ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 2, August 2013

Power Compensation in Distribution System Based on Optimization Technique

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Abstract*—Distributed generation is an electric power generation source connected directly to the distribution network or on the customer side of the meter. The application of Particle Swarm Optimization (PSO) technique for active and reactive power compensation of power distribution loss has been proposed. The active and reactive power compensation can be obtained by the optimal placement of DG and Capacitor. Effectiveness of the proposed algorithm has been verified on a 13 bus system. The locations of DG and capacitor play an important role in maintaining voltage profiles. The results obtained indicate that by installing DG and capacitor whose location is optimized by PSO can significantly minimize the losses and improves the voltage profiles in distribution system. Simulation is done in MATLAB.

***Index Terms*—Distributed Generation (DG), distribution network, Particle Swarm Optimization (PSO) , Optimal location and size.**

I. INTRODUCTION

Power systems of the modern era are more reliable and serve customer load without any interruption in utility voltage. Generation facilities should have the capacity to produce required power to meet the customer demand. Bulk power generated must be transported through transmission systems over a long distance. It is responsibility of the distribution system to deliver electricity to each customer's service entrance. DG devices can be strategically placed in power systems for grid reinforcement, reducing power losses and on-peak operating costs, improving voltage profiles and load factors, differing or eliminating for system upgrades, and improving system integrity, reliability, and efficiency. Power losses in a distribution system is the sum of both active and reactive power losses. By the optimal placement of DG we can minimize active power losses associated with the active component of branch currents. The reactive power can be minimized by the optimal placement of capacitor. DG is an electric power generation source connected directly to the distribution network or on the customer side of the meter with a maximum capacity of less than 100MW [1], [2]. Optimal placement of DG and capacitor being integrated into distribution systems. In this paper, a Particle Swarm Optimization (PSO) technique [3],[4] has been used to determine the optimal location of a DG and capacitor in a distribution system. This can be achieved through minimizing The active and reactive power losses, improving the voltage profile and minimizing the cost of installation of DG and capacitor [7], [8],[10]. The rest of the paper is organized as follows. Optimal placement of DG and capacitor for the compensation of active and reactive power are explained in section II. The proposed algorithm is explained in section III. Problem formulation is given in section IV. Obtained simulation results are given in section V. Concluding remarks are given in section VI.

II. COMPENSATION OF ACTIVE AND REACTIVE POWER

A. Optimal Sizing of DG and Capacitor

Active and reactive power losses are reduced by the optimal sizing and placing of DG and capacitor. The analytical expressions for optimal placements are described here.[5] ,[6] ,[7].

The Exact Loss formula is given by

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}[\ \alpha_{ij}\left(P_i P_j + Q_i Q_j\right) + \beta_{ij}(Q_i P_j - P_i P_j) \quad (1)$$

Where

$$\alpha_{ij} = (r_{ij}/(V_i V_j))\cos(\delta_i - \delta_j)$$

$$\beta_{ij} = (r_{ij}/(V_i V_j))\sin(\delta_i - \delta_j)$$

The total active power loss of the system is minimum if

$$\frac{\partial P_L}{\partial P_i} = 2\alpha_{ii} P_i + 2\sum_{j=1, j\neq i}^{N}(\alpha_{ij} P_j - \beta_{ij} Q_j) = 0$$

From this

$$P_i = -1/\alpha_{ii}\left[\sum_{j=1, j\neq i}^{N}(\alpha_{ij} P_j - \beta_{ij} Q_j)\right] \quad (2)$$

Also

$$P_i = P_{DGi} - P_{Di} \quad (3)$$

From this

$$P_{DGi} = P_{Di} - 1/\alpha_{ii}\left[\sum_{j=1, j\neq i}^{N}(\alpha_{ij} P_j - \beta_{ij} Q_j)\right] \quad (4)$$

Similarly

$$Q_{DGi} = Q_{Di} - 1/\alpha_{ii}\left[\sum_{j=1, j\neq i}^{N}(\alpha_{ij} Q_j + \beta_{ij} P_j)\right] \quad (5)$$

Equation (4) gives the size of DG and equation (5) gives the size of capacitor.

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B. Optimal Location of DG and Capacitor –

The optimal location for the placement of both DG and capacitor is found out where there is minimum total power losses in the system.[9]

III. PROPOSED OPTIMIZATION TECHNIQUE

A. Particle Swarm Optimization Technique

PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. It is one of the modern heuristic algorithms and can be applied to non-linear and non-continuous optimization problems. PSO has roots in two main component methodologies. Perhaps more obvious are its ties to artificial life in general and to bird flocking ,fish schooling ,and swarming theory in particular.PSO applies the concept of social interaction to problem solving. It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. [3] Each particle is treated as a point in a N-dimensional space which adjusts its "flying" according to its own flying experience as well as the flying experience of other particles. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best , ***pbest***. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called ***gbest***. The basic concept of PSO lies in accelerating each particle toward its pbest and the gbest locations, with a random weighted acceleration at each time step. Each particle tries to modify its position using the current positions, the current velocities, the distance between the current position and pbest, the distance between the current position and the gbest. The modification of the particle's velocity can be mathematically modeled according the following equation:

$$V_i^{k+1} = wV_i^k + c_1\, rand_1 x\, (pbest_i^k - s_i^k) + c_2\, rand_2 x\, (gbest^k - s_i^k) \quad (6)$$

Using the above equation a certain velocity that gradually gets closer to pbest and gbest can be calculated. The current position (searching point in the solution space) can be modified by the following equation

$$s_i^{k+1} = s_i^k + V_i^{k+1} \quad (7)$$

The weight function used here is

$$w = w_{max} * [(w_{max} - w_{min}) * iter] / iter_{max}$$

Where w_{max} is the initial weight and w_{min} is the final weight. $iter_{max}$ is the maximum iteration number and iter is the current iteration number.

IV. PROBLEM FORMULATION

The problem is to determine allocation and size of the DGs and capacitors which minimizes the distribution power losses and improve the voltage profile for a fixed number of DGs and specific total capacity of the DGs .Objective is to compensate the active power and reactive power as given in

$$\text{Min } P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}[\ \alpha_{ij}(P_i P_j + Q_i Q_j) + \beta_{ij}(Q_i P_j - P_i P_j)$$

Cost function is given by

$$sub = kpg*(P_{DG}+P_{loss}) + kq*(Q_{DG}+Q_{loss}) / ((kps*(P_{lossold}-P_{loss}) + kq*(Q_{lossold}-Q_{loss}) + kv*(V_{costold}-V_{cost})$$

Where kpg is the real power production price..*kq* is the reactive power price. Ploss is the active power loss in presence of distributed generator. P_{DG} is the active production power of distributed generator. Q_{DG} is the reactive production power of distributed generator. Q_{loss} is the reactive power loss in presence of distributed generator. $P_{lossold}$ is the active power loss before installation of distributed generator. $Q_{lossold}$ is the reactive power before installation of distributed generator. $V_{costold}$ is the voltage variation from ideal condition before installation of distributed generator.

A. Proposed Algorithm

Step 1: Input line and bus data, and bus voltage limits.

Step 2: Calculate the loss using the equation.

Step 3: Generate an initial population of particles with random positions and velocities corresponding to size and location of DG in the solution space. Set the iteration counter n = 0.

Step 4: For each particle find the bus voltage and if the bus voltage is within the limits, evaluate the total loss using the given equation. Otherwise, that particle is infeasible so set it to base case loss.

Step 5: For each particle, compare its objective value with the individual best. If the objective value is lower than P*best*, set this value as the current P*best* value and note the corresponding particle position.

Step 6: Choose the particle associated with the minimum individual best P*best* of all particles, and set the value of this P*best* as the current overall best G*best*.

Step 7: Update the weight, velocity and position of particle. Declare the best particle result with optimal location and optimal size of DG and capacitor .Calculate the cost function .

Step 8: If the iteration number reaches the maximum limit, go to Step 9. Otherwise, set iteration index n = n + 1, and go back to Step 4.

Step 9: Obtain the optimal solution . The best position includes the optimal locations and size of DG and capacitor and the corresponding fitness value representing the minimum total real power loss.

V. SIMULATION RESULTS

The proposed PSO algorithm is implemented by using MATLAB and it is tested on 13 bus system. The optimization problem considered in this case is to reduce the active and reactive power loss by the optimal placement of DG and capacitor. The objective function in the optimization problem is used as a fitness function in the PSO. Table I and II shows

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that by the optimal placement of DG and capacitor both the active and reactive power losses can be reduced. From the table it is clear that placing DG and capacitor at different buses provides more reduction losses than placing at the same bus.

Table I. Simulation results Obtained by PSO

Particle Swarm Optimization Technique							
	Bus No	***Active power loss P1(kW)***	***Reactive power loss Q1(kW)***	***DG Size (MW)***	***Capacitor size (MVAR)***	***Voltage Variance***	***Cost Function***
Without DG	-	236.88	185.9	-	-	0.4195	-
With DG	10	209.92	164.8	3.446	-	0.3978	112.16
DG and capacitor at same bus	9	199.93	156.7	3.306	2.397	0.3822	109.91
DG and capacitor at different buses	9	189.43	148.6	3.306	-	0.3687	103.5
	6	189.43	148.6	-	5.388	0.3687	103.5

Table II. Percentage Loss Reduction

Cases	**Particle Swarm Optimization Technique**	
	% Loss reduction	
	Active power loss	***Reactive power loss***
With DG	11.38	11.33
DG and capacitor at same bus	15.7	15.74
DG and capacitor at different buses	20.03	20.09

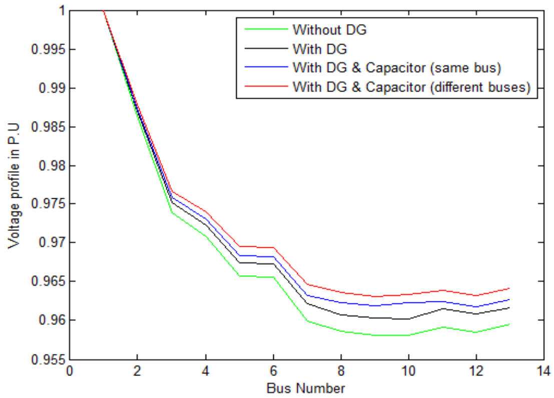

Fig 1: variation of voltage profile without DG , with DG, with DG and capacitor at same bus , with DG and capacitor at different buses

Figure shows that the voltage profile gets improved as we provide DG and Capacitor at different buses than DG and capacitor at same buses.

VI. CONCLUSION

Here one of the most efficient evolutionary optimization technique, PSO were proposed and has been implemented. The optimal placement of capacitor and DG in distribution system, reduction of active and reactive power and voltage profile improvement were considered as the optimization criteria. This approach has been tested and examined on 13 bus test system to demonstrate its effectiveness. PSO has been proposed for finding optimal sizes of DG and Capacitor at optimal locations for active and reactive power compensation for minimizing the losses in the distribution systems. Obtained results showed that placement of capacitor and DG not only reduces the losses, but also improves the voltage profile of the system. All obtained results are validated and support the proposed technique.

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