell. Solar cells are in fact large area semiconductor diodes. Due to the photovoltaic effect, energy of light (energy of photons) is converted into electrical current. The equivalent circuit for the simplest solar cell consists of a diode and a current source connected in parallel, as shown in Figure 1 [8]. The source current is directly proportional to the solar radiation and diode represents the PN junction of a solar cell.

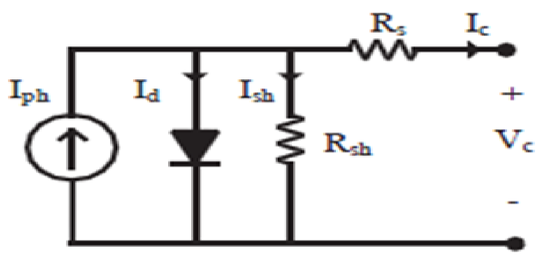

Fig.1. One diode model of PV cell

Equation of the load current is:

$$I = [(I_{ph} \times N_p) - I_d - I_{sh}] \quad (1)$$

Where:

(I_{ph}) is photocurrent (A);
(I_d) is diode current;
(I_{sh}) is the current loss because of the shunt resistance; and (Np) the parallel connected PV cell number that effects the module current.

The thermal voltage equation is:

$$V_t = \frac{kT}{q} \quad (2)$$

Where:

(k) is boltzmann constant, 1.38×10^{-23} J/K ;
(T) is solar cell temperature (K); and
(q) is charge of electron, 1.6×10^{-19} C.
The researchers represent the reverse saturation current equation for the proposed PV system using simulink on matlab as shwon in Figure. 2:

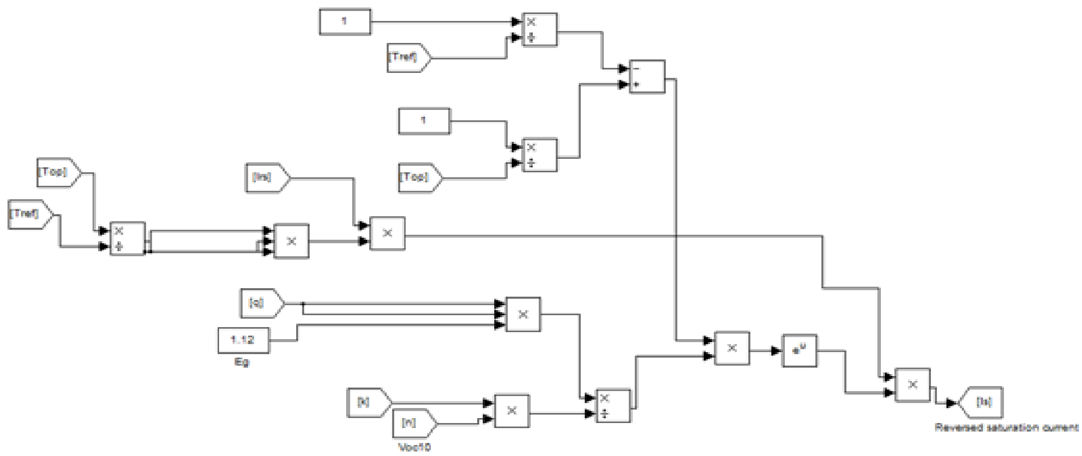

Fig.2. Reverse saturation current

$$I_s = \left[\left(\frac{1}{T} - \frac{1}{T_{ref}}\right) \times \left((q^2 \times E_g)/(k \times n)\right) e^u \left[\frac{I_{rs}}{\left(T/T_{ref}\right)^3}\right]\right] \quad (3)$$

Where:

(T) the temperature of the PV panel;
(T_{ref}) the refrence temperature of the PV panel;

The researchers represent the reverse saturation current at top equation for the proposed PV system using simulink on matlab as described in Figure. 3:

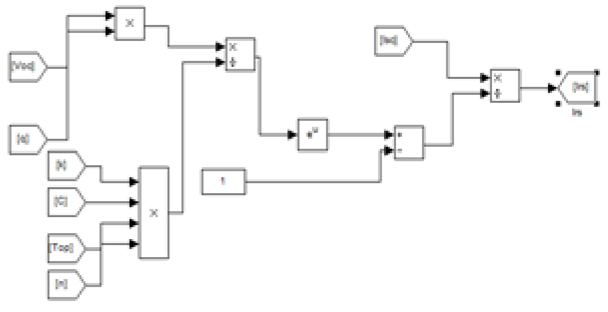

Fig. 3. Reverse saturation current at the top equation

$$I_{rs} = [(V_{oc} * q)/(K * c * T * n)]\left[{}^{I_{sc}}/_{(e^{u} - 1)}\right] \quad (4)$$

where:

(V_{oc}) open circuit voltag; and
(I_{sc}) short circuit current.
Shunt current equation:

$$I_{sh} = (V + I\,R)/R_p \quad (5)$$

Where:
(I_{sh}) shunt current;
(R_s) the series resistance of the PV panel; and
(R_p) the parallel resistance of the PV panel.

Diode current equation for the proposed PV system is described in Figure.4 as the researchers present it using Simulink on MATLAB:

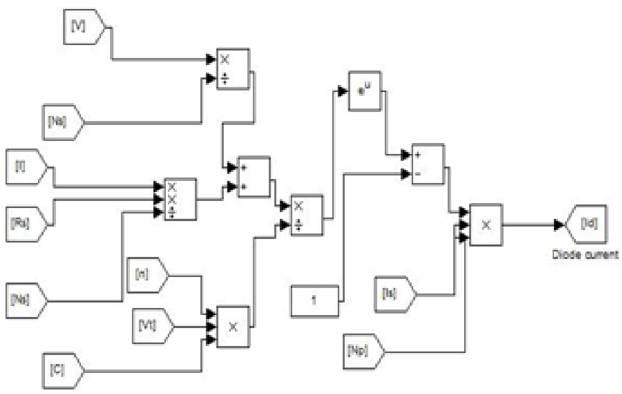

Fig. 4. Diode current

$$I_d = \left[\left[\left({}^{V}/_{N_s}\right) + \left({}^{I * R_s}/_{N_s}\right)\right]/[n * V_t * c]\right][(e^{u} - 1) * I_s * N_p] \quad (6)$$

Where:

(I_d) diode current;
(N_s) the series connected PV cell number that effects module voltage; and
(V_t) thermal voltage;
phase current equation:

$$I_{ph} = \left[\left(\left(T - T_{ref}\right) * K\right) + I_{sc}\right] * I_{rr} \quad (7)$$

Where:
(I_{rr}) irradiation.

2. Converter Model

The second part of the system is the converter. A boost DC-DC converter is used as a power electronic interface between the load and PV panels in the P-V system. The converter is a powerful electronic device used to produce a higher regulated output voltage from a lower unregulated input voltage [3]. The circuit of the converter consists of an inductor L, a power switch S, a diode, D, a filter capacitor C and a load resistor R, as shown in Figure 5 [3].

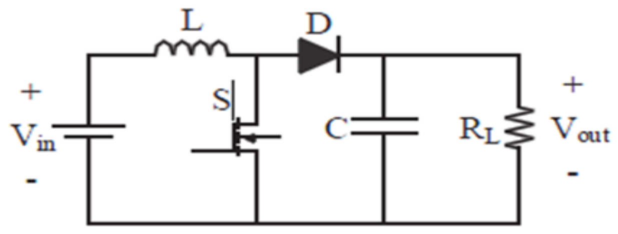

Fig. 5. Boost converter circuit

The working principle of the converter is cleared as follows: When the switch is in the ON mode, the diode is reverse biased (OFF). In this mode, the inductor is directly connected to the input voltage source and stores energy. Meanwhile, the load is powered by the capacitor. When the switch is OFF mode, the diode is forward biased (ON). In this mode, both the stored energy of the inductor and the input voltage source supply power to the load. The capacitor and the inductor values of the converter are calculated respectively by using the formulas [8]:

$$C_{min} = \frac{D I_{out(\max)}}{f_s \Delta V_{out}} \quad (8)$$

$$L_{min} = \frac{(V_{out} - V_{in}) V_{in}}{\Delta I_L f_s V_{out}} \quad (9)$$

Where:

(C_{min}) and (L_{min}) are the minimum capacitor and inductor values;
(V_{in}) and(V_{out}) are the input and output voltage of the

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converter;
(f_s) is the switching frequency;
(ΔV_{out}) is the output voltage ripple;
(ΔI_L) is the inductor current ripple; and
(D) is the duty cycle, which is the ratio between the pulse duration and period of a rectangular waveform.

3. Neural Network Controller

The third part in the system is the controller. There are numerous controllers that can be used to control dynamic systems like the PV systems. In this paper, neural network controller is used because neural networks are mostly used for fuzzy, difficult problems that do not yield to traditional algorithmic approaches. Many algorithms can be used to optimize the controller, such as Genetic algorithms (GA) [9], Differential Evolution (DE) algorithm [10] and PSO algorithm [11]. In this paper, Particle Swarm Optimization (PSO) will be used because it does not have genetic operators like crossover and mutation, since particles update themselves with the internal velocity. They also have memory, which is important to the algorithm, as will be explained later in the algorithm. Many papers used Proportional Integral Derivative controller (PID) instead of neural network. Neural network is more complex than PID controller but neural network gives a better response than the PID controller and some other kinds of controllers. In this paper, the neural network controller supported the designed model of the PV system.

A neural network is a method of computation modeled after the brain [12]. They contain a series of mathematical equations that are used to emulate biological processes such as learning and memory. What makes the artificial neural network unique from many other computer algorithms is its primitive ability to learn. Through a process of training and being told what the correct output is when given a set of inputs, the artificial neural network eventually learns the correct behavior, and can reproduce correct outputs on its own when given a set of inputs.

A neural network can predict an outcome based on the values of some predictor variables. Networks are programmed to adjust their internal weights based on the mathematical relationships identified between the inputs and outputs in a data set.

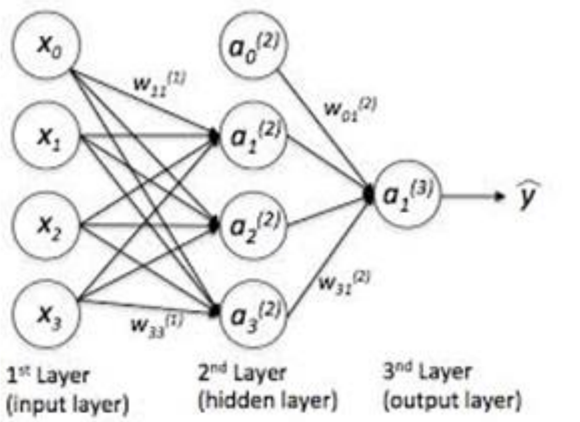

Fig. 6. Diagram of an artificial neural network

Table 1 is a brief glossary showing some common terms in the field of neural networks and their equivalent in statistics. Neural Networks are known to be universal function approximates. Various architectures are available to approximate any nonlinear function. Different architectures allow for generation of functions of different complexity and power. Those different architectures are:

- Feedforward networks
- Feedback networks
- Lateral networks

Table 1. Common Terms in Neural Networks and their Equivalent in Statistics

Neural networks	Statistics
Input	Independent (predictor) variable
Output	Dependent (outcome) variable, predicted value
Connection weights	Regression coefficients
Bias weight	Intercept parameter
Error	Residuals
Learning, training	Parameter estimation
Training case, pattern	Observation
Cross-entropy	Maximum likelihood estimation

In a neural network, the weights connecting two nodes are usually represented as where i and j are subscripts for the two nodes being connected. Estimating the optimal values of these connection weights is the major purpose behind training a neural network model. The network training algorithm is used to gradually adjust the weight and in the network to minimize the difference between the predicted output of the network o_p and the known value of the outcome variable t_p. This difference is known as the error of a neural network and is similar to the concept of minimizing the residuals in statistical regression. The total error (E) of a neural network is usually determined over the whole data set and may be calculated as shown in equation (10):

$$E = \sum_{P} (t_p - o_p)^2 \qquad (10)$$

Where E is the total error of the network o_p and is the desired or known Neural Networks versus Logistic Regression.

IV. PARTICLE SWARM OPTAMIZATION (PSO)

The Particle swarm optimization (PSO) method, suggested by Kennedy and Eberhart [13], is a computational search algorithm used to optimize a problem iteratively [14]. The algorithm is based on imitating the behaviors of a bird flock (particles) with the help of the mathematical velocity and position formulas of the particles. Each particle in the population has a memory to keep its previous best position called Pbest (candidate solutions, local minima) and fitness value. Also, the particle with minimum fitness value is called Gbest (global minima). The flowchart of the algorithm is given in Figure 7. Mathematical representations of the velocity and position of the particles are given below, respectively. Where i is the number of the particle, d is the dimension, c_1 and c_2 are the acceleration constant of the velocity, w is the inertia weight, and r_1 and r_2 are the uniformly random numbers. Optimum values for these parameters are needed to reach robust transfer function for PV system. PSO is used widely in many applications due to its many advantages including its simplicity and easy implementation. PSO has no crossover and mutation process; however, the search can be done by the speed of the particle. Only the optimum particle can transmit information to the other particles, and the speed of searching is very fast. Thereby, the researchers used PSO as an optimization tool to find the optimum values for those parameters. The basic PSO algorithm consists of three steps generating positions of particles and velocities, velocity update, and position update. Each particle represents a possible solution to the problem that changes its position from one iteration to another based on velocity updates. First, the positions, xid, and velocities, vid, of the initial swarm of particles are randomly generated. The PSO consists of many particles which form a swarm, design space. At each step, each particle updates its velocity and distance according to Equation (8) and Equation (9), respectively.

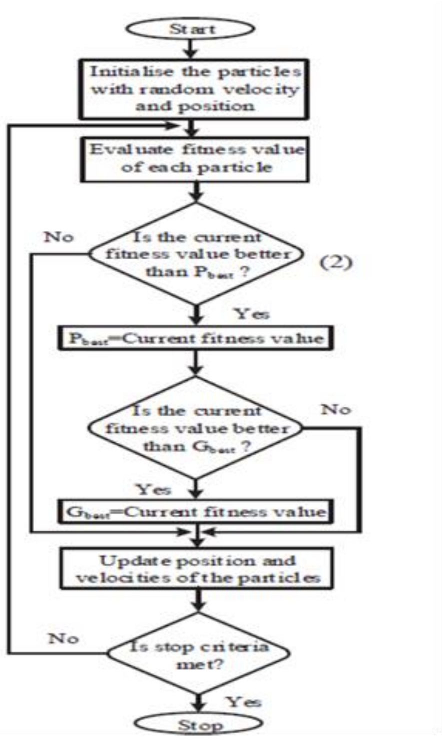

Fig. 7. A general flowchart of PSO

$$V_{id} = w \times V_{id} + c_1 \times r_1 \times (P_{id} - X_{id}) + c_2 \times r_2 \times (G_{id} - X_{id}) \qquad (11)$$

$$X_{id} = X_{id} + V_{id} \qquad (12)$$

The algorithm is ended when the stopping criteria are met.

V. SIMULATION RESULTS

According to the case study which is getting the best performance of a PV system by reducing rise time and the percentage overshoot, a neural controller is used as shown in Figure 8. Figures 9 and 10 represent the I-V and P-V characteristics of the system, respectively, with a solar irradiation input of 800W/m^2. Table 2 shows the system parameters.

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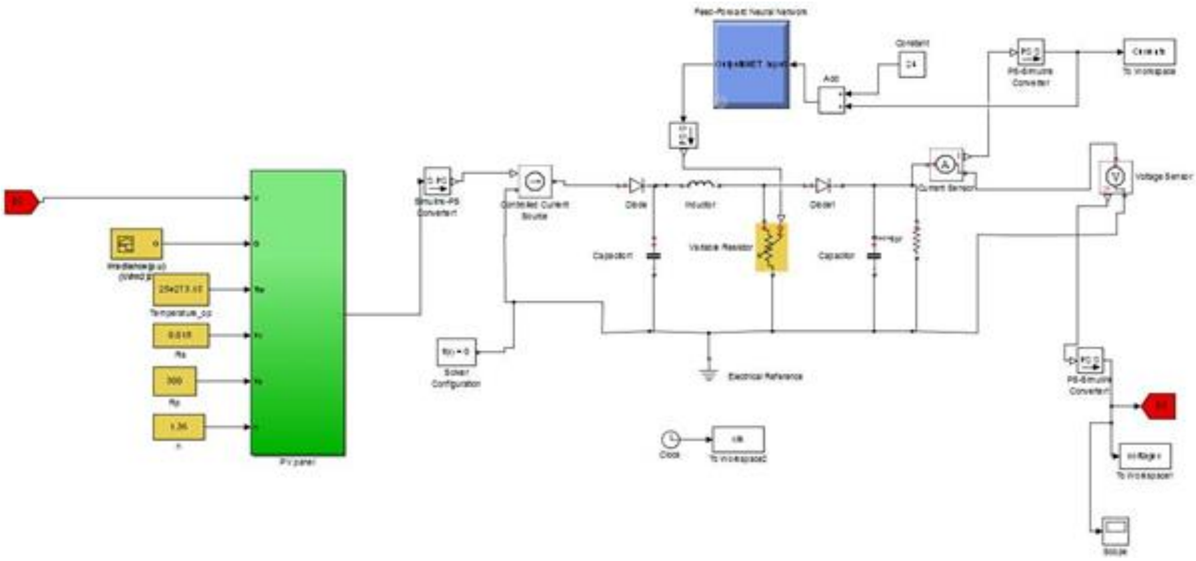

Fig. 8. Simulink/MATLAB architecture for the PV system with neural controller

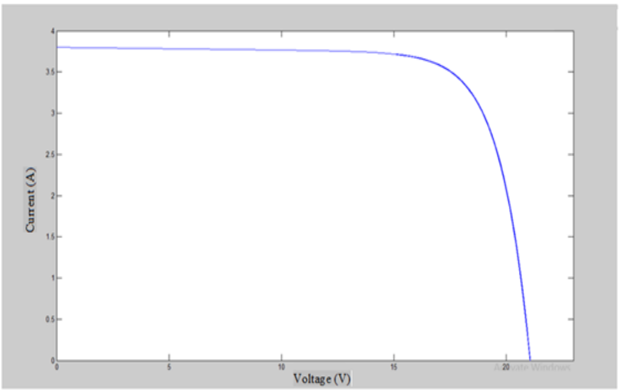

Fig. 9. Current – Voltage (I-V) characteristics of PV System

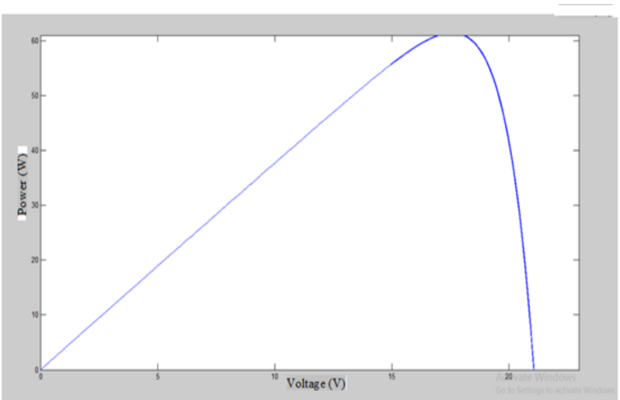

Fig. 10 Power– Voltage (P-V) characteristics of PV System

Table 2. Parameters of PV System

Parameters of Boost Converter	
Sampling frequency (T_s)	20kHz
Switching frequency (f_s)	5kHz
Output voltage (V_O)	24V
Max. output voltage ripple (ΔVC)	5%
Max. input current ripple (ΔI)	5%
Input capacitor (C_{in})	6.8mF
Output capacitor (C_{out})	11.5mF
Inductor (L)	1.25mH
Load (R)	12.5-25-50Ohm
PV panel parameters	
N_{sc}	1
N_{pc}	5
V_r	17V
I_r	3A
α	3.10^{-3}mA/°C
B	-73.10^{-3}mW/°C
I_{sc}	3.5
G_r	1000W/m^2
T_{cr}	25°C

There are a lot of types and training algorithms for neural network. In the proposed case, the researchers do not know which one will fit the best performance Therefore, they used the PSO to obtain the best neural type, training algorithm, number of hidden layers, and number of perceptions per layer. In this case, four parameters have to be determined. These parameters are shown in Table 3.

Table 3. Input Parameters of PSO

Parameters	Description	Constrains
$k1$	Neural type	From 1 to 4
$k2$	Training algorithm	From 1 to 12
k3	Number of layers	From 1 to 10
$k4$	Number of perception	From 1 to 10

In equation 12, the d represents the dimension number while the Pid represents the best previous position and the global best position is stored in Pg. To ensure good coverage of the design space, the velocity update formula includes some random parameters, represented by the uniformly distributed variables, Rand. The three terms of the velocity update equations represent current motion, particle own memory, and swarm influence. Accordingly, the original PSO algorithm used the value of 2 for both constants C1 and C2. In the proposed problem, the objective function is minimizing the overshoot, rise time for the PV system. Also, the researchers used a swarm size of 49 in their proposed algorithm. In each iteration of PSO, the best parameters is stored as the global minimum. The parameters that should be optimized are summarized in Table 3. Once the PSO chooses the optimum parameter k1, k2, k3, and k4, those parameters are set as the final parameters for setup the neural network to operate as a controller instead of PID. Hence, the number of dimensions, d, in Equation 12 is equal to 12. All the possible types and algorithms for k1 and k2 are mentioned in Table 4.

According to PSO, the optimum parameters are 2, 1, 1 and 10 for k1, k2, k3 and k4, respectively. This result reflects that the best type which fits the best performance for PV system is feed forward neural network with Levenberg-Marquardt training method, train lm. The upcoming Figure 11 will illustrate the overshoot 0.00001% and that rise time equals 0.170 seconds.

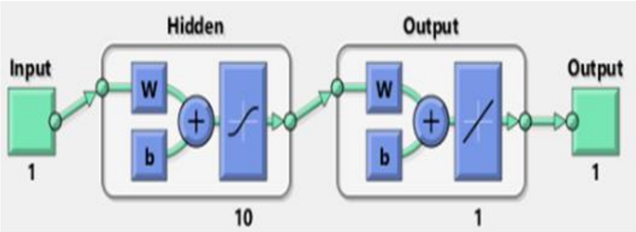

Fig. 11. Structure of the proposed neural network

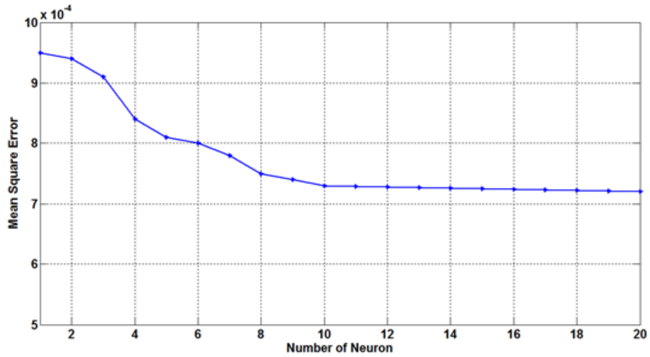

Fig. 12. The value of MSE

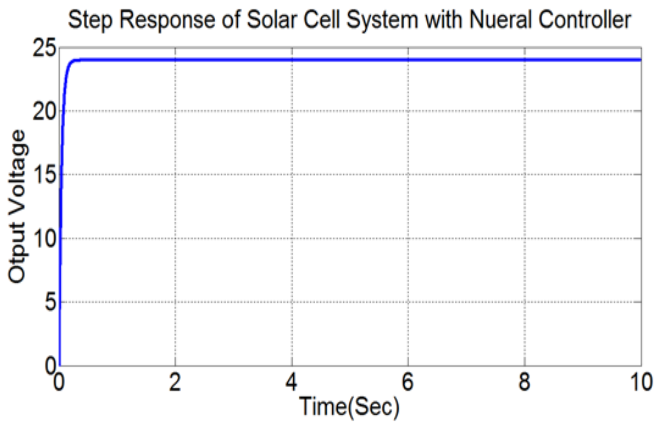

Fig. 13. Step response of process with neural controller unig Simulink

Table 4. All Possible Values and Types for k1 and k2

Parameters	Value	Type
k1	1	Cascade forward net
	2	Feed forward net
	3	Pattern net
	4	Fit net
k2	1	trainlm
	2	trainbr
	3	trainbfg
	4	trainrp
	5	trainscg
	6	traincgb
	7	traincgf
	8	traincgp
	9	trainoss
	10	traingdx
	11	traingdm
	12	traingd

VI. COMPARISON WITH PREVIOUS WORK

Figure 14 [15] shows the output voltage versus the time and the maximum overshot almost is zero. The simulation results clearly show that the PID controller gives a much better control of PV system rather than the FOPID controller. When PID tuned by a genetic algorithm is used as a control for the PV system, the rise time was 0.175 second and percentage overshoot was almost zero. In comparison to [3], this work reduced the overshoot with 0.7% and the rising time by 0.545 seconds.

Also, the neural network has better impact on the PV system rather than PID and FOPID [3] controllers. For Neural Network controller, the overshot was 0.00001, meanwhile the rise time was 0.170 seconds and Table 4 shows a comparison between all the controller types for PV system. In table 4, the first parameter is the maximum overshoot and the second parameter is the rise time. Figure 15 shows the result of the three different types of the controller that used to enhance the performance of our PV system. The line by the red circles represents the result of PID controller tuned by GA algorithm, the line by the blue crosses represents the results of the neural PSO controller and the line by the black dashes represents the results of a previous work [3]. Figure 16 shows the same result as Figure 15 but with zoomed x-axis and y-axis.

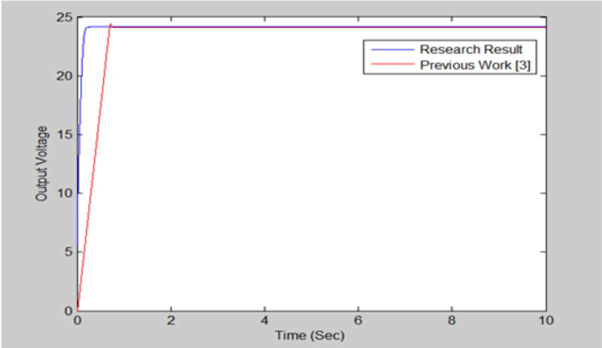

Fig. 14. Output voltage versus time

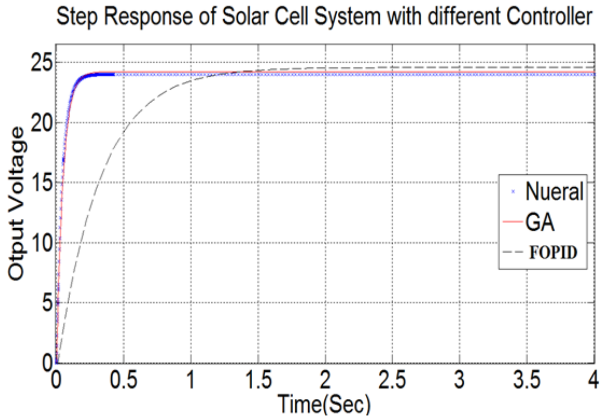

Fig. 15. Output voltage versus time.

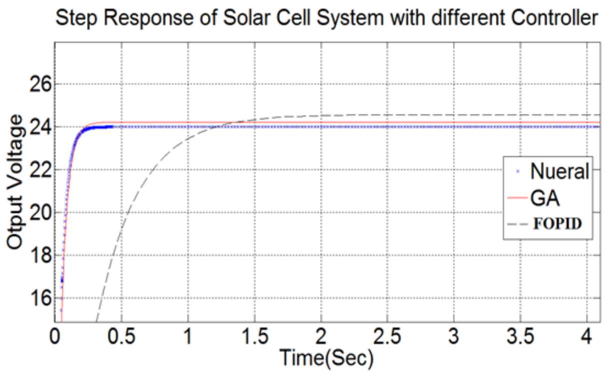

Fig. 16. Output voltage versus time with zoomed x-axis and y-axis

Table 5. Comparison between this Work and Previous Work [3,14]

Parameters	PID with genetic algoritm	[3]	Neural network controller
M_p	0.1	0.8	0.00001
T_r	0.175	0.72	0.170
P	1.7130	19.22	-
I	3.8	8.32	-
D	0.001	0.056	-

VII. CONCLUSION AND FUTURE WORK

PV system is one of vital renewable energies in the present world. Therefore, researchers made a lot of research on PV panels to enhance its performance. This paper introduces a mathematical model for PV system with neural controller. The neural controller is used to enhance the output of PV system. The PSO is used to optimize the neural controller, which led to minimum overshoot and minimum rise time. The overshoot is reduced to be 0.00001% and the rise time is set to 0.170 seconds. The results show that neural controller has a better response compared with some other kind of controllers.

For future work, different kinds of controller can be used to control the PV system and different algorithms can be replaced instead of PSO to optimize the neural network controller. The following points may be considered:

- Using different algorithms to tune the Neural Network (NN) controller.
- Using other kinds of controllers to control the PV system and comparing it with the other types used.
- Using a combination of back propagation and neural network hybrid PSO-BP.
- To reach a real time system, the different types of controllers can be implemented on Field Programmable Gate Array (FPGA).

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The Application of Solar Energy in Agricultural Systems

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***Abstract* -** Given that one day fossil fuels will end, a need arises to find alternative fuels. Renewable energy is considered an alternative to fossil fuels and nowadays it attracts much attention. Among renewable energy sources, solar is the most important because it is available in all parts of the world. Also, this energy source is used in various industries including agriculture and it can be used in cultivating crops in the farthest corners of the world. In addition, this fuel does not cause pollution, like the other fossil fuels.

Using the solar energy can be active in all agricultural areas. That will definitely help meet the increasing need for agricultural products with the increasing population. However, it is known that the agricultural land has a fixed area and, sometimes, agricultural products cannot be cultivated. That greenhouse is a method that is used nowadays and using the solar energy can help build solar greenhouses in areas far away from the city. Other applications of solar energy include irrigation, drying products, and ventilation niches. In this study, the researchers discuss some of the benefits of solar energy in agriculture.

***Keywords* -** Fossil fuels, Solar Energy, Agriculture.

I. INTRODUCTION

The energy sector has a direct impact on the economic development of a country [1]. Nowadays, 85-90% of the world's primary energy is produced from fossil fuels [2]. There is a limited storage of fossil fuels and one of the important reasons for recession in world's economy is the continuously increasing prices of these fuels [3]. To solve the problem of the decreasing economy and the energy sector's related issues, all the world is focusing on an effective utilization of renewable energy resources like solar, wind, thermal and hydro [4,5]. Fossil energy supplies became available about 200 years ago [6]. In addition, shortages of cropland, fresh water, fossil energy (fertilizers and irrigation), and biological resources now plague agricultural production in many parts of the world [7]. However, resources of fossil energy have begun to decline and this trend intensified after the year 2000 [8]. The Use of renewable energy in the farming systems have several different applications. Applications of renewable energy also include generation of power to do a number of farm works: pumping water for irrigation, for keeping livestock, or for domestic use; lighting farm buildings; powering processing operations, and other uses. These forms of renewable energy include solar energy, wind and water power, oil from plants, wood from sustainable sources, other forms of biomass (plant material), and biogas (gas produced from fermentation of manure and crop residues) [9]. The foundation of all agricultural production rests on the unique capability of plants to convert solar energy into stored chemical energy [8]. Solar energy is the most appropriate option among other renewable energy sources because the solar energy level is in line with the air condition demand [10]. Also, solar energy technologies have a long history. Between 1860 and the First World War, a range of technologies developed to generate steam by capturing the sun's heat to run engines and irrigation pumps [11]. Taking into consideration the importance of solar energy and the increased attention humans are paying to renewable energy, this paper investigates the solar energy system in farming.

II. SOLAR ENERGY TECHNOLOGIES

There are two ways to convert solar energy into electrical energy; a system using photovoltaic technology and another that uses solar capture heating systems [12]. In the photovoltaic system, the sun rays are converted directly to electricity by semiconductors. In addition, in the method of heating, electrical power via the thermodynamic processes, with help of heat exchange equipment, can be converted to mechanical energy. These two methods are centralized and non-centralized. The photovoltaic method leads to more investments. However, in recent years with advances in the field of solar energy, thermal methods are used for power supply.

Fig .1. Use of solar energy in agriculture

III. PHOTOVOLTAIC TECHNOLOGY

Solar photovoltaic (PV) cells were invented at Bell Labs in the United States in 1954, and they have been used in space satellites for electricity generation since the late 1950s [12]. In this technology, solar rays collected via small plates that are semiconductor photovoltaic, are converted into electricity. Photovoltaic cells can be built in two ways: concentrator and flat panel. Solar cells are the most common type of flat panels where the light is immediately brought to semiconductor and is converted to electricity. Yet, in the concentrator cells, first the sunlight is guided via the reflector, concentrated, and then the solar cell connects together. The solar cells are formed by solar modules. Power cells and solar modules may be enough only to charge the battery and to build a system with output significantly requires that modules (Figure.3) that work together and at same time. Given that solar cells are connected together and making modules, also the modules for creating the appropriate voltage and current, are connected in series and parallel to that unit made in this way is called the Solar Array [13].

Fig.2. Solar photovoltaic panels providing green energy for agricultural growth

IV. SOLAR DRYER

Preservation of food through drying is one of the oldest and the most widespread methods that can be used to enhance the strength of the food. Drying food is removing the moisture so that the product can be stored for a long time and be protected against corruption [14]. By reducing the microbial enzyme activity and reducing the speed of chemical reactions, drying increases shelf life of the product. In addition, reducing the weight and volume of materials and packaging, facilitates transportation and storage of products and decreases the cost of these procedures [15]. In the case of drying, in addition to preventing the loss, the marketing can be controlled at sensitive times and potatoes required by many consumers (such as barracks, restaurants, etc.) can be delivered in a dried form [16]. Using the sun for dry crops and grain is one of the oldest used applications of solar energy. Solar dryers protect grain and fruits and vegetables, reduce losses, dry faster and more uniformly, and produce a better quality product than open-air methods [17]. Solar-drying technology offers an alternative, which can process the vegetables and fruits in sanitary conditions to national and international standards and with zero energy costs. It saves energy, time, occupies less area, improves product quality, makes the process more efficient and protects the environment. [18] Much research has been conducted about the dryer that Kiebling has listed 66 different solar dryers, their (continue from the coming line) configurations, capacity, the products dried and their cost. [19] Fuller (Fuller, 1995) [20] and Ekechukwu et al. [21] have reviewed many solar dryers, and compared their performance and applicability in rural areas. Sharma [18] has presented a comprehensive review of the various designs, details of construction and operational principles of the wide variety of practically realized designs of solar-energy drying systems and a systematic approach for the classification of solar-energy dryers has been evolved. A review of new technologies, models and experimental investigations of solar driers has been presented by Ramana [22].

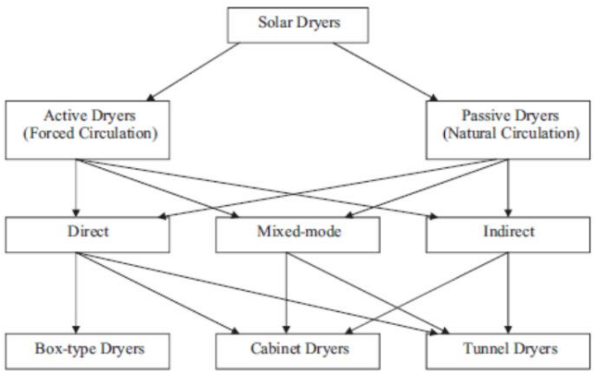

Fig.3. Classification of solar dryers and drying modes

Solar dryers are conventional dryers so that supplementary equipment is added to enable a significant proportion of the thermal energy required for drying to be replaced by solar energy. In these types of dryer, a planned, and generally optimized drying process can be achieved to obtain superior product quality and good economic performance. Any influence of the weather conditions on product quality and on the performance of the dryer can be eliminated by using an independent energy source, if needed, and proper control facilities [23]. The construction of the solar assisted dryers is relatively complex compared to other dryers. They usually consist of a solar collector, a fan, a heat storage system, a burner/heater, and a control system. They can handle large quantities and deliver good product quality [24].

V. VENTILATION SYSTEMS FOR AGRICULTURAL APPLICATIONS

Therefore, the application of PV can be the best choice because in the event of a grid power break down, PV will take over to supply power, hence potentially saving thousands of birds. Direct current motors can also operate directly with PV power and eliminate the use of an expensive inverter. The Taiwanese government increases benefits for livestock farmers who use solar energy to generate electricity specifically for pig farms to attract other farmers to build solar farms. A final report on Delaware's poultry farms reveals the economic and technical aspects of PV application for poultry farming. It also reports that PV offers additional benefits, such as security of supply, and economic and environmental advantages over grid electricity supply and conventional energy sources [25, 26].

VI. USE OF SOLAR ENERGY IN FARM HOUSES

Electrification to farm is difficult in some places and the cost is very high and for the sake of reducing costs, solar energy can be used because it is available in all locations and can provide the electricity and fuel needed, for a home can provide home lighting lamps and other appliances, with using solar energy. But the question is for cooking and heating water heaters: What should one do? It is true to fix such problems by using solar cookers and water heaters.

VII. SOLAR HOME

Seamlessly photovoltaic building that has been worn and has become one of the most popular homes. And it is used more in areas where there is not electrical grid. Photovoltaic panels are installed on the roof or walls to get sunlight. Solar energy is produced in the same location and can also save additional energy. This technology is cheaper and promising and more power can be produced for home. Figure below is a model configure to indicate buildings with photovoltaic energy. For areas where electricity grids are not very useful, it helps the region supply with the fewest problems of electricity [27]

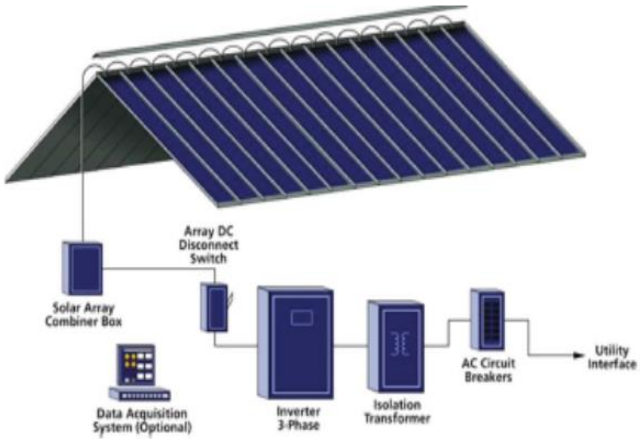

Fig.4. Building integrated photovoltaic system

VIII. SOLAR COOKER

Solar cookers are systems of clean energy, available and inexpensive sun that is used for cooking food. A solar cooker inhabited radiant heat by rays focusing it on a surface or locking it in a greenhouse space. Rather it should be used for cooking [28]. Given that in developed countries about 90% of household energy consumption is devoted to cooking [29]. These systems can do almost everything like an electric rice cooker or gas stove, such as roasting, brewing, cooking, frying or reheating refrigerated cool foods, including cases that are possible with the solar cookers [30], hence solar cookers are in two forms, direct and indirect. The direct solar cooker consists of an insulated box with transparent window, through which the sunlight enters. It is the most developed and it is for home cooking [27]. In the indirect stove fluid is used for heat transfer from the collector to a baking sheet [31].

Fig.5. Schematic solar cooker

IX. SOLAR WATER HEATER SYSTEMS

Water heaters are one of the most common applications of solar energy for home and industrial applications and similar solar dryers, water heating systems are also available in natural convection and forced convection scheme and Figure (6) shows one water heater [9]. Solar water heaters are divided into two categories: direct and indirect. In direct water heaters, water is consumed in the current collector, becomes hot and then is consumed, but in the indirect water heater, the water consumed is used for heating a fluid. The disadvantage of direct solar water heaters is that after a while the collector is blocked with a crime. Also, the thermal energy transfer to the water consumed is wasted [32].

Fig.6. A sample of a solar water heater

In general, in solar water heaters, in order to use hot water when not benefitting from the sun, the hot water is stored in the reservoir. In some solar water heaters, a water tank is installed above the collector and hot water for natural convection is stored in the tank. To the water heater said thermo syphon. In Figure (7) shows a direct solar water heater [33].

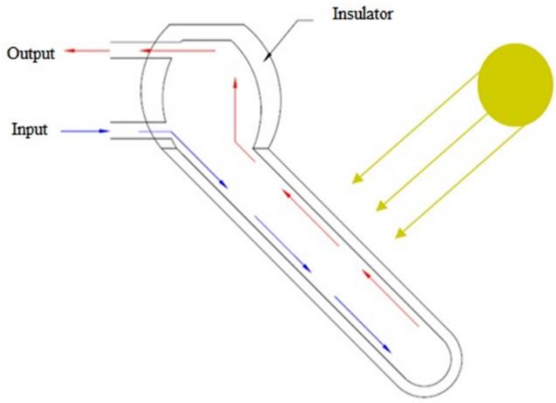

Fig.7.Schematic direct solar water heaters

In the indirect solar water heaters, a tank is installed in a separate space in order to provide power to flow in the collector by the used pump. That is why this water heater is said to be under pressure. In Figure (8) a indirect solar water heater is shown [33].

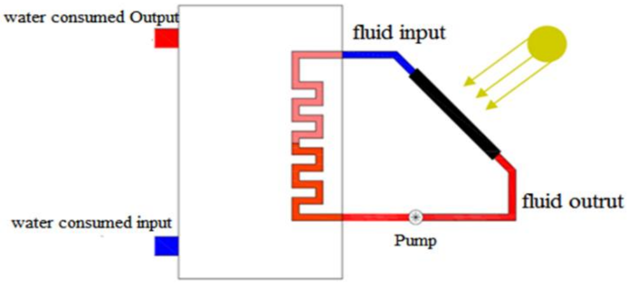

Fig.8. Schematic indirect solar water heaters

X. SOLAR GREENHOUSE

The greenhouse is a structure that nowadays is used in agriculture to grow plants with the best quality. Recently, solar energy is used for heating greenhouses so that such greenhouses are known as solar greenhouses (Figure 9) and the solar energy can be used to provide light to the greenhouse. A very good step would be to reduce the need for fossil fuels used for heating [34]. After the oil crisis in 1973, researchers tried find to a convenient and simple solution for the use of solar energy in the greenhouse. Overall, solar energy is used in greenhouses in three forms. The first type is famous as the inactive greenhouse (Passive), and it uses thermal energy from radiation solar heated greenhouse. In the greenhouse, the construction method is carried out so as to provide the maximum use of solar radiation during the day and lead to the lowest energy losses during the night in greenhouses. The second type greenhouse is called greenhouse active (Active), and it uses the pickers and transfer heated fluid, in heating greenhouses. In the third kind of greenhouses photovoltaic cells are used so that the solar radiation energy becomes Electrical and then it is used in greenhouses [35, 36].

Fig.9. A sample of a solar greenhouse

XI. CONCLUSION

The solar energy can be found in the farthest corners of the world and it can be developed to electric power production and agriculture. one reason that, agriculture is not anywhere, and is lack of energy. But Using solar energy can do the majority of cases related to agriculture. In addition, due to the reduced fossil fuel energy and Also with using solar energy in agriculture can land, that is unusable into them, created the greenhouse or place for breeding animals converted in areas outside city. On foregoing, the use of solar energy is an investment for the future because we can use it for a long time. In addition, a company can use this method to create, build panels and install them. This creates jobs and helps the economy.

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