POWER QUALITY AND METERING MONITORING APPLICATIONS FOR SMART NETWORK OPERATIONS

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ABSTRACT

Romanian TSO/DSO performed the necessary steps to implemented a nationwide Power Quality Monitoring System(PQMS) / Metering Monitoring System(MMS). First results encouraged us to consider grid extended PQMS and MMS as emerging data provides for the development of smart grids technology.

The first part of the paper provides a description of the Power Quality(PQ) and Metering Romanian regulations.

The second part presents the new PQMS hardware, software architecture and the most important results.

The third part presents in particular the concepts and application aspects of effective power monitoring tools that are being used to visualize and analyse the power network of Romania. The final part contains conclusions and recommendations for future development.

INTRODUCTION

The Romanian Power Grid “Transelectrica” / “Electrica” are the Transmission (TSO) / Distribution System Operator (DSO), the Metering Operators of the Wholesale Electricity Market (OMEPA) / Retail Electricity Market and Transelectrica is also the coordinator for the Smart Grids implementation project in Romania.

Transelectrica and Electrica are interested in developing networks Smart Grids from producers to customer power, include the integrated monitoring online systems always for metering and power quality.

On Romanian Electricity Market the power quality and metering parameters are regulated by “The Electricity Transmission Grid Technical Code” [1], “The Electricity Transmission Grid – Standard of performance” [2], and at the same time, by “The Electricity Distribution Grid Technical Code” [3], “The Electricity Distribution Grid – Standard of performance” [4], also by "Technical conditions for the connection of wind power plants to electricity grids of public interest” [5] and [6] for cogeneration plants, issued by ANRE.

The “Action Plan for implementation in the national power system of the Smart Grid concept” has been approved by the Ministry of Economy, Commerce and Business Environment. The aim of the plan is to set a roadmap towards implementation of the smart grid concept, starting from feasibility studies and requisite legislation.

According with the regulations, TSO and DSO have to monitor the power quality and the metering parameters, also has the obligation to specify in the legal document the duty of the Customer to keep the PQ parameters inside the admissible limits. PQMS and MMS create a necessary statistical database for development of PQ regulation and the ascertainment of contractual conditions. There are also Romanian energetic prescriptions that needed updating and extensions, according with international standards.

TSO’S PQ MONITORING SYSTEM

MMS for wholesale market model using, since 2006 Transelectrica has developed an integrated PQMS which includes TSO substations, DSO substations and the wind power plants. It covers 46 sites with permanent monitoring and over 25 temporary monitoring sites.

The all PQ instruments are certified of conformity with IEC 61000-4-30 ed.2 class A [7]. Internal clock synchronization for each instrument use either an internal or an external GPS receiver as mentioned in the certificate of conformity. The PQ instruments SMART feature characteristics such as compliance with applicable standards, possibility of onsite upgrade, data validation, calculation of PQ parameters, waveform and alarms recording, data transmission and WEB access.

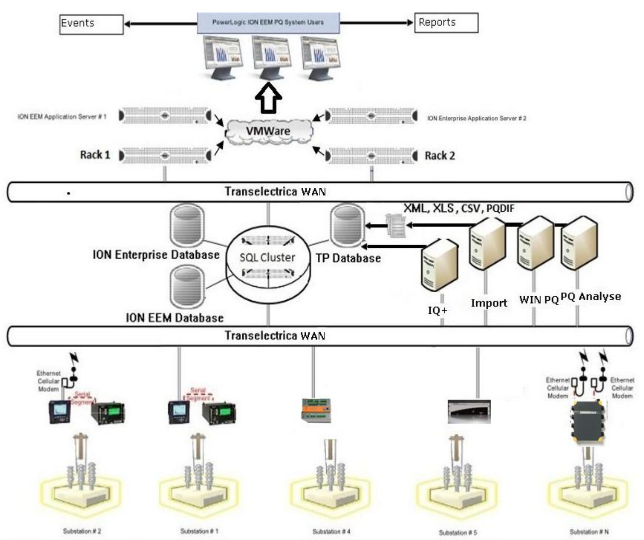


Figure 1.The architecture of Transelectrica’s PQMS

The large volume of data recorded by the PQ instruments is transmitted using the site optical fibre (OF) network, the OF networks from Transelectrica's WAN, or GSM communication for external TSO sites and the OMEPA PQ Data Management Centre (see figure 1).

In the OMEPA PQ Data Management Center, situated in Transelectrica's headquarters in Bucharest, the latest generation server system consists of two data base servers, two AD (Active Directory) servers and two VMWare (Virtual Machines) servers. On the two VMWare servers are running some virtual applications as application servers, WEB servers, data importing servers, etc. Some SMART features of the PQMS are: scalable, flexible architecture, data acquisition, interoperability, redundancy, WEB portal, reports, load curves, parameters analysis, alarms and events control, compatibility with other devices-manufacture.

The data automatically transmitted by the PQ instruments is processed by the application server which creates a SQL data base (ION Enterprise database). The application on the WEB server generates the reports required by the beneficiaries, compliance with the PQ applicable standards and is available for all licensed users. This is a flexible system that contains report templates, allows creating custom reports, import data from third parties, generating reports and data in a format adapted to user needs and exporting them to PDF, XLS, XML, PQDIF files.

Data and events management functions are very useful for the daily maintenance and the development of Transelectrica's operated personal. The reports generated EN 50160 [9] and IEC 61000-4-30 [7] present the numerical and graphical analyses of the PQ parameters: power frequency, supply voltage magnitude, supply voltage unbalanced, total harmonic, voltage harmonics, current harmonics, flicker Plt, flicker Pst, slow voltage changes, deeps / overvoltages / interruptions table. Summary report according to [8] are issued automatically for weekly analyse of cumulative probabilities 95% and the National Dispatch Centre sent regulary the PQ dedicated reports for the Economy Ministry and ANRE

Analyse of acquired data, by PQMS highlights the following facts according with [8]:

- The voltage magnitude at 110kV voltage level is difficult to keep inside the admissible limits because the reactive power are transferred at the interface between TSO and DO;
- The flicker generated by sudden variations of the load or supply voltage are causing problems to the nearest costumers, connected to the same grid;
- The total harmonic voltage are outside the limits because at a voltage level of 110kV the railway power stations are supplied by transformers connected on HV between only two phases and at a voltage level of 220kV the aluminium plant is connected;
- The unbalanced voltage, resulting from unbalanced current is sometimes generated by transmission power grid (non-transposed overhead lines, unbalanced consumers) but generally by distribution power grid;
- The temporary over voltages and the dips at 110kV voltage level in substations are usually generated by distribution power grid.

The PQMS's hardware and software architecture was designed to development in the future up to 300 monitoring sites and consumers. As PowerLogic ION EEM software application and ION type analyzers came from same manufacturer it can automatically integrate any type of analyzers from this family. Acquisition of new PQ equipment provided by other manufacturers, imposed on software supplier the need to develop several integration mechanisms into PQMS for different types of equipment, such as PQI-DA, Flk1760, Qwave PMD-A, G4500 .

As shown in figure 1 a "third party" (TP) database structure was defined for other PQ Analyzers, which is automatically recognized by PowerLogic ION EEM software application. For automatic transfer mechanism some specific information is needed, such as: standard file format type PQDIF, XLS / CSV, XML, file/directory name on Import server and also the structure of the TP database for interconnection with its own SQL database. Some highlights from the software engineer to develop mechanisms for integration: when the PQMS architecture, type of data, aggregation interval was defined, the problem of integration becomes a matter of interpretation and data conversion and it's have to design the mechanisms for automatic data import.

For these mechanisms the most common alternatives are: direct access to the database if its structure is publish and transfer the data files in standard format. In terms of data access, the main difficulty to be mentioned is the reluctance of manufacturers to publish data representation format and communications protocols, these problems are very difficult and can be solved only with the support of the manufacturers.

For transfer the data files in standard format, which can be PQDIF, XML, XLS/CSV, and any manufacturer, can provide an export file syntactically correct, from which data can be extracted, but the significance remains to be established by naming of channels specific to implementer integration mechanism. After integration efforts already undertaken we found that each manufacturer prefer to use specific names as parameters (egg, phase-phase voltages are labelled V/U12,Vab...), but complicate things, even more parameters such as voltage harmonics, unbalance and for the periods of aggregation, the week starts on Monday/ Sunday/Saturday. The rehabilitation of the substations and wind plants involves the purchase of new PQ instruments and their integration into the existing PQMS [10].

PQ AND DISTRIBUTED GENERATION

European and national authorities are focusing on renewable energy sources for some time now. Incentives for investments in this domain targeted both development of new sites and bonuses for green energy production so many

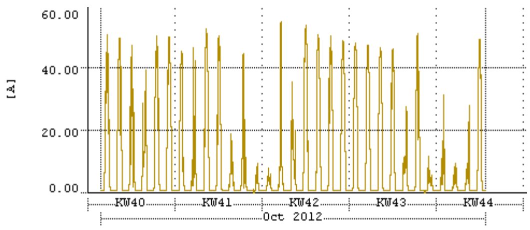
projects for small energy production plants are now either working or will be commissioned in near future.
When electrical power market was liberalized and the green certificates market was developed, the promotion of energy production from renewable resources lead to the appearance of the distributed generation as investment motivation.
FDEE Transilvania Sud is one of the three distribution branches that make up the largest distribution company in Romania: Electrica S.A. It provides services for 1,1 millions customers and covers six counties situated in the middle of the country. Particular examples presented bellow refers to Sibiu distribution subsidiary even if comparable situations are encountered all over the distribution network.
The duty of the distribution operator is to complete and optimize the systems already implemented (SCADA, SAD, GIS) in order to allow the passage to the next level of automation provided by SMART Grid.
Real-time management of distributed generation units connected to distribution needs software applications for online short-circuits calculation on large areas to ensure protections system selectivity and sensitivity.
Under these conditions must be defined and implemented a monitoring system to apply some of the principles promoted by SMART Metering concept such as:

- Hourly consumptions profiling;
- Two-way communication with the energy meters;
- Means for consumers online information about energy price;
- Power Quality permanent monitoring.

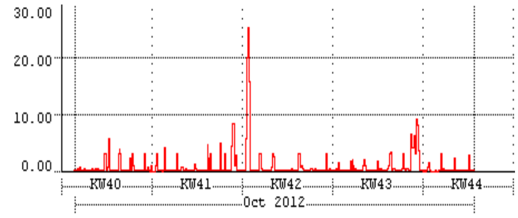
During previous years several new micro hydroelectric power plants and two medium size cogeneration power plants were connected to the distribution network, each one as an individual project.
Each project needed own customized solution taking into account facilities remote operation and distribution automation in the area. All of them must consider future integration in the overall Smart Grid concept so development principles underlining is very important
In 2011 applications for five new solar power plants, with a combined nominal power of 38 MW, were submitted to distribution operator and two of them are already in operation.
Experience gained in the past led to the inclusion of specific requirements in the technical projects for these new Distributed Generation power stations [11]:

- Technical specifications for the protections were reviewed and the inclusion in the distribution automation system for the switching equipments inside the station became a standard requirement;
- Overhead MV lines for connection of distributed generators must use technologies adapted to the harsh environment such as MV twisted insulated conductors;
- Requirements for the communication system have also been established. Data communication uses optical fiber as support because radio and GSM/GPRS isn't reliable enough in those remote areas.

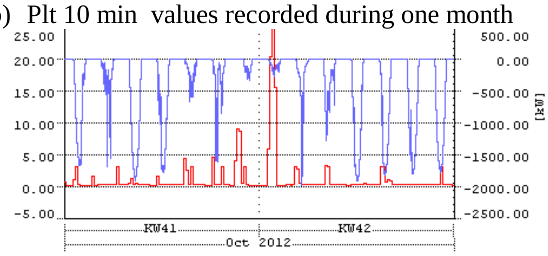
Each DG station must include permanent PQ monitoring equipment. PQ monthly reports will reveal the influence of PQ indicators that must stay in acceptable limits.



a) Current values recorded during one month



b) Plt 10 min values recorded during one month

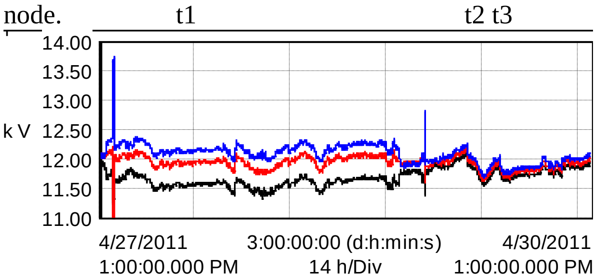


c) Correlation between power delivered to the network and high levels of flicker

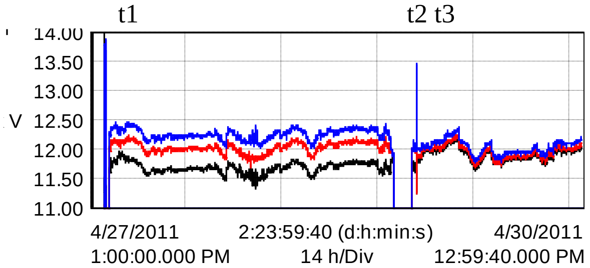
Figure 2. Flicker recordings

On the other hand recorded perturbations sand historical values will help determine how the faults in the network affect the energy production. Both cases are illustrated below: figure 2 shows recent recordings for a solar power plant. High flicker values (over 6) occur when the solar power plant is in operation. When energy production level is low due to weather condition the long term flicker becomes even worse.
Several Power Quality issues occurred during first month's operation of a micro hydroelectric power plant. A fault inside the DG installation was suspected when a series of unidentified ground faults accompanied by unbalanced voltages occurred. In order to determine the influence of distributed generation on voltage PQ parameters two monitoring units were installed at 110/20kV substation MV busbar and on the MV side of generator substation.
Phase voltages recorded at the two sites are presented in figure 3. At t1 time the earthfault occurred. During fault clearance the generator was disconnected but the separation transformer remains connected. At t2 time the separation transformer was disconnected. At t3 time the generator was switched on. First conclusion was that the fault was outside

the DG station. The second conclusion was that because of separation transformer and generator are in star connection they contribute to reduction of voltage unbalance on the network. So the DG actually improves the PQ indices in that node.



a) Phase voltages at MV substation busbar



b) Phase voltages at MV generator connection point busbar

Figure 3. Phase voltage recordings

At t1 time the earthfault occurred. During fault clearance the generator was disconnected but the separation transformer remains connected. At t2 time the separation transformer was disconnected. At t3 time the generator was switched on. First conclusion was that the fault was outside the DG station. The second conclusion was that because of separation transformer and generator are in star connection they contribute to reduction of voltage unbalance on the network. So the DG actually improves the PQ indices in that node.

In the present applications of the distributed generation using renewable resources are becoming a fact of life. Some connection solutions, the requirements for protection systems and remote operation were defined; however, there are difficulties to overcome, with each new project.

In case of advanced metering infrastructure the distribution operator will face some difficult tasks taking into account the volume of information to be updated and especially in terms of the additional content that will be needed in the relationship with the customer. In most cases the DG sites belonging to one company are spread on distribution networks belonging to different DSO's.

CONCLUSIONS

We recommend that the power quality in common couple points should be monitored with portable instruments before each new user is connected to the grid for a correct evaluation of the perturbation that needs to be maintained within the acceptable limits and continuing, after the connection, with the permanent monitoring according to the law.

For transfer the PQ data files in standard format, which can be PQDIF, XML, XLS/CSV, it should be emphasized that although all the above file formats clearly establish how data should be structured, at this moment there is no single standard for data interpretation.

SCADA and PQ equipments placed in generation nodes can prove essential for development of new SMART Grid concepts such as VPP (Virtual Power Plant). Most PQ equipments can provide detailed on line electrical measurements in generation nodes over high speed Ethernet protocols. In the near future that information must be collected trough a unified system which will integrate different equipments from different manufacturers.

One good example is the PQ monitoring system implemented at Transelectrica the Romanian TSO. It is currently under debate if each DSO will have its own permanent PQ monitoring system and a common exchange platform will be developed or a centralized system is needed in order to allow extended functionality and interoperability.

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