On-line Measurement Method and Technical Scheme of Transmission Line Crossing Point Based on Machine Vision

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Abstract. With the increasing demand for high voltage and UHV transmission, higher and higher requirements are put forward for transmission line monitoring and fault diagnosis. The traditional line measurement method has many shortcomings, which cannot ensure the measurement accuracy, measurement efficiency and high cost. Based on this, this paper first studies the principle of machine vision on-line measurement, then analyses the on-line measurement process of transmission line crossing point based on machine vision, and finally gives the error source and amelioration measures of transmission line crossing point on-line measurement.

Keywords: On-line Measurement, Transmission Line, Crossing Point, Machine Vision

1. Introduction

With the continuous growth of social economy, the demand for power in all walks of life is also constantly strengthened, which not only brings broad development opportunities to the power industry, but also brings great challenges to the transmission line capacity of the power system. With the increasing demand for high voltage and UHV transmission, higher and higher requirements are put forward for transmission line monitoring and fault diagnosis [1]. On the one hand, the transmission line condition monitoring system needs to be able to monitor the environmental parameters and operation state parameters of the line in real time and efficiently; On the other hand, it also needs to be able to scientifically and effectively evaluate the state of the whole transmission line, give early warning info in time when the line is abnormal, prompt maintenance personnel to carry out line maintenance and give corresponding guidance.

At present, the transmission line monitoring system has been put into operation in many power grid lines, and has achieved remarkable utilization results. However, with the amelioration of the complexity of the power grid system in the transmission line, especially to meet the real-time monitoring of line crossing points and the line monitoring requirements of cross regional power grid and large line crossing, the existing power grid monitoring system is still facing great pressure. In order to realize the real-time monitoring of the safe distance of transmission line crossing, the on-line monitoring system of transmission line crossing distance also needs to meet the practical requirements.
of the safe operation of the whole transmission system, so as to realize the efficient monitoring demand of the whole transmission line.

The route of transmission line is often complex. The traditional line measurement methods have many problems and shortcomings, mainly in the aspects of difficult to realize remote on-line measurement, unable to ensure measurement accuracy, high measurement efficiency and high cost. The intelligent tech represented by machine vision has made remarkable progress in recent years [2]. This tech can realize the measurement of stereo vision by integrating digital image processing. Aiming at the practical problems such as cross crossing and easy cross discharge of transmission lines, the use of machine vision tech can efficiently and accurately meet the measurement requirements. Therefore, it has high utilization value in the measurement of overhead transmission line cross crossing clearance distance.

In short, high-voltage and cross regional long-distance transmission lines have the typical characteristics of long-distance, parallel and cross crossing [3]. The complex environment of these lines makes it difficult to carry out parallel and cross crossing monitoring and measurement. The cross crossing fault of overhead transmission line is increasing year by year. It is urgent to strengthen the measurement of parallel and cross crossing of overhead transmission line. Therefore, the research on the on-line measurement method and tech of transmission line cross crossing point based on machine vision has important practical value for ensuring the safety of transmission line and maintaining the stability of transmission system.

2. Principle of machine vision on-line measurement

2.1. Concept of machine vision on-line measurement
As an important geometric parameter of power industry measurement, on-line measurement of transmission line crossing points has high requirements for the measurement system. The traditional measurement measures have low precision and slow speed, and cannot meet the practical needs of large-scale and automatic measurement [4]. The on-line measurement tech of transmission line crossing point based on machine vision belongs to non-contact measurement, which has many advantages, such as high detection accuracy, high speed, and low cost, easy implementation and so on. With the help of machine vision tech, not only the on-line measurement parameters can be obtained, but also the state of transmission line can be determined on-line in real time.

2.2. Principle of machine vision length measurement
Length measurement is widely needed in transmission line measurement. Length measurement based on machine vision has the practical advantages of high precision and high speed [5]. In the distance measurement of transmission line, the distance between the two lines is calculated according to the mathematical method by identifying and fitting the two lines of positioning distance. The least square principle of straight line fitting is shown in equation 1 below, where \( y \) is a straight line function and \( a, b \) are undetermined constants. \( \varepsilon \) reflects the deviation between the calculated value \( y \) and the actual value \( y_i \), which can be positive or negative.

\[
F(a, b) = \sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} (y_i - ax_i - b)^2
\]  

(1)

Secondly, the least square method can easily and quickly solve the linear equation, and its extreme value principle is shown in equation 2 below. The two fitted lines may not be parallel. Generally, the average distance from multiple points on a straight line to another straight line is used for approximate calculation.
2.3. Principle of transmission line segment measurement based on machine vision

In the measurement of industrial transmission line segment, the length of the segment between two endpoints is often measured. The core of line segment measurement is to find two endpoints of line segments in the image, which are usually corners in the image [6]. Firstly, the corners of the collected workpiece image are extracted. Secondly, the contour of the workpiece image is extracted, and the position of the corners is accurately located by using the contour info. Finally, the distance between the corners is calculated according to the detected corners. If the image contour info is known, the contour info can be used to judge whether the corner is on the contour. In addition, in corner detection, Gaussian low-pass filter needs to be used for smoothing, but due to the error in the detected corner position, it often has an adverse impact on the measurement accuracy.

2.4. Principle of transmission line arc measurement based on machine vision

Transmission line arc measurement is another widely used measurement form. There are too many reference points for traditional physical contact method to measure arc, so it is unable to grasp the comprehensive parameters as a whole, with slow speed and low accuracy [7]. Circle measurement based on machine vision tech can greatly ameliorate the measurement speed and accuracy. It has developed rapidly in transmission lines and its practical utilization is mature. Circle measurement based on machine vision tech first identifies and fits the contour of the circle, obtains the equation of the circle, and obtains various relevant parameters according to mathematical methods. In addition, the curvature recognition method can separate the circle and other polygons, and then solve the parameters of the target circle.

3. On line measurement of transmission line crossing points based on machine vision

3.1. On line measurement system architecture of transmission line crossing point

The on-line measurement system of transmission line crossing point based on machine vision mainly includes motion mechanism, measurement mechanism and feature marker points [8]. Among them, the main function of the motion mechanism is to help the transmission line operation and maintenance personnel move the position of the measurement system during line maintenance. In order to meet the practical requirements of remote on-line measurement, it is necessary to set up remote signal receiving and transmitting devices so that the motion mechanism can be accurately adjusted on the transmission line. Secondly, the measuring mechanism is used for on-line monitoring. The measuring mechanism at the crossing point of transmission line mainly includes various functional modules. The image acquisition unit is composed of image sensor and image acquisition module; the system unit is composed of processor, DSP, VPSs and other modules.

In addition, the system communication unit is composed of a variety of communication modes, so as to meet the needs of remote and online measurement of transmission lines in different regions and environments [9]. Similarly, the power supply unit is also provided by a variety of power supplies to achieve efficient, stable, reliable and long-term effective power supply.

3.2. Scheme of on-line measurement system for crossing points of transmission lines

The scheme of on-line measurement of transmission line crossing points based on machine vision is shown in Figure 1 below. Stable and reliable on-line measurement is realized by using embedded software and hardware. Among them, the embedded hardware realizes the personalized development and design based on user needs with the help of microprocessor to meet the diversified on-line

\[
a = \frac{n \sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n \sum_{i=1}^{n} x_i^2 - \left( \sum_{i=1}^{n} x_i \right)^2}, \quad b = \frac{1}{n} \sum_{i=1}^{n} y_i - \frac{a}{n} \sum_{i=1}^{n} x_i
\]
measurement requirements of transmission lines. Secondly, the system adopts embedded software scheme to realize multi task online processing. Its software architecture includes utilization layer, middle layer, system operation layer and driver layer, which can meet the rich hardware support.

![Diagram of on-line measurement of transmission line crossing points](image)

**Figure 1.** Framework of on-line measurement of transmission line crossing points

3.3. *On line measurement design of transmission line crossing point*

Firstly, at the software platform design level of transmission line crossing point measurement device, a machine vision camera driver is developed to realize image acquisition and meet the needs of real-time image transmission [10]. Secondly, the software detection algorithm of the transmission line crossing point online measurement system is mainly responsible for reading, analyzing and measuring the images collected by the acquisition platform to realize the automatic detection of transmission line crossing points. In addition, the corresponding geometric measurement model is calculated by obtaining the pixel coordinates of the transmission line, and then the pixel coordinates of the transmission line are spatially transformed to meet the system requirements of accurate measurement of crossing points.

4. *Amelioration of on-line measurement of transmission line based on machine vision*

4.1. *Error of transmission line on-line measurement based on machine vision*

Based on the principle of machine vision, the on-line measurement system of transmission line is constructed to calibrate the image acquisition camera, including stereo calibration and camera calibration, so as to realize the calibration and optimization of the image acquisition system. The fitting curve of transmission line for online measurement of transmission line crossing points based on machine vision is shown in Figure 2 below.
It can be seen from the figure that the depth info in the crossing scene is easier to be measured, but the crossing distance info is more difficult. In addition, the errors in the measurement process mainly come from camera calibration and image matching, which need to be ameliorated.

4.2. Amelioration of on-line measurement of transmission line based on machine vision
In the process of error calibration of the camera mechanism of the transmission line on-line measurement system based on machine vision, it is necessary to eliminate the influence of lens distortion of the machine vision camera as much as possible. The camera calibration algorithm is used to optimize the calibration error and control the re projection error, so that it can meet the practical needs of transmission line crossing measurement. In addition, at the level of transmission line measurement image matching, in order to avoid the deformation error caused by the offset of image acquisition equipment, the error optimization is usually realized by changing the transmission line measurement baseline distance.

5. Conclusion
In summary, machine vision tech combined with digital image processing can realize stereo vision measurement and meet the measurement requirements efficiently and accurately. It has high utilization value in the measurement of overhead transmission line crossing clearance distance. Based on the analysis of the principle of machine vision on-line measurement, this paper studies the measurement principle of length, line segment and arc by machine vision. Through the research on the on-line measurement of transmission line crossing points based on machine vision, the architecture of the on-line measurement system, the error sources of the measurement system and the specific measures to ameliorate the error are analyzed.

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Figure 2. The fitting curve of transmission line

The fitting curve of transmission line
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