International Industry Practice on Power-Quality Monitoring

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***Abstract*—Monitoring of voltages and currents at system buses gives the network operators information about the performance of their network, both for the system as a whole and for individual locations and customers. There is also demand from the customers and the regulatory agencies to provide information on the actual power-quality (PQ) level. Developments in enabling technology have made it possible to monitor at a large scale and to record virtually any PQ parameter of interest. While many network operators are installing monitoring equipment and while more and more monitors are available, there is a lack of knowledge and agreement on a number of aspects of the monitoring process and on processing the recorded data. As a response to this lack of uniformity in approach, data acquisition, and processing, in February 2011, CIGRE and CIRED established the Joint Working Group C4.112: "Guidelines for Power quality monitoring—measurement locations, processing and presentation of data." In order to identify the current international industry practice on PQ monitoring, the group carried out a survey in 43 countries across the world. This paper summarizes the key findings from 114 responses to the questionnaire and identifies prevalent industrial practice in PQ monitoring around the world.**

***Index Terms*—Industry practice, monitoring, power quality (PQ), survey.**

I. Introduction

THERE HAS been a noticeable increase in the amount of power-quality (PQ) 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 PQ 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 the customers and the regulatory agencies to provide information on the actual PQ level.

Developments in enabling technology (monitoring equipment, communication technology, data storage, and processing) have made it possible to monitor at a large scale and to record virtually any parameter of interest. The change in types of loads connected to the network and proliferation of nonconventional, power-electronic interface connected, generators, as well as envisaged further increase in nonconventional types of loads/storage (e.g., electric vehicles) puts additional pressure on network operators to monitor and document various aspects of network performance.

While many network operators are installing monitoring equipment and while more manufacturers have monitors available, there is a lack of knowledge and agreement on a number of aspects of the monitoring process, such as the number and location of the monitors, processing of the recorded data, and reporting of the monitoring results. The end users of the data, whether they are network operators or their customers, are increasingly asking for useful information rather than just large amounts of data to be provided by installed monitors and supporting software.

In February 2011, CIGRE and CIRED established joint working group JWG C4.112: "Guidelines for Power quality monitoring—measurement locations, processing and presentation of data" to resolve some of these issues and the spread knowledge on PQ monitoring from a small group of experts to a broader audience.

One of the first tasks of this JWG was to survey and identify the current industry practice for PQ monitoring in order to establish the state of the art. For that purpose, a questionnaire on PQ monitoring practices was developed during 2011 and distributed during 2012 to a large number of transmission system operators (TSOs) and distribution system operators (DSOs) from 43 countries on all continents.

This paper summarizes some of the key findings of that questionnaire, based on 114 responses received by January 2013. The relation with regulatory requirements and the recent recommendation by the European energy regulators are also summarized.

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The aim of this paper is not to recommend any specific approach to PQ monitoring, but rather to identify the range of existing industry motivations and practices to PQ monitoring and the approaches used by industry for establishing the level of PQ in their networks or at specific customer buses.

II. Overview of Past PQ Monitoring Projects

The results of a four-year PQ monitoring program, conducted by the National Power Laboratory (NPL), are analyzed in [1]. The monitored area covered 112 locations in the U.S. and Canada. Single-phase, line-to-neutral voltages were recorded at standard wall receptacles. The wide statistical variation of the data collected, however, hindered the definition of a typical site representing the overall PQ of the power system. The difficulty to utilize data from monitoring programs to estimate the expected electrical environment is also reported in [2], where a comparison was carried out between the monitoring results of the NPL survey and the data from two additional monitoring programs: one conducted by the Canadian Electrical Association (CEA) and one by the Electric Power Research Institute (EPRI). The CEA survey was conducted with the participation of 22 utilities throughout Canada. In this survey, 550 sites were monitored for 25 days each. Residential, commercial, and industrial customer sites were monitored at the point of common coupling (PCC). Only line-to-neutral voltages were monitored (120 or 347 V). The EPRI survey lasted for more than two years, and around 50 GB of PQ data was obtained. The survey was performed in distribution systems with voltages ratings from 4.16 to 34.5 kV supplying residential, commercial, and industrial customers. Monitors were placed at substations and along three-phase sections of feeders. Although the surveys' data were combined to obtain the range of PQ events that might be expected at the majority of locations, it was pointed out that there is difficulty in doing so due to the differences in the recording and classification of phenomena by each brand of monitor, the voltage threshold settings used in each survey, the monitored locations, etc. The voltage sag data, for example, of the EPRI survey were briefly compared against two European PQ surveys in [3]. One of the European surveys was performed in nine countries by the Distribution Study Committee of Eurelectric (formerly UNIPEDE), which collected statistical data based on over 80 years in total from 85 monitoring locations on medium-voltage (MV) networks. The second survey was performed by the Norwegian Electric Power Research Institute (EFI) by monitoring 400 sites in Norway. Similarly, significant PQ monitoring, analysis, and reporting activities have been ongoing in Australia since 2000. The Long Term National Power Quality Survey (LTNPQS) project has analyzed and reported PQ data, using indices developed specifically for the project, from thousands of sites across Australia [4]–[9].

The need for long monitoring periods is evident in [10] and [11], where data from short-term monitoring programs and for single monitoring points are considered. In [10], monitoring data from a period of eight months in three locations are presented, while in [11], the results of voltage sag measurements in two industrial facilities for a period of 17 months are studied.

The surveys discussed before are by no means the only ones conducted in recent years but they were the ones for which detailed results were available and comparable. Although it is difficult to establish the typical duration of the monitoring surveys examined since it ranges from a few months to several decades, an average duration of 2.4 years is calculated. Significant efforts in surveying PQ are also evidenced in the Benchmarking Report on the Quality of Electricity Supply of the Council of European Energy Regulators (CEER) [12]. It is reported there that the largest number of monitors is deployed in France whereas Latvia and the Netherlands report less than 30 monitors installed. In no instance, however, is an optimal deployment strategy reported in [12]. The results from the survey that resulted in the Benchmarking Report triggered the publication of guidelines of good practice on PQ monitors (referred to as "voltage quality monitors" by the European regulators) [13].

In summary, it can be said that monitoring projects require significant investment in measurement equipment and in data collection and processing. The latter must be automated in order to maintain reliable statistics on PQ events [14]. Moreover, the requirement for high accuracy of monitoring data may necessitate long monitoring periods, typically several years [15].

III. CIGRE/CIRED Joint Working Group C4.112

In February 2011, CIGRE and CIRED established joint working group JWG C4.112: "Guidelines for Power quality monitoring—measurement locations, processing and presentation of data." The aims of the JWG are to address the application aspects of PQ monitoring, in particular, including the following: 1) Guidelines for choosing locations to install monitoring equipment and for the number of monitors needed to obtain a sufficiently accurate picture of the PQ; 2) tradeoff between costs of monitoring and amount of information provided, including the practical value of additional information gained by adding more monitors against the complexity of data extraction and classification; 3) possible and potential advantages of installing a monitoring function in a large number of the metering devices and/or protection relays; 4) methods for reliable estimation of relevant PQ indices at nonmonitored locations; 5) which parameters should be recorded and at what sampling rate/resolution, including a discussion about appropriate data averaging window and viability of inclusion of waveform data; 6) how and where should the monitoring results be stored, that is, if the data are to be transmitted to a central location, should raw data or processed/compressed data be transmitted? The recommendations in this respect should not only cover existing practice but should also include possible future applications, including customer requests for past performance at a certain site, and the need for future research and development in, for example, data capture and processing; and 7) how to present the results of monitoring? It is neither possible, nor desirable, to have one way of reporting for all applications. Different ways of presenting the results of monitoring are needed for different types of applications and decision making. This recommendation should address the way of presenting statistical/probabilistic results over the entire or a large part of the service area; statistical/probabilistic results for individual customers over one or more years, and results for individual events or over a short period of time.