DISCUSSION

Detection and Localization of Inter-turn Fault in the HV Winding of a Power Transformer Using Wavelets

We have read with interest paper [1] describing a wavelet approach for identification and localization of "minor" or "small" faults within HV transformer windings during lightning impulse tests on them.

Although the authors' claim appear to be impressive, there are serious questions regarding the circuit models and computational procedures used, as well as, in the interpretation of the results obtained from the wavelet method. Therefore, the following is intended to obtain clarification from the authors and to help the reader with the usage of wavelets in addressing such problems.

1. Nowhere in the title or in the abstract, has it been mentioned that, the waveforms analyzed by the wavelet method, were only computed from simulations and not obtained from experiments. Only in the latter part of section 3, it was mentioned that the waveforms used were computed using circuit models. This progressive disclosure sends erroneous signals.
2. The authors have stated in section 4, that a "one-turn" fault had been simulated. The discussers are of the opinion that such a "one-turn" fault representation requires a more detailed circuit representation than what was described in [1]. Later, in section 6, it was claimed that "even very minute faults" could be located. As there is serious doubt whether, in fact, a one-turn fault has indeed been modeled, the authors' claim remains unproved. Can the authors give evidence that such a "one-turn" short is, in fact, being represented in the circuit model used?
3. In sections 5 and 6, "the time at which the fault has occurred" was repeatedly mentioned. In the circuit representation chosen by the authors, the fault existed at time t = 0- which implies that the fault was pre-existing even before simulation began and did not come into existence at a later instant. The so-called "time of occurrence of the fault" is, in fact, only related to some travel time. Further, the non-stationarity that has to be detected in the neutral current as a consequence of an inter-turn fault is, therefore, non-existent. Therefore, the conclusions drawn are clearly misleading.
4. It is surprising that the waveforms of the neutral currents with and without one-turn fault for the various cases were not presented. Their presentation would have assisted in gauging the difficulties in discrimination of faults in the waveforms.
5. Another conclusion drawn was that such a "very minute fault" could not be located by the transfer function method. This claim is unsubstantiated. Can the authors produce evidence from this work on which this claim was made?
6. In Figures 7, 8 and 9, the vertical axes of scalograms have scales ranging from 3.9-4.9, 3.6-4.5 and 1.6-2.6. A higher value of scale means, a lower frequency. Therefore, it is not clear how the authors detected a one-turn fault (which in reality would result in high frequency oscillations) at such high scales. Are they detecting some long-term deviation in the neutral currents (perhaps, not related to such one-turn faults)? How can the difference of scalograms lead to a 1-d data?
7. In section 1, the authors mentioned "transient admittance". In circuit theory, there is no such term. Please comment.
8. It was stated that the wavelet approach had been introduced for the first time for studying this problem. For example, "The wavelet transform approach introduced here..." (section 1) and "An entirely new method..." (section 6). Yet a reference [9] on the same topic was listed in the references list but was not discussed in the text. It is not clear whether this was a case of inadvertent omission or an example of oxymoron?

We would appreciate if the authors could respond to our questions and comments.

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1 REPLY

We wish to thank the discussers for their keen interest in our paper and for their valuable comments. The following reply is in the order of discussers' comments.

1. The authors agree with the observation, but at the same time, wish to point out that one should not judge the entire content from the title or abstract alone.
2. In all three cases in section 3, only two discs were considered for simulation of one turn fault. The remaining discs of the winding were lumped in a suitable number of sections. In a transformer, where interleaved disc winding is used, less than two discs cannot be considered for rep-

resentation. Alternately, if every turn were represented, the total number of turns to be modeled would have been approximately 3952. Hence, the inductance and capacitance matrices would also have elements of almost the same order. Any circuit solution using such large number of elements may lead to singularity in the calculation. The one turn fault was simulated by reducing the number of turns from 26.7 to 26.2 for the two discs, representing the fault.

3. "The time at which fault has occurred" referred to the time at which peaks were seen in Figures 7, 8 and 9 of [1], both in scalogram and difference plot. These were obtained, based on the neutral currents analysis using Wavelet. The method of calculation of time along the winding length, depicting the occurrence of fault has been explained in the paper on the basis of wave velocity. The changes in self and mutual inductances as well as capacitances provide a characteristic oscillation in the neutral current which facilitates the fault detection and localization by wavelet, based on travel time. As a criterion for location of fault, the authors have used the difference in non-stationarity between the neutral currents with and without one turn fault.

4. Regarding the neutral current without turn fault and with one turn fault, the authors did not consider it necessary to present the waveforms, since it is generally difficult to detect the difference if they are represented as analogue signals. This observation was also made in [1]. The current waveform without a fault is given in Figure 1 of the Reply. The neutral current is plotted for 100 μs for an applied impulse voltage of 1 V. The current waveform with one turn fault was found to be similar.

5. The "very minute fault" referred to the one turn fault, since, out of several types of faults in a transformer e.g. disc to disc, winding to winding, winding to lead, winding to core, winding to ground, etc, the turn to turn fault is probably the smallest fault which may occur in a transformer.

   While all other faults may provide a significant change in the neutral current, the turn to turn fault may yield only a minute difference. Thus, any transfer function calculated on the basis of these currents may not reveal the fault conclusively. It was observed that the window functions used in transfer function themselves lead to oscillations. These oscillations affect the exact determination of the extent of fault. The effect of window function was discussed in [2]. The noise problems associated with the comparison between two transfer functions were discussed in [3].

   It is also to be noted that in spite of several years of experience in determining the fault by the transfer function method, it still remains a diagnostic tool and has not appeared as a standard method of fault detection. Keeping this in view, the authors have stated that minor faults like one turn may not give clear indication in certain situations.

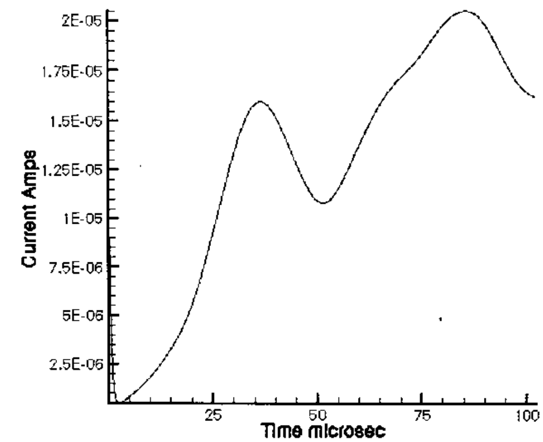

Figure 1. Neutral current vs time for case 'a' without turn fault (No. of turns =3952) using a unit impulse voltage.

6. The scale of 1.6 to 4.9 used for calculation was reflected in the scalogram. This corresponded to frequency values varying from approximately 0.2 MHz to 0.625 MHz. However, it may be noted that in a Mexican Hat Wavelet, a given value of scale allows detection of a range of frequencies falling within a window. The width of the window is proportional to the scale. Hence, it is possible to detect higher frequencies than what is determined by the scale.

7. The authors have defined the ratio of transient neutral current to the corresponding applied impulse voltage as "transient admittance".

8. It is regretted that [9] was inadvertently omitted in the text.

The authors are of the opinion that the detection and localization of turn fault by a combined approach of equivalent network simulation, neutral current analysis and Mexican wavelet has not been published so far.

M. R. Rao and B.P. Singh

REFERENCES

[1] M.R. Rao and B.P. Singh, "Detection and Localization of Inter-turn in the HV Winding of a Power Transformer Using Wavelets", IEEE Trans. DEI, Vol. 8, pp. 652–657, 2001.

[2] B. P. Singh, M.V. Prabhakar, M. R. Rao and V. Kamaraju, "Zero Loading Technique for Determination of Low Resonant Frequencies of Power Transformer by Transfer Function Technique" NPSC-2000, Dec. 20–22, IISc Bangalore, pp 135–139.

[3] R. Malewski, E. Gockenbach, R. Maier, K. H. Fellmann and A. Claudi, "Five Years of Monitoring the Impulse Test of Power Transformers with Digital Recorders and the Transfer Function Method" CIGRE 1992 Session, paper 12-201.

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