ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 10, October 2016

Optimal Distributed Generator Allocation Using Particle Swarm Optimization

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Abstract: **-- The distributed generation (DG) is one of the viable alternatives for reducing the problem of load growth, over loading of lines, quality of supply, reliability of equipment through mitigating power losses. Loss reduction is one of the prime objectives for planning of distributed generation. To improve the performance of the distribution system, optimal placement of distributed generators is critically important as identifying the location and size. Introducing DG's in distribution networks leads to reduce power loss with distribution loss allocation approach in primary distribution networks. In this paper, optimal placement of DG units using loss allocation approach with Particle Swarm Optimization (PSO) is proposed. This approach aim to minimize active power loss by placing DG in a radial distribution system by optimizing the objective function based on power loss and cost. The performance of the proposed approach is performed on standard IEEE buses and practical distribution networks.**

Index Terms—- Distributed generation, Loss allocation and sizing, Distributed OAD flow and Loss reduction.

I. INTRODUCTION

Distribution system is an integral part of power system which have been more focused nowadays due to rapid load growth Loss reduction is the major challenge in distribution network various loss reduction technology have been implemented but there is a scope to minimize these losses as compared with transmission networks. Among various power generations, thermal generation plays major share which leads to deplete fossil fuel reserves day by day. It shows the alarming situation on the fuel reserve capacity for future generations. Exploring alternative power generation to contemplate the growing load demand, renewable energy sources is the good alternative. Use of renewable energy distribution networks are to be decentralized by connecting distributed generation units where power is generated at the load points. Generating power on site has many economical and technical benefits Optimum location and size of DG's in a distribution network rather than random allocation would give the mitigation of losses, cost of energy and improved reliability.

Comparison of novel combined Loss sensitivity, Index vector and Voltage sensitivity index methods were presented for optimal location and sizing of DG in a distribution network [2]. A two stage approach is proposed [12] for DG allocation in radial distribution system using particle swarm optimization for loss minimization and voltage profile improvement in radial distribution system. A new algorithm for energy summation has been introduced for DG allocation in distribution network [7]. A comparison of exact method and its three alternative algorithms, namely, pro rata quadratic allocation and proportional allocation for DG allocation are presented [8]. Placement of DG in radial distribution network has been demonstrated [13] using GA for minimum system losses in radial distribution. Simultaneous reconfiguration and DG allocation for a 33 bus radial distribution system is proposed [9] with a MPGSA algorithm.

In these papers distributed generations which are smaller power sources like solar photovoltaic cells or wind turbines connected in the customer roof top are considered. A mixed-integer linear programming approach to solving the problem of optimal type, size and allocation of distribute generators (DGs) in radial distribution systems [11]. Fuzzy expert system (FES) is used to select the best candidate node for capacitors to be installed in order to maximize total loss reduction and total net savings. Addressing the issues related to loss allocation in radial distribution systems with DG, with a three-fold focus is presented [10]. However, this paper focuses optimal loss allocation and size of distributed generators based on loss allocation in the distributed networks using Particle Swarm Optimization.

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II. PROPOSED METHOD

In the proposed approach the DGs are optimally allocated in the radial distribution system for maximum reduction of active power loss and minimum investment cost. The proposed approach is carried out in two stages. In the first stage the buses for DG allocation are identified where the voltage is lower than the prescribed limits. In the next stage optimal size of DGs to be placed at the buses is determined using Particle Swarm Optimization. The proposed approach uses forward sweep method for load flow in radial distribution system.

A. Load flow

The proposed approach uses forward sweep method adopted to handle all types of load modeling due to its high R/X ratio rather conventional Newton Raphson method. A balanced load has been considered represented in three type's constant current, constant power, constant impedance or as an exponential load.

$$P(n)=Pn[a0+a1V(n)+a2V2(n)+a3Ve1(n)] \quad (1)$$

$$Q(n)=Qn[b0+b1V(n)+b2V2(n)+b3Ve1(n)] \quad (2)$$

Where Pn and Qn are nominal real and reactive power respectively and V (n) is the voltage at nodes n. For all the loads, equations (1) and (2) are modeled as

$$a0+a1+a2+a3=1.0 \quad (3)$$

$$b0+b1+b2+b3=1.0 \quad (4)$$

For constant power (CP) load a0=b0=1, ai=bi=0 for i=1, 2, 3. For constant current (CC) load a1=b1=1, ai=bi=0 i=0,2, 3. For constant impedance (CI) load a2=b2=1 and ai = bi=0 for I = 0, 1, 3. Composite load modeling is combination of CP, CI and CZ. For composite load a3 = b3 = 1 and ai = bi = 0 for i = 0,1, 2 and e1,e2 respectively.

B. Algorithm for load flow

The complete algorithm for load flow calculation of radial distribution network is shown below.

1. Read the total number nodes in a feeder (f), laterals (l) and sub lateral (s) respectively in a distribution network then the total number of nodes in Feeder

   Nt = f +l+s.

2. The node number of feeder is stored in a matrix Fn(i,j) where i=1,2,3….Nt and j=1,2,3…n(i) where in corresponds to the total number of nodes in the main feeder or corresponding lateral or sub laterals.

3. Read the common nodes to the feeder and laterals and store them.

4. Obtain the total number of branches equal to n(i)-1, where n(i) is the number of nodes in the corresponding feeder lateral or sub lateral i, store the branch numbers in a matrix Fb (i,j).

5. Read resistance and reactance of each branch as R (Fb(i,j) and X(Fb(i,j)).

6. Initialize base kV, base MVA, Maximum iteration itmax and convergence factor (ε =0.0001)

7. Assume voltage of each node of feeder as 1.000+ j0.000 p.u.

8. Initialize active power losses and reactive power losses of each branch are zero.

9. Use a suitable load modeling from the equation 1and 2.

10. Calculate the current in each node

$$Il(Fn(i,j)) = (P(Fn(i,j) - Q(Fn(i,j))/V(*(Fn(i,j))$$

11. Compute the current in each branch starting from the end node. Add current of the last branch I (n) to the current of preceding branch I (n-1). I (Fb (i, j)) = Il(Fn (i, j+1)) for end nodes I (Fb (i, j)) = I(Fb(i,j+1)) +Il(Fn(i, j+1)) for other nodes.

12. Compute the voltage at each node using equation V(Fn(i,j)) = V(Fn(i, j-1)) – I (Fn(i,j-1))Z(Fn(i,j-1)).

13. Compute ΔV(Fn(i,j)) = V(Fn(i,j))-V1(Fn(i, j)) for each node and find ΔVmax

14. Check if ΔVmax is greater than tolerance. Then increment the iteration count iter = iter+1 else converge solution

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15. Compute active power loss (Lp) and reactive power loss (Lq) for each branch Lp(Fb(i,j))=I(Fb(i,j))^2 R(Fb(i,j))

16. Print Solution

C. Particle Swarm Optimization

Particle Swarm Optimization is a heuristic search algorithm for optimal solution. This algorithm imitates the swarm behavior and their interaction for finding their food to search the solution of non linear problems. This algorithm executes in finding optimal values from swarm of particles through two essential reasoning capabilities like local best and global best. Each particle of swarm flies in search space or changes its position with a velocity and remembers its best position which gives minimum of objective function termed as p-best particle (local best or individual best) and the g- best (global best particle) which gives minimum of objective function among all p-best particles. Each particle decides its velocity according to its distance from personal best particle, global best particle and its previous velocity. Algorithm used for the proposed approach

1. Select locations for DG where the voltage profile is less than prescribed limits.

2. Initialize a swarm by initializing random particles in the search space. Where each particle represents size of the dg to be placed at the selected location.

Particle (n,m)=[DG1 DG2----DGm]

Where DG is the size of DG located at the sensitive location and m is the total number of location where Dg is to be allocated.

3. Initialize the PSO weight factors wo, w1, w2, W. where wo is the weight factors for previous velocity, w1, w2 is the weight factor for movement of particle towards p-best and g-best respectively.

4. Initiate random velocity for each particle.

5. For each particle if the voltage and line loading are in limits calculate the active power loss and objective function and determine its fitness.

6. Store the best fitness so far reached by each particle as its p-best value and the particle associated with as p-best particle.

7. Store the best fitness among all p-best as g-best and the particle associated with g-best particle.

8. Update the particle velocity and particle positions by equation

Velocity[n,m]=W*(w0*Velocity[n,m]+ w1* ([p-bestparticle[n,m] – particle[n,m]) + w2*(g-bestparticle [n] – particle[n,m]))

9. Update particles by adding the velocity particle (n,m)= particle(n,m) + velocity(n,m)

10. Evaluate and compare the objective function value with updated particles with p-best value. If the objective functions value is less than the p-best value set this value as current p-best, and the corresponding particle position as p-best particle.

11. Set the minimum p-best value and its corresponding position as current g-best and g-best particle.

12. Increment the iteration count if iteration count is not reached to maximum count then go to step. 8.

13. g-best particle gives the best optimal sizes of DG for selected n locations.

III. APPLICATION OF PROPOSED APPROACH

The proposed method is carried out on IEEE 34[10] for its validation bus. The 11 kV IEEE 34 bus network with 34 nodes and 33 branches with 4 lateral is show in Fig.1 the minimum voltage and active power loss obtained with the proposed load flow is 0.9417 p.u (bus no 27) and 220.67kW(for constant power method).

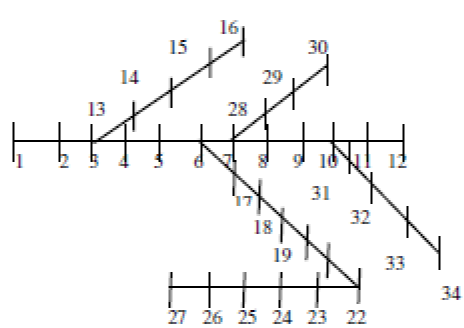

Fig.1 Single line diagram for IEEE 34 bus network

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 10, October 2016

The results obtained by the proposed approach for IEEE34 bus and 69 bus power loss, sensitive location for DG and their sizes are obtained for the proposed method at different load models are shown in the below table.1 and the voltage profile for the CP,CC and CI for different load model is shown in the below figure.

Table.1 Power loss and DG allocation table for IEEE 34 bus Network

Bus type 34 bus	DG location	DG size	Base case		Optimal case	
			Active	Reactive	Active	Reactive
Constant power	58 59 60 61 62 63 64 65	28.0 40.0 31.4 40.0 37.2 40.0 29.4 38.7	224.22	101.87	183.86	84.70
Constant current	59 60 61 62 63 64 65	40.0 35.3 40.0 38.3 37.2 29.4 33.9	19.266	88.58	140.27	66.01
Constant impedanc e	61 62 63 64 65	34.4 40.0 34.0 40.0 25.0	166.79	77.17	151.20	70.55

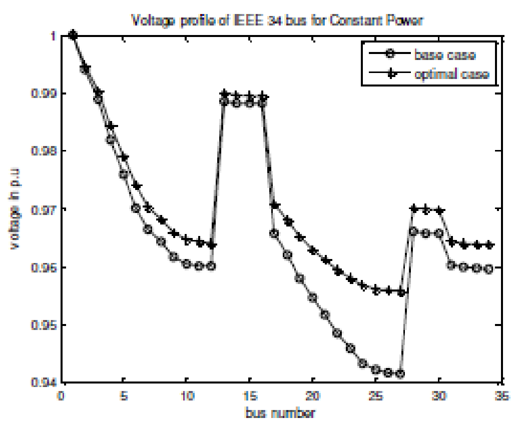

Fig.2Voltage profile of IEEE 34 for Constant Power Q

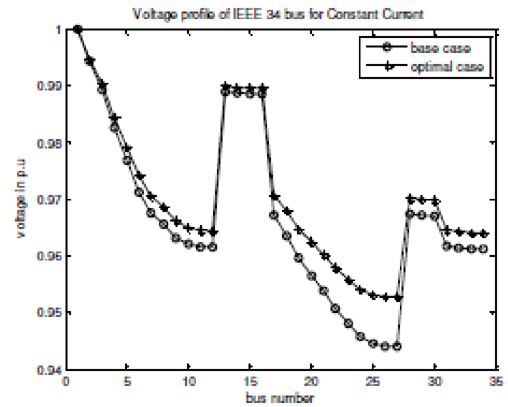

Fig.3Voltage profile of IEEE 34 for Constant Current

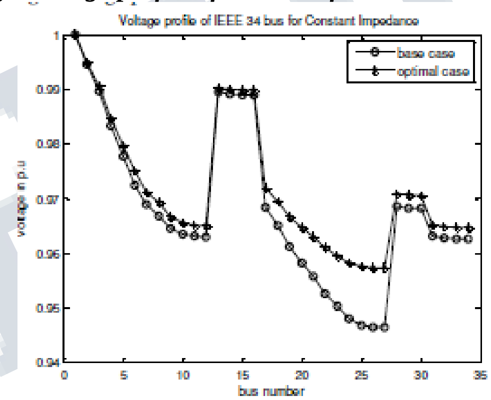

Fig.4 Voltage profile of IEEE 34 bus for Constant Impedance

The effectiveness of the proposed approach is verified on IEEE 34 bus network. The power loss, optimal DG sizes and locations at load models CP, CC and CI are shown the in below Table. 2, Table. 3 and Table. 4. For IEEE 69 bus. 33 bus and 28 bus. Voltage profiles of the networks at different load models are shown in the figure 5 to 13. This proposed method is carried out on IEEE 33 bus 69 bus and practical 28 bus network. the proposed method is implemented on IEEE 34 bus 33 bus and 69 bus networks and 28 bus network. After allocating optimal DG, Power loss is reduced as 27.05%, 18%, 68.8% and 23.36% from IEEE 34 bus, 69 bus ,28 bus and 33 bus respectively in constant power method (CP method) . The average power loss reduction is 34.3% In constant current method power loss is reduced by 17.8%, 32.51%, 15.88% and 13.84% from the above buses respectively, The average power loss is 20%.

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 10, October 2016

Table.2 Power loss and DG allocation table for IEEE 69 bus Network

Bus type 69 bus	DG location	DG size	Base case Power loss		Optimal case Power loss	
			Active	Reactive	Active	Reactive
CP	58 59 60 61 62 63 64 65	28.0 40.0 31.4 40.0 37.2 40.0 29.4 38.7	224. 22	101.87	183.86	84.70
CC	59 60 61 62 63 64 65	40.0 35.3 40.0 38.3 37.2 29.4 33.9	19.266	88.58	140.27	66.01
CI	61 62 63 64 65	34.4 40.0 34.0 40.0 25.0	166.79	77.17	151.20	70.55

Table.3 Power loss and DG allocation table for 33 bus network

Bus type 33	DG location	DG size	Base case		Optimal case	
			Active	Reactive	Active	Reacti ve
CP	14 15 16 17 18 31 32 33	40.0 37.6 30.4 37.0 36.4 40.0 23.7 38.5	197.55	131.03	151.39	99.47
CC	13 14 15 16 17 18 30 31 32 33	27.6 39.3 32.7 29.8 37.9 34.4 37.7 33.2 39.8 40.0	174.23	115.35	146.60	96.37
CI	14 15 16 17 18 31 32 33	34.5 33.9 37.5 29.7 33.4 33.3 40.0 34.4	153.83	101.65	132.52	86.93

Table.4 Power loss and DG allocation table for 28 bus network

Bus type 28 bus	DG location	DG size	Base case Power loss		Optimal case Power loss	
			Active	Reactive	Active	Reactive
CP	7 8 9 10 22 23 24 25 26 27 28	31.4 37.7 40.0 29.5 40.0 33.2 40.0 40.0 31.7 24.1 27.2	67.9	45.4	31.6	21.2
CC	24 25 26	32.4 37.6 32.6	58.97	39.43	33.04	22.12
CI	7 8 9 10 22 23 24 25 26 27 28	31.8 31.4 39.7 37.3 28.3 22.9 40.0 32.1 39.8 36.4 34.3	51.19	34.22	28.0	18.86

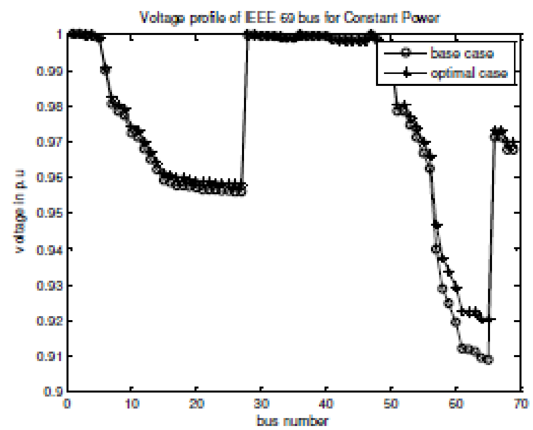

Fig .5 Voltage profile of IEEE 69 bus at constant power

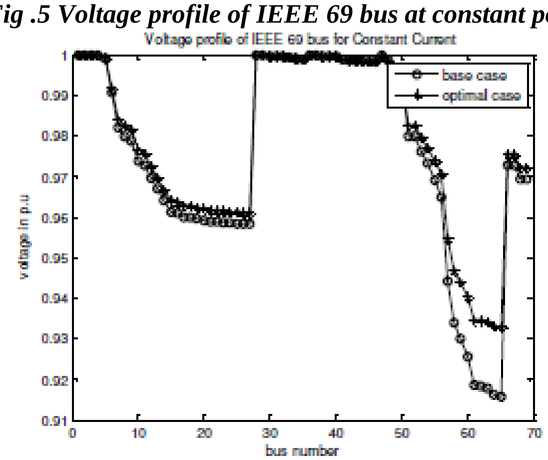

Fig.6 Voltage profile of IEEE 69 bus for Constant Current

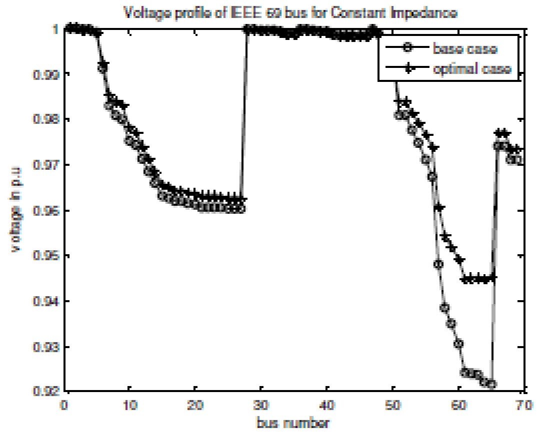

Fig.7 Voltage profile for IEEE 69 bus Constant Impedance

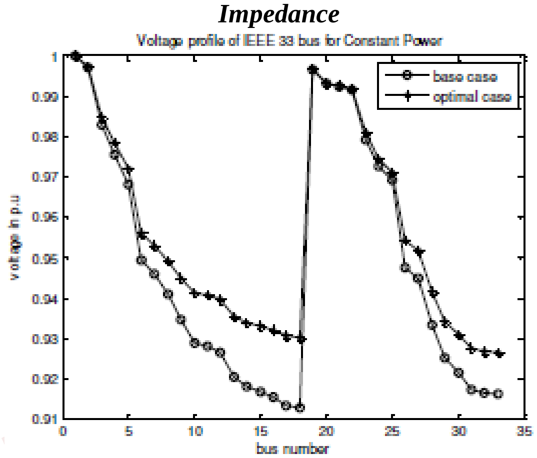

Fig.8 Voltage profile of IEEE 33 bus for Constant Power

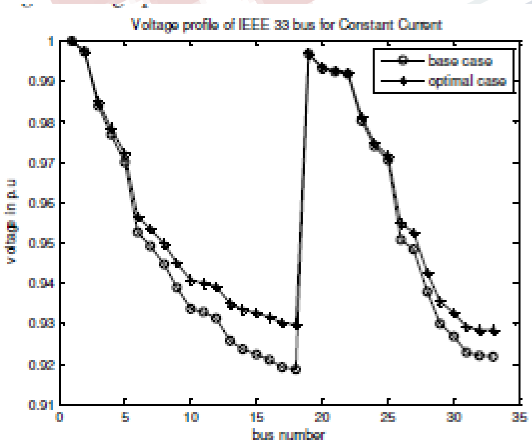

Fig.9 Voltage profile of IEEE 33 bus for Constant Current

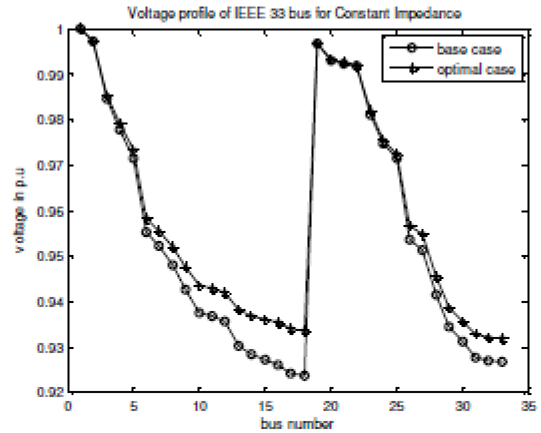

Fig.10 Voltage profile of IEEE 34 bus for Constant Current

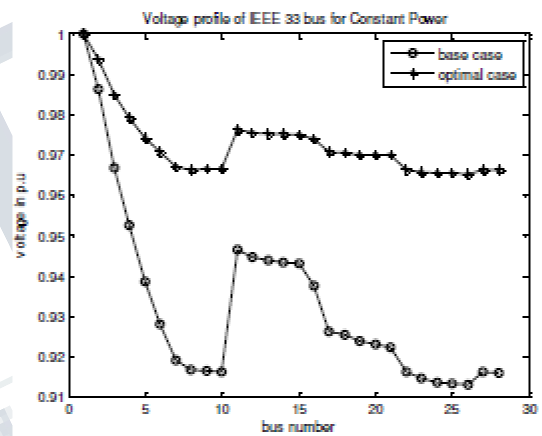

Fig.11 Voltage profile of 28 bus for Constant Power

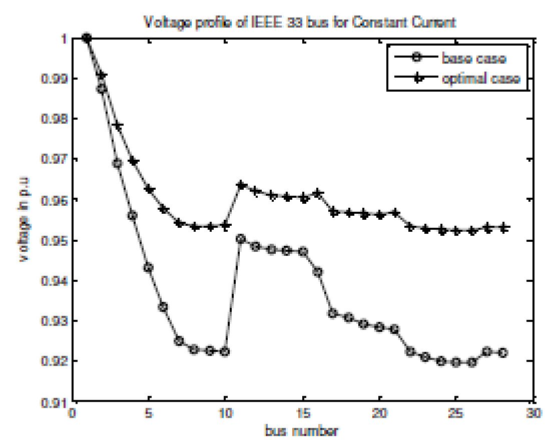

Fig.12 Voltage profile of 28 bus for Constant Current

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ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 10, October 2016

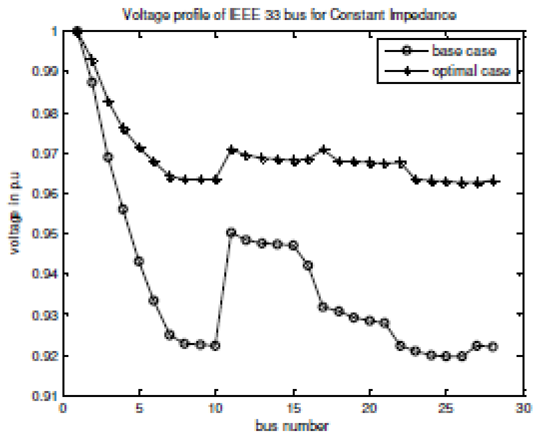

Fig.13 Voltage profile of 28 bus] for Constant Current

Table.5 Cost and benefit ratio of IEEE 34 bus and 69 bus Network

	34 bus			69 bus		
	CP	CC	CI	CP	CC	CI
Base network power loss	220.67	202.18	185.29	224.22	193.20	166.79
Optimal case power loss	160.52	162.86	152.28	183.86	140.27	112.56
Reduction in power loss	60.15	39.32	33.00	40.36	52.98	54.23
Benefit	3251200	2112600	2244000	1767800	2482200	2375300
Cost of DG	400000	7000000	500000	600000	500000	400000
Cost of benefit ratio	0.12	0.32	0.22	0.33	0.20	0.16

Table.6 Cost and benefit ratio of 28bus and 33 bus network

	28 bus			33 bus		
	CP	CC	CI	CP	CC	CI
Base network power loss(kW)	67.95	58.97	51.19	197.55	174.23	153.83
Optimal case power loss(kW)	21.20	33.04	28.05	151.39	146.60	132.52
Reduction in power loss(kW)	46.75	25.92	23.13	46.15	27.62	21.30
Benefit	1589100	1135500	1013500	292220	1210236	933231
Cost of DG	800000	200000	800000	600000	800000	600000
Cost of benefit ratio	0.50	0.17	0.78	0.26	0.66	0.64

IV. CONCLUSION

Allocation of DG's by using the proposed method reduced the power losses of 36.4% and improved voltage profile of 2.5% The effective usage of renewable energy sources to meet load demand with optimal reduction of power loss and improve voltage profile have been found from results also this method demonstrates optimal DG size, their location and cost minimization of DG installation, from the obtained results , payback period is less than a year and average loss reduction is 1/3 of base network power loss. Hence, the proposed method provides Cost viable solution and improved voltage profile

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