Intelligent quality detection system of the transmission tower

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Abstract. Aiming at the rapid development of the power transmission industry, with the huge number of iron towers and the large amount of tower material quality inspection work, however, the detection efficiency is low. This article analyzed five inspection items, inspection points, and their inspection data volume, which are required for tower material specification inspection, such as parts, galvanized layer, that must be performed in the tower material specification inspection, put forward the plan of tower material quality inspection system integrated by software management system and hardware detection instrument, and designed the system scheme, determined the typical testing equipment with real-time transmission function, and designed the architecture of tower material quality information management system. This system can realize the intelligentization of tower material testing, the digitization of the testing process, and the standardization of testing information management, greatly improving the efficiency and accuracy of tower material quality testing.

1. Introduction
A few years ago, the State Electricity Department accelerated the expansion of the power grid and the construction of UHV transmission lines targeting interregional power transmission¹, as shown in figure 1. The transmission line tower, as a steel structure supporting high-voltage or ultra-high-voltage overhead transmission line conductors, is a key facility to ensure the safety of the power grid. At the same time, with the continuous upgrading of transmission line project construction, the construction of multi-loop projects on the same tower, large-section wire engineering, and large-span projects has made the load of transmission line tower become larger and larger, and the quality requirements of transmission line tower are higher and higher. And the quality of the tower material directly determines the quality of the transmission tower.

Figure 1. UHV project
Figure 2 is a structural diagram of a transmission line tower, which is divided into a main part and an accessory part. The main part is divided into a head, a body, and a leg (including a foundation). The auxiliary part is composed of ladders, platforms, railings, etc.

According to the survey, the quality inspection of steel towers and tower materials is still mainly manual operation and paper records. It is difficult to achieve statistical analysis of tower quality data. Therefore, whereas angle bar tray are widely used in transmission lines, this article took the tower materials of angle bar tray as the research object, and developed the quality inspection and information management system of the tower materials. In order to standardize the detection means of tower material, realize the digital and intelligent detection and management of tower material, improve the quality of iron towers, and ensure the safe operation of transmission lines.

Figure 2. The structure of transmission tower: ①: ground wire bracket; ②: horizontal support; ③: upper and lower crank arms; ④: body; ⑤: legs

2. The quality inspection of tower material

2.1. Inspection items and their testing points of tower material

2.1.1. Inspection projects of tower material

The angle bar tray in the transmission line is mainly composed of angle steel, plate and its connectors. The steel used is generally carbon structural steel Q235. The hot-dip galvanizing method is used to achieve the purpose of corrosion prevention and rust prevention [2]. According to the code of spot inspection of angle towers issued by the State Grid Corporation of China, the inspection items of angle bar tray consist of five inspection items: parts, assembly welding, galvanized coating, trial assembly, and packaging and marking, as shown in figure 3.

Figure 3. The inspection items of angle bar tray

2.1.2. Detection points and data volume of tower material

The specification requires a total of more than 60 test points for five test items. Taking parts inspection as an example, the number of inspection points is 20, and the requirements for some inspection points are shown in table 1 [1], and the diagram is shown in figure 4.

Figure 4. The detection points of parts inspection
According to the sampling standard, each inspection point is selected separately according to the different types of parts. For example, the "parts" testing project requires the extraction of several types of parts such as main materials, fucai (Materials inside the tower), and connecting plates. Each type of part needs to take multiple samples according to its quantity range. Table 2 shows the number of sampling samples of the fucai in "parts". There are generally more than 50 fucai in a single iron tower, with dozens of bases in one line. It can be seen that the testing data is very large, according to standards and specifications. Without a reliable quality data management system, it is difficult to accurately judge and trace the testing data.

| Check Point                              | Code | Allowable deviation (mm) |
|------------------------------------------|------|--------------------------|
| Angle end distance                       | a    | ±1.5                     |
| Any two holes in the same group          | b    | ±0.7                     |
| Beveled margin                           | c    | ±1.5                     |
| Hole diameter                            | d    | 0.5, 0                   |
| On-range                                 | e    | ±0.7                     |
| Hole roundness                           |      | ≤1.2                     |

Figure 4. The location of some detection points. a: tip distance; b: hole distance; c: beveled margin; d: hole diameter; e: on-range

Table 2. The sampling plan of the “fucai” (one basis)

| Batch range (pieces) | Sample size (piece) |
|----------------------|---------------------|
| 91～150              | 20                  |
| 151～280             | 32                  |
| 281～500             | 50                  |

2.2. The planning and scheme of the tower material quality inspection system

2.2.1. The planning of the detection system
At present, most enterprises about the quality inspection of tower materials use common measuring instruments such as vernier calipers, tape measures, etc. to perform on-site measurement of some detection points and record manually that in the paper, then judge their eligibility, and save that in the computer. This method is highly subjective depending on the inspector. Usually, the inspector takes a small number of detection points for testing, and has poor compliance with the sampling standard. At the same time, there is a possibility of secondary errors in manual offline entry, and it is difficult to achieve data traceability. To this end, this tower material’s quality intelligent detection system adopts the "hardware (measurement instruments, computers) + software" integration mode, that is, detecting
the relevant data by the intelligent measurement instrument, managing the detection data by the intelligent quality data management system, which will be developed, then passing computers connect intelligent testing appliances and the data management system.

2.2.2. The scheme of the detection system

According to the above inspection system planning, the intelligent quality detection system of tower material adopts a software management and hardware inspection integration scheme, and its diagram is shown in figure 5.

The intelligent quality detection system of tower material is composed of intelligent detection appliances, intelligent management software for detection data and computers. Inspection of parts, group weldments, galvanized coatings and trial assembly are required the use of intelligent inspection equipment, and the inspection data of parts, assembly welding, galvanized coating, trial assembly, and packaging and marking are required the use of intelligent management software for analysis and management.

Intelligent detection not only needs to detect the data, but also needs to transmit the detection results directly to the data management software. Therefore, the measuring instruments used must also have a real-time data transmission function. The quality information management system of tower material, which consists of the intelligent management software and computer, needs to have functions such as storage, query, and automatic determination of eligibility to achieve the standardization and informationization of tower material quality inspection.

In order to facilitate the selection of measuring instruments and design the structural of the quality inspection information management system, this article divides inspection points of the tower material into three categories: small dimensions, large dimensions, and geometrical tolerance. Dimensions within 200mm are referred to as small dimensions, such as thickness, end distance; Dimensions above 200mm are referred to as large dimensions, such as length of angle steel and steel plate; geometrical tolerance include roundness, squareness of angle steel end face, and so on.

Figure 5. Scheme of the detection system
2.3. Main measuring instruments

Inspection according to the above detection system scheme requires direct measurement data of up to more than 2,000, and if indirect measurement is used, more measurement data is required. Therefore, we must consider not only the measurement accuracy, data acquisition method, testing cost, testing environment, etc. of the measuring instrument, but also whether it is convenient, fast, and real-time transmission of testing data, when selecting a testing instrument. Through the analysis and research of related instruments, measuring instruments such as smart vernier calipers, smart coating thickness gauges, and laser rangefinders are mainly used for testing.

2.3.1. Smart vernier caliper

The degree of influence of the measuring instrument on the measurement results can be evaluated with uncertainty. Based on the dimensional tolerance of the measured geometrical characteristics of the tower material, this paper determines the allowable value of the measurement uncertainty of the measuring instrument. Based on this, a vernier caliper and a laser rangefinder with a graduation value of 0.02 mm are selected for large and small measurements appliance.

If the traditional Vernier calliper is used for contact measurement, although the measurement accuracy reaches 0.02 mm, the detection data cannot be wirelessly transmitted to the quality information management system. There are also some disadvantages, such as unstable measurement accuracy, low measurement efficiency, tedious manual statistics, recording data error. In order to overcome these shortcomings, this paper chooses digital callipers and laser rangefinders with the same accuracy, digital display of measured values, and wireless Bluetooth data transmission.

2.3.2. Intelligent coating thickness gauge

At present, the galvanized layer thickness test of hot-dip galvanized steel plate mainly includes potential measurement method and magnetic induction method. Potential measurement method is also called weighing method, this method is destructive detection method; while magnetic induction method is tested by "coating thickness gauge", which can directly read the thickness value. The magnetic induction method is the most common method used by the manufacture for inspection and product acceptance[4]. In order to ensure that the detection results of the thickness of the galvanized layer can be directly and wirelessly transmitted to the quality information management system, through investigation and research, this article selects an intelligent coating thickness gauge to detect the thickness of the galvanized layer of the tower. The instrument not only measure the thickness of the galvanized layer quickly, accurately and without damage, but also carry out wireless data transmission with PC for real-time online measurement.

3. The quality information management system of tower material

The information management system can collect, transfer and store inspection data, make use of the value of process quality data, and continuously optimize the entire production system[5]. The quality inspection information management system of tower material aims to realize the combination of people, hardware (computer hardware, testing appliances, etc.) and software, and to perform statistics, analysis and processing of tower material quality data, so as to realize the intelligence and detection of tower material inspection, the digitization of the process and the standardization of the management of testing information, thereby improving the quality of the tower manufacturing industry.

The structure of the quality inspection information management system of tower material is designed according to the function purpose of the system, as shown in Fig. 6. The architecture of the quality inspection information management system of tower material is mainly divided into three levels: data collection layer, data processing layer and management decision-making layer. The data collection layer is the lowest layer of the quality inspection information management system of tower material and also the basis of subsequent operations. It is mainly that the inspector uses smart digital callipers, laser rangefinders, smart coating thickness gauges and other measuring instruments to inspect the tower
materials, the detection data will be automatically and timely transmitted to the information management system; the data processing layer is the core of the system, and its functions mainly include the analysis and judgment of the test data of the 5 inspection items; the management decision-making layer is the highest layer of the system, responsible for the quality monitoring of angle steel tower, and its main functions include: querying test data and analysis results, comprehensive query of tower material sampling results of each supplier and formation of report or printing.

Figure 6. The architecture of the quality inspection information management system of tower material

4. Conclusion
Based on the requirements of tower material testing, this paper analyzes the tower material inspection items, the content of inspection points and the amount of inspection data, and proposes an intelligent inspection system planning for the tower material quality integrated by software management system and hardware testing appliances. The typical detection instrument with real-time transmission function was determined, and the architecture of the tower material quality information management system was designed, which is of great significance for improving the overall quality of the tower manufacturing industry.

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