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DETECTION OF FAULTS IN TRANSMISSION SYSTEM BASED ON AI-APPROACH

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Abstract

The detection and placement of faults improves the reliability of the power system network. Wavelet Energy Entropy (WEE) of three phase currents as well as ground is used for fault detection and faulted phase selection by observing the magnitude of modulus of Wavelet Maxima (WMM) of the ground mode component of the modal transformation matrix and WMM of aerial mode component is used for identification of faulted phase and accurate fault point location for different types of fault. The Clarke Transformation was used to determine the position of the fault, which was then transformed into the Wavelet Transform (WT), from which the wave travelling time and fault spots were found to compute the distance of fault occurrence very accurately and thoroughly. Furthermore, several Artificial Neural Network (ANN) attempts are attempted to discover errors faster.

Keywords- Wavelet Transform, Faults, Artificial Neural Network, Fault location, Modal Transformation, Clarke Transformation

1. Introduction

The objective of fault detection and short circuited transmission line location has become a growing concern. In accordance with IEEE standard stdc37.114.2004 [IEEE], there are two basic approaches typically utilized for fault location. The first technique is based on frequency components, whereas the second way is based on high-frequency signal intrusion through a smaller sample window. In general, high frequency signal intrusion methods are dependent on the transmission system's impedance or travelling wave, which are propagated at light speed. The travelling wave is defined here as current signals for short circuit faults and voltage signals for open circuit faults, which are transformed into high frequency components utilizing WT by wavelets such as Daubecheis Wavelet, Sym Wavelet, and Haar Wavelet.

Clarke's transformation is used to these traveling signals to ensure consistency in aerial mode and ground mode components, emphasizing how simple it is to convert WT to different frequency numbers. The mode components are then compared with a digital circuit known as a comparator, which is characterized in technical terms with respect to the threshold component of the network's healthy signal.

The aforementioned scenario is run at all different fault states based on the effect duration in the network. Whatever comparison is satisfied in the WT is clearly indicated as a specific issue in the Power System. New approaches, such as RBNN [1], ANN [3] and back propagation neural network, are being developed. Transient current signals are used as input signals for the suggested approach. WT converts the three phase current signals that have been Clarke transformed into high frequency components. These WT's inputs and outputs are taken into account when training neural networks. This data is regarded as testing data for neural network knowledge transfer in the ANN approach [3].

The following is the structure of the paper: Basic principles in fault analysis are presented in Section 2, proposed algorithms in Section 3, problem formulation in Section 4, results and discussion in Section 5, and concluding remarks in Section 6.

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2. Basic Concepts in fault analysis

Faults in the power system network are commonly referred to as high-rated transients that occur with respect to voltage and current signals. In this study, fault detection is based on short circuit fault analysis, i.e. on network current signals.

2.1 Clarke Transformation [4]

Due to the influence of high electro-magnetic coupling within the conductors, the three phases overheaded line travelling waves do not have a constant propagation speed. A modal transformation is used to convert linked signals to decoupled signals in order to achieve a constant speed for these waves. For this procedure, several modal transformation matrices such as the Clarke transform, Wedepohl transform, and Karrenbauer transform can be utilized. Clarke's Transformation, for example, is used to simplify WT conversion.

Current signals in three phase fully transposed overhead line is converted as

$$\begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & -\frac{1}{2} \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \quad (1)$$

Here I_α , I_β are aerial mode components and I_0 is the ground mode component.

2.2 Wavelet Transform (WT) [5]

Wavelet Transform (WT) is the conversion of a non-stationary signal into basis-functions that contain both time and frequency information about the signal. This transform makes it simple to evaluate the transient behavior of a power system. The current signals are subjected to the Discrete Wavelet transform, which is stated as follows:

$$\mathbf{DWT\ (I, m, n)} = \frac{1}{\sqrt{a_0^m}} \sum I(k)\, \psi^* \left(\frac{n-ka_0^m}{a_0^m}\right) \quad (2)$$

Where, a_0^m and ka_0^m are the scaling and translational constant and ψ is the mother wavelet.

3. Proposed Method

The ANN programming technique can be used to accurately detect and classify faults and solve non-linear functions that are analogous to fault effects on networks. The output of ANN is trustworthy and very quick due to the training and knowledge transfer from the discrete wavelet transform components, and its operation is based on a series of relatively basic procedures.

The Clarke transform components of WT [6] components of different fault impedances responses of three phase currents and voltage signals are used in this training framework. In order to train the neural network and its relevant output components of WT, preferred current or voltage signals must be picked based on the type of defect.

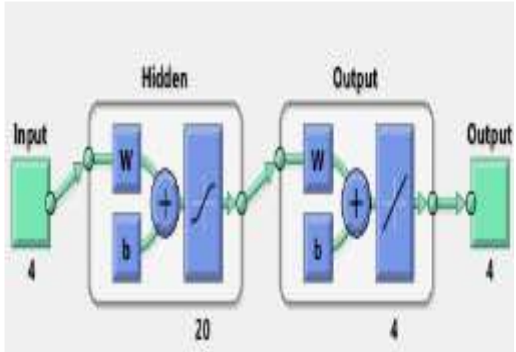

Figure 1: ANN architecture with sample representation

The final output of ANN will be digital logic, which will be expressed in binary format, i.e. 1's and 0's. The principles [7] for classifying faults based on comparator output are as follows:

Rule No:1 if (fa_2<fb_2) & (fa_2<fc_2) & GMWMM ≠ 0 A-G fault
Rule No:2 if (fb_2<fa_2) & (fb_2<fc_2) & GMWMM ≠ 0 B-G fault
Rule No:3 if (fc_2<fb_2) & (fc_2<fa_2) & GMWMM ≠ 0 C-G fault
Rule No:4 if (fa_2<fc_2) & (fb_2<fc_2) & GMWMM = 0 AB fault
Rule No:5 if (fb_2<fa_2) & (fc_2<fa_2) & GMWMM = 0 BC fault
Rule No:6 if (fa_2<fb_2) & (fc_2<fb_2) & GMWMM = 0 AC fault
Rule No:7 if (fb_2<fc_2) & (fa_2<fc_2) & GMWMM ≠ 0 AB-G fault
Rule No:8 if (fb_2<fa_2) & (fc_2<fa_2) & GMWMM ≠ 0 BC-G fault
Rule No:9 if (fc_2<fb_2) & (fa_2<fb_2) & GMWMM ≠ 0 AC-G fault
Rule No:10 else (rule 1 to 9) 3-phase fault

Table 1: ANN logic representation

Fault type	A	B	C	G
A-G	1	0	0	1
B-G	0	1	0	1
C-G	0	0	1	1
AB	1	1	0	0
BC	0	1	1	0
AC	1	0	1	0
AB-G	1	1	0	1
BC-G	0	1	1	1
AC-G	1	0	1	1
ABC-G	1	1	1	1

4. Problem formulation in fault location

The proposed scheme for determining fault location is explained. The fault period of occurrence is defined by the fault points, which are the start and end sites of faults. Assume the fault distance is 'x (kms)' and the fault frequency is 'ff' as determined by the wavelet transform component outputs. The fault location is depicted as follows because these waves travel at light speed (v = 3*10e5 km/s) in an overhead transmission line.:

$$x = v * \frac{dt_{f1}}{2} * (n_1 - n_2) \quad (3)$$

$$dt_{f1} = t_{02} - t_{01} \quad (4)$$

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$$\boldsymbol{x = v * \frac{1}{2*f_f} * (n_1 - n_2)} \quad (5)$$

$$\boldsymbol{X = L - x} \quad (6)$$

Where L is the total length of the transmission line, v is the speed of light, $\boldsymbol{n_1}$ is the fault discrete starting point, $\boldsymbol{n_2}$ is the fault discrete ending point, and $\boldsymbol{f_f}$ is the fault frequency.Equation (4) gives information about the fault location from the sending end side where as equation (5) gives fault location form the receiving end side of the network.

5. Simulation Results

The simulation is performed on an IEEE 3-bus and 6-bus transmission loop network, with the IEEE 3-bus transmission system rated parameters as basekv=220kv, BaseMVA=10MVA, operating frequency=50Hz, fault frequency=250Hz, fault starting points as 0.67ms duration in fault is 1.34ms, and 180 discrete samples of three phases. The 6-bus transmission system is rated at basekv=220, BaseMVA=100MVA.

Table 2: Sequence line data IEEE 3-bus transmission system

Node	Z_1 (pu)	Z_2 (pu)	Z_0 (pu)
1	0.0876i	0.0876i	0.0344i
2	0.0876i	0.0876i	0.0344i
3	0.2928i	0.2928i	0.6182i

Table 3: Sequence line data 6-bus transmission system

Node	Z_1 (pu)	Z_2 (pu)	Z_0 (pu)
1	0.02253+0.21503i	0.02253+0.21503i	0.36392+1.1134i
2	0.04422+0.38094i	0.04422+0.38094i	0.032i
3	0.16244+0.73912i	0.16244+0.73912i	3.75+5.92i
4	0.13269+0.57694i	0.13269+0.57694i	0.00756+0.2414i
5	0.16569+0.80649i	0.16569+0.80649i	2.82+3.872i
6	0.13034+0.61119i	0.13034+0.61119i	0.03849+0.0475i

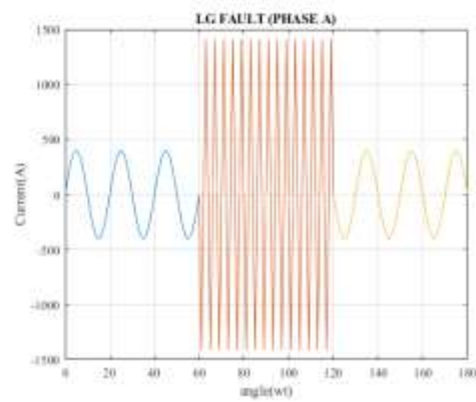

Figure 2: Unsymmetrical fault (LG fault) in IEEE 3-bus transmission system

The accompanying graph depicts the LG-phase (A) in the IEEE 3-bus transmission system, with discrete fault samples at [60,120] of fault current 1.207 kA, fault inception angle of 86.11 degrees (lagging), and fault placement at a distance of 290 kilometers from the SE (Sending End) and 594 kilometers from the RE (Receiving End).

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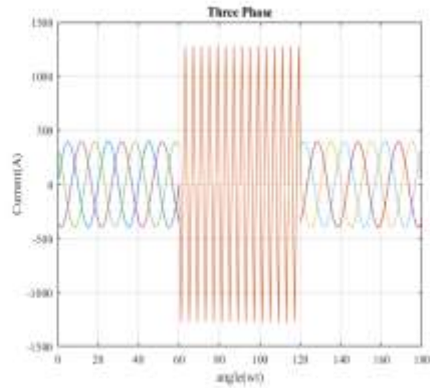

Figure 3: Symmetrical fault (LLLG fault) in IEEE 3-bus transmission system

The LLLG-phase (ABC) with discrete fault samples at [60,120] of fault current 1.292 kA with fault inception angle of 84.85 degrees (lagging) and fault placement at a distance of 290km from SE (Sending End) and 594km from RE (Receiving End) are depicted in the above graph for the IEEE 3-bus transmission system

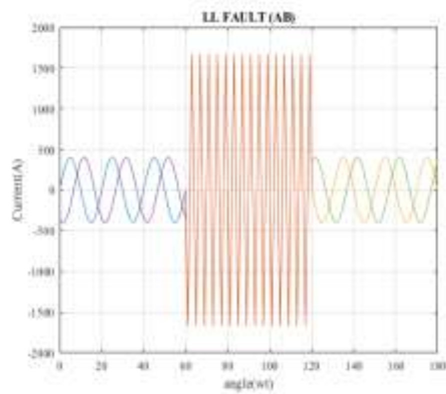

Figure 4: Unsymmetrical fault (LL fault) in IEEE 3-bus transmission system

The accompanying graph depicts the LL-phase (AB) in the IEEE 3-bus transmission system, with discrete fault samples at [60,120] of fault current 1.673 kA, fault inception angle of 180 degrees (lagging), and fault placement at a distance of 290 kilometers from the SE (Sending End) and 594 kilometers from the RE (Receiving End).

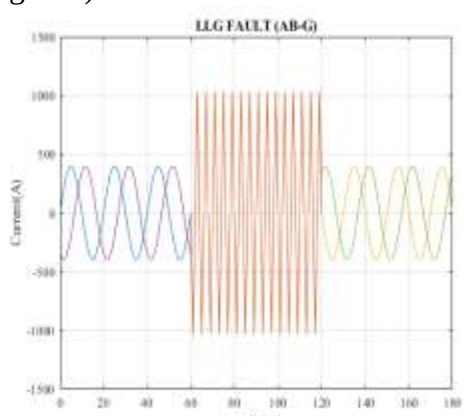

Figure 5: Unsymmetrical fault (LLG fault) in IEEE 3-bus transmission system

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The accompanying graph depicts the LLG-phase (AB-G) in the IEEE 3-bus transmission system, with discrete fault samples at [60,120] with fault current 1.03 kA, fault inception angle of 87.09 degrees (lagging), and fault placement at a distance of 290 kilometers from the SE (Sending End) and 594 kilometers from the RE (Receiving End).

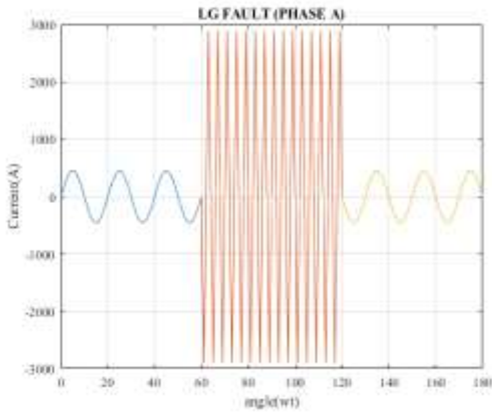

Figure 6: Unsymmetrical fault (LG fault) in 6-bus transmission system

The accompanying graph depicts the LG-phase (A) in the IEEE 6-bus transmission system with discrete fault samples at [60,120] with fault current 2.895 kA, fault inception angle of 59.05 degrees (lagging), and fault placement at a distance of 190 kilometers from the SE (Sending End) and 594 kilometers from the RE (Receiving End).

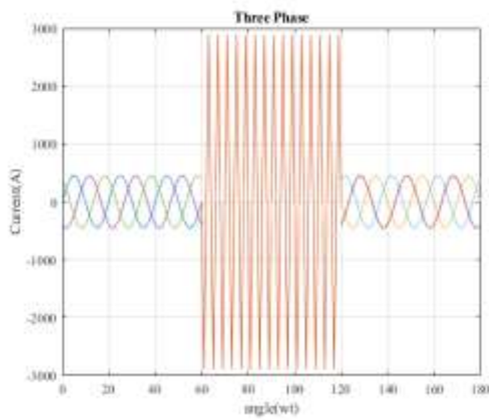

Figure 7: Symmetrical fault (LLLG fault) in 6-bus transmission system

The accompanying graph depicts the LLLG-phase (ABC) in the IEEE 6-bus transmission system, with discrete fault samples at [60,120] of fault current 2.895 kA, fault inception angle 63.65 degrees (lagging), and fault placement at a distance of 190 kilometers from the SE (Sending End) and 594 kilometers from the RE (Receiving End).

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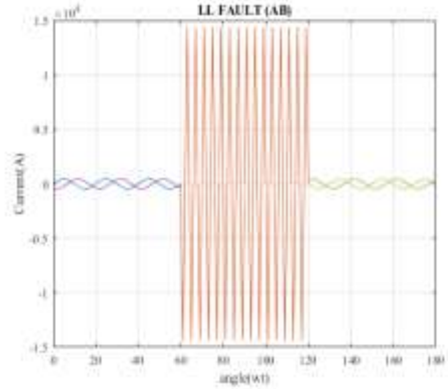

Figure 8: Unsymmetrical fault (LL fault) in 6-bus transmission system

The accompanying graph depicts the LL-phase (AB) in the IEEE 6-bus transmission system with discrete fault samples at [60,120] of fault current 14.37 kA and fault inception angle 167.60 degrees (lagging). The fault is located at a distance of 190 kilometres from the SE (Sending End) and 594 kilometres from the RE (Receiving End).

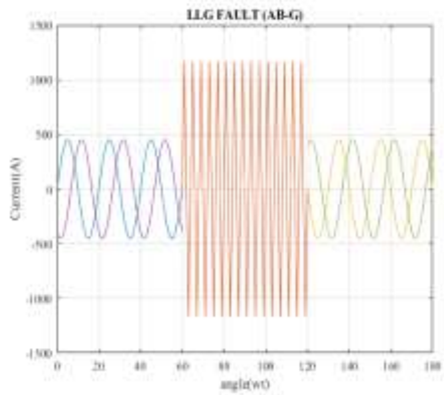

Figure 9: Unsymmetrical fault (LLG fault) in 6-bus transmission system

The accompanying graph depicts the LLG-phase (AB-G) in the IEEE 6-bus transmission system, with discrete fault samples at [60,120] of fault current 1.65 kA, fault inception angle 57.56 degrees (lagging), and fault placement at a distance of 190 kilometres from the SE (Sending End) and 594 kilometres from the RE (Receiving End).The aforementioned graphs illustrate how faults affect network currents and represent the various types of short circuit faults (LG, LL, LLG, and LLLG faults). The remaining phase faults are tested at random nodes throughout the network and are shown in the table below; take node 3 as an example. This node is compared to Wavelets case, RBNN [8], and ANN techniques in terms of computation speed and total iterations.

Table 4: IEEE 3-bus Transmission system output data of short circuit faults (Symmetrical faults and Unsymmetrical faults) at node-3

Fault type	Fault Current (kA)	Fault Inception angle(˚)	Fault location (kms)		Zf (pu)
			SE	RE	
AG	1.207	-86.1107			
BG	1.101	-206.110			
CG	1.101	-213.883			
ABCG	1.292	-84.8490			
AB	1.673	-180	290	545	0.03+0.04j

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BC	1.442	-60			
AC	1.442	-240			
ABG	1.033	-87.0979			
BCG	0.895	-327			
ACG	0.895	-207			

TABLE 5: Performance comparison between Wavelet (DB-4), RBNN & ANN

Methodology	Computation Time (secs)	Total number of iterations
Wavelets (Db-4)	5.493	-
RBNN	2.387	3
ANN	0.6551	63

TABLE 6: 6-bus Transmission system output data of short circuit faults (Symmetrical faults and Unsymmetrical faults) at node-3

Fault type	Fault Current (kA)	Fault Inception angle(˚)	Fault location (kms)		Zf (pu)
			SE	RE	
AG	2.895	-59.053	190	545	0.03+0.04j
BG	2.507	-179.05			
CG	2.507	119.053			
ABCG	2.895	-63.647			
AB	14.37	-167.60			
BC	12.44	-48			
AC	12.44	-288			
ABG	1.165	-57.565			
BCG	1.005	-298			
ACG	1.005	-178			

TABLE 7: Performance comparison between Wavelet (DB-4), RBNN & ANN

Methodology	Computation Time (secs)	Total number of iterations
Wavelets (Db-4)	5.943	-
RBNN	2.2846	3
ANN	0.786	63

From these testing methods, fault detection in the power system network at a specific location and classification can only be done using wavelets because it depends on the network's threshold constant [9], or rated parameter, whereas with AI techniques, training neural network (NN) [10] is a laborious task to make them independent of this threshold parameter. They are able to test faults using any network data without being dependent on the network's rated parameters.

5. Conclusion

On IEEE IEEE 3-bus and 6-bus transmission systems, the information on fault location is gathered using the ANN, RBNN, and wavelet method. The ANN technique is highly effective in detecting, analysing, and reliably classifying the different defects. Additionally, the test is run at various fault impedances to identify the fault type and fault inception angle in order to train the NN for evaluating the short circuit fault analysis.For accurate fault classification and fault site detection, ANN method rules over RBNN and wavelet analysis.

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