A NOVEL OPTIMIZED & ENERGY EFFICIENT HYBRID PSO ALGORITHM FOR EMISSION CONSTRAINED ECONOMIC LOAD DISPATCH

Himanshu Anand[1], Pratik Kumar Kar[2]

[1,2]*Department of Electrical Engineering, Marwadi Education Foundation Group of Institution, (India)*

ABSTRACT

The emission constrained economic load dispatch (ECELD) is a optimization problem to minimize expenses while fulfilling the power demand with including emission constraint. A key challenge for the coal-fired power plant generation loading is to abate fuel consumption and to control emission within the environmental limit. In concern environmental awareness, electrical utilities are required to reduce their emission level well below defined standards. The ECELD dispatch problem can be solved by several control algorithms. But in this paper we have proposed a new control hybrid PSO algorithm known as hybrid constriction particle swarm optimization (HCPSO) which increases the exploitation and exploration of search area more effectively. The analysis on this improved PSO is presented in this paper.

Keywords: Constriction particle swarm optimization (CPSO), Economic load dispatch (ELD), Emission constrained economic load dispatch (ECELD), Hybrid constriction particle swarm optimization (HCPSO), Particle swarm optimization (PSO)

I. INTRODUCTION

All the conventional electrical power plants employs different fossil fuel as source of energy to produce electricity and emission byproducts. The resultant emitted gaseous byproducts released to the atmosphere. Main concern out of those gases is due to the greenhouse gases like no, so_x , co_2which have tremendous impact on environment. Thus it is required to generate electricity at least possible cost as well as at minimum level of pollution. The emission constrained economic load dispatch (ECELD) problem is defined so as to reduce the operating cost with emission as constrained [1]. In concern environmental consciousness, electrical utilities are required to decrease their emission level well below the standard level [2].

We can limit level of emission by including the emission as constraint in the calculation of cost per unit generation. That's why ELD problem not only deals with minimizing the cost ensuring all constraints but at the same time it also limit the emission value [3]. The conventional ELD problem deals with the allocation of power in such a way so as to carry out generation economically with all constraints ensured [4]. But due to the continues increase in the load demand the amount fuel consumption in the power plant is also increasing respectively. Ultimately it follows an increase in total emission of gaseous pollutants from the consumption of fossil fuels. So far the only criterion of economic load dispatch is to dispatch electric power economically only and now minimization while considered emission as constraint is also important for all generation utilities [5]. But ideal generation dispatch deal with minimizing the total generation cost of system. Therefore, the overall system not only depends on the economy and relative cost of production which ensure cheapest production by adopting most convenient schemes.

There are several methods that can be implemented to solve the ECELD problem. Several Classical methods used for this purpose. But their outcome totally dependent on the parameter selection i.e. the step size. Due to this problem it can drives the whole system to oscillations for any inappropriate value of step size. That's why all such mathematical programming based algorithms such as Newton- rapson method, lambda iterative method, Lagrange relaxation, gradient based method etc does not prove to be applicable for non-linear or non-convex cost functions [6]. Also these methods involve a derivative approach which does not converges and constraint handling cannot be successfully met. The problem of constraint handling can be overcame by dynamic programming (DP) approach [7]. But DP approach can't be used in case of highly dimensional problems since it fails to converge in such problems. Thus, these classical methods does not provide solution in large scale optimization problem.

We can also optimize ECELD problems by stochastic searching algorithms such as genetic algorithm (GA)[7], particle swarm optimization (PSO), simulated annealing, artificial immune system (AIS), evolutionary programming (EP), memetic algorithm, krill herd algorithm, functional optimization, clonal algorithm, adaptive hopfield neural networks, neural approach. Compared to different classical methods of problem solving technique these methods provides better result due to their tendency to explore new solution with appropriate satisfaction of constraints and hence provides more flexible and efficient results.

PSO approach uses a random selection approach while preserving the overall population and search for better solution [8]. It has faster convergence rate and balance between the local and global search [9]. But the main problem with this approach is that if it get trapped at a particular solution i.e premature convergences. Also the velocity of particle is oscillatory in nature thts why some times it may not be able provide any stable solution [10].

The convergence towards a stable solution is one of the most important property of any good searching algorithm. In 1999, constriction factor is introduced by Clerc [11]. Constriction particle swarm optimization (CPSO) is the powerful searching technique that uses constriction factor of evolutionary programming and provide an efficient and fast solution to the optimization problem. But exact balancing of the parameters in CPSO is required for obtaining the desired results [12] or else it may suffer less exploring at the beginning of searching and sometime unable to find a appropriate solution. To overcome the various limitations to find optimum solution by PSO and CPSO we are using HCPSO which is having advantages of both PSO and CPSO.

II. FORMULATION OF ECELD METHODOLOGY

We have considered both problem of cost optimization and emission problem as constraint for formulating ECELD problem. We have formulated by considering both equality and inequality constraints.

2.1 Objective Function

Cost Function: The cost function of each thermal generator, with the valve-point effect is represented as the sum of sine and quadratic function. The fuel cost in terms of generation output can be expressed as:

$$CF = \sum_{i=1}^{U} (a_i G_i^2 + b_i G_i + |d_i \sin\{e_i (G_i^{min} - G_i)\}|) \quad (1)$$

where a_i, b_i, c_i, d_i, e_i are the cost coefficients, CF = Fuel cost function of power units, G_i = Real power generated of i^{th} unit. , G_i^{min} = Minimum power of i^{th} unit, U = Total number of power unit.

2.2 Emission Function

Emission (ton/h) of pollutants is the sum of an exponential and quadratic function can be expressed as:

$$EF = \sum_{i=1}^{U} (\alpha_i G_i^2 + \beta_i G_i + \gamma_i + \eta_i \exp(\delta_i G_i)) \tag{2}$$

where $\alpha_i, \beta_i, \gamma_i, \eta_i, \delta_i$ are the cost coefficients. EF = Amount of emission released by thermal unit.

2.3 Constraints

In power system, the ECELD is subjected to many constraints. There are two types of constraints in ECELD.

2.3.1 Equality Constraints

The total power generation from thermal units must meet the load demand and the transmission losses in the transmission lines.

$$\sum_{i=1}^{U} G_i = G_D + G_L \tag{3}$$

where G_D is the power demand, G_L is the transmission losses, which are approximated in terms of B-coefficient also called as Kron's loss formula:

$$G_L = B_{00} + \sum_{i=1}^{U} \sum_{j=1}^{U} G_i B_{ij} G_j + \sum_{i=1}^{U} B_{i0} G \tag{4}$$

2.3.2 Inequality Constraints

Generation Limit Constraint: The generation of each thermal unit is in limit of its maximum and minimum:

$$G_i^{min} \leq P_i \leq G_i^{max} \tag{5}$$

Emission Operating Limit: The emission from a generating unit is limited. The emission constraint are as:

$$EF(G_i) \leq \alpha \times EF^{max} \quad (\alpha < 1) \tag{6}$$

Where α is emission limit factor, EF^{max} is the maximum emission limit at minimum fuel cost. G_i^{min} and G_i^{max} are the minimum and maximum limit of generator output.

The generation should lie within the operating limits of the respective units for their proper operation. Emission constraint indicates maximum limits for emission as indicated:

$$EF2 = \begin{cases} (\alpha EF^{max} - EF(G_i))^2 ; & EF(G_i) > \alpha \times EF^{max} \\ 0 & ; EF(G_i) \leq \alpha \times EF^{max} \end{cases} \tag{7}$$

For power balance, equality constraints must be satisfied. The equality constraints represent total power generation should be equal to total power demand plus total line loss.

$$E1 = \begin{cases} \left(\sum_{i=1}^{G} P_i - P_D - P_L\right)^2 ; & P_D + P_L \neq \sum_{i=1}^{G} P_i \\ 0 & ; P_D + P_L = \sum_{i=1}^{G} P_i \end{cases} \tag{8}$$

2.4 Problem Description

In case of power system load-economic problem optimization we have to find best solutions by considering multi-object functions and evaluating them simultaneously [12]. But in this paper we have included emission as a constraint to get optimize the total generation cost while limiting emission level [13]. But any environmental constraint problem always gives multiple sets of optimal solution with respect to objective function. Objective function includes the operating cost function and summing of penalty term which does n't satisfy equality and inequality constraint. Constraints can be formulated as follows: Minimize CF(G_i)

III. ALGORITHM DESCRIPTION OF HCPSO

In PSO [8], the speed and location of a particle in the search area are given by V and P respectively. Also The velocity of particles are continuously updated using the global best value and personal best experience of the particle i.e. local best value and is given as:

$$V_{i,j}^{k+1} = W \times V_{i,j}^{k} + C_1 \times rand() \times (P_{i,j}^{best} - P_{i,j}^{k}) + C_2 \times rand() \times (G_j^{best} - P_{i,j}^{k}) \quad (9)$$

The inertia weight (W) can be expresses as:

$$W = W^{max} - ((W^{max} - W^{min}) \times k)/ITmax \quad (10)$$

The velocity of particles are update using the previous position and velocity in CPSO as given below:

$$V_{i,j}^{k+1} = K[W \times V_{i,j}^{k} + C_1 \times rand() \times (P_{i,j}^{best} - P_{i,j}^{k}) + C_2 \times rand() \times (G_j^{best} - P_{i,j}^{k})] \quad (11)$$

Constriction coefficient (K): As Ø increases, the factor K decreases and convergence becomes slower [11].

Where $K = 2/|2 - \emptyset - \sqrt{(\emptyset^2 - 4\emptyset)}|$ (12)

When $\emptyset^2 - 4\emptyset \geq 0 \quad (\phi = C_1 + C_2 \,,\ \phi > 4)$

The position of particles are update using the previous position and velocity as given below:

$$P_{i,j}^{k+1} = V_{i,j}^{k+1} + P_{i,j}^{k} \qquad (i = 1,2,3 \ldots.PR;\ j = 1,2,3, \ldots \ldots G;\ k = 1,2,3 \ldots\ldots ITmax) \quad (13)$$

Where

ITmax= maximum iteration number

IT = iteration number

W^{min} = final weight.

W^{max} = initial weight

PR= number of particles in group;

G= number of member in particles;

ITmax = number of iteration;

W= inertia weight factor;

C_1 and C_2 = acceleration constant.

$P_{i,j}^{k}$ = current position of j^{th} member of i^{th} particles at k^{th} iteration.

rand()=uniform random number in the range [0,1].

$P_{i,j}^{best}$ = local best position of j^{th} member of i^{th} particles.

G_j^{best} = Global best position of j^{th} member.

$V_{i,j}^{k}$ = current velocity of j^{th} member of i^{th} particles at k^{th} iteration.

P_j^{min} and P_j^{max} Least and Supreme position of j^{th} member.

The major limitation of PSO algorithm is during search process it can't find the best solution when it reaches the local search area since at that point its rate of convergence is slow for exploitation. Similarly CPSO has limited exploration ability for global search condition [2]. That is why HCPSO has been used to overcome the limitation of PSO and CPSO to find optimum solution. The algorithm implementing HCPSO for ECELD is indicated below in the flow chart. Here C factor is constant value after which exploitation is done and reduction in step size.

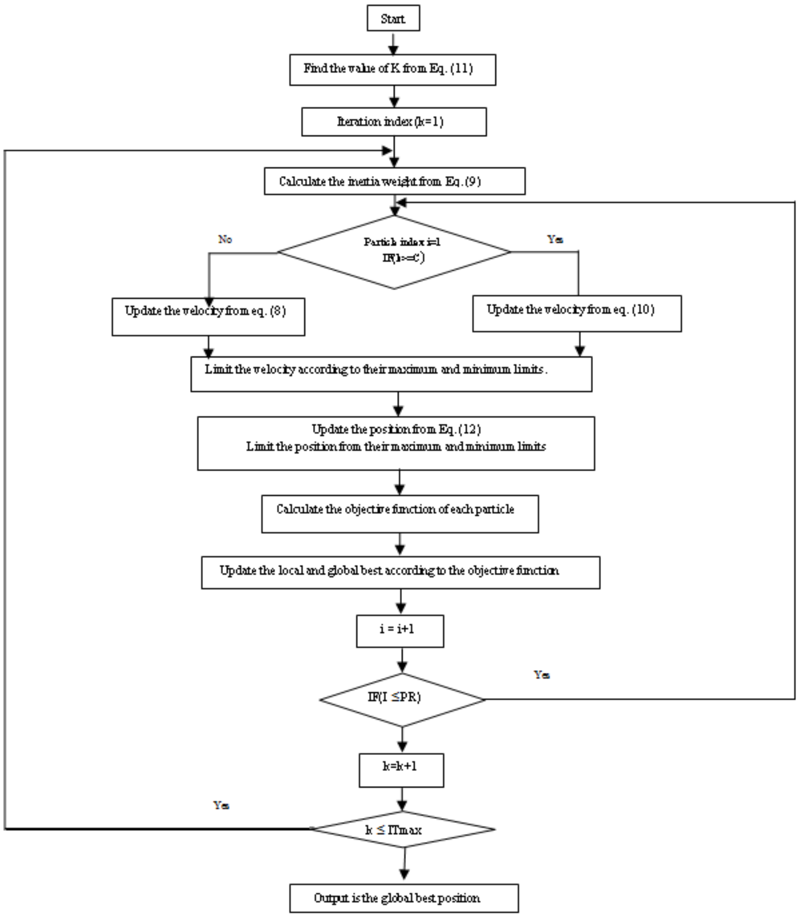

Fig1 Flowchart of Hcpso

IV. ANALYSIS OF THE RESULT

The analysis has been carried out considering six different plant having generating capacity of total 700MW. We have presented here the data regarding optimum generated power per unit plant with only considering to minimize the cost and also considering emission as constraint and selecting the parameter.

For the analysis based on HCPSO to find the stable and optimal solution for ECELD, the program is run for different value of C_1 , $C_{2,}$ $C_{3,}$ C_4, w^{max} , w^{min} , ITmax and C factor, which are given in TABLE 1.

The below table indicates a comparison between CPSO, HCPSO and MRPSO. We found that MRPSO have the best emission control but it also have optimum cost among all the other algorithm (PSO, WIPSO) results [16]. But by using HCPSO method we have optimized both cost and emission value with compared to other which is represented below.

PR	ITmax	W^{max}	W^{min}	C_1	C_2	C_3	C_4	C factor
50	500	.9	.4	2	2	2.05	2.05	150

Table 1 Different values of Parameters

Variables	ELD		Emission dispatch		ECELD		
POWER	CPSO	HCPSO	CPSO	HCPSO	CPSO	MRPSO	HCPSO
G_1 (MW)	10.00	11.43	11.84	10.84	11.78	28.941	12.858
G_2 (MW)	28.07	14.30	107.02	111.00	69.00	91.958	72.002
G_3 (MW)	140.12	122.08	64.99	140.32	150.03	108.15	155.203
G_4 (MW)	105.51	83.16	142.67	93.95	124.25	129.80	149.223
G_5 (MW)	144.16	309.22	199.31	173.64	126.29	187.28	190.452
G_6 (MW)	181.21	181.21	189.07	189.07	237.40	179.28	138.115
Cost($/h)	37288.66	37249.06	38305.23	38308.49	37613.96	38051.1	37723.08
Emission(lb/h)	539.79	537.29	468.69	451.87	485.17	460.24	460.209

Table 2 Simulation result of different dispatch using different algorithm.

At first we have only considered cost to be minimized and we have used CPSO and HCPSO algorithm for that purpose. We found out that by using HCPSO we can reduce the generation cost to a minimum value of 37249.06 $/h than compared to that of CPSO which is 37288.66 $/h at the same time the total emission is also reduced from 539.79lb/h to 537.29lb/h. Now we have considered only emission constraint problem and try to minimize total emission at the same load condition. By using CPSO it reduced to 468.69 lb/h while we got a better result of 451.87lb/h by using HCPSO with an additional cost of 3.26$/h. Results of both the algorithm with ELD emission dispatch are presented in the TABLE 2. The above table also indicates a comparison between CPSO, HCPSO and MRPSO .We found that HCPSO not only provides the best emission control that is the total emission value of only 460.209 lb/h but also have least cost of generation 37723.08 $/h among all the other algorithm results. But by using MRPSO method we have optimized combined cost 38051.1 $/h and emission value 460.24 lb/h which indeed provides better result than CPSO but its result is not superior than the results we obtain by HCPSO.

Again we have included emission limiting factor(α) for the purpose of better controlling the total level of emission. For different values of α we have estimated power output of individual plant and the cost and emission at that point.

Table 3 Simulation result of ECELD using HCPSO algorithm.

P_G (MW)	ECELD		
	α =.9	α =.86	α =.84
P_1 (MW)	10.287	12.858	11.11
P_2 (MW)	60.743	72.002	75.01
P_3 (MW)	140.462	155.203	154.39
P_4 (MW)	120.678	149.223	116.43
P_5 (MW)	143.098	190.452	196.05
P_6 (MW)	245.014	138.115	165.09
Cost($/h)	37500.28	37723.08	38084.13
Emission(lb/h)	483.062	460.209	450.28

It is clear from TABLE 3 that with the decrease of α, rate of emission decreases while corresponding cost increases. So we can operate the plant according to our higher priority objective that means if generation cost can be negotiable then we can reduce the emission level further to a lower value by regulating emission limiting factor (α).

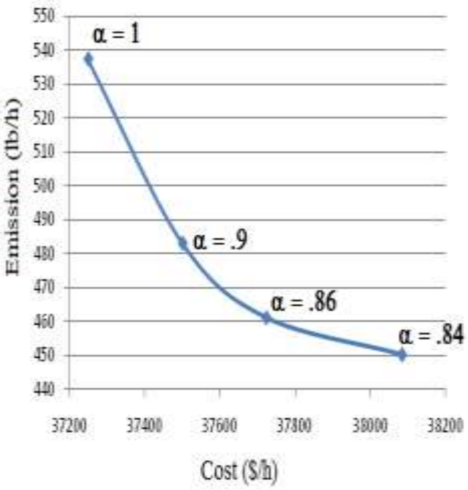

Fig 2 Cost Versus Emission Curve In Six Units

We also found out the power scheduling of different power plants at 700 mw load demand condition by using various control algorithm and we have presented the same in the TABLE 4. From the table we can see that in case of HCPSO the total power generation from the power plant is only 717.848 MW while that in case of CPSO and MRPSO is 718.75 and 725.409 respectively. It indicates the total power generation in case of HCPSO is minimum for the same load demand as compared to that of the other algorithm which implies fewer amounts of power wastage and cost saving for the same amount of power generation which intern also indicates higher efficiency of the plant.

Table 4 Simulation result of cost and power loss of generating unit.

COST($/h)	CPSO(ECELD)	MRPSO(CEED)	HCPSO(ECELD)
$CF(G_1)$	1231.96	1999.91	1267.03
$CF(G_2)$	4143.86	5596.22	4327.3
$CF(G_3)$	7543.90	5636.82	7784.39
$CF(G_4)$	6544.11	6806.92	7743.95
$CF(G_5)$	6583.24	9202.53	9343.05
$CF(G_6)$	11450.81	8793.075	6983.81
Total cost	37497.88	38035.475	37449.52
G_D(MW)	718.75	725.409	717.848
G_L(MW)	18.75	25.409	17.848

The above data is again presented in the following Fig3 for better understanding where we can see the total power loss is minimum in case of HCPSO than compared to that of MRPSO and CPSO. So by using HCPSO not only we can reduce the total cost of power generation, total emission but also we can reduce the unnecessary cost of excess power generation which intern not only increase cost and material saving and overall efficiency of the plant but also reduces the total emission level to a further value.

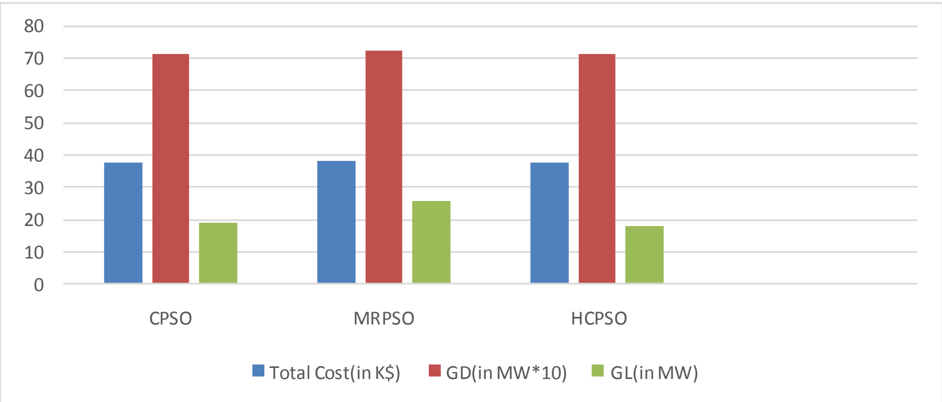

Fig 3 Total Cost, G_d, G_l Of Cpso,Mrpso Vs Hcpso

V. CONCLUSION

From the above analysis we conferred that by using HCPSO algorithm not only we can optimize the cost of power generation but also we can reduce the emission level to a lower level. Also we understood that by implementing this algorithm we can further reduce the emission level by tuning the cost of power generation. Finally this is also verified that this is indeed a algorithm which can be used to reduce the generating cost, emission and also the unnecessary amount of power generation in the power plant and hence enhancing the overall efficiency of the system.

REFERENCES

[1] Arya, L.D.; Chouble, S.C.; Kothari, D.P., "Emission constrained secure economic dispatch," International journal of electrical power & energy systems, Vol. 19, No. 5, pp. 279-285, June 1997.

[2] El-Keib, A. A.; Ma, H.; Hart, J. L.,"Economic dispatch in view of the clean air act of 1990," IEEE Transactions on Power Systems, Vol. 9, No. 2, pp. 156-175, May 1994.

[3] Lamont, J.W.; Obessis, E.V., "Emission dispatch models and algorithms for the 1990's," IEEE transactions on power systems, Vol. 10, No. 2, pp. 941-947, 1995.

[4] Ramanathan, R., "Emission constrained economic dispatch," IEEE Transactions on Power Systems, Vol. 9,No.4, pp. 1994 - 2000, Nov 1994.

[5] Delson, Jerome K., "Controlled emission dispatch," IEEE transactions on power apparatus and systems, Vol. PAS-93, No. 5, pp. 1359-1366.

[6] Kothari, D.P.; Dhillon, J.S., "Power system optimization," 2nd edition, PH1 learning private limited, 2011.

[7] Wood, A.J.; Wollenberg, B., "Power generation, operation and control," 2nd edition, John Wiley, New York, 1996.

[8] J. Kennedy, J.; Eberhart, R.C., "Particle swarm optimization," In Proc. IEEE conference on Neural Networks, pp. 1942–1948, Nov. 1995.

[9] Shi ,Y.; Eberhart ,R., "Parameter selection in particle swarm optimization" In Evolutionary programming VIZ Proc. EP98, New York: Springer Verlag, pp. 591-600, 1988.

[10] Clerc, M.; Kennedy, J., "The particle swarm-explosion, stability and convergence in a multidimensional complex space," IEEE Transanction on evolutionary computation, Vol. 6, No. 2, pp. 58–73, Feb. 2002.

[11] Eberhart, R.C.; Shi, Y., "Comparing inertia weights and constriction factors in particle swarm optimization," In Proc. congress on evolutionary computation, pp. 84–88, July 2000.

[12] Van Den Bergh, F.; Engelbrecht, A.P., "A study of particle swarm optimization particle trajectories," Information science, Vol. 176, No. 8, pp. 937-97, 22 April 2006.

[13] Abou, A.A.; Elaa, El; Abidob, M.A.; Speaa, S.R., "Differential evolution algorithm for emission constrained economic power dispatch problem," Electric power Systems research, Vol. 80, No. 10, pp. 1286-1292, Oct 2010.

[14] J.H Talaq, Ferial and M.E. EI-Hawary, "Minimum emission power flow," IEEE Transactions on powe systems, Vol. 9, No. 1, pp. 429 - 435 ,Feb 1994.

[15] Ozcan, E.; Mohan, C. K. , "Analysis of a simple particle swarm optimization problem," In Proc. Conference on Artificial Neural Networks in Engineering, pp. 253–258, Nov. 1998.

[16] Shi ,Y.; Eberhart ,R., "A modified particle swarm optimizer," IEEE Congress on Evolutionary Computation intelligence, pp: 69-73, 1998.

[17] Singh, N.; Kumar, Y., "Economic load dispatch with environmental emission using MRPSO," IEEE conference on Advance computing conference (IACC) , pp. 995 – 999, 2013.