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Active Power Loss Reduction by Particle Swarm Optimization Algorithm

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Abstract- This work presents Particle swarm optimization (PSO) algorithm for solving optimal reactive power problem. PSO is an optimization tool based on a population, where each member is seen as a particle, and each particle is a potential solution to the problem under analysis. Each particle in PSO has a randomized velocity associated to it, which moves through the space of the problem. However, unlike genetic algorithms, PSO does not have operators, such as crossover and mutation. PSO does not implement the survival of the fittest individuals; rather, it implements the simulation of social behaviour. Projected Particle swarm optimization (PSO) algorithm has been tested in standard IEEE 300 bus system and simulation results show the better performance of the proposed algorithm in reducing the real power loss.

Keywords- Optimal reactive power, Transmission loss, particle swarm optimization

I. INTRODUCTION

Optimal reactive power dispatch problem is one of the difficult optimization problems in power systems. The sources of the reactive power are the generators, synchronous condensers, capacitors, static compensators and tap changing transformers. The problem that has to be solved in a reactive power optimization is to determine the required reactive generation at various locations so as to optimize the objective function. Here the reactive power dispatch problem involves best utilization of the existing generator bus voltage magnitudes, transformer tap setting and the output of reactive power sources so as to minimize the loss and to maintain voltage stability of the system. It involves a nonlinear optimization problem. Various mathematical techniques have been adopted to solve this optimal reactive power dispatch problem. These include the gradient method [1, 2], Newton method [3] and linear programming [4-7].The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input- output function is to be expressed as a set of linear functions which may lead to loss of accuracy. Recently many global optimization techniques have been proposed to solve the reactive power flow problem [8-10]. This paper presents. Particle swarm optimization (PSO) algorithm for solving optimal reactive power problem. PSO is a quick, easy and well-organized population based optimization method. A populace of particles is initially haphazardly produced. Every molecule speaks to a potential solution and has a position spoke to by a spot vector. A swarm of particles move from start to finish the issue space, particle represented by a velocity vector. At every time step, a capacity speaking to a quality measure is figured by utilizing as information. Every molecule monitors its own best position, which is connected with the best wellness it has accomplished so far in a vector. Projected Particle swarm optimization (PSO) algorithm has been tested in standard IEEE 300 bus system and simulation results show the better performance of the proposed algorithm in reducing the real power loss.

II. PROBLEM FORMULATION

The objective of the reactive power dispatch problem is to minimize the active power loss and can be written in equations as follows:

$$F = P_L = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}\right) \quad (1)$$

Where F- objective function, P_L – power loss, g_k-conductance of branch, V_i and V_j are voltages at buses i,j, Nbr- total number of transmission lines in power systems.

Voltage profile improvement

To minimize the voltage deviation in PQ buses, the objective function (F) can be written as:

$$F = P_L + \omega_v \times VD \quad (2)$$

Where VD - voltage deviation, ω_v- is a weighting factor of voltage deviation.

And the Voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (3)$$

Where Npq- number of load buses

Equality Constraint

The equality constraint of the problem is indicated by the power balance equation as follows:

$$P_G = P_D + P_L \quad (4)$$

Where P_G- total power generation, P_D - total power demand.

Inequality Constraints

The inequality constraint implies the limits on components in the power system in addition to the limits created to make sure system security. Upper and lower bounds on the active power of slack bus (P_g), and reactive power of generators (Q_g) are written as follows:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \quad (5)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g \quad (6)$$

Upper and lower bounds on the bus voltage magnitudes (V_i) is given by:

$$V_i^{min} \leq V_i \leq V_i^{max}, i \in N \quad (7)$$

Upper and lower bounds on the transformers tap ratios (T_i) is given by:

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T \quad (8)$$

Upper and lower bounds on the compensators (Q_c) is given by:

$$Q_c^{min} \leq Q_c \leq Q_C^{max}, i \in N_C \quad (9)$$

Where N is the total number of buses, N_g is the total number of generators, N_T is the total number of Transformers,N_c is the total number of shunt reactive compensators.

III. PARTICLE SWARM OPTIMIZATION ALGORITHM

Particle swarm optimization algorithm is the evolutionary optimization algorithm based on the natural behaviour of bird and fish swarms and was firstly introduced by R. Eberhart and J. Kennedy in 1995 (Kennedy, Eberhart 1995, Eberhart, Kennedy 2001). The field of swarm intelligence is an emerging research area that presents features of self-organization and cooperation principles among group members bio-inspired on social insect societies [11–13]. Swarm intelligence is inspired by nature, based on the fact that the live animals of a group contribute with their individual experiences to the group, rendering it stronger to face other groups. The particle swarm optimization (PSO) originally developed by Kennedy and Eberhart in 1995 [11,12] is a population based swarm algorithm. Similarly to genetic algorithms [13], an evolutionary algorithm approach, PSO is an optimization tool based on a population, where each member is seen as a particle, and each particle is a potential solution to the problem under analysis. Each particle in PSO has a randomized velocity associated to it, which moves through the space of the problem. However, unlike genetic algorithms, PSO does not have operators, such as crossover and mutation. PSO does not implement the survival of the fittest individuals; rather, it implements the simulation of social behaviour. As the optimization continues, the value of w is decreasing, thus the velocity of each particle is decreasing, since w is the number < 1 and it multiplies previous velocity of particle in the process of new velocity value calculation. Inertia weight modification PSO strategy has two control parameters w_{start} and w_{end}. New w for each generation is then given by Eq. 10, where i stand for current generation number and n for total number of generations.

$$w = w_{start} - \frac{((w_{start} - w_{end}) \cdot i)}{n} \quad (10)$$

$$v(t+1) = w.v(t) + c_1 \cdot Rand \cdot (pBest - x(t)) + c_2 \cdot Rand \cdot (gbest - x(t)) \quad (11)$$

Where:
v(t+1) – New velocity of particle.
v(t) – Current velocity of particle.
c1, c2 – Priority factors.
pBest – Best solution found by particle.
gBest – Best solution found in population.
x(t) – Current position of particle.
Rand – Random number, interval <0,1>

New position of particle is then given by Eq. 12, where x(t+1) represents the new position:

$$x(t+1) = x(t) + v(t+1) \quad (12)$$

A new strategy, which is proposed in this research, alters the original way (Eq. 11) of calculating the particle velocity for the next generation. At first, three numbers b1, b2 and b3 are defined at the start of algorithm. These numbers represent limit values for different rules, so they should follow the pattern: b1 < b2 < b3. In this study following values were used:
b1 = 0.3, b2 = 0.5, b3 = 0.8. Afterwards during the calculation of new velocity of each particle a random number r is generated from the interval <0, 1>. Finally the new velocity is calculated based on following four rules: If r ≤ b1 a new velocity of particle is given by Eq. 13 :

$$v(t+1) = 0 \quad (13)$$

If b1 < r ≤ b2 a new velocity of particle is given by

$$v(t+1) = w.v(t) + c \cdot Rand \cdot (x_r(t) - x(t)) \quad (14)$$

If b2 < r ≤ b3 a new velocity of particle is given by

$$v(t+1) = w.v(t) + c \cdot Rand \cdot (pbest - x(t)) \quad (15)$$

If b3 < r a new velocity of particle is given by

$$v(t+1) = w.v(t) + c \cdot Rand \cdot (gbest - x(t)) \quad (16)$$

The priority factors c1 and c2 from original equation (Eq. 11) are replaced within this novel approach with a new parameter c. In this novel strategy parameter c defines not the priority (which is naturally given by b1, b2 and b3 setting) but the overstep value. In other words how far past the target (pBest, gBest or random particle) can the active particle go. Within this initial research, parameter c was set to 2.

IV. SIMULATION RESULTS

IEEE 300 bus system [14] is used as test system to validate the performance of the proposed algorithm. Table 1 shows the comparison of real power loss obtained after optimization

TABLE 1 COMPARISON OF REAL POWER LOSS

Parameter	Method EGA [16]	Method EEA [16]	Method CSA [15]	PSO
PLOSS (MW)	646.2998	650.6027	635.8942	625.0142

V. CONCLUSION

In this paper Particle swarm optimization (PSO) algorithm successfully solved the optimal reactive power problem. Each particle in PSO has a randomized velocity associated to it. PSO is a quick, easy and well-organized population based optimization method. A populace of particles is initially haphazardly produced. Every molecule speaks to a potential solution and has a position spoke to by a spot vector. Projected Particle swarm optimization (PSO) algorithm has been tested in standard IEEE 300 bus system and simulation results show the better performance of the proposed algorithm in reducing the real power loss.

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