Multipurpose synchronised PQ meters for isolated environments

R. Zapata, S. Ortiz, A. Llombart, J.J. Melero and M. Sanz

Fundación CIRCE and Departmento de Ingeniería Eléctrica (Universidad de Zaragoza)
María de Luna 3, 50018 Zaragoza (Spain)
Phone: +34 976 76 24 02, fax: +34 976 76 22 26, e-mail: **melero@posta.unizar.es**

Abstract. The quality of the electrical power supply is now a topic of increasin interest. Due to that fact, it is becoming important to be able to measure the quality indexes in distributed and isolated environments: electrical substations, network nodes, wind farms and so on.

Distributed power quality meters have been described previously in the literature [1,2]. In this paper, a system capable of performing these kinds of measurements is presented. It is a multipoint, multipurpose, synchronised and distributed power quality instrument, able to work even in isolated environments.

The main contributions of the system presented here are the capability of working in isolated environments and the synchronisation method it employs between individual meters.

Key words

Power quality, distributed systems, wind turbines, renewable energies.

1. Introduction

Nowadays electrical energy power quality (PQ) is getting more and more interest. The proliferation of renewable power sources, especially wind energy, may considerably affect the supply network, because these types of sources can present random generation.

These situations are usually analysed by computer simulations using software tools like PSS/E. In order to validate the models used for the simulations, real data from the electrical grid would be invaluable. These data should contain information about the electrical and quality variables at different points of the network requiring a kind of PQ meters not available in the market.

Different solutions of distributed systems have been presented in the literature [1,2]. Both of them need a LAN (Local Area Network) in order to synchronise the measurements at different points. This paper presents a distributed measurement system capable of acquiring multipoint and synchronised PQ data even among several isolated nodes such as wind farms, electrical substations, electrical network nodes, where a LAN would be inpractical. The meter acquires data subjected to the international standards of power quality, measuring all the required parameters and indexes [1-4].

A flexible and adaptable instrument has been obtained, which can be applied to a wide range of measurement situations. The same system used for PQ monitoring [5] is used to characterise the power quality of wind turbines where it is necessary to measure not only electrical parameters but also environmental variables: wind speed, wind direction, pressure and temperature [6].

An example is presented in Figure 1, where a complete group of meters can be installed in different places in a wind farm. Every single instrument is synchronised with its peers, and the meteorological data are collected via serial communication. Thus, with the same multipurpose instrument, it is possible to test the power performance of a wind turbine and to measure simultaneously the power quality at different nodes of the electrical grid.

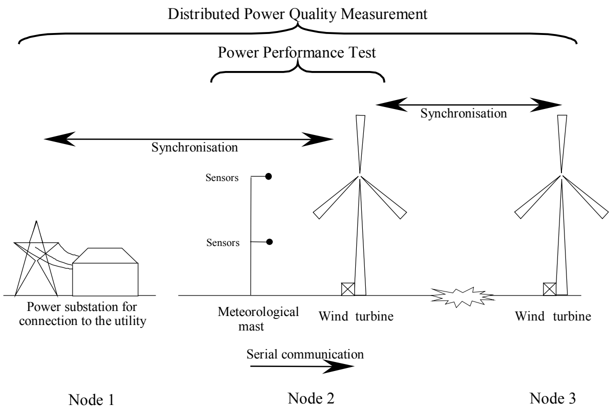

Fig. 1. Arrangement of the meteorological mast, the electrical substation and the wind turbines

2. Hardware

Each individual instrument consists of a computer hosting a DAQ (data acquisition) board, equipment to guarantee the power supply (UPS), a module to protect from damage caused by over-voltages, and a watch-dog for monitoring and controlling stability and general operation. The computer performs three main tasks. The first one is to control the acquisition system, the second, to process the acquired data when needed, and, finally, the third to communicate with other systems that are connected in different nodes of the power network.

Figure 2 shows one of these individual equipments, where it is possible to observe the signal inputs (bottom) and the human interface (screen and keyboard). It contains all the modules, the intercommunication buses, the power supply system and the central process unit.

Fig. 2. General view of the system

Each individual equipment is able to measure three different types of signals, analogue and digital inputs and meteorological data (via a serial port). Every type of input is configurable using a simple text file.
The digital inputs are used to obtain the operation states of the analysed system. The analogue inputs perform the acquisition of pure electrical signals, voltage and current, associated with the measurement of the electrical power and other kind of variables needed in some of the operation modes of the system. As an example, in power performance mode, the system acquires voltages, currents, pitch and the angular speed of the rotor in a wind turbine.

The DAQ board is linked to the power system through voltage and current transducers. These transducers are voltage and current transformers that electrically isolate and adequate the signals to the ± 5 V inputs of the DAQ board.

When meteorological data are required, they are registered by a Data logger, installed at the meteorological mast, and transmitted to each single system using serial communication. The meteorological variables registered are wind speed and direction, air temperature and barometric pressure.

The main specifications are shown in Table I. The system has been calibrated in the Laboratory of Electrical Metrology of the University of Zaragoza, accredited by EN 45.001.

TABLE I. - Specifications

Analogue inputs (single referenced)	16
· Voltage range (up to 6 channels)	± 5V
· Current range (up to 6 channels)	0-5 A
· Resolution	16 bits
· Sampling rate	6400 Hz
Digital inputs	8
Power supply (with integrated UPS)	240 V AC
Communications	
· RS-232	9.6 Kbps
· GSM	9.6 Kbps
· Ethernet	10/100 Mbps
GPS	
· Update rate	1 Hz
· Accuracy	UTC 50 ns

3. Software

The control and acquisition software has been developed with the National Instruments LabVIEW graphical programming environment. Each task has been coded as an individual software module (called VI in LabVIEW) that communicates with the other processes through TCP/IP sockets. This architecture allows the creation of different modules for different tasks in an easy way, improving the scalability of the system to adjust it to different measuring situations.

The block diagram showing the different modules and the inter process communications (IPC) is represented in Figure 3. As can be seen, there are two modules, "LOG" and "ADQ", which acquire raw data. The first one deals with meteorological data, when they are needed, received from the Data logger placed at the meteorological mast, via the serial port. The second one manages the DAQ board, retrieving digital and analogue signals. Both of them transmit the information to another module, called "ANA", establishing a TCP/IP socket. This last module analyses the raw data in order to obtain the relevant information: associated time, RMS value, amplitude, frequency, phase, mean value, standard deviation, electrical power...

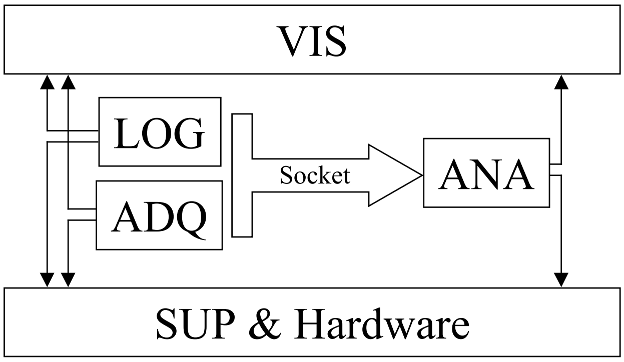

Fig. 3. Block diagram of the system

The master module "SUP" checks the correct operation of the other modules, and initiates commands to maintain global stability and let the user interact with the system. The communication with the rest of the modules is carried out with sockets.
The module "SUP" also communicates with the hardware of the computer in order to control critical aspects such as power supply and stability of the system. This is performed via the parallel port of the computer.

Module "VIS" presents visually the waveforms, states and calculated data. This client module gets the information in the sockets communication from the modules "ADQ", "LOG" and "ANA".

The use of socket communications makes possible to run every module in a different location, thus improving the flexibility and robustness of the presented solution.

Every module has the same internal structure: core, communications, control, configuration and reporter. The configuration of every module is made by text files. The sub-module "reporter" logs the events during normal operation and notifies incidents.

4. Operation modes

The system can operate simultaneously in different operation modes and is adaptable to the specifications of each measuring problem. These modes are:

A. Recorder Mode

In this mode (Figure 4), the input signals are processed every eight periods in order to calculate the typical electrical parameters. Some of these parameters are RMS value, electrical phase, mean value, frequency …

Fig. 4. Screen shot of the Recorder Mode

The meteorological data are acquired at 1 Hz. Both kinds of data, electrical and meteorological, and the states of the measured system are stored in ASCII files, and classified according to the retrieval date.

B. Oscillograph Mode

In this operation mode (Figure 5) raw data are measured and stored continuously (without any gap between contiguous data) in binary files containing waveforms of the sampled signals.

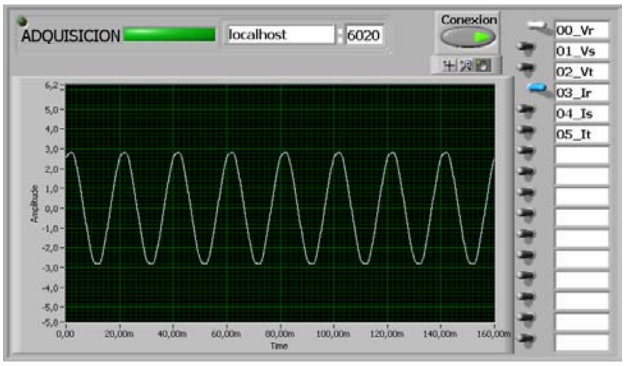

Fig. 5. Screen shot of the Oscillograph Mode

C. Power performance Mode

Using this mode of operation it is possible to acquire and analyse the data in order to test the wind turbine power performance according the criteria given by the standard IEC 61400-12.

The signals that come from the nacelle, the meteorological mast and the power system of the wind turbines are collected into the instrument placed in the base of each wind turbine. The basic scheme of the signals is shown in Figure 6.

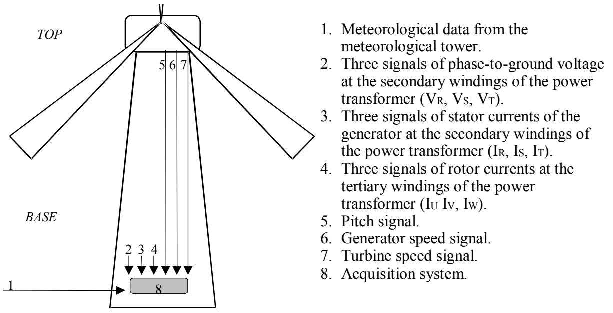

Fig. 6. Scheme of the wind turbine signals

5. Communications

There are two types of communication modes between different meters, both of them based on the TCP/IP socket protocol: Ethernet (LAN) and cellular phone (GSM). The LAN mode is very fast and distributed systems with this communication mode have been described previously [1,2]. On the other hand, the GSM mode is characterised by its low data rate, 9.6 Kb/s with GSM networks, making it impossible to maintain a high data flow between different instruments. The main characteristic of the proposed system is the capability of using this communication mode minimising the data transferred through the GSM link.

The method allows several instruments to be interconnected. As a result, a network is created without needing wired hardware. Two different topologies are proposed: a scheme based on token ring, and another based on a central server.

The first topology offers the advantage of more flexibility to add new members, but increasing the complexity of the software in every module to prevent problems in the GSM network. Note that with this mode of operation there is neither a master system nor a slave; all of the meters act as master or slave depending on the information to be exchanged.

The second topology presents the drawback of the dependence on the correct operation of the central server. Thus, without testing either topologies in a real measuring situation, the token ring based scheme appears to be the more appropriate.

A cyclic buffer of the acquired data is implemented in each individual system. When one of the meters detects an event, it selects the time frame in which the detection occurs and starts the communication with its counterpart systems, transmitting both the time and the meta-information of the event.

When a system receives a remote event or detects a local one, it transfers the data associated with the time frame from the memory ring to the hard disk.

6. Synchronisation

With this software architecture it is very important to have the same time in all the systems. Due to the different clock accuracy of the Operating System, the Data logger and the DAQ board, and also between different meters, it is necessary a good and universal time reference.

This is performed attaching a GPS receiver to each system giving final time accuracy better than 1 ms.

The time of the GPS is used to synchronise the time of the Operating System. From it, the DAQ board gets the correct time and the Data logger is synchronised every hour via serial communication using the proper commands.

7. Conclusion

In this paper, a multipoint, multipurpose, synchronised and distributed power quality instrument, capable of working even in isolated environments, has been presented.

The solution, a flexible and adaptable instrument, can be applied to a wide range of measurement situations: PQ monitoring, characterisation of the power performance of wind turbines, correlation among different electrical network nodes, logging of meteorological variables, recording of local and remote events...

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