A Novel Distance Relaying Scheme to Mitigate Phase Faults on Doubly Fed Transmission Lines

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Abstract— Conventional non-pilot distance relaying schemes having the facility of series compensated transmission line were found to fail in providing requisite protection to the transmission line during phase faults. A new novel distance relaying scheme is proposed to mitigate the misinterpretations that occur in the conventional methods due to the capacitor used, infeed/outfeedsources, pre-fault system condition, non -linear behaviour of Metal Oxide Varistor(MOV) and arc resistance The proposed method provides an elaborate study of the apparent impedance seen from its relaying point and measures the accurate value of impedance of the faulted line using symmetrical components of voltages and currents. This method has been validated through the simulations carried out on a 400 kV, doubly fed 300 km series compensated long transmission line using MATLAB/SIMULINK software. Finally an evaluation is done by comparing the conventional and the new proposed scheme is done and effectiveness of the proposed method is inferred.

Keywords - Series capacitor (SC), Metal Oxide Varistor(MOV),Single Line to Ground (SLG),Phase to Phase(PP)

I. INTRODUCTION

The series compensation is defined as the insertion of capacitor in series with the transmission line in parallel with the protective device called Metal Oxide Varistor(MOV). The cost of building a new transmission line starts increasing that leads to the way to think of using the exisisting lines by the use of SC to improve the Power transfer capability, System stability, Voltage regulation, and reduce transmission losses [4].To reduce the installation cost, the SC must be placed at the terminals of the transmission lines [5]. It can be installed on one side or both sides of the transmission line. Over voltage protection is the important factor in the design of SC. Traditionally, the over voltage imposed on the series capacitor can be avoided by using Gap-type scheme. At present, it is modified by MOV protection scheme.

During the abnormal fault condition the voltage across the capacitor starts increases. To avoid the voltage stress on the SC the MOV starts conduction and by-pass the capacitor. It consists of RL damping circuit, air-gap and by pass switch .Damping circuit is used to limits the discharge current and absorbs the capacitor energy. There is a special circuitry for the energy monitory in the MOV. This will calculate the energy dissipation, if the energy dissipation is very high it will trigger the air-gap and divert the current away from the MOV. The by-pass switch is closed when the energy limit is reached. The MOV is not conducting fully in the operation. Under a normal condition, it will possess a high resistance and it will be in an OFF state [6].

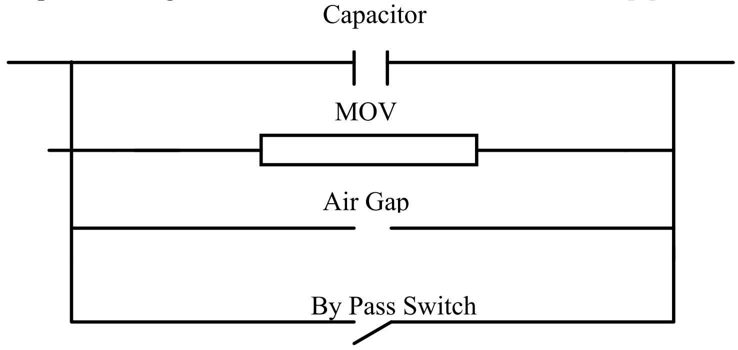


Fig.1 MOV protected series capacitor

II. Model For SC/MOV Combination And Simulation

A. Linearized Model for Parallel Combination

During the fault condition, at the time the voltage across the capacitor increases beyond the reference value, MOV starts conduction [9]. In this stage, the combination of SC/MOV becomes resistive with a small capacitive reactance. i_{pu} is the ratio of current flowing through the MOV (i) to the protective level current (i_{ref}) of SC. The equation for resistance and reactance are as follows: [10]

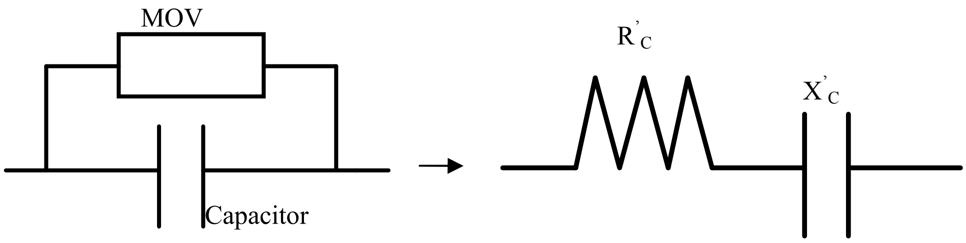


Fig.2 Equivalent circuit for SC/MOV

If i_{pu} is greater than 0.98p.u, then,

$$R_C' = X_C\left(0.0745 + 0.49e^{-0.243i_{pu}} - 35e^{-5i_{pu}} - 0.6\, e^{-1.4i_{pu}}\right) \quad (1)$$

$$X_C' = X_C\left(0.1010 + 0.005749i_{pu} - 2.088e^{-0.85566i_{pu}}\right) \quad (2)$$

The (1) and (2) equation is called as Goldsworthy's Equation.

B.Model for the Simulation

Fig.3 shows the equivalent model for the three phase series compensated line X and uncompensated line Y fed by the two source S and R .The SLG Fault is simulated on the phase A and the relay is located at the bus S.The series capacitor are placed in each phase of the transmission line X.The reverse fault is simulated on the uncompensated transmission line Y.The SC which is placed in each phase is protected by the MOV.Fig.4 shows the PP on phase A and B respectively.

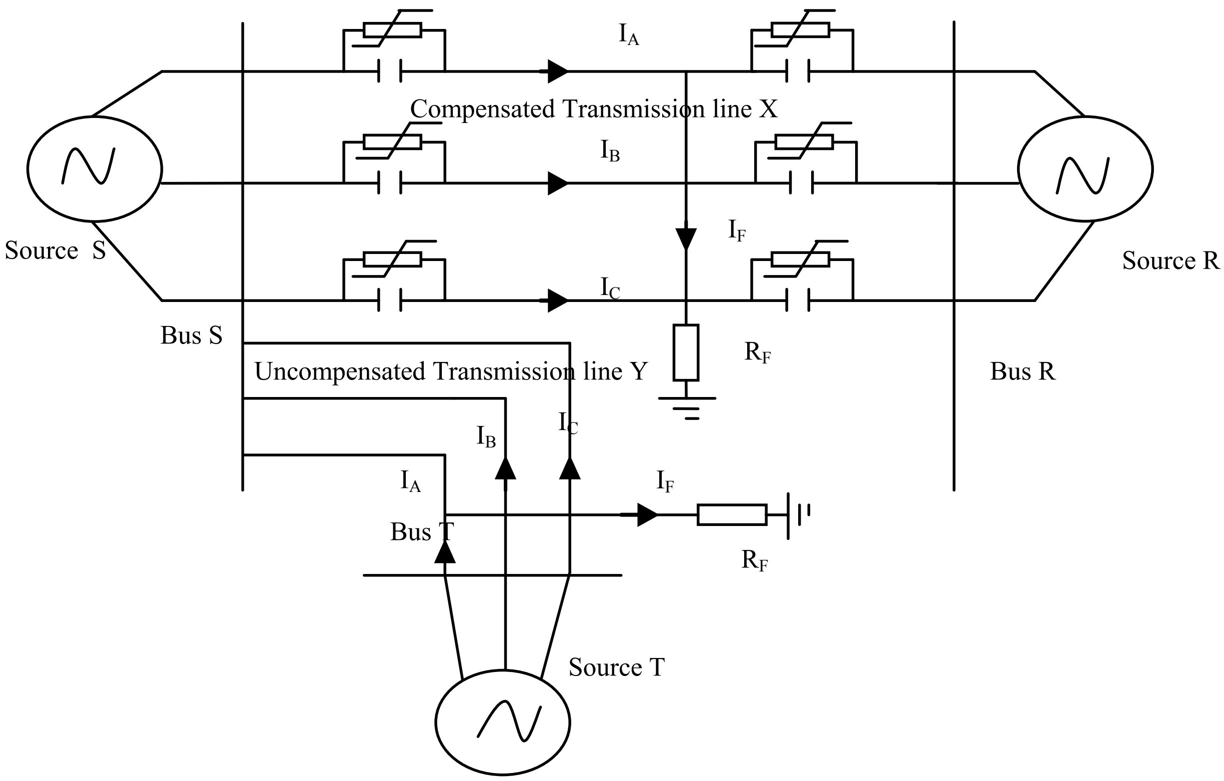


Fig.3 Model for Single Line to Ground Fault

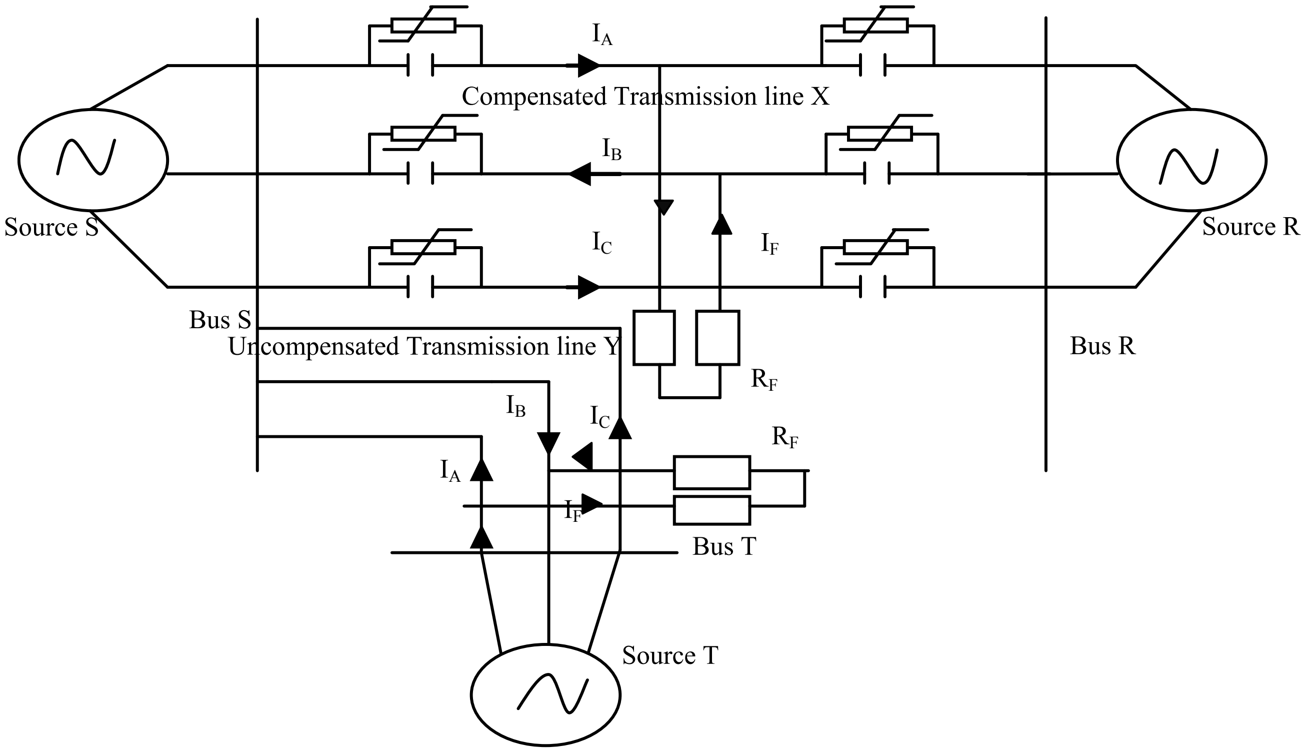


Fig.4 Model for Phase to Phase Fault

III. ANALYSIS OF SYMMETRICAL FAULTS AND MATLAB SIMULATION CIRCUIT

A. Analysis Of SLG Fault

a) Fault Impedance as Seen by Conventional Method

Consider the SLG Fault on phase A, the impedance measured by the conventional distance relay scheme is given as,

$$Z_{APP} = \frac{E_A}{I_A + K_0 I_0} \quad (3)$$

$$K_0 = \frac{Z_{L0} - Z_{L1}}{Z_{L1}}$$

E_A and I_A is the voltage and current of phase A.K_0 is known as the residual current compensation factor or zero-sequence current compensation factor.

b) Fault Impedance as seen by Proposed Scheme

Assumptions Made in the proposed scheme

The new proposed scheme is mainly based on symmetrical components of voltages and currents. These are expressed as [14],

$$V_{012}=Z_{012}I_{012} \quad (4)$$

$$Z_{012} = \frac{1}{3}\begin{bmatrix} Z_A + Z_B + Z_C & Z_A + a^2Z_B + aZ_C & Z_A + aZ_B + a^2Z_C \\ Z_A + aZ_B + a^2Z_C & Z_A + Z_B + Z_C & Z_A + a^2Z_B + aZ_C \\ Z_A + a^2Z_B + aZ_C & Z_A + aZ_B + a^2Z_C & Z_A + Z_B + Z_C \end{bmatrix}\begin{bmatrix} I_0 \\ I_1 \\ I_2 \end{bmatrix} (5)$$

From the equation (5), Z_A, Z_B, Z_C represents the Goldsworthy's equivalent impedances for the phases A,B and C of the transmission line. The term 'a' is the phase shift operator. The values of equivalent impedances Z_A, Z_B ,Z_C are different in nature. So the element in the impedance equation will never become zero and there exists a mutual coupling between the sequence elements of SC/MOV parallel combination. For the analysing purpose, the positive and negative impedance (Z_{L1} and Z_{L2}) of the transmission line are assumed to be equal. The voltages and currents of phases A,B,C of the compensated transmission line X is represented as E_A, E_B, E_C, and I_A , I_B, I_C respectively. E_{120}, I_{120} represents the sequence components voltage and current of the compensated transmission line X at the relay point. The subscript 1, 2, 0 represent the positive, negative, zero sequence components. In this case, a SLG fault is occurred on the compensated transmission line X at p percentage from the bus S. X_{MA}, X_{MB} , X_{MC} are the values of the reactance of series capacitor located at the phase A,B,C respectively. It is assumed that $X_{MA} = X_{MB} = X_{MC} = X_M/2$. X_M is the total value of reactance of the capacitor placed in the compensated transmission line X. R'_{MA} , R'_{MB}, R'_{MC} and X'_{MA}, X'_{MB} , X'_{MC} represents the equivalent resistance and reactance value for the parallel combination of SC/MOV placed in the line X.

The fault current starts flowing through the MOV with occurrence of fault. The ratio of current (i_{pu}) passing through the MOV to the reference current of SC is greater than 0.98,then the impedance of the faulted line can be changed according to the Goldsworthy's equation. The impedance of the healthy phase remains unchanged. The impedance of the SC/MOV combination of the three phases on considering the fault is at the A phase is given by,

$$Z_{MA} = R'_{MA} - jX'_{MA} \quad (i_{pu}>0.98) \tag{6}$$

$$Z_{MA} = -jX'_{MA} \quad (i_{pu}< 0.98) \tag{7}$$

$$Z_{MB} = -jX'_{MB} \tag{8}$$

$$Z_{MC} = -jX'_{MC} \tag{9}$$

The actual value of the impedance of the faulted line measured by the proposed method is given by [12],

$$Z_{ACT} = pZ_{L1} = Z_P = \frac{1}{I_K}[E_A - V_{MA} - R_F I_A] \tag{10}$$

$$I_K = I_A + K_0 I_0$$

The impedance measured by the proposed method can be also expressed as follows [12],

$$Z_{ACT} = Z_P = Z_{APP} - Z_{SC} - Z_F \tag{11}$$

From these two equations, it can be found that

$$Z_{APP} = (E_A / I_K) ; \quad Z_{SC}=(V_{MA}/ I_K); \; Z_F = R_F*(I_A / I_K)$$

The proposed method is expected to give more accurate results since the effect of series capacitor, non-linear behavior of MOV are taken into consideration. Hence the proposed scheme measures and compares the impedance of the faulted phase the set value and issues the trip signal accordingly.

B. Analysis of PP fault

a) Fault Impedance As Seen By Conventional Methods

Consider the PP Fault on phase A and B on the compensated transmission line X.

$$Z_{APP} = \frac{E_A - E_B}{I_A - I_B} \tag{12}$$

b) Fault Impedance as Seen by Proposed Scheme:

The impedance of the faulted portion of transmission line during the PP as follows,[13]

$$pZ_{L1} = \frac{E_A - E_B}{I_A - I_B} - \frac{(R'_{MA} - jX'_{MA})I_A}{I_A - I_B} + \frac{(R'_{MB} - jX'_{MB})I_B}{I_A - I_B} - R_{ARC} \tag{13}$$

On separating the above equation in to a real and imaginary part, we get the positive reactance is given as,

$$X_{L1} = \text{imaginary}\left(\frac{E_A - E_B}{I_A - I_B}\right) + \frac{jX'_{MA}I_A}{I_A - I_B} - \frac{jX'_{MB}I_B}{I_A - I_B} \tag{14}$$

It is known that the ratio of reactance (X) to resistance (R) of the transmission line remains constant. Therefore the compensated value of resistance (R_{L1}) of faulted portion of transmission line X is determined by,

$$R_{L1} = X_{L1} \times R/X$$

It is found that the positive sequence reactance (X_{L1}) and resistance (R_{L1}) is immune to the arc resistance. During the early stage of an arc the value is very small. So the arc resistance value is assumed to be 0.5Ω.The value of the line resistance is determined only by knowing the ratio of resistance to reactance value of the transmission line X. The R/X value of the line is not known .So the reactance of the faulted line is only taken into account for this case.

C. Percentage Error Calculation

The SLG and PP fault is simulated on a 400kV, 300km series compensated doubly fed transmission line. The percentage error (ε) of the resistance and reactance corresponding to the conventional method and proposed method can be calculated by using the formula given below:

$$\varepsilon_{RAPP} = R_{APP} - R_{ACT} / R_{ACT} \times 100\% \tag{15}$$

$$\varepsilon_{XAPP} = X_{APP} - X_{ACT} / X_{ACT} \times 100\%$$

$$\varepsilon_{RP} = R_P - R_{ACT} / R_{ACT} \times 100\% \tag{16}$$

$$\varepsilon_{XP} = X_P - X_{ACT} / X_{ACT} \times 100\%$$

In the above equations the resistance and reactance namely R_{APP} and X_{APP} denotes the conventional method values whereas R_P and X_P denote that of proposed method with the distance relay placed at the bus S. Similarly ε_{RAPP}, ε_{XAPP} represents the error as a percentage of the resistance and reactance measured by the conventional distance relay scheme located at the bus S. ε_{RP}, ε_{XP} represents the error as a percentage of the resistance and reactance measured by the proposed scheme located at the bus S.

D. Simulation Circuit

The model for the three phase circuit of series compensated and uncompensated doubly fed transmission lines are shown in Fig.3.It is simulated in MATLAB/SIMULINK. The compensated transmission line is connected between the source S and source R shown in Fig.5. The uncompensated transmission line is connected between the source S and source T. The source voltage for all sources are 400kV having the short-circuit level as 20,000MVA. The length of the compensated and uncompensated transmission line X and Y is assumed to be 300km.The fault breaker component in SIMULINK is used for simulating various faults. So the same circuit can be used for simulating various faults.

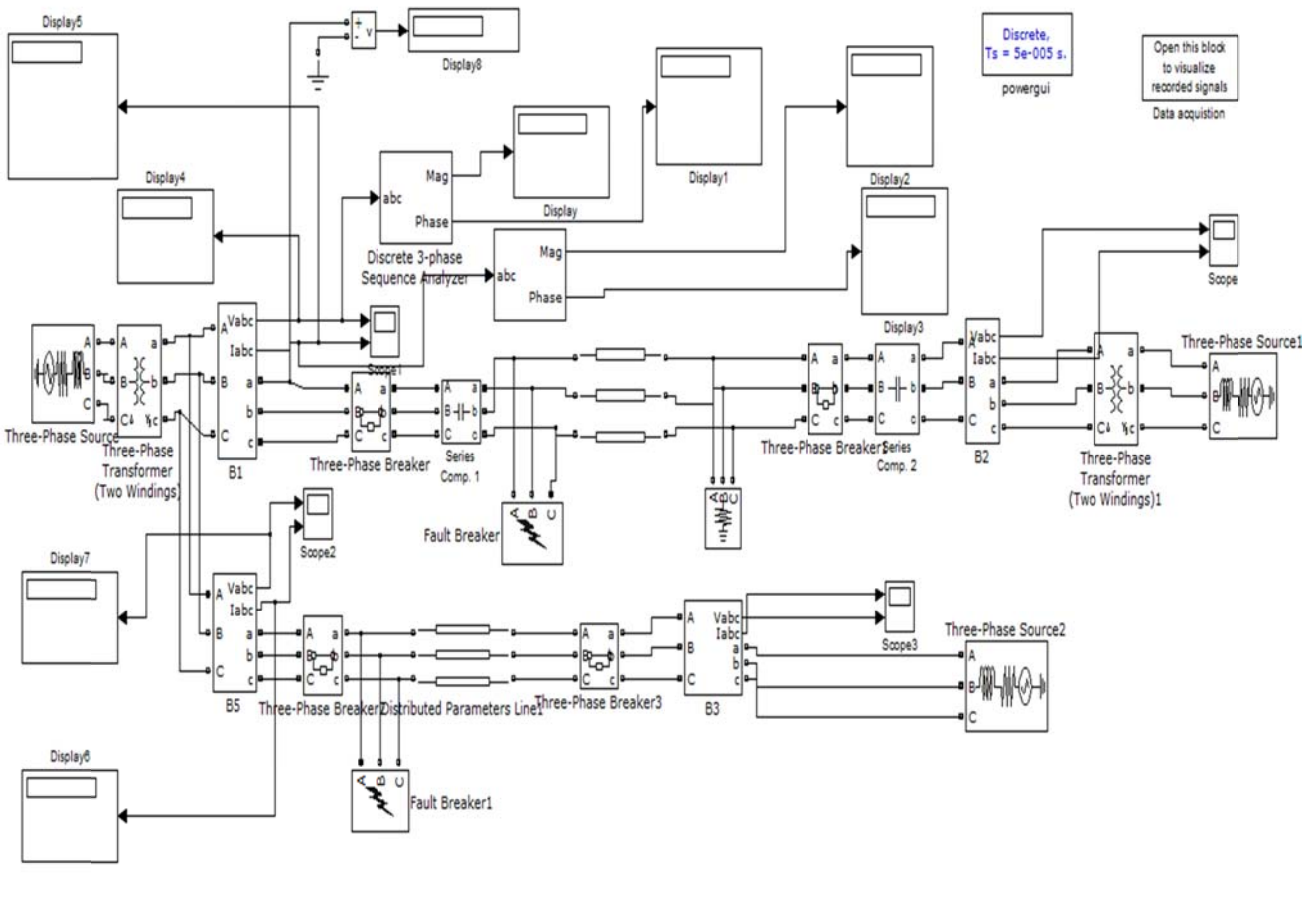


Fig.5 Simulation circuit for both faults

IV. RESULT AND DISCUSSION

A. SLG Fault

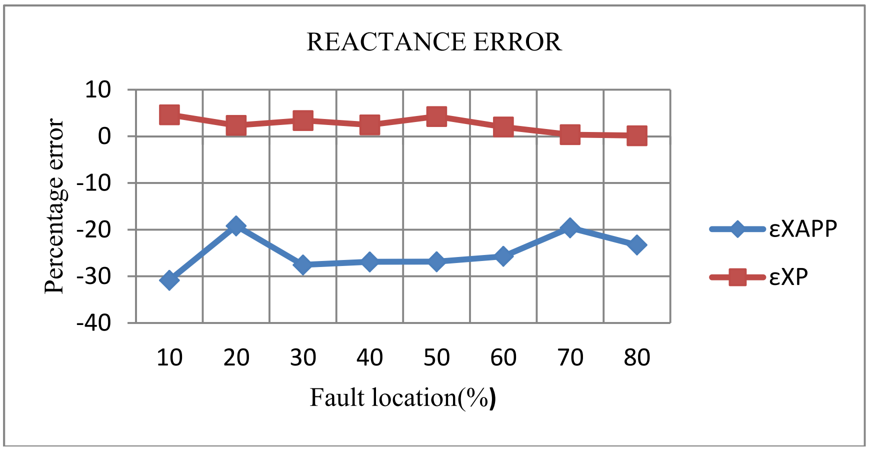
This fault is simulated on 400kV and 300km transmission line having different values of series compensation, various fault location, and power transfer angle. The zone of boundary is set to 80% of the transmission line X. A single line to ground fault is simulated on the transmission line X. Delta (δ) represents the power transfer angle between two buses S and R.K_M denotes the degree of compensation and it is the ratio of the reactance of the capacitor placed in the transmission line X to the inductive reactance of the line X. The values obtained from the simulation output is used to find the values of resistance, reactance and percentage error for both conventional and proposed method and the values are also tabulated.

a) Effect of change in Fault Location

The Table I and Fig.6 indicates the effectiveness of conventional and proposed scheme in terms of measurement of percentage error of the resistance and reactance of the faulted portion of the compensated transmission line X at different fault location (0% to 80%) having power transfer angle (δ) +15° degree of compensation (K_M =50%), fault resistance (R_F) as 50Ω.The percentage error is also calculated for both conventional and proposed method. It is found that the percentage error of conventional method is very high and it is deviate more from the actual impedance. The proposed method having the percentage error is within the range of ±5%.The percentage error of the proposed method is decreases as the fault location moves away from the relaying point.

TABLE I- EFFECT OF CHANGE IN FAULT LOCATION FOR A SLG FAULT

P (%)	R_{ACT}	X_{ACT}	R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	R_P	ε_{RP}	X_P	ε_{XP}
0	0	0	1.08	_	1.13	_	0.78	_	0.0581	_
10	0.9	9.99	1.23	37.11	6.93	-30.86	0.92	2.56	10.45	4.63
20	1.8	19.58	2.43	35.45	15.81	-19.20	1.84	2.32	20.04	2.35
30	2.7	29.97	4.96	194.9	21.70	-27.56	2.80	3.75	30.98	3.40
40	3.6	39.96	6.14	70.63	29.20	-26.91	3.73	3.62	40.93	2.44
50	4.5	49.95	7.68	70.80	36.52	-26.87	4.70	4.62	52.07	4.25
60	5.4	59.94	9.83	82.20	44.51	-25.73	5.43	0.60	61.14	2.01
70	6.3	69.93	11.03	75.14	56.21	-19.61	6.48	2.97	70.18	0.36
80	7.2	79.92	11.38	58.11	61.30	-23.28	7.24	0.56	80.03	0.14



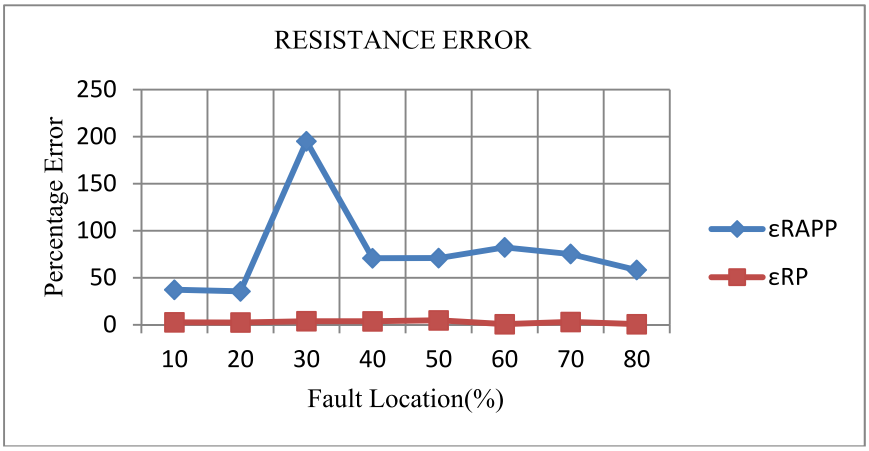


Fig.6 Percentage error measurement of R and X during SLG with values of p

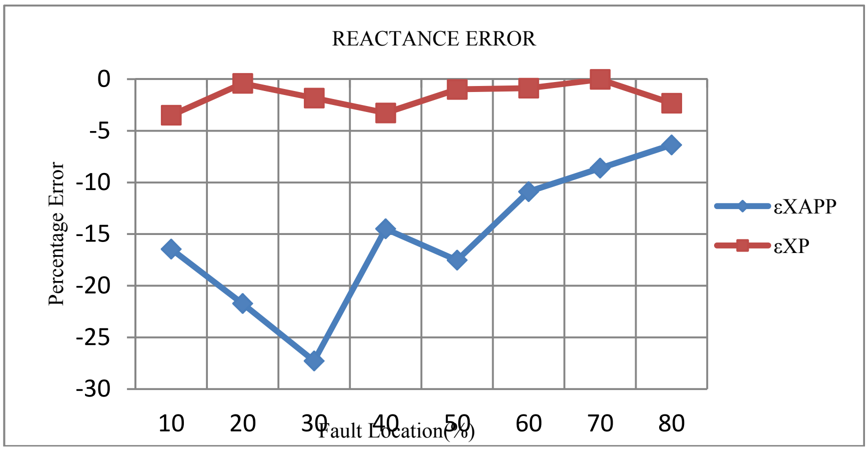
b) Effect of Change in Power Transfer Angle

The Table II and Fig.7represents the performance of the conventional distance relaying scheme and proposed scheme in terms of percentage error of resistance and reactance of the faulted line. The power transfer angle (δ) is changed to -15°with the fault resistance R_F=50Ω and degree of compensation (K_M) as 50%.

The percentage error of the proposed scheme lies within the range of ±5%.

TABLE-II EFFECT OF CHANGE IN POWER TRANSFER ANGLE FOR A SLG FAULT

P(%)	R_{ACT}	X_{ACT}	R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	R_P	ε_{RP}	X_P	ε_{XP}
0	0	0	0.13	_	1.54	_	0.84	_	0.12	_
10	0.9	9.99	1.24	37.16	8.34	-16.45	0.95	2.77	9.64	-3.49
20	1.8	19.58	3.18	77.19	15.63	-21.72	1.82	1.30	19.89	-0.41
30	2.7	29.97	3.53	31.10	21.79	-27.28	2.59	-3.96	29.42	-1.82
40	3.6	39.96	4.72	31.36	34.16	-14.49	3.70	2.86	38.65	-3.27
50	4.5	49.95	6.13	36.31	41.19	-17.52	4.34	-3.37	49.45	-0.99
60	5.4	59.94	8.38	55.26	53.41	-10.89	5.27	-2.35	59.41	-0.87
70	6.3	69.93	11.04	75.38	63.90	-8.62	6.29	-0.09	68.40	-0.02
80	7.2	79.92	13.18	83.13	74.83	-6.36	7.04	-2.08	78.06	-2.32



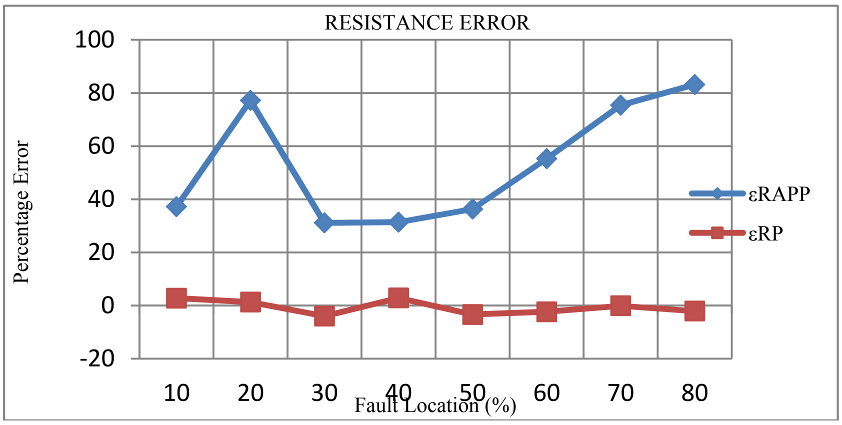


Fig.7 Percentage error measurement of R and X during SLG with values of δ

c) Effect of Change in the Level of Compensation

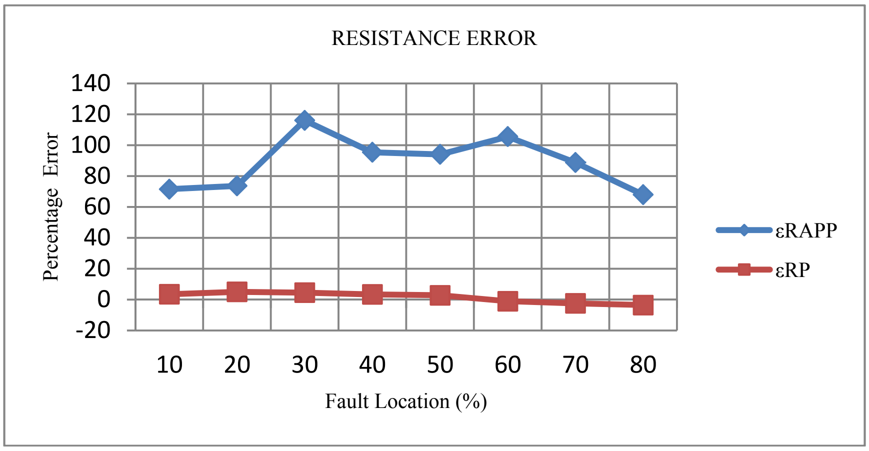
The Table IIIA , IIIB shows the percentage error of resistance and reactance for the conventional method and proposed method of the transmission lone X for the different compensation level (K_M =30%, and 70%) with the power transfer angle +15° with the fault resistance R_F=50Ω .The percentage error are plotted against the fault location is shown in Fig.8a,8b.

TABLE IIIA EFFECT OF CHANGE IN THE LEVEL OF COMPENSATION FOR A SLG FAULT (K_M =30%)

P(%)	R_{ACT}	X_{ACT}	R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	R_P	ε_{RP}	X_P	ε_{XP}
0	0	0	1.09	-	0.54	-	0.63	-	0.07	-
10	0.9	9.99	1.54	71.46	7.34	-26.51	0.93	3.44	10.04	0.53
20	1.8	19.58	3.12	73.58	14.73	-26.26	1.89	4.99	20.43	2.26
30	2.7	29.97	5.83	116.04	24.90	-16.91	2.82	4.44	29.93	-0.10
40	3.6	39.96	7.03	95.39	31.67	-20.73	3.71	3.31	40.58	1.56
50	4.5	49.95	9.73	94.05	42.53	-14.84	4.62	2.76	50.13	0.37
60	5.4	59.94	11.10	105.56	54.88	-8.43	5.34	-1.07	60.00	0.11
70	6.3	69.93	11.89	88.79	62.13	-11.14	6.14	-2.47	71.44	2.18
80	7.2	79.92	12.09	67.95	70.26	-12.08	6.94	-3.59	82.17	2.82

TABLE-III B EFFECT OF CHANGE IN THE LEVEL OF COMPENSATION FOR A SLG FAULT (K_M =70%)

P(%)	R_{ACT}	X_{ACT}	R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	R_P	ε_{RP}	X_P	ε_{XP}
0	0	0	1.03	_	1.23	_	0.57	_	0.03	_
10	0.9	9.99	1.53	71.04	14.34	43.60	0.94	4.47	10.29	3.03
20	1.8	19.58	3.78	110.17	16.93	-15.22	1.86	3.52	20.12	0.74
30	2.7	29.97	5.99	121.96	21.52	-28.19	2.63	-2.22	30.43	1.54
40	3.6	39.96	6.38	77.31	30.69	-23.18	3.72	3.36	39.82	-0.34
50	4.5	49.95	7.00	55.59	46.80	-6.29	4.60	2.34	49.32	-1.25
60	5.4	59.94	9.43	74.66	53.33	-11.02	5.38	-0.29	59.92	-0.02
70	6.3	69.93	11.10	76.23	60.40	-13.61	6.29	-0.05	70.05	0.17
80	7.2	79.92	12.93	79.60	65.83	-17.61	7.00	-2.66	78.21	-2.13



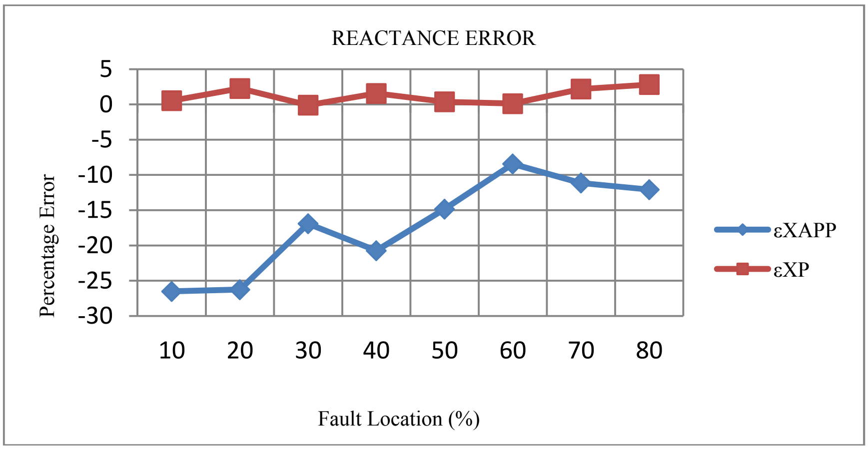


Fig.8a Percentage error measurement of R and X during SLG fault with values of K_M=30%

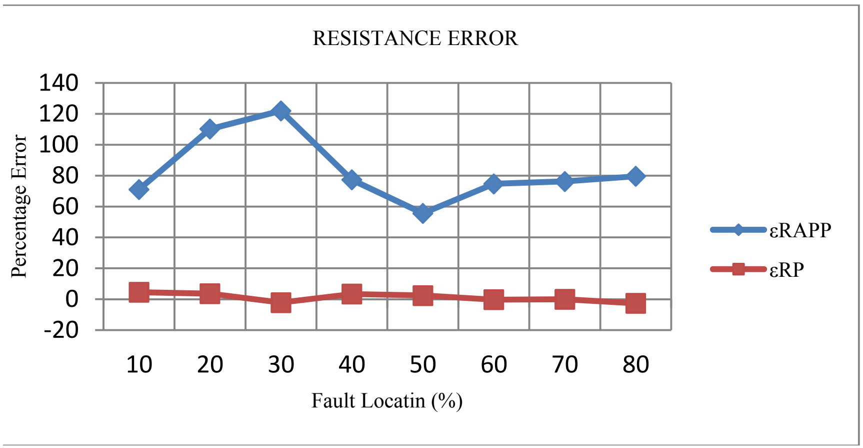


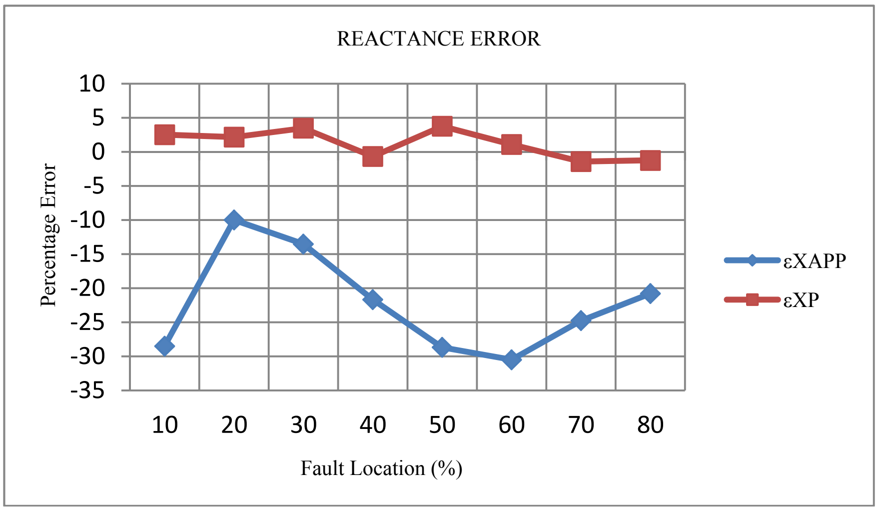
Fig.8b Percentage error measurement of R and X during SLG fault with values of K_M=70%

d) Effect of Change in Fault Resistance

The Table IV shows the percentage error of resistance and reactance for the conventional method and proposed method. The power transfer angle (δ) is changed to +15° with the different fault resistance (R_F=150Ω) and degree of compensation (K_M) as 50%. The percentage error are plotted against the fault location is shown in Fig.9.The percentage error of the proposed method is within the range of ±5

TABLE-IV EFFECT OF CHANGE IN FAULT RESISTANCE FOR A SLG FAULT (R_F=150Ω)

P(%)	R_{ACT}	X_{ACT}	R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	R_P	ε_{RP}	X_P	ε_{XP}
0	0	0	1.19	_	1.78	_	0.80	_	0.24	_
10	0.9	9.99	3.28	264.9	6.39	-35.98	0.92	2.36	10.23	2.43
20	1.8	19.58	4.69	160.74	16.18	-17.31	1.88	4.95	19.81	1.19
30	2.7	29.97	6.34	134.85	27.10	-9.55	2.75	1.90	31.14	3.91
40	3.6	39.96	8.21	128.23	29.02	-27.37	3.74	3.94	39.84	-0.28
50	4.5	49.95	9.41	109.32	35.62	-28.67	4.70	4.46	51.38	2.86
60	5.4	59.94	10.93	102.51	45.41	-24.23	5.64	4.46	60.42	0.80
70	6.3	69.93	11.30	79.43	58.12	-16.88	6.50	3.94	68.39	-2.16
80	7.2	79.92	12.83	78.32	63.10	-21.04	7.23	0.41	78.29	-2.03



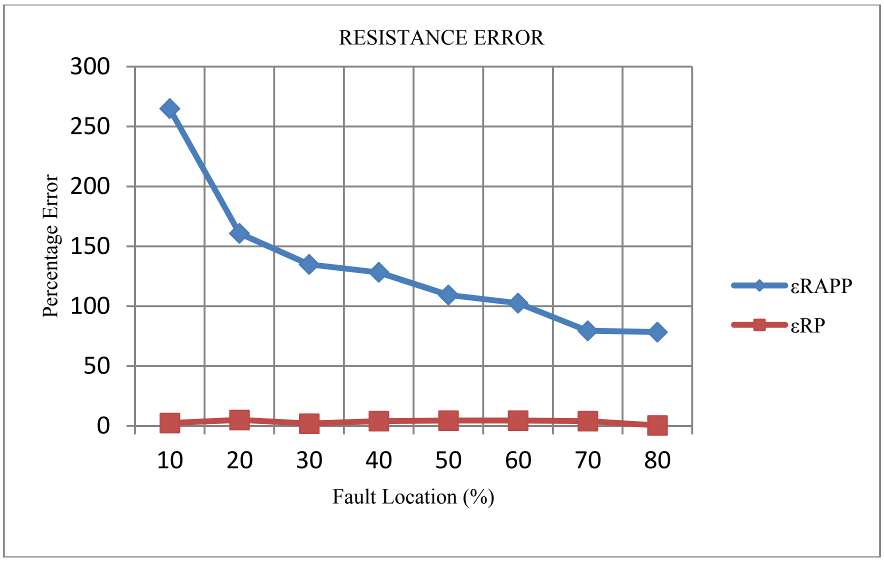


Fig.9 Percentage error measurement of Rand X during SLG fault for R_F=150Ω

B. PP Fault

To understand the effectiveness of the proposed scheme this fault is simulated on 400kV and 300km transmission line having different values of series compensation, various fault location, power transfer angle and short circuit capacity of the source.

a)Effect of Change of Fault Location and Power Transfer Angle

The TableV shows the percentage error of reactance for the conventional method and proposed method. The power transfer angle is changed to +40° and degree of compensation (K_M) as 50%. The percentage error of reactance is plotted against the fault location is shown in Fig.10 and Fig11.The fault location can be varies from 0% to 80% of the line. The percentage error measured by the proposed method is within the range of ±5%.

TABLE V EFFECT OF CHANGE IN FAULT LOCATION AND CHANGE IN POWER TRANSFER ANGLE FOR A PP FAULT

P (%)	R_{ACT}	X_{ACT}	δ =+40°						δ = -40°					
			R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	X_P	ε_{XP}	R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	X_P	ε_{XP}
0	0	0	3.29	-	-1.13	-	0.04	-	3.54	-	-1.65	-	0.03	-
10	0.9	9.99	6.04	571.11	6.428	-35.65	9.54	-4.56	6.19	587.77	6.942	- 30.93	9.54	-4.50
20	1.8	19.98	9.94	452.5	14.18	-27.62	19.76	-1.06	10.24	468.94	15.74	- 21.17	20.84	4.31
30	2.7	29.97	11.70	333.33	22.17	-26.02	30.52	1.85	13.95	416.11	25.22	- 15.86	30.45	1.62
40	3.2	39.96	12.05	284.98	27.05	-31.79	40.78	2.05	15.43	328.61	30.58	- 23.45	40.23	0.67
50	4.5	49.95	16.66	270.42	31.99	-35.95	51.81	3.78	18.93	320.71	38.42	- 23.07	51.00	2.10
60	5.6	59.94	18.65	245.37	43.12	-28.04	62.19	3.75	19.37	258.77	45.34	- 24.35	60.49	0.91
70	6.3	69.93	19.38	207.43	52.65	-24.70	73.42	4.94	20.18	220.03	52.65	- 24.70	79.42	1.35
80	7.2	79.92	19.87	176.01	65.40	-18.16	84.28	5.16	22.54	213.09	69.42	- 13.13	82.05	3.31

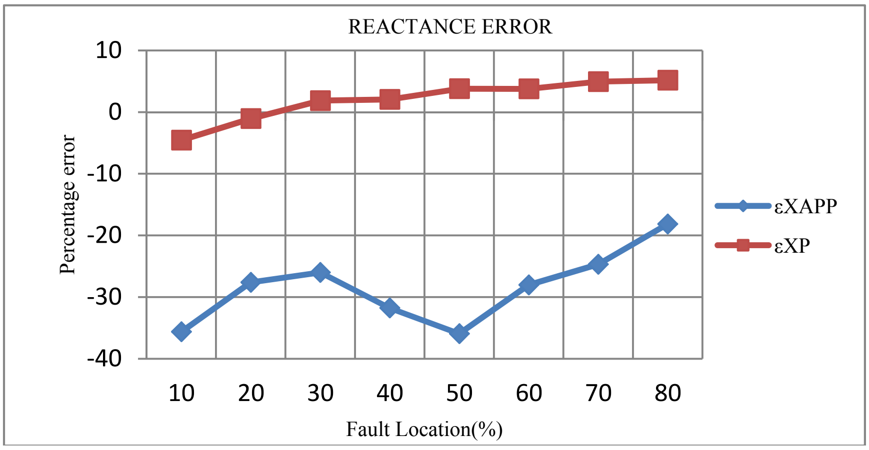


Fig.10 Percentage error measurement of R and X during PP fault for different values of p

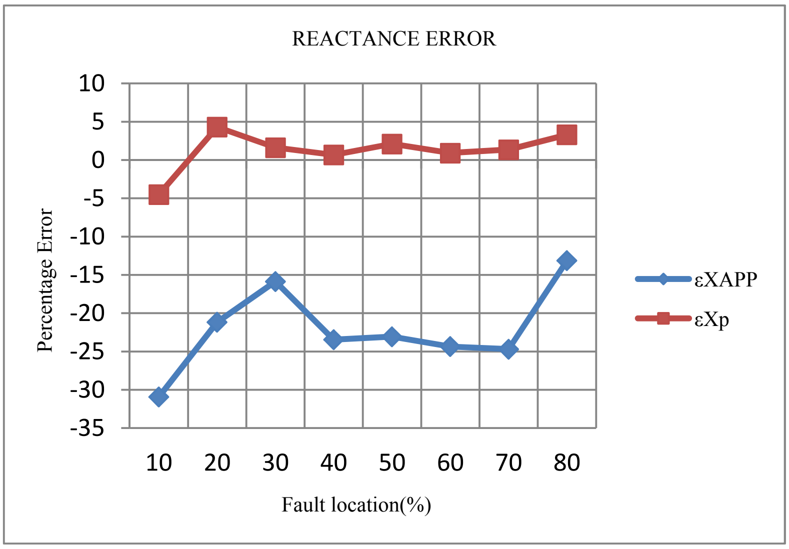


Fig.11 Percentage error measurement of R and X during PP fault for different values of δ

b) *Effect of Change in Compensation Level*

The Table VI shows the percentage error reactance for the conventional method and proposed method on varying the degree of compensation as (K_M=70%and 80%) and the power transfer angle (δ) is changed to +40°. The percentage error are plot against the fault location is shown in Fig.12a,12b.From the tabulation result ,it is found that the percentage error of the proposed scheme is within the range of ±5%.

TABLE VI EFFECT OF CHANGE IN COMPENSATION LEVEL FOR PP FAULT

P (%)	R_{ACT}	X_{ACT}	K_M=70%						K_M=80%					
			R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	X_P	ε_{XP}	R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	X_P	ε_{XP}
0	0	0	3.45	-	1.78	-	0.04	-	2.89	-	3.56	-	0.05	-
10	0.9	9.99	5.56	517.77	6.12	-38.61	9.37	-4.34	5.14	471.44	5.93	-40.40	9.54	-4.47
20	1.8	19.98	8.80	389.05	13.69	-31.43	19.86	-0.56	8.11	350.77	12.44	-37.72	19.48	-2.45
30	2.7	29.97	10.90	303.95	21.29	-28.94	30.52	1.85	9.48	251.66	19.57	-34.67	29.32	-2.16
40	3.2	39.96	12.42	245.15	30.12	-24.61	41.45	3.74	11.98	233.02	28.28	-27.69	40.24	0.71
50	4.5	49.95	15.98	235.12	40.98	-17.94	51.88	3.87	13.53	200.72	37.13	-25.65	49.99	0.08
60	5.6	59.94	17.63	226.61	54.94	-8.329	63.75	4.69	15.21	126.22	47.12	-21.38	61.49	2.50
70	6.3	69.93	18.22	189.25	65.29	-6.62	72.89	4.23	18.61	195.46	56.66	-19.01	79.48	2.91
80	7.2	79.92	19.14	165.90	71.09	-11.16	83.43	4.39	19.08	165.05	69.82	-12.63	81.38	1.82

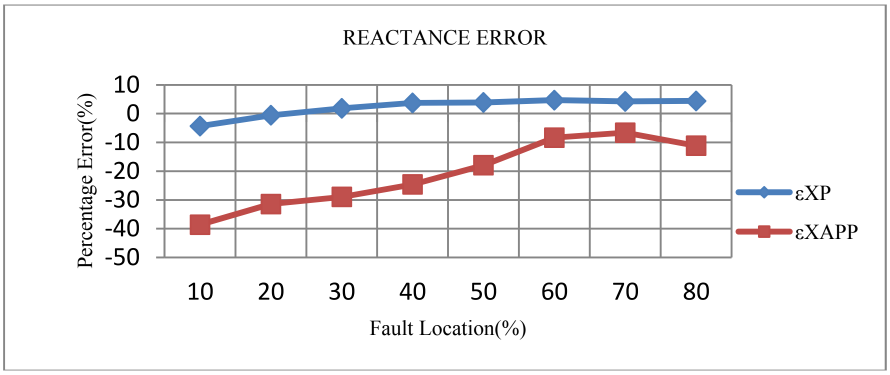


Fig.12a Percentage error measurement of R and X during PP fault for different values K_M=70%

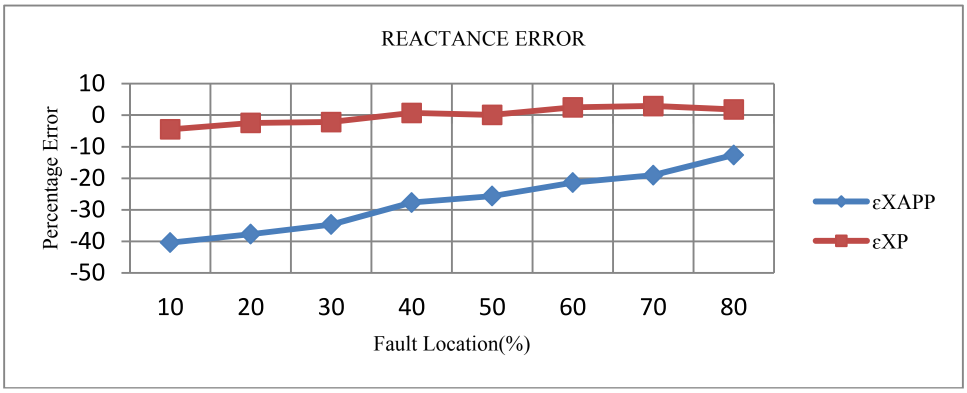


Fig.12b Percentage error measurement of R and X during PP for different values K_M=80%

c) Effect of Change in Short Circuit Capacity

The Table VII shows the percentage error of reactance for the conventional method and proposed method. In the first case the short circuit capacity of source S is assumed to be 20,000 MVA and for the source R is assumed to be 4000 MVA .For the second case the short circuit capacity for source is assumed to be 4000 MVA and for the source R is 20,000 MVA .The power transfer angle (δ)is changed to +40°and degree of compensation(K_M) as 50%. The percentage error are plotted against the fault location is shown in Fig.13a,13b. The percentage error measured by the proposed method is within the range of ±5%.

TABLE VII EFFECT OF CHANGE IN COMPENSATION LEVEL FOR PP FAULT

P(%)	R_{ACT}	X_{ACT}	SOURCE S=20,000MVA ; SOURCE R=4000MVA						SOURCE S=4000MVA ; SOURCE R=20,000MVA					
			R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	X_P	ε_{XP}	R_{APP}	ε_{RAPP}	X_{APP}	ε_{XAPP}	X_P	ε_{XP}
0	0	0	4.23	-	1.56	-	0.01	-	4.23	-	2.45	-	0.12	-
10	0.9	9.99	6.01	567.77	6.21	-37.83	9.49	-5.00	6.02	568.78	6.14	-38.53	9.537	-4.53
20	1.8	19.98	8.94	351.76	12.42	-37.87	18.94	-4.98	9.21	411.77	13.45	-32.68	19.28	-3.50
30	2.7	29.9	10.1	275.88	20.82	-30.51	29.44	-1.76	10.34	283.07	21.67	-27.69	30.79	2.73

		7	4											
40	3.2	39.96	11.05	207.05	28.00	-29.91	41.43	3.69	11.05	207.21	29.54	-26.07	38.35	-4.02
50	4.5	49.95	13.41	198.17	36.32	-27.28	50.08	1.057	13.66	203.52	37.81	-24.30	51.82	3.74
60	5.6	59.94	15.78	192.38	43.84	-26.90	60.42	0.8141	15.58	195.67	45.27	-23.47	59.45	-0.81
70	6.3	69.93	17.68	180.77	52.23	-25.50	71.49	2.23	16.48	193.43	54.67	-21.82	72.43	3.57
80	7.2	79.92	18.42	155.85	61.43	-23.13	84.09	2.720	19.68	173.43	63.42	-20.64	81.45	1.91

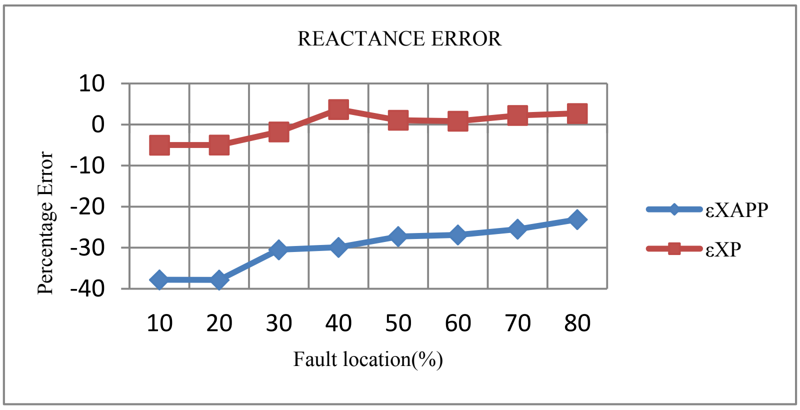


Fig.13a Percentage error measurement of R and X during PP fault for different of short circuit capacity case1

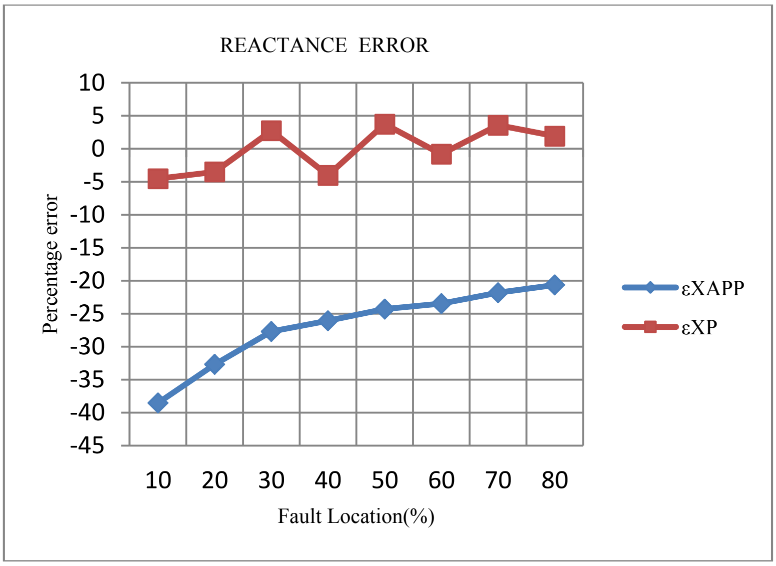


Fig.13b Percentage error measurement of R and X during PP fault for different values of short circuit capacity for case 2

V. CONCLUSION

A novel digital distance relaying scheme is presented here which measures the correct values of impedance of the faulted portion of series compensated doubly fed transmission line during SLG and PP faults. The proposed scheme is based on the symmetrical components of voltage and currents. This method measures the accurate value of impedance of the faulted line when compared to the conventional method. The proposed method is not affected by the presence of series capacitor, Non-linear device like MOV, and pre-fault system parameters. The percentage error of the proposed and conventional method is calculated and also compared with each other. The percentage error of the proposed method lies within the range of ±5%. So the accuracy of the proposed method is very high when compared with conventional method. Due to the accuracy of the proposed method, the distance relay will measures the accurate value of impedance at the faulted point, compare it with the set value of the relay. Based on that output, the relay will issues the trip or restrain signal.

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