# Distance Monitoring of the Power Quality

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*Abstract:* Nowadays, increasing attention is paid to the electrical power quality. Any deviation from its quality standards leads to disruption and damage to electrical appliances and equipment coupled to the power system, and hence, to economic losses and even danger to life and health of service staff. Since the power quality is important for both suppliers and consumers, more and more systems for its monitoring are introduced. They follow a large number of parameters and adjust them in order to obtain optimal values and to achieve cost efficiency.

This paper considers electrical power as a product which should meet certain quality norms. It describes the parameters of power quality according to the standard EN 50160, and discusses some approaches to monitoring the quality of electrical energy. On this base, two configurations for remote control of the power quality are shown which allow to establish connection between power quality analyser and control computer. The approaches could be applied in any case when Internet access or GSM coverage are available.

*Key-Words:* - power quality, distance monitoring, computer control, energy analysis

## 1. Introduction

The energy sector in Bulgaria is one of the strategic economic sectors, and a priority in the national development strategy, as it produces the largest share of GDP. In the last few years, the production and distribution of electrical energy have undergone a process of liberalization following the European Union legislation. The structure and the parameters of the energy sector in Bulgaria are presently at European and world levels, and the quantitative indicators are crucial for the Balkan energy market. Nevertheless, in order to join the common European energy market, Bulgaria needs a comprehensive integration of efforts nationwide to all areas related to the quality and effective utilization of electrical energy.

In many countries, the regulatory bodies have introduced a set of requirements, based on internationally approved standards, in order to ensure the necessary quality and safety for end-users. The definition of quality in accordance with EN ISO 9000:2007 comprises a set of properties, characteristics and indicators of products or services that satisfy existing and implicit needs and expectations of customers. For electrical energy, in particular, a clear distinction should be made between power quality and service quality:

- *Power Quality* – comprises all parameters of the voltage of electrical energy supplied in the operator's network to the final customer and the indicators derived from these parameters.
- *Quality of service* represents a combination of the characteristics of the service provided by network operators, public service providers and end suppliers.

Power quality is an issue crucial to the economy, which attracts daily attention of specialists in generation, transmission, distribution as well as end consumers. In considerable degree it largely depends on the parameters of electrical quantities: frequency, amplitude and shape of single-phase voltage and phase voltage symmetry. These parameters are subject to change during normal operation of the power system due to load changes, disturbances generated by the facility and the occurrence of accidents, caused mainly by external factors. Poor power quality can cause appearance of disturbances or damage of electrical appliances and equipment that have serious economic consequences or even become dangerous to the health of consumers and operators.

The aim of this paper is to consider approaches for monitoring of power quality. It is based on the opportunities provided by information and communication technologies (ICT) nowadays for distance monitoring, and process automation.

## 2. Power quality parameters

Before going into details of power quality parameters, it should be made clear that the electrical power is a specific product with special features:

- Production, transfer and supply in practice happen at the time of consumption (simultaniously). The possibility for storing electricity is very limited, thus it is consumed when it is generated. Therefore, the systems for production, transmission and distribution must always be in working order.
- All electricity consumers are pluged in and are supplied by a common network
- Unlike other products, consumers themselves exert influence on the power quality. Generators produce electrical enegy with certain amplitude and sinusoidal shape of AC voltage. Until electricity reaches the consumers, the power quality is affected by the parameters of transmission and distribution circuits, whereas an increase of the load increases the losses as well, nonlinear loads distort sinusoidal form of current and voltage, and asymmetric loads distort voltage symmetry. The power quality changes for consumers who are connected to the same electrical circuits.
- The power quality is different in the different points of the power system and the supply systems of consumers. A common law is that technical performance deteriorates in the direction from generators to consumers of electricity.
- The power quality can be enshured only by all stakeholders together: manufacturers, suppliers, providers and users of electrical enegy. They opportunities and responsibilities are in this order.

The main document in Europe dealing with requirements concerning parameters of electrical energy is standard EN 50160 "Voltage characteristics of electricity supplied by public distribution networks". It characterises 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 randomly over time and are affected by practically unpredictable phenomena even during the normal operation of the supply network. Therefore, the definition of values for different characteristics is given for a period of time and can be exceeded in a small number of cases (small periods of time).

There are as well other standards that specify methods and techniques for measuring of electrical energy quality characteristics in order to obtain reliable, repeatable and comparable results. Such standards are Electromagnetic compatibility (EMC) standards from series 61000:

- 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".

EN 61000-4-30 defines two classes of measurement performance:

- *Class A performance:* It is used where precise measurements are necessary, for example, for contractual applications, verifying compliance with standards, resolving disputes, etc. Any measurements of a parameter carried out with two different instruments complying with the requirements of

Table1. Power quality characteristics and their measurements according to the EN 50160

| No | Parameter | Characteristics according to EN 50160 | |
|---|---|---|---|
| | | LV | MV |
| 1 | Power frequency | mean value of fundamental measured over 10s ±1% (49.5 - 50.5 Hz) for 99.5% of a year +4% / -6% (47- 52 Hz) for 100% of the time | mean value of fundamental measured over 10s ±1% (49.5 - 50.5 Hz) for 99.5% of a year +4% / -6% (47- 52 Hz) for 100% of the time |
| 2 | Magnitude of the supply voltage | standard nominal voltage $U_n$; *U*n = 230 V, either between phase andneutral, or between phases | Declared voltage *U*c |
| 3 | Supply voltage variations | 10% for 95% of week, 10 minutes mean rms values | 10% for 95% of week, 10 minutes mean rms values |
| 4 | Rapid voltage changes | 5% normal 10% infrequently $P_{lt} \leq 1$ for 95% of the time | 4% normal 6% infrequently $P_{lt} \leq 1$ for 95% of the time |
| 5 | Supply voltage dips | Majority: duration <1s, depth <40%. Locally limited dips caused by load switching on 85 - 90% | Majority: duration <1s, depth <40%. Locally limited dips caused by load switching on 10 - 15% |
| 6 | Short interruptions of the supply voltage | (up to 3 minutes) few tens - few hundreds/year Duration 70% of them < 1 s | (up to 3 minutes) few tens - few hundreds/year Duration 70% of them < 1 s |
| 7 | Long interruptions of the supply voltage | (longer than 3 minutes) < 10 – 50 / year | (longer than 3 minutes) < 10 – 50 / year |
| 8 | Transient over-voltages between live conductors and earth | generally < 6kV, occasionally higher; rise time: ms - μs | not defined |
| 9 | Supply voltage unbalance | up to 2% for 95% of week, 10 minutes mean rms values, up to 3% in some locations | up to 2% for 95% of week, 10 minutes mean rms values, up to 3% in some locations |
| 10 | Harmonic voltage | see Table 1 of the standard | see Table 2 of the standard |
| 11 | Interharmonic voltage | under consideration | under consideration |
| 12 | Mains signalling voltage on the supply voltage | Over 99 % of a day the 3 s mean of signal voltages shall be less than or equal to the values given in Figure 1 of the standard | Over 99 % of a day the 3 s mean of signal voltages shall be less than or equal to the values given in Figure 2 of the standard |

class A, when measuring the same signals, will produce matching results within the specified uncertainty. To ensure that matching results are produced, class A performance instrument requires a bandwidth characteristic and a sampling rate sufficient for the specified uncertainty of each parameter. [2]

- *Class B performance* - It may be used for statistical surveys, trouble-shooting applications, and other applications where low uncertainty is not required. [2]

## 3. Approaches for monitoring of electrical power quality

Two approaches to quality control of electrical energy can be distinguished based on conventionally used equipment: *system and operational*.

*The system approach* can be applied to built systems with known topology and range of consumption. It is achieved through:

- Building of systems for power quality control;
- Steady – mounted equipment;
- Transmission medium;
- Multiple levels of software.

The systematic approach has the following advantages:

- Gives clear idea about the relationship of the malfunction with the topology of the system and the source of the problem;
- Provides full details of happend events for many years period;
- Virtually unlimited resource of memory.

Disadvantages of the system approach are:

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

The practice of countries advanced in the field of power quality control shows that it is inappropriate to seek high degree of integration between power quality systems and systems for automatic reading of power

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meters. This is due to the fact that the equipment meets different standards, and systems require different number of control points, and information and communication capacity competence of staff, etc.

*The operating approach* is applied primarily in response to signals in case of failures and technical diagnostics. It is achieved through:

- Use of portable equipment;
- Use of mostly local software with a high degree of integration and adaptation to the equipment;
- Universal and fast way of connection.

The operational approach has the following advantages:

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

Disadvantages of the operational approach are:

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

Both approaches should not oppose to each other – they can be combined and complement one another. Initial priority should have the operational approach – to establish a proper system structure.

## 4. Distance monitoring

As it was indicated above, the monitoring of the power quality is related to measurement of many parameters for a long period of time. Throughout the period, the data should be collected and analyzed. Based on this analyses, it might be concluded what is the power quality during the examined period. This requires the instruments that are used to be able to measure all necessary parameters of the electricity, to maintain the data for a long period of time (week, month, year, etc.) and to analyze the data collected in accordance with the agreed quality standards. Furthermore, the power quality analysis should account that normally instruments are connected to the network at the point of coupling of a customer to the public electricity network. Obviously, the specialized equipment is located on different (and sometimes remote locations), and therefore, it is necessary to ensure a possibility for controll from a center location in which all data are collected, processed and analyzed. The advances in ICT provide many opportunities nowadays for remote monitoring and control, as well as automation of measurement processes by using appropriate hardware and software technologies.

Currently, the European market offers a wide variety of devices to control the parameters of electrical energy. Provisionally, they can be divided into *portable (mobile) and stationary devices*.

- *Stationary devices* are located from the supplier in certain places of the distribution network after adequate analysis in order to diagnose in time arising problems on the network, and thus eliminate them. They are used for system power quality control and their location is previously known connection to the control center can be enshured during coupling to the network and is not a problem.
- *Portable devices* are connecting to the network at different locations for example after complains from customers or after arised problems with the power quality and are disturbed at places that previously were not known. They are used for operational quality control and their connection to the control center should be established with the help of additional devices.

There are power quality analysers with different communication capabilities – from units without any possibility to link to computer to such with built-in communication modules for USB, Bluetooth, Ethernet or RS 232. Of course with the addition of new opportunities grows the price of the unit too. In practice, the most popular analysers are with a serial interface (USB or RS 232 / RS 485). They are the best from point of view of price / performance ratio and have broad functionality. Connection to a computer is possible and such analysers can be configured through it. The data collected from them can be downloaded and analyzed with the help of powerful software running on personal computer. Thus, with relatively few additional devices they may be connected to the internet and the control computer may be placed in a control center.

There are two options for access to stored or measured data using power quality analyser.

- The first option is the device to be installed for a long period of time (e.g. 1 month) and then to be dismantled and the data to be downloded through the existing communication module. Under this option, the control device is equipped with a large amount of static memory or file format in which the information is recorded is very poor.
- The second option is the device to be remotely connected to the controling computer. In this case his work can be controlled by a control center, the accumulated data can be downloaded periodically and if necessary it is possible to make remote measurements in real time. Thus, the computer's memory is used to store the data so the device not need to have a great amount of memory.

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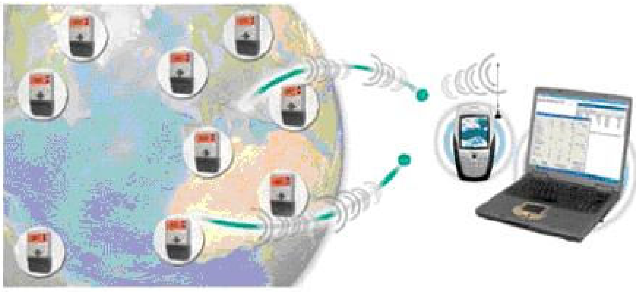

Fig. 1 Communication via GSM

Different posibilities of the communication may include:

- Multi-point reading through GSM (Fig. 1) – connection is made with help of two GSM communication modules (modems). One connected to the power quality analyser, the other is installed on the computer, which controls the analyser.

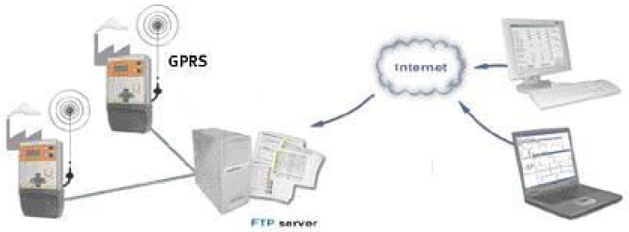


Fig. 2 Communication via GPRS

- Multi-point reading through GPRS (Fig. 2) - power quality analyser connects to the controlling computer (server) through GPRS. This is a good solution when a company has existing servers. This is a special case of the first way of communication.

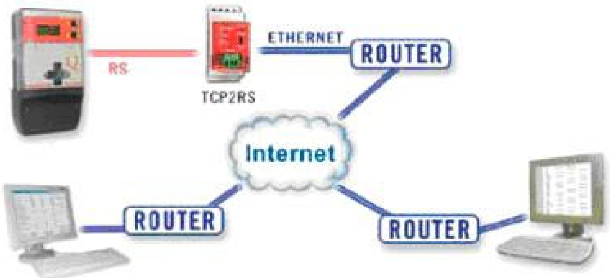


Fig. 3 Communication via Ethernet

- Multi-point reading through Ethernet (Fig. 3) - communication is done through ethernet port that allows collection of data from multiple devices via TCP / IP.

## 5. Practical implementation

The equipment used for remote control of the power quality includes: power quality analyser C.A8334B, GSM modem WirelessCOM/G10, laptop and desktop computer for power quality analyser control. The software used is DataView – commercial software for controlling the power quality analysers, HW_VSP – driver software, which adds a virtual com port to the computer and allows data exchange between the virtual com port and Internet (free for one com port and commercial for more com ports) and TeamViewer - free software to access and control a remote computer.

The power quality analyser C.A8334B is a combined instrument that can measure all necessary parameters of electrical energy. It can be connected to the electricity supply network (investigated object), using 4 schematics - single phase, dual phase, three-phase (three-wire) and three-phase (four-wire). "Multitask" technology allows to the power quality analyser simultaneous recording, monitoring and analyse 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 operator has possibility to set the coefficient of transformation and connection to the voltage transformer, which allows measuring both in the LV networks and in MV networks. These two cases completely cover the area of control of the Bulgarian regulator, and all industrial consumers.

The device has RS 232 port for communication with computer and can be configured and controlled through it.

WirelessCOM/G10 is an intelligent pre-programmed GPS 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 our case the power quality analyzer C.A8334B) and it is possible to access the device remotely through GPRS/CSD. If it is necessary to change the configuration parameters of WirelessCom, this can be done remotely using GPRS/CSD/SMS.

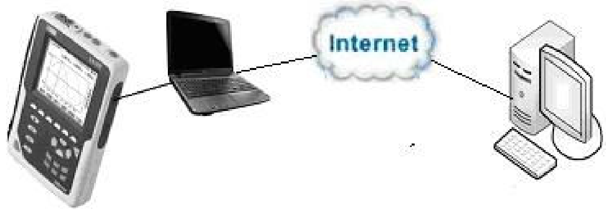


Fig. 4 Configuration for communication via Ethernet

In the first configuration shown in Fig. 4 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 ISP. On the computer in the control room is installed TeamViewer and the computer is connected to the Internet. Remote communication is done through sessions of TeamViewer. Through this sessions DataView can be started remotely on the laptop, which in turn controls the power quality analyzer.

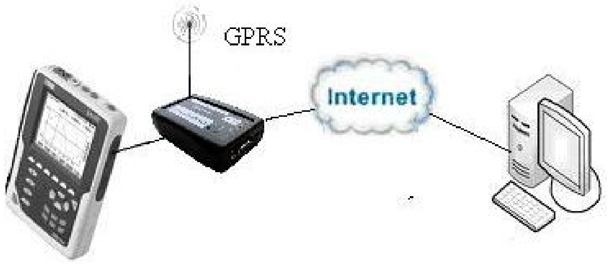


Fig. 5 Configuration for communication via GPRS

In the second configuration (Fig.5) the power quality analyzer is connected to a GPS modem WirelessCom with RS 232 cable. The control computer is running HW_VSP driver. GPS modem operates in master mode and automatically connects via GPRS to a server that is stored in its configuration (e.g. control computer). HW_VSP driver is configured in server mode and communicates with a GPS modem. Thus, at the start of a DataView on control computer the system operates in way such as the computer is connected directly to the power quality analyser via RS 232 cable.

## 6. Conclusion

The article dealt with energy as a product, which have to meet different quality requirements. The indicators covered in the standard EN 50160 concerning power quality are summarized Approaches for power quality control are shown. Two configurations for remote monitoring of the power quality are described. They are making possible to monitor and analyze all the indicators of power quality over the Internet. The connection is done through wired or wireless Ethernet technology (depending on the capabilities of the laptop used and avilable Internet service providers) or wireless via GSM / GPRS technology. In both cases the power quality analyser C.A8334B is controlled remotely from a PC via its built-in RS 232 port.

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*References:*

[1]. EN 50 160:2007, Voltage characteristics of electricity supplied by public distribution networks
[2]. EN 61000-4-30:2003, Testing and measurement techniques - Power quality measurement methods
[3]. Vassilev V., G. Milushev, Basic Moments in BDS EN 50160, Proceedings of the XVIII National Symposium with International Participation “Metrology and Metrology Assurance 2008”, September 10 - 14 2008, Sozopol, Bulgaria, p.p. 217-219 (in Bulgarian)
[4]. Milushev G., V. Vassilev, P. Tzvetkov, N. Gourov, A. Yovcheva, Main Parameters and Methodic Value of the Standards BDS 61000 – 4 - 30, BDS 61000 – 4 - 15 and BDS 61000 – 4 – 7, Proceedings of the XVIII National Symposium with International Participation “Metrology and Metrology Assurance 2008”, September 10 - 14 2008, Sozopol, Bulgaria, p.p. 220-225 (in Bulgarian)
[5]. Vassilev V., G. Milushev, P. Tzvetkov, System for Remote Power Quality Control, Proceedings of the XX National Symposium with International Participation “Metrology and Metrology Assurance 2010”, September 9 - 13 2010, Sozopol, Bulgaria, p.p. 214-218 (in Bulgarian)
[6]. Electric Power Group, Real-Time Voltage Monitoring and VAR Management System, Consultant Report, February 28, 2003
[7]. Yujin Lim, Hak-Man Kim, and Sanggil Kang, A Design of Wireless Sensor Networks for a Power Quality Monitoring System, Sensors 2010, 10, p.p. 9712-9725