Wavelet Technique-Based Fault Classification in Transmission Lines

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Abstract Power systems constitute a very big part of the electrical system pertaining in the current world. Each and every part of this system plays a very big role in the availability of the electrical power one utilizes at their homes, industries, offices, factories, etc. Power system constitutes of generation, utilization, distribution, and most importantly transmission of electricity. Any fault in any of these portions of the system causes a lot of trouble for the maintenance of the system. Overhead lines are the significant constituents of the power system and the issues happening are real purpose of concern toward this work. This paper aims to identify both the presence of faults and also the type of the fault in order to reach the conclusion to apply the best possible measure to reduce the loss that may be caused due to the fault. In order to do that simulation-based model in MATLAB is used and a code is realized in order to find out the detailed coefficient and energy of these coefficients of the faulty current signal. The coefficients are found out through the discrete wavelet transform. These characteristic features of the signal help identify and classify the fault type quickly. The GUI-based model of the code helps to bring down the human effort to calculate or compute the results.

Keywords Fault · Fault detection · Fault classification · Multi-resolution analysis
Wavelet technique

1 Introduction

Fault conditions in the power system can cause a lot of issues and losses. These losses can be fatal too. The condition of a faulty phase if not understood and taken care of quickly would most probably lead to major problems. In order to get to the

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conclusion of whether the fault is present and if yes, then which type of fault is present in the system needs to be identified as quick as possible. The electrical framework flaws are the best risk to the congruity of power supply. Deficiencies on overhead lines are an unavoidable issue. Thus, an all-around composed protection system must be given to distinguish and disengage faults quickly so that the harm and interruption brought on to the transmission system is minimized. Main part of the fault clearing system is the circuit breaker. Power circuit breakers are used at all voltage levels in a power system, i.e. faults which can either be single phase to ground (LG) or phase to phase (LL) or double phase to ground (LLG) or a three-phase fault (LLLG). Protection of power system using conventional methods is a slightly longer process. The real procedures utilized are fuzzy logic [1–3], wavelet strategy [4, 5], artificial neural systems [6, 7], wavelet-fuzzy [8], wavelet-neuro-fuzzy [9], and other latest techniques [10–13]. The accuracy of wavelet methodology is prevalent in correlation with different strategies and it gives greatly enhanced results.

The essential point of this article is to make sense of the sort of fault and whether the fault is present or not in a power system. The faults in concern are predominantly transmission line faults and all types of these faults are to be covered. This work also looks forward to providing a universal method to recognize faults and also discriminate among the types in case of any power system setup, specifications, parameters, etc. In order to reduce manual switching and calculation, the code tries to show the results of the scenario through minimum manual effort, hence providing results quicker for further measures.

2 Discrete Wavelet Transform (DWT)

A wavelet is a wave-like swaying with plentifulness that starts at zero, increments, and afterward diminishes back to zero. Wavelets can be joined, utilizing an “opposite, shift, duplicate and coordinate” procedure called convolution, with bits of a known signal to concentrate data from the obscure signal.

The DWT can be composed as

$$T_{m,n} = \int_{-\infty}^{\infty} x(t)\varphi_{m,n}(t)\mathrm{d}t. \tag{1}$$

The 1-D wavelet transform is given by

$$W_f(a,b) = \int_{-\infty}^{\infty} x(t)\varphi_{a,b}(t)\mathrm{d}t. \tag{2}$$

Table 1 MDC, E, and ER for no-fault condition

Condition	Phase A			Phase B			Phase C		
	MDC	E	ER	MDC	E	ER	MDC	E	ER
No fault	0.175	81.65	0.001	0.174	81.45	0.001	0.18	87.06	0.001

The inverse 1-D wavelet transform is given by

$$x(t) = (1/c)\int_{0}^{\infty}\int_{-\infty}^{\infty} W_f(a,b)\varphi_{a,b}(t)\mathrm{d}b\left(\frac{\mathrm{d}a}{a^2}\right), \tag{3}$$

$$\text{where } c = \int_{-\infty}^{\infty}\left(\frac{|\varphi\omega|^2}{\omega}\right)\mathrm{d}\omega < \infty.$$

3 Fault Classification Using DWT

For implementing the proposed method for fault detection and classification, a three-phase simulation model with a source voltage of 400 kV and corresponding zero load angle was used. This identification is based on the DWT energy coefficient of the signal. It generates a high-frequency component to signal. Initially generate the power signal using generator. Then design network power system using three-phase current signal. DWT analysis is performed to identify and classify the fault. Circuit breaker is used to make fault in the signal. Ratio is calculated to find the fault. Fault can be classified based on the ratio. The values of maximum detail coefficient (MDC), energy of the signal (E), and energy ratio (ER) after signal compression in no-fault condition are tabulated in Table 1. These values are used as a reference to compare with respective values in faulty conditions.

4 Numerical Simulation Results and Discussion

Output current waveform at no-fault condition is shown in Fig. 1. The detailed coefficients are close to zero in this case of fault. The energy ratios after signal compression can be seen to be similar for all the phases and nearing zero.

In LG, fault condition is shown in Fig. 2. The phase under fault can be identified by the MDC, E, and ER. From Table 2, it is clear that whichever phase the fault occurs in LG fault, that corresponding phase shows in increase in MDC, E, and ER. The other two phases show very little or no change in parameter values.

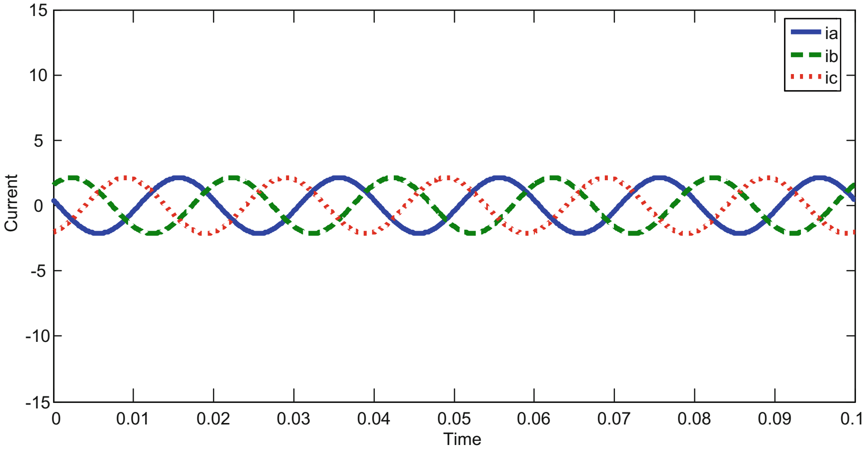

Fig. 1 Output current waveform at no-fault condition

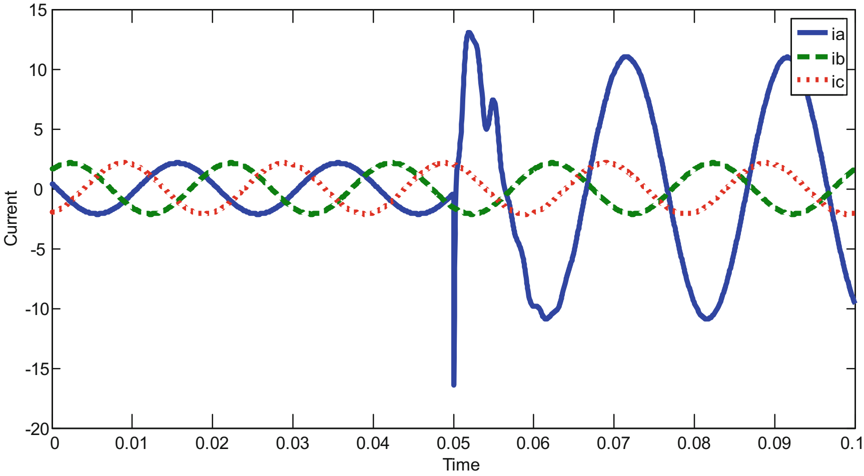

Fig. 2 Output current waveform at LG fault (AG) condition

Table 2 MDC, E, and ER for LG faults

Condition	Phase A			Phase B			Phase C		
	MDC	E	ER	MDC	E	ER	MDC	E	ER
No fault	0.175	81.65	0.001	0.174	81.45	0.001	0.18	87.06	0.001
AG	**0.966**	**195.5**	**0.008**	0.174	81.52	0.001	0.178	84.16	0.001
BG	0.175	81.51	0.001	**0.56**	**176.8**	**0.02**	0.178	84.16	0.001
CG	0.001	81.51	0.001	0.001	81.52	0.001	**0.029**	**173.6**	**0.029**

When the fault occurs in a LLG fault scenario, the current in both affected phases significantly changes as shown in Fig. 3. The unaffected phase has more or less the same characteristics as the no-fault condition. The faulty phases have maximum or higher values of detail coefficient; energy and energy ratio of the compressed signal are shown in Table 3. Here two of the phases are affected, so naturally those two respective phases have shown in increase in parameter values. The key thing to note here is that although energy ratio has increased for both the concerned phases they are not equal to each other. This is one of the key differentiators between LL and LLG fault.

In LL fault, the fault incidence in this case will show great amount of change in the faulty phases shown in Fig. 4.

Unaffected phase has the same current flow as in normal condition and also the values of detail coefficient and ratio after compression. The output values of the faulty phases are more than normal, but they being similar show that they are not in contact with ground. Here two of the phases are affected, so naturally those two respective phases have shown an increase in parameter values as shown in Table 4. The key thing to note here is that energy ratio has increased for both the concerned phases and they are equal or almost equal to each other.

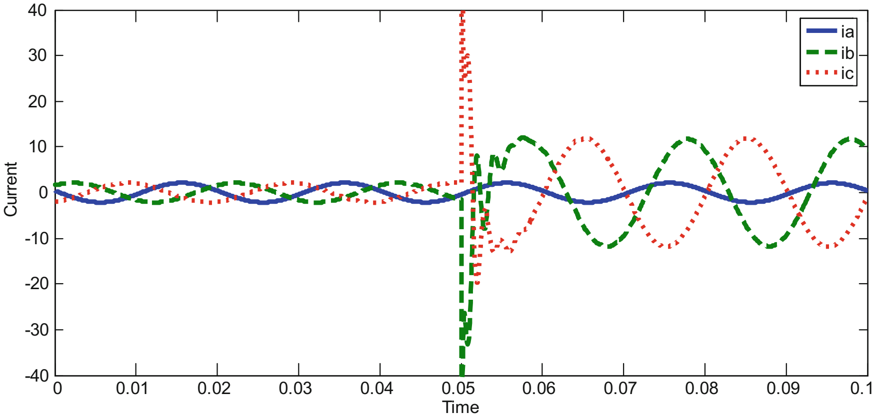

Fig. 3 Output current waveform at LLG fault (BCG) condition

Table 3 MDC, E, and ER for LLG faults

Condition	Phase A			Phase B			Phase C		
	MDC	E	ER	MDC	E	ER	MDC	E	ER
No fault	0.175	81.65	0.001	0.174	81.45	0.001	0.18	87.06	0.001
ABG	**0.966**	**195.5**	**0.008**	**0.56**	**176.8**	**0.02**	0.178	84.16	0.001
BCG	0.175	81.51	0.001	**0.561**	**176.9**	**0.02**	**0.599**	**173.7**	**0.029**
ACG	**0.966**	**195.5**	**0.008**	0.174	81.52	0.001	**0.599**	**173.7**	**0.029**

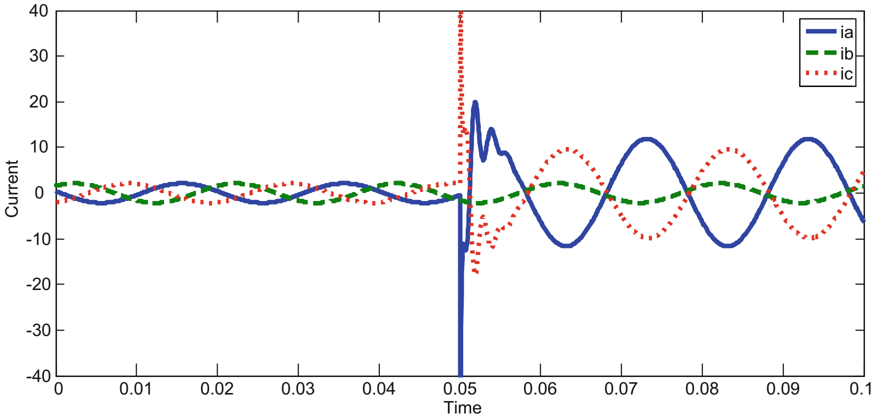

Fig. 4 Output current waveform at LL fault (AC) condition

Table 4 MDC, E, and ER for LL faults

Condition	Phase A			Phase B			Phase C		
	MDC	E	ER	MDC	E	ER	MDC	E	ER
No fault	0.175	81.65	0.001	0.174	81.45	0.001	0.18	87.06	0.001
AB	**0.006**	**180.2**	**0.006**	**0.006**	**155.4**	**0.006**	0.001	87.06	0.001
BC	0.001	81.65	0.001	**0.009**	**176.1**	**0.024**	**0.25**	**146.4**	**0.025**
AC	**0.712**	**142**	**0.018**	0.174	81.44	0.001	**0.549**	**174.7**	**0.019**

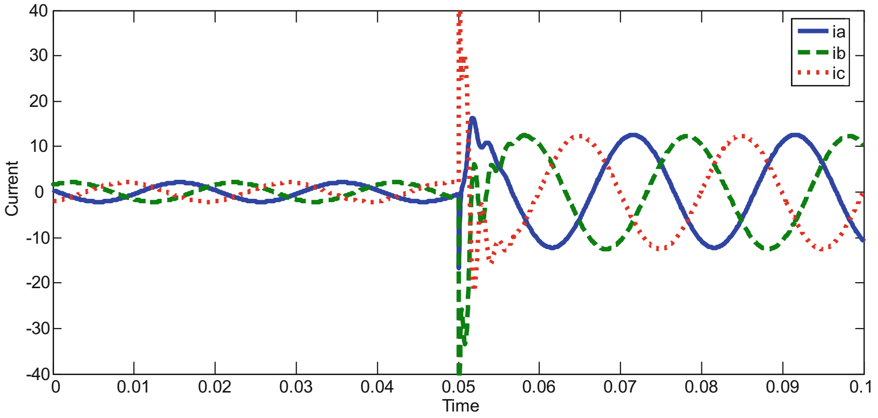

Fig. 5 Output current waveform at LLLG (ABCG) condition

In three-phase fault at fault inception, the current signal of all the three phases change drastically as shown in Fig. 5. The ratios and coefficient values can also be seen to be more than the normal condition. For three-phase fault, it can observe an

Table 5 MDC, E, and ER for LLLG fault

Condition	Phase A			Phase B			Phase C		
	MDC	E	ER	MDC	E	ER	MDC	E	ER
No fault	0.175	81.65	0.001	0.174	81.45	0.001	0.18	87.06	0.001
ABCG	**0.008**	**200**	**0.008**	**0.56**	**176.8**	**0.002**	**0.484**	**163.9**	**0.029**

increase in energy of signal and energy ratio of compressed signal for all three phases which are shown in Table 5.

5 Conclusion

The principle point of the work is to identify and classify faults in overhead lines. This is realized using wavelet analysis because it takes into consideration both frequency and time domain. This work uses parameters like MDC, E, and ER after compression to make observations. This is because these parameters are characteristic for a particular type of fault current. Hence, they are optimal for the classification process. Taking the values of the three parameters of no-fault condition as base, we can compare the respective values of the parameters of every type of fault in order to make comparisons and arrive at a conclusion. The outcome signifies that during the no-fault condition all the three parameter values for each phase are comparatively lower. Under fault conditions the value of the respective phase under fault increases and hence shows the result as to which fault is present. Using reverse bi-orthogonal wavelet for transform helps to get the result quicker and the use of this wavelet is helpful to realize the aim. Using wavelet as a method instead of other available toolbox allows faster calculation because wavelet transform considers both frequency and time domain. Using this technique a lot of effects and losses due to faults in transmission lines can be avoided. This will help in reducing damages in electrical systems and potentially help for continuous power supply.

References

1. Samantaray, S.R.: A systematic fuzzy rule based approach for fault classification in transmission lines. Appl. Soft Comput. **13**(2), 928–938 (2013)
2. Guillen, D., Paternina, M.R.A., Zamora, A., Ramirez, J.M., Idarraga, G.: Detection and classification of faults in transmission lines using the maximum wavelet singular value and Euclidean norm. IET Gener. Transm. Distrib. **9**(15), 2294–2302 (2015)
3. Prasad, A., Edward, J.B., Roy, C.S., Divyansh, G., Kumar, A.: Classification of faults in power transmission lines using fuzzy-logic technique. Ind. J. Sci. Technol. **8**(30), 1–6 (2015)
4. Pérez, F.E., Orduna, E., Guidi, G.: Adaptive wavelets applied to fault classification on transmission lines. IET Gener. Transm. Distrib. **5**(7), 694–702 (2011)
5. Prasad, A., Edward, J.B.: Application of wavelet technique for fault classification in transmission systems. Procedia Comput. Sci. **92**, 78–83 (2016)

6. He, Z., Lin, S., Deng, Y., Li, X., Qian, Q.: A rough membership neural network approach for fault classification in transmission lines. Electr. Power Energy Syst. **61**, 429–439 (2014)
7. Seyedtabaii, S.: Improvement in the performance of neural network-based power transmission line fault classifiers. IET Gener. Transm. Distrib. **6**(8), 731–737 (2012)
8. Reddy, J.M., Mohanta, D.K.: A wavelet-fuzzy combined approach for classification and location of transmission line faults. Electr. Power Energy Syst. **29**(9), 669–678 (2007)
9. Jung, C.K., Kim, K.H., Lee, J.B., Klockl, B.: Wavelet and neuro-fuzzy based fault location for combined transmission systems. Electr. Power Energy Syst. **29**(6), 445–454 (2007)
10. Moravej, Z., Pazoki, M., Khederzadeh, M.: New pattern-recognition method for fault analysis in transmission line with UPFC. IEEE Trans. Power Delivery **30**(3), 1231–1242 (2015)
11. Pan, S., Morris, T., Adhikari, U.: Classification of disturbances and cyber-attacks in power systems using heterogeneous time-synchronized data. IEEE Trans. Industr. Inf. **11**(3), 650–662 (2015)
12. Biswal, M.: Faulty phase selection for transmission line using integrated moving sum approach. IET Sci. Meas. Technol. **10**(7), 761–767 (2016)
13. Rosa, G., Costa, M.A.: Robust functional analysis for fault detection in power transmission lines. Appl. Math. Model. **40**(21–22), 9067–9078 (2016)