Protection Coordination Study in Grid Connected PV Systems

Miss Priyanka Gupta [1], Mr. Amit Agrawal[2], Dr.Dharmendra Kumar singh[3]

[1] M-TECH (Scholar)
Department of EEE ,Dr.C V Raman University

[2]Deparment of EE
Dr. C V Raman Institute of Science and Technology
Kota, Bilaspur (C.G.)

[3]Deparment of EEE
Dr. C V Raman Institute of Science and Technology
Kota, Bilaspur (C.G.)

Abstract: ***Renewable energy sources are clean source of energy and free from emission of greenhouse gases. Solar and wind power are the most common sources of renewable energy. Primary objective of this Paper is studying impact of fault current from grid tied PV system in a network. In a conventional power distribution system, power is generated and then distributed in a radial network.In distributed generation using PV cells, there are several points of power generation in a system. Conventional methods of protective relaying is originally developed for radial distribution do not hold up well in all situations with distributed generators embedded in power system. This is because of the change in fault levels caused by the contribution from distributed generators during faults.There are several situations of unintentional islanding and problems associated with reconnection of distributed generator with utility.[1]***

Keywords: Islanding, Solar,Fault.

1. Introduction

Alots of new situations introduced when there is a possibility of bidirectional power flow .These situations were not considered when designing the protection systems of present distribution networks, which is based on radial power flow. In the Fig. 1, if we consider that there are no distributed generator (DG1) is connected, for a coordinated system, fuse F1 and fuse F2 are selected so that the any fault on feeder1, F1 operates before F2. This is only possible when total clearing (TC) characteristic of F1 is below the minimum melting (MM) characteristics of F2 by a safe margin for any feeder fault. For the same network, if a distributed generator DG1 is connected as shown in Figure 2 and consider a fault in feeder1, the minimum and maximum fault current will increases from the source side due to the upstream DG unit.[2]

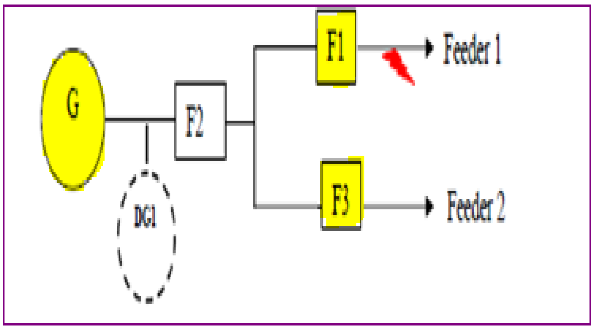

Figure 1: Distribution system with DG -1

2. Protection Issues

In the case of Fig. 1 coordination of fuse is not likely to be affected if fuses can still coordinate with the changed level of fault currents. This is just because of fuses will see only downstream faults. For the same network, if a distributed generator (DG2) is connected in the downstream of feeder 1, for a fault as shown in Figure 2, fuse F2 has to operate before fuse F1 to maintain system reliability. This is not achievable as both F1 and F2 will see same magnitude of fault current in either case (i.e. for both downstream and upstream faults). This illustrates a case of fuse-fuse is coordination problem with distributed generator in network.[3]

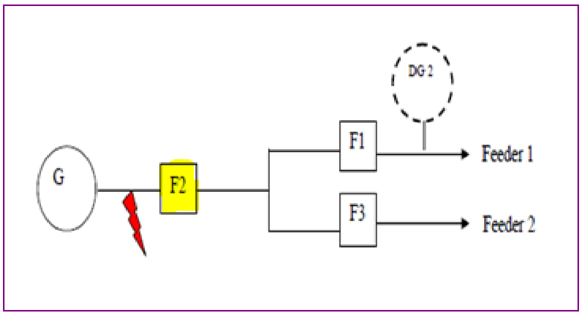

Figure 2: Distributed system with DG-2

In the network discussed above a distributed generator DG3 is connected as shown in Figure and the two different cases of faults are considered and the impact of DG size on protection coordination

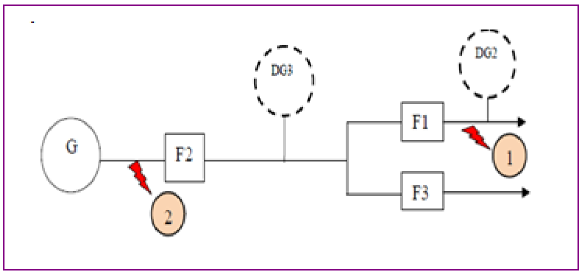

Figure 3: Distributed system with DG-2&3

If fault occurs at location 1, current flowing though fuse F2 is less than the current flowing through fuse F1, while if fault is at location 2, current flowing through fuse F2(IF2) is greater than than the current flowing through fuse F1(IF1).The difference in magnitude of IF1 and IF2 depends on the size of distributed generator (DG3). When IF1>IF2, the coordination always holds. When IF2 > IF1, difference between the magnitude of IF1 and IF2 decides the level up to which the coordination will hold well. If the difference of magnitude between IF1 and IF2 is not above a minimum value, then the coordination will not hold well. As the difference in the magnitude of IF2 and IF1 depends on the size of distributed generator(DG3), if the size of DG3 exceeds the size which is adequate to provide enough fault current to ensure minimum difference in magnitude between IF1 and IF2, then the protection coordination will not be disturbed.[4][5] Distributed generator also has the potential of disturbing the protection coordination between fuse and recloser. This issue has been discussed in details in several papers [9], [10], [11] and [12]. The recloser fuse coordination problem caused by distributed generators has been described below. In the network shown in Figure 3.4, it is initially assumed that the DG is not connected.[6]

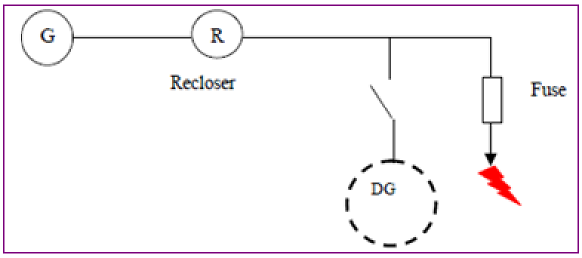

Figure -4 Fuses – recloser coordination –Impact of DG placed between recloser and fuse

In the main line the recloser has to coordinate with this fuse for all faults taking place on the feeder. For all types of faults on load feeder current in the fuse and recloser will be the same. There is two devices should coordinate for all values of fault current on the load feeder. Coordination curve is shown in Figure 5.[7]

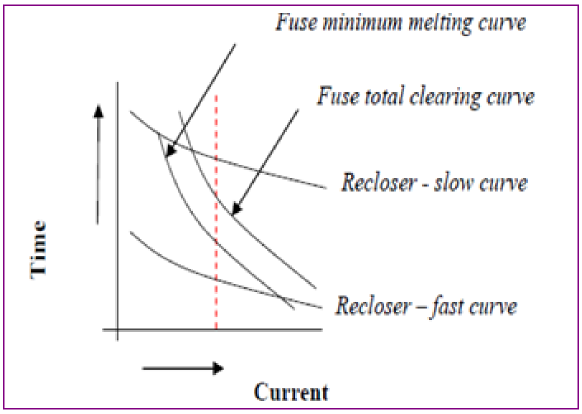

Fig-5 Fuse-recloser coordination

The protection principle is to ensure that only the fuse should operate for a permanent fault in load feeder. When temporary faults occur, recloser should disconnect the circuit with fast operation and give the fault a chance to clear. If the fault is permanent then only the fuse will disconnect. Slow mode of recloser is a backup to the fuse. Relative location of fuse and recloser has also a role to determine the criteria of coordination. If the DG is considered then the fault current seen by the recloser and fuse shall not be same.If the fault current flows through the fuse is If and the fault current seen by the recloser is Ir then the coordination holds good, only if fault currents lie within allowed margin. If the difference between If and Ir is more than the margin, fuse will operate before the recloser operates. This difference will depend upon the size of DG and distance of the DG from the feeder. Thus if DG injects more fault current, chances of coordination being lost.

Another problem with recloser is closing operation after fast mode opening is that the recloser normally energizes a dead system if there were no DGs but in this case, it connect back to live system. If this closing operation is done without synchronization then it can lead to severe damage of DG. [8]

The problem of fuse blowing is illustrated in Fig.6.In a conventional protection system, temporary fault occurring at lateral feeder, should be discriminated by fast operating recloser .However, with DG installed this way not occur (as discussed in fuse recloser coordination problem) and fuse may clear fault thus they reducing reliability.

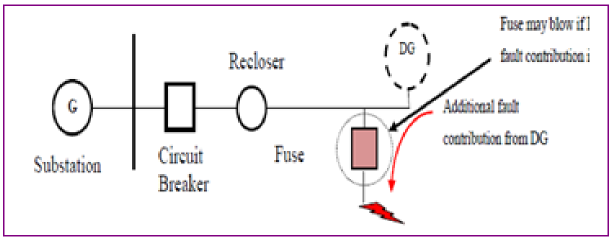

Figure 6 Fuse blowing due to fuse – recloser miscoordination

The false tripping problem is illustrated using the Fig.7. If a fault occurs in feeder 2 then circuit breaker in feeder 2 should trip, however, the circuit breaker in feeder 1 may operate as d istributed generator will try to feed fault and causes unreasonable interruption of electricity. False tripping in healthy feeder may be somewhat solved by using directional over-current relay for the circuit breakers.[9]

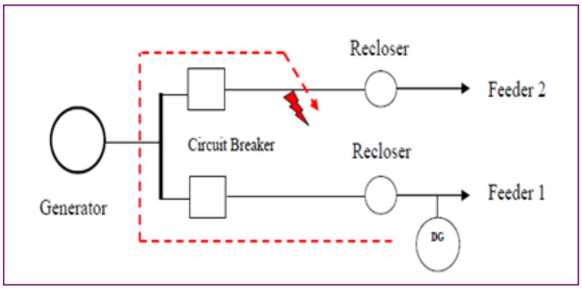

Figure 7 : False tripping of circuit breaker (sympathetic tripping)

DG sizing shall is to be done to resolve false fuse blowing and achieve better fuse recloser coordination in systems with distributed generator. As the recloser fuse coordination holds good up to a particular size of DG, it is very important to calculate the optimum DG size that it can be integrated in a system without disturbing the coordination. Figure 3.8 shows contribution of fault current from substation and DG during a fault.[9][10]

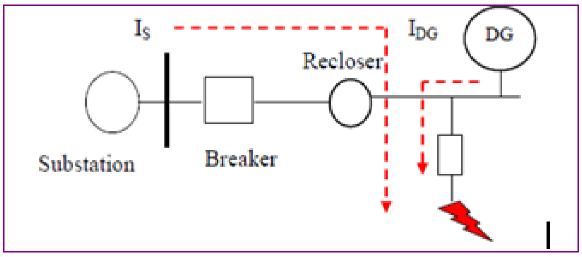

Figure.8 False-recloser coordination and DG Sizing

If fault current flows from distributed generator (DG) = Idg, fault current flows from Substation = Is The DG size should be selected so that,

$$I_S + I_{DG} < I_{Fuse\ Margin} \qquad (1)$$

Fuse margin is the maximum fault current that it can be allowed to flows through the fuse without disturbing the coordination. When the current more than Ifusemargin flows through the fuse, coordination will be lost.Operating time of recloser can be represented by the equation below

$$t = \frac{A}{\left[\left(\frac{I_S}{I_P}\right)^P - 1\right]} + B \qquad (2)$$

Where A, B and P are the curve constants and s is the set value of current for tripping. operating time of fuse can be represented by the equation below

$$\log(t) \equiv a.\log(I) + b \qquad (3)$$

Where 'I' is the current flowing through the fuse and 'a' and 'b' are curve constant, When $I_S + I_{DG} = I$ flows through fuse,

$$I_{DG} = 10^{\frac{[\log(t) - b]}{a}} - I_S \qquad (4)$$

For the condition $I_S + I_{DG} < I_{Fuse\ Margin}$ to hold good, tripping time of fuse shall not exceed the tripping time of recloser and therefore to calculate maximum size for DG, fuse tripping size shall be considered equal to maximum tripping time of recloser.

Substituting the value of time't' in equation 4 by recloser tripping time from equation 2 we can find maximum value of Idg which will keep the coordination undisturbed. The size of DG can therefore be stated in terms of short circuit MVA as

$$\sqrt{3} \times V_{DG} \times I_{DG} \qquad (5)$$

Vdg is the line to line voltage of the distributed generator. Using value of Idg from equation 4 and using equation 5 and if Vdg is the DG voltage, maximum capacity of DG can be calculated as:

$$S_{DG} = \sqrt{3} \times V_{DG} \times \left(10^{\frac{[\log(t) - b]}{a}} - I_S\right) \qquad (6)$$

3. Conclusion

By the addition of PV systems in the network the protection coordination of existing systems can potentially be disturbed. This should be reviewed when large PV systems are added to network. It is recommended that all factors that impact contribution of fault current from PV should be considered to estimate minimum and maximum fault current level of network Arithmetic addition of fault current from PV system is not sufficient for the purpose relay coordination.

Increase in magnitude of fault current beyond the design limit of the circuit breaker or the distribution board will lead to electrical and fire hazardous. Utility companies should therefore limit the maximum PV penetration in network based on proper review and recommend upgrade of distribution boards where necessary.

References

[1] IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE 1547, 2003.

[2] S.Phuttapatimok, A.Sangswaang, M.Seapan, D.Chenvidhya and K.Kirtikara , Evaluation of Fault Contribution in presence of PV Grid connected systems, Photovoltaic Specialist Conference ,2008, 33rd IEEE, Pages [1]-[5].

[3] Rajiv.K Verma, Jon Berge, I.Axente, Vinay Sharma, Ken Walsh, Determination of Maximum PV Solar System Connectivity in a Utility Distribution Feeder, Transmission and Distribution Conference and Exposition (T&D),2012, IEEE PES.

[4] Hossein Hooshyar,Mesut E.Baran, Fault Analysis on Distribution Feeders with High Penetration of PV Systems,

Power Systems 2013,IEEE Transactions on, Vol 28, Pages [2890]-[2896].

[5] Mesut E.Barun, Hossein Hooshyar, Zahn Shen, Alex Huang, Accomodating High Penetration on Distribution Feeder, Smart Grid 2012,IEEE Transactions on, Vol 3,Pages [1039]-[1046].

[6] S.Bhattacharys, T.Saha, M.J Hossain, Fault current contribution from photovoltaic systems in residential power networks, Proceedings of the Australasian Universities Power Engineering Conference, Hobart, 2013, Australia, pp.[1]-[6].

[7] Australian Standard The calculation of short-circuit currents in three phase a.c. systems, AS 3851,1991.

[8] Farid Katiraei, Investigation of Solar PV Inverter Current Contributions during Faults on Distribution and Transmission Systems Interruption Capacity, Western Protective Relay Conference,2012,Pages [5]-[6].

[9] S Chaitusaney, A Yokoyama An Appropriate Distributed Generation Sizing Considering Recloser- Fuse Coordination, Transmission and Distribution, IEEE Conference Asia and Pacific on ,2005, Pages[1]-[6].

[10] Australian Standard Grid connection of energy systems via inverter-Grid protection requirements, AS 4777.3, 2005.

[11] H.Yazdanahi, Yun Wei Li, Wilsun Xu, A New Control Strategy to Mitigate the Impact of Inverter Based DG on Protection System ,Smart grid 2012 ,IEEE Transactions on, Pages [1427]-[1436].

[12] Jamie Keller, Benjamin Kroposki, Richard Bravo, Steven Robles, Fault Current Contribution from Single Phase PV Inverters, Photovoltaic Specialist Conference,2011, 37th IEEE, Pages [1822]-[1826].