CHAPTER V

IMPACTS ON PROTECTION COORDINATION

5.1 Characteristics of Protection Devices

Typically, a distribution system is radial as shown in Figure 4-1. This system is protected by the protection devices that are installed along with the main and lateral feeders. Generally, these devices consist of circuit breaker (CB), slow recloser, lateral fuse, and fast recloser. The fast recloser will firstly operate in order to confine the interrupted area if a fault is temporary. However, lateral fuse will blow up later if the fault is permanent. In addition, the slow recloser will operate in case the lateral fuse fails to blow up. Finally, the breaker will operate when both recloser and lateral fuse fail to operate in their functions.

The inverse-time equation for overcurrent [22], [23] is used to describe the characteristic of breaker and recloser, and can be derived as:

$$t(I) = TD\left[\frac{A}{M^{p}-1} + B\right] \quad \textbf{(5-1)}$$

where t is operating time of device, I is fault current seen by the device, TD time dial setting, M is ratio of I/I_{pickup} (I_{pickup} is the relay current setpoint), A, B, p are constants for particular curve characteristic.

The second order polynomial function is used to approximate the inverse-time overcurrent for fuse characteristic on log-log curve. However, fuse curve approaches a straight line. The linear equation is assumed for the fuse characteristic curve.

$$\log(t) = a.\log(I) + b \quad \textbf{(5-2)}$$

where t and I are the associated time and current, a, and b are the coefficients of the curve fitting.

The pickup current for breaker and recloser can be calculated by multiplying the nominal current I_{nom} and overload factor OLF that depends on the equipment being protected. The impact of protection coordination is evaluated following equation 5-1 and 5-2 with the fault analysis result from section IV. The value of A, B, p are 28.2, 0.1217, and 2 respectively [22]. TD is 1 for the breaker and slow recloser, and 0.5 for fast recloser. Fuse coefficient, a, and b is chosen to be -1.8 and 5.5309 [23].

According to the system in Figure 5-1, the CB2 will operate if the fault is at bus 202. In addition, if the fault is at bus 212, the fast recloser, slow recloser and breaker will operate respectively. Moreover, all protection devices will coordinate properly with their function if the fault is at bus 217 and the fault current level is I_{F1} as shown in figure 5-2 [20], but the protection miscoordination will exist if the fault current level is I_{F2} .

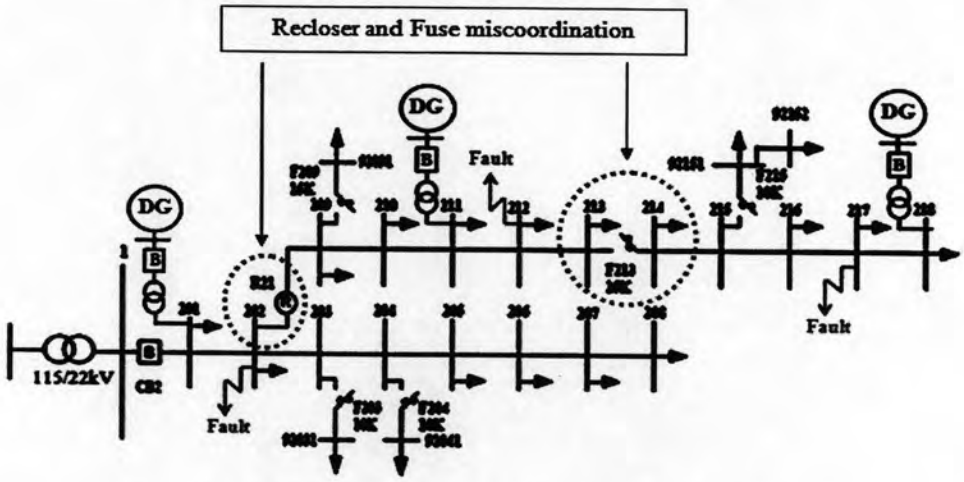

Figure 5-1 Protection coordination in the system

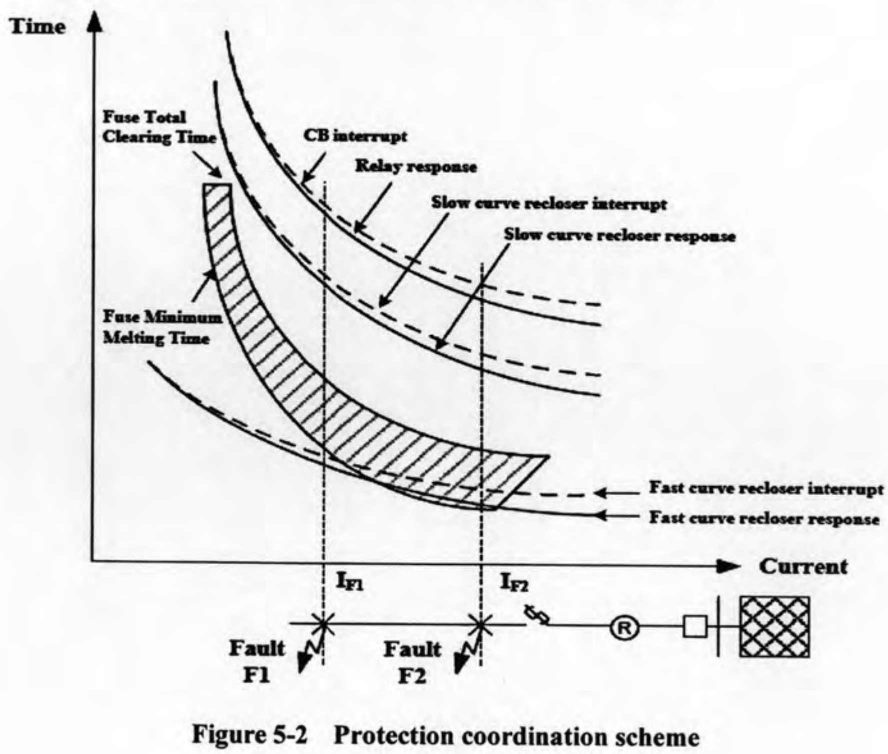

Figure 5-2 Protection coordination scheme

5.2 Results and Discussions

The system with and without DG is simulated with faults at buses 202, 212, and 217. During the simulation, the fault current at the faulted bus and the currents pass through the protection devices are recorded to plot its characteristic following the inverse-time characteristic equation 5-1 and also fuse characteristic equation 5-2. Its characteristic could illustrate whether the protection coordination in the system operate properly or not in case the DG with various penetration level is added in the system.

In this case study, the investigation of protection coordination especially, recloser and fuse miscoordination is proposed to see the impacts of fault current on protection coordination when the DG with various sizes is connected to the system. It is assumed that the characteristics of protection device in the system without DG installation is the principle of the protection coordination, it means that if the fault occurs at bus 202 between CB and recloser, the CB will operate shown in figure 5-3. Then, if fault occurs at bus 212 behind the recloser, the fast recloser, slow recloser and CB will operate respectively shown in figure 5-4. Finally, if the fault occurs at bus 217 behind the the cut off fuse, the fast recloser, fuse, slow recloser, and CB will operate properly shown in figure 5-5.

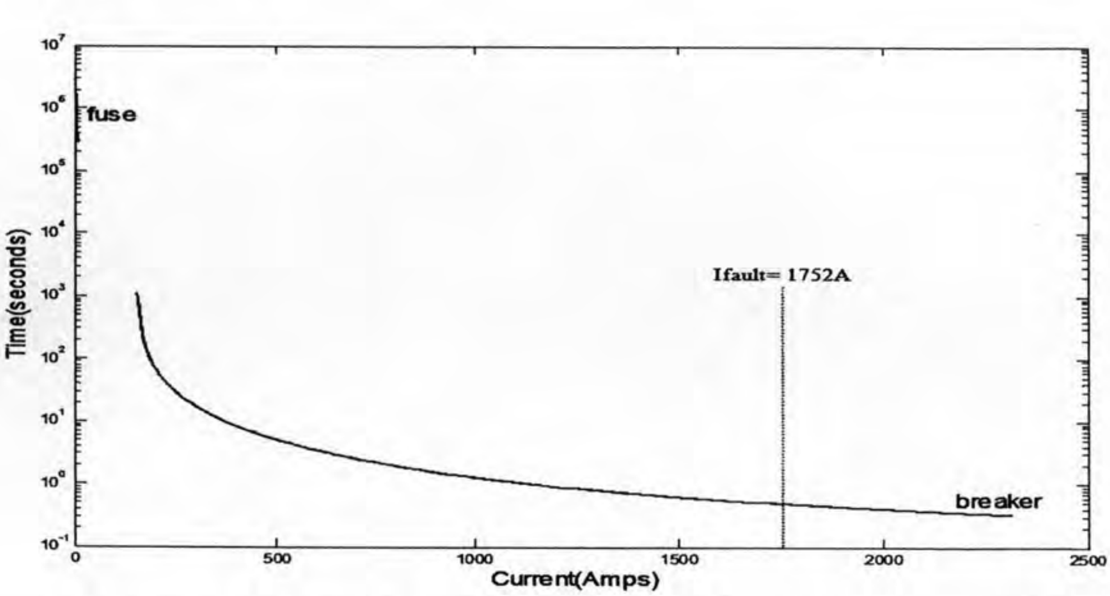

Figure 5-3 Protection coordination without DG installation when fault occurs at bus 202

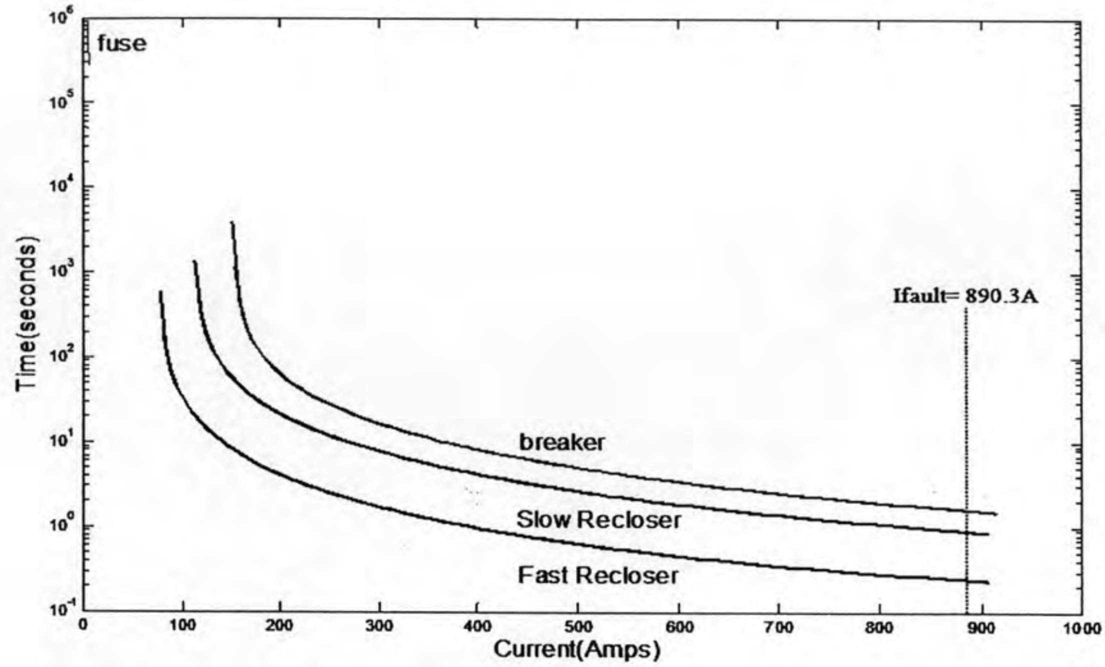

Figure 5-4 Protection coordination without DG installation when fault occurs at bus 212

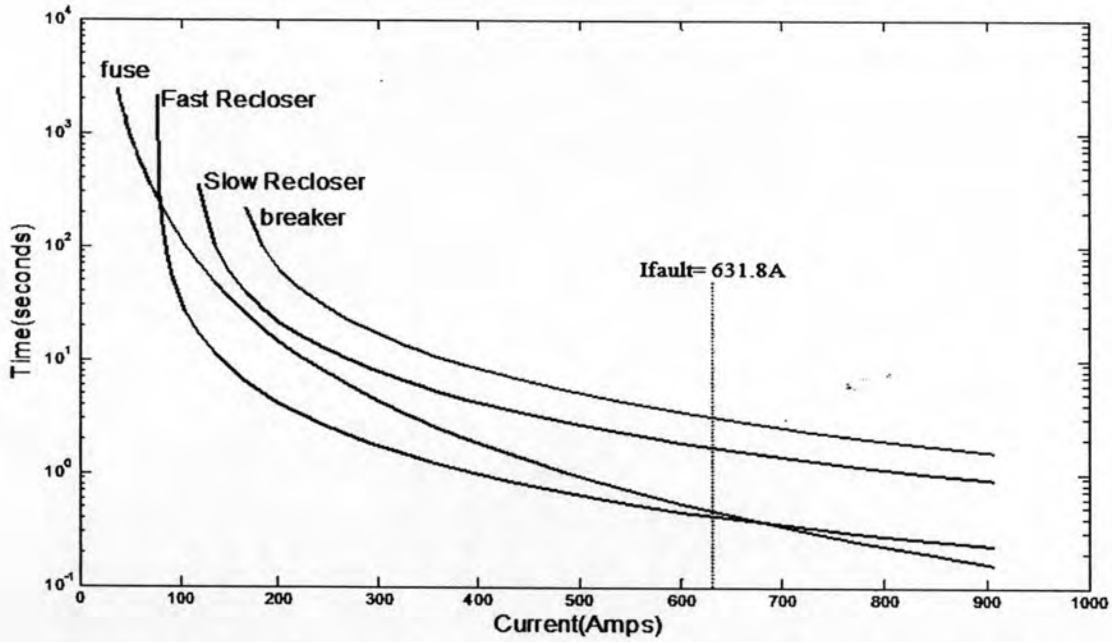

Figure 5-5 Protection coordination without DG installation when fault occurs at bus 217

From chapter IV, the presence of DG in the system will increase the fault current that will result the protection devices to fail to operate in their function, especially the recloser and fuse miscoordination. Figure 5-6 and figure 5-7 are the characteristics of protection devices while the fault assumes at bus 217 and 3 GCPVs or 3 SGs are connected in the system.

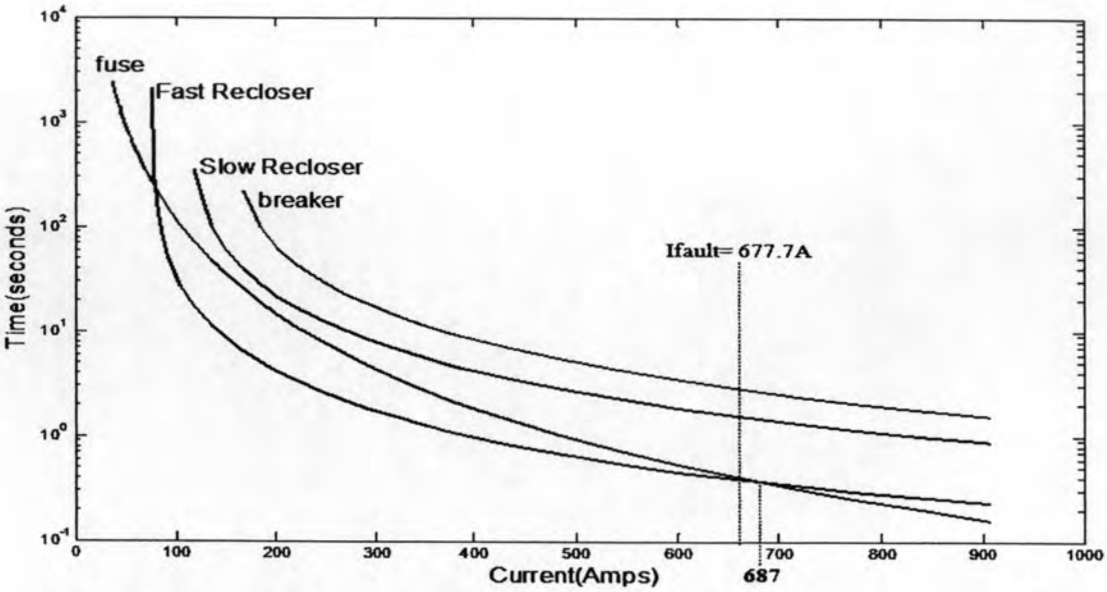

Figure 5-6 Protection coordination when 3GCPVs installed and fault occurs at bus 217

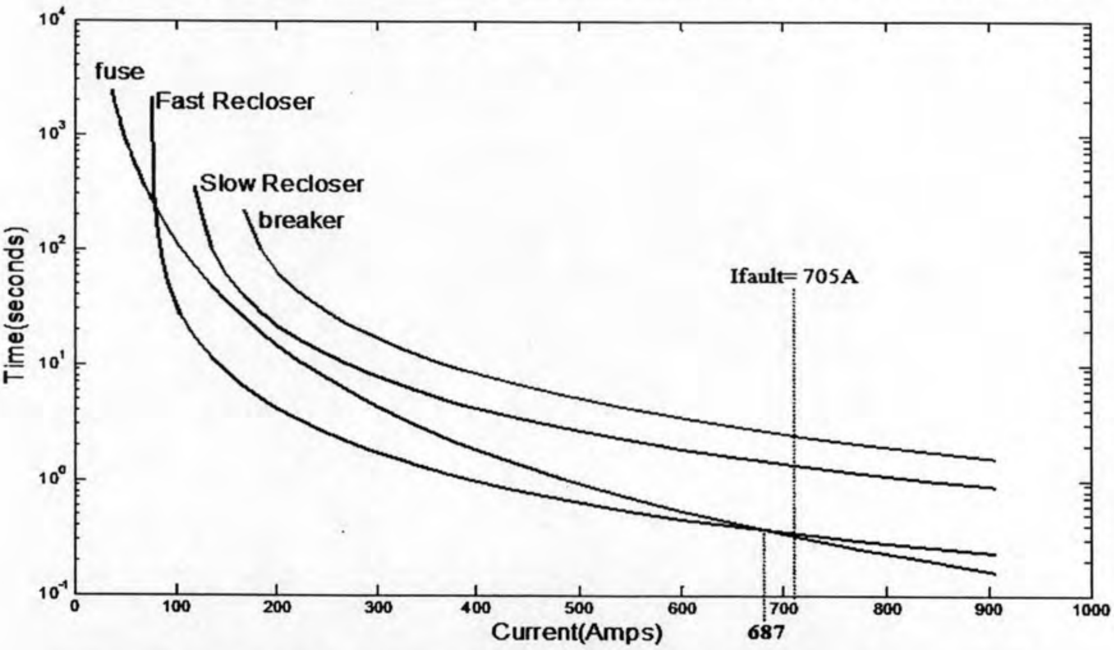

Figure 5-7 Protection coordination when 3SGs installed and fault occurs at bus 217

From the figure 5-6, it shows that the current set point for the recloser and fuse coordination is not greater than 687 A. Therefore, the protections coordination still operate properly when the 3 GCPVs are connected. In contrary, Figure 5-7 shows the fast recloser and fuse miscoordination when 3 SGs are connected because it fault current contribution is higher than 3 GCPVs.

In case there is only one 3MW DG installation at bus 201, 211, or 218. From the fault current tables in chapter IV, it shows that the protection device still operate coordinately even DG (GCPV or SG) is connected at bus 201 shown in figures 5-8 and 5-9. If the DG is connected at bus 211, the protection devices will fail to operate when SG is installed, but theses protection device still operate properly if GCPV is installed at that bus as shown in figure 5-10.

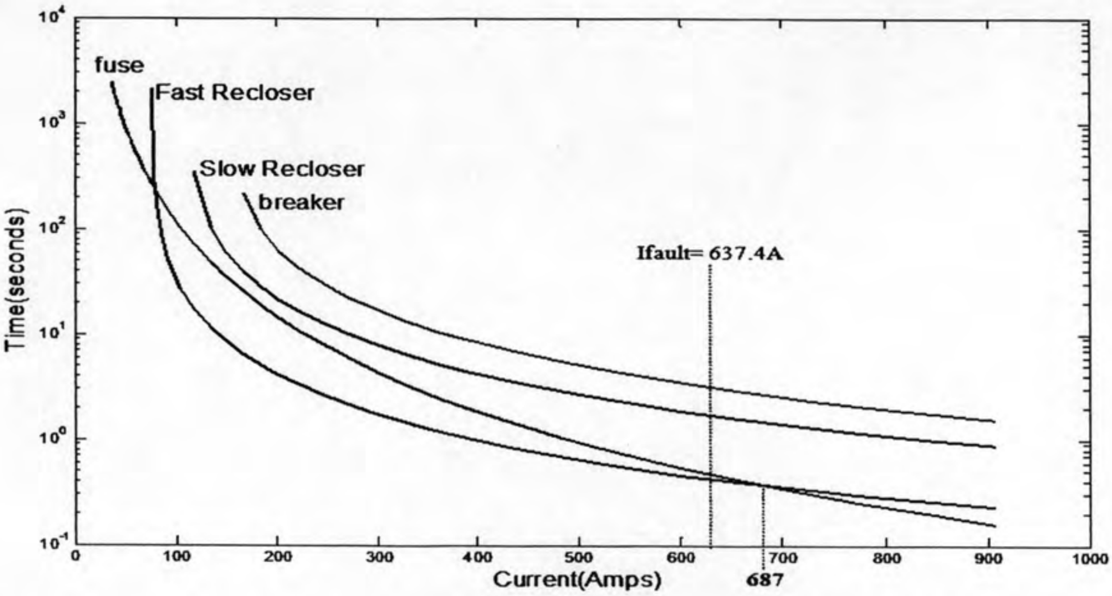

Figure 5-8 Protection coordination when one GCPV is installed at bus 201 and fault occurs at bus 217

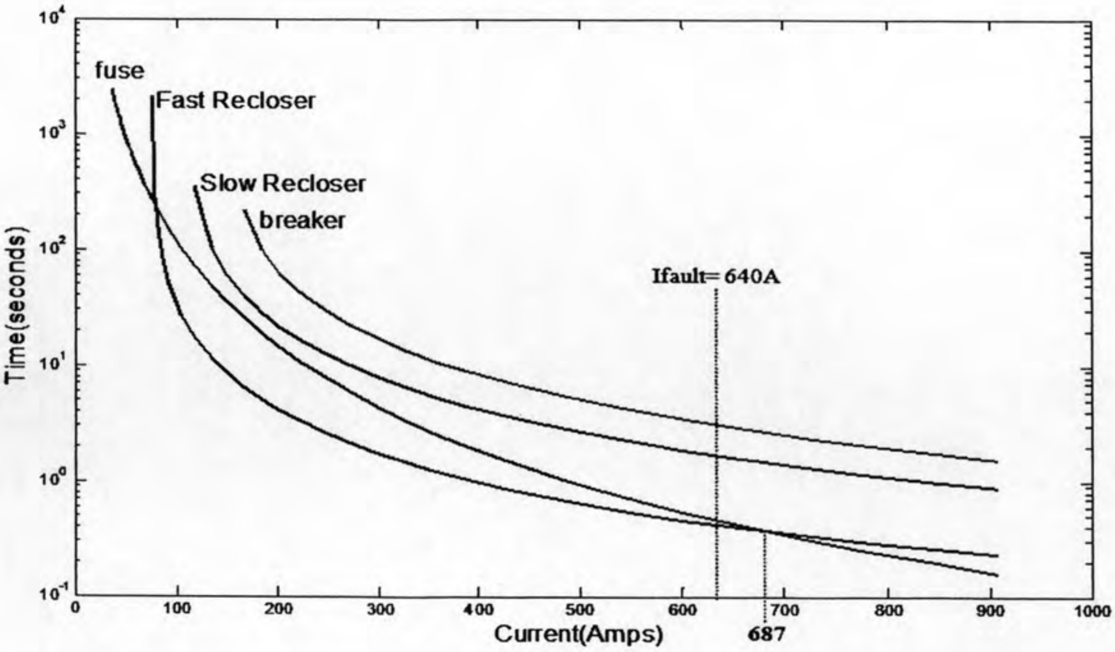

Figure 5-9 Protection coordination when one SG is installed at bus 201 and fault occurs at bus 217

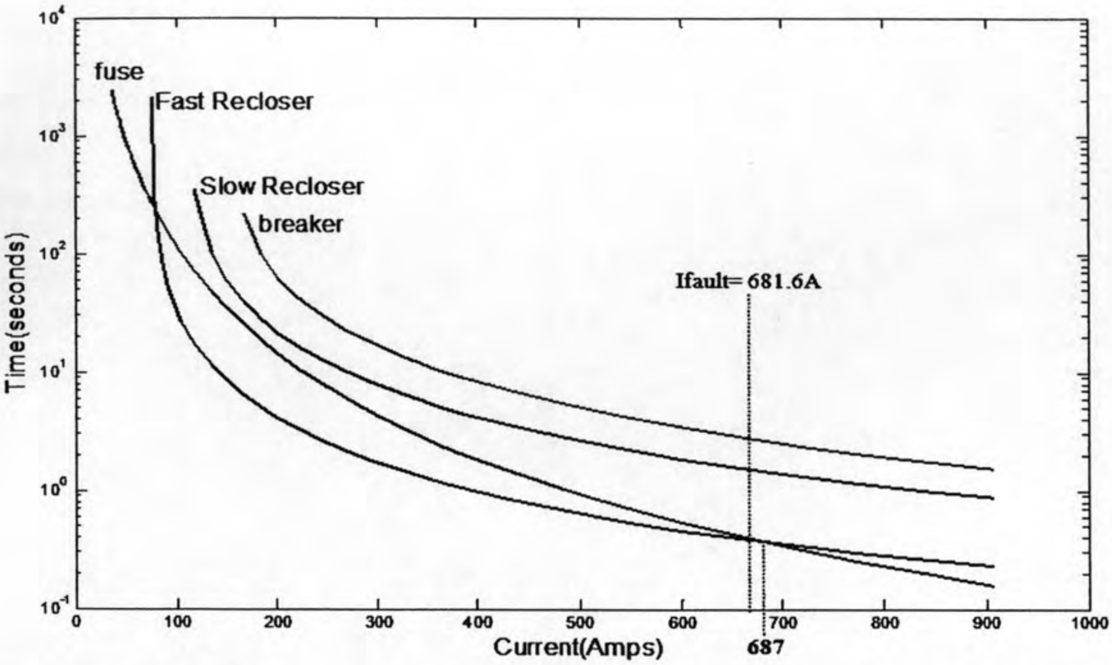

Figure 5-10 Protection coordination when one GCPV is installed at bus 211 and fault occurs at bus 217

Table 5-1 is the summary of the protection coordination scheme according the fault current contribution when the DG penetration level is connected. This table can show that the protection device still operate properly in which penetration and location of DG.

TABLE 5-1 PROTECTION COORDINATION SCHEME IN THE PRESENCE OF DG

Recloser and fuse coordination		
Faulted bus		217
3PVs with 1MW each		✓
3SGs with 1MW each		x
3MW PV is connected to bus	201	✓
	211	✓
	218	x
3MW SG is connected to bus	201	✓
	211	x
	218	x

where, ✓ represents the protection devices operate properly.

x represents the protection devices that fail in their function.

5.3 Summary

In summary, following the observations can be drawn:

- The presence of distributed generation in the system will increase the fault current that result in the protection coordination scheme to fail, especially the recloser and fuse miscoordination.
- The location of the new DG installation in the system is also a reason of the protection miscoordination as shown in the case studies.
- The type of distributed generation like SG or GCPV installation in the system is another factor to impact the protection coordination.
- GCPV installation has lower impacts on the protection coordination than SG because its fault current contribution is lower than SG.
- The DG penetration level has to be limited to ensure the protection device to operate properly.