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Analysis of power system faults in EHVAC line for varying fault time instances using wavelet transforms

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Abstract

This paper evaluates how the occurrence time of fault affects the energy entropy present in a fault signal. The diagnostic method that is proposed is based on calculating the wavelet entropy of sampled signal at different fault occurrence times. The energy of detailed coefficients of db wavelet are extracted at level 1 & level 5 for L–G fault and analysis is done for varying fault times. The analysis can further be extended to other types of faults.

Keywords: Fault detection; Fault isolation; Wavelet; Wave entropy

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1. Introduction

The quality and reliability of power needs to be maintained in order to obtain optimum performance. Therefore, it is extremely important that transmission line faults from various sources be identified accurately, reliably and be corrected as soon as possible. Voltages and currents in electrical power systems may include higher harmonics, transient components and random noise due to faults and other disturbances.

Fast assessment of parameters of the basic component of voltages and currents from measured data is very significant. The instance at which fault is initiated in the line also plays a vital role in fast fault detection using automated protective equipments. This work deals with analyzing the fault signal energy content for different instances of fault occurrence times. Wavelet transforms is used to extract the energy content of the signal at level 1 and level 5 and a comparative analysis is formulated which shows that the variation of energy content of signal for level 5 is more accurate for assessment of fault data. Db wavelet is preferred because of its higher accuracy rate in decomposing the details of the faulty signal.

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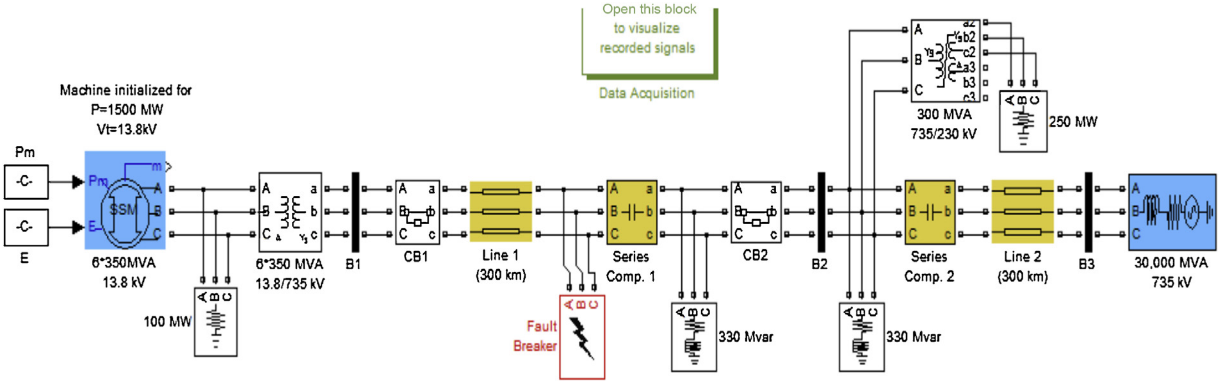

Fig. 1. Mat lab model for fault analysis.

Several transforms are used to extract information about these harmonics. In recent years, various methods of fault location estimation have been proposed. These methods are based on artificial neural networks (ANNs) (Pradhan et al., 2006; Mahanty and Gupta, 2004), Fourier transform (FT) (Lin et al., 2004), wavelet transform (WT) (Ghafoor and Rao, 2006; Murthy et al., 2016) or a combination of these techniques (Zadeh, 2004; Upendar et al., 2008). Fourier transforms (Oppenheim and Schafer, 1989) and wavelet transforms (Anon., 2016) are two major tools that are used for frequency domain analysis of any signal. While Fourier transform provides information about all the frequencies present in the signal, it gives no indication when in time these signals were present. Unlike FT, WT not only analyzes the signal in frequency bands but also provides non-uniform division of frequency domain, i.e., WT uses short windows at high frequencies and long windows at low frequencies. This helps to analyze the signal in both frequency and time domains effectively. Single-phase to ground fault at different fault times along the transmission line have been simulated and analyzed.

2. Power system simulation

A 3-Ph, 60 Hz, 735 kV power system transferring power consisting of six 350 MV A generators to an equivalent network through a 600 km transmission line. The transmission line is divided into two 300 km lines linked between buses B1, B2, and B3. In order to raise the transmission capacity, each line is series compensated to 40% of the line reactance. Both lines are also shunt compensated by a 330 Mvar shunt reactance. The shunt and series compensation are located at the B2 substation where a 300 MV A 735/230 kV transformer with a 25 kV tertiary winding feeds a 230 kV, 250 MW load. The series compensation subsystems are identical for the two lines. For each line, each phase of the series compensation module contains the series capacitor, a metal oxide varistor is protecting the capacitor, and a parallel gap protecting the MOV. When the energy dissipated in the MOV exceeds a threshold level of 30 MJ, the gap simulated by a circuit breaker is fired. CB1 and CB2 are the two line circuit breakers (Fig. 1).

3. Preliminary measurements

(Figs. 2–10) At t = (0.625/60) 0.001 s of a cycle a line-to-ground fault is applied. At t = 5 cycles the line protection relays open breakers CB1 and CB2. The fault signal is then decomposed using wavelet transforms and the energy content of the detail coefficients is extracted for level 1 & level 5. Fault data for current is taken for different fault times for L–G fault and the procedure is repeated as above.

4. Wavelet transforms

Wavelet transform has received greater attention in fault analysis due to its ability in analyzing the traveling waves than other approaches. The wavelet transform decomposes transients into a series of wavelet components having each of which corresponds to a time domain signal that covers a specific octave frequency band containing more detailed

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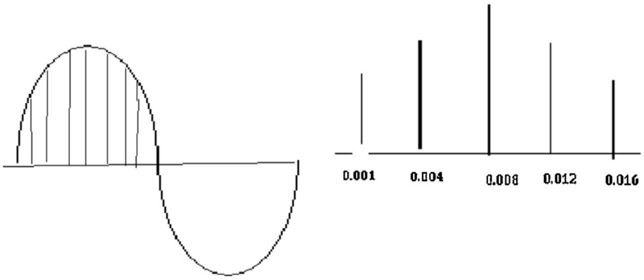
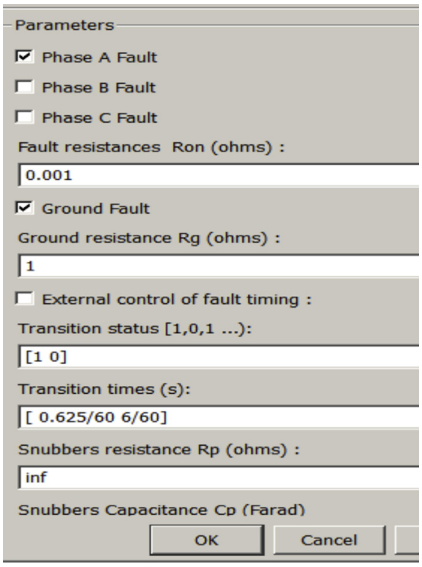


Fig. 2. Fault initiation time in seconds.



☑ Phase A Fault

☐ Phase B Fault

☐ Phase C Fault

Fault resistances Ron (ohms) : 0.001

☑ Ground Fault

Ground resistance Rg (ohms) : 1

☐ External control of fault timing :

Transition status [1,0,1 ...): [1 0]

Transition times (s): [0.625/60 6/60]

Snubbers resistance Rp (ohms) : inf

Snubbers Capacitance Cp (Farad)

Fig. 3. Fault occurrence time setting in mat-lab for t = 0.001 s.

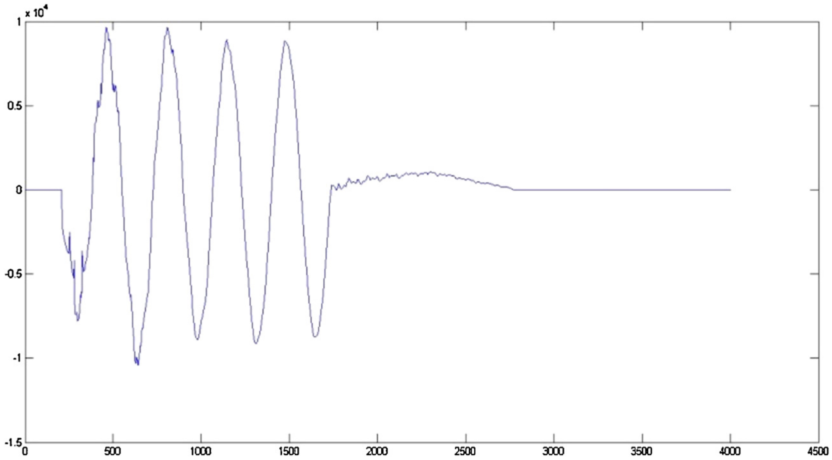


Fig. 4. Fault current when fault occurred at t = 0.001 s (0.625/60 of a cycle).

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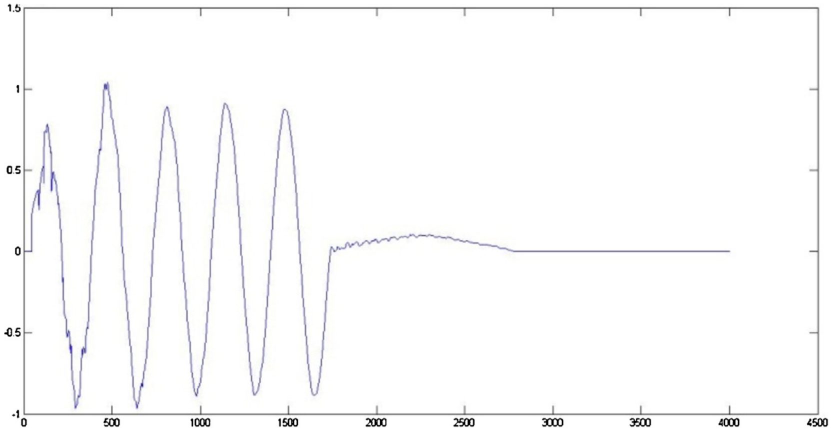

Fig. 5. Fault current when fault occurred at t = 0.002 s (0.125/60 of a cycle).

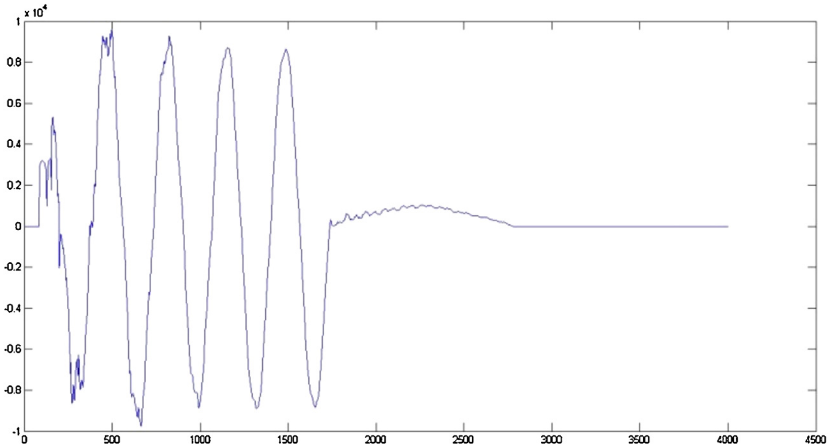

Fig. 6. Fault current when fault occurred at t = 0.004 s (0.25/60 of a cycle).

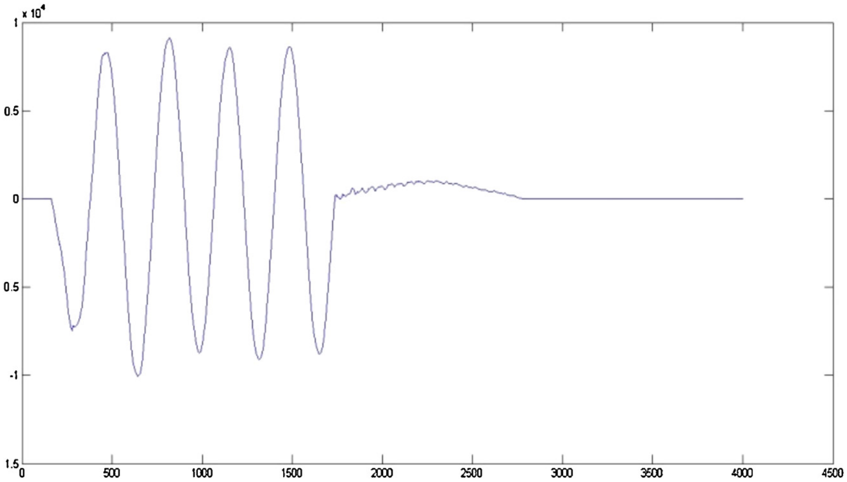

Fig. 7. Fault current when fault occurred at t = 0.008 s (0.5/60 of a cycle).

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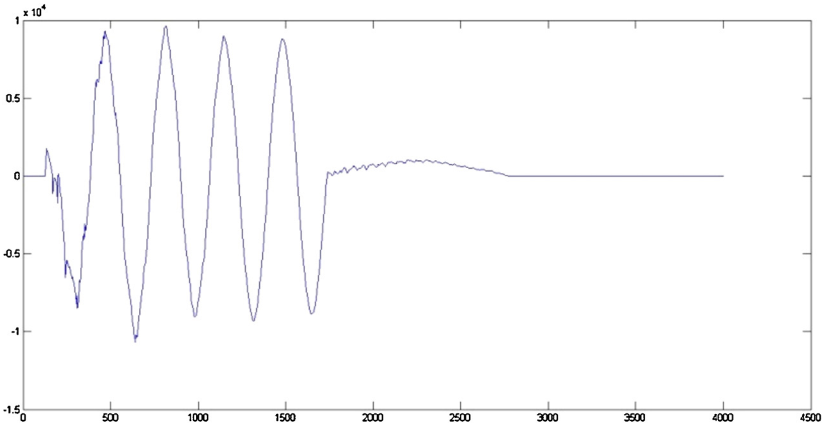

Fig. 8. Fault current when fault occurred at t = 0.006 s (0.375/60 of a cycle).

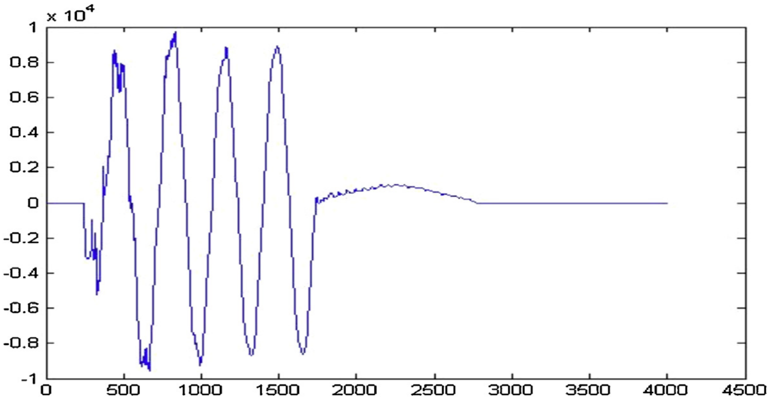

Fig. 9. Fault current when fault occurred at t = 0.012 s (0.75/60 of a cycle).

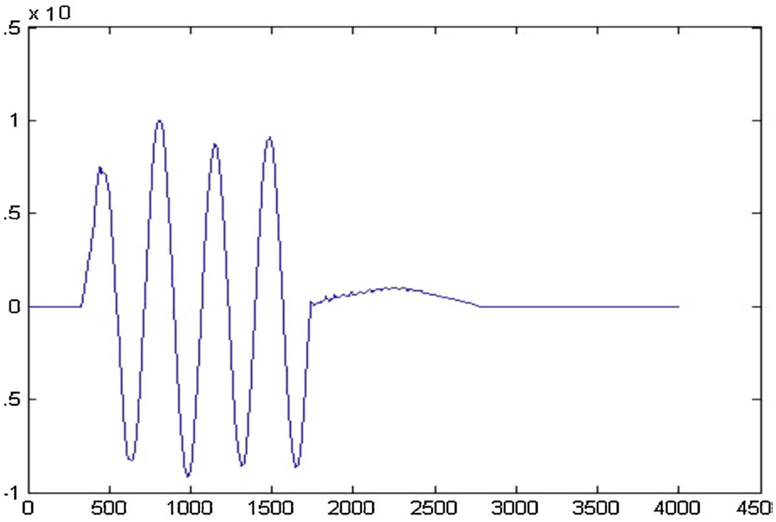

Fig. 10. Fault current when fault occurred at t = 0.016 s (1/60 of a cycle).

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Table 1
Varying energy for varying fault occurrence times.

Fault type		Db4	1/60	0.75/60	0.375/60	0.5/60	0.25/60	0.125/60	0.625/60
LG	EA	Level	100.0000	99.9935	99.9981	100	99.9956	99.9976	99.9989
	ED	1	3.5933e-005	0.0065	0.0019	3.8241e-005	0.0044	0.0024	0.0011
	EA	Level	99.9741	99.5261	99.7907	99.762	99.6213	99.7249	99.9121
	ED	5	0.0226	0.3115	0.1464	0.0206	0.2407	0.1946	0.0592

information. Multilevel 1-D wavelet decomposition scheme is used to calculate the detail coefficients. The syntax is given below

- [C, L] = wavedec (X, N, '*wname*') signal X at level N, using 'wname'. N must be a strictly positive integer (see wmaxlev for more information). The output decomposition structure contains the wavelet decomposition vector C and the bookkeeping vector L.
- [Ea,Ed] = wenergy (C,L) returns Ea, which is the percentage of energy corresponding to the approximation and Ed, which is the vector containing the percentages of energy corresponding to the details.

5. Results & discussions

Wavelet transform is proposed here for LG fault to extract the detailed coefficients for the fault signals extracted above. The results are being formulated below in Table 1. It is therefore seen that the detailed coefficient energy varies for every quarter cycle in its decreasing and increasing order. The fault signal entropy at every quarter of a full cycle for both level 1 and level 5 clearly indicated that there is an eventual increase and decrease in the energy level of both approximate and detailed coefficients for positive and negative half cycles of full cycle fault data with a sampling time of 16 ms. This analysis is useful to predict the severity of fault current magnitude based on the time of occurrence of faults which makes fault isolation more accurate.

6. Conclusion

The new criterion of analyzing the energy content of the faulty signal for different occurrence times of fault by making use of the advantage of the wavelet in dealing with sharp transitions in extracting energy content of the signal has been proposed. The importance of having the knowledge of the instant of occurrence of fault can be of greater use in the research field of power quality assessment. This study can further be done for other fault types. This can be further extended for analysis of sequence components of fault current for much accuracy in fault detection.

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