Evolution of Solution

NFAF135 Frequency Input Module for Wind Power Generation System

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As an I/O module for STARDOM FCN/FCJ, we have developed the NFAF135 frequency input module for wind power generation systems, which are attracting attention as a source of renewable energy. The STARDOM controllers with this module will help build highly reliable and accurate wind power generation systems, enabling a steady power supply. This paper introduces the technical features of NFAF135, which can accurately and reliably measure the rotation speed in a frequency bandwidth used in wind power generation control systems, and its application.

INTRODUCTION

In recent years, energy demand is tending to increase year by year due to economic growth in emerging countries. To help protect the global environment, renewable energy sources such as wind power, solar power and geothermal heat are attracting attention as alternative power sources to fossil fuel.

As a result, investment in renewable energy is increasing year by year in each country. In particular, expectations are high for wind power and investment is rising. Encouraged by the growing demand for power and investment, the generated power output of single wind turbines is increasing year by year. However, making a wind turbine larger creates challenges such as highly accurate control, reliability of control equipment for stable power generation, and the increasing number of measurement points. Thus, controllers for wind power generation are required to provide the following functions and capabilities.

1) High accuracy
   Measuring the rotation speed of a wind turbine with high accuracy and stably controlling generators to improve the efficiency of power generation
2) High reliability, easy maintenance and management
   Achieving maintenance-free wind turbines distributed over wide areas, remote monitoring and preventive maintenance for facilities, integrated management of information, and operation in high temperatures, low temperatures, or high altitudes
3) Scalability
   Flexible system configuration in response to enhancements based on the amount of power to be generated

The STARDOM network-based control system provides openness, easy engineering, high reliability, and long-term operation capability [(1)]. It has been used mainly in small- and mid-sized instrumentation markets and energy-saving markets. Recently, Yokogawa has been offering solutions with this system suitable for the markets of oil and gas mining sites and the new energy markets such as wind power generation. To strengthen the solutions for the wind power generation market, in which investment is booming, we have developed the NFAF135, a highly accurate, highly reliable frequency input module. This paper introduces an outline, technological features, and application examples of the NFAF135.

BACKGROUND OF DEVELOPING NFAF135

Market development based on STARDOM for China's wind power generation market started in 2007, since when STARDOM has been mainly used as a monitoring system. Owing to substantial experience there and the fact that STARDOM rarely breaks down, Yokogawa is well evaluated by customers.

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As noted, the increasing demand for power generation is leading to larger wind turbines. Thus, customers' demand for highly accurate measurement and high reliability has increased, and so they appreciate STARDOM as a highly reliable system for wind turbine control. Yokogawa has won an order from a major customer in China for developing a module for accurately measuring the rotation speed, to ensure stable power generation. We have developed this module in response.

CONFIGURATION EXAMPLE OF WIND POWER GENERATION SYSTEM

Figure 1 shows a configuration example of a wind power generation system using the Field Control Node (FCN), a controller of STARDOM, which is used as a main controller for the wind turbine.

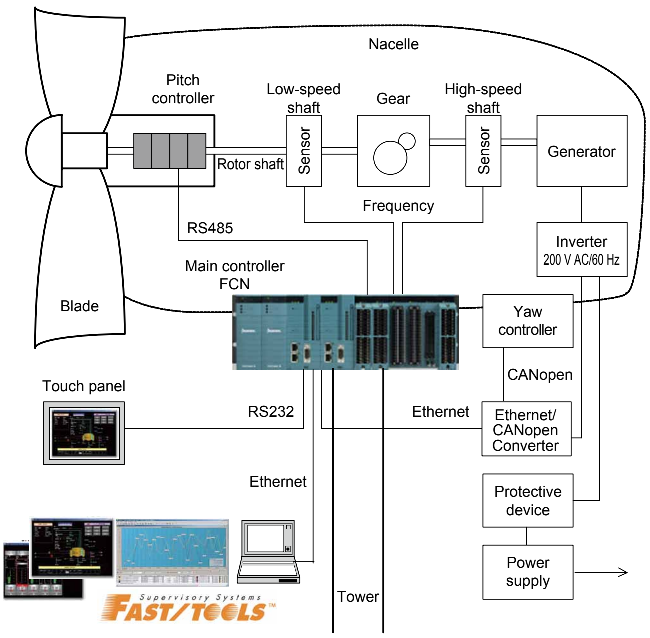

Figure 1 Configuration example of wind power generation system

The wind power generation system consists of blades for catching wind, a nacelle containing a power generator, controller, and peripheral devices, and a tower. The nacelle consists of a pitch controller for controlling blade angle, a rotor shaft for converting wind power caught by the blades into rotational energy, a gear for amplifying the rotation speed to the utility frequency, a power generator, a yaw controller for controlling wind turbine direction, and a main controller for comprehensively controlling all of these.

The NFAF135 frequency input module is inserted in the FCN, and used for measuring the rotation speed of the low-speed shaft of the wind turbine and the amplified speed of the high-speed shaft.

The main controller sends two signals to ensure stable power generation: one to the pitch controller for controlling the blade angle on the low-speed shaft side so that the rotation speed of the high-speed shaft matches the utility frequency, and another to the yaw controller for controlling the yaw angle (direction) of the nacelle to catch wind efficiently.

To protect the wind turbine, the main controller monitors the ratio of rotation speeds of the low-speed shaft and the high-speed shaft. If the ratio becomes abnormal, the controller will apply the brake to prevent blade damage. As described above, highly accurate measurement of the rotational shaft is required for ensuring stable power generation and protecting facilities. NFAF135 helps to achieve this.

OVERVIEW OF NFAF135

Position in the system

The position of NFAF135 in the system is shown in Figure 2. FCN consists of a power supply module, CPU module, I/O module, and base module. NFAF135 is one of the I/O modules inserted in FCN. The CPU module uses the process value from each I/O module to execute application programs and perform necessary control. Communication between the CPU module and each I/O module is performed via SB-BUS connected to the base module. The CPU module is connected to the user interface PC via Ethernet, and users can perform operation and monitoring on it. The upper system for wind power generation systems usually uses a supervisory control and data acquisition (SCADA) software package for operation and monitoring of the process. Yokogawa offers FAST/TOOLS as a SCADA software package, which supports more than one million I/O points and is suitable for operation and monitoring wind turbines distributed over a wide area.

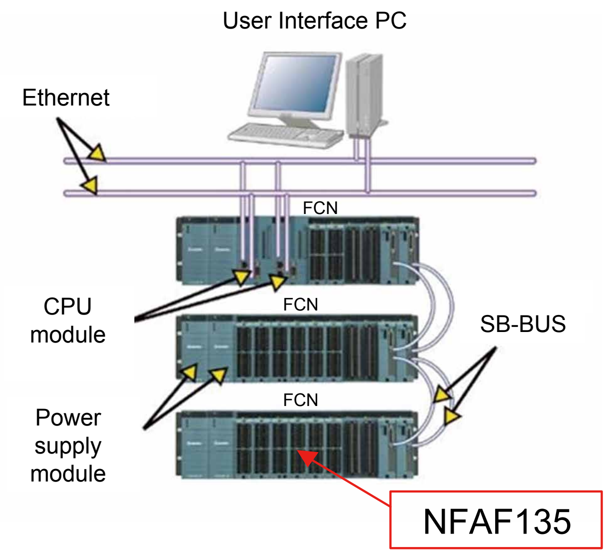

Figure 2 The position of NFAF135 in the system

The features of NFAF135

NFAF135 computes the frequency by using the number of rising edges of the pulse input from outside and the pulse intervals, and then sends the process values to the CPU module via the communication bus in the base module. Figure 3 shows the external view of NFAF135.

Figure 3 External view of NFAF135

NFAF135 satisfies the demand for high accuracy and high reliability mainly in the wind power generation market, and has the following features.

■ Feature 1: Highly accurate measurement
- Improved measurement accuracy achieved by reducing the influence of clock resolution on the accuracy by using frequency computation with the number of multiple pulses and accumulated time of their intervals
- Highly accurate measurement in the low-frequency range required for wind power generation achieved by extending the frequency output update cycle when pulse intervals are long

■ Feature 2: High reliability
- Part selection and design considering derating
- Environment-resistant evaluation considering specification margins

Table 1 outlines the specifications. The input frequency range covers from low frequency (0.1 Hz) required for wind power generation to high frequency (10 kHz) required for steam or gas turbines.

Table 1 Major specifications

Item	Description
Number of input points	8 points, individually isolated
Input frequency range	0.1 to 10 kHz
Output frequency accuracy	0.1% of reading
Output update cycle	10 ms
Input signals	Voltage pulse input Open-collector contact input Relay contact input

Outline of the hardware configuration of NFAF135

Figure 4 shows the hardware configuration of NFAF135.

NFAF135 consists of isolated eight-channel pulse interface circuits, a pulse measurement FPGA-based circuit that detects pulse edges and measures the times of pulse intervals, and an MPU for controlling the total module and computing the frequency.

The interface circuit supports multiple input modes such as for voltage input and contact input, and can supply power for contact input. Switching the input mode and the voltage for supplying contact input are set up by using configuration software, the resource configurator, provided in STARDOM.

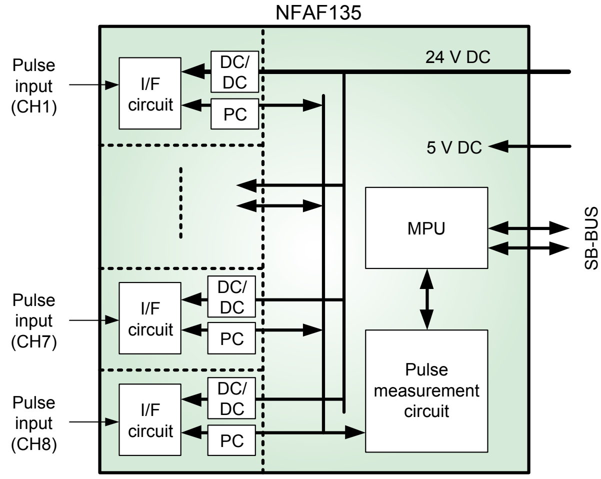

Figure 4 Hardware configuration of NFAF135

HIGHLY ACCURATE MEASUREMENT BY NFAF135

Frequency is the reciprocal of the time interval of pulse input.

$$F = \frac{1}{T}$$

F: Frequency
T: Time interval of pulse

The clock frequency of the pulse measurement circuit in Figure 4 is 4 MHz and the resolution is ±250 ns. To reduce the influence of the resolution of the clock frequency on the accuracy of the frequency measurement, NFAF135 computes the frequency after accumulating the number of pulses and their intervals for 10 ms, the frequency output update cycle. The equation for computing frequency is as follows.

$$F = \frac{C}{\sum_{n=1}^{C} T_n}$$

F: Frequency
C: Number of pulses
n: Integer
Tn: Interval between n-th pulse and (n+1)-th pulse

To measure accurately from the low-frequency region to high-frequency region as mentioned above, NFAF135 uses the following methods.

Figure 5 shows the principle of frequency measurement by NFAF135 in the case of high-frequency input.

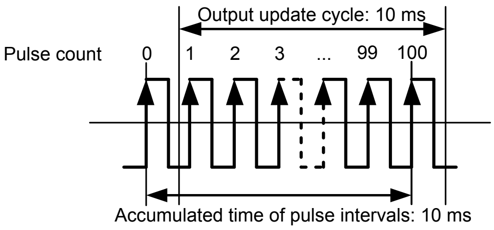

Figure 5 Principle of measuring frequency (in the case of 10 kHz input)

When the input pulse is at 10 kHz, the number of pulses is 100, and the accumulated time of their pulse intervals is 10 ms ± 250 ns. Therefore, the accuracy of frequency is 0.0025% as shown by the equation below. This fully satisfies the target accuracy.

$$F = \frac{100}{10\ ms \pm 250\ ns}$$
$$= 10\ kHz \pm 0.0025\%$$

Next, the principle of frequency measurement by NFAF135 in the case of low-frequency input is shown in Figure 6. Low-frequency input means a long time interval between pulses. Thus, the 250 ns resolution is high enough for the time interval of pulses, achieving sufficient accuracy.

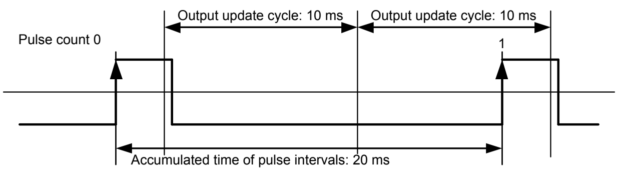

Figure 6 Principle of measuring frequency (in the case of 50 Hz input)

When the next pulse does not come within 10 ms, which is the regular update cycle time of frequency output, the cycle time is extended in units of 10 ms. When the input pulse is at 50 Hz, the number of pulses is one, and the accumulated time of its pulse interval is 20 ms ± 250 ns. Therefore, the accuracy of frequency is 0.00125% as shown in the equation below. This fully satisfies the target accuracy.

$$F = \frac{1}{20\ ms \pm 250\ ns}$$
$$= 50\ Hz \pm 0.00125\%$$

In this way, NFAF135 achieves a high accuracy of frequency from 0.1 Hz to 10 kHz.

SALES PERFORMANCE

Yokogawa fully entered the wind power market with STARDOM in 2007, and has sold many controllers, mainly in China's wind power generation market. Figure 7 shows the sales performance in China. The installations are mainly located in inland areas.

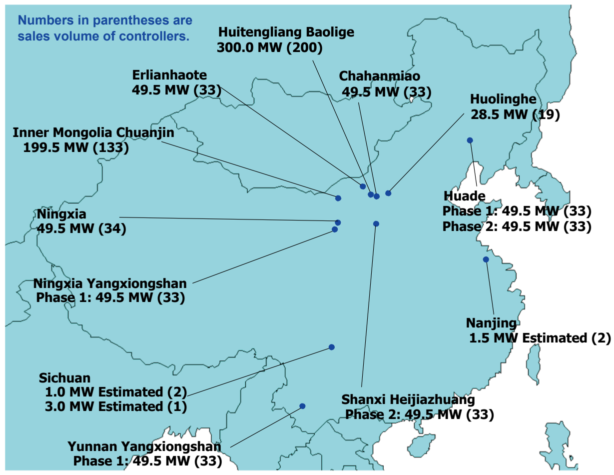

Figure 7 Sales performance in China

CONCLUSION

Yokogawa has been expanding the STARDOM lineup since its first release in order to offer systems suitable for various environments, applications, and scales. The newly developed NFAF135 meets the needs in the renewable energy industry which is expanding in overseas markets, and offers high accuracy and high reliability, which are not provided by any competitors. In addition to frequency measurement functions, wind power generation systems require conformity to the communication standard CANopen [Note 1)], which is essential for connecting peripheral devices. Yokogawa will offer the products required in this market to provide a new stable supply of electricity from wind power, thus helping to preserve the global environment.

REFERENCES

(1) Eiji Nakamoto, Satoshi Okada, "FCN and FCJ Autonomous Controllers in STARDOM," Yokogawa Technical Report English Edition, No. 33, 2002, pp. 5-8

Note 1) The CANopen communication module is under development (as of October 2011).