Optimal Placement of Renewable Distributed Generators in Radial Distribution System using PSO

J. Sivasai[1] M. S. Giridhar[2]
[1]PG Scholar [2]Associate Professor and Head
[1,2]Department of Electrical Electronics Engineering
[1,2]Sreenivasa Institute of Technology and Management studies, Chittoor, India

Abstract— This paper presents a Renewable distribution generation (DG) allocation strategy to boost node voltage and power loss of 69-bus radial distribution systems exploitation particle swarm improvement (PSO). the target is to reduce active power losses whereas keep the voltage profiles within the network among such that limit. The correlation between load and renewable resources has been nullified by dividing the study amount into many phases and treating every segment severally. To handle the uncertainties related to load and renewable resources, probabilistic techniques are used. 2 operation methods, specifically "turning off turbine generator" and "clipping turbine generator output", have additionally been adopted to limit the alternative energy dispatch to a specified fraction of system load for system stability thought. to cut back the search area and thereby to reduce the process burden, a sensitivity analysis technique has been utilized which provides a collection of locations appropriate for weight unit placement. The solutions lead to significant loss reduction and voltage profile improvement.

Key words: Distributed Generation, Particle Swarm Optimization, Renewable DG Types

I. Introduction

The combination of distributed generation (DG) with distribution system offers numerous technical and cost-effective benefits to utilities as well as to consumers. However, simple inclusion of DGs may not guarantee the enhancement in system performance. Depending on the size, location and diffusion level, DG may have negative impacts on the performance of distribution network. Hence, a proper allocation of DG units in the distribution system plays a vital role. For DG placement in the distribution systems, various issues, such as reduction of system power loss, enhancement in system voltage profile, diminish of harmonic pollution, maximization of DG capacity, minimization of savings etc., have been expected at by researchers in their single or multi-objective crisis formulations. diverse optimization techniques, such as Primal-Dual Interior Point method, mixed integer nonlinear programming, evolutionary programming (EP) technique, analytical approach, trade-off method, Hereford Ranch algorithm, linear programming technique, genetic algorithm technique, heuristic approaches, Classical Second Order method, Tabu Search approach, and Decision Theory approach have been broken to solve the optimization inconvenience for DG placement. Most of the over mentioned DG placement method are well suited to assign conventional resources based DGs like internal-combustion engines, reciprocating engines, gas turbines etc. which are transmittable and handy. These methods may not be appropriate to place DG units energized by renewable energy assets as these do not include the worries associated with discontinuous outputs from renewable energy resources based DGs. Placement of such DGs requires a little out of the ordinary techniques to switch their discontinuous outputs. Using hourly-simulated outputs from WTs, they derived an analytical expression to find out the finest position of WTGs in the distribution systems with homogeneously distributed time changing loads. To grip the uncertainties coupled with renewable resources based D G units, Carpinelli et al. [6], Celli et al. [7], and Celli and Pil o [8] measured a set of scenarios of power production from such DG units with their incidence probabilities. Then out of different sizing alternatives, they selected the best alternative equivalent to best expected value of objective function. Atwa and El-Saadany [3] and Atwa et al.[4] proposed a mixed integer non-linear programming based loom to decide the most advantageous capability and location of renewable resources based DG units in the distribution system so as to make light of the annual energy loss. They combined collectively the probabilistic models for wind speed and load to extend the generation-load replica and integrated this collective model into deterministic optimal power flow equations to calculate the annual energy loss. However, all the methods [2], [5], [6],[8], [11] do not think the association between load and renewable resources. Also, of these methods are not capable to confine the wind power dispatch to a definite percentage of a system load which is essential for maintaining the system stability.

For DG placement in the distribution systems, different issues, such as decrease of system power loss, enhancement in system voltage profile, minimization of investment, decrease of harmonic pollution, maximization of DG capacity, are minimized by separating the study period into more than a few segments and treating each segment autonomously. To handle the uncertainties connected with load and renewable resources, probabilistic techniques have been used.

Aim of the placement of PVAs and WTGs in the distribution system is to diminish active energy loss. Appropriate probabilistic models have been engaged to represent the uncertainties connected with load and renewable resources. To restrict the wind power dispatch to a certain fraction of system load, two operation strategies have also been adopted and simulated. The developed formulation has been tested on a 69-bus distribution system with encouraging results.

II. Distributed Generator Models

Distributed generation also called as decentralized generation, dispersed generation, and embedded generation is basically defined as source of electrical energy of narrow size and is connected directly to a distribution system of a power network.

DG can be motorized by number of sources both renewable and non-renewable such as fuel cells, photovoltaic system, wind turbines, etc. DG is placed in distribution networks depending on site and primary fuel accessibility or climatic environment and the judgment of DG placement is taken by owners and investors. Even though in most cases, the distribution system operator (DSO) has no control about DG location and size below a definite limit, however placement of DG vitally affects the course of action of the distribution network. Inappropriate DG placement may amplify system losses and network capital and functioning costs. If it is placed optimally network presentation can get better in terms of development of voltage profile, decline in power flows and system losses, and develop power quality and trustworthiness of system.

The subsequent approaches are embraced for reduction of distribution networks losses.

1) Strengthening of the feeders.
2) Reactive power compensation.
3) High voltage distribution networks.
4) Grading of conductor.
5) Feeder reconfiguration.
6) Distributed Generator placement.

A. Dg Planning:

DG must be satisfactorily introduced and facilitated with the breathing protective devices and plans. Higher diffusion levels of DG may cause conventional power flows to alter (reverse direction), since with generation from DG units, power may be injected at any point on the feeder. New planning systems must guarantee that feeders can suit changes in load configuration. These boundaries and struggles must be settled sooner than picking DG as a planning alternative.

There are numerous components influencing DG operation, for example, DG technologies, types, operational modes, and others. DGs placed in the distribution network can be purchased, operated and controlled by either an electric utility or a consumer. In the event that DG is an utility-claimed, then it is a functioning cycle well known as controlled by the utility. The condition of the DG working cycle relies on upon the motivation behind its utilization in the distribution system.

Consumer-owned DG working cycles are not known to the operators unless there is a unit commitment agreement between electric utility and consumer, which is not very likely. Thus, small customer owned DG operating cycles are acknowledged to be capricious processes from the perspective of the electric utility. The utility have no control on their function. This uncertainty changes the planning and operation problem from a deterministic problem to a non-deterministic one.

B. Dg Siting:

There are no agreeable limitations on location of DG units in the distribution system In the event that the DG is client possessed then, utility has no control on its position in light of the fact that it is put at the client's site. In the event that the DG is utility-possessed then the choice of its location is focused around a few electrical factors, for example:

1) Providing the required extra load demand
2) Reducing networks losses
3) Enhancing networks voltage profile and expanding substations capacities

C. Dg Sizing:

There are no unambiguous guidelines on selecting the volume and amount of DG units to be introduced in to the network.

1) To enhance the networks voltage profile and reduce power losses,
2) For reliability purposes if there should arise an occurrence of islanding,

D. Renewable Dg Models:

1) Wind Power:

Wind power is the adaptation of wind energy into a helpful shape of energy, for example using wind turbines to generate electrical power, windmills for mechanical power, wind pumps for water pumping or drainage, or sails to propel ships.

The power output from a WT depends on its rated power P_{rated}, cut-in speed V_{cut-in}, rated speed V_{rated}, and cut-out Speed $V_{cut-out}$. The mathematical function relating the power output from a WT with the wind speed can be written as

$$f^{WT}(v) = \begin{cases} 0, & for\ 0 \le v < V_{cut-in} \\ & and\ v > V_{cut-out} \\ (a.v^3 + b.P_{rated}), & for\ V_{cut-in} \le v \le V_{rated} \\ P_{rated}, & for\ V_{rated} \le v \le V_{cut-out} \end{cases} \quad (1)$$

where $f^W(v)$ is a function of wind speed v for calculating power output from a WT. Constants a and b are the functions of V_{cut-in} and V_{rated} and can be obtained by the following relations.

$$a = \frac{P_{rated}}{(V_{rated}^3 - V_{cut-in}^3)} \quad (2)$$

$$b = \frac{V_{cut-in}^3}{(V_{rated}^3 - V_{cut-in}^3)} \quad (3)$$

2) Solar Power Generation:

Solar power is the exchange of sunlight into electricity, either honestly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic convert light into electric current using the photovoltaic effect.

The rating of a PV module is expressed in peak-watt (Wp) and is equal to the maximum power produced by a module under standard test conditions (STC). STC corresponds to a radiation level of $1KW/m^2$ and a cell temperature of 25°C. The manufacturers provide the characteristics of PV module under STC by specifying I_{SC} (short circuit current in A), V_{OC} (open-circuit voltage in V), I_{MPP} (current at maximum power point in A), V_{MPP} (voltage at maximum power point in V), and N_{OT} (nominal operating temperature of cell in). The current-voltage characteristic of a PV module can be determined for a given radiation level s and ambient temperature T_A using the following relations.

$$T_C = T_A + s\frac{N_{OT} - 20}{0.8} \quad (4)$$

$$I = s[I_{SC} + C_1.(T_C - 25)] \quad (5)$$
$$V = V_{OC} - C_V.T_C \quad (6)$$

where T_C represents cell temperature in ℃,I stands for PV module short-circuit current in A, C_1 signifies short-circuit current temperature coefficient in $A/℃$, V indicates open-circuit voltage in V, and C_V is open-circuit voltage temperature coefficient in V/C.

The power output from a PVA, containing total modules, can be directly calculated as

$$f^P(s) = N.FF.V.I \quad (7)$$

where is f^P (s) a function of solar radiation level s for calculating power output from a PVA. Fill factor, FF depends on the material of PV module and is given by the following relation:

$$FF = \frac{V_{MPP}I_{MPP}}{V_{OC}I_{SC}} \quad (8)$$

E. Methods For Optimal Placement Of DG:

The operation of DG can provide benefits to distribution networks such as reduction of power losses and/or deferment of investments for network enforcing, etc. only if it is allocated properly otherwise it can cause degradation of power quality, increase losses, reliability, and control etc. The problem of optimal placement of DG can be single objective or multi-objective which can be solved by analytical method and meta-heuristic approaches.

1) Single Objective:

An analytical technique based on exact loss formula was used to find size and site of DG so as to minimize power losses. Optimal power factor, size and site of DG found by using analytical expressions. Optimal placement of DG to minimize total power losses by equivalent current injection based analytical method.

In the Meta-Heuristic Approach a Genetic Algorithm (GA) based approach was used to find best size and location of DG so as to minimize system power losses in different loading conditions. The optimal DG location and size found using maximum power stability index (MPSI) with particle swarm optimization (PSO) to reduce active power losses. Modified Teaching–Learning Based Optimization (MTLBO) algorithm propose for optimal DG in distribution systems to minimize total electrical power losses.

2) Multiobjective:

In the Analytical Approach Optimal size and power factor of DG determined using a new multiobjective index (IMO) based analytical approach for reducing power losses and enhancing loadability.

In Meta-Heuristic Approach For power loss reduction and voltage stability improvement of radial distribution system a new constrained multi- objective Particle Swarm Optimization (PSO) approach for finding best location and size of DG based on Wind Turbine Generation Unit (WTGU) and photovoltaic (PV) array used a technique based on combination of Loss Sensitivity Factor (LSF) and Simulated Annealing (SA) used to solve optimal siting and sizing problem of DGs to minimize losses and voltage stability improvement.

3) Sensitivity Analysis:

The optimal placement of DGs in the distribution systems is a combinatorial optimization problem. Search for the best combination amongst the various possible combinations for DG allocation is computationally arduous even for a small distribution system. The search space, however, can be compacted by reducing the number of candidate locations for DG placement using a suitable sensitivity analysis technique [7]. Hence, to identify suitable candidate/sensitive locations for DG integration, the proposed method starts with calculation of sensitivity of active power loss with respect to active- and reactive-power injections in the distribution system. The sensitivity of P_L active power loss in the system due to injected power is defined as

$$\text{Sensitivity of } P_L = \frac{\partial P_L}{\partial S} = \frac{{P_L}^{S+\Delta S} - P_L^S}{\Delta S} \quad (9)$$

Where S denotes the injected active- or reactive-power, ΔS denotes the increment in S and ${P_L}^{S+\Delta S}$ and ${P_L}^S$ represent the value of P_L with injected power $S + \Delta S$ and , respectively.

After calculating the sensitivity of active power loss with respect to active- and reactive-power, the buses are arranged in the descending order of sensitivity values obtained and a desirable number of most sensitive buses (say candidate locations) are selected as the possible candidates for DG placement.

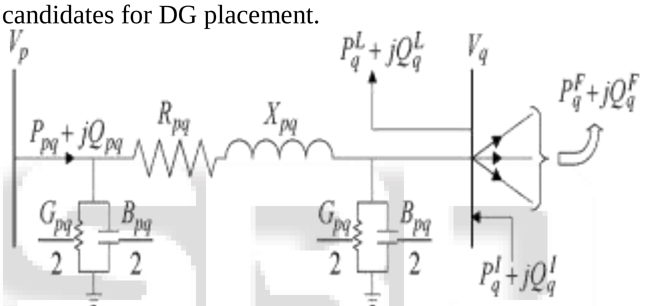

Fig. 1: Model of a branch connected between buses P and Q

F. Load Flow:

In this step, first the load flow solution is obtained for each time frame taking into account the previously developed models for the net power injections at candidate locations and for load; and then the solutions are used to analyze the system over the study period. For a branch, as shown in Fig. 1, relations for active power flow, reactive power flow and bus voltages can be given as

$$P_{pq} = {P_q}^F + {P_q}^L - {P_q}^I + \frac{G_{pq}}{2}(V_p^2 + V_q^2) + \frac{R_{pq}}{V_p^2}\left\{\left(P_{pq} - V_p^2\frac{G_{pq}}{2}\right)^2 + \left(Q_{pq} + V_p^2\frac{B_{pq}}{2}\right)^2\right\} \quad (10)$$

$$Q_{pq} = {Q_q}^F + {Q_q}^L - {Q_q}^I + \frac{B_{pq}}{2}(V_p^2 + V_q^2) + \frac{X_{pq}}{V_p^2}\left\{\left(P_{pq} - V_p^2\frac{G_{pq}}{2}\right)^2 + \left(Q_{pq} + V_p^2\frac{B_{pq}}{2}\right)^2\right\} (11)$$

$$V_q^2 = V_p^2 - 2\left\{\left(P_{pq} - V_p^2\frac{G_{pq}}{2}\right)R_{pq} + \left(Q_{pq} + V_p^2\frac{B_{pq}}{2}\right)X_{pq}\right\} + \frac{{R_{pq}}^2 + {X_{pq}}^2}{V_p^2}\left\{\left(P_{pq} - V_p^2\frac{G_{pq}}{2}\right)^2 + \left(Q_{pq} + V_p^2\frac{B_{pq}}{2}\right)^2\right\} \ (12)$$

Where $P_q{}^F = \sum_{\forall j!i=q} P_{ij}$ and $Q_q{}^F = \sum_{\forall j!i=q} Q_{ij}$ with (23) and (24) at the bottom of the next page. Here $P_{pq}(Q_{pq})$ are the sending end active (reactive) power flows; $R_{pq}(X_{pq})$ are the series resistance (reactance); and $G_{pq}(B_{pq})$ are the shunt conductance (susceptance) of a branch connected between buses p and q. $P_q{}^I(Q_q{}^I)$ are the active (reactive) power injections and $P_q{}^L(Q_q{}^L)$ are the total active (reactive) load at bus q . $P_q{}^F(Q_q{}^F)$ are the sum of active (reactive) power flows through all the downstream branches connected to bus q V_q is the magnitude of voltage at bus q. $Q_q{}^{Load}$ is the peak reactive load at bus q of the system.

$$P_q^L = l_k^t . P_q^{Load} \; and \; Q_q^L = l_k^t . q_q^{Load} \qquad (13)$$

$$P_q^I = \begin{cases} \sum_{m=1}^{N_P+N_W} \begin{bmatrix} (m,n)th\ element \\ of \\ P^I(A, s_i^t, v_j^t, l_k^t) \end{bmatrix} & if\ nth\ sensitive\ location = q \\ 0 & other\ wise \end{cases}$$

$$Q_q^I = \begin{cases} \sum_{m=1}^{N_P+N_W} \begin{bmatrix} (m,n)th\ element \\ of \\ Q^I(A, s_i^t, v_j^t, l_k^t) \end{bmatrix} & if\ nth\ sensitive\ location = q \\ 0 & other\ wise \end{cases}$$

(14)

Corresponding to a given solar irradiance state, wind speed state, load state and allocation matrix the load profile can be generated satisfying (13), while active and reactive power injections at candidate locations in the system can be obtained using (14). The system power losses, voltage magnitudes and line loadings can, then, be calculated using load flow studies by solving (10) to (12) iteratively[16].

III. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is a population-based optimization method first proposed by Kennedy and Eberhart in 1995,inspired by social behavior of bird flocking or fish schooling (Kennedy et al, 1995). The PSO as an optimization tool provides a population-based search procedure in which individuals called particles change their position (state) with time. In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjusts its position according to its own experience (This value is called Pbest), and according to the experience of a neighboring particle (This value is called Gbest), made use of the best position encountered by itself and its neighbor

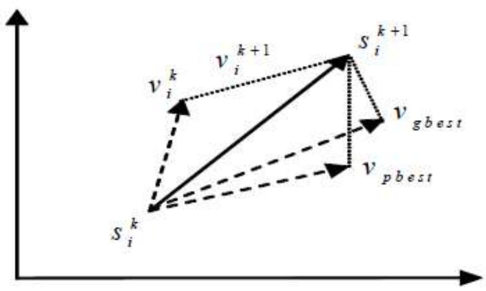

Fig. 2: Basic Model for PSO.

$$V_i^{k+1} = W.V_i{}^k + C_1R_1(Pbest_i{}^k - S_i{}^k) + C_2R_2(Gbest_i{}^k - S_i{}^k) \qquad (15)$$

$$S_i^{k+1} = S_i{}^k + V_i^{k+1}; i = 1,2,3 \ldots\ldots\ldots, N \qquad (16)$$

Where

N represents number of particle in the swarm,
i denotes the i'th particle in the swarm,
$S_i{}^k$ is the i'th particle position in iteration k,
V_i^{k+1} is the velocity of the particle j in k+1'th iteration,
$Pbest$ is the best position of i'th particle,
Gbest is the best position among all particles in the swarm,
w is the inertia weight,
C_1 and C_2 are cognitive parameter and social parameter,
R_1 and R_2 are the random numbers,
k is an iteration number,
K_{Max} is the maximum iteration .

Acceleration constant C_1 pulls each particle towards local best position whereas constant C_2 pulls the particle towards global best position.

Suitable selection of weight factor w helps in quick convergence. In this study, linearly decreasing weight w is considered instead of constant weight and it is represented by the following equation (17).

$$W = W_{max} - \left(\frac{(W_{max} - W_{min})}{K_{max}} \right) * K \qquad (17)$$

A. *Objective Function:*

The main objective of placement of PVA and WTG in the distribution system is to minimize the active power loss meeting following constraints

1) Constraints on the number of DG units to be allocated
2) Constraint on dispatched wind power
3) Constraint on voltage magnitude at different buses
4) Constraint on power flow
5) Constraint on line loading.

B. *Algorithm:*

The PSO algorithm consists of just three steps, which are repeated until some stopping condition is met:

Evaluate the fitness of each particle
Update individual and global best fitness and positions
Update velocity and position of each particle.

The process and the machinery of the PSO will be discussed in depth. The summary of traditional PSO is as follows.

1) Step 1: The population of N particles is initialized with random positions, x and the velocity, v of each particle is set to zero. Each particle can have d number of variables.
2) Step 2: The objective function is evaluated with all particles in order to find the objective value. The particles generated will be tested for it fitness to the objective. If the value of a particle and the objective value obtained from that particle are within the constraints of the system, that particle will be accepted. Meanwhile if the particle itself or the objective value obtained from that particle is out of the range of the system's constraints, new particle will be generated and this step will be repeated for the number of particles which are out of the boundary. The local best, Pbest, is set as the current position and objective value

of the particle, and the global best, Gbest and its objective value is set as the best initial particle.

3) Step 3: The new velocity,vi+1 and the new position, xi+1, is calculated using equations (1) and (2) and the values of the current Gbest and Pbest.
4) Step 4: Evaluate the objective values of all particles using the new position.
5) Step 5: The objective value of each particle is compared with its previous objective value. If the new value is better than the previous value, then update the Pbest and its objective value with the new position and objective value. If not, maintain the previous values.
6) Step 6: Determine the best particle of the whole updated population with the Gbest. If the objective value is better than the objective value of Gbest, then update Gbest and its objective value with the position and objective value of the new best particle. If not, maintain the previous Gbest.
7) Step 7: If the stopping criterion is met, then output Gbest and its objective value; otherwise, repeat step three.

C. *Advantages of PSO:*

1) The fitness function can be non-differentiable (only values of the fitness function are used). The method can be applied to optimization problems of large dimensions, often producing quality solutions more rapidly than alternative methods.
2) There is no general convergence theory applicable to practical, multidimensional problems. For satisfactory results, tuning of input parameters and experimenting with various versions of the PSO method is sometimes necessary. Stochastic variability of the PSO results is very high for some problems and some values of the parameters. Also, some versions of the PSO method depend on the choice of the coordinate system.

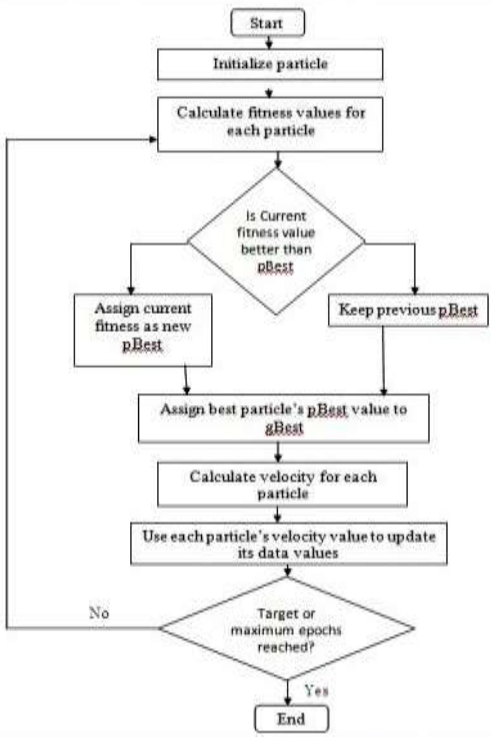

Fig. 3: Flowchart for PSO Based Technique

IV. RESULTS AND DISCUSSION

The developed algorithm is applied on a 12.66-kV, 69-bus distribution test system to find out the optimal positions of DG units. The test system is assumed to be situated near Kandla Port (State: Gujrat, Country: India), system has a peak load of 1.1079 MW. The study period of one year is divided into 12 months and each month is further subdivided into 24 segments, each referring to a particular hourly interval of the entire month. Thus, there are total 288 segments over a year and the number of hours associated with each segment is numerically equal to the number of days in the month under consideration.

Base case values of minimum and maximum voltage magnitudes and line loadings are used as the limiting values shown in Table 1.

In order to select the buses suitable for DG placement, sensitivity analysis is performed for the chosen distribution system using this approach. The active power loss sensitivities with respect to active- and reactive-power injections at different buses of test system are shown in Fig. 4.

Top 25 buses are selected as the candidate buses for placement of PVAs and WTGs in the following two configurations:

1) 1 PVA and 1 WTG, each of 0.25 MW size;
2) 2 PVAs and 2 WTGs, each of 0.125 MW size.

Energy Losses		Energy from Sub-station	
Active (MWh)	Reactive (MVARh)	Active (MWh)	Reactive (MVARh)
71.83	32.26	6028.15	4859.38

TABLE 1: BASE CASE RESULTS FOR 69-BUS SYSTEM.

For PVA, photovoltaic (PV) modules, each of rating=75 $W_p, V_{OC} = 21.98V, I_{SC} = 5.32A, V_{MPP} = 17.32V, I_{MPP} = 4.76A, C_V = 14.40mV/°C, C_1 = 1.22mA/°C, and\ N_{OT} = 43°C$ and for WTG, WTs each of $V_{cut-in} = 2.5m/s$, $V_{rated} = 11.0m/$s, and $V_{cut-out} = 21.0m/s$ The value of WPDLR is varied from 0% to 40% in steps of 10% in order to analyze the impact of dispatched wind power on the system performance. When the value of WPDLR becomes zero, WTGs cannot share any load [14]. Hence, for this case (WPDLR=0), only PVAs are allocated in the system. In each configuration, the WTGs are operated at constant lagging power factor of 0.8, while the PVAs are operated at unity power factor.

For PVAs, there are 325 possible alternatives. For WTGs, there are also 325 possible alternatives. Combing the two DG types, there are 105625 total possible alternatives.

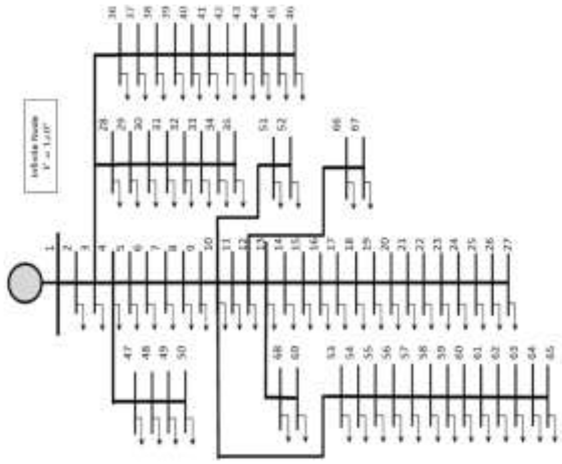

Fig. 4: IEEE 69-Bus Test System

The expected energy losses and expected energy contributions from sub-station and DG units for the two configurations with different control strategies and with different values of WPDLR are presented in Tables 2 and 3. For the sake of comparison, the obtained results for active energy loss corresponding to different placement schemes are compared with the base case value, and the percentage reductions in active energy losses are calculated and shown in Fig. 5. In this figure, the energy losses reduce with increase in the value of WPDLR. Corresponding to, around 40% reduction in active energy loss can be achieved. However, this reduction in active energy loss varies depending upon the number of DG units placed and control strategies employed.

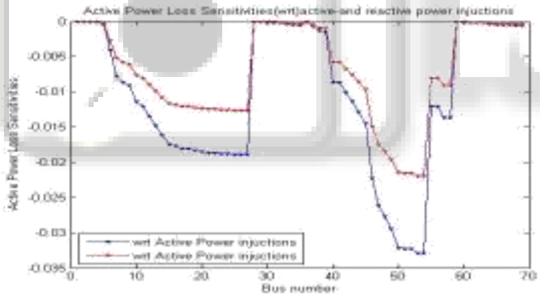

Fig. 5: Active Power Loss Sensitivities With Respect To Active And Reactive Power Injections At Different Buses Using PSO

The total energy generated by PVAs is constant and is equal to 249 MWh, as there is no restriction on the amount of solar energy dispatched. When only PVAs are located, system performance is identical; and approximately 9% reduction in active energy loss and about 4% reduction in active energy drawn from substation are observed for all cases.

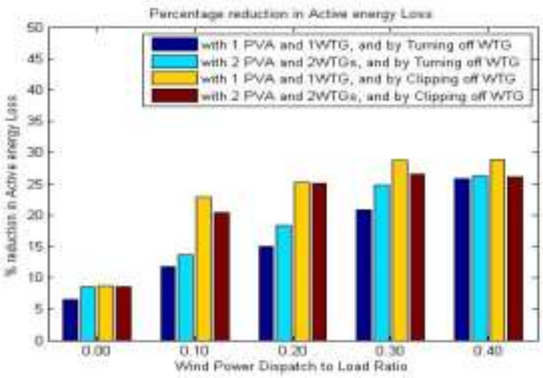

Fig. 6: Percentage reduction in active energy losses using PSO

The active energy from WTGs increases with increase in the value of WPDLR. However, the WTG output under "Clipping WTG output" control mode is more in comparison to that under "Turning off WTG" control mode. Whenever the available wind power exceeds its permissible dispatch limit, the two strategies control the wind power dispatch in entirely different manners. Corresponding to and "Turning off WTG" control strategy, 1 WTG injects 722.8MWh energy, while 2 WTGs inject 787.4MWh energy. With single WTG employing "Turning off WTG" control mode, it is turned off to maintain the value of WPDLR within the specified limit and consequently, it is unable to deliver any power to the system. In case of multiple WTGs using "Turning off WTG" control strategy, turning off process of WTGs is started from the least sensitive location until the value of WPDLR is within the permissible limit, Hence, the energy generated from WTGs under "Clipping WTG output" control strategy is constant regardless of the number of WTGs and always higher than that from WTGs under "Turning off WTG" control strategy. That is why, for a chosen value of WPDLR, "Clipping WTG output" control mode enhances the system performance in a better manner as compared to "Turning off WTG" control mode.

WPLDR	PV at bus	WTG at bus	Energy loss (MWh)	Energy sub (MWh)	Pv energy (MWh)	wind energy (MWh)
Clipping WTG Output						
0.0	53	0	59.24	5774.95	249.00	0.00
0.1	51	53	38.90	5340.67	249.00	409.28
0.2	54	50	35.54	5095.97	249.00	653.98
0.3	53	50	30.63	4966.78	249.00	783.17
0.4	53	50	30.27	4919.49	249.00	830.46
Turning OFF WTG						
0.0	53	0	62.53	5774.95	249.00	0.00
0.1	53	53	54.97	5655.80	249.00	112.15
0.2	53	53	50.36	5499.72	249.00	265.23
0.3	54	50	41.96	5226.47	249.00	528.48
0.4	53	50	34.81	5027.66	249.00	722.29

TABLE 2: Performance Of 69-Bus Distribution System By Allocating 1 Pva And 1 Wtg using PSO

WPLDR	PV at bus	WTG at bus	Energy loss (MWh)	Energy sub (MWh)	PV energy (MWh)	wind energy (MWh)
Clipping WTG Output						
0.0	53,54	0, 0	59.57	5774.95	249.00	0.00
0.1	53,54	51,53	42.62	5341.72	249.00	408.23
0.2	52,54	50,53	35.82	5095.59	249.00	654.36
0.3	50,53	50,53	33.62	4965.37	249.00	784.58
0.4	53,54	50,52	34.36	4917.99	249.00	831.96
Turning OFF WTG						
0.0	53,54	0, 0	59.57	5774.95	249.00	0.00
0.1	54,54	53,53	52.22	5576.65	249.00	188.30
0.2	52,54	52,53	45.49	5261.62	249.00	493.33
0.3	53,53	50,51	36.20	5068.10	249.00	681.85
0.4	51,54	50,53	34.20	4962.61	249.00	767.34

TABLE 2: Performance Of 69-Bus Distribution System By Allocating 2 Pva And 2 Wtg using PSO

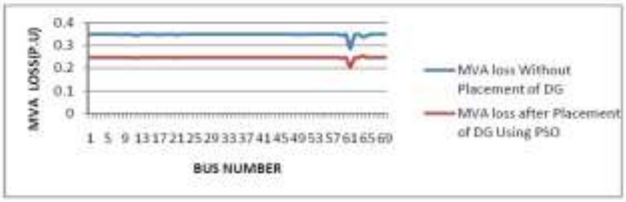

Fig. 7: MVA Loss with and without placement of DG using PSO

V. CONCLUSION

In this paper, a PSO based approach has been developed and presented for finding the optimal locations of PVAs and WTGs in a radial distribution system. The active energy loss have been minimized considering the constraints on bus voltages, line loadings, number of DGs to be placed and dispatched wind power. The system performance improved with increase in the value of wind power dispatch to load ratio. distribution system with wind turbines, "Clipping WTG output" control mode enhances system performance in a better way in comparison to "Turning off WTG" control mode. Allocation of several DG units of smaller sizes in the system is more beneficial for improvement in the system performance as compared to the allocation of few DG units of large size.

REFERENCES

[1] Dheeraj K. Khatod, Member, IEEE, Vinay Pant, and Jaydev Sharma "Evolutionary Programming Based Optimal Placement of Renewable Distributed Generators" IEEE Transactions On Power Systems, Vol. 28, No. 2, May 2013

[2] P.ChiradejaandR.Ramakumar,"Voltageprofile improvement with distributed wind turbine generation—a case study," in Proc.2003IEEE PES General Meeting, vol. 4, pp.2331–2336.

[3] Y. M. Atwa and E. F. El-Saadany, "Probabilistic approach for optimal allocation of wind-based distributed generation in distribution systems," IET Renew. Power Gen., vol. 5, pp. 79–88, Jan. 2011.

[4] Y. M. Atwa, E. F. El-Saadany, M. M. A Salama, and R. Seethapathy, "Optimal renewable resources mix for distribution system energy loss minimization," IEEE Trans. Power Syst., vol. 25, no. 1, pp. 360–370, Feb. 2010.

[5] C. Wang and M. H. Nehrir, "Analytical approaches for optimal placement of distributed generation sources in power systems," IEEE Trans. Power Syst., vol. 19, no. 4, pp. 2068–2076, Nov. 2004.

[6] G. Carpinelli, G. Celli, S. Mocci, F. Pilo, and A. Russo, "Optimisation of embedded generation sizing and siting by using a double trade-off method," Proc. Inst. Elect. Eng. Gen., Transm., Distrib., vol. 152, pp. 503–513, Jul. 2005.

[7] G. Celli, E. Ghiani, S. Mocci, and F. Pilo, "A multiobjective evolutionary algorithm for the sizing and siting of distributed generation," IEEE Trans. Power Syst., vol. 20, no. 2, pp. 750–757, May 2005.

[8] G. Celli and F. Pilo, "MV network planning under uncertainties on distributed generation penetration," in Proc. 2001 IEEE PES Summer Meeting, vol. 1, pp. 485– 490.

[9] S. H. Karaki, R. B. Chedid, and R. Ramadan, "Probabilistic performance assessment of autonomous solar-wind energy conversion systems," IEEE Trans. Energy Convers., vol. 14, no. 3, pp. 766–772, Sep. 1999.

[10] D. K. Khatod, V. Pant, and J. Sharma, "Analytical approach for wellbeing assessment of small autonomous power systems with solar and wind energy sources," IEEE Trans. Energy Convers., vol. 25, no. 2, pp. 535–545, Jun. 2010. 54

[11] Y. M. Atwa and E. F. El-Saadany, "Optimal allocation of ESS in distribution systems with a high penetration of wind energy," IEEE Trans. Power Syst., vol. 25, no. 4, pp. 1815–1822, Nov. 2010.

[12] D. B. Fogel, "Evolutionary computation: Toward a new philosophy of machine intelligence," in IEEE Press Series on Computational Intelligence, 3rd ed. Hoboken, NJ: Wiley, 2006, pp. 64–71.

[13] J. Yuryevich and K. P. Wong, "Evolutionary programming based optimal power flow algorithm," IEEE Trans. Power Syst., vol. 14, no. 4, pp. 1245–1250, Nov. 1999.

[14] A. Mani, Handbook of Solar Radiation Data for India. New Delhi, India: Allied Publishers Private Limited, 1980, pp. 99–116. [34] A. Mani and D. A. Mooley, Wind Energy Data for India. New Delhi, India: Allied Publishers Private Limited, 1983, pp. 96, 191 , 361, and 362.

[15] L. Wang and C. Singh, "Multicriteria design of hybrid power generation systems based on a modified particle swarm optimization algorithm," IEEE Trans. Energy Conversion., vol. 24, no. 1, pp. 163–172, Mar. 2009.

[16] M. H. Haque, "A general load flow method for distribution systems,"Elect. Power Syst. Res., vol. 54, pp. 47–54, Apr. 2000.