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Biogeography-Based Optimization for the solution of the Combined Heat and Power Economic Dispatch Problem

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***Abstract*— in this paper a new approach for the solution of THE COMBINED HEAT AND POWER ECONOMIC DISPATCH PROBLEM (CHPED) is being presented using BIOGEOGRAPHY-BASED OPTIMIZATION (BBO). BIOGEOGRAPHY-BASED OPTIMIZATION (BBO) is a type of evolutionary algorithm which is based on the theory of biogeography and is inspired from the two concepts-migration of species between "islands" via flotsam, wind, flying, swimming, etc. and mutation. The proposed test system takes into account seven units and also a comparison with ARTIFICIAL BEE COLONY ALGORITHM (ABC) is being made. From the results it is seen that BBO provides best solution than ABC.**

***Index Terms*—Artificial Bee Colony Algorithm (ABC), Biogeography-Based Optimization (BBO), Combined Heat and Power Economic Dispatch Problem (CHPED), Cogeneration.**

I. INTRODUCTION

The main objective of economic dispatch is to minimize the total generation cost such that the demand and constraints are satisfied, that is, we have to optimally generate power generation. We initially assume some values such that the demand and losses are met. In thermal power plants, there are steam driven turbines. As far as steam is considered, the important factors are it's temperature and pressure. The admitted steam will be having a typical value of temperature and pressure. But on the output side of the turbine, this steam will be having a pressure and temperature which will be lower than the typical value. We have to utilize this steam that means we have to consider the thermal limits of the system that is the main objective of this project. Say, this steam could be used to preheat water or in case of coal fired systems this steam out can be used to dry the coal etc. In short, here we are combining the emission problem along with the power economic dispatch problem. Earlier both these problems were considered as separate ones. In Lambda-iteration method we alter the initial values such that the output will be minimum. In optimization method using BBO new species is not generated, only existing ones are modified. In [1], ABC algorithm was developed for the CHPED problem, but from the results this method did not provide better results than the proposed method. In [3] a dual quadratic programming technique was developed for solving the CHPED problem. Guo *et al.*, [4] converted the CHPED problem into two sub-problems, heat dispatch and power dispatch problem. Sudhakaran *et al.*, [5] tested a four-unit system employing a hybrid genetic algorithm with tabu search(GT). Subharaj *et al.*, [6] applied self adaptive real-ended genetic algorithm (SARGA). Wang *et al.*, [7] developed multi objective PSO for solution of the CHPED problem. In [8] a hybrid DE was explained. In [9] and [10] swarm intelligence techniques were given for solving the same. But all of these methods did not take into account the transmission losses and also required much computational time. This paper proposes BBO algorithm for solution of the CHPED problem. From the comparison with ABC algorithm it is clear that BBO solution has lower production cost.

II. PROBLEM FORMULATION

The test system consists of a total of seven units, of which first four of them are real power units, fifth and sixth are real power and heat units (that means cogeneration or combined units) and the seventh one is the heat only unit.

The objective function is as follows:

Minimize

$$\sum_{i=1}^{\alpha} F_{ti}(p_i) + \sum_{i=\alpha+1}^{\beta} F_{ci}(P_i,H_i) + \sum_{i=\beta+1}^{n} F_{hi}(H_i) \quad (1)$$

s.t. equality constraints

$$\sum_{i=1}^{\alpha} Pi + \sum_{i=\alpha+1}^{\beta} Pi = P_D + P_l \quad (2)$$

$$\sum_{i=\alpha+1}^{\beta} Hi + \sum_{i=\beta+1}^{n} Hi = H_D \quad (3)$$

And inequality constraints

$$P_i^{min} \le P_i \le P_i^{max} \quad (4)$$

$$P_i^{min}(Hi) \le P_i \le P_i^{max}(Hi) \quad (5)$$

$$H_i^{min}(Pi) \le H_i \le H_i^{max}(Pi) \quad (6)$$

$$H_i^{min} \le H_i \le H_i^{max} \quad (7)$$

The losses are calculated using the transmission loss equation as:

$$P_L = \sum_{i=1}^{\beta}\sum_{j=1}^{\beta} P_i B_{ij} P_j \quad (8)$$

F_{ti}, F_{ci}, F_{hi} Fuel characteristics of respective real power, cogeneration and heat units

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H_D, P_D System heat and power demands
P^{min}, P^{max} Unit power capacity limits
H^{min}, H^{max} Unit heat capacity limits

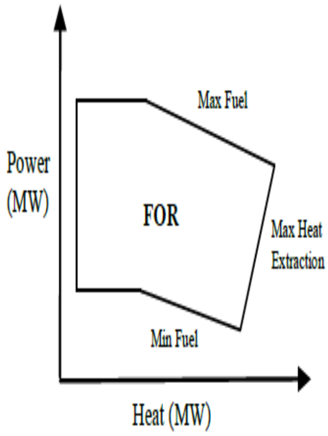

Fig 1: Cogeneration unit feasible operation region

The system under consideration has power only units, combined heat and power units, and heat- only units. Figure 1 shows the heat-power Feasible Operation Region (FOR) of a combined cycle cogeneration unit. The feasible operation is enclosed by the boundary curve. FOR means the cost must be minimized as well as constraints must be satisfied within the stipulated limits.

III. BIOGEOGRAPHY-BASED OPTIMIZATION

A. Algorithm

Biogeography is the study of the geographic distribution of biological organisms. BBO is the optimization technique which was developed on the basis on this biogeography concept was given by Dan Simon in the year 2008[2]. The different terms associated with this algorithm are explained as follows. A population or island is geographically isolated from one another and this is termed as a habitat. The habitat where the species thrive well is said to have a high HSI, that is, Habitat Suitability Index, which means, some islands are more suitable for habitation than others. Habitability is related to features such as rainfall, topography, diversity of vegetation, temperature, etc. and these factors are collectively known as Suitability Index Variables (SIVs). In BBO, we can also see how species migrate from one population to another population. Suppose in a particular location A, people have a tendency to settle in a developed location B. This is termed as immigration. There also exists a case where the economically backward settle in location A itself. And this is known as emigration. Say in location B attractive salary is one of the factors besides several luxuries. That is here cost is the objective function and the above explanation implies the if the objective function is higher people move towards that particular location. In location A immigration rate is higher and in location B emigration rate is higher i.e., in overall, the total exchange will be the same. In short, population will be higher where the objective function is higher. Say, if there are three locations, we have to see where the objective function is higher, that means we have to choose the best location. We will be getting the feedback or information from those who are well settled in location B. This is known as mutation and correspondingly we have mutation factor (i.e., from where the knowledge comes). HSI, that is, the suitability means the environment. The environment includes different factors like climate etc. and these factors are collectively known as SIVs. Mathematical modeling of BBO is given as follows. If Ps(t) denotes the probability that a habitat contains exactly S species at time t, at time t+Δt the probability is:

$$P_s(t+\Delta t) = P_s(t)(1 - \lambda_s\Delta t - \mu_s\Delta t) + P_{s-1}\lambda_{s-1}\Delta t + P_{s+1}\mu_{s+1}\Delta t \quad (9)$$

Where λ_s immigration rate
μ_s emigration rate
If time Δt is negligible, then the following equation results:

$$P_s = \begin{cases} -(\lambda_s + \mu_s)P_s + P_{s+1}\mu_{s+1}; & S = 0, \\ -(\lambda_s + \mu_s)P_s + P_{s+1}\mu_{s+1} + P_{s-1}\lambda_{s-1} & 1 \le S \le S_{max} - 1 \\ -(\lambda_s + \mu_s)P_s + P_{s-1}\lambda_{s-1}; & S = S_{max} \end{cases} \quad (10)$$

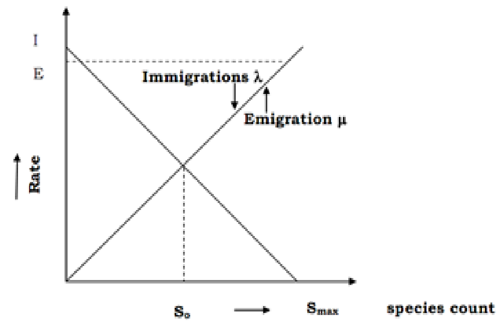

Fig 2: Species Model of a Single Habitat

From figure 2;

$\mu_k = E * k / n$ (11)

$\lambda_k = I * (1 - k/n)$ (12)

Where E maximum emigration rate
I maximum immigration rate
n total number of species in that habitat
When E=I

$\lambda k + \mu k = E$ (13)

From figure 1, the following conclusions are drawn:
As habitat suitability improves:

- The species count increases
- Emigration increases (more species leave the habitat)
- Immigration decreases (fewer species enter the habitat)

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B. Migration

Here we have Pmod, which is known as the Modification Ratio where the solution is modified according to this ratio. For the modification of a particular solution we use it's immigration rate λ_i to probabilistically decide whether or not to modify each suitability index variable (SIV) in that solution. If a given SIV in a given solution Si is selected to be modified, then we use the emigration rates μ_j of the other solutions to probabilistically decide which of the solutions should migrate a randomly selected SIV to solution Si.

C. Mutation

The term mutation refers to a sudden change or a sudden variation. In the context of BBO this indicates variation in the population due to spontaneous changes. Mutation rate can be calculated as follows:

$$m(s) = m_{\max}\left[\frac{1-P_S}{P_{\max}}\right] \quad (14)$$

Where mmax user-defined parameter.

By using mutation factor, we need to develop the random values. This mutation has a probability and based on this we have to do the modifications. If this mutation probability is greater than the random value, we have to modify the mutated value. And consequently we arrive at the best solution. We have the migration as well as the mutation updation in order to avoid the pre-convergence problem.

C. Steps used in BBO Algorithm

1. Initialize a set of solutions to a problem
2. Compute "fitness" (HSI) for each solution
3. Compute S, λ, and μ for each solution
4. Modify habitats (migration) based on λ, μ
5. Mutation
6. Typically we implement elitism
7. Go to step 2 for the next iteration if needed

IV. OUTPUT AND RESULTS

The test data containing valve point effects coefficients of fuel cost equations and loss coefficients are obtained from [1] and [11]. The results are as indicated in table 1.

	BBO	**ABC**
P1 (MW)	46.115	76.269
P2 (MW)	103.375	122.662
P3 (MW)	146.188	174.571
P4 (MW)	227.891	251.269
P5 (MW)	100.053	100.132
P6 (MW)	46.729	46.412
H5 (MWth)	22.256	48.990
H6 (MWth)	18.865	52.946
H7 (MWth)	129.552	129.688
P1 (MW)	7.515	7.993
Cost ($)	10563.548	10588.328

Table 1: Results obtained from BBO and ABC

V. CONCLUSION

This paper has presented a BBO algorithm for the solution of the CHPED problem. BBO has given the best solution satisfying the constraints as well as demand. BBO is an efficient algorithm for optimization and is good at exploiting the solutions. Also, the solutions doesn't die at the end of each generation like other optimization algorithms. The inclusion of security constraints in this problem is limited to due to the insufficiency of line and bus data for power and heat dispatch. Further modifications are possible using other variations of BBO.

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