# Research on Image-based Oil Level Monitoring Technology for Power Transformer Pillow

Yiping Ma [a], Xuefeng Shao [b], Zhengyong Wang [c]

Ningbo Electric Power Design Institute Co., Ltd.. Ningbo 315000.Zhejiang Province. China

[a]51101204@163.com, [b]S51103688@126.com,[c]wzy_330@163.com

## Abstract

**In order to monitor the oil level status of the oil pillow of power transformer in real time, a method of oil level detection based on visible and infrared images is proposed. Firstly, the visible image of the oil pillow is detected, and the edge contour of the oil pillow is extracted as a match template. The infrared image is extracted by edge contour and matched by matching template, then the oil pillow area is extracted, and the extracted oil pillow image is pre-processed by filtering and contrast stretching, followed by morphological and edge detection operations. The oil level interface is initially detected, and then the oil level interface is determined by linear fitting method. Finally, the oil level interface is determined according to the oil level interface. The proportion of oil level is obtained. Experiments show that the proposed method is feasible and can automatically detect transformer oil level. It can be applied to the infrared inspection and warning system of power equipment in unattended substations.**

## Keywords

**Image processing, Power transformer, Oil level status of oil pillow, Real-time monitoring.**

## 1. Introduction

In recent years, with the rapid development of China's economy, the power system is developing towards a strong smart grid with UHV as the main body and coordinated power grids at all of levels[1]. The so-called "self-healing" requires not only that the power grid can quickly remove the fault part and restore the power supply in the fault-free area, but also that it can monitor and warn the power grid online, detect defects in time and take measures to eliminate hidden dangers so as to restore the healthy operation of the power grid[2]. Experience shows that in the early stage of power system failure, many power equipment will be shown as local or overall temperature rise. Infrared detection technology uses the principle of infrared radiation and instruments to obtain the temperature changes of power equipment in operation, and to analyze the hidden dangers. Infrared detection technology is widely used in power system fault diagnosis because of its non-contact, high security, fast response, easy operation, accurate judgement and other advantages that traditional conventional detection methods cannot match[3-7].

At present, most infrared detection methods use hand-held infrared devices to inspect power equipment regularly, and then analyze the acquired data and infrared images by manual methods[8-11]. In recent years, there has also been a long-distance image monitoring system to achieve the regular collection of equipment running pictures, send the images back to the control room for manual analysis[12-13], to a certain extent, reducing manual labor. However, it is still not free from the dependence on artificial analysis, time-consuming and laborious, and difficult to obtain timely and accurate diagnostic results.

Literature [14] proposes an infrared remote viewing and security early warning system for substation electrical equipment, which can automatically collect images, segment them, store the temperature information of each electrical equipment or its components in the database, and carry out security early warning according to simple rules. However, the research on the method of fault diagnosis based on infrared temperature measurement image information is not deep enough.

Because there are many electrical equipments, complex and changeable environment and climate conditions, and various types of faults in substations, image-based research needs to be more detailed and comprehensive. At present, there is still a big gap between the research results and the actual needs in this field. Pillow oil level of power transformer is an important detection factor. It is of great significance to find the oil level too low or too high in time and take corresponding measures to ensure the safe operation of power transformer. The oil level of the transformer pillow should be kept within a certain range. When the oil level is too high, the oil pressure inside the transformer may increase, and at the same time, oil spill will occur. When the oil level is too low, the oil level will decrease when the transformer runs at low load (or the transformer is out of service), or when the weather becomes cold. When the oil level is below the transformer cover, the lead or core will be exposed to the air, which may cause internal flashover. At the same time, the increase of the contact surface between transformer oil and air will make the insulation performance decline rapidly. It can be seen that the power transformer requires a certain oil level in operation, and it must be checked regularly in operation. When the oil level is too high, we should try to release oil; when the oil level is too low, we should try to replenish oil to maintain qualified oil level. The traditional measurement method based on oil level meter is not only inconvenient for digital acquisition, but also inaccurate because of blocking and other reasons.

This paper presents an automatic detection method for oil level of oil pillow, which combines visible and infrared images. This method can be applied to unattended substations.

## 2. Principle of Infrared Detection Technology

In nature, all objects radiate infrared radiation, so using detectors to measure the infrared difference between the target itself and the background, different infrared images can be obtained, called thermal images. The thermal image of the same target is different from the visible image. It is not the visible image that human eyes can see, but the image of the temperature distribution on the surface of the target. Or it can be said that the human eye can not directly see the surface temperature distribution of the target, but become a thermal image representing the surface temperature distribution of the target that can be seen by the human eye. By using this method, the target can be imaged and measured by remote thermal state image, and the intelligent analysis and judgment can be made.

Infrared thermal imaging technology is a passive infrared night vision technology. Its principle is based on all objects in nature whose temperature is higher than absolute zero (-273 degrees C). Infrared radiation emits infrared rays at every moment. At the same time, this infrared radiation contains the characteristic information of objects, which provides an objective basis for using infrared technology to distinguish the temperature and thermal distribution field of various targets. Using this characteristic, the imaging device can simulate the spatial distribution of the object's surface temperature one by one after converting the power signal radiated by the object's heating part into electrical signal through the photoelectric infrared detector. Finally, the thermal image video signal is processed by the system and transmitted to the display screen, and the thermal image corresponding to the thermal distribution of the object's surface, i.e. the infrared thermal image, can be obtained.

## 3. Patrol Inspection System

The substation monitoring and warning system adopted in this paper is composed of infrared and visible light camera, spherical platform, transmission equipment, monitoring computer and supporting software. Aiming at the problem that the existing power inspection system can not accurately detect complex equipment, based on the system described in document [14], the transformer's oil pillow image is processed, and the oil level of the oil pillow is measured to realize real-time automatic diagnosis.

## 4. Automatic oil level detection method

### 4.1 Detection Ideas

Because the power transformer will emit a lot of heat during operation, one of the functions of transformer oil in oil pillow is to absorb heat. Therefore, there will be obvious temperature differences between the oil and oil-free parts of the oil pillow, and there will also be differences between the oil pillow and the surrounding environment. These temperature differences will be very obvious in the infrared image.

The interface between the oil pillow and the surrounding environment is not very obvious because of the heat transfer effect, so the method of setting temperature threshold can not be used to distinguish the oil part from the oil part. Therefore, a method based on visible light and infrared is used to segment the image of the oil pillow and detect the oil level of the oil pillow.

The infrared oil level detection steps proposed in this paper are as follows:

To acquire an image containing a target. Visible and infrared cameras are used to collect oil pillow images in suitable positions. Because the pixel sizes of the two cameras are different, corresponding size processing is needed before processing the images, so that the visible and infrared images to be processed are the same.

Image preprocessing. Due to the influence of environmental factors, there must be noise pollution in the acquired image, and the image has the problem of insufficient contrast, which requires a series of pre-processing operations such as filtering and denoising.

Edge extraction. For the edge detection of the processed visible light image, because there is a significant difference between the pillow and the surrounding environment, there can be obvious color gray changes in the contour part of the pillow. Morphological method can be used to detect the edge lines of the pillow, and then extract the edge contour of the infrared image.

Pillow area extraction. The contour of the pillow is taken out as a matching template, and matched with the contour of the infrared image to find the position of the pillow in the infrared image and extract it.

Oil level detection. The extracted infrared image is processed to find out the approximate oil level interface, and the straight line fitting method is used to further refine the oil level interface.

### 4.2 Image Preprocessing

4.2.1 Noise Filtering

The Because transformer is affected by weather, temperature and other environmental factors, the image taken by camera will be affected by noise. The noise of infrared image is mainly manifests itself as an isolated high-frequency points or blocks in spatial domain[15].

In order to protect the details of the image while removing noise, a median filtering method is selected in the image denoising method. Median filtering is a non-linear smoothing technology that uses a two-dimensional sliding template of a structure to sort the pixels in the board, and finally takes the middle value of the sort as the pixel value of the image in which the midpoint of the template is located [16]. Two-dimensional templates are usually 3 * 3, 5 * 5 regions. They can also be of different shapes, such as linear, circular, cross, circular, etc. The principle is shown in Figure 1.

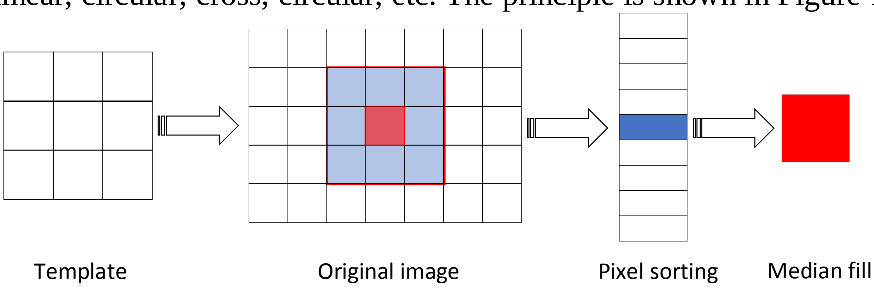


Fig. 1 Median filtering principle

4.2.2 Sharpening Treatment

Image sharpening is to enhance edges. Differential processing can be used or frequency domain filtering can be used. The sharpening operation of infrared image is to extract the important features of the image and prepare for subsequent image segmentation.

For image function $f(x,y)$ . $gray[f(x,y)]=[\frac{\partial f}{\partial x},\frac{\partial f}{\partial y}]$ .The amplitude of using $G[f(x,y)]$ instead of $gray[f(x,y)]$ ,Then $G[f(x,y)]=[(\frac{\partial f}{\partial x})^2,(\frac{\partial f}{\partial y})^2]^{\frac{1}{2}}$ Because the digital image is discrete data, differential operation can be used instead of differential operation. The classical gradient differential algorithm includes: $Robert$ . $Sobel$ . $Canny$ and other operators[17]。

### 4.3 Edge Detection

Because of the temperature difference between the oil pillow and the surrounding environment, it has obvious "edge" in infrared image. The position of the oil pillow in the image can be determined by extracting the edge. In image processing technology, the so-called edge can be defined as the discontinuity of the local characteristics of the image, which is manifested as the drastic change of grayscale in the image[18].

In this paper, an operator and a morphological edge detection operator are used to detect the edge of the oil pillow. Both operators have good edge detection effect, the operator is sensitive to noise and the edge location is accurate. Mathematical morphological edge operators are also sensitive to noise, and the detection effect depends on the selection of structural elements. The edge information in the actual image is often unknown, and the edge detection operator with a single scale can not be detected optimally. Therefore, it is necessary to set the operator type and its parameters in advance in the program according to different conditions in order to achieve better detection results.

Operator

The principle of edge detection by operator is to approximate the gradient solution by the difference between any pair of vertical directions. The gradient value is replaced by the difference of the size of two adjacent pixels in the diagonal direction.

$$\nabla f=(f(x,y)-f(x-1,y),f(x,y)-f(x,y-1))$$

In practical application, it calculates every pixel in the image, then calculates the absolute value, and finally performs threshold operation, which can be expressed by the following formula:

$$g(x,y)=\{[f(x+1,y+1)-f(x,y)]^2+[f(x+1,y)-f(x,y+1)]^2\}$$

Where $f(x,y)$ is an input function, which is a $g(x,y)$ output function.

Morphological Operator

Mathematical morphology mainly focuses on the morphological features of images. Mathematical morphology has some obvious advantages over other spatial or frequency domain image processing and analysis methods. It is not as sensitive to noise as differential algorithm, and the extracted edges are smooth. The skeleton extracted by mathematical morphology method is more continuous, with fewer breakpoints and easy to implement.

If A is the image to be processed and B is the structural element, then:

Expansion: The process of merging all background points in contact with an object into the object and extending the boundary outward. By expanding, small holes in the image and small depressions in the edge of the image can be filled. The expansion of structure B to image A is recorded and defined as:

$$A\oplus B=\{x:-B_x\cap A\neq\varnothing\}$$

Corrosion: It is a dual operation of expansion, a process of eliminating boundary points and shrinking the boundary to the interior. By means of corrosion operation, meaningless and small objects can be eliminated. Image A is corroded by structure B and is recorded as:

$$A\Theta B = \{x : B_x \subseteq A\}$$

Low-cap operation: Corrosion of image A using structure B, and then the difference between the result of corrosion and image A are calculated, and the image edge H is obtained, which is expressed by formula as follows:

$$H = A - (A\Theta B)$$

### 4.4 Contour Extraction

Because of the prominent advantages of visible image in image processing, the method adopted in this paper is to extract the oil pillow contour of transformer from visible image as a template for infrared image processing, and to detect the edge of infrared image. Because the detection method of infrared camera belongs to passive detection method, it only responds to the temperature of the detected object obviously, so the detected edge is not very precise. Indeed, further processing is needed; therefore, the edge contour obtained from the visible image is used as a template to detect the accurate contour of the oil pillow in the infrared image, and the accurate oil pillow image in the infrared image is intercepted to detect the oil level.

### 4.5 Oil Level Detection

Because the oil in the oil pillow mainly plays the role of heat dissipation and insulation, it contacts directly with the core and coil of the transformer. When transformer runs, the temperature of core and coil rises sharply, which will directly cause the temperature of oil contacted with it to rise; it makes the temperature of oil in oil pillow and air temperature in oil pillow have a big gap. Infrared camera is sensitive to temperature change, so the proportion of oil level in oil pillow can be detected by infrared image.

## 5. experimental verification

In this paper, the method is used to verify the infrared image of a power transformer pillow. All the programs are programmed with MATLAB software.

Figure 2 shows the edge points obtained by extracting the oil pillow image from the visible image and using the mathematical morphology edge detection operator for edge detection, which is used as a matching template in subsequent operations.

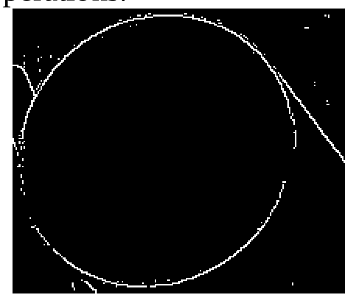

Fig. 2 Pillow edge image extracted by visible light

Fig. 3 shows the best matching result area in infrared image by matching the visible light matching template in Fig. 2.

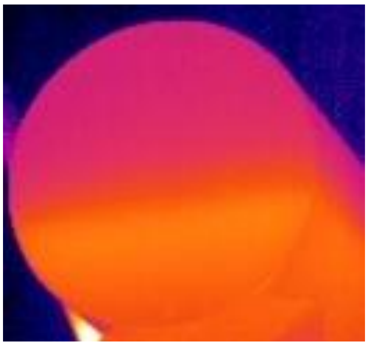

Fig. 3 Infrared Pillow Image

Fig. 4 is a gray-scale image of the infrared pillow image in Fig. 3, which is transformed from color image to gray-scale image and enhanced by contrast.

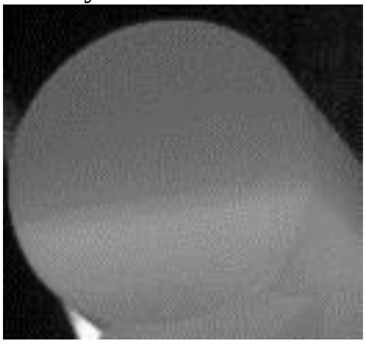

Fig. 4 Grayscale enhancement processing image

Fig. 5 is the outline of the oil-free part of the oil pillow drawn on the gray-scale image of the oil pillow after sharpening operation on Fig. 4 and edge detection using Robert operator.

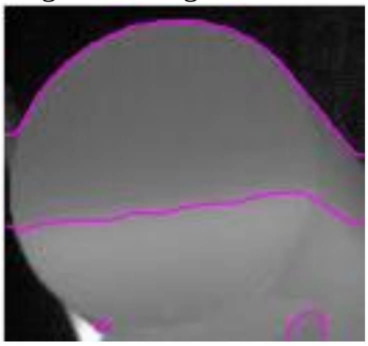

Fig. 5 Edge contour of oil-free part

Fig. 6 is the contour line of the oil-bearing part at the bottom of the pillow drawn on the gray-scale image of the pillow after sharpening operation on Fig. 4 and edge detection using Robert operator.

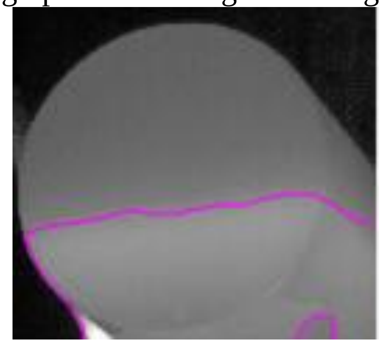

Fig. 6 shows the contour image of the oil part.

Fig. 7 superimposes the upper and lower contours of the pillow on the basis of Fig. 5 and Fig. 6 to get the image of the pillow with oil level marker; then the image is corroded with the whole image without oil level marker, and the image of the pillow with only oil level marker is obtained initially; finally, the data points on the oil level marker are linearly fitted to get the accurate oil level image.

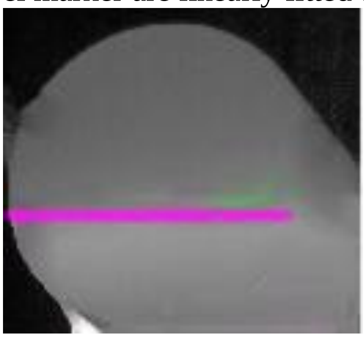

Fig. 7 Oil level image

After getting the oil level image in Figure 7, we can get the height from bottom to top of the oil pillow in the image by pixel operation. The proportion of oil level interface in the oil pillow can be obtained by oil level height. Through the actual measured parameters of transformer oil pillow, we can get the actual height of the oil pillow, so that we can monitor the oil pillow of different specifications in real time. Measure its oil level.

Article 4.4 of National Standard GB/T6451-1995 "Technical Parameters and Requirements of Three-phase Oil-immersed Power Transformer" clearly stipulates that the structure of oil storage tank of transformer with oil storage tank should be easy to clean up its interior. The volume of oil storage tank should ensure that oil does not spill out when the ambient temperature is 40 full load, and oil level gauge should be visible when it is not put into operation at - 30 C. By using this method, the proportion of oil area and oil-free part can be calculated, and the proportion of oil position of oil pillow can be calculated to be 39.8%. The state of oil position of oil pillow of transformer belongs to normal state[19].

## 6. Conclusion

The method of combining visible and infrared images to monitor oil level of power transformer proposed in this paper is feasible and can be used as an effective supplement to the substation monitoring system.

The pillow edge is extracted from the visible image as a matching template, and the pillow image can be effectively extracted from the infrared image by using the template to remove and the pillow image in the infrared image.

According to the difference of temperature between oil-bearing and non-oil-bearing parts, the interface of oil level can be distinguished. The current oil level parameters can be obtained by using the ratio between them, and then the oil level parameters can be obtained by corresponding treatment.

## References

[1] B. Li, S. M. Tian, et al. Recent progress and development trend of User domain Standardization in smart Grid, Electric Power Construction, vol. 39 (2018) No.3.

[2] Z. Song: Overview of Smart Grid and its key technologies, Theoretical research on Urban Construction, (2016) No.25.

[3] F. Han, F. L. Zheng, J. H. Su: Study on diagnosis of Defects of zinc oxide arrester by infrared temperature measurement, Electrical applications, (2013) No.S1, p.594-595.

[4] Y. F. Liu, J. G. Li: Application of infrared diagnostic technology in Suzhou power grid, High Voltage technology, vol. 34 (2008) No.2, p.413-415.

[5] Z. S. Li, J. G Yao, Y. J. Yang, et al. Analysis of the angle of view of infrared thermal imaging detection of insulator contamination grade, High Voltage technology, Vol. 34 (2008) No.11, p.2327-2331.

[6] Z. R. Xu, S. L. Tang: On-line fault diagnosis of infrared thermal imaging technology, Power Equipment, Vol. 5 (2004) No.3, p.79-81.

[7] X. M. Wang, D. L. Zhou: Application analysis of infrared diagnostic technology in power system condition maintenance, Electronic production, (2018) No.12.

[8] Q. Q. Zhang, H. Y. Lu, X. F. Huang, et al. Fault infrared diagnosis Expert system for power transformer , Power grid Technology, Vol.26 (2002) No.9, p.18-21.

[9] D. M. Fu, X. G. Li, Z. H. Tang, et al. Infrared diagnosis Technology of electrical equipment fault and its software system development, Power system Automation, Vol.25 (2001) No.9,p.55-57.

[10] Specification for infrared diagnostic applications for dl/t 664-2008 charged devices, (Beijing): China Electric Power Press, (2008).

[11] H. G. Hu: Infrared diagnostic technology and application of electric power Equipment, China Electric Power Press, (2012).

[12] R. Li: Research and implementation of fusion of infrared temperature measurement technology and substation Image Monitoring System, Power grid Technology, Vol.32 (2008), No. 14,80-84.
[13] Z. B. Zhao, Q. Gao, Z. S. Yuan, et al. A new method for on-line monitoring of electrical equipment temperature in substation, High Voltage technology, Vol.34 (2008) No.8, p.1605-1609.
[14] L. Jian.L. Lin.G. Liu.et al. A substation monitoring and warning system based on infrared technology and image separating, International Conference on Intelligent System and Knowledge Engineering, (2008) p.66-70.
[15] Y. S. Sun, K. Bai: An improved method for enhanced processing of infrared image filtering, Journal of Zhengzhou Institute of Light Industry: Natural Science Edition, Vol.24 (2009) No.6, p.75-77.
[16] X. H. Xiao,E. Du,Q. H. Chen,et al. Infrared image edge detection of high-voltage transmission line, Electric Power.(2005).
[17] X. F. Hu, H. Zhao: Visual c++/matlab image Processing and recognition practical case selection, People's post and Telecommunications press, (2004).
[18] J. Liu, C. Xie, L. H. Lin: Automatic detection method of power transformer oil level based on infrared image, High voltage Technology, Vol.36 (2010) No.4, p.964-970.
[19] M. Yi: GB/T 6451-2015 technical parameters and requirements for oil-immersed power transformers will be implemented with effect from April 1, 2016, Transformers, (2016) No.3 p.46-46.