The Application of Excel Regression Analysis Tools in the Measurement of the Winding's Temperature Rise

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Abstract

The electrical resistivity method survey conductor temperature principle is the conductor resistance value if the degrees Kelvin value has the direct ratio. The correlativity dependence may reflect between the variable exists relations, but is not the definite functional relation. Between the correlation variable, the use mathematical statistic related principle, may discover in statistics significance "the functional relation". The method of regression line has used the differential coefficient extreme value principle; with it determined winding temperature ratio at power failure uses other mean more accurate somewhat. After the power failure the winding temperature and the time are the linear relations by no means. In the testing, the data acquisition must complete in a shorter time, by now the winding temperature and the time basically assumed the linear correlation relations, calculated the data was accurate. Through to coefficient of determination r, the F-test and the residual plot analysis, obtains the variable X with Y between whether has the remarkable linear correlation relations. Reads takes intercept and the slope (X Variable) from "The result" in the regression analysis uses in to establish the regression equation.

Keyword

Temperature rise, electrical resistivity method, regression analysis, correlation coefficient, F-test, residual plot, Excel worksheet

1. Outline

Spare part its interior includes the winding in the electric motor, the transformer, the relay, the magnetic clutch and so on obtain the widespread application in the information technology equipment. When equipment normal work, passes a stronger electric current in winding of these spare part usual long time, easy to create the winding hyperpyrexia, thus causes its insulating ability to encounter the damage, even can bring the fire risk. GB4943-2001 "Information technology equipment Security" has explicitly stipulated the limiting value of the winding's temperature rise, measure the limiting value with the electrical resistivity method or the thermoelectric couple method. Measure the temperature rise of winding with the thermoelectric couple method, sometimes arranges the measuring point to be not very convenient, influence measurement accuracy. With the electrical resistivity method to be possible to avoid these insufficiencies.

The electrical resistivity method survey conductor temperature principle is the conductor resistance value if the degrees Kelvin value has the direct ratio. When examination, measures the winding resistance value after to separate the power source. Because the winding temperature gradually drops after

separates the power source, therefore obtains the resistance value certainly is not the resistance value of winding's highest temperature rise. The usual procedure is: After the separation winding power source， surveys its resistance value as soon as possible, after then separates period of time to survey its resistance value again, meets there petition to carry on the above operation, like this may obtain a series of resistance value with time correlation. These resistance value signs in the rectangular coordinates, it is take the time as the abscissa axis, the resistance value ordinate axis, connects these spots uses the curve, obtains a trend line of winding's resistance value change, when may determine the winding maximum temperature resistance value. Uses the following formula to be possible to calculate temperature rise of the winding (take copper wire as example):

$$\Delta t = \frac{R_2 - R_1}{R_1}(234.5 + t_1) - (t_2 - t_1)$$

In the formula:
T - winding rise, K
R1 - winding resistance value when starts the experiment, Ω
R2 - winding resistance value in conclusion the experiment, Ω
t1 - room temperature when starts the experiment, ℃
T2 - room temperature in conclusion experiment time, ℃

In above winding temperature rise measurement process, because must receive the environment, experiment the instrument, the operator and so on the various factor influence, the curve obtains by the measurement possibly can have a bigger difference with the actual temperature decrease curve, thus causes the measuring error.

2. Regression analysis method in winding temperature rise measurement application

2.1 Regression analysis method

Between the variable relations may divide into two kinds of types. A kind is the functional relation, may reflect the definite relations between the variable; another kind is the correlation dependence, may reflect the relations exists between the variable, but is not the definite functional relation. Between the correlation dependence variable, may discover "the functional relation" using the mathematical statistic related principle in statistics significance.

2.2 regression analyses principle of winding temperature rise measurement

After the electric power supply separation, the winding does not continue the heat generation. Along with time passing, the

winding temperature must gradually drop. Because the radiation effect and so on the various aspects factor influence, is not easy to determine the functional relation in the winding temperature (resistance value) and the time. But, it is related between the winding temperature (resistance value) and the power separates, so long as the choice measurement opportunity is appropriate, Can discover the quite close real relational curve between Winding resistance value and time, Thus calculates the winding the resistance value in the power separates, Then obtains the winding the temperature in this time.

"The method of regression line" has used the differential coefficient extremum principle, with uses the other means, determines winding temperature more accurate somewhat with it. But this method is take has the remarkable linear relations as a premise between winding temperature (y) and time (x), the winding is separated which by the power. In other words if that does not have the remarkable linear relations either the linear correlation degree is lower or has other relations between winding temperature (y) and time (x), the winding is separated which by the power. Its accuracy with difficulty guaranteed. In order to judge the winding's temperature (y) and the time (x) whether has the distinct correlativity, must calculate correlation coefficient **r**.

However the modern statistical theory proved that, merely depends upon correlation coefficient r to judge the winding temperature (y) and the time (x) between whether has the distinct linear relations is unreliable. In order to reliably judges whether has the distinct linear relations between winding temperature (y) and time (x). Not only needs to calculate correlation coefficient **r**, but also should use the many kinds of statistical indicators to verify, such as "coefficient of determination", "F-test", "residual plot" and so on. After obtains the consistent conclusion, only then may quite accurately determine the relations between winding temperature (y) and time (x).

That is extremely complex and the time-consuming work with manually calculates above these statistical indicators. Judges whether has the distinct linear relations between winding temperature (y) and time (x) to provide the enormous convenience，through the use "the Excel worksheet". The calculation of statistical indicators is greatly the simplification.
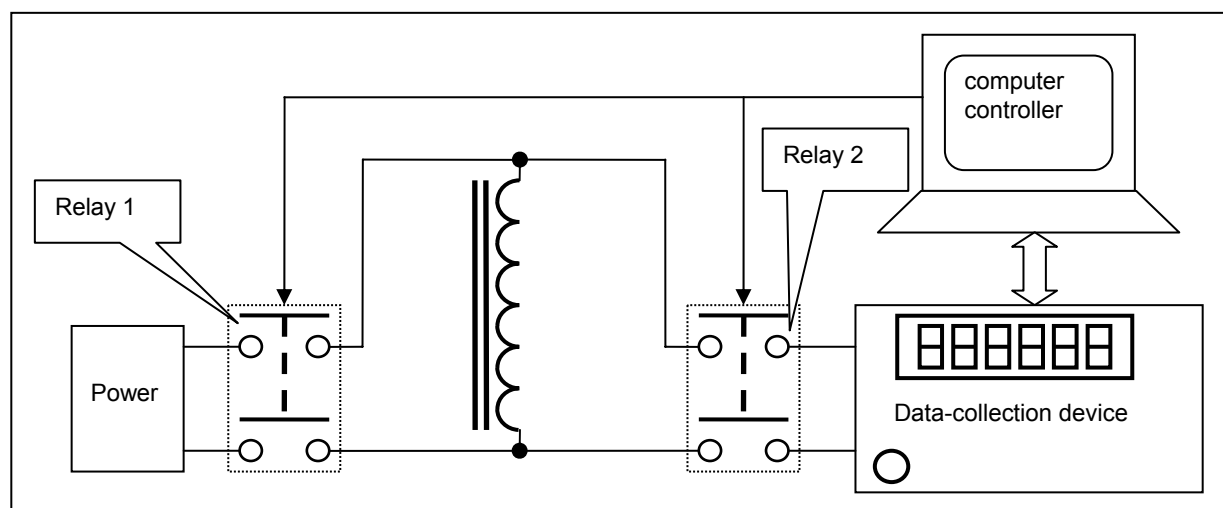

Fig. 1 winding temperature rise test schematic diagram

3. Test process

Winding temperature rise test shows fig. 1. The test system is composed by the computer, the data-collection device, the relay and the power source. A control panel is put in the computer; it is used for the control relay the active status. The data-collection device is used for to gather the winding resistance value. After the computer sends out starts the signal, according to the certain period, the data-collection device continuously gathers the winding resistance value. After the data collection process completes, the data is transmitted the computer, then automatically processed. Two relays are separately used in to control the winding power source and the data channel of data-collection device.

After the experiment starts, first separates relay 2, then closed relay 1, lets the electric current flow the testing winding. After the process that winding gives off heat had ended, first separates relay 1, then closed relay 2. Continuously collects the winding resistance according to a certain period by data-collection device. After the data acquisition had ended, winding resistance data which obtains transfer to computer by data-collection device, and carries on the data processing by the computer. Finally forms the test result.

The object heat exchange and the difference in temperature have the direct ratio. Namely when same time-gap, the difference in temperature more; the quantity of heat exchange are more. Therefore the winding temperature after power failure and the time are the linear relations by no means. Therefore, in the testing, the data acquisition completes in shorter time. By now, the winding temperature and the time basically assumed the linear relations, calculated the data was accurate.

4. Processes the data with the Excel worksheet

4.1 start the Excel worksheet input correlation data

Table 1 is a temperature rise test measurement result for a power transformer primary winding. After separation power of the winding latter 0.2 second, measures the first resistance data. Then measures another resistance data after 0.2 second, altogether gathers 20 data.

Table 1

A power transformers primary winding measurement result

Sequence number	Time t (s)	Winding resistance (Ω)	Sequence number	Time t (s)	Winding resistance (Ω)
1	0.2	70.0	11	2.2	60.7
2	0.4	61.9	12	2.4	60.5
3	0.6	61.8	13	2.6	60.4
4	0.8	61.6	14	2.8	60.3
5	1.0	61.5	15	3.0	60.1
6	1.2	61.3	16	3.2	60.0
7	1.4	61.2	17	3.4	52.9
8	1.6	61.1	18	3.6	52.8
9	1.8	60.9	19	3.8	52.6
10	2.0	60.8	20	4.0	52.5

Starts the Excel procedure, appears a blank "Excel worksheet", this table name is "Book1". Inputs in turn the winding resistance value to A row, namely A1=70.0, A2=70.1... ... A20=52.5. Inputs in turn the time which survey resistance to B row, namely B1=0.2, B2=0.4... ... B20=4.0.

4.2 Calculates the correlation statistics parameter transfer regression analysis tool

Single-clicks the "tool" option in "Excel worksheet" menu. Single-click the "data analysis" option in drop-down menu. Popup "analyzes tool" option frame from "data analysis", selects the "regression" analyze tool.

Popup the "**Regression**" analysis dialog box in "**Analyze Tool**" after single-clicks **Enter**. After that, only needs to input the corresponding data in "**Regression**" of the analysis dialog box and the determination related option then.

First, single-clicks "Y value input region (Y): " . Input observed value of resistance. After that, single-clicks "X value input region (X):" . Input **Time** value. "Output option" fills in C1. The analysis result gets up by C1 starts to show. Returns "regression" analysis dialog box in the "**Analyzes Tool**".

Except the dependent variable data input "inputs the region in the Y value" and the independent variable data input "inputs the region in X value" In regression analysis dialog box. Also has the option which some analyses needs to do. According to analyzes needs to choose. We select "residual plot" the check box. Then clicks "Enter" button. Plaster the calculated result of the regression analysis tool from the C1 unit.

4.3 determinations correlation dependence between measures the time X and coil resistance Y According to computed result

4.3.1 Coefficients of determination r^2

r^2 more close to 1, each observation value in sample more approaches the regression line. The explanation reflected each observation value of sample fitting regression equation close degree is high.

In this example, Decided coefficient r^2 is 0.99864237 which is in "regression statistics" in Regression analysis computed result. Approaches to 1. Explained it has the distinct linear correlation relations between X and Y (Namely, between time after power source separates and winding resistance value).

4.3.2 F-test

The F-test is one kind of significance test to regression equation. It tests the significance of regression equation directly from regression effect according to square sum decomposition formula. Under the specified significance level α , if $F \leq F_α(1, n-2)$, then recognized that is not distinct linear relations between variable X and Y. if $F > F_α(1, n-2)$, then recognized that is distinct linear relations between variable X and Y.

The F value in analysis of variance box is: 13240.37 in this example.

In significance level α =0.05, looks up F0.05 (1, 18) =4.41 by the F distribution list.

F=13240.37>4.41, explained that is distinct linear relations between variable X and Y. Namely, time and winding resistance is in existence distinct linear correlation relations after separates the power source.

4.3.3 residual plot appraisal

The residual plot is residue of each independent variable description the graph which forms in this place coordinates. Its take independent variable of regression equation as an x-coordinate, Take the residue εi as the y-coordinate. The description spot random distribution revolves the straight line (εi=0) , The showing regression line is good to the original observation value fitting situation. Otherwise, the showing regression line is not ideal to the original observation value fitting.

May see residual plot from the example, the residue absolute value quite is all small (does not surpass 0.06), describes the spot all about the εi=0 abscissa axis the random distribution, the explanation regression line to the original observed value fitting situation is good. Namely, It has the remarkable linear correlation relations between the variable X (time of separates power source) and Y (winding resistance value).

4.3.4 establishments regression model

Through to coefficient of determination **r**, the F-test and residual plot analysis, has drawn this kind of conclusion: It has the distinct linear correlation relation between the variable X and Y.

"The calculated result" reads takes Intercept=55.1263 and the slope (X Variable) =-0.6602 from the regression analysis. The supposition winding resistance is R (variable Y), the time of power source separated is t (variable X), then regression model as follows:

R=55.1263-0.6602t

the winding resistance is 55.126355.13 when Power source separation (t=0).

5. Conclusion

Compares with the use coordinate paper mapping, obtains the data with the regression analysis method processing winding

temperature rise test, may avoid by the person creating at will. Obtains the winding resistance value change trend line through the strict mathematics method. Processing data using the regression analysis tool of the Excel work sheet, may greatly save the time, enhances the efficiency and the accuracy.

Because the winding temperature and the time certainly are not the absolute linear relations. In order to enhance the accuracy, the data acquisition time should complete in a shorter time. Can cause the resistance value of winding and the time assume the linear correlation relations.

The data acquisition process automatically completes, may avoid the error which aspect and so on environment, operator introduces, thus enhancement measuring accuracy.