

## Real-Time Simulation System of Wind Power Based On Virtual Instrumentation

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### Abstract

Wind energy is a powerful, clear, safe and renewable green energy resource. By this method, wind power generation can be done very quickly and easily. So this system would be used effectively for academical research without the usage of wind turbine and other devices in lab, and for industry training in wind plant without the usage of potential danger of checking huge wind device on the spot. Simulation Interface Toolkit(SIT) is essentially used to communicate and control wind power simulink model. The results confirms the performance of the real-time simulation system.the advantages in this methos are:fast-to-develop, easy-to-use, high speed data transmission and high efficiency.

### 1.Introduction

Wind energy is a renewable, non-polluting and abundant energy in the whole world. Many countries are steeping into the improvement and development of wind energy to reduce the problems such as global warming. Two types of wind energy usages are there, one is the use of original wind energy, and another is to transform wind power to electrical energy. Wind power is mainly used for producing electricity.

With the problem of population pressure, environment pollution and resource shortage and renewable energy,such as wind power, has become an Big issue and raised wide interest over the world in academical and industry field. As to make a better use of this green power, operating process of wind generation system should be studied specifically. However, in the academical field, due to the uncontrollable wind velocity and large size of wind turbine, it is sometimes dif to study wind power generation system in laboratory. In the industry field, it's always dangerous and unrealistic to educate workers or technology staff by checking those huge and distributed device on the spot in

wind plant. And they won't really know the theory and operation of whole wind generation system by

this way. Besides, when using the simulink model to study wind generation system, it would be found that simulation time is usually so short that it could not supply enough time for data observation and system operation. As a result, it's indispensable to develop a real-time system which could monitor whole wind generation system.

The paper is presenting a real-time simulation system which is focused on the whole system of wind power generation. The simulink model simulates all the essential parts of wind generation, including wind velocity acquisition, pitch control, wind generator control, gird connection and so on. With the assistant of Lab VIEW SIT and matlab real time workshop, the monitoring interface in Lab VIEW could exchange data with simulink model and make simulation system runs synchronously with wind generation simulink model. Because of Shared Variable and NI-PSP technology, it becomes much easier and more effective to communicate between different Virtual instruments (VIs) and store data to Citadel Database. The Citadel Database is divided into general database and alarm database separately to record different kinds of data and events for later handling.

The experimental results show that this invention has many advantages such as simple structure, high utilization efficiency of wind energy, low start-up wind speed, high equipment reliability and good maintainability. Virtual instrument (VI) is presently one of the most popular technologies in the field of measurement and control. The computer hardware and software technology, network technology, communication technology, which is combined together, provide foundation for the improving of virtual instrument .The VI technology will be the direction of the science of the measurement, control and instrument in the future.

#### 1.1.Labview Application Areas

The following are some of the application areas of LabVIEW:

**Simulation** - simulates physical processes

**Data Acquisition** - data acquisition from outside source

**Data Processing** - built in analysis library that includes signal generation, measurement filters, windows, curve fitting Probability and statistics, linear algebra, numerical methods

**Instrument and Control** – Virtual Instruments (VI)

**Program Development** – Object oriented/graphical programming

**ToolKits** - Fuzzy Logic, Internet, Signal Processing, Control Systems, etc.

## 2. Virtual Instrumentation Technology

The VI technology has already been applied to the field of power system, such as harmonic testing, short-circuit experiment, electric signal analysis and so on. Since the local circumstance of power plant is atrocious and complex, and the Distributed Control System (DCS), which is not apt to master for the enterprise managers, is difficult to attend to each and every aspect of a matter, one tele-monitoring and warning system which is based on VI technology for power plant is researched and realized in the paper. The virtual instruments have several advantages, such as cheapness, intelligence, convenience, friendly interface, easy secondary development, free function defining and so on.

The concept of Network Virtual Laboratory has been proposed only more than ten years, but many countries are energetically plunging into investigation because of the importance and broad application prospects, so some productions have been obtained. Many virtual laboratories are built by domestic and foreign researchers from different areas of research recently, for example: Remote oscilloscope and pressure vessel experiments have been developed by National University of Singapore; An automation virtual lab has been established by University of Hannover, Germany; A robot remote control system based on the C/S mode has been developed by School of Electronic Information of Shanghai Jiaotong University, etc.

Wind energy is a clear, safe and renewable green energy resource. Because it can be supplied inexhaustibly and always be used availably, it is exploited by countries all over the world and has gradually become a new energy type.

For the sake of developing practical researches of laboratory unceasingly and studying the Remote Measure and Control Technology, a platform of Remote Measure and Control System is developed based on general software LabVIEW and MATLAB.

### 2.1. LabVIEW Simulation Interface Toolkit

The Simulation Interface Toolkit is an add-on for LabVIEW software to provide the method for creating a LabVIEW user interface for a Simulink model, converting a Simulink model into a dynamic link library (DLL), and viewing the output data of the Simulink model. By combining the capabilities of Simulink and Real-Time Workshop with LabVIEW, the Simulation Interface Toolkit helps to import simulation models into LabVIEW.

Power disturbances arising within customer facilities have increased significantly due to the increasing use of energy efficient equipment such as switch-mode power supplies, inverters for variable speed drives, and more. The monitoring and data collection of power disturbances therefore has to be conducted at the users' premises. A configurable and programmable PXI/Compact PCI, high-performance PC with high-speed data acquisition units and VI software using LabVIEW can perform the required task.

### 2.2. LabVIEW DSC Module

The DSC Module is developed for help designing industry monitoring system. It extends the LabVIEW graphical development environment with additional functionality for the rapid development of distributed measurement, control monitoring application. The DSC Module could add alarming, scaling to the shared variable and log shared variable data to the Citadel database.

### 2.3. NI-PSP communication technology

NI Publish-Subscribe Protocol (NI-PSP) is a proprietary technology that provides fast and reliable data transmission in LabVIEW or with other devices. Network-published shared variables communicate between VIs through the Shared Variable Engine. The Shared Variable Engine uses NI-PSP data transfer protocol to write and allow users to read live data.

NI-PSP uses psp URLs to transmit data between VIs.

## 3. Structure of Real Time Simulation System

The structure of real-time simulation system of wind power is shown in Fig 1. The simlulink model of wind generation system generates a series of real-time data, such as wind velocity, blade angle, torque, apparent power, reactive power and so on. Then those simulation data are read by LabVIEW user interface using protocol TCP/IP via SIT Server

6011, which is started with the launch of Matlab. The indicators and controls in front panel of LabVIEW have a point-to-point connection with output of simulink model after communication completed. In LabVIEW, the acquired data are written to corresponding shared variable by Shared Variable Engine (SVE), which is a data processing engine that manages the use and connectivity of shared variables.

Software is the core of the system. It has excellent programming and defining ability. According to the factual needs, signals increasing and deleting, function extending are available then the expenditure of hardware reconstruction could be saved.

A kind of virtual instrument which is applied to the tele-monitoring and real-time warning system for power plant. The virtual monitoring and warning system was developed based on LabVIEW software of NI Company according to the running characteristics of the power plant. It can acquire the key signals, and realize some useful functions, such as real-time monitoring and warning and so on.

It may take the Distributed Control System (DCS) effective assistance. It can status and history operating record inquiry conveniently.

The increased requirements on supervision, control, and performance in modern power systems make power quality monitoring a common practice for utilities. Power quality is the set of parameters defining the properties of power supply delivered to the users in normal operating conditions in terms of continuity of supply and characteristics of voltage (magnitude, frequency, symmetry, waveform etc.). Current electronic devices, such as microprocessors, micro-controllers, sensitive computerized equipment or telecommunications equipment etc. use ground as the reference for all their internal operations and connect throughout the plant. This makes them susceptible to ground differences and to power quality problems. Power disturbances compromise product quality, increase downtime, and reduce customer satisfaction.

Essential requirements for a successful monitoring system include extensive data gathering, processing capabilities, easily understood reports, and universal sharing of information both within the utility and with the customer's facilities personnel.

NI-PSP is used to transfer data from one VI to another via shared variable nodes. The shared variables also copy all of data to Citadel Database, which is divided into general database and alarm database for different purpose. The data processing in LabVIEW is made by DSC module to realise the function of display, analysis, storage, alarm and data transmission between VIs.

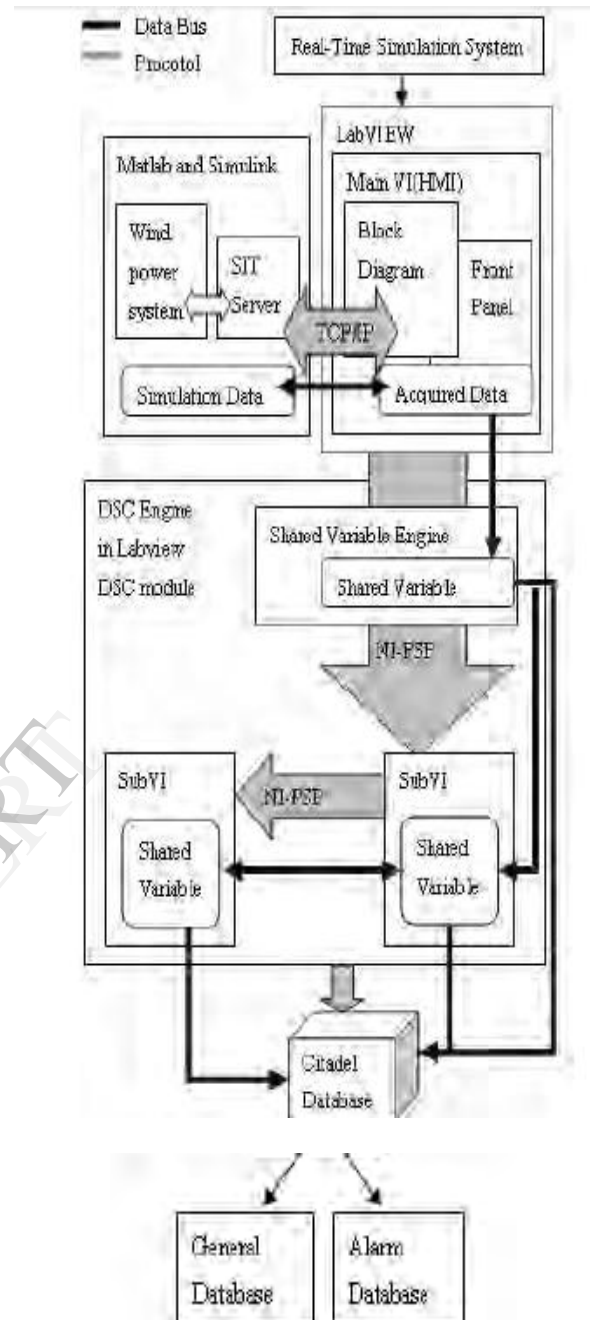


Fig. 1. Structure of real-time simulation system of wind power

## 4. Design of Real-Time Simulation System of Wind Power Generation

### 4.1. Simulink Design for Control

The closed-loop control strategy of wind generation system is designed. Before generator connecting to the grid, generator speed is controlled

by Speed controller A based on feed-back of generator speed and speed set.

Matlab is a high-performance language for technical computing and its simulink module can easily analyze model and simulate control systems[4]. In this simulink model, Simulink is working with the MathWorks Real-Time Workshop for real-time application.

In the present study, graphical programming of LABVIEW has been utilized to simulate and measure different harmonics, noise and impulsive transients in the sinusoidal voltage waveforms. Results have been displayed on instrument like front panels on a computer screen, called virtual instruments. With virtual instrumentation, engineers and scientists can reduce development time, design higher quality products, lower their design costs, and keep close watch on waveforms. This helps in efficient use of electric power, and system reliability is also improved at the same time.

#### 4.2. Simulink Design for Communication

Before establish the communication, the system environment must be checked to meet the need, that is the Matworks Matlab 6.0 or later, the Mathworks Simulink 4.0 or later, the Mathworks real-time workshop 4.0 or later, National Instrument LabVIEW 7.0 or later and NI-SIT 1.0 or 2.0 installed on the host computer. The Simulation Interface Toolkit(SIT) in LabVIEW provides a way to create a LabVIEW user interface that can be used to interact with a Simulink model.

Steps to make communication between labVIEW and Matlab/Simulink:

1. Configuring the simulink model.
2. Creating the LabVIEW monitoring interface.
3. Creating connection between the LabVIEW monitoring interface and the Simulink model.

#### 5. Simulation System Procedure Flow

The simulation system is programmed by LabVIEW 8.2 and its DSC module. The DSC module includes the following palettes: Alarms&Events, Engine Control, Historical, Security, and Shared Variables[5]. The program needs the design of user interfaces on front panel and graphic program on block diagram.

Virtual instrumentation utilizes simulation of power system monitoring using LabVIEW, a graphical programming language. By using the powerful tools of LabVIEW, 3-phase power signals and various types of disturbances are simulated within the G programming/coding. LabVIEW Environment basically consists of two parts: Front

panel and Block diagrams. Graphical and Data flow programming is the main characteristic of LabVIEW. All other properties like 'While' and 'For' loops, Arrays, Functions, Polymorphism is just equivalent to any other text-based language.

A virtual instrumentation system is computer software that a user would employ to develop computerized test and measurement system.

The main procedure of the system is described as follows:

- Data are acquired from Simulink model, the system must keep monitoring the status of grid for 10 min to make sure there is no problem before starting the wind generation system. The problem includes over-voltage, low-voltage, frequency out of the normal range and unbalanced three-phase voltage.
- If there is no problem after 10 min, the power generation system would be started automatically or manually. If any problem happens during that time, fault must be handled before monitoring for another 10 min.
- Keep waiting until wind velocity reaches 3m/s. Then the following mechanism could take an action, as yaw mechanism, pitch mechanism and Brake mechanism to get the generator speed up.
- During the procedure of grid connection and power production, both status of grid and generator should be monitored and analysed, specifically as voltage, current, torque, generator speed, apparent power, reactive power, temperature and so.
- Calculate production/consumption/yield, efficiency and utilization ratio by above data. If any of important data appears not in the normal range, the system alarms and gives warning to result the stop of system.
- All monitoring data, including general data and alarm data, would be stored in Citadel Database and later could be inquired and reviewed as history data.
- The aim of the present work is to develop an application in virtual instrumentation using LabVIEW to simulate and measure the voltage waveform disturbances and distortions in the form of harmonics, noise and impulsive transients etc. on front panel like computer screens.

#### 5.1. Block Diagrams of Labview Programming

It is a latest measurement/monitoring technology where all types of measurements are done on front panel created on PC screen. In real situations, data can be collected with the help of digital acquisition technique and given to PC through specific interfacing devices. Then this raw data can be processed or analyzed by using VI software, LabVIEW. It is

powerful VI software, which can acquire, analyze and present any electrical signal efficiently. This can be very helpful for studying, measuring, analyzing and controlling of power waveforms and for devising methods to avoid their harmful effects.

LabVIEW is a graphical development environment integrated by signal acquisition, measurement analysis and data display, which also supports development, debugging and running. The software modules of research projects are developed by LabVIEW and MATLAB.

The block diagrams of LabVIEW programming for the simulation system are shown in Fig 3.

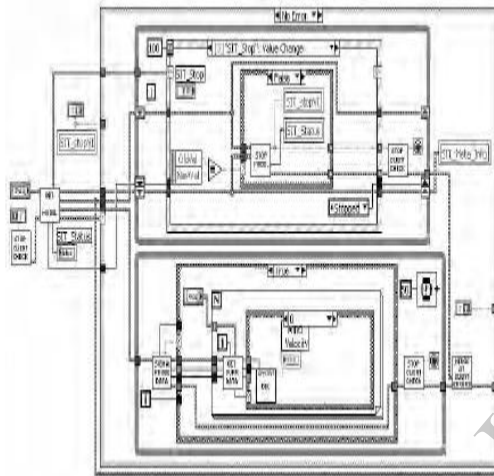


Fig.2.a. Communication between LabVIEW and Simulink

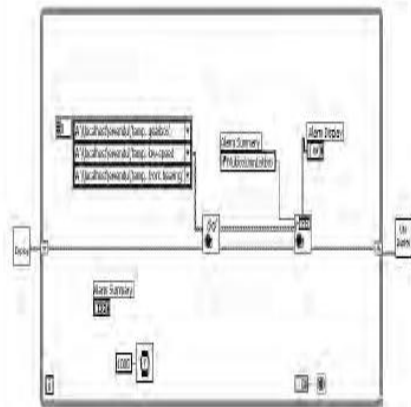


Fig.2.b. Warning and Alarm Display

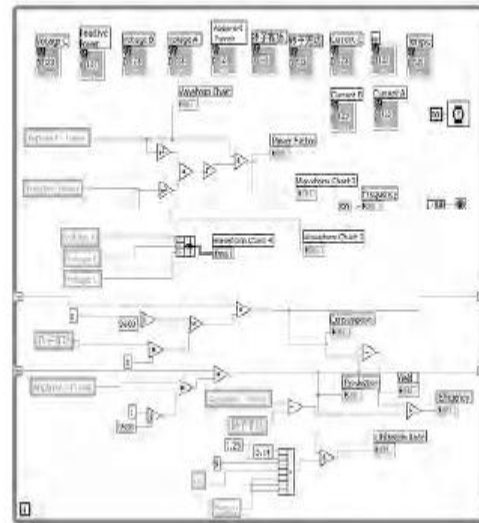


Fig.2.c. Data Transferring and Mathematic Calculation

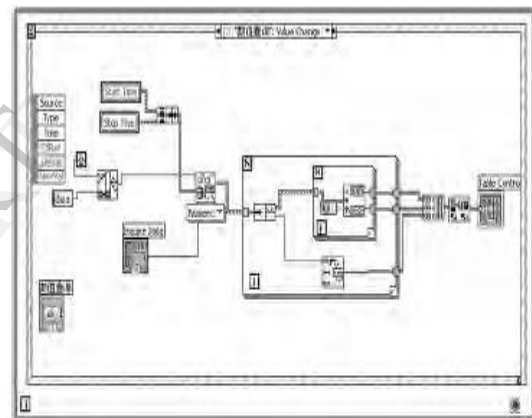


Fig.2.d. Data inquiring and History Display

## 6. Experimental Result

The virtual monitoring and warning system was developed based on LabVIEW software of NI Company according to the running characteristics of the power plant. It can acquire the key signals, and realize some useful functions, such as real-time monitoring and warning and so on. At last it can create daily report forms. If accident takes place, it will send the alarm signal and give the reason for the accident. The idea of designing the system is introduced in detail in the paper. The interface of the system is friendly and easy to use. It may take the Distributed Control System (DCS) effective assistance. It can also be taken in the analysis of the

running status and history operating record inquiry conveniently.

The experimental results show that this invention has many advantages such as simple structure, high utilization efficiency of wind energy, low start-up wind speed, high equipment reliability and good maintainability. This invention has broad application prospect in the market with great economic value, and profound social significance on the environment-friendly green energy industries of China and even the whole world.

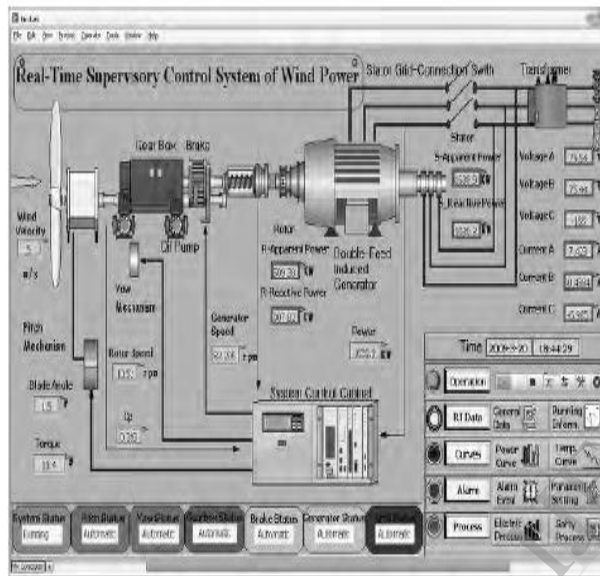


Fig.3. Main HMI VI.

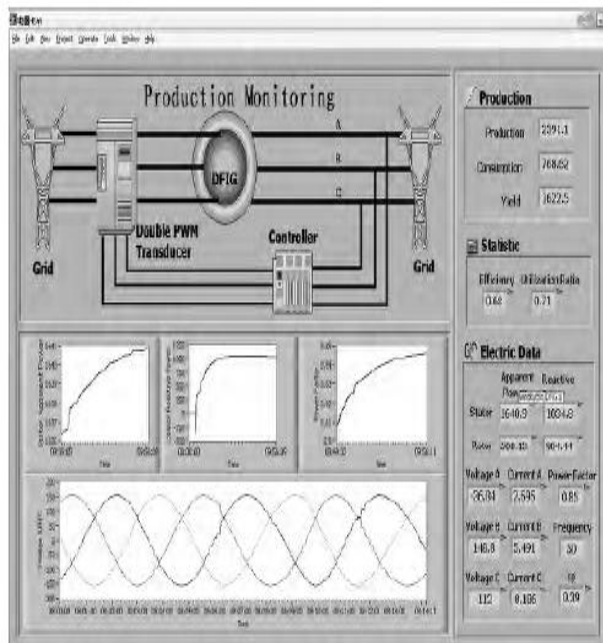


Fig.4. Production HMI VI.

Due to increased use of sophisticated electronic devices and controls in modern industries, the design tolerances of equipments and components have been going down. The system disturbances, which were tolerated earlier, may now cause interruption to industrial power system with a resulting loss of production. Power-quality disturbances can range from short interruptions to long-duration, magnitude variations and flicker. In order to evaluate and identify the disturbances and their origin, power quality monitoring is a tool that utilities and customers must use.

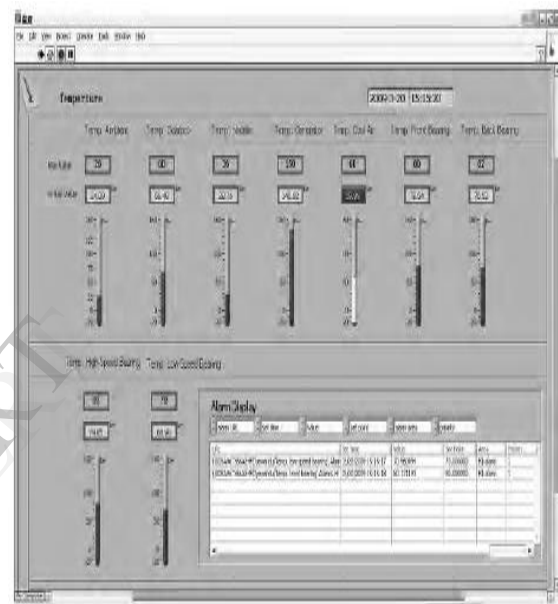


Fig.5. Temperature HMI VI.

After complete the design, the real-time simulation system is done. The system includes four programs: a main HMI program(Hunan Machine Interface), a production HMI program and a temperature HMI program and a archive view program. Fig 6 shows functions of all programs.

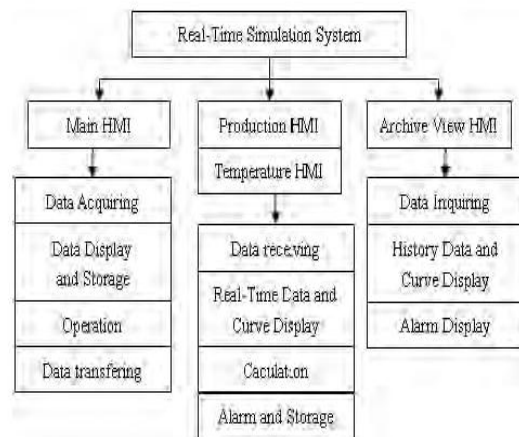


Fig.6. Architecture of the simulation system.

## 6.1. HMI Programming

The HMI program has four functions. Firstly, data acquisition: The program communicates to the simulink model and accesses the real-time data from it. Secondly, data display and storage: more than 50 signals are detected in the system and all real-time data are displayed with the icon of associated equipment. At the same time, the displayed data are stored into Citadel Database. Thirdly, operation: the Operation buttons in HMI could give orders as run/pause/stop to the simulink model for the whole system control. There are also other buttons to make operators easy to view different information, such as general data, curves, alarm event and certain process. Lastly, data transferring: the HMI program needs to transfer real-time data to sub-VIs. So that next to every data indicator, there is a small triangle indicator to show the quality of communication between VIs, green for success and red for failure. Now, we could see that all triangle indicators are green, which means we have succeed data transmission. Through the main HMI, the whole process of wind power generation could be viewed easily.

The main HMI is firstly developed to rapidly monitor the status of the wind power generation system. This interface gives a intuitive and legible picture of wind power generation.

The production HMI Program is for monitoring the status of generator and grid. Under the caption of Electric Data, real-time data transferred from the main HMI is displayed in the indicators with the green triangle label showing good communication. Those electric data reflect the current status of grid and generator during production. Then, based on those data, production data and statistic data are calculated by equation to evaluate the efficiency of wind power generation. The charts display curves of stator apparent power/reactive power, power factor and voltage A/B/C, offering intelligible and vivid characteristic trends curves of wind power. From production HMI program, the process of wind production could be clearly seen with no difficulty.

Fig 5 shows the Archive View HMI Program which accesses the data from Citadel Database. The program has function of data inquiring, history data and history curves display for multi-days, multi-signals and alarm information display. Data inquiring: choose the period of time for inquiring; under the caption of Inquire Data and Inquire Curve, click pull-down button to open menu; choose the data for inquiring from the menu; view the history data or curve after clicking OK button. History data and history curves display: Different curves are illustrated in different colour. By mathematic calculation, this program could display the

max/min/average value of the last curve. And the cursor could be used easily to indicate the value of points of the curve by moving the mouse or clicking cursor controller.

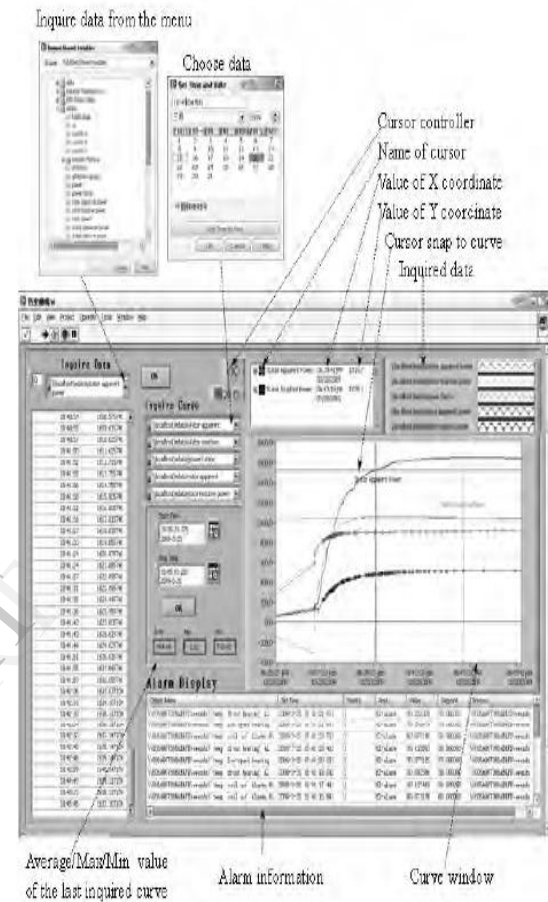


Fig.7. Archive View VI.

Once the cursor stops at one point of the snapped curve, the value of point is shown by the information like value of X/Y coordinate. When moving the cursor on the curve, value of every single point could be read immediately and intuitively. This program facilitates history inquiring and display.

## 7. Conclusion

The real-time simulation system has presented a good performance and strong ability for real-time acquisition of wind generation information from simulink model and analysis, storage, inquiry with high efficiency and reliability. The advanced technology of DSC module helps to rapidly develop the monitoring system, which has the advantage of easy-to-use, high speed data transmission, less complicated programming and perfect in function. The DSC module based system has made great progress compared to the traditional system

developed by component software or simple-version labview. In addition, shared variable technology simplify the developing process of data transmission between VIs and data storage.

On the one hand, the system could be academically used for professional research of wind power generation by experts, making the test of wind power generation system more economical and convenient compared to lab test with large-size, costly physical device and the uncertainty wind source. On the other hand, this system could become a useful training tool for operator, mechanic and other staff related to wind power regardless of the time or location limit, reducing great cost of training and guarantee the safety of learners.

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