Research on Image Processing Method of High Voltage Switchgear Temperature Measurement

Longji Du1,a, Shi Zhang2,b, Liming Chen1,c, Jinglong Ye1,d, Meiting Ma1,e, Aidi Jia1,f, Biao Ma1,g, Aihong Ming1,h, Hefeng Liu3,i

1Changji power supply co., Ltd.State Grid Xinjiang Electric Power Co., Ltd. Changji, China
2School of Electrical Engineering. Northeast Electrical Power University. Jilin, China
3Technical and Economic Center. Jilin Provincial Institute of economy and Technology. Changchun, China

aximudongtu@163.com, bzs472254835@126.com, c1875155399@qq.com, d446548292@qq.com, e1293316805@qq.com, f654615992@qq.com, g156217173@qq.com, h396161060@qq.com, isteven110531@163.com

Abstract. Accurate monitoring of electrical equipment temperature can effectively ensure the safety of electrical equipment operation. It is worth further study to use limited temperature monitoring equipment to obtain a comprehensive temperature distribution of electrical equipment. Based on the study of nearest neighbor interpolation bilinear interpolation and bicubic interpolation these three methods are applied to image processing of temperature distribution in 10kV switchgear cabinets. Compared with the three methods, bilinear interpolation and bicubic interpolation can accurately reflect the non-measured temperature, and can be used in image processing of temperature distribution in high-voltage switchgear temperature measurement system.

1. Introduction

In power system, the electrical equipment in long-term operation in high voltage and large current environment, the equipment due to aging or overload current due to temperature rise, especially the equipment contact and bus connection and other key parts, there is a greater possibility of overheating; The overheating of the equipment may lead to sudden power outages and even fire accidents [1-3]. Therefore, the research of on-line non-contact comprehensive temperature monitoring system which does not affect the safe operation of high-voltage switchgear, transformer and other electrical equipment can effectively ensure the safety of the operation of electrical equipment.

In order to master the temperature of the high voltage switchgear more comprehensively and accurately, several observation points can be set up, and the temperature distribution information of the observation point can be collected by using the temperature sensor. Considering the cost of temperature measurement and the capacity of switchgear, the number of temperature observation points is limited, the pixel of temperature distribution diagram of switchgear is very low, so the temperature of non-observed points is not easy to capture, so the method of image interpolation can be adopted. Based on the low pixel temperature distribution, the high pixel temperature distribution map
is obtained, so that the temperature distribution of non-observed points can be collected more
accurately. At present, the methods of image interpolation include nearest neighbor interpolation,
bilinear interpolation and bicubic interpolation, and three kinds of image interpolation methods. The
interpolation methods have been applied well [4-8]. However, which method is more suitable for the
image processing of high voltage switchgear has not been studied.

Based on the study of nearest neighbor interpolation bilinear interpolation and bi-cubic
interpolation three methods are applied to image processing of high-voltage switchgear temperature
distribution respectively and the most suitable image processing method of high-voltage switchgear
temperature distribution is obtained in this paper.

This article is organized as follows: Section 2 shows the basic principle of image interpolation,
Section 3 shows a real case analysis, and in Section 4 some important conclusions are provided.

2. Principle of Image interpolation

The nearest neighbor interpolation is the simplest gray interpolation, also called zero order interpolation,
which makes the gray value of the transformed pixel equal to the gray value of the input pixel nearest to
it. Nearest neighbor interpolation is the simplest interpolation method, but its calculation accuracy is
low.

The bilinear interpolation is a linear interpolation in two directions. Assume that a known image has
four pixels 

\[
(x_1, y_1), (x_1, y_2), (x_2, y_1), (x_2, y_2),
\]



, the values of them are \(Q_1\), \(Q_2\), \(Q_1\), \(Q_2\), in \(x\) direction
interpolation results in:

\[
f(R_1) = \frac{x_2 - x}{x_2 - x_1} f(Q_1) + \frac{x - x_1}{x_2 - x_1} f(Q_2)
\]

(1)

\[
f(R_2) = \frac{x_2 - x}{x_2 - x_1} f(Q_1) + \frac{x - x_1}{x_2 - x_1} f(Q_2)
\]

(2)

Where \(R_1\) the value of is \((x_1, y_1)\), \(R_2\) is the value of \((x, y_2)\).

In \(y\) direction interpolation results in:

\[
f(P) = \frac{y_2 - y}{y_2 - y_1} f(R_1) + \frac{y - y_1}{y_2 - y_1} f(R_2)
\]

(3)

Combine formula (1), formula (2) and formula (3) to obtain a gray interpolation result \(f(x, y)\) for
any point:

\[
f(x, y) = \frac{f(Q_1)}{(x_2 - x_1)(y_2 - y_1)}(x_2 - x)(y_2 - y) + \frac{f(Q_1)}{(x_2 - x_1)(y_2 - y_1)}(x - x_1)(y_2 - y) + \frac{f(Q_1)}{(x_2 - x_1)(y_2 - y_1)}(x_2 - x)(y - y_1) + \frac{f(Q_1)}{(x_2 - x_1)(y_2 - y_1)}(x - x_1)(y - y_1)
\]

(4)

Bicubic interpolation is more complicated than nearest neighbor interpolation and bilinear
interpolation. In the interpolation results, each pixel data is referenced by the known pixels in 16
fields. Assume that the pixel gray values within the 4x4 neighborhood of a point are: 
\[ f(i-1,j-1), f(i-1,j+1), f(i-1,j+2), f(i,j-1), f(i,j), f(i,j+1), f(i,j+2), f(i+1,j-1), f(i+1,j), f(i+1,j+1), f(i+1,j+2), f(i+2,j-1), f(i+2,j), f(i+2,j+1), f(i+2,j+2) \]. For location \((i+s, j+t)\), the pixel gray value at can be expressed as:

\[ f(i+s, j+t) = ABC \]  

(5)

Where \(A\), \(B\), \(C\) can be shown as:

\[
A = [R(s+1) \quad R(s+0) \quad R(s-1) \quad R(s-2)]
\]

(6)

\[
B = \begin{bmatrix}
  f(i-1, j-1) & f(i-1, j) & f(i-1, j+1) & f(i-1, j+2) \\
  f(i, j-1) & f(i, j) & f(i, j+1) & f(i, j+2) \\
  f(i+1, j-1) & f(i+1, j) & f(i+1, j+1) & f(i+1, j+2) \\
  f(i+2, j-1) & f(i+2, j) & f(i+2, j+1) & f(i+2, j+2)
\end{bmatrix}
\]

(7)

\[
C = [R(t+1) \quad R(t+0) \quad R(t-1) \quad R(t-2)]^T
\]

(8)

Where \(R(x)\) is:

\[
R(x) = \begin{cases} 
1 - 2x^2 + |x|^3; & (0 \leq |x| < 1) \\
4 - 8|x| + 5x^2 - |x|^3; & (1 \leq |x| < 2) \\
0; & (|x| \geq 2)
\end{cases}
\]

(9)

Although the accuracy of bicubic interpolation is high, the calculation speed is slow because of the increase of computation.

3. Analysis of real case

The temperature information of the current equipment temperature on-line monitoring platform can be collected as shown in Figure 1.

![Fig. 1 Interface of temperature On-line Monitoring platform for Electrical equipment](image)

The switch cabinet image in figure 1 is 16x16 pixels, and the original image temperature distribution is shown in figure 2.
Fig. 2 Original image

The original image is 20 times interpolated using the nearest neighbor interpolation, bilinear interpolation, and bicubic interpolation, as shown in figure 3, figure 4 and figure 5.

Fig. 3 Nearest neighbor interpolation image

Fig. 4 Bilinear interpolation image
From figure 3, figure 4 and figure 5, it can be seen that the results obtained by using nearest neighbor interpolation cannot accurately reflect the temperature distribution of non-measured points, while the results of bilinear interpolation and bicubic interpolation can be used to see the temperature of non-measured points.

The temperature of five non-measured points is measured randomly by a temperature measuring device, and the results are compared with the corresponding pixel temperatures in three interpolated images. The results are shown in figure 6.

It can be seen from figure 6 that the temperature of the non-measured point obtained by the bilinear and bi-cubic image interpolation is close to the actual temperature, and the temperature obtained by the nearest neighbor interpolation is larger than the actual temperature.

4. Conclusion
In this paper, the processing method of temperature image of high voltage switchgear is studied. The results show that the temperature distribution of measured point cannot be accurately reflected by nearest neighbor interpolation. The temperature distribution of non-measured points can be accurately reflected by bilinear and bicubic interpolation.

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References

[1] Yanabu S, Zaima E, Hasegawa T. Historical review of high voltage switchgear developments in the 20th century for power transmission and distribution system in Japan [J]. IEEE Transactions on Power Delivery, 2006, 21(2):659-664.

[2] Kitak P, Pihler J, Ticar I, et al. Use of an optimization algorithm in designing medium-voltage switchgear insulation elements [J]. IEEE Transactions on Magnetics, 2006, 42(4):1347-1350.

[3] Kim J K, Hahn S C, Park K Y, et al. Temperature rise prediction of EHV GIS bus bar by coupled magnetothermal finite element method [J]. IEEE Transactions on Magnetics, 2005, 41(5):1636-1639.

[4] Mahajan D, Huang F C, Matusik W, et al. Moving gradients:a path-based method for plausible image interpolation [J]. Acm Transactions on Graphics, 2009, 28(3):1-11.

[5] Han J W, Kim J H, Cheon S H, et al. A novel image interpolation method using the bilateral filter [J]. IEEE Transactions on Consumer Electronics, 2010, 56(1): 175-181.

[6] Frakes D H, Dasi L P, Pekkan K, et al. A new method for registration-based medical image interpolation [J]. IEEE Transactions on Medical Imaging, 2008, 27(3): 370.

[7] Shin D H, Yoo H. Computational integral imaging reconstruction method of 3D images using pixel-to-pixel mapping and image interpolation [J]. Optics Communications, 2009, 282(14): 2760-2767.

[8] Chen Z, Wang X, Liang R. Calibration method of microgrid polarimeters with image interpolation [J]. Applied Optics, 2015, 54(5): 995-1001.