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Combined Heat and Power Economic Dispatch using Particle Swarm Optimization

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Abstract- Combined heat and power (CHP) is well-organized and consistent approach for generating power and thermal energy utilizing only one fuel source with advantage of increasing the equipped efficiency and it also reduces the load on Electric Transmission Infrastructure through distributed generation. The objective of the combined heat and power economic dispatch (CHPED) is to find the optimal value of power and heat with minimum cost with both equality and inequality constraints are met. Particle swarm optimization (PSO) is a population based heuristic search technique which is presented in this paper to deal with the combined heat and power economic dispatch.

Keywords: Economic dispatch; Swarm; Unit commitment.

I. Introduction

Combined heat and power (CHP) generation also known as cogeneration technology proves to be promising with its greater conversion efficiencies than traditional methods. The heat, thus, produced as a by-product is available as secondary fuel to produce power[1]. CHP involves the simultaneous generation of electricity and heat utilizing a single source. These advantages of reduction in fuel consumption and emission carries a great significance. This increases the need to operate the system optimally[2]. CHP generation is a mature technology for efficient generation of energy and other environmental advantages [3]. The staple differences between conventional methods and CHP systems lies on the type of power we obtain from each one as well as their overall cycle efficiencies. The energy saving potential as well as reduced emission due to the wise use of cleaner fossil fuels burned in CHP generation units give them advantage from conventional power system[4].

II. Problem Formulation

In modern electrical system, there are various types of optimization problems containing diverse kind of issues. Economic dispatch (ED) is also one of the significant optimization issue in power system. The objective of conventional ED approach is to determine the scheduling of power for various generating units keeping the cost minimum subjected to equality and inequality constraints of power[5]. The objective of the combined heat and power economic dispatch (CHPED) problem is to obtain the optimal scheduling values of power and heat with minimum fuel cost satisfying all other constraints. Some complications arise in CHP systems because the dispatch values should be the set points of power and heat keeping the CHP units in a bounded power vs. heat plane[6]. Such type of problem is known as CHPED that has attracted a lot of interests in recent years[7]. CHPED problem is more complex than the conventional load dispatch problems. In a CHP system, there is one power demand and number of distinct heat demands[8] consisting of two dispatch problems i.e. heat and power dispatching simultaneously with interdependencies of the cogeneration units[9]. This dispatch problem is formulated in equation (4) as an optimization problem with quadratic objective function and liner constraints[10].

Objective function

Input-Output curves for conventional power and heat only units their cost functions will be convex too. Based on the separability degree, wherein the objective function of the problem is the sum of cost functions for all units:

$$C_b(H_b) = \alpha_b + \beta_b H_b + \gamma_b H_b^2 \quad (1)$$

$$C_e(P_e) = \alpha_e + \beta_e P_e + \gamma_e P_e^2 \quad (2)$$

$$C_{chp}(P_{chp}, H_{chp}) = \alpha_{chp} + \beta_{chp} P_{chp} + \lambda_{chp} P_{chp}^2 + \delta_{chp} H_{chp} + \psi_{chp} H_{chp}^2 + \xi_{chp} P_{chp} H_{chp} \quad (3)$$

$$Min(F(X)) = \sum_{e=1}^{E} C_e(P_e) + \sum_{chp=1}^{CHP} C_{chp}(P_{chp}, H_{chp}) + \sum_{b=1}^{B} C_b(H_b) \quad (4)$$

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Active power and heat balance equation

Production & Demand balance Equation for power unit, heat unit and cogeneration unit:

$$\sum_{e=1}^{E} P_e + \sum_{chp=1}^{CHP} P_{chp} = P_D + P_L \qquad (5)$$

$$\sum_{b=1}^{B} H_b + \sum_{chp=1}^{CHP} H_{chp} = H_D \qquad (6)$$

Maximum and minimum limits of power, heat and cogeneration units

Generation output of each unit should be laid between its minimum and maximum limits. Capacity Limits of conventional Power unit, heat unit and cogeneration unit:

$$P_e^{min} \leq P_e \leq P_e^{max} \qquad (7)$$

$$H_b^{min} \leq H_b \leq H_b^{max} \qquad (8)$$

$$H_{chp}^{min}(P_{chp}) \leq H_{chp}^{chp} \leq H_{chp}^{max}(P_{chp}) \qquad (9)$$

$$P_{chp}^{min}(H_{chp}^{chp}) \leq P_{chp}^{chp} \leq P_{chp}^{max}(H_{chp}^{chp}) \qquad (10)$$

Active power transmission loss

Active power transmission loss is an important factor to be considered and must be taken care of and it can be calculated by using network loss formula as follows:

$$P_L = \sum_{i=1}^{\beta} \sum_{i=1}^{\beta} P_i B_{ij} P_j \qquad (11)$$

III. INTRODUCTION TO PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is a salient optimizer used in a vast variety of complicated electrical engineering problems[5]. In 1995,Kennedy and Eberhart first introduced the PSO method, motivated by social behavior of organisms such as fish schooling and bird flocking. In a PSO system, particles fly around in a multidimensional search space. The swarm direction of a particle is defined by set of particles neighboring the particle and its history experience[11]. Higher value of the social component may result in premature convergence of particles and large value of the cognitive component would cause excessive wandering of particles through the search space[12]. It is a population based search algorithm using a group of particles[13]. Following steps are carried out while solving a generalized problem using PSO:

Step 1:

PSO algorithm define each particle as potential solution whose position and velocity of i^{th} particle in swarm is represented as

$$\vec{V}_i = \vec{V}_{i1}, \vec{V}_{i2}, \ldots, \vec{V}_{in} \qquad (12)$$

$$\vec{P}_i = \vec{P}_{i1}, \vec{P}_{i2}, \ldots, \vec{P}_{in} \qquad (13)$$

The velocity and position of all particles are randomly initialized so that they lie inside a pre-specified range:

$$\vec{V}_{ij}^{min} \leq \vec{V}_{ij} \leq \vec{V}_{ij}^{max} \qquad (14)$$

$$\vec{P}_{ij}^{min} \leq \vec{P}_{ij} \leq \vec{P}_{ij}^{max} \qquad (15)$$

Step 2:

Each dimension of an individual is checked for minimum and maximum limits and feasible operating region (FOR). Excessive violations of the values will cause the method to diverge from the optimum result[14].

Step 3:

At each iteration, the velocities of all particles are updated according to the following:

$$\vec{V}_{ij}^{new} = w \times \vec{v}_{ij} + C_1 \times rand_1() \times (\vec{P}_{ij}^{best} - \vec{P}_{ij}) + C_2 \times rand_2() \times (\vec{G}_i^{best} - \vec{P}_{ij}) \qquad (16)$$

where

C_1 is a positive constant, called as coefficient of the self-recognition component,

C_2 is a positive constant, called as coefficient of the social component,

$rand_1()$ and $rand_2()$ are the random numbers uniformly distributed in the interval [0,1].

w is the inertia weight whose Suitable selection provides a balance between global and local explorations and is given by the following expression:

$$w = w^{max} \frac{w^{max} \quad w^{min}}{IT^{max}} \times IT \qquad (17)$$

where

w^{max} initial weight,

IT^{max} maximum iteration number,

IT iteration number,

w^{min} final weight.

Step 4:

Between successive iterations, the positions of all particles are updated according to the following equation:

$$\vec{P}_{ij}^{new} = \vec{P}_{ij} + \vec{V}_{ij}^{new} (i = 1,2,\ldots, NP;\ j = 1,2,\ldots, NG) \qquad (18)$$

Step 5:

Update $\vec{P}_i^{best}$ and $\vec{G}^{best}$

Step 6:

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The algorithm repeats Step 2 to Step 5 until certain stopping rules are satisfied. Once terminated, the algorithm outputs the $\vec{P}_i^{best}$ and $\vec{G}^{best}$ as its solution.

Feasible operating region (FOR):
Constraint inequalities are used to describe feasible operating region of the cogeneration unit i.e. the area in two axis diagram that contain all possible heat-power outputs from given cogeneration units. A typical feasible operating region is an irregular quadrilateral as shown in the figure 1.

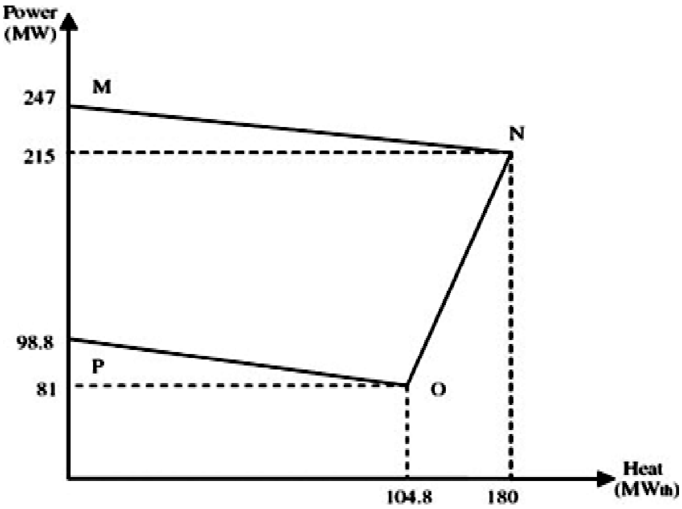

FIG. 1 Feasible Operating region for Cogeneration Unit[12].

IV. CONCLUSION

In this paper, PSO approach is employed for solving CHPED problem. In modern world, most of the optimization problems involves complex characteristics with widely varying equality and inequality constraints. The addition of CHP units to the electrical system increases the complexity of the problem due to interdependencies of the heat and power generating units in the problem[9]. Proposed technique is found to be effective in solving a wide range of engineering problems [6] wherein particles fly around in a multidimensional search space and the swarm direction of a particle is defined by set of particles neighboring the particle and its history experience [11].

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