Identify the Impact of Distributed Resources on Congestion Management

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Abstract

In the electrical systems, as load never be constant it varies from time to time. Apart from generation, transmission and distribution plays very important role. Congestion management is one of the effective methods in power systems. From the point of reducing congestion or overloading, distributed generators (DG) should be placed at strategic locations in order to exploit maximum benefits out of them. This paper provides particle swarm optimization (PSO) technique through which distributed generators are placed with an objective function of improving voltage stability. These DG units are connected in parallel with the utility grid and they are placed depending upon the availability of resources. These DG units can have impact on the practices in distribution systems such as voltage stability, reliability, voltage profile, power quality and protection. For this proposed approach is simulated in MATLAB environment by testing on IEEE33-bus and 69-bus distribution systems.

Keywords: *DG(distributed generator) ,PSO(particle swarm optimization, objective function ,voltage stability, power quality, voltage profile.*

I.INTRODUCTION

Congestion or overload in one or more transmission line may occurs due to coordination failure between generation utilities and transmission utilities or as a result of unexpected circumstances such as unplanned outage in generation, sudden increase of load demand, or equipment failure. Therefore, congestion management is one of the key functions of any system operator in the restructured power industry.

One of the key issues for secure and reliable system operations in electricity markets is overload management [1]. As many of the developing countries facing major problem is meeting the increasing power demand. Also for such operations in electricity market, the loads of distribution systems are usually treated as projected loads on the point of common coupling in electrical power systems. It is acknowledged that, in some cases, load demand control can be more effective than generation rescheduling to mitigate congestion[2]-[4].with growing demands ,Distributed Resources (DR's),including distributed generation and energy storage devices, are emerging in the industries and being dispersed throughout distribution and sub transmission systems to provide load services. it is expected that distributed resources will cover 25% of the load increase in coming 10 years in North America[5].Mainly congestion occurs if the dispatching of transactions in electricity markets exceeds the static and dynamic operation limits of transmission facilities. Congestion management issues are especially set of very complex optimization problems. The real and reactive power provided by DR's not only affects the local voltage in distribution networks, but also can cause variations in the power flow and loading conditions in the grid. Regulating voltage at the point of common coupling in distribution system is not the job of DR's, for accurate margin analysis, both the base case and the most restrictive constraints can be changed if DR devices are not present. In turn, they are helpful for electrical power system security control, they can also introduced in ancillary markets [6],[7].congestion management methods based on optimal power flow use the imitative of the function in order to determine the search direction. However, in general objective function of optimal power flow is in terms of differ in outputs[11] because of point loading of thermal units. In recent years, particle swarm optimization (PSO) method proposed by Kennedy and Eberhart [12] has been one of the popular methods used for solving complex nonlinear optimization problems such as optimal power flow [13],[14],operation schedule of generating units[15],overload management[16],etc.,.

As the society's dependency on electrical energy is greater than ever and will keep increasing in future, the analysis of a distribution system is an important area of study because distribution system along with providing vital link between the bulk power system and the consumers is the major source of power loss. A distribution circuit normally contains primary or main feeders and lateral distributors. A main feeder originates from the distribution substation and passes through the major areas of demand [4],[5].And proceeding distributors connect the individual transformers at their ends. In general, most of the distribution systems used now are have a single circuit with main feeder and are defined as radial distribution systems which are very popular now a days.

The Distribution Generation also treated as power compensation due to injection of active power by the distribution generator unit, current in the feeders comes down reducing power loss and thereby improving the voltage profile. Some of the DG applications are power loss reduction, voltage improvement, environmental friendliness and increased reliability [3], [4].

II.INSTALLATION OF DISTRIBUTION GENERATION UNIT

The installation of DG units to minimize losses is similar to locating capacitor banks to reduce losses in the system. In both cases the main difference is that DG unit may contribute active (P) and reactive power (Q). Whereas capacitor banks for reactive power flow only (Q)[5].The installation of DG units in systems are originally radial and designed to operate without any generation on distribution system ,can significantly impact power flow and voltage conditions at both end users and utility equipment locating DG units. And locating DG units also plays a vital role in achieving better benefits of the system with reduced loses and increase the system performance. The DG installation can impact the overall voltage profile .with placement of DG units can increase the voltage at feeder of distribution networks in the areas where short duration reduction in rms voltage by short circuit or total loss of power cases are concern of utilities. Borges and Falcao in 2003 already discussed impact of placing DG unit in a system and its operation on reducing losses and however research work analyzes the impact of DG on voltage regulation and losses as well as voltage flickers and harmonics are also caused by DG if it is not located properly. Also determination of maximum power that distributed generator (DG) inject into a system without causing steady state voltage violations is difficult. So with one DG unit affects all the nodal voltages in the system.

The main DG placement can be formulated by many objective functions including,

1. Power loss reduction.
2. Environmental friendliness.
3. Voltage improvement.
4. Increasing reliability.

III.VOLTAGE STABILITY INDEX

In general power system stability is defined as the characteristics of a power system to remain in state of equilibrium even after disturbance .Mainly stability deals with a system behaviour with normal as well as after interruption. A power system is said to be unstable whenever voltage after disturbance decrease due to failure of equipment, increase of demand, decrement of generation to meet demand.

Voltage instability arises mainly from load dynamics where system behaviour is influenced by voltage and frequency to re-establish energy consumption beyond the ability of production system. Voltage instability leads to voltage collapse, this condition results significantly when the reactive losses exceeding the reactive resources available to supply them and circuits are loaded above surge impendence loadings and reduced output of capacitors as voltages decline can lead to voltage drops.

Causes of Voltage Instability

The main causes of voltage instability are,

1. When the load on the transmission line is too high.
2. When the voltage sources are too far from the load centres.
3. The source voltages are too low.
4. When there is insufficient load reactive compensation.

With the help of voltage stability index we can calculate the extent of stability of radial distribution networks and thereby necessary steps can be taken if the index indicates a poor level of stability[8],[9]. Voltage stability index is used to find out the most critical node for voltage collapse. The lower the value of VSI shows more critical node and there by placing DG at the node having VSI less value can enhance the loadability of the system and voltage profile of the nodes. In order to calculate the voltage stability index the following is the equation employed as equation.1,

Equation (1),

$$SI(m2) = \{|V(m1)|^4 - 4.0\{P(m2)X(jj) - Q(m2)R(jj)\}^2 - 4.0\{P(m2)R(jj) + Q(m2)X(jj)\}|V(m2)|^2\}$$

Where,

SI (m2) =voltage stability index of node m2 (m2=2, 3 ,...NB).

(m2)=receiving end node.

V(m1)=voltage at node 1.

P(m2)=total real power fed through node 2.
Q(m2)=total reactive power fed through node 2.
R=resistance of branch 1.
X=reactance of branch 1
For better benefits always the voltage stability index is greater than or equals to zero,
SI (m2) ≥0, for m2=2,3,......NB.

After the load flow study, the voltages of all the nodes are known, the branch currents are known, therefore P(m2) and Q(m2) for m2=2,3,.....NB can easily be calculated using and hence one can easily calculate the voltage stability index of each node(m2=2,3,..NB).the node at which the value of stability index is minimum, is more sensitive to voltage collapse [9],[10].

IV.PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is a simple and efficient population-based optimization method proposed by Kennedy and Eberhart in 1995(Randy etal,.2004) [12].PSO is obtained by movement and behaviour of particles. The particle swarm optimization refers to importance of enhancing the best result out of many particles for a problem which is carried out in order to evaluate fitness. Generally in this optimization, input solutions called particles move around in a search space, group of particles is nothing but swarm. Each particle in group movies in the search space towards the optimum or a quasi-optimum solution based on its own experience, experience of nearby particles, and global best position among particles in swarm.

Each particle having own best solution is called particle best or pbest. The maximum best solution among local best is nothing but global best. Each particle makes its information available to neighbours. The changes to the position of particles within search space are based on social-psychological tendency of individuals to emulate the success of their individuals. A group consists of a set of particles, where each particle represents a best solution .particles are then flown through hyperspace, where the position of each particles changed according to own experience and that of its neighbours. Let xi (t) denotes the particles position pi is modified by inclusion of velocity vi (t) to the current position. The velocity vector drives the optimization process and reflects the exchanged information .These are discussed in three stages in detailed manner, those three stages are individual best, local best and global best[13],[14].

A. Individual best

Each individual particle maintains its position, composed of the candidate solution and its evaluated fitness, and its velocity. That particle compares its current position to its own best position, xpbest .Additionally it remembers the best fitness value it has achieved thus far during the process, this can be called as individual best fitness, and the candidate solution that achieved this fitness, referred to as individual best position or best.

The larger change in velocity to return the individual towards best position.

This can be explained in following steps,

Step.1: Initialize the swarm, pi(t) of particles of position xi(t) of each particle. pi(t) is random throughout the search space ,with t=0.

Step.2: Evaluate the performance of using each particles current position xi(t).

Step.3: Compare the performance of each particle to its best performance as,

$$F(xi(t)) < pbest \quad , then$$

$$pbesti = F(xi(t)) \quad (2)$$

$$xpbesti = F(xi(t)) \quad (3)$$

Step.4: Change the velocity vector for each particle using equation,

$$vi(t) = vi(t-1) + p(xpbest - xi(t)) \quad (4)$$

Where p, is a positive random number.

Step.5: Move each particle towards its new position.

$$xi(t+1) = xi(t) + vi(t+1) \quad (5)$$

Step.6: go to step.2, repeat until convergence.

B.Global Best

Generally calculation over for pbest obtaining the best value out of them is achieved among all particles in the swarm, called the global best fitness, and particle solution that obtained the fitness, called the global best position or global best particle solution. The social knowledge used to drive the movement of particles includes the position of best particle from the entire swarm. In addition, each particle uses its history of experience in terms of own best solution. Then the steps changes as,

Step.1: Initialize the swarm, p(t),of particles such that the position xi(t) of each particle p(t) is random within the search space, with t=0.

Step.2: Evaluate the performance of each particle, using its current position xi(t).

Step.3: compare the performance of each individual to its best performance,

$$\text{if } F(xi(t)) < pbestthen$$

$$pbesti = F(xi(t)) \quad (6)$$

$$xpbesti = xi(t) \quad (7)$$

Step.4: compare performance of each particle to global best particle:

$$\text{if } F(xi(t)) < xgbestthen$$

$$xgbest = F(xi(t)) \quad (8)$$

$$xgbest = xi(t)$$
(9)

Step.5: now by changing velocity vector for each,

$$vi(t) = vi(t-1) + C1(xpbesti - xi(t)) + C2(xgbest - xi(t))$$
(10)

Where C1 and C2 are random variables. The second term is defines as cognitive and last is social component.

Step.6: Now move each particle to new position and go to step.2 repeat the process until convergence.

C.Convergence

As xpbest is local best value which is obtained as particles influenced by best position with its own experience or by neighbourhood. While xpbest is slower in convergence than xgbest bust results best solution and searches a large part in search space. As fitness function which is used to measure closeness of corresponding particle solution to optimum in computing, this measures the performance of particles in step.2 of xpbest and xgbest.

Usually PSO is executed under a fixed number of iterations or fitness evaluations or the velocity changes reaches zero or no particles position changing.

V. PSO PARAMETERS INVOLVED

Generally standard PSO influenced by six system parameters. Which are discussed below,

A. Dimension of problem

As the dimension of problem corresponds to the particles involved as the dimension of problem increases results in increase of complexity of system.

B. Number of Individuals

Number of individuals refers to number of particles or size of the population, which directly depend on dimension of the problem.

C. Range of P

The range of particles position is set to 1 as the values are randomly generated and ranges between 0 and 1.

d. Velocity of the particle

An upper limit is placed on velocity in all dimensions. Also this limitation prevents the particle movement with rapid speed in search space.

If $vi(t) > v\max$ then

$$vi(t) = v\max$$
(12)

If $vi(t) < -v\max$ then

$$vi(t) = -v\max$$
(13)

E. Neighbourhood size

The smaller the neighbourhood radius, the more neighbourhoods can be used, the less susceptible PSO to local minima .A larger part of search space is traversed, and no one solution has an influence on all particles. The more neighbourhoods there are, the slower convergence [1],[15],[16][17].

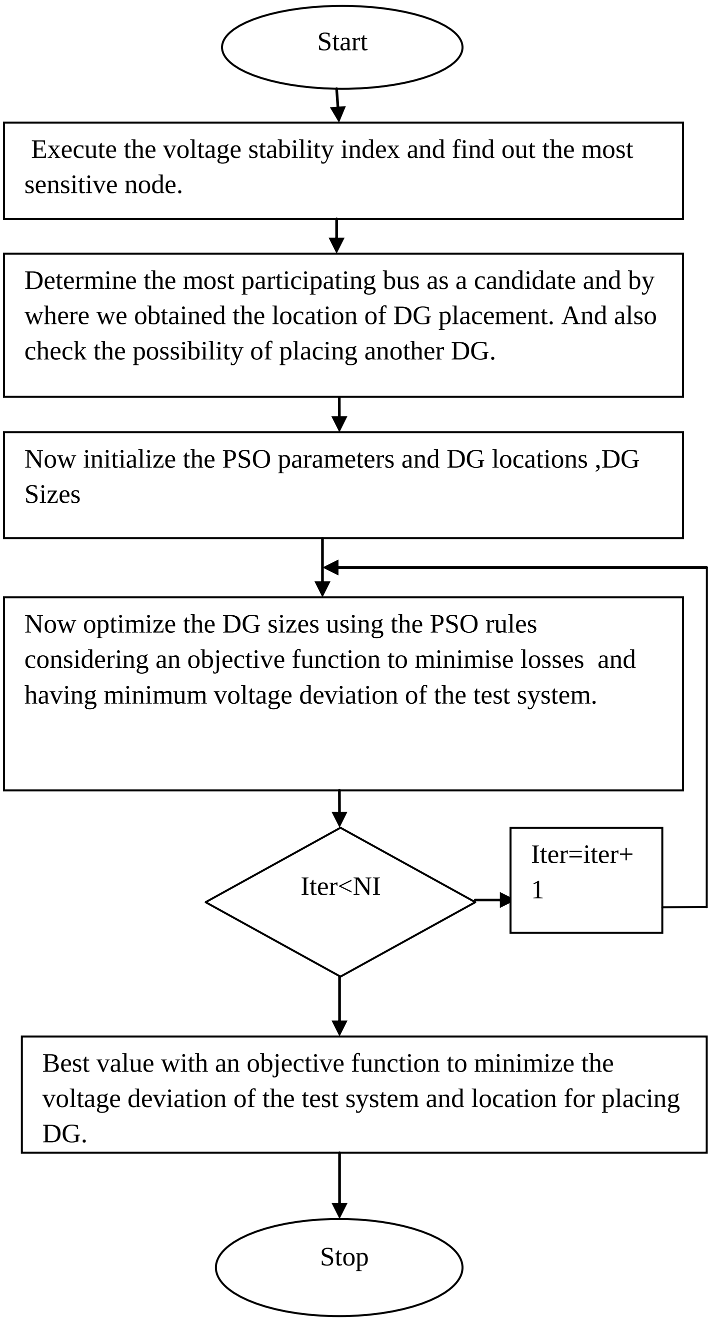
F. Inertia weight

Improved performance can be achieved through application of inertia weight applied to previous velocity:

$$vi(t) = w(j) * vi(t-1) + C1(xpbest - xi(t)) + C2(xgbest - xi(t))$$

Where w(j) is inertia weight which controls influence of previous velocities on new velocity. As the value of w(j) directly depends on search space.

VI.FLOWCHARTOF PROPOSED METHOD



VII.SIMULATION RESULTS

In practice, as we know that load varies with time to time. The optimal placement of DG location and size may vary with the demand. And it is not a economical to change DG size and location with result to load demand. So in order to place DG location and size based on load factor criteria peak load and average load conditions are taken into study[18],[19],[20].In this project ,we went through both cases and studied the cases with and without DG with an objective function to minimise voltage drop.

Here we have chosen two test radial distribution systems, the first one is 33 bus test system and the second is 69 bus test system.

In the 33-bus radial distribution system with a load of 3.72MW,2.3Mvar,33 bus ,and 32 branches and power loss is 210.998kw.A PQ model is considered for this system and the voltage and voltage stability index at each node at base case is shown in table.1.when the weakest bus is found at bus18 whose value is 0.6695.the voltage corresponding to it is 0.9039. so after after identifying the weakest bus in test system .1 an optimal DG unit using PSO is placed which results in improvement of voltage at all nodes as shown in table.2 minimum vsi at node33 also by placing another for further improvement is observed. for third DG at node25.

TABLE..I: Voltage Magnitude (p.u) and Voltage Stability Index of Each Node For 33-Node Radial Distribution Network at Base Case and Also With DG's

Node number	Voltage magnitude in P.U	Voltage stability index	1-DG Unit Case	2-DG Unit Case	3-DG Unit Case
1	1.0000	-	1.0000	1.0000	1.0000
2	0.9970	1	0.9979	0.9986	0.9988
3	0.9829	0.9881	0.9885	0.9933	0.9940
4	0.9753	0.9333	0.9845	0.9923	0.9928
5	0.9679	0.9051	0.9807	0.9916	0.9920
6	0.9495	0.8778	0.9700	0.9878	0.9878
7	0.9459	0.8127	0.9683	0.9858	0.9858
8	0.9323	0.8004	0.9705	0.9862	0.9854
9	0.9260	0.7554	0.9737	0.9882	0.9870
10	0.9203	0.7351	0.9773	0.9906	0.9890
11	0.9194	0.7172	0.9783	0.9913	0.9896
12	0.9179	0.7145	0.9803	0.9928	0.9909
13	0.9117	0.7098	0.9877	0.9984	0.9959
14	0.9094	0.6909	0.9904	1.0004	0.9977
15	0.9080	0.6840	0.9944	1.0036	1.0077
16	0.9066	0.6797	0.9999	1.0081	1.0048
17	0.9046	0.6755	1.0096	1.0162	1.0123
18	0.9039	0.6695	1.0158	1.0213	1.0172
19	0.9965	0.6677	0.9974	0.9981	0.9982
20	0.9929	0.9860	0.9938	0.9946	0.9947
21	0.9922	0.9719	0.9931	0.9938	0.9940
22	0.9916	0.9692	0.9925	0.9932	0.9933
23	0.9793	0.9667	0.9849	0.9897	0.9911
24	0.9726	0.9195	0.9783	0.9831	0.9859
25	0.9693	0.8945	0.9750	0.9798	0.9840
26	0.9475	0.8827	0.9681	0.9878	0.9879
27	0.9450	0.8061	0.9656	0.9880	0.9880
28	0.9335	0.7973	0.9544	0.9869	0.9870
29	0.9253	0.7594	0.9464	0.9866	0.9866
30	0.9217	0.7330	0.9429	0.9880	0.9880
31	0.9176	0.7213	0.9388	0.9931	0.9932
32	0.9167	0.7089	0.9380	0.9951	0.9952
33	0.9164	0.7060	0.9377	0.9980	0.9981

As it is observed that voltage at each bus and loadability of system increases with increase of the number of DG units and also the real power losses *are decreasing.*

TABLE. II: Voltage Magnitude (p.u) and Voltage Stability Index of Each Node for69 –Node Radial Distribution **System at Base Case and also With DG's**

Node number	Voltage magnitude in P.U	Voltage Stability index	1-DG Unit Case	2-DG Unit Case	3-DG Unit Case
1	1.000000	----	1	1	1
2	0.999967	0.999916	1	1	1
3	0.999933	0.999788	0.9999	0.9999	1
4	0.999839	0.999553	0.9999	0.9999	0.9999
5	0.999021	0.997900	0.9993	0.9995	0.9996
6	0.990087	0.986897	0.9941	0.9962	0.9978
7	0.980796	0.951732	0.9887	0.9874	0.9868
8	0.978580	0.923243	0.9874	0.9920	0.9955
9	0.977477	0.916709	0.9868	0.9917	0.9954
10	0.972450	0.909492	0.9818	0.9909	0.9939
11	0.971349	0.893694	0.9807	0.9908	0.9936
12	0.968191	0.888902	0.9776	0.9914	0.9934
13	0.965269	0.876880	0.9747	0.9937	0.9948
14	0.962373	0.866351	0.9718	0.9962	0.9963
15	0.959505	0.855973	0.9690	0.9988	0.9978
16	0.958972	0.847306	0.9684	0.9993	0.9981
17	0.958093	0.845263	0.9676	1.0004	0.9988
18	0.958084	0.842609	0.9676	1.0004	0.9988
19	0.957619	0.842278	0.9671	1.0016	0.9997
20	0.957321	0.840757	0.9668	1.0024	1.0003
21	0.956839	0.839791	0.9663	1.0036	1.0012
22	0.956833	0.838212	0.9663	1.0037	1.0013
23	0.956761	0.838145	0.9663	1.0044	1.0019
24	0.956604	0.837888	0.9661	1.0060	1.0031
25	0.956435	0.837281	0.9659	1.0097	1.0060
26	0.956365	0.836778	0.9659	1.0112	1.0072
27	0.956346	0.836557	0.9658	1.0120	1.0079
28	0.999926	0.999719	0.9999	0.9999	0.9999
29	0.999854	0.999595	0.9999	0.9999	0.9999
30	0.999733	0.999326	0.9997	0.9997	0.9997
31	0.999712	0.998917	0.9997	0.9997	0.9997
32	0.999605	0.998767	0.9996	0.9996	0.9996
33	0.999349	0.998294	0.9994	0.9994	0.9994
34	0.999013	0.997340	0.9990	0.9990	0.9990
35	0.998946	0.996059	0.9990	0.9990	0.9990
36	0.999919	0.999701	0.9999	0.9999	0.9999
37	0.999747	0.999316	0.9998	0.9998	0.9998
38	0.999589	0.998707	0.9996	0.9996	0.9996
39	0.999543	0.998289	0.9996	0.9996	0.9996
40	0.999541	0.998170	0.9996	0.9996	0.9996
41	0.998843	0.996956	0.9989	0.9989	0.9989
42	0.998551	0.994867	0.9986	0.9986	0.9986
43	0.998512	0.994153	0.9985	0.9985	0.9985
44	0.998504	0.994047	0.9985	0.9985	0.9985
45	0.998405	0.993938	0.9984	0.9984	0.9984
46	0.998405	0.993636	0.9984	0.9984	0.9984
47	0.999789	0.999230	0.9998	0.9998	0.9998
48	0.998545	0.996267	0.9986	0.9986	0.9986
49	0.994704	0.989220	0.9947	0.9947	0.9947
50	0.994160	0.978981	0.9942	0.9942	0.9942
51	0.978545	0.917031	0.9874	0.9920	0.9955
52	0.978535	0.916901	0.9873	0.9920	0.9955
53	0.974660	0.910105	0.9857	0.9907	0.9953
54	0.971418	0.899356	0.9845	0.9895	0.9951
55	0.966944	0.886287	0.9829	0.9880	0.9950
56	0.962576	0.870106	0.9814	0.9866	0.9960
57	0.940102	0.843569	0.9751	0.9805	0.9970

58	0.929042	0.774212	0.9720	0.9776	0.9980
59	0.924765	0.742544	0.9708	0.9765	0.9985
60	0.919740	0.728603	0.9697	0.9755	0.9994
61	0.912343	0.713809	0.9675	0.9734	0.9999
62	0.912054	0.692633	0.9681	0.9741	1.0001
63	0.911666	0.691656	0.9691	0.9751	1.0005
64	0.909766	0.690450	0.9740	0.9801	1.0022
65	0.909191	0.685059	0.9833	0.9895	1.0067
66	0.971293	0.890285	0.9807	0.9908	0.9986
67	0.971292	0.890028	0.9807	0.9908	0.9935
68	0.967861	0.878592	0.9778	0.9928	0.9932
69	0.967860	0.877509	0.9778	0.9982	0.9985

VIII. SIMULATION RESULTS

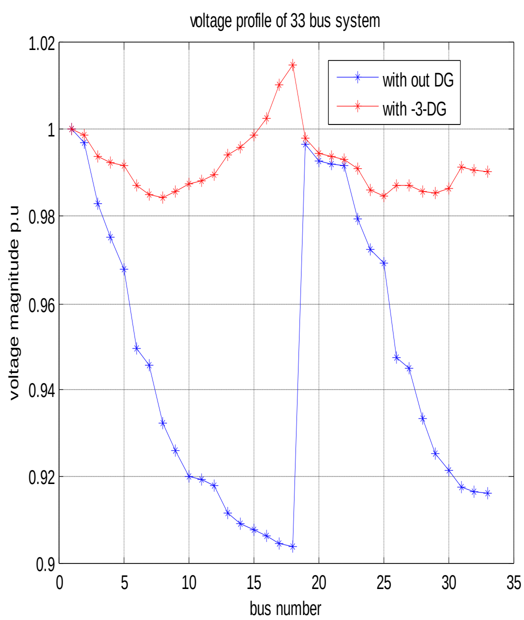


Fig.1 voltage magnitude in P.U for 33-bus system(with and without DG)

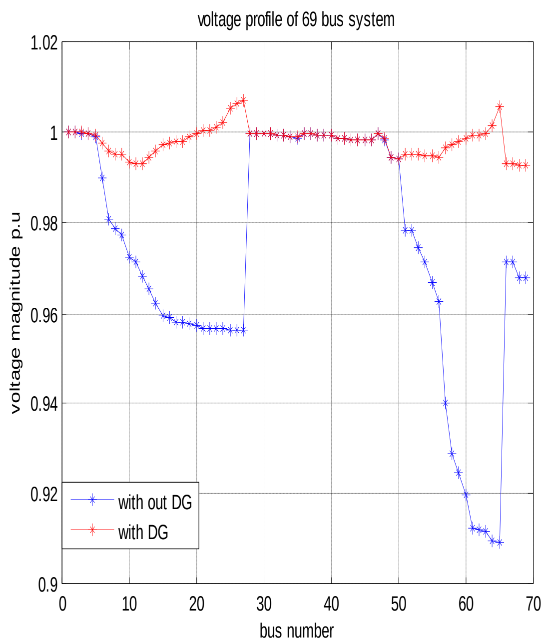


Fig.2 voltage magnitude in P.U for 69-bussystem (with and without DG)

The maximum voltage deviations of test systems that is both 33-bus and 69 bus systems for different cases of DG injection can be shown in tabular form,

TABLE.3:voltage deviation for different systems

	Voltage deviation (p.u)			
Test systems	Without DG	One DG	Two DG	Three DG
33 bus system	0.1335	0.0295	0.0034	0.0032
69 bus system	0.0991	0.0272	0.0068	8.667e-0025

IX. CONCLUSION

The project work has been carried out to find out the optimal location and size of DG unit(MW) to be placed in radial distribution system for minimum voltage deviation and to reduce the losses in order to obtain maximum beneficial output.

The optimal size is found using particle swarm optimization algorithm . A coding is developed in MATLAB environment. The study has been carried out on both 33-bus and also 69-bus radial distribution system with DG placement to overcome the overloading criteria. From the case study the following conclusions are drawn

- With single unit DG placement the voltage at all nodes have the effect that is observed when we placed the DG at weakest bus, we can observe that the voltages at all nodes in the system improved compared to the case of without DG placement.
- Also the loadability of the system is increased by placing DG units at optimal location.
- As the DG penetration level is increased, the increase in loss reduction is not much compared to the penetration level.
- As the loadability of the system increases with the increase in number of DG units whereas the power losses are decreasing, this is expected through the project.

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