Distance Protection and Fault Location for line to ground fault utilising postfault current

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Abstract: In the interconnected transmission networks, the fault current is fed by several sources and its direction depends on the fault place and is not fixed. The need for directional relaying in distribution networks has been raised due to the emergence of distributed generation (DG) units. The application of voltage as a reference quantity for the detection of fault direction is a common practice in transmission lines. Nevertheless, this approach is not applicable in distribution networks due to the absence of potential transformers. So a novel directional relaying scheme is introduced which is able to detect the fault location using only the postfault current. Also an algorithm to calculate distance of fault location during L-G is included in this system.

Keywords: Distributed generation, Fast Fourier Transform, Forward fault, Phase angle, Postfault current, Reverse fault.

INTRODUCTION

When the Electricity Supply Industry (ESI) began its activity the need for electric energy in a place was, in general, satisfied by municipal companies that installed generators located according to the distribution needs. Later on, the increasing electricity demand was satisfied installing huge generation plants, generally near the primary energy sources (e.g. coal mines, rivers, etc.). The great efficiency difference between one big generation plant and a small one, summing up the fact that the reserve margin that had to be taken in the first case was less than if the same power was installed in a distributed way, gave as a result the traditional conception of the Electrical Power Systems (EPS). Today there are technologies that allow generation using relatively small sized plants with respect to conventional generation, and with smaller costs per MW generated. Interconnecting distributed generation (DG) to an existing distribution system provides various benefits to several entities as for example the owner, utility and the final user. DG provides an enhanced power quality, higher reliability of the distribution system and can peak shaves and fill valleys. However, the integration of DG into existing networks has associated several technical, economical and regulatory questions. Penetration of a DG into an existing distribution system has many impacts on the system, with the power system protection being one of the major issues. DG causes the system to lose its radial power flow, besides the increased fault level of the system caused by the interconnection of the DG. Short circuit power of a distribution system changes when its state changes. Short circuit power also changes when some of the generators in the distribution system are disconnected. This may result in elongation of fault clearing time and hence disconnection of equipments in the distribution system or unnecessary operation of protective devices.

In this paper, a new protection philosophy based on postfault current is presented. All schemes present nowadays for detection of power flow direction depends on line voltage. Therefore, their application may be costly in non-radial distribution systems. So a new protection philosophy is required to cope with bi-directional power flows and unwanted tripping. So a new scheme for fault detection based on the postfault current can be considered. By avoiding the use of voltage or pre fault current, we are able to resolve the problems in existing methods. Moreover, the proposed scheme can be used in transmission and distribution networks.

SYSTEM MODEL

A 33-kV system including three buses is considered with the system parameters as given in Table 1. In this system, which is shown in fig 1, source A is an equivalent model of the utility grid. Moreover, source C represents an equivalent model of a microgrid which consists of a collection of DG units. F1 and F2 are faults located at the middle

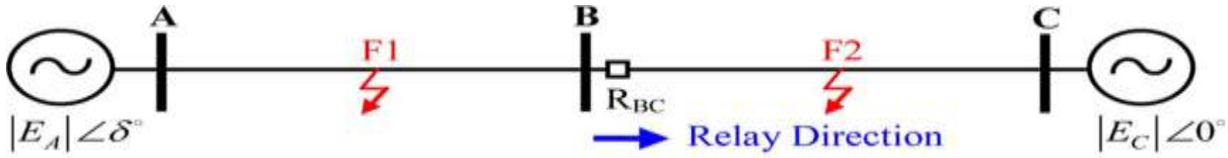

Fig. 1 System Model

of lines AB and BC, respectively. The sampling rate used in the simulation studies is 20samples/cycle. R_{BC} is a relay whose direction of operation is shown in fig 1.

TABLE 1

System Parameters.

PARAMETER	Value	Unit
System voltage	33	kV
System frequency	50	Hz
Length of line AB	10	Km
Length of line BC	12	Km
Positive seq. impedance of the lines	0.106 + j0.115	Ω/km
Zero seq. impedance of the lines	0.502 + j0.321	Ω/km
Positive seq. impedance of the sources	0.038 + j1.86	Ω
Zero seq. impedance of the sources	0.051 + j2.15	Ω

PROPOSED SCHEME

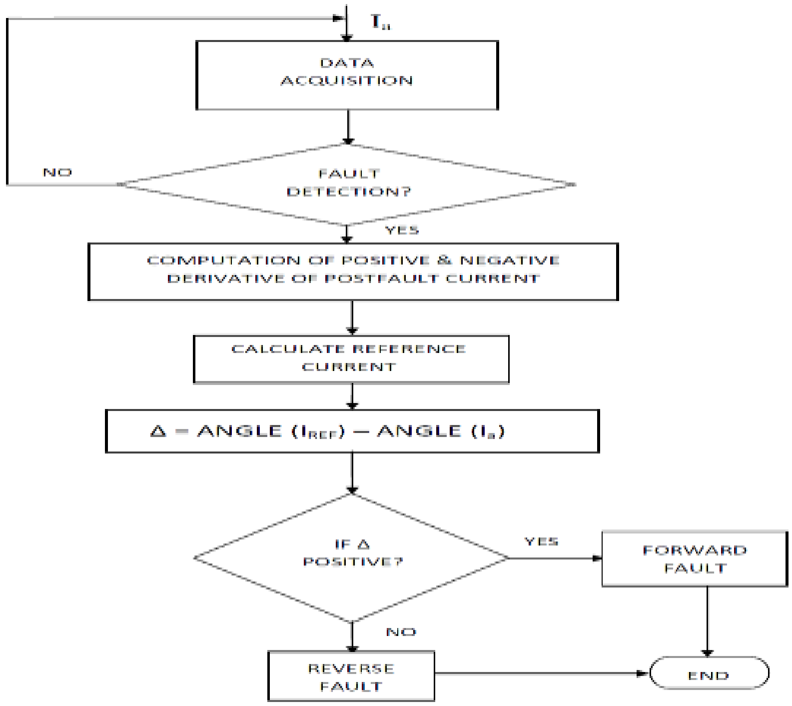

Fig. 2 Flow Chart

In this scheme, the phase current in each phase is obtained using a data acquisition technique. During normal operation this process of data acquisition continues in a regular interval. Whenever a fault occurs, both positive and negative derivative of postfault current are calculated. Also a reference current value is calculated based on the phase values of both forward and reverse currents. The difference between the angles of reference current and postfault current is used for determining the direction of fault current. If this value is positive, the fault is in the forward direction of relay and if the value is negative, the fault is in the reverse direction of the relay. This method for fault direction detection based on postfault current can be used for both bidirectional power flow systems with distributed generations.

ALGORITHM FOR DISTACE CALCULATION

For the case of line to ground fault, input parameters used for fault distance calculation are phase current phasors along with zero sequence impedance of line. Voltage phasor is not used as an input data. Fast Fourier transform (FFT) is used for calculating pre and postfault phasors.Given a phase-to-ground short circuit on the transmission line, the following complex equation is utilized in calculating the fault distance:

$$\bar{V} = [\bar{z}\,\bar{I} + (z_0 - \bar{z})\bar{I_0}]l + 3R\,\bar{J_0}$$

where $\bar{V}$ and $\bar{I}$ are the input voltage and current phasors to the faulted phase relays, $\bar{I_0}$ is the input zero sequence current to faulted phase relays, $\bar{J_0}$ is the zero sequence current at fault location, $\bar{z}$ and z_0 are the positive and the zero sequence line impedances per unit length, l is per unit distance from source to fault and R is the total fault resistance. Zero sequence current at fault location, $\bar{J_0}$ is not measurable, but it can be expressed in terms of the input zero sequence current, $\bar{I_0}$ and parameters from the zero sequence equivalent circuit of the analyzed network. By using the circuit theory, the system model can be replaced with the equivalent star circuit. For the line to ground short circuits, the sequence currents are equal to each other ($\bar{J_0} = \bar{J_d} = \bar{J_\iota}$).

$$l = \frac{\bar{I_0}\,\overline{Z_{0e}}\,(Z_{i2} + \bar{z}\,D) - \bar{I_\iota}\,\overline{Z_{\iota e}}\,(\overline{Z_{02}} + \bar{z}_0 D)}{\bar{I_0}\,\overline{Z_{0e}}\,\bar{z} - \bar{I_\iota}\,\overline{Z_{\iota e}}\,\bar{z}_0}$$

where $\overline{Z_{01}}$ and $\overline{Z_{02}}$ are the impedances of the network equivalent star circuit, $\overline{Z_{\iota 1}}$ and $\overline{Z_{\iota 2}}$ are the negative sequence impedances, $\overline{I_\iota}$ is the input negative sequence current to faulted phase relays, D is the line length, $\overline{Z_{0e}} = \overline{Z_{01}} + \overline{Z_{02}} + \bar{z}_0 D$, $\overline{Z_{\iota e}} = \overline{Z_{\iota 1}} + \overline{Z_{\iota 2}} + \bar{z}\, D$.

RESULTS AND DISCUSSION

The results in table 2 shows that the angles of $I_{Postfault}$ and I_{Ref} are varied, based on the change in power flow direction. But the value of $Ø_\Delta$ is not affected by change in power flow. For both forward and reverse power flow, $Ø_\Delta$ is +1.57rad in forward faults and -1.57rad in reverse faults.

TABLE 2

Effect of Power Flow Direction.

POWER FLOW	FAULT TYPE	FAULT LOCATION	$Ø_1$ (Rad)	$Ø_{ref}$ (Rad)	$Ø_\Delta$ (Rad)	FAULT DIRECTION
Forward	Ag	F2	-0.226	1.344	+1.57	Forward
Forward	Ag	F1	1.86	0.29	-1.57	Reverse
Reverse	Ag	F2	-1.23	0.33	+1.57	Forward
Reverse	Ag	F1	2.939	1.369	-1.57	Reverse

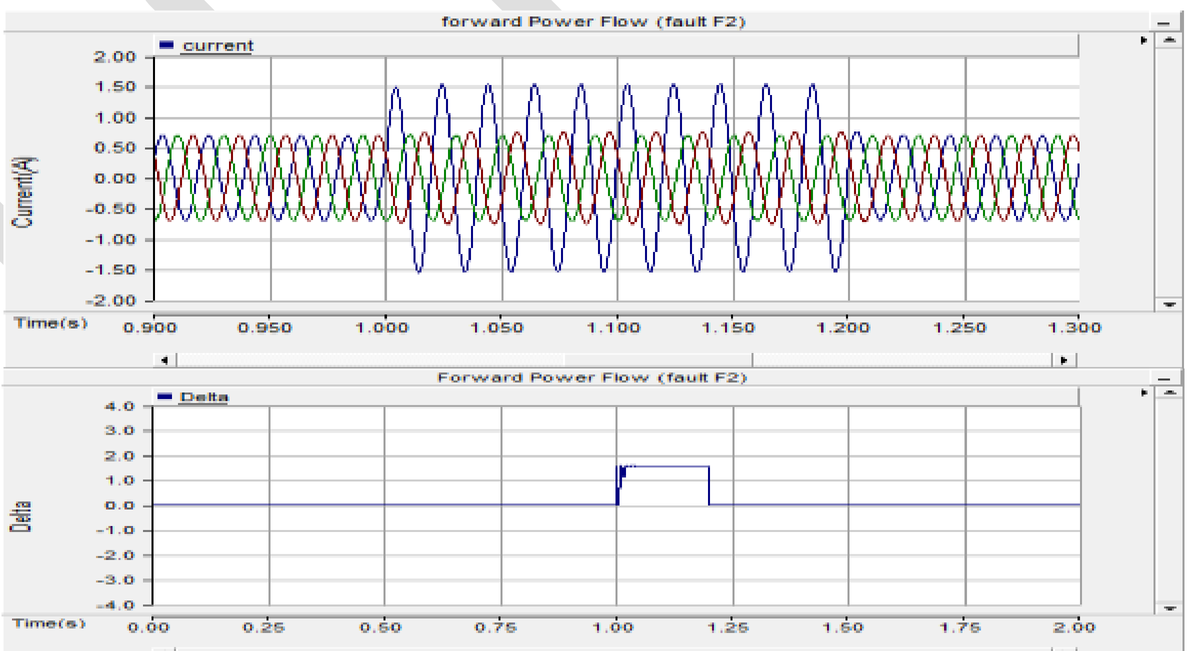

Fig. 3 Change in $Ø_\Delta$ and current with forward power flow with L-G fault at F2.

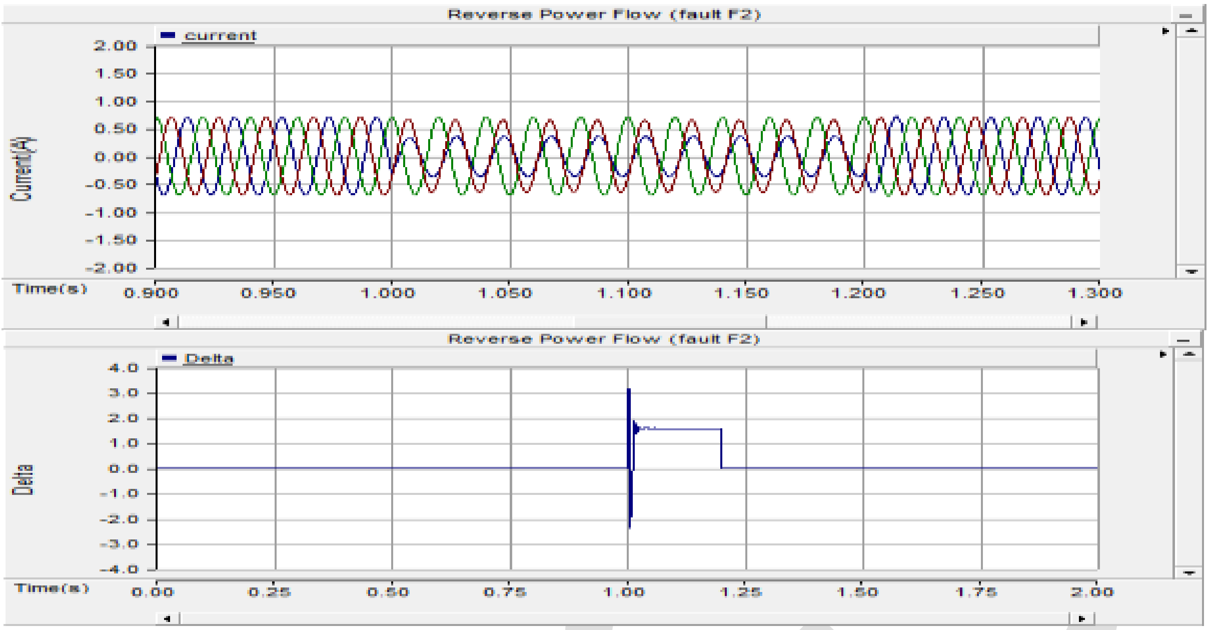

Fig. 4 Change in $Ø_{\Delta}$ and current with reverse power flow with L-G fault at F2.

Fig 3 and fig 4, show the graphs of current and value of delta during forward and reverse power flow with fault at F2. In both cases the value of delta is obtained as positive irrespective of the direction of power flow which indicates that the fault has occurred in the forward direction of relay.

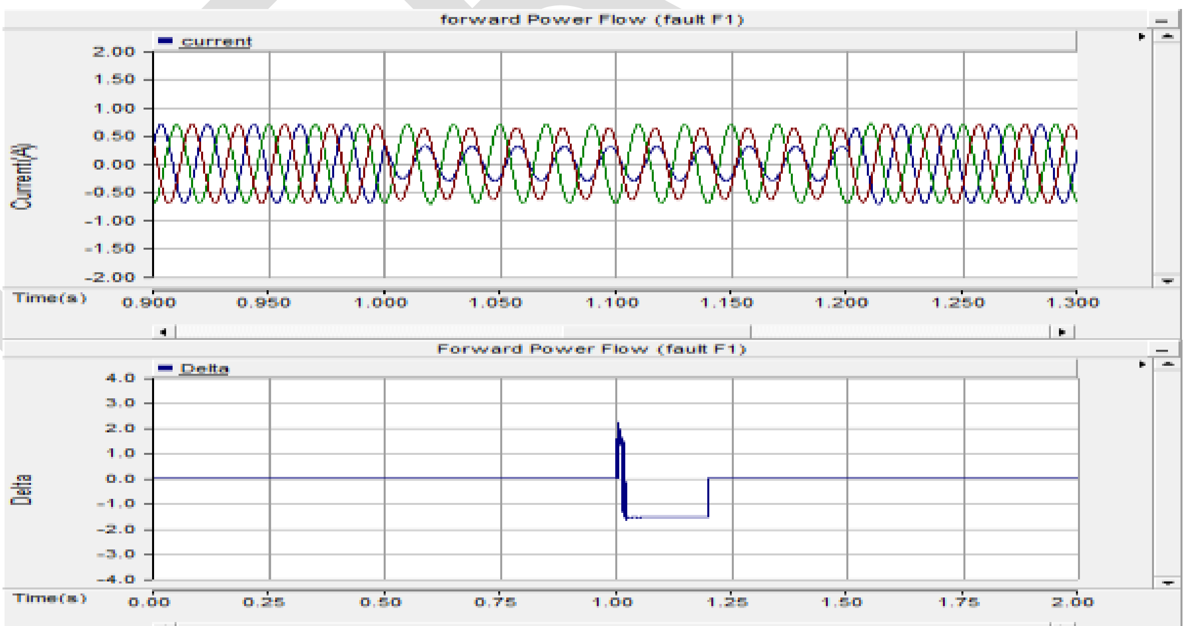

Fig. 5 Change in $Ø_{\Delta}$ and current with forward power flow with L-G fault at F1.

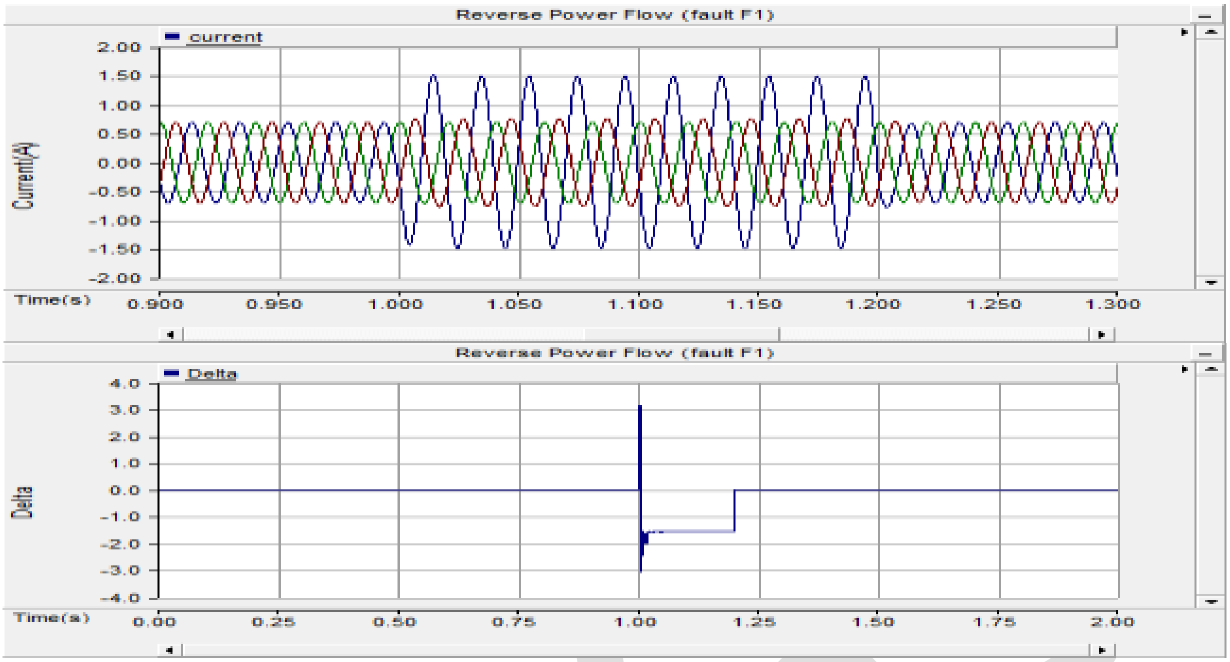

Fig. 6 Change $Ø_{\Delta}$ and current with reverse power flow with L-G fault at F1

Fig 5 and fig 6, show the graphs of current and value of delta during forward and reverse power flow with fault at F1. In both cases the value of delta is obtained as negative irrespective of the direction of power flow which indicates that the fault has occurred in the reverse direction of relay.

The reliable operation of protective relays may be affected by the fault resistance. The above system is evaluated with forward and reverse power flow against various faults in both directions with the fault resistances (R_f) between 1 to 10Ω.

TABLE 3

Effect of change in Fault Resistance.

POWER FLOW	FAULT TYPE	FAULT LOCATION	R_f (Ω)	$Ø_1$ (Rad)	$Ø_{ref}$ (Rad)	$Ø_{\Delta}$ (Rad)	FAULT DIRECTION
Forward	Ag	F2	2	-0.642	0.928	+1.57	Forward
Forward	Ag	F2	5	-0.377	1.193	+1.57	Forward
Forward	Ag	F2	10	-0.226	1.344	+1.57	Forward
Forward	Ag	F1	2	2.188	0.618	-1.57	Reverse
Forward	Ag	F1	5	2.297	0.727	-1.57	Reverse
Forward	Ag	F1	10	1.86	0.29	-1.57	Reverse
Reverse	Ag	F2	2	-0.98	0.59	+1.57	Forward
Reverse	Ag	F2	5	-0.872	0.698	+1.57	Forward
Reverse	Ag	F2	10	-1.23	0.33	+1.57	Forward
Reverse	Ag	F1	2	2.52	0.95	-1.57	Reverse
Reverse	Ag	F1	5	2.79	1.22	-1.57	Reverse
Reverse	Ag	F1	10	2.939	1.369	-1.57	Reverse

The results obtained show that the phase angle of postfault current ($Ø_1$) is affected by the change of fault resistance value. However as much as $Ø_1$ changes, the phase angle of reference current ($Ø_{ref}$) changes as well. Consequently, the phase angle, $Ø_{\Delta}$ remains fixed.

The distance to fault location from source 1 is calculated for L-G fault for both forward and reverse power flow. Here the Fast Fourier Transform (FFT) technique is used for calculating the pre and postfault phasors. Table 4 and 5 shows the results obtained for distance calculation for L-G fault during forward and reverse power flow. Here by analyzing the results we can conclude that the accuracy of distance calculation is less when the fault is situated near source 1 or source 2. When the distance from sources increases the accuracy of locating the fault also increases.

TABLE 4

Fault distance Calculation for L-G fault during Forward Power Flow.

POWER FLOW	POSTFAULT CURRENT						DISTANCE TO FAULT FROM SOURCE 1		FAULT DIRECTION
	POSITIVE SEQUENCE		NEGATIVE SEQUENCE		ZERO SEQUENCE				
	MAGNITUDE	ANGLE	MAGNITUDE	ANGLE	MAGNITUDE	ANGLE	ACTUAL	CALCULATED	
Forward	0.582383	-1.60379	0.34418	-1.84468	0.372174	-1.89781	4	8.8187	Reverse
Forward	0.578514	-1.58226	0.337528	-1.81162	0.355314	-1.83811	6	9.2938	Reverse
Forward	0.574726	-1.56265	0.331345	-1.78112	0.340002	-1.7777	8	10.0767	Reverse
Forward	0.446439	-1.55125	0.20623	-1.89219	0.217195	-1.99365	10	10.8267	Reverse
Forward	0.448338	-1.53253	0.20539	-1.85041	0.205929	-1.90869	12	11.3145	Forward
Forward	0.450397	-1.5149	0.204983	-1.8105	0.196274	-1.81606	14	12.3507	Forward
Forward	0.452588	-1.49846	0.205024	-1.77268	0.188545	-1.71594	16	13.7447	Forward
Forward	0.454943	-1.48327	0.205521	-1.73721	0.183074	-1.60935	18	15.3317	Forward
Forward	0.457487	-1.46938	0.20648	-1.70432	0.180165	-1.49846	20	16.9962	Forward

TABLE 5

Fault distance Calculation for L-G fault during Reverse Power Flow.

POWER FLOW	POSTFAULT CURRENT						DISTANCE TO FAULT FROM SOURCE 1		FAULT DIRECTION
	POSITIVE SEQUENCE		NEGATIVE SEQUENCE		ZERO SEQUENCE				
	MAGNITUDE	ANGLE	MAGNITUDE	ANGLE	MAGNITUDE	ANGLE	ACTUAL	CALCULATED	
Reverse	0.189352	-2.75073	0.339935	-1.88802	0.367585	-1.94116	4	8.8189	Reverse
Reverse	0.177529	-2.72969	0.335277	-1.85386	0.352945	-1.88035	6	9.2937	Reverse
Reverse	0.166689	-2.71002	0.331023	-1.82226	0.339672	-1.81891	8	10.0767	Reverse
Reverse	0.137351	2.73065	0.204082	-1.85325	0.214934	-1.95471	10	10.8266	Reverse
Reverse	0.128696	2.72244	0.204417	-1.81037	0.204954	-1.86865	12	11.3144	Forward
Reverse	0.120332	2.71462	0.205182	-1.76935	0.196464	-1.77492	14	12.3508	Forward
Reverse	0.112288	2.70743	0.206399	-1.73044	0.189811	-1.67369	16	13.7446	Forward
Reverse	0.104561	2.70174	0.208086	-1.69386	0.185359	-1.566	18	15.3317	Forward
Reverse	0.0971501	2.69864	0.210255	-1.65987	0.18346	-1.45402	20	16.9960	Forward

CONCLUSION

A new protection philosophy is developed for identifying the direction of fault based on post fault current. The phase angle difference between reference current and current in each phase were calculated and based on the sign of this value the direction of fault is estimated. Also an algorithm to calculate distance of fault location during L-G fault is included in this system. Here post fault phase current phasors are required to calculate the distance to fault point. The reliability of the system for various operation conditions such as change in power flow direction and change in fault resistance were analysed for different fault positions. Also accuracy of distance calculation for line to ground were analyzed for fault at different lengths in both forward and reverse power flow conditions.

REFERENCES:

[1] Mario Vignolo and Raul Zeballos, "Transmission Networks or Distributed Generation?", Power, 1990.
[2] Angel Fernández Sarabia, "Impact of distributed generation on distribution system", Aalborg, Denmark, June 2011.
[3] Murari Mohan, Saha Ratan, Das Pekka Verho and Damir Novosel, "Review of Fault Location Techniques for Distribution Systems," Power Systems and Communications Infrastructures for the future, Beijing, September 2002.
[4] J. Sadeh, M. Bashir and E. Kamyab, "Effect of distributed generation capacity on the coordination of protection system of distribution network," Transmission and Distribution Conference and Exposition: Latin America (T&D-LA),IEEE/PES, Nov. 2010, pp. 110-115.
[5] A. Ituzaro, R. H. Douglin, and K. L. Butler-Purry, "Zonal overcurrent protection for smart radial distribution systems with distributed generation," in Proc. IEEE Power Energy Soc. Innovative Smart Grid Technol., Feb. 2013, pp. 1–6.
[6] S. M. Hashemi, M. T. Hagh, and H. Seyedi, "Transmission-line protection: A directional comparison scheme using the average of superimposed components," IEEE Trans. Power Del., vol. 28, no. 2, pp.955–964, Apr. 2013.
[7] P. Jafarian and M. Sanaye-Pasand, "High-speed superimposed-based protection of series-compensated transmission lines," Proc. Inst. Eng.Technol. Gen. Transm. Distrib., vol. 5, no. 12, pp. 1290–1300, 2011.
[8] K. Pradhan, A. Routray, and G. S. Madhan, "Fault direction estimation in radial distribution system using phase change in sequence current," IEEE Trans. Power Del., vol. 22, no. 4, pp. 2065–2071, Oct.2007