Indices for the Power Quality Monitoring in the Romanian Power Transmission System

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***Abstract*—The power quality monitoring is one of the modern issues of the electricity market. The permanent monitoring of power quality parameters is used to verify the contractual requirements presented in regulations. There is a need for common power quality indices that are the result of synthesis, reducing or extracting from a large volume of power quality measurement data. The values for these indices have to be compared to the limits described by the national regulator. The paper presents in a synthetic manner, indices for the continuity and power quality monitoring in the Romanian Power Transmission System. Are identified the main causes of worsening power quality in some areas of the transmission system.**

***Index Terms*—power quality, transmission network, allowable limits, monitoring.**

I. INTRODUCTION

The power quality problems, which are important for the operation of all energy systems, have become in recent years an actuality and have special importance mainly due to the occurrence of consumers that are increasingly more sensitive to disturbances.

Opening of the electricity market, deregulation and restructuring of the electricity industry are changing the framework in which power quality is being addressed [1], [2].

Deregulation introduced new players and intermediaries in the electricity market (wholesale electricity brokers, private producers, retailers, etc.). Contracts between those parties may include levels of power quality to be met. Moreover, regulators may also impose penalties in case of nonobservance of the basic quality objectives set for the clients in general.

Network operators now have to deal with a number of outside players, each one having their own and sometimes diverging interests. This situation increases the possibilities of disagreement between the parties whose specific responsibilities with respect to quality can be difficult to determine. In addition to its traditional technical basis, the quality of supply now raises commercial and legal stakes.

This situation has made the current stage a constant concern for power quality, planning and monitoring of quality indices, standardization of disturbing emissions and the establishment of compatibility levels both internationally and in Romania [3]-[9].

System indices are used by the network operator to assess the performance of a whole system.

They can be used to compare year-to-year performance, where the effect of weather variations should also be considered. The results of such a performance assessment or comparison can be used as a basis for improvements in the system.

The indices are not a benchmark by which to judge different networks against each other but can be used to identify typical levels of disturbances for various types of network and for ongoing monitoring of any one network.

For steady state disturbances, such as harmonics, flicker and unbalance, two categories of indices can be distinguished given their use [10]:

- Indices for planning purposes. These are used primarily by the system operator to assess internal quality objectives (planning levels) in setting emission limits for large disturbing loads and evaluating the impact of all disturbing loads on the supply system. These could be detailed indices and be comparable to those used for contractual emission purposes (more than one index may be needed here for controlling the impact of higher emissions allowed for short periods of time);
- Indices for voltage characteristics, for characterizing and reporting system performance. These are used to assess external quality objectives or limits within which any customer can expect the voltage characteristics to remain under normal operating conditions. These should be simple indices and could be used for reporting performance to management, contracting to power quality performance in general and for reporting performance at a regulatory level.

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The monitoring of the point of delimitation and of the disturbances observance of the assigned limits is significant to provide appropriate operation.

II. POWER QUALITY INDICES IN THE ROMANIAN TRANSMISSION SYSTEM

The power quality is a notion generally including the following problems:

- the quality of the supply (determined by the evaluation of the continuity of electricity supply);
- the quality of the voltage (determined by the evaluation of the deviations from the sin form of the electrical amounts curves, of the deviation from the balance of the three phases quantities, of the deviations from the nominal frequency and from the nominal voltage);
- the commercial quality (determined by the evolution of relations between participants in the electricity market).

The electricity supply continuity represent the degree to which the user can rely on its availability at all times.

The indicators used for characterizing the power supply continuity are: Energy Not Supplied and Average Interruption Time.

Energy Not Supplied (ENS) is defined as the energy not supplied due to interruptions with network losses excluded:

$$ENS = \sum_{i=1}^{n} \left(P_i \cdot \frac{D_i}{60} \right) \quad [MWh / year] \tag{1}$$

where:

Pi – interrupted power (MW) upon discontinuation i (measured before the last power outage);

Di – the duration (minutes) of consumer withdrawal to discontinuation i (from the moment of voltage disappearance until restart);

n – total number of interruptions.

Average Interruption Time (AIT) represents the average period of time, in minutes, during which the power supply has been interrupted:

$$AIT = 8760 \cdot 60 \cdot \frac{ENS}{AD} \quad [minutes/year] \tag{2}$$

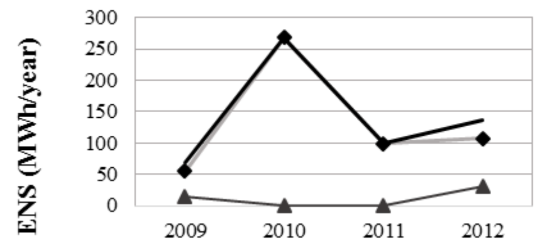
where:

AD – the annual demand of electricity consumption (without losses in the electricity transmission and distribution network), including export (MWh).

Figure 1 shows the ENS index and Figure 2 shows the AIT index for the period: 2009-2012. The Transmission System Operator (TSO) has to ensure the continuity of the power supply in accordance with the performance level set by the standard [11], being obliged to make every effort to reduce the duration of interruptions and schedule them, as far as possible, to the dates and times that will affect users the least [12].

The frequency permanently reflects the balance between load and generation. The deviations affect system security by activating part of the primary reserve intended to cover large generation or load outages, limiting its use over longer time periods. Significant deviations can cause all the primary reserves to be activated without a critical incident having occurred. The main consequences of this are additional cost, leading to increased prices for end-users.

Furthermore, on the generation side, system frequency deviations often require plant equipment to operate inefficiently and beyond standard design specifications. This not only increases environmental emissions but eventually also leads to greater operational costs.



	2009	2010	2011	2012
due to the users	14	0	1	30
due to TSO	55	268	99	107
Total	69	268	100	137

Figure 1. The Energy Not Supplied (ENS) per year.
(data processed from website: http://www.transelectrica.ro)

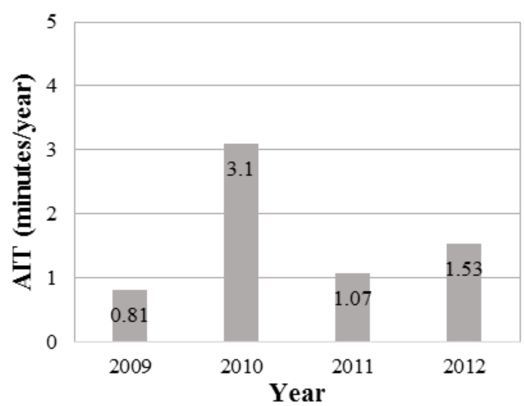


Figure 2. The Average Interruption Time (AIT) per year.
(data processed from website: http://www.transelectrica.ro)

In normal operation, the frequency may vary around the nominal value, due to the virtually continuous changes of the electrical system load and of the adjustments that are carried out to cover the load curve. Frequency control is basically conducted to the level of the entire energy system and cannot be influenced by local actions. The normal variation range of the operating frequency is:

- the first interval: 49.90-50.10 Hz during 90 % of the week;
- the second interval: 49.75-50.25 Hz during 95 % of the week;
- the third interval: 49.50 – 50.50 Hz during 99.5 % of the year;

- the fourth interval: 47.00-52.00 Hz during 100 % of the year.

Frequency monitoring is performed continuously by recording its values (to 2 seconds, with an accuracy of 1 MHz), which is a basis for determining percentages of the week, month and year in which the frequency was within the normal range.

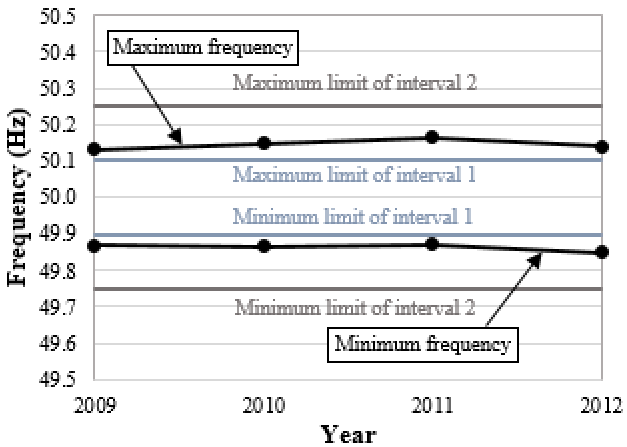


Figure 3. Frequency variation.
(data processed from website: http://www.transelectrica.ro)

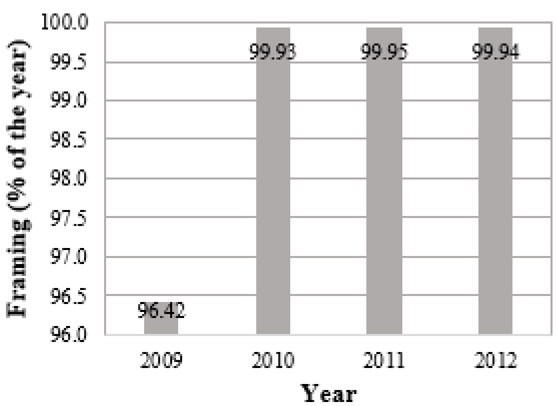


Figure 4. Framing duration of frequency within the normal range of variation: (49.90-50.10) Hz.
(data processed from website: http://www.transelectrica.ro)

Figure 3 shows the minimum and maximum limits of frequency variation in the 2009-2012 timeframe. There are excesses in the first interval of frequency variation but no excesses in the second interval frequency variation: 49.75-50.25 Hz. The minimum values of the normal range of frequency variation (49.90-50.10 Hz) are shown in Figure 4.

Historically, dispatchers have manually adjusted generation output to closely follow demand. But today the liberalized market model has made hourly step generation scheduling common practice. This appears to be the main cause of the frequency deviations – a short time mismatch between load and generation occurs because the generation schedule follows the market rules rather than the real-time demand.

For example, current market rules require load planners to order generation output in one hour blocks, which generators supply as closely as possible to the schedule in order to control costs. But as the load increases continuously, an imbalance often occurs with the stepwise increase in generation, causing the frequency deviation. The same phenomenon occurs when the load decreases.

Voltage characteristics are limits or values within which any user can expect the voltage characteristics to remain under normal operating conditions.

The normal ranges of variation of the voltage operation are:

- for the 750 kV network, the admissible voltage range is: 735-765 kV;
- for the 400 kV network, the admissible voltage range is: 380-420 kV;
- for the 220 kV network, the admissible voltage range is: 198-242 kV;
- for the 110 kV network, the admissible voltage range is: 99-121 kV.

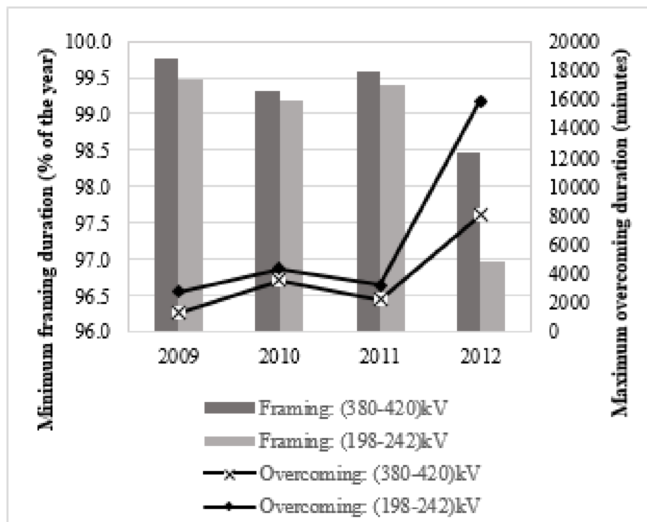


Figure 5. Overcoming the admissible voltage range on voltage levels (220 kV si 400 kV).
(data processed from website: http://www.transelectrica.ro)

Figure 5 shows the maximum values for the overcoming duration of the admissible voltage range (minutes) and the minimum values of the framing duration in the admissible voltage range (% of the year).

The quality of the voltage curves is determined by monitoring: the harmonic distortion factor (with a normal value of maximum 3%), the dominant harmonics value of rank 3 and rank 5 (with a normal value of maximum 2%) and the unbalance factor (with a normal value of maximum 1%). The electrical flow values are also registered on the fundamental waveform and the harmonics.

Table I shows the maximum values for the overcoming duration of the normal limits for the harmonic distortion factor and Table II shows the maximum values for the overcoming duration of the normal limits for the negative sequence unbalance factor.

Harmonic distortion levels have increased rapidly in electric power systems in recent years due primarily to the increasingly widespread application of non-linear semi-conductor devices, which produce the majority of harmonic distortion.

TABLE I. OVERCOMINGS OF THE HARMONIC DISTORTION FACTOR $\leq$ 3% ON A PERIOD OF TIME $\geq 95\%$

2009	2010	2011	2012
0	546 hours (North Roman station)	16 hours (Alba Iulia station)	0

Source: Transelectrica

TABLE II. OVERCOMINGS OF THE NEGATIVE SEQUENCE UNBALANCE FACTOR $\leq$ 1% ON A PERIOD OF TIME $\geq 95\%$

2009	2010	2011	2012
23 hours (Brasov station)	51 hours (Iaz station)	118 hours (Gheorgheni station)	821 hours (Otelarie station)

Source: Transelectrica

Table III shows some of the indices of commercial quality with reference to the power quality in the power transmission system.

TABLE III. THE COMMERCIAL QUALITY INDICES

The commercial quality indices	2009	2010	2011	2012
Number of requests for contracting of transmission service	7	8	70	30
The average time for issuing the contract offer for the transport service	15 day	15 day	11 day	3-4 day
Number of complaints on the voltage level	0	0	0	0
The average time to resolve complaints on the the voltage level	0	0	0	0
Number of complaints on the voltage level that could not be solved	0	0	0	0
Number of complaints on the quality of the voltage curve	1	9	1	0
The average time to resolve complaints about the quality of the voltage curve	-	5 day	5 day	0
Number of complaints on the quality of the voltage curve that could not be solved	1	0	0	0

Source: Transelectrica

Some representative values of quality indices were presented, which are extracted from a large volume of power quality measurement data in order to allow comparison of performance with time.

III. CONCLUSIONS

The data presented highlights the existence of power transmission system nodes where the power quality indicators are outside the admitted values or are close to the limit values.

Changes made in the functioning of the electricity market, the permanent changes of producers and users of the power transmission networks, and the implementation of more stringent standards regarding the safety in the electricity supply, are arguments for continuous monitoring of the indicators of power quality.

The highly complex process of power quality monitoring allows the detection of interference sources, identifying improvement solutions, applying these solutions and time tracking of the results.

The increase in recent years of the power in the installed power plants which use the renewable energy resources (particularly wind power), the disruptive users directly connected to the transmission network, the operation of network areas with voltages that exceed permissible limits in low load hours and limited control of the reactive power circulation, are the main causes of the power quality worsening in some areas of the power transmission system.

If from the point of view of electricity supply continuity, the responsibility belongs in to greatest extent of the energy system as a whole, responsibility for the voltage quality belongs to the users of the power transmission networks.

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