Overloading of Transmission Lines Management by using Grasshopper Optimization Algorithm

Manpreet Kaur , Er. Ravinder Kumar

ABSTRACT: **This paper proposes an algorithm for congestion management (CM) in a pool based electricity market based on Grasshopper Optimization Algorithm (GOA). The proposed approach effectively relieves line overloads with minimum deviations in generations from market settlement. Security constraints such as line loading and load bus voltages are effectively handled in the optimization problem using penalty approach. Numerical outcomes on modified IEEE 30 Bus system is presented for experimental purposes and results are also compared with the particle swarm optimization. The experiment results prove that GOA is one of the best method among the challenging optimization methods, which is capable of obtaining higher quality solutions for proposed congestion management problem.**

Index Terms - Congestion management, objective function, constraints, GOA, Modelling of GOA, concept of exploration and exploitation.

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1. INTRODUCTION

Along with the process of the deregulation of electricity industry, frequent electric transactions lead to significant power flow variation, which threatens safe operation of electric power system. The study to ensure secure and economical operation of power system under the competitive market is widely focused on, among which congestion threatening safe operation of power system is an outstanding problem. Different kinds of market models applied by SOs (System Operators) result in different the congestion management model. Therefore, restraint conditions and optimizes goals built for congestion management varies in different markets. Paper [1] has proposed the basic principle and method when ISO deals with the congestion in the emerging energy market. Congestion managements applied in various kinds of electricity market are evaluated in [2], and a numerical example is utilized to manifest the principle involved. Paper [3] presents the application to large scale systems of an OPF model. Spot price, the byproducts of OPF and congestion charge provide economic signals to marker participant. Paper [4] examines two approaches to dealing with management of costs. The first approach is based on pool model and the second approach is based on bilateral model. That paper explains the basis for these models including a game-theoretic evaluation of some of its aspects. A Primal– dual Interior Point Linear Programming method is applied to solve congestion model in [5]. This method can be used to solve real-time congestion. In [6] objective is modeled in terms of maximizing the satisfaction degree felt by the participants in the market. The essence of this model is to minimize the adjustment amount of the trade when congestion taking place, but the different from the past goal function is that this model has introduced the concept of the fuzzy set when adjusting the trade. In order to maintain supply reliability, it is necessary for an index to evaluate it.

Conventional optimization techniques such as gradient-based algorithm are not good enough to solve the problems having non-linear objectives functions with more number of constraints. Because, it depends on the first and the second derivatives of the objective function. Since the proposed algorithm is a complex optimization one, use of heuristic algorithm is inevitable. In the past decade, a global optimization technique such as genetic algorithms, Simulated Annealing have been successfully used to solve power optimization problems such as unit commitment, capacitor placement in distribution system, optimal placement of FACTS devices for enhancing system security etc. SA is very effective, general-purpose optimization technique [9], which can effectively converge asymptotically to a global optimal solution with probability 1. Application of SA for unit commitment problem has been proposed in [10]. One main drawback of Simulated Annealing is that it takes larger CPU time to find the global-near minimum. The GOA method is usually faster than SA method because PSO has parallel search technique, which emulates natural genetic operations. However, the convergence of GA lowers its performance and minimizes its search ability that results to a higher probability towards obtaining a local optimum. Random search method is yet another powerful search method for solving optimization problem and their computational method is given in [11]. GOA is an exciting methodology in evolutionary computation that is somewhat similar to a genetic algorithm in that the system is initialized with a population of random solutions [12-14]. GOA has been found to be extremely effective in solving a wide range of engineering problems. References [15-16] reveal the applications of GOA to various power system problems.

This paper proposes an algorithm for congestion management by optimal generator rescheduling using PSO. The proposed method is tested on mmodified IEEE 30 Bus system and test results validate the potential of thee proposed algorithm.

2. CONGESTION MANAGEMENT STRATEGY

In Deregulated power system transmission companies (TRANSCOs), Generation companies (GENCOs) and Distribution Companies (DISCOs) work under different organizations. To maintain the co-relation between them there will be one system operator in all types of deregulated power system models, generally, there is Independent system operator (ISO). Several utilities join together to form a pool, with a central-broker in place, to co-ordinate the operation on hour-to-hour basis. In a pool market, GENCOs and DISCOs submit the sell and purchase decision in the form of sell or buy bids to the market operator, who in turn clears the market using an appropriate market-clearing procedure. Finally, it results in 24 hours energy prices to be paid by consumers and charged by producers. More often than not, pool market results originate network congestion problem which may results in preventing new contracts, infeasibility in existing and new contracts, additional damages to the system components. When such a scenario arises the ISO should determine the minimal charges in the market results that ensure a secure operation. In this paper, congestion is done by source of optimal rescheduling of generators based on the incremental and decremental price bids submitted by GENCOs to alter their scheduled productions from initial market clearing values.

3. MATHEMATICAL FORMULATION

The objective function is introduced in this to find optimal profile of active power generation which further helps us to minimize total congestion cost, along with satisfying constraints. The objective function is formulated as given below:

$$T^C = \sum_{j \in Ng} (C_{k.} + _{\Delta PGj} + D_{k.-\Delta PGj}) \quad \$ / \text{hour.} \qquad (3.1)$$

T^C = Sum of cost incurred for changing the real power generation of participating generators.

C_k and D_k = Price bids for generator k. and its function is to increase or decrease its pool power schedule for congestion management.

ΔP_{Gj}^{+} and ΔP_{Gj}^{-} = Active power increment or decrement of generator j due to congestion management [25].

3.1 Constraints

Depending upon the nature of power system under study of congestion, In TCM two types of constraints are used:

(i) Equality constraints
(ii) Inequality constraints

3.1.1 Equality constraints

$$P_{Gk} - P_{Dk} = \sum_j |V_j V_k Y_{kj}| \cos(\delta_k - \delta_j - \Theta_{kj}) \qquad j= 1, 2....NB \qquad (3.2)$$

$$Q_{Gj} - P_{Dk} = \sum_j |V_j V_k Y_{kj}| \sin(\delta_k - \delta_j - \Theta_{kj}) \qquad j= 1, 2......NB \qquad (3.3)$$

$$P_{Gk} = P_{Gk}^C + \Delta P_{Gk} - \Delta P_{Gk;} \qquad k= 1,2.......Ng \qquad (3.4)$$

$$P_{Dj} = P_{Dj}^C \qquad j= 1, 2........Nd \qquad (3.5)$$

Equation (4.1) and (4.2) represents real and reactive power balances in each node.

Constraints (4.3) and (4.4) represent final powers as a function of market clearing values.

P_{Gk}^C and P_{Dj}^C represent active power produced by the generator k and consumed by demand j

P_{Gk} and P_{Dj} represent final real power generation of generator k and final real power consumption of demand j.

V_j and V_k are voltage magnitude of bus j and k respectively.

δ_j and δ_k are bus voltage angle of bus j and k respectively.

Θ_{Kj} is admittance angle of line between buses k and j respectively.

Ng, Nd, NB represents number of generators, loads and buses.

3.1.2 Inequality constraints

These constraints are limits for equipment loading and operating requirements come under this category.

$$P_{Gk}^{min} \leq P_{Gk} \leq P_{Gk}^{max}; \qquad (3.6)$$

$Q_{Gk}^{min} \leq Q_{Gk} \leq Q_{Gk}^{max}$; (3.7)

$(P_{Gk} - P_{Gk}^{min}) = \Delta P_{Gk}^{min} \leq \Delta P_{Gk} \leq \Delta P_{Gk}^{max} = (P_{Gk}^{max} - P_{Gk})$ (3.8)

$\Delta P_{Gk^+} \geq 0;\ \Delta P_{Gk^-} \geq 0$ (3.9)

Above constraints (4.5, 4.6, 4.7) provide us upper and lower bounds for real and reactive power of generators.

Constraint (4.8) tells us about the incremental and decremental values of real power as positive [25].

3.2 Severity Index

Exigency analysis is an important factor of power system security assessment. The burden on the power system due to exigency may be expressed on the behalf of SI.

$SI = \sum_{k=1}^{ovl} (P_k/P_k^{max})^{2m}$ (3.10)

Ovl = the set of overloaded lines.

P_k = Line flow in k^{th} branch.

P_k^{max} = Loading limit of branch k

m= weight coefficient. {If value of m= 1 then masking effect reduces}.

For secure system, the value of SI is zero.

4. GRASSHOPPER OPTIMIZATION ALGORITHM

4.1 Overview:

Grasshopper is insects. They are treated as a pest due to their harm to crop production and agriculture. The life cycle of grasshoppers is shown in Fig. 4.1 Even if grasshoppers are normally seen independently in nature, they involve in one of the largest colony of all creatures. The range of the swarm may be of global scale and a horror for farmers. The particular fact of the grasshopper swarm is that the gathering behavior is found in both dryad and fecundity. Millions of dryad grasshopper's jump and move like rolling cylinders. In their track, they chew almost all vegetation. After this behavior, when they become fecundity, they form a colony in the air. In this way, grasshoppers drift over large distances. The main feature of the swarm in the larval phase is gradual movement and small steps of the grasshoppers. In addition to this feature long-range and sudden movement is the fundamental feature of the swarm in fecundity. Food source searching is a vital feature of the gathering of grasshoppers. It is nature energized algorithms reasonable divide the search process into two aspects: Exploration and Exploitation. In exploration, the search agents are determined to move suddenly, they contribute to move locally during exploitation. These two functions acts as a target seeking are achieved by grasshoppers naturally.

4.2 Modeling of GOA

The mathematical model which can be used to simulate the gathering behavior of grasshoppers is given below:

$X_i = S_i + G_i + A_i$ (4.1)

X_i = the position of the i-th grasshopper

S_i = social interaction

G_i = gravity force on the i-th grasshopper

A_i = the wind advection.

We provide random behavior to this modeling and equation is written as below:

$X_i = r_1 S_i + r_2 G_i + r_3 A_i$ (4.2)

Where r_1, r_2, r_3 are random variables.

We also define S_i for this modeling which gives by the summation of the product of distance between i^{th} and j^{th} grasshopper and the unit vector from i^{th} grasshopper to j^{th} grasshopper.

$S_i = \sum_{j=1}^{N} s(d_{ij})\, d_{ij}^{\wedge}$ (4.3)

d_{ij} = distance between the i^{th} and j^{th} grasshopper.

$d_{ij}^{\wedge}$ = unit vector from i^{th} grasshopper to j^{th} grasshopper [26].

The *S* function defines the social forces is estimated as given below:

$S(r) = fe^{-r/l} - e^{-r}$ (4.4)

Where;

f = the intensity of attraction

l = the attractive length scale.

The function *S* shows the effects on the social interactions which are attraction and repulsion properties of grasshopper [17].

5. RESULTS

Simulated cases for proposed work is as given in the below table 5.1.

Case Name	Type	Congested lines	Line power flow (MW)	Total power violation (MW)

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A	Outage of line 1-2	1-7 7-8	147.264 136.136	22.4176
B	Outage of 1-7 and load at all bus raised by 50%	1-2 2-8 2-9	310.48 97.123 103.467	166.2000

We took number of search agents = 100

Maximum iterations = 500

The global optimum value of GOA is = 2.602e-08.

Case- A

In this case, such as 1-7 and 7-8 gets overloaded as a result of line 1-2 out. The actual power flow in these lines are 147.264 MW and 136.136 MW. But its power flow limit is 130 MW. Net power violation is found to be 22.4176 MW. For secure system, the power flow in the transmission lines should not exceed their permissible limits. So, suitable corrective action should be carried out to alleviate the overloaded lines. The main objective of this study is to relieve overloaded lines by optimal rescheduling of generators in minimal amount from initial market clearing values.

Table 5.2 : Contribution of generators for congestion management for Case- A

Methods	ΔP_{G1}	ΔP_{G2}	ΔP_{G3}	ΔP_{G4}	ΔP_{G5}	ΔP_{G6}
PSO	-8.6123	+10.4059	+3.0344	+0.0170	+0.8547	-0.0122
GOA	-8.1340	+10.0006	+2.9975	+0.4170	+0.5563	-0.3122

Table 5.3 Results of study which shows power flow after relieving congestion and cost of relieving congestion.

Type	Congested lines	Line power flow	Net power contribute to relieve congestion (MW)	Power flow after relieving congestion (MW)	Cost of relieving congestion
Outage of line 1-2	1-7 7-8	147.264 136.136	22.4176	126.8471 117.2948	510.1867 $/hr

Case- B

In this case, lines 1-2, 2-8, 2-9 gets overloaded as a result of outage of line 1-7 along with increase in real and reactive power of system load by 50%. The power flows in above said overloaded lines are 310.48 MW, 97.123 MW, 103.467 MW respectively. Line 1-2 is found to be loaded heavily beyond its maximum limit of 130 MW. The total power violation is found during study 166.2000 MW. The overloads should be alleviated as rapid as possible otherwise it may lead to partial or complete system black out.

Table 5.4 shows that the percentage of line loading factor before and after rescheduling of generators.

Case	Lines	% line loading factor before generator rescheduling	% line loading factor after generator rescheduling	Net power contributed (MW)	Cost for relieving congestion ($/hr)
B	1-2 2-8 8-9	2.44 1.49 1.6	99.44 93.12 99.01	166.2000 MW	5228 $/hr

6. CONCLUSIONS

This paper presents an algorithm for congestion management in pool based electricity market based on Grasshopper optimization algorithm. The proposed approach effectively relieves the congestion economically with minimum shift in generation real power from initial market clearing values. Line overload due to unexpected line outage and sudden load variations are considered in this work. Numerical results are tested on IEEE 30 Bus system and are also compared with Simulated Annealing, particle swarm optimization and Random search method in terms of solution quality.

The proposed method is tested with various line outage and load variations. However, only two cases are presented namely Case A and Case B for IEEE 30 Bus system. The Best cost obtained using GOA is 510.1867 $/hr for Case A and 5228 $/hr for Case B which is much lower than cost resulted by other approaches.

7. FUTURE SCOPE

GOA is only compatible to solve single- objective problems with contentious variables. In future, it is expected to solve binary and multi objective versions of the algorithm may be invented to solve discrete and multi-objective functions. These are carried out by some other advanced techniques or more advanced implementations of GOA.

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