Guidelines for Power Quality Monitoring – Results from CIGRE/CIRED JWG C4.112

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***Abstract*—This paper summarizes major results of the CIGRE/CIRED JWG C4.112 - "Guidelines for Power quality monitoring – measurement locations, processing and presentation of data". The results presented in this paper cover the work of JWG from January 2011 to January 2014. The paper provides information about the current PQ monitoring practices and makes recommendations for future monitoring campaigns considering monitoring locations, selection of monitoring parameters, and presentation of monitoring results.**

***Index Terms*— Power quality, power quality measurements, power quality monitoring, power quality parameters.**

I. INTRODUCTION

There has been a noticeable increase in the amount of power quality monitoring taking place in electric power systems in recent years. A number of monitoring projects have been performed around the world with the main objective of assessing the overall power quality of power systems at different voltage levels. Monitoring of voltages and currents in the electric power system undisputedly gives the network operator or utility information about the performance of their network, both for the system as a whole and for individual locations and customers. There is also pressure from customers and regulatory agencies to provide information on actual power quality levels. Developments in enabling technology (monitoring equipment, communication technology, data storage and processing) have made it possible to monitor on a large scale and to record virtually any parameter of interest. The change in types of loads connected to the network including proliferation of power electronic interface connected generators as well as the envisaged further increase in non-conventional types of loads/storage (e.g., electric vehicles) places additional pressure on network operators to monitor, report and control various aspects of network performance.

While many network operators are installing monitoring equipment and more and more manufacturers have monitors available, there is a lack of knowledge and agreement on a number of aspects of the monitoring process, including the number and location of monitors, processing of the recorded data and reporting of monitoring results. The users of the data, be it network operators or their customers, are increasingly requesting concise information rather than just large amounts of data be provided.

The objective of this paper is to provide general conclusions and recommendations from CIGRE/CIRED JWG C4.112 which for the last four years has been investigating topics related to PQ monitoring. Full discussion and conclusions of the work from WG can be found in CIGRE Technical Brochure (TB) which will be available from late 2014. Discussion in this paper is based on the TB draft from February 2014 [1].

II. OBJECTIVES FOR POWER QUALITY MONITORING

Before establishing a PQM system it is necessary to define the objective(s) to be address. This will define the monitoring technology used, the number of monitors deployed and their locations, the parameters that are measured and how often they are measured. In general, the following six main objectives for power quality monitoring can be distinguished:

- Compliance verification,
- Performance analysis,
- Site characterisation,
- Troubleshooting,
- Advanced applications and studies,

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- Active power quality management.

Compliance verification compares a defined set of power quality parameters with limits given by standards, rules or regulatory specifications. Performance analysis is usually an issue for a network operator and results are used primarily for internal purposes (e.g., strategic planning, asset management). Site characterisation is used to describe power quality at a specific site in a detailed way. Troubleshooting measurements are always based on a power quality problem (e.g. exceeding levels, equipment damage, etc.). Advanced applications and studies are growing in popularity due to the higher resolution and complexity of the data and its more timely communication. Advanced applications cover new, highly sophisticated methods to improve the efficiency of network operation. Active power quality management includes all applications where any kind of network operation control is derived from the measurement results.

III. Overview of Existing Approaches to Power Quality Monitoring

The majority of utilities monitor the PQ on their system to some extent. There is a wide variety of approaches used. Some devote significant resource to PQ, and are concerned with the overall performance of the system, using IEC 61000-4-30 Class A monitors fixed at many sites and reporting to their customers and regulators. Elsewhere, the activities are more restricted, using portable PQ monitors to capture and assess individual incidents in response to customer complaints.

The system-wide monitoring of PQ in each utility is heavily influenced by its regulatory environment. For some parameters (voltage levels, harmonics) the requirements are often clearly defined (by national or international standards) and mandatory. Other parameters (for example the number and severity of PQ disturbances) may be monitored and reported, but are less often regulated. The same applies at individual sites, where a customer may be sensitive to PQ issues – or a customer may need to be constrained to control the level of disturbances emitted.

Several national and international documents discuss PQ monitoring specifically, and utilities equipment and systems follow their recommendations. However monitors, and monitoring systems, may be in use for many years, while PQ research is advancing continually.

The technology behind PQ monitoring itself is relatively mature. Existing PQ monitors will input raw signals of voltage and, often, current, and the basic algorithms to extract PQ parameters such a harmonics and flicker are well established (although developments such as "flagging" are relatively new). The system operators typically have a limited number of types of monitors, both permanently installed and portable, and are familiar with their capabilities. Where a utility develops its own specific PQ policy, this is more related to ancillary questions, e.g., which aspects of PQ are important, who are the "customers" for the information.

Most utilities use PQ monitors to analyse system problems, to respond to customer complaints, and to monitor specific problematic sites. The performance and accuracy of PQ monitoring, and so its usefulness, is influenced by several factors including: i) What proportion of sites are monitored; ii) Whether to monitor continually using fixed equipment or use sampled data from portable units; which (if not all) PQ parameters to include; iii) Whether to adopt one or two sources of monitoring system (and associated proprietary software) or to develop a more general monitoring structure; iv) How to combine information from specialised PQ monitors with data from SCADA, EMS and elsewhere; v) How to present the PQ monitoring results, how often, and to whom.

While a portable monitor, or a fixed monitoring system, may be used for many purposes there are distinct differences in emphasis as shown by the variety of responses which a utility may give to these questions of policy. The utility's PQ concerns are driven by regulation, by customers or by internal policies, and are reflected in the system adopted. In general, transmission system operators (TSOs) put more emphasis on overall standards and PQ limits, and the design of mitigation measures, while distribution system operators (DSOs) are more concerned with specific events, customer complaints and troubleshooting. Almost all utilities are typically monitoring the same PQ parameters (e.g., voltage levels, harmonics and unbalance) there is greater emphasis in Europe (compared to the aggregate of the rest of the world) on *fluctuations* in voltage and frequency.

A significant consequence of the variety of PQ monitoring approaches adopted by utilities around the world is that the PQ information is obtained in different ways so comparison or benchmarking between utilities is difficult. Although benchmarking is inherently difficult between systems of widely different size and structure, this would be helped by the adoption of more standardised approaches.

Finally, it should be mentioned that a significant operational cost is involved in data management (communications, processing and storage) and analysis and presenting the results of monitoring, arguably more than the capital cost of acquiring and deploying the monitors themselves. The question of how much resource to devote to systematic PQ monitoring was beyond the scope of this JWG work.

The above conclusions are supported by the results of the international survey carried out by the JWG during 2012. A total of 114 responses were obtained from TSOs and DSOs all over the world. Further discussion of the results of the survey is available in [2].

IV. Selection of Monitoring Locations

Power quality monitoring (PQM) locations are strongly related to power system architecture and infrastructure and to the monitoring goals. In classic power systems and in a conservative approach, power quality monitoring points are usually located at the frontiers between the four fundamental component segments: classic generation, transmission, distribution and customer. In future power networks with large penetrations of renewable and distributed generation a new layer of monitoring might be added at the interconnection points of these new types of energy sources. The new types of generation raise concerns related to harmonic distortion, unbalance, voltage regulation and flicker emissions and for this reason PQM at their connection points is of particular interest.