Investigation of The DGs Effect on The Coordination Between Protective Elements in Distribution Network

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Abstract

Addition of Distributed Generators (DGs) to the electric network have more advantages to the network. It improves the voltage profile and the power flow in the network. In the last decade, DGs is used in power system, especially the distribution system. Coordination study for protective devices must be performed on the distribution network with DGs to reach selectivity with minimum clearance time of fault. Due to DG insertion to the electric system, the short circuit level is changed and coordination between protective elements should be done. This paper presents a technique to avoid the miscoordination problem between protective devices due to the impact of DG unit's insertion without any additional costs. The proposed technique depends on activating and updating the setting of network relays to achieve correct coordination. Also, it doesn't need any additional costs or any additional equipement to be installed in the electric network. This paper makes studies on a real radial system of power transformer with its feeders of a 66kV utility substation before and after adding DGs. ETAP software is used to simulate the network under study.

Keywords: *Coordination; Distributed Generators (DG); Relays; ETAP.*

1. Introduction

Selectivity and coordination of protection devices problems is one of the points linked to the effects of inserting distributed generators. These problems has an directly effect on the safety of equipment, persons and continuity of service. Analysis should be done to find out if the protective devices of the network should have a suitable coordination after adding distributed generators or not. Connecting the DGs to distribution systems gives several economical, environmental and technical advantages such as reduction of environmental pollution, reduction of electric losses, improvement of voltage profile, increasing of distribution system capability and increasing of system reliability [1]. The effect of insertion of DG of distribution network on the short circuit level is shown in papers [2-6]. This can cause directly effect on coordination between protective devices because of the generator capability to provide large fault currents to the faulted point. The impact of inserting DG on relay coordination has an effect on the operating time of relay. Thus, the coordination between main and back up relays isn't appropriate in the presence of distributed sources. Hence, the addition of DG in the distribution network causes negative effect on protection. The adaptive protective scheme of an overcurrent relays to obtain an optimal coordination with the network of inserted DG was proposed in [7], where new relay setting technique was applied for the load and the generation changes. The practical impacts of DG on fuse and the technique to overcome the DG impact is in [8]. This paper study the impact of DG on coordination between protective devices of a radial system of power transformer with its feeders of a 66kV utility substation. Due to DGs insertion to the network, miscoordination occurs between protective devices. This paper present the method to overcome the DG impact. The miscoordination problem is solved without changing any protective device or any additional cost and without changing the coordination method. It depends on activating and updating the setting of network relays to achieve correct coordination. Also, the fault analysis on feeder is discussed in this paper to test the coordination between protective devices before and after adding DGs to the radial system under studying by using ETAP software.

2. The Approach

2.1 System Under Study

The simulated network is a real radial system of an actual transformer with its feeders in the substation no.5 of 10th of Ramadan and Sharkia, Egypt as shown in fig.1. The network components are: power grid of 66kV, four buses, power transformer of 66/11 kV and feeders of shown load currents in table2. The data of the network components is in table1 and 2.

Main Components Rating	**Utility**		**MVASC**	**Z%**	**kV**	
			2000	10%	66	
	Busbars		**Rated kV**			
		Bus 1	66			
		Bus 2	66			
		Bus 3	11			
		Bus 4	11			
	Cables		**C.S.A**	**Cable Type**	**Rated kV**	
		Cable 1	380mm^2	Aluminuim	66	
		Cable 2	3x1x400mm^2	Aluminuim	11	
	Two-Winding Power Transformer		**MVA**	**Turns Ratio**	**X/R ratio**	**Impedance%**
			25	66/11	28.2	10%

Table 1. Network Components Rating

Protection Devices	**Current Transformers**		**Turns Ratio of CT**			
		CT 1	300/5			
		CT 2	1500/5			
	Circuit Breakers		**A**	**KA**		
		C.B 1	1250 A	31.5 kA		
		C.B 2	1600 A	31.5 kA		
	Differential Relay		**Protected Component**		**Relay Model**	**Full Load Current**
		R1	Power Transformer		Siemens, 7UT51	
	Overcurrent Relays	**R2**	Feeder13		Siemens, 7SDJ602	450 A
		R3	Feeder14			450 A
		R4	Feeder15			450 A
		R5	Feeder16			490 A
		R6	Feeder17			490 A
		R7	Feeder18			475 A
		R8	Feeder20			475 A

Table 2. Protection Components Rating

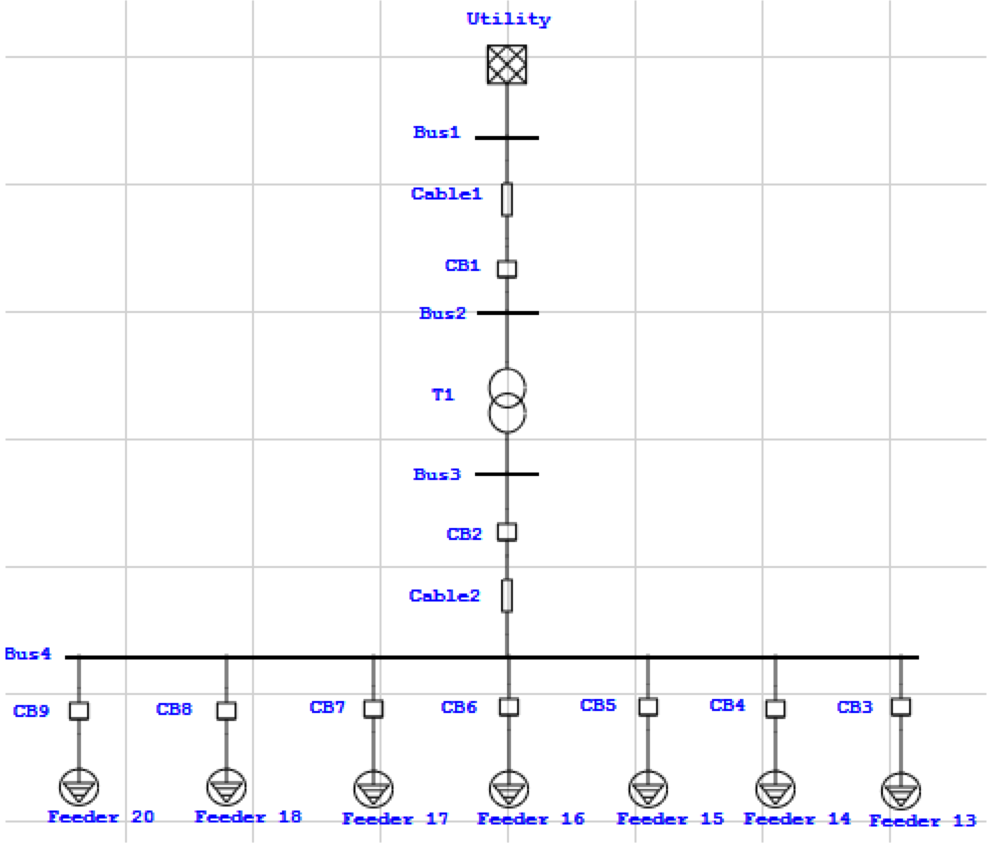

Figure 1. Single Line Diagram of the Network using ETAP

2.2 Coordination Study of the Distribution Network without DG

To obtain correct sequence of operation for the protective devices when a fault occurs on feeder, the setting of network relays should be adjusted to determine the primary protection of feeder and the back up protection of feeder. This sequence between protective devices is called coordination. For the network used, if a fault occurs on any feeder, an overcurrent relay of connected feeder should operate first to isolate and separate the faulted section from the healthy other parts of the network to achieve continuouty of service for the system. And the differential relay of power transformer should operate after feeder overcurrent relay with certain delay time as a back up protection if feeder overcurrent relay doesn't operate due to damage or any failure. Table3 shows suitable setting of the network relays. Fig.2 shows the time current curve TCC of all network relays according to the relay setting of table3

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Before Adding DG			
ID	**Load Current**	**Pick up Current**	**Time Dial**
Relay1	………..	150 A	7.29
Relay2	450 A	630 A	0.08
Relay3	450 A	630 A	0.08
Relay4	450 A	630 A	0.08
Relay5	490 A	686 A	0.11
Relay6	490 A	686 A	0.11
Relay7	475 A	665 A	0.09
Relay8	475 A	665 A	0.09

Table 3. Relay Setting of the Network Without DG

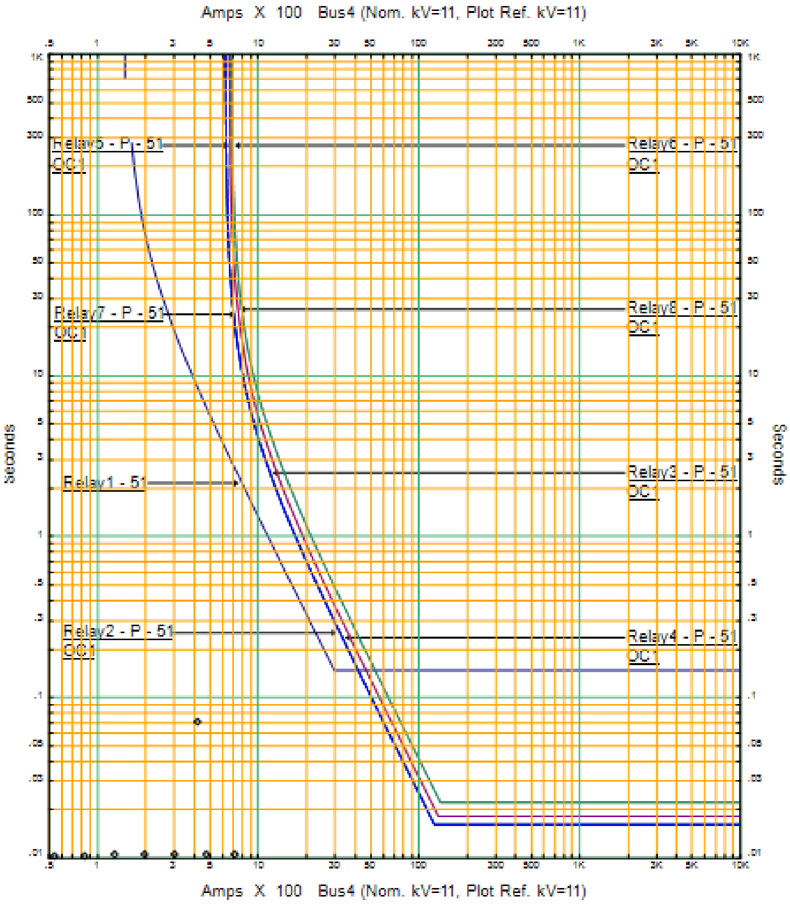


Figure 2. TCC Curves according to Setting of table3

2.3 The Effect of DGs on Protection Coordination

After adding two DG's at feeder16 and feeder17 as shown in fig.3, the drawing feeder currents and voltage drop at buses are reduced. So, adding DG's to the system improves the power flow and voltage. Also, the S.C level is increased. Hence, the coordination is affected as shown in table4. Fig.3 and fig.4 show the result of an actual case study due to three phase fault on feeder15 after adding DGs to feeders under the relay setting of fig.2. Table4 shows the actual tripping of all network relays after adding DG. According to the actual tripping in the table4 due to inserting DG to the network, the network needs new coordination.

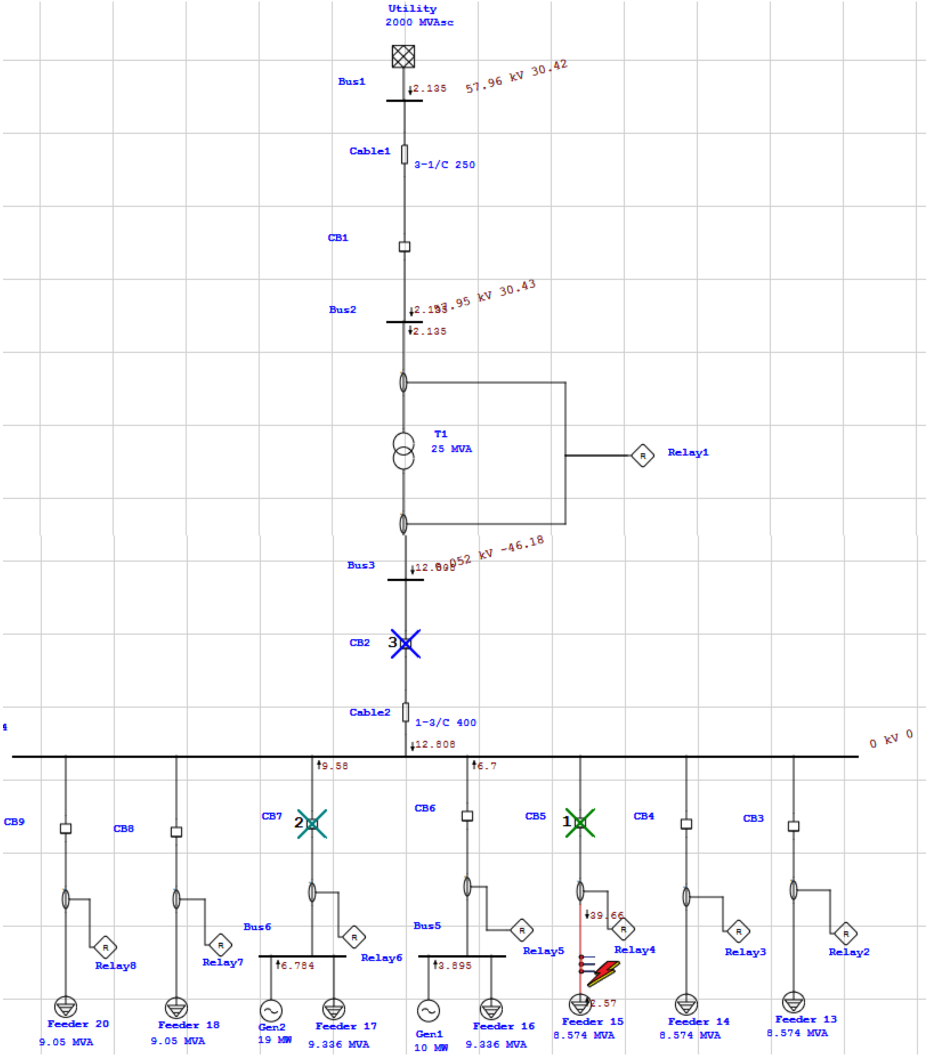
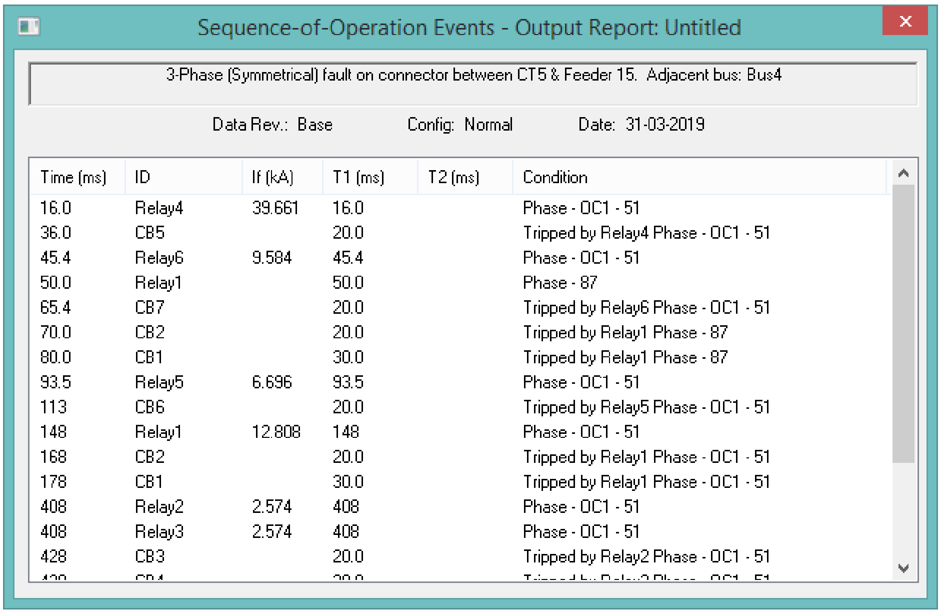


Figure 3. Fault Analysis on Feeder15


Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on connector between CT5 & Feeder 15. Adjacent bus: Bus4

Data Rev.: Base Config: Normal Date: 31-03-2019

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Time (ms)  ID       If (kA)  T1 (ms)  T2 (ms)  Condition
16.0       Relay4   39.661   16.0              Phase - OC1 - 51
36.0       CB5               20.0              Tripped by Relay4 Phase - OC1 - 51
45.4       Relay6   9.584    45.4              Phase - OC1 - 51
50.0       Relay1            50.0              Phase - 87
65.4       CB7               20.0              Tripped by Relay6 Phase - OC1 - 51
70.0       CB2               20.0              Tripped by Relay1 Phase - 87
80.0       CB1               30.0              Tripped by Relay1 Phase - 87
93.5       Relay5   6.696    93.5              Phase - OC1 - 51
113        CB6               20.0              Tripped by Relay5 Phase - OC1 - 51
148        Relay1   12.808   148               Phase - OC1 - 51
168        CB2               20.0              Tripped by Relay1 Phase - OC1 - 51
178        CB1               30.0              Tripped by Relay1 Phase - OC1 - 51
408        Relay2   2.574    408               Phase - OC1 - 51
408        Relay3   2.574    408               Phase - OC1 - 51
428        CB3               20.0              Tripped by Relay2 Phase - OC1 - 51
428        CB4               20.0              Tripped by Relay3 Phase - OC1 - 51
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Figure 4. Sequence of Operation of Protective Elements of 3-ph fault of fig.3

Fault Location	**Actual Tripping**		**Correct Tripping**	
	Primary Protection	**Back up Protection**	**Primary Protection**	**Back up Protection**
Relay2 Zone	Relay2	Relay6	Relay2	Relay1
Relay3 Zone	Relay3	Relay6	Relay3	Relay1
Relay4 Zone	Relay4	Relay6	Relay4	Relay1
Relay5 Zone	Relay5	Relay6	Relay5	Relay1
Relay6 Zone	Relay6	Relay1	Relay6	Relay1
Relay7 Zone	Relay7	Relay6	Relay7	Relay1
Relay8 Zone	Relay8	Relay6	Relay8	Relay1

Table 4. The Actual Tripping of the Network With DG Under the Old Relay Setting

2.4 New Coordination of the Network Relays with DG

To design new coordination between protective devices, S.C analysis is needed. The purpose of short circuit analysis is to adjust the delay time of the backup relay curve at S.C current of main protection relay curve to achieve correct back up protection. After adding DG, S.C level is increased and new setting for all network relays is shown in table5 and its TCC curves is shown in fig.5.

After Adding DG			
ID	**Load Current**	**Pick up Current**	**Time Dial**
Relay1	………	150 A	7.4
Relay2	450 A	630 A	0.08
Relay3	450 A	630 A	0.08
Relay4	450 A	630 A	0.08
Relay5	490 A	686 A	0.11
Relay6	490 A	686 A	0.17
Relay7	475 A	665 A	0.1
Relay8	475 A	665 A	0.1

Table 5. Relay Setting of the Network With DG

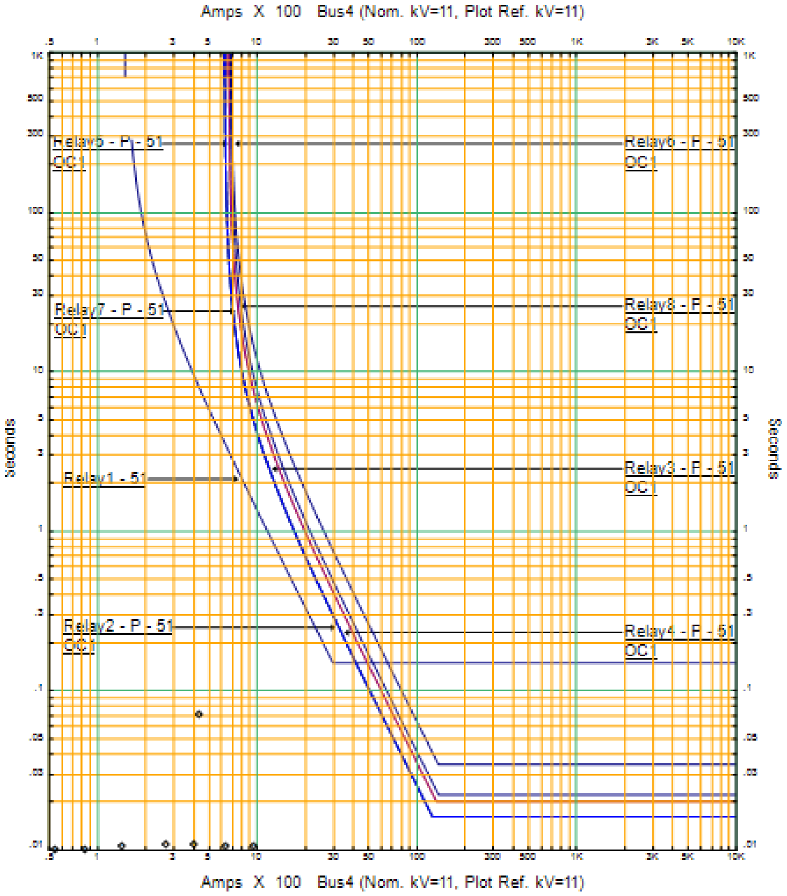

Figure 5. TCC Curves according to Setting of table5

3. Results and Discussions

3.1 Coordination Study of the Distribution Network without DG

Before inserting DGs to feeders16 and 17, the actual tripping of all network relays is shown in table6. Table6 shows eight case studies due to three phase fault. Table6 shows the main and back up protection relays with their trip times for each case study under the relay setting of table3 and fig.2.

Fault Location	Actual Tripping of all Relays at Full Load due to Three Phase Fault				
	Primary Protection	Fault Current	Trip Time of Primary Protection	Back up Protection	Trip Time of Buck up Protection
Transformer	Relay1	………..	50 ms	Relay1	146 ms
Relay2 Zone	Relay2	28.985 kA	16 ms	Relay1	50 ms
Relay3 Zone	Relay3	28.985 kA	16 ms	Relay1	50 ms
Relay4 Zone	Relay4	28.985 kA	16 ms	Relay1	50 ms
Relay5 Zone	Relay5	28.757 kA	22.1 ms	Relay1	50 ms
Relay6 Zone	Relay6	28.757 kA	22.1 ms	Relay1	50 ms
Relay7 Zone	Relay7	28.842 kA	18 ms	Relay1	50 ms
Relay8 Zone	Relay8	28.842 kA	18 ms	Relay1	50 ms

Table 6. Actual Tripping of the Network Relays without DG
at Full Load due to Three Phase Fault

From table6, before adding the DGs to the network, the fault currents in between 28.757kA and 28.985kA. And the main protective relay of feeder make trip time in between 0.8 cycle and 1.1 cycles and the back up protective relay make trip at 2.5 cycles, hence, this means fast response from protective relays to fault.

3.2 Coordination Study of the Distribution Network with DG

After inserting DGs to feeders16 and 17, the actual tripping of all network relays is shown in table7. Table7 shows eight case studies due to three phase fault. Table7 shows the main and back up protection relays with their trip times for each case study under the relay setting of table5 and fig.5.

New Coordination After Adding DG					
Fault Location	Actual Tripping of all Relays at Full Load due to Three Phase Fault				
	Primary Protection	Fault Current	Trip Time of Primary Protection	Back up Protection	Trip Time of Buck up Protection
Transformer	Relay1	………..	50 ms	…………	……………
Relay2 Zone	Relay2	39.661 kA	16 ms	Relay1	50 ms
Relay3 Zone	Relay3	39.661 kA	16 ms	Relay1	50 ms
Relay4 Zone	Relay4	39.661 kA	16 ms	Relay1	50 ms
Relay5 Zone	Relay5	35.539 kA	22.1 ms	Relay1	50 ms
Relay6 Zone	Relay6	32.65 kA	34.1 ms	Relay1	50 ms
Relay7 Zone	Relay7	39.518 kA	20.1 ms	Relay1	50 ms
Relay8 Zone	Relay8	39.518 kA	20.1 ms	Relay1	50 ms

Table 7. Actual Tripping of the Network Relays with DG at Full Load due to Three Phase Fault

From table7, After adding the DGs to the network, the fault currents in between 32.65kA and 39.66kA, this means the short circuit level is increased due to DG insertion, hence, the coordination is changed due to increased short circuit amount. Also, from the results, the main protective relay of feeder make trip time in between 0.8 cycle and 1.7 cycles and the back up protective relay make trip at 2.5 cycles, hence, this means fast response from protective relays to fault.

3.3 The Adaptive Setting of the Network

From the two-above analysis before and after adding the DGs to the network, there are two setting of the network relays. The first setting of relays before connecting DG is shown in fig.2 and the second setting of relays after inserting DG is shown in fig.5. If the network is operated without DG, the first setting of relays should be adjusted. And if the network is operated with DG, the first setting of relays should be turned into the second setting of relays to achieve the correct coordination before and after adding DGs. From the mentioned results, this approach doesn't need any additional cost or additional equipement.

4. Conclusions

This paper presents a study for the effect of adding the distributed generators (DGs) on coordination of protective devices of a real radial system of 66kV utility substation. Also, this paper introduces an approach to overcome this effect. The proposed approach depends on updating the setting of all network relays after DG insertion to achieve correct coordination. Also, the proposed approach is tested using ETAP program and the results show a correct coordination between all protective devices before and after adding DG to the network.

5. Acknowledgement

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6. References

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