REVIEW: WAVELET ENTROPY BASED TRANSMISSION LINE PROTECTION

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ABSTRACT

This paper gives a review of the use of wavelet transform for protection of transmission line. For a modern power system, selective high speed clearance of faults on excessive voltage transmission line is essential and this review indicates the efficient and promising implementations for fault detection, classification and fault location in electricity transmission line protection. The work done in this place prefer use of various mother wavelet for transmission line in different conditions of protection to facilitate safer, secure and reliable power systems. The focal point of this paper is at the most current strategies based on wavelet transform utilized in transmission line protection.

Keyword: - *Fuzzy logic, wavelet transform, ANN.*

1. INTRODUCTION

Transmission lines are among the power system components with the highest fault incidence rate, since they are exposed to the environment. Line faults due to lightning, storms, vegetation fall, fog and salt spray on dirty insulators are beyond the control of man. The balanced faults in a transmission line are three phase shunt and three phases to ground circuits while Single line-to-ground, line-to-line and double line-to-ground faults are unbalanced in nature.

In an electric power system, a fault is any abnormal flow of electric current. Example, the fault in which current flow bypasses the normal load we called it as a short circuit. Open circuit fault occurs if the circuit is interrupted by some failure. In three phase (3Ø) systems, a fault occurs between one or more phases and a ground, or also may arise only between phases. In "Ground Fault", the current follows the earth path.

In power systems, the protective devices will detect fault conditions and operate circuit breakers and other devices to limit the loss of service due to a failure. In a poly phase system, a fault may influence all phases equally which is a "symmetrical fault". When only some phases are affected, the resulting "asymmetrical fault" becomes more complicated to analyze due to the simplifying assumption of equal current magnitude in all phases has being no longer applicable. Analysis of such type of fault is more often simplified by using methods such as symmetrical components. A symmetric or balanced fault affects each of the three phases equally. In the transmission line faults, roughly 5% are symmetric. Which upon comparison with asymmetric fault, three phases are not affected equally. In practical, mostly unbalance faults occur in power systems. An asymmetric or unbalanced fault does not affect each of the three phases equally.

In this paper, various techniques for protection of transmission line based on wavelet transform are discussed mainly focuses on the various methods to achieve fault detection, classification and isolation in transmission line.

Those techniques include Wavelet transform. In a modern power system, high speed fault clearance is very critical and to achieve this objective different techniques have been developed.

2. WAVELET TRANSFORM

Wherever Wavelet transforms have become one of the most important and powerful tool of signal representation. Nowadays, it has been used in image processing, data compression, and signal processing. Wavelet analysis is a relatively new signal processing tool and is applied recently by many researchers in power systems due to its strong capability of time and frequency domain analysis [11], [12]. The two areas with most applications are power quality analysis and power system protection [13]–[16]. The definition of continuous wavelet transform (CWT) for a given signal x(t) with respect to a mother wavelet ψ(t) is

$$CWT(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\varphi(\frac{t-b}{a})dt$$

where a is the scale factor and b is the translation factor.

For CWT, t, a, and b are all continuous. Unlike the Fourier transform, the wavelet transform requires the selection of a mother wavelet for different applications. The application of wavelet transform in engineering areas usually requires a discrete wavelet transform (DWT), which implies the discrete form of t, a, and b in (1). The representation of DWT can be written as

$$DWT(m,n) = \frac{1}{\sqrt[n]{ab}\sum_{k} x(k)} \varphi(\frac{k-nx}{a})$$

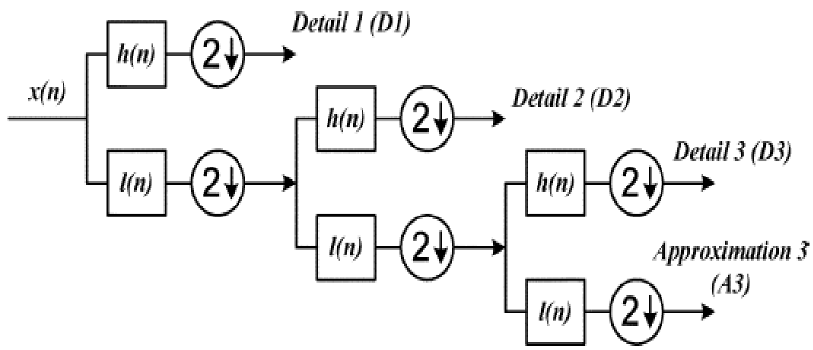

Fig 1. Wavelet multi-resolution analysis.

A very useful implementation of DWT, called multi-resolution analysis, is demonstrated in Fig. 1. The original sampled signal x(n) is passed through a high-pass filter h(n) and a low pass filter l(n). Then the outputs from both filters are decimated by 2 to obtain the detail coefficients and the approximation coefficients at level 1 (D1 and A1). The approximation coefficients are then sent to the second stage to repeat the procedure. Finally, the signal is decomposed at the expected level. In the case shown in Fig. 1, if the original sampling frequency is F, the signal information captured by D1 is between F/4 and F/2 of the frequency band.D2 captures the information between F/8 and F/4, D3 captures the information between F/16 and F/8, and A3 retains the rest of the information of original signal between 0 and F/16. By such means, we can easily extract useful information from the original signal into different frequency bands and at the same time the information is matched to the related time period.

3. WAVELET BASED TRANMISSION LINE POTECTION

3.1 The Digital Protection scheme using relay logic

In this section review different techniques based on wavelet transform for protection of transmission line. High speed, computationally economical theme for protections of transmission lines utilize the relay logic consists of three parts: directional protection, fault classification and fault location. moving ridge remodel is employed for extracting data from the fault transients and solely the primary level high frequency details of the voltages and currents area unit used. Planned protection logic compares the directional signals from each terminal to discriminate between faults within and outdoors the zone of interest. Fault classification is achieved mistreatment native terminal current data [1].

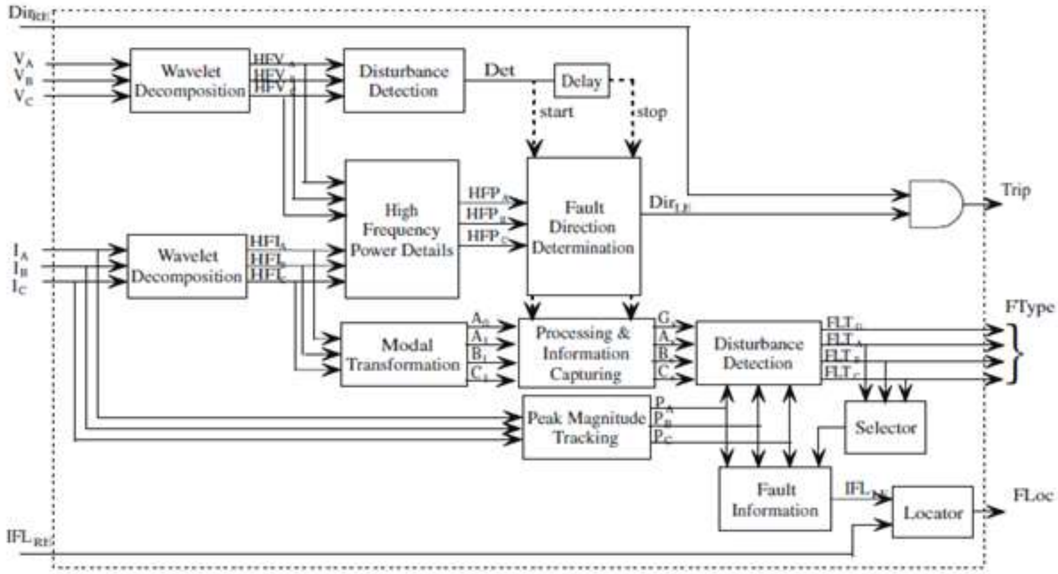

Fig 2:- Block diagram of proposed Digital protection scheme using wavelet transform [1].

The logic is settled and might work faithfully within the presence of fault resistance, load variation and CT saturation. A high degree of process potency is achieved because of the utilization of single level wave decomposition. Directional protection needs solely minimum communication from the remote finish and provides high-speed operation (sub-cycle operative time). Fault classification logic uses solely native terminal current info. Fault location logic uses solely peak current info from anybody of the faulted phases of each terminal. The performance of the relay isn't stricken by the variation in load settings and power flows, so creating it inherently adaptive. It will work faithfully within the presence of CT saturation, fault resistances and ranging supply resistivity. The relay operation is selective, reliable and secure. Figure 2 shows the block diagram of proposed digital protection scheme.

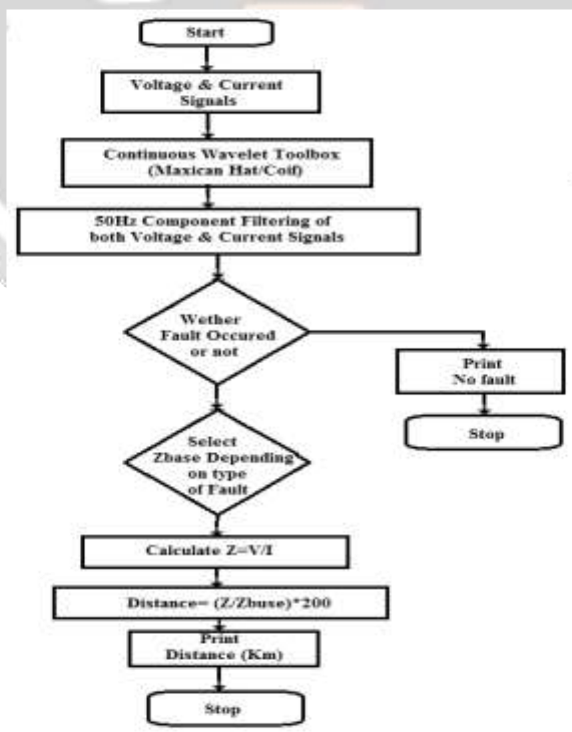

Fig 3:- Overall flowchart of proposed method [2]

3.2 Using Impedance calculation

One of the system model is based upon a mix of the electrical impedance calculation and the Continuous wavelet Transformation (CWT) methodology to notice the disturbance beside distance of Fault prevalence [2]. This scheme measures the impedance of the line up to the fault point from relay location. As the measured quantity is proportional to the distance along the line, the measuring relay is called a distance relay. Modern distance relays provide high-speed fault clearance. They are used where over current relays become low, and there is difficulty in grading time for complicated networks. For 132kv and above systems, the recent trend is to use carrier current protection. The relaying units used in carrier current protection are distance relays and are operated under the control of carrier signals. In case of failure of carrier signal, distance relay act as back up protection. Figure 3 shows the flowchart of proposed method.

Distance relays are double actuating quantity relays with one coil energized by voltage and the other coil energized by current. The torque produced is such that when V/I reduce below a set value, the relay operates. During a fault on a transmission line the fault current increases and the voltage at the fault point decreases. V and I are measured at the location of CT'S and VT'S. The voltage at VT location depends on the distance between the VT and the fault. If fault is nearer, measured voltage is lesser. If fault is farther, measured voltage is more. Hence by assuming constant fault resistance, each value of V/I measured form relay location corresponds to distance between the relaying point and the fault along the line. Hence such protection is called Impedance protection or

Distance protection. The distance protection is high speed protection and is simple to apply. These relays are called as phase measuring units and are energized by line to line voltages and difference in line currents, so that they measure the positive sequence impedance.

This CWT formula is distinguishing the fault from the moment at that faulted sample knowledge enters the window and conniving the fault distance at intervals 0.5 cycle when the fault origin.

For all the faults under consideration with moving window algorithm, the error in the fault location is varied from -10% to 13%. As the fault resistance in the fault increases the %error increases and the increase in %error is rapid at high fault resistances.

The impedance of the circuit during fault condition and healthy condition to calculate the distance where the fault has occurred, the %error in the distance measurement increases with the increase in fault resistance. If the fault resistance increases then resistance of the circuit under fault condition will be increased which may dominate the effect of reactance in that case and thus there may be some increase in % error.

3.3 Using Artificial Neural Network

In system [3], discrete wavelet transform of voltage signals at the two ends of the transmission lines are analyzed. Transient energies of detail info for two consecutive data windows at fault are used for analysis. Four layer feed forward back propagation neural networks are designed to classify and find the fault at different single line to ground fault conditions. Figure 4 shows the neural network based fault analysis method.

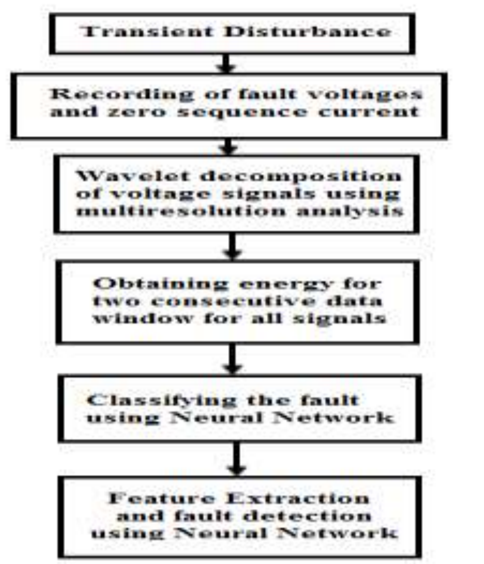

Fig 4:- Procedure for fault analysis [3]

The line voltage signals from both the ends of are used for fault analysis on the transmission line. The signals are sampled at a frequency of 320 KHz, which gives 6400 samples per cycle. Daubechies „db5" wavelet is employed since it has been demonstrated to perform well. Using multi resolution wavelet analysis of all the six voltage signals their detail D1 and D5 components are extracted. The fifth level detail D5 contains harmonics ranging from 5 kHz-10 kHz and the first level detail D1 contains harmonics ranging from 80 kHz-160 kHz.

Energy of two consecutive windows of all six voltage signals 5_{th} level detail along with energy of zero sequence currents at the two terminals for the same data window was taken as input. Initial three outputs show the status of three lines; output is high (1) if a fault exists and low (0) if there is no fault. The fourth output is to distinguish earth fault and line fault; a high (1) indicates the earth fault and low (0) indicates the line fault. After successful classification, details of fault signals are used to locate the fault. The classification of faults was exact and the location of the faults was identified with above 95% accuracy.

In system [6], proposes associate improved solution supported wavelet transform and self-organized neural network utilized for transmission line protection. The measured voltage and current signals square measure preprocessed first then decomposed using wavelet multi-resolution analysis to get the high frequency details and low frequency approximations. The patterns shaped supported high frequency signal parts square measure organized as inputs of neural network #1, whose task is to point whether or not the fault is internal or external. The patterns shaped mistreatment low frequency approximations square measure organized as inputs of neural network #2, whose task is to point the precise fault sort.

The three-phase secondary voltage and current signals are obtained at the sampling rate of 200 kHz. The zero-sequence voltage and current are obtained by adding up the phase values. Through the signal preprocessing stage, the prefault steady state component is removed from each signal. Then the wavelet multiresolution analysis is used for decomposing each signal into low frequency approximation and high frequency details. The information is used for extracting the features and forming the patterns for neural-network algorithm. Two neural networks are trained to handle the boundary protection and fault classification, respectively. The final conclusion can be made by simultaneously combining the conclusions of the two neural networks and then appropriate actions should be issued by the relay. A pickup unit is introduced before the neural network algorithms as a threshold to screen the non-fault. The proposed protection system is shown in figure 5.

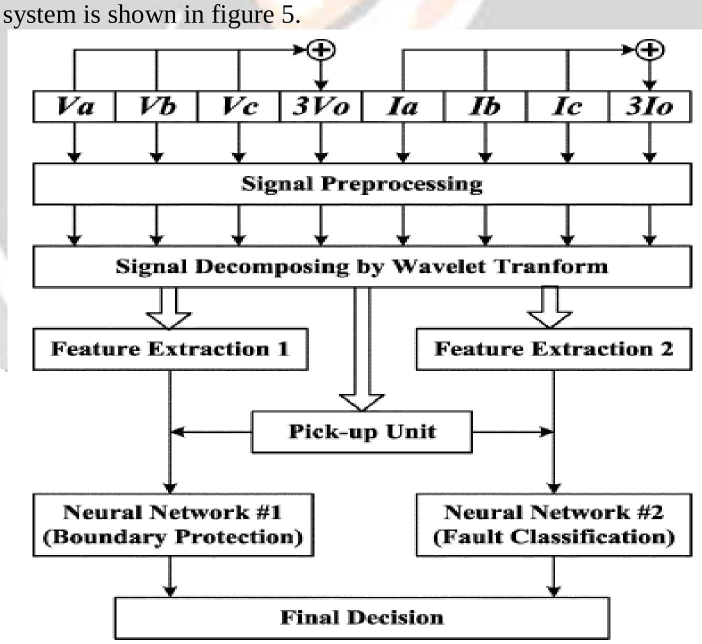

Fig 5:- Overview of the proposed protection scheme [6].

Disturbances in a low frequency band (such as overload, power swing, etc.) and in a high-frequency band (such as noise, switching, lightning, etc.). The signal preprocessing stage eliminates most of the influences from prefault loads, system conditions, and power swings. Neural networks take a half-cycle data window; therefore, the protection speed is satisfied.

New scheme [9], a fault generated transients based protection method is brought through which the entire line length receives primary protection using the idea of bus capacitance. This scheme implements improved solution based on wavelet transform and self-organized neural network. The measured current and voltage signals are preprocessed first after which decomposed the usage of wavelet multi-resolution evaluation to reap the excessive frequency and low frequency data. The training patterns are shaped based on high frequency components and the low frequency components of all three phase voltages and current. Zero sequence voltage and current also are used to identify faults related to grounds. The input sets fashioned based totally on the excessive frequency additives are arranged as inputs of neural network-1, whose task is to signify whether the fault is inner or outside. The input units fashioned primarily based at the low frequency components are organized as inputs of neural network- 2, whose task indicate the kind of fault. The new technique makes use of each low and excessive frequency statistics of the fault signal to reap an advanced transmission line safety scheme. The transient based protection scheme is shown in figure 6.

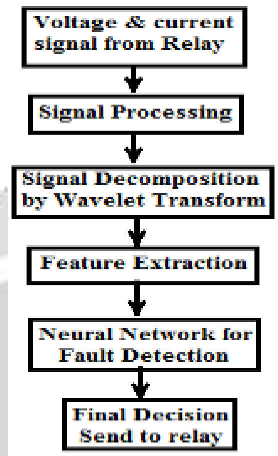

Fig 7:- Overview of transient based protection scheme [9].

The three-phase secondary voltage and current signals are obtained at the sampling frequency of Fs = 200 kHz. The zero-sequence voltage and current are computed by adding up the corresponding phase values. Through the signal preprocessing stage, the pre-fault steady state component is removed from each signal. Then the wavelet multi-resolution analysis (MRA) is used for decomposing each signal into low frequency approximation and high frequency details. The information is used for feature extraction stage and forming the patterns for neural-networks. Two neural networks are so trained so that to achieve the aim of boundary protection and fault classification respectively. The final conclusion can be made by simultaneously combining the outputs of the two neural networks and then appropriate signal should be issued by the relay to its associated circuit breaker. Both neural networks take a post-fault one cycle data of the voltage and current waveforms; therefore, the protection speed is improved. It can work as a unit protection scheme to protect the entire length of transmission line while it does not have to use the communication link. The proposed scheme is shown in figure 7.

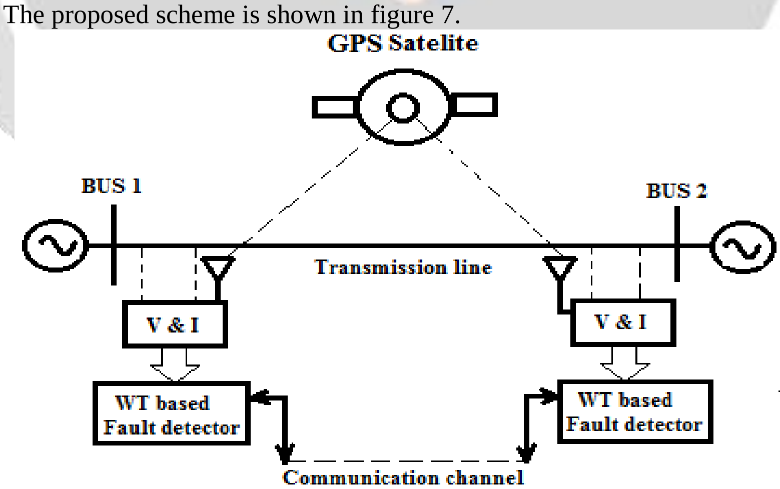

Fig 7:- Transmission line system with FACTS device implemented with proposed scheme [4]

3.4 Using GPS technology

In system [4], a novel technique is applied to detect fault in the transmission line using wavelet transform. Three phase currents are monitored at both ends of the transmission line using global positioning system synchronizing clock. Wavelet transform, which is very fast and sensitive to noise, is used to extract transients in the line currents for fault detection. Fault index is calculated based on the sum of local and remote end detail coefficients and compared with threshold value to detect the fault. Synchronized sampling of three phase currents and voltages is carried out at both the ends with the help of a GPS satellite. Wavelet analysis of these sampled signals is performed and level-1 detail coefficients are used to calculate fault index and detect fault. These sampled currents are then analyzed with Debauches' wavelet to obtain level-1 detailed coefficients (CD1) over a moving window of half-cycle length. These coefficients indicate high frequency components in the currents due to fault. Currents in faulted phase indicate a large magnitude of coefficients which are used to detect fault.

The detail coefficients received from the remote bus (bus-2) are added to the local bus (bus-1) detail coefficients. A threshold value (*ITH*) is then set such that *ITH* < *IfI* of faulted phase and *ITH* > *IfI* of healthy phase. This algorithm is tested for various faults and a common threshold value is selected.

Table 1:- Comparison of wavelet based transmission line protection methods.

Sr No.	Title of paper	Simulation software	Type of wavelet	Type of mother wavelet	Decompos-ition levels	Parameter used for wavelet	Sampling frequency	Type of faults analyzed
1	Wavelet transform based digital protection for transmission lines.	MATLAB	Discrete	Daubechies'	Level 6	3 phase voltages and currents at local terminal and a directional signal from remote end.	1000 Hz	LG, LL, LLG, LLL
2	Detection & Localization Of Faults In Transmission Lines Using Wavelet Transforms(Coif Let & Mexican Hat)	MATLAB	Continuous	Coif let and Mexican hat	Level 4	Current from CT and Voltage from PT.	8000Hz	LL, LG, LLL
3	Fault Detection and Classification on a Transmission Line using Wavelet Multi Resolution Analysis and Neural Network	MATLAB	Discrete	Daubechies'	Level 5	Detail components of line voltage signals from both the ends of line at level 1 and level 5	320 KHz	LG only
4	Detection of Transmission Line Faults by Wavelet Based Transient Extraction	MATLAB	Discrete	Debauches'	Level 1	Currents and voltages is carried out at both the ends of line with the help of a GPS satellite.	-------------	LG, LL, LLG, LLL, LLLG

5	Transmission Line Distance Protection Using Wavelet Transform Algorithm	PSCAD/EMTDC	Discrete	Daubechies	Level 8	voltages and currents measured by relays	1920 Hz	LL, LLLG, LLG, LLL
6	Transmission Line Boundary Protection Using Wavelet Transform and Neural Network.	ATP–LCC subroutine, ATP and MATLAB	Discrete	Daubechies	Level 5	voltage, current, zero sequence component of voltage and zero sequence component of current of each phase signals from relay	200 kHz	LLG, LG, LL, LLL, LLLG
7	Protection of Transmission Lines using Discrete Wavelet Transform	MATLAB	Discrete	Daubechies	Level 6	Three phases current signals	200 kHz	LG, LL, LLG, LLL
8	Accurate Fault Classification of Transmission Line Using Wavelet Transform and Probabilistic Neural Network	MATLAB and PASCAD/EMPT	Discrete	Daubichies's	Level 4	Each phase current and zero sequence current.	20 kHz.	LG, LLG, LLL, LL
9	A Novel Approach for Transmission Line Protection Using Wavelet Transform and Neural Network	MATLAB 7	Discrete	Daubichies's	Level 5	Three phase secondary voltage and current signals, also zero sequence current and voltage.	200 kHz.	LLG Only
10	Wavelet-Based Method for Transmission Line Fault Detection and Classification during Power Swing	EMTP reference model for transmission line relay testing, which is introduced	Discrete	Daubichies's	Level 8	samples of voltage and current	-------------	Power swing, Normal condition, LG, LLG, LLL, LL

		by the IEEE PES Power System Relaying Committee (PSRC) WG D10						

4. CONCLUSION & FUTURE SCOPE

This paper is an effort to review the most recent techniques which are used for protection of transmission line using Wavelet transform. Wavelet transform with neural network for classification of transmission line fault and isolation is considered to be a fast, robust and accurate technique. But, Fuzzy logic systems are subjective and heuristic and are simpler than the wavelet transform or the neural network based techniques. But, most of the available tools for fault detection and classification are not efficient and are not investigated for real time implementation. So, for this there is a need for new algorithms that have high efficiency and suitable for real time usage and wavelet transform serves for this purpose. All these techniques have their own features and researches are still going on to obtain lesser operating time of relay at high speed. Wavelet based transmission line protection will be extended in future for Parallel Transmission Line protection and multi-terminal transmission line protection. This review also useful in including innovative features in microprocessor based distance relays.

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