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Analysis of the Impacts of Decentralized Production on Distribution Grids

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***Abstract*— *This paper presents an analysis of the impacts of decentralized production on electrical distribution grids. The impact on power flow and the impact on the values of currents in case of the fault are presented. The study has been applied to the IEEE 9 bus for testing the effects of the distributed generator connected to the distribution grid. Four default types are simulated in order to obtain sure results; also different scenarios are varied to show the influence of the power injected by distributed generator DG and the influence of the fault location according to DG. The presented results show that the short-circuit current increased at the injection points of DG and the direction of the power flow became bidirectional if the injected power is greatest.*

***Keywords*—Decentralized generation, Distribution grid, IEEE test grid, Power flow, Short circuit.**

I. INTRODUCTION

Decentralized generation DG has an increasingly important role in the infrastructure and the electrical system market. It is defined as the development of a set of sources of electrical energy connected to an existing energy distribution infrastructure. To meet the increase in annual energy demand, there is a significant increase in the integration of decentralized generation. As a result, part of the energy demand is provided by the centralized generation and another part is produced by decentralized generation [1].

The integration of distributed generators, based on renewable energies, into the MV distribution network is currently the trend followed in the energy sector. This integration brings economic and energy interests. These generators are smaller than traditional generators and are closer to customers, resulting in lower transmission and distribution costs, and sometimes fewer power losses, but they can create technical and safety issues. It is therefore essential to evaluate the technical impacts of DG in distribution grids in order to have high quality operation [2].

In this paper, the data of IEEE test grid and the simulation scenarios are presented in the second section and the results are shown in the third one. This study focused on the impact of decentralized production on the power flow and on the short-circuit current in terms of the injected power and the localization of default according to DG. Finally, the last section contains a conclusion.

II. IEEE Test Grid

The simulated system includes three synchronous generators, three loads with 315 MW as total active power and 115 MVar as total reactive power, three transformers and six lines. The topology of this grid is presented in Fig. 1.

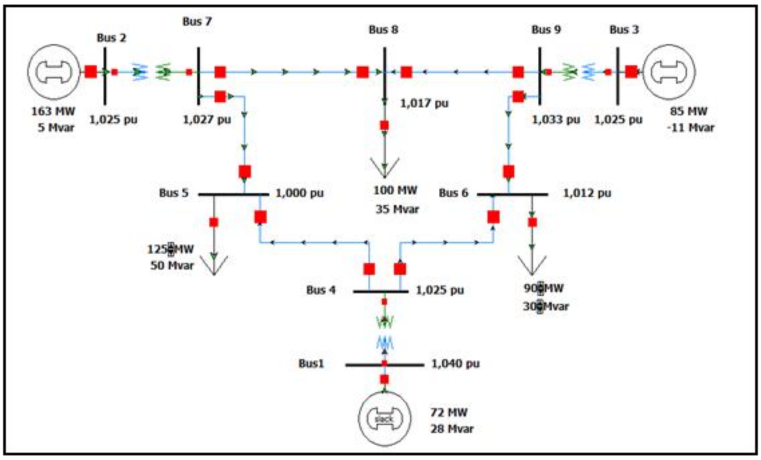

Fig. 1 – Topology of IEEE 9 bus test grid

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The characteristics of generators and loads are presented respectively in Tables 1 and 2. The distribution lines are characterized by the distance between the phase conductors and their impedances. The impedance values and other configuration parameters are presented in Table 3.*Table 1: Characteristics of the generators*

Bus	***U [kV]***	***S_G[MVA]***	***PF***	***X_d''[pu]***
1	*24*	*512*	*0,9*	*0,2*
2	*18*	*720*	*0,85*	*0,185*
3	*15,5*	*125*	*0,85*	*0,134*

Table 2: Load characteristics

Bus	***P_l [MW]***	***Q_l [MVar]***
5	*125*	*50*
6	*90*	*30*
8	*100*	*35*

Table 3: Characteristics of lines

N°	**From bus**	**To bus**	**R [Ω/km]**	**X [Ω/km]**	**B [S/km]**
1	4	5	0,01188	0,008062	$5736{,}89.10^{-6}$
2	4	6	0,002021	0,010912	$5148{,}99.10^{-6}$
3	5	7	0,003850	0,019203	$9943{,}04.10^{-6}$
4	6	9	0,004713	0,020771	$11619{,}96.10^{-}$
5	7	8	0,001009	0,006826	$4858{,}119.10^{-}$
6	8	9	0,001418	0,01197	$6807{,}29.10^{-6}$

In the short-circuit modeling, the transient and subtransitory impedance sequences of the synchronous generators, integrated into the network, were necessary [4]. The parameters are summarized in Table 4 and the four different cases that are chosen to study the impact of decentralized generation on the short-circuit level of the distribution network are presented in Table 5 [5].

Table 4: Parameters of synchronous generators

5-10MVA 13,8 kV	**Ra [pu]**	**X'd [pu]**	**X''d [pu]**
	0,00 4	0,250	0,134

To obtain valid and sure results, different scenarios are varied. The simulation involved examining the occurrence of four types of three-phase, single-phase, two-phase and two-phase isolated fault (3ph, LG, LL and LLG) at three different buses 4, 5, 8 respectively. The bus selection where the fault can occur has been made in the middle and at the end of the network to deal with all possible cases.

Table 5: Different scenarios to examine

Scenarios	***Condition***
Scenario 1 (S1)	*Without DG*
Scenario 2 (S2)	*DG connected to bus 6 of 5 MVA*
Scenario 3 (S3)	*DG connected to bus 6 of 10 MVA*
Scenario 4 (S4)	*DG connected to bus 8 of 5 MVA*
Scenario 5 (S5)	*DG connected to bus 8 of 10 MVA*

III. RESULTS OF THE SIMULATION

In this study, we are only interested in the impact of power flow and the impact of the DG on the values of the short-circuit current. It will be assumed that the voltage plan is not infected by the integration of the decentralized generation and that the voltage is within the allowed limits.

3.1 Impact on Power Flow

Distribution networks are passive electrical circuits in which active and reactive powers flow from HV to LV, relying on a unidirectional energy exchange [6]. With the introduction of distributed generation in these networks, they become active electrical circuits in which energy flows can, under certain conditions, pass from the distribution network to the transmission network.

In order to see the effects of dispersed power generation on power flow, we simulated the test grid with and without DG. The power transits on the network without the distributed energy generation are shown in Fig. 1. It will be noted that the energy flows in one direction, from the network to the loads. The connection of a DG at node 5 of 45 MVA power and a DG at node 6 of the same power on the network, modifies the power flow as shown in Fig. 2. The power flow flows in both directions and thus becomes bidirectional.

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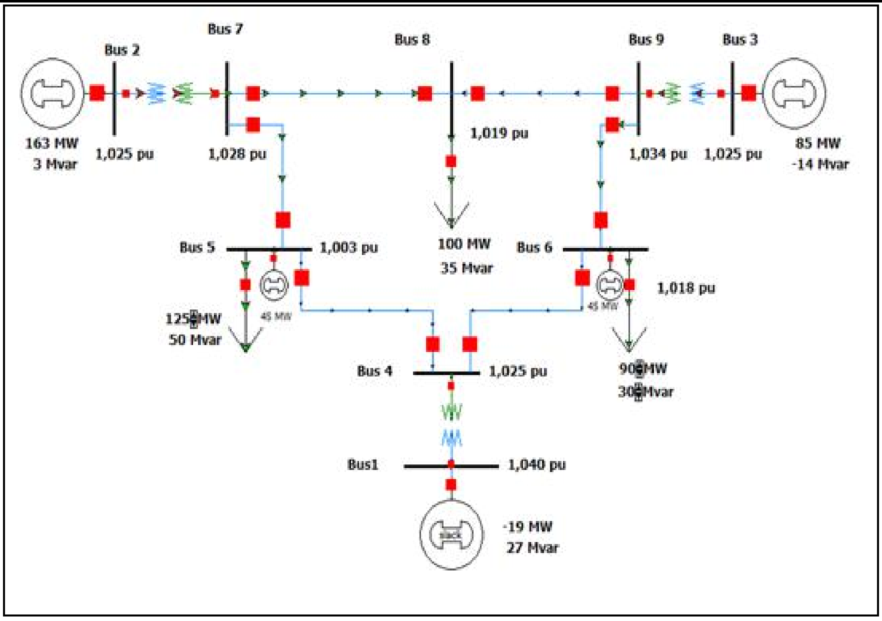

Fig. 2 –Power flow with two DGs connected to node 5 and 6.

In general, if DGs are significantly integrated into the distribution network, it is possible that energy can flow back to the transmission networks. This bidirectionality must therefore be taken into account when managing the network. It must also be verified that the transit capacity of the network is respected because the injected power by the DGs can lead, in certain branches of the network, to higher power flows than the electrical resistance of the equipment (lines, cables, etc.). , which may lead to faster aging, or even defects in this material related to heating [7].

3.2 Impact on the Short-Circuit Current

The connection of the distributed generation to the network changes its overall impedance, which influences the values of the short-circuit current and the short-circuit power. This modification of the short-circuit current may cause the protection equipment to malfunction. In the event of default, the fault current may exceed the allowable limit of network elements because of the inserted producers.

The simulation results for the short-circuit current analysis examining the four fault types for the different scenarios are shown in Table 6.

Table.6: Results of the simulation of short circuit currents in [kA]

Location of fault	**3-Phase Fault**				
	S1	S2	S3	S4	S5
Bus 4	64,33	66,73	68,84	64,85	65,29
Bus 5	43,28	44,07	44,74	43,75	44,16
Bus 8	45,22	45,72	46,13	49,40	53,57
	Line to Ground Fault				
	S1	S2	S3	S4	S5
Bus 4	45,55	48,14	50,16	45,98	46,32
Bus 5	30,35	31,13	31,71	30,73	31,03
Bus 8	32,67	33,16	33,51	37,40	42,02
	Line-to-Line Fault				
	S1	S2	S3	S4	S5
Bus 4	55,71	57,79	59,62	56,16	56,54
Bus 5	37,48	38,16	38,75	37,89	38,25
Bus 8	39,17	39,59	39,94	42,78	46,39
	Line-to-Line Ground Fault				
	S1	S2	S3	S4	S5
Bus 4	58,54	60,89	62,94	59,03	59,45
Bus 5	39,37	40,14	40,78	39,82	40,19
Bus 8	41,31	41,79	42,18	45,39	49,49

3.1.1 Influence of Type of Default

The three-phase fault occurrence presents the highest impact on the short-circuit level in the five different applied scenarios. It is then followed by the isolated two-phase fault. Conversely, the single phase fault presents the lowest impact in comparison with the other three evaluated types of fault.

3.1.2 Influence of the Injected Power from the DG

The short-circuit current variation between the scenarios without and with the DG is an index that gives an idea of how the DG influences the planned protection devices for a network without these production units [2].

Figures 3-6 show the short-circuit currents in different scenarios for the four types of fault, it is noticed that there is a slightly narrow change in the results shown for the short-circuit current values in case of scenarios 2, 3, 4 and

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5 (DG connected) in comparison with scenario 1 (without DG).

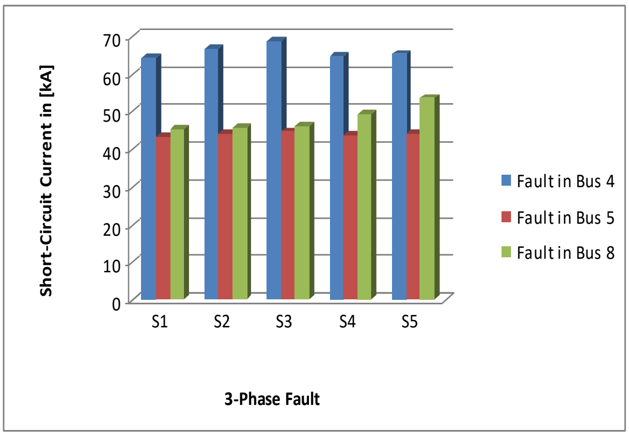

Fig. 3 – Short-circuit currents in the different scenarios for the three-phase fault

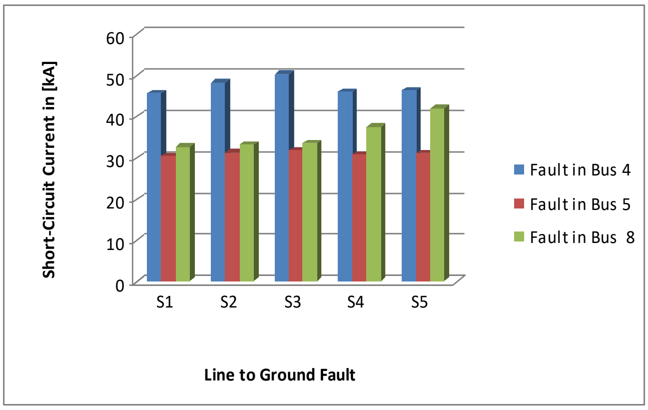

Fig. 4 – Short-circuit currents in different scenarios for single-phase fault

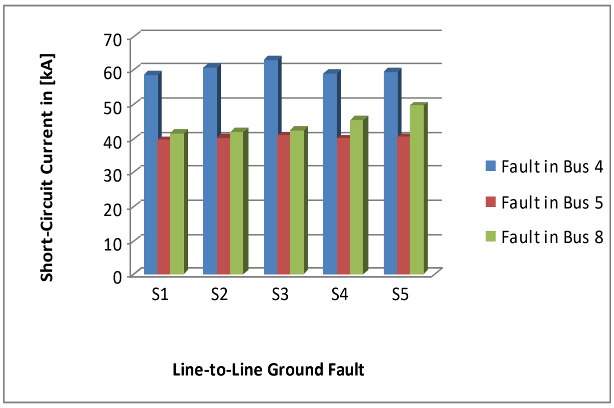

Fig. 5 – Short-circuit currents in the different scenarios for the two-phase faul

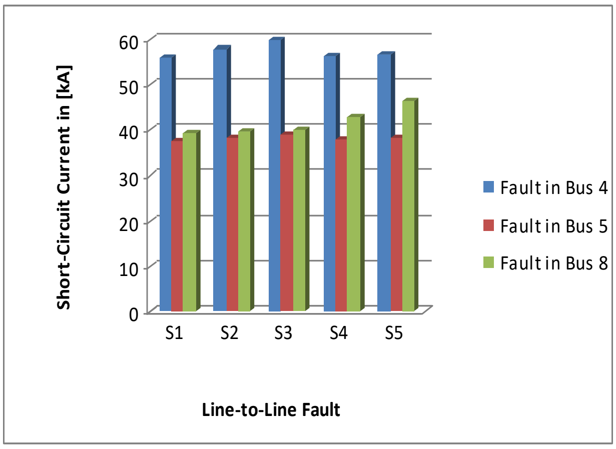

Fig. 6 – Short-circuit currents in different scenarios for isolated two-phase fault

The simulation results show that the integration of a generator into the distribution network, in the event of a fault, has an influence on the values of the short-circuit currents [8]. It can be seen that the values of the short-circuit current are important for the scenarios S2 (DG connected to bus 6 of 5 MVA) and S4 (DG connected to bus 8 of 5 MVA) in comparison with S3 (DG connected to bus 6 of 10 MVA) and S5 (DG connected to bus 8 of 10 MVA) and this for all types of faults, which explains why the higher the power of the dispersed energy generation, the short-circuit current increases. It can be concluded that the connection of the DG to the distribution network causes, in case of default, an increase in fault currents directly related to the injected power.

3.1.3 Influence of the Location of the DG

The increase in short-circuit current depends on the location of the fault according to the DG as shown in Table 7.

Table 7: Three-phase short-circuit current simulation results

Fault location	***B4***	***B6***	***B7***	***B8***	***B9***
Short-Circuit Current in [kA]	*65,34*	*38,45*	*58,35*	*45,43*	*51,54*

When there is a fault in the bus 4, the value of the short-circuit current is smaller in the bus 8 (S4, S5) than in the bus 6 (S2, S3) because the distance between the bus 4 and 6 is shorter than the distance between bus 4 and 8. This is the same case if there is a fault in bus 8, the value of the short-circuit current is greater in the bus 8 because it was both the fault point and injection of the DG. Then the buses connected to the DG and which are closest to the fault bus, have the largest short circuit current values. In general, all the generators of a network participate in the current of the fault. The participation of each generator

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depends on the electrical distance that separates it from the fault [9].

However, the variation of the short-circuit currents can become more important in these three cases:

- If the power of the DG increases.
- If the fault is of three-phase type.
- If the DG injection point is closer to the default point.

IV. CONCLUSION

Currently, the trend is the massive insertion of decentralized production, based on renewable energies, into the electricity grid, which is due to a sharp increase in the annual demand for energy. In order to support future developments in the energy sector, it is necessary to study the impacts of this production on electricity distribution networks, more specifically, analyze the impact on power flows and study the evolution of current values when the DG is introduced into the network. That's why we did a simulation on a standard 9 bus IEEE distribution network.

The simulation results showed that short-circuit currents increase in the presence of DG, which has a significant impact. It is also noted that the amplitude of the short-circuit currents increases with the injected power and depends on the location of the fault, with respect to the DG. From this, it can be deduced that the connection of decentralized generation units in MV distribution networks has consequences for the operation of the protection relay and for selectivity, which may accelerate the aging of the network equipment.

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