IJDACR
ISSN: 2319-4863

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 3, Issue 7, February 2015)

Identification of Faults and Its Location in Transmission Line by Using Wavelet Transform

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***Abstract* — In order to reduce damage of transmission line due to fault and reliability, high-speed, sensitive and dependable protection system is a primary requirement of today's interconnected power system. Accurate pin-pointing of fault location and diagnosis is also required to expedite service reinstallation and thus, to reduce outage time, operating costs, and customer complaints. In the power system, stability and reliability must be ensured to provide continuity of service. Transmission lines run over several kilo meters will have the chance for occurrence of fault. In order to maintain stability and reliability, faults clearance should be at short span of time with recent advancements in signal processing. In this paper, a novel technique for the protection of transmission lines is proposed. The projected system uses Discrete Wavelet Transform (DWT) which is widely used in recent times for power scheme protection. DWT is used here to take out the hidden factors from the fault signals by performing decomposition at different levels. Daubechies wavelet "dB5" is used with single level decomposition and adaptive threshold is calculated to discriminate and detect the faulty phase. The locality of faults is carried out by obtaining the local fault information and remote location fault information along with the transmission line length. The system is independent of any statistical system data and has negligible fault resistance. Test system is modelled in EMTP and fault signals are generated to test the reliability of the algorithm. The proposed system promises the result by detecting, classifying and locating all the ten faults possible in the transmission line of the power system.**

***Index Terms*— Fault detection, Fault classification, Fault location, Discrete wavelet transform, Transmission line.**

I. INTRODUCTION

Transmission line is a vital part in power system. Faults in transmission line causes instability and damage to equipment. Therefore, it is necessary to protect the electric power system from faults. For efficient protection, fault should be detected quickly for immediate isolation of faulty line from the system. Subsequently fault classification and its location must be performed for restoration and speed recovery of the system. Competitive electric power industry. Accurate pin-pointing of faults is required by operators and utility staff in order to expedite service restoration and, thus, to trim down outage time, operating costs, and consumer complaints.

According to fault transients, there are number of algorithms have been developed for detection of faults and its classification. In this proposed algorithm, how transient features are extracted from original fault signal is an important issue. Wavelet Transform (WT) is selected as the strongest tool to analyze the fault because of its perfect time frequency localization ability (2-6).

Effective feature extraction using wavelet has been proposed in (4). Suitability of WT for non-stationary signal analysis is dealt in (7). Local analysis of relaying signal with the help of WT expressed in (8, 9). WT is applied in (10) to capture the high frequency components of travelling waves for detection of faults and faulty phase selection. Discrete Wavelet Transform (DWT) is used to design the fault classification tool for series compensated transmission lines in (11). DWT is used as online tool for relaying applications (12). Even though the WT is highly suited for analysis of transient waves, some improvements are needed in WT to detect and classify the faults. There are certain limitations to exhibit several fancy pictures and its transformed output still contains large number of data which need further processing. This hinders the automatic feature extraction in fault detection and classification.

The combined features like WT with ANN, WT with fuzzy logic have already been applied (1, 7, 8, and 19).These techniques are fully depends on huge samples and training for knowledge representation, which gives complication to complete a job. Also, uncertain factors in the transmission system will cause problems in managing them.

The focus of this paper is to develop a novel technique for real-time fault detection, classification and location by applying discrete wavelet transform to the fault signals. The inputs for the system are three-phase current samples provided when a fault is generated. Only a single level of decomposition is employed; hence, the computational requirements are reduced considerably when compared to multilevel decomposition employed in most of the works reported earlier. The proposed logic detects, classifies and locates the faults at high speed with good accuracy. The logic is easy to comprehend and implement. An important feature of

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this paper is that the logic is deterministic, which makes it system independent and avoids the need for collecting historical data which may not be readily available.

This paper is organized as follows: basic introduction of discrete wavelet transform explain in section II, proposed fault detection, classification and location algorithm is introduced in section III. In section IV we present simulation case studies in EMTP & MATLAB package on a two bus system. Section V concludes the paper

II. DISCRETE WAVELET TRANSFORM

Discrete Wavelet Transform is found to be useful in analyzing transient phenomenon such as that associated with faults on the transmission lines. Multi-Resolution Analysis (MRA) is one of the tools of Discrete Wavelet Transform (DWT), which decomposes original, typically non-stationary signal into low frequency signals called approximations and high frequency signals called details, with different levels or scales of resolution. It uses a prototype function called mother wavelet for this. At each level, approximation signal is obtained by convolving signal with low pass filter followed by dyadic decimation, whereas detail signal is obtained by convolving signal with high pass filter followed by dyadic decimation. The decomposition tree is shown in Figure.1. The DWT maps the one dimensional time domain signal f (t) into two dimensional signals as:

$$F(t) = \sum_{k} cj(k)\,Ø(t-k) + \sum_{k}\sum_{j} dj(k)\,\Psi(2\text{-}jt\text{-}k) \qquad (1)$$

Where cj and dj are approximate and detail coefficient respectively; Ø (t) and Ψ (t) are scaling and wavelet functions respectively and j is the decomposition level.

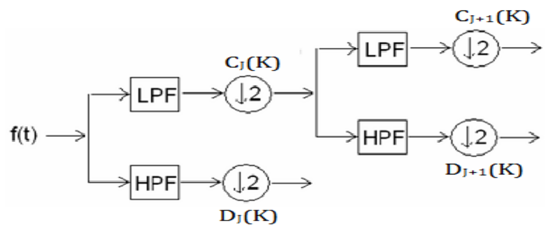

Figure.1. Decomposition tree

III. PROPOSED SYSTEM LOGIC

The proposed logic uses wavelet transform for extracting the hidden information in the current waveforms when a fault occurs, which is then suitably transformed to extract fault signatures to characterize and locate the faults.

III.A. Wavelet Decomposition

The three-phase current signals are fed through a discrete wavelet decomposition filter to decompose transients into a series of wavelet components, each of which corresponds to a time domain signal that covers a specific octave frequency band containing more detailed information. Such wavelet components appear to be useful for detecting, localizing, and classifying the sources of transients. Wavelet transform is largely due to this technique, which can be efficiently implemented by using only two filters, one high pass (HP) and one low pass (LP) at level (k). The results are down-sampled by a factor two and the same two filters are applied to the output of the low pass filter from the previous stage. The high pass filter is derived from the wavelet function (mother wavelet) and measures the details in a certain input. The low pass filter on the other hand delivers a smoothed version of the input signal and is derived from a scaling function, associated to the mother wavelet. The choice of mother wavelet is very important in detecting and localizing different types of fault transients. The daubechies (dB) is the commonly used mother wavelet suitable for protection applications. In this paper db5 wavelet is used which decomposes the signal effectively. The filter output consists of high frequency details, which can be down sampled by two to get level-1 high frequency detail coefficients HFDR, HFDY, and HFDB in the range of 500 to 1000 Hz.

III.B. Fault Detection

A fault detector must detect the fault inception and to issue an output signal representing this condition. During usual operating conditions the currents and voltages of the power system are sinusoidal signals. Load variation with time may produce slow amplitude changes in current signals and, in a lesser extent, in voltage signals. The inception of the fault introduces abrupt changes of amplitude and phase in current and voltage signals. Fault signals can be contaminated with different transient components such as exponentially-decaying dc-offset (mainly in current signals) and high-frequency damped oscillations (mainly in voltage signals), among other components. These changes of amplitude and phase, and the appearance of transient components, can be used to detect the inception of a fault.

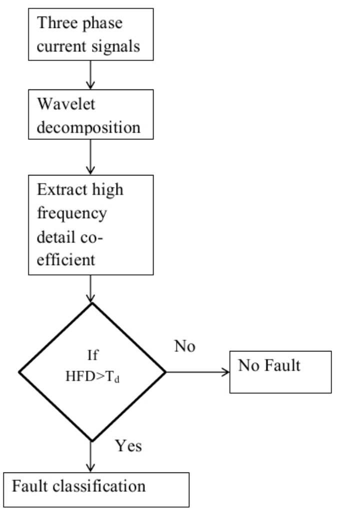

Figure.2. Block diagram of detection algorithm

IJDACR
ISSN: 2319-4863

International Journal Of Digital Application & Contemporary Research

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Figure.2. presents the block diagram of the decomposition algorithm. Phase currents IR, IY, IB are obtained when a disturbance is detected. Then these currents are subjected to decomposition using discrete wavelet decomposition filter to extract high frequency details from the current signals. If the absolute value of the first difference of the high frequency detail coefficients of the corresponding line currents is greater than a threshold value then fault is detected on that particular line. After the fault has been detected in that line the output value is logic 1 indicates the presence of fault or logic 0 indicates absence of fault. The Detect signal goes high, if a disturbance is detected in any one of the three-phase currents and the detected signal is subjected to fault classification to determine the type of fault. The threshold value Td can be fixed based on the maximum range of analog input to the signal pre-processor, sampling frequency, and the wavelet chosen. Td is set to provide maximum detection of fault generated for this paper, considering a maximum analog input magnitude of 10 V, a sampling frequency of 1 KHz, and "db5" wavelet. The time required for disturbance detection is less than half cycle.

III.C. Fault Classification

The algorithm presented in this paper is based on db5 wavelet and first decomposition level with sampling rate of 1 kHz. Samples which are used by the algorithm are collected over a short time span of 0.3 seconds. The fault classification algorithm consists of two separate logic, depending on whether the fault involves ground or not. This is essential, as the characteristics of a fault involving ground are considerably different from that which does not involve ground and have to be handled separately.

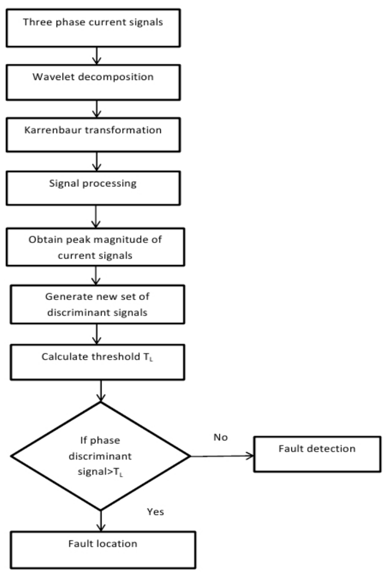

Figure.3. Block diagram of classification algorithm

The classification algorithm enables to discriminate between:

- Single phase to ground faults: L1-G, L2-G, and L3-G.
- Double phase to ground faults: L1-L2-G, L1-L3-G, and L2-L3-G.
- Double phase faults: L1-L2, L1-L3, and L2-L3.
- Three phase faults: L1-L2-L3.
- Three phase to ground faults: L1-L2-L3-G.

Figure.3.presents the block diagram of classification of algorithm is presented. The coupling effect of the mutually coupled three-phase transmission line must be nullified effectively before the information is provided for discriminating the type of faults. A simple transformation called karrenbaur transformation is used to achieve this. The karrenbaur transformation is achieved with summers/substrates alone without any need for multipliers. The transformation matrix is given as:

$$T = \begin{pmatrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{pmatrix}$$

The transformed signals R0, R1 and R2 are obtained by multiplying the transformation matrix with the high frequency details coefficients obtained earlier. Similarly, with phases Y and B as references, Y0, Y1, Y3, B0, B1 and B3 can be obtained. It is observed that R0=Y0=B0, R1=B2, Y1=R2, and B1=Y2. Hence the fault information can be obtained from four signals, R0, R1, Y1 and B1. When the detect signals goes high, indicating a fault, these four signals are squared and cumulatively added to get Rinfo, Yinfo, Binfo, and Ginfo .

The information must be gathered for a short span of time to ensure that the signal become stable and sufficient information is gathered, obtained information are used to classify the different types of fault occurrence in the preferred line.

III.D. Fault Location

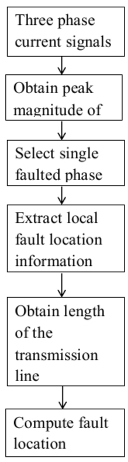

Figure.4.Block diagram of the fault location algorithm

IJDACR
ISSN: 2319-4863

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International Journal Of Digital Application & Contemporary Research

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After detection and classification of the fault, the location algorithm is performed. The block diagram of the location algorithm is presented in Figure.4. In the location algorithm the three phase current signals after decomposed, the peak magnitude of the currents at the end of a half cycle is provided as input to the fault locator. A single faulted phase is selected from the output of the fault classifier and is used to extract the local fault location information FLST from the source terminal. In a similar way the local fault location information FLRT from the remote terminal. The length of the transmission line is denoted as TL.
The fault location is computed using the formula given as:

$$\frac{FL_{RT} \times T_L}{FL_{ST} + FL_{RT}} \qquad (5)$$

IV. Modeling and Simulation Methodology

The overall framework of simulation methodology is shown in Fig. 5. ATP is free version of Electromagnetic Transient Program (EMTP) [26], which is widely used to implement accurate and fast electromagnetic transient simulation. Power system is simulated in ATP. Time synchronized samples are then generated in ATP file. This data is then processed in MATLAB. Algorithm for fault location is implemented in MATLAB. The entire implementation consists of two parts:

- Simulation of power system in ATP
- Algorithm implementation in MATLAB

IV.A. Simulation Results

A 500-kV, 118 km -long line was chosen for simulation. The parameters of this line are in Appendix 1 the line sections on two sides of the fault point were modeled as coupled PI sections with the steady state source at both ends. ATP model of the system considered is shown in following fig. 5.

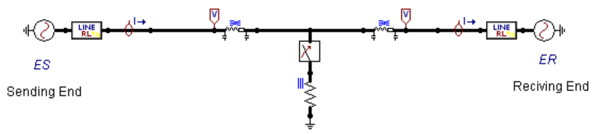

Fig.5 ATP model of the transmission line.

In order to study the performance of fault location scheme discussed above Alternative Transients Program (ATP) and fault detection, classification and location algorithm is implemented in MATLAB. The algorithm is 1 if there is any fault in the system otherwise output will be 0 result obtained from algorithm is shown in Table 1.The percentage error for fault location is calculated as

$$\%Error = \frac{|\,Actuallocation - Faultlocation\,|}{Totallinelength} \times 100$$

The fault classification, location and detection process of the test system is explained as follows. For discussion a two phase fault (RY) with respect to bus1 and a phase to ground fault (YG) with respect to bus1 are considered. When a fault occurs the phases R, Y, B can be found faulty if Rv, Yv, or Bv exceeds the prefixed threshold Tp which is being set with different values for the three phases. A ground fault can be found if Gv exceeds the ground threshold Tg. The faulty phase is identified in this case if the discriminant signal Rv, Yv, or Bv exceeds the adaptive threshold Tc. Figure.6, and Figure 7 shows the high frequency details of the phase fault (RY) and ground fault (YG). It can be observed that the faulty phase consists of significant amount of high transients compared to the non-fault phase. Fault location case studies for mid section of line is shown in Table 2.

Table 1: Performance of fault detection & classification method using data obtained from EMTP analysis

Fault type	**Fault Detection (0 or 1)**			**Fault Type (Line or Ground)**
	R	**Y**	**B**	
RG	1	0	0	Ground
YG	0	1	0	Ground
BG	0	0	1	Ground
RY	1	1	0	Line
YB	0	1	1	Line
RB	1	0	1	Line
RYG	1	1	0	Ground
YBG	0	1	1	Ground
RBG	1	0	1	Ground
RYB	1	1	1	Line
RYBG	1	1	1	Ground

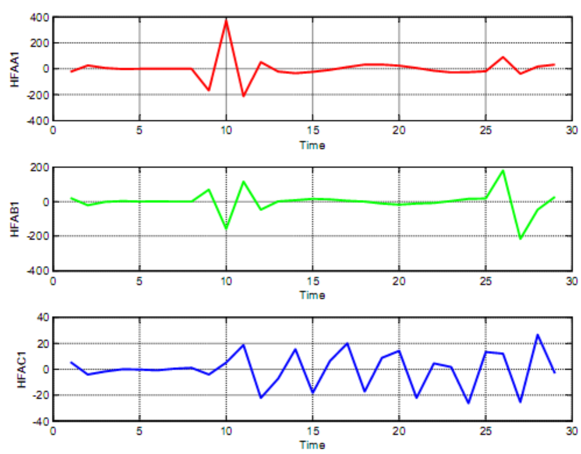

Figure.6.High frequency details for RY fault with respect to bus 1

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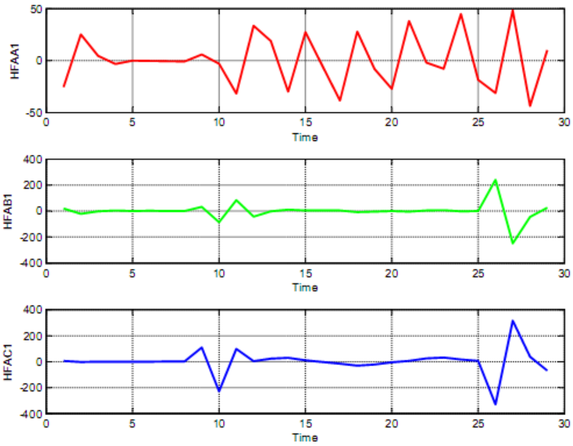

Figure.7. High frequency details for YB fault with respect to bus 1

Table 2: Fault location case studies

Fault type	**Fault Detection (0 or 1)**			**Actual Location (Km)**	**Percentage Error**
	R	**Y**	**B**		
RG	1	0	0	59	-0.38
YG	0	1	0	59	0.33
BG	0	0	1	59	4.72
RY	1	1	0	59	0.51
YB	0	1	1	59	0.76
RB	1	0	1	59	1.25
RYG	1	1	0	59	5.59
YBG	0	1	1	59	-0.43
RBG	1	0	1	59	4.47
RYB	1	1	1	59	5.59
RYBG	1	1	1	59	5.42

V. Conclusion

A novel technique for fault detection, classification and location in transmission lines is proposed. WT used to extract information from three phase current signals and to process the high frequency details to derive information about the fault. The salient features of this proposed logic are single "dB5" high pass wavelet filter is enough for each phase, need for multipliers avoided using karrenbaur transformation, simple transient energy calculation required for fault detection, classification and location is done. For ground fault adaptive threshold calculation is employed. The logic is fully deterministic, easy to understand, and also the classifier operation is fast and reliable. Simulation results are verified under various fault cases using EMTP.

Appendix 1

Line data of 500-kV, 118 km length.

Line Length = 118 km

$R_1 = 0.249168 \Omega/\text{km}$

$L_1 = 0.00156277 H/\text{km}$

$C_1 = 19.469\text{E-9 F/km}$

$R_0 = 0.60241 \Omega/\text{km}$

$L_0 = 0.004830 H/\text{km}$

$C_0 = 12.06678\text{E-9 F/km}$

Source impedance

Sending End

$Z_{S1} = 17.177 + j45.5285 \Omega$

$Z_{S0} = 2.5904 + j14.7328 \Omega$

Receiving End

$Z_{S1} = 15.31 + j45.9245 \Omega$

$Z_{S0} = 0.7229 + j15.1288 \Omega$

References

[1] K. M. Silva, B. A. Souza, and N. S. D. Brito, ''Fault detection and classification in transmission lines based on wavelet transform and ANN,'' *IEEE Trans. Power Del.*, vol. 21, no. 4, pp. 2058--2063, Oct. 2006.

[2] T. B. Littler and D. J. Morrow, ''Wavelets for the analysis and compression of power system disturbances,'' *IEEE Trans. Power Del.*, vol. 4, no. 2, pp. 358--364, Apr. 1999.

[3] A. M. Gaouda, M. M. A. Salama, M. R. Sultan, and A. Y. Chikhani, ''Power quality detection and classification using wavelet-multiresolution signal decomposition,'' *IEEE Trans. Power Del.*, vol. 14, no. 4, pp. 1469--1476, Oct. 1999.

[4] X. Xu and M. Kezunovic, ''Automated feature extraction from power system transients using wavelet transform,'' in *Proc. Int. Conf. Power System Technology*, 2002, vol. 4, pp. 1994--1998.

[5] C. L. Tu, W. L. Hwang, and J. Ho, ''Analysis of singularities from modulus maxima of complex wavelets,'' *IEEE Trans. Inf. Theory*, vol. 51, no. 3, pp. 1049--1062, Mar. 2005.

[6] T. Le-Tien, H. Talhami, and D. T. Nguyen, ''Simple algorithm for wavelet maxima modulus extraction in time-scale representations,'' *IEEE Electron. Lett.*, vol. 33, no. 5, pp. 370--371, Feb. 1997.

[7] O. Chaari, M. Meunier, and F. Brouaye, ''Wavelets: A new tool for the resonant grounded power distribution systems relaying,'' *IEEE Trans. Power Del.*, vol. 11, no. 3, pp. 1301--1308, Jul. 1996.

[8] O. A. S. Youssef, ''New algorithm to phase selection based on wavelet transforms,'' *IEEE Trans. Power Del.*, vol. 17, no. 3, pp. 908--914, Jul. 2002.

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 3, Issue 7, February 2015)

[9] O. A. S. Youssef, ‘‘Fault classification based on wavelet transforms,’’ in *Proc. IEEE Transmission&Distribution Conf. Expo.*, Atlanta, GA, Oct. 28--Nov. 2, 2001, pp. 531--536.

[10] A. A. Hajjar, M. M. Mansour, and H. A. Talaat, ‘‘High-phase order power transmission lines relaying approach based on the wavelet analysis of the fault generated traveling waves,’’ in *Proc. 39th Int. Univ. Power Eng. Conf.*, 2004, vol. 1, pp. 805--809.

[11] A. I. Megahed, A. M. Moussa, and A. E. Bayoumy, ‘‘Usage of wavelet transform in the protection of series-compensated transmission lines,’’ *IEEE Trans. Power Del.*, vol. 21, no. 3, pp. 1213--1221, Jul. 2006.

[12] O. A. S. Youssef, ‘‘Online applications of wavelet transforms to power system relaying,’’ *IEEE Trans. Power Del.*, vol. 18, no. 4, pp. 1158--1165, Oct. 2003.

[13] S. G. Mallat, ‘‘A theory for multi-resolution signal decomposition: The wavelet representation,’’ *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 11, no. 7, pp. 674--693, Jul. 1989.

[14] D. Chanda, N. K. Kishore, and A. K. Sinha, ‘‘Application of wavelet multiresolution analysis for classification of faults on transmission lines,’’ in *Proc. IEEE Conf. Convergent Technologies for Asia-Pacific Region*, vol. 4, pp. 1464--1469.

[15] J. D. Duan, B. H. Zhang, and H. X. Ha, ‘‘A novel approach to faulted phase selection using current traveling waves and wavelet analysis,’’ in *Proc. Int. Conf. Power System Technology*, 2002, vol. 2, pp. 1146--1150.

[16] Q. L. Su, X. Z. Dong, Z. Q. Bo, and F. Jiang, ‘‘New approach of fault detection and fault phase selection based on initial current traveling waves,’’ in *Proc. IEEE Power Eng. Soc. Summer Meeting*, 2002, vol. 1,pp. 393--397.

[17] Z. Q. Bo, R. K. Aggarwal, A. T. Johns, H. Y. Li, Y. H. Song, R. L. King, D. Novosel, and M. Kezunovic, ‘‘A new approach to phase selection using fault generated high frequency noise and neural networks,’’ *IEEE Trans. Power Del.*, vol. 12, no. 1, pp. 106--115, Jan. 1997.

[18] N. Zhang and M. Kezunovic, ‘‘Transmission line boundary protection using wavelet transform and neural network,’’ *IEEE Trans. Power Del.*, vol. 22, no. 2, pp. 859--869, Apr. 2007.

[19] Zhengyou He, Ling Fu, Sheng Lin, and Zhiqian Bo, ‘‘Fault Detection and Classification in EHV Transmission Line Based on Wavelet Singular Entropy,’’ *IEEE Trans. Power Del.*, vol. 25, no. 4, Oct.2010.

[20] Mamta Patel, R. N. Patel, “Fault Detection and Classification on a Transmission Line using Wavelet Multi Resolution Analysis and Neural Network,” *Int. Journal. Computer Applications*, vol.47, no.22, June 2012.

[21] V.S.Kale, S.R.Bhide, P.P.Bedekar and G.V.K.Mohan, ‘‘Detection and Classification of Faults on Parallel Transmission Lines using Wavelet Transform and Neural Network,’’Int. Journal. Electrical and computer engineering,22,2008.

[22] Dr. Hilal Al-Nasseri, ‘‘Fault Detection in Overhead Transmission Lines Using the Wavelet Transform,’’ GCC POWER 2010 CONFERENCE & EXHIBITION, 18-20 Oct. 2010.

[23] Mamta Patel and R. N. Patel, ‘‘Transient Energy and its Impact on Transmission Line Faults,’’ World Academy of Science, Engineering and Technology 56. 2011.

[24] Xiaolei Liu, Ahmed H. Osman, Om P. Malik, ‘‘Real-Time Implementation of a Hybrid Protection Scheme for Bipolar HVDC Line Using FPGA,’’ ,’’ *IEEE Trans. Power Del.*, vol. 26, no. 1, JAN. 2011.

[25] B. Ravindhranath Reddy, Dr. M. Vijay Kumar, Dr. M.Surya Kalavathi, Y. Venkata Raju, ‘‘Detection and localization of faults in transmission line using wavelet transforms’’, Journal of theoretical and applied information technology, 2009.

[26] Alternative Transients Program (ATP) - Rule Book, CanAm EMTP User Group, Portland, OR, Sep. 1992, [online]. Available: www.emtp.org.