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Congestion Management in Transmission Line by Generator Reschedule using PSO Algorithm

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ABSTRACT: Power system congestion is a major problem that the system operator (SO) would face in the post-deregulated era. Therefore, investigation of techniques for congestion free wheeling of power is of paramount interest. One of the most practiced and an obvious technique of congestion management is rescheduling the power outputs of generators in the system. However, all generators in the system need not take part in congestion management. Development of sound formulation and appropriate solution technique for this problem is aimed in this project Contributions made in the present paper are twofold. Firstly, a technique for optimum selection of participating generators has been introduced using generator sensitivities to the power flow on congested lines. Secondly this paper proposes an algorithm based on Particle Swarm Optimization (PSO) which minimizes the deviations of rescheduled values of generator power outputs from scheduled levels. The PSO algorithm, reported in this paper, handles the binding constraints by a technique different from the traditional penalty function method. The effectiveness of the proposed methodology has been analyzed on IEEE 30-bus.

KEYWORDS: Generator rescheduling, particle swarm optimization algorithm, Newton Raphson method, congestion management.

I.INTRODUCTION

With increasing demand for electric power all around the globe, electric utilities have been forced to meet the same by increasing their generation. However, the electric power that can be transmitted between two locations on a transmission network is limited by several transfer limits such as thermal limits, voltage limits and stability limits with the most restrictive applying at a given time. When such a limit is reached, the system is said to be congested. Ensuring that the power system operates within its limits is vital to maintain power system security, failing which can result in widespread blackouts with potentially severe social and economic consequences [13]. Congestion management, that is, controlling the transmission system so that transfer limits are observed, is perhaps the fundamental transmission management problem. The methods generally adopted to manage congestion include rescheduling generator outputs, supplying reactive powersupport or physically curtail transactions. System operators generally use the first option as much as possible and the last one as the last resort. The development of smart cities in India will require a smart grid for power generation, transmission and distribution systems with a continuous power supply [2]. The transmission line is one of the major elements to supply continuous power to the smart cities via a smart grid [2].

Generator rescheduling leads to generation operation at an equilibrium point away from the one determined by equal incremental costs [12]. Mathematical models of pricing tools may be incorporated in the dispatch framework and the corresponding cost signals obtained. These cost signals may be used for congestion pricing and as indicators to the market participants to rearrange their power injections/extractions such that congestion is avoided [13]. Congestion management for the multiple overloads is relieved by corrective switching [7].

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II. PROBLEM FORMULATION

The optimal congestion management minimizing re-dispatch cost can be expressed as,

Minimize: Σ_g^{Ng}=$C_g(\Delta P_g)$ ΔP_g

$subject\ to$: Σ_g^{Ng} $\Delta P_g = 0$

Operating limit constrains:

$\Delta P_g^{min} \leq \Delta P_g \leq \Delta P_g^{max}$

$\Delta P_g^{min} = P_g - P_g^{min}$ And $\Delta P_g^{max} = P_g^{max} - P_g$

Line flow constrains:

$\Sigma_g^{Ng}[(GS_g(\Delta P_g) + F_k^0] \leq F_k^{max}$; g=1, 2… …$N_g$

…. (4)

The basic power flow equation on congested line in Newton Raphson method can be written as,

P_{ij} = -$V_i^2 G_{ij}$+$V_i V_j G_{ij}$ cos $(\theta_i - \theta_j)$+$V_i V_j B_{ij}$sin$(\theta_i - \theta_j)$

…. (5)

Where and are the voltage magnitude and phase angle respectively at the i_{th} bus; $G_{ij}$and B represent, respectively, the conductance and susceptance of the line connected between buses i and j; neglecting P-V coupling, can be expressed as

$GS_g = \frac{\partial P_{ij}}{\partial \theta_i} * \frac{\partial \theta_i}{\partial P_{Cg}} + \frac{\partial P_{ij}}{\partial \theta_j} * \frac{\partial \theta_j}{\partial P_{Cg}}$….. (6)

The first term of the two products in (3) are obtained by differentiating (4) as follows:

$\frac{P_{ij}}{\partial \theta_i}$ = -$V_i V_j G_{ij}$ sin $(\theta_i - \theta_j)$ + $V_i V_j B_{ij}$cos$(\theta_i - \theta_j)$ …… (7)

$\frac{P_{ij}}{\partial \theta_j}$ = -$V_i V_j G_{ij}$ sin $(\theta_i - \theta_j)$ - $V_i V_j B_{ij}$cos$(\theta_i - \theta_j)$ …… (8)

$\frac{P_{ij}}{\partial \theta_j} = \frac{\partial P_{ij}}{\partial \theta_j}$…… (9)

The active power injected at a bus-s can be represented as

P_S = PG_S -PD_S….. (10)

where $PD_S$is the active load at bus s and $P_S$can be expressedas

$P_S = |V_S| \Sigma((G_{St}\cos(\theta_S - \theta_t) + B_{St} \sin(\theta_S - \theta_t)|V_t|$

$P_S = |V_S|^2 G_{SS} + |V_S| \Sigma((G_{St}\cos(\theta_S - \theta_t) + B_{St} \sin(\theta_S - \theta_t)|V_t|$ ….. (11)

Where n is the number of buses in the system.

Differentiating (10) w.r.t θ_S and θ_t , the following relations can be obtained:

$\frac{\partial P_S}{\partial \theta_r} = |V_S||V_t|\ [G_{St}\sin(\theta_S - \theta_t)$ - B_{St} $\sin(\theta_S - \theta_t)]$ ….. (12)

$\frac{\partial P_s}{\partial \theta_s} = |V_S|\ [-G_{St}\cos(\theta_S - \theta_t) + B_{St} \sin(\theta_S - \theta_t)|V_t|]$ ….. (13)

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Neglecting p-v coupling, the relation between incremental change in reactive power at system busses and the phase angles of voltages can be written in matrix form as

$[\Delta P]_{n-1}= [H]_{n*n}[\Delta\theta]_{n*1}$ ….. (14)

$$[H]_{n*n} = \begin{bmatrix} \frac{\partial P_1}{\partial\theta_1} & \frac{\partial P_1}{\partial\theta_2} \dots\dots\dots & \frac{\partial P_1}{\partial\theta_n} \\ \frac{\partial P_2}{\partial\theta_1} & \frac{\partial P_2}{\partial\theta_2} \dots\dots\dots & \frac{\partial P_2}{\partial\theta_n} \\ \frac{\partial P_n}{\partial\theta_1} & \frac{\partial P_n}{\partial\theta_2} \dots\dots\dots & \frac{\partial P_n}{\partial\theta_n} \end{bmatrix} \text{.....} \quad (15)$$

$[\Delta\Theta] = [H]^{-1} [\Delta P]$

$= [M] [\Delta P]$ where $[M] = [H]^{-1}$

To find the value of in $\frac{\partial\theta_i}{\partial P_{Cg}}$ and $\frac{\partial\theta_j}{\partial P_{Cg}}$ (3), [M] needs to be found out. However, [H] is a singular matrix of rank one deficiency. So, it is not directly invertible. The slack bus in the present work has been considered as the reference node and assigned as bus number 1. The elements of first row and first column of [H] can be eliminated to obtain a matrix $[H]^{-1}$ which can be inverted to obtain a matrix [M-1]. Using these relations, the following equation can be obtained:

$[\Delta\Theta]_{-1} = [M_{-1}] [\Delta P_{-1}]$

The actual vector $[\Delta\Theta]$ can be found by simply adding the elements $[\Delta\Theta]$ to the above equation as shown I the relation

$[\Delta\Theta]_{n*1} = \begin{bmatrix} 0 & 0 \\ 0 & [M_{-1}]_{n*n} \end{bmatrix} [\Delta P_{n*1}]$….. (16)

The modified value of $\frac{\partial\theta_i}{\partial P_{cg}}$ and $\frac{\partial\theta_j}{\partial P_{cg}}$ to calculate GS values. Large GS generators will be selected for re-dispatch since they are more influential on the congested line. The system operator selects the generators having non-uniform and large magnitudes of sensitivity values as the one most sensitive to the power flow on the congested line and to participate in congestion management by rescheduling their power outputs.

III.PARTICLE SWARM OPTIMIZATION

The method of particles warm optimizationisan evolutionary algorithm and was first introduced by Kennedy and Eberhart in 1995. The motivation was social behaviour of organisms such as fish schooling and bird flocking. It was observed that a flock of birds stochastically find food in an area. Not all birds in a flock know the exact location of food but they know the position closesttoit (thefood).The simplestand most effective way to search for food is to search the area around the present best position, i.e., the position closest to food. Similar to seeking food, the solution to an optimization problem or the best solution is found out from a solution space with a population based search procedure in which the particles, like birds, change their positions (states) with time. Each particle represents a potential solution to a problemin an dimensional space (where the number of dimensions corresponds to the number of variables). The particles are randomly generated (a particle size between 10 to 100 is usually considered sufficient) initially with two parameters each-position and velocity in the dimensional space such as position and velocity . Each particle is then flown over the search space in order to find potential solution regions of the landscape and adjusts its flying velocity and direction according to its own flying experience as well as that of its neighbours. Positions of the particles (tentative solutions) are evaluated at end of every iteration relative to an objective or fitness value. Particles are assumed to retain memory of the best positions they have achieved in course of flying and share this information among the rest. The collective best positions of all the particles taken together is termed as the global best position given as and the best position achieved by the individual particle is termed as the local best or position best and for the particle given as . Particles use both of these information to update their positions and velocities as given in the following equations

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The technique of PSO has already been applied in several problems of optimization in the power system [12]. In, PSO has been applied to solve the economic dispatch of generators in a power system. A technique has been proposed in to control reactive power and voltage to maintain power system security from voltage stability point of view. Sensitivity based congestion management using PSO has been discussed in. However, it doesnot reveal about procedure of handling of constraints. The PSO algorithm proposed in the present paper has been modified to handle the constraints in a way different from the traditional penalty function method. Moreover the algorithm in has only been tested on the IEEE 30-bus New England system [13].

Compared with traditional optimization algorithms, PSO does not need the information of the derivative of functions in the process model. The algorithm can work as long as fitness values for optimization model can be calculated. Besides, the algorithm of PSO is simple enough for people to understand it easily and has a profound intellectual background at the same time.

IV.IEEE 30 BUS SYSTEM

The IEEE 30-bus system consists of six generator buses and 24 load buses. The numbering of buses has been done in a way that the generator buses are numbered first followed by the load buses [1]. Slack node has been assigned bus number 1. Here, twolines have been found to be congested, that are between buses 1 and 2 and that between buses 6 and 8. Before rescheduling the power generation of units are given as which are shown in the following table I.

TABLE.I

Before Reschedule					
Power generation of units					
Unit-1	Unit-2	Unit-3	Unit-4	Unit-5	Unit-6
262.80	40.00	-0.00	0.00	0.00	-0.00

These congested line details of IEEE 30 bus system the power flow and line limit are shown in the following table II.

TABLE.II

Congested Line Details of 30-Bus System		
Congested line	**Power flow (MVA)**	**Line Limit (MVA)**
1 - 2	208.44	180.00
6 - 8	35.59	32.00

Congested line flow of the 30-bus system has been presented in Table II.

The values of generator sensitivities computed for the congested line 1-2 are presented in Table IV. Close values of sensitivities point out that the 30-bus system is practically a very small system compared to a realistic power network. All the generators show strong influence on the congested line flow. This is because a small system is generally very tightly connected electrically. Thus, all the generators are chosen to participate in congestion management and the next part of the algorithm, i.e., solving the congestion management problem using PSO has been proceeded with. It is also indicative that significant simplifications can be visible only on large networks suchasthe118-bussystem.

The generator cost curves have been assumed to be quadratic such that cost of rescheduling is proportional to the square of the change in active power output as represented in Table VI. Generators selected for participation in congestion management are asked to reschedule their outputs optimally on the basis of their bids so that the cost of rescheduling gets minimized. However, the algorithm does not consider the change of nodal prices or generator bids at pre or post congestion management situation.

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A. Generator rescheduling

Rescheduling Generation which leads to generation operation at an equilibrium point away from the one determined by equal incremental costs [14]. Mathematical models of pricing tools may be incorporated in the dispatch framework and the corresponding cost signals obtained. These cost signals may be used for congestion pricing and as indicators to the market participants to rearrange their power injections/extractions such that congestion is avoided. After generator rescheduling process the power generation units is given as shown in the table III.

TABLE III

After Re-schedule					
Power generation of units (MW)					
Unit-1	Unit-2	Unit-3	Unit-4	Unit-5	Unit-6
215.68	34.01	13.25	3.63	4.88	26.23

B. Generator senstivity factor

The Generator sensitivity (GS) technique indicates the change of active power flow due to change in active power generation [12]. The generators in the system under consideration have different sensitivities to the power flow on the congested line. A change in real power flow in a transmission line k connected between bus i and bus j due to change in power generation by generator g can be termed as generator sensitivity to congested line (GS). Mathematically, GS For line k can be written as.

$$GS_g = \frac{\Delta P_{ij}}{\Delta P_{Gg}}$$

The power flow on the previously congested line is given in the following table.

TABLE IV

Power Flow on Previously Congested Line		
Congested line	**Power flow (MVA)**	**Line Limit (MVA)**
1-2	179	180.00
6-8	29	32.00

V.SIMULATION RESULT

From the results of all the three systems studied, it can be observed that the PSO algorithm has successfully been used to manage congestion and reduce system losses. The convergence of the PSO method with parameter values as described above has been shown inFig.2. The graph demonstrates that the rescheduling cost gradually decreases with number of iterations and converges to a minimum value. The convergence pattern is also indicative of the fact that these lection of PSO parameters is appropriate. Execution time of this algorithm is approximately

The simulation result after the congestion management by generator rescheduling is given the following figure and plots. The following graph shows that the active power rescheduling with respect to the number of generating units. And also, the generator sensitivity with respect to the generating units. Generation sensitivity shows in negative to positive for the number of generators changes their generating units

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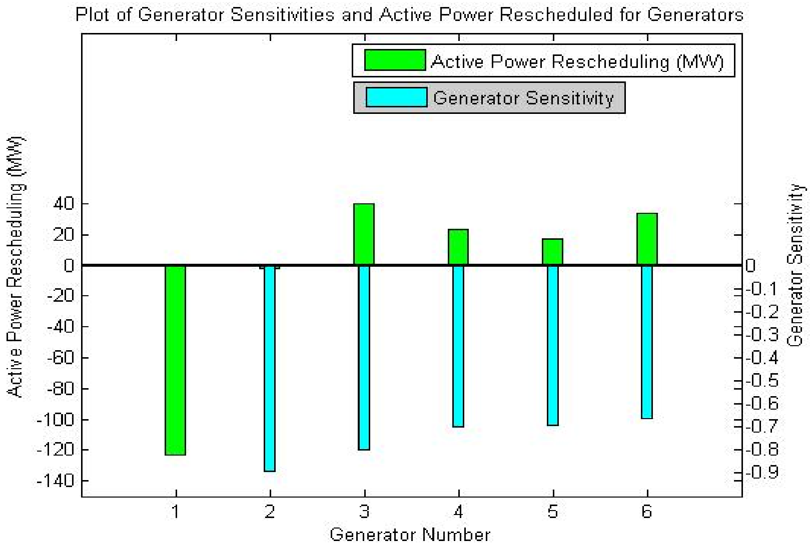

Fig.1 Represent Plot of Generator Sensitives and Active Power Reschedule.

The algorithm is found to converge between 100-1000 iteration which is shown in Fig2.The relationship of generator sensitivities with the change in power outputs of generators for congestion management has been graphically represented in Fig.2 and rescheduled power at various generators is given in table III.

TABLE V.

GS FOR IEEE 30-BUS SYSTEM						
Congested Line	**Generator Sensitivity**					
1-2	0.00	-0.89	-0.80	-0.70	-0.69	-0.66
6-8	0.00	-0.01	-0.01	-0.88	-0.03	-0.03

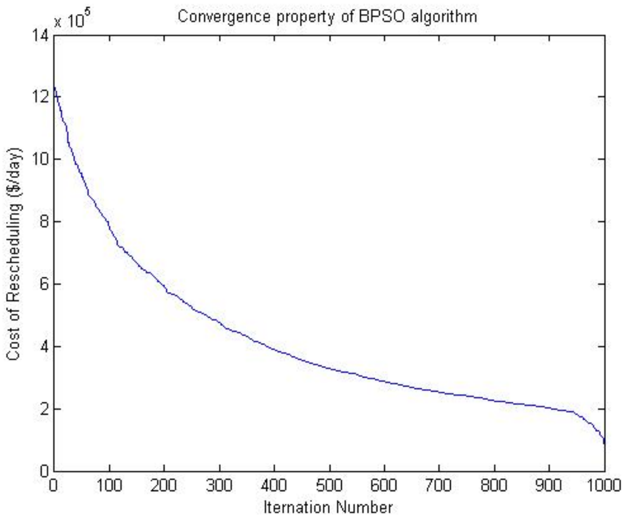

Fig.2 Convergence Property of PSO Algorithm

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Change in power generation of unit and the cost of the generator rescheduling is shown in the following table VI.

TABLE VI.

Change in Power Generation of Units (Mw)					
1	2	3	4	5	6
-47.1	-6.0	13.3	3.6	4.9	26.2
Cost of generator rescheduling = 894.98					

VI. CONCLUSION

The present paper focuses on demonstrating a technique for optimum selection of generators for congestion management and additionally the application of PSO in the solution of the congestion management problem. Generators from the system are selected for congestion management based on their sensitivities to the power flow of the congested line followed by corrective rescheduling. The problem of congestion is modelled as an optimization problem and solved by particle swarm optimization technique. The method has been tested on IEEE 30-bus system successfully and also in IEEE 32-bus and 18-bus systemin [13]. The appropriateness of the generator selection methodology has also been compared with reported techniques on IEEE 30-bus system. PSO algorithm has many advantages such as simple concept and easy understanding; the entire complex decision making. The robustness of the algorithm is demonstrated by solving three different networks of different sizes and complexities with equal performance. Since the convergence of the PSO algorithm depends on the appropriate selection of particle size, inertia weight and maximum velocity of particles, improper choice of these parameters may lead to inferior results or nonconvergence. However, test results reveal that the proposed implementation is effective in managing congestion and outperforms.

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