MICRO-GRID BASED OPTIMAL SOLUTION FOR PENETRATION OF DISTRIBUTED GENERATION CONSIDERING SYSTEM LOSS AND VOLTAGE STABILITY

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Abstract- Distributed Generation (DG) has brought a whole new era for electrical power systems by improving the power quality. Penetration of DG in proper location reduces energy loss but inappropriate modeling. The generation and loads might be regarded as a micro-grid and split from the distribution system to cut off the micro-grid's load from the disturbance without harming the integrity of distributed network. The proposed work talk about the operation principle of the distributed generation system and the various influences it introduced into the distributed network system. The observation is made on sitting and sizing of distributed generation system which influences the power loss of the grid and control of voltage profile. We considered a self-designed distribution network with standard IEEE line data and regulations for the simulation in 'POWER WORLD SIMULATOR' introducing full Newton Raphson (NR) method in proposed algorithm and investigate the system performance under various DG situations at diverse load levels.

Keywords— Distributed Generation; Optimal Location; Line Loss Reduction; Voltage Level Improvement; Cost Efficient.

I. INTRODUCTION

Over the past few years, developments have been made in finding digital computer solutions for power-system load flows. This involves increasing the reliability and the speed of convergence of the numerical-solution techniques. The characteristics and performance of transmission lines can vary over wide limits mainly dependent on their system. Hence, the load flow method is used to maintain an acceptable voltage profile at various buses with varying power flow. The state of any power system can be determined using load flow analysis that calculates the power flowing through the lines of the system. There are different methods to determine the load Flow for a particular system such as: Gauss-Seidel, Newton-Raphson, and the Fast-Decoupled method.

Distributed Generation (DG) is a promising solution to many power system problems such as voltage regulation, power loss, etc. Distributed generation is small-scale power generation that is usually connected to or embedded in the distribution system. Numerous studies used different approaches to evaluate the benefits from DGs to a network in the form of loss reduction. This project implements the identification of optimal DG locations by single DG placement algorithm. This method first evaluates the voltage profile using the Newton-Raphson method and then it calculates the total I^2R loss of the system. After that by placing the DG at each bus, it evaluates the corresponding total I^2R losses and hence obtained the optimal placement of DG for loss reduction and best suited voltage profile evaluation [1].

II. DISTRIBUTED GENERATION (DG)

Since the increase of power demand is stressing the transmission and generation system capabilities that might lead to frequent power outages, engineers around the world are developing different methods to improve the reliability, protection and security of the electrical power system. These frequent power outages due to the overloaded grid will costs millions of Dollars per year. Newer technologies authorize the production of electrical energy in an efficient, reliable and secure way, causing fewer damages to the environment. One of the significant solutions is to build generation closer to the power consumption areas. This is known as distributed generation.

It has been reported that the distribution system planning problem is to identify a combination of expansion projects for the least cost network investment that satisfies load growth requirements without violating any system and operational constraints. The DG benefits are numerous and the reasons for implementing DGs are-

a. an energy efficiency or rational use of energy,
b. deregulation or competition policy,
c. diversification of energy sources,
d. availability of modular generating plant,
e. Ease of finding sites for smaller generators, shorter construction time and lower capital costs of smaller plants and proximity of the generation plant to heavy loads, which reduces transmission costs.

The DG system intended to use in this project is Basic PV Solar System (min 1MW and max 10 MW). The DG system is allocated using the proposed algorithm and incorporating cost efficiency and loss minimization, most appropriate size and location is being selected.

III. PROBLEM FORMULATION

The installation of DG units at non-optimal places may not result as beneficial as it could have been otherwise. Since the impacts of distributed generation on system performance depend on system operating conditions and the characteristics of the distributed generation, it is necessary to use some solutions in planning and operation to attain the best performance. In large distribution systems to select best place(s) for installation of optimal size DG units is a complex combinational optimization problem.

The flow solution is implemented by using non-linear N-R iterative method. IEEE bus data have been modified and it's based upon the proper location of DG in distributed network system. Bus data is taken from [3] and the transmission length has been modified accordingly as shown in TABLE 1.

When a DG is connected to a bus, corresponding bus is assdumed to be a P-V bus and the N-R method applied here is available in standard books.

a. INJECTED POWER

The complex power injected at bus 'i' is given as-

$$S^*_i = \sum_{j=1}^{n} [Y_{ij} V_i] \quad (1)$$

From this relation, the mathematical formulation of the power flow problem results in a system of algebraic non-linear equation which must be solved by iterative technique.

b. POWER FLOW

After the iterative solution of bus voltages, the next step is computation of line flow and considering the line connection between two busses i & j.

Power flow from i^{th} to j^{th} bus-

$$S_{ij} = V_i I^*_{ij} = V_i [(V_i - V_j)/Z_{ij} + V_i Y_{ijo})] \quad (2)$$

Similarly, power flow from j^{th} to i^{th} bus-

$$S_{ji} = V_j I^*_{ji} = V_j [(V_j - V_i)/Z_{ji} + V_j Y_{jio})] \quad (3)$$

c. LINE LOSSES

The complex power flow S_{ij} and S_{ji} are shown in equation (2) & (3). Therefore, the power loss in the $(i-j)^{th}$ line are given by algebraic sum of the power flows determined from equation (2) & (3), i.e.,

$$P_L = \sum_{j=1}^{n} \sum_{i=1}^{n} (S_{ij} + S_{ji})$$

$$P_L = \sum_{j=1}^{n} \sum_{i=1}^{n} (P_{ij} + Q_{ij}) + (P_{ji} + Q_{ji}) \quad (4)$$

d. OBJECTIVE FUNCTION

The main objective of the power flow solution has been directed towards optimization of objective function governed by relation-

Minimize $f = C (P_{DG})$

$$C (P_{DG}) = a_{DG} + b_{DG} P_{DG} + c_{DG} (P_{DG})^2$$

a_{DG}, b_{DG} and c_{DG} are quadratic cost coefficients of the specified DG.

DG rating limits- $P^{min}_{DG} < P_{DG} < P^{max}_{DG}$

e. DG ALLOCATION STEPS

The computational steps involved in proposed simulation following the algorithm for finding the optimal (DG) size and location to minimize the loss in a radial distribution system are summarized in following:

I. Perform the load flow analysis by using N-R method for determining the voltage profile and Total Loss for Radial Distribution system.

2. In load flow analysis obtain the branch current I_{ij} between two buses by using,

$$I_{ij} = (V_i - V_j)/R_{ij}$$

Where, V_i=*Voltage of bus i*, V_j=*Voltage of bus j* R_{ij} =*Resistance between bus i and j*

3. Obtain the active component (I_a) and reactive component (I_r) of the branch currents I_{ij}.

4. We calculate total $I^2{}_a R$ loss by using-

$$P_L = \sum_{i=1}^{n} [I^2_i R_i]$$

where,

$P_{La} = \sum_{i=1}^{n} [I^2_{ai} R_{ij}]$, Due to active component of the current

$P_{Lr} = \sum_{i=1}^{n} [I^2_{ri} R_{ij}]$, Due to reactive component of the current

5. We calculate the power loss (*new*) associated with the active component of branch current when DG is connected.

It is given by- $(P_{Lnew}) = \sum_{i=1}^{n} [I_{ai} + D_i I_{DG}]^2 R_i$

Where, D_i=1; if branch i$\epsilon\alpha$

=0; otherwise

$'\alpha'$ is the set of branches connected between the source and the bus m where DG is placed.

6. Repeat steps 1 to steps 5 and calculate P_L(new) as per algorithm proposed in this work.

7. The bus at which the total system loss will be minimum & cost efficiency holds good is the required location for placing the DG.

IV. SIMULINK DATA

Nominal Voltage: 11kV

No. of Generators: 2+1(Slack)

Generator MVA Base= 100

No. of DG: 1

No. of Load: 4

Size of DG: Min= 1MW & Max=10MW

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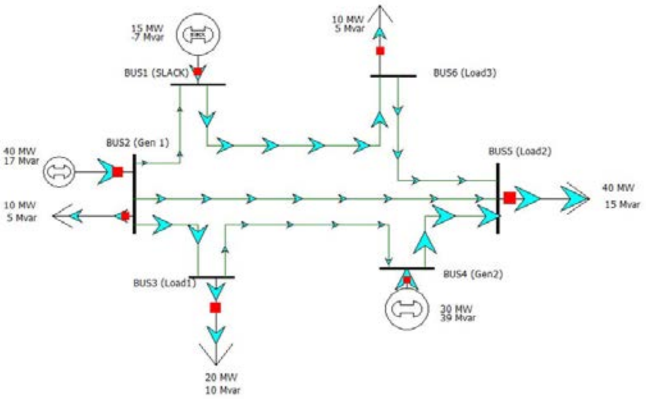

Fig. 1. IEEE 6-Bus system diagram

TABLE 1. LINE DATA MODIFICATION

From Bus	To Bus	Standard IEEE Data		Line Length in Simulink (km)	Modified Data	
		R_{pu}	X_{pu}		R_{pu}	X_{pu}
1	2	0.05	0.20	50	0.1553	0.6214
2	3	0.10	0.50	20	0.1247	0.6214
3	4	0.20	0.80	20	0.2485	0.9942
4	5	0.10	0.30	15	0.0932	0.2796
5	6	0.20	0.40	25	0.3107	0.6214
6	1	0.10	0.15	100	0.6213	0.9321
2	5	0.20	0.50	150	1.8641	4.6603

V. SIMULATION RESULT

TABLE 2. SYSTEM DATA WITHOUT DG

BUS NO.	NAME	NOM KV	PU VOLT	VOLT (KV)	ANGLE (DEG)	LOAD (MW)	LOAD (MVAR)	GEN (MW)	GEN (MVAR)
1	SLACK	11	1.0000	11.000	0			15.02	-7.33
2	GEN1	11	1.0410	11.451	-0.02	10	5	40	34.5
3	LOAD1	11	0.9929	10.923	-7.72	20	10		
4	GEN2	11	1.0710	11.781	-10.23			30	26.39
5	LOAD2	11	0.9659	10.626	-13.73	40	15		
6	LOAD3	11	0.9218	10.140	-10.04	10	5		

TABLE 3. SYSTEM DATA WITH DG

BUS NO.	NAME	NOM KV	PU VOLT	VOLT (KV)	ANGLE (DEG)	LOAD (MW)	LOAD (MVAR)	GEN (MW)	GEN (MVAR)
1	SLACK	11	1.0000	11.000	0			2.92	-10.24
2	GEN1	11	1.0410	11.451	1.44	10	5	40	34.03
3	LOAD1	11	0.9943	10.937	-5.21	20	10		
4	GEN2	11	1.0710	11.781	-6.10			30	25.18
5	LOAD2	11	0.9904	10.894	-9.48	40	15		
6	LOAD3+ DG	11	1.0000	11.000	-6.28	10	5	10	8.75

TABLE 4. PERCENTAGE LOSS REDUCTION

PARAMETER	WITHOUT DG	WITH DG	% LOSS REDUCTION
TOTAL LOAD (MW)	80	80	
TOTAL LOAD (MVAR)	35	35	
TOTAL GENERATION (MW)	85.0	82.9	
TOTAL GENERATION (MVAR)	48.5	43.8	
MW LOSS	5	2.9	42.00
MVAR LOSS	13.5	8.5	37.04

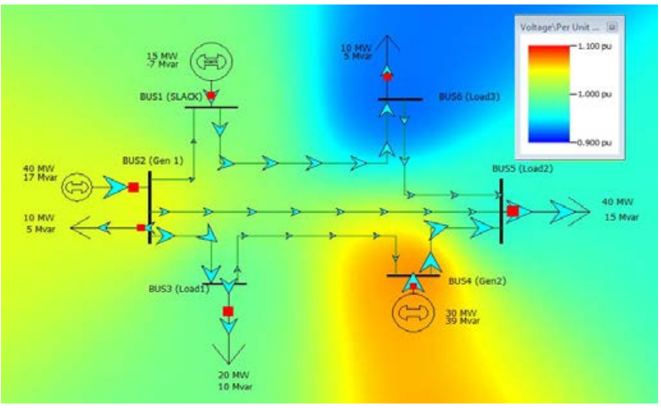

Fig. 2. Contouring Of Per Unit Bus Voltages Without DG

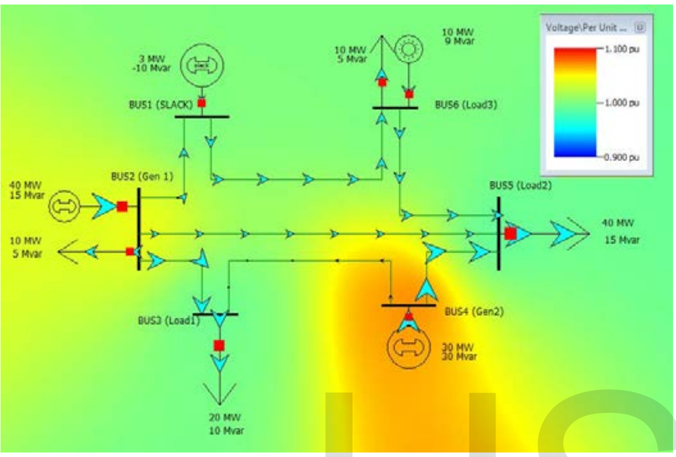

Fig. 3. Contouring Of Per Unit Bus Voltages With DG

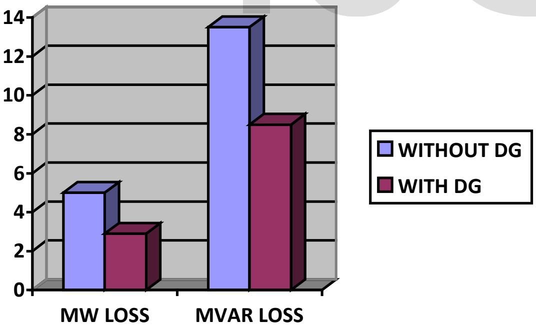

Fig. 4. Losses with and without DG

VI. CONCLUSION

Experiment was carried out to explore the optimal location of DGs in 6 bus system. Location and capacity of DG are the two important parameters for installation of DG in any system. The analysis of the results showed that the DG must be placed in particular location in order to get minimum losses. Manually it becomes lengthy and tough procedures to insert DGs in each point and find the losses at each point. The proposed procedure with the combination of DG algorithm and Newton-Raphson method minimizes the labour and provides efficient and effective results in less time with little complexity.

The electricity world of future will reach a new face if Conventional power and Distributed power generation work together well. With the development of distributed power, distributed power generation technology in large-scale power grids will play an important positive role in incident. So our future intended work is optimizing DG penetration in higher bus system.

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VIII. REFERENCES

[1]. Mohd Ilyas, Syed Mohammed Tanveer, and Asadur Rahman, ‘’ Optimal Placement of Distributed Generation on Radial Distribution System for Loss Minimization & Improvement of Voltage profile”. IJMER Vol.3, Issue 4, July 4 Aug.2013, PP 2296-2312.

[2]. Srikanth Apparaju, Sri Chandan K, “ Impact of DG on Voltage levels in Radial Distribution System”, IJERA Vol.1, Issue 2, PP 277-281.

[3]. Bhakti Nitve, Rajani Naik, “Steady State Analysis of IEEE 6-Bus system using PSAT power toolbase”. IJESIT Vol. 3, Issue 3, May 2014.