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Wavelet technique for identification, classification and mitigation of power system faults and disturbances

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Abstract

Fast detection, identification of disturbances, and quick problem classification are very important features of electrical power generation industries to prevent the consumers from power quality problems. FACTS compensated power transmission line can improve the quality of power, but a Wavelet technique along with compensating device gives more information to the operating engineers by giving time-frequency representation of the faulty signal. FACTS compensated transmission line along with Wavelet entropy algorithm and proposed algorithm can identify, classify, and give the information about the fault location. Wavelet entropy is used to provide a safe, secure, and accurate algorithm for this concept. To control the converters of UPQC in shunt and series, a new method has been introduced in this paper whose test system and results are obtained by MATLAB/SIMULINK. .

Key Words and Phrases: wavelet technique, Wavelet

entropy, Distance protection, and Unified Power-Quality Conditioner.

1 Introduction

Fast problem detection and fast protection is very important feature of electrical power system. Transmission lines will face so many disturbances because of permanent and temporary faults [1-4]. The variations of load may also cause fluctuations of voltage in the transmission lines. If the voltage fluctuation is not clear within the certain time limit, the

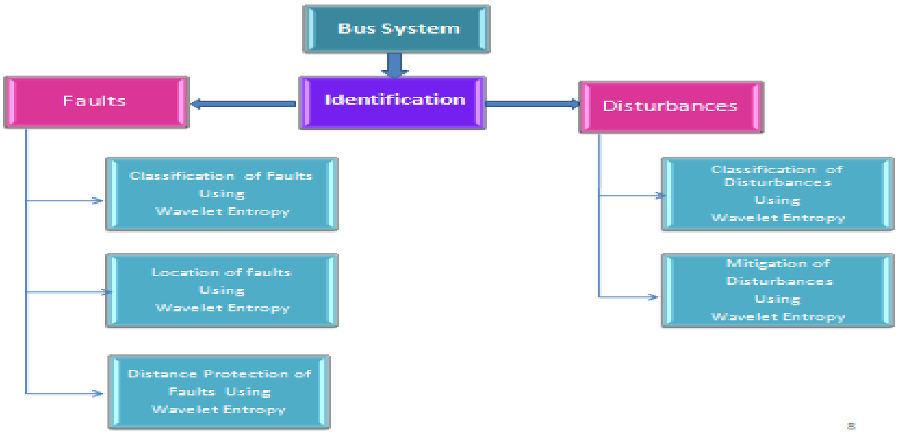

Fig. 1 Abstract in short

electrical devices may damage. So many protection schemes are there to prevent these line problems. To provide safety and security to the electrical equipment, identification of the fault is necessary. With the output waveforms, resistance of fault and the location of fault can be found [5-7].

For the protection of compensated and uncompensated power system networks adaptive kalman filtering has been used, but it is to find its limitation that it needs more filters to do the operation. Neural networks are proposed, but this concept requires large training set generation and training time. Different methods are there for fault classification and location, i.e., S-Transform, TT-Transform, fuzzy logic and also SVM method. The above said procedure is simple and utilizes voltage and current signal i.e. noted at line's one end and no need to put them in sync. This does not depend on the way how compensating devices operate and is applicable to both unsymmetrical and symmetrical faults and it avoids pre- trained neural network. The algorithm is more common, simple and it uses V-I signals. The results for various faults and also location with respect to FACTS devices using given algorithm are examined [8-11].

2 Wavelet Transform

The wavelet transform has been divided into two types i.e. Discrete wavelet transformation and Continuous wavelet transformation. CWT is only applied for stationary signals i.e. a signal which is constant irrespective to the time. DWT is used to analyze non-stationary signals. Non stationary signals are which vary with respect to the time. The computation time is very less in case of DWT [12-14].

Transient behavior of waveform includes lots of information about the fault and faulty equipments of the electrical power systems. And it is useful for fault signal analysis. Therefore reliability, accuracy of the power system has been improved. High frequency and instant breaks in signals are the characteristics of transient signals. The information of frequencies band contained in component of signal $D_j(k)$ and $A_j(k)$, determined by reconstruction are as follows.

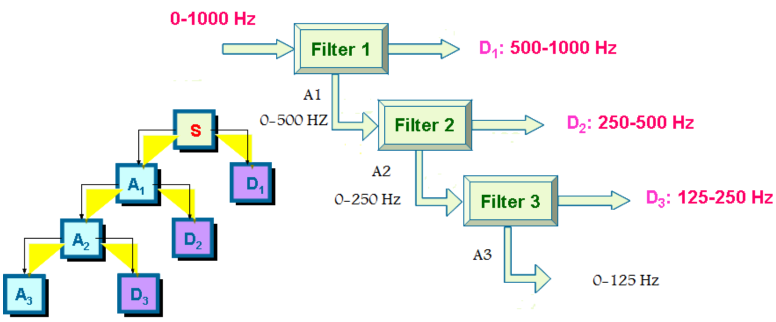

Fig.2 Tree algorithm

The Wavelet is executed with two FIR filters called a quadrature mirror filters. The outputs of the two FIR filters distinguish high and low levels of frequency for the signal.

3 Fault Monitoring

Current detail coefficients of norm exceeds the threshold value M, it detects the interruption. The window data is started again, and one more window data is started from the sample where the deffect has been identified. Every time, a new sample gets into the window, the signal's phasors are assessed and the impedances of the faulty phases are determined and compared with the protection zone of the line [4] [5] [6]. If the Z value gets into the area where it trips, a trip signal is given to the CB. Fig.3 shows a flowchart for the said WT distance-protection procedure. The location where the fault exists, whether it is internal or external can be done by utilizing fresh samples in the data window after the interruption starts.

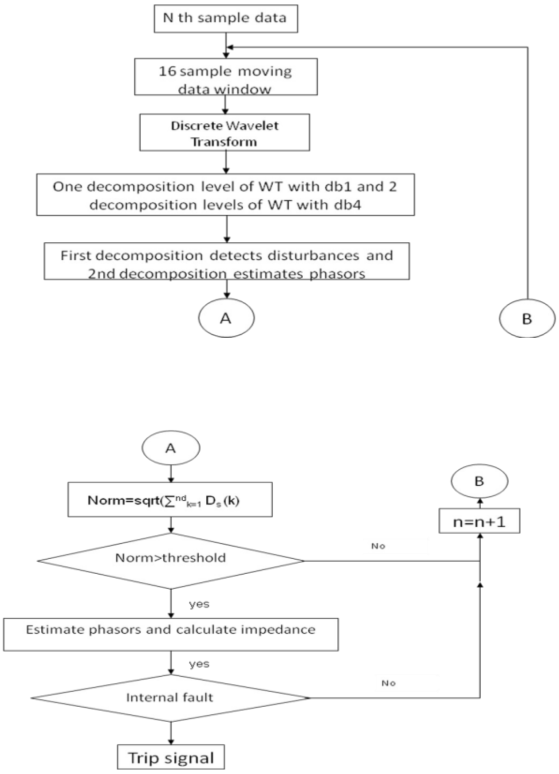

Fig. 3 Flow chart for fault Detection and Protection using wavelet

4 Wavelet Entropy

Transient behavior of waveform includes lots of information about the fault and faulty equipments of the electrical power systems. And it is useful for fault signal analysis. Therefore reliability, accuracy of the power system has been improved. High frequency and instant breaks in signals are the characteristics of transient signals. The information of frequencies band contained in component of signal $D_j(k)$ and $A_j(k)$, determined by reconstruction [8] are as follows.

$$D_j(k) \;:\; [2^{-(j+1)} f_s ,\; 2^{-j} f_s]$$

(j = 1,2,…….m)

: $A_j(k)$ $[0 , 2^{-(j+1)} f_s]$

f_s - sampling frequency

$A_j(k)$ -low frequency component coefficient The original signal $x(n)$ is

$$x(n) = D_1(n) + A_1(n) = D_2(n) + A_2(n)$$

$$= \sum_{j=L}^{j} D_j(n) + A_j(n)$$

The non-normalizes Shannon entropy is given as

$$E_j = -\sum_k E_{jk} \log E_{jk}$$

$E_{jk} \rightarrow$ *wavelet entropy spectrum at scale j*

k $\rightarrow$ *instant*

$E_{jk} = |D_j(k)|^2$

5 Power Quality Monitoring

Power quality monitor algorithm shown in fig.4. The algorithm used to observe the power quality disturbance signals when undergone to an environment which is noisy. As per the algorithm are the modules of the Discrete Wavelet Transform, the algorithm related to suppression of noise and the detector of disturbance. Here, the analog waveforms are received and converted into digital form by an A/D converter.
Based on the resultant data, the module of the discrete wavelet transform is used as band filters to get the signals out of different frequency bands. After various scaling values, there are discrete wavelet transform power quality interrupt signals. The power quality interrupt signals at high scale give the low frequency state of the source wave, while those at below indications represent the detailed designs [9].

Different scales of the discrete wavelet transform signals, the suppression of noise procedure is implied for dealing with the noises by flexibly reducing the wavelet transform coefficients basig on the interrelationships at adjacent scales.

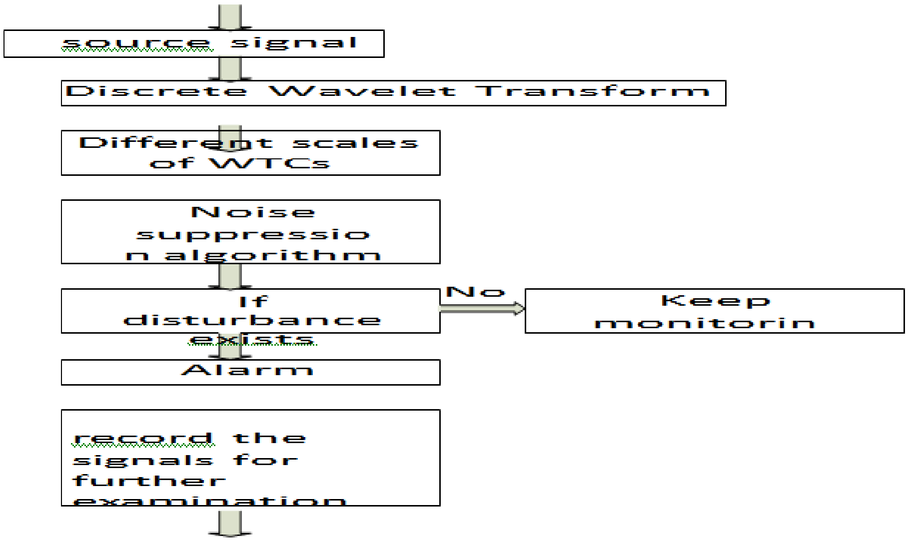

Fig. 4 Power quality monitoring algorithm

6 Results

I. Identification and classification of Faults

Fault Identification and classification of the test system done from the details of the basic disintegration level of the noted signals current employing mother wavelet. Calculation of the mean of the coefficients of details for the current signals, the phases on interruption can be examined. Mean value D1 of some signal detail coefficients exceeds the threshold value, an interrupt is identified. The test system was designed using MATLAB/SIMULINK. After applying various types of faults, one can observe the performance of the system.

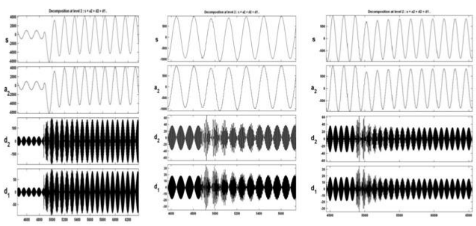

Fig. 5 Current wave forms and its approximation, dilations during LG fault phase A, B & C.

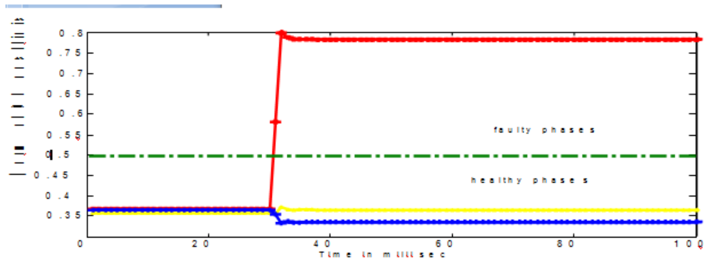

Fig. 6 Mean of D1 coefficients for Line-Ground fault

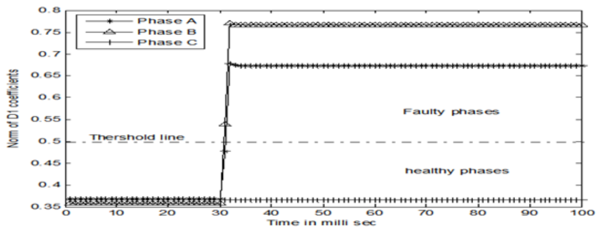

Fig. 7 Mean of D1 coefficient for high impedance fault between phases A and B

Fig. 5 and 6 shows the trajectories of the Z computed to the fault location for LG fault and high impedance fault using the said Wavelet Transform method. The impedances estimated with WT are taken from the data window started again after the fault begins. The trajectory in Fig. 7 arrived the last value faster in 3 ms.

II. Identification and classification of Disturbances

The decomposition of signal by multi-resolution phenomenon is an easy way to identify and distinguish interruptions. The time and frequency domain information is given by this theory. Interrupt type and some more information from the raw signal is also given at various resolutions.Signal analysis is made by wavelet Db4. The first level of decomposition d1 is employed to locate any interrupt.

The coefficients of WT and their higher values show disturbance in PQ events and the appropriate area of the disturbance. The appropriate location of the disturbance is shown by Detail d1. Finally a5 approximation shows the fixed markings of the wave.

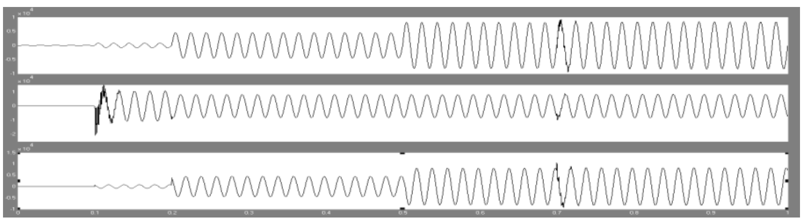

Fig. 8 Voltage signal of phase A, B and C

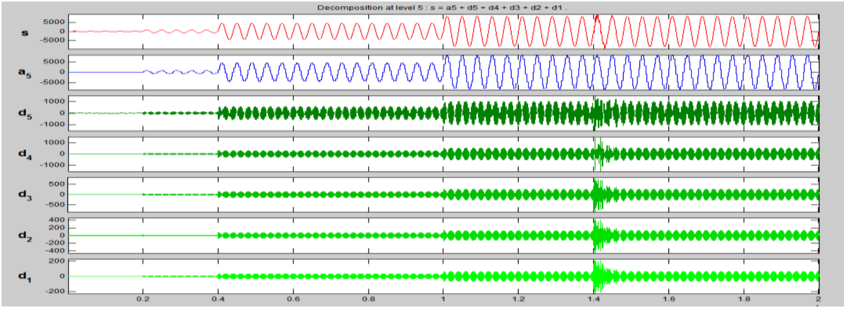

Fig. 9 Discrete Wavelet Transform of Phase A

III. Mitigation of power quality Disturbances

In this paper, the considered system has been mitigated by FACTS devices, STATCOM and UPFC. It is also observed that for Single-Line-Ground fault after the STACOM, the phase selection included in the fault was impossible using total of currents .The responses of the currents of 3-phases in case of fault prior and after can be noticed in fig. 10 and 11. Therefore before compensation the total harmonic distortion is 135.76%. And it is after compensation reduced to 0.08%.

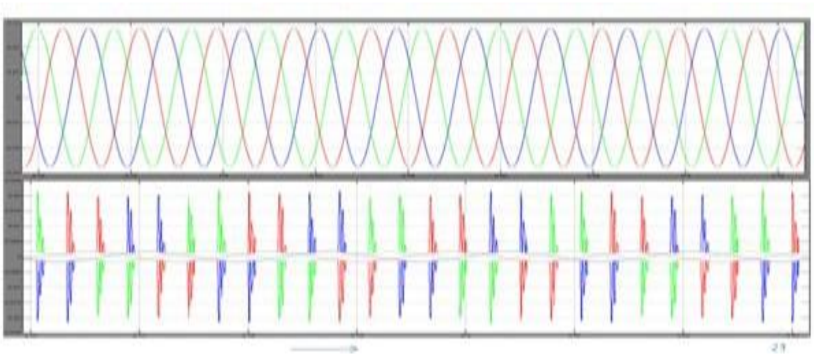

Fig.10 V-I wave forms before applying STATCOM(source side).

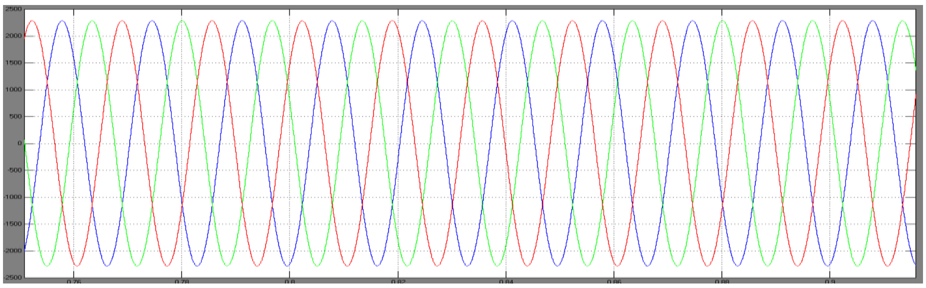

Fig.11 Current waveforms after applying STATCOM(source side).

For observing before and after the UPFC, different fault types of each voltage and current is given. After using UPFC, the phase included in fault cannot be identified. For fault before the UPFC, the responses of the 3-phase currents during fault before the UPFC are shown in fig.12. Similarly, the outputs of the 3-phase current faults after UPFC are shown in fig. 13.

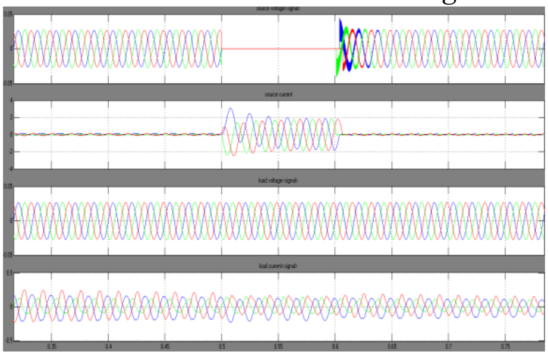

Fig.12 V_s, I_s, V_l, and I_l waveforms of the system before applying UPFC

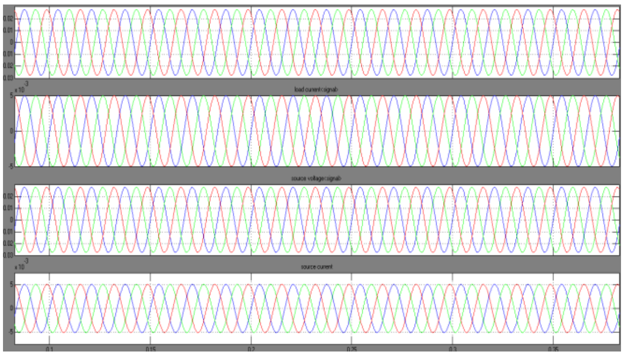

Fig.13 V_s, I_s, V_l, and I_l waveforms of the system after applying UPFC

7 Conclusion

Only with Flexible AC transmission Systems, identification and classification of faults is a very complicated task. Therefore it needs some more advancement in fault analysis and classification. For this one should know the frequency information of the transient signal. Wavelet transformation is an ultimate solution to find out the information of frequency of faulty signals. Along with the application of entropy algorithm can easily find out the type and also the location of the fault. It also provides classification and identification of power quality disturbances with an accuracy of 99.7%. Mitigation of all these power quality disturbances with minimum total harmonic distortion and minimum number of switches by the application of online monitoring by Wavelet Transform-Based Control method in UPFC. Finally the performance of UPFC has been evaluated by creating power quality disturbances under different conditions and for also load changes.

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