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Voltage Profile Improvement in Distribution System Using Particle Swarm Optimization Algorithm

V.Veera Nagireddy[1], C.Srinivasa Rao[2] and V.Madhusudhan[3]
Assistant Professor, EEE Department, MJRCET, Piler, Chittoor(Dt.), Andhra Pradesh, India[1]
Professor, EEE Department, G.Pullaiah College of Engineering and Technology, Kurnool, Andhra Pradesh, India[2]
Professor, EEE Department, K.S.R.M College of Engineering and Technology, Kadapa, Andhra Pradesh, India[3]

ABSTRACT
The traditional method in electric power distribution is to have centralized plants distributing electricity through an extensive distribution network. Distributed generation (DG) provides electric power at a site closer to the customer which reduces the transmission and distribution costs, reduces fossil fuel emissions, capital cost, reduce maintenance costs and improve the distribution feeder voltage profiles. In the case of small generation systems, the locations of DG and penetration level of DG are usually not priori known. In this paper, Particle Swarm Optimization (PSO) algorithm attempts to calculate the boundaries of the randomly placed distributed generators in a distribution network. simulations are performed using MATLAB, and overall better improvements are determined with estimated DG size and location. The proposed PSO approach is compared with conventional method on IEEE 34 bus distribution feeder network.
Index Terms: Particle Swarm Optimization(PSO), radial distribution network, voltage stability, loss minimization, load flows, distributed generation.

I. INTRODUCTION

This paper introduces the effects of the distributed generation (DG) devices onto the electrical power distribution system. This is to treat that the DGs as a separate source, designed to limit the effects in the distribution system. DG devices installed at the consumer level reduces profits, but DG systems provide some benefits to the utility like improvement of the voltage profile across the distribution feeder, reducing the loading level of system and distribution transformers and also provide environmental benefits by avoiding fuel emissions [1]. It brings down the distribution losses level to 6-8% in India with the improved technological options like computer based algorithms in the Electrical Power Distribution systems which enhances better controlling and monitoring [3]. In addition, Utility distribution economic benefits include loss reduction, green pricing benefits, etc. Generally, DGs are designed to operate at near unity power factor and provides active power to the utility distribution systems. This type of design maximizes the customer benefits by charging only for the active power that drawn from the grid. DG systems operate at a greater than 0.85 power factor for the output greater than 10% of rating and specially designed DG systems which provide voltage support or reactive compensation operates outside of this limit [2]. The integrated method can be proposed for planning distribution networks by which the distributed generators (DGs) operation and process of cross-connections is designed. Distribution network lines and distribution transformers are upgraded optimally in order to make improvement in system reliability and also to minimize distribution line losses under utility load growth [9].

HPSO approach for capacitor placement in radial distribution feeders has been introduced to improve the voltage profile and reduce the real power loss. This approach involves the estimation of location for capacitor placement and the size of the capacitor at the identified location [4]. The guide facilitates of IEEE Std 1547-2003 for distributed resource (DR) methods and their related interconnection problems and also provides background and technical requirements, techniques, tips, and rules of thumb. In [5] technical background and application details to support understanding of IEEE Std 1547-2003 has been provided. A new heuristic method for minimizing nonlinear continuous space functions is presented which was the new method converges faster and with more certainty than other global optimization methods [12]. The novel approach for the optimization of nonlinear functions by using particle swarm methodology is introduced and the evolution and implementation of several paradigms is described [13]. There are major issues in integration of multiple distributed power resources with the grid few of them are lack of uniform interconnection standards and for interconnection operation, and the lack of uniform building, safety codes and electrical are understood [14].

II. MATHEMATICAL FORMULATION FOR DG MODEL

The main objective function for voltage profile improvement and reduce power losses is:

$$minimize\ f = \sum_{ij=1}^{n} P_{lossij} \quad ...(1)$$

with the following constraints

Each node voltage magnitudes should be within permissible limits.

$$v_j^{min} \le v_j \le v_j^{max} \quad ...(2)$$

In each branch, magnitudes of Currents should be within their permissible limits.

$$I_{ij} \le I_{ij}^{max} \quad ...(3)$$

In any network of total connected load should not exceed the total power source limits.

$$P_{ij} \le P_{ij}^{max} \quad ...(4)$$

$$Q_{ij} \le Q_{ij}^{max} \quad ...(5)$$

The DG active power losses are always lesser than or equal to the total active power losses of the line.

$$\sum_{ij} P_{lossG} \le \sum_{ij} P_{loss} \quad ...(6)$$

The total power generation of DG should be limited to a 10% of penetration level. (i.e. it should be less than or equal to 10% of total network load) [10].

$$\sum_{j} P_{Gj} \le 0.1 \sum_{j} P_{Lj} \quad ...(7)$$

$$\sum_{j} Q_{Gj} \le 0.1 \sum_{j} Q_{Lj} \quad ...(8)$$

III. PSO ALGORITHM

Particle swarm optimization (PSO) has been inspired by social behavior of fish schooling and bird flocking [15]. It is a recent heuristic search approach whose methodology is inspired by the collaborative behavior or swarming of biological populations. It also optimizes a solution to improve a candidate solution in iterative method. This method is formulated to select the location and size of DG units using particle swarm optimization (PSO) which maximizes the overall DG penetration level for the IEEE 34 test system as shown in fig 2.[11] The flow chart of fitness evaluation for each agent or particle solution by PSO is shown in Fig.1. Each particle solution from PSO is passed to the classical power flow with comparision.

In Particle Swarm Optimization algorithm, each individual agent (particle) flies in m-dimensional space S as per hysterical experiences of its own and its colleagues. The k^{th} agent velocity is represented as $u_k = (u_{i1}, u_{i2}, \dots\dots, u_{im}, \dots\dots u_{iM})$ and the the agent location is $y_k = (y_{i1}, y_{i2}, \dots\dots, y_{im}, \dots\dots y_{iM})$. The better previous position is represented as $p_i = (p_{i1}, p_{i2}, \dots\dots, p_{im}, \dots\dots p_{iM})$, called p_{best}. The index of the best p_{best} is represented by g, called g_{best}. The agents or particles are calculated at each step by following equations [8]:

$$u_{in} = v.u_{in} + a_1.rand().(p_{im} - y_{im}) + a_2.rand().(p_{gm} - y_{im}) \quad ...(9)$$

$$y_{im} = y_{im} + u_{im} \quad ...(10)$$

Where v is inertia weight, a_1 and a_2 are acceleration Constants $rand()$ are random variables ranges from 0 to 1.

In particular stage of evaluation, the particles which are not active, may present since there should be too closeness of p_{best} and g_{best}. The loss of diversity for $|p_{im} - p_{gm}|$ is occurred in the later part of evolution process. The PSO version introduces mutations randomly on the y_{im} of agents or particles of small probability d_n [6]. It is difficult to determine along with the evolution process, which is not be too large to avoid swarm disorganization. This process can be improved by a Gaussian distribution method [7], but the step-size along with the particle search process is mostly preferable. The bare bones version [8] for fulfilling of such requirements is to be replaced the equation (1) by Gaussian mutation of the mean $(p_{im} + p_{gm})/2$ and the value of standard deviation $|p_{im} - p_{gm}|$, it may be also be not efficient when $|p_{im} - p_{gm}|$ should be very small [16].

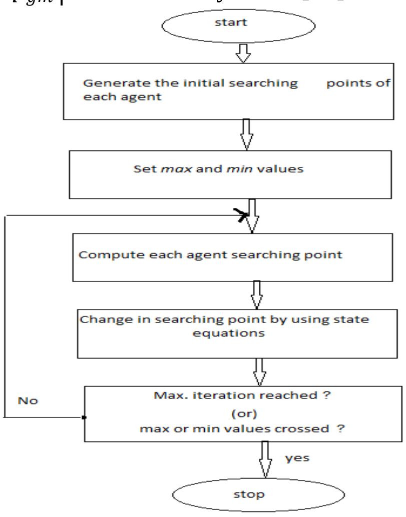

Fig. 1 Flow chart of PSO

IV. RESULTS AND DISCUSSIONS

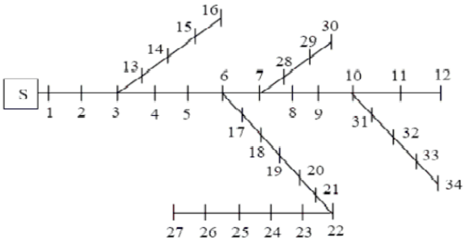

Fig. 2 Single line diagram of IEEE 34 distribution network

The IEEE-34 bus distribution system is considered as a test system as shown in fig. 2. This system has the voltage rating of 11 kV and the real power demand of 4.636 MW and the reactive power demand of 2.873 MVAr. The classical load flow analysis without DGs placement has been performed to find the node voltage magnitudes, voltage profile is shown in Fig. 3. The utility distribution system real power loss and reactive power loss and total losses respectively are 223.77kW and 170.6989kVAR. In the conventional radial distribution system (CRDS), It is observed from fig.4 that the voltages at nodes 19, 22, 20, 21, 23, 24, 25, 26, 27 are having poor voltage profile i.e. below the voltage constraint limits. Therefore, there is a necessacity for placing DGs at appropriate locations to improve the voltage profile through out the distribution feeder with loss reduction. The proposed PSO method and the conventional methods are applied to test system of IEEE 34 distribution system as shown in fig 2. The effectiveness of PSO compared with the conventional method with and without DG integration have been analysed. The values of inertia weights ω_{min} and ω_{max} are constant as 0.4 and 0.9 respectively which are independent of type of problems. It is noticed that PSO parameters are as C1 = C2= 2.05, rand1 =0.1, rand2 = 0.2, Si=0.729, CR = 0.9 and F = 0.8. The voltage profiles (i.e node voltage comparison) for three cases are without DGs integration, with integration of multiple DGs based on PSO method as shown in fig. 3.

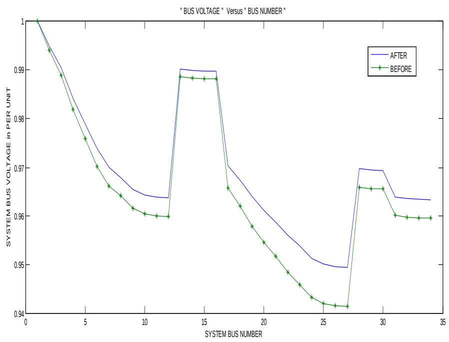

Fig. 3 System bus voltage before and after DG compensation based on PSO method.

The load flow study is performed with 10% DG capacity of the total feeder loading capacity to determine optimal DGs size and placement. In this scheme the system is studied based on changes in real power & reactive power at the candidate node with respect to local Distributed Generation. By that DGs generate and deliver power to the distribution system independent of the node voltage. This type of DG source is called as a negative load which delivers active power. The voltage profiles performances in two cases as without integration of DGs, with integration of DGs using PSO based method. From the results, it is observed that Particle Swarm Optimization method gives best voltage profile improvement. The comparison of voltage profiles (i.e. bus voltages at all buses) are shown figure 3. The comparison of power loss with PSO method and conventional method is shown in figure 4. It is concluded from the figures that voltage profile has been improved and the active power loss has been decreased with PSO algorithm method.

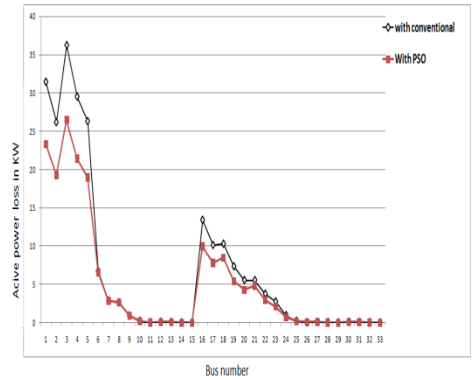

Fig. 4 Real power loss before and after DGs compensation based on PSO method.

By proposed Particle Swarm Optimization method, the best location and appropriate size of DGs can be estimated by that best voltage profile can be obtained. The bus voltages profile of IEEE 34 distribution system is as in fig.4 shows that the proposed PSO method can improve voltage profile. The results of comparison for minimum voltage and size and location of DGs are tabulated in table.1. The proposed Particle Swarm Optimization method suggested that two DGs of ratings of 1.186 MVA at node 23 and 0.672 MVA at node 19, in which active losses are 178.779 KW. The minimum bus voltage is 0.9415 p.u with classical radial distribution system. It can be improved to 0.9496 p.u with PSO based method. The analysis of results obtained from load flow using conventional and PSO methods is tabulated in Table 1 and Table 2. It observed that the voltage profile has improved and the real power loss has decreased in distribution system due to DGs placement. By comparing the performance of conventional method and PSO, there is an extra loss reduction and better voltage profile improvement in PSO algorithm over conventional method. It is concluded that, the Particle Swarm Optimization based method has the percentage of loss reduction as 20.10% and the percentage of improvement in voltage profile is 0.86% respectively. Therefore, the proposed PSO algorithm method is proven to be better.

Table. 1 Results of DGs location & sizing

Bus No.	19	22	23	27	Total KVAR
PSO	672	----	1186	----	1858

Table. 2 Total power loss (KW) and minimum bus voltage

Total real power loss (KW)		Minimum voltage (p.u)	
Before DGs placement	After DGs placement With PSO	Before DGs placement	After DGs placement With PSO
223.77	178.779	0.9415	0.9496
% decrease	20.10	% Increase	0.86

V. CONCLUSION

This paper presents a Particle Swarm Optimization algorithm, to calculate the optimum DGs size and location in radial utility distribution system to voltage profile improvement and to reduce losses. The integration of multiple DGs to distribution system with active and reactive power generation wth optimal location and size reduces the system real losses and improves voltage profiles. As DGs can generate and supply a partial reactive and real power to the local loads, hence the voltage profiles throughout distribution system feeders are improved. This paper presents a comparison between PSO and conventional method. The simulation results show that proposed PSO method is competitive and robust to conventional method for sizing and placement of DGs. It is concluded that there is reduction in real power loss and improvement in voltage profile using PSO method.

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