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# Development of Reliability Indices for Electric Distribution Network in Egypt

Eman Ahmed, Sherein Abdulla, Kamelia Youssef and Hatem Waheed

Egyptian Electric Utility and Consumer Protection Regulatory Agency

[sharino@hotmail.com](mailto:sharino@hotmail.com), [white\\_storm100@yahoo.com](mailto:white_storm100@yahoo.com)

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

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

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

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

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

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

## I. INTRODUCTION

The Egyptian Electricity Holding Company (EEHC) mission towards the society is to supply electricity to all types of consumers according to international performance standards taking into consideration all environmental, social and economic determinates

and also the terms and conditions set by The Egyptian Electric Utility and Consumer Protection Regulatory Agency (EGYPTERA).

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

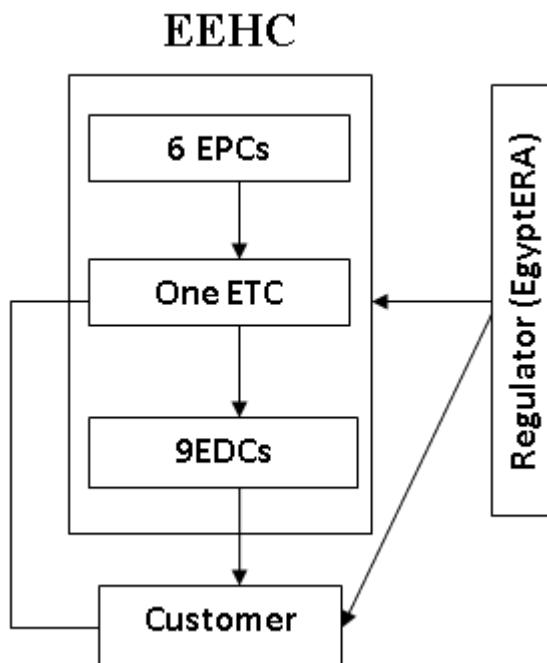


Fig. 1. the relation between EEHC and Egypt ERA

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

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

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

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

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

## II. PERFORMANCE INDICES (PIS)

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

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

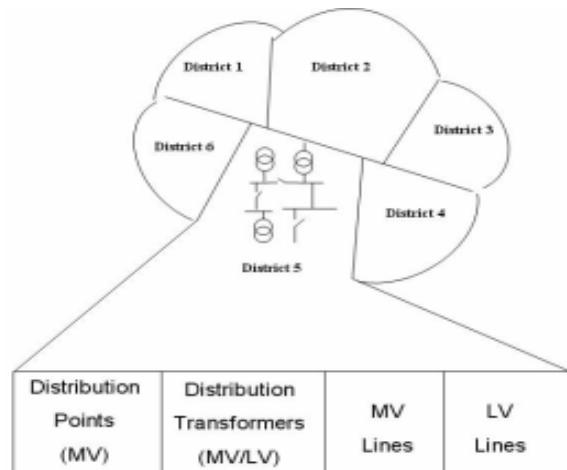


Fig. 2. Part of geographical area of an EDC

## III. SYSTEM RELIABILITY INDICES (RIS)

### A. System Average Interruption Frequency Index (SAIFI)

It measures the average number of interruptions experienced by each customer. All planned and unplanned interruptions are used in calculating the index. SAIFI can be calculated as follows:

SAIFI = (No. of interruptions during one year)/ (No. of customers).

### B. System Average Interruption Duration Index (SAIDI)

It measures the yearly average interruptions duration per customer. It can be calculated as follows:

SAIDI = ( $\Sigma$ duration of interruption in min)/ (No. of customers).

### C. Customer Average Interruption Duration Index (CAIDI)

It measures the average time required to restore service to the average customer per interruption. The following formula is employed for calculating CAIDI:

CAIDI = (SAIDI)/ (SAIFI). [4], [5]

## IV. CONTINUITY OF POWER SUPPLY

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

- Continuity of power supply or sustained outage – an outage that lasts longer than a specified amount of time .SAIDI, SAIFI and CAIDI are all based on sustained outage .The duration of a sustained outage varies from state to state. IEEE -1366 defines the duration of sustained outage to be 5 minutes.
- Power quality – measure of the purity of the electric waveform on power lines. A power quality event, which is not the same as an outage, occurs when one of the waveforms differs from a pure sinusoidal waveform or one or two phases of power are lost. [10]

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

#### A. International example

A review of some countries revealed the SAIDI and SAIFI performance shown in “Table 1”. These countries also put greater emphasis on power quality [3], [11]

#### B. Variables affecting reliability indices

- Longer circuits lead to more interruptions. It is easier to provide higher reliability in urban areas; line lengths are shorter.
- The distribution supply configuration greatly impacts reliability. Long radial lines provide the poorest service; grid networks are exceptionally reliable.
- Higher primary voltages tend to be more unreliable, mainly because of longer lines.

Table 1. EUROPEAN RELIABILITY PERFORMANCE, WITH MAJOR EVENTS

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

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

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

#### C. Relation between SAIFI & CAIDI

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

- Find optimum and customer satisfied: “A” area, represents the area of biggest reliability, move towards the origin, the performance will be better.
- Customer dissatisfied: Balanced area represents the lower reliability, divided to:
- Region “B” indicates for the excess number of interruptions but for short time durations.
- Region “C” indicates for little number of interruptions but for long time durations.
- Vertical axis “X” and horizontal axis “Y” give the reliability indices threshold.

#### D. Performance indicators for EDC

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

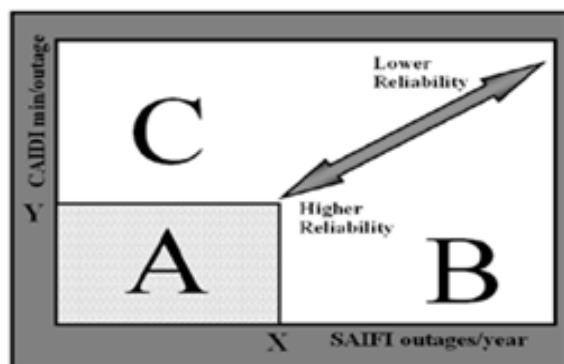


Fig.3. Relation between SAIFI and CAIDI

Table 2. DEVELOPMENT OF CAIDI FOR EDCS

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

Table 3. DEVELOPMENT OF SAIFI FOR EDCS

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

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

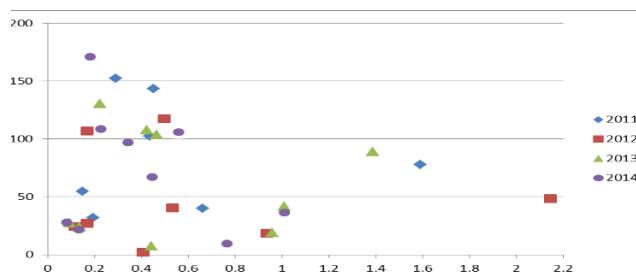


Fig.4. relation between SAIFI&CAIDI for EDCs (data 2011-2012-2013-2014)

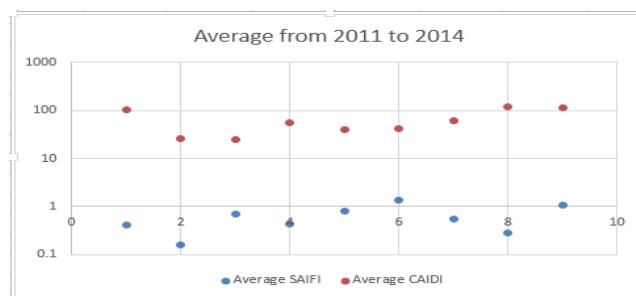


Fig.5 Relation between SAIFI and CAIDI for EDCs in 2014

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

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

Notes:

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

## V. CONCLUSION

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

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

The reliability indicators for electric network in Egypt are used by EEHC and Egypt Era to benchmark performance and scenarotize investments in generation, transmission and distribution network, to improve performance. Also, these indicators are used by system planners and operators as a channel to improve the level of customer service.

Reliability level for its delivery facilities and, where appropriate to improve performance.

The results are the reliability performance objectives for EDCs, ETC, and EPCs shall have threshold objective designed to help maintain the acceptable envelop.

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