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Optimal Integration of Distributed Generation in Distribution System to Improve Short Circuit Current Level

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***Abstract*—Distributed Generations (DGs) are an effective and dominant smart grid technologies, it contributes to meet the ultimate-goal to provide sustainable energy in world. Although many benefits that are associated with DGs. However, it has also an adverse effect on power system that should be tackled as well. The Paper describes problems associated with the degree of fault contributions with and without a Distribution System and conclude the optimal location of DG in distribution System with variation in short circuit current. The different cases are taken for the study short circuit analysis with different types of DGs (Diesel, PV system and Type 3 Wind DFIG) integrated with the Distribution System. Conclusions are drawn from the comparative analysis that has been observed from the considered cases. ETAP, an Electrical Transient Analyzer Program has been used for performing short circuit analysis.**

***Index Terms*— Distributed Generations, Fault Analysis, IEEE 33 Bus Distribution System, Desensitization Factor.**

I. INTRODUCTION

THE Pakistani electricity sector is facing enormous energy crises. The difference between supply and demand is increasing day by day, results in more than Ten hours in a day. The main contributors to the scenario are inadequate production, demand modeling and load forecasting, as well as high losses in transmission and distribution [1]. Power Stations are usually away from the load centers. In the transmission system, extra high voltage is used to reduce conductive losses and their size [2].The integration of Distributed generation (DG) has made it possible to respond more optimally to consumer demand and to minimize transmission losses [3].The main advantage of renewable energies, since reduction of environmental pollution is less harmful, which ultimately allows to install a power plant nearby or even in a city [4]. DG has various effects on the distribution system, such as operation changes in short circuit capacity, stability, relay, relay performance [5].In DG, most PV systems are connected to Distribution Network (DN) through an inverter connected to the network. However, high penetration of DGs into the DN causes undesirable technical problems, such as voltage fluctuation, increased magnitude of short circuit current, changes in power system protection schemes [6]. DG interconnection changes the system fault current. Relays can sense smaller or larger current, depending on the size and position of DG [7]. This Paper presents the fault analysis on IEEE-33 Bus radial distribution system and comparative analysis has been performed from considered cases and conclude an optimal location for DG for the distribution system. The contribution of fault current considering different DG types is being observed.

II. DISTRIBUTION SYSTEM AND MODELS OF DISTRIBUTED GENERATION

A. Distribution System

IEEE-33 Bus radial distribution system is considered for the analysis. The Load (active and reactive) connected with system is 3.72MW and 3.2MW [8]. The bus voltage is 12.66KV. The IEEE 33 test model is created in edit mode with normal configuration in the ETAP software. The buses, branches, utility grid, and load are the key components of the test system. They are comprised of 33 buses, 32 branches, 32 loads as shown in Fig 1. Power is delivered to load by inductive load. DGs are connected at buses considering different cases. The rating of each DG is assumed to be the same, since it is prepared to carry out comparative fault current analysis considering various types of DGs. An IEEE 33 bus network's line and load data are given below in Table 1.

B. Diesel DG

Generally, the Diesel Distributed Generations are intended to meet the load demands on the Distribution system. To supply the peak loads, they utilize conventional fossil fuels. Diesel energy is transformed into mechanical form and mechanical energy is transformed into electrical power by using synchronous generators. Three DGs are equal in rating are taken for analysis in Case 2, and for Case 5 single DG is interconnected. Diesel DG's rating is 1021 KVA and it will supply an amount of 868 KW to DS. This generator's generating voltage is managed to hold at 12.66KV.

C. Solar PV DG

A solar PV turns the photon energy into electric energy and an energy provided by the solar PV cell is usually 1-2.9 W. Therefore, a set of the solar PV cells are linked in series and parallel, a module is constructed that should be capable of supplying a few watts. A single module's rating takes 240 W and on the AC side, 60 modules are connected and produce a total power of 868 kW with a 12.66 KV. The Solar PV is operated at constant power factor. Three DGs are equal in rating are considered for analysis in Case 3 and for Case 5 single DG is connected.

D. Wind DG

The Wind Generator produce the mechanical energy and then converted into electrical energy. By changing the wind speed the mechanical energy can be varied. The classifications of Wind Turbine Generators are presented in [10]. Type1 and Type2 WTGs are taken to perform Short Circuit Studies (SCS), presented in [9]. The stator of Type3 Wind distributed generator is linked to the power grid and the rotor is linked to the power grid via power electronic converter. The Power electronic converter are used to control the power of Wind turbine. Wind turbine's rating taken for analysis is 1021 KVA and supply the active power of 868 KW to the Distribution system. Three wind distributed generations are linked in Case4 and for Case5 only one wind DG is linked for performing SCS.

III. METHODOLOGY

Short circuit analysis on the DS are performed with and Without DGs and the changes in the existing contributions to the fault current are to be analyzed at system buses from the power grid. Analysis are to be taken at the buses considering one near to DG, half of distance from grid and last end of system bus is considered. Symmetrical fault is introduced at assumed buses. Desensitization factor is to be determined in order to highlight the difference in the contribution of fault current at chosen buses, using the expression given in eq.(1).

$$\textit{Desensitization factor} = \frac{I_G - I_{DG}}{I_G} \tag{1}$$

Where, I_G is the grids contribution without DG during fault.
I_{DG} is the grids contribution with DG during fault.
The positive desensitization factor can cause the delay in the working of CB from prescribed time, while as the negative desensitization factor can cause the advance in operation of CB from predefined time. The DF reflects risk of failure of operation of the circuit breaker on the distribution system, in case with the variations in DGs related, settings are not updated. Symmetrical fault analysis is conducted evaluating different types of DG and DF is calculated.

IV. RESULTS AND DISCUSSION

A. Case 1- Short circuit studies without DG

The source fault current is provided by this case for performing comparative study. Relay settings totally depend upon fault current levels analyzed in this case. The fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 and results are given in Table II.

B. Case 2- Short circuit studies with Diesel DGs

The Diesel DGs are integrated with synchronous generator at the substation. Three different conditions are considered for DGs connection. DGs are connected at bus 2,9,23 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the first condition and results are given in Table III, DGs are connected at bus 6,18,33 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the second condition and results are given in Table IV, and DGs are connected at bus 4,12,24 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the third condition and results are given in Table V.

C. Case 3- Short circuit studies with Solar PV DGs

The Solar DGs produce DC power and then by using inverter it is converted into AC. Three different conditions are considered for DGs connection. DGs are connected at bus 2,9,23 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the first condition and results are given in Table VI, DGs are connected at bus 6,18,33 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the second condition and results are given in Table VII, and DGs are connected at bus 4,12,24 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the third condition and results are given in Table VIII.

D. Case 4- Short circuit studies with Type 3 Wind DGs

Type 3 Wind DG uses rotor converter for control of power, which actually contributes in producing the fault current. Three different conditions are considered for DGs connection. DGs are connected at bus 2,9,23 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the first condition and results are given in Table IX, DGs are connected at bus 6,18,33 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the second condition and results are given in Table X, and DGs are connected at bus 4,12,24 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the third condition and results are given in Table XI.

E. Case 5- Short circuit studies with all three combination of DGs

In this case, all types of DGs are linked with the buses in DS. Three different conditions are considered for DGs connection. DGs are connected at bus 2,9,23 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the first condition and results are given in Table XII, DGs are connected at bus 6,18,33 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the second condition and results are given in Table XIII, and DGs are connected at bus 4,12,24 and fault is introduced at bus 3,4,6,12,18,19,22,23,24,25,30,32 for the third condition and results are given in Table XIV.

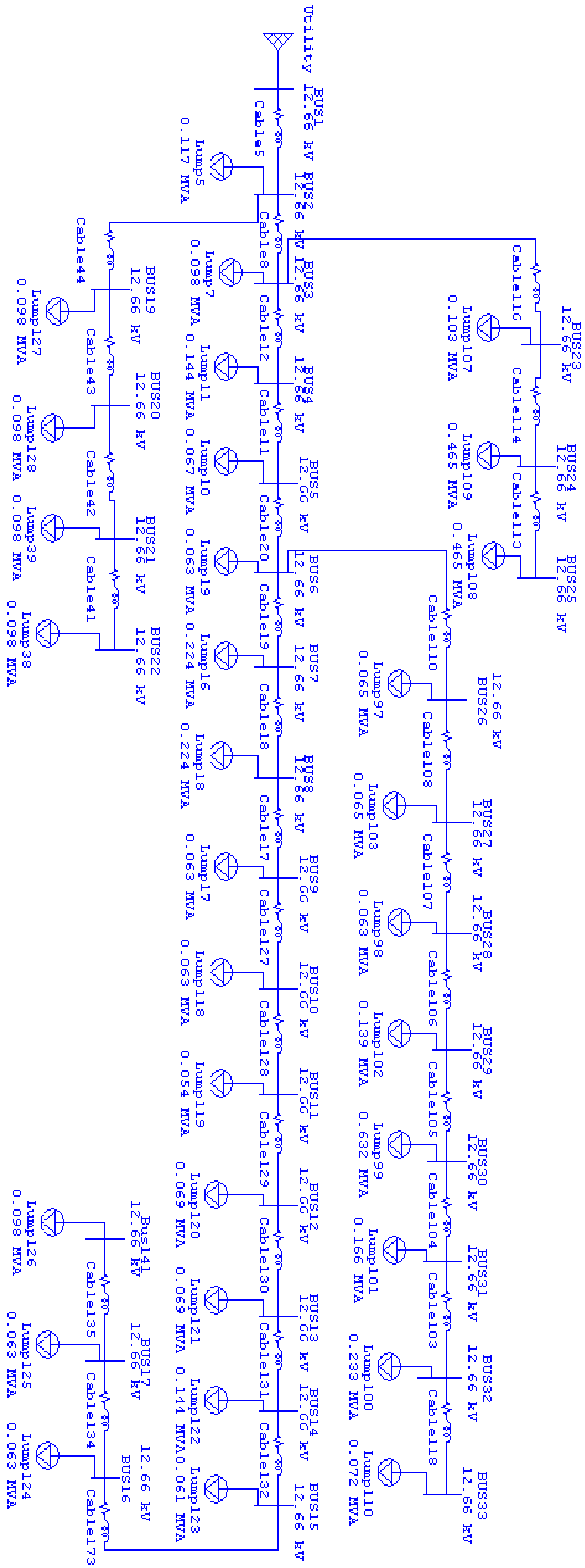

Fig.1. IEEE 33 bus system ETAP model without DG

Table I: Branch and load data of IEEE 33 bus network

From Bus	To Bus	R(Ω)	X(Ω)	Load at To Bus	
				P(Kw)	Q(Kvar)
1	2	0.0922	0.047	100	60
2	3	0.493	0.2511	90	40
3	4	0.366	0.1864	120	80
4	5	0.3811	0.1941	60	30
5	6	0.819	0.707	60	20
6	7	0.1872	0.6188	200	100
7	8	0.7114	0.2351	200	100
8	9	1.03	0.74	60	20
9	10	1.044	0.74	60	20
10	11	0.1966	0.065	45	30
11	12	0.3744	0.1298	60	35
12	13	1.468	1.155	60	35
13	14	0.5416	0.7129	120	80
14	15	0.591	0.526	60	10
15	16	0.7463	0.545	60	20
16	17	1.289	1.721	60	20
17	18	0.732	0.574	90	40
2	19	0.164	0.1565	90	40
19	20	1.5042	1.3554	90	40
20	21	0.4095	0.4784	90	40
21	22	0.7089	0.9373	90	40
3	23	0.4512	0.3083	90	50
23	24	0.898	0.7091	420	200
24	25	0.896	0.7011	420	200
6	26	0.203	0.1034	60	25
26	27	0.2842	0.1447	60	25
27	28	1.059	0.9337	60	20
28	29	0.8042	0.7006	120	70
29	30	0.5075	0.2585	200	600
30	31	0.9744	0.963	150	70
31	32	0.3105	0.3619	210	100
32	33	0.341	0.5302	60	40

V. COMPARATIVE STUDY

Symmetrical Fault It is noted that in the scenario of individual fault current, synchronous DG feeds fault current more than Solar and Wind DGs. It is found that fault current at bus is high in Case 2 and minimum in Case 3. The fault current contribution in different cases for different conditions as given in Fig 2, Fig

3 and Fig 4 respectively. The fault current depends upon the location of fault in case of synchronous DGs whereas it remains unchanged considering Wind and Solar DGs despite of location of fault current. The fault current contribution including DGs different types are presented in Tables III-XIV. If the Desensitization factor is more which can enhance the substation failure rate of CB.

Table II: Fault Currents on Distribution System WITHOUT DGs

Buses	Fault Currents (KA)	Fault MVA
3	12.873	282.268
4	8.629	189.209
18	0.663	14.538
19	18.973	416.023
22	2.048	44.907
23	7.397	162.195
24	3.976	87.182
25	2.695	59.093
30	1.847	40.499
32	1.358	29.777

A. When DGs are interconnected at bus 2,19,23

Table III: Fault Currents on Distribution System WITH DGS (Diesel)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	12.972	284.437	-0.77
4	8.61	188.792	0.22
18	0.65	14.253	1.96
19	19.303	423.259	-1.74
22	2	43.854	2.34
23	7.543	165.396	-1.97
24	3.99	87.489	-0.35
25	2.76	60.519	-2.41
30	1.8	39.469	2.544
32	1.34	29.382	1.32

Table VI: Fault Currents on Distribution System WITH DGS (SOLAR PV)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	12.769	279.987	0.81
4	8.531	187.060	1.13
18	0.645	14.143	2.71
19	18.998	416.571	-0.31
22	1.996	43.766	2.53
23	7.38	161.822	0.23
24	3.986	87.401	0.98
25	2.675	58.655	0.74
30	1.797	39.403	2.71
32	1.335	29.273	1.69

Table IX: Fault Currents on Distribution System WITH DGS (WIND)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	13.026	285.623	-1.19
4	8.648	189.626	-0.22
18	0.64	14.0334	3.46
19	19.38	424.948	-2.14
22	2.001	43.8762	2.29
23	7.558	165.725	-2.58
24	4.003	87.7743	-0.68
25	2.701	59.2252	-0.22
30	1.801	39.4907	2.5
32	1.337	29.3166	1.54

Table XII: Fault Currents on Distribution System WITH COMBINATION OF THREE DGs

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	12.987	284.768	-0.9
4	8.645	189.56	-0.18
18	0.635	13.9237	4.22
19	19.256	422.229	-1.49
22	2.004	43.9419	2.14
23	7.576	166.12	-2.42
24	3.99	87.4892	-0.35
25	2.686	58.8962	0.33
30	1.801	39.4907	2.5
32	1.333	29.2289	1.84

B. When DGS are interconnected at bus 6,18,33

Table IV: Fault Currents on Distribution WITH DGS (Diesel)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	12.877	282.356	-1.75
4	8.64	189.450	-0.127
18	0.67	14.691	-1.05
19	18.99	416.396	-0.49
22	2.046	44.863	0.09
23	7.401	162.283	-0.05
24	3.958	86.788	0.45
25	2.688	58.940	0.2
30	1.86	40.784	-0.7
32	1.37	30.040	-0.8

Table VII: Fault Currents on Distribution System WITH DGS (SOLAR PV)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	12.867	282.136	0.04
4	8.638	189.406	-0.1
18	0.668	14.647	-0.75
19	18.964	415.825	0.05
22	2.045	44.841	0.15
23	7.38	161.822	0.23
24	3.931	86.1955	1.13
25	2.683	58.830	0.4
30	1.836	40.258	1.13
32	1.368	29.996	-0.73

Table X: Fault Currents on Distribution WITH DGS (WIND)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	12.88	282.421	-0.05
4	8.639	189.4284	-0.11
18	0.67	14.691	-1.05
19	18.981	416.199	-0.04
22	2.046	44.863	0.097
23	7.412	162.524	-0.2
24	3.964	86.919	0.3
25	2.688	58.940	0.26
30	1.84	40.345	0.38
32	1.37	30.040	-0.88

Table XIII: Fault Currents on Distribution System WITH COMBINATION OF THREE DGs

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	12.885	282.531	-0.09
4	8.638	189.406	-0.104
18	0.669	14.670	-0.9
19	18.982	416.220	-0.05
22	2.045	44.841	0.15
23	7.405	162.370	-0.11
24	3.949	86.590	0.67
25	2.686	58.896	0.33
30	1.854	40.653	0.67
32	1.369	30.0182	-0.81

C. When DGS are interconnected at bus 4,12,24

Table V: Fault Currents on Distribution System WITH DGS (Diesel)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	13.222	289.920	-2.71
4	8.906	195.283	-3.21
18	0.705	15.459	-6.33
19	19.1	418.808	-0.67
22	2.066	45.301	-0.88
23	7.623	167.150	-3.05
24	4.145	90.888	-4.25
25	2.769	60.716	-2.74
30	1.86	40.784	-0.7
32	1.388	30.435	-2.21

Table VIII: Fault Currents on Distribution System WITH DGS (SOLAR PV)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	12.815	280.996	0.045
4	8.587	188.288	0.49
18	0.668	14.647	-0.75
19	19.2	421.000	-1.2
22	2.07	45.389	-1.07
23	7.45	163.357	-0.72
24	3.967	86.985	0.23
25	2.75	60.300	-2.04
30	1.801	39.491	2.49
32	1.35	29.602	0.6

Table XI: Fault Currents on Distribution WITH DGS (WIND)

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	13.329	292.266	-3.54
4	8.991	197.147	-4.19
18	0.715	15.678	-7.89
19	19.129	419.444	-0.82
22	2.086	45.740	-1.86
23	7.684	168.488	-3.88
24	4.194	91.962	-5.48
25	2.791	61.199	-3.56
30	1.837	40.280	-0.54
32	1.369	30.0182	-0.81

Table XIV: Fault Currents on Distribution System WITH COMBINATION OF THREE DGs

Bus Faulted	Fault Currents (KA)	Fault MVA	% Desensitization Factor
3	13.11	287.464	-1.84
4	8.782	192.564	-1.77
18	0.705	15.459	-6.33
19	19.059	417.909	-0.45
22	2.075	45.499	-1.32
23	7.611	166.887	-2.89
24	4.147	90.932	-4.98
25	2.782	61.001	-3.23
30	1.826	40.039	-4.98
32	1.363	29.887	-0.37

D. When DGS are interconnected at bus 2,19,23

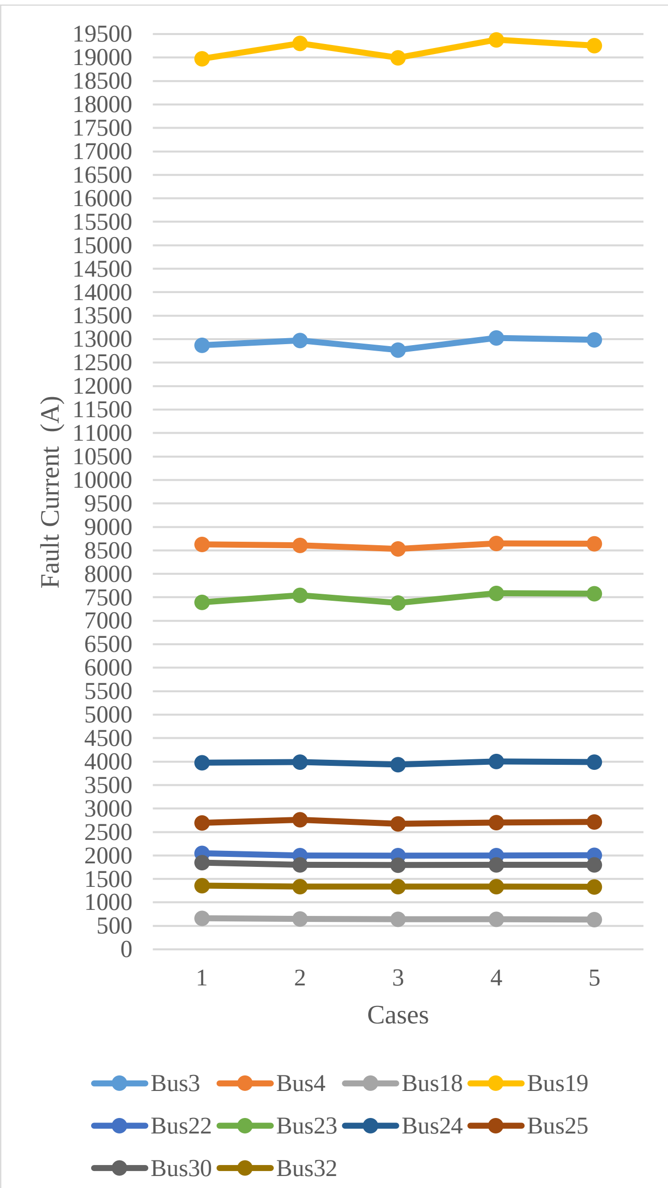

Fig.2. Fault Current Variation at buses

E. When DGS are interconnected at bus 6,18,33

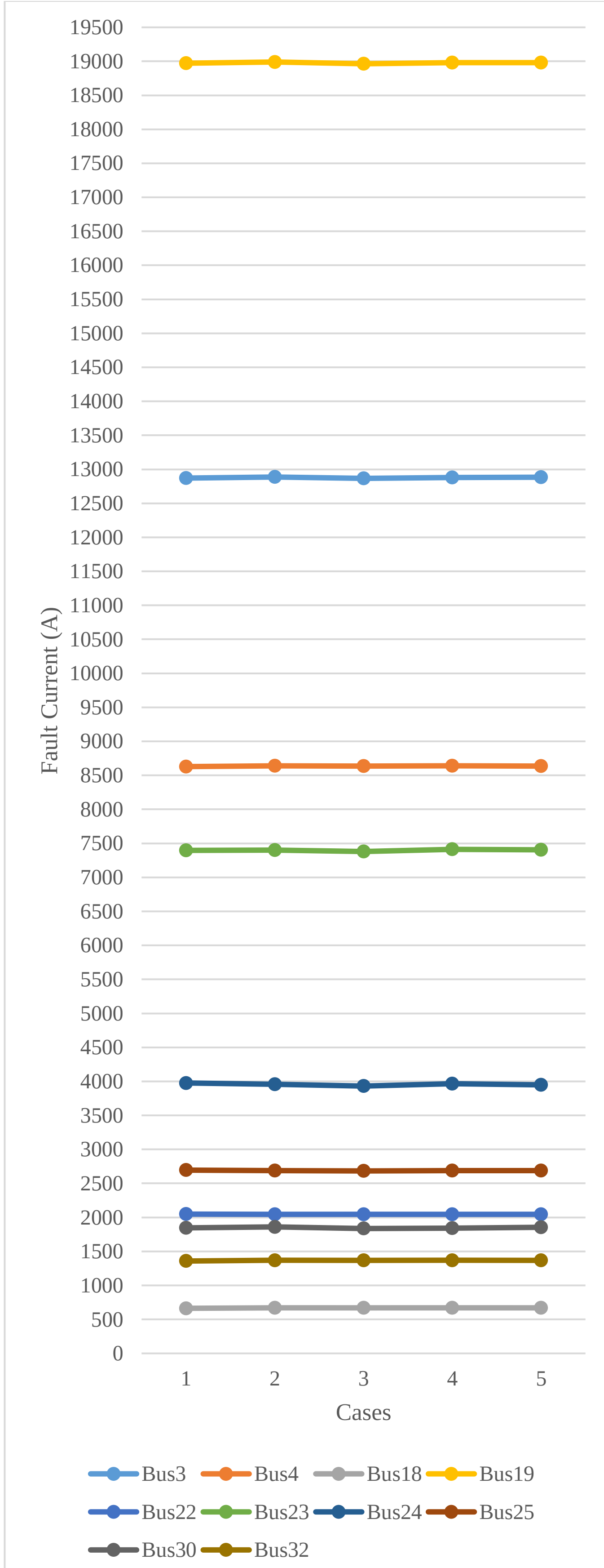

Fig.3. Fault Current Variation at buses

F. When DGS are interconnected at bus 6,18,33

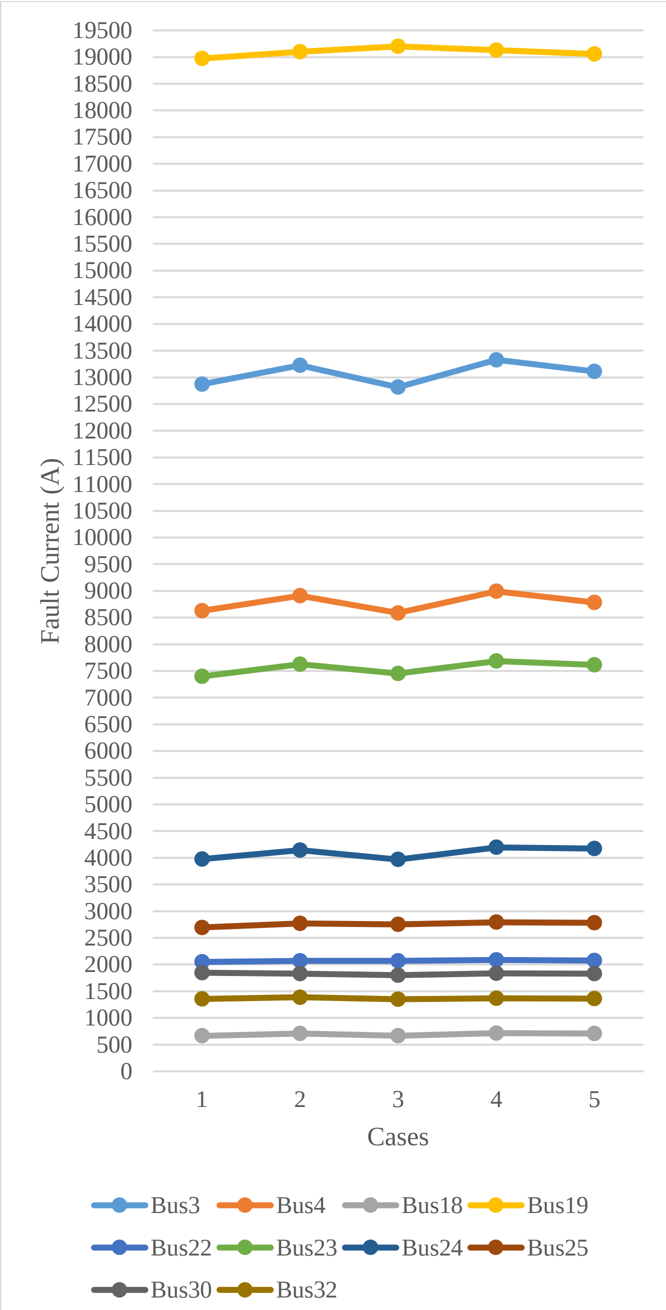

Fig.4. Fault Current Variation at buses

VI. CONCLUSION

It can be observed the fault current contribution depends upon the types of DGs connected to the bus as well as the location of fault at the bus. In addition, this suggests a need in the change settings of protection. if DGs are interconnected without analysis, result may be dangerous and may lead to long shutdown and expensive maintenance or replacement of system components. If the setting of protection relay is not considered with inclusion of DG, results may be either nuisance tripping or relay blinding. However, Solar DGs can cause less the variation in fault current. The desensitization factor of substation CB can be held to a minimum by choosing a different mixture of DGs. Desensitization factor is to be observed in different cases for three condition, although it is observed that the desensitization factor is minimum when the DGs are connected at bus 6,18,33. So it is concluded that the optimum location for the DGs for an IEEE 33 test model is 6,18,33 considering short circuit fault analysis.

REFERENCES

[1] Halepoto, I. A., Uqaili, M. A., & Chowdhry, B. S. (2014). Least square regression based integrated multi-parameteric demand modeling for short term load forecasting. *Mehran University Research Journal of Engineering and Technology*, *33*(2), 215-226.

[2] Mithulananthan, N., & Oo, T. (2004). Distributed generator placement in power distribution system using genetic algorithm to reduce losses. *Science & Technology Asia*, 55-62.

[3] Surendra, K., & Vyjayanthi, C. (2018, December). Short Circuit Studies on a Distribution System Integrated with Various Distributed Generations. In *2018 IEEE 8th Power India International Conference (PIICON)* (pp. 1-6). IEEE.

[4] Li, L. (2012, September). A research of feeder protection 10kV distribution neteorks including distributed generation. In *2012 China International Conference on Electricity Distribution* (pp. 1-4). IEEE.

[5] Dulău, Lucian Ioan, Mihail Abrudean, and Dorin Bică. "Effects of distributed generation on electric power systems." *Procedia Technology* 12 (2014): 681-686.

[6] Sadiq, H., Hameed, U., Raza, S. A. H., & Imran, K. (2018, November). Impact of PV Penetration on Short Circuit Current of Radial Distributed Feeder and Existing Power System Protection of NUST. In *2018 International Conference on Computing, Electronic and Electrical Engineering (ICE Cube)* (pp. 1-6). IEEE.

[7] Uqaili, M. A., Sahito, A. A., Halepoto, I. A., Memon, Z. A., & Dars, S. B. (2014, May). Impact of distributed generation on network short circuit level. In *2014 4th International Conference on Wireless Communications, Vehicular Technology, Information Theory and Aerospace & Electronic Systems (VITAE)* (pp. 1-5). IEEE.

[8] Ramachandran, T., Reiman, A., Nandanoori, S. P., Rice, M., & Kundu, S. (2019). Distribution System State Estimation in the Presence of High Solar Penetration. *arXiv preprint arXiv:1904.08036*.

[9] Salman, S. K., & Rida, I. M. (2001). Investigating the impact of embedded generation on relay settings of utilities electrical feeders. *IEEE Transactions on Power Delivery*, *16*(2), 246-251.