ANN Based Fault Classification and Fault Location for Double Circuit Transmission Lines

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Abstract—**Fault classification and location is important in modern power systems to improve protection schemes, service reliability and reduce line outages. But in double-circuit lines it faces typical problems in fault location due to mutual coupling effect.. Although several methods are proven to be accurate in double-circuit line fault location, they suffer from certain situations like where there is lack of synchronization between the measuring ends, identification of type of fault, requirement of pre fault and post fault data, three phase faults etc. In order to overcome some of these difficulties, in this paper an Artificial neural network based algorithm is proposed by using Probabilistic Neural Network (PNN) for fault classification and Generalized Regression Neural Network (GRNN) for fault location. The proposed algorithm uses the fundamental current phasor magnitudes measured at both ends of double circuit to classify and locate the fault. A 200 km over head transmission line is simulated by using MATLAB/SIMULNK for all types of faults by varying fault location, fault resistance and fault inception angle to verify the proposed method.**

***Keywords*—Double circuit transmission line, fault location, fault classification, Artificial neural network (ANN), Probabilistic neural network (PNN), Generalized regression neural network (GRNN).**

I. INTRODUCTION

Transmission line is a structure used in electrical power systems to transmit electrical energy over along large distances. Based on tower structure and conductor design transmission lines can be designed as single circuit transmission line, double-circuit transmission line, multi terminal transmission lines. In modern power systems double-circuits are used where greater consistency and security is required. This double circuit lines enables the transfer of more electrical power with less cost. But running two circuits in parallel will cause mutual coupling between the conductors increases addition problems in protection schemes.

Fault location is a process aimed at locating the occurred fault with accuracy. Quick identification of faults in transmission lines is needed otherwise they can destroy the whole power system. The purpose of fault location is to improve service reliability, saves time and money for repair and reduce line outages and economic losses.

There are several methods for fault location in double circuit transmission lines such as impedance based methods[1]-[6],high frequency based methods [7],travelling wave method [8] and knowledge based methods[9]-[14]. Out of these the direct, simple, economical way of calculating the fault location is achieved by using the impedance based method. Recently an impedance based fault location algorithms for parallel lines which uses impedance parameters of a line to calculate the fault location are proposed in [1]. Yuan Liao et al in [2] used sparse current measurements from one or two branches but in this algorithm type of fault classification is required. Ning kang et al [3] proposed an algorithm by harnessing voltage measurements from one or more branches and uses synchronized voltage measurements using PMUs. Behnam Mahamedi et al. [4] proposed an impedance based fault location based on negative sequence voltage but this method does not hold good for three phase faults. V.S Kale in [7] uses a combination of neural network and wavelet transform consisting of time frequency analysis of fault generated transients. In [8], Bo Jiang proposed an improved fault line identification method based on initial process of zero sequence currents and voltage travelling waves. In [9] ANN structure is applied for fault classification and fault location in double-circuit transmission lines. The best structure is carried out by a software tool called SARENEUR. Anamika Jain in [10] discussed an algorithm to classify and locate the fault by using only single end data. Even though it is sensitive to remote in feed it is not applicable to all types of faults.In [11] a fault location method is developed for double circuit line using the Artificial Neural Networks (ANN) by utilizing the fundamental components of three phases current & voltage signals of both the circuits which are given as an input pattern to learn the hidden relationship.

In all the above mentioned methods there are some difficulties like need of synchronization measurements, classification of fault type, unavailability of pre fault and post fault data, some of them are unable to locate three phase faults etc. In order to overcome some of these difficulties an Artificial Neural Network is used to classify and locate the fault. For fault classification PNN (probabilistic neural network)is employed to classify the type of fault by using pattern recognition. PNN are a kind of radial bias network suitable for classification problems and for fault location GRNN (Generalized Regression Neural Network) is used. A GRNN approximates any arbitrary function between input and output vectors, drawing the function estimate directly from the training . A standard system of 200 km 400 kv double-circuit transmission line is taken and simulated by using MATLAB\SIMULINK and tested by the method in[4]. The results are found to be accurate.

This paper is organized as follows. Section I presents the introduction, section II of this paper describes the application of artificial neural network in power systems, section III discusses the proposed scheme. The numerical simulation results for double circuit transmission line using Artificial Neural Network and comparison with [4] is presented in Section IV. Finally, conclusions are drawn in Section V.

II. APPLICATION OF ARTIFICIAL NEURAL NETWORKS TO POWER SYSTEMS

Artificial neural networks are computational models inspired by biological neural networks and are used to approximate functions that are generally unknown. These belong to a family of non linear statistical models and learning algorithms.ANN is widely used in power systems because it is powerful in pattern recognition, classification, generalization and fault tolerance capability. ANN can be trained with off-line data. They have excellent features such as generalization capability, immune to noise and robustness. Recently most attracted areas implementing ANN are load forecasting, fault diagnosis/fault location, economic dispatch, security assessment and transient stability.

A. Probabilistic Neural Network (PNN)

B.

A Probabilistic neural network (PNN) is a feed forward neural network, which was derived from the Beyesian network and a statistical algorithm called kernel fisher discriminant analysis.PNN is a kind of radial bias network suitable for classification problems. PNN works based on conditional probability and probability density function. Architecture of probabilistic neural network is shown below.

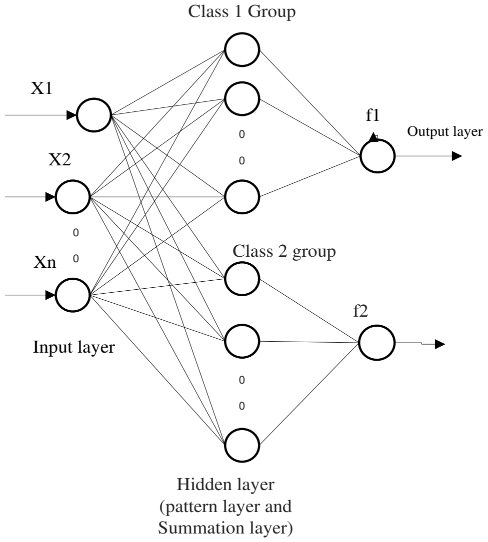

Fig. 1. General structure of PNN

A probabilistic neural network has three has three layers namely they are input layer, hidden layer and output layer. The figure below displays the architecture for a PNN that recognizes K = 2 classes, but it can be extended to any number K of classes. The input layer (on the left) contains N nodes: one for each of the N input features of a feature vector. Every input node is connected to the hidden layer so that each hidden node receives the complete input feature vector **x**. The hidden nodes are collected into groups: one group for each of the K classes.

Each hidden node in the group for Class k corresponds to a Gaussian function centered on its associated feature vector in the k^{th} class. All of the Gaussians in a class group feed their functional values to the same output layer node for that class, so there are K output nodes. The Gaussians function formulas are:

$$g_1(x)=[1/\sqrt{(2\prod\sigma^2)^N}]\exp\{-\|X-X^{(p)}\|^2/(2\sigma^2)\}$$

$$g_2(y)=[1/\sqrt{(2\prod\sigma^2)^N}]\exp\{-\|Y-Y^{(p)}\|^2/(2\sigma^2)\}$$

B.Generalized Regression Neural Network (GRNN)

A Generalized regression neural network is frequently used for function approximation. GRNN is also a radial bias neural network with small difference it is based on kernel regression network. A GRNN approximates any arbitrary function between input and output vectors, sketches the function approximation straightly from the training. It is not an iterative training process it is an approximation. If a GRNN is trained with a large number or sample data then the error should reduces to zero. Here GRNN is used to estimate the fault distance.

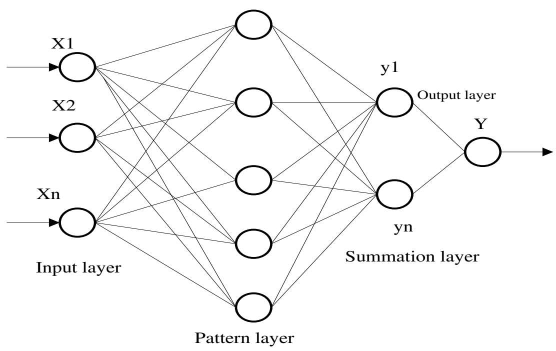

Fig. 2.General structure of GRNN

GRNN consists of four layers namely they are input layer, pattern layer, summation layer and output layer. The number of input units depends upon number of observation parameters. The input layer is connected to the pattern layer where training of data takes place and this pattern layer is linked to the summation layer. This summation layer has two units namely one is single division unit and the other one is summation units. The summation unit is connected to the output layer. Both summation and output layer together carry out normalization of output. In training each pattern layer is connected to two neurons in summation layer namely S and D. The neuron S in summation layer calculates the sum of weighted response of pattern layer. On other side the neuron D in summation layer computes the un-weighted outputs of pattern neurons. The output layer divides the output of each neuron S in summation layer to the output of neuron D in summation layer yields the value to the unknown input vector x as

$$Y' = \frac{\sum_{i=1}^{n} y.exp-D(x,xi)}{\sum_{i=0}^{n} exp-D(x,xi)}$$

$$D(x, xi) = \sum \{ (x_i - x_{ik}) / \sigma \}^2$$

III.PROPOSED METHOD

An ANN based fault location and classification for long transmission lines in power systems is developed in this section. Here for classification and location are found by using current phasors as inputs. The currents phasors in three phases at four bus bars are taken as total inputs and training is done by using the off line phasors for a large number of various fault conditions. The number of conditions increases the accuracy rate for fault location and classification.

A. Fault Classification

Fault type classification exhibits an important role in relay protection for transmission lines in power systems thus a robust and accurate algorithms are needed. so a new method is proposed and implemented here by using probabilistic neural network. The PNN inputs here are the magnitudes of three phase currents measured at both ends of line1 and line2. Thus there are twelve inputs for each line.

Input vector =[ia1,ib1,ic1,ia2,ib2,ic2,ia3,ib3,ic3,ia4,ib4,ic4]

In order to determine the type of fault pnn needs sufficient number of fault patterns to learn the problem. The pnn is trained by 1407 fault patterns by varying different fault locations, fault resistance and fault inception angles. Now according to the type of fault corresponding outputs are 1,2,3,4,5,6,7,8,9,and 10 for AG, BG, CG, AB, BC, CA, ABG, BCG, CAG and ABC faults respectively.
Outputs= [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]

Applying the above input and output data pattern to the PNN for training it is found that PNN classifies all types of faults in each circuit correctly.

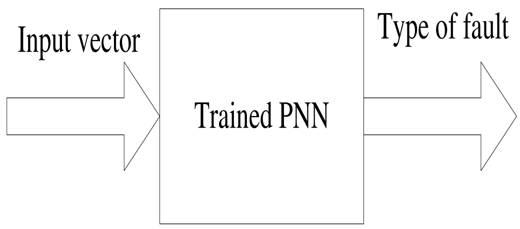

Fig. 3. Block diagram of PNN based fault classifier

B. Fault Location

It is extremely essential to locate the fault in transmission line to maintain efficient and trustworthy operation of power system so the proposed method is implemented to locate the occurred fault with accuracy by using generalized regression neural network GRNN.
The inputs for GRNN are the current magnitudes of both healthy and faulted line at two ends.

GRNN input=[ia1,ib1,ic1,ia2,ib2,ic2,ia3,ib3,ic3,ia4,ib4,ic4]
So total number of inputs are twelve. The grnn is trained for 1407 different fault location conditions and for training is done for every 3 km distance of total 200 km line length. Since an efficient training is providing here it must be able to locate the fault for nearer and farer distance also which will not be done in [4]. The output for the grnn is the fault location distance. The block diagram using grnn is shown below

Fig.4. Block diagram of GRNN based fault locator

The following flow chart gives an clear information regarding the fault location and fault classification with the help of Geeneralized Regression Neural Network (GRNN) and Probabilistic Neural Network (PNN). The architecture for ANN based fault classifier and fault locator is shown in the flowchart.

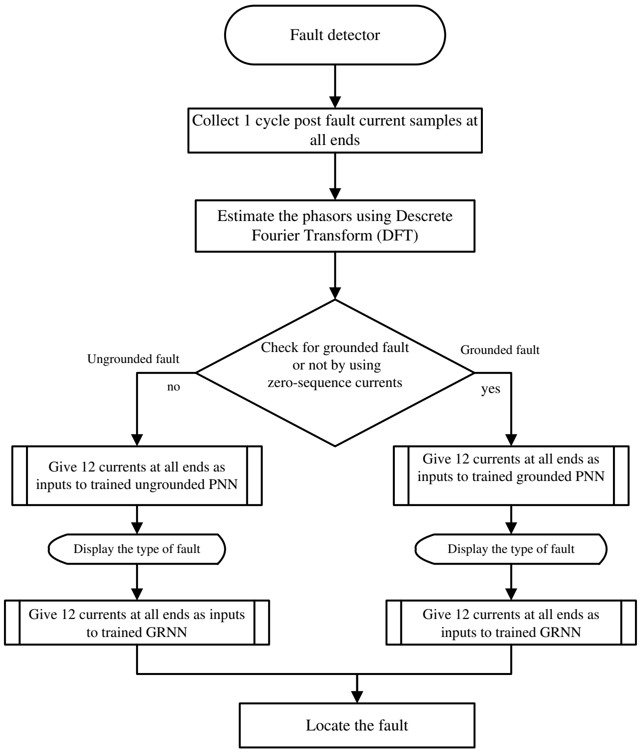

Fig.5. Flow chart for fault location in double circuit transmission line

When the input vector fed to the already trained GRNN network with different fault conditions then the function approximates an arbitrary function between input and output vectors and the distance location is achieved by function approximation straightly from the training.

IV. SIMULATION RESULTS

A double-circuit transmission system as shown in fig.6 is chosen for verifying the proposed fault location method. Simulation is done using MATLAB/SIMULINK and system parameters are provided in Appendix. A sampling frequency of 48 KHz is used for voltage and current signals.

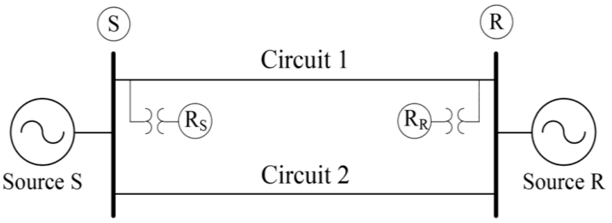

Fig. 6. Double circuit transmission network

The efficiency of the algorithm is tested by creating different fault conditions with varying fault types, fault resistances, fault inception angles and fault locations. The following representative cases indicate the accuracy of the proposed method and shows that it overcomes the disadvantage in
recent method proposed in [4].

a). Unsymmetrical fault (AG fault)

Consider a single line to ground fault (AGF) in line-2 at 100 kms from relay-S with a fault resistance of 0.01ohms and fault inception at 0.02 sec. The following figure (5) shows the voltage and current signals measured from relays during fault inception.

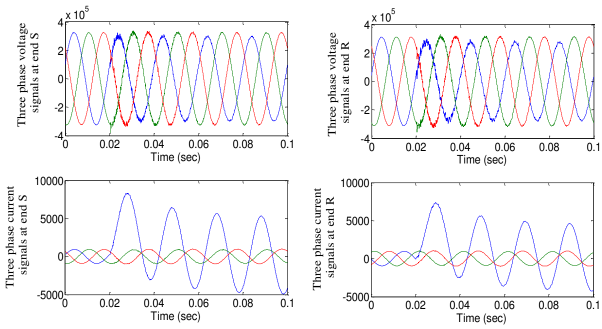

Fig.7. Three phase voltage and current signals measured at two ends for AG fault at 100 kms and fault inception time at 0.02 sec

Table-I shows the performance of the proposed method for several fault situations.

TABLE.I. FAULT LOCATION RESULTS FOR DIFFERENT FAULT SITUATIONS UNDER UNSYMMETRICAL FAULT

Type of fault	Actual distance (km)	Fault Resistance (Ω)	Inception angle (°)	Fault Location results for unsymmetrical fault with different fault conditions	
				Estimated distance	% Error
AG	10	0.01	0	10.2746	-2.745
		10	30	10.0752	-0.752
	80	0.01	90	80.5353	0.6691
		25.0	180	80.1979	0.2473
	150	0.01	30	149.832	0.112
		50.0	90	150.190	-0.1266
BCG	30	0.01	20	30.6363	2.121
		100	40	30.4160	1.386
	100	10	90	100.107	0.107
		50	120	100.199	0.199
	170	0.01	180	167.654	1.380
		50	30	169.634	0.2152
CA	20	5	30	20.3225	1.6125
		100	60	20.3958	1.9791
	70	0.001	90	70.7117	1.0167
		25	0	70.2402	0.3431
	130	0.01	180	129.759	0.1853
		50	60	129.915	0.0653

From the above table it is clear that accurate results are obtained using Generalized Regression Neural Network for unsymmetrical faults.

b) Symmetrical faults (ABC fault)

Consider a three phase fault (ABC) in line-2 at 100 kms from relay-S with a fault resistance of 0.01ohms and fault inception at 0.02sec. The following figure (6) shows the voltage and current signals measured from relays during fault inception.

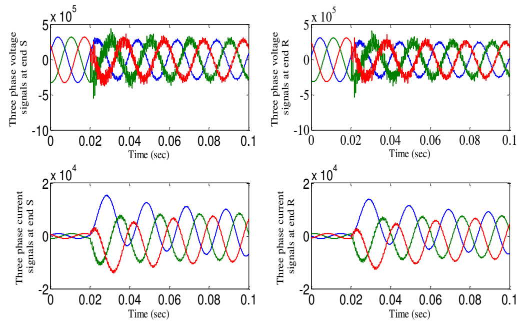

Fig. 8.Three phase voltage and current signals measured at both ends for ABC fault at 100 kms and fault inception time at 0.02 sec

In this the proposed method can locate fault very accurately with 0% error whereas method [4] locates fault distance with huge % errors. Table-II shows the performance of the proposed method for several fault situations when considering both unsymmetrical and symmetrical fault by comparing with method given in [4].

TABLE.II. COMPARISION OF FAULT LOCATION RESULTS FOR BOTH UNSYMMETRICAL AND SYMMETRICAL FAULTS

Type of fault	Actual distance (kms)	Fault Resistance (Ω)	Inception angle (^{0})	Method in [4]	% Error	Proposed Method	% Error
BG	40	0.01	0	37.93	5.71	39.90	0.25
		5	90	38.83	2.95	39.19	2.05
	120	20	180	119.6	0.33	121.3	1.08
		50	30	120.9	0.75	120.3	0.25
ABG	20	0.1	60	18.93	5.3	20.45	2.25
		50	120	19.05	4.7	19.86	0.7
	50	0.01	20	50.77	1.54	49.48	1.04
		25.0	110	50.80	1.6	49.64	0.72
BC	10	0.01	10	10.77	0.77	9.861	1.4
		25.0	170	9.113	8.8	9.772	2.2
	150	25.0	80	148.7	0.86	150.7	0.466
		50.0	160	148.8	0.8	149.3	0.46
ABC	20	0.01	30	27.39	36	20.00	0.02
		50	90	23.4	17	20.76	3.822
	120	50	90	142.3	18	120.0	0.004
		100	0	126.5	5.3	119.7	0.183

From the above results it can be observed that the method [4] (Fault location using negative-sequence voltage magnitude) , In case of symmetrical fault, method [4] is unable to locate the fault accurately and error percentage is drastically increased. In all case studies, the proposed method gives accurate location results for all types of faults with very less error percentage i.e. within 2%. This method claims to be capable of locating faults during unsymmetrical and symmetrical fault conditions.

V. CONCLUSION

Fault location becomes hard and complex in double circuit lines due to mutual coupling effect. Several techniques developed earlier to locate the fault in double-circuit transmission lines are still facing some drawbacks like need of synchronization , lack of availability of pre fault and post fault data etc. In this paper, an Artificial Neural Network based fault classification and fault location method is implemented for double-circuit transmission system. The proposed method utilizes current phasor -magnitudes from all ends of both the lines. The method gives exact results for different types of fault conditions. The proposed method is evaluated by comparing with the performance of a recent method. Simulation results in MATLAB environment indicate the accuracy and shows that it is capable of locating both symmetrical and unsymmetrical faults very accurately with less percentage error.

APENDIX

The parameter of the simulated system is as follows:

The positive-, negative- and zero-sequence impedance behind the relay R_S are

$Z_{1S}=Z_{2S}=0.32+j5.44\Omega$ and $Z_{0S}=0.8+j4.48\Omega$

The voltage source behind relay R_S is $V_S=400\angle 20°$ KV

The positive-, negative- and zero-sequence impedance behind the relay R_R are:

$Z_{1R}=Z_{2R}=0.48+j8.32\Omega$ and $Z_{OR}=3.68+j13.12\Omega$

The voltage source behind relay R_R is $V_R=380\angle 5°$ KV

The distributed parameters of double circuit transmission line are:

The positive-, negative- and zero-sequence impedances and capacitances are:

$Z_{1L}=Z_{2L}=0.0268+j0.3139\Omega$/km and $Z_{0L}=0.2102+j1.1657\Omega$/km

$C_{1L}=C_{2L}=11.662$ nF/km and the mutual coupling impedance and capacitance between the zero sequence circuit is as follows:

Z0M=0.1834+j0.7621Ω/km and C0M= -2.1088 nF/km

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