A Comparison of Different Mother Wavelet for Fault Detection & Classification of Series Compensated Transmission Line

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Abstract

This paper proposes a Comparison for Different Mother Wavelet For Fault Detection & Classification of Series Compensated Transmission Line. Voltages and currents with fault signal can be properly analyzed by using the wavelet transform. However, the effectiveness of the wavelet analysis is largely influenced by the choice of the mother wavelet. This paper evaluates seven different mother wavelets: Haar, Daubechies, Symlets, Coiflet, BiorSplines, Reverse BiorSplines, Meyer families. Fault Detection & Classification is done on the basis of % Energy of Current Signal. The Matlab Wavelet Toolbox is used for Calculation of % Energy of Current signal.
Keywords: Haar, Daubechies, Symlets, Coiflet , BiorSplines ,Reverse BiorSplines, Meyer

I. INTRODUCTION

Transmission lines constitute the major part of power system. Transmission and distribution lines are vital links between the generating unit and consumers to achieve the continuity of electric supply. To economically transfer large blocks of power between systems and from remote generating sites, High voltage (HV) and Extra high voltage (EHV) overhead transmission systems are being used. Transmission lines also form a link in interconnected system operation for bi-directional flow of power.

The majority of faults tend to occur on overhead transmission lines. The Post-analysis of faults is an important issue to confirm the occurrence of the fault, determine the fault duration and location, define the fault nature or type, assess relay and circuit-breaker (CB) performances, as well as to develop fault diagnosis methods.

Wavelet transform is tool which helps the signal to analyze in time as well as frequency domain effectively. It provides non-uniform division of frequency domain i.e. it uses short window at high frequencies and long window at low frequencies. Using multi-resolution analysis a particular band of frequencies present in the fault signal can be analyzed.

The effectiveness of the wavelet analysis is largely influenced by the choice of the mother wavelet. The choice of the appropriate mother wavelet depends on the nature of the signal and on the type of information to be extracted from the signal.

This paper evaluates seven different mother wavelets: Haar, Daubechies, Symlets, Coiflet, BiorSplines, Reverse BiorSplines, Meyer families in order to select the most suitable wavelet applied for fault detection and classification by using the analysis of voltages and currents with fault-induced transients.

II. TRANSMISSION LINE MODEL

The single-line diagram shown above represents a three-phase, 50 Hz, 735 kV power system transmitting power from a power plant consisting of six 350 MVA generators to an equivalent system through a 600 km transmission line. The transmission line is split into two 300 km lines connected between buses B1, B2, and B3.

To increase the transmission capacity, each line is series compensated by capacitors representing 40% of the line reactance. Both lines are also shunt compensated by a 330 Mvar shunt reactance. The shunt and series compensation equipment is located at the B2 substation where a 300 MVA-735/230 kV transformer feeds a 230 kV-250 MW load. Each series compensation bank is protected by metal-oxide Varistors (MOV1 and MOV2). The two circuit breakers of line 1 are shown as CB1 and CB2.

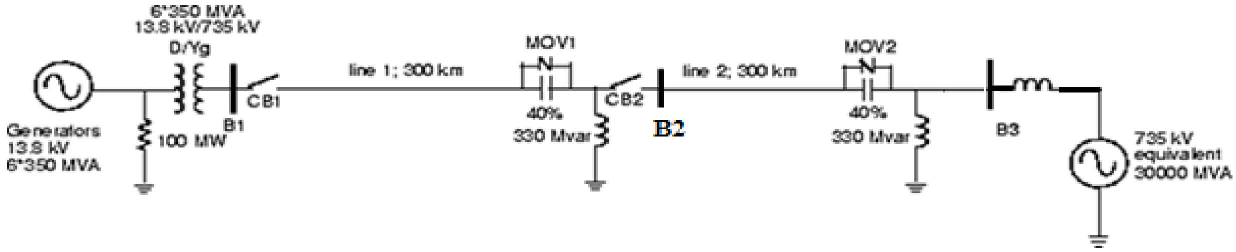

Fig. 1: Transmission line Model

A. Series Compensation Unit:

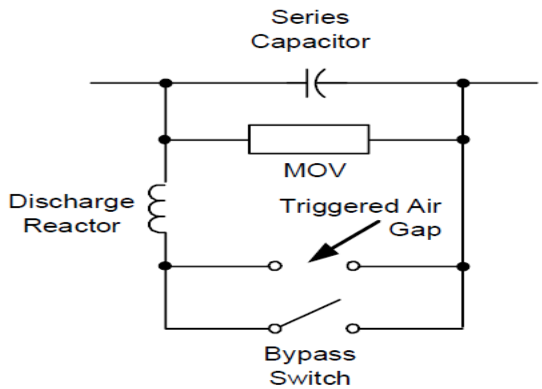

Fig. 2: Series compensation unit

The transmission line is 40% series compensated by a 62.8 µF capacitor. The capacitor is protected by the MOV block. It consists of 60 columns and that its protection level (specified at a reference current of 500 A/column or 30 kA total) is set at 298.7 kV. A gap is also connected in parallel with the MOV block. The gap is fired when the energy absorbed by the surge arrester exceeds a critical value of 30 MJ. To limit the rate of rise of capacitor current when the gap is fired, a damping RL circuit is connected in series

III. DISCRETE WAVELET TRANSFORM (DWT)

Wavelet transform is a mathematical technique used for many applications of signal processing. Wavelet is much more powerful than conventional method. In wavelet transform the band of analysis can be adjusted so that low frequency hand high frequency components can be windowing by different scale factors.

Wavelet is a waveform of effectively limited duration that has an average value of zero. Wavelet transform is to analyze non-stationary signals i.e.; whose frequency response varies in time. Wavelet transform gives variable resolutions. It can analyze signals simultaneously in time and frequency domain.

Discrete Wavelet transform (DWT) uses filter with different cut off frequency to analyze a signal (image in our case) at different resolutions. The fundamental idea behind wavelets is to analyze according to scale. The Wavelet Analysis Procedure is to adopt a wavelet prototype function called an analyzing wavelet or mother wavelet .Any signal can be represented by translated and scaled version of mother wavelet .Wavelet analysis is capable of revealing aspects of data that other signal analysis techniques such as Fourier analysis miss aspects like trends, breakdown points, discontinuities in higher derivatives and self-similarity.

Furthermore, because it affords view of data than those presented by traditional techniques, it can compress or de-noise a signal without appreciable degradation. The wavelet multiresolution analysis is a new and powerful method of signal analysis and is well suited to traveling wave signals. Wavelet can provide multiple resolutions in both time and frequency domains. The windowing of wavelet transform is adjusted automatically for low and high {frequencies .i.e. it uses short time intervals for high frequency components and longtime interval s for low frequency components.

Wavelet analysis is based on the decomposition of a signal into `scales' using wavelet analyzing function called `Mother wavelet' Wavelet associated with the traveling waves are typically non-periodic signals that contain localized high frequency oscillations Superimposed on the power frequency and its harmonics.

The wavelet transform allows time localization of different frequency components of a given signals like the STFT but its transformation functions called wavelets which adjust their time widths to their frequency in such a way that higher frequency wavelet will be narrow and lower frequency once will be broader. Wavelet `s time frequency resolution provides a useful tool for decomposing and analyzing fault transient signals.

IV. WAVELET FAMILY

A. *Wavelet Type:*

1) *Orthogonal wavelets with FIR filters:*

These wavelets can be defined through the scaling coefficient. Predefined families of such wavelets include Haar, Daubechies, Coiflets, and Symlets.

2) *Biorthogonal wavelets with FIR filters:*

These wavelets can be defined through the two scaling coefficient, for reconstruction and decomposition respectively. The BiorSplines wavelet family is a predefined family of this type.

3) *Orthogonal wavelets without FIR filter, but with scaling function:*

These wavelets can be defined through the definition of the wavelet function and the scaling function. The Meyer wavelet family is a predefined family of this type.

4) *Wavelets without FIR filter and without scaling function:*

These wavelets can be defined through the definition of the wavelet function. Predefined families of such wavelets include Morlet and Mexican hat.

5) *Complex wavelets without FIR filter and without scaling function:*

These wavelets can be defined through the definition of the wavelet function. Predefined families of such wavelets include Complex Gaussian and Shannon.

V. FAULT SIMULATION

A. *No Fault:*

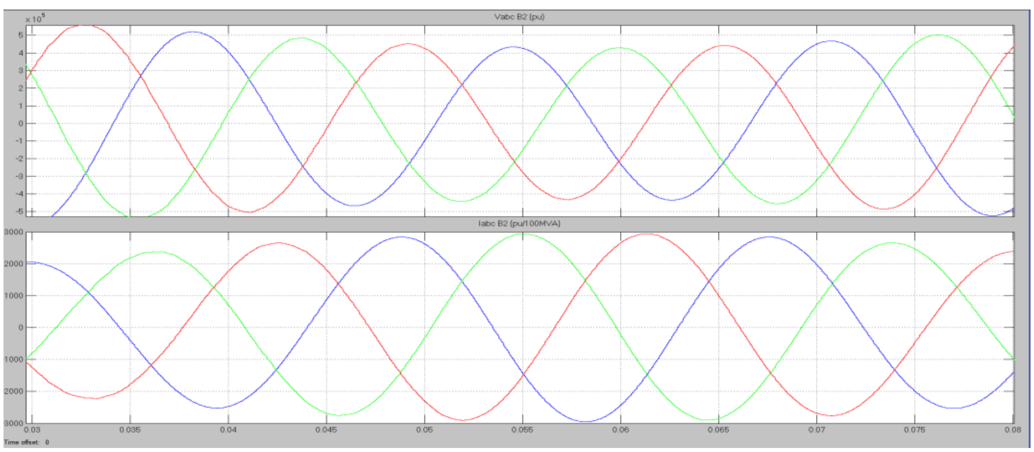

Fig. 3: No Fault

B. *LLG Fault:*

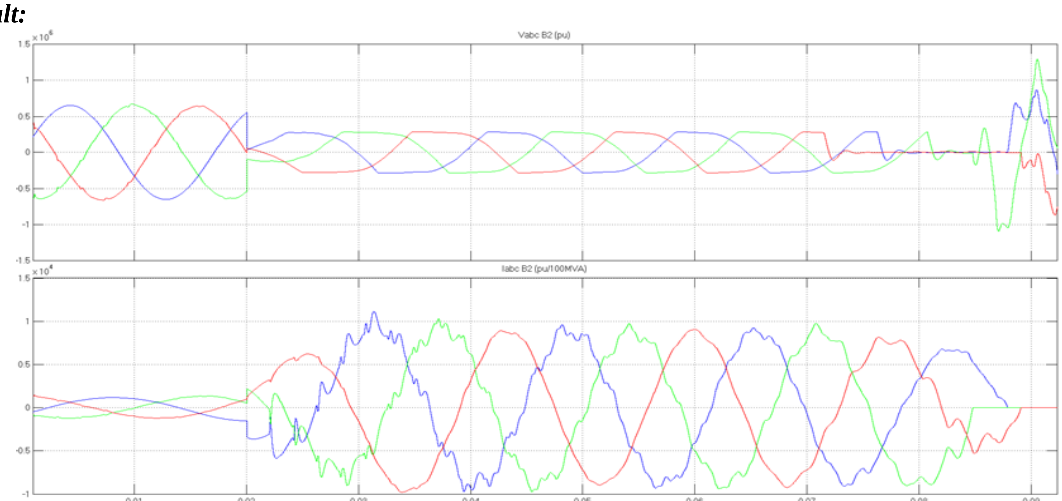

Fig. 4: LLG Fault

Voltage and current waveform characteristics before, during, and after a fault may be significantly different.

VI. ENERGY BASED FAULT DETECTION AND CLASSIFICATION

Fault Signal provide reliable information regarding the fault. The analysis of energy of fault signal by means of the wavelet transform can provide a high speed fault detection, classification, and location. The energy of the current Signal is used to identify the most suitable mother wavelet for fault detection and classification purpose.

Matlab Wavelet Toolbox(Wave menu) is used for calculation of energy of signal. The system is simulated for LLG Fault .the fundamental energy is calculated using the toolbox.

The fault occurs on the line has comparatively less energy than healthy phase.

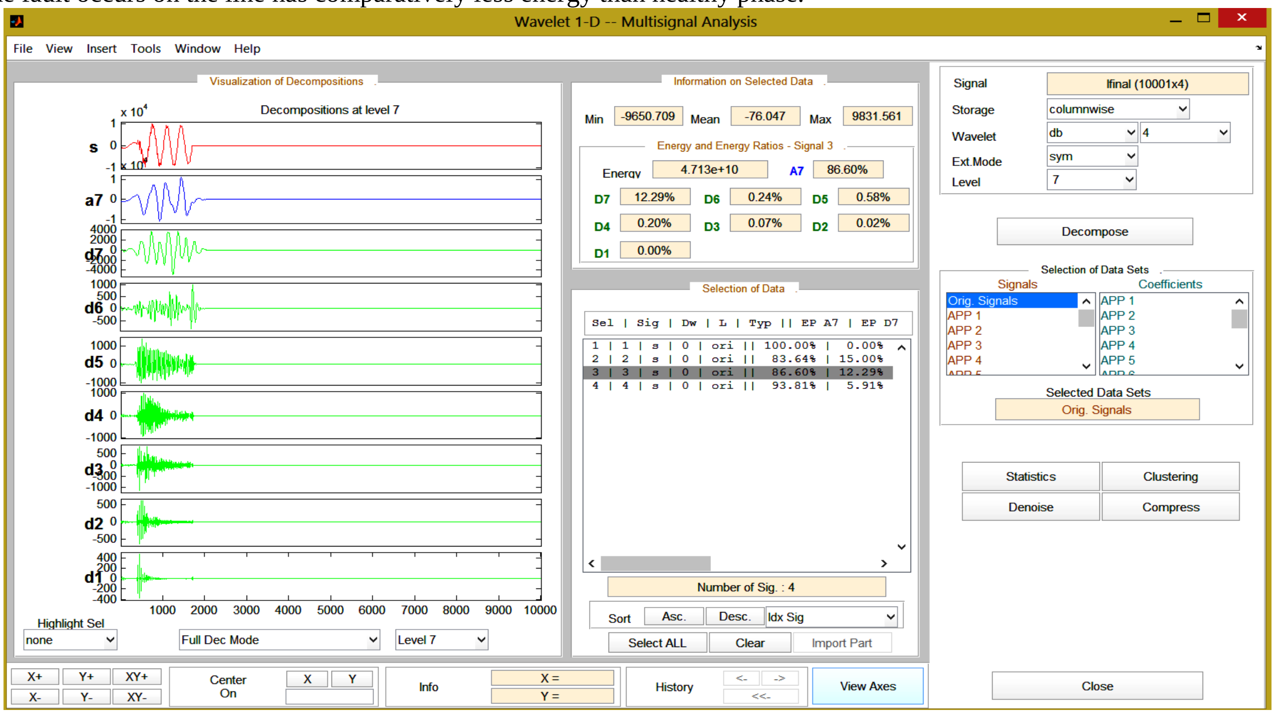

Fig. 5: Energy Based Fault Detection and Classification

VII. COMPARISON TABLE OF MOTHER WAVELET

Table – 1
Comparison Table of Mother Wavelet

Wavelet	*Energy of Signal in %*				
	A	*B*	*C*	*C/A*	*C/B*
	Haar Wavelet				
haar	*64.06*	*65.48*	*68.63*	*1.071339369*	*1.048106292*
	Daubechies Wavelet Family				
db1	*64.06*	*65.48*	*68.63*	*1.071339369*	*1.048106292*
db2	*77.59*	*76.17*	*83.16*	*1.071787601*	*1.091768413*
db3	*79.52*	*81.26*	*89.79*	*1.129149899*	*1.104971696*
db4	*83.64*	*86.6*	*93.81*	*1.121592539*	*1.083256351*
db5	*89.17*	*88.96*	*94.82*	*1.063362117*	*1.065872302*
db6	*89.89*	*89.13*	*95.65*	*1.064078318*	*1.073151576*
db7	*88.64*	*90.74*	*97.47*	*1.099616426*	*1.074167952*
db8	*91.01*	*93.08*	*98.28*	*1.079881332*	*1.055865922*
db9	*94.02*	*93.36*	*97.88*	*1.041055095*	*1.048414739*
db10	*93.28*	*92.92*	*98.15*	*1.052208405*	*1.056284976*
	Symlets Wavelet Family				
Sym2	*77.59*	*76.17*	*83.16*	*1.071787601*	*1.091768413*

Sym3	79.12	81.26	89.79	1.134858443	1.104971696
Sym4	82.63	85.25	92.69	1.121747549	1.087272727
Sym5	88.71	87.84	93.66	1.055799797	1.066256831
Sym6	87.29	89.35	96.06	1.100469699	1.075097929
Sym7	90.29	91.89	97.2	1.076531177	1.057786484
Sym8	90.08	91.85	97.64	1.0839254	1.063037561
	Coiflets Wavelet Family				
coif1	74.16	75.88	84.72	1.142394822	1.116499736
coif2	83.82	85.79	93.91	1.120376998	1.094649726
coif3	88.12	90.1	97.06	1.101452565	1.077247503
coif4	90.69	92.68	98.44	1.085455949	1.062149331
coif5	92.44	94.35	99.09	1.071938555	1.050238474
	BiorSplines Wavelet Family				
bior1.1	64.06	65.48	98.63	1.539650328	1.506261454
bior1.3	69.02	69.95	75.3	1.090988119	1.076483202
bior1.5	71.49	72.18	78.3	1.095258078	1.08478803
bior2.2	89.48	90.43	94.55	1.056660706	1.045560102
bior2.4	91.16	91.96	95.29	1.045304958	1.036211396
bior2.6	91.92	92.66	95.76	1.041775457	1.033455644
bior2.8	92.32	93.05	96.08	1.040727903	1.032563138
bior3.1	97.06	97.12	98.56	1.015454358	1.014827018
bior3.3	98.07	97.92	98.72	1.006627919	1.008169935
bior3.5	98.14	98.05	98.78	1.006521296	1.007445181
bior3.7	98.16	98.12	98.82	1.006723716	1.007134121
bior3.9	98.19	98.16	98.85	1.006721662	1.00702934
bior4.4	88.36	89.68	95.68	1.082842915	1.06690455
bior5.5	83.63	85.92	95.67	1.143967476	1.113477654
bior6.8	91.75	93.09	97.83	1.06626703	1.050918466
	Reverse BiorSplines Wavelet Family				
rbio1.1	64.06	65.48	68.33	1.06665626	1.04352474
rbio1.3	81.36	82.64	88.52	1.088003933	1.071151985
rbio1.5	87.95	88.06	94.14	1.070380898	1.069043834
rbio2.2	45.27	46.99	61.4	1.356306605	1.306660992
rbio2.4	59.31	61.91	80.74	1.361321868	1.304151187
rbio2.6	67.88	71.15	89.87	1.323954037	1.263106114
rbio2.8	73.97	77.72	94.44	1.276733811	1.21513124
rbio3.1	11.82	12.61	16.7	1.41285956	1.324345757
rbio3.3	27.95	29.55	45.65	1.633273703	1.544839255
rbio3.5	39.87	41.41	66.31	1.663155255	1.601304033
rbio3.7	50.17	51.16	79.46	1.583815029	1.553166536
rbio3.9	58.93	59.13	87.12	1.478364161	1.473363775
rbio4.4	75.93	77.71	88.49	1.165415514	1.138720885
rbio5.5	87.43	88.52	93.98	1.074917077	1.061680976
rbio6.8	85.26	87.49	96.33	1.129838142	1.101040119
	Meyer Wavelet Family				
dmey	97.2	97.65	99.56	1.024279835	1.019559652

VIII. COMPARISON FOR FAULT DETECTION

Table summarizes the % energy of signal for LLG fault. From the table it is clear that db10 wavelet presented the maximum value of fundamental energy. Therefore, the db10 is the best wavelet among Daubechies Wavelet Family for fault detection based on % Energy of fault Signal. However, in real-time applications, the wavelet coefficients computed with the db4 is faster than the db10.

Similarly From the table it is clear that coif5 wavelet presented the maximum value of fundamental energy. Therefore, the coif5 is the best wavelet among coif1, coif2, coif3, and coif4 for fault detection based on % Energy of fault Signal From table The Haar, sym8, bior6.8, rbio6.8 & dmey presented the maximum value of energy in their family.

IX. COMPARISON FOR FAULT CLASSIFICATION

According to table , the fault can be classified by means of the ratio of C/A & C/B .For Classification of fault there is no significant difference in Daubechies & Haar Wavelet Family.Db1,Db2,Db5,Db6,Db7,Db10 best for fault Classification.Sym5, bior3.7 ,bior3.9, rbio5.5, dmey are best wavelet for Fault Classification in their respective family.

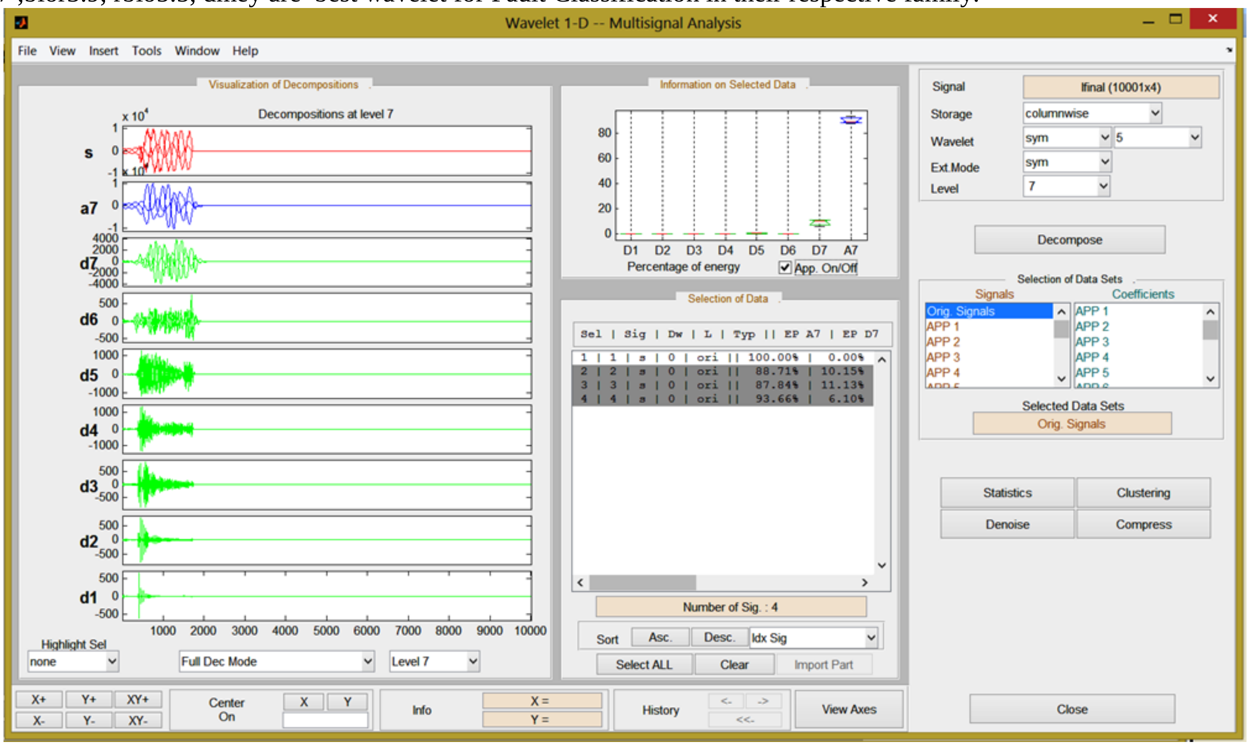

Fig. 6: fault classification

X. CONCLUSION

The paper has made a comparative study of the different mother wavelet techniques for fault detection & Classification of Series Compensated transmission line. Different mother Wavelet evaluated in this paper in order to select the most suitable mother wavelet for fault detection and classification by using the analysis of voltages and currents signal.

The bior3.9 wavelet followed by the Meyer, Coiflet 5 , Daubechies 10, and Symlets 8, were the most suitable candidates for fault detection. All these wavelets provide fast computation of the wavelet coefficients and they are excellent candidates for real time fault detection. With regard to fault classification, the Haar was the most appropriate candidate.

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