Analysis of the normative documents for the electrical energy quality

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Abstract – **Ensuring and supporting of the electrical energy quality is a basic duty of the electric supplying companies. The consumers have every right to require and to get qualitative electrical energy. The operative standards of the electrical energy quality are studied in the paper.**

Keywords – **electrical energy, quality, voltage**

I. INTRODUCTION

The combination of such characteristics of the supplying system, in which consumers of electrical energy can execute functions deposited in them, is defined by the general term *electrical energy quality*. The electrical energy quality has two basic components – continuity and voltage level.

Often the concept of electrical energy quality is used to describe the specific characteristics of the supply voltage. The most important of them are: harmonics and voltage deviation; voltage fluctuations, especially these caused flicker; voltage sags and short interruptions; voltage asymmetry in three phase systems; transitory overvoltages.

Today, the complication of the technological processes imposed the wide using of variable semiconductor drives, power excavators, arc welding furnaces, arc welding aggregates and electric trucks. Characteristic feature of these loads is that they affect on the electrical energy quality of the supplying network. The normal work of the electric equipments depends on electrical energy quality of the power supplying network. The mutually influence of the electrical equipment and the supplying system is defined by the term *electromagnetic compatibility*.

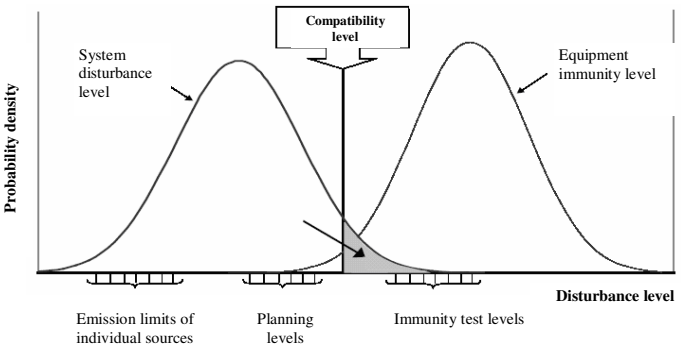

Fig. 1. Probability distribution of the disturbance level and immunity level of public low voltage power system

Fig. 1 shows probability distribution of the disturbance level and immunity level of public low voltage power system [1].

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The most probable causes for worsening electrical energy quality are given in Table I.

TABLE I
THE MOST PROBABLE CAUSES FOR WORSENING ELECTRICAL ENERGY QUALITY

Electrical energy quality indexes	**The most probable causes**
Voltage deviation	Electric supplying company
Voltage fluctuation	Users with non-linear load
Harmonics	Users with non-linear load
Voltage asymmetry in three phase systems	Users with non-linear load
Frequency deviation	Electric supplying company
Voltage sags	Electric supplying company
Pulse voltage	Electric supplying company
Temporary overvoltage	Electric supplying company

II. OPERATIVE STANDARDS AND NORMATIVE DOCUMENTS FOR ELECTRICAL ENERGY QUALITY

European parliament and Council directive 96/92/EC is accepted in 1996. This directive defines the frame of producing, transfer, distribution and supplying of electric energy to the end users. It determines rules of an organization, functioning of the united energy market. The electric energy production and wholesale market are efficiently opened for competition in most European countries, but the retail market is liberated to a different extent in each country [2].

There are two base European Union directives about electromagnetical compatibility. Directive 85/374 since July 1995 describes the electrical energy as a product, which has to posses the obligatory requiring indexes for quality. Directive 89/336 since May 1989 describes details of electromagnetical compatibility and radiation from the electrical power systems. This is the one of so - called new approach directives. It is typical for this approach to be given only in the most general and important demands along with administrative principles. The detailed technical demands are not included here, which gives an opportunity for their developing and changing without revising the directive itself.

Numbers of harmonized European standards for electromagnetical compatibility are applied to directive 89/336: EN 50065, EN 50081, EN 50082, EN 50083, EN 50091, EN 61000.

In 1999, European organization for standardization in the electromagnetic field approved European standard EN 50160, which reflects the theoretical level, level of the measuring techniques and exploitation practice in the electrical energy quality field during the past years. It includes the following basic indexes of electrical energy quality [3]: frequency

TABLE II
NORMS OF THE INDEXES TO ELECTRICAL ENERGY QUALITY FOR LOW AND MIDDLE VOLTAGE ELECTRICAL DISTRIBUTION NETWORKS ACCORDING TO EN 50160

Characterization	Low voltage networks	Middle voltage networks
Frequency	49,5-50,5 Hz (for 99,5% from 1 year period) or 47-52 Hz (whole year)	49,5-50,5 Hz (за 99,5% from 1 year period) or 47-52 Hz (whole year)
Voltage deviation	U_H ±10% (for every period from one week, 95% from the average effective voltage value per 10 min); U_H +10/-15% (for every period from 1 week, all average effective voltage values per 10 min)	U_H ±10% (for every period from one week, 95% from the average effective voltage value per 10 min); U_H +10/-15% (for every period from 1 week, all average effective voltage values per 10 min)
Fast voltage fluctuations	Less than 5% U_H; fluctuations up to 10% U_H with short duration may advent few times per day in some conditions. Flicker: $P_{lt} \leq 1$ (for 95% from period from 1 week)	Less than 4% U_H; fluctuations up to 6% U_H with short duration may advent few times per day in some conditions. Flicker: $P_{lt} \leq 1$ (for 95% from period from 1 week)
Voltage asymmetry	95% from the average effective voltage value with back sequence per 10 min must to be in limits from 0 to 2% U_H from the right sequence for every period of 1 week. In some power network areas may have values up to 3% U_H	95% from the average effective voltage value with back sequence per 10 min must to be in limits from 0 to 2% U_H from the right sequence for every period of 1 week. In some power network areas may have values up to 3% U_H
Harmonics	95% on the average effective voltage value of each harmonic formation of voltage per 10 min for every period of one week must be: $U_3 \leq 5\%$, $U_5 \leq 6\%$, $U_7 \leq 5\%$, $U_{11} \leq 3.5\%$, $U_{13} \leq 3\%$; total harmonic distortion $\leq 8\%$	95% on the average effective voltage value of each harmonic formation of voltage per 10 min for every period of one week must be: $U_3 \leq 5\%$, $U_5 \leq 6\%$, $U_7 \leq 5\%$, $U_{11} \leq 3.5\%$, $U_{13} \leq 3\%$; total harmonic distortion $\leq 8\%$
Voltage dip	Expected number may be from few scores to one thousand per one-year period.	Expected number may to be from few scores to one thousand for a year period.
Short-time interruptions	Values: from a few scores to several hundred	Values: from a few scores to several hundred
Long-time interrupting	Values: (interrupting over 3 min) annual frequency from 10 to 50, depending on area	Values: (interrupting over 3 min) annual frequency from 10 to 50, depending on area

deviation; voltage deviation; fast voltage fluctuations; voltage asymmetry; harmonics; short-time and long-time interruptions; voltage dips. The norms of electrical energy quality indexes for low and middle voltage electric distribution networks are given in Table II according to EN 50160.

The basic indexes for the electrical energy quality are legalized in Russian state standard for electrical energy quality GOST 13109-97 [4]: voltage deviation; flicker; harmonics; voltage asymmetry; frequency deviation; voltage dip; pulse voltage; momentary overvoltage.

BSS 10694-80 continuing to be operative for user's indexes electrical energy quality in Bulgaria [5]. This standard and all state standards have advisable statute in virtue of the National standardization act (become operative since May 05, 2006). Moreover it contains smaller indexes than in the European EN 50160. In this standard are legalized basic indexes for electrical energy quality: frequency deviation in normal work condition, when the system works independently; frequency fluctuation in normal work condition; voltage deviation at user's terminals; average statistic value of the voltage deviation for receivers supplied from power network for general-purpose; voltage value with back consistency; voltage value with zero consistency in networks with mono-phase electrical lamps and home receivers; harmonics. The norms of electrical energy quality, according to BSS10964-80, are shown in Table III.

In conformity with the general tendency in Bulgaria, the number of standards was accepted in the field of electromagnetic compatibility. These standards determine the electrical energy quality.

The State Energy and Water Regulatory Commission accepted and published the quality indexes of the electrical energy [6], which are identical to these in EN 50160, in June 2004.

III. ANALYSIS OF THE NORMATIVE DOCUMENTS FOR THE ELECTRICAL ENERGY QUALITY

Ensuring and supporting electrical energy quality is a basic duty of the electric supplying companies. On the other hand, the consumers have right to require and receive qualitative electrical energy. But they should to have obligations, with their consumers and their work regimes, not to worsen the indexes of electrical energy quality in electric supplying systems.

In the last years, in Bulgaria begin to pay attention on the activities for ensuring and control of the indexes of the electrical energy quality. Not only electric supplying companies are interested in this, but consumers who more often express their claims, determined by realizing their rights or by introducing modern equipments. Their functioning is connected with requirements to the quality of the electrical energy.

From the differences between EN 50160 и BSS 10694-80, we will separate special attention to these, which refer to interruptions of the electric supply.

TABLE III
NORMS FOR ELECTRICAL ENERGY QUALITY ACCORDING TO BSS 10964-80

Indexes	Standard values
1. Frequency deviation in normal regime, when system works independently.	± 0,1 Hz; Difference between the astronomic and synchronous time < 2 minutes. The system is allowed to work temporary with ± 0,2 Hz
2. Frequency fluctuations in normal regime.	Less than 0,2 Hz, bigger from the deviation in point 1. Frequency deviations at the points above are not valid for after-failure recovery power system period.
3. Voltage deviation at user's terminals except for given below: 3.1. Voltage deviation at the terminals of electric motors and start stop devices.	Not bigger than ± 5 %U_H In limits between – 5 to 10 %
4. Average statistical value of voltage fluctuation for receivers, supplied from power network for general purpose, except for given below: 4.1. Average statistical value of the voltage fluctuation: - Of the electrical lamps and radio-electronic device terminals; - Of the radio apparatus terminals, dispatcher and audio system, control-measuring devices and computers; - In the receivers with AC supply.	Not bigger than 2,5 %U_H (by unlimited frequency fluctuations) -Values smaller than given in a graph: fluctuation size in % in a function of frequency fluctuation in Hz; - Not bigger than 1,5%U_H (in not limited frequency of the fluctuations); -Not bigger than 5 %U_H (in frequency up to 25 Hz)
5. Voltage value with back consistency: - In three phase networks with electrical lamps and public receivers; - Of the terminals in each three phase symmetrical receiver.	- Voltage deviation have to be in the limits given in points 3 and 3.1; - Not bigger than 2 %U_H.
6. Voltage value with zero consistency in networks with mono-phase electrical lamps and public receivers.	Voltage deviation must be in the limits given in points 3 and 3.1;
7. Voltage harmonics of all receivers - Of the electrical lamps and public receivers terminals.	The effective value of all high harmonics must be lower than 5% from the effective value of the voltage with main frequency: - Value not bigger than this in which deviation limits are given in points 3 and 3.1, attended to the effective value of the voltage with main frequency.

The following basic indexes for interruptions of the electric supply are determined:
- Total number of the electric supply interruptions for definite period (month, three months, a year);
- Total continuity of the electrical supply interruptions for definite period (month, three months, a year);
- Average continuity of one interruption.

In the most European countries are adopted the electrical supply continuity indexes using in the practice of the USA electric supplying companies. These indexes have statistical character and they bear a proportion of the interruptions and the duration of the interruptions to the total number of connected consumers or to the number of interrupted consumers.

In the standard EN 50160 interruptions are determined as:
- Planed, for which the consumers are informed in advance from the electric supplying company;
- Accidental (non-planed), which are caused by stable or transitive failures of equipments, incorrect manipulations etc., and for which on the whole is not possible to inform consumers in advanced.

The accidental interruptions are separated to short and long-time interruptions.

In the standard EN 50160, short-time interruptions are those with duration less than 3 minutes, and long-time interruptions – with the bigger duration than 3 minutes. For the different European countries and for the electric supplying companies this limit is accepted from 1 to 5 minutes and depends on the level of automation and telecontrol in the substations and the distribution networks.

At the present stage, in Bulgaria can be accepted a limit of 10 minutes, which depends on network modernization and taking into the automate control in the future could be reduced.

The accidental interruptions indexes are following:
- System Average Interruption Frequency Index, number/year:

$$SAIFI = \frac{\text{Total number of interruptions}}{\text{Total number connected consumers}}, \quad (1)$$

- System Average Interruption Duration Index, minutes:

$$SAIDI = \frac{\text{Total duration of the interruptions}}{\text{Total number supplyed consumers}}, \quad (2)$$

- Customer Average Interruption Frequency Index, number/ year:

$$CAIFI = \frac{\text{Total number interruptions}}{\text{Total number interrupted consumers}}, \quad (3)$$

- Customer Average Interruption Duration Index, minutes:

$$CAIDI = \frac{\text{Total duration of the interruptions}}{\text{Total number interruptions}}. \quad (4)$$

For events, which have accidental character is not always possible to use simple certain indexes. Because of this in the practice of many countries there are not normative electric supply interruption indexes (accidental interruptions), observation of which is controlled or took in consideration customer demands. The definite numerical values of these indexes are used for comparison valuations and analysis.

The imperfections of BSS 10694-80 and taking into work of EN 50160, approved to be accomplished series of activities as: acquainting with the wide circle of specialists with the requirements and prescriptions in the European standard, and adopting respective methods and equipment for studying electrical energy quality indexes in a comparatively short period. Not in the last place, there would be established and estimated the real index quality parameters in our networks, to plan the concrete steps for supplying an appropriation with the requirements and norms, put in EN 50160.

IV. CONCLUSION

From the analysis and comparison of international standards and normative documents for electrical energy quality with the working standards and normative documents in Bulgaria, could be made the following conclusions:

- In the last years is observed a tendency of growing numbers and capacity of the consumers, but also these who made increasing requirement to the quality.
- Corresponding with the preparation activities for the future joining of our country to the European Union and the adopted policy for harmonization of the Bulgarian standards to these of the European Union, many European standards are accepted in our country in the field of electromagnetic compatibility. These standards determined also indexes which are direct or indirect connected with the quality of supplying electrical energy, as with voltage sags, voltage fluctuations, voltage harmonics, flicker and etc.
- The present operative electrical energy quality standard in Bulgaria BSS 10694-80 is outdated and consisted less indexes than the European standard for electrical energy quality EN 50160.
- For ensuring electrical energy quality it is necessary the indexes to be in correspondence with EN 50160 and electrical supplying indexes adopted by Resolution №P-3 since June 30, 2004 of the State Energy and Water Regulatory Commission.

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