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CONGESTION MANAGEMENT IN DERGULATED MARKET USING FIREFLY OPTIMISATION

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ABSTRACT: In a interconnected grid system the optimum power flow (OPF) is an important operation with respect to transmission line losses and other operational constraints of the power system. Moreover with the deregulation of the power industry the methods of operation and control strategies of optimum power flow (OPF) have undergone huge changes. The increase in power transaction with respect to real time increase in demand and for satisfying those demand the competition of the market players (GENCOs), are creating stress on the power system and preventing normal flow of power, thus leading to power congestion in the system. In this paper a firefly optimization algorithm has been utilized to solve the problem of Power Congestion by rescheduling of active power of generators, which are selected on the basis of sensitivity to congested network. Here a comparative study has been made among solutions obtained from congestion management and unmanaged network in IEEE 30 bus system. It is observed that the proposed method is capable of producing better results.
Keywords: Management, Firefly Optimization, GENCO, Non-linear programming, OPF.

1. INTRODUCTION

Transmission congestion may be defined as the condition where more power is scheduled or flows across transmission lines and transformers than the physical limits of those lines and transformers. The objective of congestion management is to take actions or control measures to relieve the congestion of transmission networks. In principle, congestion management can be considered at different timescales, such as:

i. long-term transmission capacity reservation that can be made yearly, monthly, weekly or daily;
ii. short-term scheduling of transmission constraints in the day-ahead market; or
iii. Re-dispatching of generation in the real time balancing market.

Depending on market structures and market rules, one or more of these congestion management processes may be applied. Effective congestion management is crucial for the efficient operation of any electricity market where congestion exists. However, it has been recognized that completely eliminating all transmission congestion is neither necessary nor efficient. In other words, congestion management should compromise between the benefits and costs of solutions. In the short term, the objective of congestion management is to maintain the physical and operational reliability and security of the electricity transmission network and facilitate a competitive electricity market.

Several Optimal Power Flow (OPF) based congestion management schemes for multiple transactions also have been proposed. The OPF optimizes a power system operating objective function, while satisfying a set of system constraints. In general, OPF problem is a large dimension nonlinear, non-convex and highly constrained optimization problem. It is non-convex due to existence of nonlinear AC power flow equality constraints, non-convex unit operating cost functions and units with prohibited operating zones. This non-convexity is further increased when valve point loading effects of the thermal generators have to be included [16] or FACTS devices are included in the network. Many classical techniques have been reported in the literature [9–12], such as nonlinear programming (NLP), quadratic programming (QP) and linear programming (LP). The gradient based methods [5,12] and Newton methods [15] suffer from the difficulty in handling inequality constraints. Moreover, these NLP and QP methods rely on convexity to obtain the global optimum solution and as such are forced to simplify relationships in order to ensure convexity. To apply linear programming [2], input–output function is to be expressed as a set of linear functions, which may lead to loss of accuracy. Moreover they are not guaranteed to converge to the global optimum of the general non-convex OPF problem. These days, genetic algorithm (GA) and evolutionary programming techniques (EP) [18,20] has been suggested to overcome the above-mentioned difficulties of classical methods. In these days, an evolutionary programming approach has been used to solve OPF for the analysis of deregulated model [13,14]. So it is necessary to validate the proposed approach with the help of well known basic classical technique likes gradient steepest descent method. In this paper, OPF algorithm using firefly optimization is developed and applied to IEEE-30 bus test system.

2. OBJECTIVE FUNCTION

The congestion management in our work is done using firefly optimization. We have considered the case of IEEE 30 bus system. Load flow is done after adding extra load in network at random buses to show congestion. Load flow will locate the congestion in the network after load increment as power flow limits violation at buses can be checked. Renewable sources are placed on buses where congestion seems to occur. But the optimum size of renewable sources is a major factor to avoid cost increment as it shouldn't be like the losses due to congestion are less and cost occurred in placing new renewable sources is more. So firefly optimization is done to find out the optimal sizing of new source. It considers an objective function which takes cost into consideration. The objective function is described as in mathematical form:

The cost function determining the cost of rescheduling of generators for congestion management is

$F = \sum_{g \in Ng} (C^u_g \times \Delta P^u Gg + C^d g \times \Delta P^d Gg)$

Where

F=total cost incurred for congestion management in ($/hr)

$\Delta P^u Gg$ = active power increment of generator g due to congestion management (MW)

$\Delta P^d Gg$ = active power decrement of generator g due to congestion management (MW)

C^u_g = price bids submitted by generator g to increase its pool power for congestion management ($/MWhr)

$C^d g$ = price bids submitted by generator g to decrease its pool power for congestion management ($/MWhr)

The optimization problem is subjected to a number of inequality and equality constraints.

Equality Constraints

i) $P_{Gi} - P_{Di} = V_i \sum N_j^i Vj (G_{ij}\cos\theta_{ij} - B_{ij}\sin\theta_{ij})$ i & j =1, 2,……NB

ii) $Q_{Gi} - Q_{Di} = V_i \sum N_j^i Vj (G_{ij}\mathrm{sins}\theta_{ij} - B_{ij}\cos\theta_{ij})$

i & j = 1,2,……NB

NB = no. of buses

P_{Gi} = generated real power at bus i (MW)

P_{Di} = real load power at bus i (MW)

Q_{Gi} = generated reactive power at bus i (MVar)

Q_{Di} = reactive load power at bus i (MVar)

V_i = voltage at bus i (Volt)

G_{ij} = conductance of line between i & j (mho)

B_{ij} = suseptance of line between i & j (siemens)

θ_{ij} = admittance angle of line between buses i and j (radian)

The equality constraints represent the power flow equation. The constraints maintain that the generated power at a bus satisfy both the load and the loss successfully for both real and reactive power.

iii) $P_{Gg} = P^C_{Gg} + \Delta P^u_{Gg} - \Delta P^d_{Gg}$

iv) $P_{DJ} = P^C_{DJ}$

k = number of participating generator

P_{Gg} = final real power generation of generator g (MW)

$P^C_{\mathbf{Gg}}$ = active power produced by generator g as determined by the market clearing price (MW)

P_{DJ} = final real power consumption at load bus j (MW)

P^C_{DJ} = active power consumed by load bus j as determined by the market clearing price (MW).

Inequality Constraints

i) $P^{min}_{Gg} \leq P_{Gg} \leq P^{max}_{Gg}$ $g \in Ng$

P^{min}_{Gg} = minimum real power limit of generator (MW)

P^{max}_{Gg} = maximum real power limit of generator (MW)

P_{Gg} = final real power generation of generator (MW)

The generated real power of generator is within the upper and lower limit of the generator

ii) $Q^{min}_{Gg} \leq Q_{Gg} \leq Q^{max}_{Gg}$ $g \in Ng$

Q^{min}_{Gg} = minimum reactive power limit of generator (MVar)

Q^{max}_{Gg} = maximum reactive power limit of generator (MVar)

Q_{Gg} =final reactive power generation of generator (MVar)

The generated reactive power of generator is within the upper and lower limit of the generator

iii) $Pg - P^{min}_g = \Delta P^{min}_g \leq \Delta Pg \leq \Delta P^{max}_g = P^{max}_g - Pg$

The upper and lower bound of real power adjustment
iv) $V_l^{min} \leq V_l \leq V_l^{max} \quad l \in N_l$
V_l^{min} = minimum voltage of load bus (Volt)
V_l^{max} = maximum voltage of load bus (Volt)
V_l = voltage of load bus (Volt)
N_l = no. of load bus
This is a security constraint and provides the upper and lower voltage bound of load buses.
v) $P_{ij} \leq P_{ij}^{max}$
Pij = real power flow in line i-j (MW)
P_{ij}^{max} = maximum power flow limit of line i-j (MW)
The line loading should not exceed the maximum limit.
The Fitness Function
The fitness function to be minimized to get the desired minimum rescheduled cost is given by
Z=F+P
Where P is a penalty function based on distance of a solution from the feasible region
$P = pf1 * \sum_{i=1}^{Nl} \max(0, Pl) + pf2 * \sum_{j=1}^{NB} \max(0, Pv) + pf3 * \max(0, Ps)$
Pf_1, Pf_2, Pf_3 are user defined and P_l, P_v, P_s are given as

$$P_l = \begin{cases} 0 & if \quad P_{ij} \leq P_{ij}^{max} \\ (P_{ij} - P_{ij}^{max})^2 & if \quad P_{ij} > P_{ij}^{max} \end{cases}.$$

$$P_v = \begin{cases} 0 & if \quad V_l^{min} \leq V_l \leq V_l^{max} \\ \left(V_l^{min} - V_l\right)^2 & if \quad V_l \leq V_l^{min} \\ (V_l - V_l^{max})^2 & if \quad V_l^{max} \leq V_l \end{cases}$$

$$P_s = \begin{cases} 0 & if \quad P_{Gg}^{min} \leq P_{Gg} \leq P_{Gg}^{max} \\ \left(V_l^{min} - V_l\right)^2 & if \quad P_{Gg} \leq P_{Gg}^{min} \\ (V_l - V_l^{max})^2 & if \quad P_{Gg}^{max} \leq P_{Gg} \end{cases}$$

It is seen that the congestion can be managed by rescheduling of generator output of the network and that mere rescheduling of any generator may relief the congestion of an already congested line but also leads to congestion of an uncongested line. Thus for rescheduling, the generators are to be wisely selected such that after rescheduling, the network remains congestion free.

3. RESULTS

Congestion management is necessary to tackle load demand in power system. In our work we have done this by using firefly optimization for IEEE 30 bus system. The IEEE 30 bus system consists of 6 generators buses, 24 load buses and 41 transmission lines. System data are taken from [Appendix B]. The real load of the system is 283.4MW and reactive load is 126.2MVAR. The load bus voltages are maintained between 0.9 and 1.1 p.u. Price bids are submitted by Generating Companies (Gencos) for test system according to which rescheduling of generators occur. To add congestion in the network we intentionally added Outage of the line 2-5 and increase of load at bus 2,3,4,5 by 35%. It helps us to demonstrate the congestion management scheme in the system. After adding congestion newton raphson load flow analysis is done and power flow in branches is noted for both cases i.e. with congestion and compensated congestion (discussed ahead) along with the maximum limits of power flow in each line. If any line violates this limit then congestion is considered in that line. In this case, line such as 1-2 and 28-27 get overloaded as consequence of outage of line 2-5. The flow limits in those lines are 130 MW & 16 MW. Net power violation is found to be 85.3 MW as given in table 1. For secure system, the power flow in the transmission line should not exceed their permissible limit. Hence suitable corrective action should be carried out to alleviate the above said overloa

ds.

Table 1: Simulated Case

Type of Contingency	Congested Lines	Line Power (MW)	% Overload	Total Power Violation (%)
Outage of line 1-2 and line 28-27	1-2	214.7133	65	75.8267
	28-27	17.732	10.8267	

To take out the potential buses sensitivity analysis is done and we have picked up the top 5 highest sensitive buses on which renewable energy source will be inserted to provide extra power to mitigate congestion. These are 6, 28, 22, 25 and 27. On these buses renewable energy source will be added to get more active power in the system. Here in this work only active power insertion in the system is considered, so renewable energy source like solar cell, wind plant which generates active power can be introduced in our system to avoid congestion. Firefly optimization is used to decide the optimal size of the renewable energy source placed on the potential buses. The effectiveness of optimization technique lies with the fact that its fitness function should be minimized with iterations and should stay at minimum value for number of iterations, as with our case. The objective function is combination of total cost incurred in congestion management and penalty function based on distance of a solution from the feasible region, so it should be minimized. The outcome of fitness function by firefly optimization is shown in figure 1. It is clear that a minimum value is set after 30 iterations of firefly algorithm and this holds it for last iteration. It shows our objective function is minimized and gained the minimum value very earlier, increasing the efficiency of algorithm.
The results obtained for change in power generation of participating generators are given in table 2.

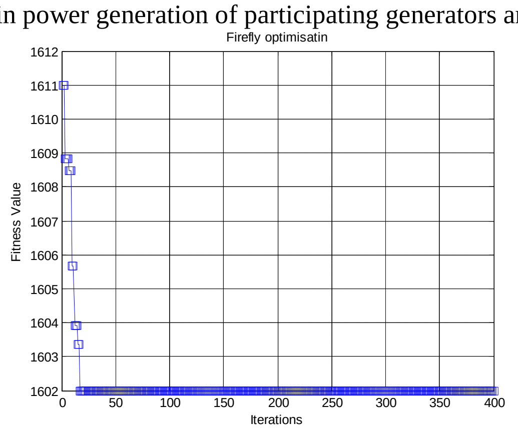

Figure 1: Firefly optimized fitness function for 400 iterations

Table 2: Adjustment of Active Power Generation of Participating Generator (MW)

ΔP_{G1}	3.12418390398526
ΔP_{G2}	-40.0564272387137
ΔP_{G3}	0
ΔP_{G4}	0.422384028928490
ΔP_{G5}	0.217000000000000
ΔP_{G6}	0.284672170435533
Total rescheduling of power (MW)	44.1047
Cost	653.1750 $/hr

The rescheduling of active power generation requires the decrease in active power generation from generator 2 and increase the power generation from generator 1, 4, 5, 6. A bar graph representation of these changes in active power generation is shown in figure 2 below. The cost incurred for relieving congestion is 653.1750 $/hr. based on the bidding cost of generators for change in power generation.

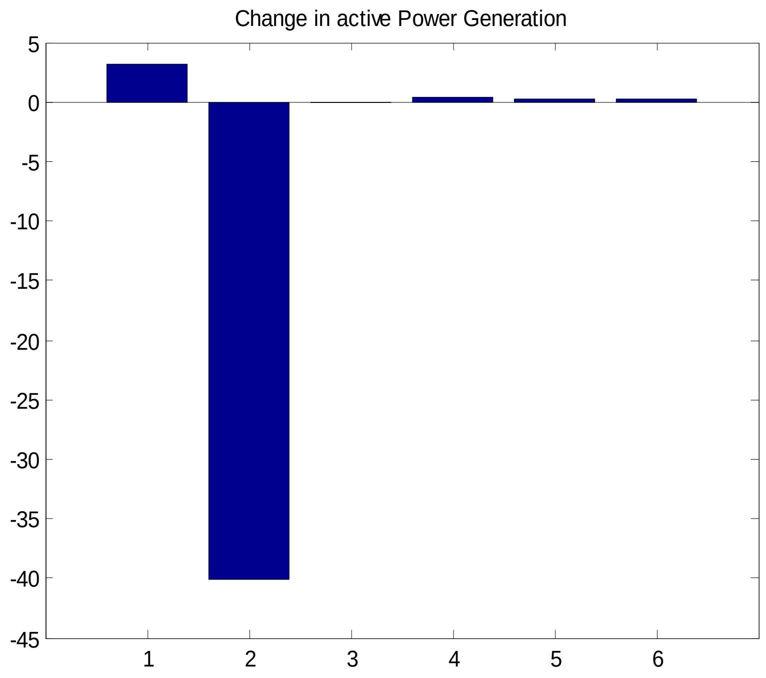

Figure 2: Changes in active power generation after congestion management.

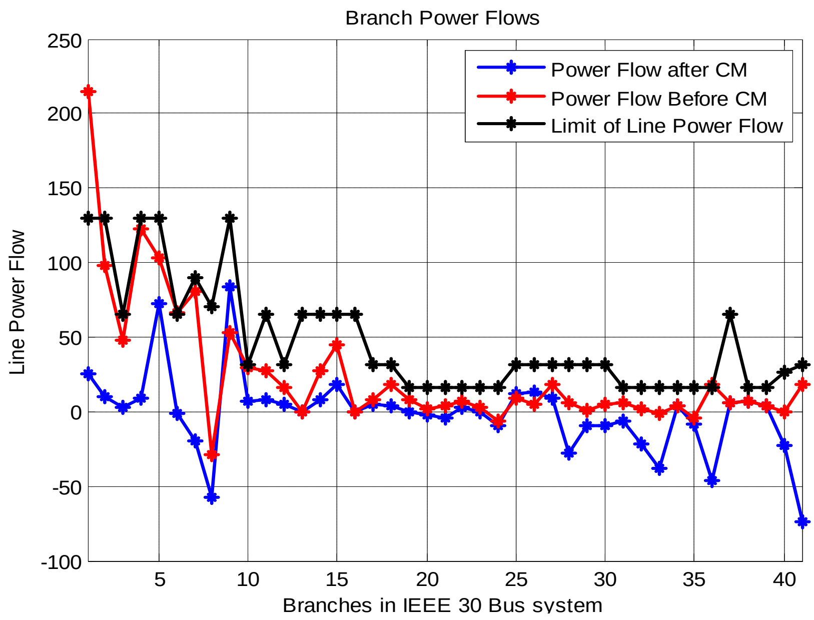

Figure 3: Power flow in various scenarios before and after congestion management.

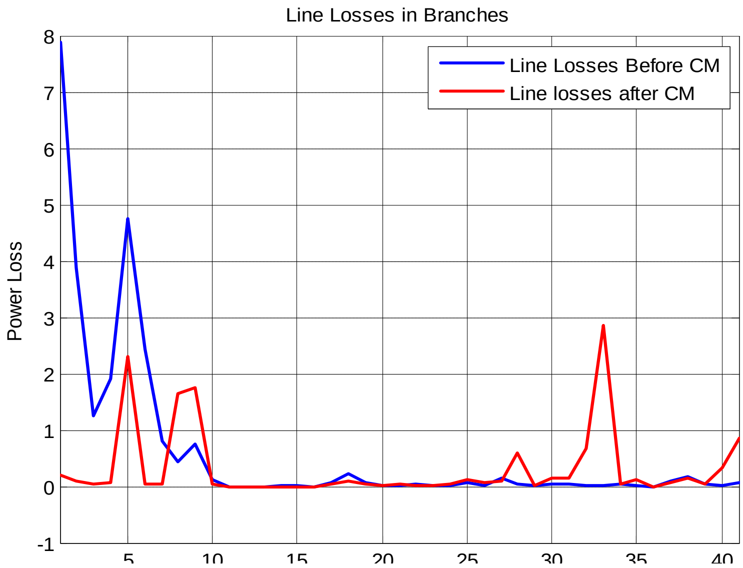

Figure 4: Line flow losses in IEEE 30 bus system

Figure 3 shows the comparison curve for the line flow power after congestion management with prior to management and a black curve shows the maximum line flow limit. Losses in lines will also decrease once congestion from lines are removed. Figure 4 shows the outcome of line losses in our case.

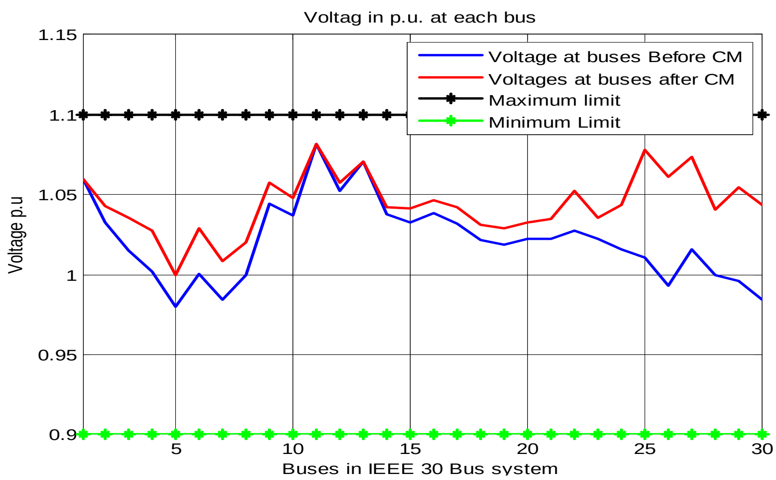

Figure 5: Voltage profile p.u. at 30 buses

The generating power added at potential buses and that is demonstrated by placing renewable source in IEEE 30 bus system in figure 6.

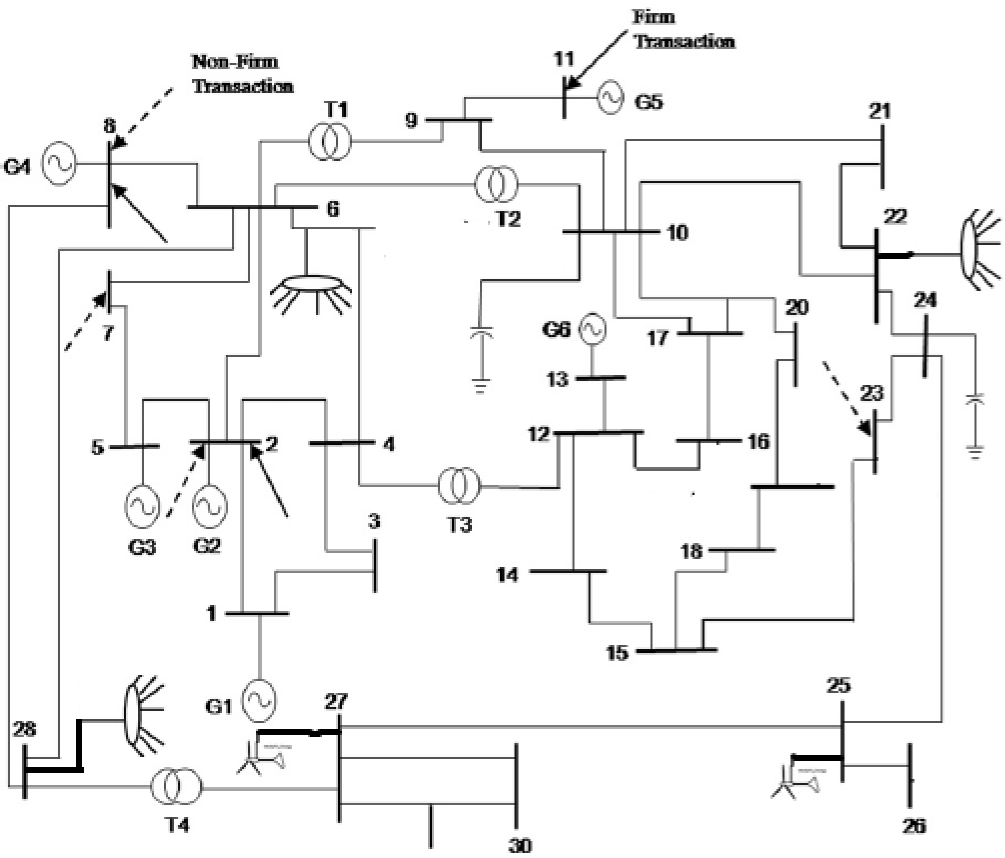

Figure 6: Renewable sources added in IEEE 30 bus system

4. CONCLUSION

The objective of this project is to minimize or alleviate power congestion of the network by rescheduling of active power of generators at minimum cost satisfying the operational constraints. The method proposed here using firefly optimization has been implemented on IEEE 30 bus system. The congestion is knowingly introduced by increasing the outage in line 2-3 for the test purpose and has been successfully managed with minimum cost and maintaining system constraints. The results obtained are quite satisfactory and checked on the ground of power losses and voltage profile improvement after congestion management. Thus it can be said that rescheduling of generators for congestion management is fruitful process as it maintained the supplied quality, security of the grid and also taking care of the interest of the consumers without shedding any load.

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