ELEMENTARY EVALUATION OF RELIABILITY INDICES FOR POWER SYSTEM IN EGYPT

Hafez ELSALMAWY
Egyptera – Egypt
salmawy@link.net

Kamelia YOUSSEF
Egyptera – Egypt
info@egyptera.org

Shereen ABDULLA
Egyptera – Egypt
sharino@hotmail.com

Salma HUSSEIN
Egyptera – Egypt
salma.hussin@egyptera.org

ABSTRACT

Reliability indices are the elemental benchmark used by Egyptian Electricity Holding Company (EEHC), the Electric Utility and Consumer Protection Regulatory Agency (Egypt Era) to evaluate the continuity of supply, which meets the customer's requirements and satisfaction. EEHC has sixteen affiliated companies; six generation, nine distribution and one electricity transmission.

The power system is very complex, integrating many different types of generating resources to supply electric power through transmission system to a number of customers with varying requirements.

The basic function of power 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).

The envelope of acceptable supply for relation between reliability indices is defined and evaluated for power systems consisting of generation, transmission and distribution networks. 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.

Elementary indices used to disaggregate the contribution of generation, transmission and distribution systems, to final satisfaction area.

The paper presents the reliability indices, relation between indices and satisfaction area to highlight the appropriate guideline values for power systems.

INTRODUCTION

Power outages disrupt more businesses than other problems (lightning, floods, fires…and earthquakes). End users expect good reliability while anticipation kept uprising. Reliability indices, based on long-duration interruptions are the primary benchmark used by the Egyptian Electricity Holding Company (EEHC), and the Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA) to identify service quality. EgyptERA most commonly uses reliability indices, SAIFI, SAIDI and CAIDI, to benchmark reliability. These characterize the frequency and duration of interruptions during the reporting period (usually one year) (IEEE std 1366-2000).

THE ELECTRIC UTILITY

EEHC has sixteen affiliated companies (six production, nine distribution and one electricity transmission).

The Electricity production company (EPC) consists of number of power stations (PSs), each one has several units (generations, transformers, and auxiliaries).

The electricity transmission company (ETC) consists of geographical zones, having transmission lines (TLs) and transformers (TRs) for different high voltage levels.

As for the electricity distribution company (EDC), it consists of number of geographical sectors, which have number of districts. The district network consists of distributors, distribution transformers and LV, MV lines.

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.

EgyptEra selects aspects of the continuity of supply like:

-Type of interruption, scheduled or unscheduled (forced).

-The duration of interruption.

-The voltage levels of faults.

-The type of continuity factors; frequency and durations of interruptions.

Many performance indicators have been introduced to quantify the reliability of power system into:

-SAIFI (System Average Interruption Frequency Index).

-SAIDI (System Average Interruption Duration Index).

-CAIDI (Customer Average Interruption Duration Index).

[CAIDI = SAIDI/SAIFI].

"Fig.1", "Fig.2" and "Fig.3" represent the performance indicators for electric production company (EPC), electrical transmission company (ETC) and electrical distribution company (EDC) respectively.

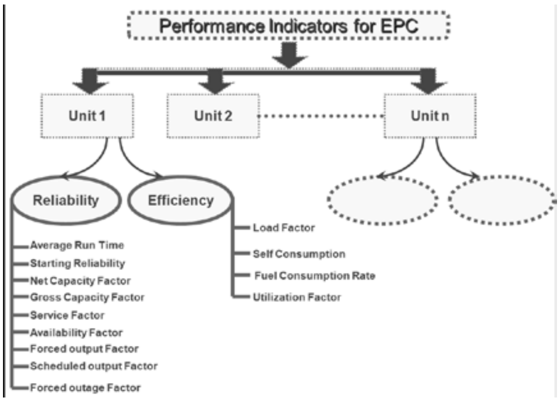

Fig 1. Distribution of indicators for Electrical Production Company (EPC)

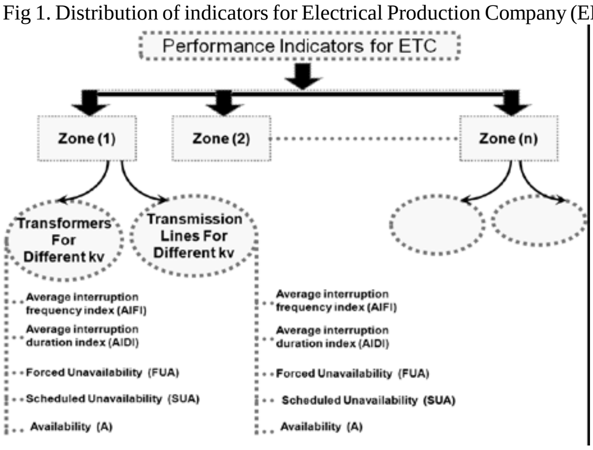

Fig.2. Distribution of indicators for Electrical Transmission Company (ETC)

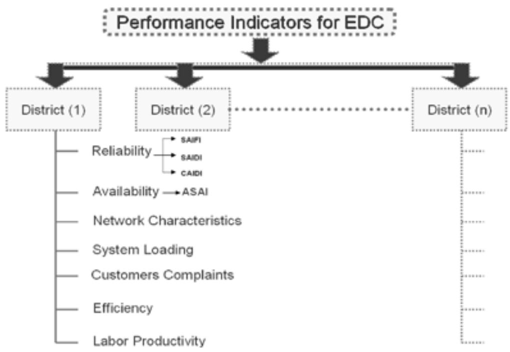

Fig.3. Distribution of indicators for Electrical Distribution Company (EDC)

Variables affecting reliability indices:-

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

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.

Relation between SAIFI & CAIDI:-

The envelope of "acceptable supply" for relation between frequency of interruptions and longest duration per interruption is shown in fig.4, which divided to:

- 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.

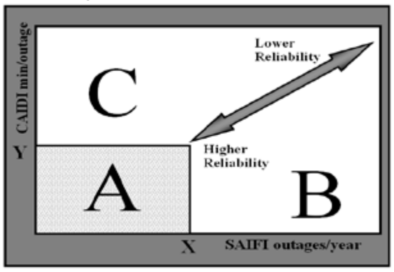

Fig.4. Relation between SAIFI and CAIDI

The reliability indices threshold

EgyptEra complies with requirements of reliability indices threshold at the second assessment date, according to SAIFI or SAIDI or CAIDI threshold:

Each one for the twelve months ending on the second assessment date is less than the three years average

$SAIFI_{(future\ year)} = \sum_n SAIFI_n$

$SAIDI_{(future\ year)} = \sum_n SAIDI_n$

$CAIDI_{(future\ year)} = \sum_n CAIDI_n$

Where n is three year before future year, for example

$$SAIFI_{2009} \leq \left\{ \frac{SAIFI\,2006 + SAIFI\,2007 + SAIFI\,2008}{3} \right\}$$

If $SAIFI_{2009} \leq$ SAIFI (2006-2008)

$\therefore$ The threshold is not breached.

International example:

Unplanned interruptions duration in Europe.

Table I presents unplanned interruption excluding exceptional events, in minutes lost per year, according to voltage levels (year 2007)

TABLE I

source: 4th CEER benchmarking report on quality of electric supply 2008

Country	Voltage level	Minute lost per year
Austria	HV,MV	< 50
Denmark	HV,MV	
Germany	HV,MV,LV	
France	HV,MV,LV	50:100
Iceland	HV,MV,LV	
Italy	HV,MV,LV	
Portugal	HV,MV,LV	100:125
Spain	HV,MV,LV	

For 14 Distribution Network Operators across UK in 2002/2003

- The average number of customer interruptions per 100 customers was 86.2.
- The average number of minutes customers were off supply was 110.4.

RESULTS

The performance indicators have been calculated, according to EgyptEra software, based on the huge separate data provided by EPCs, ETC and EDCs.

Performance indicators for EPCs

The evaluation of two indicators is presented for steam generation units (≥ 300 MW rating) in EPCs. They are:

-Self consumption (%) is the amount of energy consumed by the station auxiliaries, and equals

$$\left[\frac{Generated\ Energy - Sent\ Energy}{Generated\ Energy} * 100\right]$$

-Fuel Consumption rate (gr./kwh) is the ratio of the fuel quantity consumed to the net actual generation, and equals:

$$\left[\frac{fuel\ quantity}{net\ actual\ generation}\right]$$

Fig.5 represents 23 steam generation units (≥300 MW)

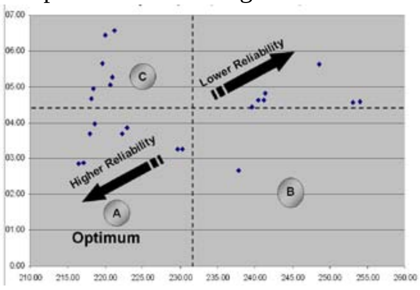

Fig.5. Self consumption (%) (y-axis) and fuel consumption rate (gr/kwh) (x-axis) -Average of 3 years (2006-2007-2008)

The notes:

- Eight units in optimum area (A area), the indicators are less than weighted average (4.47% & 232.64 gr./kwh)
- Eight units in region B, out of optimum area
- Seven units in region C, out of optimum area

Performance indicators for ETC

For power transformers:

-TR-AIFI is transformers-Average Interruption Frequency Index=

$$\left[\frac{No.\ of\ forced\ outages\ for\ Trs\ at\ "x"\ kv\ level\ in\ a\ zone}{No.\ of\ Trs\ at\ "x"\ kv\ level\ in\ a\ zone}\right]$$

-TR-AIDI is Transformers-Average Interruption Duration Index=

$$\left[\frac{Duration\ of\ forced\ outages\ for\ Trs\ at\ "x"\ kv\ level\ in\ a\ zone}{No.\ of\ Trs\ at\ "x"\ kv\ level\ in\ a\ zone}\right]$$

Where: x is 500, 220, 132, 66 or 33 kv.

For transmission lines:

-TL-AIFI is transmission lines-Average Interruption Frequency Index=

$$\left[\frac{No.\ of\ forced\ outages\ for\ TLs\ at\ "Y"\ kv\ level\ in\ a\ zone}{Total\ Length\ of\ TLs/100km\ at\ "Y"\ kv\ level\ in\ a\ zone}\right]$$

-TL-AIDI is transmission lines-Average Interruption Duration Index=

$$\left[\frac{Duration\ of\ forced\ outages\ for\ TLs\ at\ "Y"\ kv\ level\ in\ a\ zone}{Total\ Length\ of\ TLs/100km\ at\ "Y"\ kv\ level\ in\ a\ zone}\right]$$

Where: Y is 500, 400, 220, 132, 66 or 33 kv. And there are six zones.

Fig.6. represents the relation between AIFI &AIDI of Trs and TLs for six zones

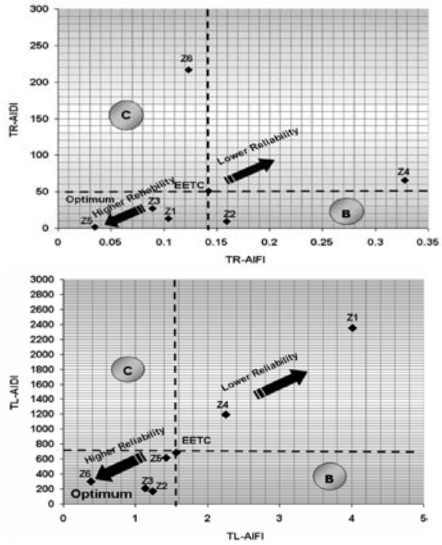

Fig.6. Relation between AIFI &AIDI of Trs and TLs for six zones.

The notes:

- For transformers, indicators for zones z1, z3, z5 are in optimum area.
- For transmission lines, indicators for zones z2, z3, z5, z6 are in optimum area.

That means z3 and z5 are in "high optimum area".

Performance indicators for EDC

Table (II) represents the development of SAIFI and CAIDI during 2006:2009 for EDCs. If indicators through the three years are abnormal (as CAIDI for EDC3 & EDC5), the stray number must be dropped out.

Table II
Development of indicators for EDCs

company	SAIFI				
	2006	2007	2008	Average	2009
EDC1	0.54	0.52	1.2	0.75	1.66
EDC2	0.86	0.9	0.96	0.91	0.92
EDC3	1.23	1.53	1.3	1.35	0.86
EDC4	0.99	0.59	0.41	0.66	0.38
EDC5	1.32	1.52	2.04	1.63	0.19
EDC6	0.37	0.37	0.22	0.32	0.24
EDC7	0.6	0.64	0.43	0.56	0.38
EDC8	0.54	0.98	0.79	0.77	0.57
EDC9	0.69	0.47	0.38	0.51	0.43

company	CAIDI				
	2006	2007	2008	Average	2009
EDC1	32.15	32.57	73.24	45.99	87.23
EDC2	51.68	46.27	41.52	46.49	51.81
EDC3	68.44	4.24	3.84	Abnormal	4.41
EDC4	60.79	70.32	107.58	79.56	75.66
EDC5	320.9	20.1	19.41	Abnormal	67.63
EDC6	118.53	132.33	115.77	122.21	129.23
EDC7	63.98	72.12	58.78	64.96	59.25
EDC8	117.03	72.88	89.08	92.0	88.43
EDC9	72.16	71.13	109.54	84.28	119.02

The relation between SAIFI and CAIDI for 9 EDCs during 2006:2009 is presented in fig.7.

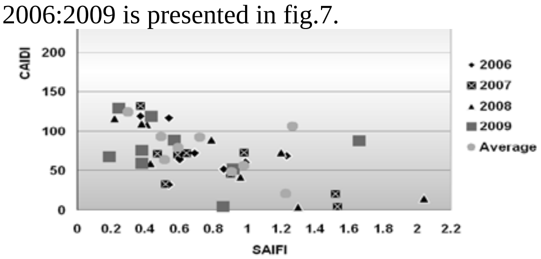

Fig.7. Relation between SAIFI & CAIDI for EDCs (data 2006-2007-2008-2009)

Fig.8 represents the envelope of "acceptable supply" for relation between SAIFI and CAIDI for EDCs in 2009. According to IEEE 1366, 2001 the target of SAIFI and CAIDI are 1.0 and 90 minute respectively, they are close to the calculated threshold values.

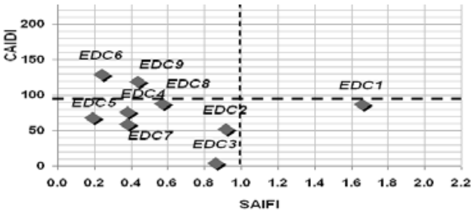

Fig.8. Relation between SAIFI and CAIDI for EDCs in 2009

The notes:

1- SAIFI and CAIDI are improved in 2009 for most EDCs.
2- EDC2, EDC3, EDC5, EDC7 are in optimum area.

Improving reliability

Methods of reducing long-duration interruptions include:

Table III

Aim	Targeted solution
Reduce Faults	-Tree Wire -Animal guards -Adding more Arresters
Find and Repair Faults Faster	-Faulted circuit indicators -Outage management system-Better cable fault finding
Reduce the number of customers interrupted	-Sectionalizes -Reclosers -More HRC fuses
Only interrupt customers for permanent faults	-Reclosers instead of fuses -Configuration changes
Improve restoration time	-Sectionalize circuit -Reduce the repair time -Faulted circuit indicators -Outage management system

The two main plans to improve reliability to customers are:-

1. Minimize the effect of faults: by using automation system, more protective devices, reclose faster and improve coordination.
2. Minimize Faults: by using equipment replacement programs, better arrester application, audits to ensure quality, inceptions and maintenance.

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 EgyptEra to benchmark performance and scenariotize investments in generation, transmission and distribution network, 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.

REFERENCES

[1] L.Goel, "based reliability studies of adistribution test system", *Monte Carlo simulation [Online]*. Available: www.sciencedirect.com

[2] H.Haroonabadi, and M.R.Haghifam,"Generation Reliability Assessment in Power Markets Using Monte Carlo simulation and intelligent system", *World Applied Sciences Journal* 5(3):302-310, 2008

[3] Kamelia Youssef and Hafez El-Salmawy, "Indices of supply: Benchmarking EDCs in Egypt", *MEPCON 2009*, Assuit University,Egypt.

[4] Kamelia Youssef and Hafez El-Salmawy,"Power Quality: reliability indices for transmission system in Egypt", *The conference of the power quality and harmonics (JCNC)*, Amman, Jordan.

[5] Math BOLLEN, and Anders HOLM, "A customer – oriented approach towards reliability indices" *CIRED, 19th International Conference on Electricity Distribution*, Vienna, 2007

[6] Konstantin Petrov, and Daniel Grote, "Quality of supply", *Presentation for ERRA Tariff Committee*, April 2010

[7] “Electricity Distribution Quality of Service Report2002/2003,” *14 Distribution Network Operators*, Great Britain, July 2004

[8] A. Sumper, A. Sudria, and F.Ferrer, "International Reliability Analysis in Distribution Networks" *CITCEA*, Universitat Politecnica de Catalunya, Spain.