



Data acquisition system for testing of vertical axis wind turbine

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Abstract

Wind tunnel test bench is one of the important methods to research the characteristics of vertical axis wind turbine (VAWT). To improve the test performance, intelligent test equipment for VAWTs is developed. The whole equipment is divided into three sub system. support and adjustment, intelligent data-acquisition and analysis and loading system, each of them is analyzed and designed. An intelligent test bench is established, with which, the performance of a rotor is tested and analyzed. The results show that the test equipment is simple structured, convenient to manufactured, reliable to operate, and able to intelligently acquire the important data such as wind speed, rotor torque and power etc., which provides an effective way to study the performance of the wind turbines.

Keywords — Wind energy; Wind tunnel test; Vertical axis wind turbine (VAWT); Test equipment.

I.INTRODUCTION

Wind energy as a renewable resource without pollution has currently become one of the important energy researched and developed by countries all over the world at present. Vertical axis wind turbine (VAWT) has many advantages

such as no affected by the wind direction, no need for yaw system, low noises, low center of gravity, simple structure and low cost thus to manufacture and maintain easily. As a core component of VAWT, the design and performance parameters (starting wind speed, rated wind speed, torque, power and power coefficient, etc.) of VAWT rotor are mainly analyzed and calculated in theory, susceptible to simplification of models, assumptions and conditions, resulting in big error between the design results and the expecting performance. At present, to improve wind energy conversion efficiency of VAWT, two common methods are used to research on VAWT, which are wind tunnel test and CFD simulation. One type of simple straight-flow wind tunnel and an universal test equipment for VAWT were researched and built. Different type of vertical axis wind turbine was studied through wind tunnel and numerical methods. Multi-field coupling test methods and system for vertical axis wind turbine were put forward. A numerical analysis using a dynamic simulation model and a wind speed sensor-less performance monitoring was developed to detect the deterioration in the wind turbine performance. Therefore to combine both approaches is the optimal solution for me for study on VAWT, and it is imperative to develop intelligent test equipment. To study the aerodynamic characteristics and power efficiency of VAWT rotor with different size and structure, a novel type

of intelligent test equipment is developed to provide a suitable platform for the wind tunnel tests of wind turbines which can acquire and analyze the performance parameters in designing the VAWT, also provide the design parameters for the matched permanent magnet generator.

II.STRUCTURE DESIGN AND IMPLEMENTATION METHODS OF THE VAWT TEST BENCH

A. Overall Block Diagram of the Test Bench

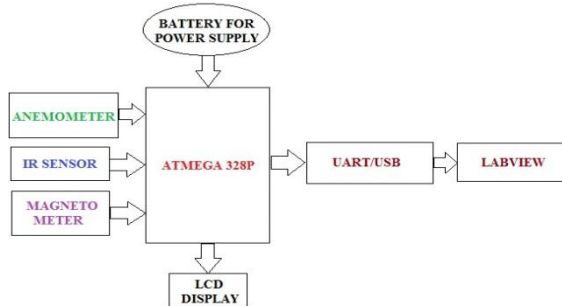


Fig.1 Schematic diagram of the VAWT test bench

The VAWT rotor test bench is divided into two sub-systems. support and adjustment subsystem, intelligent data-acquisition and analysis subsystem. The support and adjustment subsystem, including fixed support frame and adjusting components, is used to fix and adjust the rotor position. The intelligent data-acquisition and analysis subsystem mainly including sensors, microcontroller, LCD display and a computer, is used to measure, storage and process the important data such as wind speed, wind speed direction, rotating speed and torque of rotor etc.

B. Intelligent data-acquisition and analysis subsystem design

As shown in Fig.1 intelligent data-acquisition and analysis subsystem mainly includes wind speed sensors, rotating speed sensors, wind direction sensor and computer (including the microcontroller).

1) Selection of anemometer sensor for wind speed



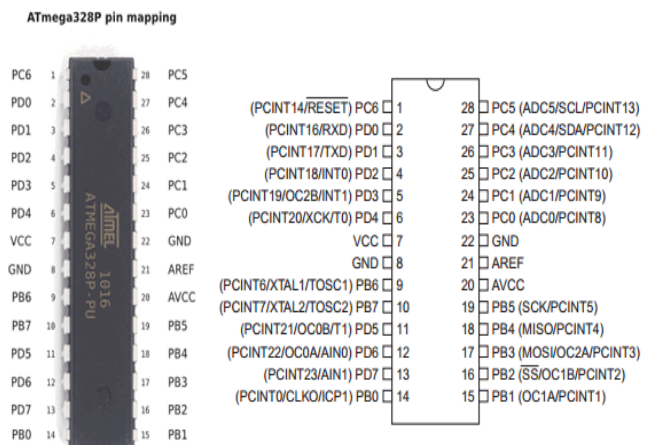
As the wind tunnel is driven by an 30KW mixed flow fan and the highest wind speed is about 30m/s, and the outlet cross section of tunnel is a square, outlet air flow from which is inconsistent, so wind velocity need be measured at multiple different points, in this paper five points A, B, C, D, E. were chose to place the wind speed sensors. Taking all this into account, KA12 4CH anemometric with probes modeled as 0963-00 was selected. The

measurement range is wind speed 0.1-50m/s, measurement accuracy $\pm 0.5m/s$ between 10-24.9 m/s. Which can monitor wind speed from 4 channels at the same time, transmit data to computer by a standard RS-232 serial communication interface equipped and analog output. A handheld anemometer KIMO LV107S with measurement range 0.3-35m/s was also used for purposes of comparison.

2) Selection of sensor for rotating speed and wind speed direction

Knowing the direction of the wind is an important part of the vertical axis wind turbine. A wind vane is a tool for measuring wind direction and was probably one of the first weather instrument ever used. To determine the wind direction, a wind vane spins and points in the direction from which the wind is coming and generally has two parts, or ends. One that is usually shaped like arrow and turns into the wind and one end that is wider so that it catches breeze. The arrow will point to the direction the wind is blowing from so if it coming from the east. Additionally, wind direction is blowing from. Therefore a west wind is blowing from the west. Wind direction is measured by the wind vane. When constructing a weather vane, the design must be planned to allow for free movement about the vertical axis. The surface area of the wind turbine design must be asymmetrical, unequal, which enables the smaller area to turn into the wind. However, the weight must be equally distributed on both sides of the axis of rotation to allow the wind vane to spin freely. The small end points in the direction from which the wind is coming, and the larger end points where the wind is going. The individual installing the wind vane would need to align the directional markers with the geographic directions of north, south, east and west. The directional markers allow observers to identify the wind direction easily. The infrared ray sensor is used to measure the rotating speed of the vertical axis wind turbine.

2) micro controller



The sensors are interfacing with the atmega 328p microcontroller. the controller is having high performance, low power AVR 8-bit microcontroller. Advanced RISC

architecture.32, 8-bit GP register.3,8-bit i/o ports.32 kb flash memory.1KB EEPROM and 2KB SRAM. on chip 10 bit A/D converter. 16 bit timer.The three sensors such as anemometer, IR sensor and magnetometer sensor are interfaced with the microcontroller. The output of these all three sensors are in the form of analog, these are converted into digital by A/D converter. The digital output is giving to the microcontroller as input. The output is displayed in the LCD.

4) Torque

The output of the rotating body is obtained from the product of torque and angular speed.

$$P=M*w$$

P=output in N-m/s(1N-m/s= 1W =0.00136 metric hp)

M=torque in Nm

w=angular speed in s-1

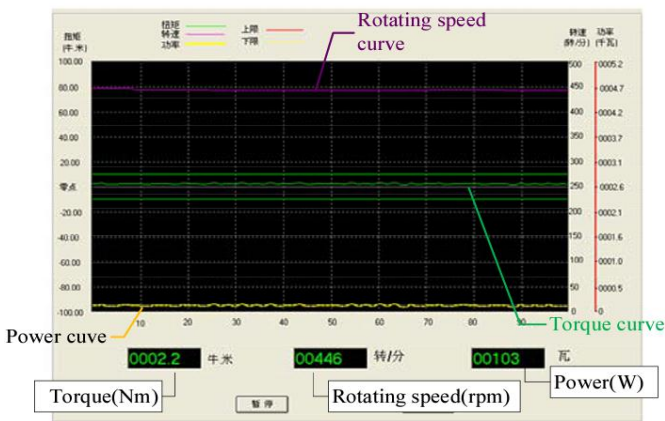
N=Rotational speed in rpm

$$w=pi*(n/30)$$

transformation and some other steps give the relationship for torque, the quality to be measured.

$$M=(p/n)*(30/pi)$$

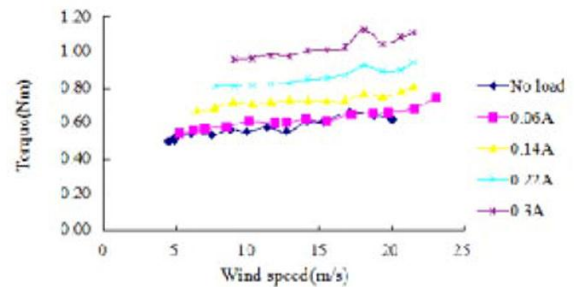
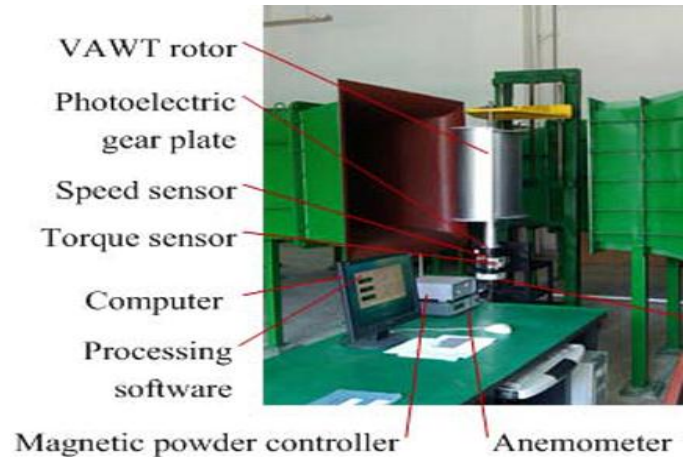
5) Analysis software



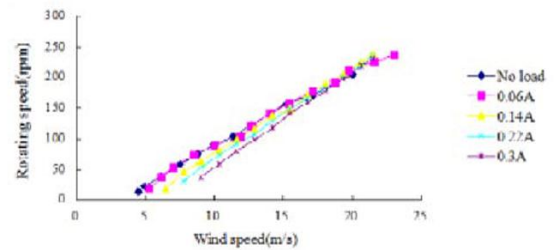
The working interface of HX-90D is shown in Fig. Real-time data of rotating speed and torque of VAWT rotor are displayed in two ways: curve and digital. The real-time power is also calculated and displayed in the same way. All of the data can be stored in Microsoft excel format in the computer for further analysis.

III. VAWT ROTOR TEST AND RESULTS

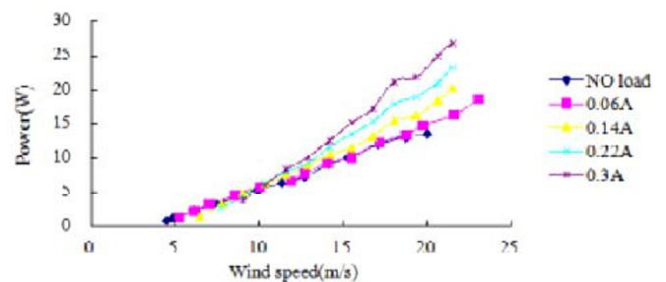
According the analysis and design result above, the VAWT rotor test equipment was built up shown as in Fig. Using this experimental equipment developed, the performance of a new type of wind wheel (vertical-axis three-hastate wind wheel) is tested. The prototype is shown in Fig. the main parameters of the model are as follows: Height H = 900mm, height to diameter ratio H / D = 1, The prototype is made of aluminum.



A) Torque versus speed



B) Rotating speed versus wind speed



C) Power versus wind speed

Relationship between rotating speed of the prototype and wind speed is shown in A. As the wind speed increase, rotating speed of the rotor increases approximate linearly. And rotating speed of the rotor decreases with the increase of the load. With this result, the operating characteristics of wind rotor can be inferred.

Fig.B and Fig.C show torque and power output of three-state VAWT at different wind speed and load. They all increase with wind speed and load. which reflect the performance of power output and characteristic of wind rotor to drive the generator.

All these test results show that the VAWT wind tunnel test equipments meet the design requirements, perform well at acquiring wind speed, rotating speed, torque and power output of experimentation intelligently.

conclusion

In this paper, one kind of intelligent VAWT rotor experimental system has been designed to implement all kinds of experiments. The properties of all types of VAWT rotors with different diameter (less than 900mm) and height to diameter ratio, can be tested on the equipment at different wind speed and load condition. The influence of wind speed, load and wind turbine structure parameters on the efficiency of power output and wind energy can be analyzed. The corresponding design parameters can also be provided to the matching permanent magnet generator. The testing device is suitable for a preliminary study of the property of wind turbines. It provides a good test platform for many researchers and has a prospect of wider application. Future improvements of the test device can be made as the following aspects:

1. As the test rotor can be fastened only on the upper end, there are horizontal forces exert on the torque sensor, and it's hard to adjust the equipment for vertical alignment. So a device should be designed to fixed the bottom of rotor to the fastened support frame.
2. The test equipment is usually working at very high rotating speed (up to 600rpm) and wind speed (up to 30m/s). For security reasons, removable protection equipment is needed to be installed between the test section of wind tunnel.
3. To make it easier to operate, software for anemometer and torque coupler could be integrated into one, and a central control cabinet be designed to collect computer, frequency converter, power supply and all other switches for integrated control.

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