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Resolution of economic dispatch problem of the moroccan network using crow search algorithm

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ABSTRACT

The economic dispatch problem of power plays a very important role in the exploitation of electro-energy systems to judiciously distribute power generated by all plants. This paper proposes the use of Crow Search Algorithm (CSA) for solving the economic dispatch problem of two electricity networks: a testing system 6 units and the morocco network. The crow search algorithm (CSA) is a recently developed metaheuristic search algorithm inspired by the intelligent behavior of crows. The results obtained by CSA are compared with various results obtained in the literature. Simulation results show that using CSA can lead to finding stable and adequate power generated that can fulfill the need of both the civil and industrial areas.

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1. INTRODUCTION

Smart grids are a set of technologies, concepts and approaches, allowing the integration the generation, transmission, distribution and use into one internet by full use of advanced sensor measurement technology, communications technology, information technology, computer technology, control technology, new energy technologies [1]. However, Smart Grid uses digital technology to control grid and choosing the best mode of power distribution to reduce energy consumption, reduce costs, increase reliability and also increase transparency in the network. Therefore, the system intelligent will have will have a significant impact in the fields of finance and economics of the power industry [2]. Although, The traditional network is a one-way network in which the electrical energy produced in power plants is channeled to consumers without information to create an automated and distributed network of advanced power supplies.

ED is also applied in the integrated system for scheduling power plants. A few methods have been published to solve the ED problem and Optimal Power Flow (OPF). Researchers have published a few methods to solve ED and OPF problems. Direct method is accurate and very simple but limited by the quadratic objective function [3].

The economic dispatch (ED) is one of the power management tools that is used to determine real power output of thermal generating units to meet required load demand. The ED results in minimum fuel generation cost, minimum transmission power loss while satisfying all units, as well as system constraints [4-5].

The rise of energy demand and insufficient of energy resources are required for quality and secured dispatch [6]. A well-coordinated and optimized power system operation help in satisfying Economic

Dispatch (ED) among users of power networks. Hence, studies need to be conducted in order to analyze and develop new tools so that the optimization issues in ED could be overcome. Basically, the principal objective of load dispatch is to minimize the total fuel cost while satisfying the requirements of some important operational parameters. In today's environment, efficient load dispatch requires not only to schedule the power generation at the least cost but also to consider other performance factors to be optimized in power flow over the networks. The obligation of social attentions has influenced the reduction of energy conservation and pollution emission produced by power plants [7].

Facing the electric bulimia experienced by the world and as an urgent and efficient solution is sought, it is essential to optimize the cost of producing electricity. As such, tiny cuts costs conceal huge potential savings, this is part of this paper, and we look at the overall optimization purposes known economic load distribution (OPF) or economic dispatch (ED) [8].

The ED is a static problem is to say we must define at a given powers generated by each power plant to power a load as economically as possible. To solve this problem the optimization methods are used.
Conventional optimization techniques [9-10]. have long been applied to solve the ED problem such as Quadratic Programming [11-12]. linear programming [13] sequential approach with a matrix framework (SAMF) ,[14]. modified Lambda-iteration method [15], Newton Raphson and Lagrangian multiplier (LM) algorithms [16], In the real-design cases, the number of decision variables (i.e. power units) of the ED area are very large. The objective criterion to be minimized could also have too many local minimum which might not lead to the minimum cost and the best generation schedule of power system units. Therefore, efficient search algorithms are needed.

Nature-inspired metaheuristic search algorithms gain a popularity due to their promising performance on solving many real-world optimization problems which are complex, nonlinear and multi-model. In the past two decades, the literature of metaheuristic search has expanded extensively.
Some of the well-known metaheuristic approaches are Genetic Algorithms [17], Genetic Programming [18-20], Particle Swarm Optimization [21-22], Simulated Annealing [23], Artificial Bee Colony (ABC) [24], Cuckoo Search [25-26], etc.

The remaining organization of this paper is as follows. Section 2 presents the mathematical formulation of the ED. Handling of constraints and implementation of the proposed CSA to ED problem are addressed in Sect. 3. Section 4 reports results of the proposed CSA method. A number of case studies using standard test systems are used to test the proposed method. The comparisons of results between the proposed method and existing methods are also carried out in this section. The discussion is followed in Sect. 5. After all, the conclusion is given.

2. MATHEMATICAL FORMULATION OF ED

The overall research methodology involved in the Economic Dispatch (ED) was classified into four stages. The first task was to achieve the objective of the study which was to establish a new technique particularly to solve ED optimization problem. The research approach was to design a new optimization technique taking some inspiration from the Meta-EP mutation strategy. The development also included identifying suitable objective functions which were significant to ED problem along with some constraints as discussed in the following section [27]. In order to achieve the research objective, the development of the new single objective technique was to be accomplished. The performance of the developed technique was evaluated and compared with other techniques namely the AIS and Meta-EP along with Base technique. The developed techniques were tested on the standard IEEE 26 and 57 bus system in order to minimize the total fuel cost, emission dispersed and system losses.

The objective function of the ED problem is to minimize the total production cost, which be written as:

$$Minimize F_T = \sum_{i=1}^{N} F_i(P_i) \; i = 1,2, \ldots., N \qquad (1)$$

Mathematically, the fuel cost of a thermal generation unit is represented as quadratic function [4]:

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \qquad (2)$$

The solution of ED can be highly improved by introducing higher order generator cost functions. Cubic cost function displays the actual response of thermal generatorsmore accurately.

The cubic fuel cost function of a thermal generating unit is represented as follows [28]:

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 + d_i P_i^3 \qquad (3)$$

Subject to Real power balance equation The total active power output of generating units must be equal to total power load demand plus power loss:

$$\sum_{i=1}^{N} Pi = P_D + P_L \quad (4)$$

where the power loss PL is calculated by the below formulation [4]:

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N} P_i\, B_{ij} P_j + \sum_{i=1}^{N} B_{Oi}\, P_i + B_{OO} \quad (5)$$

Generator capacity limits The active power output of generating units must be within the allowed limits:

$$P_{i.min} \le P_i \le P_{i.max} \quad (6)$$

3. CROW SEARCH ALGORITHM

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2], [5]. The discussion can be made in several sub-chapters.

The crow search algorithm (CSA) is a new population-based stochastic search algorithm recently proposed by [29]. The CSA is a newly developed optimization technique to solve complex engineering optimization problems [30-31]. It is inspired by the intelligent behavior of crows.The principles ofCSA are listed as follows [29]:

a. Crows live in the form of the flock.
b. Crows memorize the position of their hiding places.
c. Crows follow each other to commit thievery.

Crows protect their caches from being pilfered through probability.

Following the above assumptions, the core mechanism of the CSA consists of three basic phases, namely initialization, generate a new position, and updating the memory of crows. At first, the initial population of crows represented by n dimension is randomly generated. At iteration t, the position of crow is specified by $x^{i,t} = [x_1^{i,t}, x_2^{i,t}, \ldots\ldots, x_n^{i,t}]$and it is assumed that this crow has memorized its best experience thus far in its memory $m^{i,t} = [m_{m1}^{i,t}, m_2^{i,t}, \ldots\ldots, m_n^{i,t}]$To generate a new position, crow i select randomly a crow j, for example, from the population and attempts to follow it to find the position of its hiding place (mj). In this case, according to a parameter named awareness probability (AP), two states may happen:

a. State 1: Crow j does not know that crow i is following it. As a result, the crow i will determine the hiding place of crow j.
b. State 2: Crow j knows that crow j is following it. As a result, to protect its cache from being pilfered, the crow j will fool crow i by going to another position whitin the search space.

According to States 1 and 2, the position of the crows is updated as follows:

$$x^{i,iter+1} = \begin{cases} x^{i,iter+1} + r_i \times fl^{i,iter} \times (m^{i,iter} - x^{i,iter}),, \\ r_j \ge AP^{j,iter} \text{A random positonofsearch spaceotherwise} \end{cases} \quad (7)$$

Where rj is a uniformly distributed fuzzy number from [0; 1] and $AP^{j,iter}$ denotes the awareness probability of crow j at iteration iter. Finally, the crows update their memory as follows:

$$m^{i,iter+1} = \begin{cases} x^{i,iter+1}, \text{if } f(x^{i,iter}) \text{is better than } f(m^{i,iter}) \\ m^{i,iter}, \text{otherwise} \end{cases} \quad (8)$$

Where f(-) denotes the objective function value. It is seen that if the fitness function value of the new position of a crow is better than the fitness function value of the memorized position, the crow updates its memory by the new position. The above process is repeated until a given termination criterion (itermax) is met. Finally, the best solution of the memories is returned as the optimal solution found by the CSA. The main steps of the CSA are outlined in Algorithm:

Algorithm Crow Search Algorithm

Randomly initialize the position of a flock of (N_P) crows in the search space.
Evaluate the position of the Crows
Initialize the memory of each Crow
While ($iter \leq iter_{max}$) **do**
for i = 1: to N_P **do**
Randomly choose one of the crows to follow (for example, j)
Define an awareness probability
if ($r_j \geq AP^{j,iter}$) **then**
$x^{i,iter+1} = x^{i,iter} + r_i * fl^{i,iter} * (m^{j,iter} - x^{i,iter})$
else
$x^{i,iter+1}$=a random position of search space.
end if
end for
Check the feasibility of new positions
Evaluate the new position of the Crows
Update the memory of crows
end while

4. RESULTS AND DISCUSSION

In this section, we present the results obtained based on CSA for solving the ED problem and compare this results with the CM **(**Conventional Method) [15] and Particle Swarm Optimization [32]. A six units power unit system to explore our idea on using CSA to find the optimal set of power generation of the system. CSA will be used in this paper to solve the problem of economic dispatch of a test network of 26 nodes and the morocco network. The programs are developed in MATLAB 7.9 environment.

The adopted system is expected to produce demand power of 700 MW. The tuning parameters for CSA are given in Table 1, the Table 2 shows the cost coefficient of the six generators, under study, while the matrix is the loss coefficient matrix of the six units power system. From the results of Table 3, we notice that CSA give us the same production cost, and CM gives a slightly lower cost of $ 0.08 / h, by cons, delta given by CM is larger than that given by CSA, mean it is less accurate although we also see that it is the fastest. CSA gives us a good production cost and good accuracy.

Table 1. parameters of CSA [34]

Algorithm/parameters	AP	fl
CSA	0 .2	2

In Figure 1, we show the convergence of the metaheuristic search process based on CSA in both the best and average cases. To see the difference between our new approach and another known method, we will compare the production cost found by CSA to that found by PSO [33]. The comparison is represented by the graph in figure 2. It can be seen that CSA provided the minimum fuel cost in this case compared to other reported methods in the literature. This shows that the CSA is more effective in finding the best load for the three generator system.

In this case, we will test the operation of CSA. For this, we will use a simple network of 26 nodes with 6 production units. The total demand of the network is equal to 700 MW and loss coefficients are as follows:

$$B_{ij} = 10^{-5}\begin{bmatrix} 1.4 & 1.7 & 1.5 & 1.9 & 2.6 & 2.2 \\ 1.7 & 6.0 & 1.3 & 1.6 & 1.5 & 2.0 \\ 1.5 & 1.3 & 6.5 & 1.7 & 2.4 & 1.9 \\ 1.9 & 1.6 & 1.7 & 7.2 & 3.0 & 2.5 \\ 2.6 & 1.5 & 2.4 & 3.0 & 6.9 & 3.2 \\ 2.2 & 2.0 & 1.9 & 2.5 & 3.2 & 8.5 \end{bmatrix}$$

The simulation results are presented in Table 3.

Table 2. The parameters of the cost function and generators limits of the six-unit system

Units	a ($/MW2)	b ($/MW) c ($) Pmin (MW) Pmax (MW)
1	0.15240	38.53 756.79886 10 125
2	0.10587	46.15916 451.32513 10 150
3	0.02803	40.39655 1049.9977 35 225
4	0.03546	38.30443 1242.5311 35 210
5	0.02111	36.32782 1658.5696 130 325
6	0.01799	38.27041 1356.6592 125 315

Table 3. Results of the economic dispatching of six-unit system

	CM	PSO	CSA
P1 (MW)	29.4552	28.28	29.45
P2 (MW)	10	10	10
P3 (MW)	118.814	119.02	118.702
P4 (MW)	118.420	118.79	118.339
P5 (MW)	230.559	230.78	230.441
P6 (MW)	212.511	212.56	212.394
Pl (MW)	19.3361	19.4319	19.3128
Delta (MW)	0.000702	0.006688	0.000677
Fuel cost ($/h)	36926	36912.16	36906
t (s)	64.61	43.72	43.45

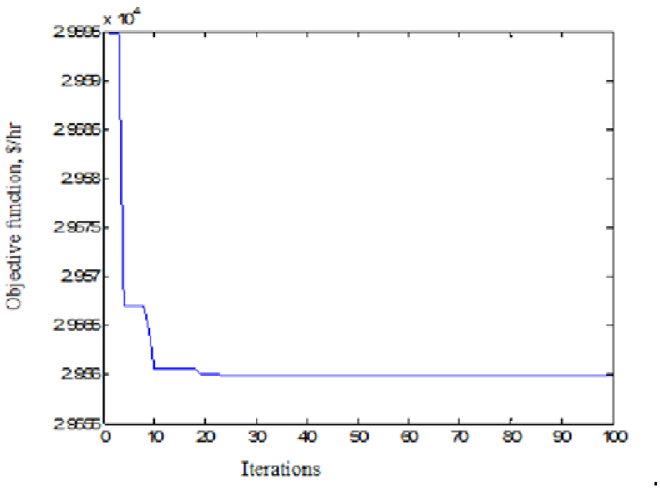

Figure 1. The convergence of CSA in the case of economic dispatch of six-unit system

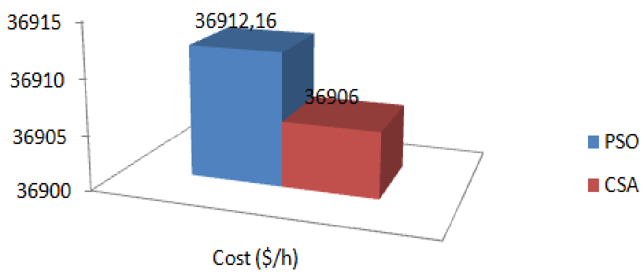

Figure 2. Comparison graph between CSA and PSO

5. CONCLUSION

In this paper, we proposed a crow search algorithm to solve the problem of economic dispatch of the morocco electricity network. The practicality of the proposed metaheuristics CSA was tested for six power generators test case. The gained results were compared to existing results based on PSO and CM methods. It was shown that CSA are superior in obtaining a combination of power loads that fulfill the problem constraints and minimize the total fuel cost. CSA found to be efficient in finding the optimal power generation loads. CSA was capable of handling the non-linearity of ED problem. The evolved power using CSA minimized both the cost of generated power, the total power loss in the transmission and maximizes the reliability of the power provided to the customers. The programs were developed using MATLAB and tested a network of 26 nodes. The results have shown that our CSA to give us a better performance with optimal results in all cases and respecting the constraints imposed.

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