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ANN Based Fault Classifier and Fault Locator for Double Circuit Transmission Line

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Abstract— Accurate and fast fault detection, classification and location is very important from the service restoration and reliability point of view. However in case of double circuit transmission line due to mutual coupling effect this may result in poor discrimination between faulty and healthy line. This paper presents an artificial neural network based fault classifier and locator for double circuit transmission line. The neural network was trained by various sets of data available from simulation of model for different faults conditions. The obtained simulation result shows the proposed system works satisfactorily.

Keywords—Double circuit transmission line, artificial neural network, fault detection, fault classification, fault location.

I. INTRODUCTION

An overhead transmission line is one of the main components in every electric power system. The transmission line is exposed to the environment and the possibility of experiencing faults on the transmission line is generally higher than that on other main components. Line faults are the most common faults, they may be triggered by lightning strokes, trees may fall across lines, fog and salt spray on dirty insulators may cause the insulator strings to flash over, and ice and snow loadings may cause insulator strings to fail mechanically [1].

Fault classification, faulted phase selection and location play a critical role in the protection for a transmission line. Accurate and fast fault detection, classification and location under a variety of fault conditions are important requirements from the point of service restoration and reliability. Purposes of fault classification, faulted phase selection and location:-

1. Identifying the type of fault, e.g., single-phase to ground fault, phase-to-phase fault, etc. Therefore the relay can select different algorithm elements to deal with different fault situations.
2. Identifying the faulted-phase to satisfy single-pole tripping and auto reclosing requirements for operation.
3. Correct location of the fault distance, the maintenance crew can find and fix the problem to restore the service as quickly as possible. Rapid restoration of the service reduces outage time and loss of revenue [2].

The speed and accuracy of protective relay can be improved by accurate and fast detection and classification.
Methods of Fault Detection:

The high voltage transmission line fault detection may be classified into the following three methods:-
1 Circuit theory based method.
2 Traveling theory based method.
3 Intelligent systems.

1 Circuit theory based method:-

This is the conventional method. In this method fault detection is through the nodal voltage, the line currents and the impedance changes.

2 Travailing theory based method: -

This method identifies the fault using the return time of the pulse wave.

3 Intelligent systems: -

This method uses several approaches such as expert systems, fuzzy logic and artificial neural network.

Due to many possible causes of fault and the nonlinear operation of some power devices under various fault conditions, conventional methods may not be work satisfactory in some application particularly in the case of complex transmission line [3]. In this paper neural network based fault classification scheme is used.

II. ARTIFICIAL NEURAL NETWORK

A neural network is a massively parallel distributed processor that has a propensity for storing experiential knowledge and making it available for use. Artificial neural networks simulate the neural systems behavior by means of the interconnection of the basic processing units called neurons. Neurons are highly rated with each other by means of links. The neurons can receive external signals or signals coming from the other neurons affected by a factor called weight. The output of neuron is the result of applying a specific function, known as transfer function, to the sum of its inputs plus threshold value called bias. With these general characteristics it is able to develop different network structures. Basic processing model of ANN has neurons, synaptic weights, summing junction and activation function [4].

Below figure 1 a simple neuron model in which x1, x2 and x3 are the inputs and w1, w2 and w3 are corresponding weights respectively. The net input, y1 is the sum of the weighted inputs from x1, x2, and x3 and bias i.e.

$$y1 = w1x1+w2x2+w3x3+b$$

The net-input, y1 is passed to the activation function f to get the output y.

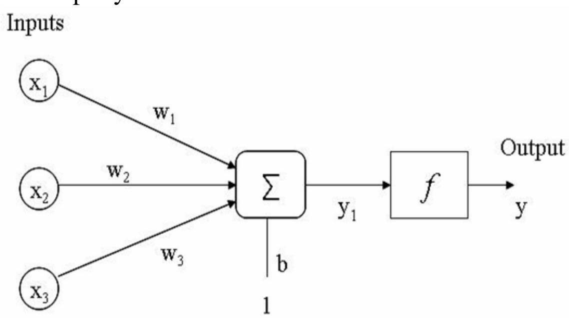

Figure 1. Simple Neuron Model

The net-input, y1 is passed to the activation function f to get the output y.

ANN has the ability to learn from examples. Once the network is trained, it is able to properly resolve the different situations that are different from those presented in the learning process. The weights of the network are adjusted automatically to get a particular target output for specific input. The neural networks can have several layers. Each neuron in one layer has direct connections with all others neurons in the next layer. There can be also hidden layers. By inserting hidden layers, increasing its size and number, the nonlinear model of system is developed. The multi layered feed forward network has the ability to handle complex and nonlinear input output relationship with hidden layers. In this method, the error can be propagated backwards. The idea of back propagation algorithm is to reduce errors until the ANN learns the training data. The training begins with the random weights and the goal is to adjust them so that the error will be minimal. The multilayered feed forward network has been chosen to process the prepared data obtained from simulation [5].

III. POWER SYSTEM UNDER CONSIDERATION

The system studied is composed of 100 kilometre 220KV double circuit line connected to source at each end. Short circuit capacity of the equivalent thevenin sources on two sides of the line is considered to be 1.25 GVA. Source to line impedance ratio is 0.5 and X/R is 10. The transmission line is simulated using pi section line model using MATLAB software [6]. The figure 2 shows the single line diagram of the simulated system.

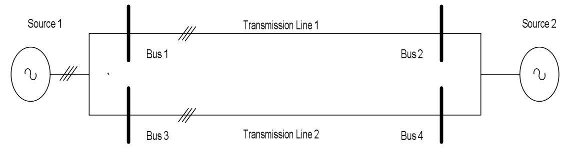

Figure 2. Single line diagram of the simulated system

The parameters for source 1 and 2 & three phase pi-section are given according to parameters give in Table 1.

Table 1. Parameters of source and line

Source Parameters	
Voltage	220 kV
Frequency	50 Hz
Phase angle	0, 15 degrees
Short circuit level	1250 MVA
X/R ratio	10
Transmission Line Parameters	
Positive and Zero sequence resistance	0.01809 and 0.2188 Ohms/km
Positive and Zero sequence inductance	0.00092974 and 0.0032829 H/km
Positive and Zero sequence capacitance	12.571 and 7.855 nf/km

Figure 3 shows the current waveforms when an ‘A1’-phase to earth fault occurs at 25 KM on transmission line 1 at 20 ms with fault resistance 0.001ohm.

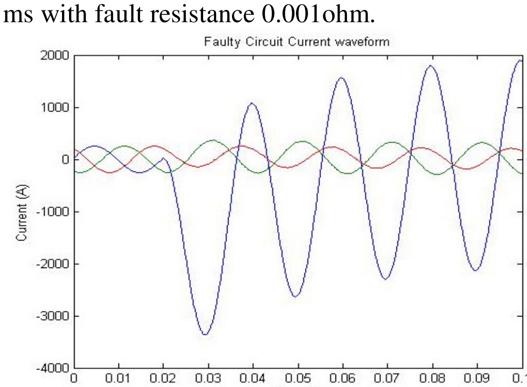

Figure 3. Current waveform of faulty line

As expected, a current is also induced in the 'A2'-phase of healthy line 2 due to the mutual coupling between the two circuits as shown in below figure 4.

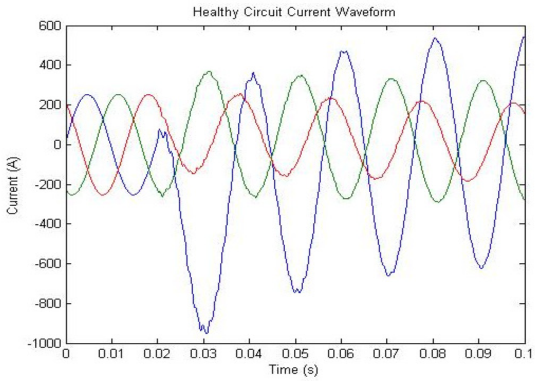

Figure 4. Current waveform of healthy line

As a consequence, the coupled phase on the healthy circuit may be wrongly diagnosed as being the faulted phase in case of conventional relay.

IV. PROPOSED ANN BASED FAULT CLASSIFIER AND FAULT LOCATOR.

The magnitude of current is used as input signals to ANN to detect the fault. The figure 5 shows the ANN proposed scheme for fault detection and classification.

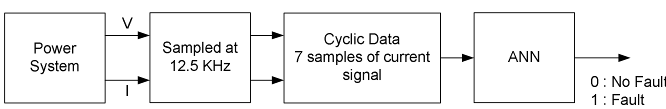

Figure 5. ANN based Fault Classifier

The power system model is simulated and the Current signals from the power systems are sampled at 12.5 KHz frequency. Then seven samples of current is taken and given as inputs to ANN which gives output either 1 or 0 indicating fault state or no fault state.
The figure 6 shows the ANN proposed scheme for fault locator.

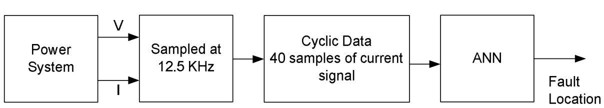

Figure 6. ANN based fault locator

The magnitude of current is used as input signals to ANN to classify the fault. Current signals from the power system are sampled at 12.5 KHz frequency and 40 samples are used.
The design process of the ANN based fault classifier and locator goes through the following steps:
1. Selection and computation of features that can potentially classify the input signals.
2. Preparation of a suitable training data set comprising of all possible cases that the ANN needs to learn.
3. Selection of a suitable ANN structure for a given application.
4. Construction of Target matrix.
5. Training the ANN.
6. Evaluation/validation of the trained ANN using test patterns to check its correctness in generalization.
Details of Fault Classifier:
a) The features used for fault detection are 7 readings of current values of all three phases. Hence the feature of one training sample will contain 7 X 3 = 21 values.
b) For the purpose of training 1244 signals are used for training. This gives us a 21 X 1244 sized vector matrix of features.
c) The ANN structure used is feed forward neural network with 21 input neurons, 25 Hidden Neurons and 2 output neurons. The input neurons are always equal to the number of features of a single signal. The hidden neuron is a value arrived at experimentally and more the number of neurons in the hidden layer, more is the variation in the input signal taken care of appropriately. The number of output layer neurons is equal to the number of classes (namely normal and faulty).
d) The Target matrix 2 X 1244 is constructed in the following way (2 rows to indicate normal and faulty signals and 1244 columns indicate total number of signals):
Set the first row (for normal type) 1 in column numbers (signal number) which signal vectors are normal.
Set the second row (for faulty type) 1 in column numbers (signal number) which signal vectors are faulty.
e) The network is thus trained with the training vectors and the target matrix for 100 epochs.
g) The trained network is tested on the training data and also on test data which is different from the training data. The current data of both the lines is tested one by one (i.e. 3 phases of line 1 and 3 phases of line 2 = Total 6 testings). Since the signal type (i.e. normal or faulty) is already known to us, we can compare the output of the neural network and actual expected output to get the accuracy. With this approach the neural network is evaluated. Matlab provides Sim function which takes two arguments namely the trained neural network and the feature vector of the test signal. Example of output is as follows:

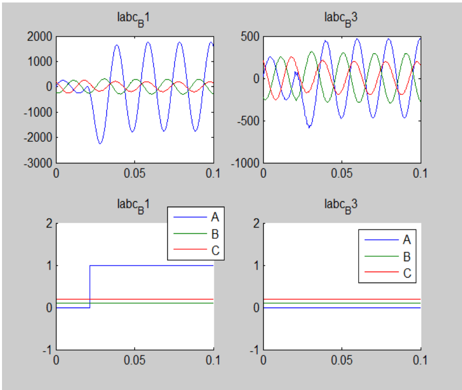

Figure 7. Output of fault classifier

Details of Fault Locator:

a) The features used for fault detection are 40 readings of current values of all three phases. Hence the feature of one training sample will contain 120 values.

b) For the purpose of training 99 signals (Signals for fault at 1Km, 2Km … 99Km) are used for training.

c) The ANN structure used is Feed Forward neural network with 120 input neurons, 25 Hidden Neurons and 1 output neurons. The input neurons is always equal to the number of features of a single signal. The hidden neurons is a value arrived at experimentally and more the number of neurons in the hidden layer, more is the variation in the input signal taken care of appropriately. The number of output layer neurons is equal to the number of classes (namely normal and faulty).

d) The Target matrix 1 X 99 is constructed

e) The network is thus trained with the training vectors and the target matrix for 100 epochs.

f) The trained network is tested on the training data and also on test data which is different from the training data. The current data of all the three phases is taken as input and tested. Since the distance of fault is already known to us, we can compare the output of the neural network and actual expected output to get the accuracy. With this approach the neural network is evaluated. Matlab provides Sim function which takes two arguments namely the trained neural network and the feature vector of the test signal.

The error in fault location is defined as

Error (km) = Actual distance of fault in transmission line - ANN fault locators output

Table 2 contains test results of fault locator i.e. the actual fault location, ANN output and error in location.

Table 2. Test results of fault locator

Fault Location (km)	ANN Output (km)	Error in Fault Location (km)
1	0.37726	0.62274
2	5.7033	-3.7033
3	2.3565	0.6435
4	3.4668	0.5332
5	4.4824	0.5176
6	5.5066	0.4934
7	6.3596	0.6404
8	7.5053	0.4947
9	8.5948	0.4052
10	9.5828	0.4172
11	10.676	0.324
12	11.683	0.317
13	12.627	0.373
14	13.616	0.384
15	14.599	0.401
16	15.574	0.426
17	16.583	0.417
18	17.582	0.418
19	18.591	0.409
20	19.584	0.416
21	20.578	0.422
22	21.479	0.521
23	22.587	0.413
24	23.661	0.339
25	24.659	0.341
26	25.637	0.363
27	26.636	0.364
28	27.654	0.346
29	28.672	0.328
30	29.711	0.289
31	30.608	0.392
32	31.741	0.259
33	32.66	0.34
34	33.932	0.068
35	34.793	0.207
36	35.817	0.183
37	36.837	0.163
38	37.852	0.148
39	38.867	0.133
40	39.883	0.117
41	40.904	0.096
42	41.909	0.091
43	42.92	0.08
44	43.931	0.069

45	44.922	0.078
46	45.957	0.043
47	46.966	0.034
48	47.98	0.02
49	48.987	0.013
50	49.994	0.006
51	51.018	-0.018
52	52.007	-0.007
53	53.012	-0.012
54	54.015	-0.015
55	55.018	-0.018
56	56.017	-0.017
57	57.016	-0.016
58	58.014	-0.014
59	59.01	-0.01
60	59.989	0.011
61	60.971	0.029
62	61.994	0.006
63	62.991	0.009
64	63.988	0.012
65	64.986	0.014
66	65.985	0.015
67	66.949	0.051
68	67.983	0.017
69	68.936	0.064
70	69.986	0.014
71	70.992	0.008
72	71.925	0.075
73	72.808	0.192
74	74.041	-0.041
75	75.219	-0.219
76	76.07	-0.07
77	77.083	-0.083
78	77.799	0.201
79	77.206	1.794
80	78.171	1.829
81	81.135	-0.135
82	82.08	-0.08
83	83.089	-0.089
84	84.191	-0.191
85	83.379	1.621
86	85.923	0.077
87	86.692	0.308
88	87.508	0.492
89	85.564	3.436
90	89.844	0.156
91	88.517	2.483
92	92.032	-0.032
93	92.897	0.103
94	93.752	0.248
95	76.784	18.216
96	95.813	0.187
97	96.752	0.248
98	234.23	-136.23
99	37.583	61.417

Test results of fault locator are also shown in below figure no.8.

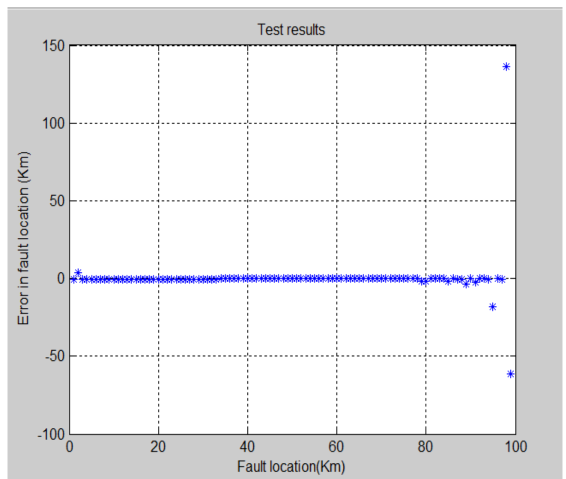

Figure 8. Test results of ANN fault locator for phase a to ground fault

V. CONCLUSION

An efficient neural network based relay for transmission line protection has been presented. The presented test results demonstrate the effectiveness of fault classifier and locator in EHV transmission line. The presented scheme offline and can be modified and implemented online.

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