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A Novel Approach for Economic power Dispatch of power producer Using Autonomous group of Particle Swarm Optimization

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Abstract: *In Modern power system Economic power dispatch is useful tool for optimal operation and planning. EDP problem need to solve effectively, conventional methods have the assumption on fuel cost characteristic of a generating unit is a continuous and convex function, resulting fairly satisfied. This proposed work to the design and application of efficient gray wolf optimization algorithm for the solution of the EPD problem. Here the non-convex characteristics of the generator along with ramp rate limits of the practical generator operation are taken for simulation. By using power system Analysis toolbox the power flow carried out for bench test system with six generating units having ramp rate was taken for simulation in Matlab environment. The proposed method is to solve the EPD by using Autonomous Group of Particle Swarm Optimization(AGPSO) and the result obtain are compared with Fitness distance ratio Particle swarm optimization (FDRPSO), the proposed method for optimization for non-convex Economic power dispatch is upshot excellence, reliability and calculation rapidity.*

Keywords: *Economic power dispatch, power flow, ramp rate limits, Fitness Distance Ratio Particle Swarm Optimization, Autonomous Group of Particle Swarm Optimization.*

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I. Introduction

The conventional EDP problem involves a location of different thermal generating units to minimize the operating cost subject to equality and inequality constraints and makes the EDP problem[1] a large scale highly non linear constrained optimization problem such as linear programming, quadratic programming[2], Dynamic programming[3], Newton-based and Interior point methods[4]. All these methods are made as assumption that the fuel cost characteristics of a generating unit is a smooth, convex function. For example, this situation originate when valve-points loading, Ramp limits are present these situation are represent the unit's fuel cost characteristics as a convex function. So, for the accurate global optimum of the problem could not be reach simply. Novel mathematical methods are needed to survive with these complications especially those with high pace search to the optimal and not being fascinated in local minima.

In Morden existence, the Genetic Algorithm [5], Particle swarm optimization [6] (PSO) the population of particle exists in the n-dimensional search space. All particles have firm quantity of knowledge and strength shift about the search space on the basic of this knowledge. The particle has a quantity of inertia attributed to it and thus force continues to have a part of motion in the direction to its moving. The particle knows its position in the search space and will run into with the best solution. The particle will then adjust its path such that it has further part towards its own best position pbest and towards the on the whole best position gbest. The particle can able to update its velocity and position.he introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

In this proposed work, Autonomous Group of Particle swarm optimization (AGPSO) technique [7] is presented and used to solve the EDP, non-continuous, non-convex, non-linear cost function. An application was performed on the 26bus benchmark test system with 6 generating units having ramp rate limits. The result obtained through Autonomous group is compared with FDRPSO [8] and it confirms the efficacy of likely any one Autonomous group upshot excellence and calculation rapidity.

II. Problem Formations

Mathematically optimization of fuel cost of each power producers in the system has been formulated based on power flow problem with line flow constraints and the overall generation cost of power system is expressed as following form:

$$\text{Minimize } F(G) = \sum_{j=1}^{ng} (f_j \ (p_j \ )) \quad (1)$$

Where F(G) is the operating fuel cost of jth power producer and ng is the number of power producers in the given power system network. The fuel cost function of a jth power producer is written as:

$$f_j(p_j) = a_j + b_j \ P_j + c_j \ P_j^2 \qquad \$/h \quad (2)$$

Where pj is active power output of an jth power producer, fj(pj) is the fuel cost of jth power producer and a*j*, b *j* , c*j* are the fuel cost co-efficient of the jth power producer. Power balance constraint is net power generated by the power producers which includes system load demand as well as losses in transmission network.

$$\sum_{j=1}^{ng} p_j - p_l - \ p_d \ = 0 \quad (3)$$

Equation (3), is denotes the constraint of power balance equation for EPD, Where pd is the total load of the system and pl is transmission losses in the system. The output level of the power producer which expressed as:

$$p_{L=} \ \sum_{j=1}^{ng} \sum_{k=1}^{ng} B_{jk} \ p_k \ p_k + \sum_{j=1}^{ng} p_j \ B_{j0} \ B_{00} \quad (4)$$

Equation (5), denotes the Kron’s loss formula which approximated the losses as a function of the system output level. Where $1 \leq j$ and $k \leq ng$ are power producers indexes and Bjk, Bj0, B00 are co-efficient of losses (or) B loss co- efficient. Bjk is (ng x ng) matrix. The inequality constraint on real power generation Pj of each power producer j is given by:

$$p_{jmin} \ \leq \ p_j \ \leq p_{jmax} \quad (5)$$

Ramp Rate limits is an inequality constraint of the power producer and it can be either increases (or) decreases the power generation. The on-line units have operating ranges which are restricted by their elastic limits or Ramp Rate limits. When the power producers operate within the elastic limits. Power producers are permitted to widen their limits, the life of the rotor will be getting fatigue. These inequality constraints of Ramp Rate limits are expressed as:

$$p_{j0} - p_j \ \leq D_{rj} \quad (7)$$

$$p_j - p_{j0} \ \leq U_{rj} \quad (6)$$

Equation (6 & 7), denote the increase in power generation and decrease in power generation due to Ramp Rate limit Urj and Drj are Ramp up Rate and Ramp down Rate and pj0 is previous operating state of power producer. Combining (5,6&7) which give the following equation:

$$p_{jmin}^{'} \ = max \ (p_{jmin} \ , p_{j0} - D_{rj} \ ) \quad (8)$$

$$p_{jmax}^{'} \ = \ min \ (p_{jmax} \ , p_{j0} + U_{rj} \ ) \quad (9)$$

$$MVAf_{p,q} \leq MVAf_{p,q}^{max} \quad (10)$$

Where MVAf is the maximum rating of transmission line connecting p and q.

III. Autonomous Group Of Particle Swarm Optimization

Particle swarm optimization deals with the fine tuning of the weighing factor c1 and c2, by balancing these weighting factor the global minima is found along with the fast convergence speed is also achieved. Here the researchers propose the Autonomous Group Particle Swarm Optimization concept as per modification of the existing PSO technique. In this search space of AGPSO, according to its own strategy is related to the tuning of c1 and c2, these autonomous groups contains linear, constant, and exponential of time varying parameters of c1 and c2. AGPSO concept is inspired by individual in its group of particle. Individual in a group of particle is not quite same as in their ability and intelligence. Each individual do their duties as a member of workgroup. In some particular situation the ability of individual is very useful to perform their objective. Consider a termite colony that consist of four various termites such as worker, queen, babysitter and solider having various ability to battle with enemies.

The diverse ability of an individual in a workgroup is very important for survival from their enemies. These four termites are considered as four autonomous groups, all termites work together with common objective of their colonys' survival. By using their divergence ability of an individual in an autonomous group with common objective in any population based optimization algorithm hypothetically provides result in additional randomized and direct search concurrently.

The mathematical model of Autonomous group PSO are using the various strategies of updating c1 and c2, strategies updated by implementing with continuous function with the interval. Those functions may be either ascending or descending linear and polynomial, as well as logarithmic nature and which are used to update the social factor and cognitive. The modified Autonomous group includes AGPSO1, AGPSO2 and AGPSO3, SPSO[9], IPSO[10], MPSO[11] and TACPSO[12].

The dynamic co-efficient of these modified autonomous group are given in Table 1a, Table 1b and Table 1c. Here the maximum number of iteration is represented as 'T' and the current iteration is represented as 't '. AGPSO updating strategies contains the logarithmic and exponential functions for c1 and c2 which are made effective on the performance of the PSO. These divergent functions are chosen with various curvatures, slopes and intersecting point to examine the effectiveness of these characteristics and to improve the performance of particle swarm optimization. AGPSO could be more efficient and better adaptable than the general PSO in solving a wide range of complex optimization problem. AGPSO is compared with some modified PSO, the Time varying accelerator are recent modified particle swarm optimization such as SPSO, MPSO, IPSO, TACPSO and their c1 and c2 co-efficient are given in Table 2.

Group	**Updating strategies of various AGPSO1**	
	c1	**c1**
G1	$(-2.05/T)^t + 2.55$	$(1/T)^t + 1.25$
G2	$(-2.05/T)^t + 2.55$	$(2t^3/T) + 0.5$
G3	$(-2t^3/T^3) + 2.5$	$(1/T)^t + 1.25$
G4	$(-2t^3/T^3) + 2.5$	$(2t^3/T^3) + 0.5$

Table 1a. updating strategies of AGPSO 1

Group	**Updating strategies of various AGPSO2**	
	c_1	**c_1**
G1	$2.5-(2log(t)/log(T))$	$(2log(t)/log(T)) + 0.5$
G2	$(-2t^3/T^3) + 2.5$	$(2t^3/T^3) + 0.5$
G3	$0.5 + 2exp[-(4t/T)^2]$	$2.2-2exp[4t/T)^2]$
G4	$2.5 + 2(t/T)^2 -2(2t/T)$	$0.5-2(t/T)^2 + 2(2t/T)$

Table 1b. updating strategies of AGPSO2

Group	**Updating strategies of various AGPSO3**	
	c_1	**c_1**
G1	$1.95-2t^{1/3}/T^{1/3}$	$2t^{1/3}/T^{1/3} + 0.05$
G2	$(-2t^3/T^3) +2.5$	$(2t^3/T^3) +0.5$
G3	$1.95-2t^{1/3}/T^{1/3}$	$(2t^3/T^3) +0.5$
G4	$(-2t^3/T^3) +2.5$	$2t^{1/3}/T^{1/3} +0.05$

Table 1c. updating strategies of AGPSO3

Algorithms	Updating strategies of Modified PSO	
	c_1	c_1
SPSO	2	2
MPSO	$(-2.05/T)^t + 2.55$	$(1/T)t + 1.25$
IPSO	$2.5 + 2(t/T)^2 - 2(2t/T)$	$0.5 - 2(t/T)^2 + 2(2t/T)$
TACPSO	$0.5 + 2exp[-(4t/T)^2]$	$2.2 - 2exp[-(4t/T)^2]$

Table 2. Updating strategies of various Modified PSO

IV. Implementation Of AGPSO For Computation Of Ramping Cost For Power Generator

The operation of the generating unit is narrow with their power limits (real and reactive). But in real situation load commitments beyond their power limits for a given time duration contingencies are makes rotor fatigue. Even though reliability of power system operation is must need to take care and this operation is foreseeable therefore generating units are realistically compensated by the system operators. The change in state of their operation is also narrow by their RR limits. The RC are incurred with the operating fuel cost of the power producers Any violation regarding the elastic RR limits for maintaining the system protection.

The minimal generating cost of the power producers were obtained using in any one of the Autonomous Group algorithms along with transmission line constraints. The power flows were compute by using Newton Raphson. The simulation studies were carried out on Intel Pentium Duel Core, 2 GHz system in MATLAB environment. The usefulness of the proposed technique has been performed on the 26bus benchmark test system with 6 generating units having ramp rate limits. The power producer has operating power limits and operating power along with the RR limit to get new operating power limits and its fuel cost function shown below in Table 3. are taken from [13].

Gen no.	p_{jmin}	p_{jmax}	p_{j0}	Drj	Urj	P'_{jmin}	P'_{jmax}	a_j	b_j	c_j
Generator1	100	500	440	80	120	321	500	240	7	0.0070
Generator2	50	200	170	50	90	80	200	200	10	0.0095
Generator3	80	300	200	65	100	101	266	220	8.5	0.0090
Generator4	50	150	150	50	90	60	150	200	11	0.0090
Generator5	50	220	190	50	90	100	220	220	10.5	0.0085
Generator6	50	120	111	50	90	50	120	190	12	0.0075

Table 3. Power generation limits after adding Ramp Rate limits and its fuel cost

V. 26-Bus Benchmark Test System

The optimal generating cost of the power producers were obtained using AGPSO1, AGPSO2, AGPSO3, MPSO, SPSO, IPSO and TACPSO algorithm, when subjected with base load condition, multiple contingency and combined bilateral and multilateral wheeling transactions.

5.1 Base Load Condition

The power flow is carried out for the test system with the 100 base MVA, and the load demand 1263. B loss co- efficient (Boo) of test bus system from [13] is shown below in Table 4.With this base load the optimal generation cost is obtained through the AGPSO1, AGPSO2, AGPSO3, MPSO, SPSO, IPSO and TACPSO algorithms and its obtained individual fuel cost and optimum fuel cost values are compared with results from Anitha et.al [14] which are shown below in Table 5 and Table 6.

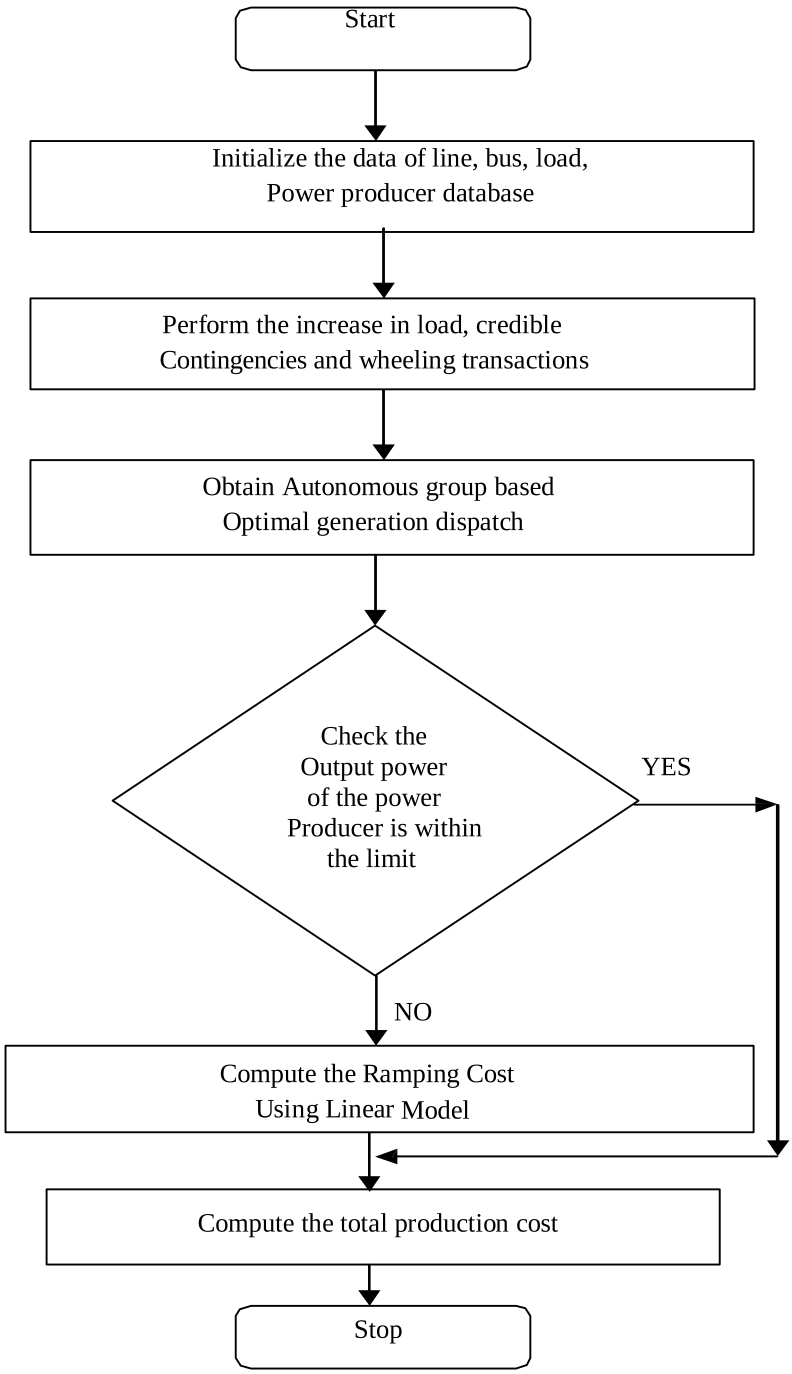

Fig 1. Flow chart of swarm intelligence and meta- heuristic optimization algorithms

B	0.0017 0.0012 0.0007 -0.0001 -0.0005 -0.0002 0.0012 0.0014 0.0009 0.0001 -0.0006 -0.0001 0.0007 0.0009 0.0031 0.0000 -0.0010 -0.0006 -0.0001 0.0001 0.0000 0.0024 -0.0006 -0.0008 -0.0005 -0.0006 -0.0010 -0.0006 0.0129 -0.0002 -0.0002 -0.0001 -0.0006 -0.0008 -0.0002 0.0150
B0	1.0e-003 * (-0.3908 -0.1297 0.7047 0.0591 0.2161 -0.6635)
B00	0.0056

Table 4. B loss co-efficient for 26 bus system base load

Autonomous Group	Gen-1	Gen-2	Gen-3	Gen-4	Gen-5	Gen-6
NR Method ($/H)	447.69	173.19	263.48	138.81	165.58	87.02
AGPSO1 ($/H)	443.81	172.22	266.01	128.46	169.30	83.14
AGPSO2 ($/H)	443.92	169.80	265.43	131.50	166.93	85.39
AGPSO3 ($/H)	453.10	162.72	264.93	122.98	171.76	87.48
MPSO ($/H)	443.92	169.80	265.43	131.50	166.93	85.39
SPSO ($/H)	441.27	175.11	260.51	125.41	173.89	86.79
IPSO ($/H)	441.39	191.38	256.10	140.01	164.36	69.74
TACPSO ($/H)	444.71	164.21	260.94	118.74	154.50	119.86
FDRPSO [14] ($/H)	418.68	183.46	254.89	143.36	200.98	61.60

Table 5. Comparison of individual generator cost during base load condition

During the initial iteration Autonomous group are finding the feasible solutions to the problem after that the value settles down to the best optimum value. From Fig.1, shows clearly that AGPSO algorithms find the best optimal value compared to the other optimization methods. From Table 6 and 7, it is obvious that, AGPSO gives the best optimal cost of generation for the test system under Base load condition. Parameter setting of th proposed algorithm having 20 numbers of Search agents with 5000 iteration. The converged characteristic of the AGPSO1, AGPSO2, AGPSO3, MPSO, SPSO, IPSO and TACPSO algorithm for the base load condition better than FDRPSO [14] are shown in the Fig 2.

Autonomous Group	Min Fuel cost F(G)	Base Load condition
NR Method ($/H)	15447.72	1263
AGPSO1 ($/H)	**15276.2616**	
AGPSO2 ($/H)	15276.6906	
AGPSO3 ($/H)	15277.1481	
MPSO ($/H)	15300.2521	
SPSO ($/H)	15276.5714	
IPSO ($/H)	15284.5165	
TACPSO ($/H)	15289.3174	
FDRPSO [14] ($/H)	**15296.94**	

Table 6. Comparison of overall fuel cost during base load condition

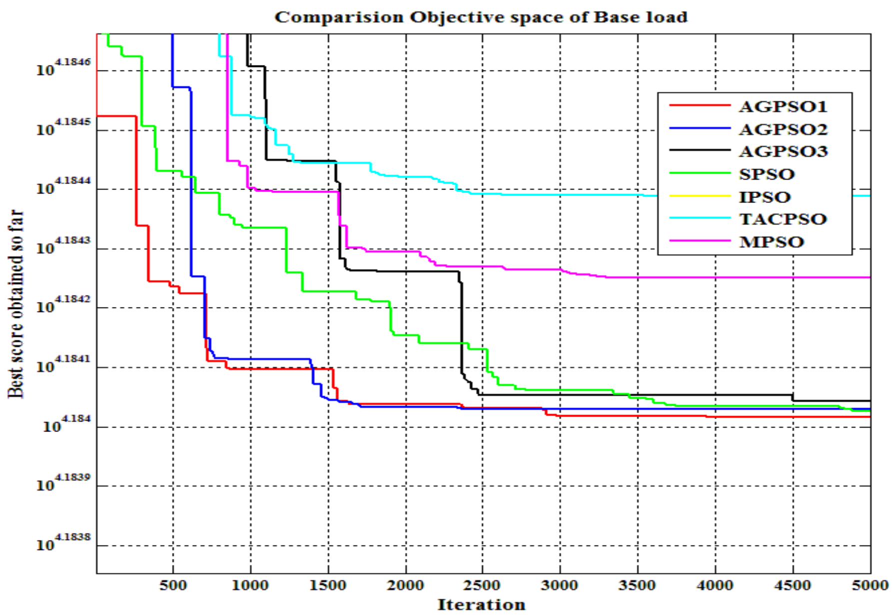

Fig 2. Converged characteristic in base load condition

5.2 Optimal Production Cost with Line Contingency with Increase in Load Condition

In this case, the optimal generation cost of the test system obtained through the AGPSO1, AGPSO2, AGPSO3, MPSO, SPSO, IPSO and TACPSO, when subjected to increase in load demand upto 1389.29MW is illustrated by making the transmission line contingency ie, single line outage, between the buses 20 and 21 . The B loss co-efficient (Boo) were calculated [15] which are given in the Table 7.

B	0.0017 0.0012 0.0007 -0.0001 -0.0005 -0.0001 0.0012 0.0014 0.0009 0.0001 -0.0006 -0.0001 0.0007 0.0009 0.0031 0.0000 -0.0011 -0.0006 -0.0001 0.0001 0.0000 0.0025 -0.0007 -0.0007 -0.0005 -0.0006 -0.0011 -0.0007 0.0118 -0.0001 -0.0001 -0.0001 -0.0006 -0.0007 -0.0001 0.0145
B0	1.0e-003 * (-0.3440 -0.1107 0.7326 0.0994 -0.0637 -0.4675)
B00	0.0056

T**able7**, B loss co-efficient during line contingency with increase in load condition

Autonomous Group	Gen-1	Gen-2	Gen-3	Gen-4	Gen-5	Gen-6
NR Method [$/H)	490.69	200	265	150	188.74	109.96
AGPSO1 ($/H)	472.75	199.90	266	150	193.14	107.49
AGPSO2 ($/H)	498.72	200	262.05	144.09	166.62	117.79
AGPSO3 ($/H)	465.54	200	265.99	150	205.87	101.
MPSO ($/H)	498.72	200	262.05	144.09	166.62	117.79
SPSO ($/H)	476.85	182.05	279.96	144.33	195.14	110.94
IPSO ($/H)	499.65	177.28	266	149.99	198.92	97.43
TACPSO ($/H)	493.75	164.38	266	125.47	220	119.67
FDRPSO [14] ($/H)	478.83	198.94	271.81	124.49	199.18	116.01

Table8, Comparison of individual generator cost during line contingency condition with increase in load condition

With this line contingency with increase in load condition the optimal generation cost is obtained through the AGPSO1, AGPSO2, AGPSO3, MPSO, SPSO, IPSO and TACPSO algorithms and its obtained individual fuel cost and optimum fuel cost values are compared which are shown below in Table 8 and 9, and it is obvious that, AGPSO gives the best optimal cost of generation for increase in load condition and line contingency condition.

Autonomous Group	Min Fuel cost F(G)	Increase in Load demand
NR Method ($/H)	17184.39	1389.29
AGPSO1 ($/H)	**16975.7647**	
AGPSO2 ($/H)	16988.8914	
AGPSO3 ($/H)	16977.3551	
MPSO ($/H)	16975.9249	
SPSO ($/H)	**16972.7152**	
IPSO ($/H)	16982.5554	
TACPSO ($/H)	16993.9239	
FDRPSO [14] ($/H)	**16978.87**	

Table 9. Comparison of overall fuel cost during line contingency condition with increase in load condition

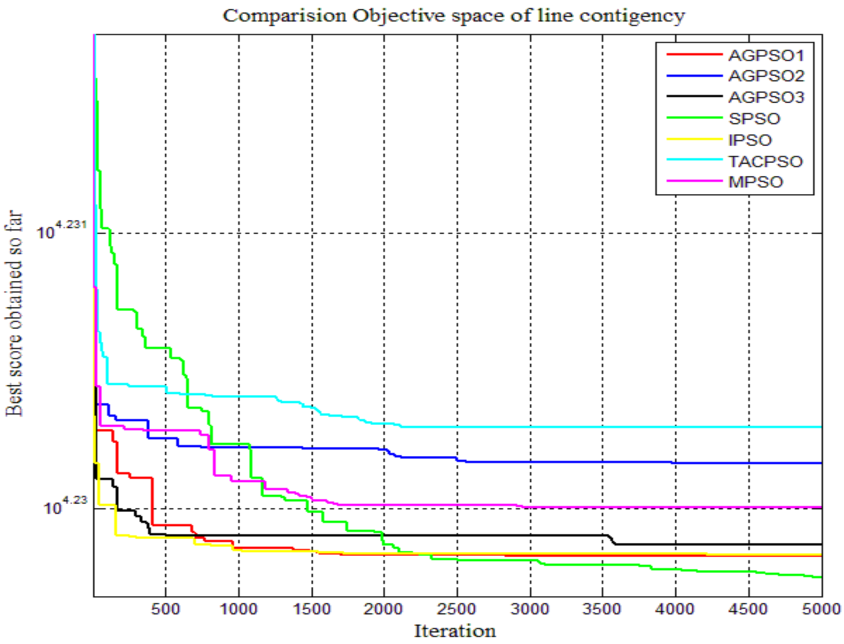

Fig 3. Converged characteristic during increase in load demand and line contingency condition

Parameter setting of the proposed algorithm having 20 numbers of Search agents with 5000 iteration. The converged characteristics of the AGPSO1, AGPSO2, AGPSO3, MPSO, SPSO, IPSO and TACPSO algorithm for the line contingency condition with increase in load demand is better than FDRPSO [14] shown in Fig 3.

VI. Conclusion

This proposed work explained the Individual in a group of particle is not quite same as in their ability and intelligence. Each individual do their duties as a member of workgroup. In some particular situation the ability of individual is very useful to perform their objective. This Autonomous group particle swarm optimization which includes AGPSO1, AGPSO2, AGPSO3, MPSO, IPSO, TACPSO and SPSO algorithm has the better optimum performance than FDRPSO algorithms. The proposed algorithm demonstrated for the 26 bus test system with Ramp rate limit considering base load and increase in load condition along with line contingency. The compared results give the feasible economic dispatch to the producer to meet the load demand when subjected at any cause of risk condition to the power system. More over this AGPSO algorithm has better performance in both constraints as well as unconstraint problem.

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