Remote Monitoring of the Electrical Power Quality

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Abstract—**This paper considers electrical power as a product which should cover certain quality norms. The voltage characteristics limits according to the standard EN 50160 are accepted as quality norms. The article discusses the approaches to the monitoring and inspection of the electrical power quality. On that aim, two configurations for remote control of the power quality analysers by a computer were tested. The practical realisation could be applied in any case when Internet access or Mobile Network coverage are available.**

Keywords-power quality, remote monitoring, computer control, quality analysis, electrical energy

I. INTRODUCTION

Electricity is universal in terms of opportunities for generation from various energy-carriers and optimal in terms of transmission and transformation into other forms of energy – thermal, mechanical, light, electromagnetic, etc. This universality implies the need of strict monitoring of parameters of the electricity at all levels of the electricity power system: generation, transmission, distribution and consumption. On one hand the conformity with the quality parameters is necessary to increase the production efficiency and to reduce the losses in the transmission on different levels, according to the requirements of the liberalized market. On the other hand the diversity of consumers leads to: strong influence of the load over the quality parameters; the necessity to take into account the load specifics and to take on time decisions for adequate corrections in this ongoing process.

Electrical energy as a product should satisfy the proper quality requirements. Often the national regulators leave the power quality supervising only to the final suppliers. Then appear a mixture between the quality of the product and the quality of the service.

The quality of the electricity (the product) includes all the characteristics of the voltage supplied by the operator's network to the final customer and parameters derived to these characteristics

The quality of the service is a combination of characteristics of the service provided by the network operators, public service providers and final suppliers.

The object of the present article is an aspect of the product quality conformity assurance.

Practically, the permanent increasing of the nonlinear consumption leads to growing the influence of the consumers over the quality of electricity and effects to its deterioration. As a result, the level of the quality of the electrical energy is a compromise between user and supplier.

However, the electrical energy is a specific product and the quality assurance of the electricity has some specifics:

- Generation, transportation and supply are in practice at the time of consumption. The storage abilities of the electricity in any significant quantities, is limited, so it is consumed at the instant it is generated. Measurement and evaluation of the quality of the supplied power has to be made at the time of its consumption. The measurement of electrical power quality is complex, since the sensitive electrical equipment of the user is also a source of disturbances.
- Generation systems, transportation and distribution networks must always be in working order and able to meet the current demands of power.
- Unlike other products, the quality of electric power depends on the mutual influence of the consumers themselves.
- The voltage quality differs from point to point of the electrical power and supply systems.
- The quality of the electricity can only be provided simultaneously by manufacturers, suppliers, providers and users of electrical energy. Thus, maintaining satisfactory quality is a joint responsibility of the producer, supplier and the user. The influence abilities and responsibilities are in the same order.

II. POWER QUALITY NORMS AND MEASUREMENT METHODS

The main European document treating the norms of the energy quality is the standard EN 50160 "Voltage characteristics of electricity supplied by public distribution networks". It define the voltage parameters of electrical energy at "network user's supply terminals in public low voltage (LV) and medium voltage (MV) electricity distribution networks under normal operating conditions" [1]. These parameters vary during the time in random manner and are affected by practically unpredictable phenomena even during normal operation of supply network. The electrical power quality conformity assessment is the confirmation of the correspondence of these variable parameters to the specified norms. Actually, the national energy regulators take the care about the recognition of the standard norms as national norms [2].

To uniform the methods implemented into the different measuring instruments and to reach reliable, repeatable and comparable results is the aim of standards from series 61000 Electromagnetic compatibility (EMC). Such standards are:

EN 61000-4-30 „Testing and measurement techniques - Power quality measurement methods"

EN 61000-4-15/A1 „Testing and measurement techniques - Flickermeter - Functional and design specifications"

EN 61000-4-7 „Testing and measurement techniques - General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto".

The norms and methods are two of the basic components of the conformity assessment as both: internal or independent quality inspection [3].

III. ELECTRICAL POWER QUALITY MONITORING AND INSPECTION APPROACHES

Two main approaches to the monitoring and inspection of the electrical power quality, based on the kind of used equipment and information structures applied, can be defined: Systematic and Operational [3].

Systematic approach is implemented through steady-mounted hardware with known transmission medium. It is used to build complete systems for electrical power quality monitoring and control. Usually it has hierarchical structure with several hardware and software levels.

Its pros can be formulated as follows:

- Gives clear idea about the relation of the malfunction with the topology of the system and the source of the problem;
- Provides full details of recorded events for long (months, years) period;
- Virtually unlimited resource of memory is available.

Its cons are:

- Expensive;
- The quality of performance and results directly depend on the equipment and architecture;
- Requires full time service by qualified personnel;
- Clumsy in respect to points of connection;
- Requires precision engineering, and long-term investment planning

This approach normally is applied in built systems with known topology and scope of consumption.

The Operational approach is implemented by portable equipment and uses mainly local software with a high degree of integration and adaptation to the measurement equipment. It has universal and rapid way of attachment to the object and is suitable for occasional inspection.

The pros are:

- High flexibility in terms of connecting to the object;
- Quick installation;
- Easy interpretation of results;
- Quick release of documents

Cons can be specified as:

- Hard synchronization when there is a necessity of simultaneous measurements at different points;
- Limited amount of memory;
- Limited time coverage of a single inspection.

The Operational approach is applied mainly in response to signals, in case of failures and for technical diagnostics.

Both approaches can be used as addition to each other. They are not in a conflict and can be combined and complement one another. When there is necessity, as a first should be used the Operational approach – to establish a proper system structure and than, according the necessity – the system approach – to find all causes for malfunctions and to monitor the system.

IV. DISTANCE MONITORING

Distance monitoring is a kind of Operational approach which takes some advantages of the Systematic approach. To monitor the quality parameters is necessary to measure them for an extended period of time. Throughout that period the data can be remotely collected and analyzed.

Instruments used should: cover all necessary parameters of the electricity; maintain the data for a long period of time (week, month, year, etc.) and analyze the data collected in accordance with accepted quality norms. Obviously, the specialized equipment, located on different (and sometimes remote) locations, need a connection to the center location where all data are collected, processed and analyzed. The advantages of the Internet Technologies provide many opportunities for remote monitoring and control.

Nowadays the market offers a wide variety of devices to control the parameters of electrical energy. Conditionally they can be divided into mobile and stationary ones.

Stationary devices are located in certain places of the distribution network after an adequate analysis in order to diagnose in time problems on the network and thus eliminate them. They are used for Systematic quality control and their location is previously known.

Mobile devices could be connected to the network at various locations when there are signals from customers or when there are problems with the electrical power quality, which previously were not known. They are used for Operational quality control and their connection to the control center should be done with additional devices and software.

There are power analyzers with different communication capabilities - from ones without any possibility to link to a computer to such with built-in communication modules for USB, Bluetooth, Ethernet and RS 232. Of course with addition of new communication abilities grows the price of the unit too. The most popular units have serial interface (USB or RS) [4]. They are the best from point of view of price/performance ratio. They have broad functionality, can be connected to a computer and configured through it. The data collected can be downloaded and analyzed by powerful software running on the computer. With relatively small amount of additional devices and software they may be connected via Internet to the computer placed into a control center.

There are two options to access the measured or stored values using power quality analyzer:

- The first option is a device to be installed for a long period of time (e.g. 1 month) and then to be disconnected from the electricity network. In this case the data collected during the measurement period can be downloaded through the local interface. In that case, the device needs a large amount of static memory.

- The second option is remote connection of the device to a control computer located in a control center. The accumulated data can be downloaded periodically and/or remote measurements can be done. The computer's memory, in this case, keeps the largest part of the information so the device does not need a great amount of memory.

Different ways of communication may include:

- Multi-point reading through GSM - made with two GSM communication modules. One connected to the power quality analyzer and the other installed on the computer.
- Multi-point reading through GPRS – the power quality analyzer is connected to a control computer through GPRS. This is a good solution when a company has existing servers.
- Multi-point reading through Ethernet - communication is done through Ethernet port that allows data collection from multiple devices via INTERNET.

V. HARDWARE AND SOFTWARE USED

The equipment used for remote control includes: power quality analyzer CA8334, GSM modem WirelessCOM/G10, laptop and desktop computer for power quality analyzer control. The software used is DataView – commercial software for controlling the power quality analyzers, HW_VSP – driver software, which adds a virtual COM port to the computer and allows data exchange between the virtual COM port and Internet and TeamViewer – free software to access and control a remote computer.

The power quality analyser CA8334 is a complex instrument for measuring of all necessary parameters of electrical energy. It can be connected to the electricity supply network (investigated object), using 4 schemes - single phase, dual phase, three-phase (three-wire) and three-phase (four-wire). "Multitask" technology allows to the analyser simultaneous recording, monitoring and analysing multiple parameters.

The four connecting schemes cover practically all methods of coupling, making that power quality analyser applicable to all types of power systems. The possibility of connecting different types of current sensors, as well as the connection of the current transformer with primary side 5A and set of the coefficient of transformation enables connection to various loads with different power and consumption. The device has RS 232 port for communication with computer and can be configured and controlled through it.

The device can operate as multitasking measurement system, which allows to it simultaneously to perform all functions needed for measurement of various parameters, detection, continuous recording and showing on the display without restrictions. It allows great flexibility in the choice of sensors: from a few hundred milliamps (MN93A) to several kilo amps (AmpFLEX).

Basic measurements and calculations that can be made with CA8334 are:

- Measuring the effective value of AC voltage (RMS AC voltage) to 600 V (phase-neutral) and 690 V (phase-phase), the voltage between phase and mass can not exceed 600 V;
- Measuring the effective value of alternating current (RMS AC current) up to 6500 A;
- Measuring the frequency of the network from 40 Hz to 69 Hz;
- Calculation of peak factor for current and voltage;
- Calculation of the K factor for current (for transformers);
- Measuring of phase shift of harmonics up to 50^{th} order and their levels in relation to the basic harmonic of voltage, current or power;
- Calculating the total level of harmonic distortion;

- Measurement of active, reactive and apparent power phase and total;
- Calculation of power factor, displacement factor and tangence;
- Calculation of total energy generated and consumed starting from the time chosen by the operator;
- Track average of each parameter over a period of 1 second to 15 minutes. Save the values for a period limited only by the memory of the instrument;
- Saving and recording the time, disturbances: over-voltages, swells, sags and interruptions of powers, harmonic thresholds, etc.

WirelessCOM/G10 is an intelligent pre-programmed GSM modem for making GPRS/CSD connections. Configuration (or pre-programming) of the modem can be done using any terminal software. Once configured, it can be connected physically to the serial port of remote device (in the case C.A 8334) and it is possible to access the device remotely through GPRS/CSD. On necessity to change the configuration parameters of WirelessCom, it can be done remotely using GPRS/CSD/SMS.

Figure 1. Configuration for communication via Ethernet

In the first configuration shown in Fig. 1 the power quality analyzer is connected to the laptop via RS 232 cable. On the laptop are installed DataView and TeamViewer. The laptop is connected to the Internet through a local Internet Service Provider (ISP). On the computer in the control room a TeamViewer is installed and the computer is connected to the Internet. Remote communication is realized by the TeamViewer sessions. During these sessions DataView can be started remotely on the laptop.

Figure 2. Configuration for communication via GPRS

In the second configuration (Fig.2) the power quality analyzer is connected to a GSM modem by RS 232 cable. The control computer is running HW_VSP driver. GSM modem operates in master mode and automatically connects via GPRS to a server stored in its configuration. HW_VSP driver is configured in server mode and communicates with a GSM modem. At the start of the DataView on the control computer the system operates in way such as the computer is connected directly to the power quality analyzer via RS 232 cable.

VI. SYSTEM, WORKING VIA GPRS

First step from the building up the measurement system is to connect all the hardware parts:

CA8334 has to be connected depending on the chosen connection schemas. The main supply charging cable of the analyzer also has to be connected to the electricity network (230V, 50Hz). The last step is to connect the data cable to the analyzer.

Now the WirelessCOM/G10 modem has to be prepared for programming by installing the SIM card into the modem, connecting the antenna and the supply cable of the modem.

Programming the modem with HW_VSP – driver software by the computer is able after connecting the modem via RS232 cable (Fig. 3).

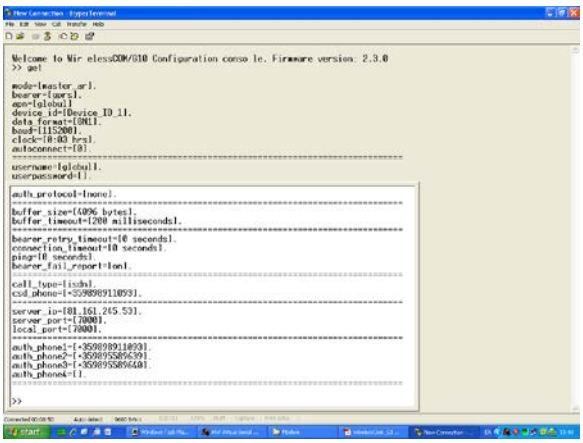

Figure 3. Programming the modem

After finishing the programming of the modem the CA8334 is ready to be connected via the data cable to the WirelessCOM/G10 modem. Switching on the analyzer and the modem ends the process of the hardware preparation of the system.

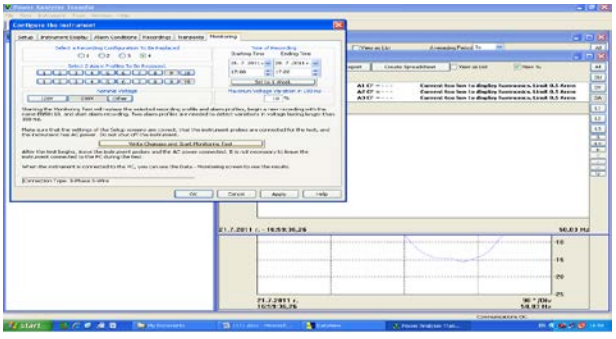

Figure 4. Remote configuration of the analyzer

The fully operational status of the system could be proved with distance configuration of the energy analyzer (Fig. 4) and data transfer (Fig. 5 and Fig. 6).

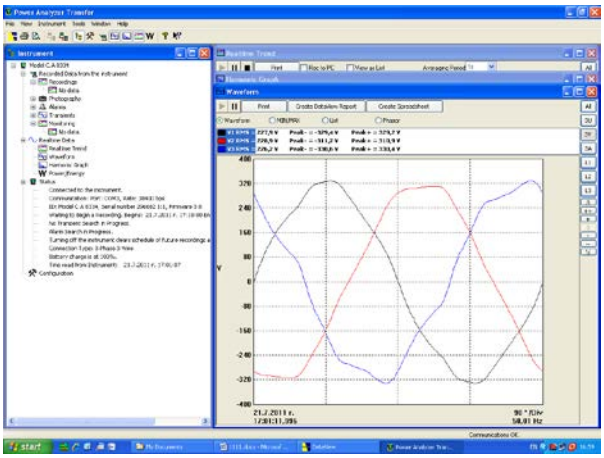

Figure 5. Remote real time data transfer

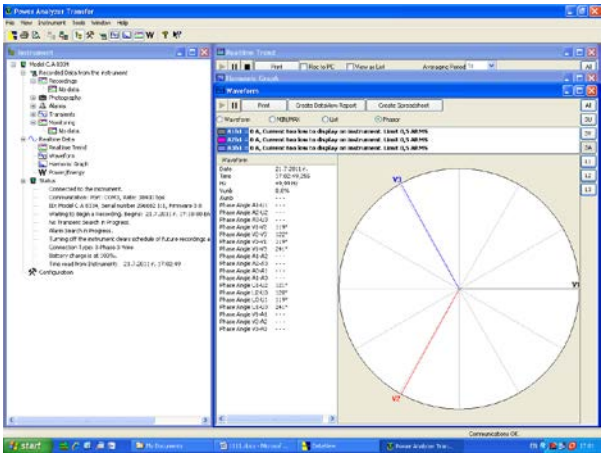

Figure 6. Remote real time data transfer

These screens could be observed on the monitor of the operator's computer which can be placed on every point of the world. The only one condition to connect to the CA8334 is to be connected to Internet.

The operator feels like computer is physically connected with the CA8334 via data cable. He can browse trough the different submenus of the software DataView and to analyze the different measurement data, such as voltage curves, phasors, harmonic graphs and etc.

It is possible to download saved on the CA8334's memory measurement data as it is shown on the Fig.7

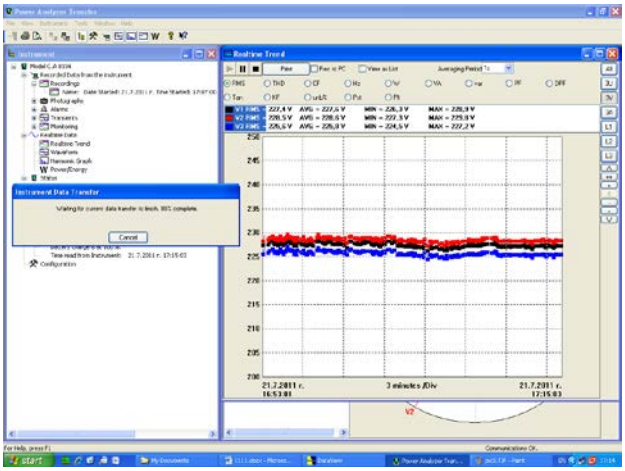

Figure 7. Remote download of saved measurement data

VII. CONCLUSION

The article considers the electrical power as a product, which have to meet the requirements of the quality norms according to the standard EN 50160. Two main approaches for power quality monitoring and inspection are discussed. The reviewed two configurations make possible to monitor and analyze all the parameters of the electrical power quality over the Internet. The connection is done through wired or wireless Ethernet technology (depending on the capabilities of the laptop used and available Internet service providers) or wireless via GSM/GPRS technology. In the both cases the power quality analyzer CA8334 is remotely controlled.

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