Economic dispatch of electric power using clone optimization technique

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ABSTRACT
The main aim of this paper is to solve the economic dispatch problem (EDP). The objective of the EDP of electric power generation, whose characteristics are complex and highly nonlinear, is to schedule the committed generating unit outputs so as to meet the required load demand at minimum operating cost while satisfying system constraints. Hence, for economic operation of the system, the total demand must be suitably shared among the generating units with an objective to minimize the total generation cost for the system. Economic Dispatch is a procedure to determine the electrical power to be generated by the committed generating units in a power system so that the total generation cost of the system is minimized, while satisfying the load demand simultaneously. An clone optimization technique for solving the economic dispatch problem in a power system is very useful and gives accurate result compared to other classical methods. The proposed technique implemented Clonal Selection algorithm with cloning, mutation and selection approaches. For solving economic load dispatch problem this approach was tested. For generating unit at varies loading condition, the feasibility of proposed technique was demonstrated on a system. The Artificial Immune System optimization technique with Reproduction Crossover and mutation has provided the best result in terms of cost minimization and least execution time.

Introduction
The system consisting of generating station’s transmission lines and distribution system which provide continuous and reliable electrical energy is called power system. Clone optimization technique provide the information about exact loading of generators when there are number of generators having different fixed & variable cost [1]. The power demand is shared among the generating units and economic of operation is the main consideration in assigning the power to be generated by each generating units. The procedure to ensure for economic operation of a power system is called Economic Dispatch (ED). Economic Dispatch problem is an optimization problem that determines the optimal output of online generating units so as to meet the load requirement with an objective to minimize the total generation cost [2]. Various mathematical methods and optimization techniques have been employed to solve for ED problems. Among the conventional methods that were previously used include lambda iteration method, base point and participation method and the gradient method [3]. These numerical methods assumed the incremental cost curves of the generating units are monotonically increasing piecewise linear functions. However, this assumption may cause these methods to be infeasible because of the nonlinear characteristics of the actual systems. Dynamic programming (DP) method was implemented for solving the ED problem. Nevertheless, the DP method may cause the dimensions of the ED problem becomes extremely large, hence requires massive computational effort. In the past decade, global optimization techniques such as simulated annealing (SA), genetic algorithms (GAs) and evolutionary programming (EP) have been increasingly used to solve for power system optimization problems [4]. The SA method is an optimization approach in accepting candidate solutions in the search process so that it can jump out from the local optimal solutions to approach the near global solution [5]. On the other hand, it is difficult to appropriately set the control parameters of the SA based algorithm and in addition, the speed of the algorithm is slow when applied to real power system problems [6]. GAs have been successfully employed to solve for economic dispatch problem due to its ability to model any kind of constraints using various chromosome coding scheme according to specific problem [7]. However, long execution time and non-guaranteed in convergence to the global optimal solution contribute the main disadvantages of GAs [7]. Similarly, evolutionary programming optimization technique long execution time posed its main disadvantage [8]. Artificial immune systems can be defined as metaphorical systems developed using ideas, theories and components, extracted from the natural immune system [9]. The natural immune system is a very complex system with several mechanisms for defense against pathogenic organisms. The main purpose of the immune system is to recognize all cells within the body and categories those cells as either self or non self. The immune system learns through evolution to distinguish between dangerous foreign antigens and the body’s own cells or molecules. From an information-processing perspective, the immune system is a remarkable parallel and distributed adaptive system. It uses learning, memory and associative retrieval to solve recognition, classification and optimization tasks [10]. A few computational models have been developed based several principles of the immune system such as immune network model, negative selection algorithm, positive selection algorithm and clonal selection principle [11,12]. In this paper, a new method for solving ED problem based on the clone optimization technique is presented.
The total generation cost is taken to be the affinity measure for the clone optimization-based ED problem. Individual with lower total generation cost is considered to have higher affinity. The aim of the clonal operator is to produce a variation in the population around the parents according the affinity [13]. Hence, the searching area is enlarged and therefore the problem can be solved better, avoiding premature convergence. Several loading scenarios on a practical system having 18 generating units with a number of inequality and equality constraints were investigated in order to demonstrate the robustness and feasibility of the proposed technique.

**Economic load Dispatch Mathematical Expression:**

The economic dispatch problem (EDP) is to determine the optimal combination of power outputs of all generating units to minimize the total fuel cost while satisfying the load demand and operational constraints. It plays an important role in operation planning and control of modern power systems. Under a new deregulated electricity industry, power utilities try to achieve high operating efficiency to produce cheap electricity. Therefore, precise generation costs analysis required [14]. Solving the Economic Dispatch optimization problem with an objective to minimize the total cost of generation. The solution gives the optimal problem is to solve an generation output of the online generating units that satisfy the system’s power balance equation under various system and operational constraints. The Economic Dispatch problem can be formulated mathematically as follows: Equation (1) is the total generation cost to be minimized and therefore the objective function to the problem. Its value is taken to be the affinity to individual in the clone optimization technique.

\[
P_T = \sum_{i=1}^{N} P_i \sum_{j=1}^{n} f_i(P_i)
\]

Equation (1)

\[
F_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2
\]

Equation (2)

The cost of power generation for each generating unit is given by equation (2). Parameters \( \alpha_i, \beta_i, \gamma_i \) in the equation symbolizes constants on the Input-Output Curve of a generating unit. The ED problem considered in this paper is the classic ED, wherein the losses are neglected. Hence, the power balance equation is given by equation (3), which is the equality constraint that has to be satisfied. While equation (4) is the inequality constraint, indicating the generation limits for each generating unit in the system.

\[
P_T = P_1 + P_2 + P_3 + \cdots + P_N = P_D
\]

Equation (3)

\[
P_{i_{\min}} \leq P_i \leq P_{i_{\max}}
\]

Equation (4)

**How Does the Immune System Work?**

The immune system defends the body from attack by invaders recognized as foreign. It is an extraordinarily complex system that relies on elaborate and dynamic communications network that exists among the many different kinds of immune system cells that patrol the body. At the heart of the system is the ability to recognize and respond to substances called antigens whether they are infectious agents or part of the body (self antigens).

<table>
<thead>
<tr>
<th>Killer cell</th>
<th>Target cell (infected with virus)</th>
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</thead>
<tbody>
<tr>
<td>Target-located</td>
<td></td>
</tr>
</tbody>
</table>
Surface contact

Death of both cell and virus

**Immune system and artificial immune system:** When some optimization concept like crossover, mutation and tournament selection add with immune system concept then new concept generates that is called Artificial immune system concept. Artificial immune systems can be defined as metaphorical systems developed using ideas, theories and components, extracted from the natural immune system.

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**Clonal Selection Algorithm:** - The immune process described in section 3.0 & 3.1 is known as Clonal Selection Algorithm. Only those cells that recognized the specific antigens would be selected to produce offspring and thus go through the process of affinity maturation. In the selection stage, B cells with high similarity with respect to an antigen i.e recognized the antigen; are activated and stimulated to proliferate producing a large number of clones. In the maturation process, these clones mutate and turn into plasma cells which then secrete large number of antibodies. Some of the B cells clones mature into memory cells that have the memory of the antigenic pattern for future infections. The antibodies secreted from the second response would have higher affinity than those of the earlier response. In the computational point of view, this strategy suggests that the process perform a greedy search, where the individual will be locally optimized and the newcomers would yield a broader exploration of the search space. This characteristics makes the clonal selection algorithm is suitable for solving multi-modal optimization problems.

When the clonal selection algorithm is implemented for solving optimization problem, a few adaptations have to be made as follows [12]:-

a) An objective function is optimized without explicit antigen recognition. Therefore the affinity of an antibody refers to the evaluation of the objective function.

b) All antibodies are to be selected for cloning.

c) The number clones generated by the antibodies are equal.

However, this study investigated the effect of varying the number of clones according to the affinity and the results were compared to that obtained from standard cloning process.

**Implementation of Clone Optimization Technique for Solving Economic Dispatch:-**

The developed clone optimization technique using Clonal Selection algorithm was implemented to solve the economic dispatch problem on a practical system having 18 generating units [7]. Real number was used to represent the attributes of the antibodies. Each antibody attribute will be in a form of a pair of real valued vector (xi,dj), dj ∈ {1,...,μ}, where μ is a strategy parameter[13]. Each antibody will go through the mutation process according to the expression given by equations (5) and (6).

\[ D_I(j) = D_I(j) \exp(TN(0,1)+TN(0,1)) \]  \hspace{1cm} (5)

\[ X_I(j) = X_I(j) + D_I(j) N(j,1) \]  \hspace{1cm} (6)

where,

\[ N(0,1) \] is a normally distributed random number with zero mean and standard deviation equals to one.

\[ T = (2n)^{1/2} / (1/2) - 1 \]  \hspace{1cm} (7)

\[ \bar{T} = (2n)^{1/2} - 1 \]  \hspace{1cm} (8)

n = number of attribute for an antibody

The clonal selection was implemented according to the following procedures [15]:-

a) Initial population is formed by a set of randomly generated real numbers. Each antibody was tested for any constraint violation using equations (3) and (4). Only antibodies that satisfy the constraint are included in the population set.

b) The similarity value of each antibody in the population set is evaluated using equation (1).

c) Clone the individuals in the population, giving rise to a temporary population of clones.

d) The population of clones undergoes maturation process through genetic operation i.e mutation. The fitness of the mutated clones are evaluated.

e) A new population of the same size as the initial population is developed based on the fittest antibody will produce more clones compared to weaker ones. Equation (7) is implemented to determine the number of clones according the affinity measures or the fitness.

\[ \text{No. of clones} = \frac{f_i}{\sum f_i} \times 200 \]  \hspace{1cm} (9)

Results:- The generator operating limits and quadratic cost function coefficients for the 18 generators in the test system are as in reference [7]. The maximum total power output P of the generators is 433.22 MW. Various tests were made with varying percentage of the maximum power as the power demand. The results from the simulation are summarized in Table 1. These results give the minimum generation cost for each approach after 5-10 runs. It was observed from the runs, the variation in the cost of generation is very small. This table shows the minimum generation cost.

<table>
<thead>
<tr>
<th>Parameter Representation</th>
<th>Fitness(Minimum Generation Cost /Rs.)</th>
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<tbody>
<tr>
<td>75%P</td>
<td>951165</td>
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</table>

It can be observed that the minimum generating cost is obtained by the clone optimization technique that implemented cloning, mutation strategy and crossover with total generation cost of Rs 951165. The average execution time for technique is about 1 s. The results obtained from the proposed technique
implementing cloning, mutation strategy and crossover. From the results, it shows that the proposed technique has performed much better than the other classical optimization technique, GA [7]. The proposed clone optimization technique was much faster than the other techniques. It takes about 1 seconds to provide the optimal solution. The tests were carried out on an Intel(R) Core(TM) Duo CPU E7500 @ 2.93GHz, 2.94GHz personal computer.

Conclusion:

This paper introduces a new Clone optimization approach for the solution of ED problem with AIS. Real number representation of the antibody attributes was implemented that represent the optimal output of the generating units. Several modifications were made on the cloning, mutation and selection schemes of the developed Clone optimization technique. The results has shown that the proposed optimization technique with cloning scheme, mutation and crossover is capable to provide better results with reduced computation time. Hence, the study shows that clone optimization technique could be a promising technique for solving complicated optimization problems in power system operation.

References: