Australian Journal of Basic and Applied Sciences, 5(7): 1006-1012, 2011
ISSN 1991-8178

Effect of DG on Distribution System Protection, Part II: Simulation and FCL Application for Solving the Problem

[1]M. Safaeian, [2]M. Abapoor

[1]Hidaj branch, Islamic Azad University, Hidaj, Iran.
[2]Abhar branch, Islamic Azad University, Abhar, Iran

Abstract: Protection of feeders and equipment becomes more complex when relatively large amounts of power are generated in distribution networks. In order to analyze thoroughly the effects of distributed generation on the requirements for the protection of distribution networks, detailed simulation studies are necessary. This paper focuses on the simulation of distribution protection problems coursed by DG penetration in distribution networks. The detailed analysis is carried out in part I of these series. Also, Fault current limiters (FCL) is proposed as a method for fault current limiting that can be able to solve the problem. So, in this paper simulation is carried out without and using FCL for illustrates the effect of FCLs. In these studies PSCAD/EMTDC transient simulation software has been applied.

Key word: DG, distribution system, protection coordination, fault current limiter

INTRODUCTION

Power can flow in a bidirectional way within a certain voltage level, but it usually flows unidirectional from higher to lower voltage levels, i.e. from transmission to distribution grid. An increased share of DG units may induce power flows from low into medium-voltage grid. Thus, different protection schemes at both voltage levels may be required. High penetration of DG will have an impact on short circuit capacity, protection coordination, system transient stability, voltage control and power quality, which can significantly influence the proper operation and protection performance of the power system (Viawan, F.A. *et al,* 2005), (Kumara, J.R.S.S. *et al*, 2006).

The mostly cited influential issue on system reliability is the coordination of protective devices. The presence of DG tends to affect the protection coordination. Evidently, the short circuit current would be altered due to the contribution of DG, especially the aggregate contributions of several DG sources. The unacceptable operation of protective devices might occur and finally lead to the decrease in system reliability. For example, the recloser fast operation should discriminate a temporary fault, occurring mostly in distribution system, and operate faster than a fuse. However, fuse may operate faster than recloser and cause electricity interruption when the total fault current is changed by the contribution from DG fault current. With fuse operation, the fault will turn to be permanent and considered unacceptable for system reliability (Kauhaniemi, K. *et al,* 2004), (Gomez, J.C. *et al,* 2005). In this paper, interesting cases of such problem are discussed together with proposed solution. In this paper using fault current limiter is proposed as a solution of protection problems.

Simulation Results:

Fig. 1 shows a typical radial distribution feeder with multiple loads. The system parameters are shown in table 1. Also DG parameters are shown in table 2.

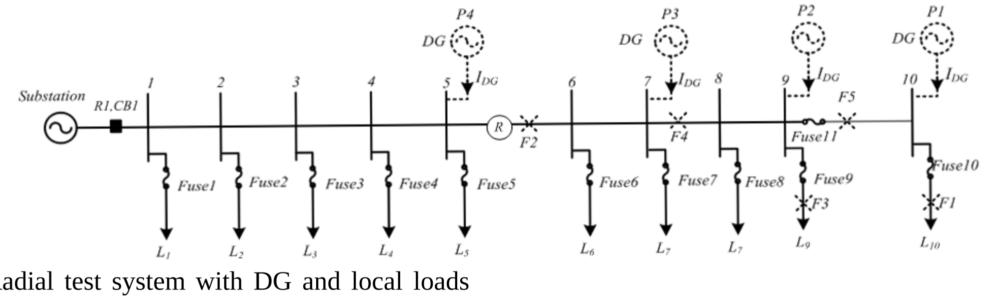

Fig. 1: Radial test system with DG and local loads

Corresponding Author: Mehdi Safaeian, Hidaj branch, Islamic Azad University, Hidaj, Iran.

Table 1: system parameters

From	To	R(ohm)	X(ohm)	P(KW)	Q(KVAR)
1	2	0.1233	0.4084	1840	460
2	3	0.014	0.5969	980	340
3	4	0.7463	1.1938	1790	446
4	5	0.6984	0.5969	1598	1840
5	6	1.9831	1.4137	1610	600
6	7	0.905	0.7886	780	110
7	8	2.0552	1.1624	1150	60
8	9	2.45	1.5708	980	130
9	10	3.0434	1.885	1640	200

Table 2: distribution system parameters

Parameter	Value
Rated Active power/ MW	2.6
Rated Reactive power/ MVAR	3.1
Rated Voltage/ kV	20
Resistance (Ra) pu	0.01
Synchronous Reactance (Xd)/ pu	2.2
Transient Reactance (X· d)/ pu	0.22
Sub transient Reactance (X··d)/ pu	0.14

In this simulation for minimizing the impact of DG on protection coordination, FCL is installed in series with DG. The simulation results can be summarized as follow:

A. False tripping:

As shown in fig.1 a fault is occurring in F3. Fig.2 (a) shows the fault current. In next step a DG is installed in P1. As shown in fig.2 (b) the fault current produced by DG is passed through fuse 11 and it is possible to trip it. For solving this problem FCL is installed between bus 10 and DG. Fig.2 (c) shows the fault current through fuse11. As shown in this figure the fault current decreases therefore false tripping probability is minimized.

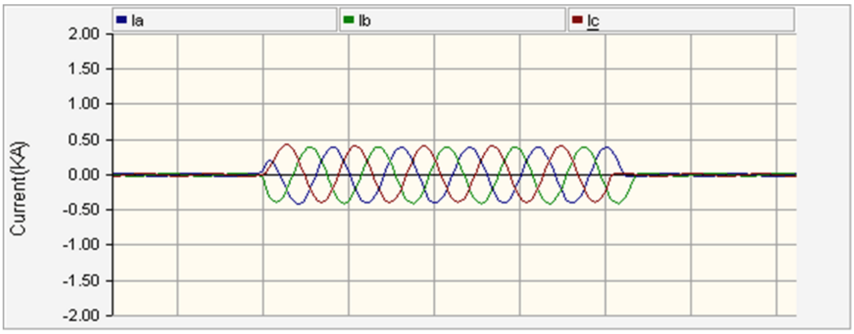

Fig. 2(a): Fault current waveforms without DG

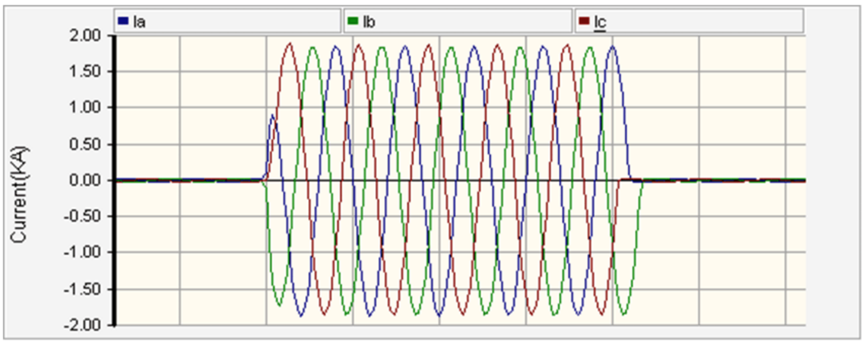

Fig. 2(b): Fault current waveforms with DG installation

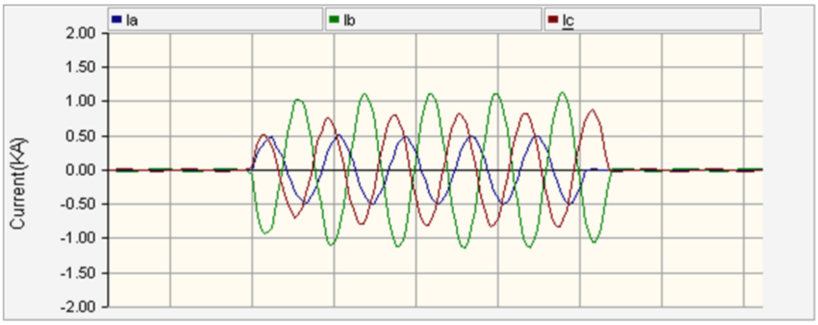

Fig. 2(c): Fault current waveforms with DG installation and using FCL

B. Exceeding the Interruption Capacity of Circuit Breaker from its Rating:

Fig.3 (a) shows the fault current when a fault occurs in F2. Fig.3 (b) shows the same fault current after DG installation at P4. As shown in this figure the fault current level increases because of DG penetration in fault current producing and may cause the fault current exceeding higher than the interruption capacity of circuit breaker. As shown in fig.3 (c) FCL limits the fault current generated by DG and solves this problem.

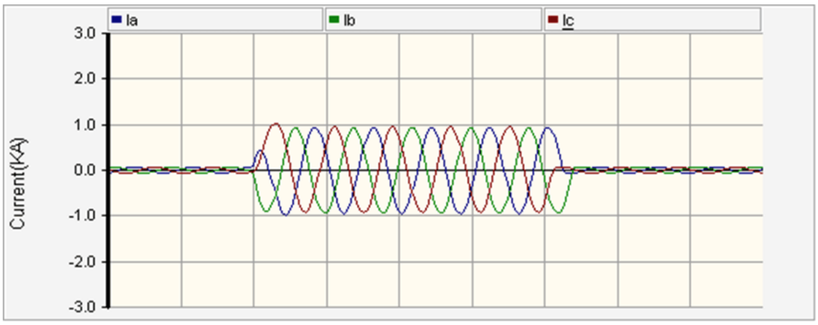

Fig. 3(a): Fault current waveforms without DG installation (fault at F2)

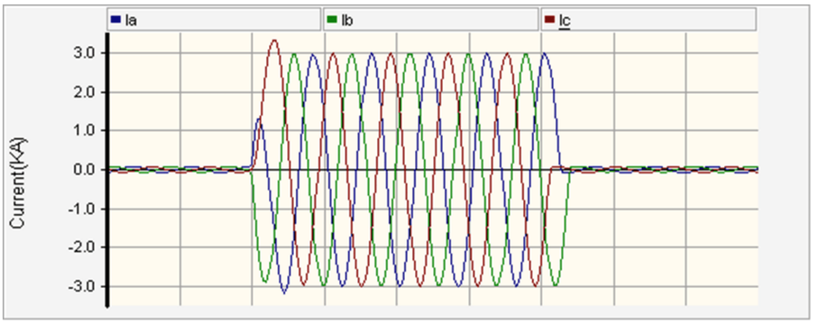

Fig. 3(b): Fault current waveforms with DG installation at P4 (fault at F2)

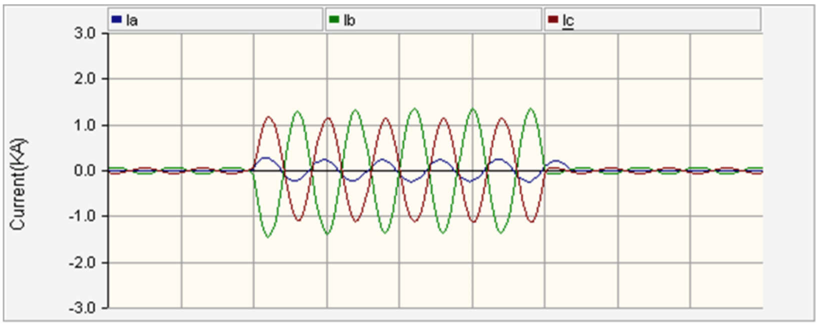

Fig. 3(c): Fault current waveforms with DG installation at P4 (fault at F2) and using FCL

C. Relay Operating Error:

As shown in fig.1 with a fault in F4 the fault current passes through recloser. If DG is installed in P3, the fault current generated by DG do not pass through recloser. So, reclose is not able to recognize full fault current. Therefore this may cause recloser operating error. Fig.4 (a) shows the fault current in faulted location with installing DG. Also fig.4 (b) shows the same fault current passes through the reclose. After FCL installation the fault current generated by DG is decreased. Thus the probability of operating error decreases, too. This shows in fig.4 (c) and (d).

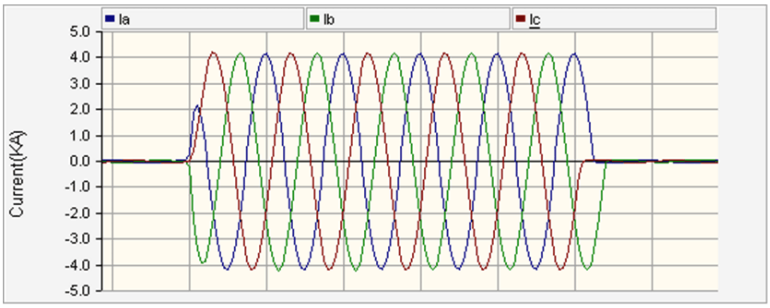

Fig. 4(a): Entire fault current waveforms with DG installation at P3 (fault at F4)

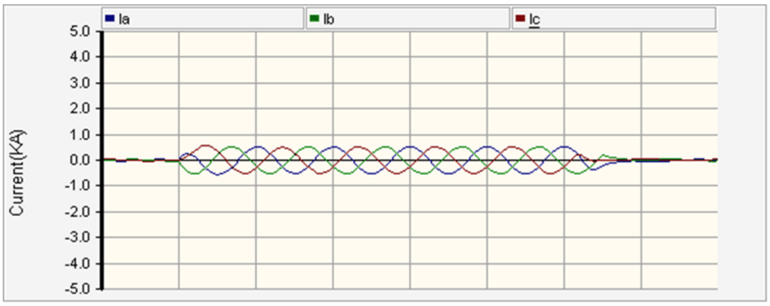

Fig. 4(b): fault current waveforms passes through recloser with DG installation at P3 (fault at F4)

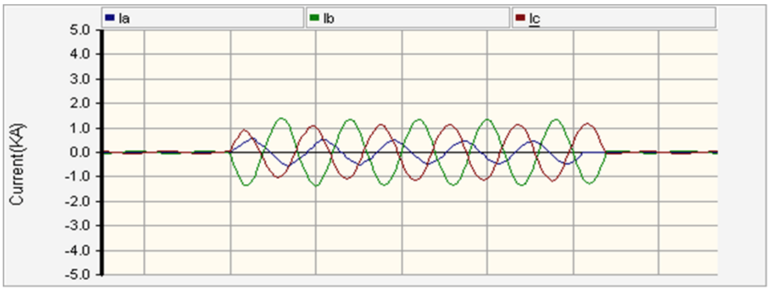

Fig. 4(c): Entire fault current waveforms with DG installation at P3 and using FCL (fault at F4)

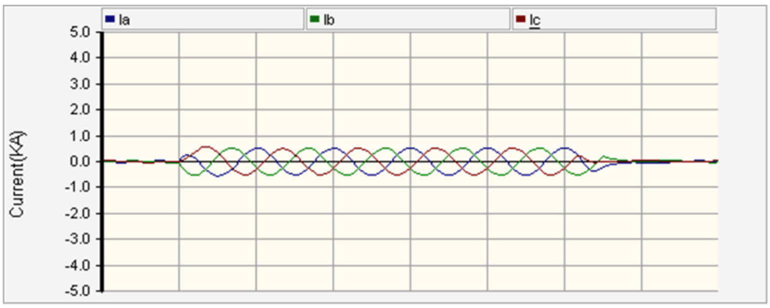

Fig. 4(d): fault current waveforms passes through recloser with DG installation at P3 and using FCL (fault at F4)

C. Miss Coordination of Protection Devices:

The typical miscoordination in distribution systems are fuse-fuse and fuse recloser. So, these two types are simulated here.

C.1. Fuse-fuse Miscoordination:

As shown in fig.1 fuses 10 and 11 be coordinated based on minimum melting characteristic and maximum fault clearing time. In this simulation DG is installed at P1 and fault is occurred in F1. As shown in fig.5 (a) the fault current passes through fuse10 exceeds from maximum fault current that is need for fuse 10 and 11 coordination. As shown in fig.5 (b) by installing FCL in series with DG, fault current level is decreased and the problem is solved.

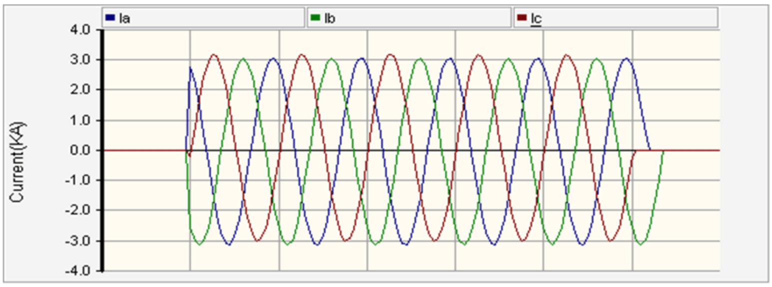

Fig. 5(a): fault current waveforms passes through fuse10 with DG installation at P1 (fault at F1)

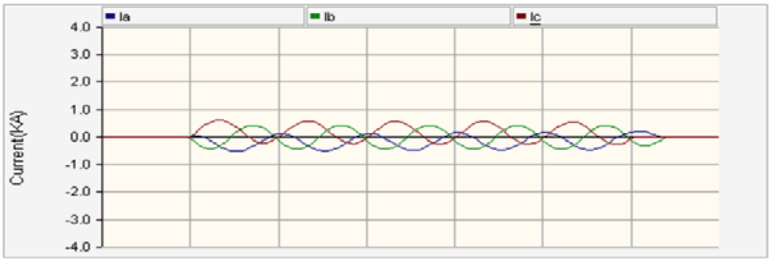

Fig. 5(b): fault current waveforms passes through fuse10 with DG installation at P1 and using FCL (fault at F1)

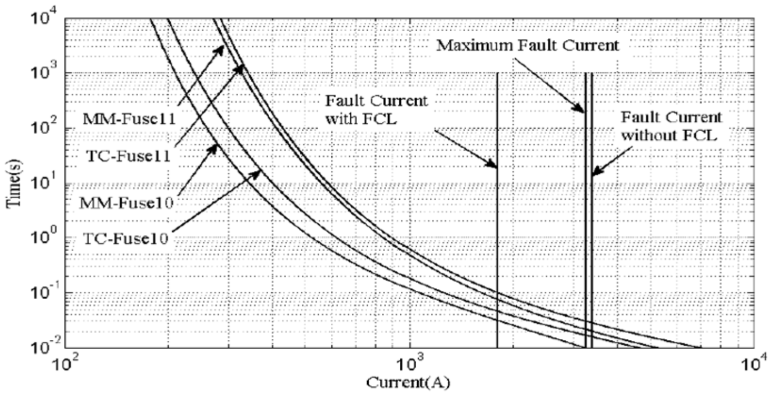

Fig. 5(c): MMT and MCT curves of fuse10 and 11

C.2. Fuse-recloser Misscoordination:

With coordination of reclosers and fuse, it is common for the recloser to protect the fuse from temporary faults and still have the fuse blow for permanent faults. The recloser should reach through the fuse and trip instantaneously for a fault on the load side of the fuse before the fuse starts to melt. This requires that the crossover of the recloser “A” curve and minimum-melt curve of the fuse be to the right of the maximum fault current at the location of the fuse.

Once the recloser closes back into the circuit, if the fault is permanent, the fuse should melt and clear before the first time delayed operation of the recloser. This requires that the fuse total-clearing curve be below the recloser "B" curve up to the maximum fault current level at the fuse. If the fault is temporary, the recloser will successfully reclose. This way, the load feeder does not get disconnected for every temporary fault. Recloser also provides back up to fuse through slow mode. Since temporary faults constitute 70% to 80% of faults occurring in distribution system, this arrangement improves the reliability and decreases the maintenance cost. According to Fig.1, DG is located at P2 and a fault occurs at F5. In this case, the fault current flowing through the recloser is different from the fault current flowing through the fuse. It is obvious that the fault current seen by fuse11 is higher than the fault current seen by recloser and it may cause to operate fuse11 before recloser and every temporary fault change to permanent interruption. As shown in fig.6 (a), (b) and (c) the maximum current followed through fuse11 is higher than maximum coordination current between fuse and recloser. Fig. 6 (d) shows the fault current through fuse11 by using FCL. As shown in this figure the fault current decreases and the coordination problem is solved.

Conclusion:

This paper presents the results obtained by research on the influence of distributed generation (DG) on protection in the distribution network. Generation connected to the grid is subject to protection regulations. In this paper protection misscoordination due to DG penetration in distribution system was reviewed. Also the effect of FCL to enhance protection coordination is studied in detail. The results show that in most of cases FCL is able to solve the coordination problem.

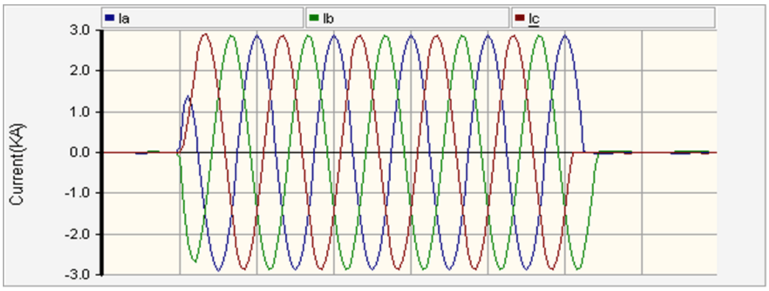

Fig. 6(a): fault current waveforms passes through fuse11 with DG installation at P2 (fault at F5)

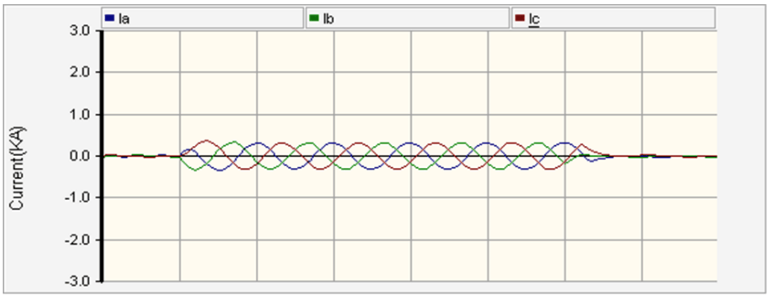

Fig. 6(b): fault current waveforms passes through recloser with DG installation at P2 (fault at F5)

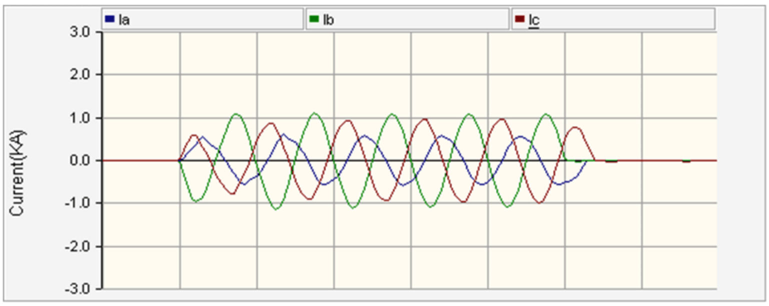

Fig. 6(c) fault current waveforms passes through fuse11 with DG installation at P1 and by using FCL (fault at F1)

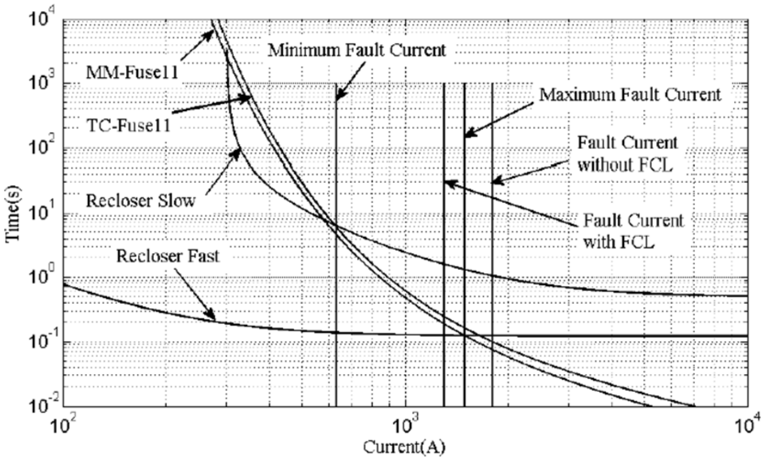

Fig. 6(d): coordination characteristics between recloser and fuse11

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