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Modeling And Simulation Of Differential Relay For Stator Winding Generator Protection By Using ANFIS Algorithm

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Abstract

In this research , a three – phase differential relay (87 G) is designed to protect the stator winding generator by using an adaptive neuro-fuzzy inference system algorithm (ANFIS) . Its operation principle is based on the comparison between of the input current and output current at each phase winding .

The adaptive neuro-fuzzy inference system (ANFIS) is designed from two block . the first block works to detect the faults in the protected zone , the second block works to classify the fault types such as line to line and line to ground . the relay is tested under two scenarios . the first scenario relay was tested the behavior & performance of the relay while the fault is out of the protected zone or no fault , the second scenario relay is tested while the faults is inside the protected zone.

the differential relay will issue instantaneous trip signal to circuit breaker (C.B) to separate the fault from the generator , if the fault occurres within the protected zone .

Keywords: Generator protection, Stator differential relay , ANFIS, Classification of fault

1- Introduction

The Differential Protection relay is one of the most important protective function (commonly known as 87) [1]. This electrical protection is based on the detection of differential current between the input current and the output current of the stator winding generator . it prevents damage in the stator winding of the generator in case of phase-to-phase or three-phase faults. the 87G is based on the measurement of the differential current between the generator neutral side and the terminal side, the generator differential protection has two sets of current transformers the first CT is connected to the terminal side of the generator and the other is connected to the neutral side of the generator in each phase [2]. [3]

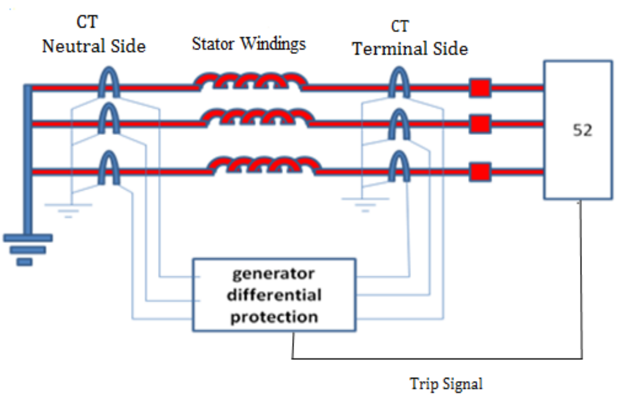

Figure 1. Simplified scheme of generator with differential protection.

The protected zone is the area bounded between the neutral side and the terminal side of the generator the Figure 1. Shows that .

when a fault occurs in the protected zone of the generator, it is necessary to detect and identify the type of the fault to separate the fault and return the power system to its normal case as soon as possible.

when the fault happens in the protected zone the first block of ANFIS will detect the fault and at the same time sending a signal trip to circuit breaker (C.B) to separate the fault from the generator .

2- ANFIS Algorithm (Adaptive Neuro Fuzzy Inference System)

ANFIS algorithm is incorporation of the fuzzy inference system (FIS) mechanism is described in the neural network architecture. ANFIS architecture is assumed with two inputs x and y and one output z. ANFIS uses Takagi- Sugeno model for learning algorithm so that it obtains membership functions. The ANFIS structure consists of 5 layers with different function for each layer [4]. The ANFIS architecture is shown in fig. 2, where each node in the same layer has similar function. Each node is expressed as node i in the layer I is 0/,1[5],[6].

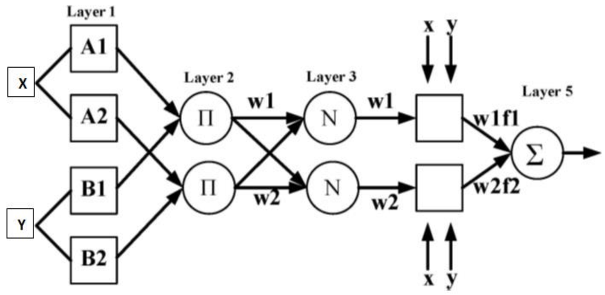

Figure 2. ANFIS structure of two inputs Takagi-Sugeno model [3]

Rule1: If x is A_1 and y is B_1 (1)

Rule2: If x is A_2 and y is B_2 (2)

Layer 1: every node i in the layer is an adaptive node with node output equation as follow:

$O_{1,i}=\mu_{Ai}(x)$, for i=1,2

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$O_{1,i}=\mu_{Bi-2}(y)$, for i=3,
where, x or y is the input to node Il A and Il B is a fuzzy set associated with this node function. Outputs of this first layer are membership function values of the premise part.

Layer 2: The function of node is multiplied with incoming signals. Every node in this layer is a fixed node. The output layer declares degree every fuzzy rule. Equation in the second layer is shown as follow:

$$Q_{2,i} = w_i = \mu_{A\,i}(x)\mu_{B\,i}(x) \qquad i=1,2$$

The every node output represents the firing strength of rule.

Layer 3: every node in this layer is fixed node. The i – the node summing of all rules firing strength. Equation in the third layer is shown as follow.

$$Q_{3,i} = \overline{w_i} = \frac{w_1}{w_1 + w_2} \qquad i=1,2$$

Layer 4: every node is an adaptive node. Every node is multiplied with p, q, r parameter. Equation in the fourth layer is shown as follow:

$$Q_{4,i} = \overline{w_i}\, f = \overline{w_i}\,(p_1 x + q_1 y + r_1)$$

where w; is the normalized activation degree from layer 3 and (p;,q;,r;) are the parameter sets of this node, which are referred as consequent parameters.

Layer 5: the single node in this layer is a fixed node. The single node computes the overall output as summing all of inputs. Equation in the fifth layer is shown as follow.

$$Q_{5,i} = \sum \overline{w_i}\, f_i = \frac{w_1 f_1 + w_2 f_2}{w_1 + w_2}$$

Thus, the first to fifth layers can construct adaptive network that has precisely the same function as takagi -sugeno model.

3- Modeling Of Differential Protection Relay

The differential protection relay consist of three part, Conversion and subtraction , ANFIS block, and logic C.B part as shown in Figure 3.

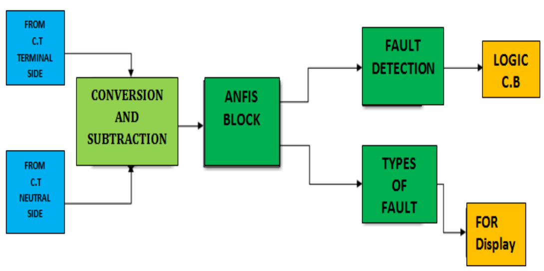

Figure 3. Block diagram of differential protection relay

3-1Conversion And Subtraction part

This part received a signal from the current transformer of the terminal side and the Neutral side , after that this signal is convert from P.P to RMS , both current signals in each line are sending to SUM block , if the output from the SUM block equal to the zero this mean that there is no fault in stator winding of the generator , otherwise then the stator winding of the generator has a fault , this part is shown in Figure 4.

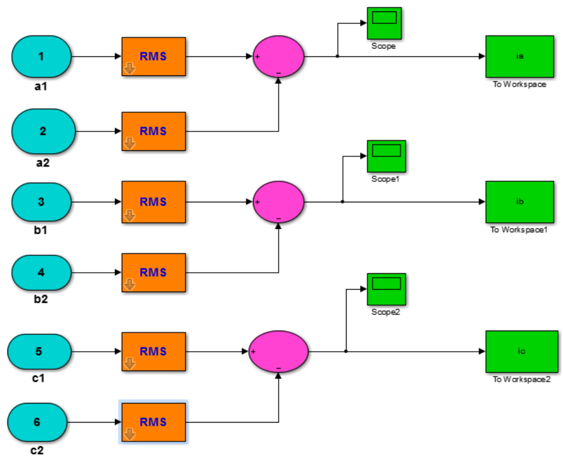

Figure 4. Conversion And Subtraction part of differential protection relay

3-1 ANFIS Part

This part has two Function ,the first function is to detect the fault in the protected zone **,** here the protected zone start from Neutral to output terminal of the stator winding . if the fault happens in the protected zone then the ANFIS block will send a signal to C.B for isolate the generator with electric grid .
The second function is to detect the type of fault as line to line short circuit or line to ground short circuit. all of the types fault and current are showing in command window of matlab, the Figure 5.Shown ANFIS block of differential protection relay.

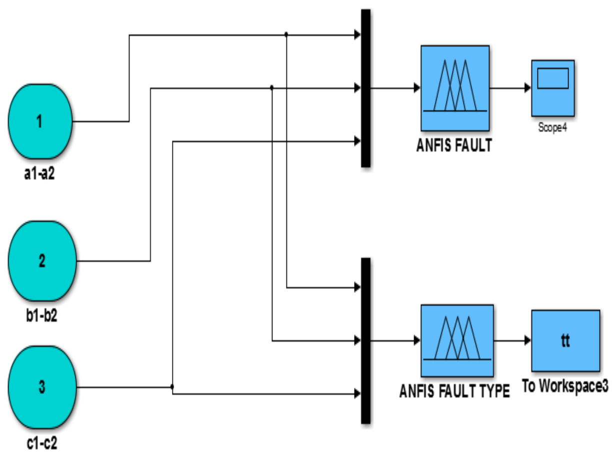

Figure 5. ANFIS Part of the differential protection relay

3-3Logic C.B

This part receives a signal trip logic '1' from the ANFIS fault Part and after that this signal enters in a sample and hold block in order to hold and convert this signal to '0' Logic because the circuit breaker tripping under logic ‘0’ . The Figure 6 .Shows this part.

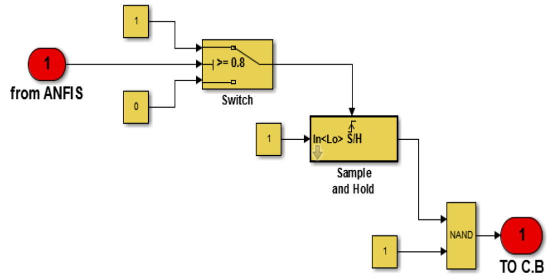

Figure 6. Logic C.B part of differential protection relay

Figure 7. shows the modeling of the of differential protection relay in one block.

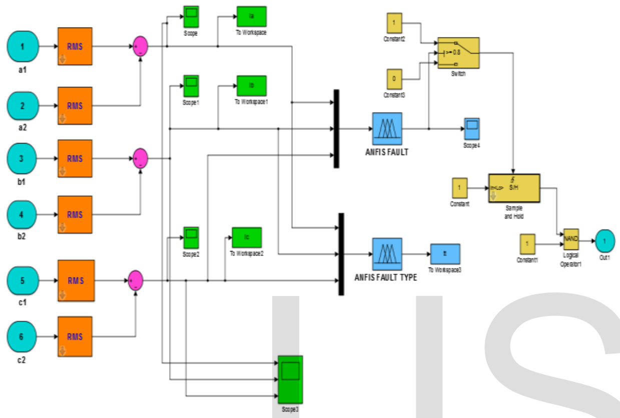

Figure7 the modeling of differential protection relay in one block.

4-Simulations Of differential protection relay

For testing and simulation the differential protection relay, an electric network is used as shown in Figure8. illustrate Electric network (Grid) which contains.

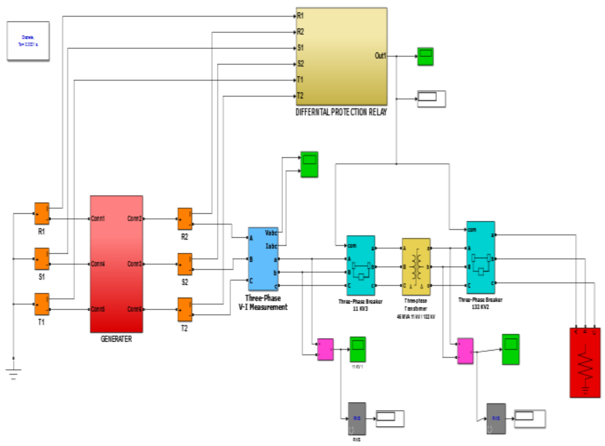

Figure 8. differential protection relay connection with generator.

- Three phase generator 11 KV , 50 HZ , 45MW.
- Circuit Breaker (11 KV, 132 KV).
- UP Transformer (11KV TO 132 KV).
- C.T and V.T for Measuring.
- RLC Load(45MW).
- Differential Protection Relay.

the relay will be tested under two scenarios . the first scenario is the behavior of the relay during the fault is out of the protected zone or no fault , the second scenario during the fault is inside the protected zone.

4-1first scenario

At “1” sec the fault happens in line A- G but the generator does not tripped because the differential relay does not response to the fault because the fault happenes out of the protected zone. figure 9 ,10, 11 ,and 12 , represents the current and voltage output of the generator, ANFIS message, relay state, and fault current

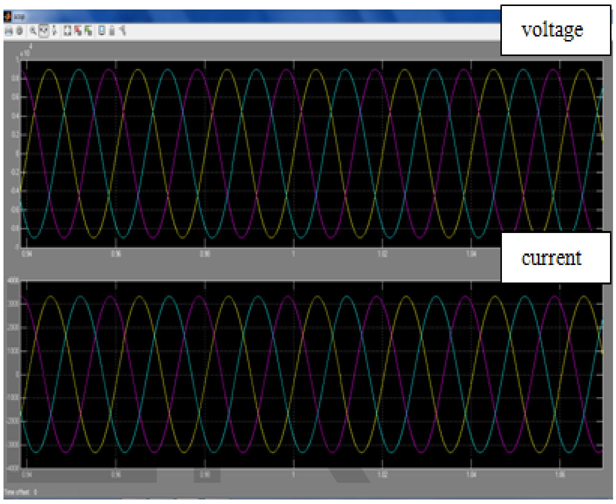

Figure 9 current and voltage output

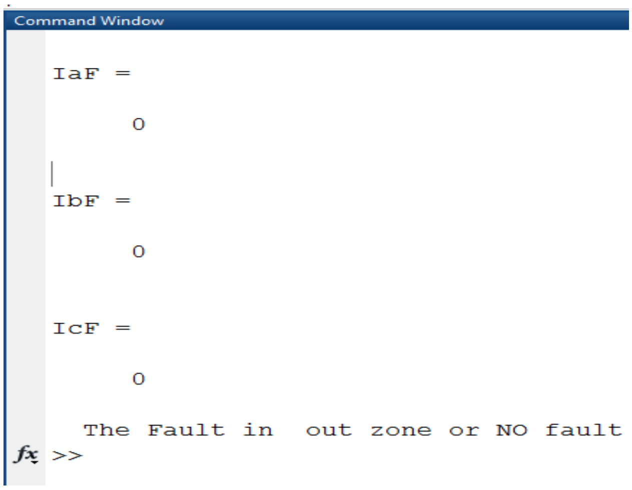

Figure 10 ANFIS message of first scenario

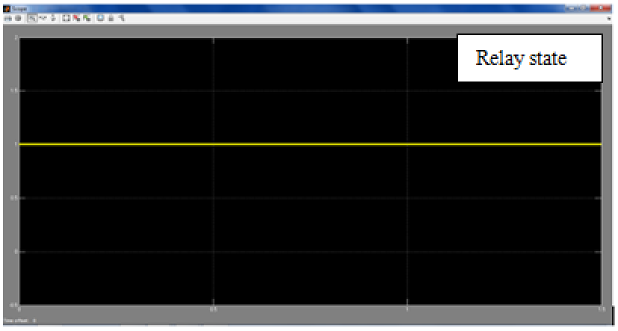

Figure 11 relay state of first scenario

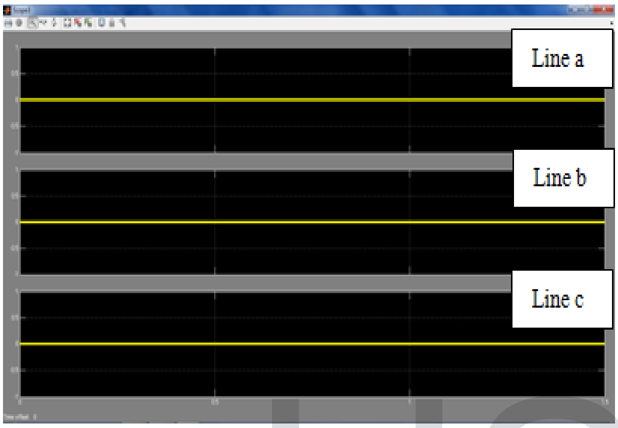

Figure 12 . fault current of first scenario

4-2 second scenario

This scenario Contains 10 faults cases and all the faults happens inside the protected zone ,this paper discusses only three cases . the other cases can be seen in the table1.

<u>case 1</u> :

at '1' sec the fault happenes between the line (A-G) and then the generator trips , the figure 13,14,15,and 16 represent the current and voltage output of the generator, relay state, fault current and ANFIS message.

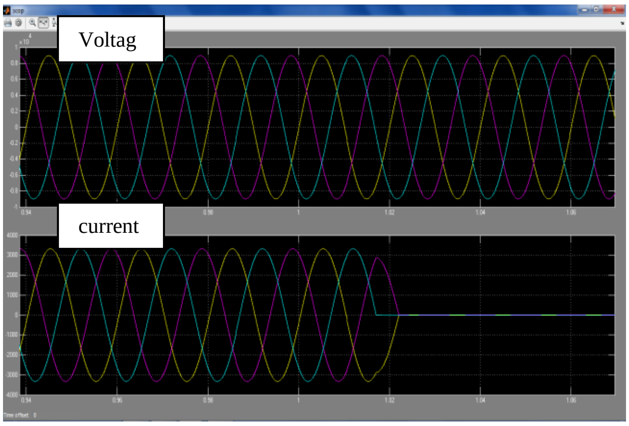

figure 13. current and voltage output of generator in case 1

Figure 14 relay state of case 1

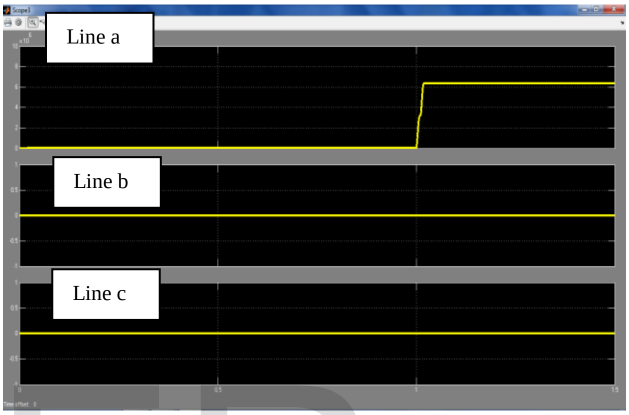

Figure 15 fault current of case 1

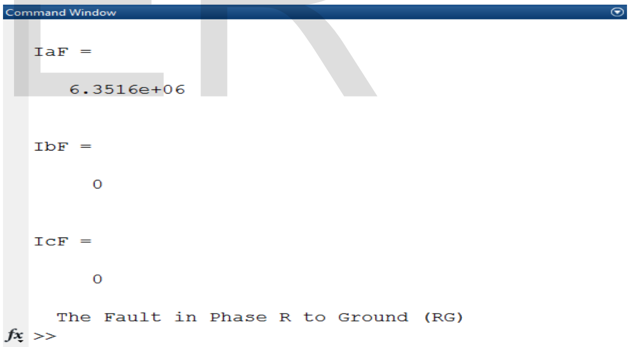

Figure 16 ANFIS message of case 1

<u>case 2</u> :

In this case the fault happens between the line to line (A-B) and then the generator trips Figure 17,18, 19, and 20 represent the current and voltage output of generator, relay state, fault current and ANFIS message.

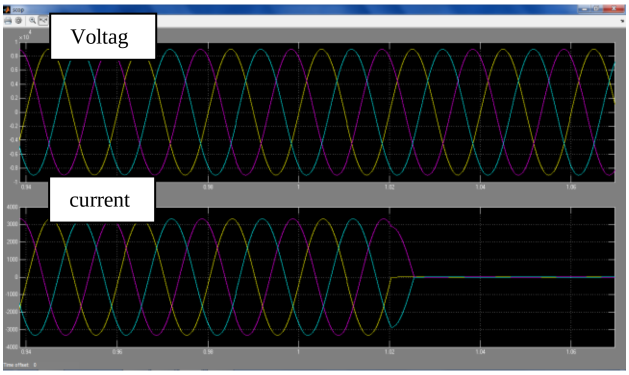

figure 17. current and voltage output of generator in case 2

Figure 18 . relay state of case 2

Figure 19. fault current of case 2

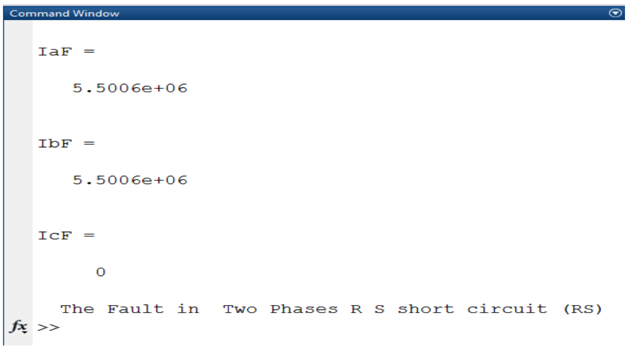

Figure 20 . ANFIS message of case 2

case 3 :

In this case the fault happens between the line to line (A-B-C) and then the generator trips Figure 21,22, 23, and 24 represent the current and voltage output of generator, relay state, fault current and ANFIS message.

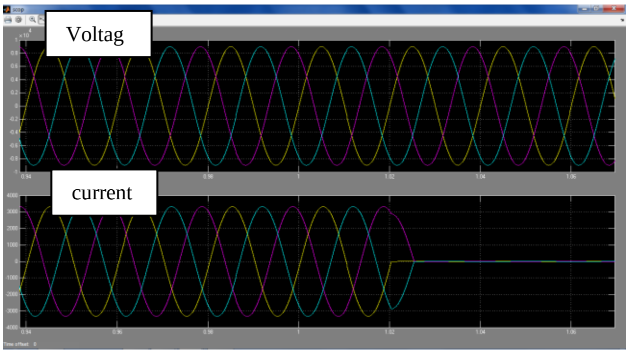

figure 21. current and voltage output of generator in case 3

Figure 22 . relay state of case 3

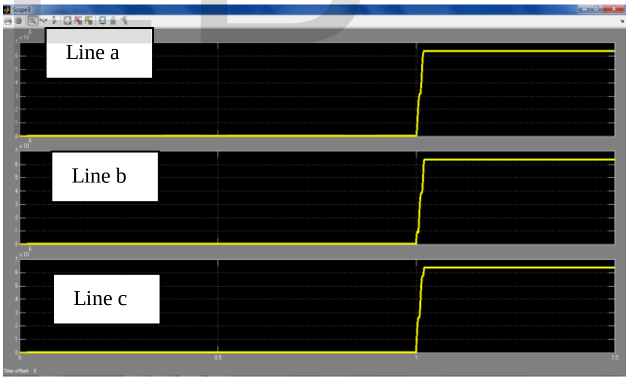

Figure 23. fault current of case 3

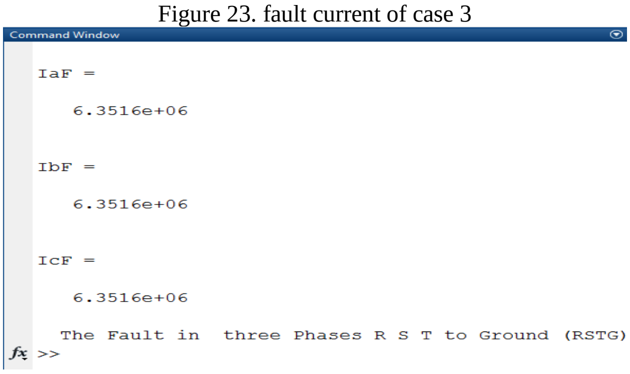

Figure 24 . ANFIS message of case 3

Case NO	Fault Calcifica tions	Load Current (A)	Fault Current (A)			Relay State
			IA	IB	IC	
1	A-G	2351	6.3516* 10^6	0	0	trip
2	A-B	2351	5.5006* 10^6	5.5006* 10^6	0	trip
3	A-B-C -G	2351	6.3516* 10^6	6.3516* 10^6	6.3516 *10^6	trip
4	B-G	2351	0	6.3516* 10^6	0	trip
5	C-G	2351	0	0	6.3516 *10^6	trip
6	A-B-G	2351	6.3516* 10^6	6.3516* 10^6	0	trip
7	A-C-G	2351	6.3516* 10^6	0	6.3516 *10^6	trip
8	B-C-G	2351	0	6.3516* 10^6	6.3516 *10^6	trip
9	B-C	2351	0	5.5006* 10^6	5.5006 *10^6	trip
10	A-C	2351	5.5006* 10^6	0	5.5006 *10^6	trip

table 1. all fault cases of second scenario.

CONCLUSION

The paper has presented the modeling and simulation of the generator differential protection relay by using matlab simulink the protection relay has been designed by using an adaptive neuro-fuzzy inference system algorithm (ANFIS). It was very successful in detecting the faults in the stator winding of generator as well as determining the fault and classifying the faults type. through the different scenarios these models help the fresh engineers to develop the analytical skills and visualize the system behavior under normal and abnormal conditions.

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