Research Paper

A NEW APPROACH FOR OPTIMAL DG PLACEMENT AND SIZING BASED ON VOLTAGE STABILITY MAXIMIZATION AND MINIMIZATION OF POWER LOSS

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ABSTRACT
Power utilities are facing major challenges as the demand of power system is growing exponentially. The existing transmission line infra-structure e is not capable to support such a huge power demand. The present need is either to invest in transmission system to increase the capacity or provide the consumer demand locally by Distributed Generation (DG). A new multi-objective approach for optimum DG placement, considering minimization of power losses and maximization of voltage stability due to finding weakest voltage bus as well as due to weakest link in the system. Considered Particle Swarm Optimization (PSO) technique to solve the multi-objective function.

KEY WORDS: Distributed Generation (DG), Particle swarm optimization (PSO)

I. INTRODUCTION

Power utilities are facing major challenges as the demand of power system is growing exponentially. The existing transmission line infra-structure e is not capable to support such a huge power demand. The present need is either to invest in transmission system to increase the capacity or provide the consumer demand locally by Distributed Generation (DG). Different authors have given different definitions of DG."Distribution Generation is an electrical power source connected directly to the distribution network or on the consumer side of the meter". Also it can define as DG a term commonly used for small-scale generations, offers solution to many of these new challenges. The word distributed generation is also subjective and changes with respect to the region. For example, 'embedded generation' term is used in Anglo-American countries, 'dispersed generation' is used in North American countries, and 'decentralized generation' term is used in Europe and parts of Asia. CIGRE define DG as the generating plant with a maximum capacity of less than 100 MW, which is usually connected to the distribution networks and that are neither centrally planned nor dispatched. Distributed Generation (DG) have many different types ranging from conventional fossil fuel based combustion engines to the renewable energy including wind, photo-voltaic cells, micro-turbines, small hydro turbines, CHP or hybrid. DG can also be categorized on the basis of the power ratings:

Micro-distributed generation	~ 1W < 5 kW
Small-distributed generation	5kW<5MW
Medium-distributed generation	5MW< 50MW
Micro-distributed generation	50MW< 300MW

DG has many advantages over centralized power generation, including reduction of power system losses and improved voltage profile. The optimum DG placement and sizing at planning stage of distribution system is necessary to achieve the maximum benefits. The non-optimum DG placemen t and sizing could results in increase power losses and affect the system voltage profile. However the optimum DG placement results in reduce distribution and transmission line losses and thus increases the overall system capacity of the power system. The system capacity is usually limited by two factors, thermal limits and voltage limits. Thermal limit or thermal capacity is the capacity or maximum current carrying capacity limit of the conductor. The current carrying capacity is limited by the conductor's maximum design temperature, which is determined by the insulation class use. However the voltage limit is the allowable minimum–maximum voltage variation for safe operation of power system and connected load. But the maximum loadability of the distribution system is limited by the voltage limit rather than the thermal limit.PSO algorithm has been developed for optimal placement of multiple DGs in a micro grid to minimize the real power loss within voltage and power generation limits placement. PSO approach has been used by the authors to determine the optimal placement of DG's and the result obtained from PSO technique have also been compared with the analytical approach results.

II. OBJECTIVE

Objective of power system operation is to meet the demand at all the locations within power network economically and reliably as possible. In the present environment the justification for the large central-station plants is weakening, due to depleting conventional resources, increased transmission and distribution costs, deregulation trends, heightened environmental concerns, and technological advancements Distributed Generations (DGs), a term commonly used for small-scale generations, offer solution to many of these new challenges. The optimal locations and size of the DG's have been determined by minimizing the power distribution loss. The particle swarm optimization (PSO) technique has been used to solve the optimal placement of DGs. The results obtained from the PSO technique have also been compared with existing DG placement Methods.

III. METHODOLOGY

Minimization of power losses, maximization of bus voltage stability and maximization of line voltage stability are considered as fitness function for optimum DG placement and sizing. SI index is used to find the weakest voltage bus and L_{mn} index is used to find the weakest link in the system which can lead to voltage instability, when load will reach to its critical limits. The formulation of SI Index and L_{mn} index is as follows:

SI Index, is utilized to find the weakest voltage bus in power system. This index will find the most optimum weakest link in the system which could lead to voltage stability in future, when the load will increase. The value of index is given by following eq. and termed as Stability index (SI).

$$SI = |V_s|^4 - 4 \times \{P_r x_{ij} - Q_r r_{ij})\}^2 - 4 \times \{P_r r_{ij} + Q_r x_{ij}\}^2 \times |V_s|^2 \geqslant 0$$

Where, SI is the stability index, Vs is the sending bus voltage, Pr is active load at receiving end, Q_r is the reactive load at receiving end, rij is the resistance of the line i–j and xij is reactance of the line i-j

Under stable operation , the value of SI should be greater than zero for all buses. When the value of SI becomes closer to one, all buses become more stable. In the proposed algorithm, SI value is calculated for each bus in the network and sort from highest to lowest value. For the bus having the lowest value of SI, will be considered in fitness function.L_{mn} Index, will find the weakest link in the system which could lead to voltage stability in future, when the load will increase. The value of index is given by following eq. and termed as line stability index (L_{mn}).

$$L_{mn} = \frac{4 \times Q_r}{[V_s \sin(\theta - \delta)]^2} \leqslant 1.00$$

where L_{mn} is the line voltage stability index, V_s is the sending end bus voltage, θ is the line impedance angle, Q_r is the active load at receiving end, x is reactance of the line i–j, and σ is angle difference between sending and receiving end bus; Under stable condition, value of L_{mn} should be less than unity; when L_{mn} exceeds unity, system become unstable. Thus the formulation of SI and L_{mn} are opposite to each other, lower values in SI shows bus instability while higher values of L_{mn} represents line instability.

In the present work, both indices are combined together and termed as Combined Bus and Line Voltage Stability Index (CBL_VSI), given by following eq. In problem formulation, CBL_VSI will be considered as the first fitness function and need to be minimized.

$$CBL\_VSI = 0.5 \times Min\{SI(nbus)\} + 0.5 \times \frac{1}{Max\{L_{mn}(nbr)\}}$$

where CBL_VSI is Combined Bus and Line Voltage Stability Index; n bus is the total number of busses in the test system ; nbr is the total number of branches in the test system.

From above eq., it should be noted that, the value of SI need to minimize and the value of L_{mn} need to maximize, thus the inverse of L_{mn} is considered in CBL_VSI formulation. Further it should also be noticed that to bring symmetry in the results of CBL_VSI, both terms are multiplied with the constant 0.5, thus the value of CBL_VSI will also range from 0to1.

Thukaram load flow method is used here to carry out the load flow analysis for the radial distribution system. Thukaram load flow is based on forward–backward sweep. In backward sweep, the load current is computed for nth nodes in the network, using following eq.

$$I_i = conj(S_i/V_i) \quad i = 1, 2, 3, \ldots, n$$

However, in forward sweep, the receivin g end voltage is calculated using Eq.

$$V_r = V_s - I(R + jX)$$

Apply the same approach to n buses in the radial system . The convergence criteria proposed is given by following eq..

$$Max[V_i^k - V_i^{k-1}] < tolerance \quad i = 1, 2, 3, \ldots, n$$

Where, k is no. of iteration and n is total number o fbuses.

IV. Problem Formulation

Problem formulation will be made for optimum multi DG units' placement and sizing, considering:

- Line stability need to improve.
- Bus voltage stability need to improve.
- Reduce the power system losses.

To achieve the first two tasks, CBL_VSI is considered as the first fitness function and need to be minimized, to increase the bus and line voltage stability.

$$Fitness_1 = Min\{CBL\_VSI\}$$

Minimization of system power losses (I2R) are considered as second fitness function and given by following eq.

$$Fitness_2 = Min\left\{P_L = \sum_{i=1}^{nbr} |I_i|^2 R_i\right\}$$

Since the fitness unit of both objective functions are different (power losses are in ''kW'' and CBL_VSI index has no unit),thus the normalization process is needed. The following formulation is used to normalize the fitness function values in between 0 and 1.

$$F_1 = Norm\_CBL\_VSI(i_j) = \left|\frac{CBL\_VSI(i) - Min\_CBL\_VSI \times k}{Max\_CBL\_VSI - Min\_CBL\_VSI \times k}\right|$$

$$F_2 = Norm\_Losses(i_j) = \left|\frac{P_{Losses}(i) - Min\_P_{Losses} \times k}{Max\_P_{Losses} - Min\_P_{Losses} \times k}\right|$$

Here it should be noticed that 'k' has a major significance in normalization process. If k = 1,the fitness function can trapped at 0(when the jth value is also the minimum value in ith iteration),thus in the present case k is set equal to 0.1.

The normalized fitness functions are combined together using the formulation , given by following Eq.

$$Overall\ Fitness\ Function = Minimization\ of\ CBL\_VSI\ index + Minimize\ power\ losses\ PL$$

Technique Used: Particle swarm optimization technique:

Particle Swarm Optimization (PSO) is used here to find the optimum DG placement and sizing. As the PSO technique is a heuristic global optimization method or an optimization algorithm, which is based on swarm intelligence.PSO Technique is developed by Dr. Kennedy and Dr. Eberhart in 1995 inspired by social behavior of bird flocking or fish schooling. PSO has no overlapping and mutation calculation

Suppose the following scenario:

A group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food i. But they know how far the food is in each iteration. So What's the best strategy to find the food?

The effective one is to follow the bird which is nearest to the food.

PSO learn from scenario & used it to solve optimization problem. In PSO, each single solution is a 'Bird' in a search space we call it as "Particle". All of particles have fitness values which are evaluated by the fitness function to be optimized & have velocities which direct the flying of the particles. The particles fly through the problem space by following the current optimum particle.

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 particles (this value is called gbest), making use of the best position encountered by itself and its neighbors

Mathematically, the position of particle in an n-dimensional vector is represented as:

$$X_m = (x_{m,1}, x_{m,2}, x_{m,3}, \ldots x_{m,n})$$

The current position is modified according to the following equation:

$$S_{id}^{k+1} = S_{id}^{k} + v_{id}^{k+1}, \quad i = 1, 2, \ldots, n, \quad d = 1, 2, \ldots, m$$

where S^k is the current position of particle and S^{k+1} the modified position of particle.

The velocity of each particle is also in an n-dimensional vector,

$$V_m = (v_{m,1}, v_{m,2}, v_{m,3}, \ldots v_{m,n})$$

Velocity of each particle can be modified according to the following
equation:

$$v_{id}^{k+1} = \omega_i v_{id}^{k} + c_1 rand \times (pbest_{id} - s_{id}^{k}) + c_2 rand \times (gbest_{id} - s_{id}^{k})$$

where v^k is the current velocity; v^{k+1} the modified velocity of particle
i; Vpbest the velocity based on pbest; Vgbest the velocity based on gbest; n the number of particles in a group; m the number of members in a particle; pbesti the pbest of particle i; gbesti the gbest of the group; xi the weight function for velocity of particle i and ci the
weight coefficients for each particle.

The following weight function is used:

$$\omega_i = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{k_{max}} . k$$

Where and ω_{max} are the minimum and maximum weights respectively. k and k_{max} are the current iteration and maximum number of iterations. Appropriate values for c1and c2 lies in the range 1–2. For fast convergence of the PSO algorithm,
final values are considered as: c1 = c2 = 2, $\omega_{min} = 0.4$ and $\omega_{max} = 0.9$.

After each iteration, the velocity and position of the particles are updated.

In the proposed method of optimum DG placement and sizing, PSO is used to find the fitness function, by above given Eq. This approach is used for solving multi objective problems [23].

$$Min\ (f) = w_1 \times F_1 + w_2 \times F_2$$

where f is equal to fitness function, and w1 and w2 are weightage factors (w1 = w2 = 0.5).

In the present case of DG placement and sizing, the ith particle (xi) is a two dimension vector (P_{DG}, P_{DG}), representing random DG positions (P_{DG}) and DG size (PDG). Subjected to the following constraints Eqs.

$$0 \leqslant size\ of\ DG\ (\mathbf{P}_{DG}) \leqslant \sum \mathbf{P}_{load}$$

The proposed algorithm is also compared with analytical method and Grid search algorithm.

V. CONCLUSION

From this project stage I we conclude that here presented a new multi-objective approach for optimum DG placement, considering minimization of power losses and maximization of voltage stability due to finding weakest voltage bus as well as due to weakest link in the system. Considered Particle Swarm Optimization (PSO) technique to solve the multi-objective function. In this work the proposed approach is going to be compare with existing analytical and grid search algorithm.

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