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A DISCRETE WAVELET TRANSFORM APPROACH TO FAULT LOCATION ON A 138KV TWO TERMINAL TRANSMISSION LINE USING CURRENT SIGNALS OF BOTH ENDS

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Abstract

This paper presents discrete wavelet transform based fault locator for a three phase two terminal transmission line using fault current data of both terminals of transmission line. The magnitudes of approximate and detail coefficients of a three phase current achieved using discrete wavelet transform toolbox of MATLAB are used for the evaluation of fault location. The proposed technique has been checked for various types of faults with variation in location of fault. The test results of the proposed work demonstrate that the proposed technique is not affected by variation in fault type and fault location.

Keywords:

Discrete Wavelet Transform, Fault Location and Two Terminal Transmission Line Protection

1. INTRODUCTION

Location of faults on the modern extra high voltage three phase transmission lines is necessary to supply reliable flow of power. Detection, classification and location of faults on the two terminal transmission lines are done by many researchers using various techniques. In recent times, discrete wavelet transform has been effectively used for the protection of power system equipment like transformer, induction motor, three phase synchronous alternator, bus-bars and transmission lines. Various techniques to fault location on two terminal transmission lines have been reported by various authors so far. Along with the various schemes introduced, extreme learning machines based fault location technique has been proposed for locating fault on a HVDC transmission line in [1]. In [2], a travelling wave based fault location technique is used for the protection of hybrid multi-terminal power transmission system. Authors in [3] proposed wavelet transform based fault detection and faults discrimination technique for four terminal transmission lines connected to SVC using PV and wind energy source. In [4], machine learning in conjunction with wavelet transform is used for locating faults in hybrid transmission lines. In [5], location of fault of travelling waves using the combination of wavelet transform and recurrent neural network is introduced for the protection of three terminal transmission lines. In [6], a scheme based on discrete wavelet transform for fault detection, classification and location has been proposed for the protection of three phase transmission lines. In [7], feed forward artificial neural network is used for the classification and location of faults on 132kV transmission line using the samples of three phase current signals. In [8], a faulty phase selector technique based on adaptive cumulative sum approach has been proposed for the protection of double circuit transmission lines. Discrete wavelet transform is used in [9] for the location of faults and evaluation of fault distance on three phase transmission lines. Artificial neural network is used in combination with S-transform for the location of fault and selection of faulty phase in a triangle network [10]. In [11], wavelet transform based protection technique is proposed for protecting the extra high voltage asymmetrical three terminal transmission lines. Support vector machines is used in [12] for the recognition of location of faults in three phase transmission lines. Discrete wavelet transform is used in combination with back propagation neural networks for locating the faults on single circuit three phase power transmission lines [13]. Wavelet transform based approach is used in [14] for detecting and locating faults in HVDC power transmission system. Wavelet transform based high resistance fault detection and location technique is used in [15] for the protection of two terminal parallel transmission lines. In [16], a multi-resolution morphological gradient based ultra-high speed protection technique has been proposed for three phase transmission line protection. Wavelet transform is used in [17] for the protection of series compensated transmission lines. In [18], a fault location scheme based on artificial neural network is proposed for locating faults on three phase transmission lines. Support vector machine is used in [19] for the location of faults on three phase transmission lines. In [20], artificial neural network based algorithm has been introduced for the classification of double circuit transmission line faults.

The work described in this paper deals with the location of fault on a 138kV, 50Hz, two terminal transmission line using discrete wavelet transform approach. A discrete wavelet transform based fault location scheme has been developed and tested on a two terminal power transmission line for the evaluation of fault location. The performance of proposed scheme has been tested at various locations on a two terminal transmission line

This paper is organized as follows: section 2 of the paper is devoted to the simulation study of two terminal transmission line using MATLAB, section 3 contains proposed DWT based fault location scheme, section 4 contains test results of the proposed technique, and section 5 contains the conclusion.

2. DOUBLE CIRCUIT TRANSMISSION LINE

The power transmission system consists of a 138kV, 50Hz, three phase transmission line of 300km length connected to three phase sources at the sending end and receiving end. The transmission line is divided into six sections each of 50km length extended between two sources. During the healthy condition of a power system, the current is measured at Bus-2 located at receiving end side of a power system. During the occurrence of fault, the three phase fault current is measured at Bus-1 located at the sending end side of power system (as demonstrated in Fig.1.). These signals are additionally analyzed and then decomposed using discrete wavelet transform toolbox of Matlab to remove approximate and detail coefficients at level-1 for the evaluation of fault location. The single line diagram of the proposed two terminal power system under consideration is represented in Fig.1. The proposed two terminal transmission line test system is modelled and simulated with pie parameter transmission line block using Simscape Power System toolbox of Matlab/Simulink.

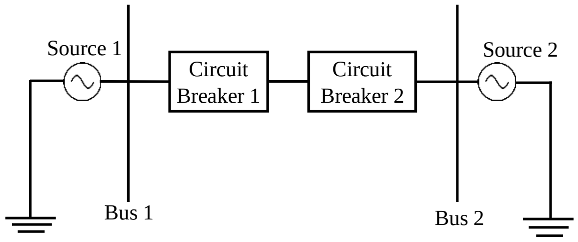

Fig.1. Proposed two terminal transmission line test system

3. PROPOSED SCHEME

In the area of digital signal processing, the methods based on wavelet transform have become one of the most powerful mathematical tools and since 1980's these methods became trendier. As a substitute to short time Fourier Transform (STFT), the wavelet transform (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. Wavelet transform is recently developed mathematical tool that divides up data, function or operation into different frequency components. Fourier analysis cracks up a signal into 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.

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

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 [3]. In the proposed work, daubechies-5 (Db5) is chosen as mother wavelet for analyzing the pre fault and post fault current signals.

The flow illustration of the proposed technique based on discrete wavelet transform for the evaluation of fault location on a two terminal transmission line is demonstrated in Fig.2. The primary stage is to simulate various fault occurrences varying the location of fault in a two terminal transmission line network, consequently processing the pre-fault and post-fault three phase current signals measured at both ends of the transmission line using discrete wavelet transform and then calculating the maximum and minimum scale of pre-fault and post-fault approximate and detail coefficients at level-1 at various locations. The location 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 [9].

The proposed DWT based fault location scheme is evaluated using a 138kV, 50Hz, two terminal power transmission line of 300km length.

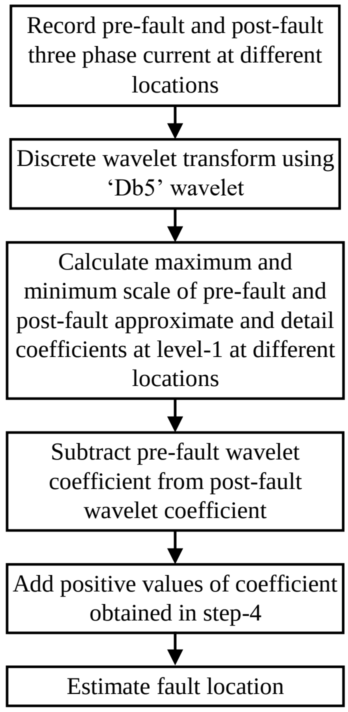

Fig.2. Flow diagram of proposed fault location technique

4. PERFORMANCE ASSESSMENT

The performance of the proposed discrete wavelet transform based fault location technique is evaluated for various shunt faults varying fault type and locations of fault for confirming the suitability of the proposed technique. MATLAB has been used for accomplishing a variety of simulation studies. Test results of the proposed fault location scheme have been demonstrated in the following subsections. Using Eq.(2), the %*Error* in fault location estimation is calculated so as to estimate the effectiveness of the proposed fault location technique [4].

$$\%Error = \left[\frac{AFL - EFL}{TSL}\right] \times 100 \qquad (2)$$

where, *AFL* is authentic fault location, *EFL* is evaluated fault location and *TSL* is total length of section. Thus, the performance of the proposed technique is evaluated for various fault situations to check the effectiveness of the technique for varying locations of fault.

4.1 PERFORMANCE DURING PHASE-'A-g' FAULT AT 50 KM FROM BUS-1

The performance of the proposed technique is observed for phase-'A-g' fault at 50km from Bus-1 of a two terminal power transmission network. The Fig.3 depicts the pre-fault three phase current of a two terminal transmission line network recorded at 300km from Bus-1. The Fig.4 demonstrates the three phase current at 50km from Bus-1 during phase-'A-g' fault with $R_f = R_g = 0.001\Omega$ at *FIT* = 0.0166 seconds. The three phase current signals as shown in Fig.3 and Fig.4 are further processed using discrete wavelet transform with Db5 wavelet to extract appropriate feature vector for fault location evaluation. The Fig.5 depicts the pre-fault discrete wavelet transform coefficients of three phase current at 300km from Bus-1 which has been recorded at Bus-2 using ‘Db5’ wavelet. The Fig.6 points up discrete wavelet transform coefficients of a three phase current during phase-‘A-g’ fault at 50km from Bus-1 recorded at Bus-1 using ‘Db5’ wavelet. The Table.1 summarizes the pre-fault wavelet coefficients of three phase current at 300km and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). Similarly, the Table.2 demonstrates the wavelet coefficients of three phase current during phase- ‘A-g’ fault at 50km from Bus-1 and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). The Table.3 illustrates the maximum and minimum scale of coefficients of three phase current for phase-‘A-g’ fault at 50km using ‘Db5’ wavelet. From the Table.3, it can be observed that for evaluating the location of fault, the values of pre-fault coefficients of three phase current obtained at 300km are subtracted from the values of post-fault coefficients of three phase current obtained at 50km from Bus-1 and then the positive values of the coefficients are added. From the Table.3, it can be noticed that the fault location result of proposed technique is precise with the % error of -1.5333%.

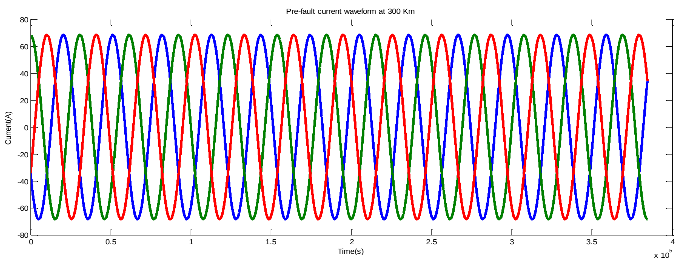

Fig.3. Pre-fault three phase current at 300km from Bus-1

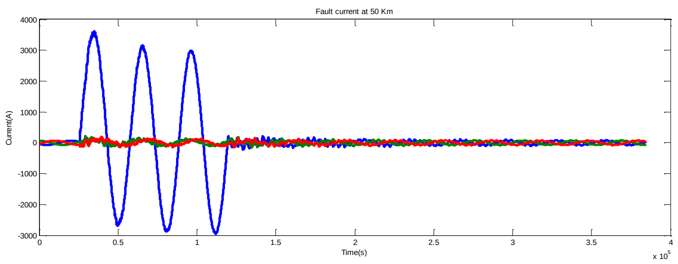

Fig.4. Three phase current at 50km from Bus-1 during phase-‘A-g’ fault

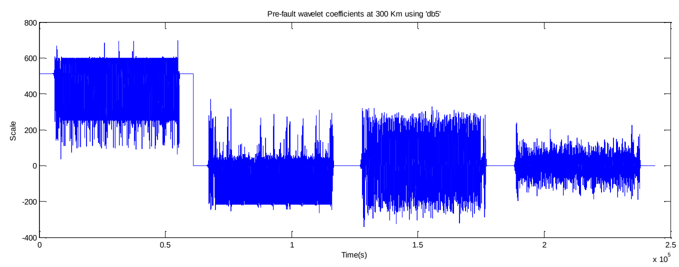

Fig.5. Wavelet coefficients of three phase current during no-fault at 300km from Bus-1 using ‘Db5’ wavelet

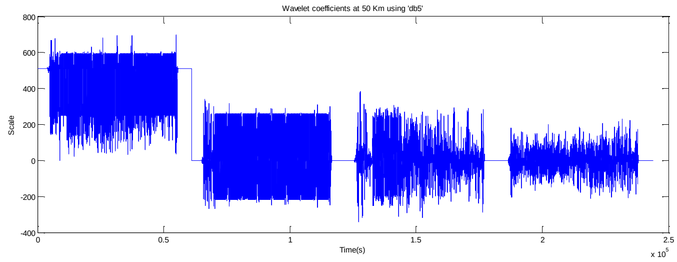

Fig.6. Wavelet coefficients of three phase current during phase-‘A-g’ fault at 50km from Bus-1 using ‘Db5’ wavelet

Table.1. Wavelet coefficients at 300km during no-fault

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	35.13
Horizontal (H1)	368.7	-262.5
Vertical (V1)	330.2	-341.2
Diagonal (D1)	237.9	-194.5

Table.2. Wavelet coefficients at 50km during phase- ‘A-g’ fault

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	-0.063
Horizontal (H1)	338.8	-266.9
Vertical (V1)	384.8	-341.7
Diagonal (D1)	231	-210.5

4.2 PERFORMANCE DURING PHASE-‘A-g’ FAULT AT 100KM FROM BUS-1

The performance of the proposed technique is examined for phase-‘A-g’ fault at 100km from Bus-1 of a two terminal power transmission network. The Fig.7 shows the pre-fault three phase current of a two terminal transmission line network recorded at 300km from Bus-1. The Fig.8 shows the three phase current at 100km from Bus-1 during phase-‘A-g’ fault with $R_f = R_g = 0.001\Omega$ at FIT = 0.0166 seconds. As already being discussed in the previous sub-section, the three phase current signals as shown in the Fig.7 and Fig.8 are further processed using discrete wavelet transform with Db5 wavelet to extract appropriate characteristic vector for fault location evaluation. The Fig.9 demonstrates the pre-fault discrete wavelet transform coefficients of three phase current at 300 km from Bus-1 which has been recorded at Bus-2 using ‘Db5’ wavelet. The Fig.10 illustrates the discrete wavelet transform coefficients of a three phase current during phase-‘A-g’ fault at 100km from Bus-1 recorded at Bus-1 using ‘Db5’ wavelet. The Table.4 demonstrates the wavelet coefficients of three phase current during no-fault at 300km and includes the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). Similarly, the Table.5 shows the wavelet coefficients of three phase current during phase- ‘A-g’ fault at 100km from Bus-1 and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). The Table.6 summarizes the maximum and minimum scale of coefficients of three phase current for phase-‘A-g’ fault at 100km using ‘Db5’ wavelet. From the Table.6, it can be examined that for evaluating the location of fault, the values of pre-fault coefficients of three phase current obtained at 300km are subtracted from the values of post-fault coefficients of three phase current obtained at 100km from Bus-1 and then the positive values of the coefficients are added. From the Table.6, it can be noticed that the fault location result of proposed discrete wavelet transform based technique is precise with the % error of 2.4666%. Test results of fault location evaluation and the % error achieved by using discrete wavelet transform approach during single line to ground faults with varying location of fault are presented in the Table.7. Test results represents that the proposed DWT-based fault location scheme is not affected by varying the fault location.

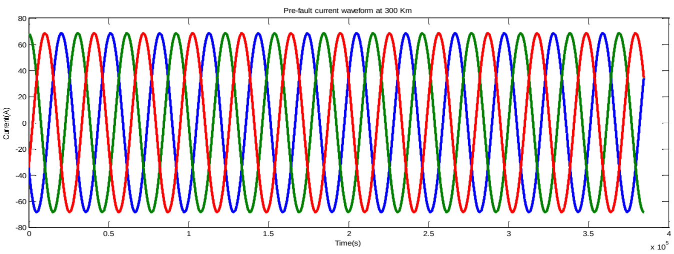

Fig.7. Pre-fault three phase current recorded at 300 km from Bus-1

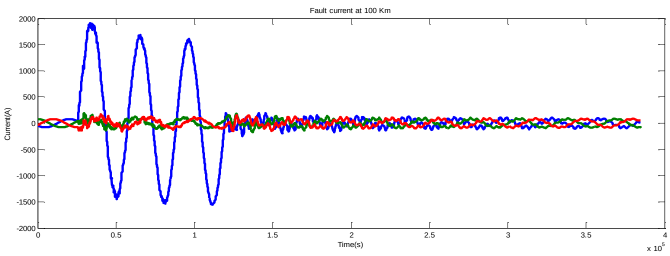

Fig.8. Three phase current at 100 km from Bus-1 during phase-'A-g' fault

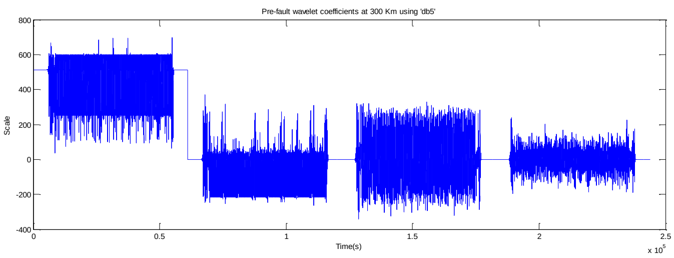

Fig.9. Wavelet coefficients of three phase current during no-fault at 300 km from Bus-1 using 'Db5' wavelet

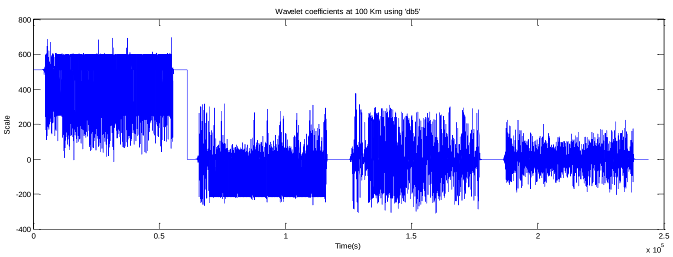

Fig.10. Wavelet coefficients of three phase current during phase-'A-g' fault at 100 km from Bus-1 using 'Db5' wavelet

Table.3. Maximum and minimum scale of coefficients of three phase current for phase-'A-g' fault at 50km using 'Db5'

	Db5 max				Db5 min			
Coefficients	**A1**	**H1**	**V1**	**D1**	**A1**	**H1**	**V1**	**D1**
Coefficients at 50km	697.1	338.8	384.8	231	-0.063	-266.9	-341.7	-210.5
Pre-fault coefficients	697.1	368.7	330.2	237.9	35.13	-262.5	-341.2	-194.5
Differences	0	-29.9	54.6	-6.9	-35.19	-4.4	-0.5	-16
Estimated Distance (km) = 54.6								

Table.4. Wavelet coefficients of a three phase current at 300km during no-fault

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	35.13
Horizontal (H1)	368.7	-262.5
Vertical (V1)	330.2	-341.2
Diagonal (D1)	237.9	-194.5

Table.5. Wavelet coefficients of a three phase current at 100km during phase-'A-g' fault

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	-14.73
Horizontal (H1)	316.3	-268.4
Vertical (V1)	384.8	-317.1
Diagonal (D1)	251.8	-232.9

Table.6. Maximum and minimum scale of coefficients of three phase current for phase-'A-g' fault at 100km using 'Db5'

	Db5 max				Db5 min			
Coefficients	**A1**	**H1**	**V1**	**D1**	**A1**	**H1**	**V1**	**D1**
Coefficients at 50km	697.1	316.3	384.8	251.8	-14.73	-268.4	-317.1	-232.9
Pre-fault coefficients	697.1	368.7	330.2	237.9	35.13	-262.5	-341.2	-194.5
Differences	0	-52.4	54.6	13.9	-49.86	-5.9	24.1	-38.4
Estimated Distance (km) = 54.6 + 13.9 + 24.1 = 92.6								

Table.7. Fault location evaluation and % Error varying fault location

Authentic fault location (km)	Fault location evaluated (km) using 'Db5' wavelet	% Error
50	54.6	-1.5333
100	92.6	2.4666

5. CONCLUSION

This paper presents a fault location technique for shunt faults that occur on the two terminal transmission lines using discrete wavelet transform. Widespread simulation studies have been done to estimate the impact of variation in fault type and the location of fault. The proposed technique uses the maximum and minimum scale values of level-1 pre and post fault DWT approximate and detail coefficients of a three phase current signal measured at both terminals of a three phase two terminal transmission line. Simulation results for various shunt faults exemplifies that the discrete wavelet transform based fault location technique is suitable and dependable under various fault circumstances. The future extension of this technique will be on fault detection, classification and location evaluation of series capacitor compensated three phase and six phase transmission lines.

REFERENCES

[1] F. Unal and S. Ekici, "A Fault Location Technique for HVDC Transmission Lines using Extreme Learning Machines", *Proceedings of 5th IEEE Istanbul Smart Grid and Cities Congress and Fair*, pp. 125-129, 2017.

[2] R.J. Hamidi and H. Livani, "Travelling Wave-Based Fault Location Algorithm for Hybrid Multi-Terminal Circuits", *IEEE Transactions on Power Delivery*, Vol. 32, No. 1, pp. 135-144, 2017.

[3] Y.M. Sree, R.K. Goli, G.V. Priya and V. Ramaiah, "A Four Terminal Transmission Line Protection by Wavelet Approach in the Presence of SVC using Hybrid Generation", *Proceedings of IEEE Innovations in Power and Advanced Computing Technologies*, pp. 1-6, 2017.

[4] H. Livani and C.Y. Evrenosoglu, "A Machine Learning and Wavelet-Based Fault Location Method for Hybrid Transmission Lines", *IEEE Transactions on Smart Grid*, Vol. 5, No. 1, pp. 51-59, 2014.

[5] A. Tabatabaei, M.R. Mosavi and P. Farajiparvar, "A Travelling-Wave Fault Location Technique for Three-Terminal Lines Based on Wavelet Analysis and Recurrent Neural Network using GPS Timing", *Proceedings of IEEE Smart Grid Conference*, pp. 268-272, 2013.

[6] K. Saravanababu, P. Balakrishnan and K. Sathiyasekar, "Transmission Line Faults Detection, Classification and Location using DWT", *Proceedings of IEEE International Conference on Power Energy and Control*, pp. 233-238, 2013.

[7] K. Lout and R.K. Aggarwal, "A Feed Forward Artificial Neural Network Approach to Fault Classification and Location on a 132kV Transmission Line using Current Signals only", *Proceedings of IEEE 47th International Universities Power Engineering Conference*, pp. 1-6, 2012.

[8] M.R. Noori and S.M. Shahrtash, "A Novel Faulted Phase Selector for Double Circuit Transmission Lines by Employing Adaptive Cumulative Sum-Based Method", *Proceedings of 11th IEEE International Conference on Environment and Electrical Engineering*, pp. 365-370, 2012.

[9] S.S. Adamu and S. Iliya, "Fault Location and Distance Estimation on Power Transmission Lines Using Discrete Wavelet Transform", *International Journal of Advances in Engineering and Technology*, Vol. 1, No. 5, pp. 69-76, 2011.

[10] H. Shu, Q. Wu, X. Wang and X. Tian, "Fault Phase Selection and Distance Location Based on ANN and S-transform for Transmission Line in Triangle Network", *Proceedings of 3rd IEEE International Congress on Image and Signal Processing*, pp. 3217-3219, 2010.

[11] V.R.K. Bhupatiraju and R.R.V. Pulipaka, "A Wavelet Based Protection Scheme for EHV Asymmetrical Teed Circuits", *Proceedings of IEEE International Power Engineering Conference*, pp. 384-389, 2010.

[12] Z. Wang and P. Zhao, "Fault Location Recognition in Transmission Lines Based on Support Vector Machines", *Proceedings of* 2nd *IEEE International Conference on Computer Science and Information Technology*, pp. 410-404, 2009.

[13] A. Ngaopitakkul and C. Pothisarn, "Discrete Wavelet Transform and Back- Propagation Neural Networks Algorithm for Fault Location on Single Circuit Transmission Line", *Proceedings of IEEE International Conference on Robotics and Biometrics*, pp. 1613-1618, 2009.

[14] P.K. Murthy, J. Amarnath, S. Kamakshiah and B.P. Singh, "Wavelet Transform approach for Detection and Location of Faults in HVDC System", *Proceedings of IEEE Region 3rd International Conference on Industrial and Information Systems*, pp. 1-6, 2008.

[15] B. Bhalja and R.P. Maheshwari, "High Resistance Faults on Two Terminal Parallel Transmission Line: Analysis, Simulation Studies, and an Adaptive Distance Relaying Scheme", *IEEE Transactions on Power Delivery*, Vol. 22, No. 2, pp. 801-812, 2007.

[16] M. Yang and S. Tan, "Research on Ultra-High-Speed Protection Based on Multi-resolution Morphological Gradient", *Proceedings of IEEE International Conference on Power System Technology*, pp. 1-5, 2006.

[17] A.I. Megahed, A.M. Moussa and A.E. Bayoumy, "Usage of Wavelet Transform in the Protection of Series-Compensated Transmission Lines", *IEEE Transactions on Power Delivery*, Vol. 21, No. 3, pp. 1213-1221, 2006.

[18] H.P. Amorim and L. Huais, "Faults Location in Transmission Lines through Neural Networks", *Proceedings of IEEE/PES Transmission and Distribution Conference and Exposition*, pp. 691-695, 2004.

[19] Z. Jin and H. Renmu, "A New Algorithm of Improving Fault Location Based on SVM", *Proceedings of 8th IET IEE International Conference on Developments in Power System Protection*, pp. 204-207, 2004.

[20] H.K. Zadeh, "Artificial Neural Network Approach to Fault Classification for Double Circuit Transmission Lines", *Proceedings of IEEE/PES Transmission and Distribution Conference and Exposition*, pp. 859-862, 2004.