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Congestion Management in Dergulated Market along with the Promotion of Renewable Energy Resources Using PeSOA Optimisation

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Abstract: ***As we have seen that the load demand is increasing day by day & also due to massive demand there is the competition among the generating companies (GENCOS).Due to the high demand losses are increasing because lines are operation beyond their limits i.e. thermal, voltage, stability limits, thus violating the stability constraints so called congestion. To fulfill this massive load demand we cannot replace the whole transmission system as it incurs high cost, so what we can do is to find out the ways which can reduce congestion. So in this paper we have used PeSOA(Penguin search optimization algorithm) to reduce congestion on IEEE-30 bus system & its comparison to PSO(Particle swarm optimization). Although PSO also reduces congestion but PeSOA is better than PSO ,as can be seen from results.***

Keywords: GENCO, Non-linear programming, Congestion Management, PeSOA(Penguin search Optimization algorithm), PSO (Particle Swarm Optimization)

1. Introduction

When more power is scheduled or flows across transmission lines and transformers thus eradicating the physical limits of those lines and transformers congestion takes place. The aim of congestion management is to take counter measures to alleviate the congestion of transmission networks. In principle, congestion management can be considered at different timescales, such as:

1) We can made long-term transmission capacity reservation, monthly, weekly or daily;
2) We can do short-term scheduling of transmission constraints in the day-ahead market; or
3) Re-dispatching of generation in the real time balancing market.

Based on market structures and market rules, one or more of these congestion management processes may be applied. For the efficient operation of electricity market effective congestion management should be applied when congestion occurs. Complete elimination of 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.

Congestion is managed by active power rescheduling of generators i.e. to add extra energy resources to mitigate congestion. Here we have used renewable energy resources like solar & wind. Penguins are sea birds they forage into several groups. They feed as a team & follow their local guide which has found most food in the last dive . they forage under water until their oxygen reserve is depleted, After a no of dives they return to the surface & communicate via inra – group & inter –group communication to find out local best & Global best solution. In the next dive the changed their positions & oxygen reserve is updated, if the Global best is better than previous than this is the new Global best position (i.e maximum abundance of food) otherwise previous remains best solution . In this way Global & Local best continuously get improving.

2. Objective Function

The congestion management in our work is done using PeSOA 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

$F = \sum g_{\epsilon N_g} (C^u{}_g \times \Delta P^u Gg + C^d g \times \Delta P^d Gg)$

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.

Constraints satisfying equality criteria:

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

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_{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).

Constraints satisfying inequality criteria:

i) $P^{min}_{Gg} \leq P_{Gg} \leq P^{max}_{Gg}$ g € 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 € 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) $V_l^{min} \leq V_l \leq V_l^{max}$ l € 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) $Pij \leq P_{ij}^{max}$

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

$P = pf1^* \sum^{Nl}_{i=1} \max (0, Pl) + pf2^* \sum^{NB}_{j=1} \max (0, Pv) + pf3^*\max (0, Ps)$

Pf_1, Pf_2, Pf_3 are user defined and P_l, P_v, P_s are given as

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

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

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

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 fulfill the increasing load demand . In our work we have done this by using Penguin Search 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 7-10 and increase of load at bus 7,8,9,10 by 50%. 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, 3-4,2-6 and 28-27 get overloaded as consequence of outage of line 7-10. The flow limits in those lines are 130 MW, 130MW, 65MW, 32MW & 16 MW. Net power violation is found to be 167.91 MW as given in table 1. For secure system, the power flow in the transmission line should not violate permissible limits. Hence suitable corrective action should be carried out to alleviate the above said overloads.

Table 1: Simulated Case

Type of Contingency	Congested Lines	Line Power (MW)	% Overload	Total Power Violation (%)
Outage of lines	1-2	219.71323	68.86	167.91
	3-4	148.4769	14.21	
	2-6	79.16	21.78	
	6-8	43.1810	34.94	
	28-27	20.9895	31.18	

To take out the potential buses sensitivity analysis is done and we have picked up the 4 sensitive buses on which renewable energy source will be inserted to provide extra power to mitigate congestion. These are 27, 9, 10, 11and 12. On these buses renewable energy source will be added to get more active power in the system is considered. 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. PeSOA 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 PeSOA optimization is shown in figure 1. It is clear that a minimum value is set after 3 iterations of PeSOA 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.

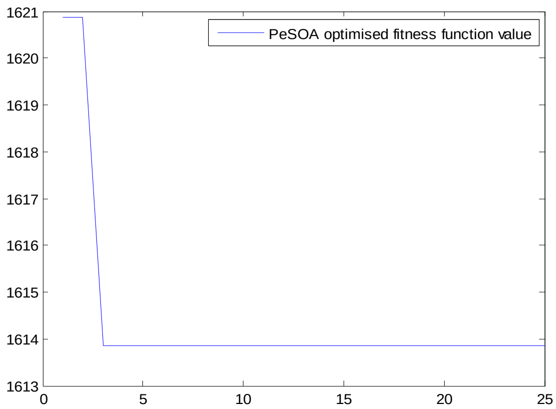


Figure 1: PeSOA optimized fitness function

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

ΔP	Using PeSOA	Using PSO
$\Delta PG1$	0.16456223	0.3631350
$\Delta PG2$	-39.609630	-39.669771
$\Delta PG3$	0	0
$\Delta PG4$	-0.08326790	-0.0132270
$\Delta PG5$	0.2929500	0.2929500
PG6	-0.0103766	-0.0015004
Total rescheduling of power (MW)	40.1608	40.3406
cost	736.0268$/hr	739.0268$/hr

The rescheduling of active power generation requires the decrease in active power generation from generator 2,4 6and increase the power generation from generator 1, 5. A bar graph representation of these changes in active power generation is shown in figure 2 below. The cost incurred for relieving congestion is 733.567 $/hr. based on the bidding cost of generators for change in power generation.

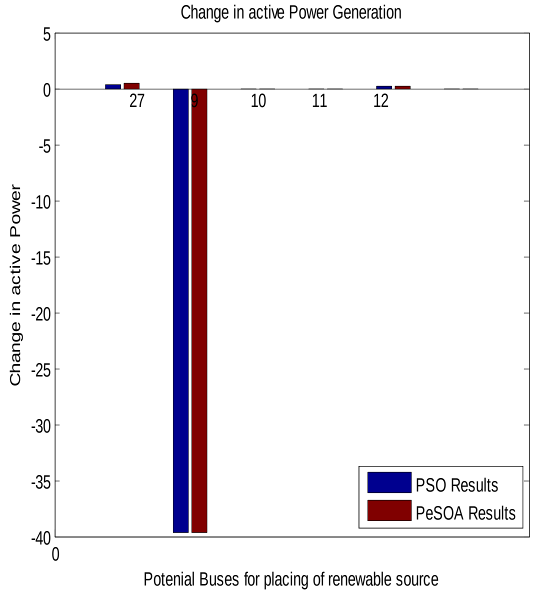
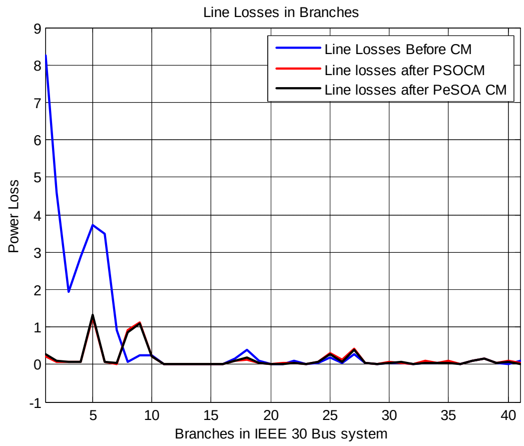


Figure 2: Changes in active power generation after congestion management.



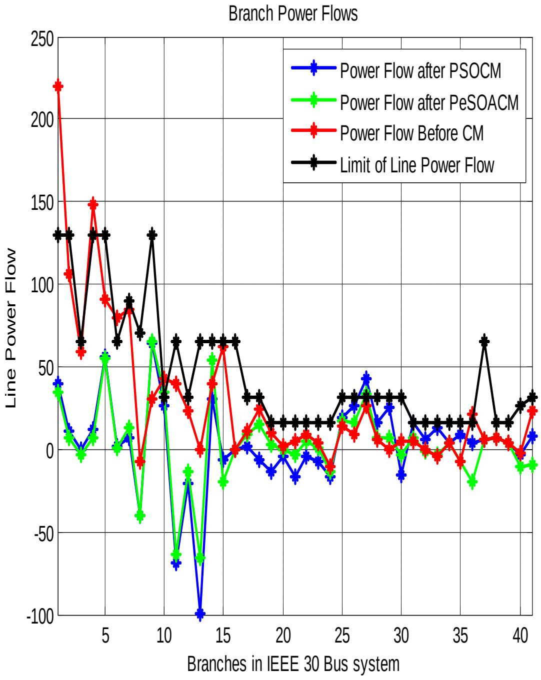


Figure 3: Power flow in various scenarios before and after congestion management.

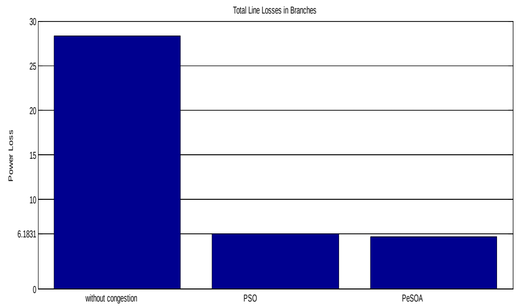


Figure 4: Line flow losses in IEEE 30 bus system

Figure 3 shows the comparison graph for the line flow power after congestion management by PeSOA & PSO with prior to management. Losses in lines will also decrease once congestion from lines are removed. Figure 4 shows the outcome of line losses in our case

Before Congestion management(MW) (LINE LOSSES)	After Congestion managed by PeSOA	After congestion management by PSO
28.3036	6.1831	5.3844

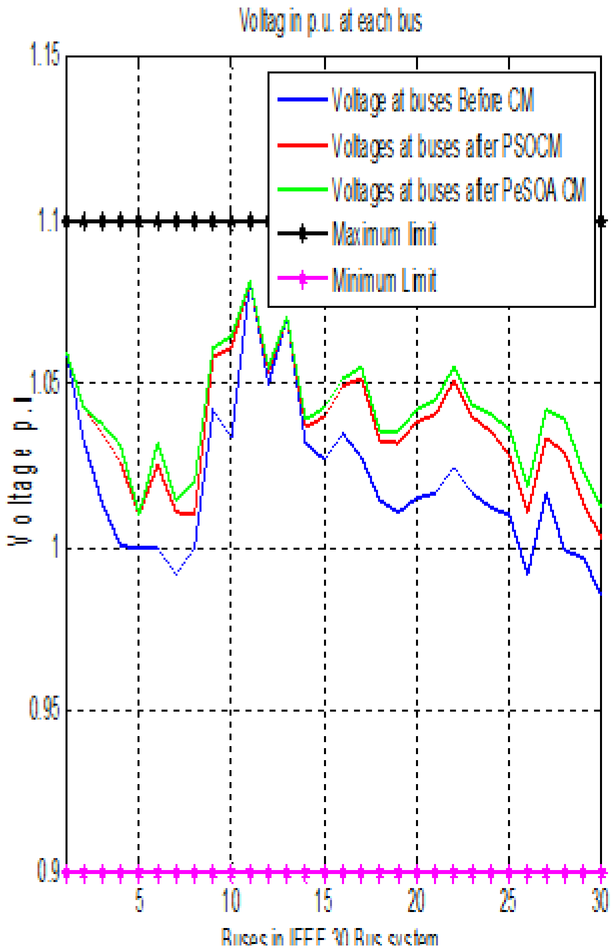


Figure 5: Voltage profile p.u. at 30 buses

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

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 PeSOA optimization has been implemented on IEEE 30 bus system. The congestion is knowingly introduced by increasing the outage in line 7-10 & 50 iterations 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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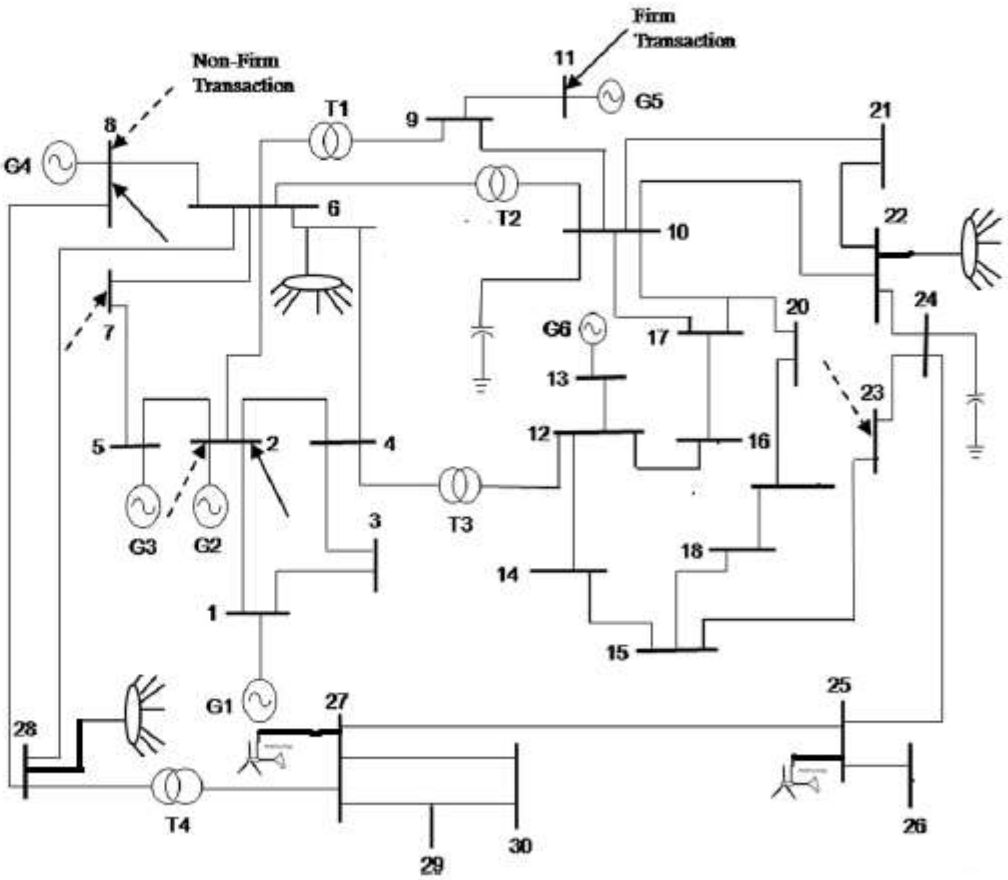

Figure 6: Renewable sources added in IEEE 30 bus system