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USING A MATHEMATICAL TOOL IN ELECTRIC MACHINE DIAGNOSTICS BY MEANS OF THE SURGE GENERATOR PSG 215 A

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Abstract − Surge wave diagnostics is based on the principle of discharging two identical capacitors (high-frequency surge) into two loads (windings), and subsequent displaying resonant damped processes on loads by means of the two-channel oscilloscope. To increase the ability to identify failures, this signal must be, however, digitised and analysed by means of a mathematical tool. Generally, it has been stated that through this method, one of ten turn-to-turn short circuits can be identified without digitising the signal; after signal digitising, the identification of failures being improved approximately tenfold.

Keywords: Surge wave, elektric machine, diagnostic

1. EVALUATION CRITERIA

The simplest method of failure detection is an amplitude tolerance band. Along the whole length of the reference (comparative) curve there is the same tolerance band. Those devices will stand the test, with which all points of the curve measured occur just in the mentioned tolerance band.

$$VH = \max, \min, pk - pk\left|u_{z1}(t) - u_{z2}(t)\right| \qquad (1)$$

An area below the curve is another criterion. Areas below the comparative and the compared curve are calculated. The difference between those areas is the area of failure expressed as a percentage of the reference curve.

$$VH = \int_{t_1}^{t_2} \left|u_z(t)\right| \cdot dt \qquad (2)$$

A differential area is a similar criterion. The area formed between both the curves is being calculated.

$$VH = \int_{t_1}^{t_2} \left|u_{z1}(t) - u_{z2}(t)\right| \cdot dt \qquad (3)$$

One of rather modern means used for signal analysis is a so-called wavelet transformation. The wavelet transformation is a localised time-frequency analysis and is an unambiguous representation of the local Fourier information of the function studied. More generally, we define the wavelet transformation as follows:

$$\Psi f(\alpha, \beta) = \int_R f(t) \cdot \overline{\psi(\alpha, \beta, t)} \cdot dt \qquad (4)$$

where $\alpha \in R - \{0\}$ expresses the dilatation parameter (characterising frequency) and $\beta \in R$ carries the information on translation (shift). The function ψ is a so-called mother wavelet represented by a wave acquiring positive and negative values. However, it need not be symmetric, and is formed by means of linear combinations of scaling functions $\phi(t)$.

For each α and β, the wavelet transformation provides information on the studied function in the given frequency band. As soon as $|\alpha| \to \infty$, then this transformation represents a piece of high-frequency information on the function $f(t)$, and on the other hand, if $|\alpha| \to 0$, the transformation furnishes a piece of low-frequency information on $f(t)$ close to $t = \beta$.

The majority of analyses are orientated towards the smoothing or eliminating a random noise signal term. At the Fourier filtration, we multiply all Fourier coefficients by the weighting function that eliminates or suppresses all spurious frequencies. At the wavelet filtration, the procedure is similar, but the effect of smoothing is merely local. Thus filter can adapt itself to the local character of the signal, and where it shows a higher dynamic range (it carries a useful piece of information at higher frequencies), it can decrease a rate of reduction of high-frequency components.

2. EXPERIMENTS CONDUCTED

Measurements in the laboratory of technical diagnostics were taken on the wound coil (968 turns, D = 25.5 mm, l =1885 mm, R =0.713 Ω , r = 1.7 mm) with tapped turns for the purpose of measurement.

Both the measurements were done simultaneously on one coil. One measuring channel was connected to the whole coil, and through the other measuring channel, all tapped turns were gradually measured. Before these measurements, 100 measurements had been carried out on the whole coil (968 turns) with the aim to find out the statistical distribution of the value measured. Thus a possibility of quantifying the probability of undetecting failures modelled has been achieved.

3. EVALUATION

From the made measurements that were carried out to get the statistical distribution of chosen types of the mathematical tool, two types of the distribution were separated (Weibull distribution for criteria according to relations (2) and (3) and standard one for criteria according to relation (1)). From Fig. 1 it follows that merely the only criterion (according to relation (2)) has satisfied our expectations as for signal digitising; we are able to identify about 60 turn-to-turn short circuits at 968 turns. All other criteria could identify failures at high inaccuracy, which was not appropriate for our decision-making.

The use of the wavelet transformation (Fig. 2) for calculations of criteria has brought rather significant progress. All evaluation criteria identify turn-to-turn short circuits from 5 to 968 according to the criterion selected. Only the criteria according to relation (3) have not satisfied our expectations, and can be used for evaluation no more. We have achieved the best results with criteria determining min and pk – pk from the curves (after 5 turn-to-turn short circuits, we are able to detect a failure at 99.95% probability).

4. CONCLUSIONS

By means of the mathematical tool the accuracy of evaluating the turn-to-turn short circuits can be improved, especially in the case of multi-turn coils. Separate criteria have certain limits that will be a subject of the next study. The application of the wavelet transformation has evidently increased the probability of detecting the short circuits that occur with a less number of turns. In contrast to the previous determinations, we have increased a possibility of detection from 60 to 5 turn-to-turn short circuits.

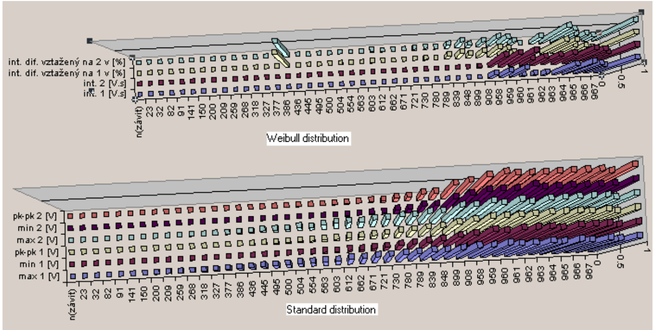

Fig. 1.

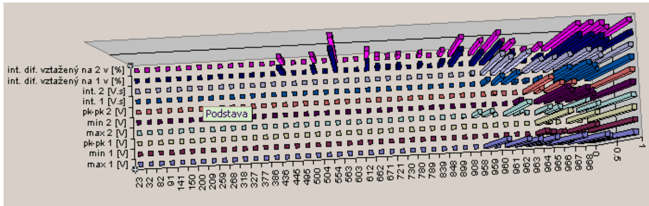

Fig. 2.

REFERENCES

[1] Nailen R. L. :Try surge - comparison testing for electrical troubleshooting, Power, 1986.

[2] Schlichting S. :Automated digital winding test analysis methods.

[3] Tůma J. : Zpracování signálů získaných z mechanických systémů užitím FFT, (Processing of signals obtained from mechanical systems by FFT using), Sdělovací technika, Prague, 1997, 32 – 81pp.

[4] Častová N. : Časově - frekvenční analýza (Time – frequency analysis), VŠB - TU, Ostrava, 1997.

[5] Veselý V. : Wavelety a časově - frekvenční analýza dat, Analýza dat 95/II., (Wavelets and time – frequency analysis of data, Data analysis) Pardubice, 1995.

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