

RELIABILITY OF ELECTRICITY SUPPLY INDICES IN POWER DISTRIBUTION NETWORK – JP ELEKTROPRIVREDA BiH, SARAJEVO

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INTRODUCTION

Liberalization and deregulation of power system market actualize the problem of quality of electricity supply, thus giving the greater significance and new techno-economical dimensions to this issue.

Power quality is usually observed through: (1) reliability of electricity supply indices and (2) voltage quality indices at supply point.

This paper deals with reliability of electricity supply indices in power distribution network and presents the results of systematic registration process of these indices in power utility JP Elektroprivreda BiH, one of the several power utilities in Bosnia and Herzegovina.

JP Elektroprivreda BiH performs the activities of electricity generation, distribution and supply, based on initial licence issued by Regulatory Commission for Electricity in Federation of Bosnia and Herzegovina (FERK) in December 2005. According to the Initial licence for Power distribution [4] JP Elektroprivreda BiH is obliged to distribute electricity in accordance with the quality requests defined in valid regulations on electricity supply (General Conditions for Electricity Supply and Distribution Grid Code), to establish outages and interruptions database and to register number and duration of customers interruptions. JP Elektroprivreda BiH has started with outages monitoring system and had selected reliability of electricity supply indices before it was granted with licence for power distribution. Chosen solutions are focused on international standards and practices of European distribution companies, providing to meet most of the conditions of FERK.

First chapter of this paper gives a brief review of the commonly used reliability indices identified by IEEE 1366-2003 Standard [1] and presents the experiences of European distribution companies in quality of electricity supply assessment. Second chapter deals with results of reliability of electricity supply monitoring for distribution network of JP Elektroprivreda BiH.

RELIABILITY OF SUPPLY INDICES ACCORDING TO IEEE 1366 STANDARD

Institute of Electrical and Electronic Engineers (IEEE) has published IEEE 1366-2003 „Guide for Electric Power Distribution Reliability Indices” which identifies distribution reliability indices and factors that affect their calculation.

Calculation of reliability indices is based on registration of number of interruption, duration of interruption and interruption consequences. Depending on chosen manner of interruption consequences registration, reliability indices are calculated according to number of customers interrupted or energy not supplied. Indices for short and long interruptions can be calculated separately in term of interruption duration.

IEEE 1366 Standard defines several reliability indices and describes methods of their calculation. However, available data and distribution network structure determine the range of chosen indices as mentioned in distribution company reports. Commonly used reliability indices are:

- System Average Interruption Frequency Index – SAIFI indicates how often the average customer experiences a sustained interruption in supply of electricity over a predefined period of time. It is calculated according to the given equation:

$$SAIFI = \frac{\sum \text{Total Number of Customers Interrupted}}{\text{Total Number of Customers Served}}$$

- System Average Interruption Duration Index – SAIDI indicates the total duration of interruption for the average customer during a predefined period of time. It is usually measured in customer minutes or customer hours of interruption during one year or short time period. It is calculated according to the given equation:

$$SAIDI = \frac{\sum \text{Customer Interruption Duration}}{\text{Total Number of Customers Served}}$$

- Customer Average Interruption Duration Index – CAIDI represents the average time required to restore service. Mathematically, this is given in equation:

$$CAIDI = \frac{\sum \text{Customer Interruption Duration}}{\sum \text{Total Number of Customers Interrupted}}$$

IEEE Working Group on Quality of Supply continues to follow the implementation of Standard in distribution companies in USA, and also to prepare brief reports and amendments to Standard based on practical experiences. Based on these approaches, very instructive annexes are given in standard. Beside an overview of reliability indices of surveyed distribution companies, a list of characteristic cause codes is given in annexes enabling benchmarking among surveyed companies.

QUALITY OF ELECTRICITY SUPPLY MONITORING IN EUROPEAN COUNTRIES

Council of European Energy Regulators – CEER has established the Working Group for Quality that publishes Benchmarking Report on quality of electricity supply since 2001, with a view to internal benchmarking, harmonized activities in continuity of electricity supply monitoring and helping to those distribution companies who are in the stage of introducing monitoring system.

In the last Third Benchmarking Report that was published in December 2005 [2], according to the statement of Working Group for Quality, significant improvements have been made in continuity of supply monitoring and number of surveyed countries has increased. Third Benchmarking Report includes information from 20 countries (Austria, Belgium, Czech Republic, Estonia, Finland, France, Great Britain, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Slovenia, Spain and Sweden) which is sufficiently great number to understand widely accepted practice in Europe.

Data for Third Benchmarking Report were obtained on single questionnaire and Report summarizes the four main features of continuity of supply:

- The type of interruption
- The duration of each interruption
- The voltage levels of interruption

- The type of continuity indices

Due to the scope of this paper, several main conclusions were drawn from the CEER Report for each of those analyzed features.

The type of interruption. Interruptions in continuity of electricity supply can be observed as planned or unplanned interruptions. Planned interruptions are the results of deliberate interruptions of supply that are previously notified to customer for the purposes of preventive maintenance of the network, investment projects etc. Other interruptions are treated as unplanned interruptions.

In all other countries, with the exception of Latvia, planned and unplanned interruptions are registered separately. The number and duration of unplanned interruptions show a significant downward trend.

The duration of each interruption. In accordance with European technical standard EN 50160, interruptions are divided on long interruptions, short interruptions and transient interruptions. Long interruptions last more than 3 minutes, short interruptions last more than 1 second and less than 3 minutes, and transient interruptions last less than 1 second.

Most of the surveyed countries make no distinction between registration of long and short interruptions, while transient interruptions are generally not registered. Short interruptions are counted separately in only a few countries (Finland, France, Hungary, Great Britain and Italy). This practice extension can be expected due to increasing usage of equipment sensitive to short interruptions. Beginning in 2006, companies in Norway will introduce separate recording of short interruptions.

Expected reduction in number of long interruptions and expected growth in number of short interruptions are generally not present, despite an increased move to automation and remote control techniques, what is especially emphasised in CEER Report.

The voltage levels of interruption. There are two different practices in registration of interruptions originating at any voltage level: recording interruptions at all voltage levels (high, middle and low voltage) or excluding some voltage level from registration (usually low voltage).

Originating from all voltage level, interruptions are registered particularly in most of surveyed countries (Czech Republic, Finland, France, Greece, Great Britain, Hungary; Lithuania; Italy, Norway, Portugal, Sweden). Interesting example could be found in Belgium where low voltage interruptions are registered only if longer than 15 minutes while all interruptions on higher voltage levels are registered. Only in a few countries (Austria, Estonia, Latvia, Slovenia, Spain) recording is limited to high voltage and middle voltage only, what appears to be rational choice considering that interruptions at middle voltage level have greatest impact on reliability indices values.

Reliability of supply indices. As measure of reliability of supply, the commonly used indices are those defined in IEEE 1366 Standard (SAIFI; SAIDI, MAIFI) which are calculated and expressed annually. Concerning the different spatial scope of measurement practices, comparison and benchmarking are not always possible. Reliability of supply indices could be calculated at country level, at region/municipality level or at each distribution company level. For the purpose of easier benchmarking of reliability indices, territorial classification is usually done in terms of demographic and energy characteristics of an area i.e. population density, customer density, percentage of cable network, average length of lines per customer etc.

Third Benchmarking Report underlines the efficiency of territorial classification for regulatory agencies enabling them to observe the network performances both in rural and urban areas, but without direct possibility for comparison among countries.

Beside standard reliability indices, a range of other specific indices has been introduced (i.e. average number of interruption, average duration of interruption etc).

RESULTS OF RELIABILITY OF ELECTRICITY SUPPLY MONITORING SYSTEM IN DISTRIBUTION NETWORK – JP ELEKTROPRIVREDA BIH

Basic data of the distribution branch offices

JP Elektroprivreda BiH is the company with five distribution branch offices: Bihać, Mostar, Sarajevo, Tuzla and Zenica. Working area covers the territory of one or two cantons, depending on regional organization of Federation of Bosnia and Herzegovina. Basic data for distribution branch offices of JP Elektroprivreda BiH are given in Table 1.

TABLE 1 – BASIC DATA OF THE DISTRIBUTION BRANCH OFFICES OF JP ELEKTROPRIVREDA BIH

No.	Data	Unit	ED Sarajevo	ED Tuzla	ED Zenica	ED Bihać	ED Mostar	JP EP BiH
1	Number of customers	number of customers	193.080	159.676	172.030	88.809	32.404	645.999
2	Total annual consumption in 2005	MWh	1.039.705	952.141	758.803	371.285	151.983	3.273.917
3	Length of MV network	km	1.625	1.834	2.457	1.829	750	8.495
4	Participation of cable lines in MV network	%	56%	14%	16%	6%	16%	21%
5	Length of LV network	km	3.664	6.108	7.639	3.096	1.783	22.290
6	Surface area	km ²	1.526	2.649	5.884	4.125	2.570	16.754
7	Customer density	customers/km ²	127	60	29	22	13	39
8	Consumption density	MWh/km ²	681	359	129	90	59	195
9	Length of MV network per 1000 customers	km/1000 customers	8,4	11,5	14,3	20,6	23,1	13,1

Distribution branch offices have different spatial, demographic and energetic parameters. Distribution branch office Sarajevo has characteristics of urban area with large number of customers, high population density and high consumption density. Other distribution branch offices have much lower parameters of population and consumption density, but significant differences could be found among them.

Overview of outages monitoring system and methods for calculation of reliability of supply indices

Uniform outages registration system and methods for calculation of reliability of electricity supply indices on middle voltage network have been set in JP Elektroprivreda BiH since March 2005. Elapsed period represents the first phase of system development, providing only registration of outages on middle voltage network. It is estimated that conditions, needed for efficient and reliable registration of outages on low voltage network, still do not exist and that high voltage plant (110 kV and higher) are not in jurisdiction of distribution company but in jurisdiction of transmission company Elektroprivreda BiH.

Outages monitoring system is organized in all distribution branch offices, with adequate information technology support and consists of:

- daily registration of outages on middle voltage network in Dispatcher Reports prepared in Dispatching services
- monthly analysis of Dispatcher Reports and calculation of selected indices that are published afterwards in Statistical bulletin of JP Elektroprivreda BiH.

Detailed directions for data registration in Dispatcher Reports, also describe classification of type and cause of outages and methods for registration of characteristic events (step restoration process, multiple interruptions caused by non-selective protection etc.).

In Dispatcher Reports, outages on middle voltage network are registered chronologically with the following data:

- Voltage level and object

- Type and causes
- Duration
- Interruption consequences
- Reliability indices

Voltage levels and objects of outages. Outages are registered on 35 kV and 10(20) kV transformers, lines and cables.

Location of lockout is also a data recorded in Dispatcher report i.e. (transformer station, switchyard, line recloser or line connector).

Type and causes. In accordance with type, outages can be planned or unplanned. Causes of unplanned outages might be: (1) faults on distribution objects, (2) interventions – unplanned activities for preventing greater damage (3) inattention of other parties. Causes of planned outages might be: (1) regularly and investment maintenance, (2) investment works on network and (3) works on transmission network or other parties substations previously announced to customers.

Additional classification for outage cause could also be made, especially for detailed registration of faults.

Duration of an outage. Starting and ending time of an outage are registered in Dispatcher report, and duration of an outage is calculated.

Interruption consequences. Interruption is an outage that causes interruption of electricity supply and following measures of consequences are registered: (1) area without supply (municipality), (2) connected kVA of load interrupted and (3) number of customers interrupted.

Since January 2006, interruption consequences are registered in all distribution branch offices, after determination of registration methods for connected kVA of load interrupted and for number of customers interrupted. Like in most European distribution companies [2], measures of interruption consequences are estimated. Quantity of connected kVA of load interrupted is determined in accordance with the distribution network scheme and total installed power of interrupted transformers. The number of customers interrupted is based on actual customer number connected to each transformer station. Data are gathered from billing system application.

Reliability indices. Based on data registered in dispatcher report, the following indices are calculated both for JP Elektroprivreda BiH and for each distribution branch office separately:

- reliability indices identified by IEEE 1366 Standard (SAIFI, SAIDI, CAIDI)
- other reliability indices intended for internal benchmarking in JP Elektroprivreda BiH [3]

Results overview

Since March 2005, several testing of outage registration system have been made and certain improvements have been accomplished. Final form of dispatcher report was set in September 2005, and all data on interruption consequences have been registered since January 2006. That was the reason for separate data analyses: 12 months period (May 2005-April 2006), 8 months period (September 2005-April 2006), while reliability indices are expressed only for 4 months period (January 2006-April 2006)

Total number, causes of outages and total number of interruptions. Data for total number and causes of outages, but also for number of interruptions registered from May 2005 to April 2006, are presented in Table 2. Even this is not calendar year period, it could be considered in that way.

Figure 1. shows the percentage participation of characteristic causes of outages in total annually registered number of outages for JP Elektroprivreda BiH.

35% of outages are planned outages caused by works that were previously announced to customers, and other 65% of outages are the results of unplanned network events. Only in distribution branch office Sarajevo, planned outages dominate in total number of outages.

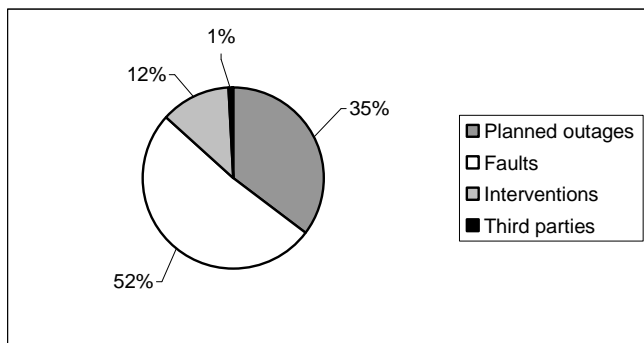
Unplanned outages are usually caused by faults and they participate with 52% in total number of outages at company level. Similar situation is in all distribution branch offices.

In average, 94% of outages caused the interruption of electricity supply for customers.

TABLE 2 – NUMBER OF OUTAGES, CAUSES OF OUTAGES AND NUMBER OF INTERRUPTIONS

No	Data (May 2005-April 2006)	ED Sarajevo	ED Tuzla	ED Zenica	ED Bihać	ED Mostar	JP EP BiH
1	Total number of outages	3.061	2.723	4.098	3.938	791	14.611
1.1	Planned outages	2.039	942	1.346	694	153	5.174
1.2	Unplanned outages	1.022	1.781	2.752	3.244	638	9.437
1.2.1	Faults	868	1.550	2.271	2.308	496	7.493
1.2.2	Interventions	99	186	471	924	124	1.804
1.2.3	Third parties	55	45	10	12	18	140
2	Total number of interruptions	2.866	2.444	3.777	3.906	767	13.760
3	Participation of interruptions in total number of outages	94%	90%	92%	99%	97%	94%

FIGURE1 – PARTICIPATION OF DIFFERENT CAUSES IN TOTAL NUMBER OF OUTAGES



Total number of interruptions and interruption duration. Data for total number of interruptions and interruption duration in last 8 months period (September 2005-April 2006) are shown in Table 3.

TABLE 3 – TOTAL NUMBER OF INTERRUPTIONS AND INTERRUPTION DURATION

No	Data (September 2005-April 2006)	Units	ED Sarajevo	ED Tuzla	ED Zenica	ED Bihać	ED Mostar	JP EP BiH
1	Number of customers	customers	193.080	159.676	172.030	88.809	32.404	645.999
2	Total number of interruptions	interruptions	2.197	1.547	2.451	2.438	585	9.218
3	Total duration of interruption	hour:minutes	7119:36	3190:51	10929:44	6686:59	2722:28	30649:38
4	Average number of interruptions per 1000 customers	interr./1000 cust.	11	10	14	27	18	14
5	Average duration of interruption	minutes	194	123	267	164	279	199

Because of need for internal comparison of distribution branch offices, several internal indices were set based on available data for number and duration of interruptions:

- average number of interruptions on 1000 customers, calculated as ratio of total number of interruptions and total number of customers supplied in one distribution area,
- average interruption duration, calculated as ratio of total duration of all interruptions and total number of interruptions during a predefined period of time
- number of interruptions classified by time needed for service restoration - internal classification (service restored in less than 1 hour, service restored in period between 1 hour and 24 hours, and service restored in over than 24 hours),

Reliability of electricity supply indices (SAIFI, SAIDI and CAIDI). Table 4 presents the reliability of electricity supply indices calculated from gathered data for number of customers interrupted and data for interruption duration. Indices are calculated for the last 4 months period (January 2006-April 2006).

TABLE 4 – RELIABILITY INDICES DEFINED IN IEEE 1366-2003 STANDARD

No	Reliability indices (January-April 2006)	Units	ED Sarajevo	ED Tuzla	ED Zenica	ED Bihać	ED Mostar	JP EP BiH
1	SAIFI	interruptions/ customer	1,99	5,93	4,37	9,57	5,43	4,81
2	SAIDI	minutes	129,11	462,74	370,09	484,77	554,42	345,98
3	CAIDI (SAIDI/SAIFI)	minutes	64,75	78,10	84,69	50,64	102,03	71,88

The existence of qualitative difference between distribution branch office Sarajevo and other branch offices of JP Elektroprivreda BiH is confirmed despite the fact that reliability indices are calculated only for four months period. Distribution branch office Sarajevo supplies about 30% of all customers in JP Elektroprivreda BiH and has characteristics of urban area with customer density of 127 customers/km², consumption density of 681 MW/km² and great participation of cables in network (over 50%).

CONCLUSION

System for registration of outages in middle voltage networks and calculation of reliability of electricity supply indices for each of five company branch offices, provide that JP Elektroprivreda BiH meets the basic conditions of Regulatory Commission for Electricity in Federation of Bosnia and Herzegovina (FERK) set in the Initial licence for Power Distribution. Base for benchmarking and comparison with other distribution companies in region is created after the selection of data and reliability indices.

System development necessarily requires:

- Maintaining the continues system monitoring, its uniformity and methodology in order to accomplish long enough period of statistic data analyses and to get annually expressed reliability indices,
- Expansion of monitoring process to include low voltage networks and
- Suggestion to FERK, a regulatory agency, to verify selected methodology for monitoring of reliability of electricity supply.

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