FAULT CURRENT ANALYSIS IN A DISTRIBUTION SYSTEM WITH DISTRIBUTED GENERATION

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ABSTRACT

This paper studies about the symmetrical fault current analysis (3-Phase Faults) in a distribution system with distributed generation and also describes the consequences and operating limitations of installing distribution generator (DG) to electric power systems (distribution system). Transmission line faults can be classified using the bus voltage and line fault current. Monitoring the performance of these two factors are very useful for very useful for power system protection devices. This paper will discuss the changes in fault current by comparing the changes during the fault current occur without distribution generator (DG) and with the distribution generator (DG). So this paper will evaluate fault current due to effect in electric power system with the adding of the distribution generator (DG) in distribution system. The simulation will be implemented on an IEEE 69-bus distribution system by using power system simulation programme for planning, design and analysis of distribution system which is Power System Simulator/Advanced Distribution Engineering Productivity Tool (PSS/ADEPT) software. The results of maximum fault current in a distribution system with the presence of DG might be useful for power system engineer to consider protection devices before installing DG in the system.

KEYWORDS:

Fault Analysis, Symmetrical Fault, Distribution System, Distributed Generation

1.0 INTRODUCTION

1.1 DISTRIBUTION SYSTEM

Distribution system provides a final link between the high voltage transmission system and the consumers. A radial distribution system has main feeders and lateral distributors. The main feeder originates from substation and passes through different consumer loads. Laterals are connected to individual loads. In general, the main advantages of radial configuration are its simplicity and its low cost. In radial configuration, the number of disconnecting devices reduces and design of a protection system is not complicated. Conventional configuration of distribution systems has always been based on the fact that there is no distribution generation in network. But in recent years, some issues like environmental and geographical restrictions of generation units, increasing trend of load growth in distribution systems and the necessity for constructing new power plants as its consequence, tendency toward applying clean energies and independence from fossil fuels, have caused distributed generation to draw attention to a great extent. Presence of DGs in distribution networks, like many other technologies, has some disadvantages along with so many advantages it can have **[1]**.

1.2 FAULTS CURRENT

The phenomenon of fault is a situation call a malfunction in the power system network. Most faults are the results of short circuits. Existence of distributed generation causes errors in power frequency based fault location methods which use apparent impedance seen from the substation as a condition to estimate the distance to the fault point. Furthermore, coordination of relays and other protective devices becomes unmanageable by these methods due to in feed currents from distributed generators. There are the effects of DG on protective device (fuse-fuse, recloser-fuse, and relay-relay) **[2]** **[3]**.

Fault location problem in distribution systems becomes more complicated with the presence of DGs. The impacts of DGs considerably change depending on their location and size. It is known that an increase in generation capacity increases the fault current. Thus, introduction of DGs to the radial distribution systems requires further study on existing protective device coordination and protection configuration.

When a fault occurs, the fault current consists of not only the source current but also the DG current. There is an increase in fault current due to the increase in generation capacity, however there is a decrease in source current since the DG is also supplying the fault current. The decrease in source current leads a higher voltage at the measurement location. Since there is an increase in voltage and decrease in current, the impedance seen from the source location will be higher than the value obtained for the same fault conditions on the distribution system without DG **[3]**.

Fault is an important part of power system analysis. The problem consists of determining bus voltages and line currents during varies types of faults. The faults in power systems can mainly be classified into two such as series faults and parallel faults. Series faults are referred as the faults that occur along the transmission line serially such as conductor aging, breaking and others. While Parallel faults may subdivide into two categories such as symmetrical fault and unsymmetrical faults. However, for this project only the parallel (symmetrical) fault/3-phase fault will be considered. This fault gives an impact to the real power and reactive power value and also the total power loss **[4]**.

1.3 DISTRIBUTED GENERATION

Distributed generation (DG) is defined as energy resources of limited size ($\leq$10MW) and interconnected at the substation, distribution feeder or customer load points. Penetration of DG to the distribution system has increased in the recent years due to active promotion on in renewable energy utilization. Increasing need for localized power support in high-density load area has also resulted in the widespread of DG proliferation **[5]**.It is expected that DG could contribute in the following areas of distribution system operation:-

a) Quality improvement such as dynamic voltage compensation, voltage profile improvement, etc.
b) Reliability improvement such as service restoration and uninterruptible power supply.
c) Economic benefits such as energy efficiency, loss minimisation and load leveling.

There are many technical issues to be considered when connecting DG to the distribution system such as system fault levels stability, reverse power flow capabilities of tap-changers, line drop compensation, steady-state voltage rise, power losses, thermal rating of equipment, power quality (such as flickers and harmonics) and protection **[6][7][8]**.

DG technologies include photo voltaic, wind turbines, small and micro sized turbine packages and IC engine generators. DG has some specific characteristics which distinguish it from conventional generating units to perform reliability evaluation. Therefore an appropriate modeling of DG is necessary to know the impact of DG on reliability of the distribution system **[8]**.

2.0 THREE PHASE FAULTS

Three phase faults are unique in that they are balanced (symmetrical) in the three phases, and can be calculated from the single one line diagram. It is a symmetrical fault that affects the three-phases of the power system. All three phases of a transmission line are shorted together. Three-phase fault is the most severe short-circuit. The fault currents of three-phase fault are used to determine the breaking capacity of the circuit breaker, switchboard and others **[4] [9]**.

The three phase fault generally leads to the highest short circuit currents at the fault location and is therefore used as reference for the other faults. Since this fault is symmetric, the limitation occurs in all phases. Furthermore, the absolute values of the currents and voltages of each phase are the same.

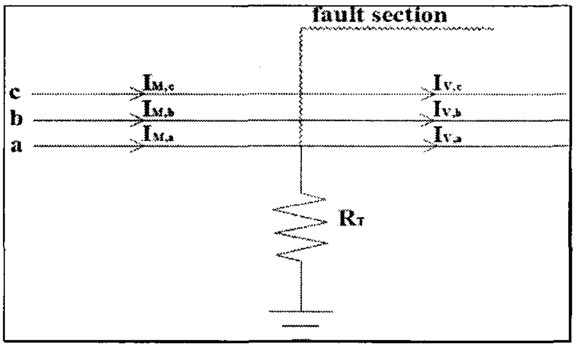

Figure 1: 3-Phase Fault Current

Three-phase fault, $\text{Fault MVA} = \frac{\text{MVAbase}}{\text{Zpu}}$..... (1)

Three-phase Fault Current, $I_F = \frac{\text{Fault MVA}}{\sqrt{3} \times V_{Line}}$ ... (2)

$\text{Fault Level} = \frac{1}{X_{eq}}$ ...... (3)

3.0 OPTIMAL LOCATION AND OPTIMAL SIZING OF DG

In order to obtain maximum benefit from the distributed generator, suitable location and sizing has to be determined before its installation. This paper is discussed more on the effects of DG in distribution system due to the Three-Phase Faults Current. So the location of the DG is choosing by comparing the voltage magnitude and the power losses. This method also compares loss minimization and voltage improvement achieved by the distributed generator allocation in the system. By this method the suitable DG placement is founded.

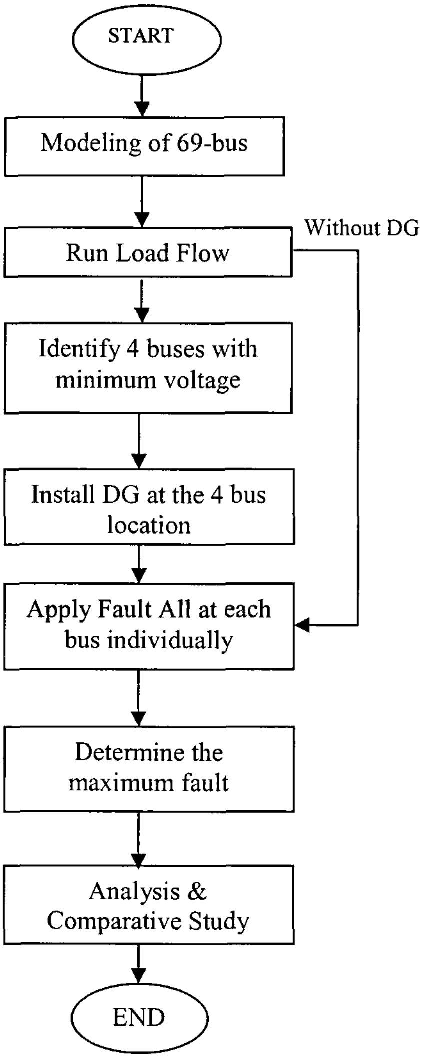

Figure 2: Basic flowchart of fault current analysis

The size of the DG also can determine using the equation below in ordered to get optimal sizing of DG.

$$\sum P_{DG} + \sum P_{GEN} = \sum P_{LOAD} + \sum P_{LOSS} \ldots\ldots\ldots\ldots (4)$$

$$\sum P_{DG} = \sum P_{LOAD} + \sum P_{LOSS} - \sum P_{GEN} \ldots\ldots\ldots\ldots (5)$$

$$\sum Q_{DG} = \sum Q_{LOAD} + \sum Q_{LOSS} - \sum Q_{GEN} \ldots\ldots\ldots\ldots (6)$$

4.0 MODELING TEST SYSTEM

The simulation was executed using a load flow program called PSS/Adept. PSS/Adept or Power System Simulator and Advanced Distribution Engineering Productivity Tool, is a network simulation program for planning, designing and analyzing distribution system. PSS/Adept utilizes the Gauss-Seidel method for the solving load flow equations. In PSS/Adept, Load Flow analysis is used to determine the network configuration such as voltage magnitude, total power losses and also the fault current. Start by modeling the IEEE 69-bus distribution system as show in Figure 3. Then, the line data and load data was inserted in the 69-bus system. Next, the load flow analysis was run and the result was obtained at power flow detail report. For 3-phase fault analysis, the Fault All Current was run on the 69-bus distribution system.

5.0 SIMULATION RESULT AND DISCUSSION

5.1 RESULTS FOR LOAD FLOW ANALYSIS

The proposed method of fault analysis was tested on a Distribution system consisting of 69 buses. An IEEE 69-bus distribution system is used in all simulation tests. The test was run with implemented DG and without DG in the 69-bus system. The one-line diagram of the 69-bus test system is shown in Figure 3. From the simulation the result for the power losses and the voltage magnitude was obtained. The results of the power flow analysis for 69-bus test system are shown in Table 1 and Table 2. Various simulations were carried out and the result obtained was shown below.

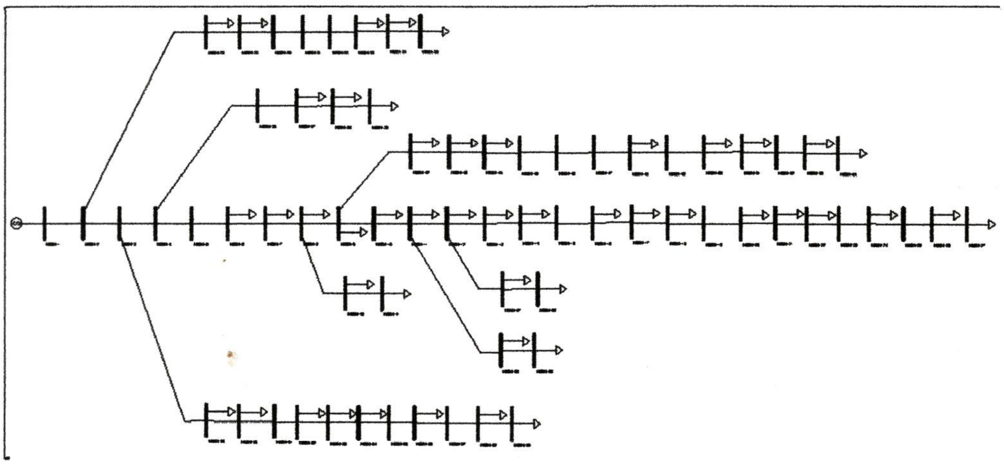

Figure 3: IEEE 69-bus test system

Table 1: Comparison of Power Losses of the system at different DG location

Nodes	**Power Losses (Kwatts)**				
	W/O DG	**DG at node 49**	**DG at node 50**	**DG at node 51**	**DG at node 52**
49	11.028	0.318	0.26	0.209	0.144
50	14.504	12.164	0.341	0.273	0.189
51	0.115	0.096	0.095	2.07	1.966
52	0.139	0.116	0.115	0.115	3.057
TOTAL	25.786	12.694	0.811	2.667	5.356

Table 2: Comparison of minimum voltage in the system with DG installed at different location

Nodes	**Voltage Magnitude (pu)**				
	w/o DG	**DG at Node 49**	**DG at Node 50**	**DG at Node 51**	**DG at Node 52**
Node 49	0.9173	1.0000	0.9988	0.9977	0.9960
Node 50	0.9097	0.9930	1.0000	0.9987	0.9969
Node 51	0.9094	0.9927	0.9997	1.0000	0.9981
Node 52	0.9090	0.9924	0.9994	0.9996	1.0000

From the power flow detail result, 4 buses are choosing from the 69 buses that were tested due to the low voltage magnitude. The bus was bus 49, 50, 51 and 52. Then the DG was installed at the different bus to increase the voltage magnitude, here the voltage magnitude and total power losses was obtained. The comparisons of total power losses were show in Figure 4. The voltage magnitude also increased when the DG was installed as show in Figure 5.

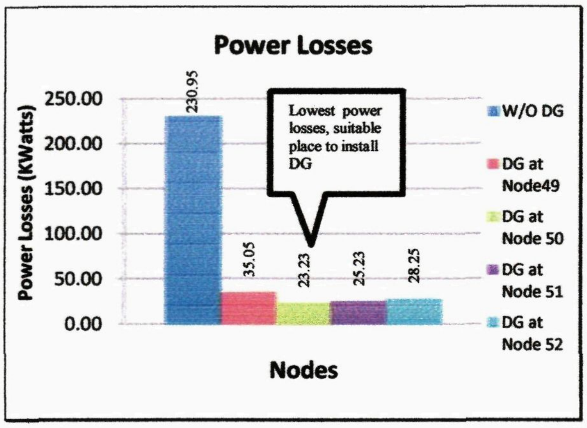

Figure4: Total power losses without DG and with DG at different nodes

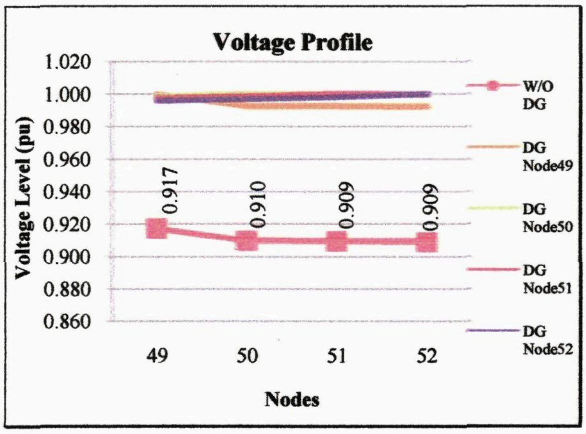

Figure 5: Voltage profile without DG and with DG at different nodes

From Table 1 and Figure4 shows, it could be observed that bus 50 has the lowest power losses and therefore it is chosen as the suitable location for distributed generator (DG). While from graph show in Figure 5, it could be obtained that by installing a DG in distribution system it will increase the voltage magnitude. Increasing in voltage magnitude is desirable in distribution system.

However, for comparison, buses 49, 51, 52, 53 and 54 were also selected for distributed generator allocation so that the improvement on the network performance under fault condition could be analyzed. The results for each case are to be compared with the network without DG. The size of the DG that needs to install at bus 50 was obtained from **equation (5).** The value of $\sum P_{LOSS}$ and $\sum P_{GEN}$ are obtained from the power flow analysis while the $\sum P_{LOAD}$ is obtained from 69-bus data line.

$$\sum P_{DG} = \sum P_{LOAD} + \sum P_{LOSS} - \sum P_{GEN}$$

$$=3802.19 \text{ kW} + 23.23 \text{ kW} - 1981.3 \text{ kW}$$

$$= 1.844\text{MW}$$

$$\sum Q_{DG} = \sum Q_{LOAD} + \sum Q_{LOSS} - \sum Q_{GEN}$$

$$= 2694.60 \text{ kVAR} + 60.37 \text{ kVAR} - 1363.9 \text{ kVAR}$$

$$= 1391.07 \text{ kVAR}$$

So the size of DG that installed at node 50 is 1.844MW.

5.2 RESULTS FOR FAULT ALL CURRENT ANALYSIS

The Fault All Current report is available only after Fault All calculation has been performed. It contains fault current at each node in the network for each fault type that specified in the Short Circuit tab of the Analysis Options Property sheet. For 3-Phase Fault current analysis, also 6 buses were used to make comparison which is bus 49, 50, 51, 52, 53 and 54. But only four buses were installed by DG which is bus 49, 50, 51 and 52. The result of 3-Phase Fault current was show in Figure 6, 7, 8, 9,10,11,12 and 13. The result was compared between without DG and with DG in the distribution system according to the node selected.

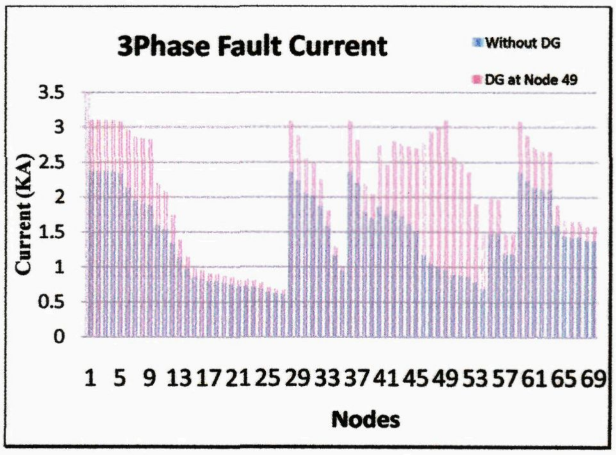

Figure 6: 3-Phase Fault Current with DG at node 49

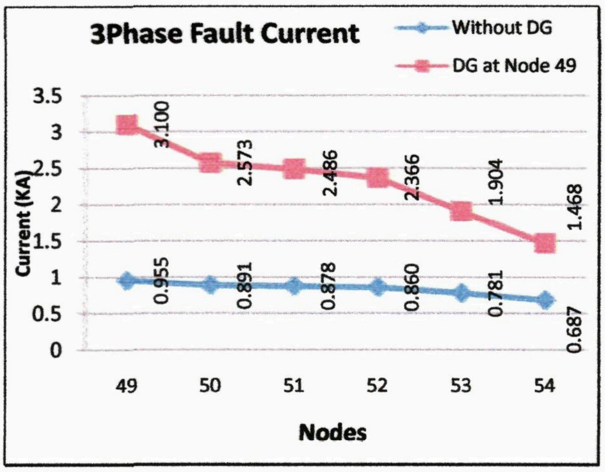

Figure 7: 3-Phase Fault Current with DG at node 49 and five different nodes nearest the DG

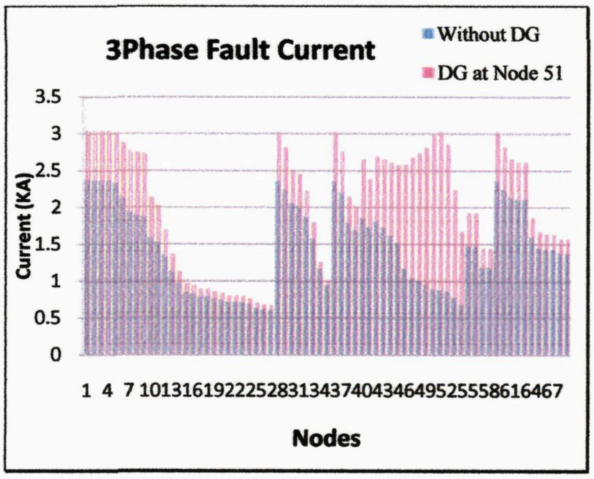

Figure 10: 3-Phase Fault Current with DG at node 51

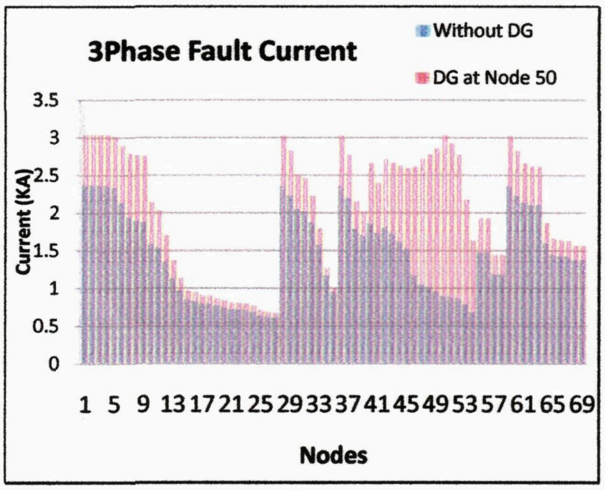

Figure 8: 3-Phase Fault Current with DG at node 50

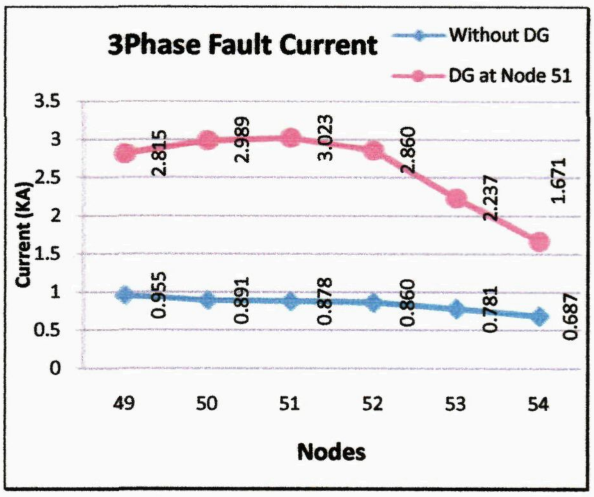

Figure 11: 3-Phase Fault Current with DG at node 51 and five different nodes nearest the DG

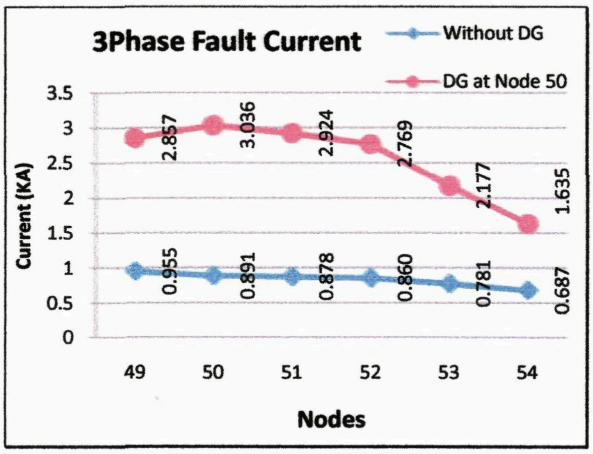

Figure 9: 3-Phase Fault Current with DG at node 50 and five different nodes nearest the DG

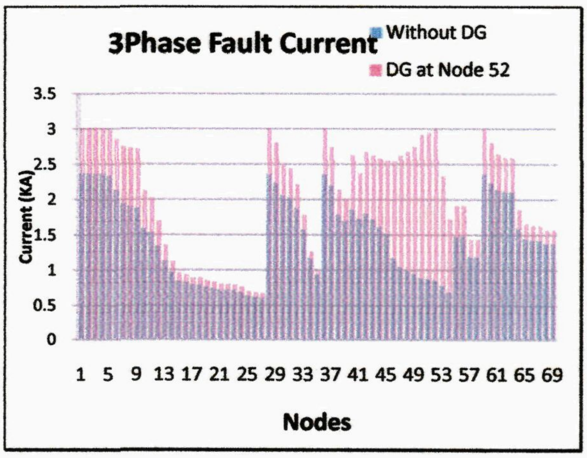

Figure 12: 3-Phase Fault Current with DG at node 52

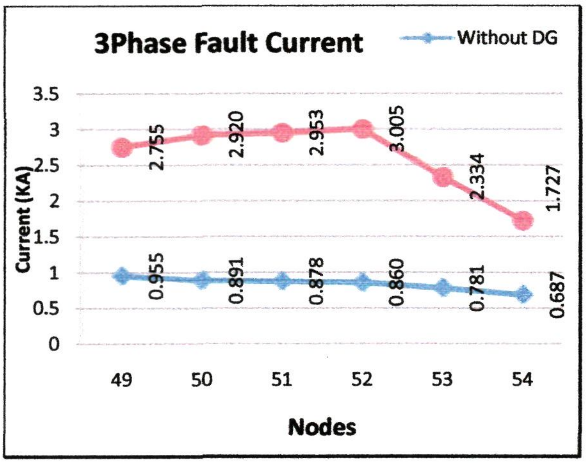

Figure 13: 3-Phase Fault Current with DG at node 52 and five different nodes nearest the DG

From the graph show in Figure 6, 7, 8, 9,10,11,12 and 13, it could be observed that by installing a DG in distribution system it will affect the 3-Phase fault current by increasing the 3-Phase Fault current compared to the distribution system without DG. The 3-Phase fault current high at the node that was installed by DG and also the node near to that DG. The percent changes of 3-Phase fault current refer to node 50 with DG was tabulated in Table 3.

Table 3: Percent changes of 3-Phase fault current

Faulted Bus	(If) without DG (kA)	(If) with DG at node 50 (kA)	Percent Change %
NODE1	2.3695	3.0429	28.42%
NODE2	2.3686	3.0421	28.43%
NODE3	2.3686	3.0421	28.43%
NODE4	2.3658	3.0397	28.49%
NODE5	2.3394	3.0195	29.07%
NODE6	2.1343	2.8942	35.61%
NODE7	1.9461	2.7866	43.19%
NODE8	1.9042	2.7641	45.16%
NODE9	1.8823	2.7525	46.23%
NODE10	1.5926	2.1454	34.70%
NODE11	1.5359	2.0381	32.70%
NODE12	1.3465	1.7048	26.61%
NODE13	1.1339	1.3694	20.77%
NODE14	0.9735	1.1382	16.92%
NODE15	0.8494	0.9704	14.24%
NODE16	0.8296	0.9444	13.84%
NODE17	0.7941	0.8984	13.13%
NODE18	0.7937	0.8979	13.12%
NODE19	0.7648	0.8609	12.57%
NODE20	0.7472	0.8386	12.24%
NODE21	0.7203	0.8049	11.74%
NODE22	0.7193	0.8035	11.72%
NODE23	0.7135	0.7965	11.64%
NODE24	0.6883	0.7653	11.19%
NODE25	0.6393	0.7054	10.33%
NODE26	0.6210	0.6833	10.02%
NODE27	0.6112	0.6715	9.86%
NODE28	2.3596	3.0273	28.30%
NODE29	2.2358	2.8278	26.48%
NODE30	2.0523	2.5117	22.38%
NODE31	2.0215	2.4609	21.74%
NODE32	1.8753	2.2287	18.85%
NODE33	1.5791	1.7971	13.80%
NODE34	1.1699	1.2675	8.34%
NODE35	0.9467	1.0035	6.00%
NODE36	2.3589	3.0284	28.38%
NODE37	2.1995	2.7714	26.00%
NODE38	1.7877	2.1487	20.20%
NODE39	1.6966	2.0188	18.99%
NODE40	1.8593	2.6671	43.45%
NODE41	1.7319	2.3997	38.56%
NODE42	1.8060	2.7117	50.15%
NODE43	1.7231	2.6708	55.00%
NODE44	1.6174	2.6250	62.30%
NODE45	1.5232	2.5927	70.21%
NODE46	1.1711	2.6136	123.18%
NODE47	1.0461	2.7207	160.09%
NODE48	1.0040	2.7784	176.73%
NODE49	0.9554	2.8570	199.03%
NODE50	0.8908	3.0360	240.81%
NODE51	0.8783	2.9239	232.91%
NODE52	0.8602	2.7689	221.88%
NODE53	0.7812	2.1766	178.61%
NODE54	0.6869	1.6346	137.98%
NODE55	1.4780	1.9328	30.77%
NODE56	1.4767	1.9304	30.73%
NODE57	1.1855	1.4483	22.17%
NODE58	1.1846	1.4469	22.15%
NODE59	2.3596	3.0273	28.30%
NODE60	2.2360	2.8281	26.48%
NODE61	2.1341	2.6625	24.76%
NODE62	2.1062	2.6182	24.31%
NODE63	2.1046	2.6157	24.28%
NODE64	1.5991	1.8668	16.74%
NODE65	1.4493	1.6631	14.76%
NODE66	1.4315	1.6395	14.53%
NODE67	1.4274	1.6340	14.48%
NODE68	1.3801	1.5717	13.89%
NODE69	1.3797	1.5712	13.88%

At all DG location selected above, the result shows that installing DG in distribution system will produce high 3-Phase fault current. The 3-Phase fault current increase compared to the nominal fault current before installing DG.

6.0 CONCLUSION

In this paper, the effect on 3-Phase fault current by implementing Distributed Generation (DG) in distribution system for minimizing the power loss and improving voltage profile under fault condition were analyzed. The 69-bus distribution system was analyzed and the DG was installed at the node with low voltage profile with minimum total power losses which is the node 50. At the node 50, the 3-Phase fault before implemented DG is about 0.8908 kA and the 3-Phase fault after implemented DG is about 3.0360 kA which was increase about 240.81%. The results of 3-Phase fault current were compared with the system without DG. From the numerical simulation, the 3-Phase fault current was increase in distribution system when the Distributed Generation (DG) was implemented. The 3-phase fault current increase at the bus installed by DG and also affected the buses nearest to the bus installed by DG. Increasing in 3-phase fault will need the new type and size of protective devices in the distribution system. The simulation was carried out using software PSS/Adept with various location of DG during Fault All conditions.

7.0 FUTURE DEVELOPMENT

For future use, this 3-Phase fault current analysis can help in designing the suitable protection devices in electric power system. The increasing of 3-Phase fault current due to implemented of DG in distribution system is very important for the power system engineer to design the suitable protection devices. There are several works that could be done in discovering the impact of the fault to distribution system stability. Fault current calculation is very important to determine the correct rating and size of the protection devices.

8.0 ACKNOWLEDGEMENTS

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