Protection Scheme based on Fault Detection and Fault Classification using Fuzzy inference system in IEEE-9 Bus System

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Abstract—**In any electrical power network the continuity of power flow with high level of reliability is necessary. It is necessary to detect and classify the fault in any power system network . This paper Proposed the Protection Scheme in IEEE-9 bus system based on Fault Detection and Classification using Fuzzy Inference System.In this Scheme the Magnitude of Positive Sequence Voltage ,Positive Sequence Current ,Zero Sequence Voltage and Zero Sequence Current signals are used. This feature of IEEE-9 bus system is obtained using Discrete Fourier Transform. The 3-Phase Positive Sequence Voltage , Positive Sequence Current ,Zero Sequence Voltage and Zero Sequence Current signals are collected at one end of a transmission line in a bus thus the communication link which is used to collect remote end data dependability is removed. In this scheme four fuzzy FIS modules are developed to detect the presence of fault in any of the 3-Phase and to identify the presence of Ground. Fault Simulation is done in MATLAB/Simulink for all possible Symmetrical and Unsymmetrical fault combinations by varying Fault Location , Fault Resistance, Fault Inception Angle, Load Angle ,Load Magnitude, Generator Supply and Generator Supply Frequency. The Results shows that proposed scheme is able to perform the Tripping action and Classify the Fault therefore the scheme can be employed in practical application.**

Keywords— **Fault Detection & Classification, IEEE-9 Bus System ,Positive Sequence Voltage , Positive Sequence Current, Discrete Fourier Transform, Fuzzy Logic ,Fuzzy inference system(FIS)**

I. INTRODUCTION

The Three stages in any Power System are Transmission, Generation and Distribution.. Industries mainly use synchronous generator for power generation. The Power System are designed to do a continuous power supply that maintain stability. Due to some unwanted events like lightening, short circuit between the wires of the transmission lines, accidents or any other unpredictable event which may occur is called a fault. Due to these fault occurring in system which may cause any severe damage [1].

Modern power system is a network which requires high speed and reliability. In any power system fault is unavoidable and mostly in any overhead transmission lines faults are higher as compared to any other major components. In Double Circuit line the fault classification is difficult due to the mutual coupling in the circuit [2].

The work reported in these part is based on fault detection and classification which comes under a protective scheme of power system. The protective relays[3].

1. Reliability
2. Selectivity
3. Speed of operation
4. Simplicity
5. Economic

Many schemes which uses fuzzy system for protection of three phase power system[4-7].

The fuzzy inference system approach for fault detection and classification for a three phase power system using current samples are explained in[4] followed by statistical technique.

The fuzzy logic approach for detection of simultaneous series shunt fault with the location of fault in double circuit power system have been reported in [5].

The directional relaying scheme with fault classification and fault location approximation using fuzzy logic is discussed in[6].Another work based on fault classification using fuzzy inference system is reported in[7].The protection scheme using auto reclosing of a double circuit transmission is discussed in [8] using fuzzy logic.

There is an effect reported in [9] on changing sampling frequency in the fault detection algorithm which is based on ANN.

The usage neural network approach for fault classification is a successful methodology but it requires lot of time in its training hence it is taking and had lots of complexity.

The fuzzy logic based classification technique are comparatively simple as it requires some fuzzy rules.

In [10] the nature of fault is identified not the phase involved in it. In [11] that drawback is improved using the fuzzy neural technique and considering both symmetrical and unsymmetrical fault but this method requires an extra training effort of ANN. In [12] it should all ten types of faults identification by fuzzy neural approach.

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In [13,14,15] proposed fuzzy logic methodology for 2 bus system. A travelling wave and fuzzy logic method is used for fault classification has been shown in [16].In [17] fuzzy logic approach is used to classify fault .In this fuzzy logic uses the full cycle Discrete Fourier Transform. Also for fault classification and detection wavelet technique is used, the technique uses the method of oscillography [18].

ANN based fault location scheme which uses current and voltage components in [19]. The faulty phase detection scheme in [20] are developed using fault generated frequency noise and combination of coupling capacitance by ANN. Some fault classification scheme have been developed utilizing combined unsupervised/supervised neural network [21], PSO trained ANN [22],fuzzy [23,24],fuzzy neuro[25],combined fuzzy wavelet scheme [26,27] for protection against faults in transmission lines. There are two algorithm for multi terminal double circuit transmission line based on "Impedance calculation", "current diversion ratio" in[28].

The synchronization of current and voltages at all the buses are required. In [29] Double circuit transmission line fault location algorithm is developed . It is essential to classify the fault and to determine fault location. Then the practical 1kHz [30].In [31] Fault classification and Detection in single circuit transmission line is based on reactive power of symmetrical components.

In this paper protection scheme based on fault detection and classification using fuzzy logic has been proposed. Till now the fuzzy based algorithm has been used for protecting purpose in less bus system. In this IEEE-9 bus system is used for simulation purpose as IEEE-9 bus system is practically exist power system. Our protection scheme is based on DFT FIS approach for detection and classification of symmetrical and unsymmetrical faults. Further section 2 deals with proposed methodology and section 3 gives a detailed analysis of results and its interpretation at different fault condition. Section 4 concludes the significance and effectiveness of proposed methodology and its adaptability in IEEE-9 bus system to provide suitable protection scheme.

II. METHODOLOGY

The flow chart of Proposed protection scheme is shown in Figure 1.There are four separate Fuzzy Inference System module are designed for giving signal to the relay tripping. Input of this Fuzzy Inference System are the Positive Sequence Voltage, Positive Sequence Current, Zero Sequence Voltage and Zero Sequence Current. Corresponding to the three phases and ground there are four outputs which are provided by the network to determine which of the three phases: A, B, C and/or ground are present in the fault. After, Detection Fault Classification is done through AND logic gate and Displayed . If there is the fault then the Display will show '1' and otherwise the output will be '0'. There are Displays which shows the classification of 11 different types faults.

A. PROPOSED METHODOLOGY

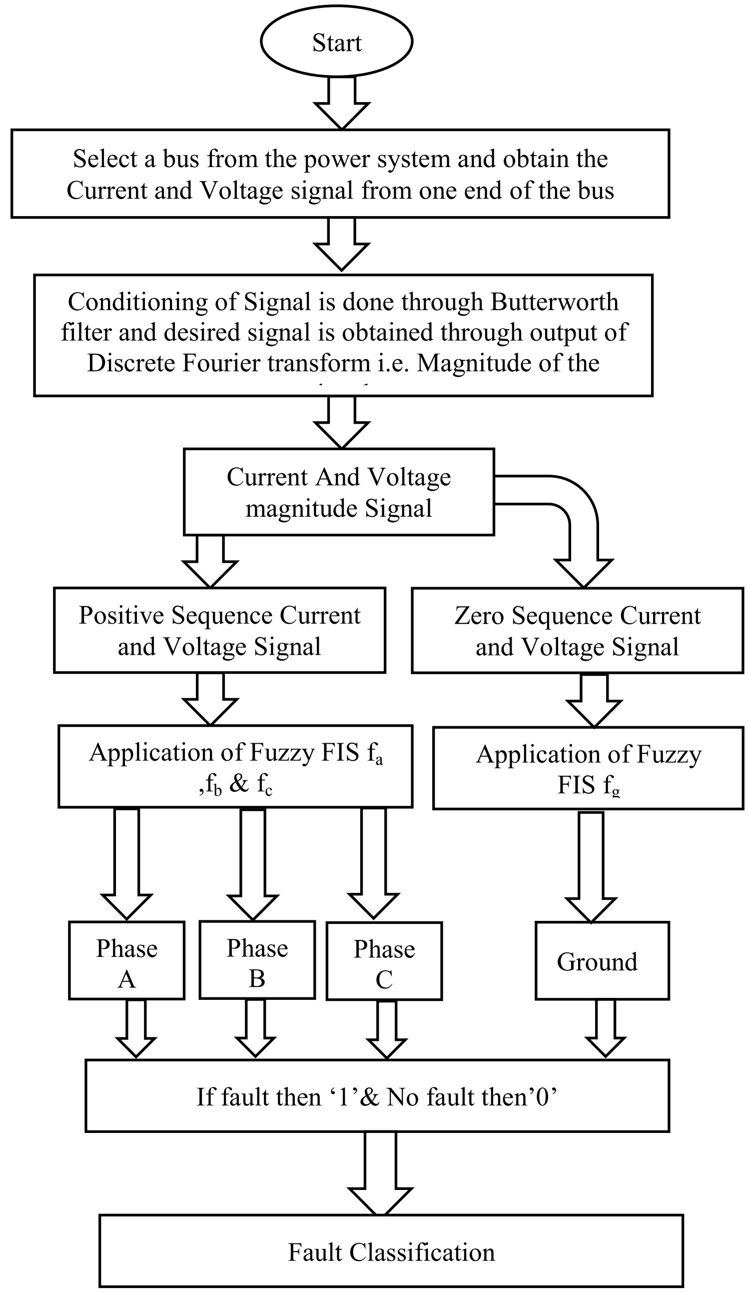

Figure 1. Flow Chart of proposed methodology

The bus 7 is selected in the IEEE-9 bus system. The Current and voltage signals are collected at one end of transmission line i.e. Bus 7.The Current and Voltage signals are the sampled and filtered to remove noise and other disturbance from the signals at 400Hz and 1e-03 sampled period respectively . Then the Discrete Fourier Transform is used to obtained the Magnitude of the Voltage and Current signals. As during Fault in the Phase only Positive Sequence Current and Positive Sequence Voltage is obtained.. Also , When Ground Fault is the ground current will be obtained using Zero Sequence Block. Then, the input of this is given to respective

Fuzzy Inference Module . The Fuzzy Inference Module will detect the fault in the phase and the ground if included. After this the Fault Classification is done using AND logic.

B. Design of Fuzzy Inference System for Detection and Classification

In this protection scheme four different fuzzy inference module have been designed to detect the presence of faulty phase from any of the three phase and to identify the involvement of ground of ground in the fault. Input of the faulty phase detection fuzzy inference system are the positive sequence component of three phase current, voltage and zero sequence current is detection of ground fault.

Each input signal divided in three different ranges with triangular membership function i.e. Low, Medium and High as shown in Figure 2.There are four outputs for faulty phase detection i.e. 3 phase A,B,C and ground fault. The trip logic which gives output signal also contain two ranges of triangular membership function i.e. Trip low TL (0) if there is no fault condition and Trip high TH(1) if there is fault condition as shown in Figure 2.The fuzzy inference engine will work on the basis of membership function and its fuzzy rules. The Fuzzy rules of all the Fuzzy Inference Modules are same shown below:-

- If (Voltage is VL) and (Current is IL) then (Trip is TL) (0)
- If (Voltage is VH) and (Current is IL) then (Trip is TL) (0)
- If (Voltage is VM) and (Current is IL) then (Trip is TL) (0)
- If (Voltage is VL) and (Current is IM) then (Trip is TL) (0)
- If (Voltage is VM) and (Current is IM) then (Trip is TL) (0)
- If (Voltage is VH) and (Current is IM) then (Trip is TL) (0)
- If (Voltage is VL) and (Current is IH) then (Trip is TH) (1)
- If (Voltage is VM) and (Current is IH) then (Trip is TH) (1)
- If (Voltage is VH) and (Current is IH) then (Trip is TH) (1)

The Fuzzy Rules defined for identification of Ground fault

- If (Zero Sequence Current is IL) then (Trip is TL)(0)
- If (Zero Sequence Current is IM) then (Trip is TL)(0)
- If (Zero Sequence Current is IH) then (Trip is TH)(0)

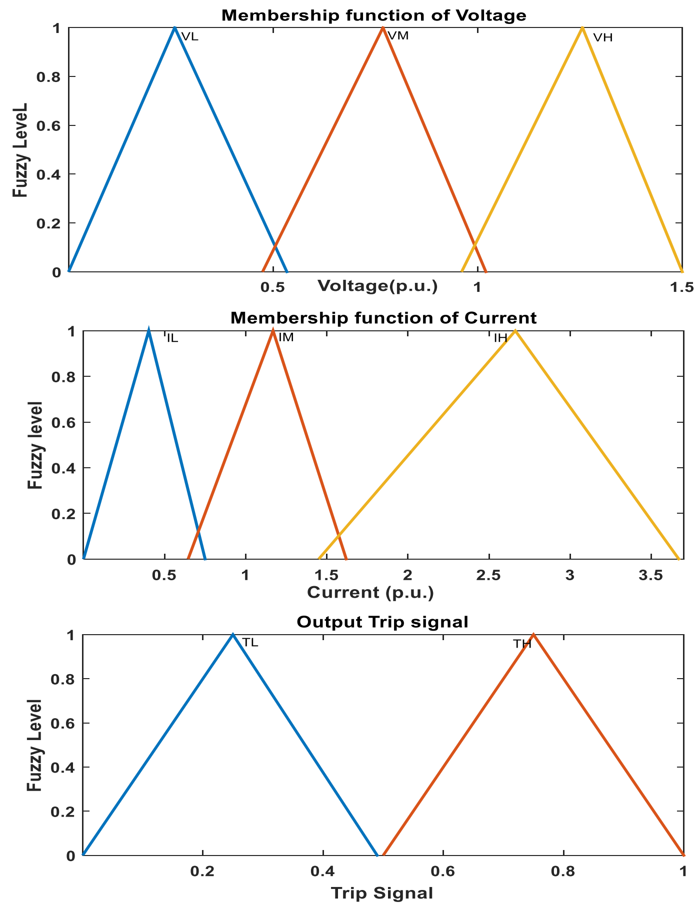

Figure 2. Degree of Fuzzy Membership Function (A)Membership Function of Voltage. (B)Membership Function of Current. (C)Membership Function of Trip Signal.

C. IEEE-9 Bus System

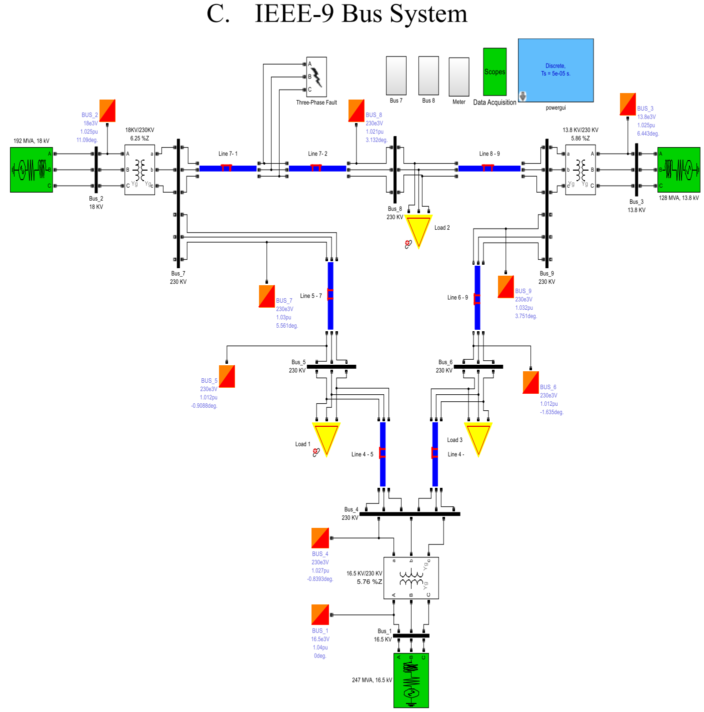

Figure 3. IEEE-9 Bus System

The IEEE-9 bus system consists of 3 generators ,3 loads and 9 buses shown in Figure 3 . The fault block is connected between bus 7 and bus 8.

- Generator 1(3phase): 18kV (phase to phase voltage)
  50Hz (Frequency)
- Generator 2(3phase): 13.8kV (phase to phase voltage)
  50Hz (Frequency)
- Generator 3(3phase): 16.5kV (phase to phase voltage)
  50Hz (Frequency)
- Transformer 1(3phase): 18kV/230kV
  50Hz (Frequency)
- Transformer 2(3phase): 13.8kV/230kV
  50Hz (Frequency)
- Transformer 3(3phase): 16.5kV/230kV
  50Hz (Frequency)
- Static Load 1: Active Power- 90MW
  Reactive Power- 30MW
- Static Load 2: Active Power- 90MW
  Reactive Power- 30MW
- Static Load 3: Active Power- 90MW
  Reactive Power- 30MW

III. Result & Discussion

To Evaluate the Performance of Proposed Methodology simulation have been carried out for all 11 symmetrical and unsymmetrical fault combinations which are important for 3 phase Power System by varying different fault parameters such as Fault Resistance(0Ω-100Ω), Fault Inception Angle (0^0-360^0) and Fault Location(1 k.m. – 99 k.m.). The response of proposed protection scheme by varying different power system power network such as Voltage(+/-5%), Frequency (+/- 0.2%), Short Circuit Capacity(+/- 250 MVA), Load Magnitude(+/- 250 MVA) and Load Angle (+/- 10^0) of Source 1 and Load 1.

The Results and responses after simulation in IEEE-9 bus system of proposed algorithm are being discussed in following case studies

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A. Performance of Fault Detection and Classification Fuzzy Inference system

The Figure 4 Shows the performance of the fuzzy inference system in detection and classification of the fault. The figure 4 represents the Fault detection and Classification of Fault AG. By making parameters constant at their standard values. The fault resistance is set at 60Ω and inception angle is set at 15^0 .

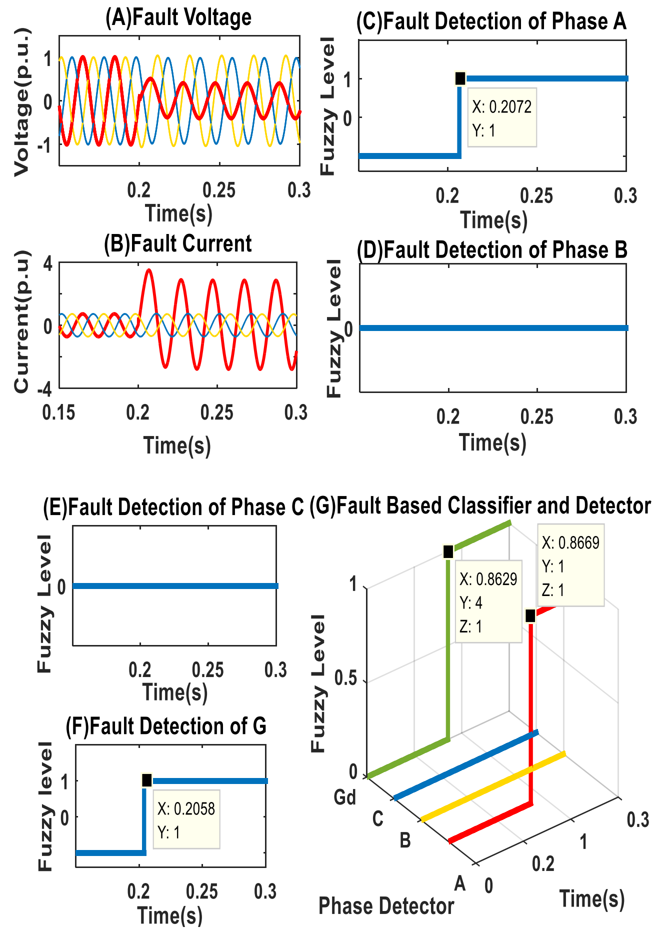


Figure 4. Fault Detection and Fault Classification

In the Figure 4(a) Fault voltage and in Figure 4(b)Fault current is shown observed at Bus7.The Disturbance at Instantaneous Voltage and Instantaneous Current can be seen in the waveform. The Figure 4(c) shows the detection of fault at Phase A .The AG fault is initiated at 0.2 ,so it takes about 7.2 milliseconds to detect the fault at Phase A by Fuzzy Inference System Module $f_{a.}$. As it is AG fault so the Fuzzy Inference System f_b and f_c doesn't sense it shown in Figure 4(d) and Figure 4(e) respectively. The Figure 4(f) shows the detection of fault involving ground. The Fuzzy Inference System f_g takes about 5.8 millisecond to sense the ground fault. The Classifier classifies the AG fault is shown in Figure 4(g) The X axis of the Classifier Classifying between the faulty phase and/or ground fault .The Minimum time to operate the relay tripping of transmission line between Bus 7 & Bus 8 is 5.8 millisecond.

B. The Relay Tripping Time of proposed protection scheme at boundary conditions(i.e. Near end and far end)from bus 7

It is very vital for any protection scheme to sense the fault at near bus and also to sense at remote end. As when there is fault at near the bus the voltage is small. Whereas at the remote end i.e. 99k.m from the bus 7 conventional relays will not operate .So, it is important to check the working of the Fuzzy Inference system at both the end. TABLE 1 and TABLE 2 shows the Detection and classification of 11 faults and Relay Tripping time.

TABLE 1
Detection and Classifcation of fault at near end i.e. 1 km from bus 7

Fault Detection(ms)					Fault Type
A	B	C	G	RT	
4.2	--	--	2	2	AG
--	5.1	--	2	2	BG
--	--	6.1	5	5	CG
4.1	4.1	--	--	4.1	AB
--	8.9	8.5	--	8.5	BC
5.1	--	4.8	--	4.8	CA
4	4.3	--	5	4	ABG
--	5.6	6.1	3	3	BCG
4.1	--	5.7	2	2	CAG
5.1	4.5	5.8	--	4.5	ABC
3.9	4.5	5.8	7	3.9	ABCG

TABLE 2
Detection and Classifcation of fault at Remote end i.e. 99 km from bus 7

Fault Detection(ms)					Fault Type
A	B	C	G	RT	
6.6	--	--	4	4	AG
--	11.5	--	5	5	BG
--	--	7.6	5	5	CG
11.2	11.53	--	--	11.2	AB
--	10.7	10.3	--	10.3	BC
8.5	--	6.3	--	6.3	CA
6.5	11.3	--	5	5	ABG
--	11.4	2.6	4	2.6	BCG
6.4	--	7.5	5	5	CAG
6.3	11.3	7.5	--	6.3	ABC
6.3	11.3	7.5	8	6.3	ABCG

Table 1 and Table 2 shows the performance of proposed protection scheme . The relay operation of detection and classification is less than a cycle of time (20ms). Therefore the results shows efficiency in both the cases of proposed protection scheme i.e. near end and far end.

C. The Relay Tripping Time of proposed protection scheme at different fault location

The Proposed protection scheme performance at different fault location is shown in TABLE 3. It is necessary for any protection scheme to work at all over the transmission line as it is about 100 kilometer long.. The fault is varied all over the transmission line with Fault Resistance is kept at 60Ω and inception angle is 15^0. It can be observed from the TABLE 3 that the proposed algorithm is able to Detect and Classify between the fault all over the transmission line. The table shows the different fault location from one end i.e. from Bus 7. The fault detection time is also given in the table and the minimum time to required is the relay tripping time . Once the fault is detected then it is able to classify the fault easily

TABLE 3
Detection and Classifcation of fault at Different Fault Location

Fault location(km)	Fault Detection (ms)					Fault Type
	A	B	C	G	RT	
50	**7**	**--**	**--**	**5**	**5**	**AG**
45	--	5.3	--	4	4	BG
36	--	--	9.2	9	9	CG
27	6.2	5.6	--	--	5.6	AB
13	--	10.1	10.7	--	10.1	BC
91	10.8	--	8.5	--	8.5	CA
89	7.4	5.8	--	9	5.8	ABG
72	--	5.7	9.5	5	5	BCG
62	7	--	9.4	4	4	CAG
58	6.9	5.2	9.3	--	5.2	ABC
18	6.4	4.7	8.9	7	4.7	ABCG

D. The Relay Tripping Time of proposed protection scheme in different fault resistance

In Phase to ground faults may occur with or without fault resistance this resistance is due to the arcing phenomena and tower grounding resistance. In most of the cases the range of Fault resistance is between 10Ω- 60Ω.. The Fault Resistance can be in case of both Phase to Phase or Phase to Ground Fault. As any object through which the phase is connected with a Phase due to which phase to phase fault occur can be stone , wood or any type of object whose resistance is enough to conduct in that case a small fault current will flow which is detected by our Fuzzy Inference System efficiently. Also, it is same in the case for phase to ground fault but in the case of ground resistance is negligible and fault resistance is due to the object resistance which is connected in the phase and ground. To evaluate the effectiveness of the proposed protection scheme the fault resistance is varied from 0.01Ω-100Ω .The TABLE 4 shows the ability of protection scheme to detect and classify the fault keeping fault location at 50 kilometer and inception angle at 15^0. The relay tripping time for any fault resistance (0Ω-100Ω) is within a cycle of time i.e. 20 milliseconds.

TABLE 4
Detection and Classifcation of fault at Different Fault Resistances

Fault Resistance(Ω)	Fault Detection (ms)					Fault Type
	A	B	C	G	RT	
56	5.2	--	--	3	3	AG
60	--	1.2	--	4	1.2	BG
68	--	--	N.S	6	6	CG
72	6.4	11.5	--	--	6.4	AB
16	--	9.1	8.4	--	8.4	BC
10	5.3	--	5	--	5	CA
17	4.3	5.3	--	6	4.3	ABG
28	--	9.7	6.3	3	3	BCG
32	4.6	--	6.7	3	3	CAG
44	4.8	9.7	6.3	--	4.8	ABC
54	5	9.9	6.5	7	5	ABCG

E. The relay Tripping Time for proposed protection scheme at different inception angle

The Fault Inception Angle is the most important parameter of any fault.. The fault inception changes in any fault due to DC component in the fault current. It is very important that the proposed protection scheme is not influencing through change in the inception angle. Different types of faults are simulated in the IEEE-9 bus system by keeping the fault resistance at 0.01Ω and fault location at 50 kilometer. TABLE 5 shows the Detection, Classification and Relay Timing by varying in the inception angle from 0^0-360^0. The results show the proposed protection scheme is able to detect and classifies the fault within a cycle 20ms.

TABLE 5
Detection and Classifcation of fault at Different Inception Angle

Inception angle (Degree)	Fault Detection (ms)					Fault Type
	A	B	C	G	RT	
0^0	6.7	--	--	3	3	AG
18^0	--	10	--	4	4	BG
60^0	--	--	3.67	2.67	2.67	CG
45^0	10.3	10.9	--	--	10.3	AB
135^0	--	4.4	4.7	--	4.4	BC
225^0	4.9	--	3.7	--	3.7	CA
270^0	9.2	5.2	--	5.3	5.2	ABG
315^0	--	3.9	8.9	4.5	3.9	BCG
36^0	6.2	--	4.2	3.8	3.8	CAG
72^0	10.3	5.9	3.2	--	3.2	ABC
12^0	3.83	9.3	4.3	8	3.83	ABCG

F. The relay tripping time of proposed scheme for Different fault Inception angle and for Different fault location

TABLE 6
Detection and Classifcation of fault for Different Inception Angle and at Different Fault Location

Inception Angle (Degree)	Fault location (km)	Fault Detection (ms)					Fault Type
		A	B	C	G	RT	
0^0	50	5.7	--	--	4	4	AG
90^0	48	--	10.8	--	4	4	BG
22.5^0	35	--	--	8.2	9.5	8.2	CG
45^0	26	9.5	8.6	--	--	8.6	AB
30^0	13	--	8.3	6.8	--	6.8	BC
60^0	13	5	--	11.7	--	5	CA
75^0	31	7.8	5.4	--	7.5	5.4	ABG
180^0	39	--	11	7.3	4	4	BCG
225^0	41	5.8	--	5	3.5	3.5	CAG
270^0	62	10.9	6.6	4.9	--	4.9	ABC
315^0	81	8.4	6.2	10.1	8	6.2	ABCG

The importance of Inception Angle and Fault location has been discussed in previous section 3.5 and 3.3. This is the simulation of the case when there is DC components due fault at different location all over the transmission line. The TABLE 6 shows the results of varying the Inception angle from 0^0-360^0 and Fault location is the distance from the Bus-7 (1km-99km). In this case the simulation is done in the IEEE-9 bus system using the proposed scheme fault is able to Detect and Classifies keeping Fault resistance 56Ω.

G. The relay tripping time of proposed scheme for Different inception angle and for different fault resistance

TABLE 7
Detection and Classifcation of fault for Different Inception Angle and for Different Fault Resistance

Inception angle (Degree)	Fault Resistance (Ω)	Fault Detection(ms)					Fault Type
		A	B	C	G	RT	
0^0	4	4.6	--	--	4	4	AG
180^0	57	--	10.7	--	5	5	BG
90^0	72	--	--	4.5	4	4	CG
45^0	27	10.6	10.9	--	--	10.6	AB
30^0	5	--	7	5.9	--	5.9	BC
60^0	52	12.7	--	4.23	--	4.23	CA
120^0	49	7.93	4.83	--	3.3	3.3	ABG
150^0	58	--	6	4.1	9	4.1	BCG
40^0	82	11.4	--	4.7	6.7	4.7	CAG
36^0	97	11.6	9.7	5.4	--	5.4	ABC
180^0	0.01	4.3	5.4	6.1	5	5	ABCG

The importance of Inception Angle and Fault Resistance has been discussed in previous section 3.5 and 3.4.The TABLE 7 shows the simulation result by varying the Fault resistance (0.01Ω-100Ω) and Inception Angle (0^0-360^0). This is also important as During High Fault Resistance and High Inception Angle the Fault Current is low. So, it is difficult to detect the fault using the conventional methods. The Result shows the proposed protection scheme is able to detect and classifies the fault efficiently by keeping fault location at 40 kilometer from Bus 7.

H. The Relay Tripping time of proposed scheme at different fault location and for different fault resistance

The importance of combination we have seen in previous section in 3.6 and 3.7. So, in this section simulation is done by varying fault location(1km-99km) and varying fault resistance (0.01Ω-100Ω). The simulation is for the case when in any transmission line any object or any conductor causes Phase to Phase fault or Phase to Ground Fault anywhere in the transmission line. The proposed protection scheme is able to differentiate between the faults and able to detect the fault within a cycle of time i.e. 20 milliseconds.
As, in this case of simulation the fault can happen all over the transmission line with any fault resistance but keeping inception angle constant at 0^0. As at this inception angle maximum DC offset current is presence in any fault. So, the TABLE 8 shows the results of simulation results of the proposed protection by varying fault location and fault resistance.

TABLE 8
Detection and Classifcation of fault at Different Fault Location and for Different Fault Resistance

Fault location (km)	Fault Resistance (Ω)	Fault Detection(ms)					Fault Type
		A	B	C	G	RT	
81	86	7.3	--	--	4	4	AG
27	62	--	10.9	--	4.2	4.2	BG
18	58	--	--	N.S.	6	6	CG
13	72	6.7	11.8	--	--	6.7	AB
29	18	--	9.4	8.9	--	8.9	BC
35	13	5.7	--	5.2	--	5.2	CA
42	21	4.8	9.6	--	6	4.8	ABG
56	9	--	10.2	6.6	8	6.6	BCG
67	0.01	4.6	--	N.S.	3	3	CAG
72	1	4.6	9.4	6.3	--	4.6	ABC
81	4	4.7	9.9	6.5	8	4.7	ABCG

TABLE 9
Detection and Classifcation of fault at Different Fault Location , for Different Fault Resistance & for different inception angle

Fault Distance (km)	Inception angle (Degree)	Fault Resistance (Ω)	Fault Detection (ms)					Fault Type
			A	B	C	G	RT	
5	180^0	10	4.4	--	--	2	2	AG
6	90^0	19	--	9.4	--	3	3	BG
3	45^0	22	--	--	4	3.5	3.5	CG
12	135^0	16	5.4	4.6	--	--	4.6	AB
11	30^0	82	--	10.1	9.3	--	9.3	BC
5	225^0	52	12.7	--	4.5	--	4.5	CA
56	270^0	76	10.7	6.4	--	4	4	ABG
24	315^0	12	--	3.9	8.7	4.5	4.5	BCG
82	60^0	0.01	10.77	--	3.67	5.67	3.67	CAG
92	120^0	0.12	7.43	4.23	4.53	--	4.23	ABC
75	240^0	11	10.87	7.17	3.67	8	3.67	ABCG

I. The Relay Tripping Time of Proposed Protection Scheme at Different Fault Location , for Different Fault Resistance and For Different Inception Angle

In the previous section we have individually studied the effect of change of parameters and then the combination of 2 parameters of Fault Resistance , Fault Location & Inception Angle. But if the variation of parameter is there i.e. the 3 parameter are varied simultaneously to simulate the effect of any fault across all over the transmission line. This simulation shows us the efficiency of our Fuzzy Inference System in Detection and Classification of the fault at any inception angle from 0^0-360^0, at any fault location all over the transmission line between Bus 7 and Bus 8. Also it does not get affected
By varying the fault resistance form 0.01Ω-100Ω. The TABLE 9 shows the ability of Proposed Protection scheme to detect and classifying the fault without getting affected by varying the Fault Parameters i.e. Fault Resistance , Fault Location & Impedance Angle. It shows the suitability of our Fuzzy Inference System that it is able to detect and classify practically also .As, it doesn't get affected by varying the fault parameters practically it shows the Fault due any accident or due to any storm i.e. natural disaster can cause any fault the the proposed protection scheme is able to detect it and classify it.

J. The Relay Tripping Time of Proposed Protection Scheme for Variation in Generator Supply i.e. Source 1 Supply

As during the fault there are fluctuation is always there that can be due to input mechanical power or due to the fault in the synchronous generator or due to some other reasons. The simulation deals with these type of condition when there is fluctuation in the supply. The fluctuation in magnitude is take in Source 1 supply is +/- 5%. During Fluctuation the voltage can be low or high according to which current also changes. The Proposed Protection Scheme is able to detect the fault and classify the fault within the given cycle of time 20 millisecond keeping frequency of generation at 50Hz. Also the Fault Location is 50 km from Bus 7 , Fault Resistance is 60Ω , Inception angle is kept constant at 240^0. And Generator supply Frequency 50Hz. The TABLE 10 shows the ability of our Proposed Protection Scheme to Detect and Classifies the fault without any modifications in Fuzzy Inference System.

TABLE 10
Detection and Classifcation of fault for vary in Generator Supply Voltage

Generator Supply (KV)	Fault Detection (ms)					Fault Type
	A	B	C	G	RT	
17.1	11.17	--	--	2.67	2.67	AG
17.4	--	7.27	--	5.67	5.67	BG
17.323	--	--	3.97	1.3	1.3	CG
17.42	9.97	9.97	--	--	9.97	AB
17.41	--	5.97	4.77	--	4.77	BC
17.50	6.77	--	3.61	--	3.61	CA
17.51	10.97	7.3	--	2.7	2.7	ABG
18.2	--	6.8	3.7	2.7	2.7	BCG
18.324	10.2	--	3.5	5.7	3.5	CAG
18.431	10.2	6.9	3.5	--	3.5	ABC
18.780	10.1	6.8	3.5	8	3.5	ABCG

K. The relay Tripping Time of proposed Protection Scheme for Variation in Generator Supply Frequency

TABLE 11
Detection and Classifcation of fault for vary in Generator Supply Frequency

Generator supply Frequency (Hz)	Fault Detection (ms)					Fault Type
	A	B	C	G	RT	
50.085	11.7	--	--	3.5	3.5	AG
50.05	--	9.1	--	7.5	7.5	BG
49.95	--	--	5.1	3.5	3.5	CG
49.9	11.6	11.8	--	--	11.6	AB
50.01	--	8	6.6	--	6.6	BC
50.051	13.45	--	4.8	--	4.8	CA
50.002	11.7	9.1	--	4.5	4.5	ABG
50.10	--	8.9	N.S.	4.5	4.5	BCG
50.024	11.5	--	4.9	7.5	4.9	CAG
50.03	11.5	8.9	4.9	--	4.9	ABC
50.035	11.5	9	4.8	7	4.8	ABCG

As the previous section deals with the change in the magnitude and this section deals with the change in the frequency. These two changes are the major changes in the generator that mostly effect the protection scheme. The Change in Generator Supply Frequency is due to sudden change in load that generator is not able to cope up or due to synchronization process with parallel synchronous generator. The TABLE 11 shows the ability of the proposed protection scheme to Detect and Classify the Fault within the variation of Frequency of (+/-0.2%) keeping Fault location at 45 kilometer from Bus 7 , Inception angle at 45^0 , Fault Resistance 82Ω & Generator Supply is 18 Kilovolt From the Table it can be clearly seen that our Proposed Protection Scheme will be able to do its work without getting affected through the change in frequency.

L. The Relay Tripping Time of Proposed Protection Scheme for Variation in Generator Supply And Generator Frequency

The Previous two sections i.e. 3.11 & 3.10 deals with the change in individual parameter of Generator. If both the Parameter are Varied in combination then the Protection Scheme should be able to protect it. The TABLE 12 shows the ability of Proposed Protection Scheme to Detect And Classify the Fault within a cycle of time i.e. 20 milliseconds keeping Fault location at 85 kilometer , Inception Angle at 315^0 and Fault Resistance at 56Ω. In the Simulation the Generator Supply Voltage varied from +/-5% and Generator Supply Frequency is varied from +/-0.2%.

TABLE 12
Detection and Classifcation of fault for vary in Generator Supply Voltage and Frequency

Generator Supply (kv)	Generator supply Frequency (Hz)	Fault Detection(ms)					Fault Type
		A	B	C	G	RT	
17.32	49.98	8.3	--	--	5.5	5.5	AG
17.34	49.92	--	6	--	3.5	3.5	BG
17.4	49.97	--	--	10.4	8.5	8.5	CG
17.6	50.10	7.1	6.8	--	--	6.8	AB
18.1	50.08	--	10.6	11.8	--	10.6	BC
18.15	50.018	11.1	--	8.9	--	8.9	CA
18.25	50.028	7.6	5.4	--	8.5	5.4	ABG
18.35	50.032	--	5.4	9.7	5.5	5.4	BCG
18.4	50.016	7.7	--	9.8	3.5	3.5	CAG
18.8	50.092	7.3	5	9.4	--	5	ABC
18.9	50.096	7.2	5	9.4	7	5	ABCG

M. The Relay Tripping Time of Proposed Protection Scheme for variation in Load Magnitude and Load Angle

Variation in Load and Load angle Causes the fluctuation in fault Voltage and Fault Current. The Load 1 which is near to Bus 7 is selected for these variation. The Load is varied from +/- 250 MVA and load angle is varied from +/-10^0. Due to change in load the Fault Current and Voltage change. The Proposed Protection scheme is able to Detect and Classify the fault by keeping Fault Location at 56 kilometer, Inception Angle is 180^0 and Fault Resistance is at 50Ω.. The TABLE 13 shows the ability of Proposed Protection Scheme to Detect and Classify the fault. So, these shows that our proposed protection scheme is able to do its work under some variation also , this shows the practical applicability of the Proposed Protection Scheme. These Simulation Deals with the fact that during any low load Fault in the Transmission line occurs due which cause low fault current to flow through the Transmission line. The Protection Scheme is able to Detect that Fault and classify it.

TABLE 13
Detection and Classifcation of fault for vary in Load Magnitude and Load Angle

S_{load} in MVA	δ_{load}= Load angle	Fault Detection (ms)					Fault Type
		A	B	C	G	RT	
94.86	18.43^0	6.6	--	--	4	4	AG
107.70	21.80^0	--	10.8	--	4	4	BG
110.68	18.435^0	--	--	7	6	6	CG
127.48	41.82^0	11	11.4	--	--	11	AB
156.20	39.81^0	--	10.5	8.7	--	8.7	BC
160.10	38.66^0	6.9	--	6.5	--	6.5	CA
163.25	40.03^0	5.8	9.7	--	7	5.8	ABG
167.11	38.93^0	--	9.9	7	4	4	BCG
170.3	40.24^0	5.7	--	7	4	4	CAG
174.14	39.2^0	5.5	9.9	6.8	--	5.5	ABC
210.95	31.43^0	4.9	4	5.9	8	4	ABCG

TABLE 14
Detection and Classifcation of fault for vary in Short Circuit Capacity of Generator

Short Circuit Capacity (MVA)	Fault Detection (ms)					Fault Type
	A	B	C	G	RT	
200	5.7	--	--	4	4	AG
220	--	10.3	--	4	4	BG
240	--	--	6.2	6	6	CG
260	5	10.65	--	--	5	AB
280	--	8.7	7.8	--	7.8	BC
300	4	--	5.05	--	4	CA
320	3.85	7.85	--	5	3.85	ABG
340	--	8.1	4.54	3	3	BCG
360	3.55	--	4.65	3	3	CAG
380	3.3	3.85	4.75	--	3.3	ABC
400	3.15	3.35	4.85	5	3.15	ABCG

N. The Relay Tripping Time of Proposed Protection Scheme on Varying the Short Circuit Capacity of the Generator

The TABLE 14 Shows the Performance of Proposed Protection Scheme in varying the Short circuit capacity of the generator. In this case the generator is supposed to have internal faults due to which the short circuit capacity of Generator varies. The Results shows the proposed Fuzzy Inference System is able to detect the Fault within a cycle of time i.e. 20 milliseconds. The Fault is Generated in the Transmission line between Bus 7 & Bus 8.The Fault location is 1 kilometer away from the Bus 7 , the Fault Resistance is 56Ω and Inception angle is 300^0. The Results of this simulation shows the proposed protection scheme will be able to detect and classify the fault with in the limit +/- 250 MVA..

O. The Relay Tripping Time on Varying Sampling Time

The TABLE 15 shows the ability of proposed Protection Scheme to detect and classify the fault within a cycle of time keeping Fault location at 99.5 km from bus 7 , Inception angle is at 100^0 and Fault Resistance is 58Ω . The Change in Sampling Frequency is done to take samples fast and system will be protected

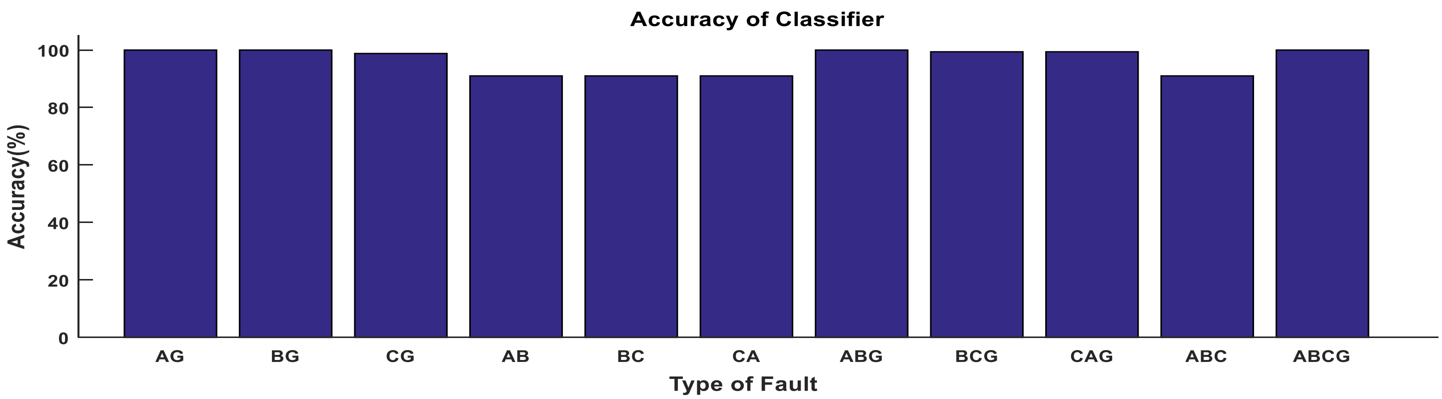
TABLE 15
Detection and Classifcation of fault at Different Sampling Rate

Sampling Frequency (KHz)	Fault Detection (ms)					Fault Type
	A	B	C	G	RT	
1	6.6	--	--	4	4	AG
20	--	11.6	--	5	4	BG
20	--	--	7.7	7	6	CG
20	11.3	13.3	--	--	5	AB
2	--	10.9	10.5	--	7.8	BC
2	8.7	--	6.8	--	4	CA
2	6.7	11.6	--	7	3.85	ABG
5	--	11.6	7.7	4	3	BCG
5	6.5	--	7.5	5	3	CAG
5	6.3	11.4	7.5	--	3.3	ABC
5	6.3	11.4	7.5	8	3.15	ABCG

TABLE 16
Performance Evaluation of the Proposed Protection Scheme on the basis of Detection and Classification of Different Type of Fault

Fault Type	Accuracy(%)	Precision	Sensitivity	Specificity	F Measure
AG	100	1	1	1	1
BG	100	1	1	1	1
CG	98.79	1	0.867	1	0.93
AB	91	0.5	1	0.9	0.67
BC	91	0.5	1	0.9	0.67
CA	91	0.5	1	0.9	0.67
ABG	100	1	1	1	1
BCG	99.39	1	0.93	1	0.964
CAG	99.39	1	0.93	1	0.964
ABC	91	0.5	1	0.9	0.67
ABCG	100	1	1	1	1

FIGURE 5
Accuracy of Classifier for Different Fault



P. Performance Evaluation of Proposed Protection Scheme on the basis of Detection and Classification of different Fault

The TABLE 16 shows the Performance Evaluation of the Proposed Protection Scheme on Bus-7 in IEEE-9 bus System. The Performance Evaluation uses five parameter to evaluate that are Accuracy , Precision , Sensitivity , Specificity and F-Measure. The Parameters are calculated using the Confusion Matrix. The Confusion Matrix Requires Data in form of True Positive, True Negative, False Positive and False Negative. These data's are collected after simulation of 11 faults after 225 simulation of Different Faults . In the TABLE 16, the accuracy shows the how much system is accurate to Detect and Classify the fault. The Figure 5 Shows the Bar Graph of the Accuracy of the Proposed Scheme. The Second Parameter in the TABLE 16 i.e. Precision can be defined as the Degree of exactness. A low Precision value indicates its less exact the Protection Scheme . So for certain Faults the classification Precision is 0.5 but in almost all the cases it is 1. Also, the System is able to detect the fault where the precision is less within a cycle of time 3 phase relay will be tripped and system will be safe. The next parameter is the Sensitivity of the proposed Protection Scheme in Detection and Classification of Fault. It Directly give us the completeness of the detector and Classifier. From TABLE 16 it can be seen that proposed protection scheme sensitivity is almost 1 and above 0.85 in all the case. This shows the Sensitivity of the Proposed Protection Scheme is good. The Fourth Parameter is Specificity i.e. the ability of the Proposed Protection Scheme to be specific about Detecting and Classifying the Faults. The Figure 6 shows the Specificity of the Proposed Protection Scheme in the form of Bar Graph. The last but the most important parameter which prove the usefulness of our Proposed Protection Scheme is F-measure. The F-measure consist of both the Degree of Exactness and the Degree of Completeness. The F measure below 0.5 is not considerable to use as classifier. From the TABLE 16 F-measure of the Proposed Protection Scheme is minimum at 0.67. Thus it proves that the Classifier is efficient and can be Practically use. The Figure 7 shows the Bar Graph of the F measure of the Proposed Protection Scheme. So from the TABLE 16 overall Performance Evaluation of the Proposed Protection Scheme is done and shows it usefulness.

FIGURE 6
Specificity of Classifier for Different Fault

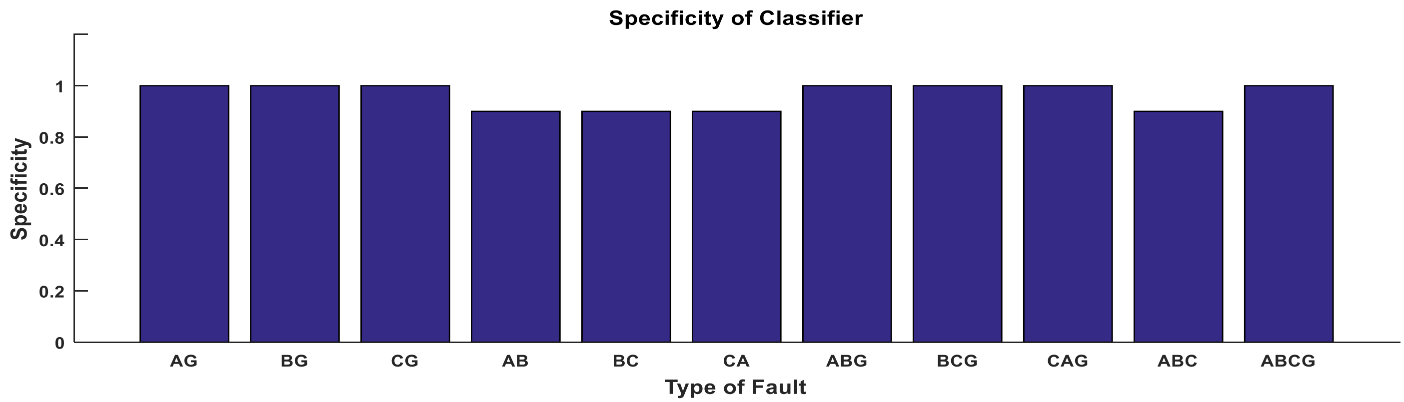
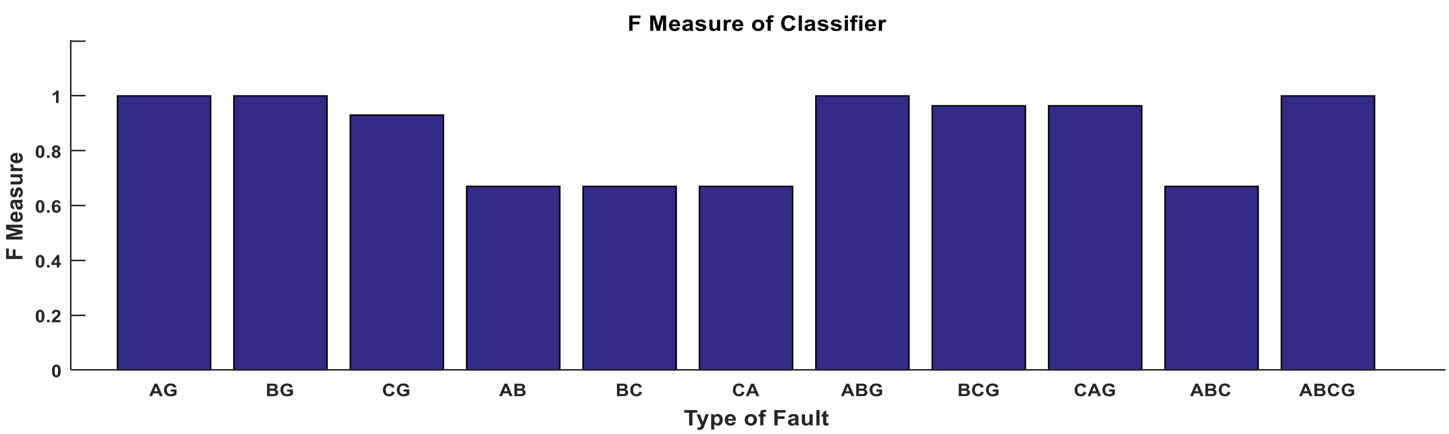


FIGURE 7
F Measure of Classifier for Different Fault



IV. CONCLUSION

In this paper Proposed Protection based on Discrete Fourier Transform using Fuzzy Inference System for Detection and classification of Faults in IEEE-9 Bus system. has been successfully simulated. By Performing at numerous operating condition with different parameters such as Fault Location ,Fault Resistance & Inception angle. The Proposed Protection Scheme Accuracy and F measure is calculated according to which our Proposed Protection System is Reliable for Classification and Detection of the Faults. The Mean accuracy of the Proposed Protection Scheme is 96.50 %. Further the Proposed Protection Scheme is able to detect the fault within a cycle of time i.e.20 milliseconds. There are total 225 simulation of 11 different faults are simulated. Thus the Proposed Protection Scheme is reliable , adaptable to different parameter change and can be practically use in more than one synchronous generator system i.e. IEEE-9 Bus system.

V. COMPARISON

TABLE 17 Shows the Comparison with different papers which propose the Protection Scheme based on Fault Detection and Classification .Similar Approach for Fault Detection and Classification is used in [32] but there are lot of difference in results which shows the classifier is reliable to detect and classifies the fault .In [33] uses the wavelet analysis and the linear discriminant analysis for fault detection and classification . The detection Time in this approach is a cycle of time i.e. Relay Tripping Time and for 99% of transmission line. In [31] Fuzzy logic approach in a single circuit transmission line to detect and classify the fault using reactive power. In[34] Fuzzy logic approach in transmission line to detect and classify the fault using positive sequence current. As Accuracy is mentioned only in two paper [32,33]. The accuracy can not be only judging parameter for the classifier. For any binary Classifier other important parameters need to be calculated like Precision , Sensitivity , Specificity & F measure. F measure is one of the important parameter to judge the reliability of the binary classifier. The F measure mean is 0.87 and the minimum value for any classifier to be installed practically is 0.5. So, the Paper approach using fuzzy logic is reliable and practical by taking input positive sequence current and positive sequence voltage magnitude only .The comparison table shows the clear comparison between different papers with our proposed scheme.

TABLE 17
Comparison Table with other research papers

	Model & Approach	Fault Length & Relay Tripping Time	Suitability
Mehdi Saradarzadeh , Majid Sanaye-Pasand[32]	Fuzzy logic approach in a transmission line with multi-generator to detect and classify the fault using current and voltage phase	Not Mentioned	Accuracy is 99.875%, Precision , Sensitivity, Specificity measure not defined
Anamika Yadav , Aleena Swetapadma[33]	The wavelet analysis and the linear discriminant analysis for fault detection and classification	99% of transmission line & within a cycle of time	Accuracy is 100% , Precision , Sensitivity, Specificity measure not defined
B. Mahamedi , J.G. Zhu[31]	Fuzzy logic approach in a single circuit transmission line to detect and classify the fault using reactive power.	Not mentioned	Not mentioned
R.N. Mahanty , P. B. Dutta Gupta[34]	Fuzzy logic approach in transmission line to detect and classify the fault using positive sequence current	Not mentioned	Not Mentioned
Proposed Scheme	Fuzzy Logic Approach is used for Detection and Classification in a transmission line of IEEE-9 Bus System using Positive Sequence Current and Positive Sequence Voltage Magnitude only	For 100% of Transmission Line & within a cycle of time	Accuracy is 96.50%.Precision is 0.82, Sensitivity is 0.976, Specificity is 0.96, F measure is 0.87

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