The Solution of Economic Dispatch for 26 Bus Power System Using Chaotic Ant Swarm Optimization (CASO)

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Abstract — **This paper proposed Chaotic Ant Swarm Optimization (CASO) method to solve the problems of economic dispatch of thermal generators in power system. The algorithm combines the behavior of ant colonies that have a smart and organized action in the irregularities of each individual ant in the foraging process. In this method, the active power generated by each generating unit which is a candidate solution will be represented by each individual ant. Through the process of self-organization, the ants behave as individuals in the initial conditions will behave the same, which is the optimal solution. Simulation results demonstrated that the method can obtain feasible and effective solutions, and it is a promising alternative approach for solving the Economic Dispatch problems in the 26-bus power systems.**

Keywords— **Chaotic ant swarm optimization, economic dispatch, ant colony, swarms intelligent.**

I. Introduction

Common problems faced by electric power system operation is how to produce an optimal output power with minimize operating costs. The level of electricity demand increased operating expenses resulted in the rising generation. To serve the energy needs, generating machines are connected in a web of electric power systems; require a function which can minimize power costs caused by the changing energy needs of each period of time.

Predicted increase in the burden of each period of time required to optimized economic dispatch in power systems, so that can be estimated the amount of energy that must be raised to meet the needs of a changing load.

Power system optimization problems have attracted the attention of researchers since the use of electricity as the main energy source. There have been many mathematical optimization methods developed for settlement of economic dispatch optimization problem, namely: the gradient method [1], linear programming algorithm [2]. To solve the problem of operation of generating units by ignoring thermal losses from the transmission used lambda iteration method [3], quadratic programming [4], non-linear programming algorithm [5], Lagrangian relaxation algorithm [6]. Artificial intelligence technology has improved developed to solve economic dispatch problems, such as genetic algorithm [7-9], neural networks [10.11], simulated annealing and tabu search [12], evolutionnary programming [13.14], particle swarm optimization [15], ant colony optimization [16]. Jiejin Cai et al. presented an algorithm called Chaotic Ant Swarm Optimization (CASO) which combined the chaotic behavior of individual ant and the intelligent organization actions of ant colony, and successfully employed it to solve ED problems in three different power systems [17].

In this paper, we developed CASO approach for solving the ED problem in power system. The proposed CASO method for the ED was demonstrated to be feasible by the application in the 26-bus power systems.

II. Mathematical Model of Economic Dispatch

The ED problem is to determine the optimal combination of power generations for minimizes the total generation cost and satisfies various constraints. Its mathematical model can be mathematically described as follows:

1. Objective Function

The purpose of the ED is minimize the total generation cost rate and considering the load demand control system for a suitable period while satisfying various equality and inequality constraints. The objective functions as follow:

$$\min F_t = \sum_{i=1}^{m} F_t(P_i) = \sum_{i=1}^{m} \left(a_i P_i^2 + b_i P_i + c_i\right) \quad (1)$$

where,

F_t : The total cost of generating units.
F_i : The cost functions of ith of generator.
P_i : The electrical output of ith of generator.
a_i, b_i, c_i : The cost coefficient of ith of generator.
m : The number of generators committed to the operating system.

2. Power balance constraint

$$\sum_{i=1}^{m} P_i = P_D + P_L , \quad i = 1,\ldots\ldots\ldots\ldots, m \qquad (2)$$

Where P_D is the total load demand, and P_L is the transmission network losses, which is a function of unit power outputs that can be represented using kron's loss formula:

$$P_L = \sum_{i=1}^{m}\sum_{j=1}^{m} P_i B_{ij} P_j + \sum_{i=1}^{m} B_{0i} P_i + B_{00} \qquad (3)$$

3. Generation limits constraint

$$P_{i\min} \le P_i \le P_{i\max} \qquad (4)$$

where P_{imin} and P_{imax} is the minimum and maximum generation limit (MW) of *i*th generator.

III. Chaotic Ant Swarm Optimization [17]

CASO is essentially a search algorithm based on the chaotic behavior of individual ant and the intelligent organization actions of ant colony. In CASO, the search behavior of the single ant is chaotic at first, and the organization variable r_i is introduced to achieve self-organization process of the ant colony. Initially the influence of the organization variable on the behavior of individual ant is sufficiently small. With the continual change of organization variable evolving in time and space, the chaotic behavior of the individual decreases gradually. Via the influence of the organization variable and the communication of previously best positions with neighbors, the individual ant alters his position and moves to the best one they can found in the search space. In order to simulate the behaviors of ants in nature, according to the distance between ant and their neighbors, a definition of neighbor, called *dbest*, is introduced. The general algorithmic model of CASO is shown as follows

The searching area of ants corresponds to the problem search space. The algorithm searches for optima in the search space R^l, which is the *l*-dimensional continuous space of real numbers. A population of *K* ants is considered. These ants are located in a search space *S* and they try to minimize a function *f*: *S*→*R*. Each point *s* in *S* is a valid solution to the considered problem. The position of an ant *i* is assigned the algebraic variable symbol $S_i = (z_{i1}, \ldots, z_{il})$, where *i*=1, 2, . . ., *K*. Naturally each variable can be of any finite dimension. During its motion, ach individual ant is influenced by the organization processes of the swarm. In mathematical terms, the strategy of movement of a single ant is assumed to be a function of the current position, the best position found by itself and any member of its neighbors and the organization variable:

$$y_i(n) = y_i(n-1)^{1+r_i}$$

$$Z_{id}(n) = \left(Z_{id}(n-1) + \frac{7.5}{\psi_d}\right) exp\left(\left(1 - exp(-a y_i(n))\right)\left(3 - \psi_d\left(Z_{id}(n-1) + \frac{7.5}{\psi_d}\right)\right)\right) - \frac{7.5}{\psi_d} V_i + exp(-2a y_i(n) + b)\left(P_{id}(n-1) - Z_{id}(n-1)\right) \qquad (5)$$

where *n* means the current time step, *n*−1 the previous step, $y_i(n)$ the current state of the organization variable, $y_i(0) = 0.999$, *a* a sufficiently large positive constant and can be selected as *a* = 200, *b* a constant and $0 \le b \le 2/3$, r_i □ (0,0.5) a positive constant less than one and is termed by us as the organization factor of ant *i*, $z_{id}(n)$ the current state of the *d*th dimension of the individual ant *i*, *d*=1, 2, . . ., *l*, ψ_d determines the selection of the search range of *d*th element of variable in search space, and $0 \le V_i \le 1$ determines the search region of *i*th ant and offers the advantage that ants could search diverse regions of the problem space. The values *Vi* should be appropriately selected according to the concrete optimization problems. In this model we can select the initial position of individual ant as

$$Z_{id}(0) = \frac{7.5}{\psi_d}(1 - V_i)rand(\,), \text{ where } \psi_d > 0 \qquad (6)$$

The neighbor selection can be defined as the following two ways. The first is the nearest fixed number of neighbors. The nearest *m* ants are defined as the neighbors of single *i*th ant. The second ways of the number of neighbor selection is to consider the situation in which the number of neighbors increasing with iterative steps. This is due to the influence of self-organization behaviors of ants. The impact of organization will become stronger than before and the neighbors of the ant will increase. That is to say, the number of nearest neighbors is dynamically changed as time evolves or iterative steps increase. The number *q* of single ant is defined to increase for every *T* iterative steps.

The general CASO is a self-organizing system. When every individual trajectory is adjusted toward the successes of neighbors, the swarm converges or clusters in optimal regions of the search space. The search of some ants will fail if the individual cannot obtain information about the best food source from their neighbors.

IV PROPOSED METHODE

CASO used to determine the optimal power of each generating unit operating at a certain period in order minimize the total generation cost.

Let the generation power output of each unit be a parameter element. The elements of all the units, which are submitted to operate at the specific period, comprise a vector that means the position of an individual ant and represents a candidate solution for the ED problems. Many individual ants (expressed by the position parameters) constitute an ant swarm which is called a population. For example, if there are m units that must be operated to provide power at the specific period, then the ith individual ant Pgid can be defined as follows:

$$P_{gid} = [P_{i1}, P_{i2}, \ldots, P_{im}],\ i = 1, 2, \ldots, N \qquad (7)$$

where N is the population size, which means the total number of the ant swarm, m is the number of generators for dispatch, and P_{im} is the generation power output of the mth unit at ith individual ant. The dimension of a population is $N\times m$. The fitness of each ant individual is evaluated by the evaluation function. Considering the generation cost function and the power balance constraint as in (1) and (2), we choose the sum of them as the evaluation function, which is shown as (8)-(10)

$$f = F_{cost} + P_{pbc} \qquad (8)$$

$$F_{\cos t} = \sum_{i=1}^{m}\left(a_i P_i^2 + b_i P_i + c_i\right) \qquad (9)$$

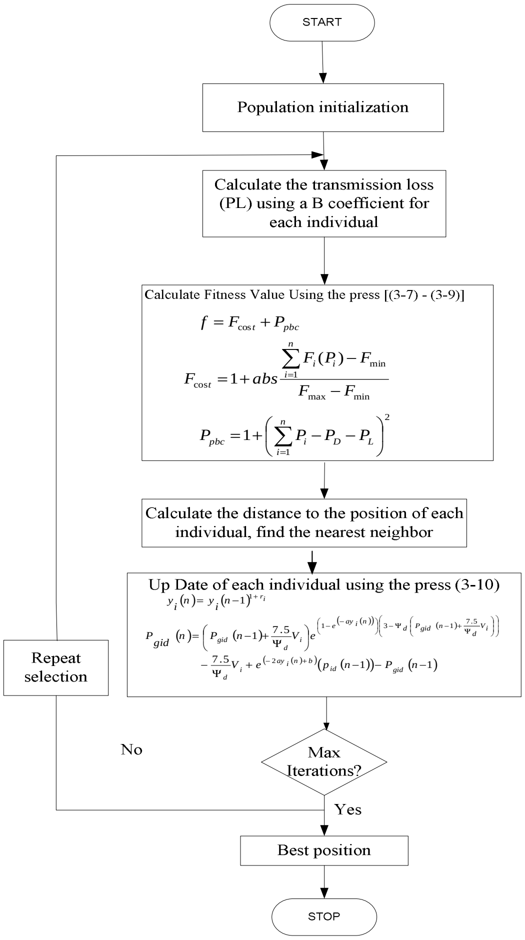

Figure 1. One-line diagram of 26 bus system

$$P_{pbc} = 1 + \left(\sum_{i=1}^{n} P_i - P_D - P_L\right)^2 \qquad (10)$$

Before estimating the power output must satisfy the constraints in (3) and (4), thus evaluation value of each individual, the generation we limit the evaluation value of each individual of the population within a feasible range. If one individual satisfied all the constraints, then it was a feasible individual and F_{cost} had a small value. Otherwise, we penalized the F_{cost} value of the individual with a very large positive constant.

The search procedures of the proposed CASO for ED problem are described as follows:

1. Specify the lower and upper bound generation power load of every unit. Randomly generate the initial positions of all the ants in the search space. These initial ant individual positions must be feasible candidate solutions that satisfy the practical operation constraints. Set the initial organization variable $yi(0)$ as 0.999.
2. For each individual ant position Pgid in the ant swarm, calculate the transmission loss PL using the kron's loss Formula (3). If the transmission loss is not considered, go to step 3 directly.
3. Calculate the evaluation value of each individual ant position Pgid in the ant swarm (population) employing the evaluation function f given by (8)–(10).
4. Let the ants communicate with their neighbors, calculate the distances between positions of each ant, find the nearest neighbors of each ant, and find the best position *pid* in this step.
5. Update every individual ant position in the swarm and the organization vector according to (11).

$$P_{gid}(n) = \left(P_{gid}(n-1) + \frac{7.5}{\psi_d}\right)\exp\left(\left(1-\exp(-ay_i(n))\right)\left(3-\psi_d\left(P_{gid}(n-1)+\frac{7.5}{\psi_d}\right)\right)\right) - \frac{7.5}{\psi_d}V_i + \exp(-2ay_i(n)+b)\left(P_{id}(n-1) - P_{gid}(n-1)\right) \qquad (11)$$

6. If the iterations number reaches the maximum, then goto step 7. Otherwise, go back to step 2.
7. The best position *pid* at last step of the ant swarm is means the optimal generation power output of the units.

V. SIMULATION RESULTS

The IEEE 26-bus test system is used as plant for simulation. The system consists of 6 generator buses and 20 bus loads. Figure 2 shows the configuration of the system. The details of the characteristics and data of this system are given in Ref. [18]. The generator's operating costs in \$/h,with P_i in MW are as follow :

$H_1 = 240 + 7.0\,P_1 + 0.0070\,P_1^2$
$H_2 = 200 + 10.0\,P_2 + 0.0095\,P_2^2$
$H_3 = 220 + 8.5\,P_3 + 0.0090\,P_3^2$

$$H_4 = 200 + 11.0\,P_4 + 0.0090\,P_4^2$$
$$H_5 = 220 + 10.5\,P_5 + 0.0080\,P_5^2$$
$$H_{26} = 190 + 12.0\,P_{26} + 0.0075\,P_{26}^2$$

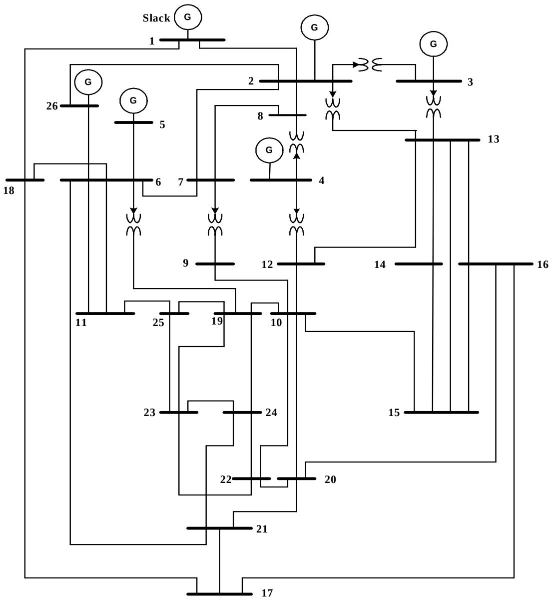

Figure 2. One-line diagram of 26 bus system [18]

Tabel 1. Best Solution of 26 Bus Power System

Methode		CASO	Lagrange
Optimal Dispach Of Generation (MW)	P1	446,596	447,692
	P2	171,244	173,194
	P3	261,363	263,486
	P4	134,053	138,814
	P5	178,752	165,588
	P26	83,800	87,026
Total Losses (MW)		12,801	12,807
Total Generation Cost ($/h)		15446,8	15447,72

As seen in Table 4, CASO method gets a different load dispatch scheme from Lagrange method. As an operating result, the total generation cost using CASO is better than Lagrange method.

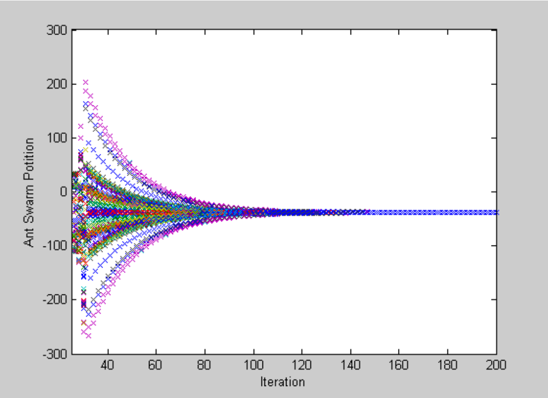

Figure 3. Plot of the ant swarm potition as function of iteration

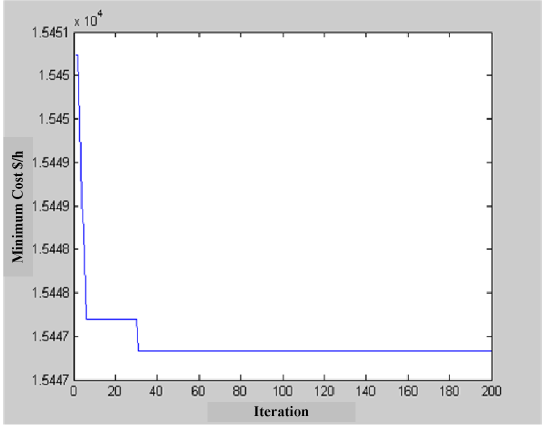

Figure 4. Plot of the minimum losses as function of iteration

Figure3 depict the ant swarn potition as function of iteration. Figure. 4 depicts the minimum losses as function of iteration when objective function was used. According this figure indicate that population of antibodies converged in 30 iteration.

IV. CONCLUSION

This paper developed a novel CASO for solving the ED problems of thermal generators in power systems. The proposed algorithm was successfully employed to solve the ED problem considering some constraints, such as power balance constraints and generation limits constraints. The numerical simulation results show that the CASO is feasible for solving ED problem for practical power systems.

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