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Group Search Optimization Technique based Minimization of Reactive Power Generation in Power System

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Abstract : *Power system structure is undergoing through restructuring process since a decade. Everyday a bulk amount of power is generated, transmitted and distributed via transmission network. The active power or the real power generated from the generator needs the reactive power for supporting its own transmission. This reactive power generation has some minimum limit which if generator fails to produce it has to take support from system operator for smooth real power flow in worth of paying money. While the generator produces excess reactive power it can expect remuneration from the system operator. In deregulated power system minimal reactive power generation is considered as an important issue as cost is related to it. In this paper IEEE 14-bus test system is considered for solving the problem. As a solving tool a well known population based metaheuristics technique: group search optimisation is chosen which tries to optimize the problem by controlling the generator bus voltage. The choice of the objective function and the mentioned optimisation technique is considered by through literature survey.*
Keywords: *group search optimisation, Minimal of reactive power generation, real power output.*

I. Introduction

Around the world, the power system structure is undergoing through restructuring process during the last decades [1]. Before deregulation a traditional monopoly structure in the power sector was ruling the market. In the deregulation process the buyers and sellers starts to interact among them regarding power transaction and maintain system security through system operator. That means a competitive market environment develops via several gencos (Generating Companies), transcos (Transmission Companies) and discos (Distribution Companies) along with the system operators, Under the competitive market each and every essential terms like active power output, balanced voltage profile, reactive power generation etc related to system operation and control are accounted as a commercial product [2]. The shipment of generator active power needs the support of reactive power generated from the same generator. Therefore generated reactive power from any generators is utilized to compensate required reactive power loss developed in the system along with the supporting of real power flow. In connection with deregulatory power environment the target is to minimise reactive power generation required for supporting real power flow. If the reactive power generation remains within the minimum value no penalty charge will be paid. From the viewpoint of profit, the power producers should try to sell as much as active power with minimum generated reactive power keeping the system security uninterrupted. Therefore overall cost minimization of active and reactive power generation depends on minimum reactive power generation. The term minimal reactive power generation may be explained as least amount of reactive power needed from each generator to maintain smooth real power flow along with stable voltage profile. If generator produces more reactive power with respect to minimum value, it will be counted for system security and the power producers should expect remuneration from the system operator. On the other hand if generator is lagging behind the minimum reactive power generation, it has to take support of system security to sell active power in worth of paying money [3-4]. Thus in the deregulatory power environment this remuneration concept via system operators facilitates competitive situation in terms of system voltage security. This motivates to maximize profit in terms of real and reactive power generation for power producing companies.

Wang *et al.* shows why and how minimum reactive power generation is important and can be determined [5]. In another paper Wang *et al.* shows an investigation of minimum reactive power generation requirement on a real life power system field [6]. Furthermore Wu and co-workers studies thoroughly the same problem for 39-bus test system [7]. They consider nonlinear programming technique as interior point method and its modification to solve the same. As the problem is nonlinear as well as convex in nature, soft-computing method may be fit to solve it. With this motivation in this paper Group Search Optimisation (GSO) technique [8-9] is proposed to solve minimal reactive power generation (MRPG) problem. In this paper focus has been given to minimise reactive power generation as much as possible to supply real power demand keeping all the constraints of the system uninterrupted. As a test case IEEE 14-bus system is chosen where minimal reactive power generation is experienced for four generator buses. In this paper next section elaborates the problem formulation; third section describes the GSO algorithm. The results and discussion with future scope are given in the fourth section of the paper which is followed by the references.

II. Problem Formulation

Minimal reactive power generation (MRPG) problem helps to control the generator function in terms of reactive power generation and smooth real power flow in the deregulatory environment. Target of the problem from the view point of power producing companies are to maintain reactive power generation under minimum value such that it can support its own real power transmission and even extra remuneration can be obtained from the system operator. Reactive power generation is directly associated with the control of bus voltage

The objective function of the MRPG problem is expressed by equation (1). The objective function is minimized by controlling the generator terminal voltage (V_G) while other dependent variables are kept at their specific operating range.

Mathematically MRPG problem is expressed as:

min f(x) subject to:

$$\left.\begin{array}{l} g(x) = 0 \\ h(x) \leq 0 \end{array}\right\} \quad (1)$$

Now *f(x)* is the objective function which typically means minimization of reactive power generation where *x* represents the control or independent variable $[V_G]^T$. In this connection, the MRPG problem can be expressed as:

$$min\ Q_{Gen} = \sum_{i=1}^{ng} Q_i \quad (2)$$

where, ng is the total number of generator buses in the network, Q_i is the individual generator reactive power and Q_{Gen} is the total generator reactive power. In this paper, power generation is calculated with load flow study via Newton Raphson method [10].

The minimization of the above objective function is subjected to a number of equality and inequality constraints [12];

Equality Constraint:

$$g(x) = 0 \quad (3)$$

i.e. can be represented by typical load flow equations:

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{NB} V_j \left[G_{ij} \cos(\delta_i - \delta_j) + B_{ij} \sin(\delta_i - \delta_j)\right] = 0 \quad (4)$$

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{NB} V_j \left[G_{ij} \cos(\delta_i - \delta_j) + B_{ij} \sin(\delta_i - \delta_j)\right] = 0 \quad (5)$$

where NB is the number of buses, P_G is the real power generation, Q_G is the reactive power generation, P_D is the active load demand, Q_D is the reactive load demand, δ_i and δ_j is the voltage angle of bus i and j respectively and G_{ij} and B_{ij} are the conductance and the susceptance between bus i and j respectively.

Inequality Constraint:

$$h(x) \leq 0 \quad (6)$$

These constraints are:

1. Generation constraints: Generation bus voltages, reactive power outputs are restricted by their lower and upper limits as:

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max},\ i = 1,\ldots,G \quad (7)$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max},\ i = 1,\ldots,G \quad (8)$$

2. Transformer constraints: Transformer tap settings are restricted by their lower and upper limits as:

$$T_i^{min} \leq T_i \leq T_i^{max},\ i = 1,\ldots,NT \quad (9)$$

3. Shunt VAR constraints: Shunt VAR compensators are restricted by their lower and upper limits as:

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max},\ i = 1,\ldots,NC \quad (10)$$

4. Security Constraints: This includes the constraints of voltage at load buses as:

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max},\ i = 1,\ldots,G \quad (11)$$

where NT, NC, NL and V_L are transformer tap settled buses, shunt capacitor connected buses, load buses and load bus voltages respectively. As the objective function is fixed Particle Swarm Optimisation Technique is applied to solve the problem in hand.

III. Group Search Optimisation

Group search optimization (GSO) is a novel stochastic optimisation algorithm that was developed by (S. He et al., 2009). This algorithm is inspired by the foraging behaviour of animals. The entire population of the GSO algorithm is termed a group and each individual in the population is called a member. There are three types of members namely: producers, scroungers and rangers. In order to achieve this foraging task the producer- scrounger strategy is engaged. Producing signifies to the action of searching for food and scrounging means joining the group for foraging. Rangers perform random walks in the search space. According to the GSO algorithm only one member is chosen to be the producer and the remaining members are scroungers and rangers. The producer constantly looks and finds the resources and the scroungers just join the producer. During iterations, the member that is found to have the best fitness value is chosen as the producer. The producer scans the environment to look for its resources. Scanning is a vital factor of search orientation.

In the GSO algorithm, at the k^{th} iteration the producer X behaves as follows. The producer will first scan at zero degree and then choose three random points:

i) A point at zero degree
ii) A point crosswise at the right hand side of the producer
iii) A point crosswise at the left hand side of the producer.

$$X_z = X_p^k + r_1\, l_{max}\, D_p^k\, (\varphi^k) \quad (12)$$

One point in the right hand side:

$$X_r = X_p^k + r_1\, l_{max}\, D_p^k\, (\varphi^k + r_2\theta_{max} / 2) \quad (13)$$

One point in the left hand side:

$$X_r = X_p^k + r_1\, l_{max}\, D_p^k\, (\varphi^k + r_2\theta_{max} / 2) \quad (14)$$

where r_1 is where $r_1 \in R^1$ is a normally distributed random number with mean 0 and standard deviation 1 and $r_2 \in R^{n-1}$ is a uniformly distributed random sequence in the range *(*0, 1*)* and θ_{max} is the maximum pursuit angle and $\theta_{max} \in R^1$ and maximum pursuit distance $l_{max} \in R^1$

If the producer finds a better position than its current position then it will move to that point otherwise it will stay in its current position and turn its head angle using the formula:

$$\varphi^{k+1} = \varphi^k + r_2\, \alpha_{max} \quad (15)$$

$\alpha_{max} \in R^1$ is the maximum turning angle.

In case the producer cannot find a better position after a iterations, then it will turn its head back to zero degree:

$$\varphi^{k+a} = \varphi^k \quad (16)$$

where $a \in R^1$ is a constant.

During iterations a number of group members are selected as scroungers. The scroungers will keep searching for opportunities to join the resources found by the producer. At the k^{th} iteration, the area copying behaviour of the i^{th} scrounger can be modelled as a random walk toward the producer:

$$x_i^{k+1} = a.r_1\, l_{max} \quad (17)$$

and move to the new point:

$$x_i^{k+1} = x_i^k + l_i\, D_i^k\, (\varphi^{k+1}) \quad (18)$$

Different strategies were adopted by the animals to restrict their searches. GSO algorithm uses a strategy called as bounded search space. According to this strategy if any member is outside the search space it will turn back into the search space by setting the variables that violated the boundary criteria.

IV. Results & Discussion

The proposed algorithm is developed using MATLAB-10 software. In this paper GSO algorithm is applied to solve minimal reactive power generation by controlling V_G keeping all the equality and inequality constraints under deregulated power system operating range. Optimization process stops whenever preset convergence criteria matches. In this paper, as test case IEEE 14-bus system [11] is considered where four generator buses are there for which minimal reactive power generation is tried to be implemented. Here as a control variable generator bus voltages ($V_{g2,}$ V_{g3}, V_{g6} and V_{g8}) at a range of 0.95 to 1.10pu are tuned by PSO method. All the load bus voltages are remained at 0.9 to 1.05pu range except slack bus i.e. bus 1 for the mentioned system. The line parameters and load flow data are taken from elsewhere [11]. At light load condition the base value of minimum reactive power generation is 5.89 MVAR [9].

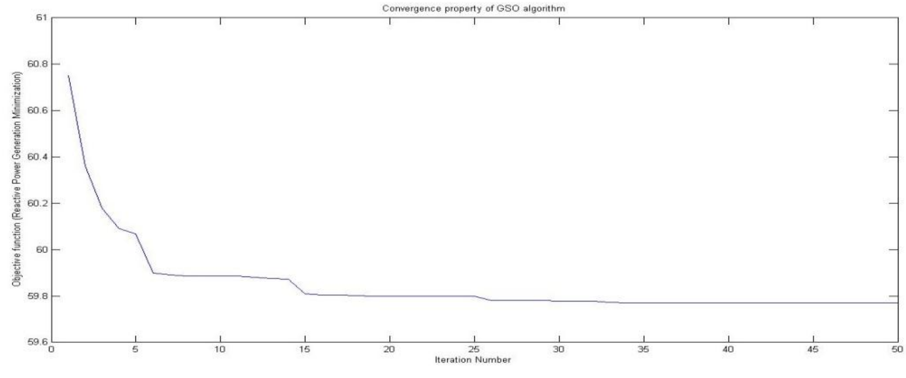

Fig.1 Minimization of Reactive power Generation using GSO with respect to Iteration

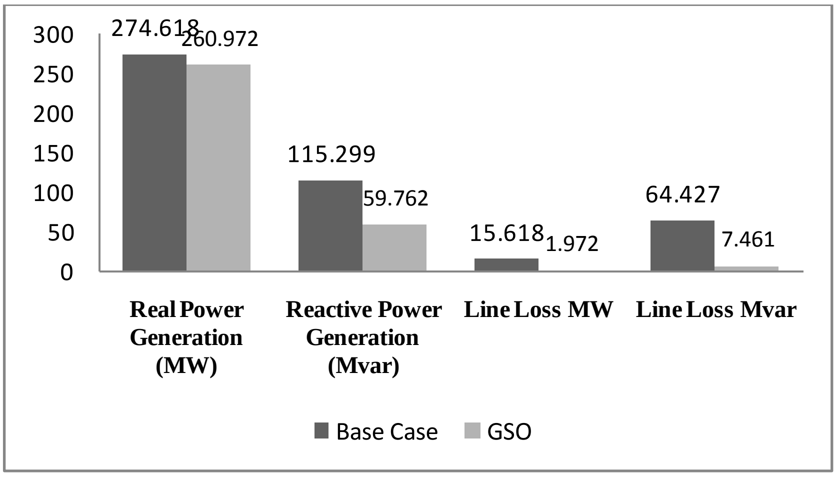

Fig.2 Comparison of Power Generation & Line Loss with Base Case & GSO

Fig. 1 shows the minimization of reactive power generation using GSO with respect to iteration. From the Fig 1 it can be concluded that optimal value comes after 26th iteration and the searching process was at its high altitude between 5th to 26th iteration. Thereafter the searching process remains fixed until the last but final iteration comes.

Fig.2 shows the comparison of power generation and line losses with Base Case and GSO. It can be seen that with GSO, the line losses are comparatively lower than the Base Case.

V. Conclusion

In this paper the MRPG problem is solved to make smooth real power flow in supporting to generators requirement with the help of GSO technique for IEEE 14-bus system. Initially parameter estimation is processed by tuning the variables and thereafter the result is obtained by increasing the population Size. According to the problem criteria, minimization of reactive power generation brings a new corner in the field of deregulated power environment. MRPG problem is a very important aspect for the power generating companies as reward in terms of money is related to this. GSO is a very well known soft-computing technique which is applied previously to solve similar problem like optimal power flow, reactive power dispatch etc. The application of GSO technique to solve MRPG problem raising a value of 3.5000MVAR from the base value of 5.89MVAR shows credibility. Due to sake of simplicity some parameters are neglected during the network analysis like voltage index and sensitivity analysis which may be included in future study. Furthermore, MRPG problem is considered as single objective problem which can be improved as multi-objective problem by incorporating cost or real power loss minimization in the future study. On account of novelty of the proposed issue, GSO based MRPG problem solved in this paper shows satisfactory performance.

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