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Impact of Solar PV Integration on Short Circuit Current and Protection of Distribution System

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***Abstract*—** Injection of solar power to current distribution system has provide many benefits such as power quality is improved, reliability is increased and peak demand is full filled. when a solar source is injected despite of it benefits it has some negative impact on protection system that in turn effect reliability and stability of system. injecting solar PV to system cause to increase fault current and severely effect protection system. We use IEEE 13 bus system for simulation with software ETAP.we inject solar PV on different buses and apply fault on different location. we compare the result of short circuit study of normal case and when PV is added. We also increase the penetration of PV and see it impact short circuit current . This comparison enables us to investigate impact of solar PV on short circuit current level and impact of this current on protection scheme and devices in this paper we will investgate the impact of injecting solar power on fault current level of distribution system and study the consequent effect of this fault current on protection system and devices of long transmission line and line losses is also reduced so it encourages to generate electricity in local and supply the near by load rather than constructing a long transmissionline.

***Keywords*—**Photovoltics(PV) ,ETAP,IEEE13 Bus System, Protection System, Distributed Generation (DG)

I. INTRODUCTION

As we observe electricity demand is increasing day by day and it is task of power engineer to generate electricity from other sources to meet the demand but it same time to generate electricity from such sources which has less effect on environment so renewable energy source has taken greater importance.

However the problem occur when we generate electricity from these sources and integrate it with distribution system .In current distribution system power flow from generating station to load center .The over current protection for current system is based on single direction of power flow .when a distributed energy source such as PV is added the current also flow from DG side .This flow from distributed source effect the protection system by increasing or decreasing the fault current .This increase or decrease in fault current consequently effect the protection system of distribution system.

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II. DISTRIBUTED GENERATION AND ITS TYPES

DG refer to those generations which are very close to the consumer. In DG the distance between the consumer and generating unit is very small.AS the distance between the consumer and generating unit is very small so there is no need. The IEEE defines DG “Those generations whose generating capacity is usually less then the capacity of gentral generating units[3]. The international energy agency defines DG as “Distributed generation are those generation which are feeding the consumer on site[4].

Distribuded generation (DG) is usually placing a small power plant near the load center whose capacity is from 5 kw to 25 kw [5]. The distributed generation is of two types .The DG is coupled with grid by two methods .it can be coupled directly with the grid or it can coupled with grid through inverter so we can say DG are of inverter type or rotating machine type .Inverter are used in dc system .The output of DG source is either dc or ac .we need voltages and frequency of certain voltage .in order to achieve the frequency and voltage of desired level we first convert the output of DG source to dc by using specific converter .The dc is then converted to desired value ac .THE rotating machine type DG will be directly connected to grid[5]

The DG technologies are such as photo voltaic system, wind turbines, fuel cells synchronous and induction type generator.

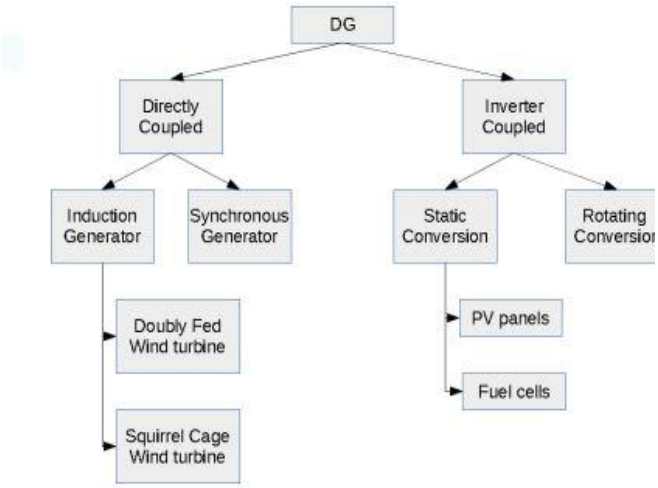

Figure 1. Classification of DG

III. PHOTOVOLTAICS SYSTEM AND ITS CLASSIFICATION

The photovoltaics use the light of the sun and convert the sun light in to usable electrical power. solar cell is used to convert the light of the sun light of the sun in to electrical energy. The Solar cell is made of semi conducator materials . when these semiconductor materials are exposed to sun light it converts the light energy which are present in photon to electrical energy.

When few solar cells combine it form solar array. The solar array is either kept fixed or movable. The array is made movable to truck the sun. The reason of tracking trucking sun is to maximize the power that we get from solar panel. we get energy from solar by two techniques either by active solar technique or passive solar technique .in active solar technique we use directly the power of the sun such as in photovoltaics and concentrated solar power. If we orient our building in sun direction it is passive solar technique. As we see the global warming is increasing .it is because of the waste gas and other environment harmful gas in the environment .in diesel power plant lot of the waste goes in to environment. we need to generate energy from the sources that are environment friendly so sun is the biggest sources of renewable energy. This system is environment friendly because there is no emission of the waste which are harmful for the environment. Sun has high potential to generate electricity. the united nation development found that in 2000 that sun has potential of to generate 1575 to 49837 EXA JOULE energy per year .it is several times greater than the world consummation of the energy. Solar system is very easy to design and it require only sun as fuel. The disadvantage of this system is that it has high initial cost and it require large space [8].

PV system are classified in to several categories. The classification is based on the base of function, operational needs and how the components are connected with other power sources.[13] The main classification of solar system is as under

1. Grid connected photovoltaic system
2. Standalone solar system
3. Hybrid photovoltaic system

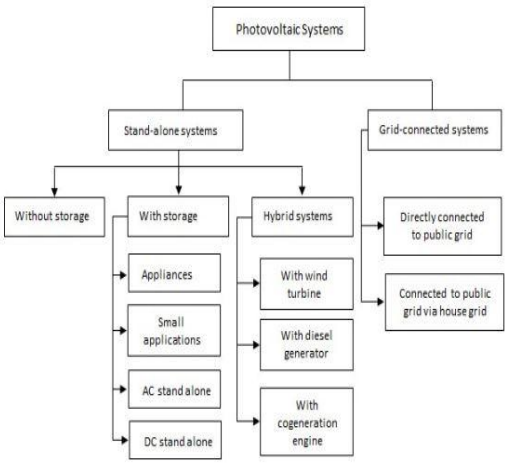

Figure 2. classification of photvolticsystem

IV. IMPACT OF DISTRIBUTED SOLAR PV ON SHORT CIRCUIT CURRENT

The short circuit current value or fault current of the system is changed when a distributed generating source is injected.it is observed that short circuit current level increase as we insert or inject a DG sources when this fault current is compared with fault current of without DG.

The circuit level even also increases if we inject a small generating unit to the system. The increase in fault current with injecting DG depends on many factors.it depends on the size of DG, location of the DG, generating capacity of DG, distance between the generating source and fault and on the type of DG [6]. Let consider a scenario in which we add only one small distributed energy source to the network. The fault current of network increase when fault occur on different location in system. The increase in fault current level due to a small single DG source is not much significant and this increase is very small so DG of very small not cause any problem to the protection system scheme of the network and fuse breaker work in normal way and coordination of the system is remain intact [6]. If we add more the then one small DG it causes increase to fault current level and this increase is very dominant and it has severe effect on the distribution protection scheme. This cause miss co-ordination between the protective device and system not work in normal way. If one large centralized DG is injected to network, it also has more dominant effect on system fault current level. The dg contributes to faults and faults increase and utility contribution in such scenario is reduced [7].

If distance between fault and SOLAR PHOTOVOLTIC source is changed the percentage contribution by DG to fault is also varied however fault current increase in all case. if smaller unit is injected to system whose generating capacity to one large central source, the fault current increase but the increase is smaller as compared to one centralized source. The increase in fault current depends on the type of DG technology we are using. The contribution to fault is very high in case of separately excited synchronous generator.it contribution become more dangerous after few cycle. The inverter type DG contributes less to the fault current level.[14].

V. IMPACT OF SOLAR DG ON PROTECTION OF DISTRIBUTION FEEDER

The power flow in current traditional power system is in radial direction. The radial flow means power flow in single direction that is from generating station to far away load center. protective devices are placed on the feeder and branches of distribution system to protect the equipment of system from damage and there is continuous flow of electricity to the loads [7]. The protection of the system is not simple or straight forward but we have to take some consideration in to account to protect the whole system. The are several protective devices are placed in network and each has to protect certain area the protection system has to protect this area in very reliable way. however, we solar DG source is added it cause the problem of reduction of reach in same cases. The problem occurs when a solar DG is embedded in a system because there is single

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direction of power flow in current system and all device are coordinated for single power flow direction. The case is not true in case of solar DG because current also flow from DG side also.The solar PV has very significant effect on protective device and distribution feeder protection.

A. False trip or mail trip

it is the condition in which the protection system remove the healthy portion of the system. The system not operate in correct fashion and did the unwanted or unnecessary tripping.[9] Let us see in figure there are two feeders connected to bus and operated in parallel fashion.

The both feeder is feed from grid. A distributed generating source such as PV is connected to one of feeder. if the fault occurs on the feeder which has no PV source connected so it is required the breaker of this feeder to operate and isolate this feeder only. however, PV source contribute to the fault and case the healthy feeder to trip which is not necessary [6][12].

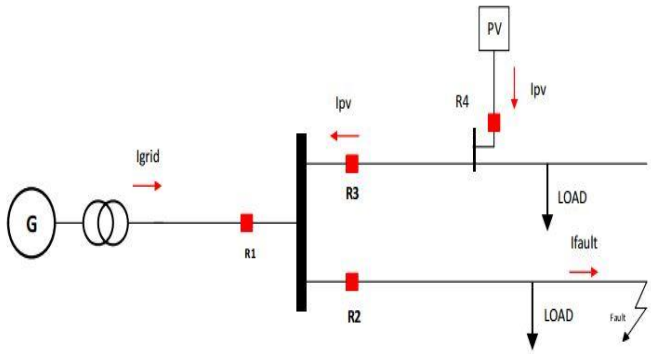

Figure 3. Flase Trip

B. Blinding or fail to trip

In some cases, when a PV generating source is injected to radial system it can blind. the protection system. The protection system is blind and not see the fault and faulted section is still connected with system even fault occur on system. As in figure a radial system is shown and a downstream fault occur. if the contribution from PV source so very less current then flow through R1.the current is very less than the pickup current of relay so relay not sense fault and not operated and faulted section is still connected. [6 [2][7]

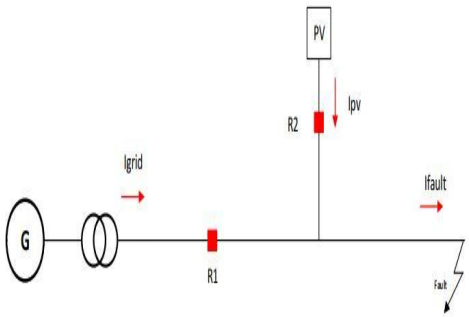

Figure 4. Blinding OR Fail to Trip

C. Reduction of reach

in power system every protective device has to protect certain area or distance .in some case when a PV power is added, the system is unable to protect its protection zone .it is unable to reach its protective distance [10]. As we see in figure R1 must cover or protect all area from node a to b. when a PV is added and the contribution from PV source so very less current then flow through R1.the current is very less than the pickup current of relay so relay not sense fault and not operated and faulted section is still connected R1 is not able to detect fault in their protective zone [7] [15].

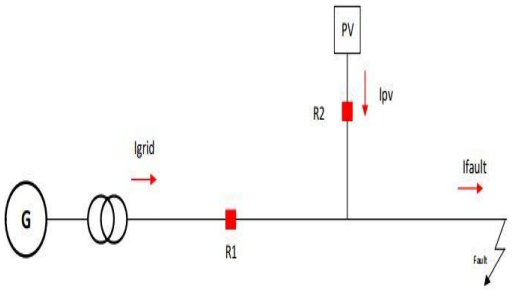

Figure 5. Reduection of Reach

VI. SIMULATION AND RESULTS

The system used for the simulation is IEEE13 bus system. we run simulation on IEEE 13 bus system by applying fault on different location in the system.First we apply fault on different buses without connecting any PV sources to the system. These values are considered as base values. Then we connect PV sources to the system with different configuration and these results are compared with the result of the base case.The system which is used for simulation is shown below [13].

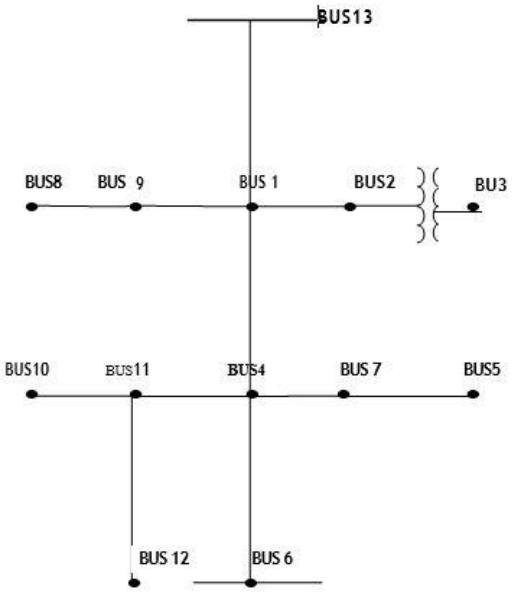

Figure 6. IEEE 13 BUS SYSTEM

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We run simulation for different configuration of PV connected to the IEEE 13 BUS SYSTEM .THE FOLLOWING cases is simulated by applying fault on different buses.

Case 1:Simulation of system with out injecting any pv power

Case 2:Simulation of system when pv power of 6MW is injected on the bus 1

Case 3:Simulation of system when pv power of 6MW is injected on the bus 3

Case 4:Simulation of system when pv power of 6MW is injected on the bus 4

Case 5:Simulation of system when pv power of 6MW is injected on the bus 6

Case 6:Simulation of system when pv power of 9MW is injected to three different buses in the system

On running the simulation for above case by applying fault on different buses .THE result which is obtained during simulation is listed below

TABLE I. TABLE 1 FAULT CURRENT OF ALL SCENARIO WHEN FAULT OCCUR ON DIFFERENT BUSES

Faulted bus	Case1	Case2	Case3	Case4	Case 5	Case6
Bus 1	7.12	8.781	7.85	7.84	7.210	8.45
Bus 2	5.12	5.965	6.56	5.57	5.19	5.663
Bus 3	16.99	17.905	30.3	19.5	17.451	17.163
Bus 4	4.214	4.32	4.65	5.78	4.720	4.7
Bus 5	2.946	2.975	3.27	3.35	4.045	4.08
Bus 6	2.510	2.528	3.32	3.94	4.408	3.856
Bus7	4.214	4.23	4.65	5.72	4.371	4.773

The result that is obtained from the simulation is used to investigate impact of PV POWER on short circuit or fault current and it impact on protection scheme .in simulation we get four types of result but we are using one type that occur mostly on power system and that is when single line touch ground known as SLG fault. The above listed table show as the fault current when fault occur in different location in the power system. This table is used to generate comparison chart for each case and then we compare all case with the standard case that is without PV power.

VII. DISCUSSION

Now we will disscuss the impact of this fault current or short circuit current level on protection system of distrinution network. In case1 we run simulation on the IEEE 13 bus system without adding any distributed generation source to the system. From this we get the standard response of the system. the below graph shows the result that are obtained during the simulation. The below chart tells us about the fault current when we apply fault at different location in the network. These values are considered as the standard or base value and the value that is obtained during the simulation when we add PV source to the system is compared with these standard values. This case result set the value of the all protection equipment that will be used in system.as we see from the result the highest fault current is recorded when fault occur on the bus 3. This is because of the transformer that is connected B/W bus2 and bus 3. The PV are operating on the low-tension side of the transformer that why high fault current is recorded on this bus.

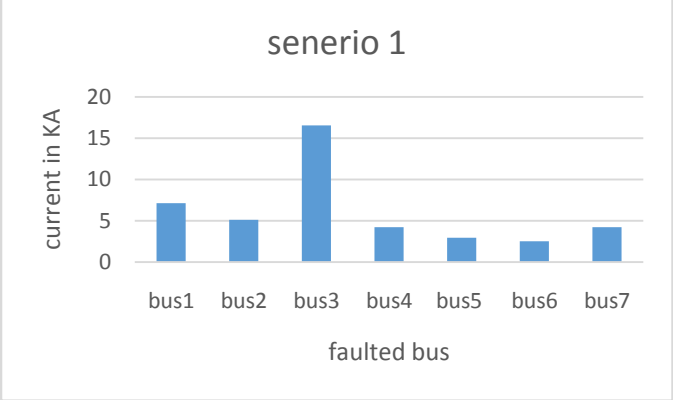

Figure 7. case1

During case 2 we added PV SOURCE to the system whose rating is 6mw.The PV source is connected to the bus 1. when fault occur at different location in the system the fault current value is noted and this fault current value is compared with the value of the case 1. The purpose of doing this to study the impact of the connected PV source. The comparison between the case one and case 2 are shown in below fig.

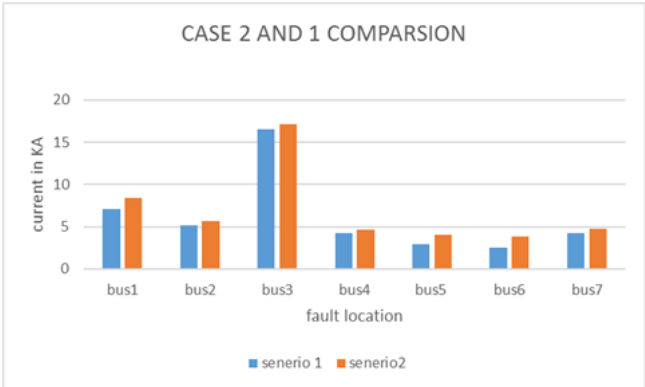

Figure 8. Comparing case 2 and case 1

We see from the comparisons that we add PV source to the bus 1. The level of the short circuit current is increased on all the buses of the system. if we closely see the fig we come to know that maximum increases in the short circuit current level is noticed on the bus 1. This is because of small distance between the faulted bus and PV source so this close location leads to increase the fault current contributions from the PV source. The increase in short circuit level on all the other bus is

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very small as compared to BUS 1 because the small distance between PV source and utility and fault location. During case 3 we connect PV source to the bus 3. The PV source used is centralized dg source. We run simulation for different fault location in the system and noted fault current value and these value is then compared with case 1 value. The fig listed below show us the comparison between both the case.

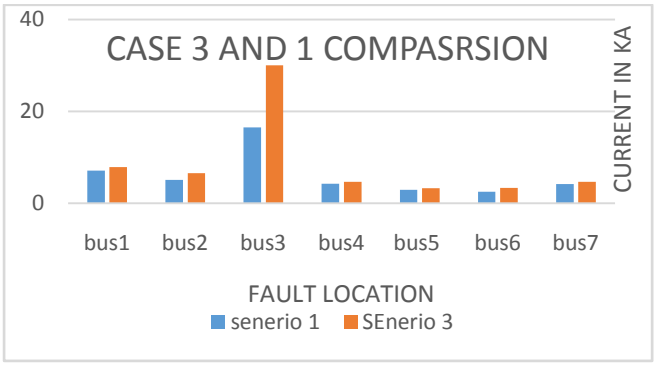

Figure 9. Comparing case 3 and case1

By seeing the above figure, we come to know that when a PV power source is located at bus location on bus 3. There is small increase in all buses short circuit current levels. When fault occur on the bus 3 the PV source contributes a lot to the fault current. We see from figure the fault is increased almost by 90%.the contribution of dg to the fault is very high because faulted bus and photovoltaic source has close distance. Secondly PV operate on low-tension side of transformer so SC current contribution is very high from solar. THE solar and fault both are on low tension side of the transformer so that's why increase in fault current is so high we transform this current to high voltage side of the transformer its value is decreased by apply transformer ratio the current come out 16.3ka on high voltage side of transformer. During case 4 a DG source of 6 mw is connected at BUS 4.the source is centralized DG source which is connected to BUS 4.by applying fault at different bus short circuit current value is noted down. the noted value is compared with the value of the case 1.

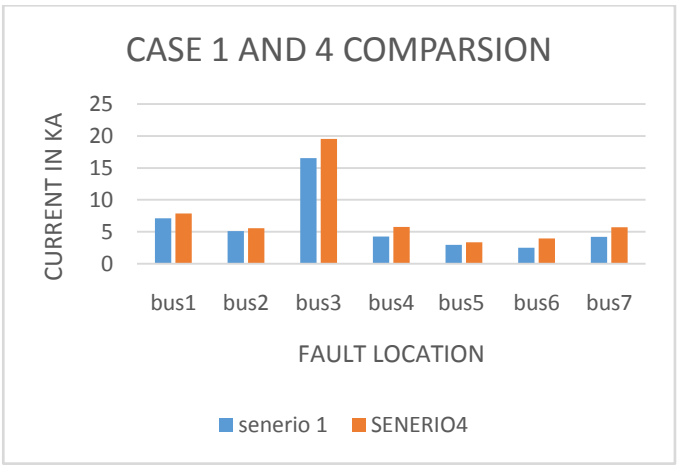

Figure 10. Comparing case 4 and case 1

When solar power source is located on BUS 4 and fault occur on different buses in network the short circuit current level of the system is increased. The largest increased is noted when fault occur on the BUS 4. The fault current is increased by 33%.the increase is due to close location of fault and photovoltaic source.

As we increase distance of fault location and photovoltaics, the solar source contribution to fault current is decreased. We can say the rise in rise in fault current is decreased. in simple word as distance between generating station and fault location is increased the generating station contribute less to fault current.During case 5 we connect photovoltaic source injected to the BUS 6. The photovoltaic source used is centralized source. We run simulation for different fault location in the system and noted fault current value and these value is then compared with case 1 value. The fig listed below show us the comparison between both the case.

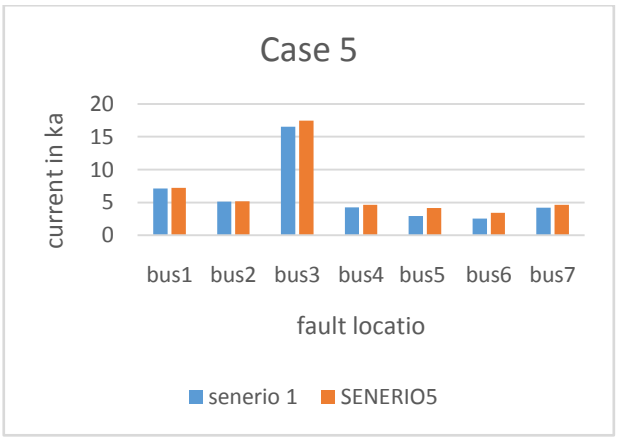

Figure 11. Case 5 and Case 1 Comparing

when we see the figure, it shows us the comparison between the cases. During case 6 the short circuit current level of the network is increased. By placing solar on BUS 6 it has significant effect on the whole system. When fault is applied at BUS 6 the short circuit start to flow in branch BUS 4 to BUS 6. The current that flow from bus 6 to bus 4 is neglected in other scenario. The current flowing in this branch cause lot of the problem to the existing protection scheme because there is no current flowing in this branch in all other cases. The protection system is designed for the case when there is no current flowing in this branch. The protection equipment used for the protection of this part is unable to project the network and cause problems of reduction of reach.

In this case we connect 3 photovoltaic sources each of 3 mw to the network at 3 different buses.in this case we replaced this single centralized solar by multiple decentralized PV sources. We connect the same generating capacity to the network but we divide it in the small PV sources. We connect 3 mw dg at BUS 1, BUS 4 and BUS 5.

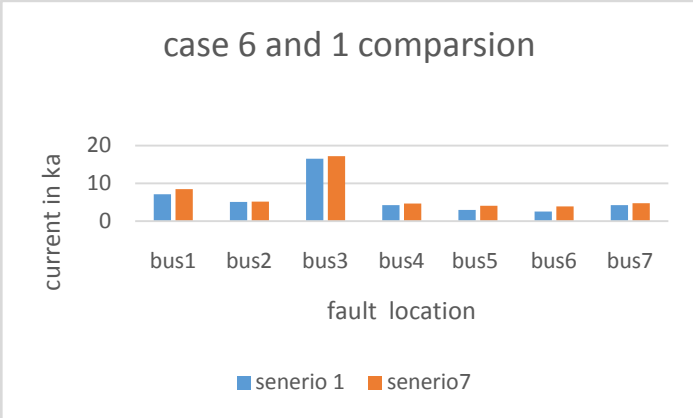

Figure 12. Case 6 and 1 Comparing

This figure is used to study the impact of single centralized and multiple decentralized generation. From figure we see that PV sources increase the fault current level of the network .it increase the fault current of all location at which PV is connected this increase depends on the configuration at which we connect dg to the system. The difference between single centralized and multiple decentralized dg sources is identified from the percentage contribution to the fault current by dg source and substation. In decentralized generation we see that the percentage contribution to the fault by PV sources is increased. The fault current almost increases for all the location in the network. The percentage contribution by the substation is decreased in decentralized PV sources. The fault current highly increases on bus 1 because of photovoltaic solar located on same bus secondly distance of this bus from Substation is very small.

The current flowing in bruch bus 1 to bus 4 is noted from simulation .The below listed graph show the current flowing in bruch bus 1 to 4.

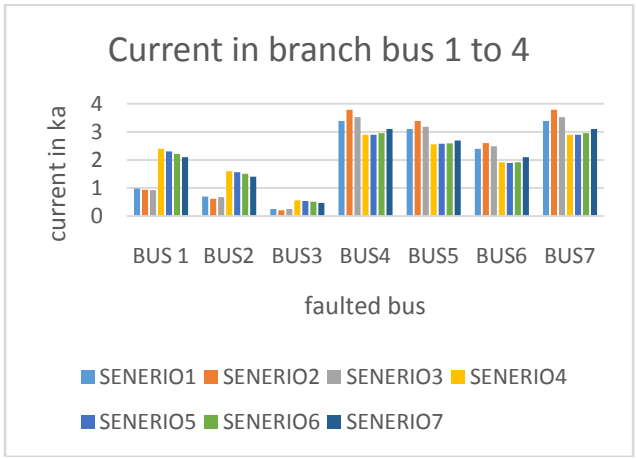

Figure 13. current in branch bus1 to bus4

The branch from bus1 to 4 is consider very important.it is considered as main branch of network. The current first pass through this brunch and then delivered to other lateral and load connected. When a photovoltaic source is injected to network, current flowing through this branch is increased in all cases but in some case increase is so high that is very difficult job to design protection scheme for this main lateral. The high current can cause a severe damage to distribution system. If we observe the above listed comparison it is concluded that case 2 and 3 are considered to be best location for PV solar to injected in network because variation in current is very low for both situation and it is about 9% to 11% so it is not much high to disturb our current protection scheme. if you inject photovoltaic source at other bus the short circuit current level is very high and it is increase up to 200 percent of normal case fault that is without PV source so such scenario makes very difficult to design protection scheme for network.

CONCULSION

when a solar photovoltaic is injected the short circuit current level of the system is increased. The radial flow of power is lost with injection of PV because fault current flow from photovoltaic side also. When the distance between solar photovoltaic source and fault occurring location is increase the fault current decrease when we connect photovoltaic source to bus6 it effects the current protection scheme and case the problems of reduction of reach because in all other scenarios fault current is zero in this branch from bus6 to bus5 and fault current flow only when photovoltaic is on bus6 In some case fault current is decrease in certain branches so relay of designed protective scheme become blind and not able to isolate the faulty section when pentratation of pv power is increase the fault current increase more .in simple word we have to reconfigure our protection scheme when we add distributed source to system.

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