Power Quality Control on The Romanian Energy Market

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Abstract: - Power quality is one of the important objectives of the transmission and distribution network. The paper presents several aspects of the PQ monitoring interface between the transmission network and the distribution network. 110 kV voltage level, in view of the current situation and perspective is considered. The system used for the power quality parameters monitoring is presented. As a study case it is used a representative substation within the Romanian Power System (Iernut substation).

Key-Words: - Power Quality, Control, Energy Market

1 Introduction

The quality of a product or service represents an amount of features and essential ones that define it and are able to meet the needs expressed or potential of the user. At the same time, the concept of quality must summarize those characteristics that, in relation to the specific product, they weights and distinct meanings. In any area of activity, the quality is not a static concept; its content varies over time due to technological development and evolution of social life. Although the requirements of users are increasingly large, the product delivered will not ever be perfect and therefore it should be made permanent improvement in quality.

Power quality (PQ) is a complex and controversial issue, whose importance in proved by role that the electric energy has within the contemporary society. In 1985 the European Commission Directive 85/374 EC, established that the electricity is a “product”, requiring clear definition of features. A perfect electricity supply is characterized by the fact that it is always available, assuring the voltage and frequency values within the admissible limits and a perfect sinusoidal voltage without “noise”.

This paper presents several aspects of the PQ monitoring interface between the transmission network (TNE) and the distribution network (DNE), 110 kV voltage level, in view of the current situation and perspective. The permanent or temporary PQ monitoring is effectuated in the common point of connection (CPC), where the system operator/provider has the obligation to provide power to the quality contract, and the supplier/consumer is required to limit the perturbations within the National Power System (NPS) below the quota.

The knowledge of the situation in the TNE buses and sources of disturbance requires a complex program of measurements, using acquisition and processing equipment dedicated to the private TNE-DNE interface.

Incidents that occur in the TNE, defective insulation, conturination and puncturing due over-voltages, causing large variations in voltage, goals, interruption of short and long term, leading to disturbance in power to consumers. Quality of electricity in DNE is affected both by voltage values outside the admissible range and the distortion of the voltage and power curves. In DNE power quality monitoring involves tracking buses within the network and the joint connecting users and setting for each user connected level disturbance generated.

2 Power Quality Indicators

Power quality is one of the important objectives of the transmission and distribution network. In this sense, lately, within CIGRE and CIRED, as well as research teams in Romania, there is an intense interest in defining a clear set of indices to assess the power quality, setting limits accepted by employers, their development of methodology for allocation of the disturbance, setting a strategy for detecting perturbed buses, disturbance sources, the design of specific solutions to improve the power quality and the establishment of damage that may occur in offense against the limits of quality indices.

Depending on the place where the disturbances occur, indices are divided into the main PQ indices, which are based on particular activities in the field of production, transmission and distribution of electricity. There are also established the secondary indices determined primarily by the operation of the disturbing consumers.
Their monitoring is effectuated in the common coupling point, representing a bus within the supply network, not specific to a particular consumer or several consumers could be connected to it.

The PQ primary indices are the followings one:
- the frequency of supply voltages (controlled by the power adjustment P-f);
- voltage magnitude on the supply buses (controlled by adjusting Q-U and adjustment and electrical transformers, autotransformers within the existing network);
- temporary and transient over-voltages (limited and controlled by over-voltages protection system);
- voltage gaps (limited by the protection relay);
- interruptions (short and long term) indices of quality service (Power Supply), as set by the supplier together with the consumer, according to its requirements.

The PQ secondary indices are the followings one:
- harmonics and inter-harmonics (nonsinusoidal schemes);
- rapid fluctuations of voltage;
- slow voltage fluctuations (flicker effect);
- nonsymmetrical wave forms.

3 Power Quality Control
The system used for power control simulations is composed of the equipment and software presented in Table 1.

Analyzer PQ type 7650 ION, manufactured by Power Measurement, is a three phase measuring device, having advanced power quality analysis features, metering and several communication ports.

The analyzer is configured by the manufacturer to perform all the functions for basic electricity monitoring, providing increased monitoring facilities, analysis and control of the PQ within the three-phase power networks. The analyzer has a modular structure and an open design for the development of function utilities. It adapts itself to virtually any specific application, provides flexibility and computing power required for a full monitoring process. In general it is used as a fixed assembly. The ION 7650 analyzer has multiple communication ports: Ethernet, RS-232, RS-485, port optical front. The link between equipment and personal computer can be a RS-485, using a modem connected sites on leased telephone lines or dedicated, fiber optic and/or radio link.

The equipment can be integrated into SCADA system or network equipment for monitoring energy management thereof, is available as a large variety of communication protocols.

### Table 1. Equipment and software used within the analyze

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment</th>
<th>Produced by</th>
<th>Type</th>
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<tbody>
<tr>
<td>1</td>
<td>Analyzer CEE</td>
<td>Power Measurement Canada</td>
<td>7650 ION™</td>
</tr>
<tr>
<td>2</td>
<td>Modem PSTN</td>
<td>US Robotics</td>
<td>Courier 56K Bussines</td>
</tr>
<tr>
<td>3</td>
<td>Data server</td>
<td>Hewlet Packard</td>
<td>Processor Pentium 4</td>
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<td>4</td>
<td>Software licenses</td>
<td>Power Measurement Canada</td>
<td>ION Enterprise 5.5</td>
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PSTN modem is a U.S. Robotics Courier 56K Business dial-up telephone line switched on. 19.200 baud/s speed of communication is selected. This type of modem settings own store in case of accidental voltage power.
The data server is a personal computer HP Intel P4, 3GHz. Due to the high volume of data recorded, for processing in their various forms of statistical, capacity storage 1024MB RAM, 120GB HDD Sata is used. Auxiliary power is provided by UPS. The server database has an LCD monitor 19” and also a color multifunctional A4 printing system. The analyzers communication with the system is effectuated connecting the server to external modem outlined above, the analog telephone circuit.

Operating system is Microsoft Windows NT. The analyzer PQ is compatible with software for monitoring ION Enterprise 5.5 company Power Measurement, installed on this server. Upon request to take data transmitted by light and automatically stored in a dedicated database. The system allows external storage of data transmitted through the built-RW and DVD while securing them.

The entire database stored on the server database can be accessed on demand for generating own programs for data processing primary data listing, graphs, reports.

As Figure 1 shows the system architecture, the simplified version that includes only one location from the field and the central point. At the measurement point, within a specific substation, the equipment is installed in a measuring protection cell or room protection. As seen in figure, analyzers have been installed in the assembly fixed on the closet Metering cell properly monitored.

At the central point of the Transmission Branch Sibiu, from the Romanian Power Grid Company, was installed a database server and dedicated application office SSCPA.

4 Experimental Results
Experimental results from each point of measurement will be presented:

- schedule normal operation of the substation for conversion of electricity;
- location point for measuring the delimitation of the area dotted element network;
- continuity in the supply point of measurement;
- maintain the analyzer PQ mounted at the point of measurement;
- the graphical representation of weekly analysis of the PQ indices;
- representation of numerical analysis for the annual PQ indices;
- nonframing indices analysis within the limits allowed by their reflection in the curves of load, active and reactive.

The active and reactive energy is flowing in both directions through the measurement point being recorded by the PQ analyzer, but also by the metering system. This meter has been installed by the electric energy remote-metering within the wholesale market, providing a superior accuracy measurement PQ analyzer. The data recorded by the remote-metering of the electric energy within the wholesale market have been used in the following analysis. It has been developed a software dedicated for this analysis and it was represented the monthly active and reactive power evolution. Excel application is used to represent load curves (Figure 2), containing an area that allows the selection of alphanumeric interval analyzed. It also contains a graphical area plotting the time evolution of energy through the network. The user is requested to select the month from the list of options, which will be represented in the chart at the top, power flow evolution. A set of buttons is available for detailed analyses that allow the change of the interest area (green rectangle in the chart above), representing it within the chart at the bottom. This is the effect of the “magnifying glass” that allows the simultaneous observation of the development of both monthly and the area of interest.
Figure 3. Iernut’s substation oneline scheme

Figure 4. 2006 year summary PQ indices for the case of the 110kV autotransformer from the Iernut substation

Color code in these graphs is as follows: active power flows within 110kV network – navy, active power flows received from 110kV network – red, reactive power flows received from 110kV network – blue, reactive power flows to 110kV network – pink.
Starting from the in-depth analyses of the recorded events, the effective causes that are leading to power quality indices mitigation have to be determined. Also, this analysis has to be correlated with the operation data from the substations and electric networks including the ones archived in SCADA systems.

Analysis of nonframing causes indices within the PQ limits has been archived only at the measuring point within the substation Iernut 400/220/110kV (Figure 3), the Romanian Power Grid Company Transelectrica S.A.– Sibiu Transmission Branch.

Substation 400/220/110kV Iernut is an important bus within the National Power System and the area north and central Transylvania in view of its multiple functions:

- the 400kV substation ensures the power transit from surplus areas of the NPS, to Transylvania lacking areas;
- the 220kV substation ensures the power produced within the Iernut substation (there are installed generating groups of 125MVA-G1, G2-125MVA, G5 and G6-250MVA-250MVA) to be transmitted within the National Power System;
- the 110kV substation ensures the power produced within the Iernut substation (generating groups G3 and G4 125MVA-125MVA) to be transmitted and also, power consumption in their own area.

Within Iernut substation, the measurements have been effectuated during 25.02-30.12.2006. During this interval, according to Figure 4, it can be observed that the voltage magnitude supply voltage is not within the imposed limits on all phases. Detailed analysis of the nonframing causes requires its correlation with information related to the continuity in operation, the amount and purpose of active and reactive power flows, power factor, the measuring transformers loading degree, voltage control. According to Figure 5, the reactive energy has an important reactive component, independent of the sense of the active energy flows, negatively impacting the PQ.

5 Conclusions

For the moment, several PQ issues are not sufficiently well established, defined and unanimously accepted within the international research environment, within the CIGRE, CIRED. Taking into consideration these facts, within the research groups in our country, there is an intense concern for defining a set of notions, of basic indices which would allow to:

- assess the power quality;
- set limits allowed by their employers;
- develop methodologies for disturbance allocation;
- establish a strategy for detecting perturbed buses;
- design specific solutions for improving power quality;
- establish the damages occurring taking into consideration the deviation of the limits of the PQ indices.

The PQ monitoring indices, performed with portable or fixed dedicated analyzers, allow the normal limits to be respected and create the database required for accomplishing and correction of the standards. Since the disturbances are random, it has to be performed a statistical PQ analysis, with appropriate mathematical models, using tracking equipment improved and advanced digital techniques.

The feasibility study conducted for this system stresses that its implementation will ensure rapid access to information needed all the responsible factors. It is necessary to establish concrete measures designed for reducing electromagnetic disturbances and to diminish the effects of:

- further reduction of losses in power transmission networks and consumers to fund directly from TNE, mainly by reducing the level of harmonics, voltage unbalances and current in electrical transmission networks;
- proper functioning of equipment whose functions and performance are affected by the presence of harmonics and voltage unbalances and / or current,
• reducing the operating expenses for the operations of preventive or corrective maintenance of equipment that are affected by disturbances that damage the power quality;
• increasing the life of the equipment within the TNE and consumers to fund directly from TNE, mainly by reducing the level of temporary over-voltages and current and voltage harmonics on the network (which require insulation and lead to an additional warming as a result of losses caused the currents harmonics);
• increasing the efficiency of the generating units, processing units, lines and electric motors (including the ones for the ancillary services of the substations);
• reducing the costs of power generation / power transmission and, in general, reducing the investment within the National Power System, that would result from the need of over sizing the network elements to cover the effects of electromagnetic disturbance with offenses against limits;
• reducing the reactive power flows and reduce reactive power exchanges between TNE and DNE;
• reducing the damages to consumers caused by voltage (the violation of the nominal value, voltage gaps and short term interruptions). Particular attention should be paid to large disturbing consumers (metallurgy, mining, aluminum) connected directly to TNE. Disturbance introduced by these consumers, spreads throughout the network of high and very high voltage levels, affecting the quality of long-distance to the point of connection of the consumer. Computing the disturbance allocation level for these consumers (harmonics, flicker), the monitoring in the delimiting point and checking the disturbances to be situated between the corresponding limits, have an important role in reducing active power losses in TNE, limiting the disturbances in the network and the level of quality assurance for all consumers in the system. Only full-time monitoring and statistical processing of the results can provide the information necessary to adopt decisions on recognizing the limits assigned to the consumer.

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