International Journal of Electrical Electronics & Computer Science Engineering
Volume 5, Issue 1 (February, 2018) | E-ISSN : 2348-2273 | P-ISSN : 2454-1222
Available Online at www.ijeecse.com

Congestion Management by Considering Optimal Location and Size of Distributed Generation using Firefly Algorithm

Subhasish Deb
Assistant Professor, Department of Electrical Engineering, Mizoram University, Aizawl, Mizoram, India
subhasishdeb30@yahoo.co.in

Abstract: ***Power system deregulation has brought competition among the sellers and buyers of electricity markets which results complicated power systems. The complexity of system started due to the restructuring process and also with the penetration of alternative energy sources. The fastest growing demands of electricity sometimes create undesirable line power flow which goes beyond to its line thermal limits. This situation of transmission line is known as transmission congestion. The Independent System Operator (ISO) is fully responsible for the congestion management in deregulated market by several ways. Apart from traditional ways like load shedding, generator rescheduling or integration of Flexible AC Transmission System (FACTS) devices, Distributed Generation (DG) can take a part in congestion management. Proposed work focuses mainly on the utilization of distributed generations in addition to generator rescheduling process for congestion management. Firstly, generator sensitivity factor (GSF) and power transfer distribution factor (PTDF) are calculated based on congested line power flow. The optimal location of distribution generators is decided based on the value of PTDF and also the optimal selection of generators is done based on GSF value. Firefly Algorithm (FA) is a newly developed metaheuristic algorithm utilized in this proposed work for minimizing congestion cost and also to decide the optimal size of the DG. The proposed work is tested on IEEE 39 Bus New England Test System.***

Keywords: ***Generator Rescheduling, Congestion Management, Power Transfer Distribution Factor, Generator Sensitivity Factor, Distributed Generation, Firefly Algorithm.***

I. INTRODUCTION

The restructuring of electrical power systems creates complexity in the system as well as competition among the market players. At the same time, the growing demand of electricity imposes pressure on generation and transmission network. When transmission network is unable to transfer the desired amount of electrical power, network congestion occurs. In deregulated electricity market system, Independent System Operator (ISO) takes care of market settlement and also network security issues. Thus, congestion management in deregulated power markets is a big task for ISO. Generally, various methods are adopted by ISO to mitigate transmission congestion in order to maintain reliable and secure operation of power systems [1]-[2].

Transmission congestion management in different power markets by considering pay based priority to avoid load curtailment is presented in [3]. Congestion management by rescheduling all the system generators are presented in [4]. Rescheduling is done by considering the Relative Electrical Distance (RED) concepts where both transmission losses and voltage profile are also discussed. Congestion management by identifying zones are presented in [5]. Real power transmission congestion distribution factor (PTCDF) and reactive power transmission congestion distribution factor (QTDF) calculations are given in [5]. Considering the PTCDF and QTCDF value, the rescheduling of generators real and reactive power for managing transmission congestion is done. In [6]-[7], Optimal rescheduling of generators for congestion management is done by particle swarm optimization. Here, generator sensitivity factor (GSF) is calculated in order to identify the number of participated generators in congestion management. Congestion management using FACTS devices are presented in [8]-[10]. Different types of FACTS devices are used in order to manage the transmission congestion. In [11], the combined operation of hydro-thermal generators is discussed for congestion management. The rescheduling of hydro generators and thermal generators are done to alleviate transmission congestion. In [12]-[14], the impact of distributed generations (DG) in electricity market is shown. Distribution generators can play a vital role in power system and its impact can manage transmission congestion in ower system. The optimal selection of DG is done by the sensitivity analysis which is presented in [12]-[13]. In [14], the optimal location of DG is identified based on locational marginal pricing (LMP).

The contribution of the present work is to reduce the congestion cost while managing the transmission congestion. The present work is carried out by rescheduling the optimal generators in the presence of DGs in the system. The optimal generators are identified based on generator sensitivity factor (GSF) and optimal location of DG is identified based on power transfer distribution factor (PTDF) value. The size of DG and optimal congestion cost is solved by exploring a newly developed meta-heuristic algorithm i.e.; Firefly Algorithms (FA).

II. FIREFLY ALGORITHM

Firefly algorithm (FA) was introduced by Xin-She Yang [15]-[16]. This firefly algorithm was based on the behavior of the flashing characteristics of fireflies:

- Firstly, all fireflies are unisex and each one of them is attracted to other fireflies despite of their sex;

- Secondly, the brightness of each firefly indicates the attractive characteristics of individuals therefore, the less bright firefly will move towards the brighter firefly. With the increase in distance, the attractiveness or bright characteristic decreases. Therefore one firefly will move randomly if it does not get another brighter firefly;
- Lastly, optimizing the objective function, the brightness or light intensity of a firefly is determined.

For a maximization problem, the brightness of firefly is proportional to the objective function to be solved.

```
Firefly Algorithm
Objective function f(x), x = (x1, . . ., xd)T
Initialization of population of fireflies xi (i = 1, 2, . . .,
 n)
Define light absorption coefficient _
while (t < Maximum Generation)
for i = 1: n all n fireflies
    for j = 1: i all n fireflies
    Light intensity Ii at xi is determined by f(xi)
       if (Ij > Ii)
         Move firefly i in all d dimensions towards j
       end if
      Attractiveness changes  with distance r by
     expression  [-γ r^2]
      Assess new solutions and update light intensity
    end for j
end for i
Rank the fireflies based on brightness and find the
current best
end while
Results and discussion
```

Fig. 1. Pseudo Code of Firefly Algorithm

The i^{th} firefly movement is attracted to brighter j^{th} firefly is determined by

$$x_i^{t+1} = x_i^t + \beta_0 e^{-\gamma r_{ij}^2}(x_i^t - x_j^t) + \alpha\varepsilon_i^t \quad (1)$$

Where β_0 is the attractiveness at r = 0, the second term is representing the attraction, while the third term is randomization with the vector of random variables ε_i being drawn from a Gaussian distribution function.

The Cartesian distance between any two i^{th} and j^{th} fireflies at x_i and x_j can be $r_{ij} = \| x_i - x_j \|$. For most cases, we take $\beta_0=1$, $\alpha \in [0,1]$, and $\gamma=1$.

III. Generator Sensitivity Factor And Power Transfer Distribution Factor

The real power P_{ij} flow through a line-*m* connected between bus-*i* and bus-*j* can be written as:

$$P_{ij} = |V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j) - V_i^2 Y_{ij}\cos\theta_{ij} \quad (2)$$

where V_i, V_j and δ_i, δ_j are the voltage magnitudes and angles at bus-*i* and bus-*j* respectively. Y_{ij} and Θ_{ij} are the magnitude and angle of Y_{Bus} matrix ij^{th} element.

Generator sensitivity factor (GSF) describes a change in real power flow through a transmission line *m* connected between bus *i* and bus *j* to the change in generator (g) real power output [7].

Mathematically,

$$GSF_g = (\Delta P_{ij} / \Delta P_{Gg}) \quad (3)$$

$$GSF_g = \frac{\partial P_{ij}}{\partial \delta_i} \cdot \frac{\partial \delta_i}{\partial P_{G_g}} + \frac{\partial P_{ij}}{\partial \delta_j} \cdot \frac{\partial \delta_j}{\partial P_{G_g}} \quad (4)$$

The detail derivations for GSF are discussed in [7].

Power transfer distribution factor (PTDF) for a line m describes as change in real power flow in a line m joined between bus *i* and bus *j* to the change in n^{th} bus real power [5]. Mathematically,

$$PTDF_n^k = \frac{\Delta P_{ij}}{\Delta P_n} \quad (5)$$

$$PTDF_n^k = a_{ij} m_{in} + b_{ij} m_{jn} \quad (6)$$

Where

$$a_{ij} = V_i V_j Y_{ij} \sin(\theta_{ij} + \delta_j - \delta_i) \quad (7)$$

$$b_{ij} = -V_i V_j Y_{ij} \sin(\theta_{ij} + \delta_j - \delta_i) \quad (8)$$

The detail derivations for PTDF are discussed in [5].

Optimal Generators for rescheduling are selected based on non-uniform flow of sensitivity indexes whereas optimal location of DG units are selected based on PTDF values.

IV. Problem Formulation

The total congestion cost

$$Minimize\left(\sum_{g=1}^{N_g} C_g(\Delta P_g)\Delta P_g\right) + C_{dg}P_{dg} \quad (9)$$

Subject to:

$$\sum_{g=1}^{N_g}((GSF_g)\Delta P_g) + L_m^0 \le L_m^{max} \qquad m = 1, 2, ...n_1 \quad (10)$$

$$P_g - P_g^{min} = \Delta P_g^{min} \le \Delta P_g \le \Delta P_g^{max} = P_g^{max} - P_g \qquad g = 1, 2, ...N_g \quad (11)$$

$$P_g^{\min} \le P_g + \Delta P_g \le \Delta P_g^{\max} \quad g = 1, 2, ... N_g \tag{12}$$

$$P_{dg}^{\min} \le P_{dg} \le P_{dg}^{\max} \tag{13}$$

$$V_i^{\min} \le V_i \le V_i^{\max} \tag{14}$$

$$\sum_{g=1}^{N_g} \Delta P_g = 0 \tag{15}$$

Where,

Cg: incremental/decremented price bids of generator-*g* participating in congestion management.

C_{dg}: incremental/decremented price bids of DG units.

ΔP_g: g^{th} generator real power adjustment.

P_g^{min} & P_g^{max}: Minimum and maximum limit of g^{th} generator.

ΔP_g^{min}, ΔP_g^{max} : Minimum and maximum adjustable limits of g^{th} generator .

L_m^0: Actual power flow in transmission line m.

L_m^{max}: Maximum power flow limit of m^{th} transmission line connected between bus-*i* and bus-*j*.

V. Results And Discussions

The present work is tested on IEEE 39 bus New England Test System which consists of 10 generator buses and 29 load buses. The network topology (in figure 2) and test data for IEEE 39 bus system can be found on [17].

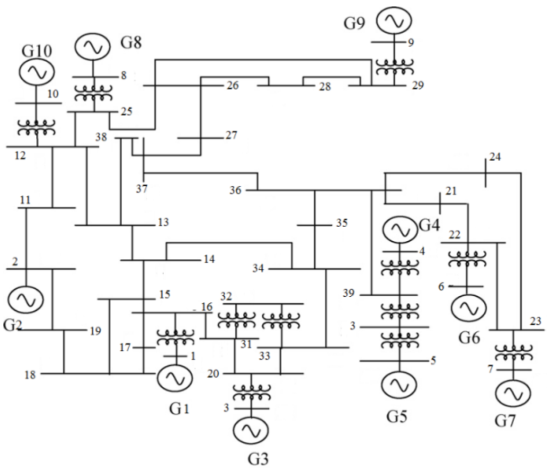

Fig 2. IEEE-39 bus New England Test System

In this work, Firefly algorithm (FA) has been applied to minimize the congestion cost. Rescheduling of generators is done by firefly algorithm with the presence of DG in the system. Considering line 14-34 outage, which results in thermal limit violation on line 15-16, hence line 15-16 is known to be congested. By considering the outage of line 14-34, PTDF values are calculated. The most sensitive PTDF value is chosen to install the DG units in that sensitive bus.

Table I. Ptdf Values For Selected Buses

Bus No	PTDF for selected buses
1	0
8	-0.0198
9	0.0289
10	-0.0401
12	-0.0404
14	-0.2551
16	-0.0049
19	-0.0328
25	-0.0216
27	0.0487
34	0.4188
38	0.0206

Among these all buses, bus no 14 shows most negative value of PTDF. Hence bus no 14 is chosen for DG installation point. This work considers line 15-16 as congested line due to the outage of line 14-34. Values of generator sensitivity factor (GSF) have been given in figure 3 with respect to congested line 15-16.

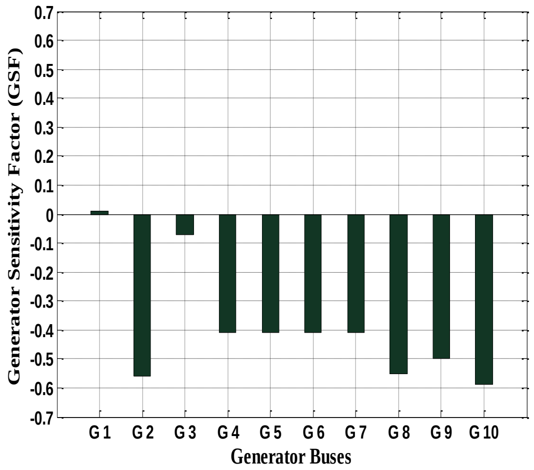

Fig. 3. Generator Sensitivity Factor for 39 Bus New England Test System

It is observed from the load flow study that power flow through congested line (L 15-16) is 627 MVA at base case solution. Considering the power flow of L 15-16, GSF values are determined. From figure 3, it is observed that generators No. 4, 5, 6, 7 have uniform flow of sensitivity indices whereas generators no. 2, 3, 8, 9 and 10 have non-uniform flow of sensitivity values. So these generators (having non uniform sensitivity values) are rescheduled to minimize transmission cost considering the presence of DGs in the system.

Table II. Generator Rescheduling Using Fa

Gen No.	Amount of Rescheduling (MW)		
	Result Reported in [4]	Result Reported in [7]	Considering DG Units using FA (Proposed Work)
1	-99.59	-149.1	-122.52
2	98.75	65.6	49.0
3	-159.64	-129	-1.0
4	12.34	Not Participated	Not Participated
5	24.69	Not Participated	Not Participated
6	24.69	Not Participated	Not Participated
7	12.34	Not Participated	Not Participated
8	24.69	75.4	75.0
9	12.34	52.1	-111.0
10	49.38	83.0	-15.0
Net Amount (MW)	518.45	554.2	373.52

Table 2 describes the effectiveness of proposed work in terms of total power rescheduling by the selective generators considering DG units in the system. Here, only five generators are rescheduled which shows minimum rescheduled amount compared with other reported results. Slack bus generator is rescheduled at the end of optimization process to minimize system overall losses.

Table III. Some Parmeters Before and After Rescheduling

System Parameters	Before Rescheduling	After Rescheduling		
		Result Reported in [4]	Result Reported in [7]	Proposed Work
Ploss (MW)	59.9	58.0	57.31	52.28
Vmin (p.u.)	0.934	0.932	0.945	0.9405

Table 3 describes the effectiveness of proposed work by considering DG in the system. Prior to rescheduling, the total active power loss and system minimum voltage is 59.9 MW and 0.934 p.u.

Table IV. Rescheduling Cost and Optimal Size of Dg Units

	Result Reported in [6]	Proposed method with DG Units
Rescheduling Cost ($/MW-Day)	92.817	49.5645
Optimal DG Size (p.u.)	2.2195 p.u.	

These system parameters are improved significantly after rescheduling process. Result of proposed work is compared with other reported results. It is observed that proposed work shows improvement in real power loss and system minimum voltage.

Table 4 shows the optimal size of DG which achieves after solving the optimization process using FA. The optimal size of DG for proposed work is 2.2195 p.u. Moreover, table 4 indicates the rescheduling cost which is very less as compared with reported result in [6].

Table V. Condition of Critical Lines Pre and Post Rescheduling

Lines / Transfor--mers Connected between Buses	Line No.	Actual Flow (MVA)			Line Flow limit (MVA)
		Before Rescheduling	Result reported in [6]	After Rescheduling Considering DG using FA	
L_{39-5}	36	519.10	518.6	506.08	1200
L_{22-6}	43	683.63	682.50	650.0	1200
L_{23-7}	42	575.51	575.21	558.39	1100
L_{25-8}	41	539.46	611.54	613.74	1100
L_{29-9}	40	825.85	873.73	715.72	1100
L_{12-13}	32	431.99	538.53	383.81	600
L_{13-14}	30	250.68	323.11	129.32	600
L_{15-16}	26	628.60	495.23	449.14	500
L_{21-22}	17	614.72	614.21	594.44	1200

Table 5 shows the power flow through congested line and some other critical lines pre and post rescheduling process. It is noted that presence of DG units improves power flow significantly through all the critical lines. Congested line power flow even also less than the result reported in [6]. Congested line power flow before rescheduling is 628.60 MVA which reduces drastically i.e. 449.14 MVA using proposed method.

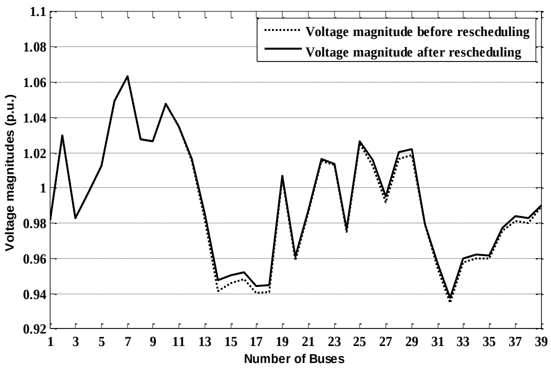

Fig. 4. Voltage Variations of All The Buses

Figure 4 shows the voltage variation of all generator and load buses before and after rescheduling. It is clearly observed that minimum voltage magnitude improves using the proposed method. Post rescheduling considering DG units in the system shows better voltage profile than the congested system.

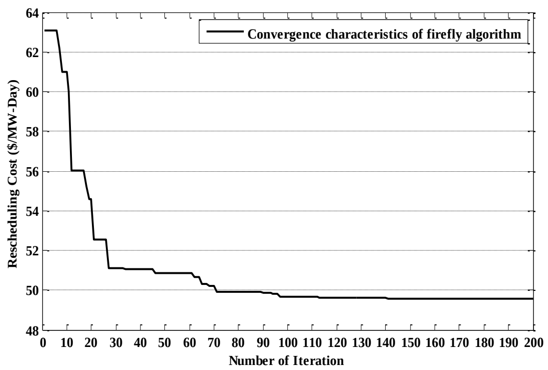

Fig. 5. Convergence Characteristic of Firefly Algorithm

Figure 5 represent the convergence characteristics of objective function using firefly algorithm. The cost of objective function reduces as number of iteration increases. The optimal congestion cost is 49.5645 $/MW-Day.

VI. CONCLUSIONS

The proposed work considers DG units of larger size in the transmission system to avoid the transmission congestion and minimize the congestion cost. The generator rescheduling method is also adopted in this proposed work. The optimal size of DG is found during optimization process by exploring FA. FA is one of the newly developed metaheuristic algorithm which is used to solve the objective function. Proposed work also shows the drastic reduction of real power loss and significant improvement in minimum voltage which results in better stable system.

VII. REFERENCES

[1] Mohammad Shahidehpour, M. Alomoush, “Restructured Electric Power System”, Marcel Dekkar, 2001.

[2] K. Bhattacharya, M.H.J. Bollen, & J.E. Daalder, Operation of Restructured Power Systems (Kluwer Academic Publishers, 2001).

[3] Fang RS, David AK. “Transmission congestion management in an electricity market”., IEEE Trans Power Syst 1999;14(3):877–83.

[4] G. Yesuratnam and D. Thukaram, “Congestion management in open access based on relative electrical distances using voltage stability criteria,” Elect. Power Syst. Res., vol. 77, pp. 1608–1618, 2007.

[5] A. Kumar, S. C. Srivastava, and S. N. Singh, “A zonal congestion management approach using real and reactive power rescheduling,,” IEEE Trans. Power Syst., vol. 19, no. 1, pp. 554–562, Feb. 2004

[6] Subhasish Deb.; Arup Kumar Goswami., ”Mitigation of congestion by generator rescheduling Using Particle Swarm optimization”, Power and Energy in NERIST (ICPEN), 2012 pp: 1 – 6, 28-29 Dec 2012

[7] S. Dutta, S.P. Singh, “Optimal rescheduling of generators for congestion management based on particle swarm optimization”, IEEE Transactions on Power Systems 23 (4) (2008) pp. 1560–1569.

[8] A Kumar, Charan Sekhar, “Comparison of Sen Transformer and UPFC for congestion management in hybrid electricity market”, International jurnal of eletrical power & energy systems, 2013(47), 295-304.

[9] Ashwani Kumar , Charan Sekhar , Congestion management with FACTS devices in deregulated electricity markets ensuring loadability limit, International journal of Electrical Power and Energy Systems 46 (2013) pp. 258–273.

[10] Masoud Esmaili,Heidar Ali Shayanfar,”Locating series FACTS devices for multi objective congestion management improving voltage and transient stability”, European journal of operational research, 236(2014) 763-773.

[11] Kanwardeep Singh, N P Padhy, J Sharma, “Congestion Management considering hydro-thermal combined operation in a pool based electricity market”, International jurnal of eletrical power & energy systems, 2011(33), 1513-1519.

[12] A.K. Singh, S.K. Parida,”Congestion management with distributed generation and its impact on electricity market”, International jurnal of eletrical power & energy systems, 48(2013), 39-47.

[13] Kanwardeep Singh, V K Yadav, N P Padhy, J Sharma., ”Congestion management considering optimal placement of distributed generator in deregulated power system networks”, Electric Power Components and Systems, 2014 , Vol:42, Issue:1, pp: 13-22.

[14] M.A Paqaleh, A.A Tehrani Fard, M. Rashidinejad., ”Distributed generation placement for congestion management considering economic and financial issues”, Electrical Engineering, 2010,Vol:92, pp: 193-201.

[15] Xin-She-Yang, Seyyed Soheil Sadat Hosseini, Amir Hossein Gandomi,”Firefly Algorithm for solving non-convex economic dispatch problem with valve loading effect”, Applied soft computing 12(2012), 1180-1186.

[16] Xin-She-Yang, “Multiobjective firefly algorithm for continuous optimization”, engineering with computers 2013(29), 175-184.

[17] K. R. Padiyar, Power System Dynamics: Stability and Control. NewYork: Wiley, 1996, p. 601.