INTEGRATION OF POWER QUALITY MONITORING SYSTEM IN CROATIAN DISTRIBUTION SYSTEM

Tomislav CAPUDER
University of Zagreb
tomislav.capuder@fer.hr

Ivan PERIŠA
HEP-ODS
ivan.perisa@hep.hr

Dinko HRKEC
HEP-ODS
dinko.hrkec@hep.hr

Matija ZIDAR
University of Zagreb
matija.zidar@fer.hr

Tomislav TOMIŠA
University of Zagreb
tomislav.tomisa@fer.hr

Davor ŠKRLEC
University of Zagreb
davor.skrlec@fer.hr

ABSTRACT

Power market liberalization meant that power quality (PQ) became a market commodity, bringing more attention to its monitoring and necessary improvements in the infrastructure. Up until now, power quality monitoring was conducted only if a consumer would complain and then it was done by mobile measurement devices. Although some of the newly installed distribution substations have the necessary equipment to remotely supervise quality power quality, there is no systematic monitoring or processing of the same ones. Research and implementation projects around Europe do not propose a solution where existing infrastructure is optimally used for this purpose. Presented paper gives a original solution for fulfilling regulatory requirements for entire system monitoring of power quality.

INTRODUCTION

Liberalization of electricity sector in Croatia began in the early 2002, restructuring it from vertically structured single company to an open market environment. Through this process Distribution System Operator (DSO) and Transmission System Operator (TSO) became independent operators and were obligated to make significant changes in their regular everyday business operations. The existence of new market subjects required legislative changes which set obligations for each of the new market participants. In accordance with Energy Law [1], Grid Code [1] and General Rules for power supply, Distribution System Operator (DSO) was appointed responsible for ensuring power quality to the final consumer.

The project which Croatian DSO began in 2009 for power quality monitoring needed to be financially feasible, meaning it was not sustainable to buy or develop entirely new software and hardware backbone from the scratch; existing infrastructure has to be used in the most efficient way. The main idea is to define power quality monitoring system as a part of distributed automatization. Examples are protection relays and control units (so called IED) or “smart” meters, both having functions which can be used for power quality monitoring. These devices already exist and only need to be appropriately programmed. Computer systems with open architecture in control centres enable integration of data obtained from those devices into the central system for control and planning of the distribution network. Advanced usage of the modern IED devices also enables detailed statistical analysis of network disturbances. For example, voltage sags can be registered directly or they can also be analyzed thru the records of short circuit records stored in historical data base.

These devices record and store data temporarily and open architecture computer systems enable data storage into databases for later usage and analysis. Distribution Management System (DMS) enables integration of grid topology data, power quality data, process data, advanced applications for normal and critical network states; all in function of optimal control and planning of the distribution network.

Figure 1 demonstrates an idea for the concept of power quality monitoring system as a segment integrated into distributed automatization.

PQ MONITORING SYSTEM AS A PART OF DISTRIBUTION AUTOMATZATION

According to the European norm EN 50160 voltage quality parameters are determined as statistical average of measured data. For this reason, demands on the equipment for power quality monitoring determines that it has to be able to locally store and process measured data.

Distributed automatization is composed from a sequence of devices which have a capability to measure PQ parameters. By integrating them into the ICT system it is possible to obtain a valuable set of information for power quality monitoring system.

Another aspect taken into consideration were data that is collected in permanently installed measurement equipment:

- remote stations for supervision and control
- digital multi meters for online drive measurements (DMM)
- numeric protection relays
- bay controller
- digital automated meter reading devices
- PQ monitors

Above listed equipment can, under certain conditions, can be used as a data source for PQ evaluation according to IEC 61000-4-30. This is considered to be B or S class of accuracy.

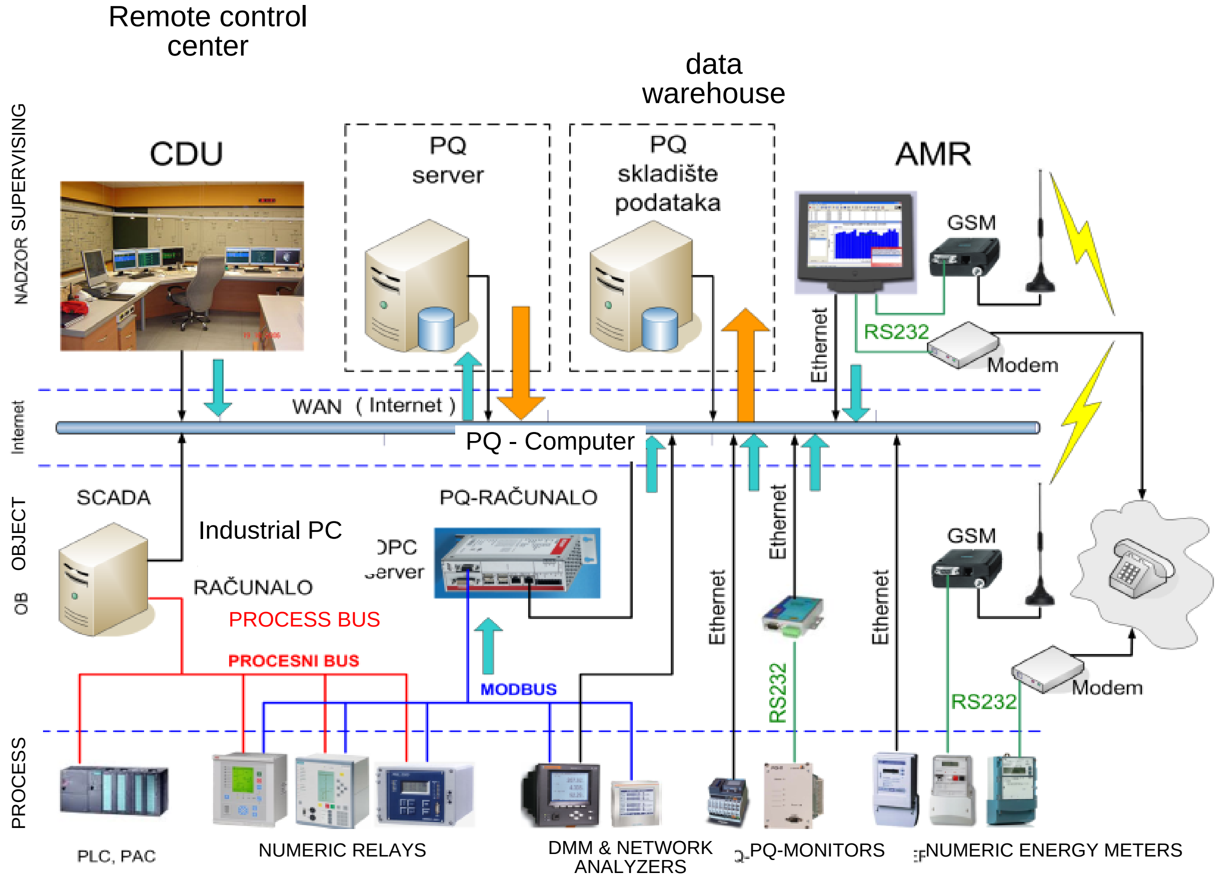

Figure 1. Concept of PQ monitoring system as a part of DA.

Proposed conceptual solution presents ICT system in three levels:

- process level
- local level
- supervision level

Process level

Measurement devices such as digital multi meters, numerical relays, bay controllers, RTU, PQ monitors etc present the ICT process level of PQ monitoring system.

Digital relays (DMM) in most cases have serial communication ports (RS232/RS485) and communicate with Modbus RTU protocol. In most cases those devices are not connected and integrated into a surveillance system. For this reason the basic idea is to install a industrial computer with Modbus OPC server installed. This server communicates with DMM and refreshes the Data Socket from which specially developed application reads the data and creates data structures. Those data structures are then transferred to PQ server with FTP protocol. Newer generations of DMMs are equipped with Ethernet communication channels and communicate with Modbus TPC protocol. These DMMs are connected thru Ethernet onto LAN switch. PQ computer is also connected to LAN and collects data. Measured data has a predefined data structure and is transferred over FTP protocol to PQ computer.

Numeric relays most commonly have 3 communication ports. Practically all numerical relays support Modbus protocol. To collect measurement data over Modbus protocol it is necessary to copy memory locations into registers (mapping) which are then fetched thru OPC server installed on a PQ computer. PQ computer creates data in a predefined format and sends it with FTP protocol to PQ server.

Bay controllers are integrated protection relays and programmable control relay, meaning they combine a lot more functions than the ordinary protection relays. Some of the new bay controllers also have some of the, so called, PQ device functions such as voltage and current wave form snapshots. Communication ports are identical to those of protection relays meaning Modbus protocol needs to be additionally mapped according to requirements. OPC server collects the data on PQ computer thru communication bus and creates predefined data structure which are then sent thru FTP protocol to PQ server.

Network analyzer are software and hardware upgraded DMM which, along side three phase currents and voltages, can measure and record harmonic distortions. They have several communication possibilities from RS485 communication bus to Ethernet LAN switches. It is possible to connect several devices thru gateway connecting them with RS485 communication bus. This can be connected to Internet enabling access to all network analyzers thru one TCP/IP connection. OPC server collects the data on PQ computer thru communication bus and creates predefined data structure which are then sent thru FTP protocol to PQ server. Certain types of network analyzers can store measured data up to one month; they have storage organized as FIFO (first in first out) container. This type of devices do not need PQ industrial computer.

PQ monitors are measurement devices intended for power quality monitoring according to EN 50160. Device is in its base DMM device supported with the powerful processor. The basic idea is that off line data processing should be done in a control centre. Since the amount of data is extensive, there is a justified need for a fast communication link. For this reason data transfer is done by Ethernet of Ethernet/RS232 converters. New generation PQ monitors also have the capability to locally store and process data, in compliance to EN 50160. If data collecting and processing is conducted in the control centre, appropriate software applications need to be installed which will create predefined data structures from the historical data base, and send them via FTP protocol to PQ server.

Local level

Local level contains station industrial computer and additional PQ computers in objects being supervised. PQ computers are installed in objects which are not interconnected and have no possibility for local data storage. Another issue is differences in data format from different devices. The installation of a PQ computer, which is in fact industrial PC (IPC) has a multiple role of creating a universal data format as well as storage and communication with control centre. The main difference between IPC and standard computer are size and robustness as well as a certain number of communication ports such as RS485/RS422.

Supervision level

Supervision level consists of control centres, advanced meter reading process centre and newly organized PQ centre.

SCADA centres store measurements collected from supervised objects into a historical database. Since control centre has a fast internet connection, the idea is to install software application which will gather the data relevant to power quality and create data structures. Prepared data is then sent to PQ server.

Advanced meter reading (AMR) system [3] is based on a computer application that collects information from digital meters equipped with communication ports. Communication ports are build into theses meters according to available communication media - PSTN, ISDN, GSM (new generations of AMR support Ethernet, WiFi, PLC). Most of these devices in Croatia are connected to AMR centre thru GSM (plan is to switch to GPRS). These devices are used for billing and thus collect power and energy data from measurement sites. Since these values are calculated from measurements of voltage, current, frequency and phase angle these values are in fact stored in memory registers. Newer generations of AMR have the possibility to measure voltage distortions as well as to register outages.

In PQ centre server and computer with warehouse need to be installed. Hierarchically; PQ centre has a vertical communication to local and process level, and horizontal commutation with control centre and AMR centre.

CROATIA CASE

The project for the entire distribution network in Croatia began with collecting information on all existing equipment in every distribution control area. Analyzing the possibilities of communication and data collection from each device installed (all types are described in previous sections), number of potential PQ measurement points were detected and solutions for those devices were proposed. This analysis has shown, as expected, that not all points can be integrated into the new PQ centre. For this reason installation of few types of PQ monitors in certain load points were suggested. The final step was creating a data warehouse for PQ centre. This data warehouse has to be able to collect a large amount of data from all measurement points, store them with the time stamp, location stamp and structural order. This last requirement was solved with parent-child relationship in case of a several voltage layer distribution grid (e.g. Substation 110/35 kV is parent to all 35/10 kV stations connected to her). The sole collection of data was not the only purpose for the creation of this data warehouse. As required by its customers regulatory agency, DSO has to be able to produce reports on distribution network power quality. Since measured values are hard to present in report form, list of events with limits is created and those are to be shown when producing a report. These list can be seen in Table 1.

Nr.	Symbol	Description	Category
1	FRE01	$50,5 < f \leq 52,0$	Frequency
2	FRE02	$47,0 \leq f < 49,5$	
3	FRE03	$f > 52,0$	
4	FRE04	$f < 47,0$	
5	NAP01	$u < 0,01\ U_n$	Voltage
6	NAP02	$u > 1,1\ U_n$	
7	NAP03	$0,01\ U_n \leq u < 0,85\ U_n$	
8	NAP04	$0,85\ U_n \leq u < 0,90\ U_n$	
9	FLI01	Pst > 0,7	Flickers
10	FLI02	Plt > 0,5	
11	FLI03	Plt > 1	
12	NES01	nes > 2,0 %	Voltage symmetry
13	THD01	THD > 1,5 % (30, 35)	THD
14	THD02	THD > 2,0 % (10, 20)	
15	THD03	THD > 2,5 % (0,4)	
16	THD04	THD > 8,0 %	
17	COSFI	$\cos\varphi \leq 0,95$	Power factor

Table 1. List of events for report generating

CONCLUSION

Securing quality of power supply is imposed by regulatory rules and Energy Law.

Up until now power quality monitoring was conducted only on demand of the customers and even then a customer had to have a justified reason to make such a demand. Transition to constant online monitoring of the entire system is a complex and expensive task. Despite several projects started around Europe, experiences show that distribution system operators usually decide to combine those with installation of smart meters with the end consumers. This way the system operator has a excellent information of the power quality on end points of its network. On the other hand this does not give a complete picture of power quality in the entire system and is usually very expensive. The presented paper demonstrates an original idea how to maximally use the existing installed equipment. Even though not described in details due to the extensiveness of the work, the paper gives an overview of all the conducted actions; from detailed gathering of device information and their specifications for the whole Croatian distribution system, to local level solution and supervision centre solutions.

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REFERENCES

[1] Official Gazette Nr. 68/2001

[2] Official Gazette Nr. 36/2006

[3] I.Hadjina, M. Kavurčić: 2008, "Implemented HEP-ODS Remote Automated Meter Reading System", *Proceedings CRO Cired*, SO6