New Type of On-line Monitoring System for Tilt Angle of Power Tower

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Abstract

With the deepening of China's scientific and technological progress and industrial upgrading, the importance of safe and stable operation of the power system, as the key infrastructure of the lifeline of the national economy, has become increasingly prominent. As the core support structure of transmission and distribution network, the running state of power tower is directly related to the reliability of the whole power system. At present, the traditional manual inspection method widely used in the industry has some prominent problems such as long inspection cycle, large consumption of human resources, and insufficient real-time monitoring ability. In view of this situation, this study designed and developed a set of integrated power tower condition monitoring system. The device realizes real-time acquisition of three-dimensional attitude of the tower through high-precision inclination sensor, and is equipped with multi-parameter meteorological sensor for synchronous monitoring of environmental factors. The data transmission channel is constructed by NB-IoT low-power wide-area Internet of Things technology. Realize the remote visual monitoring of the running status of the tower. The application of the monitoring system will effectively improve the limitations of the existing tower inspection mode, provide reliable technical support for the intelligent operation and maintenance of the power grid infrastructure, and have important engineering practical value to ensure the safe operation of the power system.

Keywords

Tower tilt, MEMS, NB-IoT, on - line monitoring.

1. Introduction

Provided that our human society intends to acquire and enjoy long-time prosperity, it is advisable for humans to maintain the power system’s safety. Transmission poles and towers towards power system, without a doubt, is the stepping stone which ensures the power transmission lines are supported, enables the power system operates safely, and enhances their efficiency. At the same time, many reasons can cause transmission tower tilting, such as extremely bad weather, crustal movement, man-made sabotage, burn-in and so on. In the electrical inspection operations, inclined tower, tower base, and other parts of the state judgment is an important content[1]. So, it is necessary to design a system that can monitor the tower inclination in real time.

In recent years, multitudinous methods for monitoring the status of towers have been developed. Dae Woong Ha et al. proposed a wireless MEMS-based inclinometer sensor node for structural health monitoring, which achieved monitoring of transmission towers through a micro-electro-mechanical system[2]. Yang et al. proposed a tower tilt detection and analysis method based on monocular vision images. The monocular camera collects the profifile and contour features of the tower, and the tower tilt model is combined to realize the calculation and analysis of the tower tilt[3]. Dong et al. proposed a wireless multifunction system based on a MEMS accelerometer, which achieved real-time monitoring of transmission towers through the combination of ZigBee and GSM[4]. However, ZigBee and Bluetooth are suitable only for short-range wireless transmission and are not suitable for long-distance wireless transmission, so there are considerable limitations.

To solve the above problems, this paper designs an on-line monitoring system for transmission tower tilt based on MEMS sensor technology and NB-IoT communication technology. In this system, MPU6050 sensor is used to collect the data of transmission tower, which is used as the basis of on-line monitoring and tower tilt warning. NB-IoT wireless network communication technology is used to complete the interaction between the data collected by the sensor and the command issued by the remote monitoring center in the specified wireless network. The combination of solar power supply and rechargeable battery can monitor the running status of the transmission tower in real time under extreme weather and special terrain conditions, and feedback the running status of the transmission tower to the maintenance personnel in a timely and effective manner. The experimental results show that the design has the advantages of high feasibility, low energy consumption and high monitoring accuracy, which can prevent the collapse of power tower.

2. Theory of the Text

With the development of sensor technology, more and more low-cost and high-precision MEMS (Micro-Electro-Mechanical System) sensors are used for information measurement, which greatly promotes the ability of human social information perception[5]. Inclination measurement is one of the typical applications of MEMS inertial measurement units, in which accelerometers and gyroscopes are the two most common inertial measurement units in inclination measurement. The power tower is in the three-dimensional space, and its tilt Angle belongs to the three-dimensional index, which can be described by the three-axis tilt Angle. MEMS technology can combine multiple axes of precision gyroscopes, accelerometers, magnetometers, and pressure sensors into a single device to obtain Pitch, Roll, and Yaw angles after attitude fusion. Figure 1 shows the three-axis Euler Angle. Taking an aircraft as an example, the Pitch Angle can be understood as the Angle generated by the nose tilt down or up, the Roll Angle can be understood as the Angle generated by the fuselage roll left and right, and the Yaw Angle can be understood as the Angle generated by the nose turn left and right while the fuselage remains level.

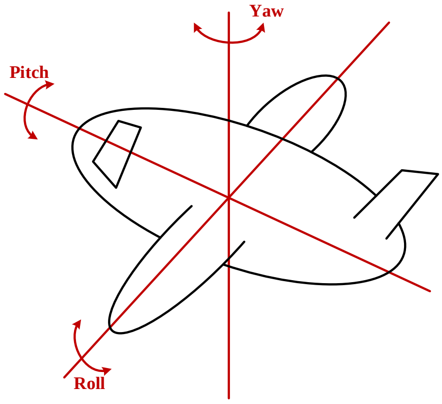

Figure 1 Triaxial Euler Angle diagram

In the inclination measurement scenario, MEMS inertial measurement unit is often used. Among them, the accelerometer is used to measure the speed change and obtain the position information[6], the gyroscope is used to measure the angular speed and obtain the direction, and the inclination Angle, angular speed and other information are measured through data fusion.

2.1. Accelerometers measure inclination principle

As a typical inertial sensing unit, the inclination detection principle of accelerometer is to calculate the component of gravity acceleration on each axis of the accelerometer. The accelerometer has static stability. When the device is in static or quasi-static environment, the attitude Angle of three-dimensional space can be deduced by establishing a mathematical model based on the projection relationship between each axial component and the gravitational acceleration[7].The measurement Angle formula of the accelerometer is shown as follows.

$$\alpha = \arctan\left(\frac{g_x}{\sqrt{g_y^2 + g_z^2}}\right) \tag{1}$$

$$\beta = \arctan\left(\frac{g_y}{\sqrt{g_x^2 + g_z^2}}\right) \tag{2}$$

$$\gamma = \arctan\left(\frac{\sqrt{g_x^2 + g_y^2}}{g_z}\right) \tag{3}$$

2.2. Gyroscope measurement inclination principle

MEMS gyroscope is an inertial measurement unit that measures the angular velocity of the three axes. It can directly measure the rotational angular velocity of the object, and the tilt Angle can be obtained by integrating the angular velocity of each axis. In the actual situation, there will be a certain deviation between the gyroscope output data and the real tilt Angle. The main reason for the deviation is that the temperature change inside the device will have a certain effect on the zero angular velocity voltage. The angular velocity output of the gyroscope can be integrated to obtain the tilt Angle data. The formula is as follows:

$$\theta_{t2} = \theta_{t1} + \int_{t1}^{t2} \omega_{gyro} dt = \theta_{t1} + \int_{t1}^{t2} \left(\omega + r_g\right) dt \tag{4}$$

3. System scheme design

The tower tilt monitoring system adopts modular architecture design, which is mainly composed of sensor module, core processor, remote communication unit and renewable energy power supply system. The hardware configuration of the system includes three-axis attitude sensing module (MPU6050), AHT20 temperature and humidity sensor, and integrated wind speed and direction detection unit. STM32F103CT86 microcontroller is selected as the edge computing node for the main control chip, and the iot transmission link is built with the NB-IoT wireless communication module[8]. The power supply system consists of a monocrystalline silicon solar photovoltaic panel and a lithium-ion battery pack to form an off-grid hybrid power supply system to ensure long-term stable operation of the equipment in the field environment.

In terms of work flow, the MPU6050 collects the original data of triaxial acceleration and angular velocity of the tower in real time through the I^2C bus, and transmits it to the STM32 microcontroller through SPI interface for multi-source data fusion processing. The main control unit adopts the hierarchical filtering strategy, and implements the algorithms of digital filtering and noise reduction, Kalman dynamic estimation, rigid body dynamics solution, etc., and finally output the 3D attitude Angle parameters with high precision. The processed tower inclination data and environmental parameters are driven by the NB-IoT module through the AT

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instruction set, encapsulated by relevant protocols, and then uploaded to the cloud monitoring platform.

3.1. System hardware construction

In this scheme, MPU6050 triaxial MEMS inertial sensor is used as the core monitoring unit, and multi-dimensional data acquisition of the running state of the tower is realized through integrated high-precision gyroscope and accelerometer. The sensor has a built-in 16-bit high-resolution ADC analog-to-digital conversion module and a programmable digital low-pass filter, which can effectively eliminate high-frequency noise interference. Its advantages are mainly reflected in: the minified package design significantly saves installation space, has high measurement accuracy error control ability, and can still maintain reliable data acquisition performance in complex environments. The hardware model of the terminal device is shown in Figure 2.

Figure 2. Hardware model of the terminal device

3.2. System software design

Based on the overall architecture of the system software, the main control module program of the terminal of the power tower inclination detection device is designed and realized. The core function of the inclination detection device mainly depends on the STM32F103C8T6 microcontroller, which as the main control module is responsible for the initialization of the MPU6050 attitude sensor, AHT20 temperature and humidity sensor, integrated wind speed and direction sensor and NB-IoT communication module. At the same time, the data collected by each sensor should be analyzed, processed and stored, and uploaded to the cloud platform through the NB-IoT module to facilitate the visual management of data. Figure 3 shows the flowchart of the terminal main program.

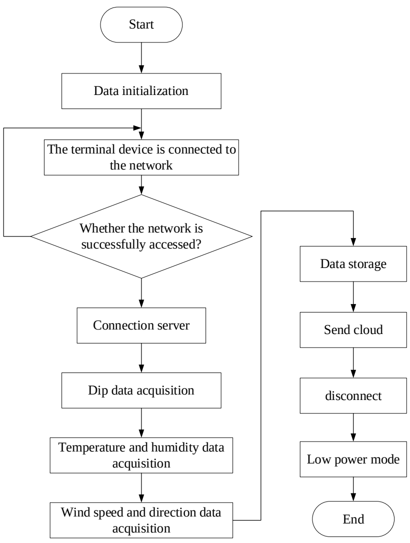

Figure 3. Main control module program design

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3.3. Internet of Things cloud platform design

In the development of the power tower inclination online monitoring system, the Internet of Things cloud platform is an indispensable and important link, which is the bridge between the detection terminal and the monitoring system. In this design, OneNET platform is selected for design and development.

OneNET platform is a one-stop Internet of Things open platform created by Zhongwei Internet of Things Co., Ltd. based on Internet of Things technology and industrial characteristics. It contains rich apis and various industry application templates, and can adapt to various standard Internet of Things protocol types including MQTT, HTTP, LwM2M, etc. It can support the access of various types of sensors, various modules and equipment, and can realize the rapid access of equipment, data acquisition and storage, data processing and analysis, intelligent transformation, big data analysis and other functions. It has high openness, high security and scalability, and can meet the realization and development of online monitoring system for power tower inclination detection.

After the design is completed according to the design process of the cloud platform, the visual interface needs to be designed. This paper uses the View 3.0 data visualization tool of OneNET platform to design the interface. The data visualization interface of power tower inclination detection system is shown in Figure 4.

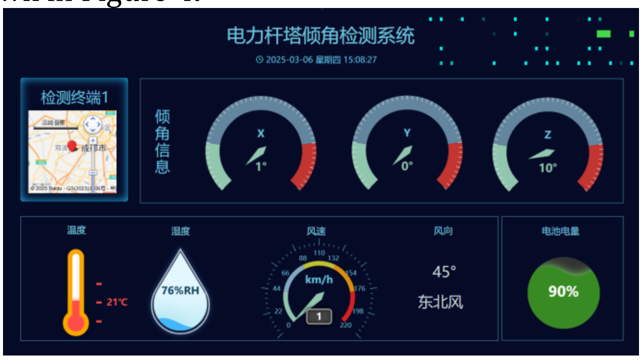

Figure 4. System visualization interface

4. Conclusion

The monitoring system innovatively integrates MPU6050 six-axis sensor, AHT20 temperature and humidity module, wind speed and direction sensor and NB-IoT communication module to build a wireless iot monitoring network. The scheme adopts distributed deployment architecture, and a single transmission tower only needs to be configured with integrated monitoring terminals and multi-parameter sensor arrays. Through wireless transmission, the geographical limitation of traditional wired monitoring is effectively broken, and the wiring cost and operation and maintenance difficulty are significantly reduced, while the system construction cost is reduced. The energy supply uses a solar-lithium battery compound energy storage system to ensure continuous monitoring under different geographical and climatic conditions. Through the actual test verification, the system tilt Angle detection accuracy reaches ±0.5°, the temperature measurement error is ±0.3 °, the wind speed resolution is 0.1m/s, and the success rate of data upload is 99.2%, which effectively realizes the real-time visual supervision of the health status of the transmission line. The test results show that the solution has significantly improved reliability, economy and environmental adaptability compared with existing technologies, and provides an innovative technological path for smart grid infrastructure monitoring.

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