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Six Phase Transmission Line Series Fault Locator using Artificial Neural Network

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Abstract— **This paper addresses to locate open conductor (series) fault distance location scheme in six phase transmission line using the Artificial Neural Network. Voltage and current signals fundamental components measured at relay location are used as input to train Artificial Neural Network (ANN). MATLAB® software its associated simulink® and simpowersystem® toolboxes have been used to simulate the six phase transmission line. A sample 138 kV system of 68 km length, the model of Allegheny power system has been selected for study. The effect of variation in fault inception angle and its distance location has been taken into account. The testing results show that maximum absolute error of proposed scheme is less than 1%. It validates the accuracy and suitability of proposed protection scheme.**

Keywords- Artificial Neural Networks, Fault Location, Six Phase Transmission Line.

I. INTRODUCTION

Power system consists of generators, transmission lines, distribution lines and transformers. Protection of these generators, transmission lines, distribution lines is very important for continuity of supply without interruption for business, industrial and residential usage. So transmission line protection is also very important issue to protect the electrical power system. Six phase line can be a possible alternative to increase transmission line capacity. When fault occurs in a transmission line, it is essential to find the location of fault as early as possible for quick system restoration and minimize the damage. Series faults are basically open conductor faults. During open conductor fault the power supplied to consumer will be distressed. So it is necessary to locate the series fault quickly.

II. SIX PHASE TRANSMISSION LINE

Due to harmonics effect and various other reasons six phase systems and six phase machines are not popular but six phase transmission lines are more popular due to its increased power transfer capacity, maintaining the same conductor configuration, better efficiency, better voltage regulations, greater stability and greater reliability [1].

The existing double circuit three phase transmission line can be successfully converted into a single circuit six phase transmission line [2].

In this paper, a simple ANN is used to develop the six phase open conductor faults which can occur in the six transmission line. ANN based technique have been reported for protection of single circuit and double circuit earlier. Faulted phase selection based on superimposed components is proposed in [6] and [7]. Faulty phase selection and distance location using neural network for single circuit transmission line has been reported in [8]. In companion paper [9] and [10], fault classification and fault distance location for single line to ground faults on double circuit transmission line using neural network has been reported respectively. From the extensive literature survey it has been found that the various protection technique based on ANN has been reported for protection of single circuit and double circuit transmission line for locating the fault but protection technique based on ANN for location of series faults i.e, open conductor fault has not been reported so far.

The algorithm employs the fundamental components of six phase voltages and six phase currents of line at one end only. The performance of proposed scheme has been investigated by number of offline tests. The simulation results show that the proposed ANN technique is able to locate the series fault after one cycle after the inception of fault.

III. POWER SYSTEM MODEL UNDER STUDY

The six phase transmission line studied is composed of 138 kV, 68 km length, connected to source at each end. Its single line diagram is shown in Fig. 1. Short circuit capacity of the sources on two sides of the line is considered to be 1.25GVA and X/R is 10. The transmission line is simulated using MATLAB®7.01. To create series fault in the line two three phase circuit breakers are used in between the line.

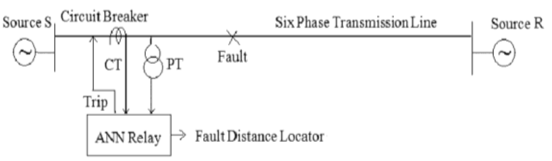

Fig. 1.Single line diagram of six phase transmission line under study.

IV. SERIES FAULT ANALYSIS

Fault can be detected by measuring the change in the parameters of power system. During fault condition the magnitude of voltage and current signals changes. In series fault magnitude of current is decreases to zero and voltage slightly changes. The change in voltage and current in six phase line is used to develop the ANN based fault locator for location of series fault in the line.

The change in the voltage waveform during pre-fault and post fault conditions are shown in Fig. 2 and Fig. 3

respectively.

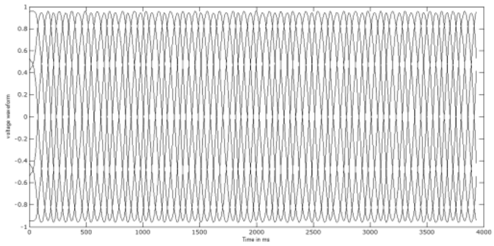

Fig. 2.Six phase voltage waveform in healthy condition.

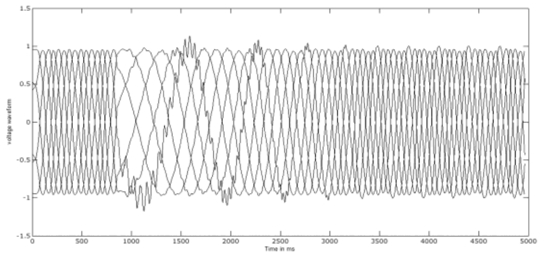

Fig. 3.Six phase voltage waveform in faulty condition

Similarly the change in current waveform during pre-fault and post fault conditions are shown in Fig. 4 and Fig. 5 respectively.

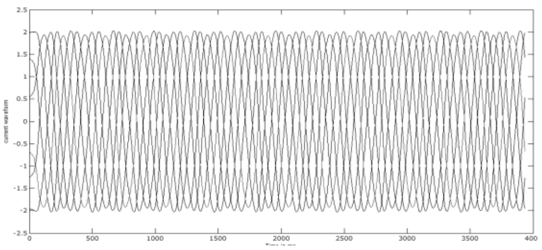

Fig. 4.Six phase current waveform in healthy condition.

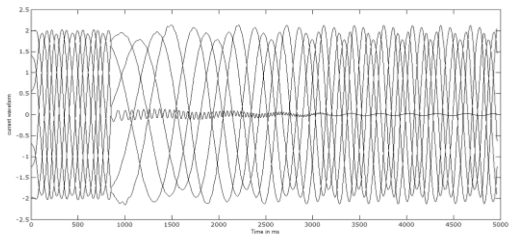

Fig. 5. Six phase current waveform in faulty condition.

It is clear from figures that after occurrence of the fault voltage and current in all the six phases are changing. The protection scheme based on those changes during pre-fault and post fault conditions.

The simulation result for six phase transmission line voltage and current waveform during one open conductor fault condition at 45 km from sending end with inception angle of 95 are shown in Fig. 3 and Fig. 5. Series fault types are shown in Table. I.

TABLE 1 SERIES FAULT TYPES

Series Fault Type	Total Number of combinations	Faulted Phases
1-open conductor	**6**	**A,B,C,D,E,F**
2-open conductor	**15**	**AB,AC,AD,AE,AF,BC,BD,BE,BF,CD,CE ,CF,DE,DF,EF**
3-open conductor	**20**	**ABC,ABD,ABE,ABF,ACD,ACE,ACF,AD E,ADF,AEF,BCD,BCE,BCF,BDE,BDF, BEF,CDE,CDF,CEF,DEF**
4-open conductor	**15**	**ABCD,ABCE,ABCF,ABDE,ABDF,ABEF ,ACDE,ACDF,ACEF,ADEF,BCDE,BCD F,BCEF,BDEF,CDEF**
5-open conductor	**6**	**ABCDE,ABCDF,ABCEF, ABDEF,ACDEF,BCDEF**
6-open conductor	**1**	**ABCDEF**

V. PREPROCESSING SIGNALS

After simulating the six phase transmission line model in MATLAB® software, low pass butter worth filter with cut of frequency of 480 Hz is used to restrict the bandwidth of signal for both six phase currents and voltages and further sampled at sample frequency of 1.2 KHz. Then the one full cycle discrete fourier transform was utilized to calculate the fundamental components of voltage and currents. The fundamental components of voltage and currents have been generated followed by normalization process by ±1. After pre- processing the value of six phase voltage and currents are fed as the input for ANN model [3].

VI. ARCHITECTURE OF ANN BASED FAULT LOCATOR

To enable the method to be implemented in fault location task only the fundamental component of voltage and current obtained from preprocessing signals are used as input to neural network. As the proposed ANN based protection scheme locates the fault in kilometer, in the output total number of neuron is one. Thus the input X and output Y for the fault locator are

$$X = [Va, Vb, Vc, Vd, Ve, Vf, Ia, Ib, Ic, Id, Ie, If]$$

$$Y = [Distance\ location]$$

VII. TRAINING OF ANN BASED FAULT LOCATOR

Using simulink® and simpowersystem® toolboxes of MATLAB® software open conductor faults type at different locations and fault inception angles 0º, 90º and 180º have been simulated. 3 fault inception angles and 9 fault locations were taken as shown in Table. II. In order to create input matrix to 5 post fault samples has taken from each combination. Some samples of no fault conditions have also been included in input matrix say around 25 samples. Therefore, total number of samples in input matrix for each series fault as shown in Table. II. All these are arranged in matrix as shown in Table. II. Input layer of ANN has 12 neurons. Therefore, the input matrix has 12 rows; corresponding target matrix has been prepared. As the output layer has one neuron. The target matrix consists of one row. Here input and output matrix columns are number of samples.

TABLE II Training Patterns Generation

Fault Type	Inception Angle	Distance (Km)	Number Of Combinations	Total Number Of Sequences
1-open conductor	0,90&180	1,10,20,30,40 ,50, 60,65	6*3*9= 162	162*5=810+ 25 =835
2-open conductor	0,90&180	1,5,10,20,30, 40,50, 60,65	15*3*9= 405	405*5=2025 +25=2050
3-open conductor	0,90&180	1,5,10,20,30, 40,50, 60,65	20*3*9= 540	540*5=2700 +25=2725
4-open conductor	0,90&180	1,5,10,20,30, 40,50, 60,65	15*3*9= 405	405*5=2025 +25=2050
5-open Conductor	0,90&180	1,5,10,20,30, 40,50, 60,65	6*3*9= 162	162*5=810+ 25=835
6-open Conductor	0,90&180	1,5,10,20,30, 40,50, 60,65	1*3*9= 27	27*5=135+2 5=160

The number of hidden layer neurons and transfer function for both hidden layer and output layer has varied. Tangent sigmoid transfer function for two hidden layers and output layer has been used for each open conductor fault are shown in Table. III.

TABLE III DURING TRAINING ANN TRANSFER FUNCTION IN EACH LAYER FOR EACH FAULT

Fault Type	Input Layer Transfer Function	First Hidden Layer Transfer Function	Second Hidden Layer Transfer Function	Output Layer Transfer Function
1-open conductor	None	Tansig	Tansig	Tansig
2-open conductor	None	Tansig	Tansig	Tansig
3-open conductor	None	Tansig	Tansig	Tansig
4-open conductor	None	Tansig	Tansig	Tansig
5-open conductor	None	Tansig	Tansig	Tansig
6-open Conductor	None	Tansig	Tansig	Tansig

Neural network was trained by Levenberg-Marquardt training algorithm. Finally, the best performance is obtained by two hidden layers with 5 neurons in the first hidden layer and 5 neurons in second hidden layer for 1-open conductor fault. Similarly, for each open conductor fault number of neurons for each layer is shown in Table. IV.

TABLE IV AFTER TRAINING ANN NEURONS IN EACH LAYER FOR EACH FAULT

Fault Type	Input Layer Neurons	First Hidden Layer Neurons	Second Hidden Layer Neurons	Output Layer Neurons
1-open conductor	12	5	5	1
2-open conductor	12	8	8	1
3-open conductor	12	8	9	1
4-open conductor	12	8	9	1
5-open Conductor	12	5	5	1
6-open Conductor	12	3	4	1

The overall structure of ANN based 1-open conductor fault distance locator is shown in Fig. 6.

The desired performance error goal was set to 1*e-5. This learning strategy converges quickly. And the mean square error decreases in 930 epochs to 9.81*e-6for 1-open conductor fault is shown in Fig. 7.

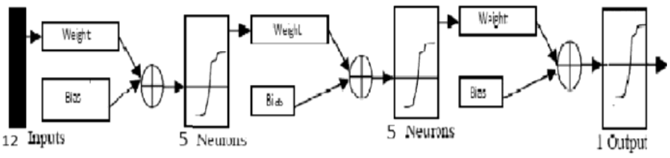

Fig. 6.ANN structure for 1-open conductor fault distance locator

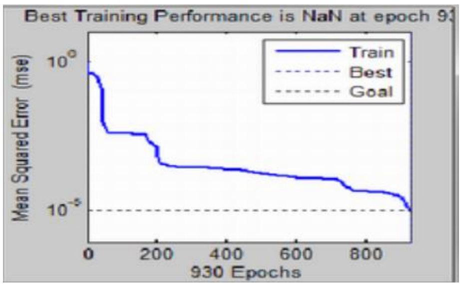

Fig. 7.Training of ANN for 1-open conductor fault

Neural network was trained by Levenberg-Marquardt training algorithm. The overall structure of ANN based 2-open conductor fault distance locator is shown in Fig. 8.

The mean square error decreases in 1280 epochs to 9.98*e-6 for 2-open conductor fault is shown in Fig. 9.

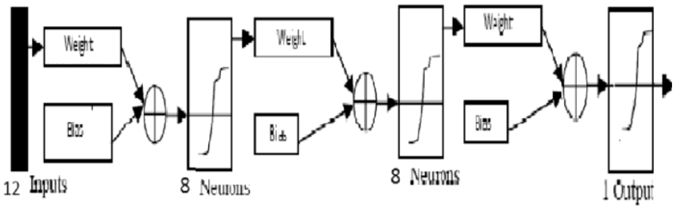

Fig. 8.ANN structure for 2-open conductor fault distance locator.

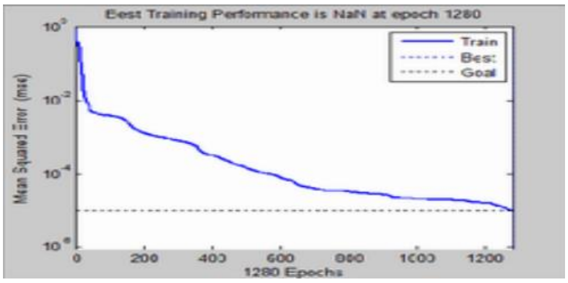

Fig. 9.Training of ANN for 2-open conductor fault.

Neural network was trained by Levenberg-Marquardt training algorithm. The overall structure of ANN based 3-open conductor fault distance locator is shown in Fig. 10.

The mean square error decreases in 845 epochs to9.89*e-6 for 3-open conductor fault is shown in Fig. 11.

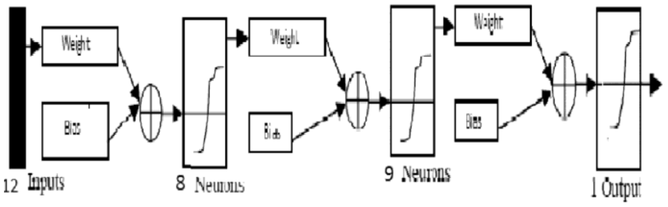

Fig. 10.ANN structure for 3-open conductor fault distance locator.

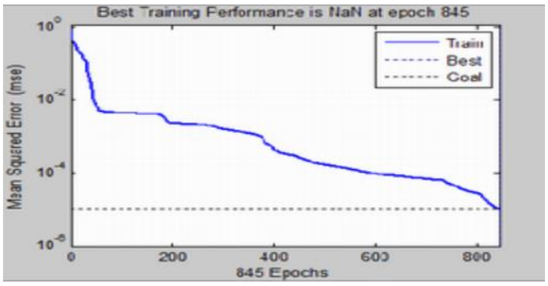

Fig. 11.Training of ANN for 3-open conductor fault.

Neural network was trained by Levenberg-Marquardt training algorithm. The overall structure of ANN based 4-open conductor fault distance locator is shown in Fig. 12.

The mean square error decreases in 492 epochs to 9.98*e-6 for 4-open conductor fault is shown in Fig. 13.

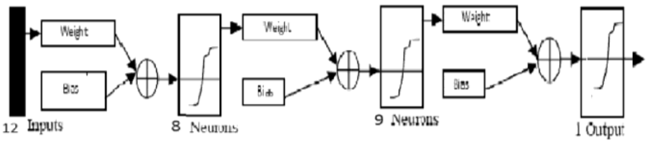

Fig. 12.ANN structure for 4-open conductor fault distance locator.

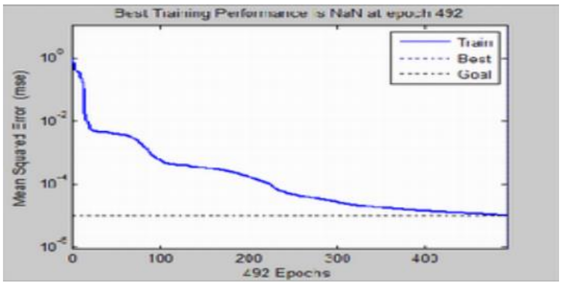

Fig. 13.Training of ANN for 4-open conductor fault.

Neural network was trained by Levenberg-Marquardt training algorithm. The overall structure of ANN based 5-open conductor fault distance locator is shown in Fig. 14.

The mean square error decreases in 342 epochs to 6.81*e-6 for 5-open conductor fault is shown in Fig. 15.

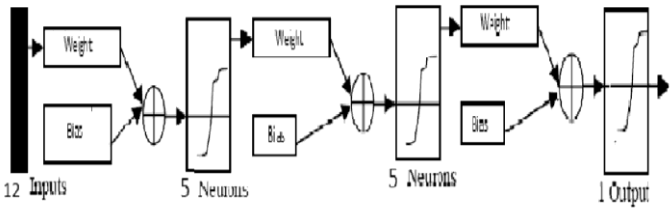

Fig. 14.ANN structure for 5-open conductor fault distance locator.

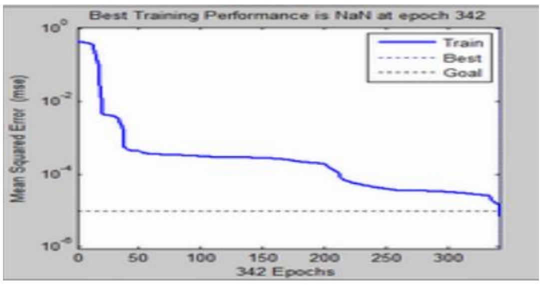

Fig. 15.Training of ANN for 5-open conductor fault.

Neural network was trained by Levenberg-Marquardt training algorithm. The overall structure of ANN based 6-open conductor fault distance locator is shown in Fig. 16.

The mean square error decreases in 302 epochs t 9.81*e-6 for 6-open conductor fault is shown in Fig. 17.

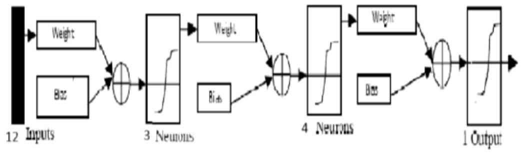

Fig. 16.ANN structure for 6-open conductor fault distance locator.

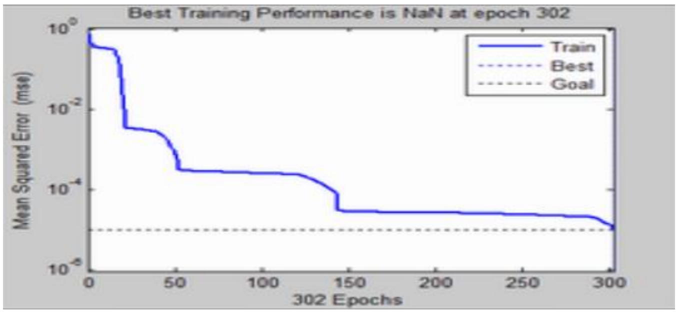

Fig. 17.Training of ANN for 6-open conductor fault.

TABLE V TRAINING RESULTS OF FAULT LOCATION FOR EACH FAULT

Fault Type	Number Of Epochs	Mean Square Error
1-openconductor	930	$9.81*e^{-7}$
2-openconductor	1240	$9.98*e^{-7}$
3-openconductor	845	$9.89*e^{-7}$
4-openconductor	492	$9.98*e^{-7}$
5-openconductor	342	$6.81*e^{-7}$
6-open conductor	302	$9.81*e^{-7}$

VIII. TEST RESULTS

After training it is required to test the network testing data are generated various fault parameters such as fault inception angle between 0º to 360º and fault location from 0 to 68 km for each open conductor fault type is shown in Table VI.

TABLE VI Test Result For Fault Location

Fault Type	Fault Inception angle (Deg°)	Actual fault location	Estimated fault location	Absolute Error(%)
A-open conductor	325	38	38.0237	0.033
B-open conductor	6	56	55.929	-0.104
C-open conductor	222	17	16.9354	-0.095
D-open conductor	98	31	31.0518	0.075
E-open conductor	49	51	50.9479	-0.077
F-open conductor	95	12	11.9504	-0.073
AB-open conductor	53	9	9.350	0.537
AC-open conductor	20	27	27.1149	0.1689
AD-open conductor	320	51	50.9371	-0.925
AE-open conductor	260	33	33.0869	0.1277
AF-open conductor	90	1	1.0245	0.036
BC-open conductor	75	58	57.9236	-0.1123
BD-open conductor	60	18	18.057	0.08382
BE-open conductor	280	4	3.6332	-0.5494
BF-open conductor	115	66	65.7763	-0.328
CE-open conductor	80	15	15.0559	0.0822
CD-open conductor	140	37	37.0761	0.111
CF-open conductor	80	49	48.9796	-0.03
DE-open conductor	130	28	28.1005	0.1477
DF-open conductor	25	9	9.3650	0.5367
EF-open conductor	40	11	11.1299	0.191
ABC-open conductor	115	27	27.0163	0.023
ABE-open conductor	50	39	39.1161	0.170
ABD-open conductor	10	27	27.6396	0.939
ABF-open conductor	95	32	31.7003	-0.441
ACD-open conductor	35	57	56.8718	-0.189
ACE-open conductor	90	1	0.7528	-0.364
ACF-open conductor	300	22	22.0553	0.080
ADE-open conductor	225	64	64.1075	0.107
ADF-open conductor	5	3	2.3343	-0.979
BCD-open conductor	260	16	16.0969	-0.141
BCE-open conductor	110	47	47.0567	0.082
BCF-open conductor	95	8	8.1326	0.194
BDE-open conductor	45	21	20.9750	-0.036
BDF-open conductor	75	61	61.079	0.116
CDE-open conductor	42	13	12.9062	-0.138
CDF-open conductor	120	35	34.9860	-0.020
DEF-open conductor	125	2	1.41954	-0.854
AEF-open conductor	84	18	17.9696	-0.045
CEF-open conductor	325	38	38.0237	0.033
BEF-open conductor	50	1	0.8046	-0.288
ABCD-open conductor	18	33	32.9609	-0.058
ABCE-open conductor	155	55	54.9884	-0.017
ABCF-open conductor	112	6	5.8776	-0.18
ABDE-open conductor	6	15	15.0107	0.014
ABDF-open conductor	120	59	59.021	0.030
ABEF-open conductor	12	3	2.3568	-0.945
ACDE-open conductor	3	38	38.0670	0.098
ACDF-open conductor	52	66	65.7709	-0.338
ACEF-open conductor	83	9	9.1799	0.263
ADEF-open conductor	75	24	24.0155	0.022
ABDF-open conductor	122	54	54.0665	0.097
BCDE-open conductor	6	13	13.0383	0.055
BCDF-open conductor	9	28	28.0138	0.020
BCEF-open conductor	110	43	43.0150	0.122
BDEF-open conductor	32	53	52.884	-0.17
ABCDE-open conductor	33	2	1.2924	-0.987
ABCDF-open conductor	22	14	13.9546	-0.067
ABCDF-open conductor	335	64	64.0778	0.113
ABCEF-open conductor	235	9	9.2082	0.305
ABDEF-open conductor	6	26	26.0025	0.003
ACDEF-open conductor	210	48	47.9939	-0.010
BCDEF-open conductor	65	6	6.1218	0.177
ABCDEF	89	28	28.0196	-0.027
ABCDEF-open conductor	6	56	55.929	-0.104

Testing of each open conductor fault is carried on each test samples. It is clear from the Table. VI the proposed network is locating entire open conductor fault correctly. The absolute error for fault location is expressed based on the equation.

$$Abosolute\ error = \frac{estimated\ fault\ location - actual\ \ fault\ location}{total\ line\ length} \times 100$$

It is clearly evident from the test results that the maximum absolute error of the proposed scheme is less than %1.

IX. CONCLUSION

An accurate algorithm for distance location of series fault i.e, open conductor fault on six phase transmission line fed from sources at both end is presented. The algorithm employs the fundamental components of six phase voltages and six phase currents of line at one end only. The algorithm locates the fault after one cycle after the inception of fault. The performance of proposed scheme has been investigated by number of offline tests. The results show valuable operation of proposed ANN fault locator in the estimation of fault location for each conductor fault and maximum absolute error of proposed scheme is less than %1.

REFERENCES

[1] M.W.Mustafa,M.R.Ahmad, “Transient stability analysis of power system with six phase converted transmission line,” in International power and Energy Conference, Putra Jaya., 2006, pp. 262-266.

[2] R. Shariatinasab,M. Akbari,M.A. Golkarand O. Shariat, “Distabance analysis in conversion double three phase to six phase transmission network,”in IEEE Conference,Bali,2011,pp.888–892.

[3] Anamika Jain ,A.S.Thoke and R.N. Patel “Double circuit transmission line fault location using artificial neural networks,” in IEEE Conference, Coimbatore., 2009, pp. 262-266.

[4] M. Tarafdar, Hagh K Ragi and H. Taghzadeh “Fault classification and location of power transmission lines using artificial neural networks,” in International Power Engineering Conference, 2007, pp. 1109-1114.

[5] A. J. Mazon, I. Zamora, J.Grasia, K.Sagastabeitia, P.Eguja,F.Jurado,andJ.R.Saenz “Fault location system on double circuit two terminal transmission lines based on ANNs,” in IEEEPorto Power Tech Conference, 2001, volume 3.

[6] D.W.P.Thomas,M.S.Jones, and C.Christopoulos “Phase selection on superimposed components,” in Proc. Inst. Elect. Eng.—Gener.,Transm. Distrib.,1996, vol. 143,pp.295-299.

[7] M.S.Jones,D.W.P.Thomas, and C.Christopoulos “A nonpilot Phase selector based on superimposed components for protection double circuit lines,” inIEEE Trans Power Del.,1997, vol.12, pp.1439-1444.

[8] A.Jain, V.S.Kale and A.S.Thoke. (2006, March). Application of artificialneural networks to transmission line faulty phase selection andfault distance location.Journal.[Online].volume (issue), pages. Available: https://www.actapress.com/Content_Of_Proceeding.aspx?ProceedingID=347

[9] Anamika Jain, A.S. Thoke and R. N. Patel. (2009, December.). Classification of Single line to ground faults on Double Circuit Transmission Line Using ANN. International Journal of Power and Energy conversion [Online].volume (2),pp. 109-125. Available:http://www.inderscience.com/info/inarticle.php?artid=37041

[10] Anamika Jain, A.S. Thoke and R. N. Patel. (2009, January.). Double Circuit Transmission Line Fault Location Using Artificial Neural Network. CSVTU Journal [Online].volume (2),pp.40-45. Available:http://www.ipedr.com/vol75/11_ICQM2014-024.pdf