Available online at: https://ijact.in

Date of Submission	22/01/2019
Date of Acceptance	19/02/2019
Date of Publication	28/02/2019
Page numbers	3042-3046 (5 Pages)

ISSN:2320-0790

An International Journal of Advanced Computer Technology

WT AND ANN BASED SMART FAULT LOCATION FOR INTERCONNECTED POWER TRANSMISSION GRIDS

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Abstract: Transmission lines which carries bulk amount of power from generating units to the end users are more prone to fault, since they exposed to atmosphere. Thus the protections of transmission lines are vital in maintaining the continuity in services, and to reduce its impact on rest of the power system. Locating the fault in an interconnected power system is necessary to ensure good selectivity in the protection scheme. This paper proposes a smart approach for locating the fault in interconnected power transmission grids with the help of discrete wavelet transform (DWT) and artificial neural network (ANN), the combined use of WT and ANN ensures an adaptive and accurate scheme for locating the fault. The proposed algorithm is analyzed and validated on a nine bus system using MATLAB/Simulink software.

Keywords: Artificial Neural Network (ANN); Discrete Wavelet Transform (DWT); Wavelet Transform (WT).

I. Introduction

The transmission lines are pair of electrical conductors which carry plenty of power to the consumer premises from generating units. These transmission lines are more prone to small and large disturbances while carrying the power. There are various types of disturbances which may affect the transmission line but the chance of occurrence of these disturbances are different [1-2] .

Faults on transmission lines may cause serious power system problems. Locating the fault immediately after its occurrence is necessary for taking required protective actions. Smart approach in locating the fault is gaining interest now days, since it uses computational techniques for locating the fault. Various computational techniques like ANN, WT, Fourier transform (FT), fuzzy logic, genetic algorithm can be used for identifying the fault location [3].

WT is found good in many power system applications. In comparison with Fourier transform, WT can be used for the analysis of signal both in time and frequency domain. Fault location is one of such application of WT [4-5], which extracts the high frequency components during the transient condition for locating the fault effectively.

Artificial neural network is one of the substantial tool for prediction and parameter estimation purposes. Since the state of the power systems are changing dynamically, which can be easily adaptable by an ANN makes it superior for power system applications, especially in locating the fault[6].

It is difficult to discriminate internal and external faults in an inter-connected transmission line, thus locating the fault too [7]. This paper suggests a technique for locating the fault in an inter-connected transmission line, which sectionalize the grid into various areas. Firstly, the algorithm identifies the faulted area, secondly the faulted line in the identified area, and then the WT is used to

extract the high frequency components, and lastly the extracted features is given to an ANN for locating the fault. Thus it ensures an adaptive and accurate fault location scheme.
The rest of the paper is organized as follows. Section II explains about the model of the interconnected power grids. Section III demonstrates about problem formulation. ANN and WT based fault location algorithm is discussed in section IV. The simulation analysis of proposed algorithm are presented and discussed in section V. Finally, the paper is concluded in section VI.

II. MODEL OF THE INTERCONNECTED POWER GRIDS

The system considered for the study is a nine bus system with transmission lines of length 100km as shown in Fig. 1. Shunt faults such as LG, LLG, LL and LLL faults are considered for study, which are applied at different locations on transmission line. For an interconnected system it is difficult to identify the fault location because of the increased number of areas and lines. So for an inter-connected system, fault location algorithm need to identify the faulted area first, then the faulted line and using the idea of WT and ANN, the fault is located in the identified line.

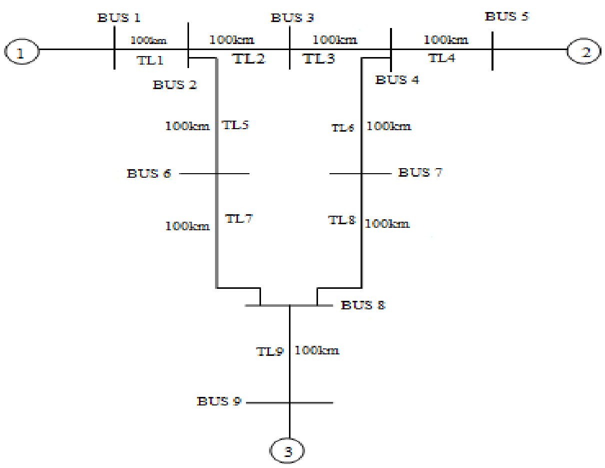

Fig. 1: System under study

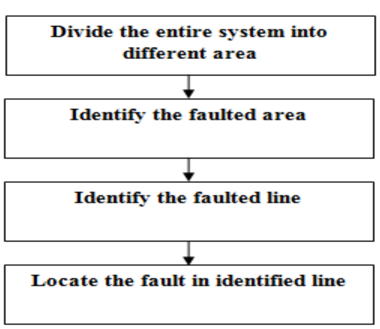

Fig. 2. Process flow of proposed fault location scheme

III. PROBLEM FORMULATION

The system considered for the study is a nine bus system. Here first identify the faulted area, then faulted line and next to locate the fault using WT and ANN.

Process flow of the proposed fault location scheme is shown in Fig. 2. In the proposed techniques each bus is represented as an area. Upon a fault the area close to the fault experiences the least voltage and it is identified as the faulted area. Then the lines connected to the faulted area need to be checked for maximum absolute value for the difference of the current angles measured from both ends of the transmission line, and it is identified as the faulted line.
After identifying the faulted line, the current signals measured from both ends of the faulted line is passed through a DWT to get the high frequency detailed signals. Here Daubechies wavelet (Db4) is used as the mother wavelet. Among the various decomposition levels, aggregations of fifth level detailed coefficients are extracted. Further, ANN is employed to locate the fault in the faulted line. The outputs of the WT were used as inputs to ANN and corresponding fault distance as output of ANN.

IV. WT AND ANN BASED FAULT LOCATION ALGORITHM

Main difficulty of locating the fault in an inter-connected transmission line is that it includes many areas and many transmission lines. So for such a system, faulted area is identified firstly, and secondly faulted line connected to that particular area is identified. Identification of faulted area and line is based on two components, positive sequence component of each phase voltage and positive sequence component of current angles measured at both ends of the transmission line[7]. When fault is occurred on a system, voltage at the bus gets reduced. So bus with minimum voltage indicates the nearest area to the fault. Mathematically it can be represented as (1)

$$|Vm| = Min\{|V1|, |V2| .... |Vn|\} \quad (1)$$

Where 1,2,….n indicates the area.

After the recognition of faulted area next step is to spotting the faulted line. Suppose nearest area to the fault is indicated by 'm'. From the absolute difference of current angles of all the lines connected to the faulted area and choose the maximum one. The line with maximum absolute current angle difference indicates the faulted line. Mathematically it can be represented as(2)

$$|\Delta\Phi mn| = Max\{|\Delta\Phi m1, |\Delta\Phi m2| ...., |\Delta\Phi mn|\} \quad (2)$$

where $|\Delta\Phi mn|$ is the absolute angular difference of positive sequence current angles for a transmission line connecting area "m" with area "n".

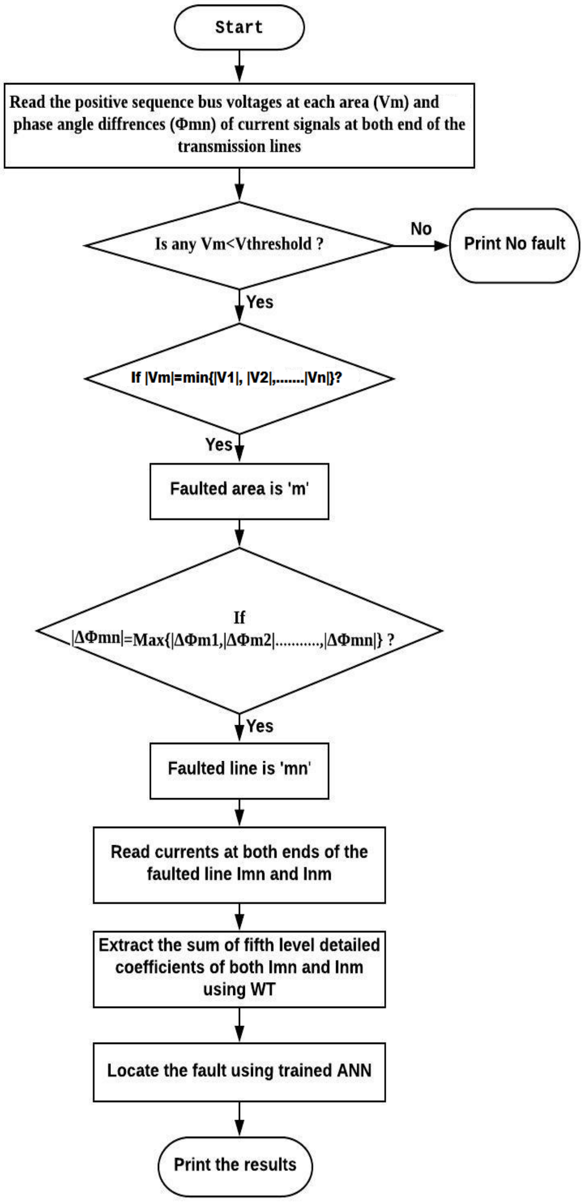

Fig. 3: Flow chart of fault location algorithm

$$|\Delta\Phi mn|=|\Phi mn-\Phi nm| \quad (3)$$

The current signals in each phase from both ends of the faulted line are given to the DWT filter for feature extraction [8]. Sum of fifth level detailed coefficients are chosen as feature. This extracted feature is given as the input to the trained neural network and it predicts the fault location. ANN is trained using the sum of fifth level detailed coefficients as input and target as fault location. The algorithm for the fault location is shown in Fig.3.

V. Smart Fault Location Using Proposed WT and ANN Based Algorithm

MATLAB/Simulink model of the system used for the analysis is shown in Fig. 4. Voltage is measured at each node and current is measured at both ends of the transmission lines. Identification of the faulted line and area is shown in Fig. 5.

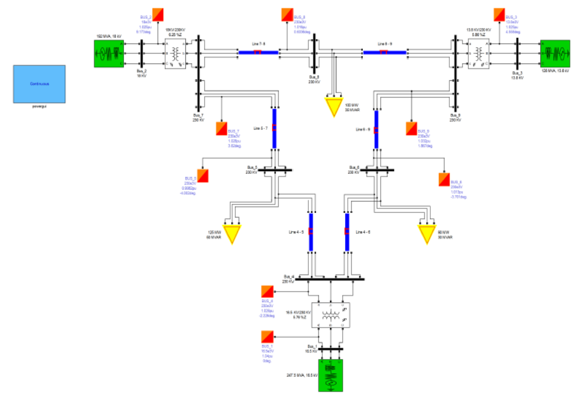

Fig. 4: MATLAB/Simulink model of the interconnected power grids

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Faulted area is @ Bus7
Faulted line is either TL6 / TL8
Faulted line is TL8
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Fig. 5: Identification of faulted area and line

Error histogram of the ANN for locating the fault is shown in Fig. 6. The blue line, green line and red line indicates the training, validation and test data respectively.

The linear regression plots for the training, validation and testing of the ANN used for locating the fault is shown in Fig.7. Dashed line represents the ideal results, which means that output and target are same. Solid line represents the best fit linear regression between output and target. Best validation performance graph is shown in Fig. 8 and it is clear that the mean squared error is very low in the order of 4e-4.

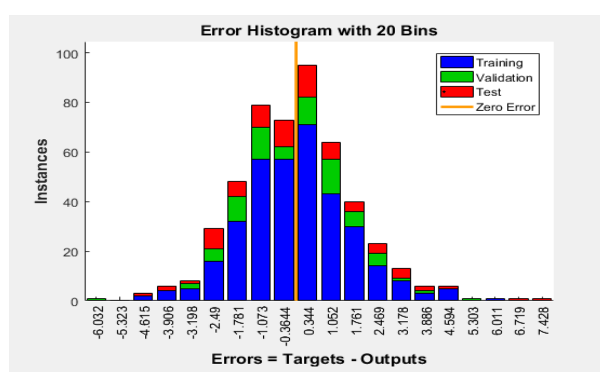

Fig. 6: Error Histogram

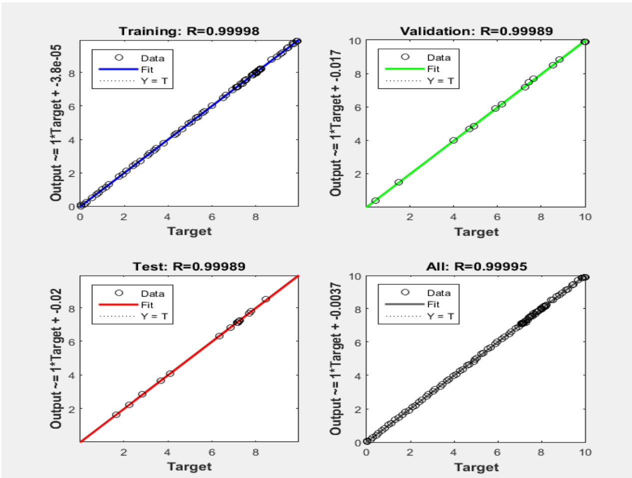

Fig. 7: Regression Plot

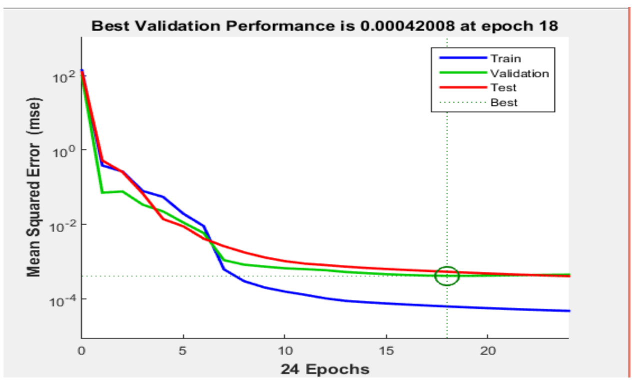

Fig. 8: Validation Plot

TABLE I
FAULT LOCATION FOR VARIOUS FAULTS IN TRANSMISSION LINE 8 FOR R_f= 0.001ohm

Type of Fault	Actual Fault Distance(km)	Fault distance estimated by ANN (km)	% error
AG	5	4.985	0.3
BG	10	9.962	0.38
CG	15	15.00268	-0.017
AB	20	20.0368	-0.184
AC	25	25.0987	-0.394
BC	30	30.158	-0.526
ABG	35	35.089	-0.254
ACG	40	40.032	-0.08
BCG	45	45.0035	-0.0077
ABC	50	50.058	-0.116

TABLE II
FAULT LOCATION FOR VARIOUS FAULTS IN TRANSMISSION LINE 8 FOR Rf= 1ohm

Type of Fault	Actual Fault Distance(km)	Fault distance estimated by ANN (km)	%error
AG	5	5.030	-0.602
BG	10	10.0065	-0.065
CG	15	15.125	-0.833
AB	20	19.985	0.075
AC	25	24.862	0.552
BC	30	30.0086	-0.0286
ABG	35	35.112	-0.32
ACG	40	40.035	-0.0875
BCG	45	45.0023	-0.00511
ABC	50	50.086	-0.172

TABLE III
FAULT LOCATION FOR VARIOUS FAULTS IN TRANSMISSION LINE 8 FOR R_f=10ohm

Type of Fault	Actual Fault Distance(km)	Fault distance estimated by ANN (km)	%error
AG	5	5.00265	-0.0083
BG	10	10.00698	-0.019
CG	15	14.9717	0.00708
AB	20	19.9625	0.0833
AC	25	24.9125	0.175
BC	30	30.128	-0.232
ABG	35	35.0169	-0.028
ACG	40	40.017	-0.026
BCG	45	44.9013	0.00141
ABC	50	51.00365	-1.33

The predicted fault distance using ANN for transmission line 8(TL8) at fault resistances Rf=0.001ohm, Rf=1ohm and Rf=10ohm are shown in Table I, Table II and Table III.

It is clear from the result that the ANN locates the fault with high accuracy and fastness. The proposed method holds true for wide range of fault resistances. From tables I, II, and III, it is clear that the worst case error is well within ±125m, and the fault is located within a time of milliseconds.

VI. CONCLUSION

WT and ANN based fault location scheme for interconnected power transmission grid is proposed here. Proposed method is effective in locating the fault for wide range of fault impedances. The proposed scheme is adaptive to dynamic changes in the power system and locates the fault with high accuracy. Thus the combined use of WT and ANN ensures an adaptive and accurate scheme for locating the fault.

APPENDIX

TRANSMISSION LINE PARAMETERS

PARAMETER	RATING
Positive sequence resistance	0.0298 ohms/km
Zero sequence Resistance	0.162 ohms/km
Positive sequence inductance	1.05e-3 H/km
Zero sequence inductance	3.44e-3 H/km
Positive sequence capacitance	12.79e-9 F/km
Zero sequence capacitance	7.75e-9 F/km

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