DETECTION & LOCALIZATION OF FAULTS IN TRANSMISSION LINES USING WAVELET TRANSFORMS(COIF LET & MEXICAN HAT)

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ABSTRACT

Power transmission and distribution lines are the vital links that achieve the essential continuity of service of electrical power to the end users. Transmission lines connect the generating stations and load centers. As the generating stations are far away from the load centers they run over hundreds of kilometers. Hence, the chances of fault occurring in transmission lines are very high. Since faults can destabilize the power system they must be isolated immediately. Fault analysis is very important issue in power system engineering in order that to clear faults quickly and restore power supply as soon as possible with minimum interruption. Signal processing is one of the most important parts of the digital distance protection schemes. The faulted phases identification is done by analyzing the detail coefficients of the phase currents. To distinguish ground faults from phase to phase ones, the analysis of the smooth coefficients of the neutral current can be used. The proposed model is based upon a combination of the impedance calculation and the Continuous Wavelet Transformation (CWT) method to detect the disturbance along with distance of Fault occurrence. MATLAB/Simulink is used to generate fault signals and verify the correctness of the algorithm. Simulation results reveal that the performance of the proposed fault detection indicator is promising.

Keywords: *Power Transmission And Distribution, Fault, Transmission Lines, CWT, Algorithm, Simulation*

I. INTRODUCTION :

Wavelet transform (WT) is a novel signal processing technique developed from the Fourier transform (FT) and has been widely used to signal processing application [1]-[3]. The wavelets possess multidimensional characters and are able to adjust their scale to the nature of the signal features. Singularities and irregular structures in signal waveform often carry important information from an informatics-theoretic point of view. The WT analysis provides a kind of mathematical "microscope" to zoom in or zoom out on those interesting structures [3]. Furthermore, wavelets can be orthonormal and are able to capture deterministic features. Therefore, WT can decompose a signal into localized contributions labeled by so-called dilation and translation parameters. These parameters represent the information of different frequency component contained in the analyzed signals *[3]*. To monitor the quality of an electric power system, a sinusoidal waveform at a rated voltage magnitude and frequency is a proper index. Thus, any electric power disturbance (or fault) can be thought of as a deviation from that sinusoidal waveform. The other problem that should be noticed when a fault occurs on a power system is that fault current is almost greater than the pre-fault load current in any system element. A very simple and effective fault detecting principle is that of using the current magnitude as an indicator of a fault of the power system. Since the wavelet transform with its ability allowing the localization both in time and frequency domain, some publications [4]-[6] introduced the wavelet transform as a tool to analyze power system disturbances. In this work, the authors apply the different wavelet transform like Coif Let and Mexican Hat to analyze three phase-currents of a power system. Meanwhile, the faulted-phase can also be identified. The proposed algorithm is implemented by using moving data window technique. The simulation studies show that this fault detection indicator is with fast response time, which provides an alternative approach for transmission line protection.

The organization of the paper is described as follow. First, the Continuous Wavelet Transform (CWT) is introduced. Basic idea and the proposed algorithm are described in Section III. Then, the simulation studies are shown in Section IV. Finally conclusions are given.

II. THE CONTINUOUS WAVELET TRANSFORM (CWT)

Choose a finite energy function $\psi(t)$ fulfilling the "admissibility condition"

$$C_\psi := 2\Pi \int_{-\infty}^{+\infty} \frac{|\hat{\psi}(\omega)|^2}{|\omega|} d\omega < \infty \quad (1)$$

Any finite energy function satisfying 1 will be called a "wavelet". Then the "continuous wavelet transform" (CWT) of the signal $f(t)$ is denoted with $L_\psi f(a, t)$ and reads

$$L\psi f(a,t) = \frac{1}{\sqrt{c_\psi}} \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} \overline{\psi}\left(\frac{u-t}{a}\right) f(u) du \,(a \neq 0), t \in R$$

(2)

Again, the over line denotes complex conjugation if $\psi(t)$ is complex valued.

(i) for simplicity reasons the constant factor $1/\sqrt{c\psi}$, related to the admissibility condition 1, has been omitted.

(ii) For practically relevant wavelets admissibility condition 1 is fulfilled, When

$$\int_{-\infty}^{\infty} \phi(t) dt = 0 \quad (3)$$

ψ will oscillate around the t-axis, since the contributions of positive and negative function values to the total area, bounded by the function graph and the t-axis, must cancel each other.

Since, moreover, $\psi(t)$ is of finite energy, for $t \to \pm\infty$ the function $\psi(t)$ will decrease rapidly. Both facts taken together explain the term "wavelet".

(iii) for the function $\psi(t)$. the CWT 2 is a kind of multiresolution analysis, since $L\psi f(a, t)$ provides information about signal details of size $\approx a$. Correspondingly, a will be called "detail size" or "scale factor".

The Mexican-hat-wavelet

(iv) Here

$$\phi_{MH}(t) = -\frac{2}{\sqrt{3}} \pi^{\frac{-1}{4}} e^{\frac{-t^2}{2}} \quad (4)$$

The corresponding wavelet is called "Mexican-hat-wavelet" and reads

$$\psi_{MH}(t) := \frac{d^2\phi_{MH}}{dt^2}(t) = \frac{2}{\sqrt{3}} \pi^{\frac{-1}{4}} \left(1 - t^2\right) e^{\frac{-t^2}{2}}$$

(5)

Condition for the Mexican-hat-wavelet reads

$$\int_{-\infty}^{\infty} \psi_{MH}(t) dt = \int_{-\infty}^{+\infty} \psi_{MH}(t) t dt = 0$$

(6)

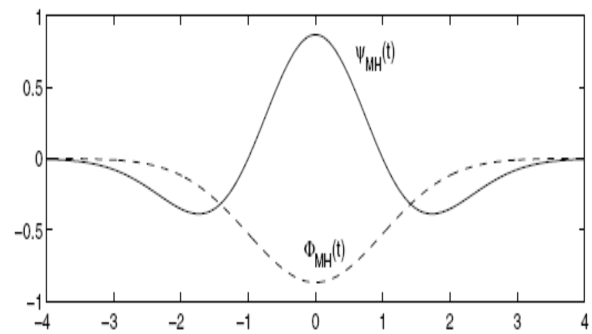


Fig. 1 Mexican-hat-wavelet

A careful choice of the mother wavelet φ is crucial to the Wavelet Transform, (WT).
The mother wavelet should in a certain way "reproduce itself" when it is subject to scaling. More specifically, the mother wavelet ψ satisfies a linear identity having the following structure:

$$D_2 \phi(t) = \sum_{k=0}^{n} c_k \varphi(t-k)$$

(7)

where D_2 is a scaling operation such that $D_2\varphi(t) = \varphi(t/2)$.

Coif let : In order to select the most suitable mother wavelet, the maximum sum value (this is over a 1-cycle period at power frequency) of d1 coefficients based on wavelet analysis is adopted for this work. when employing the coif4 mother
wavelet, although there is a discernible difference between the levels attained for the faulted "a" phase and the two healthy phases, in comparison to the previous three mother wavelets considered, they are significantly lower. Also, equally important is that the differences in magnitudes between the faulted and healthy phases in the case of coif4 is much

smaller than the corresponding other types of mother wavelets.

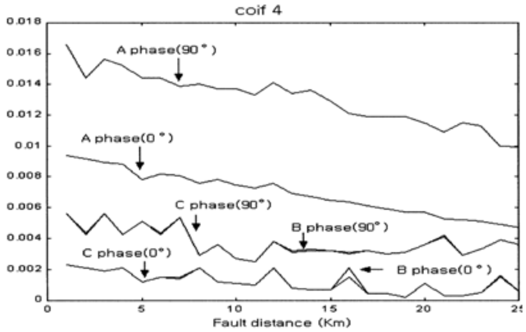


Fig. 2. Coefficients for three-phase current signals coif4 mother wavelet.

III- BASIC IDEA & PROPOSED ALGORITHM

Distance protection is a widely used protective scheme for the protection of high voltage and extra high voltage transmission lines. 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.

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.

According to the above descriptions, the proposed fault detection and faulted-phase selection algorithms are described below.

Three distance relays are required to locate seven phase faults (i.e., L-L, L-L-G, and L-L-L). 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.

In Ground Fault Measuring Units the positive sequence impedance of the line up to the fault point from [5]is

$$Z_{phase} = \frac{V_A}{I_A + KI_{A0}} \qquad (8)$$

where $K = \dfrac{Z_0 - Z_1}{Z_0}$

Since the impedance of the total line length is a known quantity, the distance to the fault will be obtained proportional to the imaginary component of the measured impedance. The overall flowchart of the proposed algorithm is shown in Fig. 4.

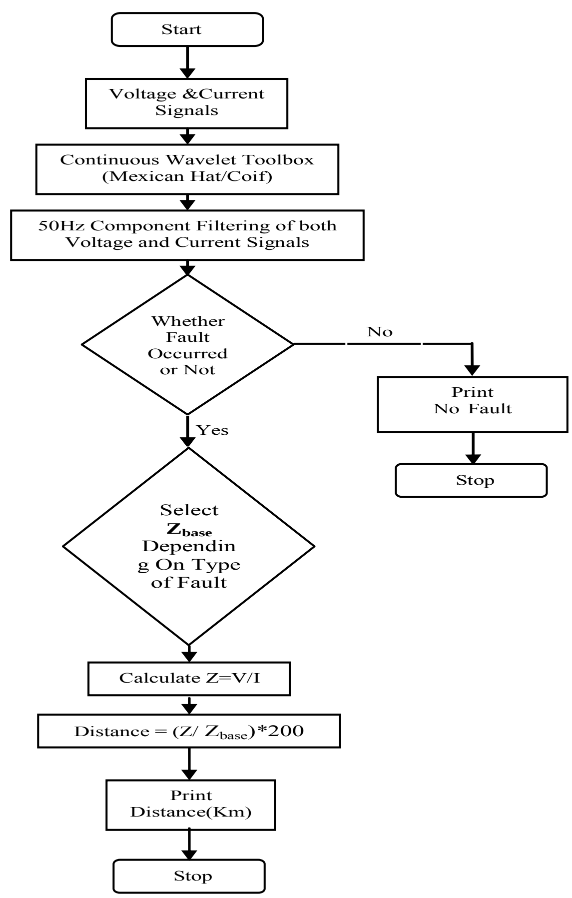


Fig. 4 The overall flowchart of the proposed algorithm

IV. SIMULATIOEXPERIMENTS

A. Simulation System

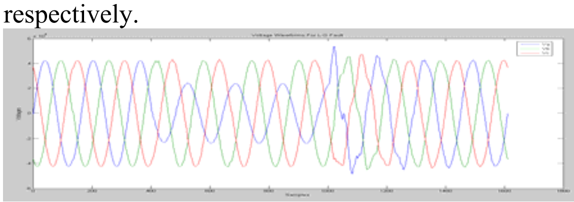
For evaluating the performance of the proposed algorithm, the authors adopt MATLAB/ Simulink for fault data generation and algorithm implementation. Fig. 5. depicts the single-line diagram of the simulated system, which is a **500kV , 50Hz, Transmission Line Length : 200Km, PI-section.**

Fig. 5 The single-line diagram of the simulated system.

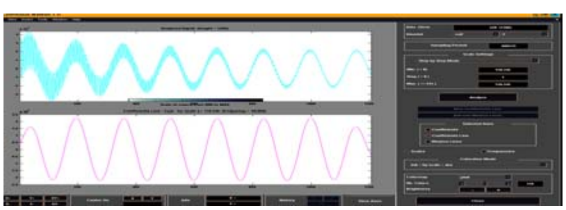
B. Example Studies

In this part**,** the authors select all the possible cases to illustrate the performance of the proposed fault indicator under internal fault events.

L-G Fault: First, a phase-'a' to ground fault is selected as a simulation case whose fault locations are tabulated along with the %error to compare the deviation from the calculated value using both mother wavelets Mexican hat & Coif Let respectively.



(a) L-G Fault Voltage waveform



(b) Coif let as mother Wavelet

Fig.6.

Sampling Period = 0.000125,For scale a = 110.345 the outp waveform will have a frequency of 50Hz.

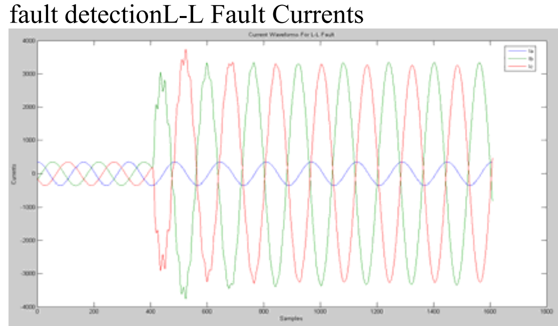
Table-1

LG Fault(**Mexican Hat**)		
Actual Distance (KM)	Calculated Distance (KM)	% Error
50	49.37	-1.26
100	100.56	0.56
150	152.92	1.94
200	207.83	3.915

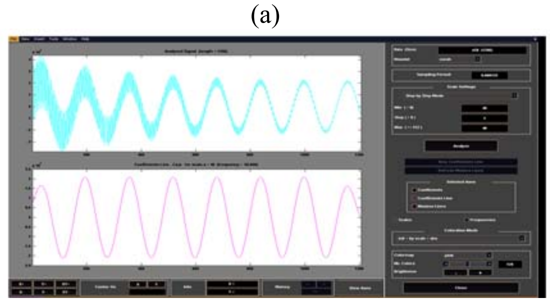
Table-2

L-G Fault(Coif let)		
Actual Distance (KM)	Calculated Distance (KM)	% Error
50	51.38	2.76
100	104.11	4.11
150	158.83	5.88
200	214.30	7.15

L-L Fault : Fig. 7 depicts the behaviors of fault detectionL-L Fault Currents



(a)



(b)

Fig.7. (a) LL Fault current waveform, (b) Mexican hat as mother wavelet

Similar treatment for localizing the LL fault has been done and the results are tabulated in Tables 3 & 4.

Table-3

LLL Fault(Coif let)		
Actual Distance (KM)	Calculated Distance (KM)	% Error
50	50.12	0.24
100	99.92	-0.08
150	149.24	-0.506
200	199.74	-0.13

Table-4

L-L Fault (Coif let)		
Actual Distance (KM)	Calculated Distance (KM)	% Error
50	69.61	39.22
100	119.64	19.64
150	154.31	2.873
200	192.49	-3.755

L-L-L Fault : Fig. 8 depicts the behaviors of fault detectionL-L-L Fault voltages

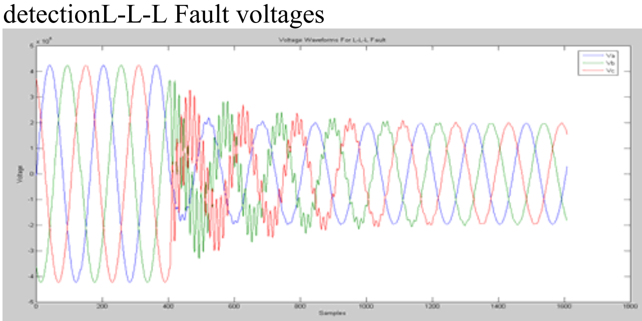


Fig. 8. LLL- Fault voltages Waveform.

The localization of LLL fault has been tabulated along with the % error in tables 5&6.

Table-5

LL Fault(Mexican Hat)		
Actual Distance (KM)	Calculated Distance (KM)	% Error
50	64.69	29.38
100	105.67	5.67
150	144.74	-3.49
200	188.55	-5.725

Table-6

LLL Fault(**Mexican Hat**)		
Actual Distance (KM)	Calculated Distance (KM)	% Error
50	47.89	-4.22
100	96.04	-3.96
150	145.82	-2.786
200	196.21	-1.895

V- CONCLUSIONS

In the present work , fault location is calculated by using Continuous Wavelet Transform (CWT) using MATLAB simulation model. 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. As we are taking 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. Tests including phase to ground faults and phase to phase faults and simulation results show that this CWT algorithm is identifying the fault from the instant at which faulted sample data enters the window and calculating the fault distance within half cycle after the fault inception. Identification of the frequency components in power system waveforms by using Mexican hat and Coif let as mother wavelet is also presented. The results of the present work will be useful in including innovative features in microprocessor based distance relays.

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