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A Solution to Economic Load Dispatch Problem Using Imperialistic Competition Algorithm

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Abstract: Electrical power industry restructuring has introduced a highly vibrant and competitive market which altered revolutionized many aspects of the power industry. In this changed scenario, the scarcity of energy resources, the ever increasing power generation cost, environmental concerns, ever growing demand for electrical energy necessitate optimal economic dispatch. This project presents a novel and efficient optimization approach the imperialistic competitive algorithm (ICA) for solving this ED problem. So before going to ED problem here we study the performance of ICA algorithm, show its efficiency and effectiveness, the ICA is applied to benchmark functions to understand its performance and way of attaining the given objective. Practical economic dispatch (ED) problems have nonlinear, non-convex type objective function with intense equality and inequality constraints. The conventional optimization methods are not able to solve such problems due to local optimum solution convergence. In the past decade, Meta heuristic optimization techniques especially Imperialist Competitive Algorithm (ICA) has gained an incredible recognition as the solution algorithm for such type of ED problems. The application of ICA in ED problem which is considered as the most complex optimization problem.

Key words: Economic Load Dispatch · Imperialist Competitive Algorithm · Power System

INTRODUCTION

ECONOMIC load dispatch (ELD) allocates generation among the committed generating units in the most economical manner subject to different operational constraints.Various investigations on ELD have been undertaken to date asbetter solutions would result in significant saving in operatingcost. The fuel cost characteristics of modern generating unitsare highly nonlinear with demand for solution techniques having no restrictions on to the shape of the fuel cost curves. The calculus-based methods fail in solving these types of problems. The dynamic programming approach, proposed by Wood and Wollenberg, though does not impose any restriction on the nature of the cost curves, but suffers from the curse of dimensionality and larger simulation time. Modern meta-heuristic algorithms are a promising alternative for solution of complex ELD problems.

In this paper, an imperialist competitive algorithm (ICA) is proposed to solve Economic load dispatch problems. ICA is recently proposed by Atashpaz-Gargari and Lucas. This algorithm is inspired by the imperialistic competitive. ICA has shown good performance in solving optimization problems in different areas such as template matching, DG planning,optimal design of plate-fin heat exchangersand electromagnetic problems. This algorithm also has been successfully applied to power system problems like as PSS (power system stabilizer) design, linear induction motor design, unit commitmentand model reduction of a detailed transformer model. The chaotic version of the ICA is presented infor global optimization [1].

Application of ICA to benchmark and large scale DED test cases showthat ICA is capable to find better results comparing with other heuristic algorithms.

Formulation of the Eld Problem

Smooth Economic Dispatch Problem: The objective of the ELD problem is finding the optimal combination of power generations that minimizes the total generation cost while satisfying an equality constraint and inequality constraints [2]. The most simplified cost function of each generator can be represented as a quadratic function as given in (2) whose solution can be obtained by the conventional mathematical methods (Wood AJ., & Wollenberg BF. 1984):

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$$C = \sum_{j \in J} F(P_j) \quad (1)$$

The economic dispatch is a non-linear programming optimization problem. The main objective is to minimize the total fuel cost at thermal plants subject to the operating constraints of power system. The most simplified cost function of each generator can be represented as a quadratic function given in (1) which can be solved by the mathematical method.

$$F_j(P_j) = \alpha_j + b_j P_j + c_j P_j^2 \quad (2)$$

where,
C: Total generation cost
F_j: Cost function of generator j
a_j b_j c_j: Cost coefficients of generator j
P_j: Electrical output of generator j
J: Set for all generators.

Constraints

Power Balance: While minimizing the total generation cost, the total generation should be equal to the total system demand plus the transmission network losses. However, the network losses are considered here. Thus, the equality constraint is given by:

$$\sum_{j \in J} P_j = P_D + P_L \quad (3)$$

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} P_j B_{i,j} P_j + \sum_{j=1}^{n} B_{0,j} P_j + B_{00} \quad (4)$$

where, P_0 is the total system demand, $B_{i,j}$, B_{0j} and B_{00} are the loss coefficients that can be assumed to be constant under a normal operating condition.

Generating Capacity: The generation output of each unit should be between its minimum and maximum limits i.e.: the following inequality constraint for each generator should be satisfied:

$$P_{i,min} \le P_j \le P_{j\,max} \quad (5)$$

where, $P_{i\ min}$ and $P_{j\ max}$ *i*s the minimum, maximum active power of generator j.

General Aspects of Ica: Evolutionary optimization algorithms are generally inspired by modeling the natural processes and other aspects of species evolution, especially human evolution. But Imperialist Competitive Algorithm (ICA) uses socio-political evolution of human as a source of inspiration for developing a strong optimization strategy [3]. In particular, this algorithm considers imperialism as a level of human social evolution and by mathematically modeling this complicated political and historical process, it arrives at a tool for evolutionary optimization. Since its inception, this novel method has been widely adopted by researchers to solve different optimization tasks. It is used to design optimal layout of factories, adaptive antenna arrays, intelligent recommender systems and optimal controller for industrial and chemical possesses [4].

Imperialism is the policy of extending the power and rule of a government beyond its own boundaries. A country may attempt to dominate others by direct rule or by less obvious means such as a control of markets for goods or raw materials. The latter is often called neo-colonialism (Atashpaz and Lucas 2007). ICA is a novel global search heuristic that uses imperialism and imperialistic competition process as a source of inspiration.

Like other evolutionary algorithms, the proposed algorithm starts with an initial population(countries in the world). Some of the best countries in the population are selected to be the imperialists and the rest form the colonies of these imperialists. All the colonies of initial population are divided among the imperialists based on their power. The power of an empire seen as the counterpart of the fitness value in Genetic Algorithm (GA) is inversely proportional to the costs it incurs. Atashpaz Gargari and Lucas introduced the imperialistic competition algorithm in 2007 which is inspired by imperialistic competitions. They applied this method to some of benchmark cost functions.ICA uses the concepts of imperialism and imperialistic competition process as a source of inspiration. Similar to other evolutionary algorithms, ICA starts with an initial population consisting of 'countries'(individuals in other evolutionary algorithms) which are divided in two groups. The ones with the best objective function values are selected to be the 'imperialists', whereas the remaining ones are their 'colonies' [5]. The colonies are then shared among the imperialists according to each imperialist's power (objective function value). The power of an imperialist in a minimization problem is inversely proportional to its cost function. The more powerful an imperialist is, the more colonies he will possess. In the language of ICA an imperialist with his colonies forms an 'empire'. One of the characteristics of the interaction between imperialist powers and their colonies is that in the course of time colonies start to change their culture in such a way that it becomes more similar to the one of their dominating imperialist. This process is implemented in ICA by moving the colonies towards their imperialist and it is called 'assimilation'. During this event there is the possibility for a colony to become more powerful than its imperialist and in this case the colony will take the place of the imperialist and the imperialist will become one of its colonies [6].

It can be furthermore observed that during imperialistic competition the most powerful empires tend to increase their power, while weaker ones tend to collapse. These two mechanisms lead the algorithm to gradually converge into a single empire, in which the imperialist and all the colonies tend to have the same culture.

Algorithm: Steps Involved: The pseudo code of Imperialist competitive algorithm is as follows:

- Select some random points on the function and initialize the empires.
- Move the colonies toward their relevant imperialist (Assimilation).
- Randomly change the position of some colonies (Revolution).
- If there is a colony in an empire which has lower cost than the imperialist, exchange the positions of that colony and the imperialist.
- Compute the total cost of all empires.
- Pick the weakest colony (colonies) from the weakest empires and give it (them) to one of the empires (Imperialistic competition).
- Eliminate the powerless empires.
- If stop conditions satisfied, stop, if not go to 2.

Generating Initial Empires: At the beginning of the algorithm, an initial population called countries should be created. In an N-dimensional optimization problem, the position of the ith country is defined as,

$$Country_i = [x_i^1, x_i^1, ..., x_i^N], \quad i = 1,2,...,N_{cnt},$$

where N_{cnt} is total number of the countries. The cost function of the countries can be found by evaluating the function f at the variables $[x_i^1, x_i^2, ..., x_i^N]$. Then the cost of the ith country is as follows:

$$f(Country_i) = f([x_i^1, x_i^2, x_i^3, ..., x_i^N]) \quad (6)$$

Then N_{imp} of the most powerful countries are selected to form empires. The remaining N_{col} countries will be the colonies of these empires. In the next step, the colonies must be divided among the imperialists based on their power [7]. The imperialist's powers are inversely proportional to their cost function in a minimization problem. The initial number of colonies of an empire is directly proportional to its power. To do this, the normalized costs of the empires are defined as.

$$Ic_n = ic_n - max\{ic_i\} \quad (7)$$

where ic_n is the cost of the nth imperialist and IC_n is the normalized cost.

The normalized power of each imperialist is defined by

$$IP = \frac{IC_n}{\sum_{i=1}^{Nimp} IC_n} \quad (8)$$

Then the initial number of colonies of an empire will be

$$Nc_n = round\{IP_n, N_{col}\} \quad (9)$$

where NC_n is the initial number of colonies of the nth empire. For each imperialist, NC_n of the colonies are randomly selected and are given to it. These colonies along with their imperialist form the nth empire.

Moving the Colonies Toward Their Imperialists: In this stage, the colonies start to move toward their relevant imperialists. The positions of the colonies of the nth empire are updated as follows:

$$newcol_n^i = col_n^i + rand \times \beta(I_n - col_n^i) \quad (10)$$

where col_n^i is the position of the ith colony of the nth imperialist, *rand* is a random number in (0,1), β is a weight factor and I_n is the position of the nth imperialist. To search different points around the imperialist, a random amount of deviation is added to the direction of movement. Fig. 3.3 shows the movement of a colony toward its relevant imperialist in the new direction. In this following figure, θ is a random angle between $(-\gamma, \gamma)$ where γ is the parameter that adjusts the deviation from the original direction.

Updating Positions of the Imperialists: During the previous stage, a colony may reach to a position with lower cost than that of the imperialist. In such a case, the positions of the imperialist and that colony must be exchanged. Then the rest of the colonies of this empire move toward the new position of the imperialist.

Exchanging Positions of the Imperialist and a Colony: While moving toward the imperialist, a colony might reach a position with lower cost than the imperialist. In this case, the imperialist and the colony change their positions. Then the algorithm will continue with the imperialist in the new position and the colonies will be assimilated by the imperialist in its new position.

Calculating Total Power of an Empire: The total power of an empire depends on both the power of the imperialist and the power of its colonies. But it is mainly affected by the power of the imperialist. The total power of an empire is defined as

$$Tp_n = \text{cost(imperialist)} + \xi \text{ (colonies of empire)}\} \quad (11)$$

where is TP_n the total power of the nth empire and ξ is a positive number which is considered to be less than 1. In fact, ξ represents the role of the colonies in determining the total power of an empire.

Imperialistic Competition: In this stage, the imperialistic competition begins and all the empires try to take possession of the colonies of other empires. This competition is modeled by picking some of the weakest colonies (usually one) of the weakest empires and making a competition among all empires to possess these (this) colonies. Each of the empires will have a likelihood of taking possession of these colonies based on their total powers; therefore, the more powerful empires have greater chance to possess the mentioned colonies. To do this, the possession probability of each empire must be found [8-10]. The normalized total power of each empire is calculated as follows

$$TP_n = TP_n - max\{TP_i\} \quad (12)$$

where NTP_n is normalized total power of the nth empire The possession probability of each empire is given by

$$NTP_n = TP_n - max\ \{TP_i\} \quad (13)$$

where NTP_n is normalized total power of the nth empire. The possession probability of each empire is given by

$$ps_n = \frac{NTP_n}{\sum_{i=1}^{Nimp} NTP_i} \quad (14)$$

where ps_n is possession probability of the nth empire.

Then the vector PS is formed to divide the mentioned colonies among the empires:

$$PS=[ps_1, ps_2, \dots \dots \dots, ps_{Nimp}] \quad (15)$$

After that, a random vector with the same size as PS is created as follows:

$$R=[r_1, r_1, \dots \dots \dots\ r_{Nimp}] \quad (16)$$

where $r_1, r_2, \dots \dots \dots\ r_{Nimp}$ are randomly generated numbers in(0,1).

At last, the vector D is formed by subtracting R from PS:

$$D= PS-R = [d_1, d_2, \dots \dots \dots\ d_{Nimp}]$$
$$= [ps_1 - r_1\ ps_2 - r_2, \dots \dots, ps_{Nimp} - r_{Nimp}] \quad (17)$$

The mentioned colonies will be handed to an empire which has the maximum relevant index in D vector.

Eliminating the Powerless Empires: The powerless empires will collapse in the imperialistic competition. Different criteria can be defined for collapse mechanism. In this paper, an empire is assumed collapsed when it loses all of its colonies [11-15].

Convergence: After some imperialistic competitions, all the empires except the most powerful one will collapse and all of the countries under their possession become colonies of this empire. All the colonies have the same positions and the same costs and there is no difference between the colonies and their imperialist. In such a case, the algorithm stops.

Implementation of Algorithm in Test Functions

Test Functions: A set of benchmarks (test functions) are commonly used in order to test optimization procedures dedicated for multidimensional, continuous optimization task. In order to test the adopted algorithm, MATLAB coding is done for the following test functions.

De Jong's Function: The first function of De Jong's is one of the simplest test benchmark. Function is continuous, convex and unimodal that is function having only one local optimum. This is relatively easy to analyze for optimums. The function is used for checking the speed of optimization and convergence. It has the following general definition

$$f(x) = \sum_{i=1}^{n} x_i^2$$

Test area is usually restricted to hypercube $-5.12 \le x_i \le 5{,}12$, i = 1,2 ... ... n.

Global minimum f(x) = 0 is obtainable for $x_i = 0$, i = 1 ... ...,n.

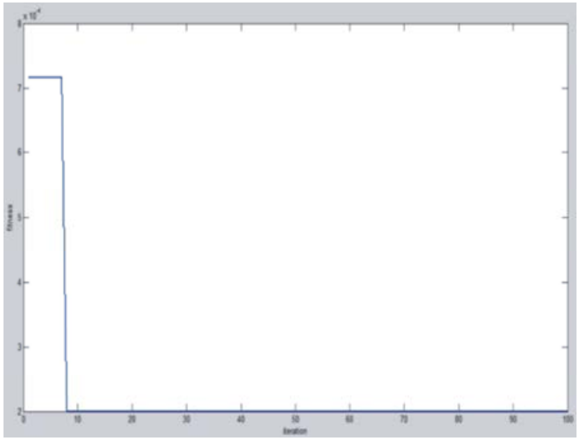

Fig. 1: Output for DeJong's Function

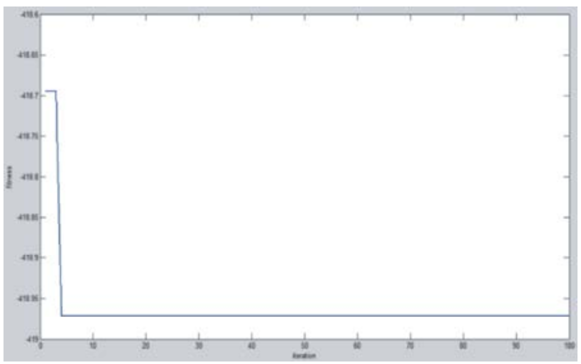

Fig. 2: Fitness versus Iteration plot for Schwefel's function

Schwefel's Functio:n The SchwefelFunction, frequently used as a Benchmark for certain Optimization Techniques. The Schwefel's function is non-convex, multimodal and additively separable. It is deceptive in that the global minimum is geometrically distant, over the parameter space, from the next best local minima. Therefore, the search algorithms are potentially prone to convergence in the wrong direction.

Function definition:

$$f(x) = \sum_{i=1}^{n} [-x_i \sin(\sqrt{|x_i|}) \quad -500 \le x_i \le I$$

Global minimum: f(x)=-418.9829n, x(i)=420.9687, i=1:n

CONCLUSION

In this paper the imperialistic competitive algorithm was studied for finding the best global minima of a given problem, based on its efficient search procedure. Imperialistic competitive algorithm (ICA) program was developed in MATLAB software for basic optimization test functions namely De Jong's function and Schwefel's function. Thus the function was simulated using ICA algorithm program and its simulation results were obtained.

REFERENCES

1. Gargari, E. A. and C. Lucas, 2007. Imperialist competitive algorithm: An algorithm for optimization inspired by imperialistic competition, in Proc. IEEE Congr. Evolutionary Computation.
2. Jahani, R., H. Chahka nd I. Nejad, 2011.
3. Using A New Advanced Intelligent Algorithm for Optimal Power Distribution. Australian Journal of Basic and Applied Sciences, 5(5): 659-669.
4. Soroudi, A. and M. Ehsan, 2011. Imperialist competition algorithm for distributed generation connections. Published in IET Generation, Transmission & Distribution.
5. Moosa Moghimi Hadji and BehroozVahidi, February 2012. A Solution to the Unit Commitment Problem Using Imperialistic Competition Algorithm, IEEE Transactions on Power Systems, 27(1): 117-123.
6. Ebrahim Hosseini Nasab, Mohsen Khezri, Morteza Sahab Khodamoradi and Esmaeil Atashpaz Gargari. 2010. An application of Imperialist Competitive Algorithm to Simulation of Energy Demand Based on Economic Indicators. Evidence from Iran, European Journal of Scientific Research, ISSN 1450-216X, 43(4): 495-506.
7. Leandro Dos S. Coelho, Leonardo D. Afonso and Piergiorgio Alotto, February 2012. A Modified Imperialist Competitive Algorithm for Optimization in Electromagnetics, IEEE Transactions on Magnetics, 48(2): 579-581.
8. Caro Lucas, Zahra Nasiri-Gheidari, Farid Tootoonchian, 2010. Application of an Imperialist Competitive Algorithm to the design of a linear induction motor, Energy Conversion and Management, 51: 1407-1411.
9. Chahkandi Nejad, H., R. Jahani and M. Mahvy, 2011. Applying Imperialist Competitive Algorithm for Optimal Placement of Unified Power Flow Controller in Power System American Journal of Scientific Research, pp: 20-33.
10. Kalyanmoy Deb, 2002. Optimization for Engineering Design-Algorithms and Examples, PrenticeHall of India, fifth printing.

11. Tatyana Aleksandrovna Skalozubova and Valentina Olegovna Reshetova, 2013. Leaves of Common Nettle (Urtica dioica L.) As a Source of Ascorbic Acid (Vitamin C), World Applied Sciences Journal, 28(2): 250-253.
12. Rassoulinejad-Mousavi, S.M., M. Jamil and M. Layeghi, 2013. Experimental Study of a Combined Three Bucket H-Rotor with Savonius Wind Turbine, World Applied Sciences Journal, 28(2): 205-211.
13. Vladimir G. Andronov, 2013. Approximation of Physical Models of Space Scanner Systems World Applied Sciences Journal, 28(4): 528-531.
14. Naseer Ahmed, 2013. Ultrasonically Assisted Turning: Effects on Surface Roughness World Applied Sciences Journal, 27(2): 201-206.
15. Tatyana Nikolayevna Vitsenets, 2014. Concept and Forming Factors of Migration Processes Middle-East Journal of Scientific Research, 19(5): 620-624.