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Congestion Management by Generator Rescheduling using Genetic Algorithm Optimization Technique

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ABSTRACT: Congestion management is one of the important problem and aspect in restructuring environment. The technical reason which occurs in the deregulated environment is the Transmission line congestion. In the restructuring era, the task of ISO is the congestion free power system. Generator rescheduling is one of the important techniques to reduce congestion in power system. The proposed paper uses the Genetic Algorithm based rescheduling of generators for alleviation of congestion. The GA is one of the optimization technique which is based on the nature of the chromosomes. The proposed method is tested on the standard IEEE 30 bus system in MATLAB.

KEYWORDS: Genetic Algorithm; Congestion Management; Severity Index; Optimization technique; Generator Rescheduling.

I. INTRODUCTION

The electricity industry has undergone drastic changes due to a worldwide deregulation or privatization process that has significantly affected energy markets. Congestion in the transmission lines is one of the technical problems that appear particularly in the deregulated environment. Congestion may occur due to lack of coordination between generation and transmission utilities or as a result of unexpected contingencies such as generator outage, sudden increase of load demand, or failure of equipments. It is found that voltage limit violation and line loading limit violation have been responsible for several incidents of major network collapses leading to partial or even complete blackouts. Alleviation of line overloads is the suitable corrective action in this regard. Various control action strategies available for relieving the line over loads are generation rescheduling, use of phase shifting transformers, power flow control through HVDC link(s), line switching, operating FACTS devices and load shedding. One of the most practiced and an obvious technique of congestion management is rescheduling the power outputs of generators in the system. Various congestion management schemes that have been reported in literature are as follows. Congestion management for a pool based electricity market using ac power flow is addressed in [1]. Congestion management by optimal rescheduling of generators using particle swarm optimization are reported in [2], [3]. Corrective switching method is proposed for relieving overloads in [4]; where as in [5] corrective rescheduling method is discussed. Local optimization method is proposed for rescheduling of generators and load sheds in [6].Real time congestion management in Deregulated markets using Artificial neural Network is reported in [7].The cost control in transmission congestion based on ant colony optimization was reported in [8].The economic power dispatch of electrical power dispatch using GA algorithm was reported in [9].In the restructuring markets congestion is alleviated using demand response and FACTS devices was reported in [10].The evaluation of market power due to congestion effects on transmission system is reported in [11].

II. CONGESTION ALLEVIATION PROCEDURE

In deregulated power system transmission companies (TRANSCOs), generation companies (GENCOs) and distribution companies (DISCOs) are under different organizations. To maintain the coordination between them there will be one system operator in all types of deregulated power system models, generally it is independent system operator (ISO). Several utilities join together to form a pool, with a central broker in place, to co-ordinate the operations on an hour-to-hour basis. Within the pool, GENCOs and DISCOs submit the purchase and sell decisions in

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the form of sell or buy bids to the market operator, which, in turn, clears the market using an appropriate market-clearing procedure. Finally it results in 24 hourly energy prices to be paid by consumers and to be charged by producers. More often than not, pool market results originate network congestion problems, and the ISO should determine the minimal changes in the market results that ensure a secure operation. In this paper congestion management is done by means of optimal Rescheduling of generators based on the price bids submitted by GENCOs so that the total congestion management cost gets minimized. This cost is considered as revenues for suppliers for their contribution towards congestion management.

III. METHODS OF CONGESTION

Though congestion in a transmission system is unavoidable, it should not persist beyond a short duration because this could lead to cascading outages with uncontrolled loss of load. Thus congestion is an important matter of concern and measures to be taken to decrease its effect if not managed entirely. It has been seen that there are many methods for congestion management and these can be broadly classified under two domains. The prime techniques are out aging of congested lines, operation of transformer taps operation of FACTS devices, rescheduling of power generators and load shedding.

IV. CONGESTION MANAGEMENT AND MARKET DESIGN

Congestion management is best seen through the operation of Transmission Loading Relief (TLR). TLR has several inherent inefficiencies in the electric energy market. TLR depends strongly on the determination of total transmission capability (TTC) or the amount of power that can be transmitted between two points, and also on the available transfer capability or the amount of power that can be transmitted between two points simultaneously with other transactions and reserves needed for reliability. However, ATC costs are not considered in the calculations, and the method's inherent lack of accuracy and uncertainty can result in either under utilization or overselling of transmission line capacity.

V. PROBLEM FORMULATION

The idea of congestion management is implemented by increasing or decreasing the active power output of the generators. The amount of rescheduling required by the selected generator is obtained by solving the following optimization problem:

$$\min \; f(x) = (P_k^{\max} - P_k^i) + \sum_{i=1}^{m} \Delta P_g \tag{1}$$

where,

$P_k^{\max}$ is the maximum amount of power at line k

P_k^i is the power at line k

Δp_g is the change in real power generation

Thus the objective function is subjected to equality, security constraints and voltage constraints.

A) Equality constraints

$$P_{Gk} - P_{Dk} = \sum_{j=1}^{NB} V_j V_k Y_{kj} \cos(\delta_k - \delta_j - \vartheta_{kj});\; k \forall NB \tag{2}$$

$$Q_{Gk} - Q_{Dk} = \sum_{j=1}^{NB} V_j V_k Y_{kj} \sin(\delta_k - \delta_j - \vartheta_{kj});\; k \forall NB \tag{3}$$

$$P_{Dj} = P_{Dj}^c \;;\; j = 1, 2, Nd \tag{4}$$

where P_{Dj}^c is the active power consumed by demand *j* as determined by the market clearing procedure, P_{Gk} is the real power generation of generator *k* and P_{Dj} is the real power consumption of demand *j* after congestion management. Q_{Gk} and Q_{Dk} are the reactive power generation and reactive power demand at k th bus respectively; V_j and V_k are

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the voltage magnitude of bus *j* and *k* respectively; δ_j and δ_k are the angles of bus voltage *j* and *k* respectively; Y_{kj} and θ_{kj} are the magnitude and angle of bus admittance matrix. N_g , N_d and NB are the number of generators ,loads and buses respectively.

Constraints (2) and (3) are the real and reactive power balances in each bus respectively. Constraint (4) is the final powers.

B) Inequality constraints:

The limits of the loading of the equipments and the requirements of operation usually consist of the inequality constraints of the problem.

$$P_{Gk}^{\min} \le P_{Gk} \le P_{Gk}^{\max}, k \in N_g \qquad (5)$$

$$Q_{Gk}^{\min} \le Q_{Gk} \le Q_{Gk}^{\max}, k \in N_g \qquad (6)$$

$$\Delta P_{Gk}^{+} \ge 0; \Delta P_{Gk}^{-} \ge 0; \qquad (7)$$

Constraints (5) and (6) are the upper and lower limits of the real and reactive power of generators. Constraint (7) shows that the incremental and decremental powers are positive.

C) Security constraints:

For the safe operation of the transmission line loading factor L_{ij} is kept within the upper limit as follows:

$$L_{ij} = (P_{ij} / P_{ij}^{\max}) \le 1 \qquad (8)$$

Where P_{ij} and $P_{ij}^{\max}$ were the real power flow of the line *i-j* and maximum flow limit of line *i-j*.

D) Voltage constraints:

The load bus voltage level at the load bus is maintained within upper and lower bounds which is expressed as:

$$V_n^{\min} \le V_n \le V_n^{\max}, \forall n \in Nd \qquad (9)$$

(E) Severity Index:

For any power system, unexpected outage of the lines or transformers occurs due to faults or other disturbances. These are referred as congestion which causes overloading of lines or transformers. The stress on power system due to congestion may be expressed as follows:

$$SI = \sum_{k \in Lo} (P_k / P_k^{\max}) \wedge 2m \qquad (10)$$

where L_o is the set of overloaded lines, P_k is the real power in the branch k , $P_k^{\max}$ is the maximum flow limit of the *k* th branch, and *m* is the weighting coefficient.

The value of m is chosen as 1 to decrease the masking effect. For the safe system value of SI is zero. The greater value the more severe congestion would be.

VI. GENETIC ALGORITHM

Genetic algorithms were formally introduced in the United States in the 1970s by John Holland at University of Michigan. The continuing price/performance improvements of computational systems have made them attractive for some types of optimization. In particular, genetic algorithms work very well on mixed (continuous and discrete), combinatorial problems. They are less susceptible to getting 'stuck' at local optima than gradient search methods. But they tend to be computationally expensive. The Genetic Algorithm is the search heuristics that mimics the process of natural selection.GA is usually inspired by the Darwin’s theory about evolution. These generate solutions to the optimization problems using technique inspired by the natural solution such as inheritance, mutation, selection and cross over. The fitness function is used to evaluate individuals and reproductive success varies with fitness

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Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached. Genetic algorithms find application in bioinformatics, phylogenetics, computational science, engineering, economics, chemistry, manufacturing, mathematics, physics and other fields. To use a genetic algorithm, you must represent a solution to your problem as a genome (or chromosome). The genetic algorithm then creates a population of solutions and applies genetic operators such as mutation and crossover to evolve the solutions in order to find the best ones.

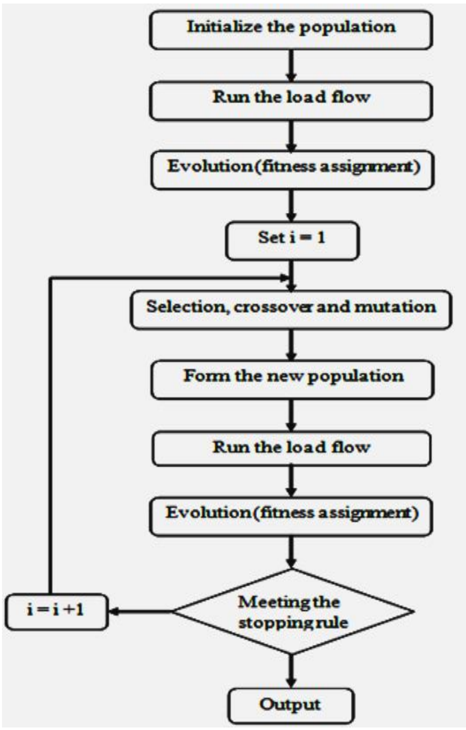

Fig. 1 GA flowchart for congestion management

A. Initialization of Population

The strategy used to determine the initial population consists of randomly generating non-dominated feasible solutions only. This strategy produced better results when compared with strategies that randomly generate solutions of any type (feasible or non-feasible) or feasible solutions (dominated or non-dominated) only.

B. Genetic Operators

The genetic operators are section, crossover and mutation. The operator selection involves the process of selecting best population of individuals for new generation. During each successive generation, a proportion of the existing population is selected to breed a new generation which is based on the objective function. This is an important operator in Genetic Algorithm. In the crossover, the values are going to change according to the objective function by comparing two successive values. Two-point crossover has been used, because it produced better results than one-point and uniform crossover. The mutation indicates the self changing of values to solve the problem. This represents the self changing of value to the optimal value based on the objective function. This is an important operator in Genetic Algorithm.

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VII. RESULTS AND DISCUSSION

The proposed paper discusses the concept of generator rescheduling for the Congestion Management using GA optimization technique has been illustrated on IEEE 30 bus system[12].The 30 bus system is the representation of 6 generators,4 load buses and 41Transmission lines. In the study of the congestion management analysis is conducted for base case generations and also the demand in order to find the most severe lines. For the each line outages Gauss Siedel load flow method had been employed for identifying the overload cases. Among all the lines line 1-2 is identified to be the most severe one and the severity index yields to be greater than 1.

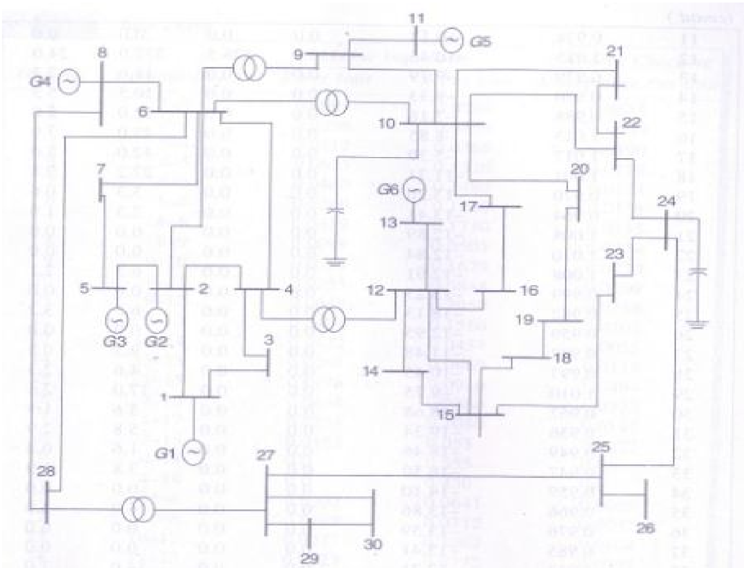

Fig. 2 IEEE 30 bus system

A.Testing of proposed GA

The proposed GA is tested for the three cases.For each load scenario the overloaded linesand the amount of rescheduling were done using Gauss siedel power flow method.The GA parameters were:

Cross over fraction:0.8.

Elite count:1

Generations:100

Hybrid function:[]

Migration interval:20

Migration fraction:0.2

Population Type:’bit string’

Case A

The load at bus 14 is increased by80%from the base case values from (6.2+j1.6)MVA to (11.16+2.88j)MVA.Due to the outage of the line 1-2 it resu;lts in the overloading on two lines 1-3 and 3-4 respectively.The actual power flow in these lines*:* were 153.091MW and 141.094 MWand the flow limit is 130MW.The overloads should be alleviated as fast as possible for the security cases .Hence measure should be carried out for the alleviation of congestion by optimal rescheduling .of generators. Hence the rescheduling power after rescheduling is 29.01 MW.

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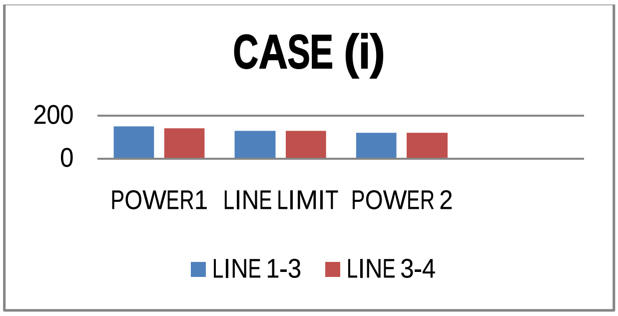

Fig. 3 Power flow in overloaded lines in case A

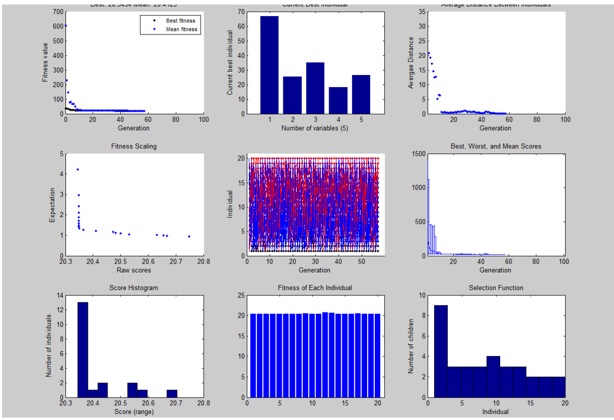

Fig. 4 Performance characteristics of load at bus 14 is increased by80%from the base case values with line1-2 out

Case B

The load at bus 19 is increased by55%from the base case values.Due to the outage of the line 1-2 it resu;lts in the overloading on two lines 1-3 and 3-4 respectively.The actual power flow in these lines were 153.581MW and 141.522MWand the flow limit is 130MW.The overloads should be alleviated as fast as possible for the security cases. Hence measure should be carried out for the alleviation of congestion by optimal rescheduling .of generators. Hence the rescheduling power after rescheduling is 30.5MW.

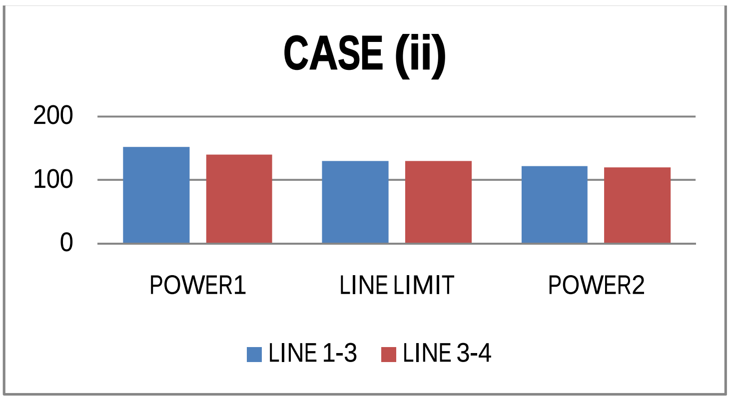

Fig. 5 Power flow in overloaded lines in case B

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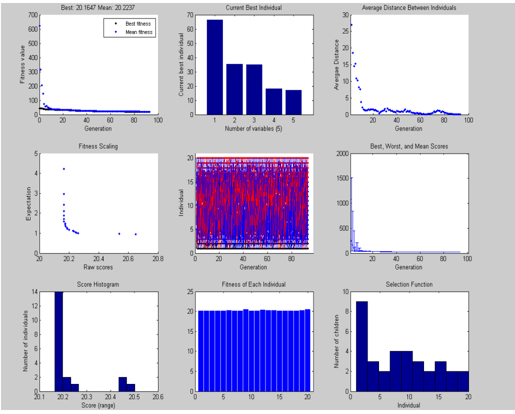

Fig. 6 Performance characteristics of load at bus 19is increased by 55%from the base case values with line1-2out

Case C

The load at bus 10 is increased by 60%from the base case values .Due to the outage of the line 1-2 it resu;lts in the overloading on two lines 1-3 and 3-4 respectively.The actual power flow in these lines were 151.234MW and 139.483 MWand the flow limit is 130MW.The overloads should be alleviated as fast as possible for the security cases .Hence measure should be carried out for the alleviation of congestion by optimal rescheduling .of generators. Hence the rescheduling power after rescheduling is 27.8 MW.

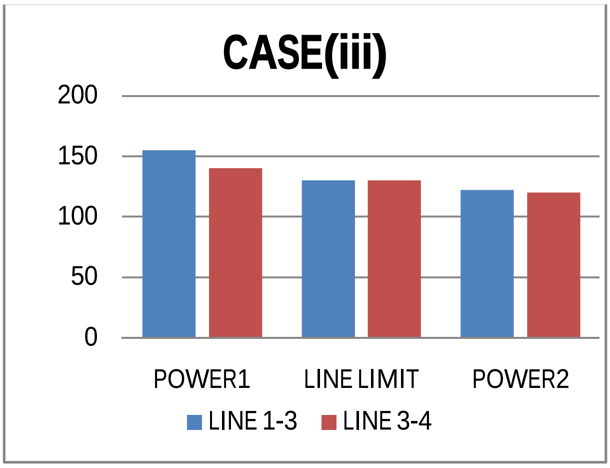

Fig. 7 Power flow in overloaded lines in case C

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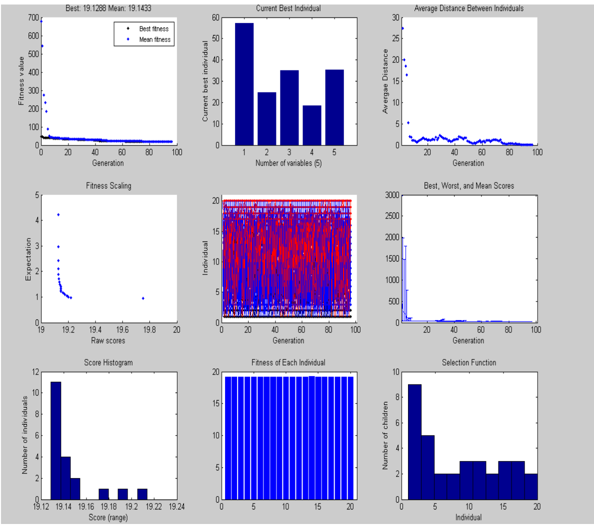

Fig. 8 Performance characteristics of load at bus 10is increased by 60%from the base case values with line1-2out

The table 1 shows the simulated case for the different load scenario cases and also the power flow in each case without GA. Power flow in the identified overloaded lines before and after rescheduling is shown in fig. 8 for the cases considered. Hence from the figure it is clear that power flow after rescheduling shows that they are within the limits. Thus it ensures that overload is alleviated completely by rescheduling of generators. Hence, also the performance characteristics of different load scenarios had been implemented and are shown in figs. 4,6,8. Hence the execution time will be very less and hence the optimal solution is obtained. Hence the proposed approach is very suitable and best for the real time congestion management.

TABLE1.Simulated case for different load scenerios without GA

	Load scenario	Overloaded lines	Line flow (MW)	Total Power violation(MW)
1.	Case A	1-3 3-4	153.091 141.094	34.185
2.	Case B	1-3 3-4	153.581 141.522	35.103
3.	Case C	1-3 3-4	151.234 139.483	30.717

VIII. CONCLUSION

For the efficient operation of the power system possible methods of congestion management need to know. Here the rescheduling of generator active power has been adopted for the congestion management. Hence the GA is chosen as the optimization technique to find the amount of rescheduled power to the congested lines. The results were tested on the IEEE 30 bus system. Hence the Severity Index can be used to find the stress on the power system due to congestion. The fitness value for the individuals are selected and based on that, the problem has solved which has the objective function of minimization of change in real power and is subjected to several constraints. It is also found that GA gives generator rescheduling values almost accurately. Hence the proposed technique completely alleviates overloading of lines for all the cases considered in this study.

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