Neural Network and Fuzzy Logic Based Protection of Series Compensated Double Circuit Transmission line

Bhawna Nidhi, Ramesh Kumar, Amrita sinha
(Electrical Engineering Department, M.Tech. student, NIT Patna, India)
(Electrical Engineering Department, Associate Professor, NIT Patna, India)
(Electrical Engineering Department, Professor, NSIT Patna, India)

ABSTRACT

Main purpose of every relay is to detect and classify the fault and isolate the faulty part as soon as possible. Protective distance relays, which make use of impedance measurements in order to determine the presence and identification of faults, are not accurate to that extent after installed series capacitance on the line. In this proposed scheme, Neural network and Fuzzy logic are proposed for protection of series compensated double circuit transmission line. A Neural Network is used to estimate the actual power system condition that improves the protection system selectivity. Fuzzy logic is used for decision making that offers an appropriate tripping decision. The effect of series compensation, mutual zero-sequence coupling, remote infeed and fault resistance have been considered.

Keywords - mutual coupling, series compensation, adaptive protection, artificial neural network, fuzzy logic

I. INTRODUCTION

Now-a-days demand of reliable and smooth power supply is going to increase due to use of electronic devices in industries and in home appliances. To meet this high demand, power system has become more complicated so the protection has become challenging task for the engineers [1]. Fixed series compensation and parallel lines are the ways commonly used for better utilization of transmission system [2-3]. Such type of transmission system requires more advance security control to deliver smooth power supply.

Performance of the conventional digital distance relay is affected by the presence of zero sequence mutual coupling impedance between double circuit lines and also by the values of the fault resistance [4]. Series compensation along with its protective devices can undermine the effectiveness of many of the protection schemes used for long distance transmission lines [8-9]. In order to overcome the problems related to series compensation as well as parallel lines we need an adaptive and robust system.

Successful application of Adaptive Neural and fuzzy systems in electrical power system has demonstrated that this powerful tool can be employed as an alternative method for solving problems accurately and efficiently. The features of ANN such as ability to learn, generalize and robustness of fuzzy system are combined to make more efficient system. Several researches carried out for fault analysis of single circuit transmission line using ANN [5-7]. Srivani has given adaptive protection method for series compensated single line with double end fed [8]. However, in this paper effects of mutual coupling are missing. Pradhan has proposed a positive sequence directional relaying scheme for single line series compensated circuit but has not considered mutual coupling [9]. Thoke proposed protection method using ANN for double circuit transmission line but series compensation has not considered in his paper [10]. Kale and Gracia has also given the methods for double line protection without series compensation [7]. Makwana proposed method for protection of double circuit transmission line with series compensation by using symmetrical component theory [11].Parikh in his work used SVM for fault classification in series compensated line.[12]

In this paper an adaptive scheme using ANN and Fuzzy logic is proposed for protection of transmission line. Different faults are introduced in transmission line then pre-fault and post-fault data

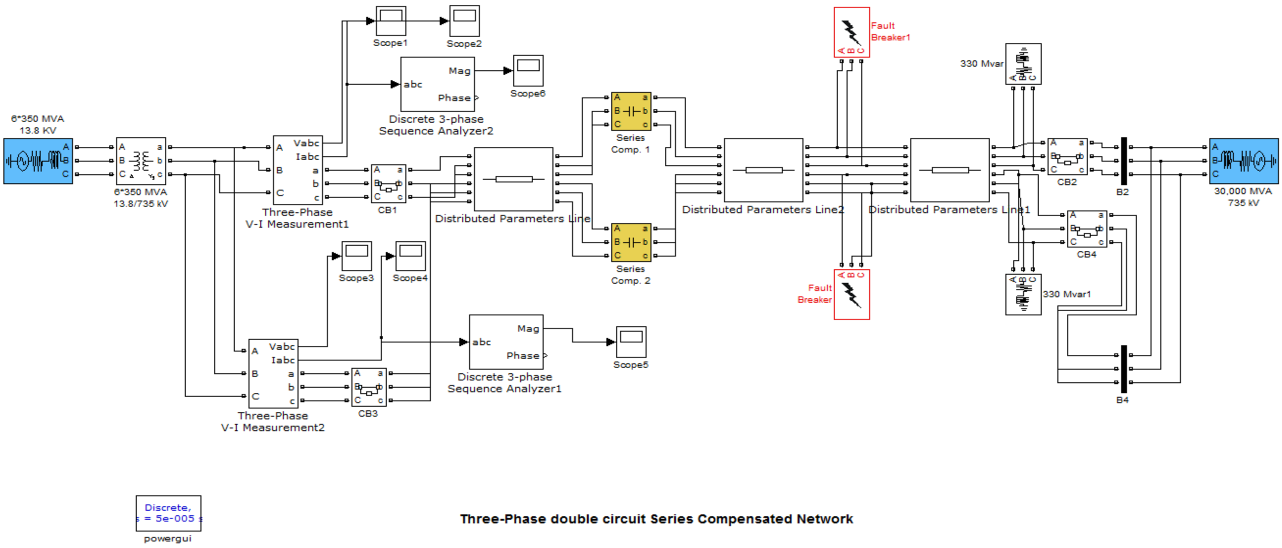


Fig-1 Simulated circuit of double circuit series compensated network

are collected for proposed method. The influence of the power system condition is summarized as given in the Table-2. Finally, the results of the application of concepts are presented in this paper.

The aim of this paper is in two fold. Firstly, it is shown that ANN compensates the actual power system condition as compensation level, fault resistances, inception angle, fault location, which influences the protection system. ANN is also capable of estimating the general power system condition by using local measurement. Secondly, fuzzy logic expresses complex system linguistically by using IF, THEN condition. Fuzzy logic system used to discriminate different types of faults and phase involved, so that make trip decision accurate. This method is robust and requires very less time in detection and classification of faults without using remote end data.

II. POWER SYSTEM NETWORK SIMULATION

A three-phase, 50 Hz, 735 kV power system transmitting power from a six 350 MVA generators to an equivalent network through a 300 km transmission line has been considered as shown in Fig-1. Both lines are series compensated indicate in block diagram. For each line, each phase of the series compensation module contains the series capacitor, a metal oxide varistor (MOV), protecting the capacitor, and a parallel gap protecting the MOV. When the energy dissipated in the MOV exceeds a threshold level of 30 MJ, the gap simulated by a circuit breaker is fired. Parameters of double circuit Transmission line are shown in Table- 1.The power system network simulation has been performed with MATLAB-SIMULINK.

Table1-Parameters of Parallel Transmission Line

Positive sequence resistance R1, Ω/KM	0.01809
Zero sequence resistance R0, Ω/KM	0.2188
Zero sequence mutual resistance , R0m Ω/KM	0.20052
Positive sequence inductance L1, H/KM	0.00092974
Zero sequence inductance L0, H/KM	0.0032829
Zero sequence mutual inductance, L0m, H/KM	0.0020802
Positive sequence capacitance C1, F/KM	1.2571e-008
Zero sequence capacitance C0, F/KM	7.8555e-009
Zero sequence mutual capacitance C0m, F/KM	-2.0444e-009
Length	300

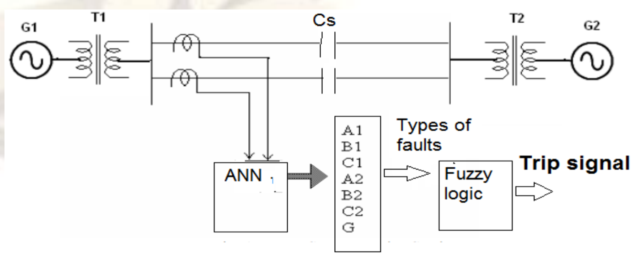


Fig 2 . Proposed protection scheme

Simulation Result

Typical examples of different types of simulated faults are shown in figure 3

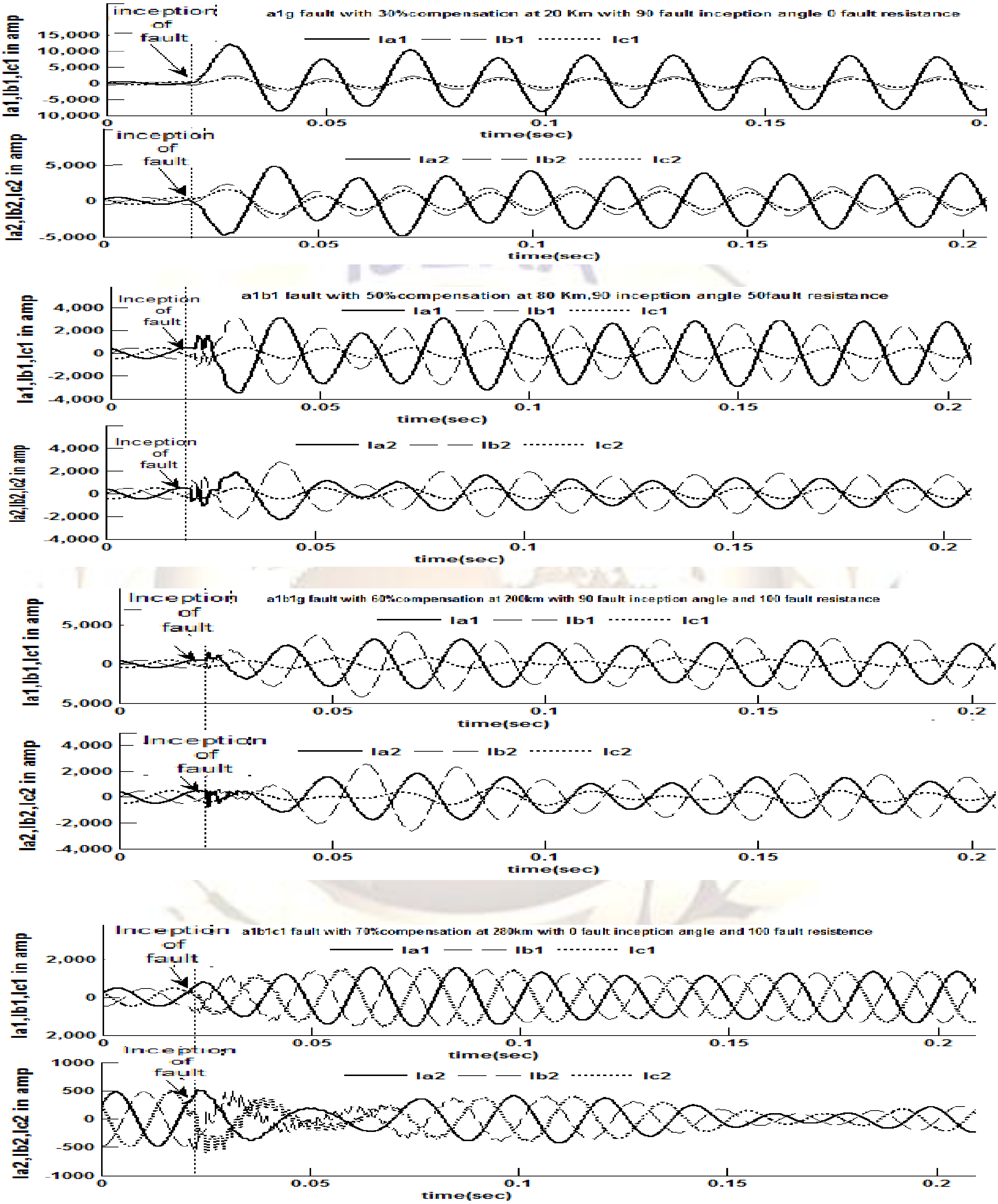


Figure3- Current Waveform Of Different Types Of Fault

III. RELAY MODELING BASED ON NEURAL NETWORK AND FUZZY LOGIC

Major functional blocks of proposed relay are shown in figure-4

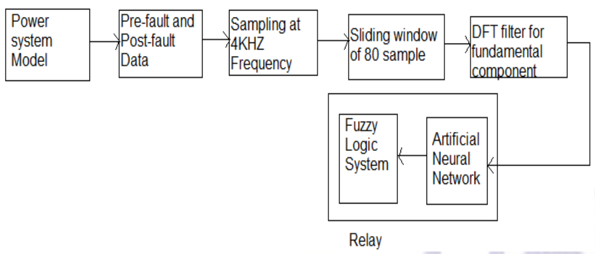


Fig-4.Process for Generating Input Patterns to the Relay

3.1 Neural Network Modelling

The Neural network model has designed to be used in distributed and learning based environment. The architecture provides learning from data and approximate reasoning.

3.1.1 Input Layer

The neurons of input layer represent the input variable. Here currents of six phases, the phase voltages and zero and negative sequence currents are given as input to the neural network. The current (I) and voltage (v) signals are processed so as to simulate a 4 kHz sampling process (80 samples per 50Hz cycle) .This sampling rate is compatible with sampling rates presently used in digital relays for protection process.

DFT is used for calculating the fundamental components of currents and voltages of different phases. Negative and zero sequence are calculated from sequence analyzer block of MATLAB toolbox.

Input X= [Ia1,Ib1,Ic1,Ia2,Ib2,Ic2,Ineg1,Izero1,Ineg2,Izero2, Va, Vb, Vc]

3.1.2 Output Layers

Output layer of ANN consist 7 neurons. Each output gives values corresponding to six phase of double line and ground.

Output Y= [A1, B1, C1, A2, B2, C2, G]

3.1.3 Training set

Training set of neural network has to accurately represent the problem. For Preparing the training set that represents cases the ANN needs to learn pre fault and post fault data are processed. These data are generated by varying different parameter of power system. Parameters that are vary during data collection are shown in table-2

Table 2 Pattern Generation

SL NO	PARAMETER	SET VALUE
1	% of compensation	30,40,50,60,70
2	Fault Location(KM)	20,40,80,120,200,240,280
3	Fault Inception angle	0 & 90 deg
4	Fault Resistance	0,50 and 100 ohm
5	Fault type	a1g,a2g,b1g,b2g,c1g,c2g,a1b1,a2b2,a1c1,a2c2,b1c1,b2c2,a1b1g,a2b2g,a1c1g,a2c2g,b2c2g,b1c1g,a1b1c1,a2b2c2

Total 3520 samples including no fault data has been used for training for ANN.10 % of data is used for testing which chosen arbitrary and remaining 90% used for training

The fully connected three-layer feed-forward neural network (FFNN) was used to classify faulty/non-faulty data sets and the error back-propagation algorithm was used for training. One hidden layer was found to be adequate for the fault classification application. Hyperbolic tangent function was used as the activation function of the hidden layer neurons. Pure linear function was used for the output layer. Training is done with Back Propagation algorithm and Levenberg-Marquardt (LM) algorithm.

The input layer simply transfers the input vector x, to the hidden neurons. The outputs u_j of the hidden layer with the sigmoid activation function and transferred to the output layer, which is composed of seven neurons. The output value of the neuron in the output layer with the linear activation function gives the phase of the transmission line in which fault occur1 (the presence of a fault) or 0 (the non-faulty situation). After training, the neural fault detector was tested with 90 new fault conditions and different power system data for each type of fault are given in Table 3-4.

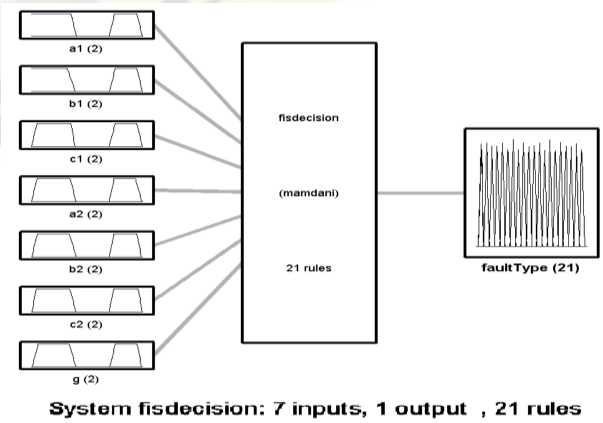


Figure-4 Fuzzy System

Table- 3:.Change In Fault Location (Km)
Inception Angle 0, Compensation 60%, Fault Resistance=0

output	Fault=a1g			fault=ab1		
	D=20	D=200	D=280	D=20	D=200	D=280
a1	0.999	0.987	0.92	0.999	0.9962	0.9961
b1	2.0e-04	0.0093	0.031	0.999	0.9999	0.99
c1	0.0034	3.4e-04	0.00	0.026	6.4e-05	3.2e-05.
a2	0.0261	0.0052	0.016	0.000	1.1e-05	0.0086
b2	0.0167	0.002	0.007	0.000	0.0087	0.027
c2	0.0423	0.0186	0.00	3.7e-06	0.0326	2.1e-04
g	0.989	0.999	0.934	1.0e-05	0.0032	.0034

Table-4: Change In Level Of Compensation
Inception angle=0, Distance=20Km, fault resistance=0

Output	**Fault=a2g**			**Fault=ac2g**		
	30%	**50%**	**70%**	**30%**	**50%**	**70%**
a1	0.024	0.117	0.200	1.10e-05	0.000	0.098
b1	0.144	0.007	0.020	0.005	5.59e-06	0.026
c1	0.077	0.006	0.167	6.48e-05	0.000	0.413
a2	0.972	0.950	0.742	0.996	0.997	0.716
b2	0.000	0.427	0.081	0.008	0.019	0.134
c2	0.004	0.070	0.017	0.832	0.981	0.80
G	0.997	0.791	0.957	0.999	0.794	0.977

3.2 Fuzzy logic based Decision making Module

Fuzzy logic Module has been designed to translate the linguistic variable into symbolic terms. The behavior of such systems is described through a set of fuzzy rules, like:

IF <premise> THEN <consequent>

That uses linguistics variables with symbolic terms. Each term represents a fuzzy set. The terms of the input space (typically 5-7 for each linguistic variable) compose the fuzzy partition.

The output of ANN has been used as input variable to the Fuzzy system. The seven output nodes of ANN module are converted into fuzzy variables. The numerical output data of ANN has been represented as linguistic variable low and high. The output of fuzzy logic module has been defined by linguistic variable as normal and types of faults in series compensated double line as shown in table- 5.The trapezoidal membership function is used for input and triangular for output.

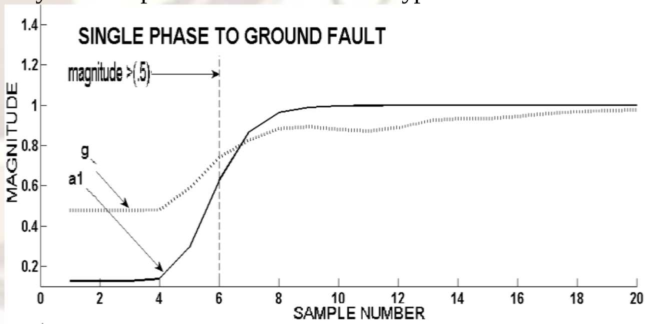
While the output data from Fuzzy unit are:

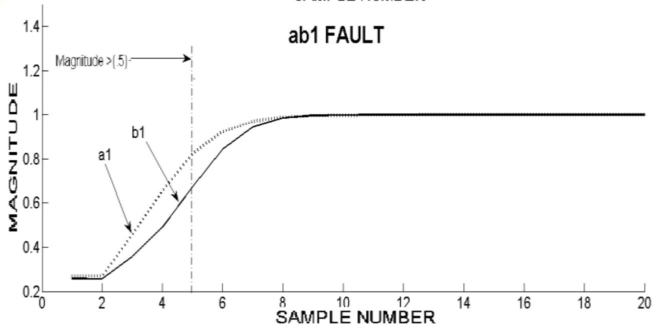
- \- 1 ≤ output <0.5 for no fault (**No Trip)**
- 0.5≤ output <1.5 for a1g fault (**Trip line one)**
- 15≤ output < 2.5 for b1g fault (**Trip line one)**
- 2.5≤ output <3.5 for c1gfault (**Trip line one)**
- 3.5≤ output < 4.5 for ab1fault (**Trip line one)**
- 4.5≤ output <5.5 for ac1fault (**Trip line one)**
- 5.5≤ output < 6.5 for bc1fault (**Trip line one)**
- 65≤ output <7.5 for ab1g fault (**Trip line one)**
- 75≤ output < 8.5 for ac1g fault (**Trip line one)**
- 85≤ output <9.5 for bc1g fault (**Trip line one)**
- 9.5≤ output<10.5 for abc1 fault (**Trip line one)**
- 10.5≤output<11.5for a2g fault (**Trip line Two)**
- 11.5≤output<12.5 for b2gfault (**Trip line Two)**
- 12.5≤ output <13.5 for c2g fault (**Trip line Two)**
- 13.5≤ output < 14.5 for ab2 fault (**Trip line Two)**
- 14.5≤ output <15.5 for ac2 fault (**Trip line Two)**
- 15.5≤ output <16.5 for bc2 fault (**Trip line Two)**
- 16.5≤ output<17.5 for ab2g fault (**Trip line Two)**
- 17.5≤ output<18.5 for ac2g fault (**Trip line Two)**
- 18.5≤ output<19.5 for bc2g fault (**Trip line Two)**
- 19.5≤ output<20.5forabc2 fault (**Trip line Two)**

IV. ANALYSIS OF RESULT

4.1 Speed of proposed scheme

This system provides very high speed in detection and classification of different types of fault. It takes only 6-9 sample of fault to detect its types.





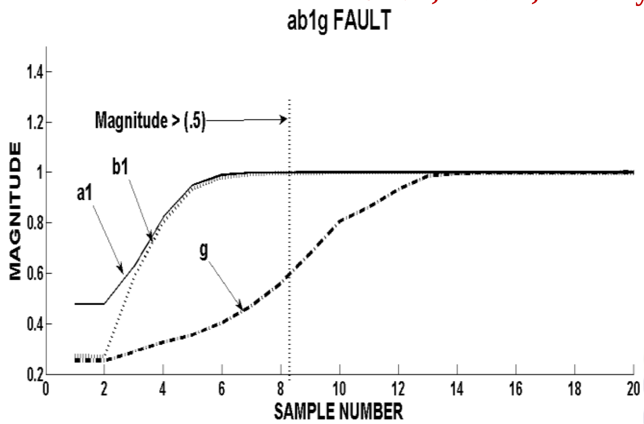


Fig-5 Performance Of System With Sample Number

4.2 Accurate Tripping

Fuzzy logic module issue trip signal only when it confirms that fault is of permanent type. In the case of transient fault or no fault condition no trip signal is issued. This module is used for decision making and to prevent mal-operation of the relay. Response of fuzzy system for different condition shown in table-5

4.3 Decisions of fault type

The proposed system can also distinguish between transient fault, permanent fault and no fault condition. For differentiate between fault and transient condition we compare some sample of output, here 5-10th sample of output used for this.

Z=Yn-Yn-1 =0 **No Fault**
Z=Yn-Yn-1 <0 **Transient Fault**
Z=Yn-Yn-1 >0 **Permanent Fault**

From above analysis it is clear that the trained Neural network with Fuzzy logic is robust to different parameter variations. Due to the fact that this system is a nonlinear compensator which adapts to the variation between faulted voltages, currents and fault positions under different fault resistance conditions.

V. CONCLUSION:

The influence of the mutual coupling of parallel circuit and impedance of series capacitor on the accuracy of relays depends on actual power system condition.

The proposed adaptive protection offers an approach to cope with the influence caused by variable power system conditions .The selectivity of the protection system is increased, and so is the power system reliability. It is shown that ANN can very well be used to construct the relation between local measurement and actual power system condition. Most importantly, sensitivity of the relay to power system condition change is reduced to almost zero with Fuzzy logic decision making system.

The adaptive protection scheme is tested under a defined fault type, but for different compensation, fault locations, fault resistances and fault inception angles. All the test results clearly show that the proposed adaptive protection technique is well suited for series compensated double-circuit lines with remote end infeed.

REFERENCES

1. P.M.Anderson, *Power system protection.* New York: IEEE Press, 1999.
2. A.G.Phadke and Stanley H.horowitz, "power system relaying"
3. P.M.Anderson, *"Series compensation of power system'.* PBLSH Inc.Encinitas CA
4. Y.Hu, D.Novosel, M.M.Saha and V.Leitloff, An adaptive scheme for parallel line distance protection , *IEEE Trans. Power Del. Vol.17 no1,pp.105-110,jan 2002*
5. Bouthiba ,Tahar(2004) ,Fault location in EHV transmission line using artificial neural networks,*Int.J.Appl.Math.Compt.Sci*.Vol-14 ,no.1,pp.69-78
6. J. Gracia and A. J. Mazón and I. Zamora, (2005) ,Best ANN Structures for Fault Location in Single and Double-Circuit Transmission Lines, *IEEE transactions on power delivery, vol. 20, NO. 4,*
7. Kale ,V.S and Bhide,S.R and Bedekar, P.P. and G.V.K.Mohan (2008), Detection and Classification of Faults on Parallel Transmission Lines using Wavelet Transform and Neural Network , *International Journal of Electrical and Computer Engineering , vol-3,pp-15*
8. Srivani, S.G.and Vittal, K.P.(2010), Adaptive distance relaying scheme in series compensated transmission lines, *IEEE Conference Publications Power Electronics, Drives and Energy Systems (PEDES)* , , Page(s): 1 - 7
9. Pradhan, A and Jena, P (2011), A positive sequence directional relaying algorithm for series compensated line, *IEEE Trans. Power and Energy Society General Meeting,* , Page(s): 1 – 1
10. *Jain, Anamika and Thoke A.S. (2009),* Classification of single line to ground fault on double circuit transmission line using ANN, *Int .journal of computer and electrical engineering, vol-1, no-2*
11. Vijay H.Makwana and Bhavesh R.Bhalja ,A New Digital Distance Relaying Scheme for Series-Compensated Double-Circuit Line During Open conductor and Ground

Fault , *IEEE Trans On power delivery,Vol-27,No-2,April-2012*

12. Urmil B.Parikh ,Biswarup Das and Rudraprakash Maheshwari (2010) , Fault classification technique for series compensated transmission line using support vector machine. *International jaournal of Electrical power and energy system. Vol-32, page 629-636*

Table5 Fuzzy logic based control unit output

a1	**b1**	**c1**	**a2**	**b2**	**c2**	**g**	**Fuzzy output**	**Trip**
1.0000	0.1225	0.9965	0.0024	2.1e-05	0.0482	2.4e-04	0.93	1
1.0000	1.0000	0.4105	0.0036	0.0047	1.4e-08	6.8e-04	1.2	1
1.0000	0.0943	0.0200	1.6e-05	1.07e-04	5.7e-06	1.0000	0.83	1
0.0103	2.4e-06	9.7e-07	1.0000	0.8243	0.0671	0.0904	1.87	2
4.1e-06	2.1e-04	2.9e-07	1.0000	0.0045	0.0031	0.9165	1.63	2
9.8e-06	6.0e-06	2.1e-07	1.0000	0.0045	0.9382	0.9147	1.97	2
0.0019	0.0854	0.0072	2.4e-06	1.0000	1.0000	0.2494	2.3	2
4.7e-04	0.0038	0.9999	0.1342	1.7e-07	1.6e-07	1.0000	0.69	1
0.0341	0.0023	0.0089	0.0263	0.0752	0.0863	0.0097	-0.32	0
0.0045	0.2452	0.3187	0.0031	0.4231	0.3473	0.0213	0.27	0
1.0000	0.9999	0.9999	4.7e-06	3.3e-06	0.0100	0.0011	1.45	1