ISSN: 2395-1680 (ONLINE)
DOI: 10.21917/ijme.2020.0155

EVALUATION OF FAULT LOCATION IN THREE-PHASE TRANSMISSION LINES BASED ON DISCRETE WAVELET TRANSFORM

Gaurav Kapoor
Department of Electrical Engineering, Modi Institute of Technology, India

Abstract

This paper proposes an application of discrete wavelet transform for the evaluation of the location of fault in three-phase transmission lines. The first level approximate, and the detailed discrete wavelet transform coefficients of current at both ends are used for the evaluation of the location of faults. MATLAB has been used to simulate the three-phase transmission lines. The proposed technique is tested with varying types of fault and locations of fault. The simulation results confirm the successful evaluation of fault location in three-phase transmission lines.

Keywords:

Discrete Wavelet Transform, Fault Location Evaluation and Three-Phase Transmission Line Protection

1. INTRODUCTION

Detection and location of faults on transmission lines are essential to supply proficient and dependable flow of power. Many authors proposed various schemes for the evaluation of the location of faults in three phase transmission lines. Along with the different methods of fault location evaluation on three phase transmission lines demonstrated so far, authors in [1] used deep neural networks for the location of fault on a series compensated three terminal transmission line.

In [2], an artificial neural network based scheme is proposed for the detection and location of faults in multi-terminal direct current systems. In [3], wavelet energy is used for the detection and classification of faults in TCSC compensated transmission lines. Fuzzy multi-sensor data fusion based fault location technique is used in [4] for the location of faults in three phase transmission lines. A technique based on discrete wavelet transform has been proposed in [5] for the detection and classification of HVDC transmission line faults. Identification and classification of transmission line faults using wavelet transform is reported in [6]. The wavelet transform is used in conjunction with artificial neural networks for the classification and location of faults on transmission lines [7]. Artificial neural network based fault location technique is proposed in [8] for locating faults in power transmission system.

In [9], artificial neural network is used for the location and classification of double circuit transmission line faults. A combination of discrete wavelet transform and support vector machine is used in [10] for locating faults on overhead transmission lines combined with underground cables. Discrete wavelet transform is used in [11] for the location of faults and its distance evaluation on three phase power transmission lines. The wavelet transform is also used in [12] for the protection of extra high voltage three terminal transmission line network. Discrete wavelet transform is used in conjunction with back propagation neural networks for locating faults in single circuit transmission line [13]. Wavelet transform based technique is used in [14] for the classification of faults in three phase double circuit transmission line. In [15] [16], wavelet transform is used for the protection series compensated transmission lines. In [17], spectral energy of voltage signals decomposed using wavelet transform is used for the fault detection, classification and faulted phase selection on three phase series compensated transmission line. Artificial neural network is used in [18] to the classification of faults on double circuit transmission lines. A technique based on wavelet transform has been proposed in [19] for the discrimination of transmission line faults.

The work described in this paper deals with the evaluation of fault location in a 400kV, 50Hz three phase transmission line using discrete wavelet transform approach. A discrete wavelet transform based fault location scheme has been developed and tested on three phase power transmission line for the evaluation of fault location. The performance of proposed scheme has been tested at various locations on a proposed test system.

This paper is organized as follows: section 2 of the paper is devoted to the simulation study of three phase transmission line using MATLAB. Section 3 contains proposed DWT based fault location evaluation technique. Section 4 contains simulation results of the proposed technique. Section 5 contains the conclusions.

2. PROPOSED TEST-SYSTEM

The single line diagram of the power system under deliberation is represented in Fig.1. The power system consists of 400 kV, 50 Hz transmission line divided into six sections each of 50 km length extending between three phase source and load. At bus-2, a load of 132kV, 1MW is connected. The proposed test system is modelled and simulated with three phase pie section transmission line block using Simscape Power System toolbox of MATLAB. During no-fault, the current signals are measured at Bus-2. During fault situations, the current signals are measured at Bus-1. These signals are further decomposed using discrete wavelet transform toolbox with Db5 wavelet of MATLAB to obtain approximate and detail discrete wavelet coefficients at level-1 for the fault location evaluation.

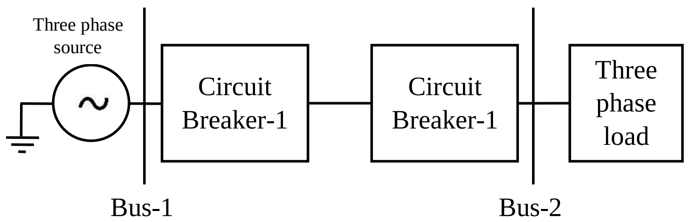

Fig.1. Single line diagram of proposed test system

2.1 DB5 WAVELET-BASED FAULT POSITION VALUATION SCHEME

The flow diagram of Db-5 wavelet-based fault position calculation scheme has been presented in Fig.2. Hence, for calculating the position of fault on TL, firstly simulate the TL model for various faults and measure three-phase currents at Bus-1 and Bus-2. Next, process the three-phase currents using “Db-5” wavelet filters. Evaluate the higher and lower value of approximate and detail coefficients at various positions. Then subtract the pre-fault Db5 coefficients from post-fault Db5 coefficients. Addition of all the positive signed outputs of currents collected in the previous step will give the final position of fault.

The performance of proposed scheme is tested on a system of 400kV, 50Hz three-phase power transmission system designed in Matlab/Simulink software.

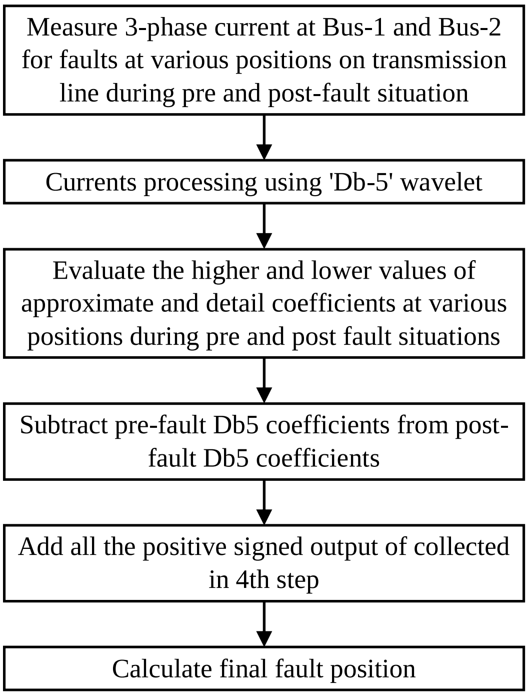

Fig.2. Flow illustration of proposed fault location scheme

3. PERFORMANCE APPRAISAL

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. The simulation outcomes of the proposed fault location scheme have been demonstrated in the following subsections. Using equation 2, the % error in fault location estimation is calculated so as to estimate the effectiveness of the proposed fault location technique.

$$\%Error = [(GFL - EFL)/TSL]*100 \quad (1)$$

where, *GFL* is genuine 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 positions of fault.

3.1 PERFORMANCE DURING SINGLE-LINE TO GROUND A-G FAULT AT 50 KM

In this sub-section, the performance of Db5 wavelet transform-based fault position estimation technique has been tested for “A-G” one-phase to ground fault. The “A-G” fault has been created at a distance of 50km away from the power source. The current of phase “A” during no-fault situation which is recorded at Bus-2 is presented in Fig.3. The current of phase “A” recorded at Bus-1 when the “A-G” fault is switched at a position of 50km away from the power source for three cycles of fundamental frequency has been presented in Fig.4. The “A-G” fault has been switched among the fault and ground resistances of 0.001Ω, respectively and the switching time at which the “A-G” fault is triggered is 0.0166s. To extract the suitable distinctive vector for fault position estimation, the currents which are shown in Fig.3 and Fig.4 are additionally decomposed using Db5 wavelet for obtaining the Db5 coefficients of no-fault and faults currents. The Db5WT coefficients of phase-A for no-fault (pre-fault) situation is presented in Fig.5.

The Fig.6 shows the Db5WT coefficient of phase-A during “A-G” fault (post-fault) situation at 50km. The amplitudes of maximum and minimum scales of approximate and detail Db5WT coefficients obtained during pre-fault situation are presented in Table.1. The amplitudes of maximum and minimum scales of approximate and detail Db5WT coefficients obtained during “A-G” fault situation are presented in Table.2. The pre-fault Db5WT coefficients which are shown in Table.1 are subtracted from the post-fault Db5WT coefficients of Table.2. Thus, the differences of Db5WT coefficients obtained are presented in Table.3. The Table.3 presents the location of fault obtained after adding the positive values of coefficients. Hence, for the “A-G” fault which was created at 50km on TL, the location of fault estimated using Db5WT is 52.5km with % error of -0.8333%. Hence, the Db5WT-based fault location technique effectively located the fault in transmission line.

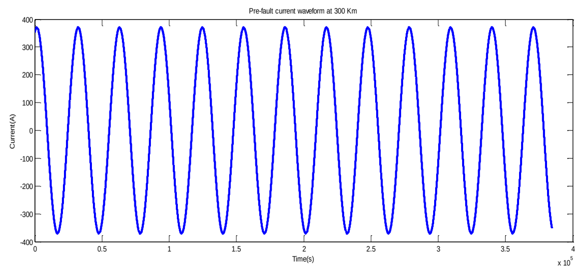

Fig.3. Pre-fault current of phase-A recorded at Bus-2

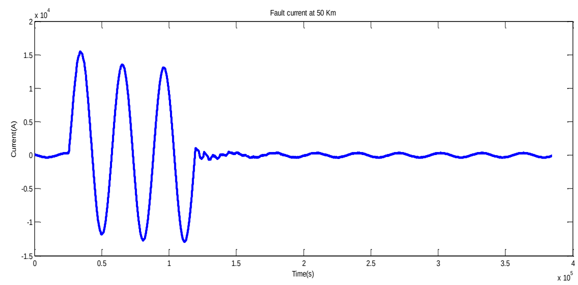

Fig.4. Post-fault current of phase-A recorded at Bus-1 for “A-G” fault at 50km from power source

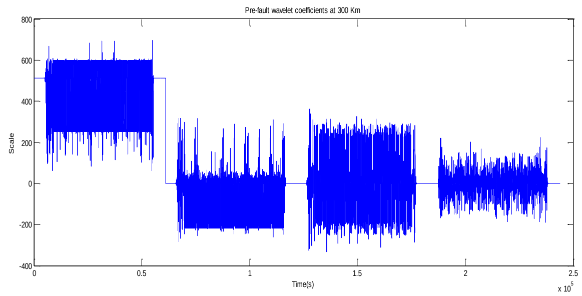

Fig.5. Pre-fault Db5WT coefficients of phase-A current

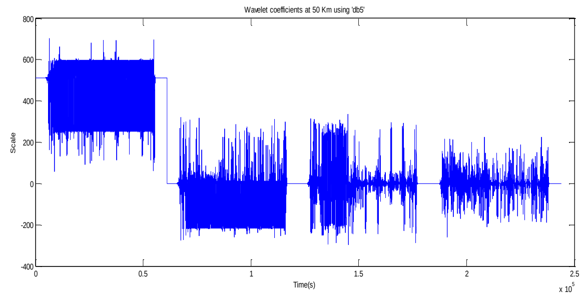

Fig.6. Post-fault Db5WT coefficients of phase-A current for "A-G" fault at 50km

Table.1. Pre-fault Db5WT coefficients of phase-A current

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	61.16
Horizontal (H1)	316.3	-284.5
Vertical (V1)	362	-334.3
Diagonal (D1)	224.5	-188.9

Table.2. Post-fault Db5WT coefficients of phase-A current for "A-G" fault at 50km

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	57.97
Horizontal (H1)	319.2	-274.1
Vertical (V1)	335.5	-295.1
Diagonal (D1)	224.5	-260.4

3.2 PERFORMANCE DURING SINGLE-LINE TO GROUND "A-G" FAULT AT 100 KM

In this sub-section, the performance of Db5 wavelet transform-based fault position evaluation technique has been tested for "A-G" one-phase to ground fault. The "A-G" fault has been created at a distance of 100km away from the power source. The current of phase "A" during pre-fault situation which is recorded at Bus-2 has been presented in Fig.7. The current of phase "A" recorded at Bus-1 when the "A-G" fault is switched at a position of 50km away from the power source for three cycles of fundamental frequency has been presented in Fig.8. The "A-G" fault has been switched among the fault and ground resistances of 0.001Ω, respectively and the switching time at which at "A-G" fault is triggered is 0.0166s. To extract the suitable distinctive vector for fault position estimation, the currents which are shown in Fig.7 and Fig.8 are additionally decomposed using Db5 wavelet for obtaining the Db5 coefficients of no-fault and faults currents. The Db5WT coefficients of phase-A for no-fault (pre-fault) situation is presented in Fig.9. The Fig.10 shows the Db5WT coefficient of phase-A during "A-G" fault (post-fault) situation at 100km. The amplitudes of maximum and minimum scales of approximate and detail Db5WT coefficients obtained during pre-fault situation are presented in Table.4. The amplitudes of maximum and minimum scales of approximate and detail Db5WT coefficients obtained during "A-G" fault situation are presented in Table.5. The pre-fault Db5WT coefficients which are shown in Table.4 are subtracted from the post-fault Db5WT coefficients of Table.5. Thus, the differences of Db5WT coefficients obtained are presented in Table.6. The Table.6 presents the location of fault obtained after adding the positive values of coefficients. Hence, for the "A-G" fault which was created at 100km on TL, the location of fault estimated using Db5WT is 114.7km with % error of -4.9%. Hence, the Db5WT-based fault location technique successfully located the fault in transmission line.

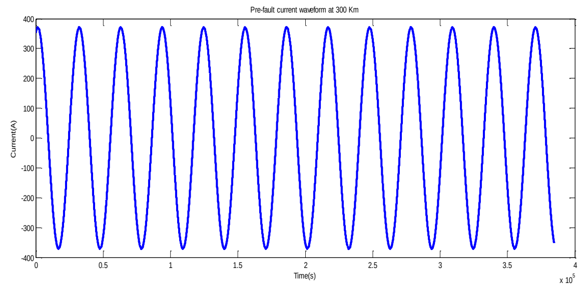

Fig.7. Pre-fault current of phase-A recorded at Bus-2

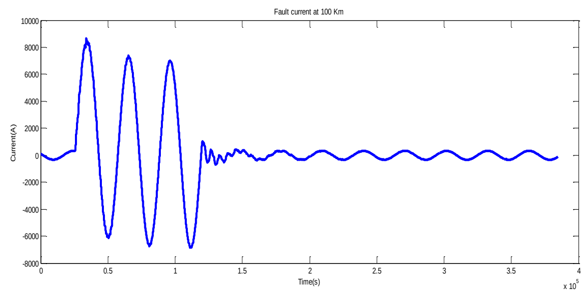

Fig.8. Post-fault current of phase-A recorded at Bus-1 for "A-G" fault at 100km from power source

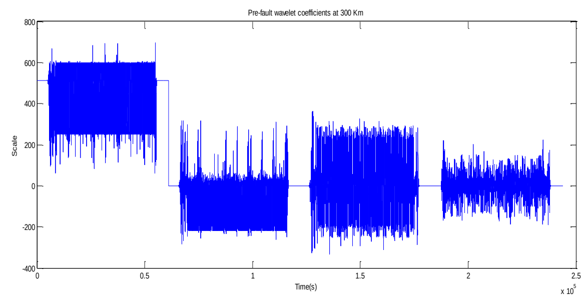

Fig.9. Pre-fault Db5WT coefficients of phase-A current

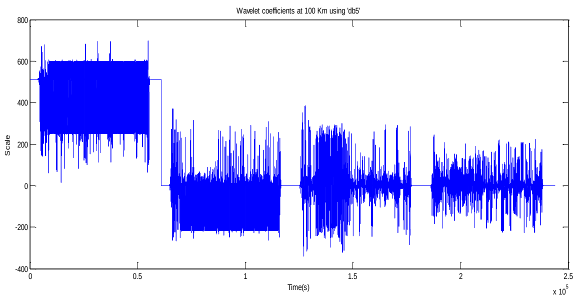

Fig.10. Post-fault Db5WT coefficients of phase-A current for "A-G" fault at 100km

Table.3. Fault location result for "A-G" fault at 50km using Db5WT

	Db5 max				Db5 min			
Coefficients	**A1**	**H1**	**V1**	**D1**	**A1**	**H1**	**V1**	**D1**
Coefficients at 50 km	697.1	319.2	335.5	224.5	57.97	-274.1	-295.1	-260.4
Pre-fault coefficients	697.1	316.3	362	224.5	61.16	-284.5	-334.3	-188.9
Differences	0	2.9	-26.5	0	-3.19	10.4	39.2	-71.5
Estimated Distance (km) = 2.9 + 10.4 + 39.2 = 52.5 km								

Table.4. Pre-fault Db5WT coefficients of phase-A current

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	61.16
Horizontal (H1)	316.3	-284.5
Vertical (V1)	362	-334.3
Diagonal (D1)	224.5	-188.9

Table.5. Post-fault Db5WT coefficients of phase-A current for "A-G" fault at 100km

Coefficients	Maximum Scale	Minimum Scale
Approximate (A1)	697.1	14.39
Horizontal (H1)	370.7	-266.6
Vertical (V1)	385	-341.7
Diagonal (D1)	243.9	-227.4

Table.6. Fault location result for "A-G" fault at 100km using Db5WT

	Db5 max				Db5 min			
Coefficients	**A1**	**H1**	**V1**	**D1**	**A1**	**H1**	**V1**	**D1**
Coefficients at 100km	697.1	370.7	385	243.9	14.39	-266.6	-341.7	-227.4
Pre-fault coefficients	697.1	316.3	362	224.5	61.16	-284.5	-334.3	-188.9
Differences	0	54.4	23	19.4	-46.77	17.9	-7.4	-38.5
Estimated Distance (km) = 54.4 + 23 + 19.4 + 17.9 = 114.7								

Table.7. Fault location estimation and % error obtained for different fault locations

Genuine fault location (km)	Fault location estimated (km) using Db5WT	%Error
50	52.5	-0.8333
100	114.7	-4.9

4. CONCLUSION

A fault location evaluation technique for three-phase transmission lines based on discrete wavelet transform is presented in this paper. A 400kV, 50Hz, three-phase transmission line of 300km length is simulated for various system situations and with fault parameters variation. The outcome of variations in location and type of fault has been investigated. The proposed fault location evaluation technique uses the current recorded at both the ends of the transmission line. The performance of the proposed technique is examined by a number of simulations. The simulation outcomes demonstrate that the location of all types of faults can be precisely evaluated. The proposed fault location evaluation technique is found resistant to the effects of variations in the type and the location of faults.

REFERENCES

[1] Mahdi Mirzaei, Behrooz Vahidi and Seyed Hossein Hosseinian, "Fault Location on a Series-Compensated Three Terminal Transmission Line using Deep Neural Networks", *IET Science, Measurement and Technology*, Vol. 12, No. 6, pp. 746-754, 2018.

[2] J.O.A. Torres and R.C.D Santos, "An ANN-based Algorithm for Fault Detection and Location in MTDC Systems", *Proceedings of IEEE Simposio Brasileiro de Sistemas Eletricos*, pp. 1-6, 2018.

[3] S. Biswas, K. Kumar, A. Ghosal and P.K. Nayak, "Fault Detection and Classification for TCSC Compensated Transmission Lines using Wavelet Energy", *Proceedings of IEEE 4th International Conference on Recent Advances in Information Technology*, pp. 1-5, 2018.

[4] Z. Jiao and R. Wu, "A New Method to Improve Fault Location Accuracy in Transmission Line Based on Fuzzy Multi-Sensor Data Fusion", *IEEE Transactions on Smart Grid*, Vol. 10, No. 4, pp. 4211-4220, 2019.

[5] U. Saleem, U. Arshad, B. Masood, T. Gul, W. A. Khan and M. Ellahi, "Faults Detection and Classification of HVDC Transmission Lines of using Discrete Wavelet Transform", *Proceedings of IEEE International Conference on Engineering and Emerging Technologies*, pp. 1-6, 2018.

[6] S. Kirubadevi and S. Sutha, "Wavelet based Transmission Line Fault Identification and Classification", *Proceedings of IEEE International Conference on Computation of Power, Energy Information and Communication*, pp. 737-741, 2017.

[7] A.S. Neethu and T.S. Angel, "Smart Fault Location and Fault Classification in Transmission Line", *Proceedings of IEEE International Conference on Smart Technologies and*

Management for Computing, Communication, Controls, Energy and Materials, pp. 339-343, 2017

[8] L. Teklic, B. Filipovic Grcic and I. Pavicic, "Artificial Neural Network Approach for Locating Faults in Power Transmission System", *Proceedings of IEEE International Conference on Eurocon*, pp. 1425-1430, 2013.

[9] N. Saravanan and A. Rathinam, "A Comparative Study on ANN Based Fault Location and Classification Technique for Double Circuit Transmission Line", *Proceedings of 4th IEEE International Conference on Computational Intelligence and Communication Networks*, pp. 824-830, 2012.

[10] H. Livani and C.Y. Evrenosoglu, "A Hybrid Fault Location Method for Overhead Lines Combined with Underground Cables using DWT and SVM", *Proceedings of IEEE Power and Energy Society General Meeting*, pp. 1-6, 2012.

[11] Sunusi Sani Adamu and Sada 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.

[12] V.R.K. Bhupatiraju and R.R.V. Pulipaka, "A Wavelet based Protection Scheme for EHV Asymmetrical Teed Circuits", *Proceedings of IEEE International Conference on IPEC*, pp. 384-389, 2010.

[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 Biomimetics*, pp. 1613-1618, 2009.

[14] F. Martin, J.A. Aguado, M. Medina and J. Munoz, "Classification of Faults in Double Circuit Lines using Wavelet Transforms", *Proceedings of IEEE International Conference on Industrial Technology*, pp. 1-6, 2008.

[15] V.J. Pandya and S.A. Kanitkar, "A Novel Unit Protection Scheme for Protection of Series Compensated Transmission Line using Wavelet Transform", *Proceedings of IEEE Australasian Universities Conference on Power Engineering*, pp. 1-5, 2007.

[16] Ashraf 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.

[17] C. Aguilera, E. Orduna and G. Ratta, "Fault Detection, Classification and Faulted Phase Selection Approach Based on High-Frequency Voltage Signals Applied to a Series-Compensated Line", *IEE Proceedings-Generation, Transmission and Distribution*, Vol. 153, No. 4, pp. 469-475, 2006.

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

[19] O.A.S. Youssef, "A Wavelet-based Technique for Discrimination between Faults and Magnetizing Inrush Currents in Transformers", *IEEE Transactions on Power Delivery*, Vol. 18, No. 1, pp. 170-176, 2003.