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Application of wavelet multiresolution analysis for discrimination of lightning transients and faults on transmission lines

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***Abstract*—A novel approach for multiresolution analysis (MRA) based discrimination of lightning transients and faults on transmission lines are proposed in the article. The main contribution of the paper is to evaluate the peak absolute value and summation of 3rd level output of MRA detail signal of current in each phase extracted from the original signals. The test system is carried out for 220kv, 200 km and 400kv, 200 km long line fed from both ends using EMTP. Simulation results are used to examine the effects of fault distance, fault inception angle and fault impedance and hence the proposed method is more effective and robust it is promising in high impedance fault detection.**

***Keywords*— Wavelet transforms; Multiresolution analysis; EMTP; Fault classification**

I. INTRODUCTION

A fault on power system will generate wideband transient signal, whose high-frequency components contain more information about the fault type, location and direction than power-frequency signal does. Some new protective relaying principles have been developed relying on the measurement of the fault-generated high frequency transients [1,2]. These protection principles have many advantages over the conventional protection principles. For example, they can realize a complete transmission line protection without communication link and are affected little by fault conditions such as fault type, fault resistance and fault position, etc. However, lightning strokes also cause similar high frequency transients, which will be captured by these protective relays and result in their wrong response. Therefore, it's valuable to distinguish lightning strokes from faults. It would provide useful information for the design of new protection schemes.

Because of many stochastic factors, transients caused by lightning strokes vary greatly not only in waveform, but in magnitude. It is difficult to discriminate between lightning strokes and faults .with the use of characteristics only in time domain or frequency domain. Wavelet transform is powerful tool for signal analysis [3]. Wavelets are local in both frequency and time. Therefore, they are suitable for accurate analysis of power system transient phenomena.

This work presents an application of wavelet multiresolution analysis technique to fault analysis and proposes a new fault classification algorithm. The MRA is one of the most active branches of WT theory, Introduced by Mallet [4,5] in 1989. The 3rd level MRA detail signal is found to be most suitable and is used for the analysis, which reduces the computational burden considerably. The algorithm is generalized in nature. Although, it depends on some threshold level for identification of faults, it is generalized as p.u.values and ratios are used for determining the threshold level. However, it does not depend on any threshold value for classification of different types of fault conditions irrespective of the system voltage or parameters. Further, the algorithm is independent of the effects of fault inception angle, fault distance and fault impedance. Simulation results indicate that this method is very effective in detecting and classifying the faults.

II. FAULT CLASSIFICATION USING WAVELET MRA

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Wavelet applications for transmission line faults analysis are enriched by some interesting research studies. Therefore, an attempt is made for a brief exposition of wavelet transform to give an adequate emphasis to depict the real-time implementation of fault classification algorithm.

The MRA details at various levels contain the features for detection and classification of faults. Owing to the unique feature of providing multiple resolutions both in time and frequency by wavelets, the sub band information can be extracted from the original signal. Thus for transmission line fault analysis in a power system, applied to faults, these sub-band information are seen to provide useful clues regarding the faults for their classification in an elegant way [6,7]. By randomly shifting the point of fault on the transmission line, a number of simulations are carried out employing MATLAB. The generated time domain signal for each case is analyzed using Wavelet transform. Amongst different decomposed levels, only 3rd level output is considered for the analysis [8,9], because the absolute values of the summation of 3rd level output for all the inception angles considered for the analysis are found to be higher as compared to those from other level outputs. It indicates that the total area under the characteristics of 3rd level outputs is more than that of other level outputs. Another reason for the 3rd level output to be selected as the parameter for fault classification is that the summation of 3rd level output Satisfies the characteristic relationships for all types of faults for classification purposes. Thus based on third level

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outputs, an efficient generalized algorithm for fault classification based on the Wavelet analysis is depicted below.

III. SIMULATION

A. Single line model for 220 KV transmission system

The model of 220 KV Transmission system [11] considered for the analysis is as shown in Fig. 1.

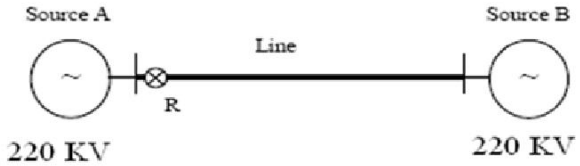

Figure 1. Test power system

The base values of the voltage and the power in the system are taken as 220 kV and 100MVA. The frequency of the system is taken to be 50 Hz. The sequence parameter line model is selected for the transmission line, as this is the most suitable model for a transmission line in the event of faults.

The transmission line parameters are:

(A) Zero sequence parameters: $R0$ = 0.4054Ω/km, $X0$ = 2.8125 mH/km, $C0$ = 0.0044μF/km;

(B) Positive sequence parameters: R_1 = 0.07375Ω/km, X_1 = 1.0794 mH/km, C_1 = 0.0075μF/km; and

(C) Negative sequence parameters: same as positive sequence parameters.

The total impedance of the generator and the transformer together on both sides are taken as (0.2 + j4.49)Ω, which corresponds to a X/R ratio of 22.45. The current signals recorded at the two ends, considered for the analysis are generated by simulating the system on EMTP. The generated time domain signals are sampled every 80 µs and then used for the analysis using wavelet transform.

B. Single line model for 400 KV transmission system

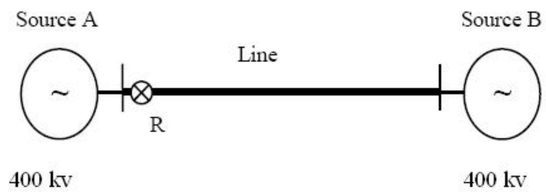

Figure 2. Test power system

The single line diagram of the power system model considered for simulation study is shown in Fig. 2.

The length of the transmission line considered is 200 km having a source voltage (Vs) of 400 kV. The positive sequence parameters such as resistance, inductance, and

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capacitance values of the transmission line are 2.34 Ω, 95.10 mH, 1.24 µF, respectively. The negative sequence line parameters are same as the positive sequence parameters. The zero sequence line parameters are 38.85 Ω, 325.08 mH, 0.845 µF, respectively. The positive, negative sequence of source impedance (Zs) is (0.45 + j5) Ω per phase, and the zero sequence impedance is one and half times the positive sequence impedance. An active power of 500 MW has been considered for the case studies [10].

IV. IDENTIFICATION OF FAULTS

In case of a fault, the signatures of all the three phases are required to ascertain the faulted and the healthy phases. Through an exhaustive experimentation, the parameter found to be suitable for the identification is the peak absolute value of 3rd level output for the three phase currents and the mean of these three peak values of phase currents. As the simulation results show that inception angle has considerable effect on the current signal and, therefore, on the wavelet transform output and moreover as the waves are periodic in nature, hence the variation of the parameters for identification of faults with respect to fault inception angle are studied in the range of 0–180^0.

If A_a = peak absolute value of 3rd level component for current in phase 'a';

A_b = peak absolute value of 3rd level component for current in phase 'b' and;

A_c = peak absolute value of 3rd level component for current in phase 'c'.

Further, if $r_1 = A_a/A_b$; $r_2 = A_b/A_c$; $r_3 = A_c/A_a$; and

.

These parameters are used for identification of different types of disturbances.

A. Discrimination of lightning transients from faults

Simulation results indicate that if any one value of (r_1, r_2 or r_3) is equal to or less than a threshold value *r*th, then a fault is said to have occurred. However, if any one value of (r_1, r_2 or r_3) is more than *r*th, then it is a lightning transient as in the case of lightning transient, the current in the affected phase or phases are very high and hence at least one of the ratios of currents in two phases is observed to be more than *rth.*

For finding out the threshold value of *r*th, simulations are carried out considering lightning transient, L–G, L–L–L, L– L–G, L–L faults. The most common type of transient, which a transmission line often comes across, is a lightning transient. Hence, a standard lightning transient of 1.2/50 µs with a peak value equal to the system voltage level is considered on phase 'a'. The variation of the ratio r_1 with inception angle for lightning strike on phase 'a' at 195 km from the generator no.1, L–G, L–L–L, L–L–G, L–L faults involving phase 'a' occurring at a distance of 5 km from generator no.1 is shown in Fig. 2. As the current signals employed for the analysis are recorded at the generator no.1, hence the transients at the other end of the line i.e. at generator no.2 will have smaller amplitude as compared to that at or near the generator no.1. Thus, the lightning strike at 5 km will have much higher amplitude as compared to the

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lightning strike at 195 km. Hence, for determining the threshold value, lightning strike at the far end i.e. at 195 km is compared to different types of faults at the near end i.e. at 5 km to show that even the minimum value of current due to lightning strike at the far end of the line also has a much higher value as compared to different types of faults occurring near the recording end.

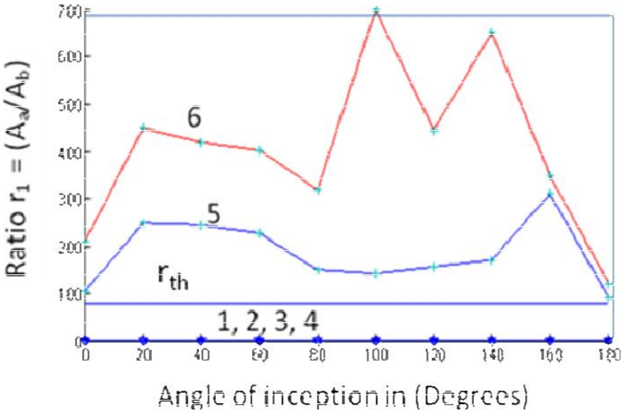

Fig.3. For 230 kV Transmission system, The Variation of r_1 with inception angle for faults involving phase 'a' at 5km.(1) L-L-L fault, (2) L -L fault, (3) L-L-G fault, (4) L-G fault, (5) lightning strike at 195km, and (6) lightning strike at 5km.

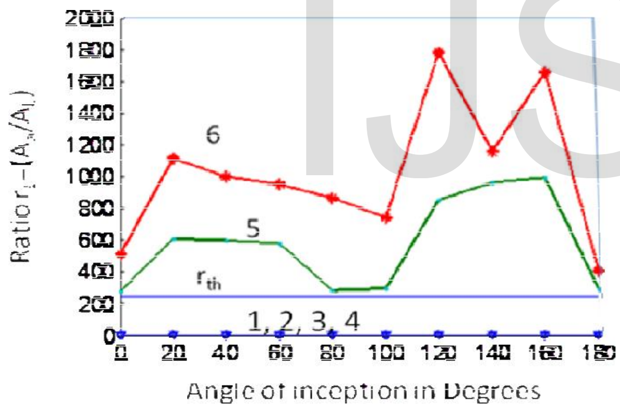

Fig.4. For 400 kV Transmission system, The Variation of r_1 with inception angle for faults involving phase 'a' at 5km. (1) L-L-L fault, (2)L -L fault, (3) L-L-G fault, (4) L-G fault, (5) lightning strike at 195km, and (6) lightning strike at 5km.

Since the faults and the lightning transients considered involve phase 'a', variation of r_1 is only considered. Similarly, r_2 or r_3 will be considered if the faults or the lightning strikes involve phase 'b' or phase 'c', respectively.

As can be seen from Fig. 3 and Fig.4, the ratio r_1 for the lightning transient is very high as compared to faults. Hence, a threshold level for the ratio r_1 can be selected so that proper discrimination of lightning transient from faults can be done. Considering the effect of fault distance also into account, a value of *r*th is selected as 80 for the system under 220 KV Transmission system and 250 for the system under 400kv transmission system are shown in the fig.3, and fig.4, respectively.

B. Classification of faults

The transmission line faults in a power system are usually classified as single line to ground (L-G), double line to ground (L-L-G), double line (L-L), and 3 phase symmetrical (L-L-L) and (L-L-L-G-) faults. The fault inception angle has a considerable effect on the phase current samples and therefore also on wavelet transforms output of post-fault signals as confirmed from several simulation studies. As the waves are periodic, it is sufficient to study the effect of inception angle in the range of $0–180^0$ [9]. The algorithm proceeds as follows:

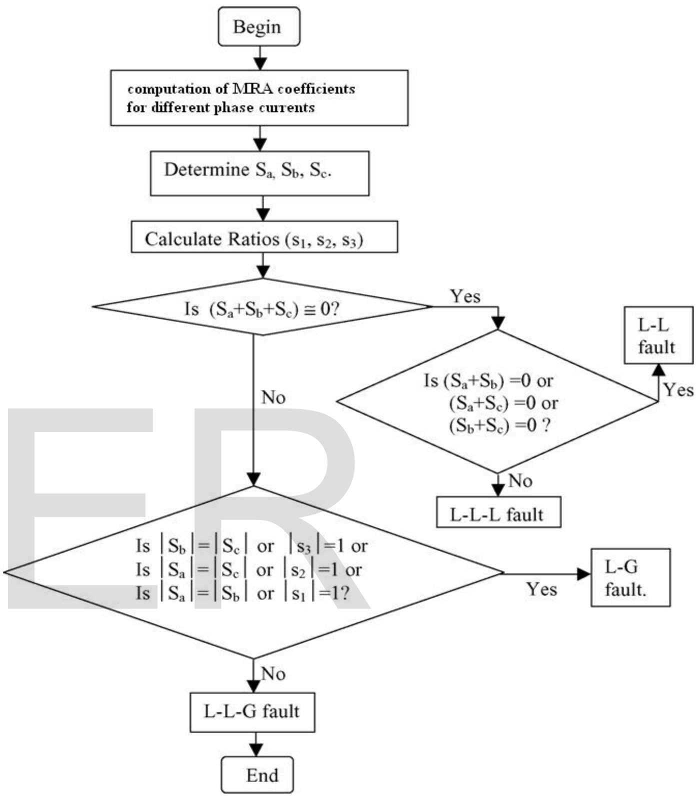

Fig.5. A Flow-chart for the fault classification algorithm

Let S_a, S_b, and S_c be the summation of third level values for current in phases a, b and c respectively. When the summation of S_a, S_b and S_c is equal to zero, then the fault can be either L-L-L or L-L fault. The discrimination between these two types of faults is based on the fact that the magnitudes of S_a, S_b and S_c are comparable to each other in case of L-L-L fault. But in case of L-L fault, the addition of any two phases summations namely, either $S_a + S_b$ or $S_b + S_c$ or Sc + Sa tends to nearly equal to zero and remaining phase summation coefficient is very small and almost negligible compared to other two summation having equal values with opposite signs. When the summation of S_a, S_b, and S_c is not equal to zero, then it can be either L-G or L-L-L-G fault. If the absolute value of any two summations is equal and always much smaller than the absolute value of the third level summation, then it is a L-G fault. If the absolute value of any two third level summations is not equal to zero and is always much higher than the absolute

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value of remaining third level summation, then it is a L-L-G fault. The fault classification algorithm is depicted in Fig. 5

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V. SIMULATION RESULTS FOR FAULT CLASSIFICATION:

A. Simulation results for 220 kv transmission system

In order to show the effectiveness of the proposed algorithm, different types of faults are as shown below. While Fig. 6 shows the plot for a L–L–L fault at 5 km, Fig. 7 shows the same for a L–L–L fault at 195 km.

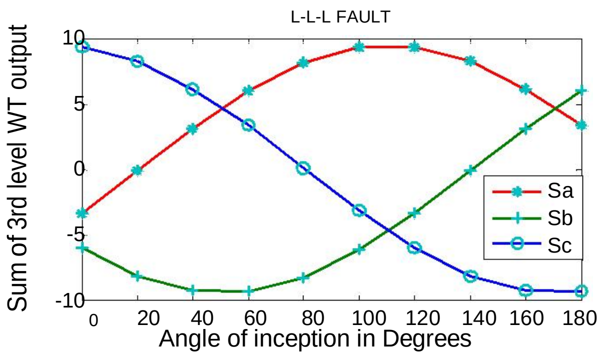


Fig.6. Effect of inception angle for L-L-L fault at 5km

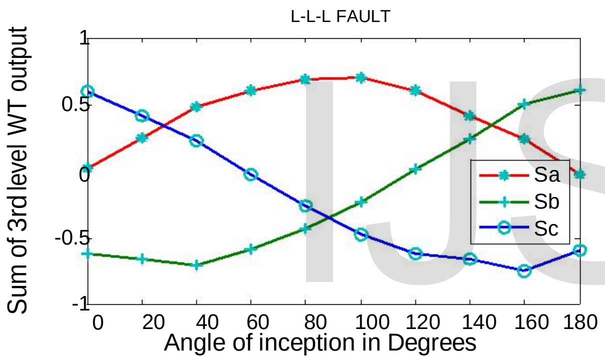
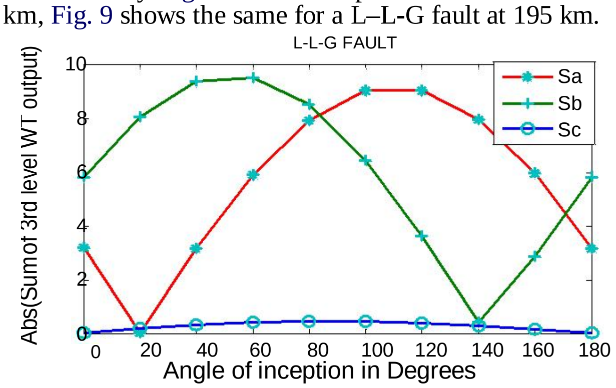


Fig.7. Effect of inception angle for L-L-L fault at 5km

The results for the two extreme ends of the line are presented here to show the efficacy of the algorithm even at the far end of the line as at the far end of the line, the amplitude of the current signal is always less when the measurement is done at the other end i.e. at the sending end. Hence, if the algorithm is valid at the far end, it will be valid at any distance over the total length of the line.

Similarly Fig. 8 shows the plot for a L–L-G fault at 5 km, Fig. 9 shows the same for a L–L-G fault at 195 km.



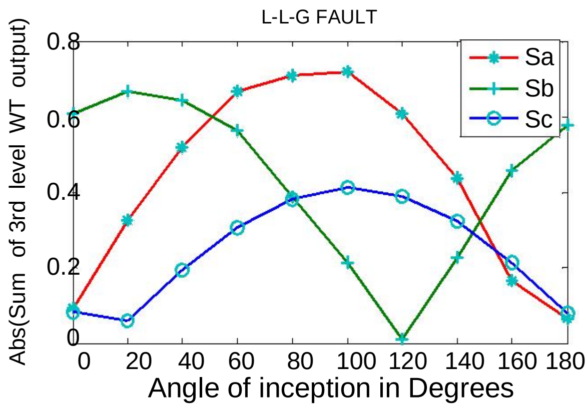


Fig.9. Effect of inception angle for L-L-G fault involving phases 'a', 'b' and ground at 195km.

Similarly the remaining faults are also obtained by using the algorithm shown in Fig.5. The proposed method is also effectively suitable for high impedance faults.

B. Simulation results for 400 kv transmission system

Fig.8. Effect of inception angle for L-L-G fault involving phases 'a', 'b' and ground at 5km.

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Fig. 10 shows the plot for a L–L-L fault at 5 km, Fig. 11 shows the same for a L–L-L fault at 195 km, for 400kv transmission system.

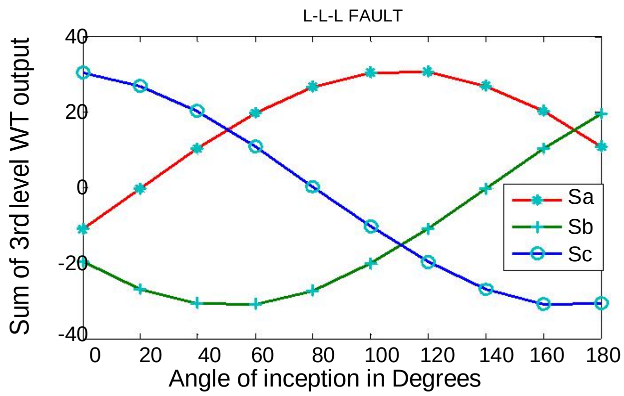

Fig.10. Effect of inception angle for L-L-L fault at 5km

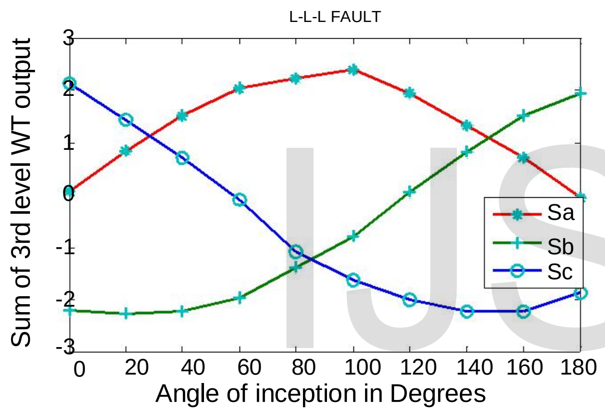

Fig.11. Effect of inception angle for L-L-L fault at 195km

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Fig. 12 shows the plot for a L-L–G fault at 5 km, Fig. 13 shows the same for a L–L-G fault at 195 km.

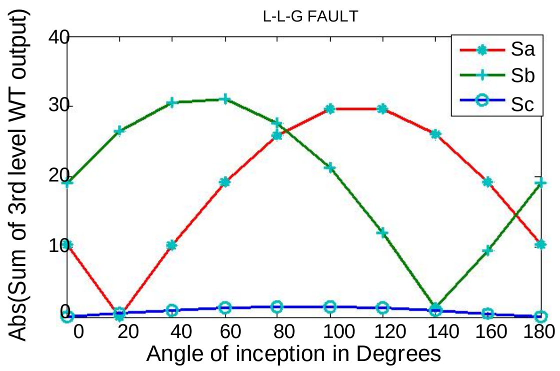

Fig.12. Effect of inception angle for L-L-G fault involving phases ‘a’, ‘b’ at 5km.

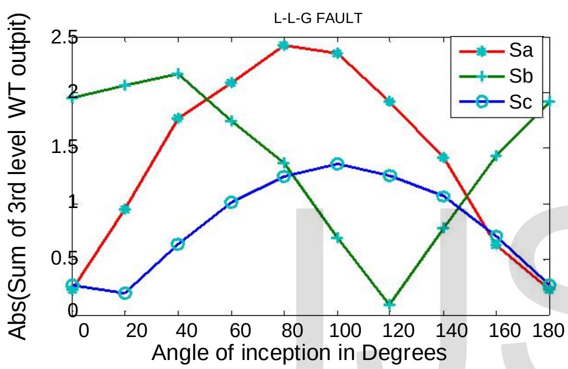

Fig.13. Effect of inception angle for L-L-G fault involving phases ‘a’, ‘b’ at 195km.

Similarly the remaining faults are also obtained by using the algorithm shown in Fig.5, and the proposed method is also effectively suitable for high impedance faults.

VI. Conclusions

1. The significant criterion established in the work is about an application of wavelet MRA theory has been invented for discrimination of lightning transients and faults on transmission lines, and also classification of faults on a power transmission lines.
2. This new method is verified that it is used for discrimination of lightning transients and faults on transmission lines, for both the systems of 220 kV and 400 kV transmission lines by using wavelet MRA.
3. It can be followed for the identification of high impedance faults and therefore the generalized algorithm has the features of effectiveness and robustness.

References

[1] A. T. Johns, R.K.Agganva1, Z .Q. Bo. “Non-unit protection technique for EHV transmission systems based on fault - generated noise”, Part l: signal measurement. IEE Proc. Gener. Transm. Distrib. 1994, 141(2): 133-140

[2] Z Q Bo. “A new non-communication protection technique for transmission lines”. IEEE Transactions on Power Deliverv. 1998. 13(4): 106-113

[3] D.C. Robertson, Q.I. Camps, J.S. Mayer, W.B. Gish. “Wavelets and electromagnetic power system transients”. IEEE Transaction on Power Delivery, 1996, II (2): 1050-1056

[4] Mallat, S., “A theory for multiresolution signal decomposition: the wavelet representation”. *1EEE Transactions on Pattern Analysis and Machine Intelligence,* 1989, 11(7), 674-693.

[5] Mallat, S., “Multifrequency channel decompositions of images and wavelet models”. *1EEE Transactions on Acoustics, Speech, and Signal Processing,* 1989, 37(12), 2091-2110.

[6] Youssef Omar AS. “Combined fuzzy-logic wavelet-based fault classification technique for power system relaying”. IEEE Trans Power Delivery 2004;19 (2):582–9.

[7] Khorashadi-Zadeh H, Aghaebrahimi MR. “A novel approach to fault classification and fault location for medium voltage cables based on artificial neural network”. Int J Comput Intel 2005;2 (1):90–3.

[8] Chanda D, Kishore NK, Sinha AK. A “wavelet multiresolution analysis for location of faults on transmission lines”. Electr Power Energ Syst 2003;25:59–69.

[9] Chanda D, Kishore NK, Sinha AK. “Application of wavelet multiresolution analysis for classification of faults on transmission lines”. In: IEEE conference on convergent technologies for Asia-Pacific region, vol. 4. 2003. p. 1464–9.

[10] Mahanty RN, Dutta Gupta PB. “An improved method for digital relaying of transmission lines”. Electr Power Compo Syst 004;32: 1013–30.

[11] Chanda D, Kishore NK, Sinha AK. “Application of wavelet multiresolution analysis for identification and classification of faults on transmission lines”. Electric Power Systems Research 73 (2005) 323-333.

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