Development and Application of Multi-dimensional Perception-based Integrated Monitoring System for Pole Group Towers

Hongli Liu [1], Nan Li [2*], Ye Zhao [3], Liyun Zhang [4] and Xuetao Zhou [5]

Hebei Power Teansmission& Transformastion Co., Ltd. Shijiazhuang, China

[1]e-mail: sbd_liuhl@he.sgcc.com.cn;

[2]e-mail: sbd_lin@he.sgcc.com.cn;

[3]e-mail: sbd_zhaoy@he.sgcc.com.cn;

[4]e-mail: sbd_zhangly@he.sgcc.com.cn;

[5]e-mail: sbd_zhouxt@he.sgcc.com.cn

[*]corresponding author

Keyword: Pole group tower; comprehensive monitoring; multi-dimensional perception

Abstract: The pole group tower is an important part of the power transmission and transformation project. This project is indispensable in the process of UHV AC power. However, there is a great safety risk in the work of holding towers, and the quality of the project is also affected by many factors. Aiming at the problems that have arisen, this paper proposes to construct a multi-dimensional perception-based integrated monitoring system for pole group towers. From the perspectives of cable tension measurement, inclination angle measurement, field wind speed measurement, wireless video surveillance, etc., a construction plan for an integrated monitoring system is proposed. Through practical application, the results show that the force error of the traction rope, support rope and outer cable is within 10%, which meets the project construction requirements.

1. Introduction

China is a large power-consuming country. Every year, power transmission and distribution companies lay a large number of power transmission lines to send electricity to millions of households. During the construction process, due to the complexity of the construction environment, the safety and efficiency of the construction site are affected [1]. Construction safety and construction quality are issues of general concern to all sectors of society [2]. The research on the integrated monitoring system of the pole group is carried out, and the environmental factors such as the inclination of the tower crane, wind speed, dust, and noise can be fully understood before the system operation platform, and early warning is automatically performed [3]. This can eliminate hidden safety hazards during the construction process and improve the efficiency, safety and reliability of the tower assembly construction.

In power system construction monitoring, tower crane monitoring, etc., many experts and scholars have conducted research. In [4], in order to monitor the tilt displacement of the top position of the transmission tower, the author proposed an improved IM-DINSAR model implementation algorithm. This method uses the phase difference to measure the phase of the residual differential interferometry to obtain the tilt displacement of the tower top position. In [5], the author researched and designed a new type of wireless power transmission system based on electromagnetic resonance coupling with high voltage operating characteristics, which is used to monitor the charging of equipment on 110 kV high voltage transmission lines. In [6], the author proposed an efficient routing method for wireless sensor networks for smart grid transmission line monitoring. This method provides reliability, efficiency, and reduces packet loss and fault tolerance. The above studies have played a role in monitoring, but the factors considered are not comprehensive, and the

  DOI: 10.25236/icme.2019.042

quality and safety of the power construction site must be considered. The emergence of comprehensive monitoring system can effectively respond to various problems and improve construction quality and safety.

Multi-dimensional perception considers many factors, and can comprehensively deal with different aspects in the construction operation process to achieve a relatively balanced effect. Multidimensional sensing has been applied in many fields and has achieved fruitful results. In [7], the author applied multi-dimensional perception to the study of food taste similarity of consumers in the food court of the pedestrian street to help understand consumers' perception of business continuity. In [8], the author applied multi-dimensional perception to the assessment of the quality of the living environment, and obtained a multi-story satisfaction model. In [9], the author used the multi-dimensional sensing method to predict the accuracy of the energy meter, which guaranteed the performance of the energy meter in actual work. In [10], the author used multidimensional perception for emotional representation to understand people's emotional development, and made them more familiar with individual emotional changes. Based on multi-dimensional perception, the factors considered are more comprehensive, making the process or result more credible. Therefore, it is considered to use multi-dimensional perception for the research on the integrated monitoring system of pole group towers.

Aiming at the quality and safety problems existing in the power construction of pole-mounted towers, this paper proposes the research of a comprehensive monitoring system for pole-mounted towers based on multi-dimensional perception, with a view to strengthening operation control and improving personnel safety. Hope to provide reference for related fields.

2. Design Scheme of Tower Monitoring System

2.1 Places to be monitored and weak links

The construction process flow of the pole holding tower is shown in Figure 1.

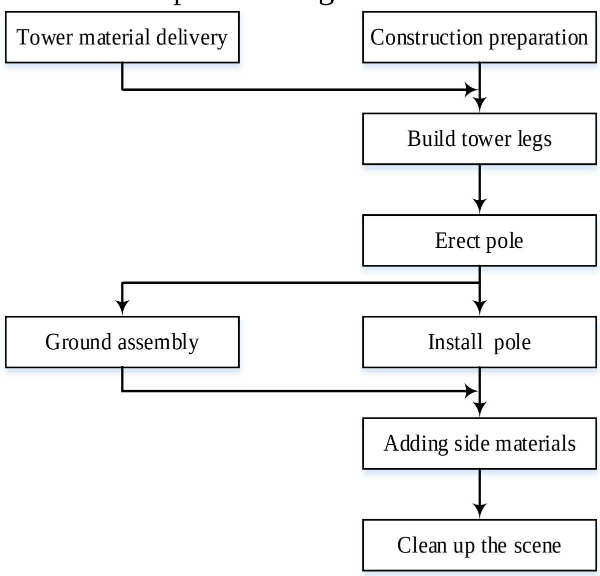

Figure 1. Construction process flow of pole-holding tower

In view of the characteristics of transmission and distribution lines and towers with poles, there are some weak links in the organization of construction that need attention:

2.1.1 During the construction of the iron tower, the force of each part of the pole system cannot be accurately detected and controlled. When an unexpected situation occurs, it may lead to a safety accident.

2.1.2 A single steel pipe has the longest length of 13 meters and the heaviest weight of 6.5 tons, heavier lifting weight, greater stress on each pole system and increased safety risks.

2.1.3 The tower is too high, the communication of the staff is affected, and the operation process takes time and effort.

2.1.4 The root of the tower is larger and the working surface is wider. Commanders cannot monitor multiple operating points at the same time, nor can they send operational instructions in a timely manner. The length of the outer pull wire is too large, and it is difficult to control the position of the part.

2.1.5 The suspension is greatly affected by the wind, and the force on the traction rope increases. Lifting with a mobile winch tower is slow, inefficient, and without safety equipment.

2.2 The composition of the tower monitoring system

The system is mainly divided into five parts: cable tension measurement, tilt angle measurement (holding pole, lifting rope), field wind speed measurement, tower power and alarm, wireless video monitoring.

2.2.1 Cable tension measurement

Install tension sensors on the four tension lines on the top of the pole to detect the tension and measure the value of the tension line; install tension sensors on the four support ropes at the bottom of the pole to detect the tension and measure the tension on the support rope. By measuring the tension, it can help determine whether the cable and the pole are within the safe force range.

2.2.2 Tilt angle measurement (holding pole, lifting rope)

Install a tilt sensor on the pole to measure the tilt angle of the suspension pole; two tilt sensors are mounted on two lifting ropes to measure the tilt angle of the lifting rope relative to the boom. When lifting a tower, the fixing rod should be tilted towards the side of the hanger, but the tilt angle should not exceed 10 degrees. According to the measured angle value, determine whether it is within the safe range.

2.2.3 Wind speed measurement

An anemometer is mounted on the top of the pole to measure the wind during the tower assembly process and adjust the operation in real time based on the wind. When the wind speed is greater than level 6, any construction work is prohibited. Therefore, installing an anemometer on the site to measure and monitor wind speed can control the site construction conditions in real time, thereby ensuring the safety of operations.

2.2.4 Tower power and alarm

Considering the maximum bearing capacity of the pole, the hydraulic traction machine produced by Henan Wandutong Electric Machinery Co., Ltd. Was selected. During use, it is equipped with a pressure system to facilitate monitoring and measurement of traction. Before lifting, set the traction on the tractor’s on-board computer. The preset value is less than the allowable value of the traction rope.

2.2.5 Wireless video surveillance

To ensure that you can clearly see the status of the pole, the working situation and the lifting of the device, a camera is installed here to monitor the construction process of the tower. By watching the monitoring video, you can directly understand the actual construction status of the site and control the construction status.

3. Image Feature Recognition Method

Considering the dynamic nature of the surveillance video, it is necessary to identify the features of the video image, and a motion video image feature recognition method based on the spatiotemporal matrix is proposed. The characteristics of the image are critical. The surveillance video image is processed to define the space-time matrix T ’:

$$T'_{i'j'}[n'] = \begin{cases} n', T'_{i'j'}[n'] = 1 \\ F'_{i'j'}[n'-1] \end{cases} \tag{1}$$

In the above formula, $F'_{i'j'}$ represents the feedback input of the image pixel matrix. This expression reflects the spatial and temporal information of the surveillance video image. The elements in the space-time matrix are not 0. The smallest element in the space-time matrix corresponds to the maximum gray value of the surveillance video image.

The barycenter of the space-time matrix is $(i_c^{'}, j_c^{'})$, and the barycenter coordinates are calculated as follows:

$$i_c^{'} = \sum_{i'}\sum_{j'} i' T'_{i'j'},\; j_c^{'} = \sum_{i'}\sum_{j'} j' T'_{i'j'} \tag{2}$$

In order to be able to perform the feature recognition of the spatiotemporal matrix on the local edges of the surveillance video image, it needs to be normalized:

$$i_{c0}^{'} = i_c^{'} / M',\; j_{c0}^{'} = j_c^{'} / N' \tag{3}$$

In the above formula, M 'and N' represent pixels of a moving video image. Formula (3) is able to maintain a good invariance when the surveillance video image is scaled, rotated, translated, and noise interfered with, and the gray value of the surveillance video image is used to realize the adaptive recognition and expression of the local features of the surveillance video image. The formula is:

$$\delta = i_{c0}^{'} + j_{c0}^{'} + (T'_{i'j'}[n'] \cdot \theta_0) \tag{4}$$

Through the calculation and normalization of the discrete matrix of surveillance video images, the local feature recognition results of surveillance video images based on neural network spatiotemporal matrix are obtained.

4. Experiment

The cable is the main force component during the assembly of the tower with the rod. Analyzing the force of cables and measuring and monitoring are important measures to ensure construction safety. In the selection of the tension sensor, four high-precision tension sensors should be selected to measure the tension on the upper outer pull wire of the rod and the lower support rope. The maximum load of the outer pull line is 50kN, and the maximum load of the pull-off rope is 78kN. In the selection of the pressure sensor, a thin film pressure sensor is used, and this type of sensor performs well in the measurement of contact force and pressure. The inclination sensor transmits the bus signal, and then displays it in the form of graphics, text, etc., with an accuracy of up to 0.1 degrees. The anemometer is selected as YS-CF-B / S. The anemometer is developed using advanced circuit module technology, which can be used to measure ambient wind speed and output standard current signals. As for the camera, a 30x integrated color night vision dual-purpose intelligent high-speed dome camera is used.

5. Results

In order to verify the effectiveness of the multi-dimensional sensing-based pole-tower integrated monitoring system proposed in this paper, the system in this paper is applied to transmission line engineering. In the construction project, the tower is 110 meters high and weighs 132 tons. Among them, the mass of the single main material in the 10th stage is 730 kg, and the weight of the single-sided cross iron is 312 kg. In the field measurement and calculation data comparison, the force error of the outer pull wire exceeds 20%. After the analysis, a tension sensor was installed at the connection between the pole and the pull wire to measure the force of the pull wire. The measured value includes the weight of the external cable. When calculating the force of the outer pull wire, the weight of the outer pull wire itself is not considered. Now, when lifting the corresponding tower, multiply the length of the external cable by the weight per meter, and then add the calculated weight to correct the force. The comparison of the stress data of a single main material is shown in Table 1, and the comparison of the stress data of cross iron is shown in Table 2.

Table 1**.** Comparison of the force data of a single main material

	Measured force (kN)	Calculated force (kN)	Error	Force after correction (kN)	Corrected error
Outside pull line	9.1	6.54	28.1%	6.9	5.3%
Supporting rope	23.4	21.1	9.7%		
Leash	13.6	12.3	9.6%		

Table 2**.** Comparison of stress data of cross iron

	Measured force (kN)	Calculated force (kN)	Error	Force after correction (kN)	Corrected error
Outside pull line	3.6	2.06	42.8%	2.16	4.5%
Supporting rope	15.7	14.3	8.9%		
Leash	6.4	5.95	7.0%		

According to the comparison of the measurement data, calculation data and correction data of the above two tables, the force error of the traction rope, support rope and outer cable is within 10%. The results show that the monitoring system basically achieves the expected results and meets the requirements of the project construction.

In terms of application effects, the monitoring system of the pole holding tower accurately calculates the force situation and inclination angle of the traction rope, supporting rope, and outer pull wire to ensure the safety of operation. During the construction of the project, the commanders issued operating instructions through the video surveillance system, ensuring that personnel communicated unobstructed and no visual blind spots appeared. The outdoor environment is also affected by the environment such as wind speed, and the corresponding operations are adjusted in time through the wind speed detection data.

6. Conclusion

The construction process of the pole group tower is very complicated and is affected by many natural and human factors. Therefore, this paper proposes a comprehensive monitoring system for the pole group based on multi-dimensional perception. The monitoring of the forces and angles of the various parts of the rod system has changed the previous working method that relied on field operations and commanders to make judgments based on experience, and enhanced the safety of the pole assembly. It is hoped that the research in this article can provide a reference for the work in related fields.

References

[1]. Yang Heng, Tao Tao, Shen Ping, Yang Yuan, & Yang Yang. (2017). An ice region recognition method for transmission lines based on improved pixel clustering algorithm. Modern Electronic Technology, 40 (20), 181-183.

[2]. Xu Ruilin. (2018). Safety and quality control management of power engineering construction. Heilongjiang Science, 9 (2), 130-131.

[3]. Chen Weibing, & Shan Yicai. (2017). Design of tower crane remote monitoring system based on short message communication module. Mechatronic Engineering Technology, 46 (12), 45-47.

[4]. Wu, B., Tong, L., & Chen, Y. (2018). Revised Improved DINSAR Algorithm for Monitoring the Inclination Displacement of Top Position of Electric Power Transmission Tower. IEEE Geoscience and Remote Sensing Letters, 15(6), 877-881.

[5]. Cai, C., Wang, J., Liu, R., Fang, Z., Zhang, P., Long, M., & Lin, Z. (2018). Resonant Wireless Charging System Design for 110-kV High-Voltage Transmission Line Monitoring Equipment. IEEE Transactions on Industrial Electronics, 66(5), 4118-4129.

[6]. Priya, P. M., & Samundeeswari, E. S. (2018). An Efficient Routing Method of Wireless Sensor Network for Transmission Line Monitoring in Smart Grid. Journal of Computational and Theoretical Nanoscience, 15(11-12), 3341-3343.

[7]. Andriani, S., Pratiwi, D. D., Ariawan, F., Murtianto, Y. H., & Yustinaningrum, B. (2018). Analysis of Consumers' Perception at the Food Court of Lampung Walk by Using Multidimensional Scaling Approach. Al-Jabar: Jurnal Pendidikan Matematika, 9(2), 209-219.

[8]. Muslim, M. H., Karim, H. A., Abdullah, I. C., & Ahmad, P. (2018). Assessing Residential Satisfaction by Level of Residence in Off-Campus Environment. Asian Journal of Behavioural Studies, 3(10), 11-22.

[9]. Shanshan Hu, Leping Zhang, & Ji Wang. (2018). Prediction model of energy meter accuracy under multi-dimensional conditions based on multi-layer perceptron. Electric Measurement and Instrumentation, 55 (16), 22.

[10]. Nook, E. C., Sasse, S. F., Lambert, H. K., McLaughlin, K. A., & Somerville, L. H. (2017). Increasing verbal knowledge mediates development of multidimensional emotion representations. Nature human behaviour, 1(12), 881.