Discrete Wavelet Transform and Support Vector Machines Algorithm for Fault Locations on Single Circuit Transmission Line

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***Abstract*— This paper proposes a technique using discrete wavelet transform (DWT) and support vector machines (SVM) for fault location on single circuit transmission lines. The ATP/EMTP is used to simulate fault signals. The mother wavelet daubechies4 (db4) is employed to decompose high frequency component from these signals. The first peak time in first scale capable of detecting fault of each bus is used as input pattern for the training pattern. It is shown that the proposed technique gives satisfactory results.**

***Index Terms*—Wavelet Transform, Fault Location, Transmission Line, Support Vector Machines**

I. Introduction

In generally, when fault occurs on transmission lines, detecting fault is very necessary in order to clear fault before it generates the damage to the power system. Conventional method of fault location which is employed by Electricity Generating Authority of Thailand (EGAT) is the Line Fault Locator (LFL) Type "c". However, LFL has disadvantage bebause the devices of LFL are complicated and expensive. Several algorithms employed in fault detection and fault location have been developed for the protective relays [1-6].

In the literature for fault location, the currently most effective technique for identifying fault location, based on a travelling wave, has been proposed in the 1980s [7-8]. Most researches have only considered the fault location based on travelling wave for Type A and Type D mode. Type A is one-end algorithms which estimate a distance to fault with the use of voltages and currents acquired at a particular end of line. A correct fault location estimation is influenced by many factors such as influence of zero-sequence mutual effects on the components, untransposed line, charging capacitance, and etc. Type D is two-end algorithms which require both an accurate method of time synchronization and an easy means of bringing the measurements from the two terminals to a common point so that the fault location can be determined. The Type D mode is more accurate than Type A mode and is able to minimize or eliminate the effects of fault resistance, loading and charging current. While calculating a Type D, result requires communication with the data acquisition units in two or more substations, it does not have to be "on-line" and can, therefore, use any communications channel. In previous research works [9], discrete wavelet transform (DWT) based on travelling wave is employed to detect the high frequency components, and to identify fault locations in the underground distribution system. The first peak time that can detect fault obtained from all buses are compared, and the fastest two first peak times obtained from comparison are used as input data for travelling wave equation. Although the travelling wave technique can provide precise results in fault location, it requires a high sampling rate and has difficulties in distinguishing between travelling waves reflected from the fault point versus those from the remote end of the line [10].

The development of the algorithm for locating fault on the transmission line with the wavelet transform was initially proposed by F. H. Magnago et al [11]. Artificial intelligence (AI) has been also reported in the literature for fault location [2, 12]. Although artificial neural network algorithm can give precise results in fault locations, but it is partly limited by the slow training performance. In order to overcome this problem, a new algorithm has been developed. It is interesting to investigate an appropriate support vector machines algorithm if the fault locations on the transmission line can be identified using wavelet transform and support vector machines for being included in newly-developed protection systems.

Therefore, this paper presents a development of a new decision algorithm used in the protective relays in order to identify fault locations along the transmission systems. The fault conditions are simulated using ATP/EMTP. The current waveforms obtained from the simulation, then, are extracted using the DWT. The validity of the proposed algorithm is tested with various fault inception angles, fault locations and faulty phases. In addition, the construction of the decision algorithm is detailed and implemented with various case studies based on Thailand electricity transmission systems. Moreover, the results from the proposed algorithm are compared with those from the travelling wave [9] and the BPNN [12] in order to show the advantage of the proposed method.

II. Power System Simulation using EMTP

The ATP/EMTP is used to simulate fault signals at a sampling rate of 200 kHz. The fault types are chosen based on the Thailand's transmission system as shown in Figure 1. Fault patterns in the simulations are performed with various changes in system parameters as follows:

- Fault types considered in this study are : single line to ground (SLG : AG, BG, CG), double-line to ground

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(DLG : ABG, BCG, CAG), line to line (L-L : AB, BC, CA) and three-phase fault (3-P : ABC).

- Fault locations are varied from 10% to 90%, with the increase of 10% of the transmission line length measured from the bus MM3.
- Inception angle on a voltage waveform is varied between 0°-330°, with the increasing step of 30°. Phase A is used as a reference.
- Fault resistance is equal to 10 Ω.

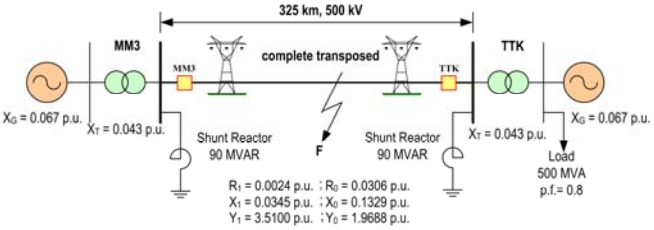

Fig. 1 The system used in simulation studies [13].

The example of simulated fault signals by ATP/EMTP is illustrated in Figure 2. This is a fault occurring in phase A to ground at 30% of transmission line length measured from the bus MM3 as depicted in Figure 1. The fault signals generated using ATP/EMTP are interfaced to MATLAB for the fault detection algorithm.

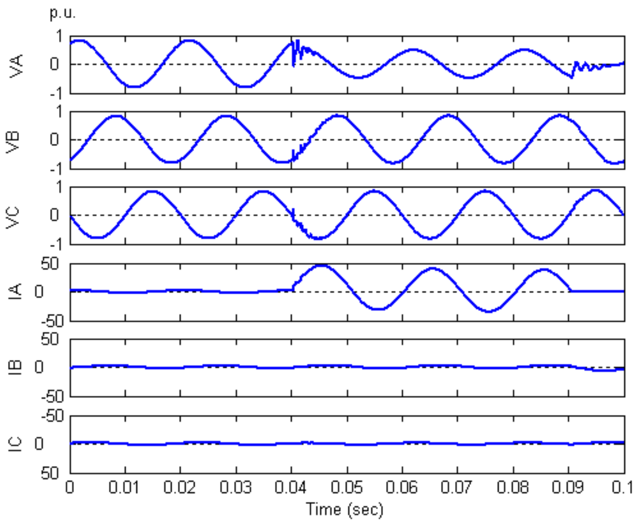

Fig. 2 Example of simulated fault signals by ATP/EMTP for AG fault at sending end.

The Clark's transformation matrix is employed for calculating the positive sequence and zero sequence of currents. With several trial and error processes, the fault detection decision algorithm on the basis of computer programming technique is constructed as shown in Fig. 3. The mother wavelet daubechies4 (db4) [9, 12, 14] is employed to decompose high frequency components from the positive sequence current signals. Fault detection decision algorithm [2, 9, 12] is proceeded using positive sequence current signal. Coefficients obtained using DWT of signals are squared so that the abrupt change in the spectra can be clearly found, and it is clearly seen that the coefficients of high frequency components, when fault occurs, have a sudden change compared with those before an occurrence of the faults as shown in Fig. 3. The fault detection decision algorithm has been proposed that if coefficients of any scales are change around five times before an occurrence of the faults, there are faults occurring on transmission lines.

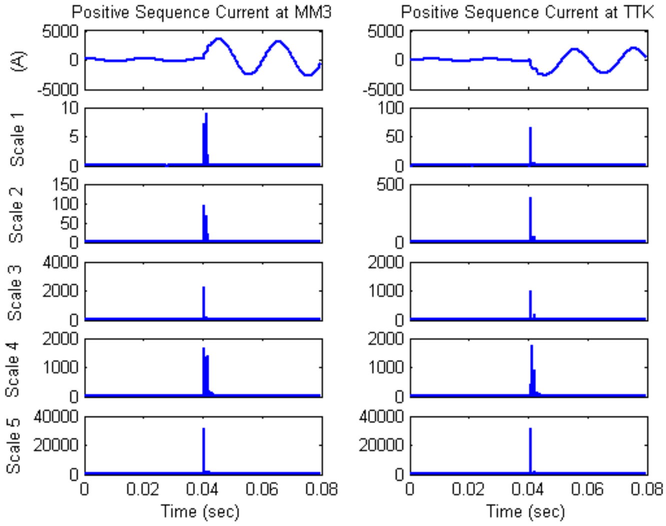

Fig. 3. Wavelet transform from scale 1 to 5 for the positive sequence of current signal shown in Fig. 2.

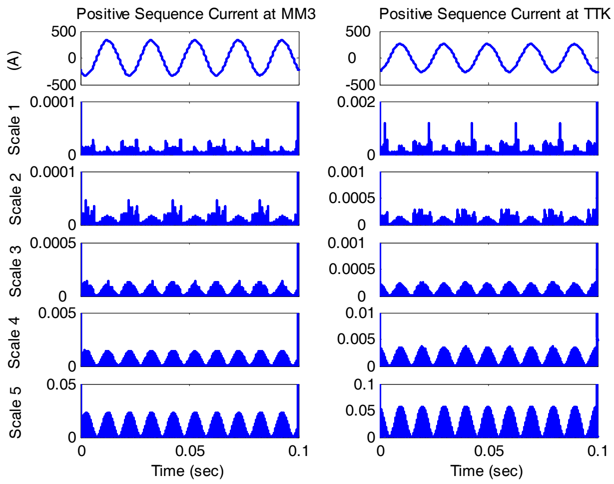

Fig. 4. Wavelet transform from scale 1 to 5 for the positive sequence of current signal in normal condition.

From Fig. 4., the coefficient in each scale of the wavelet transform does not clearly change then it presumes that these signals are in normal operating condition. By performing many simulations, it has been found that the coefficient in scale 1 from DWT seems enough to indicate the fault inception on the single circuit transmission line. As a result, it is unnecessary to use other coefficients from higher scales in this algorithm, and the coefficients in scale 1 from DWT are used in training processes for the neural networks later.

III. Decision Algorithm and Result

From the simulated signals, DWT are applied to the quarter cycle of voltage and current waveforms after the fault inception. The coefficients of scale 1 obtained using the DWT are used for SVM. The basic idea of SVM is to map the training data from the input space into a higher dimensional feature space via kernel function. In this feature space optimal hyper plane is determined to maximize the generalization ability of the classifier.

Before the training process, input data are normalized and divided into 720 sets for training and 360 sets for test. A structure of the support vector machines consists of 2 inputs,

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5 SVM models and 1 output. The input patterns are the first peak time in first scale of faulty buses at ¼ cycle of positive sequence for post-fault currents as illustrated in Figure 5. The output variables of the support vector machines are designated as value range from 1 to 15, which corresponds to various locations of fault as shown in Table 1.

Table 1 Output of SVM for identifying the fault locations

Models of SVM	Output of SVM	Fault location (Distance measured from the sending end) (%)	Distance measured from the sending end for radial structure (km)
1	1	10%	32.5
	2	20%	65
	3	Other fault location	NA
2	4	30%	97.5
	5	40%	130
	6	Other fault location	NA
3	7	50%	162.5
	8	60%	195
	9	Other fault location	NA
4	10	70%	227.5
	11	80%	260
	12	Other fault location	NA
5	13	90%	292.5
	14	Other fault location	NA
	15	Other fault location	NA

During training process, five SVM models are investigated and each model contains two fault locations as shown in Table 1. For each SVM model, the adjusted parameters with minimum error are selected as the most appropriate parameters so that only the output is permitted as distance of fault or other fault location.

After the training process, case studies are varied so that the decision algorithm capability can be verified. The total numbers of the case studies are 360. Various case studies are performed with various types of faults at each location on the transmission line including the variation of fault inception angles and locations at each transmission lines as shown in Table 2. In addition, the results obtained from the comparison of average error among decision algorithm using the proposed technique, BPNN algorithm and decision algorithm using the DWT based on travelling wave theory developed by Markming et al [9] are shown in Table 2. It can be seen that the accuracy of fault locations from the prediction of the algorithm is highly satisfactory. This is an improvement of the fault location which is detected using the travelling wave theory developed by Markming et al [9] as well as BPNN [12].

IV. CONCLUSION

This paper has proposed an algorithm based on a combination of DWT and SVM algorithm to identify fault location on the single circuit transmission systems. Daubechies4 (db4) is selected as a mother wavelet. The DWT has been employed to decompose high frequency components from fault signals. Positive sequence current signals are used in fault detection. The maximum coefficients of the positive sequence current obtained from all buses are compared in order to detect the faulty bus on the transmission system. It is found that the fault detection algorithm can detect fault with the accuracy of 100% using scale 1 only. SVM has been selected in the decision algorithm for predicting the location of fault. The first peak times obtained from the faulty bus are used as an input for the training process of SVM in a decision algorithm. The comparison of the average error from the results due to the algorithm proposed in this paper is concluded in Table 2. The results show clearly that the new algorithm can provide a better performance in predicting the fault locations with the average error of 0 km. The further work will be the improvement of the algorithm by taking into account the effects of other transmission line configurations, instance loop circuits or double circuits for the development of the practical protection system.

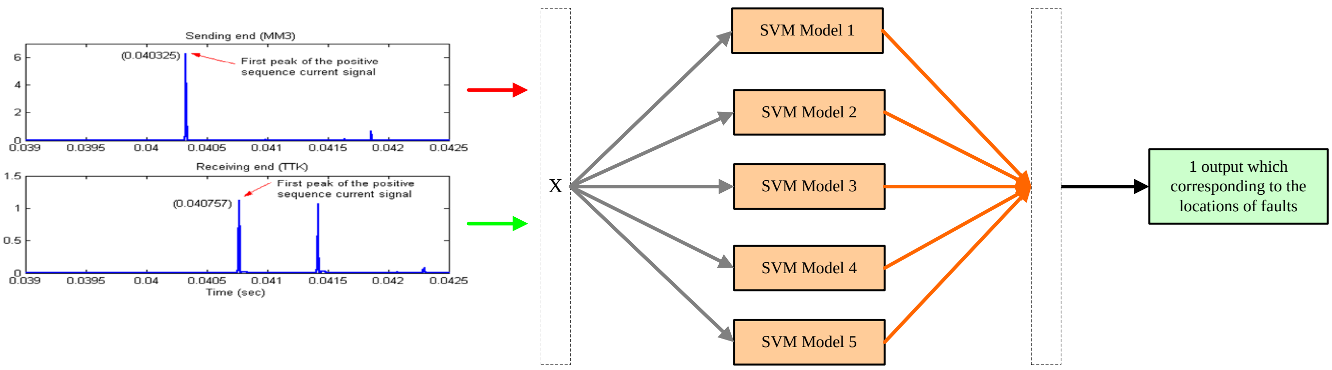

Fig. 5 Structure of SVM for identify fault location.

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Table 2 Average error of test set for locating fault

Average error (km)	Wavelet and BP [12]		Wavelet based on Travelling wave [9]	DWT and SVM
	Case 1	Case 2		
Single phase to ground (SLG)	0.0379	1.0096	1.075	0.00
Double-line to ground (DLG)	0.0167	0.5707	1.075	0.00
Line to line (LL)	0.0298	1.4133	1.075	0.00
Three-phase (3 – P)	0.0173	0.2248	1.075	0.00
Average	0.025425	0.8047	1.075	0.00

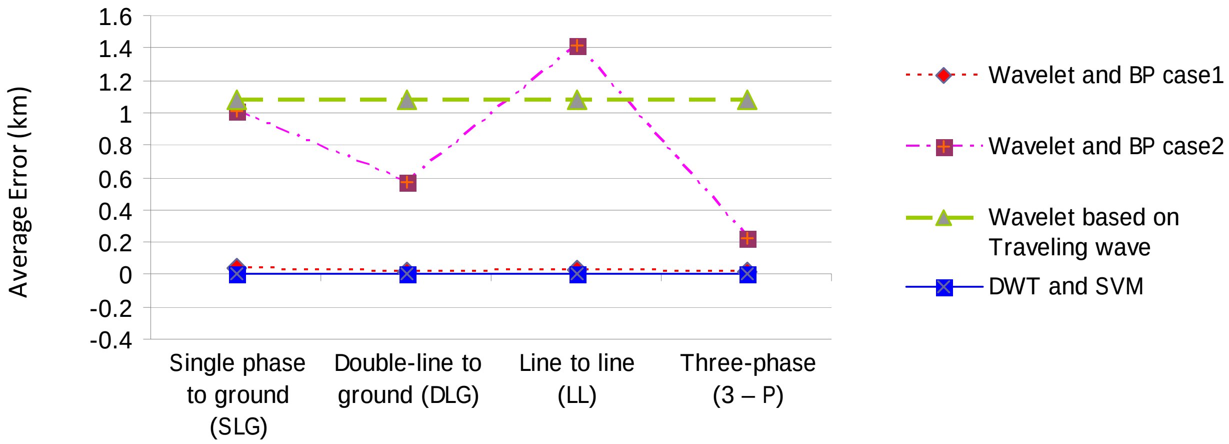

Fig 6. Comparison of average error for fault location for various types of faults

References

[1] C. Fan, L. Liu, Y. Tian, "fault location method for 12-phase transmission lines based on twelve-sequence component method", *IEEE/PES Transaction on Power Delivery*, Vol. 26, No. 1, pp. 135-142, 2011.

[2] A. Ngaopitakkul, and C. Jettanasen, "Combination of Discrete Wavelet Transform and Probabilistic Neural Network Algorithm for Detecting Fault Location on Transmission System" *International Journal of Innovative Computing, Information and Control*, Vol. 7, No. 4, pp. 1861-1874, 2011.

[3] M. Jayabharata Reddy, D.K. Mohanta, "A wavelet-fuzzy combined approach for classification and location of transmission line faults" Electrical Power and Energy Systems, Vol. 29, pp. 669-678, 2007.

[4] Simi P. Valsan, K.S. Swarup, "Wavelet transform based digital protection for transmission lines" *Electrical Power and Energy Systems*, Vol.31, pp. 379-388, 2009.

[5] P. Chiradeja, and C. Pothisarn, "Identification of the fault location for three-terminal transmission lines using Discrete Wavelet Transform" In Proceedings of IEEE International Conference on Transmission and Distribution (T&D Asia 2009), Korea, pp. 1-4, 2009.

[6] J. Izykowski, E. Rosolowski, M.M. Saha, M. Fulczyk and P. Balcerek, "A Fault-Location Method for Application With Current Differential Relays of Three-Terminal Lines", *IEEE Trans. on Power Delivery*, Vol. 22, no. 4, pp. 2099-2107, 2007.

[7] P. A. Crossley, P. G. McLaren., "Distance Protection Based on Travelling Waves", *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-102, No. 9, pp. 2581-2589, 1983.

[8] P. G. McLaren, S. Rajendra., "Travelling Wave Techniques Applied to the Protection of Teed Circuits: Principle of Travelling Wave Techniques", *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-104, No. 12, pp. 3544-3550, 1985.

[9] P. Markming, S. Bunjongjit, A. Kunakorn, S. Jiriwibhakorn and M. Kando, "Fault diagnosis in transmission lines using wavelet transform analysis", *IEEE/PES Transmission and Distribution Conference and Exhibition 2002 : Asia Pacific, 2002*, Vol. 3, pp. 2246-2250, 2002.

[10] E. H. Shehab-Eldin, P. G. McLaren. "Travelling Wave Distance Protection-problem Areas and Solutions", *IEEE Transactions on Power Delivery*, Vol. 3, No. 3, pp. 894-902, 1988.

[11] H Fernando, Magnago and Ali Abur, "Fault Location Using Wavelets", *IEEE Transactions on Power Delivery*, Vol. 13, No. 4, pp. 1475-1480, 1998.

[12] A. Ngaopitakkul and C. Pothisarn, "Discrete Wavelet Transform and Back-propagation neural networks algorithm for fault location on Single-circuit transmission line" *In Proceedings of 2008 International Conference on Robotics and Biomimetics (ROBIO2008)*, Thailand, pp. 1-4, February 2009.

[13] "Switching and Transmission Line Diagram", Electricity Generation Authorisation Thailand (EGAT).

[14] N. S. D. Brito, B. A. Souza and F. A. C Pires, "Daubechies wavelets in Quality of Electrical Power," Proc. IEEE/PES ICHQP, pp511-515, 1998.