Combined Heat and Power Economic Emission Load Dispatch Optimization using Constriction Particle Swarm Optimization

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Abstract— **The Combined heat and power economic emission load dispatch (CHPEED) is an optimization problem to minimize the cost and emission while ensuring the fulfilling the power and heat demand and feasible constraints. This paper presents hybrid constriction particle swarm optimization (HCPSO) technique to solve CHPEED with bounded feasible operating region. The main potential of this technique is that it proper the balance between global and local search. A comparative analysis of the HCPSO with (RCGA), (NSGAII), (SPEA2) is presented.**

Keywords— Combined Heat and Power; Economic Emission Load Dispatch; Hybrid Constriction Particle Swarm Optimization.

INTRODUCTION

Generation of power from these fossil fuels result in release of various gases in the atmosphere. Main concern out of these gases is regarding the greenhouse gases like nox, sox , co2 that causes pollution in the environment [1]. The emission of these pollutants causes global warming that affect not only humans but also other forms of living beings like plants and animals. Thus it is required to produce electricity at minimum possible cost as well as at minimum level of pollution.

But the excessive use of non-conventional form of energy is a great matter of concern for the society as it is having hazardous impact on environment like green house effect etc [2]. This has forced the power industry to make optimal utilization of the fuels. Combined Heat and Power is one of the most efficient and reliable method for generation of heat and power [3]. The generated heat can be efficiently used to support local industry development and thus increasing the overall efficiency of the power plant. In combined heat and power, the heat and power demands are to be met simultaneously which make the CHPED complex optimization problem.

Combined heat and power economic emission dispatch using non-dominated sorting genetic algorithm-II [4]. The superiority of constriction factor PSO (CPSO) over inertia weight PSO is showed in [5] in which the maximum velocity Vmax is limited in dynamic range of the variable. Modified PSO (MPSO) is developed by [5] to overcome the non-smooth cost function problem in ED problem. [5] Implemented time varying acceleration coefficients particle swarm optimization (TVAC-PSO) algorithm is used to solve CHPED problem. In this approach the quality of original PSO and premature merging problem is reduced by varying the acceleration coefficients along the iterations proposed CPSO to solve ELD problem with valve point loading effect which have non-smooth cost function with equality and inequality constraints.

Number of techniques has been evolved in last decades to solve this complex CHPEED problem. Several methods which have been used to find out CHPED with constraints are Mixed Integrating Programming, Lagrange Relaxation, and Newton-Raphson etc. But all these methods have drawbacks like problems related to constraints handling, convergent problem etc. So, to overcome the above-mentioned problem of traditional techniques some alternative approaches have to be used. These alternative approaches include Genetic Algorithm (GA), PSO, EP, DE, etc [4-7].

PSO is an active random search technique that traverses good regional solution very quickly. The concurrence towards a stable solution is the primary requirement of any search algorithm so a new factor has been introduced called constriction factor [11]. PSO is effectively used for solving complex problem. Due to complex problem CHPEED there large number of constraints handling PSO generally cannot go out optimal solution to reach the global best ones. In literature view CPSO, TVACPSO has better than PSO which increase convergence rate and improved the search. PSO has limited number of control parameter adjustment of these parameter tends effective solution.

In this paper, optimization of combined heat and power economic emission dispatch problem using CPSO is carried out. The test system is applied on 1 heat unit, 3 cogeneration units and 1 thermal generating unit without considering ramp rate limit at constant load. The optimizations of the problem and simulation results have been computed in FORTRAN 90.

This paper is organized as follows: Section II describes the mathematical formulation of combined heat and power economic emission dispatch problem. Section III presents a brief overview of Constriction Particle Swarm Optimization. In section IV the simulation is carried out for 1 heat generating units, 3 cogeneration units and 1 thermal generating units and result is discussed. In section V the conclusion is given showing the feasible solution of the problem and future work.

I. PROBLEM FORMULATION OF CHPEED

The main aim of CHPEED problem is to obtain the optimal scheduling of power and heat with minimum cost and emission while ensuring all equilaty and inequality constraints using weigtes sum method. Mathematically, the problem can be formulated as:

Min CT=

$$\sum_{k=1}^{n_t} C_t(p_k)+\sum_{l=1}^{n_s} C_s(h_l)+\sum_{m=1}^{n_{co}} C_{co}\left(p_m,h_m\right)+\sum_{k=1}^{n_t} E_t(p_k)+\sum_{l=1}^{n_s} E_s(h_l)+\sum_{m=1}^{n_{co}} E_{co}(p_m,h_m) \quad (1)$$

where nt , ns and nco are the number of thermal units, heat units, and cogeneration units respectively.

Cost of all units can be defined as:

$$C_t\left(p_k\right)=ac_k(p_k)^3+bc_k(p_k)^2+cc_k(\ p_k)+dc_k \quad (2)$$

$$C_s\left(h_l\right)=\propto c_l(h_l)^2+\beta c_l(\ h_l)+\gamma c_l \quad (3)$$

$$C_{co}\left(p_m,h_m\right)=\theta c_m\left(p_m\right)^2+\sigma c_m(p_m)+\mu c_m+\emptyset c_m(h_m)^2+\partial c_m(h_m)+\epsilon c_m(p_m,h_m) \quad (4)$$

where Ct(pk)represent kth cost of individuals generating units for producing power(pk). ack ,bck ,cck , dck and eck are the cost coefficients of kth thermal units including valve point effect. Cs(hl)represents cost of lth for producing heat (hl). βcl and γcl are cost coefficients of heat only units. Cco(pm,hm) represent cost of mth cogeneration units for producing heat (hm) and power (pm) are the cost coefficients of m_{th} cogeneration units.

Emission of all units can be defined as:

$$E_t\left(p_k\right)=ae_k(p_k)^2+be_k(\ p_k)+ce_k+\ dc_k\exp^{e_k\times p_k} \quad (5)$$

$$E_s\left(h_l\right)=\beta e_l(\ h_l) \quad (6)$$

$$E_{co}\left(p_m,h_m\right)=\sigma e_m(p_m) \quad (7)$$

where Et(pk)represent kth emission of individuals generating units for producing power(pk). aek ,bek ,cek , dek and eek are the emission coefficients of kth thermal units including valve point effect. Es(hl)represent emission of lth for producing heat(hl). γel are emission coefficients of heat only units. Eco(pm,hm) represent emission of mth cogeneration units for producing heat(hm) and power(pm). are the emission coefficients of m_{th} cogeneration units.

CHPD problem is subjected to following constraints:

$$\sum_{k=1}^{n_t} p(k)+\sum_{m=1}^{n_{co}} p(m)=p_D+p_L \quad (8)$$

$$\sum_{l=1}^{n_s} h(l)+\sum_{m=1}^{n_{co}} h(m)=h_D \quad (9)$$

$$p_i^{min}\leq p_i\leq p_i^{max} \quad (10)$$

$$h_m^{min}\leq h_m\leq h_m^{max} \quad (11)$$

$$p_m^{min}(h_m)\leq p_m(h_m)\leq p_m^{max}(h_m) \quad (12)$$

where p_i^{min} and p_i^{max} are the power limits of thermal units. h_m^{min} and h_m^{max} are limits of heat only units. p_D and h_D is power and heat demand. Where $p_m^{min}(h_m)$ and $p_m^{max}(h_m)$ are the power limit of mth CHP which are the function of heat produced. $h_m^{min}(p_m)$ and $h_m^{max}(p_m)$ are the heat limit of mth CHP which are the function of power produced. $p_{m,}h_m$ Coordinates should lie in the feasible operating region of cogeneration units as shown in Fig 1 and should satisfy the test system equations for two cogeneration units.

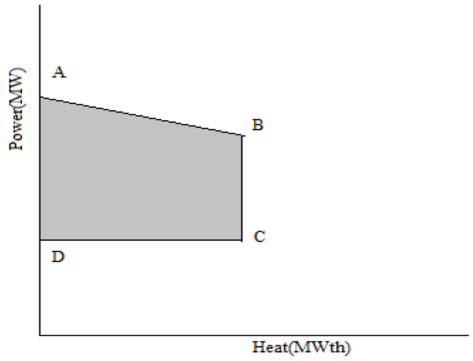

Fig 1. Feasible operating region of the cogeneration units

II. CONSTRICTION PARTICLE SWARM OPTIMIZATION ALGORITHM

Kennedy & Eberhart in 1995 introduced PSO which is stochastic search algorithm [9]. In the PSO, population is consisted of randomly initialized and moved around in the N-dimensional search space according to fitness function [10].

The velocity of the particle is given by

$$v_{i,j}^{k+1}=w\times v_{i,j}^{k}+C_1\times ran\times(X_{i,j}^{best}-X_{i,j}^{k})+C_2\times ran\times(G_j^{best}-X_{i,j}^{k}) \quad (13)$$

The inertia weight (W) can be expresses as:

$$w=w^{max}-\left(\left(w^{max}-w^{min}\right)\times k\right)/itr_{max} \quad (14)$$

$$K=2/|2-\emptyset-\sqrt{(\emptyset^2-4\emptyset)}| \quad (15)$$

$$\text{when } \emptyset^2-4\emptyset\geq 0 \quad (\phi=C_1+C_2\ ,\ \phi>4) \quad (16)$$

$$v_{i,j}^{k+1}=K\times(w\times v_{i,j}^{k}+C_1\times ran\times(X_{i,j}^{best}-X_{i,j}^{k})+C_2\times ran\times(G_j^{best}-X_{i,j}^{k})) \quad (17)$$

The position of the particles keeps on updating by utilizing earlier positions and velocities

$$X_{i,j}^{k+1}=v_{i,j}^{k+1}+X_{i,j}^{k} \quad (18)$$

$$(i=1,2,3….PR;j=1,2,3,……G;k=1,2,3…..IT_{max})$$

III. RESULTS AND DISCUSSION

The analysis of method CPSO has been carried out considering one conventional thermal generator, three combined heat and power units and a heat-only unit. The heat and power generating capacity are 150(MWth) and 300(MW). Case data carry fuel coefficients and emission coefficient without considering transmission loss and heat-power operating feasible regions [9]. Effectiveness of CPSO method applies to CHPEED and compare with other algorithms RCGA, SPEA2 and NSGA-II. Fuel cost and emission are minimized individually using HCPSO and compare with RCGA. Due the complex problem of CHPEED selection of the parameter after 50 trails population size and iteration are 60, and 300 for the cost, emission and combined economic emission minimization. During fuel cost optimization, fuel cost (13773.550$/h) is less as compared to RCGA(13776.14$/h) and emission (9.61Kg/h) as shown in table 1. Fig. 2 depicts cost and emission convergence obtained from CPSO for this test system.

Table2. Results of ELD from RCGA, CPSO

Control	RCGA[9]	CPSO
P1(MW)	134.9904	135
P2(MW)	49.9525	14.12434
P3(MW)	25.0827	94.89742
P4(MW)	89.9744	55.97563
H2(MWth)	73.5089	30.72386
H3(MWth)	35.8519	16.00548
H4(MWth)	1.2916	71.79156
H5(MWth)	39.3476	31.4791
Cost($/h)	13776.14	13773.55
Emission(Kg/h)	12.0647	9.61

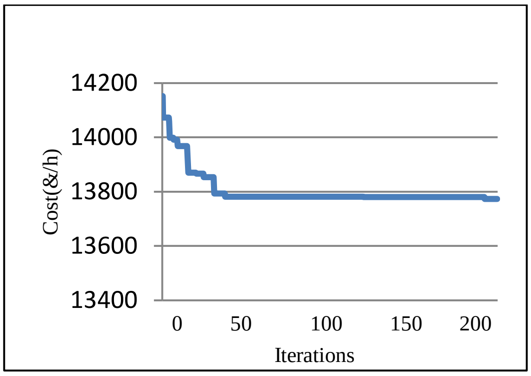

Fig2. convergence curve of cost with iteration

During emission optimization, at fuel cost (17174.33$/h) emission is (0.9616058Kg/h) less as compared to RCGA (1.446Kg/h) as shown in table 1. Fig. 3 depicts emission convergence obtained from CPSO for this test system.

Table2. Results of EMD from RCGA, CPSO

Control	RCGA[9]	CPSO
P1(MW)	39.2	35.3591
P2(MW)	125.8	51.44831
P3(MW)	45	90
P4(MW)	90	123.1926
H2(MWth)	32.3998	31.3562
H3(MWth)	55	39.48866
H4(MWth)	24.9999	49.64892
H5(MWth)	37.6002	29.50623
Cost($/h)	17048.75	17174.33
Emission(Kg/h)	1.446	.9616058

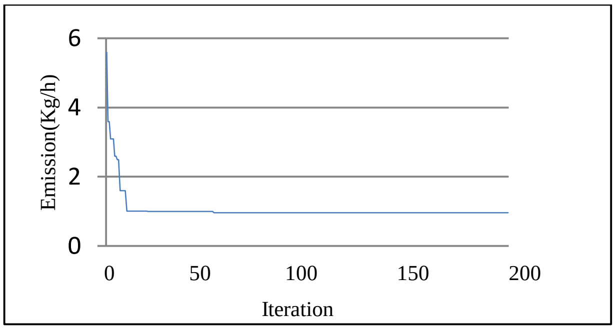

Fig2. convergence curve of emission with iteration

It is clear from fig 4 that with the decrease of emission while corresponding cost increases which show the deflecting behavior. So we can operate the plant according to our higher priority objective that means by varying the weighing of objective cost and emission. The results obtained during combined heat power economic and emission dispatch from CPSO are 14165.16$/h and 6.023406Kg. Table-3 show that fuel cost and emission in CHPEED is less than NSGA-II (15008.7$/h, 6.0563Kg) and SPEA-2 (14964.3$/h, 6.3667Kg). Fuel cost in HCPSO is 399.14$/h less than SPEA2 and emission in CPSO is 0.223294Kg/h less than SPEA2.

Table 3. Results of CHPEED from NSGAII, SPEA2, HCPSO

Control	NSGAII[9]	SPEA2[9]	CPSO
P1(MW)	93.9044	96.4846	118.3239
P2(MW)	72.8298	71.1705	15.18831
P3(MW)	43.3448	44.5018	105
P4(MW)	89.9210	87.8431	61.48775
H2(MWth)	84.925	84.766	42.2236
H3(MWth)	22.6032	10.2186	0
H4(MWth)	2.6268	17.9054	89.38037
H5(MWth)	39.8449	37.11	18.39606
Cost($/h)	15008.7	14964.3	14565.16
Emission(Kg/h)	6.0563	6.3667	6.143406

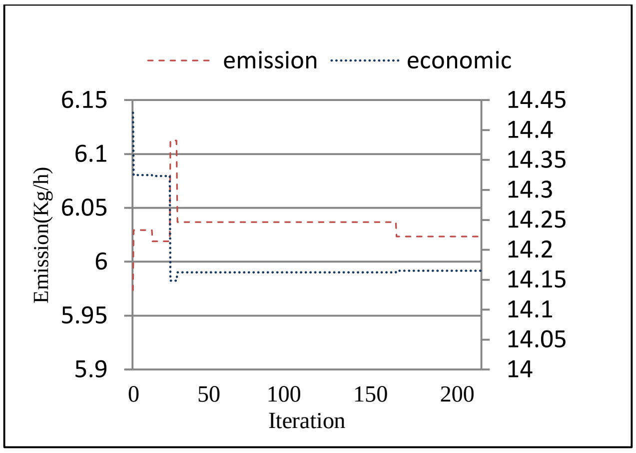

Fig 4. Convergences curve of cost and emission with iteration

IV. CONCLUSION

This paper has presented HCPSO algorithm for solving combined heat and power economic emission dispatch problem. The problem has been formulated as multi-objective optimization problem with competing production cost and emission objectives. Results obtained from the HCPSO algorithm have been compared with those obtained from RCGA2, NSGA-II, SPEA-2. It is seen from the comparison that the HCPSO algorithm provides a competitive effectiveness in terms of solution quality and a better performance in terms of CPU time.

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