A Test Facility for the Data Acquisition and Signal Analysis of the Wind Power System

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***Abstract*—A test facility for monitoring the performance of the wind power system is presented in this paper. Based on the LabVIEW software and the NI data acquisition card, the proposed system has the functions of data acquisition, data storage and signal analysis of the wind power system. This entire system involves the integration of a personal computer, data acquisition card and relative conditioning circuits. It is proved by experimental results that it can effectively reflect the real function state of the system. The proposed system permits the rapid system development and has the advantage of flexibility in case of changes; it can also be extended to control the wind power system.**

I. Introduction

ALONG with the rapid development of renewable energy technology, a significant amount of wind power systems were installed during the last two decades. To better evaluate and optimize the performance of such a system, it is necessary to get detailed information of the meteorological and electrical parameters [1, 2, and 3]. This test system proposed is designed to collect and store such data as well as monitor its real time performance, using LabVIEW software. The data acquisition (DAQ) of LabVIEW can measure a wide variety of signals while in this proposed system, voltage, current and wind velocity is collected. In order to evaluate the quality of the power generated by wind turbines, the signal analysis function is also designed to execute the Fourier transform and the autocorrelation function. Sensors are used to transfer other kinds of signals (like wind velocity) to the signal of voltage while the conditioning circuits are used to force the voltage signal at a definite range that is suitable for the data acquisition card to collect. The sensors used in this system contain the voltage transformer, the current transformer and the anemograph. The voltage transform is used to measure the lone voltage of the wind turbine and the current voltage is designed to measure the output DC current that flows out of the rectifier. Anemograph should be waterproof and voltage-output which is easy for the data acquisition card to collect. Fig. 1 points out the hardware architecture of the data acquisition system.

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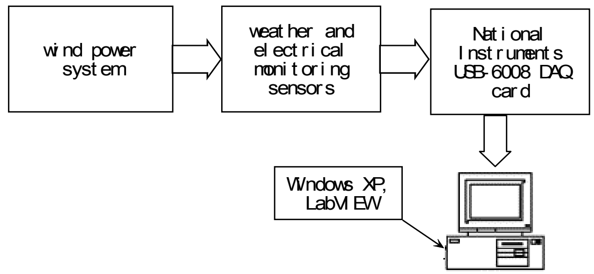

Fig. 1. The architecture of the data acquisition system

LabVIEW is a kind of virtual instrument based on PC and data acquisition card, and its special function can be determined by different customers according to their needs. Compared with traditional instrument, the virtual instrument will significantly shorten the developing cycle of a system using software programming rather than hardware equipment. The system described in this essay used data acquisition card NI-USB 6008 to get the data which has experienced the conditioning process, including temperature of PV array, current and voltage generated by PV array . NI USB 6008 has 8 analog inputs with 2 analog outputs. Its maximum sample rate is 10kS/s and its input voltage range is ±10V. As most of signal collected in this system is DC voltage signal, the sample rate is enough for use in this system.

II. Hardwaree

Wind power system is composed of a wind turbine, a rectifier, a battery charger, a battery, an inverter and DC/AC loads; the facility used for get the wind velocity signal is the anemograph [4], shown as the Fig.2.

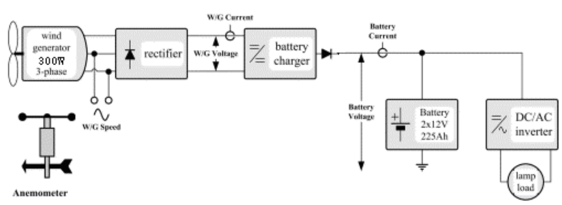

Fig 2. The hardware of the measured system

Wind turbine generates energy in the system. The rated power of the wind turbine that is been measured here is 300W. The rectifier is used to transfer the AC voltage generated by the wind turbines to DC format. The battery charger is also important equipment used in the system whose main responsibility is to detect the input voltage and current to control the charging and discharging of the storage battery,

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the voltage of which can be chosen according to different systems [5, 6]. When the power generated by the system exceeds the load's demand, the controller sends the required power to the load while at the same time stores the residual power in the battery. When the power generated by the system is insufficient to meet the load's demand, the energy stored by the battery will be used to maintain the stabilization of the load. As to the battery, Lead-acid storage battery is preferred for its low cost, high capability and free maintenance. The system is capable of providing not only steady DC voltage to drive the DC load but also the AC voltage to drive the AC load, towards which the Inverter is used.

III. SOFTWARE DESIGN

The data acquisition card is controlled by a properly developed program using the LABVIEW software, running on the PC. It consists of two parts: (a) a graphical environment with components such as displays, buttons and charts in order to provide a convenient-to-use environment for the system operator, and (b) the block diagram, which consists of built-in virtual instruments (VI), performing functions such as analog channel sampling, mathematical operations, file management etc [7, 8, and 9]. The flow chart of the developed LabVIEW program is illustrated in Fig. 5.

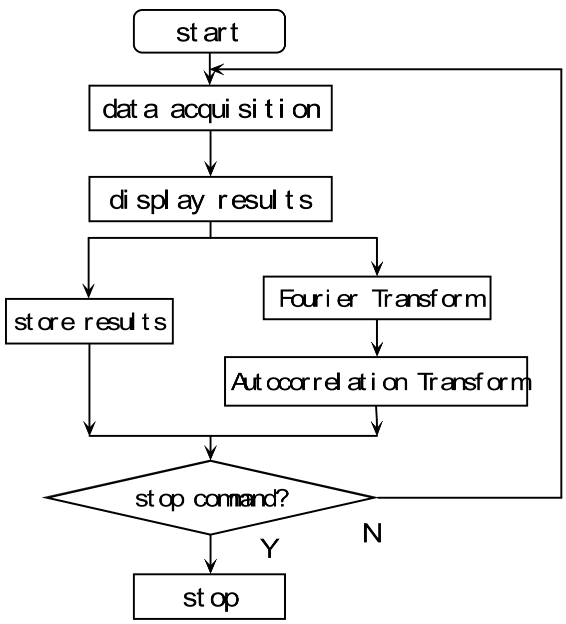


Fig. 3. Flow chart of the LabVIEW based testing system

Initially, all analog signals are sequentially sampled and the input voltage data is collected by the data acquisition card. Then the program shows the relative curves and values on the front panel. The Fourier Transform is introduced as a mean to evaluate the quality of the power provided and the autocorrelation function is used to detect the periodical component of the signals. Also, the program performs every 1 min and stores the values on the PC hard disk, in files named with the current date. These files contain the exact time of the measurement along with each measured parameter identification and value. The above described LABVIEW program runs continuously. Fig. 4 points out the front panel of the Labview program.

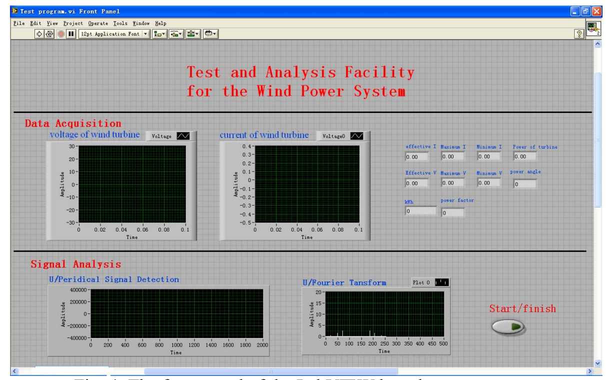


Fig. 4. The front panel of the LabVIEW based test program

A. Data Acquisition and Curve Display

In this proposed system, the main responsibility of the DAQ is to collect data at real time and send it to the relative virtual instrument to process and store collected data. The most frequently used method is using the DAQ Assistant, shown as in Fig. 5.

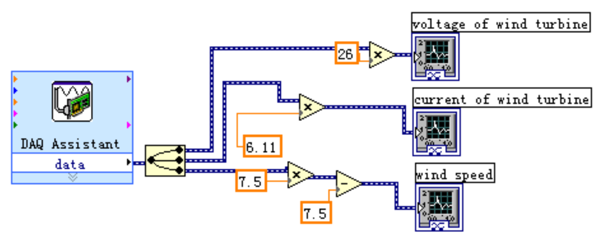


Fig. 5. The data acquisition part of the system

In the data acquisition part of a system, the DAQ Assistant is a simplified and effective way to get the data from the channels of a DAQ card. In the DAQ Assistant, the Acquisition mode is set to be "N samples" mode and the rate is set to be 1k Hz. The clock type is set to be internal which is more accurate and the "samples to read is set to be 1000 which signifies that in one second, 1000 data is colleted and sent out of the DAQ Assistant to an array. The "split signals vi" is used to split the signals to different types according to their channel numbers. Then the data getting out of the split vi are sent to graphs to display their curves.

B. Fourier Transform

The Discrete Fourier Transform is a frequently used method to determine the quality of the power generated by wind turbines, shown as in (1):

$$F(k) = \sum_{n=0}^{N-1} f(n) e^{-jkn\frac{2\pi}{N}} \quad (k=0,1,2\ldots N-1) \qquad (1)$$

Where $f(n)$ is the sampled sequence of the signal.

It can be seen from (1) that the effective value of each harmonic components can be derived after the Fourier Transform. Lots of harmonic components locating in the signal simply signify the poor quality of a wind turbine generation system. The part of Fourier Transform software design is shown in Fig. 6.

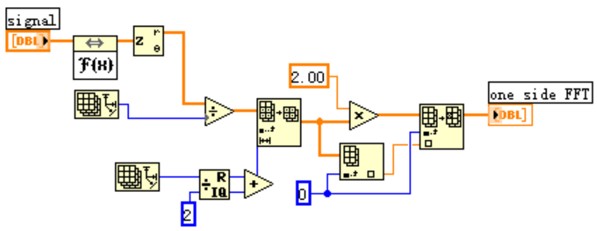


Fig. 6. The block diagram of the Fourier Transform part

The "FFT.vi" used is to change the signal to a bilateral Fourier Transform. However, the most frequently used FFT is the one-side FFT thus some codes are added into the block diagram to change it to a one side FFT, shown as in Fig, 6.

C. Autocorrelation Function

The autocorrelation function is usually used to detect whether there are periodical components in the signal and the value of the period [10]. If the input signal is:

$$y(t) = s(t) + n(t) = A\cos(\omega t + \varphi) + n(t) \qquad (2)$$

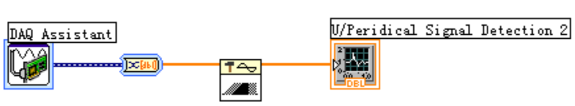
Its autocorrelation function is shown in (3):

$$\begin{aligned} R_Y(\tau) &= E[y(t)\cdot y(t+\tau)] \\ &= R_S(\tau) + E[s(t)\cdot n(t+\tau)] + E[s(t+\tau)\cdot n(t)] + R_N(\tau) \end{aligned} \qquad (3)$$

The correlation function can be expressed by (4).

$$\begin{aligned} R_S(\tau) &\cong R_S(\tau) = \frac{1}{T-\tau}\int_0^{T-\tau} s(t)s(t+\tau)dt \\ &= \frac{1}{T-\tau}\int_0^{T-\tau} A\cos(\omega t+\varphi)\cdot A\cos[\omega(t+\tau)+\varphi]dt \\ &= \frac{1}{T-\tau}\int_0^{T-\tau} \frac{A^2}{2}\cos[\omega(2t+\tau)+2\varphi]dt + \frac{A^2}{2}\cos(\omega t) \end{aligned}$$
(4)

If the noise signal is the standard white noise, the E[n{t}] and E[n(t+ τ)] is also changed to be zero, thus the E[s(t)n(t+ τ)] and E[s(t+ τ)n(t)] is also zero, simultaneously, the autocorrelation between the noises is also zero. The autocorrelation transform calculate the autocorrelation function of the input signal and the signal that delayed τ . It makes use of the irrelevance of the input signal and the noise signal to increase the signal to noise ratio. In LabVIEW software, an "autocorrelation vi" has been designed for this use, shown as in Fig. 7.



Fig, 7. The codes for autocorrelation transform

D. Data storage

The main work of the data storage step is to record the important data generated by the system, such as the effective value of the line voltage generated by wind turbine, the value of the DC current and the value of the wind velocity. The energy generated by the wind turbine daily, monthly and yearly are also calculated and properly stored in the computer disk. The code for data storage is shown in Fig. 8:

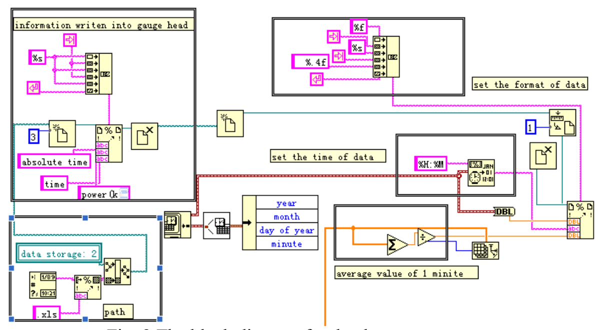


Fig. 8 The block diagram for the data storage part

First, the program asks the customer to indicate a path for the computer to store. The program will generate files according to the given path with ".xls" format by using the current date as the file name. Then the required information should be written to the gauge head of the excel file, which is equal to select a proper name for the first line of the excel file. Time information is also added into the generated files and the information of time and the relative stored data are synchronous. In order to store the data every minute, the average value of the data in one minute is calculated. The data format is all set to be4-digit numbers. The program for storing the daily, monthly and yearly energy generated by wind turbine is a little different; it is designed as a Sub-vi, shown as in Fig. 9.

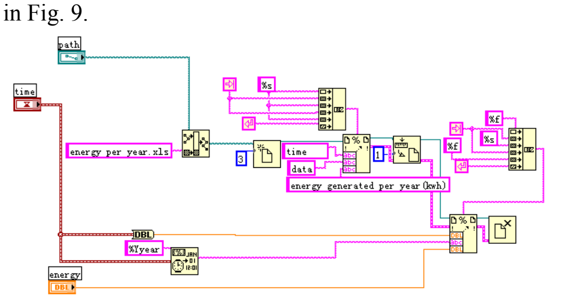


Fig. 9. The block diagram for the data storage of yearly generated power

The program will decide whether it is a new day, month or year now, by comparing the time information between now and a minute before. If so, the program will turn to store the calculated data in the hard disk.

IV. RESULTS AND ANALYSIS

Fig. 10 points out the collected wind velocity graph.

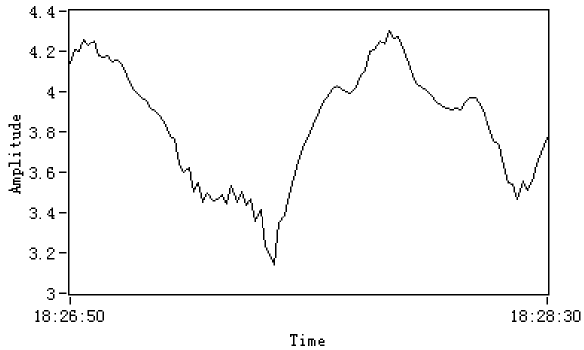


Fig. 10. The curve of wind velocity collected

As shown in Fig, 10, the wind energy resources of an area in rather unstable. It fluctuates from 3 m/s to 4.4 m/s in one minute. The output signal of wind turbine is decided by the wind velocity thus the voltage of wind turbine is also unstable. Fig. 10 shows the curve of wind turbine's voltage and the signal analysis of it under the wind velocity of about 5.5 m/s.

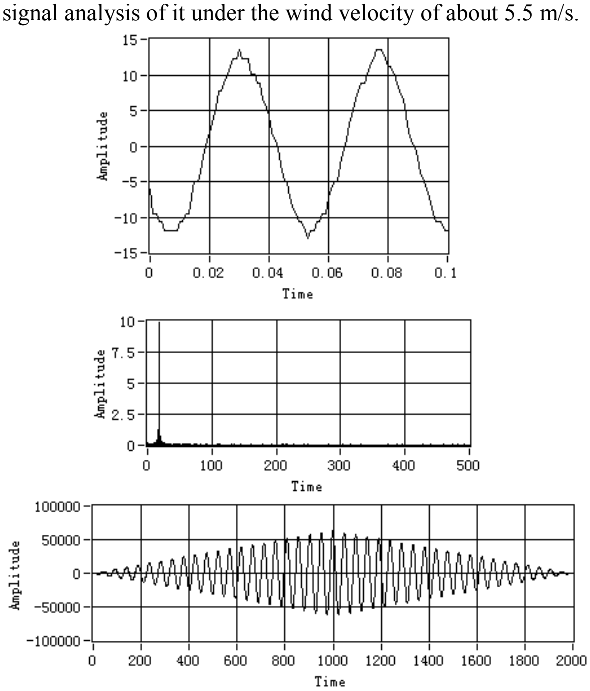


Fig. 11. The voltage of wind turbine and its signal analysis

It can be seen from Fig. 11 that the effective value of the output voltage is about 9.5 V when the wind speed is at 5.5 m/s. The result of the Fourier Transform shows that there are some harmonic components contained in the output signal, which is mainly between 10 Hz to 30 Hz. A strong periodical component is detected by the autocorrelation function and the result shows that the frequency of the AC wind turbine is about 20Hz. The generated file that named "2008-5-11.xls" is shown in Fig. 12.

	A	B	C	D
1	absolute time	time	power(kw)	wind velocity
2	3293329691	13:48	0.117	7.5002
3	3293329741	13:49	0.1043	7.4458
4	3293329801	13:50	0.1066	7.4867

Fig. 12. Part of the generated file for data storage

As can be seen from Fig. 12, the generated file stored the relevant data per minute and the file is used to provide information for the operation status of the wind turbine. With the wind velocity data stored in the hard disk, it is feasible to evaluate the wind power generation potentials of the local area. With the power data collected, the whole performance characteristics will be recorded.

V. CONCLUSIONS

The building of an integrated virtual instrument based data acquisition, signal analysis and data storage system is described. The system uses DAQ and LabVIEW software to process, collect and store data. Using LabVIEW and data acquisition card is proved to be a relatively new and efficient way of building adequate data acquisition systems for the renewable power system. The proposed system has the advantage of fast response and flexibility in case of changes and provides sufficient information in the hard disk for evaluations and further optimization. It can also be extended to the function of help controlling the wind power system.

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