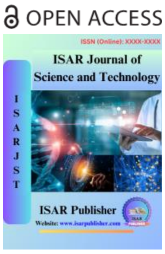

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Optimal improvement of voltage fluctuation caused by high power photovoltaic systems connected to the electrical power grid

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Abstract: The aim of this research was the optimal management of overvoltage in the photovoltaic system with the aim of maintaining voltage stability and reducing network losses. In the simulation process, we considered the number of buses and 10 scattered production sources as the path and simulation process. We considered the number of 10 scattered production sources with a capacity between 18 and 25 MW. Examining the preliminary results of the system has shown that the range is low Medium and high stability is considered based on the distance between each bus with scattered production sources. So that basses 1 to 3 have the lowest range of oscillation because they are located in the closest distance to the production sources. Similarly, basses 7 to 17 have more distances than the production source and have more fluctuation. In order to meet the needs of the network for optimumThe distribution of the production of scattered production sources, which usually have non-constant conditions, especially from bus 7 onwards, it is possible to observe the amount of waste in the network due to the lack of coordination of the scattered production with the network demand, we used the optimal management of overvoltage . The amount of overvoltage of each distributed generation source varies from 25 MW to 18 MW and in each bus this requirement is investigated in the network. and the measurement has been placed. This optimal distribution rate was matched with the amount of consumption and demand of the network in overvoltage and we showed that, for example, in the first bus, the amount of demand of the network is 800 megawatts and the amount of production of the main network in overvoltage is equal to 770 megawatts and a deficit of 30 megawatts has been observed. Using the optimal management of overvoltage of 25 megawatts of the entire networkFrom scattered productions, the power is transferred with this bus to compensate the deficit to a large extent. In the following, in order to formulate an optimal management model for overvoltage distribution, the establishment of a balance point for the activity of network buses along with the ten sources of distributed generation has been investigated. For this purpose, by categorizing all network buses into four modes that include all buses, each mode (average We compared multiple bus sets) in each bus and showed that in the first bus and the first mode, the optimization rate of overvoltage control management was equal to 68.73% and in one turn, not considering the first mode for the bus network and only in Considering the fourth mode, which includes buses 7 to 17, the amount of network optimization has increased by 11.71%. In other words, in the fourth mode Without having six buses, we were able to optimize the network by 11.71% with the help of overvoltage control management.

Keywords: Overvoltage, photovoltaic system, power grid, bus.

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1. Introduction

Today, due to the significant growth of distributed generation, there is a growing interest in the use of microgrids. Microgrids are a combination of different distributed generation sources that supply electricity or heat to a group of local loads as a controllable system at the distribution voltage level [1]. On the other hand, due to the large power fluctuations at the distribution voltage level, microgrid systems may face problems in supplying consumers. Therefore, by dividing consumers into smaller units, several microgrids are used and each load unit is fed by a microgrid [2]. By using several microgrids in a low voltage network, the concept of integrated microgrids with multiple ownership is proposed.

Reference [3] deals with AC load distribution in an independent microgrid and its goal is to regulate only the voltage and angle of the buses using AC. Reference [3] deals with load distribution to control the output power of distributed generation. Reference [4] has also considered network losses in its formulation in addition to voltage stability. The modified Newton-Raphson method is presented in [5] and its ultimate goal is to improve the voltage and angle of the buses and reduce losses in the independent microgrid. In the articles reviewed so far, the microgrids are independent and are not connected to the main grid in the national grid with interconnected AC microgrids. In this paper, the goal is to solve the load distribution.

2. Simulation

In this section, an interconnected microgrid is used to distribute the AC load, the topology of which is shown in Figure 1. The line information is presented in Table 1. All loads are assumed to be 400 KVA with a power factor of 0.85.

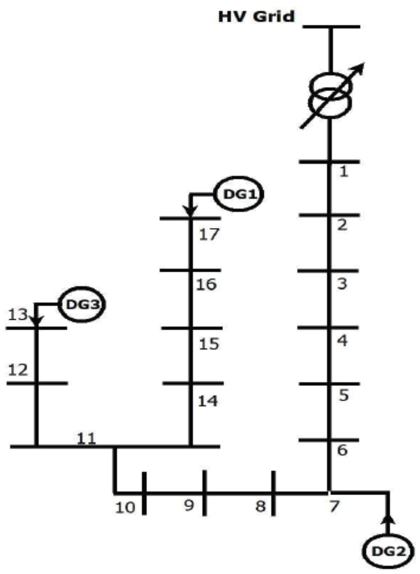

Figure 1. Microgrid Interconnected Test Network for Overvoltage

Table 1: Microgrid Interconnected Test Network Line Information for Overvoltage

From bus	To bus	L[km]	r[ohm/km]	l[mH/km]
1	2	0.942	0.125	0.493
2	3	0.810	0.125	0.493
3	4	0.266	0.125	0.493
4	5	0.642	0.125	0.493
5	6	0.809	0.206	0.608
6	7	0.266	0.206	0.608
7	8	1.000	0.125	0.493
8	9	1.200	0.125	0.493
9	10	1.126	0.206	0.608
10	11	0.378	0.125	0.493
11	12	0.935	0.519	1.957
12	13	0.595	0.519	1.957
11	14	0.640	0.206	0.608
14	15	0.400	0.206	0.608
15	16	1.500	0.519	1.957
16	17	2.000	0.519	1.957

In this section, we present the results on an IEEE test system with 10 distributed generation sources and 17 buses. A three-phase short circuit fault occurs on bus number 14 of this system, which is cleared after tcl=0.2 seconds when the transmission line between buses 17 and 14 opens. In this section, we examine the effect of using these distributed generation sources at times 0 to 2 seconds to create transient stability on the route. We consider the typical conditions on a route with a number of voltage fluctuations for a route feeding line of a location as follows.

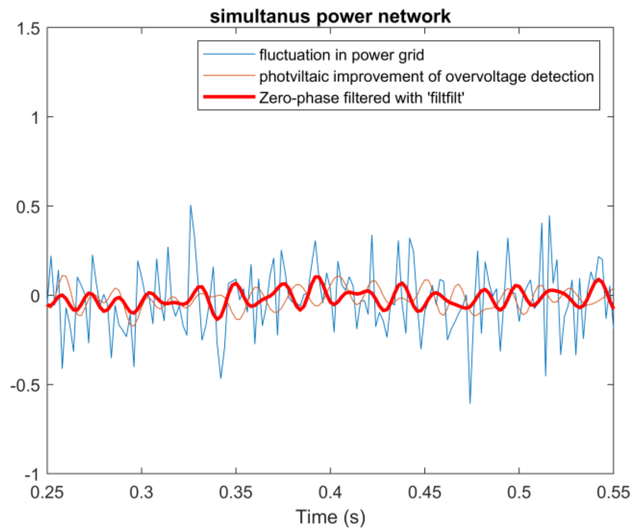

Figure 2. Generation fluctuation in buses in the network with the presence of 10 distributed generation sources

The states obtained from the impact of distributed generation resources in the system, considering the kinetic energy and acceleration of the distributed generation resources at the moment the fault is removed, are listed in Table 2.

Table 2: Buses under investigation in the presence of candidate distributed generation resources

Critical states in interconnected microgrids for overvoltage	1	2	3	4
Buses involved in microgrids interconnected for overvoltage	1, 2, 3	4, 5	5, 6	7, 8, 9, 10,11, 12, 13,14,15, 16 ,17
Oscillation range	low	medium	medium	High

In the 17-bus route in the interconnected microgrid for AC load distribution and in a 2-second period, we have a distribution of a current fluctuation in four parts as low, medium, medium and very high. In other words, in the first to third buses, the fluctuation rate was examined in two seconds and the current drop and fluctuation rate is very low because they are in the closest distance to the generation sources and in buses 4 to 6 it is medium and in buses 7 to 17 the fluctuation and drop rate is very high. In this paper, transient stability is considered by considering the generation rate of each distributed generation source, the consumption rate and network demand in AC load distribution, and the distance of each bus to the distributed generation source. The description of the aforementioned conditions is given in Table 3.

Table 2: Network information, overvoltage, bus distances

Distributed generation source	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Overvoltage level of each distributed generation source	25 MW	25 MW	25 MW	20 MW	18 MW	18 MW	20 MW	25 MW	25 MW	25 MW
Overvoltage Rate of Network Consumption and Demand	800 MW	810 MW	820 MW	830 MW	840 MW	850 MW	860 MW	870 MW	880 MW	890 MW
Overvoltage rate of main network generation	770 MW	780 MW	790 MW	800 MW	810 MW	820 MW	830 MW	840 MW	850 MW	860 MW
Distance of each bus to the generation source	10km	20km	30km	40km	50km	60km	70km	80km	90km	100km

Considering the additional voltage power resulting from the introduction of distributed generation sources along the network route, which is 100 km, it is observed that 226 MW has been added to the generation power in the interconnected microgrid for AC load distribution, while the demand along the route has increased slightly (from 800 MW to 890 MW). In the first bus, the demand was 800 MW and the generation was 770 MW. The first distributed generation was able to cover the network deficit to a large extent and create good transient stability. In the second bus, the conditions were similar and the 25 MW distributed generation source was able to cover the network deficit and with the addition of the first distributed source, a total of 50 MW was injected into the power grid. While the consumption increased by 10 MW, the generation increased by 50 MW, and this created very good transient stability for the network. In the subsequent buses, the generation of the distributed generation source was between 18 and 25 MW per bus has increased while demand has steadily increased by 10 MW.

A condition that can affect the quality of the network for stability is the voltage drop due to the distance of the distributed generation source to higher buses such as buses 7 to 17. This condition affects the transient stability level, but due to the cumulative load caused by the voltage increase, the transient stability level is somewhat appropriate and optimized. The controller balance point and the critical energy of the system for the candidate modes are given in the table below. Also, the normalized potential energy margin ($\Delta VPEn$) was calculated for the candidate modes. By comparing these results, it is observed that the normalized energy margin for mode 1.3 has the lowest value. Therefore, this mode will be the main mode of the system. Taking the balance point related to this mode as an initial guess, the actual controller balance point was calculated using the Newton-Raphson method and is given in Table 3 along with the stable balance point of the system.

Table 3: Controller equilibrium point for candidate modes and critical energy of the system in these modes

Overvoltage level of each distributed generation source	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mode 1 to 3	68.73	-20.38	74.19	73.41	7.86	73.59	9.28	5.17	8.89	-15.80
Mode 4 and 5	69.05	-17.96	74.50	10.96	10.28	73.90	11.70	7.59	21.31	-13.38
Mode 5 and 6	66.69	-14.69	72.14	14.22	13.55	14.40	14.97	10.86	24.58	-10.1
Mode 7 to 17	1.71	-12.53	75.39	16.39	15.71	16.57	17.13	13.02	26.74	-7.95

Table 4: Overvoltage rate of each distributed generation source

Overvoltage level of each distributed generation source	11	12	13	14	15	16	17	Vcr
Mode 1 to 3	39.23	23.28	34.25	24.19	14.24	11.37	8.52	9.93
Mode 4 and 5	45.18	23.73	11.14	17.06	4.63	9.19	1.63	5.89
Mode 5 and 6	12.63	-8.1	11.63	2.55	4.44	-6.47	-8.67	-10.06
Mode 7 to 17	0.24	-10.24	-1.92	3.59	-12.79	-20.83	-28.17	-33.01

Table 5: Normalized potential energy margin of the system for candidate modes

MOD	ΔV_{PEn}	V_{KEcorr}	ΔV_{PE}
Mode 1 to 3	3.94	3.15	12.43
Mode 4 and 5	3.11	3.01	9.37
Mode 5 and 6	1.48	2.75	4.07
Mode 7 to 17	1.64	1.56	2.62

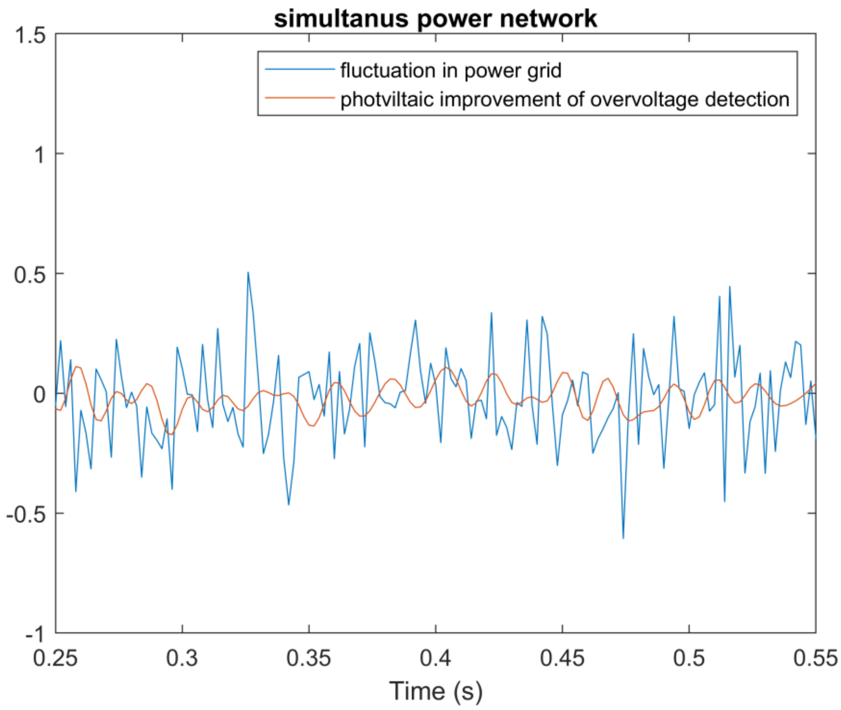

Figure 4. Stable equilibrium point and system controller equilibrium point after fault

Table 6: Overvoltage level of each distributed generation source/stable balance point/controller balance point bus 1 to 10

Overvoltage level of each distributed generation source	1	2	3	4	5	6	7	8	9	10
Stable equilibrium point	14.37	-9.87	19.83	19.05	18.38	19.23	19.80	15.68	29.40	-5.29
Controller balance point	49.08	-29.11	14.86	44.74	44.54	45.19	46.14	28.84	48.52	5.84

Table 7: Overvoltage level in distributed generation source/stable balance point/bus controller balance point bus 11 to 17

Overvoltage level of each distributed generation source	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Stable equilibrium point	11.17	-10.15	5.11	1.32	-2.24	-3.41	-8.02
Controller balance point	-1.08	-15.2	-6.51	-7.22	-12.19	-18.63	-23.78

The critical fault clearance time for the above short circuit fault is 0.34 seconds, which is used here as a benchmark for the above results. In this paper, we have shown that by increasing the number of distributed generation units in the energy path with a number of 17 buses, the amount of distributed source load spread, which was severely in buses 7 to 17 for up to 2 seconds, has now reached its minimum and it can be expected that the amount of current stability in these buses will increase.

Table 7: System energy margin for different times - error correction

MOD	ΔV	**Error correction time t_{cl}**
Mode 1 to 3	0.17	0.30
Mode 4 and 5	0.19	0.42
Mode 5 and 6	-0.23	0.45
Mode 7 to 17	-0.97	0.78

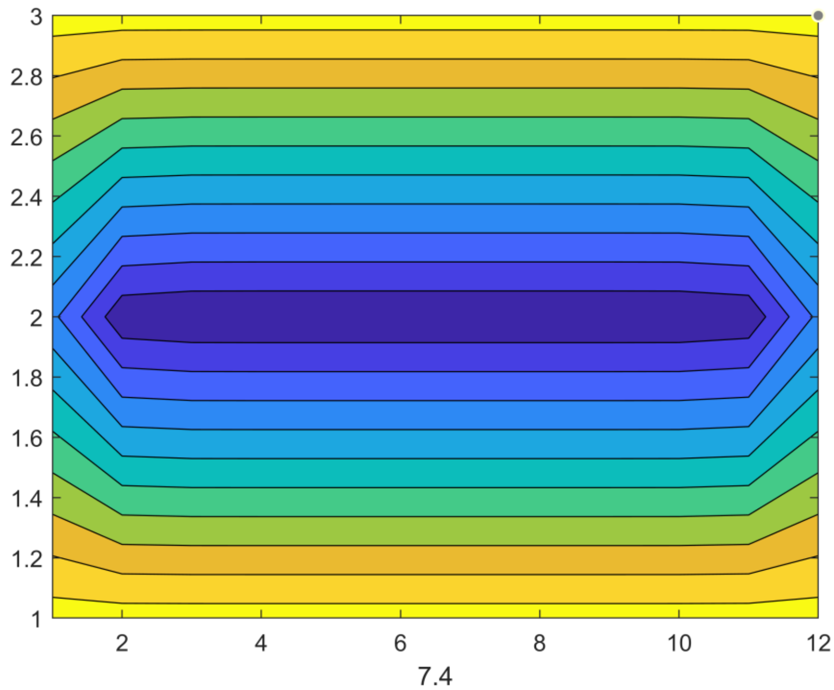

Figure 5. System energy for different times - troubleshooting

3. Conclusion

The initial results of the system showed that the low, medium and high range of stability was considered based on the distance between each bus and the distributed generation sources. In this paper, transient stability was considered in the load distribution by considering the production rate of each distributed generation source, the consumption rate and the demand of the network, and the distance of each bus to the distributed generation source. It was shown that with the increase in the number of distributed generation units in the energy path, with the number of 17 buses, the load distribution of the distributed source, which was severe in buses 7 to 17 in the time of 0 to 2 seconds, has now reached its minimum level and it can be expected that the flow stability rate in these buses will increase. In other words, the flow stability rate in these buses has been significantly optimized by increasing the number of distributed generation sources from 1 to 10.

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