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Optimal Rescheduling Of Generators For Relieving Transmission Congestion Based On Appso

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***Abstract*: One of the major operating challenges in the deregulated electric power industry is the Transmission Congestion. Congestion occurs when there is an insufficient transmission capacity to simultaneously accommodate all requests for transmission service within a region. To relieve this Congestion we use rescheduling of the generator active power outputs. But all the generators may not be taking part in this process. Participating generators are optimally selected based on the generator sensitivity factor. In the literature, Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) is used for minimizing rescheduling cost of the generators, where as in the proposed method Anti Predatory Particle Swarm Optimization technique (APPSO) is used for minimizing rescheduling cost of the generators. The proposed method was developed on IEEE standard 30 bus and 57 bus test systems in MATLAB software environment.**

***Keywords:* Genetic Algorithm, Congestion Management (CM), Transmission System Overload, Anti Predatory Particle Swarm Optimization, Generator Sensitivity Factor**

I. INTRODUCTION

The privatization of electricity markets has a very large impact on almost all power systems around the world. Competitive electricity markets are complex systems with many participants who buy and sell electricity. In view of system/market operator's system security plays a vital role in competitive market. Due to the increased number of participants in the deregulated electricity industry, number of transactions in the system will be more. All these transactions depend on the transmission system in the form of transmission. The utilities had control over the generation and transmission system in the conventional electricity market. But the current transmission system was designed in the olden days and it was not planned for the restructured power system. This causes congestion in the transmission system. Due to the increased demand the utilities are increasing the generation in order to meet the demand. Due to thermal, stability and voltage limits of the transmission lines, congestion will be occur when such limits exceeded. One of the most important and critical tasks of the independent system operator is manage congestion. Hence, congestion management is a process to relieve congestion in the transmission line by suitable techniques.

In literature, congestion management can be done by load curtailment [1]. In this process customer has been not satisfied. CM can be done by FACTS devices and this technique associated with more cost [2]. CM can be done by rescheduling of the generators output powers [3]. In this method all the generators may not be participating and generator sensitivity is used for participation of the generators optimally [4]. In power system, PSO algorithm applied in several optimization problems [3] and it also solves economic dispatch of generators in a power system [5].

This paper investigates Anti Predatory Particle Swarm Optimization technique to reduce the rescheduling cost and to avoid congestion in the transmission lines. This paper also investigates the comparison between GA, PSO and APPSO techniques for minimizing the rescheduling cost and APPSO technique was implemented on IEEE 30 and IEEE 57 bus systems.

Congestion Management with real power constraints discussed in section-II. Anti Predatory Particle Swarm Optimization discussed in section-III. Mathematical modeling and flowchart of Anti Predatory Particle Swarm Optimization was discussed in section-III. IEEE 30 bus and IEEE 57 bus system was discussed as case study in section-IV. In section-V results was discussed. Conclusion was discussed in section-VI.

II. CONGESTION MANAGEMENT WITH REAL POWER CONSTRAINTS

Here, participation of generators is based on Generator Sensitivity Factor [3]. Mathematically, Generator Sensitivity for line n can be expressed as

$$GS_G = \frac{\Delta P_{jk}}{\Delta PG_G} \qquad \dots (1)$$

Where,

P_{jk} is the real power flow on congested line-n

PG_G is the real power generated by the G_{th} generator

Required amount of real power for rescheduling based on the bids received from the participating generators is evaluated by solving the Optimization problem is as follows:

Minimize $\sum_{GE=1}^{NG} C_{GE}\ (\Delta P_{GE})\ \Delta P_{GE}$ ... (2)

Subjected to:

$\sum_{GE=1}^{NG} GS_{GE} \Delta P_{GE} + F_l^0 \leq F_l^{max}$ ... (3)

Where l=1, 2……L

$P_{GE} - P_{GE}^{min} = \Delta P_{GE}^{min} \leq \Delta P_{GE} \leq \Delta P_{GE}^{max} = P_{GE}^{max} - P_{GE}$ ... (4)

Where GE=1, 2 ….NG

$\sum_{GE}^{NG} \Delta P_{GE} = 0$ ... (5)

C_{GE} = Incremental and decremental cost of Generator GE.

ΔP_{GE} = Active power adjustment at bus GE.

ΔP_{GE}^{min} = Minimum adjustment limit of generator GE.

ΔP_{GE}^{max} = Maximum adjustment limit of generator GE.

P_{GE} = Active power output

P_{GE}^{min} = Minimum generation limit of generator GE.

P_{GE}^{max} = Maximum generation limit of generator GE.

F_l^0 =Power flow caused by all contracts requesting the transmission service.

F_l^{max} = Power flow limit of line l.

III. ANTI PREDATORY PARTICLE SWARM OPTIMIZATION

The Anti Predatory Particle Swarm Optimization is used for minimizing the rescheduling cost of generators. APPSO is derived from the PSO but some extra components will be added to it. PSO contains only one component is called good experience component. In APPSO bad experience component will be included with the good experience component. By using bad experience component the particle can always try to occupy a better position and bypassing its previous worst position. Each particle is evaluated based on fitness of the particle and selection operation of local best (Pi), global best (GB), local worst (PW) and global worst (GW) is used to meet the constraints.

The new particle updates its velocity and positions with following equations [6] are

$$V_{ij}^{r+1} = W^r V_{ij}^r + C_1 R_1 (Pb_{ij}^r - P_{ij}^r) + C_2 R_2 (P_{ij}^r - Pw_{ij}^r) + C_3 R_3 (Gb_j^r - P_{ij}^{r-1}) + C_4 R_4 (P_{ij}^r - Gw_{ij}^r) \quad ...(6)$$

$$P_{ij}^{r+1} = P_{ij}^r + V_{ij}^{r+1} \quad ...(7)$$

In the PSO algorithm [3] only local best and global best are considered. Where as in APPSO algorithm, local worst and global worst are incorporated along with local best and global best to occupy a better position and bypassing its previous worst position.

The APPSO flow chart is as follows:

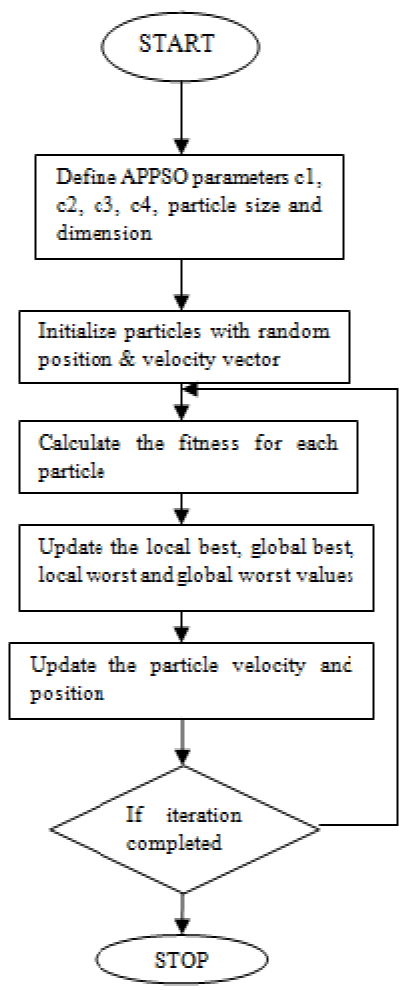

Fig 1: Flow chart for APPSO

IV. CASE STUDY

The proposed APPSO technique is to relieve congestion and reduce rescheduling cost was implemented using MATLAB programming software. The performance of the algorithm has been studied on IEEE 30 bus & IEEE 57 bus test systems.

A.The Ieee 30 Bus System

The usefulness of this proposed algorithm explained by considering the IEEE 30 bus system. This system consists of 6 generators, 30 buses, 37lines, 4 transformers and 21 loads. Total real and reactive power of load is 283.40 MW and 127.0706 MVAR respectively. The upper and lower limits of reactive power generation are taken to be 100MVAR and -30 MVAR respectively. Bus data, line data and incremental and decremental price bids are taken from the references [7]. Load bus voltages are maintained to be between 0.8 and 1.2 per unit. Fig.2 shows single line diagram of the IEEE 30 bus system.

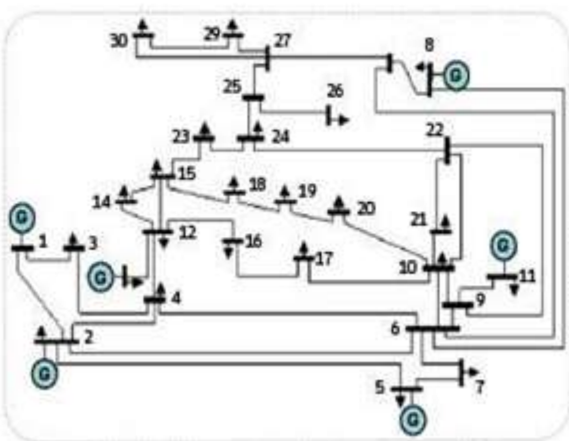

Fig 2: single line diagram of IEEE 30 bus system

B. Ieee-57 bus system

The proposed algorithm is tested using the IEEE 57 bus system, which has 7 generators, 57 buses, 63 lines, 17 transformers and 42 loads Total real and reactive power of load is 1250.8 MW and 312.1744 MVAR respectively. The upper and lower limit of reactive power generation is taken to be 100MVAR and -30 MVAR respectively. Bus data, line data and incremental and decremental price bids are given in references. Load bus voltages are maintained to be between 0.8 and 1.2 per unit. Fig.3 shows single line diagram of the IEEE 57 bus system.

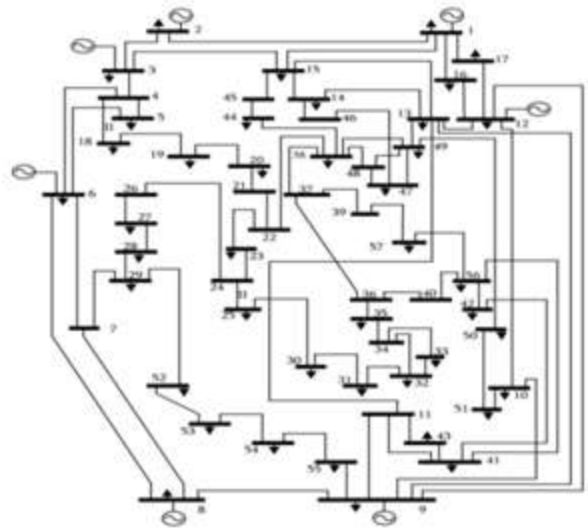

Fig 3: single line diagram of IEEE 57 bus system

V. RESULTS

C.IEEE-30 bus system:

In IEEE 30 bus system the analysis of Congestion management can be done by considering the simulated test case shown in Table-I. Congestion occurs in line 1-2 due to the outage in line 1-3.

The amount of congestion can be finding out by conducting Newton Raphson Power flow analysis for IEEE 30 bus system. In this case line 1-2 power flow limit is 100 MW and present power flow is 141.31 MW then overload is 41.31 MW. But secure system line flow must be within limits should not exceed the line flow limits. Then the appropriate corrective actions are to be done for relieve the congestion. So, by using Anti Predatory Particle swarm optimization algorithm the optimal power rescheduling is done to manage Congestion.

TABLE I

Simulated test case-IEEE 30 bus system

Type	**Congested line**	**Line flow**	**Total power violation**
Outage of line 1-3	1-2	141.31 MW	41.31 MW

D.Parameter selection of appso:

In the APPSO algorithm the generator outputs are taken as members of the particles. The generator outputs are generated randomly within limits and satisfy the congestion management constraints. By using members of the particle find out the fitness of the particles. If the solution is not feasible then the corresponding particle is regenerated. This is repeated for all the particles in the every iteration. The performance of the APPSO depends on the parameters C1, C2, C3, C4 and weight factor W. These parameters affect the rescheduling cost. Hence, the different values for parameters are selected based on minimum fitness value. Effect of variation in APPSO parameters is shown in below table II.

TABLE II
Effect of variation of APPSO parameters

S. no	W max	W min	C1	C2	C3	C4	Cost of rescheduling ($/hour)
1	0.8	0.5	2	2	2	2	1489.00
2	0.9	0.2	1.4	1.4	2	2	1478.80
3	0.5	0.4	1	1	2	2	1487.00
4	0.9	0.4	2	1.5	2	2	1478.30
5	0.8	0.4	1.5	1.5	2	2	1487.80
6	0.9	0.4	2	2	2	2	1486.00

The effect of variation of total cost by variation in particle size is given in table III.

TABLE III
Effect of variation of particle size

SI.NO	Particle size	Cost of rescheduling ($/hour)
1	10	1500.90
2	20	1508.10
3	30	1480.20
4	40	1479.40
5	50	1488.60
6	60	1481.90
7	70	1480.80
8	80	1478.30
9	90	1481.10
10	100	1481.60

From the analysis of the above studies the parameters set for the APPSO algorithm is W max=0.9, W min=0.4, C1=2, C2=2, c3=2 and c4=2 and the particle size is selected as 80. Generator outputs before and after rescheduling is given in Table IV.

TABLE IV
Comparison of generator outputs

Generator No.	Initial power output (MW)	Power output after rescheduling (MW)	Amount of power rescheduled (MW)
1	138.582	93.272	-45.310
2	57.56	80.00	22.440
5	24.56	34.12	9.560
8	35.00	35.0032	0.0032
11	17.93	23.86	5.930
13	16.91	23.820	6.910

Power flow in the congested line is obtained after performing rescheduling is to be 91.955MW where as the limit is 100MW and the total cost for congestion management is found to be 1478.30$/hour. APPSO convergence characteristics are shown in the Fig 4.

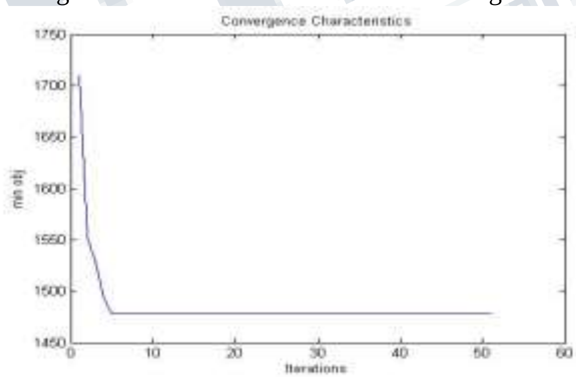

Fig 4: Convergence characteristics of APPSO for IEEE 30 bus system

The generators have the different sensitivity factors to the power flow on the congested line. Then the participation of generators selected based on the generator sensitivity factor. The system operator selects the generators having large magnitudes of sensitivity values as the ones most sensitive to the power flow on the congested line and to participate in congestion management by rescheduling their active power outputs. Table V shows generator sensitivity factors for IEEE 30 bus system.

TABLE V
Generator sensitivity factors for IEEE 30 bus system

Generator	1	2	5	8	11	13
Generator sensitivity	0	-.8833	-.8615	-.7705	-.7498	-.7107

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E.IEEE-57 bus system:

In the IEEE 57 bus system the analysis of Congestion management can be done by considering the simulated test case shown in Table-V1. From this Table VI Congestion occurred in the line 1-15 due to outage of line 2-3.

The amount of congestion can be finding out by conducting Newton Raphson Power flow analysis for IEEE 57 bus system. In this case line 1-15 power flow limit is 200 MW and present power flow is 239.45 MW then overload is 39.45 MW. For the relieving above congestion APPSO algorithm is used. For this particular line overload the generator sensitivity factors are given in table VII.

TABLE VI

Simulated test case for IEEE57 bus system

Type	**Congested line**	**Line flow**	**Total power violation**
Outage of line 2-3	1-15	239.455 MW	39.455MW

TABLE VII
Generator sensitivity factor for 57 bus systems

Generator Index	Generator Sensitivity
1	0
2	-0.0834
3	-0.3721
6	-0.3815
8	-0.3655
9	-0.3732
12	-0.368

When all the generators are selected for congestion management total cost of congestion management is found to be 11483.4 $/hour where as when only 6 generators are selected for generation rescheduling the total congestion management cost is found to be 9796.5$/hour. The generators selected are 3,6,8,9 and 12.

The APPSO convergence characteristics are shown in Fig.5 and Fig.6 Also the comparison of the generator rescheduling with and without considering the generator sensitivity factors are given in the table VIII.

TABLE VIII
Comparison of the generator rescheduling with and without considering the generator sensitivity factors

Gen.no	**Initial generation (MW)**	**Final generation-7 generators participating (MW)**	**Final generation-6 generators participating (MW)**
1	492.317	216.325	314.4029
2	30	60	30
3	0	8.521	23.8067
6	40	80	80
8	420	461.2851	418.6784
9	0	14.0064	13.4340
12	310	410	410

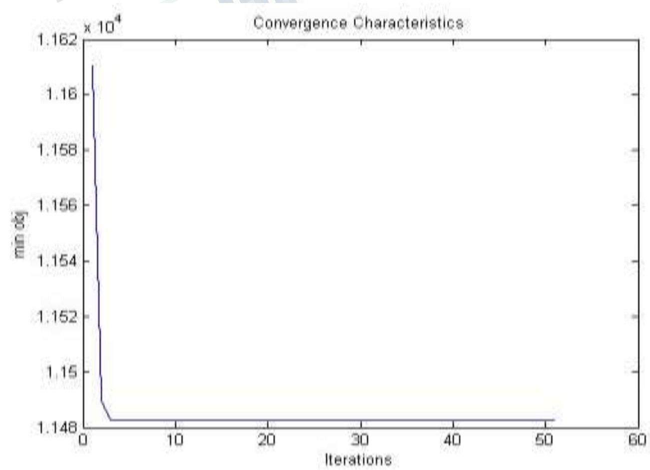

Fig 5: Convergence characteristics of IEEE 57 bus system with all generators participating in congestion management

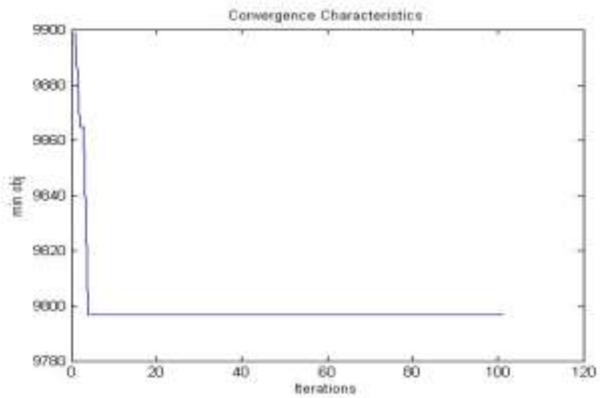

Fig 6: Convergence characteristics of IEEE 57 bus system where only 6 generators are participating

From the results it is clear that Congestion is relieved by generator scheduling using APPSO for both IEEE 30 and IEEE 57 bus systems.

TABLE-IX: Comparison GA, PSO and APPSO techniques

Total congestion management cost	GA	PSO	APPSO
IEEE 30 bus system	1633.7$/hour	1519.20$/hour	1478.30$/hour
IEEE 57 bus system without GS	11847$/hour	11562$/hour	11483.4$/hour
IEEE 57 bus system with GS	10237$/hour	9934.4$/hour	9796.5$/hour

Table IX shows the generator rescheduling cost to relieve Congestion by using GA, PSO and APPSO.

VI. CONCLUSION

Based on the result, Anti Predatory Particle Swarm Optimization is better approach for Congestion Management when compare to the Genetic algorithm & Particle Swarm Optimization.

It is also proved that APPSO technique is effectively minimizing the rescheduling cost of the generators when compare to Genetic algorithm & Particle Swarm Optimization on IEEE 30 and IEEE 57 bus systems.

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