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Hybrid Approach based Optimal Distributed Generation in Integrated Distribution System

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***Abstract*— Electricity demand is increasing rapidly from last few decades. The modern power system is more complex in terms of integrating system components, maintenance and its operation. The distributed generation plays a vital role in distribution system. Among all its significant advantages and role, the system losses, voltage profile improvement and cost reduction are major concerns of distributed generation. Many studies shows and explains the non optimal placing and sizing of DGs may leads to increase in system losses, reduction in voltage profile and adversely affects the overall system performance. Therefore, identifying the place and size of DGs optimally acquire more attention in integrated distribution system. This paper presents optimal placing and sizing DG in distribution system for real power loss reduction, voltage profile improvement. Power flow analysis is carried out by using hybrid approach based method in MATLAB platform for IEEE-33 bus test system.**

Keywords- Distributed generation, power loss minimization, voltage stability index, particle swarm optimization, cuckoo search algorithm.

I. INTRODUCTION

Electricity is an essential requirement for all of our daily life. It has been so recognized as a basic human need and it is critical complexity on which the country's economic development depends. With ever growing population in world, increasing in living standard of the humanity, modernization, industrialization of the developing countries, the global demand for energy is expected to increase rather significantly in the present and near future.

Due to limitation on fossil fuel resources, alternative solutions to present large power stations are under high priority in recent days to meet growing energy demand of the future, [1], [5], and [6]. Also large power stations are discouraged due to many environmental concerns. On the other hand, these renewable energy resources have been considered as the best alternative to traditional fossil fuels. The sizes of renewable energy based electricity generators would be very small as compared to large fossil fuel based power plant. Technically, they are suitable for installation at low voltage sided distribution system, near loads centers.

Distributed generation (DG) also called decentralized or dispersed generation. The dispersed generation generally refers to small-scale (typically 1kW - 50MW) electric power generators that produce electric power at a site near to the load. DG's share has been increased in the power system from the last few years. DG has many advantages [5] and [6] such as it increase the power capacity in power system, it reduces the power losses in power system, and it increases the voltage profile of the distribution system as it is in radial nature.

The minimization of power loss reduction in distribution system have great initiatives, [23], [13] and activated due to the increasing greater cost of supplying electricity, the shortage in fuel with ever-increasing cost to produce more power, and even the global warming concerns. One of the methods is to minimize power losses is optimal allocation of distributed generation. By considering many system parameters help in placing DG's are explained in [19] and [20] and DG models are discussed in [8]. To place distributed generation optimally in system [2], [9], [10], [11], [15] and [23] is by employing the feeder loss. The optimal size of DG for minimum system losses is identified at each bus. Penetrating the optimal DG size for the buses one by one, corresponding system losses are calculated and compared to decide the appropriate location. More over the heuristic search requires exhaustive search for all possible locations which may not be applicable to more than one DG. This method is used to calculate DG size based on approximate loss formula may lead to an inappropriate solution. In the literature, genetic algorithm and PSO have been applied to

DG placement [16-18]. Inspired by some social behavior bird flocking, the population based optimization particle swarm optimization (PSO) method was proposed by Kennedy and Eberhart [25]. A conception comparison of the cuckoo search [26], particle swarm optimization [24], differential evolution and artificial bee colony algorithms' explained in [22]. The evolutionary search [21], binary particle swarm optimization [12], analytical [7], tabu search [3], for DG placement and sizing are discussed.

Many researches are discussed and analyzed the hybrid optimization techniques fuzzy-genetic algorithm [4], GA-PSO [16], [17] and multi DG placement [14]for DG sizing and placing. In this paper, an intelligent hybrid PSOCSA is made and results are tested and verified in this paper on the case of standard 33-bus test system by using MATLAB platform with considering appropriate objective function for system enhancement intern system voltage profile and DG placing are mentioned. This paper proposes a method for selecting the suitable location and correct size of DG for minimizing the system losses and improves the system performance characteristics.

II. Problem Formulation

The prime objective of is to find the best location and allocation of distributed generation unit which results in voltage profile improvement and minimizing the power loss and greater benefits to the system.

Many objective functions are explained from previous survey for the adequate DG placement and allocation. The intelligent optimizing techniques shows their best efficiency towards the membership functions and are found, it can be maximizes by past experiences and new systematic approach techniques, [16], [17] as follows;

The results are shown in the table I are the voltage profile before the DG places. If there is voltage profile violates the limits in the system, by considering the voltage limits in reliably, emergency and finally maximum voltage limits to place DG adequately. The constraints for DG in a system are as follows:

A. Load balance constraint

For each bus, the following equations should be satisfied:

$$P_{gi}\text{-}P_{di}\text{-}V_i\sum_{j=1}^{N} V_j Y_j \cos(\delta_i-\delta_j-\theta_j)=0 \quad (1)$$

$$Q_{gi}\text{-}Q_{di}\text{-}V_i\sum_{j=1}^{N} V_j Y_j \sin(\delta_i-\delta_j-\theta_j)=0 \quad (2)$$

where $i=1, 2, \ldots N$

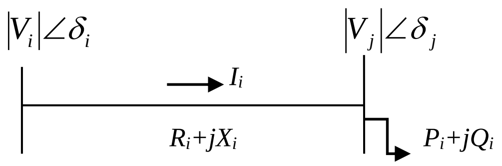

Fig.1 A simple branch representation of a radial distribution system

Fig.1shows a simple branch representation of a radial distribution system sending end voltage V_i and receiving end voltage as V_j.

B. Voltage limits

The generator voltage will be the summation of load/bus voltage, impedance of the line and the power flows along that line stated. It is evidence for larger voltage rise where the system line impedance is higher. The increased active power flows on distribution system have a greater impact on the voltage level because resistive parameter of the lines on distribution system is much higher than other lines. This leads to an ratio of X/R will be approximately 1 rather than in transmission system.

The voltage must be kept within standard limits at each bus

$$V_i^{min} < V_i < V_i^{max} \quad (3)$$

C. DG capacity technical constraints

As DG capacity is inherently limited by the energy resources for any given location, and it is significant issue to define capacity between the maximum and the minimum levels. The DG limit expressed by:

$$P_{gi}^{min} < P_{gi} < P_{gi}^{max} \quad (4)$$

D. Thermal limit

The distribution system line should be within the thermal limits and it should be exceeded:

$$S_i < S_i^{max} \quad (5)$$

where, i=1,2, …..N.

III. Objective Function

A. For optimal location of DG

The optimal placement of DG is prime objective in distribution system. The analysis carried out to find out voltage sensitive nodes for distributed generation penetration. The voltage sensitivity index can be found by running load flow analysis. When DG is connected at bus j, voltage sensitivity index for bus j is expressed as;

$$VSI_j = \sum_{p=1}^{n} \frac{(1-V_p)^2}{n} \quad (6)$$

where, V_p is voltage at p^{th} node and n is the number of nodes.

The least voltage sensitivity index of the bus to considered for optimal location of DG which results in increase voltage magnitude at each buses and power loss minimization.

B. For optimal size of DG

The DG is placed where the bus having least voltage stability index. The optimal size is determined by placing and varies DG allocation till the minimum power loss in system is achieved. The DG size corresponding to minimum system loss is taken as optimal size of DG, [3], [4].

IV. PROPOSED METHODOLOGY

A. Particle Swarm Optimization

Particle swarm optimization is population based intelligent, stochastic optimization method based on the swarm movement idea over a given space. This algorithm updates the swarm velocities and the each swarm member positions from its past activity. In PSO, the velocity v_n^d and position x_n^d of the d^{th} dimension of the n^{th} particle are updated as follows:

$$V_n^d = w.V_n^d + c_1.r_1.(p_{best\ n}{}^d - x_n^d) + c_2.r_2.(g_{best\ n}{}^d - x_n^d) \quad (7)$$

$$x_n^{d+1} = x_n^d + v_n^d \quad (8)$$

where, x_i : position of the n^{th} particle

v_n : velocity of particle n
pbest n : best location in search space ever visited by particle *n*
gbest : best location found so far
w : inertia weight that controls the impact of previous velocity of particle on its new one
r_1, r_2: independently uniformly distributed random variables with range (0,1)
c_1, c_2: positive constants (acceleration) coefficients which control the maximum step size

The new velocity is calculated by using equation (7) from its past velocity and to the distance of its new position from its own best position and other swarm positions. Generally, the value of each component in velocity, *v* can be stated between the range [$-v_{max}$, v_{max}] to control unnecessary distance travelled by particles outside the search area. Then the particle flies and reaches towards a new position. This process is repeated until a user-defined stopping criterion is reached. The linearly decreasing inertia weight from maximum value w_{max} to minimum value w_{min} is used to update the inertia weight:

$$w^k = w_{\max} - \frac{w_{\max} - w_{\min}}{k_{\max}}.k \quad (8)$$

where, K_{max} is maximum iteration number.

B. Cuckoo Search Algorithm

The brief algorithms steps of CSA are given below:

1. Read the line and load data
2. Run base case load flow and save initial voltages and losses
3. Locate and size the DG
4. Define the constraints and bounding, algorithm parameters and number of iterations
5. Initiate the random population host nest for iteration
6. Get a cuckoo randomly by levy flight
7. Evaluate the fitness function as require and select the nest 'n' randomly
8. Check fitness condition, if yes replace by new solution
9. Remove 'pa' for bad nests and build new one and keep and pass best solution
10. If constraints satisfied and then save best solution.

C. Hybrid PSO-CSA Optimization

The hybrid PSO-CSA optimization gives very promising results than PSO and CSA optimization techniques. The results are evaluated and shown in table II.

V. TEST CASE STUDY AND NUMERICAL RESULTS

The hybrid algorithm is tested and verified for IEEE-33 bus network having system operating voltage 12.66 kV and the total real power and reactive power demand of 3.715 MW and 2.295 MVAR respectively by using MATLAB R2013a with 32 bit, core i3 processor took elapse time of 2.724458 seconds. Fig.2 is single line diagram of IEEE-33 bus system.

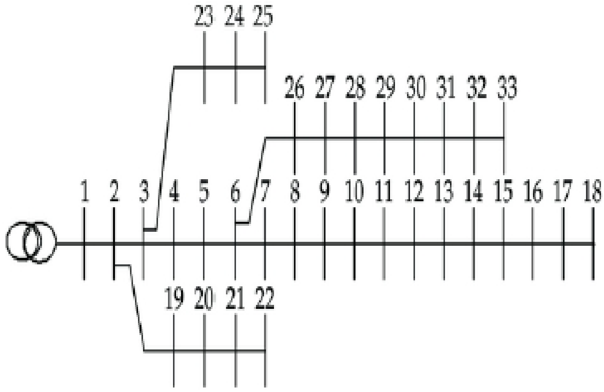

Fig.2 Single line diagram of IEEE-33 bus distribution feeder

The test case was analyzed by choosing voltage sensitivity index for 33 bus system. The voltage profiles are found using load flow method and results of all nodes of the system are evaluated and are discussed in table I.

The simulated results are verified by hybrid particle swarm optimization and cuckoo search algorithm method of DG placement. The voltage profile in all nodes made with acceptable limits by placing DG in voltage violated nodes. Many publications are presented with considering the objective function with voltage level of entire feeder and so on. In this work, identifying the DG placing is made based on critical voltage level of all nodes in the network. The results from table I identifying the critical node and found 0.913 p.u at bus 18 and Fig.3 shows the voltage profile before DG placement in the system and it clears the optimal DG placement is at bus 33 distribution system.

TABLE I
SYSTEM BASE VOLTAGE MAGNITUDE AT ALL BUSES IN P.U

Bus	V in p.u	Bus	V in p.u
1	1.000	**18**	**0.913**
2	0.997	19	0.997
3	0.983	20	0.993
4	0.975	21	0.992
5	0.968	22	0.992
6	0.950	23	0.979
7	0.946	24	0.973
8	0.941	25	0.969
9	0.935	26	0.948
10	0.929	27	0.945
11	0.928	28	0.934
12	0.927	29	0.926
13	0.921	30	0.922
14	0.919	31	0.918
15	0.917	32	0.917
16	0.916	33	0.917
17	0.914	--	--

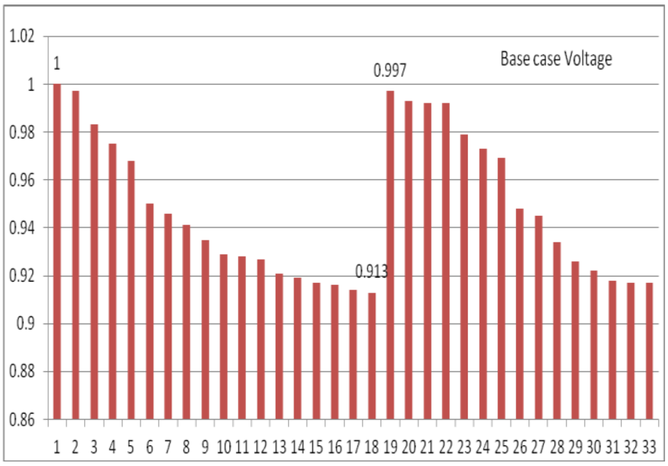

Fig.3 Base bus voltage of 33 bus test system in p.u

The results from table II, where the voltage sags at bus 18 has improved from 0.913 p.u to 0.94748 p.u after and distributed generation are placing at bus 18. And throughout the system, voltage profile achieving the constraints of quality in the system. The voltage profile at bus 32 is with least value found as 0.94234 p.u. Further, DG number can be increased to improve the voltage profile at all buses in distribution system.

TABLE II
SYSTEM VOLTAGE MAGNITUDE AFTER DG PLACEMENT AT ALL BUSES IN P.U

Bus	V in p.u	Bus	V in p.u
1	1	18	0.94748
2	0.99707	19	0.99506
3	0.98700	20	0.97823
4	0.98251	21	0.97360
5	0.97821	22	0.97014
6	0.97170	23	0.98343
7	0.97106	24	0.97678
8	0.96260	25	0.97347
9	0.95923	26	0.96993
10	0.96268	27	0.96758
11	0.96277	28	0.95711
12	0.96306	29	0.94961
13	0.96048	30	0.94642
14	0.95969	31	0.94301
15	0.95318	**32**	**0.94234**
16	0.95142	33	0.94715
17	0.94850	--	--

Fig.4 shows bus voltage of IEEE 33 bus test system in p.u and at bus 32 the voltage profile is 0.94234 p.u.

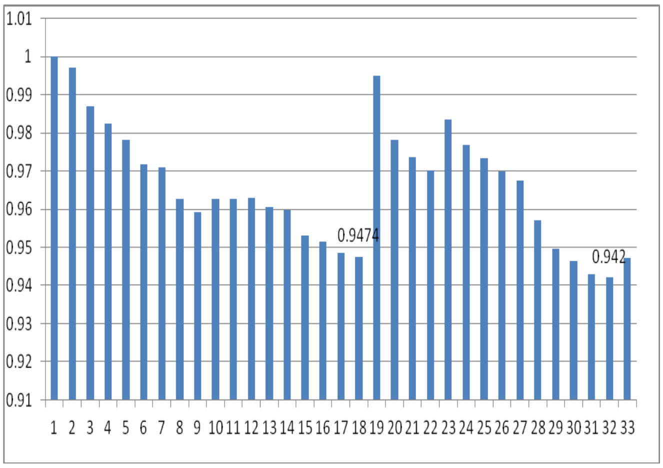

Fig.4 Bus voltage of IEEE 33 bus test system after DG placement in p.u

Fig.5 shows bus voltage of IEEE 33 bus test system before and after DG placement in p.u.

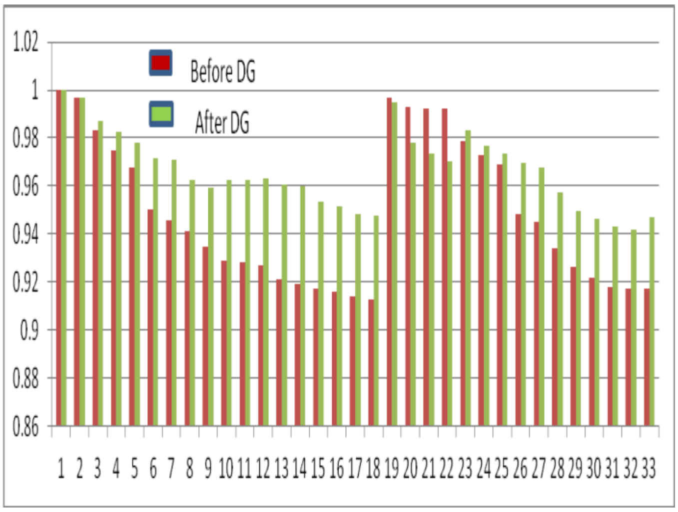

Fig.5 Base bus voltage of 33 bus test system in p.u

The voltage stability index of the system is evaluated in fig.6. First base case load flow (without DG) analysis is done to calculate the bus voltage magnitudes and total network power loss in the radial distribution system (RDS). Further, load flow with DG capacity of 25% of the total feeder loading capacity is carried out to find VSI at various buses. Figure 3 shows the variation of VSI at various buses.

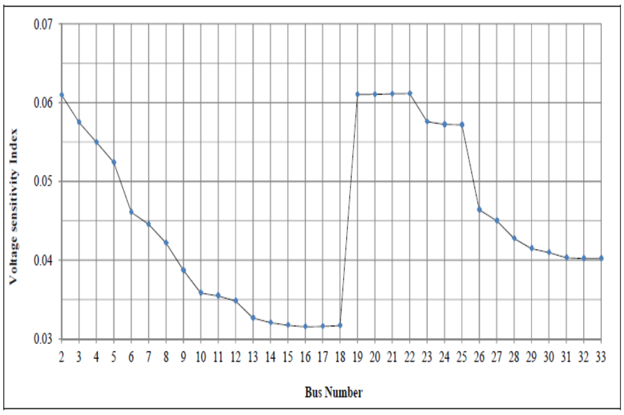

Fig.6 Variation of VSI at various buses

VI. CONCLUSION

DG is new trends in power system operation used to support the increased energy demand. Distributed Generation refers to a mobility energy source, which connects directly to the distribution system or on the demand side. This provides and enhances power quality and high reliability of distribution system. By employing the distribution generation in distribution system, results in drastic improvement in voltage magnitude and minimizing line losses. In this paper, a hybrid particle swarm optimization and cuckoo search algorithm is introduced to implement DG's optimally. The technique has been tested IEEE 33-bus test system; there is improvement in voltage profile as well as reduction of real power losses in the system. The minimum voltage occurs at bus 18 before DG penetration is 0.9036 p.u, real power is 0.201 p.u and voltage stability index is 0.6686. After single DG penetration the voltage profile improves to 0.9546 p.u, voltage stability index is 0.8323 p.u and real power loss index is 0.178 p.u and when two DG penetration is real power loss index is 0.134 p.u.

This analysis tool is made so significant role in integrated distribution planning and operation of system. And also explains the affects of DG impacts, penetration and its effects on distribution system network including futuristic network feeder restructuring and operations.

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