Measurement 43 (2010) 771–780

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

# A web-based distributed measurement system for electrical power quality assessment ☆

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ARTICLE INFO

*Article history:*
Received 17 June 2008
Received in revised form 4 January 2010
Accepted 17 February 2010
Available online 21 February 2010

*Keywords:*
Distributed measurement system
Power Quality (PQ)
Smart sensors

ABSTRACT

Industries' systems are shifting toward almost entirely sophisticated electronic devices. Power Quality (PQ) analysis is getting importance for the economy because this equipment is highly sensitive to PQ events. Control and supervision of an industrial process has mainly been focused on the electrical protection, and little attention has been paid to the quality of the electrical supplies. Nowadays, measurement and communications systems have advanced to enable the installation of web-based sensors within a PQ assessment scenario. In this sense, this paper presents an innovative low-cost measurement system, as well as investigates the challenges and trends in the development of distributed PQ measurement systems using smart sensors.

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## 1. Introduction

As more and more electronic equipment enter the residential and business environment, the subjects related to Power Quality (PQ) and its relationship to vulnerability of installations is becoming an increasing concern to the users. The two main aspects of PQ are:

- Technical PQ, which includes: Continuity of supply or reliability (sustained interruptions) and Voltage Quality (VQ), that is voltage level variations and voltage disturbances.
- Commercial services associated to the wires are regulated (such as the delay to get connected to the grid, etc.) as well as commercial services for energy retail to regulated customers.

Sustained interruptions, which occur when voltage falls to zero for more than one minute, are the reliability problem with which most electricity consumers have the greatest direct experience and are the key phenomena measured in traditional utility service quality and reliability statistics. Indices such as and System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index respectively (CAIDI), do not capture PQ perturbations.

Assessment of VQ and power disturbances involves looking at electromagnetic deviations of the voltage or current from the ideal single-frequency sine wave of constant amplitude and frequency. VQ problems commonly faced by facilities operations include transients, sags, swells, surges, outages, harmonics, and impulses that vary in quantity or magnitude of the voltage [1]. A consistent set of definitions can be found in [2]. The quality of the power

☆ This work was funded and supported by the Andalusian Government towards the Research Unit PAIDI-TIC-168, and by the Spanish Ministry of Science and Innovation via the project TEC2009-08988.

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doi:10.1016/j.measurement.2010.02.009

supply delivered by utilities varies considerably and depends on a number of external factors. Things like lightning, industrial premises which apply and remove large loads, non-lineal load stresses, inadequate or incorrect wiring and grounding or short circuits caused by animals, branches, vehicular impact and human accidents involving electric lines. Some power providers seek to determine compliance with limits established in standards such as [3].

Among all categories of disturbances, the voltage sag (dip) and momentary interruption are the nemeses of the automated industrial processes [4]. Voltage sag is commonly defined as any low voltage event between 10% and 90% of the nominal RMS voltage lasting between 0.5 and 60 cycles. On the other hand, voltage swells (which are not so common) do not normally disrupt sensitive load, but can cause harm to equipment. Momentary voltage interruption is any low-voltage event of less than 10% of the nominal RMS voltage lasting between 0.5 cycles and 3 s. Voltage sags can be caused by natural events (e.g., trees falling on power lines or lightning striking lines or transformers), utility activities (e.g., routine switching operations or human error), or customer activities (e.g., starting of large motors). Voltage sags at a customer bus are different depending to his location in the electrical network [5]. Because of the short duration of these PQ events, residential customers are rarely aware that a VQ event has taken place. However, for many industrial customers, they pose a far more significant problem than outages because of their much greater frequency of occurrence and overall because of that their incidence can cause hours of manufacturing downtime [6]. It has been discovered that the 85% of power supply malfunctions attributed to poor VQ are caused by voltage sag or interruptions under one second of duration.

Some major problems associated with unregulated line voltages (in particular, long-term voltage sags) include equipment tripping, stalling, overheating, and complete shutdowns of sensitive equipment if it is designed to operate within narrow voltage limits, or it does not have adequate ride-through capabilities to filter out fluctuations in the electrical supply. These subsequently lead to lower efficiencies, higher power demand, higher cost for power, electromagnetic interference to control circuits, excessive heating of cables and equipment, and increased risk of equipment damage. The need for line voltage regulation still remains a necessity to meet demands for high industrial productivity. There are several conditioning solutions to voltage regulation, which are currently available in the marketplace. Among the most common are Un-interruptible Power Supply systems (UPS). Recently, new technologies like Custom Power devices based on power electronic concepts have been developed to provide protection against PQ problems [7]. However, the most significant barrier to improving the PQ is the lack of contemporaneous and historical PQ data [8].

The norm IEC 61000-4-30 [9] has been established to define the methods for measurement and interpretation of VQ parameters [10]. For each relevant type of perturbation a measurement method is established. Two different classes of measurement devices are defined according to the accuracy. Class A devices are used when precise measurements are necessary. For example, for contractual applications, verifying compliance with standards, resolving disputes, etc. Class B measuring instruments are used to determine statistical values and regulate/correct errors (troubleshooting). A proper monitoring system that is capable of observing PQ phenomena on a continuous basis is needed since the occurrence of a power disturbance is highly unpredictable [10].

The main characteristics and trends in advanced PQ measuring instruments can be found in [11–13]. Last years some experimental solutions have been proposed. In [14] the system is implemented by the use of standard LabView TCP/IP technology on a partial building low-voltage network that could be a simplified representative model of larger networks. As before, the system hardware in [15] consists of several PCs, each one hosting a data acquisition (DAQ) board, linked to the power system by a voltage transducer. The software implements different Virtual Instruments, using the well known NI LabView graphical programming language. Moreover, many utilities presently utilize dedicated PQ monitoring devices on the high and medium voltage stations to detect power quality events [16]. One of the milestone approaches was originally developed for the Electric Power Research Institute in the last decade [17]. However, the most widely extended infrastructure installed up to now is [18]. On the other hand, many automated factories presently utilize dedicated PQ measurement devices but on the point of common coupling (PCC) and with the exclusive purpose of determining the utility responsibility in PQ events.

Little empirical research, however, is available from the perspective of integrating distributed measurement inside the plant. In brief, is needed a low-cost system capable of observing PQ phenomena on a continuous basis. This is imperative since most of the hidden cause come from unlikely sources such as operation of existing factory equipment or incorrect wiring schemes. While all major events can be captured, this could result in excessive data from non-critical events. The maintenance engineer must then sort through this data to analyze the PQ disturbance. Manual methods are expensive, time consuming, and error prone. Custom software developed for each site for analyzing data, again, can be very expensive to develop, maintain, and-depending on their underlying architecture-difficult to expand. Thus, designing a system that has the ability of analyzing, condensing and interpreting voluminous raw data so that levels can be assessed against limits and can be easily expanded would become the most significant challenge in the PQ measurement arena. This paper introduces an innovative and extremely low-cost PQ web-based measurement system, which is suitable for continuous PQ measurement in an industrial or commercial plant.

The paper is structured as follows: Section 2 summarizes the strategy developed in the design. Sensor configuration is described in Section 3. The involved measurement errors are detailed in Section 4. Timing protocols compatibility is justified in Section 5. System operation is described in Section 6. Finally, conclusions are drawn in Section 7.

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