Metrological Support of the Distributed Power Quality Monitoring

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Abstract – **This paper describes basic attributes and specific examples of software based solution for distributed measurement and information system for monitoring and analysis of relevant power quality parameters, at distant locations of power delivery network, in accordance with the European quality standards (EN 50160 and IEC 61000). The presented solution of distributed measurement and information system is based on GPRS network communication between computer system in power plant control center and local remote measurement stations. The metrological support block, inside each local measurement station, contains application of advanced methods for measurement and recording of critical voltage quality parameters, with the LabVIEW based virtual instrumentation software support.**

Keywords – **Distributed measurement and information system, Power quality parameters, Virtual instrumentation**

I. Introduction

Planning and development of electrical power distribution system is very important and complex task, that includes strong interactions with planning procedures in many other economic and industrial areas. The electrical power supplier's primary goal is to meet the power demands of its customers under all possible conditions. Consistently in order to avoid the high cost of equipment failures, all customers have to make sure that they obtain an electrical power supply of satisfactory quality, and that their electrical devices and equipment are capable of functioning as required, when small level network disturbances occur.

This can only be guaranteed if the limits within which power quality parameters may vary can be specified. These limits can be defined by specific demands of a customer in a power quality contract with supplier, by national regulation documents, or by international power quality standards, such as European Union standard EN 50160 [1,2] and International Electrotechnical Commission electromagnetic compatibility standard IEC 61000 [3]. On the one hand, previous documents define the main characteristics in low and medium voltage networks under normal operating conditions, and on the other hand it gives customers new rights as regards the quality of electrical power supply. For example, according to EN 50160, a customer is entitled to complain, if the voltage quality at the coupling point does not conform to the mentioned standard demands. Therefore in a number of countries, suppliers have adjusted their pricing in accordance with accomplished quality. As a consequence, electrical power quality parameters should be constantly monitored, analyzed and assessed, and these procedures must be performed by means of advanced measuring and recording devices and equipment. Instruments for measurement and analyzing of power quality parameters, such as Fluke 433/434 or Chauvin Arnoux C.A.8332/8334 power analyzers [4], based on complex digital processing functions, are capable to allow continuous voltage quality monitoring and control. It has been designed to measure relevant power quality parameters, and to perform computer based statistical and diagnostic activities, on single phase or three phase low voltage networks, in order to verify its compliance with relevant quality standards. These devices are using as the single units at selected points in the network, or alternatively, several separated units can be combined into a complete distributed data acquisition system, for monitoring and analyzing of an entire electrical power delivery network.

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II. Distributed Power Quality Monitoring Based on GPRS Network Communication

The possibility of fast and reliable data transmission by using GPRS devices, inside the mobile GSM networks, can be used for designing and realisation of distributed measurement and data acquisition systems, typically consisting of a number of remote terminal units, that perform real-time measurements and send this data over a computer network, to system control center, for further proccessing and presentation. Each terminal measurement unit is supplied with single or a number of digital instruments and background computer software. The applied instrument is remotely configurable and controllable, able to control other devices and to temporarily retain acquired data, in order to avoid loss of information in the case that communication breakdown occurs [5].

Permanent monitoring of power system quality, including automated recording and classification of power disturbances, and calculations of relevant statistical parameters, above the rest, act as preventive activity. In addition it allows power suppliers to confirm their system's compliance to relevant quality standards. Electrical power delivery processs to be monitored and controlled is partitioned into geographically distributed cells, that can be dealt with by a single processing unit or a number of locally connected units. Internet based TCP/IP protocols, Ethernet technology or GSM/GPRS based data transfer protocols are using for designing the networking infrastructure, between single terminal units, namely remote measurement stations, and power plant control center [6,7]. General Packet Radio Service is designed as an extension to mobile GSM networks. It greatly improves and simplifies the wireless access to packet data networks, such as the Internet, allowing data rate of up to 100 kbps.

Simplified block configuration of distributed power quality monitoring system, based on data transmitting from remote measurement stations, at different network sites, by using a

GPRS transfer protocols, to delivery control center inside the power plant,. is presented on Figure 1. Presented measurement and information system consists of three functional connected parts; the measurement station at distant location of delivery network, GPRS network communication and electrical power utility control center. Sensors and measurement transducers, inside each local mesurement station, provide informations in relation to real values of voltage and current parameters, and send them to metrological support block based on application of virtual instrumentation software and analog to digital PCI acquisition card. Metrological support software, developed by using graphical programming software package LabVIEW [8], provides measurement data in respect to monitored power quality parameter values, and records it into local date base.

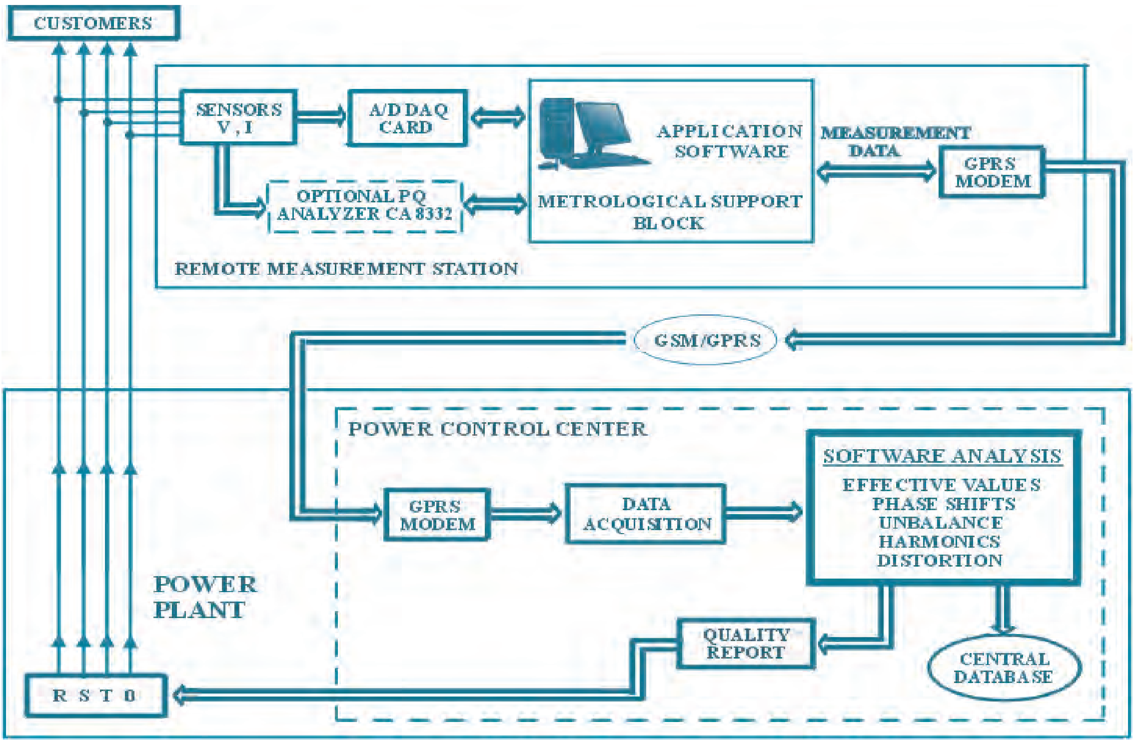

Fig. 1. Distributed power quality monitoring system based on GPRS network communication

An optional solution in local measurement station considers using of one or more power quality analyzers, such as CA 8332/34, including corresponding PC background analyzing software Dataviewer Pro. The second segment of presented monitoring system refers to the sending of measurement data, by serial port RS 232 and GPRS modem through a mobile GSM network, towards the power control center, to second receiving GPRS modem and data acquisition block, for further processing and analyzing. The major activities in the third segment of the system, power plant control center, are data acquisition, analysis of measured effective voltage values, phase shifts, voltage unbalance, level of harmonic distortion, sags and dips, transient voltages, and presentation of final power quality report, including and recording of processed measurement data into central system database.

By comparing detected unwanted events, chronologically recorded in central system database, with existing libraries of typical power quality variations, the main causes for specific network disturbance can be determined and eventually eliminated. Also, recorded data are valuable for characterizing sensitivity of end use equipment to power quality variations, that could be helpful in selecting of proper equipment, and providing specifications for protection that must be installed. Publishing the final quality report and measurement and analyzing results from central database on power utility Internet site, allows reliable and reference data to be viewed by individual power customers on remote home computers.

III. METROLOGICAL SUPPORT BLOCK WITH LABVIEW APPLICATION SOFTWARE

Applications of virtual instrumentation software allow users to implement a device that will best suit to his actual demands and requirements. These graphical-programming applications contain libraries of predesigned graphical components, that enable fast and easy implementation of the user interfaces and instrument control panels. Graphical user interface of the virtual instrumentation is a software replacement for the front panel of a classical type of instruments. It enables interaction between a program user and a software application [7].

A front panel of the virtual instrument, developed by using a graphical programming software package LabVIEW, that monitors power spectrum and three-phase voltage waveforms, performing measurement of relevant electrical power quality parameter values, is presented on Figure 2. Presented virtual instrument is developed within the scope of the project carried out at Measurement department of the Faculty of Electronic Engineering in Nis, with a support of the Ministry of Science and Environmental Protection of Republic of

Serbia. Parallel with monitoring of waveforms and effective values graphs of phase voltages V_1, V_2 and V_3, this system provides power spectrum and measurement data, regarding effective voltage values, phase shifts and total harmonic distortion level, for each of three displayed signals, showing exact date and time of recording for six successive measured values of controlled power quality parameters. Combining with additional data acquisition hardware components described virtual instrument is using as a part of the metrological support block, inside the local mesurement station, for monitoring and measurement of critical quality parameters, and for recording measurement information into local datebase. Block diagram or LabVIEW programming sequence, corresponding to shown front panel of developed virtual instrument, is presented on Fig. 3 below. A substantial number of data obtained from measurement of different power quality parameters, creates the need to analyze and evaluate practical usability of these data, with reference to measurement uncertainty of the final results. Actually, it is necessary to determine and specify the uncertainty level that is associated to the measurement results, in accordance with the recommendations of paper "Guidelines for evaluating and expressing the uncertainty of NIST measurement results" [9].

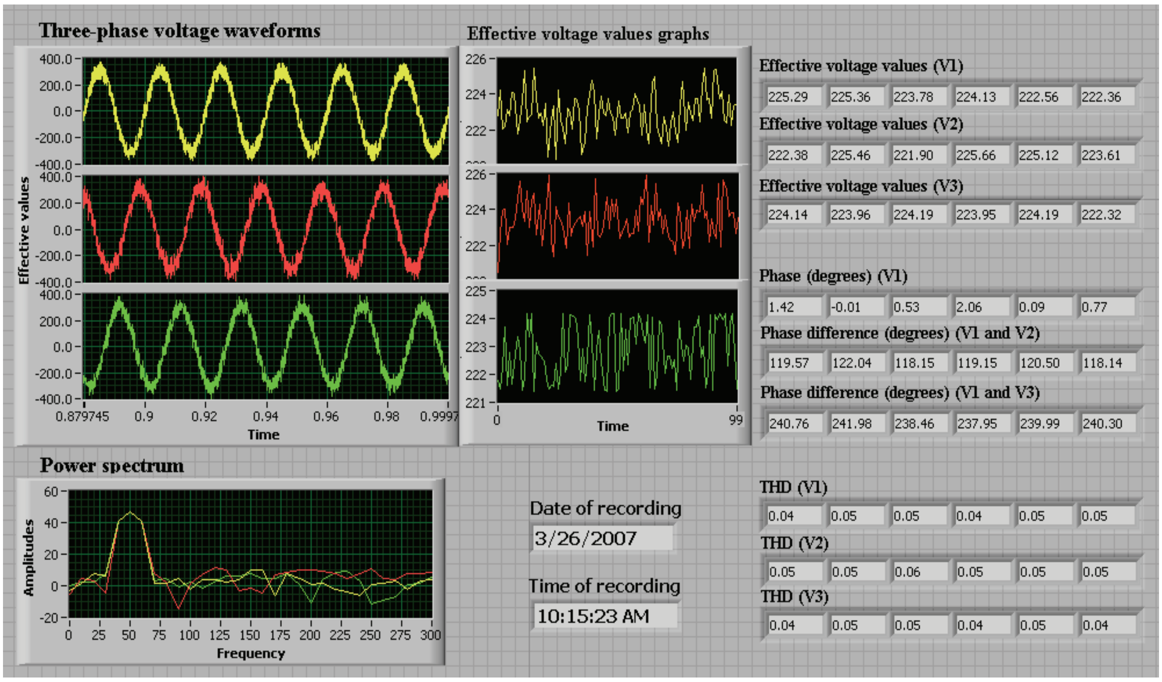

Fig. 2. Front panel of the virtual instrument developed in a graphical programming language LabVIEW

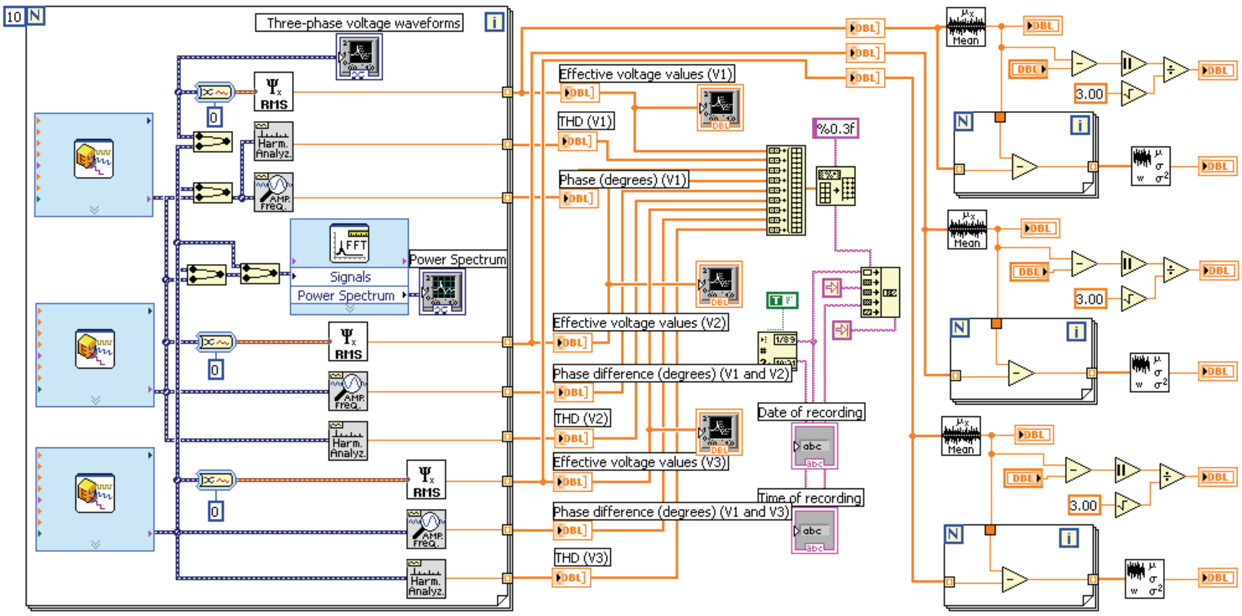

Fig. 3. LabVIEW program sequence (block diagram) of developed virtual instrument

The information concerning uncertainty level are providing by means of either statistical methods applied to experimental measurement results (uncetainty type A), or by using accuracy specifications for devices included in the system, provided by manufacturer (uncetainty type B). The automatic procedure for both types of measurement uncertainty calculation is developed and associated to the virtual instrument for metrological support, presented on Figure 2 above. A part of LabVIEW virtual instrumentation program for type A and type B measurement uncertainty calculation, concerning effective values of three-phase voltages V_1, V_2 and V_3, measured and presented on Figure 2, is presented on Figure 4.

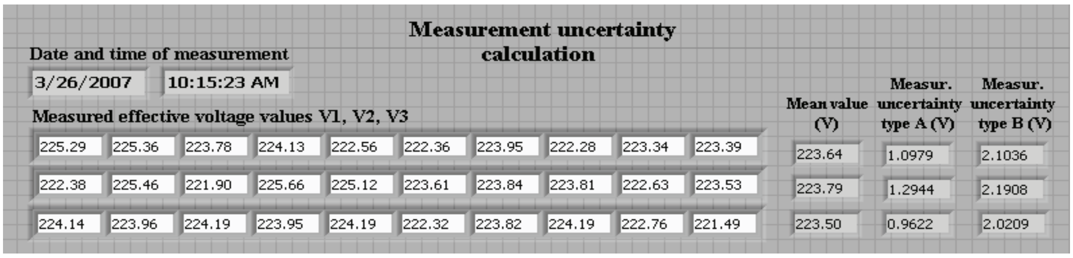

Fig. 4. LabVIEW virtual instrument for automatic type A and type B measurement uncertainty calculation

A type A evaluation of standard uncertainty is based on calculation of standard deviation of the mean of a series of independent observations. An input quantity is V_i whose mean value is estimated from n independent observations $V_{i,k}$, in this case, ten measured effective voltage values, obtained under the identical measurement conditions. The estimated value V_i is usually the sample mean:

$$\overline{V_i} = \frac{1}{n}\sum_{k=1}^{n} V_{i,k} \ , \qquad (1)$$

and the type A standard uncertainty to be associated with V_i is:

$$u(V_i) = \sqrt{\frac{1}{n(n-1)}\sum_{k=1}^{n}\left(V_{i,k} - \overline{V_i}\right)^2} \ . \qquad (2)$$

Calcualtion of the type B standard uncertainty considers an input quantity V_i whose value is estimated from an assumed rectangular probability distribution of the lower limit V_{min} and the upper limit V_{max}. In this case, the estimated value V_i is the expectation of the distribution:

$$\overline{V_i} = \frac{V_{max} + V_{min}}{2} \ , \qquad (3)$$

and the type B standard uncertainty to be associated with V_i is the positive square root of the variance of the distribution:

$$u(V_i) = \frac{V_{max} - V_{min}}{\sqrt{3}} \ . \qquad (4)$$

IV. Conclusion

According to configuration of the distributed power quality monitoring system presented in this paper, based on GPRS communication between remote measurement stations and power plant control center, the key components for providing satisfactory measurement results uncertainty level, are placed in metrological support block inside each local measurement station, that is functionally based on graphical programming application software. Presented virtual instrument, developed by using LabVIEW programming environment, continuously monitors waveforms, effective values graphs and signal power spectrum of three-phase voltages, including measurement and recording of effective values, phase shifts and total harmonic distortion level, for each of three displayed signals, indicating precise date and time of measurement. Finally, is presented an automatic LabVIEW based procedure for type A and type B uncertainty calculation of measured effective voltage values, functionally implemented into described virtual instrument. Chronological recording of previously processed and analyzed measurement quality parameter values in power plant central database and publishing these recorded data over the Internet, allows correct and reliable measurement data to be viewed by relevant individual customers on local home computers.

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