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Implementation of Social Group Optimization to Economic Load Dispatch Problem

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Abstract

Economic load dispatch (ELD) problem is a common task in the operational planning of a power system, which requires to be optimized. This paper presents an effective and reliable social group optimization (SGO) technique for the economic load dispatch problem. The performance of the proposed algorithm is investigated and tested with two standard test systems, the IEEE 14 bus with five units, IEEE 30 bus with 6 units and IEEE 57 bus with 7 units. The final results obtained using SGO are compared with PSO, DE and the results are found to be encouraging.

Keywords: Cost minimization**,** Differential Evolution Economic load dispatch, Particle swarm optimization, Social Group Optimization.

INTRODUCTION

The economic load dispatch (ELD) of power generating units has always occupied an important position in the electric power industry. ELD is a computational process where the total required generation is distributed among the generation units in operation, by minimizing the selected cost criterion, subject to load and operational constraints. For any specified load condition, ELD determines the power output of each plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load. ELD is used in real-time energy management power system control by most programs to allocate the total generation among the available units. ELD focuses upon coordinating the production cost at all power plants operating on the system. Hence, the electric demand at any instant is a continuously varying factor. So, the system is a dynamic one. Unless, there is some precious method to determine the behavior of the system, but it becomes difficult to predict the power flow, line losses, cost of generation etc. The job of the planning engineer becomes very complicated in predicting and forecasting to suit the changing needs. The increasing energy demand from the available energy source, decreasing fuel sources and increasing cost of power generation are another area which necessitates the study of economic load dispatch. In early day's unscientific method of approaches were tried for the cost-effective generation. Even with the transmission losses neglected these methods failed to minimize the cost. The solution methods for this problem are as follows. Preceding efforts on solving economic dispatch have employed various conventional methods and optimization techniques. This mathematical programming method includes Linear Programming, Gradient Method, Dynamic Programming, and Lambda iteration method and so on. The lambda iteration method is one of the important methods of mathematical programming and it is used in solving the optimal power dispatch of generators and system lambda. Lambda is the variable introduced in solving constraint optimization problem and called a Lagrangian multiplier. This is used in Gradient method and Newton method. It is important to note that the lambda can also solve manually. It is used in solving systems of equations. Lambda iteration is introduced for the benefit of computing lambda and other associated variables using a computer. In lambda iteration method, the unknown variable lambda, gets its next value based on intrusion. That is, there is no equation, compares the next iteration of lambda. It is projected by interpolating the best possible value until a specified mismatch has been reached.

Population-based optimization algorithms motivated from nature commonly locate near-optimal solution to optimization problems. Every population-based algorithm has the common characteristics of finding out global solution of the problem. A population begins with initial solutions and gradually moves toward a better solution area of search space based on the information of their fitness. Over the last few decades, numbers of successful population-based algorithms have been emerged for solving complex optimization problems. Some of the well-known population-based optimization techniques are comprehensively cited below, and readers can refer details in the respective papers.

The differential evolution (DE)[3,4] is based on being the most popular ones, are based on natural selection operators, it offers all solutions an equal chance irrespective of their fitness to get selected as parents. A technique based on swarm behavior such as fish schooling and bird flocking in nature known as Particle Swarm Optimization (PSO)[5,6] has been

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widely researched and applied to various fields of engineering-allied subjects.

To address few challenges like computational efforts, optimal solutions and consistency in providing optimal solutions, this paper proposes a new optimization technique named social group optimization (SGO) based on the human behavior of learning and solving complex problems. In this work, we have done extensive study to further investigate the performance of our proposed SGO[7] algorithm on ELD case. Furthermore, many behavioral traits such as caring, honest, compassionate, dishonesty, courageous, fearful, fair and respectful are desirable to be harnessed for solving complex problems. Group solving ability can provide more active solutions compared to the individual ability by exploring various traits of everyone in the group. In the current work, the SGO is presented to find the solution of Economical Load Dispatch problem. The results obtained by using SGO algorithm were compared with the PSO and DE algorithms

SOCIAL GROUP OPTIMIZATION (SGO)

The procedure of SGO is divided into two parts. The first part consists of the 'improving phase'; the second part consists of the 'acquiring phase'. In 'improving phase,' the knowledge level of each person in the group is enhanced with the influence of the best person in the group. The best person in the group is the one having the highest level of knowledge and capacity to solve the problem and in the 'acquiring phase,' each person enhances his/her knowledge with the mutual interaction with another person in the group and the best person in the group at that point in time. The basic mathematical interpretation of this concept is presented below.

Let $X_j ; j = 1, 2, 3, ...N$ be the persons of social group, i.e., social group contains N persons and each person X_j is defined by $X_j = (X_{j1}, X_{j2}, X_{j3}, ...X_{jD})$ where D is the number of traits assigned to a person which determines the dimensions of a person and $f_j ; j = 1, 2, 3, ...N$ are their corresponding fitness values, respectively.

Improving phase: The best person (gbest) in each social group tries to propagate knowledge among all persons, which will, in turn, help others to improve their knowledge in the group.

Hence, $g_{bestg} = \min\{f_i, i = 1, 2, ...N\}$ at generation g for solving minimization problem.

In the improving phase, each person gets knowledge (here knowledge refers to change of traits with the influence of the best person's traits) from the group's best (gbest) person. The updating of each person can be computed as follows:

for i=1:N

for j=1:D

$$X_{newij} = c * X_{oldij} + r * (gbest(j) - Xoldij)$$

End for

End for

where r is a random number, $r \sim U(0,1)$ Accept X_{new} if it gives a better fitness than X_{old} where c is known as self-introspection parameter. Its value can be set from $0 < c < 1$

Acquiring phase: In the acquiring phase, a person of social group interacts with the best person (gbest) of that group and interacts randomly with other persons of the group for acquiring knowledge. A person acquires new knowledge if the other person has more knowledge than him or her. The best knowledgeable person (here known as person having 'gbest') has the greatest influence on others to learn from him/her.

A person will also acquire something new from other persons if they have more knowledge than him or her in the group.The acquiring phase is expressed as given below:

$gbest = \min\{f_i, i = 1, 2, ...N\}$ *(* $X_i^{'}s$ are updated values at the end of the improving phase*)*

For i=1:N Randomly select one person X_r , where $i \neq r$

If $f(X_i) < f(X_r)$

for j=1:D

$$X_{newi,j} = X_{oldi,j} + r1 * (X_{i,j} - X_{r,j}) + r2 * (gbest_j - X_{i,j})$$

End for

Else

End for

Else

For j = 1 : D

$$X_{newi,:} = X_{oldi,:} + r1 * (X_{r,:} - X_{i,:}) + r2 * (gbest_j - X_{ij})$$

End for

End If

Accept X_{new} if it gives a better fitness function value. *End for*

where *r1* and *r2* are two independent random sequences, $r1 \sim U(0,1)$ and $r2 \sim U(0,1)$. These sequences are used to affect the stochastic nature of the algorithm as shown above in Equation. For further clarity and ease of implementation, the entire process is now presented in an easy-to-understand flowchart

IMPLEMENTATION OF SGO

The step-wise procedure for the implementation of SGO is given in this section.

Step 1: *Enumeration of the problem and Initialization of parameters: -*

Initialize the population size (*N*), number of generations (*g*),

number of design variables (D), and limits of design variables *(UL , LL).* Define the optimization problem as: Minimize the cost function f(X). Subject to $=(x_1, x_2, x_3, ..., x_D)$ so that $X_j = (x_{j1}, x_{j2}, x_{j3}, ..., x_{jD})$ where $f(X)$ is the objective function, and *X* is a vector for design variables such that $L_{Li} \le x_{,i} \le U_{L,i}$.

Step 2: *Initialize the population:* A random population is generated based on the features (number of parameters) and the size of population chosen by user. For SGO, the population size indicates the number of persons and the features indicate the number of traits of a person. This population is articulated as:

$$population = \begin{bmatrix} x_{1,1} & x_{1,2} & x_{1,3} & \cdots & x_{1,D} \\ \vdots & & & \ddots & \vdots \\ x_{N,1} & x_{N,2} & x_{N,3} & \cdots & x_{N,D} \end{bmatrix}$$

Step 3*: Improving Phase:*

Then, determine gbest . which is the best solution for that iteration. As in the improving phase, each person gets knowledge from their group's best, i.e., gbest

For i = 1 : N

For j = 1 : D

$$X_{newi,j} = c * X_{oldi,j} + r * (gbest(j) - X_{oldi,j})$$

End for

End for

The value of *c* is self-introspection factor. The valueof *c* can be empirically chosen for a given problem.We have set it to 0.2 in this work after thorough study of our investigated problems and *r* is a random number, $r \sim U(0,1)$ *a*ccept X_{new} if it gives better function value.

Step 4: *Acquiring phase*

As explained above, in the acquiring phase, a personof social group interacts with the best person, i.e.,gbest of the group and interacts randomly withother persons of the group for acquiring knowledge.The mathematical expression is defined in "Acquiring phase".

Step 5: *Termination criterion*

Stop the simulation if the maximum generation number is achieved; otherwise, repeat from Steps3–4.

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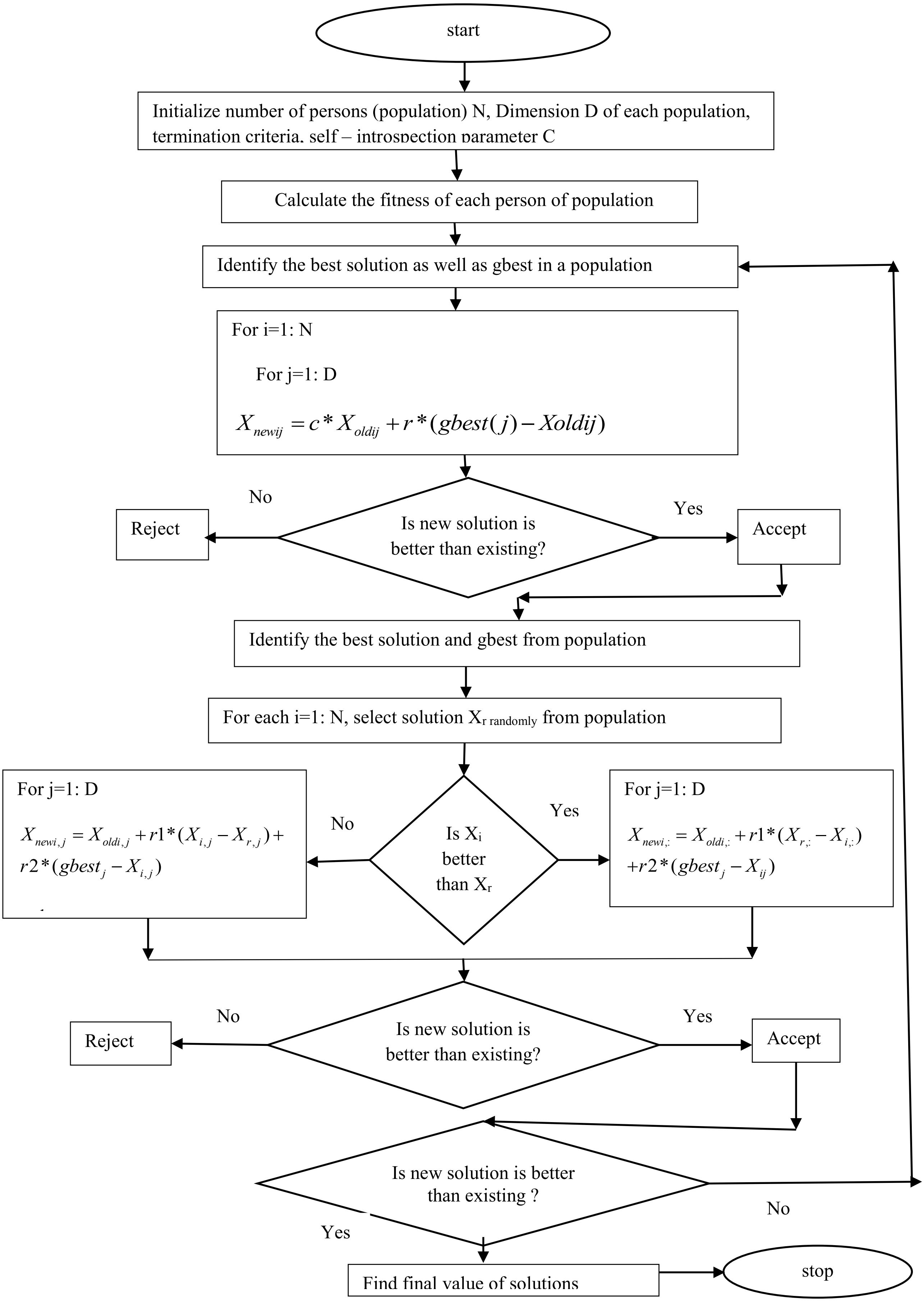

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ECONOMIC DISPATCH FORMULATION

The objective of an ELD problem is to find the optimal combination of power generations that minimizes the total generation cost while satisfying an equality constraint and inequality constraints. The fuel cost curve for any unit is assumed to be approximated by segments of quadratic functions of the active power output of the generator. For a given power system network, the problem may be described as optimization (minimization) of total fuel cost as defined F_T by under a set of operating constraints.

$$F_T = \sum_{i=1}^{n} F(P_i) = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i)$$

where is total fuel cost of generation in the system ($/hr.), a_i, b_i and c_i are the cost coefficient of the generator, P_i is the power generated by the i^{th} unit and n is the number of generators. F_T is the cost is minimized subjected to the following generator capacities and active power balance constraints.

$P_{i,\min} \le P_i \le P_{i,\max} for i = 1,2,...n$ Where $P_{i,\min}$ and $P_{i,\max}$ are the minimum and maximum power output of the i^{th} unit.

$P_D = \sum_{i=1}^{n} P_i$ where P_D is the total power demand and P_{Loss} is total transmission loss.

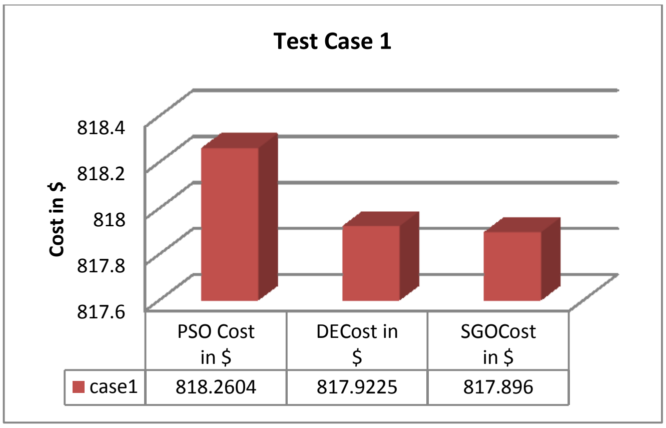
RESULTS AND DISCUSSION

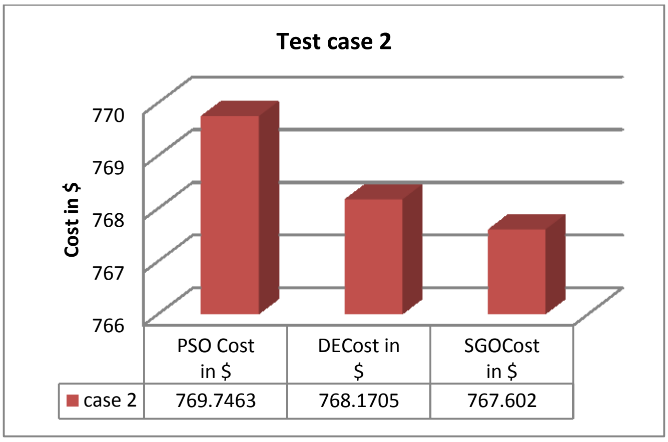
In this paper, Economic load dispatch problem was developed by social group optimization(SGO) algorithm and the results obtained are compared with the well-known evolutionary optimization algorithms like PSO and DE. The proposed algorithm was implemented on MATLAB R2013A with intel core i3 processor.

Test Case-1: IEEE 14-bus system with 5 generators and a total demand of 2.59 P. U is considered along with their generation constraints.

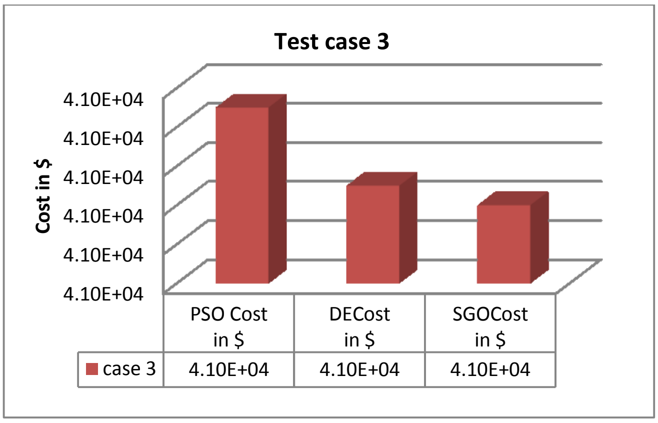
Test Case-2: IEEE 30-bus system with 6 generators and a total demand of 2.834 P. U is considered along with their generation constraints.

Test Case-3: IEEE 57-bus system with 7 generators and a total demand of 12.59 P. U is considered along with their generation constraints.





The time of operation of SGO in all the test cases is less when compared with standard PSO and DE with same number of particles as well as generations.



The following table shows the consolidated results for the proposed algorithm along with PSO and DE costs.

Test System	PSO Cost in $	DE Cost in $	SGO Cost in $
Case 1	818.2604	817.9225	817.896
Case 2	769.7463	768.1705	767.602
Case 3	4.1011e+04	4.1007e+04	4.1006e+04

From the above results the total cost of generation with 5 generating units is 818.26,817.9 and 817.89$ for different evolutionary algorithms i.e. PSO, DE and SGO respectively. There is a one-dollar decrement in the total cost of generation. Similarly, the total cost of generation is reduced when 6 and 7 generating units are considered. The proposed SGO algorithm is more suitable for higher test systems with more number of generating units.

CONCLUSION

The EDP problem is solved with the newly proposed Social group optimization algorithm for the different test cases. The results obtained were quite encouraging when compared with PSO and DE. The total cost of generation can be further reduced if more number of generating buses are considered. The proposed algorithm can further be implemented for solving optimal power flow problem by incorporating FACTS devices with certain set of constraints.

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