Research on Monitoring System of Transmission Tower Operation State Based on Multi-Sensor Data Fusion

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Abstract. In the power network system, the main role of transmission tower is responsible for supporting the transmission line, to ensure the normal operation of the power network system. But the transmission tower in the outdoor, easy to be affected by the external environment, resulting in tower collapse, wire broken and other problems. Based on this, this paper, by using multi-sensor data melting technology on transmission tower operation monitoring system are studied, in particular, the system has carried on the design of hardware, software, and then with the inspection of transmission tower temperature and humidity data fusion, the effective monitoring results, confirmed the feasibility of the system design. Through this research, the aim is to make a modest contribution to the transmission tower motion state monitoring.

Key words: Multi-sensor Data Fusion Technology; Transmission Tower; Monitoring System

Introduction
With the continuous improvement of People's Daily living standards, the increasing demand for electricity has brought great pressure to the transmission and deployment of electric energy[1]. In power network system, the transmission tower is one of the important part of the transmission line is across all areas of the support bar, the power network system to ensure normal running smoothly, but transmission lines in the negative problems caused by the environmental factors (monsoon discharge, lodging wire broken stocks, tower, etc.), suppresses the normal operation of the power network system, It caused serious economic losses[2]. In order to avoid this problem, this paper will make use of the contemporary sensor technology to dynamically monitor the temperature and humidity environment of the poles and towers, and then carry out data fusion. According to the fusion results, the operation status of the transmission poles and towers can be understood, so as to reduce the occurrence of pole and tower faults and make efforts for the safe and stable operation of the power network system.

1. Basic overview of multi-sensor data fusion algorithm
At first, data fusion technology was promoted in the military field for better development and played a good supporting role in the formulation and deployment of military strategies[3]. With the joint efforts of researchers, the data fusion system came out successively in 1990. In the data fusion system, its child nodes are composed of relatively single military sensors, which is referred to as the
first-generation data fusion system [4-6]. With the continuous advancement of this technology, the second generation system came out in the 1980s. This system broke the uniformity of child nodes, integrated a variety of sensors and data processors, made the data fusion have diversified characteristics, and could provide more reliable data support for the formulation of military strategic deployment. Although the domestic research on multi-sensor data fusion technology started late, multi-sensor data fusion technology has improved to a certain extent with the joint efforts of the country and researchers, laying a solid foundation for the subsequent development [7-8]. Different fusion algorithms are used to achieve multi-sensor data fusion. The most common fusion algorithms include weighted average method, batch estimation algorithm, Coleman filter method, Yebes estimation method and genetic algorithm, etc [9-10]. Each fusion algorithm has its own advantages and disadvantages, which can be reasonably selected according to the characteristics or requirements of the system. Since the 21st century, data fusion technology, driven by Internet technology, has made great progress and been popularized and applied in many fields. However, due to the lack of mature theoretical system guidance, it is bound to be bumpy and tortuous on the road of technology application practice, and it needs to explore and make breakthroughs constantly.

2. System hardware design

The hardware system of transmission tower motion state monitoring mainly consists of two parts: one is all the monitoring sub-nodes; The second is all the monitoring parent nodes. Therefore, the following focuses on the child node in the child hardware system and the parent node of the main control chip selection in detail.

2.1 Selection of master control chips for child nodes

After consideration, this paper chooses STC90C516RD+ as the master chip of child nodes. This single chip has high processing speed, low power consumption, super anti-interference ability, and internal integration of MAX810 special reset circuit. Specific parameters are as follows: the working frequency is 0-40MHz; 1280 bytes/512/256 bytes RAM integrated on chip; EEPROM function; There are 3 16-bit timers/counters, among which, timer 0 can also be used as 2 8-bit timers; The working temperature is 0-75℃/-40-85℃, etc. Using this single chip microcomputer, it can fully control the neutron node of the transmission tower motion state monitoring hardware system.

2.2 Selection of master chip of parent node

As the parent node is the data processing center, the master control chip of the parent node needs to select around the center of gravity. After consideration, the S3C2440A microprocessor is selected as the parent node master control chip. The chip has rich internal resource configuration and low power consumption, which can meet the data processing requirements of the hardware system in this paper.

2.3 Selection of temperature and humidity sensor

Because transmission towers are exposed outdoors for a long time, they are often affected by environmental factors, such as temperature and humidity interference, which restrain the conductivity, shear resistance and tensile resistance of transmission tower lines. At the same time, the temperature and humidity will also affect the distance between the tower lines. When the humidity is too large, it is necessary to ensure that there is enough distance between the transmission tower lines to avoid the occurrence of transmission line failures. In addition, the temperature and humidity environment will also affect the anti-corrosion performance of transmission line tower, reducing its service life. Therefore, it is necessary to dynamically monitor the temperature and humidity of transmission poles and towers, so as to ensure normal use of transmission poles and towers. In terms of monitoring sensors, this paper chooses the DHT21 high performance temperature and humidity sensor to monitor the temperature and humidity of the position of the transmission tower. DHT21 sensor has the advantages of fast response rate and strong interference. It not only has the advanced digital module acquisition technology, but also has the advanced temperature and humidity sensing technology, which
greatly enhances its reliability and can effectively overcome the negative impact of the surrounding environment on transmission towers.

2.4 Design of temperature and humidity monitoring nodes
The specific design of temperature and humidity monitoring node is shown in Figure 1.

2.5 Wireless data transmission technology of child nodes
In order to realize the wireless data transmission between the child node and the parent node, this paper uses the WSN-1101 wireless transmission module, which has low power consumption and relatively stable performance. The relevant parameters are as follows: the working frequency band is 433MHz, the wide voltage range is 3-5.5V, it has 127 working channels, the receiving working current is less than 10mA, the sleeping current is less than 20μA.

2.6 Wireless data transmission technology of parent node
In order to ensure the reliability of remote wireless monitoring of transmission tower, GPRS wireless transmission technology is selected here. During data transmission, GPRS will be involved in the form of packets, where the amount of data sent is proportional to the cost incurred. Generally, GPRS has SIM90000 communication chip, which can meet the data transmission demand to a great extent and promote the effect of remote monitoring of transmission tower.

Figure 1. Principle of temperature and humidity monitoring node
3. System software design

3.1 Error elimination

In order to avoid the interference of data errors, Dixon criterion is used here to eliminate the errors. At this point, the amount of data in the data group should be \( n \), and then the elimination process should be carried out to lay the foundation for multi-sensor data fusion. In order to reduce the complexity of data culling operation, a targeted culling scheme is adopted, as follows: First, on the basis of Dickson criterion, the collected data are sorted (from large to small), namely, \( x_1, x_2, x_3, \ldots x_{n-1} \) minus one, \( x_n \), in which there might be some error data \( x_1 \) or \( x_n \). Secondly, two data with possible errors are obtained through calculation, and then the difference between the error data and adjacent data is obtained, namely \( x_n - x_{n-1} \) or \( x_2 - x_1 \). Finally, the quotient of the difference between the two differences and the maximum and minimum values in the monitoring data is used to calculate the specific elimination process. Let this quotient be Q, then we have:

\[
\begin{align*}
Q &= \frac{(x_n - x_{n-1})}{(x_n - x_1)} \\
Q &= \frac{(x_2 - x_1)}{(x_n - x_1)}
\end{align*}
\]

As shown in Figure 2.

During the application of Dickson criterion, the number of data in the data set should be firstly verified, that is, the value of \( n \) should be determined. Then, based on the value of \( n \), the appropriate confidence of 0.90 or 0.95 should be selected. Finally, the value should be calculated according to the confidence table of Dickson criterion, as shown in Table 1.

|     | \( n \) | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-----|--------|---|---|---|---|---|---|---|---|
| \( Q_p(0.90) \) | 0.93  | 0.74 | 0.63 | 0.56 | 0.50 | 0.47 | 0.43 | 0.41 |
| \( Q_p(0.95) \) | 0.98  | 0.84 | 0.72 | 0.64 | 0.58 | 0.54 | 0.50 | 0.49 |

3.2 Error elimination results analysis

According to the data error elimination method, the data of A certain time monitored by transmission tower sub-nodes of Project B of Power Supply Company A is taken as the experimental object here to conduct error elimination analysis so as to observe the effect of error elimination. Before the elimination, the number of transmission tower monitoring sensors in Project B is determined to be 8, so \( n = 8 \). Combined with Dickson's criterion, the following formula can be further obtained:
The temperature and humidity measurement data collected from the transmission tower of this project are shown in Table 2.

| Temperature and humidity sensor measured value | Temperature | Humidity |
|-----------------------------------------------|-------------|----------|
| 17.7                                          | 32.1        |
| 18.2                                          | 32.3        |
| 19.1                                          | 32.6        |
| 17.6                                          | 30.1        |
| 18.3                                          | 32.6        |
| 18.2                                          | 32.5        |
| 18.2                                          | 33.1        |
| 18.1                                          | 32.2        |
| 18.1                                          | 32.19       |

Before calculating the Q value, the obtained data are processed in ascending order, and then the Q value of the temperature measurement data is respectively represented by $Q_{\text{temp1}}$ and $Q_{\text{temp2}}$, and the Q value of the humidity measurement data is respectively represented by $Q_{\text{rh1}}$ and $Q_{\text{rh2}}$, so as to achieve the purpose of differentiation. Calculated according to Equation 2, the result is as follows:

$$\begin{align*}
Q_{\text{temp1}} &= (x_2 - x_1)/(x_7 - x_1) = (17.7 - 17.6)/(18.3 - 17.6) = 0.14 \\
Q_{\text{temp2}} &= (x_8 - x_7)/(x_8 - x_2) = (19.1 - 18.3)/(19.1 - 17.7) = 0.57
\end{align*}$$

As can be seen from Table 1, $Q_{\text{temp2}} = 0.57 > Q_p(0.95) = 0.57$, so $x_8$ needs to be eliminated. Humidity data are also processed in this way. After calculation, $Q_{\text{rh1}} > Q_p(0.95)$ is obtained. Therefore, $x_1$ needs to be excluded. The results obtained after eliminating the error data are shown in Table 3.

| Temperature and humidity sensor measured value | Temperature | Humidity |
|-----------------------------------------------|-------------|----------|
| 17.6                                          | 32.1        |
| 17.7                                          | 32.3        |
| 18.1                                          | 32.6        |
| 18.2                                          | 32.5        |
| 18.2                                          | 33.1        |
| 18.3                                          | 27.82       |

Through comparison, it can be found that the temperature and humidity data after eliminating the error data have a small range of change, which can better provide convenience for the subsequent data processing.

### 3.3 Transmission tower multi-sensor data fusion

In order to realize the data fusion of multi-sensor of transmission tower, batch estimation algorithm is selected as the fusion algorithm in this paper. The specific implementation steps are as follows: First, the data after error elimination is grouped into $x_{11}, x_{12}, \ldots, x_{1m}$ and $x_{21}, x_{22}, \ldots, x_{2k}$ two sets of data, where $m \leq 4$, $k \leq 4$. Then, use Equations 3 and 4 to calculate the average value of the two sets of data.

$$\bar{X}_1 = \frac{1}{m} \sum_{i=1}^{m} x_{1i}$$

$$\bar{X}_2 = \frac{1}{k} \sum_{i=1}^{k} x_{2i}$$

Secondly, the standard variances of these two groups of data are calculated by using Equations 5 and 6.

$$\sigma_1^2 = \frac{1}{m-1} \sum_{i=1}^{m} (x_{1i} - \bar{X}_1)^2$$

$$\sigma_2^2 = \frac{1}{k-1} \sum_{i=1}^{k} (x_{2i} - \bar{X}_2)^2$$

Finally, Equation 7 is used to calculate the data fusion results.

$$X = \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2} \bar{X}_1 + \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2} \bar{X}_2$$

### 3.4 Analysis of transmission tower multi-sensor data fusion results

Here, the transmission tower multi-sensor data (Table 3) after the previous error processing is taken as an example to conduct data fusion and analyze the results. Firstly, according to the fusion process of batch estimation method, the data need to be batch processed to form two sets of data. Therefore, if
m=4 and k=3, the data situation after batch can be obtained, as shown in Table 4 and Table 5 respectively.

### Table 4. Processing results of batch estimation algorithm

|                | 1     | 2     | 3     | 4     | Average value |
|----------------|-------|-------|-------|-------|---------------|
| Measured value |       |       |       |       |               |
| Temperature    | 17.6  | 18.1  | 18.2  | 18.3  | 18.05         |
| Humidity       | 32.1  | 32.3  | 32.6  | 33.1  | 32.52         |

### Table 5. Processing results of batch estimation algorithm

|                | 1     | 2     | 3     | Average value |
|----------------|-------|-------|-------|---------------|
| Measured value |       |       |       |               |
| Temperature    | 17.7  | 18.2  | 18.2  | 18.03         |
| Humidity       | 32.2  | 32.5  | 32.6  | 32.43         |

Then, formula 3 and formula 4 are respectively used to calculate the average value of the first batch of temperature data $X_{1m} = 18.05$, and the average value of the second batch of data is $X_{2} = 18.03$. Then, the standard variance $\sigma_{1}^{2} = 0.09$ of the first batch of temperature data and the standard variance $\sigma_{2}^{2} = 0.08$ of the second batch of data are respectively calculated by using Equation 5 and Equation 6. Finally, Equation 7 is used to calculate the temperature data fusion value, as shown below:

$$X = \frac{\sigma_{1}^{2}}{\sigma_{1}^{2} + \sigma_{2}^{2}} \bar{X}_{1} + \frac{\sigma_{2}^{2}}{\sigma_{1}^{2} + \sigma_{2}^{2}} \bar{X}_{2} = 18.03$$

It can be seen that the fusion value of transmission tower temperature data is 18.03, and the fusion result is shown in Figure 3.

![Figure 3. Fusion results of transmission tower temperature data](image)

According to the temperature data fusion process, carry out fusion analysis on the transmission tower humidity data, and get the average value of the first batch of humidity data $\bar{X}_{1} = 32.52$ and the average value of the second batch of humidity data $\bar{X}_{2} = 32.43$. The standard variance of the first batch of humidity data is $\sigma_{1}^{2} = 0.19$, and the standard variance of the second batch of data is $\sigma_{2}^{2} = 0.04$. Equation 7 is used to calculate the melting value of humidity data, as shown below:

$$X = \frac{\sigma_{1}^{2}}{\sigma_{1}^{2} + \sigma_{2}^{2}} \bar{X}_{1} + \frac{\sigma_{2}^{2}}{\sigma_{1}^{2} + \sigma_{2}^{2}} \bar{X}_{2} = 32.44$$

It can be seen that the fusion value of transmission tower humidity data is 32.44, and the fusion result is shown in Figure 4.
Figure 4. Humidity data fusion results of transmission tower

4. System Implementation

In order to test the feasibility of the system design in this paper, the system is used to dynamically monitor the temperature and humidity fusion results of each sub-node of transmission tower of A power supply company B project, as shown in Figure 5.

Figure 5. Monitoring results of temperature and humidity fusion of transmission tower sub-nodes

It can be seen that the system in this paper can effectively monitor the temperature and humidity of each sub-node of transmission tower and present it in the way of data fusion, which confirms the
feasibility of using the system in this paper to monitor the temperature and humidity of transmission tower. At the same time, according to the monitoring results of temperature and humidity sub-nodes, no abnormal phenomenon was found, indicating that the transmission tower was not disturbed by temperature and humidity during operation.

5. Subtotal
To sum up, this paper first analyzes the basic situation of multi-sensor data fusion technology, so that we have a general understanding of multi-sensor data fusion technology. Secondly, on this basis, the transmission tower motion state monitoring system is designed, the main control chip of the child and parent node is selected, the temperature and humidity sensor is selected, and the wireless transmission technology is designed. Then, the software system of the transmission tower motion condition monitoring is designed. Finally, taking the temperature and humidity environment of transmission poles and towers as an example, real-time detection is carried out. The obtained results are eliminated and fused, and the fusion results of the temperature and humidity of transmission poles and towers are respectively 18.03 and 32.44. The system is applied in the transmission poles and towers of a power supply company B project to conduct dynamic monitoring of their temperature and humidity. The detailed fusion results of transmission tower temperature and humidity are obtained, which confirms the feasibility of the system design in this paper and can be applied to some extent in practice.

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