

A new tool for power performance characterization

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Abstract

A new integrated measurement system for power performance characterization has been developed by the Electrical Engineering Department of the University of Zaragoza, in collaboration with CIRCE (Centre of Research for Energy Resources and Consumption).

This integrated measurement system is specifically designed for carrying out power performance tests in wind turbines according to international standard IEC 61400-12-1:2005. Its functionalities include getting an updated view of the state of current test, immediately obtained on line no matter the distance. User-friendly interface enables to configure particular test conditions and, as a result, offers a technical report when test requirements are satisfied.

Key words

Wind energy, wind turbines, measurement system, power performance, power quality.

1. Introduction

Nowadays, wind energy clearly supposes the main renewable energy in electricity generation, excluding hydroelectric power, in most developed countries, and especially in Spain [1]. The needs for using alternative energies, besides traditional energies such as thermal plants, in order to diversify primary energy sources and eventually reduce atmospheric emissions, and a quick technology evolution have led to a wide implementation of this energy, turning into a growing-up industry.

As a consequence of this fact, new challenges have appeared in the energy system sky line. Energy distributors have to face to the great deal of evacuating all the energy generated by new wind farms and how to integrate these discontinuous sources in the general power grid. Harmonic presence, due to variable speed wind turbine converters, or flicker emission are two of the main power quality parameters affecting to installed wind farms, and limitation levels have been established to an effective connection can be done [2]-[7].

In addition, it has a special relevance to know how wind turbines behave at a specific location, once they have been erected and turned on at the wind farm, under environmental conditions that are usually far from those present in previous tests made by manufactures in the laboratory. According to that, new standards and procedures have been developed to carry out measurements and tests in electricity producing wind turbines in fields of acoustic noise, power performance and power quality [8]-[10].

Wind turbine tests require collecting simultaneously electrical and meteorological data. Measurement systems used for this purpose usually synchronize and treat all collected data at a later stage, presenting the inconvenience that the state of current test cannot be checked in real time [11]-[12].

In fact, in most cases, measurements in power performance and power quality tests are collected by independent devices (one for electrical data and another for meteorological magnitudes), and joined in a second step. No specific integrated systems are used [13]-[16].

2. Measurement system overview

The measurement system developed in our laboratory presents a whole of two complete 3-phase inputs, including neutral wire. Voltage range reaches 1000 volts rms per phase, a proper value to measure directly the voltage of most usual generators. Current range goes up to 5 amperes, matching to most current measure transformers. In both cases, data resolution is 16 bits, with a simultaneous sampling rate of 6.4 kHz per channel.

Besides the main voltage and current inputs, there are six auxiliary analogue entries which can be used to monitor some other signals, such as yaw position, pitch angle or any other parameter whose study may be interesting.

Additionally, it can be useful monitoring some digital signals (0-5 V dc), so the measurement system provides a parallel port accepting that voltage range.

Meteorological data are collected in real time by a specific serial port, and synchronized with electrical data thanks to a GPS device. According to that, time resolution is around microseconds.

External communications include Ethernet if available and mobile phone (GSM/GRPS). Figure 1 shows actual aspect of our integrated measuring system.



Figure 1: Integrated measurement system.

When monitoring power quality, an adjustable trigger allows getting at the same time information in several power grid points, which can be used to obtain an updated photograph in every single moment [17].

Using a modular software structure takes the advantage of the fact that new implementations can be set up on the basis of the same platform, so adaptations to specific requirements and standard changes can be easily adopted.

When test requirements are satisfied, a final report is automatically generated, presenting the information required according to the standard. It is also possible, if user select the option, to generate an incomplete report with available data although test requirements are not met.

3. Hardware description

The electrical inputs are connected to two conditioning PCBs, which are the responsible for turning voltage and current inputs into a voltage that is within the nominal range of the data acquisition card.

Electrical data, coming from the data acquisition card, as well as meteorological and digital data, received through specific ports, are introduced into the main-board, as shown in Figure 2.

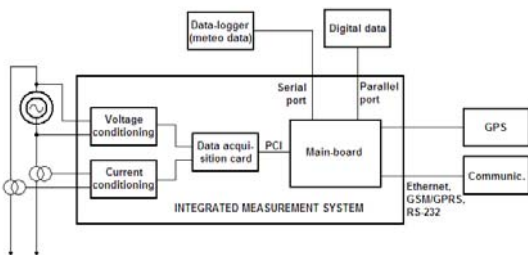


Figure 2: Hardware lay-out.

For storing all collected data, the measurement system is provided with a hard disk supported on four silent-blocks, letting its movement without damaging it. Using a laptop main-board and a laptop hard disk, occupied space is reduced and measurement system size may be shortened.

A PC power supply converts AC 230 V grid voltage to DC 12 V, 5 V and ground. Additional power supplies generate the rest of DC required voltages: 24 V, 15 V and -15 V. The total measurement system consumption is about 100 watts.

A DB-25 parallel port (female, not male as digital signals port) is located on the rear panel, assigned to connect the GPS antenna. Similarly, the GSM antenna may be connected to its respective thread. A cell phone SIM card should be placed in its slot (Figure 3).

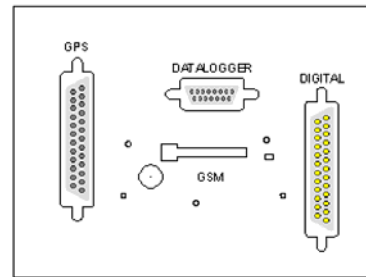


Figure 3: Rear panel connectors.

On the front panel, an ethernet connector allows connecting the measurement system to a local area network (LAN) and/or Internet. On this panel, VGA and PS2 connectors let using a monitor and a keyboard/mouse for operating on the system. Two USB connectors multiply storage and interacting chances: external hard disks, pen-drives, memory cards, printers or CD/DVD readers can easily be used (Figure 4).

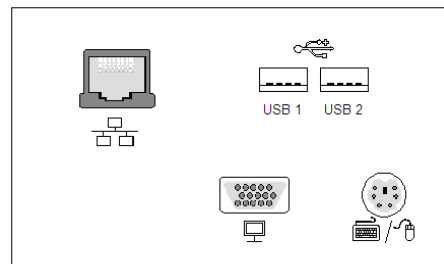


Figure 4: Front panel connectors.

4. Software description

All software applications are developed on GNU/Linux, programmed in language C and implemented modularly. Communications are set using TCP/IP protocols.

Daq application is the responsible for acquiring electrical data transmitted by the data acquisition card. *Meteo* is in charge of acquiring meteorological data received from the data-logger through the serial port. *Sincro* application gets GPS precise time and synchronizes both data, putting together in a unique string. Power performance and power quality applications operate on *Sincro* data (Figure 5).

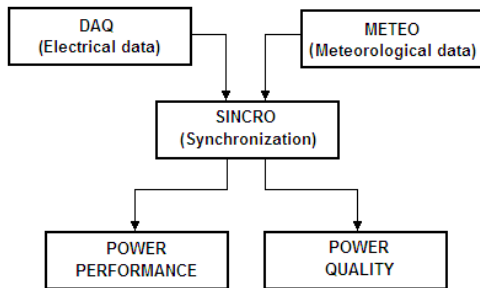


Figure 5: Software diagram.

At a higher level, a visual interface shows processing data and test configuration in real time. Visual interface is denominated as GUI (Graphical User Interface), and has been developed in Java.

Figure 6 presents an example of *Daq* visualization when only analogue channel number 6 is active. In Figure 7 an example of *Meteo* visualization is presented, covering two anemometers and wind vanes, a thermometer, a barometer, a hygrometer and a rain sensor.

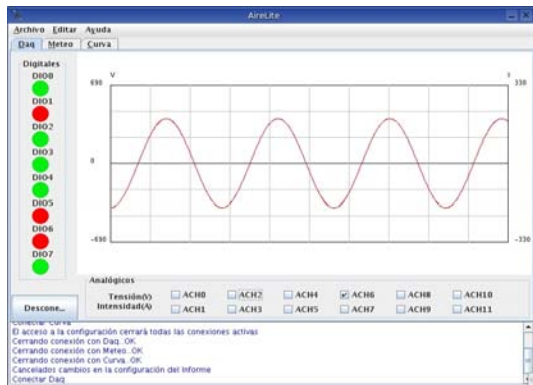


Figure 6: Electrical data visualization.

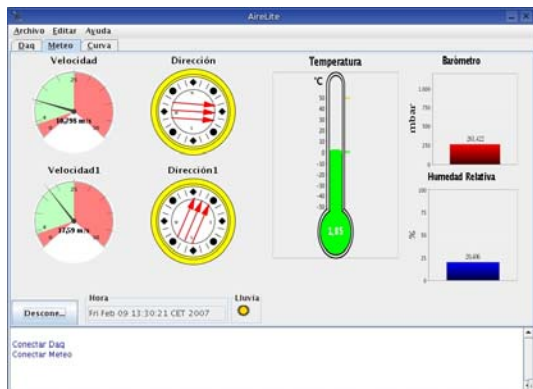


Figure 7: Meteorological data visualization.

Communication appliances (Ethernet, GSM) let the user checking the state of the current test from distance at any moment. When test requirements are satisfied, a final report is automatically generated, presenting the information required according to the selected standard. It is also possible, if user select the option, to generate an incomplete report with available data although test requirements are not met.

5. Power performance test

The last international standard IEC 61400-12-1 [9], released on December 2005, provides guidance in the measurement, analysis, and reporting of power performance testing for electricity producing wind turbines. The use of a specific procedure and methodology allows comparisons between different turbine models or different turbine settings can be made.

Wind speed and direction at hub height must be measured, and air density must be calculated using temperature and atmospheric pressure measurements. Wind speed or active electric power values are normalized depending on a pitch control is set or not.

Selected data sets (wind speed and net electric power) are sorted in intervals, called “bins”, of 0.5 m/s. Each bin is completed when includes at least 30 minutes of sampled data. Figure 8 shows average values and the state of all considered bins (those marked are completed), and presents a graph of the measured power curve.

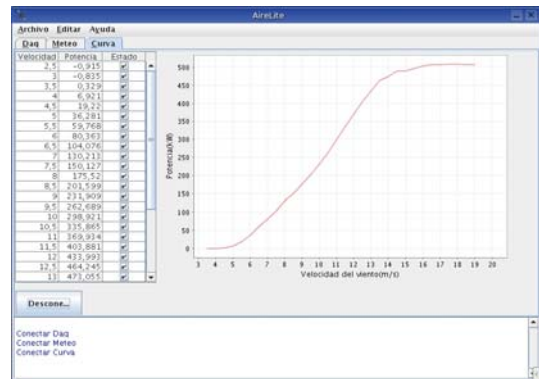


Figure 8: Power performance curve.

When power performance test is finished, additional results are obtained: annual energy production (AEP) and power coefficient C_p . AEP is estimated by applying the measured power curve to different reference wind speed frequency distributions. Parameter C_p is calculated as the ratio of the electric power output to the power available in the free stream wind.

6. Power quality test

IEC 61400-4-30 [18] defines the methods for measurement of power quality parameters in power supply systems in general.

The considered power quality parameters include power frequency, magnitude of the supply voltage, flicker, voltage dips and swells, voltage interruptions, transient voltages, supply voltage unbalance, harmonics distortion.

Nevertheless, a specific power quality normative is applied in wind turbine systems. The international standard IEC 61400-21 [10] describes measurement procedures for quantifying the power quality of a grid connected wind turbine and the procedures for assessing compliance with power quality requirements.

In addition, Spanish Wind Energy Association (AEE) has edited a "Procedure for measuring and evaluation of wind power plants response to voltage dips", P.O. 12.3 [19]. This operation procedure has the double objective of assessing wind power systems are not disconnected when a voltage sag appears and checking power and energy consumptions (both active and reactive) are not greater than their established limits (see Figure 7).

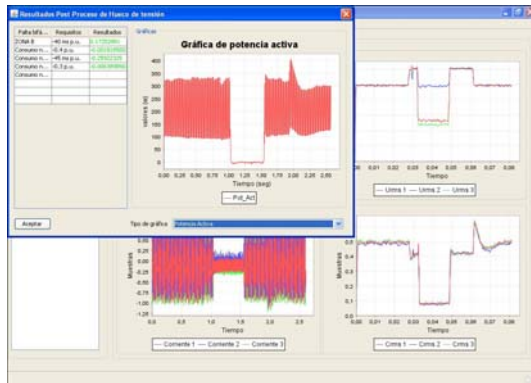


Figure 7: Voltage dip visualization.

When evaluating power quality parameters, time resolution is more critical than it is in power performance tests. The use of a GPS device is totally justified for power quality evaluation, especially for measuring transients. Our measurement system offers a time resolution of less than 1 μ s, sampling at a rate of 128 samples per second.

Analogously to power performance test, for assessing power quality characteristics in wind turbines, it is necessary synchronizing electrical and meteorological data. Here meteorological data only refer to wind speed data. As related in Software description, our measurement system automatically synchronizes both types of data.

Furthermore, power quality tests are often used in order to search and identify waveform distortion sources in a power grid [20]-[21]. Several tests are carried out at different points with the objective of considering or rejecting power generators or loads as distortion sources.

However, it should be taken into account that electrical conditions are variable in time due to changes in production and loads, and it may be hardly difficult to insulate one potential distortion source from the rest when evaluating it.

In our integrated measurement system, an adjustable trigger allows getting at the same time power quality information in several points of the analyzed power grid.

Using a GPS device, time precision is identical in all tested points and results are completely comparable. Test can be repeated evaluating different production/loads ratios, and distortion sources may easily be identified.

7. Photovoltaic power plants

The measurement system can be also used for evaluating the performance of other renewable energies sources, such as photovoltaic plants. In this case, the fundamental meteorological variable will be the solar radiation, whose value will be measured by a specific sensor called pyranometer.

Voltage and current, no matter if coming from one side of the inverter or from the other one, can be introduced in the measurement system, since it is prepared for use in alternating current (ac) as well as in direct current (dc).

Conclusions

It has been proposed an integrated measurement system, especially designed for carrying out power tests in wind turbines, but not only in wind turbines since it can be used in any other generic power grid.

The integrated treatment of electrical data and meteorological data results more effective and functional that traditional way of acquisition by two different devices and later synchronization of both types of data.

Thanks to the incorporation of a GPS device, time resolution is high and the sampling rate of 6.4 kHz enables a proper measurement of transients and waveforms.

Ethernet and mobile phone communications let the user not moving physically to the analyzed system, but configuring, knowing the state and getting a final report of the test on line in real time.

An adjustable trigger allows getting at the same time power quality characteristics in a sequence of points, providing significant information for identifying potential distortion sources.

Modular software structure makes feasible that new procedures or standard requirements can be easily adopted, on the basis of the same previously installed platform.

The measurement system has been successfully proved in different wind farms in Spain, for obtaining the power performance test and checking the response of wind power plants to voltage dips.

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