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Impact of DG on Electrical Distribution Network Under Contingency Conditions

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***Abstract*—In today's world, electric utilities are facing many challenges and issues such as rise in electricity demand, poor voltage regulation, lack of investment towards up-gradation of electric infrastructure, poor power quality, unscheduled load shedding etc. The conventional energy sources are the major contributors [up-to 60 to70%] to meet the present load. Thermal power plants are the foremost power provider in meeting the energy demand. The exponential increase in fuel and coal costs, environmental concerns thermal power plants are losing interest. The non conventional energy sources are gaining attention and playing key role in diminishing above mentioned issues. In this paper, performance of electrical distribution network is tested with and without DG under contingency conditions. The proposed algorithm is tested on seven bus network to verify the most favourable location and size of the DG to boost the overall enhancement of the network performance.**

Keywords — Distribution Network; Distributed generation; Voltage profile; Power loss; Line outages; Power quality.

Nomenclature:

DG	Distributed Generation
V_{imp}	Voltage Improvement
P_{save}	Power Saving
MW	Mega Watt
P	Active Power
PT_{loss}	Total power loss
p.u.	Per unit
V_{min}	Minimum Voltage
BC	Base case
DN	Distribution Network
R_m	Resistance of m^{th} line
I_m	Current in the m^{th} line
LFA	Load flow analysis

I. INTRODUCTION

Increase in power demand leads to over burdening of electrical infrastructure, more voltage drop, power loss, and mismatch in protective system coordination, active and reactive power flow problems [1-2]. From the literature, many researchers came with different solutions. Out of all, DG placement is the immediate and effective solution to enhance the overall network performance. At present, government policies and deregulation of electric markets are greatly supporting to the distribution generation technology [3].

The different types of DG's are used depending on their potential availability. Mainly Solar PV, wind power, cogeneration [4]. Small/ micro hydro, fuel cells, etc. The optimal penetration of the DG power depending on the network capacity plays important role in maximum power saving [5-6]. The integration of DG sizes varies from 1 kW to 300 MW. Fig.1 shows the electrical network consists of central power generating station, T&D infrastructure, commercial, residential and industrial loads [7].

The optimal placement and sizing of DG plays very crucial role in increase of voltage profile and diminishing the network loss [8]. Placement of DG is also important from the point of fault issue, placing of DG should provide good coordination between protective system by minimizing the fault parameters [9].

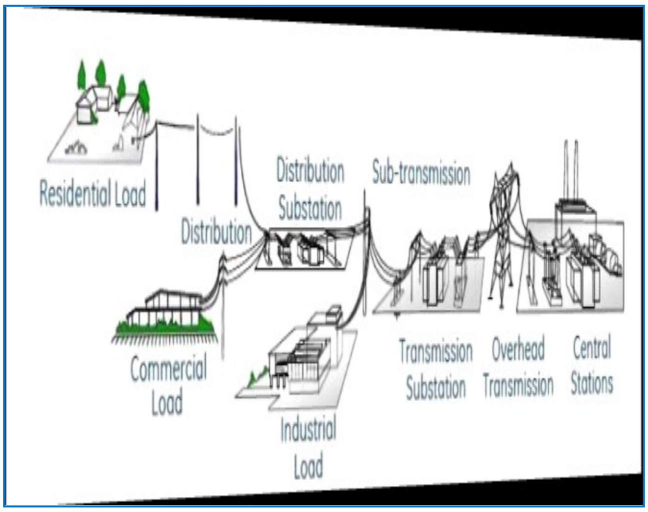

Fig.1 Electrical network

The lot of research work is carried out by scientists, academicians, industry experts, power supplying boards to enhance the overall reliability and performance of their electrical networks [10-12]. Mainly,

- Introduction fast operating power electronics devices
- DG
- Reconductoring
- Automatic Voltage Regulators (AVR) placement
- Up gradation of electrical infrastructure
- Network reconfiguration etc

In this paper, impacts of DG on network parameter are analyzed with different line outages. The optimal site with their size leads to stable, efficient and reliable operation of electrical distribution network. The Distributed Generation enhances the voltage sustainability of large interconnected network.

II. METHODOLOGY

The main objectives of this work are to boost the voltage profile with diminishing the power loss.

$$\text{Min}\{P_{TL}\}=\text{Min}\{I^2R\}$$

Without violating the voltage and power balance equations i.e.

$$V_{min}\leq V\leq V_{max}$$

$$P_G=P_D+P_{TLoss}$$

The algorithm used for DG placement and it's impact on network performance is discussed as follows.

Step 1. Enter the electrical network data i.e., line, generator and load data.

Step 2. Run the LFA and Compute P_{TL}, node voltages, percentage overloading of the lines, P_{Flow} and Q_{Flow}.

Step 3. Find the optimal location and size of DG with exhaustive LFA method.

Step 4. Compute the new P_{TL}, Voltages at each node by line outages considering one line at a time.

Step 5. Repeat step.4 for all the lines in the network.

Step 6. Compare the PT_{Loss} and voltage with and without DG to know the impact of DG.

Step 7. Choose the best location of the DG under line outages to maintain the good voltage profile in the network.

III. RESULTS AND DISCUSSIONS

Fig.2 shows the seven node SLD diagram drawn in Mi-Power-9 power system simulation package. The seven bus system consists of 56.98 MW of active power and 32.24 MVAr of reactive power loads are connected at different nodes except slack bus (Node-1) in the network. The total 69.86 MW power generated by two generators connected at nodes 1 and node-6 including 12.81 MW of P_{TL}. The seven transmission corridors are used to supply the power from generators to loads.

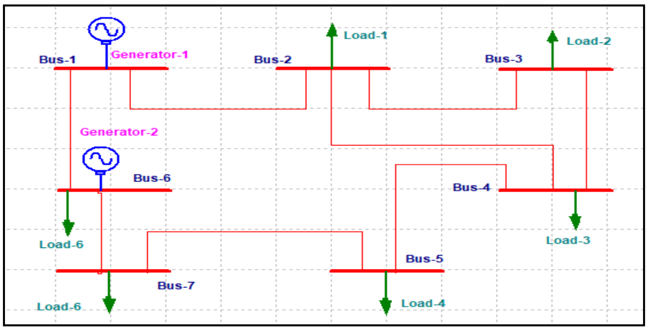

Fig.2 SLD of seven node electrical DN

Base case(without DG) results:

MW Generation: 69.8086
MVAr Generation: 49.4533
MW Load: 56.9871
MVAr Load: 32.2486
MW loss: 12.8176

TABLE-1
POWER FLOW AND POWER LOSS

FROM NODE	TO NODE	FORWARD POWER FLOW		POWER LOSS IN LINES	
		MW	MVAr	MW	MVAr
1	2	27.715	29.712	3.5065	4.7068
2	3	10.625	8.4300	0.7988	1.0719
3	4	1.8290	2.4040	0.0645	0.0861
4	5	-7.217	-1.5060	0.3719	0.4987
1	6	-17.906	19.742	3.3195	4.4552
6	7	30.803	10.557	2.8059	3.7662
5	7	-16.491	0.6080	1.4609	1.9607
2	5	3.5980	10.388	0.4898	0.6571

Table.1 shows the power flow and power loss in the different transmission corridors in the DN. For example the power flow between node-1 and node-2 is 27.715+29.712 MW with power loss of 3.5065+4.7068i MW. The positive sign indicates incoming power towards the node and negative sign indicates outgoing power from the node.

Table.2 shows optimal siting of DG by exhaustive LFA. After connecting DG at node-2 the P_{TL} in network is 10.45 MW with 18% of P_{TL} reduction. Similarly DG at node-3 shows the 26.17% of P_{TL} minimization. The best location can be chosen with maximum P_{save}. In this seven node network node-3 and node-4 can be used as best location for DG placement to enhance the overall network performance

TABLE-2
DG PLACEMENT BY EXHAUSTIVE LFA

DG SITE	PT_{loss} in MW	V_{min} in p.u.	P_{save} in MW	% PT_{loss} Reduction In MW	% V_{imp} in p.u
BC	12.82	0.7476	--	--	--
2	10.45	0.7899	2.3676	18.4715	05.658
3	09.46	0.8229	3.3545	26.1710	10.072
4	09.24	0.8490	3.5745	27.8874	13.563
5	10.19	0.8112	2.6229	20.4633	08.5070

- ***CASE-1 DG AT NODE-5***

The Fig.3 shows the in presence of DG at node-5 with line outage between node-2 and node-4 to check the impact of DG on the network behavior. The obtained results shows DG supplies the part of the load connected at a particular bus by reducing the line currents which leads to improvement in the voltage profile with minimized power loss in the network. Hence utmost care should be taken for optimal placement, type and sizing of the DG. The line outages in the network causes over loading of the entire electrical infrastructure with poor voltage profile and power losses in the network

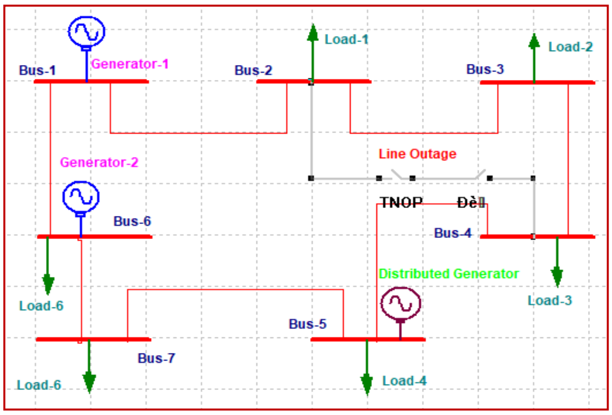

Fig.3 DG at node -5 in presence of line outage L-23

Table-3 shows the minimum voltages and P_{TLoss} for with and without DG under line outage conditions. In BC without DG P_{TLoss} 12.81 MW is observed and with integration of DG P_{TLoss} is 10.1947 MW with significant maximization of the voltage profiles. The line outage L-23 causes 19.78 MW of P_{TLoss} without DG. After connecting DG the losses are came down to 15.27 MW assuring improvement in the voltage magnitudes

TABLE-3
VOLTAGES AND P_{TLOSS} WITH DIFFERENT LINE OUTAGES

Line outage	**With DG**		**Without DG**	
	V_{min} in p.u.	**PT_{loss} in MW**	**V_{min} in p.u.**	**PT_{loss} in MW**
BC	0.8112	10.1947	0.7476	12.8176
Line 2-3	0.5324	15.2731	0.4410	19.7812
Line 3-4	0.6559	13.2615	0.6236	14.7132
Line 4-5	0.7904	10.3618	0.7033	13.2837
Line 6-7	0.5774	22.0744	0.4364	32.8448

Fig.4 shows the voltage comparison in presence of DG at node-5 under different line outages. Integration of DG in the network helps to reduce the over burden on the entire electrical infrastructure under different line outages. Fig.5 shows the voltage comparison at all the nodes under line outages without connecting any DG leads to poor voltage regulation with more power losses in the network.

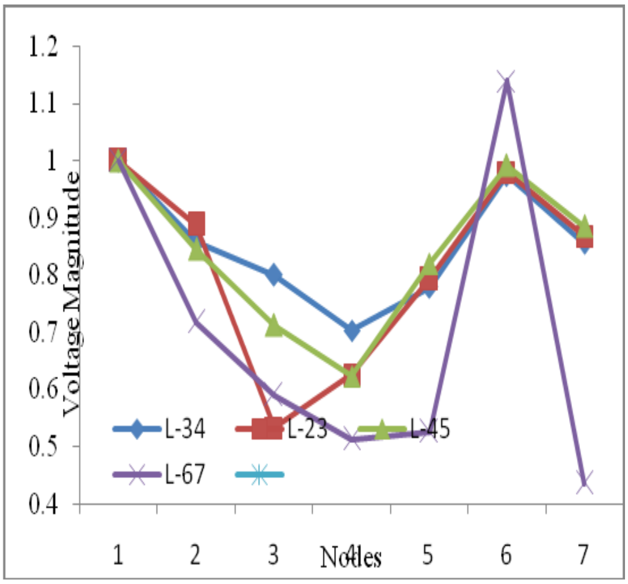

Fig.4 Voltage magnitude with DG at node-5 under different line outage conditions

Fig.6 shows power loss comparison with and without DG under L-23, L-34, L-45 and L-67 outages with DG power losses in the network leads to stable and efficient operation of the electrical DN.

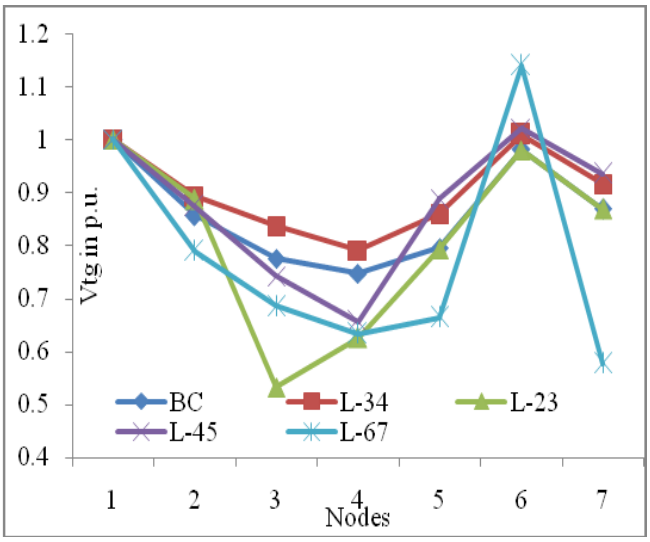

Fig.5 Voltage magnitude without DG under different line outage conditions

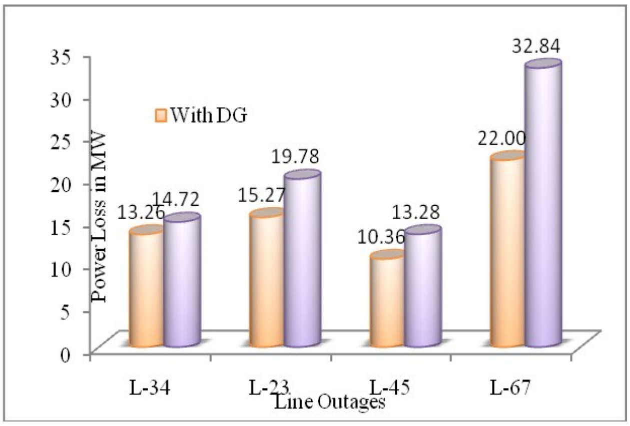

Fig.6 P_{TLoss} comparison under different line outage conditions

TABLE-4
VOLTAGES AND P_{TLOSS} WITH DIFFERENT LINE OUTAGES

Line outage	With DG		Without DG	
	V_{min} in p.u.	PT_{loss} in MW	V_{min} in p.u.	PT_{loss} in MW
BC	00.8490	9.2431	0.8112	10.1947
Line 2-3	0.6473	11.8175	0.4410	19.7812
Line 3-4	0.8388	9.9253	0.7033	13.2837
Line 4-5	0.8408	9.3783	0.6236	14.1737
Line 6-7	0.5540	22.4580	0.4364	32.8448

➢ ***CASE-2 DG AT NODE-4***

Table-4 shows the minimum voltages and P_{TLoss} for with and without DG under line outage conditions. In BC without DG P_{TLoss} 10.1947 MW is observed and with integration of DG P_{TLoss} is 9.2431 MW with significant maximization of the voltage profiles. The line outage L-23 causes 19.78 MW of P_{TLoss} without DG. After connecting DG the losses are came down to 11.8175 MW assuring improvement in the voltage magnitudes

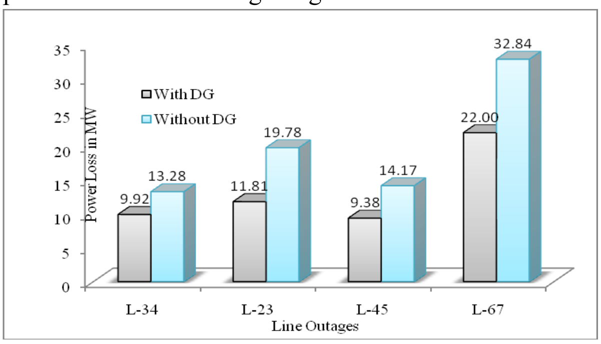

Fig.7 P_{TLoss} comparison

Fig.7 shows power loss comparison with and without DG under L-23, L-34, L-45 and L-67 outages with DG power losses in the network leads to stable and efficient operation of the electrical DN.

IV.CONCLUSION

In this paper, the impact of DG connection in the electrical network is tested under different line outage conditions. The optimal site and size of the DG plays key role in enhancement of DN performance reducing the overloading on the electrical infrastructure. The obtained result shows the DG importance in terms of P_{TLoss} and voltage profile improvement.

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