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Research Article

A Fault-location Evaluation Method of a 330 kV Three-Phase Transmission Line by Using Discrete Wavelet Transform

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Abstract

In this study, Discrete Wavelet Transform (DWT) is utilized for fault-location evaluation in a 330 kV, 50 Hz, three-phase transmission line using pre-fault and post-fault current data of both the terminals of a transmission line. The proposed fault-location method has been extensively tested using the MATLAB model of three-phase transmission line. Characteristics extorted from synchronous recording of three-phase current signals at the two terminals using DWT are used for the estimation of fault location. The efficiency of the proposed method is validated for different types of faults, and with variation in the values of fault location. The simulation results of the proposed work show that the proposed technique is not affected by varying type and location of the fault.

Keywords: Discrete wavelet transform, Fault-location estimation, Three-phase transmission lines protection

Introduction

The accurate and quick detection and location evaluation of faults on transmission lines are the main targets of any protective relaying technique to preserve the stability of power flow. For detecting and estimating the location of faults on transmission lines, many researchers have implemented various schemes. Through the frequent schemes proposed so far, deep neural network is used for the location of faults on three terminal series compensated transmission lines.[1,2] In Kumar and Saxena,[2] a travelling wave-based method has been proposed for fault-location on multi-lateral distribution network. A fault detection and classification technique has been proposed by Biswas et al.[3] using Wavelet Transform (WT) for a thyristor-controlled series capacitor compensated transmission line. In Patel et al.,[4] Discrete Wavelet Transform (DWT) is used for the detection of fault on three-phase transmission lines. Fault location of series compensated transmission lines using WT-based energy travelling wave has been discussed in Yu et al.[5] In Kirubadevi and Sutha,[6] the authors used WT for the identification and classification of faults on three-phase transmission lines. Continuous WT-based fault-location method has been proposed for three-phase transmission lines.[7] In Ahmed et al.,[8] WT-based advanced travelling wave is used for fault location on two-terminal transmission lines. S-transform-based fault-location technique has been described by Liqun et al.[9] for fault-location on three-phase transmission lines. Support vector regression-based technique for fault location on thyristor-controlled series capacitor compensated transmission line has been reported by the authors in Ray et al.[10] Current travelling wave-based technique for the location of single line to ground faults on three-phase transmission lines has been reported by Aoyu et al.[11] In Kalam et al.,[12] WT is used in conjunction with feed-forward artificial neural network for the location of faults on a three-phase transmission line. DWT-based fault-location identification technique has been proposed by Chiradeja and Pothisarn[13] for the protection of three-terminal transmission lines. In Gi-Taek et al.,[14] WT has been used for fault location using GPS on three-phase transmission line. WT is used in combination with Fourier transform for the detection and classification of faults on three-phase transmission lines in Das et al.[15]

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In this paper, a 330 kV, three-phase, two-terminal transmission line composed of 300 km long distributed parameter line block is considered. A fault-location evaluation technique is proposed in this work using DWT taking into account the event of different types of faults with varying locations of faults. Both pre- and post-fault current signals were processed through Db5 mother wavelet to obtain the first-level approximate and detail coefficients. The maximum and minimum scale values of approximate (A1), horizontal detail (H1), vertical detail (V1) and diagonal detail (D1) coefficients are considered as features of DWT to determine the evaluation of fault location in a three-phase transmission line. Test results demonstrate that the proposed technique is very effectual in evaluating the distance of fault in three-phase transmission lines.

This paper is structured as follows: Section 2 presents simulation study carried out in this work. In Section 3, DWT-based fault-location evaluation method is described. Section 4 is dedicated to the discussion of test results. Final comments are given in Section 5.

Simulation Studies

The schematic of the three-phase power system is shown in Fig. 1. System working in MATLAB includes a 330 kV, 50 Hz, three-phase transmission line of 300 km length connecting the 330 kV source at the sending end and a load at the receiving end. The transmission line is divided into six sections each of 50 km length extended between the three-phase source and the load. The three-phase current recorded at Bus-2 (located at receiving end side of a transmission line) during no-fault situation and the three-phase current recorded at Bus-1 (located at sending end side of a transmission line) during fault situation are processed using DWT to extract the approximate and detail coefficients at level-1 for the evaluation of fault-location.

Proposed Fault Distance Evaluation Scheme

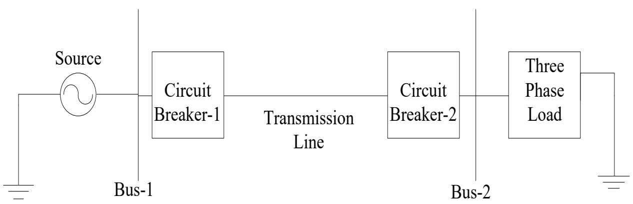

Figure 1.Schematic of 330 kV Test System

In the area of digital signal processing, the methods based on WT have become one of the most powerful mathematical tools and since 1980's these methods have become trendier. As a substitute to short time Fourier Transform (STFT), the WT was developed to grow above problems associated to its resolution trouble. More entirely, if a window of infinite length is chosen, one can attain perfect frequency resolution but without time information. WT is a recently developed mathematical tool that divides up data, function or operation into different frequency components. Fourier analysis splits up a signal into a wave of various frequencies whereas wavelet analysis breaks up a signal into shifted and scale version of the original signal. Multi-resolution analysis (MRA) is another technique which is used to examine signal to overcome the troubles associated with time and frequency resolution.

$$\mathrm{DWT}\psi f(m.k) = \frac{1}{\sqrt{a_0^m}} \sum_n x(n)\, \psi[\frac{k-n_0 b_0 a^m}{a_0^m}]$$

where, Ψ is known as the mother wavelet, the scale parameter is expressed as a_0^m and the parameters of translation are designated as a^m, n_0 and b_0.[1] In the proposed work, daubechies-5 (db5) is chosen as mother wavelet for analyzing the pre-fault and post-fault current signals.

Figure 2 depicts the flow chart of overall process of fault distance evaluation using DWT in a three-phase transmission line. The primary step is to simulate various fault events varying the fault-location in a three-phase transmission line, consequently processing the pre-fault and post-fault current signals recorded at both ends of the line using DWT and then calculating the maximum and minimum scale of pre-fault and post-fault approximate and detail coefficients at level-1 at various distances. The distance of fault can be estimated by subtracting the pre-fault wavelet coefficients from the post-fault wavelet coefficients and then adding the positive values of the coefficients.[5]

The proposed DWT-based fault-location technique is tested on a 330 kV, 50 Hz three-phase power transmission line.

Results and Discussion

To investigate the performance of the proposed fault distance estimation technique, the power transmission system as described in Section 2 is simulated extensively for various fault situations and discussed in following sub-sections. The percentage error in fault distance estimation is calculated using Eq. 2.[8]

% Error =

$$\left[\frac{\text{Authentic Fault-location} - \text{Evaluated Fault-location}}{\text{Total Length of Transmission Line}}\right] * 100$$

The proposed method is tested for various fault situations to check the effectiveness of the method for varying locations of fault.

Simulation Results of Proposed Technique for Phase-'A-g' Fault at 50 km from Section-1

The performance of the proposed technique is examined for phase-'A-g' fault at 50 km from Bus-1. Figure 3 shows phase-A current recorded at 300 km from Bus-1 during no-fault. Figure 4 exemplifies phase-A current at 50 km from Bus-1 during phase-'A-g' fault with R_f=R_g=0.001Ω at FIT=0.0166 seconds. The phase-A current signals as shown

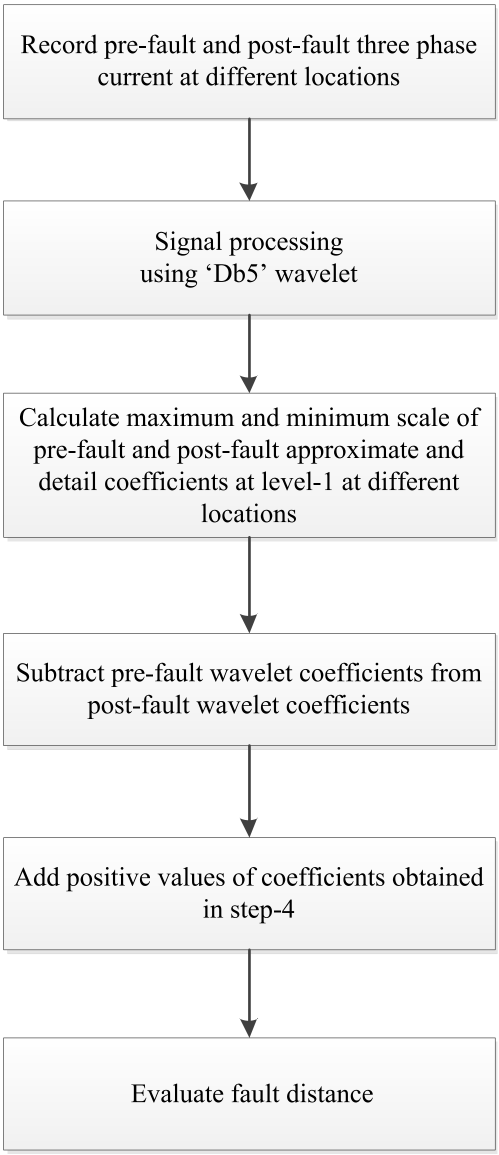

Figure 2.Proposed Fault Distance Evaluation Scheme

in Figs. 3 and 4 are further processed using discrete WT with Db5 wavelet to extract proper characteristic vector for fault-location evaluation. Figure 5 shows discrete WT coefficient of phase-A current during no-fault at 300 km from Bus-1 recorded at Bus-2 using 'Db5' wavelet. Figure 6 illustrates DWT coefficient of phase-A current during phase-'A-g' fault at 50 km from Bus-1 recorded at Bus-1 using 'Db5' wavelet. Table 1 shows the wavelet coefficient of phase-A current during no-fault at 300 km and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). Similarly, Table 2 depicts the wavelet coefficients of phase-A current during phase-'A-g' fault occurred at 50 km from Bus-1 and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). Table 3 illustrates the maximum and minimum scale of coefficients for phase-'A-g' fault at 50 km using 'Db5' wavelet. From Table 3, it can be observed that for evaluating the location of fault, the values of pre-fault coefficients of phase-A current obtained at 300 km are subtracted from the values of post-fault coefficients of phase-A current obtained at 50 km from Bus-1 and then the positive values of the coefficients are added. From Table 3, it can be noticed that the fault-location result of proposed DWT-based technique is precise with percentage error of 0.1666%, which can be seen from Table 7.

Phase-'A-g' Fault at 50 km Using 'Db5'

Response of Proposed Technique for Phase-'A-g'

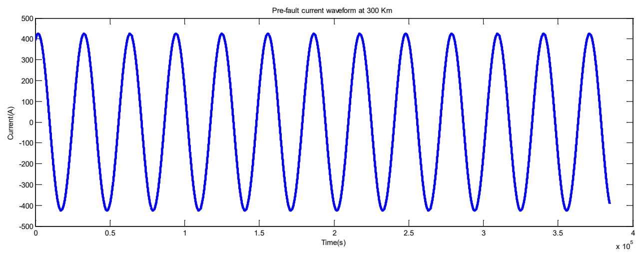

Figure 3.Phase-A current at 300 km from Bus-1 during No-Fault

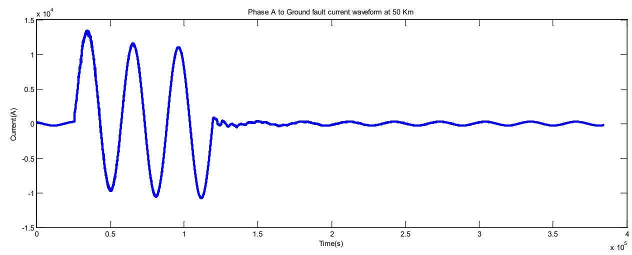

Figure 4.Phase-A Current at 50 km from Bus-1 during Phase-'A-g' Fault

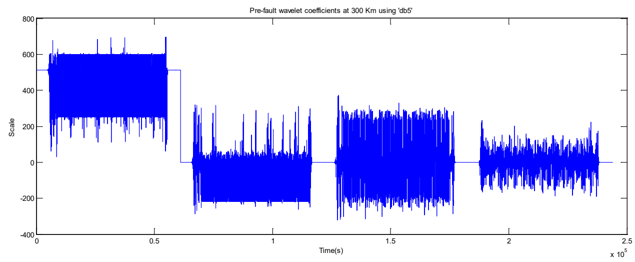

Figure 5.DWT Coefficients of Phase-A Current during No-Fault at 300 km from Bus-1 Using 'Db5' Wavelet

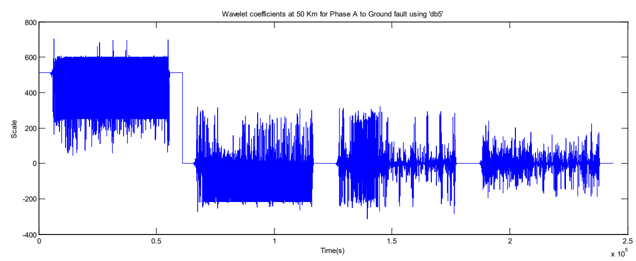

Figure 6.DWT Coefficients of Phase-A Current during Phase-'A-g' Fault at 50 km from Bus-1 Using 'Db5' Wavelet

Table 1.Wavelet Coefficients at 300 km during No-Fault

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	541.6	−119.5
Horizontal (H1)	234.4	−270.8
Vertical (V1)	232.5	−269
Diagonal (D1)	164.2	−216.7

Table 2.Wavelet Coefficients at 50 km during Phase-'A-g' Fault

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	541.6	−173.3
Horizontal (H1)	232.9	−276.6
Vertical (V1)	252.9	−296.7
Diagonal (D1)	167.6	−191

Table 3.Maximum and Minimum Scale of Coefficients for Phase-'A-g' Fault at 50 km Using 'Db5'

Db5 Maximum					Db5 Maximum			
Coefficients	A1	H1	V1	D1	A1	H1	V1	D1
Coefficients at 50 km	541.6	232.9	252.9	167.6	−173.3	−276.6	−296.7	−191
Pre-fault coefficients.	541.6	234.4	232.5	164.2	−119.5	−270.8	−269.1	−216.7
Differences	0	−1.5	20.4	3.4	−53.8	−5.8	−27.6	25.7
Estimated Distance (km)=20.4+3.4+25.7=49.5								

Fault at 100 km from Bus-1

The performance of the proposed technique is examined for phase-'A-g' fault at 100 km from Bus-1. Figure 7 shows phase-A current of a three-phase transmission line at 300 km from Bus-1 during no-fault. Figure 8 shows the phase-A current at 100 km from Bus-1 during phase-'A-g' fault with $R_f=R_g=0.001\Omega$ at FIT=0.0166 seconds. As discussed in the previous sub-section, the phase-A current signals as shown in Figs. 7 and 8 are further processed using DWT with Db5 wavelet to extract suitable characteristic vector for fault-location evaluation. Figure 9 shows DWT coefficients of phase-A current during no-fault at 300 km from Bus-1 recorded at Bus-2 using 'Db5' wavelet. Figure 10 illustrates DWT coefficients of phase-A current during phase-'A-g' fault at 100 km from Bus-1 recorded at Bus-1 using 'Db5' wavelet. Table 4 exemplifies the wavelet coefficients of phase-A current during no-fault at 300 km and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). Similarly, Table 5 shows the wavelet coefficients of phase-A current during phase-'A-g' fault occurred at 100 km from Bus-1 and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). Table 6 exemplifies the maximum and minimum scale of coefficients for phase-'A-g' fault at 100 km using 'Db5' wavelet. From Table 6, it can be examined that for evaluating the location of fault, the values of pre-fault coefficients of phase-A current obtained at 300 km are subtracted from the values of post-fault coefficients of phase-A current obtained at 100 km from Bus-1 and then the positive values of the coefficients are added. From Table 6, it can be noticed that the fault-location result of proposed DWT-based technique is precise with percentage error of 2.3666%. Test results of fault-location evaluation and percentage error achieved by using DWT approach during single line to ground faults at various locations with varying locations of fault are presented in Table 7. Test results show that the proposed DWT-based fault-location scheme is not affected by variation in fault-location.

Conclusions

A fault distance evaluation technique for three-phase transmission line using DWT is presented in this paper. A 330 kV, 50 Hz, three-phase transmission line of 300 km length is simulated for various system circumstances with variation in fault type and its location. The proposed fault distance evaluation technique uses the single-phase pre- and post-fault current signals recorded at both ends of a transmission line. The simulation results demonstrate that the proposed fault distance evaluation technique is robust for different fault locations, having satisfactory accurateness for all situations.

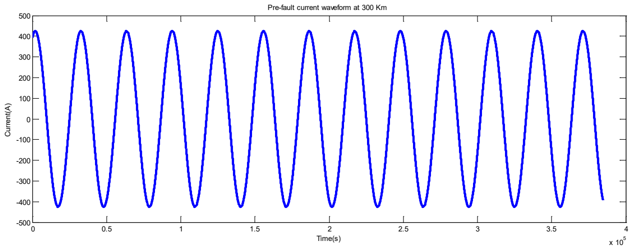

Figure 7.Phase-A Current at 300 km from Bus-1 during No-Fault

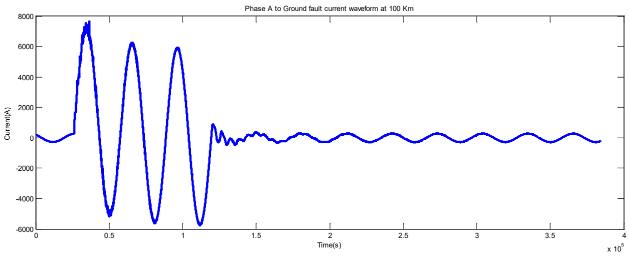

Figure 8.Phase-A Current at 100 km from Bus-1 during Phase-'A-g' Fault

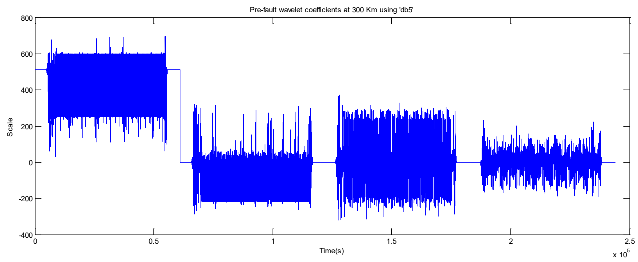

Figure 9.DWT Coefficients of Phase-A Current during No-Fault at 300 km from Bus-1 Using 'Db5' Wavelet

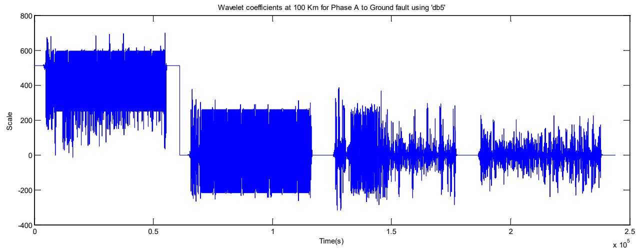

Figure 10.DWT Coefficients of Phase-A Current during Phase-'A-g' Fault at 100 km from Bus-1 Using 'Db5' Wavelet

Table 4.Wavelet Coefficients at 300 km during No-Fault

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	50.04
Horizontal (H1)	320.5	−285.2
Vertical (V1)	373	−329.9
Diagonal (D1)	231.8	−188.9

Table 5.Wavelet Coefficients at 100 km during Phase-'A-g' Fault

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	16.87
Horizontal (H1)	370.7	−266.6
Vertical (V1)	385	−341.7
Diagonal (D1)	243.9	−230.5

Table 6.Maximum and Minimum Scale of Coefficients for Phase-'A-g' Fault at 100 km Using 'Db5'

Db5 Maximum					Db5 Minimum			
Coefficients	A1	H1	V1	D1	A1	H1	V1	D1
Coefficients at 100 km	697.1	370.7	385	243.9	16.87	−266.6	−341.7	−230.5
Pre-fault coefficients.	697.1	320.5	373	231.8	50.04	−285.2	−329.9	−188.9
Differences	0	50.2	12	12.1	−33.17	18.6	−11.8	−41.6
Estimated Distance (km)=50.2+12+12.1+18.6=92.9								

Table 7.Fault-Location Evaluation and Percentage Error Varying Fault-Location

Authentic Fault Location (km)	Fault-Location Evaluated (km) Using 'Db5' Wavelet	Percentage Error
50	49.5	0.1666
100	92.9	2.3666

References

1. Mirzaei M, Vahidi B, Hosseinian HS. Fault-location on a series -compensated three terminal transmission line using deep neural networks. *IET Science, Measurement & Technology* Sep 2018; 12(6): 746-54.
2. Kumar R, Saxena D. A traveling wave based method for fault-location in multi-lateral distribution network. *Proceedings of IEEE International Conference on Power, Instrumentation, Control and Computing (PICC)* Jan 2018; 1-5.
3. Biswas S, Kumar K, Ghosal A et al. Fault detection and classification for TCSC compensated transmission lines using wavelet energy. *Proceedings of IEEE International*

Conference on Recent Advances in Information Technology (RAIT) Mar 2018; 1-5.
4. Patel TK, Panda PC, Swain SC et al. A fault detection technique in transmission line by using DWT. *Proceedings of IEEE Second International Conference on Electrical, Computer and Communication Technologies (ICECCT)* Feb 2017; 1-6.
5. Yu Liu, Sakis Meliopoulos, Nengling Tai et al. Protection and fault locating method of series compensated lines by wavelet based energy traveling wave. *Proceedings of IEEE Power and Energy Society General Meeting* Jul 2017; 1-5.
6. Kirubadevi S, Sutha S. Wavelet based transmission line fault identification and classification. *Proceedings of IEEE International Conference on Computation of Power, Energy Information and Communication (ICCPEIC)* Mar 2017; 737-41.
7. Diego Carrión, Jorge W. González, Idi A. Issac et al. Optimal fault-location in transmission lines using hybrid method. *Proceedings of IEEE PES Innovative Smart Grid Technologies Conference- Latin America* Sep 2017; 1-6.
8. Ahmed Magdy Abeid, Hossam A. Abd el-Ghany, Ahmed M. Azmy. An advanced traveling-wave fault-location algorithm for simultaneous faults. *Proceedings of IEEE Nineteenth International Middle East Power Systems Conference (MEPCON)* Dec 2017; 747-52.
9. Liqun Shang, Wensong Zhai, Pei Liu. Study of Fault-location in transmission line using S transform. *Proceedings of IEEE International Symposium on Computer, Consumer and Control (IS3C)* Jul 2016; 85-88.
10. Ray P, Mishra DP, Budumuru GK. Location of the fault in TCSC-based transmission line using SVR. *Proceedings of IEEE International Conference on Information Technology (ICIT)* Dec 2016; 270-74.
11. Aoyu Lei, Xinzhou Dong, Shenxing Shi et al. A novel current travelling wave based single-ended fault-location method for locating single-phase-to-ground fault of transmission line", *Proceedings of IEEE International Universities Power Engineering Conference (UPEC)* Sep 2015; 1-6.
12. Kalam MA, Jamil M, Ansari AQ. Wavelet based ANN approach for fault-location on a transmission line. *Proceedings of IEEE Joint International Conference on Power Electronics, Drives and Energy Systems and 2010 Power India* Dec 2010; 1-6.
13. Chiradeja P, Pothisarn C. Identification of the fault-location for three-terminal transmission lines using DWT. *Proceedings of IEEE Transmission and Distribution Conference and Exposition: Asia and Pacific* Oct 2009; 1-4.
14. Gi-Taek Kim, Hyuck-Soo Kim, Hmg-Yong Choi. Wavelet transform based power transmission line fault-location using GPS for accurate time synchronization. *Proceedings of 27th Annual Conference of the IEEE Industrial Electronics Society* Dec 2001; 495-99.
15. Das D, Singh NK, Sinha AK. A comparison of Fourier transform and WT methods for detection and classification of faults on transmission lines. *IEEE-POWERI* Apr 2006.
16. Megahed AI, Moussa AM, Bayoumy AE. Usage of WT in the protection of series-compensated transmission lines, IEEE Transactions on Power Delivery Jul 2006; 21(3): 1213-21.
17. Aguilera C, Orduna E, Ratta G. Fault detection, classification and faulted phase selection approach based on high frequency voltage signals applied to a series compensated line. *IEE-G, T & D* Jul 2006; 153(4): 469-75.
18. Khorashadi-Zadeh H. Artificial neural network approach to fault classification for double circuit transmission lines. IEEE-T&D Nov 2004; 859-62.
19. Mallat S. A Theory for multi-resolution signal decomposition: The wavelet representation. *IEEE Transaction on Power Delivery* Feb 1989; 11: 674-83.
20. Magnago FH, Akbar A. Fault-location using wavelets. *IEEE Trans on Power Delivery* Apr 1998; 13: 1475-80.

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