Power Quality Issues in Smart Grid Environment – Serbian Case Studies

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Abstract: - The paper discusses power and especially voltage quality issues in the smart grid environment. New demands that are facing the distribution network, by introducing the concept of intelligent networks (Smart Grids), are presented. Some examples of non-compliance of laws and practices in Serbia are presented as well, as the illustration of lack of strategic planning in the field. Through several case studies, a few typical problems regarding power quality, occurring in the electrical utilities in Serbia, which have to be solved in a new environment are presented. In the end, the conclusion and specific suggestions in regard with the importance of strategic planning and preparation for the customization to the expected changes are given.

Key-Words: - power quality, smart grids, power quality monitoring, harmonics, volt var control

1 Introduction

European Smart grid concept - The EU Smart Grids Technology Platform vision and strategy for Europe's Electricity Networks of the Future was launched in 2006 [1]. The Smart Grid vision is aiming for "new products, processes and services, improving industrial efficiency and use of cleaner energy resources, while providing a competitive edge for Europe in the global market place". The Smart Grid vision is highly important as a mean for support of the EU environmental as well as economical ambitions. Many of new technologies are involved, such as renewables, electric cars and power flow control equipment, while an increased use of digital communication and control, including smart metering and advanced grid wide area real-time monitoring, can also be expected.

Principal functionality characteristics of Smart Grids are [2, 3]:

1. Active consumers participation;
2. Seamless accommodation of all generation and storage options;
3. Provision of new products and services, and opening of new markets;
4. Power quality (PQ) for the digital economy;
5. Optimization of asset utilization;
6. Anticipation and response to system disturbances (self-heal);
7. Resilience against attack and natural disaster (cyber security).

To fulfill these requirements, the evolution of existing grids is necessary, and it includes:

- high use of renewables 20% – 35% by 2020,
- bidirectional metering,
- distributed storage,
- smart meters that provide near-real time usage data, time of use and dynamic pricing,
- smart appliances communicating with the grid, energy management systems in homes, and industrial facilities linked to the grid,
- growing use of plug-in electric vehicles
- networked sensors and automated controls throughout grid.

However, this evolution of existing grids will confront them with new challenges regarding power quality issues. Regarding distributed generation for instance, depending on applied technology (synchronous, single or doubly fed induction machines, or inverter technology) influence on power quality will be manifested through [4]:

- magnitude of supply voltage,
- increased unbalance,
- transient overvoltages,
- voltage sags, and
- flickers.

Based on this facts, one can conclude that voltage quality is becoming increasingly important to customers for two reasons:

a) Voltage quality levels are affected by the increased use of distributed generation and different electronic devices (inverters, battery chargers, energy saving lamps).

b) Sensitive electronic devices are strongly affected by voltage quality.

Not only for consumers, but for all stakeholders involved in new, smart grid environment, power quality deserves particular attention. Thus, potential disturbance source may be found on both, generation and consumer side. From regulator point of view, it is important to asses what should be consider in establishing a regulatory framework for voltage quality in distribution networks.

The aim of this paper is to emphasize the need of improved and enhanced power quality monitoring, taking into account new requirements and new technologies of Smart grid. Finally, actions regarding power quality cannot be treated independently, without broad strategic planning frame.

In the following Section, the need for change of actual power quality policies and the need for integrated planning of all power aspects are presented through some examples of Serbian Power Industry.

In the Section 3, new smart grid functions addressing power quality aspects are presented. Through several study cases from Serbian Electrical Utilities, the need for integrated platform including power quality is presented.

Finally, conclusions are brought regarding the change in power quality treatment in the new environment.

2 Strategic planning regarding power quality in the new environment

Until now, the main focus of quality regulation has been on the reliability and commercial dimensions of quality. In contrast, there is far less experience with the issue of voltage quality regulation, especially in integrated, multi-functional and multi-communication platform like smart grid.

The proper approach to the smart grids and all matters related to this concept, and the issue of power quality, can be of a crucial importance for the countries that will be found in the way of its application.

If serious attention is not given to strategic planning and appropriate actions for preparing the system to move to a new concept are not taken, one can easily get into a situation that much greater financial resources are spent to remedy the consequences of damage, loss coverage, or on payment of fees and penalties. The only alternative is the timely planning and implementation of actions to predict and mitigate the occurrence of such losses and to optimize the adaptation to market conditions.

Disharmony between regulatory requirements and actual network level will be explained in the case of Serbian Electric Power Industry in the last decade. First example was the question of increasing the nominal voltage in low voltage distribution systems from 380 to 400 V.

Being aware of this change, many countries have made adequate preparations so the transition did not cause adverse effects. On the other hand, Serbia did not have an adequate attitude towards this issue, so the transition to a higher voltage level was carried out without any previous preparation. As a consequence, because motors in electrical drives were not replaced with new ones, designed for rated voltage of 400 V, a large increase of reactive power consumption appeared in the whole distribution system. This is especially contributed by the fact that, with the changes of rated power, the maximal allowed voltage in distribution networks in Serbia has increased even at 440 V. The second negative consequence was much larger number of failures in electrical drives.

Another example of poor strategic planning was the lack of high level incentives for customers to reduce their reactive power consumption. Without these incentives, consumers did not have any interest to invest in reactive power reduction. The problem could have been easily resolved by introduction of an appropriate tariff system. Since this was not done, after an increase of reactive power consumption in the system, Electric Power Industry of Serbia has invested in installation of reactive power compensation units in distribution networks, with the total installed capacity of 600 MVAr.

The previous examples show that due to lack of strategic planning and appropriate actions, the huge financial resources have been spent on unnecessary delays in manufacturing processes, repair of damaged equipment, insurance premiums, coverage of unnecessary energy losses and the investments in equipment that have not been necessary. All these actions have treated only the consequences, not the real causes of the problem.

By the introduction of the smart grid concept, the focus is changed, and new information and telecommunication infrastructure is required, as presented in figure 1. Power quality monitoring has to be included in this new infrastructure as well.

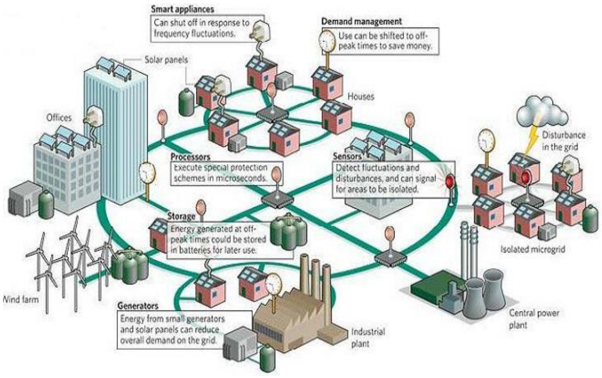

Figure 1. *Smart grid overview*

3 New Smart grid functions and power quality

The effective realization of smart grid concept is not possible without advanced distribution network automation. This automation introduces advanced distribution network operation as well, through the set of advanced distribution functions. The key aspect of electricity supply quality in a power system is the optimal application of voltage levels to all transmission and distribution networks. With significant penetration of distributed generation, the distribution network has become an active system with power flows and voltages determined by the generation as well as by the loads. Growing customer expectations and using of sophisticated electrical equipment are putting an additional responsibility upon the network operator to ensure that the delivered level and quality of supply are maintained within the parameters previously set by the regulatory bodies, while the maximal amount of distributed generation to be installed and operated is permitted at the same time. Some of innovative solution in that field are elaborated in [5, 6, 7, 8].

Integrated Volt/Var control is an important and one of the most desirable functions of a modern Distribution Automation (DA) system, as an integral part of Smart Grids. This function deals with the complexity of voltage and reactive power control in distribution systems. This complexity usually limits the capabilities of local automatic controllers which conventionally control Load Changing Transformers (LTCS) or Voltage Regulators (VRS) on the bases of local voltage measurements, and, Capacitor (CAP) banks on the bases of temperature or voltage changes.

Performing the Volt/Var control in an integrated manner provides a flat voltage profile over the feeder and at the same time minimizes the power loss in the system. In addition, a coordinated operation of VRS and CAP banks permits avoiding of an excessive and unnecessary tripping of these devices.

Centralized voltage and reactive power control is typically considered the most cost effective function of real-time DA. Rule based Centralized Capacitor Control with an objective of unity power factor has a relatively long history of real-time implementation. With development of a more reliable real-time Power Flow, the power flow based on Optimal Volt/VAr control attracts more and more attention.

Optimal Volt/VAr control allows a wider choice of objectives which can be achieved with higher mathematical accuracy. The objective of operating the distribution network within voltage and loading constraints serves as the primary objective, where other objectives – power losses, demand, etc. – serve as secondary. In addition, more and more distribution utilities are investing in remotely controlled capacitors and step voltage regulators as part of their distribution automation strategy. This offers the opportunity for periodic closed loop Volt/VAR control, which determines the optimal set of control actions and executes them immediately.

Fault Location, Isolation, and Restoration applications in a DA environment have also recently increased in importance. The trend for these applications is going towards more intelligent solutions that react to fault events and assist the operator in clearing and restoring the fault or taking action without any operator interaction at all. Fault location programs evaluate the SCADA information of breaker trip events and faults.

However, the proper introduction of these function is not possible without advanced monitoring of all important values in the power network, including the monitoring of voltage quality. In other words, power quality monitoring, together with the proper information and telecommunication techniques, is becoming the back bone of fully implemented smart grid.

A few of the case studies taken from authors experiences in Serbian power network will demonstrate the need of advanced and integrated measurement and data analysis.

ISBN: 978-1-61804-023-7

3.1 Case Study 1

The first case study represents the common problem of voltage reduction in the transmission system. Due to some problem of unbalance between production and consumption, transmission network operators are commonly performing the short term (1 – 2h) voltage reduction (of the order of 5 – 10%). This reduction is leading to the short term demand reduction, but after few hours, the demand is continuing to grow, because of the „pay back effect“. Consequently, the problem is the drastic decrease of voltage quality for many customers, affected by this wide area voltage reduction.

Figure 2 is representing voltages measured in one TS 10/0,4 kV, at the low voltage bus bars. The voltage magnitude decrease is of order of 10%, registered after 10 a.m. in total duration of 1 hour and 30 minutes.

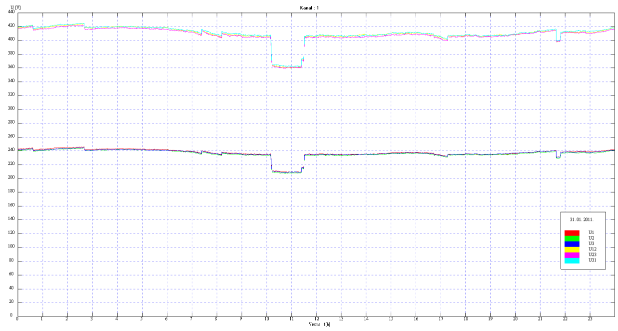

Figure 2. *Voltages measured at the low voltage bus bars in TS 10/0.4 kV „Kadinjača“ 31.01.2011.*

The distribution company has not been warned, so the situation represented in figure 1 had as the result, many customers complaints of the low voltage in their households.

Figure 3 represents diagrams of active and reactive power from the TS 400/110 kV „Petrovac“ at one 110 kV transformer bay, which supplies, through one intermediate TS 110/35 kV „Ilićevo“ and one TS 35/10 kV „21. oktobar“, the TS 10/0.4 kV „Kadinjača“, represented in figure 2.

The measurement information system (MIS) in the TS "Kadinjača", recorded data with 12 s time resolution. The architecture of measurement information system installed in TS 10/0,4 kV to record the parameters of voltage quality in power distribution networks is presented in figure 4.

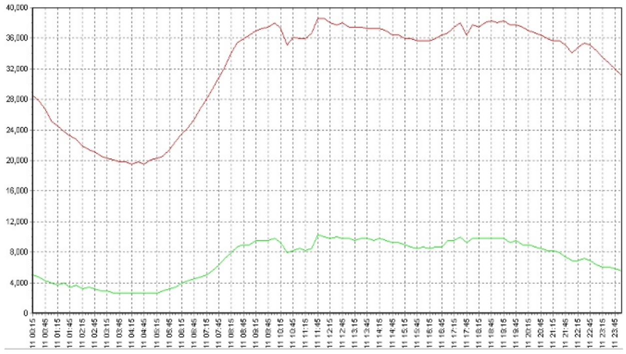

Figure 3. *Active and reactive power in the supply TS station 400/110 kV „Petrovac“ 31.01.2011.*

The measurement system which measured the active and reactive power at 400/110 kV "Petrovac" recorded the data at 900 s (15 min), and forms of change shown in the diagram would not faithfully convey.

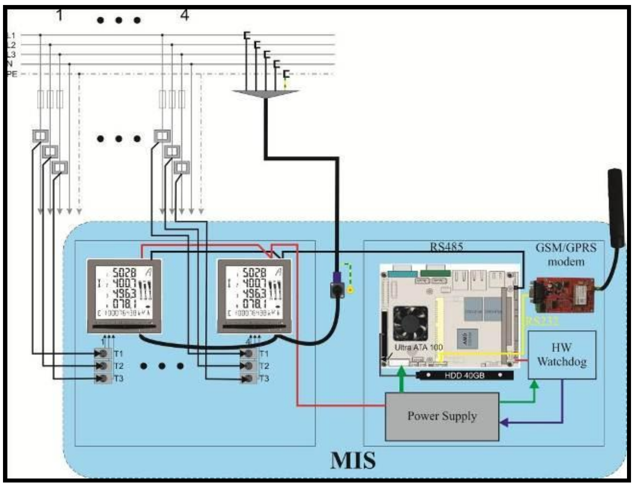

Figure 4. *MIS architecture*

The presented example aims to demonstrate the need of measuring information system with adequately allocated measuring units, and analysis software that allows the analysis of recorded data (for instance, data recorded from other distribution utilities which are equipped with similar devices). Figures 5 and 6 show the diagrams of voltage changes in two other TS 10/0,4 kV in other areas supplied by the same TS 400/110 kV.

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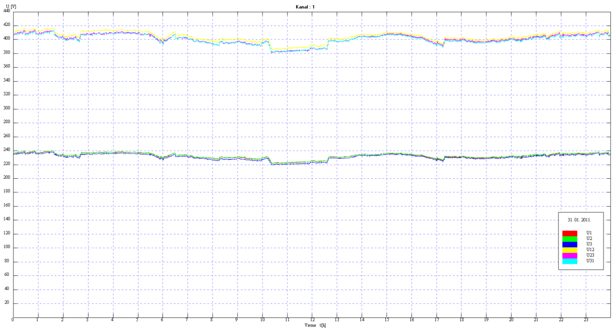

Figure 5. *Voltages measured at the low voltage bus bars in TS 10/0.4 kV "Vranje" 31.01.2011.*

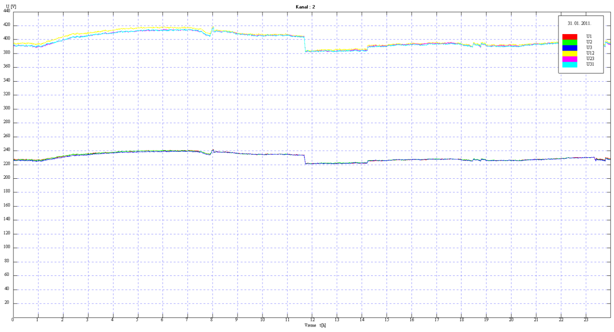

Figure 6. *Voltages measured at the low voltage bus bars in TS 10/0.4 kV "Pirot" 31.01.2011.*

It is shown that without data recorded by measuring information systems and proper analysis software, many phenomena affecting the quality of voltage in electricity distribution network, when their causes are out of the site of measurement (and even outside the territory covered by the entire company for distribution) often can not be explain.

3.2 Case Study 2

Above was already stated that performing the Volt/Var control in an integrated manner provides a flat voltage profile over the feeder while minimizing the power loss on the system. In addition, a coordinated operation of VRS and CAP banks permits avoiding of an excessive and unnecessary tripping of these devices. The simplified layout of one distribution feeder is represented in figure 7.

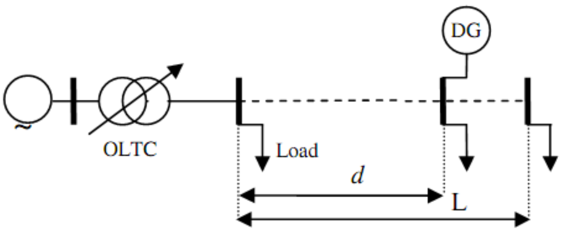

Figure 7. *Simplified model of distribution feeder*

The load connected to the main bus bars, presented in figure 7, represents one wood processing facility. Voltage variation is represented in figure 8. The problem in this particular case was the excessive operation of On Line Tap Changer (OLTC) in distribution transformer station. Only after installation of power quality measurement device and, what is more important, introduction of these measurement in the central data warehouse, the problem is solved by proper settings of OLTC in supply transformer station.

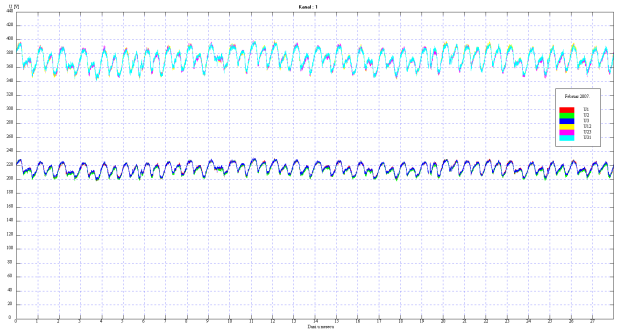

Figure 8. *Voltages measured at the low voltage bus bars in TS 10/0.4 kV at consumer side*

The same problem was registered in another TS 110/10 kV station, which supplied one TS 10/0,4 kV with voltage variations represented on figure 9.

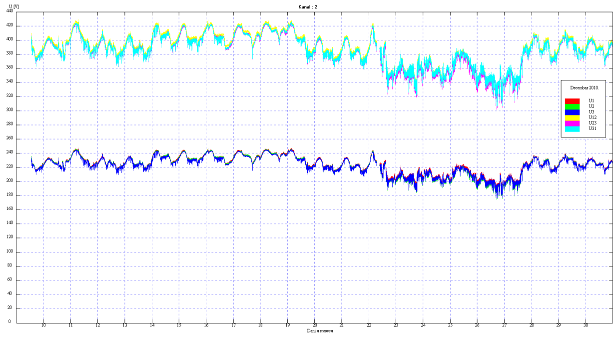

Figure 9. *Voltages measured at the low voltage bus bars in TS 10/0.4 kV in ED Nis at consumer side*

Only after detection of sources of voltage variations at the lower level, the proper setting of OLTC in supplying station were possible.

3.3 Case Study 3

The final case study is dedicated to the problem of harmonics. The following is the example of electricity customer who injected into the network a large content of higher harmonics and caused unauthorized voltage drops of other electricity customers in the region. Figure 10 represents the active, reactive, and apparent powers of the consumer.

ISBN: 978-1-61804-023-7

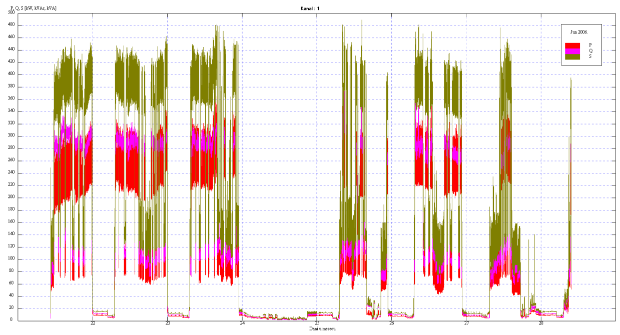

Figure 10. *Active, reactive, and apparent powers of the consumer*

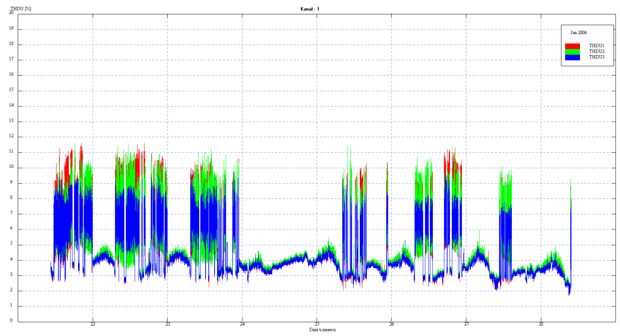

Figure 11. *THD factors of the consumer's phase voltages*

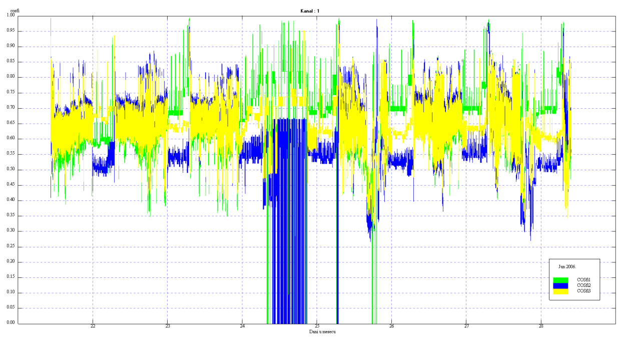

Figure 12. *Corresponding phase power factors*

Fig. 11 presents the high level of THDu (greater than 12%), while Figure 12 presents the corresponding power factor. Checking the technical requirements for the connection, the conclusion was that are connected to the network without their fulfillment.

4 Conclusion

The paper points out that the problem of monitoring power quality parameters in Serbia should be given far more serious attention in order to adopt laws and standards in the EU, and to fulfill requirements regarding EU Smart Grid technology platform.

It is shown that solutions for problems described above should not be sought independently but as part of the development concept of intelligent networks (smart grids).

Moreover, power quality problem can be one of additional "driving factors" for the implementation of Intelligent network in Serbia.

Finally, it is shown that only the elaboration of an integrated information platform is required for resolving of power quality issues in a satisfactory manner.

Acknowledgement:

The work presented here was supported by the Serbian Ministry of Education and Science (project III44006).

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