Middle-East Journal of Scientific Research 25 (4): 859-863, 2017
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2017.859.863

Generation Rescheduling Based Congestion Management in Restructured Power System

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Abstract: In restructured power system, the system operator (SO) faces a major problem called transmission congestion that occurs when the system violates the security constraints and the system security will be affected. Hence congestion management is necessary to protect the system and to satisfy the demand. Of many congestion management methodologies, Generation rescheduling is one the efficient technique chosen by SO to relieve congestion. The generator rescheduling problem is formulated as an optimal power flow (OPF) and is solved by employing Particle Swarm Optimization (PSO) technique as it gives results with high degree of accuracy. The proposed work is tested in IEEE 30 bus system and it is inferred that this technique effectively minimizes the generation cost and relieves congestion.

Key words: Congestion management · Generation rescheduling · Optimal power flow · Particle swarm optimization

INTRODUCTION

With the increasing volume of power trade in a deregulated environment, there is a maximized usage of the transmission line that leads to congestion. Thus congestion management becomes an important task for SO [1]. It is very difficult to relieve congestion with the random changes in power transmission. Hence several methods are employed to relieve the congestion [2]. The Independent System Operator (ISO) works on coordinating the independent trades in an interconnected power system and ensuring the system security. Congestion can be alleviated by using non-cost free methods such as rescheduling of generators; on-load tap-changers etc. in extreme situations, the transactions may be curtailed physically to relieve congestion [3]. Several OPF based congestion management techniques for multiple transactions have also been proposed in [4]. In [5], an approach using minimum modification to desired transaction for relieving congestion is proposed. An OPF based approach for the minimization of congestion cost is discussed in [6].

Sudipa dutta *et al* [7] proposed a PSO algorithm to minimize the cost of generation rescheduling and hence congestion cost. Using the sensitivities of generators to the congested line, number of participating generators is selected and hence the rescheduling can be done effectively. PSO is chosen as it gives accurate results and so high quality solution [8].

The OPF approach is efficient as it maintains the system security and maximizes social welfare based on congestion cost and supplies the demand in a reliable and economic manner.

Congestion Management: Congestion management is vital in a multi-buyer/multi-seller environment in order to improve market efficiency. In a vertically integrated utility system, generation, transmission and distribution are under the direct control of a single utility or a central agency. The main cause of dispatching the generation is to operate the system with least cost. The optimal dispatch solution is done by considering security constraints that eliminates the possible occurrence of

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congestion, which means that the generations dispatched are not exceeding the power flow limits on the transmission lines.

Congestion management is a mechanism for the prevention of overloading the transmission network by prioritizing the transaction and committing to a schedule. Perhaps, congestion still occurs in real time because of the forced outages of transmission line. Thus the system operator handles the situation by congestion management methodologies. It involves the remedial measures such as Allowing the transaction that keeps the transmission line within limits and In the real time system, transmission line will be overloaded even if congestion care has been taken. Hence SO plays a major role in clearing the congestion.

Rescheduling of Generators: Generators are rescheduled such that it doesn't exceed the transfer limits of the transmission line. Generators rescheduling is done based on creating a population containing generation limits which satisfies the demand. The rescheduling of generators makes the generation to operate at an equilibrium away from the one determined by equal incremental costs. Mathematical models are involved for obtaining the corresponding cost signals. The results are used in congestion pricing as an indicator for the market participants in rearranging the power injections and extractions, so that congestion can be avoided.

Rescheduling Cost: Based on the objective, rescheduling cost is the cost involved in rescheduling the generation. The increment and decrement bids submitted by GENCO can be used for determining the rescheduling cost in [1]. The bid cost is the first derivative of the objective function. The bid cost function of each generator is given by:

$$\frac{dC_i}{dP_i} = 2a_i * P_i + b_i \ \ \$/MW - hr \quad (1)$$

After calculating the MW generation required for relieving the congestion, the cost for rescheduling is calculated using the equation given below:

$$\sum_{\substack{i=1 \\ \neq S}}^{N_G} C_i(\Delta P_i)\Delta P_i \ \ \$/hr \quad (2)$$

Problem Formulation: The Elimination or alleviation of transmission lines which are overloaded and maintaining line voltages within constrained limits, i.e., congestion management (CM), in contingency /emergency situations, by means of generators rescheduling is formulated as a non-linear optimization problem. Here, we discuss the possible objective function.

Generation Cost Minimization (GCM): In this case, demand is inelastic to the price hence, the main objective is to reduce the generation and load shedding cost (GLC) and it is formulated as,

$$Minimize \sum_{i=1}^{N_G} [c_i + b_i(P_{Gi}) + a_i(P_{Gi})^2] \quad (3)$$

Equality Constraints: Nodal Power Balance Constraints: These constraints are typical load flow equations and they include the active and reactive power balances.

$$P_{G_i} - P_{D_i} = V_i \sum_{j=1}^{N_{BUS}} V_j \left(G_{ij} \cos\delta_{ij} + B_{ij} \sin\delta_{ij}\right) \quad (4)$$

$$Q_{G_i} - Q_{D_i} = V_i \sum_{j=1}^{N_{BUS}} V_j \left(G_{ij} \sin\delta_{ij} + B_{ij} \cos\delta_{ij}\right) \quad (5)$$

I=1,2,…, N_{BUS} Where $\delta_{ij} + \delta_i - \delta_j$ is the voltage phase angle difference between bus i and bus j.

Inequality Constraints:

- Generation Constraints: The outputs of generating units are restricted by their minimum and maximum limits and they are represented as,

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max}$$

The reactive power limits of generator are expressed as

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}$$

The generator bus voltage limits are represented by,

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max}$$

- Security constraints

The load bus voltage limits are represented by,

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max}$$

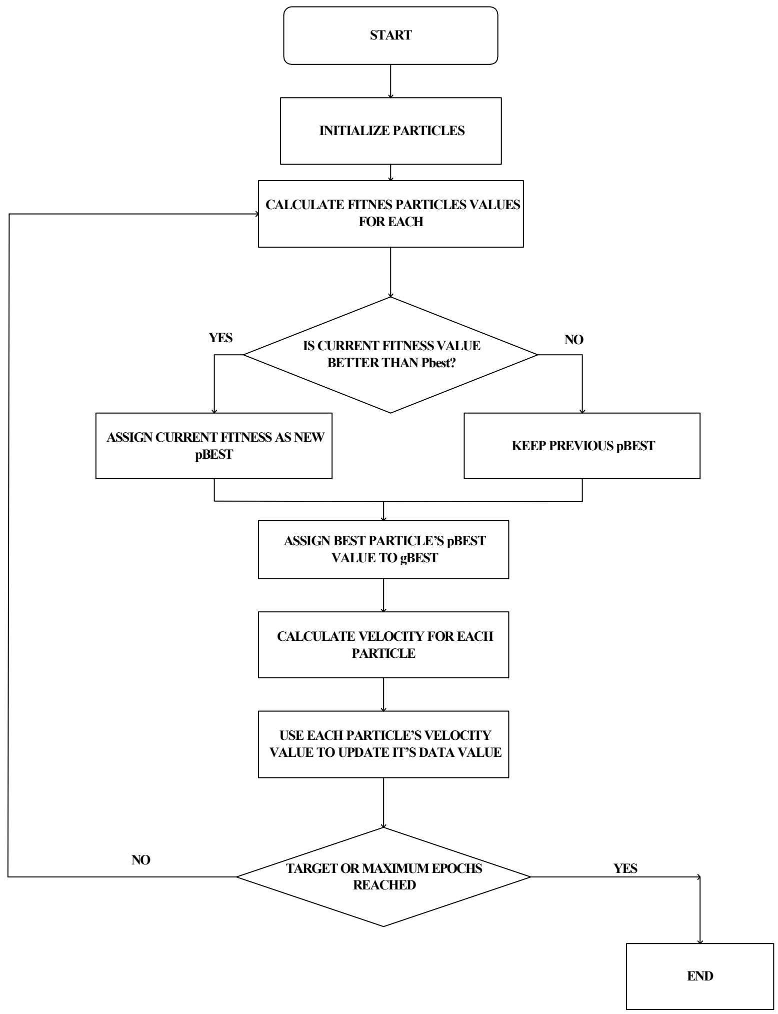


Fig.1: Flowchart for PSO

The fitness function is given by,

Min Ft(x) = Ft(x) + k1 (slack bus real power violation)+ k2 (slack bus reactive power violation)+ k3 (load voltage violation)+ k4 (line flow violation)

Particle Swarm Optimization: Particle swarm optimization is a metaheuristic algorithm introduced by Kennedy and Eberhart in 1995. It uses the ideas of computer graphics and social psychology research. It is metaheuristic because it makes few or no assumptions about the problem which is to be optimizes and provides a very large space for solution search. But it is not guaranteed with optimal solution. PSO doesn't requires the differentiation of optimization problem, which is required by classical optimization methods like Quasi-Newton and gradient methods.

PSO works with a population of candidate solutions (i.e., swarm of particles). The particles move around the searchspace for the attainment of target. The particles are guided by its own position in the searchspace as well as other particle's best known position. If any improvement is found towards the solution, the particular particle's movement will be taken into consideration. The process is repeated until a satisfactory solution is discovered. The objective function is taken as a vector of real numbers and produces output as a real number. Here the particle's movement will be based on cost minimization. Finding the global minima is the goal.

Each consists of data representing a possible solution, a velocity for indicating the particle movement, Pbest (personal Best) value for indicating the particle's data towards the goal. Like the flock of birds searching for its prey, each particle has its X, Y, Z co-ordinates. The movement of a particle which is closer to the target is considered as global Best (Gbest). The Gbest is compared with Pbest and the solution is upgraded. This process continues until the objective function is satisfied.

PSO is commonly coming under population based topologies or neighborhoods, which can be a localized subset of Gbest values. The particles of the neighborhood may have a predetermined particle movement, which helps in avoiding the particles get stuck in local minima. PSO requires less computational efforts in order to achieve a solution with higher accuracy. The velocity of the particle which approaches the goal with least cost will be taken as reference for the further movement of particles.

Fig. 1 explains the methodology of Particle swarm optimization technique that this work uses to attain the best generation values after solving OPF problem and assign the newly found generation values as Gbest values.

RESULTS AND DISCUSSION

The standard IEEE 30 bus system is considered which has a slack bus and five generator buses. Congestion management is done by rescheduling the generators and PSO is employed for congestion cost minimization.

When congestion takes place in the lines 2-6, 12-13, 9-11, 10-17, 10-22 by exceeding the reactive power injection limits, the generation range of generators vary as shown in the Table 2. It is clearly seen from the table 1 that the generator 13 exceeds its generation limit from 50 MW (maximum) to 66.1133 MW. It changes the dispatch of power through different lines. The generators are rescheduled by applying PSO as shown in the table 1. That manages congestion by re-dispatching the generation of all the generators. Figure 2 shows the PSO convergence pattern which clearly shows that the congestion management cost is effectively reduced by the use of PSO from 3087.68 Rs/hr to 3028.05 Rs/hr.

Table 2 shows the maximum allowable line flow limits, line flow violation in the IEEE 30 bus system and also the line flow after generation rescheduling. It is clearly shown that the proposed method relieves congestion in the transmission line in an effective manner.

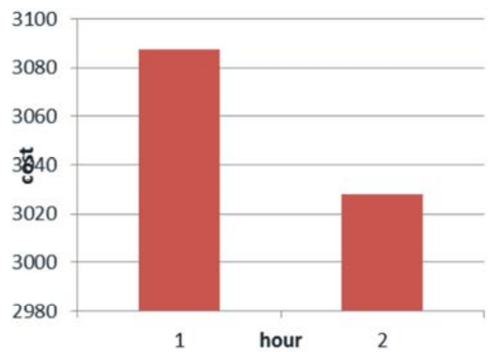
In Fig 2(a), hour 1 and 2 describes the generation cost before and after generation rescheduling respectively. Fig 2(b) shows the generation cost convergence curve using PSO.

Table 1: Generated MW before and after congestion management

Generator No.	Mw Generation For Base Case	Mw Generation after Generation Rescheduling
1	33.2115	39.6258
2	43.2644	55.3278
5	10.3568	14.4636
8	22.6311	24.9093
11	16.1050	18.0410
13	66.1133	39.4549

Table 2: Line flow calculations for base case and after generation rescheduling

From bus	To bus	Max. allowable line flow (pu)	Line flow for base case (pu)	Line flow after generation rescheduling (pu)
1	2	1	0.8968	0.981
1	3	1	1.104	0.645
2	4	0.5	0.00	0.363
3	4	0.9	1.0307	0.602
2	5	0.9	0.9979	0.265
2	6	0.5	0.00	0.467
4	6	0.7	0.5722	0.452
5	7	0.8	0.1163	0.262
6	7	0.6	0.1132	0.030
6	8	0.6	0.0314	0.297
6	9	0.8	0.1341	0.282
6	10	0.4	0.1209	0.162
9	11	0.3	0.2239	0.021
9	10	0.5	0.3580	0.282
4	12	0.7	0.3687	0.426
12	13	0.4	0.0431	0.321
12	14	0.3	0.0762	0.077
12	15	0.3	0.1683	0.171
12	16	0.3	0.0553	0.064
14	15	0.3	0.0134	0.014
16	17	0.3	0.0199	0.029
15	18	0.3	0.0506	0.056
18	19	0.3	0.0183	0.024
19	20	0.5	0.0767	0.070
10	20	0.3	0.0999	0.093
10	17	0.3	0.0703	0.060
10	21	0.4	0.1679	0.155
10	22	0.3	0.0828	0.075
21	22	0.7	0.0083	0.019
15	23	0.3	0.0470	0.044
22	24	0.3	0.0739	0.055
23	24	0.3	0.0147	0.012
24	25	0.3	0.0008	0.018
25	26	0.3	0.0355	0.035
25	27	0.3	0.0347	0.054
28	27	0.5	0.1677	0.187
27	29	0.9	0.0619	0.061
27	30	0.3	0.0710	0.071
29	30	1	0.0371	0.071
8	28	0.3	0.00	0.420
6	28	0.5	0.1682	0.191



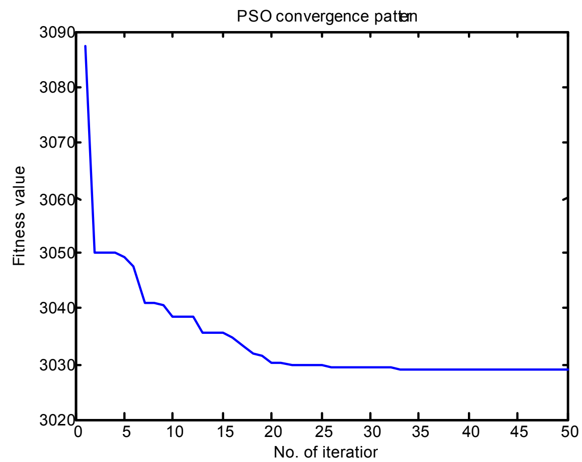


Fig. 2(a): Comparison of cost, 2(b) PSO Convergence pattern

CONCLUSION

In the present work, the congestion cost minimization is done by employing particle swarm optimization (PSO) algorithm. PSO is chosen as it gives accurate higher quality solution in less number of iterations and it is less derivative, makes it simpler. Congestion in a transmission system is created because of sudden line outages or violation of line limits which is managed by performing optimal power flow. By employing PSO algorithm, the generators are rescheduled to satisfy the operating limits. Thus the best optimal solution for generators is found and the congestion cost is minimized by using PSO.

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