APPLICATION OF A NEW HYBRIDIZATION TO SOLVE ECONOMIC DISPATCH PROBLEM ON AN ALGERIAN POWER SYSTEM WITHOUT OR WITH CONNECTION TO A RENEWABLE ENERGY

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Abstract

The most important contribution of this article is the use of four metaheuristic approaches to tackle the problem of economic dispatching, with the goal to study the influence of the injection of a renewable energy source on the electricity cost in the Algerian network, and minimizing the production cost of electrical energy while accounting for transmission losses.

A Genetic Algorithm (GA) (a real coding) and Egyptian Vulture Optimization Algorithm (EVOA), as well as two hybridizations between the metaheuristics: Classic and Modern hybridization (C.H.GA-EVOA, M.H.GA-EVOA), are presented in this work. These techniques are used to address optimization difficulties of two Algerian electricity networks. The first has three system units, whereas the second has fifteen system units. The second electricity network is connected to a solar energy source.

The findings obtained are compared with other techniques to validate the high performance of the suggested methods for addressing the economic dispatch issue. This study demonstrates that EVOA and C.H.GA-EVOA provide trustworthy results, and that M.H.GA-EVOA surpasses them.

Keywords: economic dispatching; Genetic Algorithm; Egyptian Vulture; Classic Hybridization; Modern Hybridization; solar energy.

1. INTRODUCTION

Electrical energy consumption is increasing rapidly, with global consumption having doubled on average over the last 10 years from the beginning of the nineteenth century. This has resulted in an increase in the length and complexity of electrical networks, forcing researchers in this sector to select the best feasible solutions [1-5].

To ensure that the network runs smoothly, we must address economic dispatch issues, which necessitate improving electrical energy management by lowering production costs while maintaining a balance between production and consumption [6-10].

Researchers are continuously creating algorithms that make it possible to program the production of power plants in an optimal method in order to fulfill these goals in the energy industry. Among these algorithms (CBA) chaotic bat algorithm [11] and (CSA) cuckoo search algorithm [12, 13], (PSO) particle swarm optimization, (CTLBO) chaotic teaching learning-based optimization [14], (KGMO) kinetic gas molecule optimization algorithm [15], (THS) tournament-based harmony search [16], (IA) Immune Algorithm [17], (SOA) seeker optimization algorithm [18], (MGSO) modified group search optimizer [19], (MSOS) modified symbiotic organisms search [20], (GWO) grey wolf optimization [21], (HGWO) hybrid grey wolf optimizer [22], (CSO) crisscross optimization algorithm [23], (GA) genetic algorithm [24], and (MABC) modified artificial bee colony algorithm [25]. Some of these algorithms are based on mathematical optimization methods which are continually improved in order to increase their performance so that they are exploited instantaneously at the dispatching level. In parallel, another family of methods based on linear programming and nonlinear programming has appeared [26].

The danger of convergence towards a local optimum is a drawback of these approaches, especially if the goal function is non-linear or the derivatives are difficult to compute.

In combinatorial optimization, many problems are often difficult to resolve in a manner that is accurate [27]. This is not due to a lack of mathematical knowledge, but rather to technical problems. So against these obstacles, it must resort
to methods of approximation of the solution. We will not seek more to obtain necessarily the best solution but rather a solution of good quality obtained to reduce losses and cost [28-32].

We proposed the use of two original stochastic optimization methods, the Genetic Algorithms GA and the Egyptian Vulture Optimization Algorithm EVOA, as well as two hybridizations: Classic Hybridization (C.H.GA-EVOA) and Modern Hybridization (C.H.GA-EVOA) to overcome the complexity of the problem of adaptation and to reduce costs and losses (M.H.GA-EVOA).

This study suggested a novel hybridization of GA and EVOA that uses metaheuristics of combinatorial optimization to solve the problem of the optimal allocation of active powers in two Algerian electricity networks with/without connection to solar energy production units.

For the first time, we use the EVOA, a metaheuristic approach of combinatorial optimization, to reduce the cost of producing electrical energy.

Then, with the aid of Genetic Algorithms, we apply a second technique of artificial intelligence to minimize the cost of producing electrical energy by binary encoding and then Natural by actual coding. Then we will build hybridization between: a GA and an EVOA method witch exhibited robustness, accuracy, highest performance, high precision, high stability, and simplicity.

• The first direct hybrid algorithm is a direct combination of GA and the EVOA method. In a first phase the GA explore the research space with the aim of discovering sub-spaces and providing a coarse solution, namely a solution located inside the basin of attraction of the global minimum. In a second phase, EVOA uses the best solution provided by the GA as initial estimate and continues the search according to its own mode of exploitation; it is the classic hybridization (C.H.GA-EVOA).

• The second hybrid algorithm in a first phase, the GA and the EVOA explore in parallel the research space with the aim of discovering promoter subspaces and providing coarse solutions, namely solutions located within the attraction basin of the global minimum. In a second phase, EVOA and GA use the best solution provided by the two algorithms as initial estimates and continue the search according to its own mode of operation. This principle is repeated for all the number of iterations, it is the modern hybridization (M.H.GA-EVOA).

The proposed approach has been tested on a variety of test systems, including two Algerian electricity networks, the first of which has three system units and the second of which has fifteen. The second Algerian electricity network has been optimized without and with connection to a solar energy source, with simulation results obtained in MATLAB. The results show that genetic algorithms, EVOA, classic and current hybridization have a clear interest in achieving dependable convergence to a global optimum while minimizing overall costs.

Compared with other methods, the results obtained are better in terms of minimizing the cost function.

2. PRINCIPLE OF ECONOMIC DISTRIBUTION OF POWERS

The basic goal of economic dispatch is to determine the active power contribution from each group of the electrical system's output such that the overall cost of production is reduced for any load state. The cost of manufacturing a unit varies depending on the amount of electricity it produces.

For the first time, we use the EVOA, a metaheuristic of combinatorial optimization to solve the problem of the optimal allocation of active powers. We consider a production-transport network at n node where we have ng unit nodes. The function of this network's total production cost is given by the following form. [8], [11], [14]:

$$F_{glob} = \sum_{i=1}^{ng} F_i (P_{gi})$$

(1)

With:

- $P_{gi}$: Represents the active powers generated.
- $ng$: Represents the number of nodes generators.
- $F_i (P_{gi})$: Represents the cost of production of the unit i.
- $F_{glob}$: Represents the sum of the functions of the cost of each unit.

The problem of the economic distribution of powers is to minimize the function of the total cost of fuel necessary for the production of energy requested.

This function is given by a polynomial of degree (n) in the following general form:

$$F(P_g) = a_0 + a_1 P_g + a_2 P_g^2 + \ldots + a_n P_g^n$$

(2)

The coefficients of the latter are computed using one of the interpolation methods, although in reality, this equation takes the form of a second-degree polynomial, i.e.

$$F(P_g) = c_i + b_i P_g + a_i P_g^2 \ldots \ldots \ldots \ldots i = 1, \ldots, ng$$

(3)

$a$, $b$, $c$: Represents the coefficients of the cost function specific to the unit (i) [12], [25]. It is therefore, at this stage that the problem of the optimal allocation of powers arises, it can be represented as follows:

It is necessary to minimize the cost of electrical energy for the whole of units:
Min \left\{ F_{\text{glob}}(P_i) = \sum_{i=1}^{\text{ng}} F_i(P_i) \right\} \quad (4)

Under the following constraints:

Equality constraints

\[ \sum_{i=1}^{\text{ng}} P_{gi} = \sum_{i=1}^{\text{ng}} P_D + P_L \quad (5) \]

The constraints of inequality

\[ P_{\text{g}i}^{\text{min}} \leq P_{\text{g}i} \leq P_{\text{g}i}^{\text{max}} \quad (6) \]

with:

n: Total number of nodes.
P_{gi}: Active power produced by the ith unit node.
P_{Di}: Active power consumed by ith load.
P_L: Losses total active in the network.
P_{\text{g}i}^{\text{max}}: Maximum active power produced by ith unit.
P_{\text{g}i}^{\text{min}}: Minimum active power produced by ith unit.

where \( P_D \) is the total power demand (system load) and \( P_L \) is the total transmission loss.

The exact value of the transmission losses can only be obtained from a study of the power flow. Nevertheless, in studies of the economic dispatching, transmission losses are often expressed as a function of the active powers generated. This technique is commonly referred to as the \( B \) coefficient method. In this approach, the losses are approximated by the Kron formula [30].

\[ P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} p_i B_{ij} p_j \quad (7) \]

where the terms \( B_{ij} \) are called coefficients of losses or coefficients \( B \). The coefficients of the losses are not constant, but vary according to the operating conditions of the system. However, acceptable results can be obtained if the current operating conditions are relatively close to those for which the coefficients \( B \) have been calculated [5].

3. USED METAHEURISTICS METHODS

3.1 Description of EVOA

The Egyptian vulture's optimization is based on the behavior of Egyptian vultures in quest of food, when they choose stones and hurl them with a probabilistic force and angle to break the eggs of other birds. The probabilistic decision that an Egyptian vulture singer makes to pick solutions evolves continually as the choice of stones, force, and angles of throwing stones changes [33].

This technique offered a combinatorial stochastic optimization strategy and demonstrated the speed of a novel method for finding acceptable solutions while avoiding premature convergences.

This method is versatile (it can be applied to similar versions of the same problem), robust and of course based on a population of individuals.

The EVOA algorithm is started with a random population of potential solutions, which are regarded as starting answers to the issues of food search in the search space. Each initial solution is drawn to its best choice discovery in the past, as well as the best decision discovery by its Neighborhood's first solutions. The EVOA algorithm has numerous adjustment factors that control the number of beginning values, the size of neighborhoods, and the precision with which the neighborhoods are created [34].

![EVOA’s organizational chart](image)

3.2 Genetic Algorithms

Genetic Algorithms, try to simulate the evolution process of a population. It part of a population \( N \) solutions of the problem presented by individuals. This population randomly chosen is called Initial. The adaptation degree of an individual to the environment is expressed by the value of the cost Function (Function Objective) \( f(x) \), or \( x \) is the solution that the individual represents.

It is said that an individual is much better adapted to its environment, when the cost of the solution that it represents is more low. Within this population, then intervenes the random selection of one or two parents, who produce a new solution.
(new population), through the genetic operators, such that the crossing and the mutation. By iterating, this process produces a population, richer in individuals who are better adapted [35,36].

3.3 The hybrid algorithms

The most productive way of hybridization appears to be the mix of neighborhood methods [37], evolutionary approaches, and other methods. The basic concept behind this hybridization is to take advantage of the strength of neighborhood search and evolutionary algorithm recombination on a population of solutions. Without a doubt, hybrid algorithms are among the most effective approaches [38].

3.3.1 Working principle of proposed hybridizations

Classic hybridization (C.H.GA-EVOA)

The first direct hybrid algorithm is a direct combination of GA and the EVOA method. In a first phase the GA explore the research space with the aim of discovering sub-spaces and providing a coarse global solution, namely a solution located inside the basin of attraction of the global minimum [39]. In a second phase, EVOA uses the best solution provided by the GA as initial estimate and continues the search according to its own mode of exploitation. This combination of GA and EVOA is proposed to solve problems of creation of values initials, and to reduce computation time [40].

Modern hybridization (M.H.GA-EVOA)

The second hybrid algorithm, first, the GA and the EVOA explore in parallel the research space with the aim of discovering promoter subspaces and providing coarse solutions, namely solutions located within the attraction basin of the global minimum. In a second phase, EVOA and GA use the best solution as initial estimates and continue the search according to its own mode of operation.

This principle is repeated for all the number of iterations, it is the modern hybridization (M.H.GA EVOA). Therefore, this hybrid method, such as the combination of two methods, have been proposed to eliminate each method's drawback and Weak point.

3 RESULTS AND DISCUSSION

Application 1: A- electrical network without solar energy production unit

The Algerian West 220 kV network was used to test the system. Figure 4 shows a single-line schematic of the system. The system is made up of 14 nodes, including three generators: the "Mersa El Hadjadj" power plant (node 1), the "White Ravine" power plant (node 4) and the "Tiaret" unit (node 3) [41].

Table 1 group the coefficients of the cost functions providing the fuel quantity in Nm3 / hr including the minimum and maximum powers of each unit [41].
The data of three unit test system

| Unit                  | $P_{\text{max}}$ (MW) | $P_{\text{min}}$ (MW) | $a_i$ ($$/MW^2$$) | $b_i$ ($$/MW$$) | $c_i$ ($$$) |
|-----------------------|------------------------|------------------------|-------------------|----------------|-------------|
| Mersat El Hadjadj      | 510                    | 30                     | 0.85              | 150            | 2000        |
| Tiaret                | 420                    | 25                     | 0.4               | 75             | 850         |
| Ravin Blanc           | 70                     | 10                     | 1.7               | 250            | 3000        |

The coefficients of the transmission losses

$$B=1e^{-3*\begin{bmatrix}0.00546 & -0.00052 & 0.00392 \\ -0.00052 & 0.01035 & -0.00137 \\ 0.00392 & -0.00137 & 0.01035 \end{bmatrix}}$$

The powers generated optimal values of production and losses transmitted are grouped in table 2

| Method                  | EVOA        | GA            | C.H.GA-EVOA     | M.H.GA-EVOA     |
|-------------------------|-------------|---------------|----------------|----------------|
| Mersat El Hadjadj        | 295.8071    | 294.2545      | 295.7052        | 295.6249        |
| Tiaret                  | 420         | 420           | 420             | 420            |
| Ravin Blanc             | 68.4493     | 70            | 68.5517         | 68.6346         |
| $P_d$(MW)               | 784.2565    | 784.2545      | 784.2569        | 784.2595        |
| $P_L$(MW)               | 2.2574      | 2.2547        | 2.2693          | 2.2594          |
| cost ($$/h)             | 251736.145  | 251477.237    | 251718.782      | 251705.595      |

The best fuel cost result obtained from the proposed methods EVOA, GA, C.H.GA-EVOA, and M.H.GA-EVOA is compared in Table 2, which shows that the proposed methods EVOA, GA, C.H.GA-EVOA, and M.H.GA-EVOA clearly minimized the cost and that the M.H.GA-EVOA has an approximately good solution for the power demand of 782 MW.

Figures 5 and 6 show the convergence characteristics of M.H.GA-EVOA in the search for the optimal cost for a three-generating-unit system with PD=782 MW. The figure clearly shows that the solution is converged to a high quality solution at an early iteration (29 iterations) and that the fuel cost function value does not vary rapidly after 70 iterations.

### B- electrical network with solar energy production unit

This application is interested in the economic dispatching solution with the integration of a solar center.

Table 3. West Algerian installed capacity renewable energies

| Renewable Energy unit   | Power installed (MW) |
|-------------------------|----------------------|
| SedrelLeghzet(Naâma)    | 20                   |
| Ain Skhouna(Saida)      | 30                   |
| Telagh(Sidi-Bel-Abbes)  | 12                   |
| LabiodhSidi Chikh(El-Bayadh) | 23               |

The first test of optimization Figure 7 depicts the M.H.GA-EVOA convergence characteristic when searching for the lowest cost for a three-generator system with PD=782 MW. The graphic clearly shows that the solution is converged to a high quality solution at an early iteration (50 iterations).
Table 4. Optimization results of the methods proposed for a western Algerian network connected with renewable energy units.

| Method                  | EVOA   | GA     | C.H.GA-EVOA | M.H.GA-EVOA |
|-------------------------|--------|--------|-------------|-------------|
| Mersat El Hadjadaj      | 247.1798 | 277.5990 | 214.1616  | 209.2342 |
| Tiaret                  | 419.8988 | 377.5597 | 420         | 420         |
| Ravin Blanc             | 32.1227  | 44.3062  | 65.1486    | 70          |
| SedretLeghzel(Naâma)    | 20      | 20      | 20          | 20          |
| Ain Skhouna(Saida)      | 30      | 30      | 30          | 30          |
| Telaght(Sidi-Bel-Abbes) | 12      | 12      | 12          | 12          |
| Labiodh(Sidi Chikh)     | 23      | 23      | 23          | 23          |
| Pd (MW)                 | 784.2013 | 784.4649 | 784.2342   | 784.3102   |
| Pl (MW)                 | 2.2013   | 2.4649   | 2.2342     | 2.3102     |
| Cost ($/h)              | 206697.2176 | 213165.2986 | 202548.0333 | 202343.6388 |

and that the fuel cost function value does not vary rapidly after 70 iterations.

Application 2 : An electrical network without solar energy production unit

The Algerian network characteristics are presented in Table 5 [42]. In this case, the optimization was applied to a dynamic economic dispatch problem with ramping limits constraints of the Algerian 114 bus power plan with 9 classic generators, the total load for 10 time periods of the system is given in table 5, the unit data of this system is given in table 6, and the coefficient are calculated directly with the power flow results.

Table 5. The total Load for 10 time period

| Time from (h) | to (h) | Power Demand (MW) |
|---------------|--------|-------------------|
| 1             | 2      | 2500              |
| 2             | 3      | 3000              |
| 3             | 4      | 3727              |
| 4             | 5      | 4500              |
| 5             | 6      | 4800              |
| 6             | 7      | 5500              |
| 7             | 8      | 5000              |
| 8             | 9      | 4100              |
| 9             | 10     | 3200              |

Table 7. M.H.GA-EVOA compared with C.H.GA-EVOA, GA and EVOA Methods for Algerian network Pch=3727MW without.

| Unit (MW) | M.H.GA-EVOA | C.H.GA-EVOA | EVOA | GA       |
|-----------|-------------|-------------|------|----------|
| Pg_4      | 478.1326    | 437.2393    | 438.9471 | 465.9004 |
| Pg_5      | 460.3928    | 505.4518    | 453.9453 | 445.3410 |
| Pg_11     | 99.9996     | 100         | 99.9832 | 99.9967  |
| Pg_15     | 192.5093    | 153.8415    | 156.5098 | 186.7848 |
| Pg_17     | 478.5429    | 414.1632    | 456.5655 | 433.0336 |
| Pg_19     | 188.2747    | 207.6052    | 201.6767 | 196.1141 |
| Pg_52     | 195.6971    | 205.8742    | 205.1403 | 179.2467 |
| Pg_22     | 178.6094    | 211.5898    | 239.5093 | 181.2029 |
Table 6. Generating unit data for 15 units system.

| Unit | $P_{\text{ig}}^{\text{min}}$ | $P_{\text{ig}}^{\max}$ | $a_d$($/\text{MW}^2$) | $b_d$($/\text{MW}$) | $c_d$($/)$ |
|------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 1    | 135             | 1350            | 0.0085          | 1.5000          | 0               |
| 2    | 135             | 1350            | 0.0085          | 1.5000          | 0               |
| 3    | 10              | 100             | 0.0170          | 2.5000          | 0               |
| 4    | 30              | 300             | 0.0170          | 2.5000          | 0               |
| 5    | 135             | 1350            | 0.0085          | 1.5000          | 0               |
| 6    | 34.5            | 345             | 0.0170          | 2.5000          | 0               |
| 7    | 34.5            | 345             | 0.0170          | 2.5000          | 0               |
| 8    | 34.5            | 345             | 0.0170          | 2.5000          | 0               |
| 9    | 34.5            | 345             | 0.0170          | 2.5000          | 0               |
| 10   | 30              | 300             | 0.0170          | 2.5000          | 0               |
| 11   | 30              | 300             | 0.0170          | 2.5000          | 0               |
| 12   | 60              | 600             | 0.0003          | 2.0000          | 0               |
| 13   | 20              | 200             | 0.0003          | 2.0000          | 0               |
| 14   | 10              | 100             | 0.0170          | 2.5000          | 0               |
| 15   | 10              | 100             | 0.0170          | 2.5000          | 0               |

Table 7 shows the optimal cost results using M.H.GA-EVOA, C.H.GA-EVOA, GA and EVOA with consideration of losses, the best cost obtained is 19338.7050 ($/h) found by M.H.GA-EVOA.

From the results indicated in Table 8 it can be clearly seen that M.H.GA-EVOA and C.H.GA-EVOA reduce the total cost and losses compared with GA, EVOA, PSO, FA, BA and HYB.

Table 8. Comparison of the M.H.GA-EVOA, C.H.GA-EVOA, GA and EVOA with different evolutionary methods for Algerian network.

| The algorithms used | Total output | Total Cost ($/h) |
|---------------------|--------------|------------------|
| M.H.GA-EVOA         | 3828.6531    | 19338.7050       |
| C.H.GA-EVOA         | 3828.6492    | 19389.8918       |
| EVOA                | 3828.64566   | 19404.5899       |
| GA                  | 3828.64955   | 19456.0767       |
| PSO [42]            | 3833.362     | 19442.08         |
| FA [43]             | 3831.5453    | 19445.51         |
| BA [43]             | 3830.9054    | 19439.99         |
| HYB [43]            | 3830.2206    | 19441.80         |

Figure 9 shows the convergence characteristic of M.H.GA-EVOA, while Figure 15 shows the convergence characteristic of C.H.GA-EVOA in the search for the optimal generation cost over 70 iterations. We can see that both methods, M.H.GA-EVOA and C.H.GA-EVOA, converge quickly towards the global optimum, with M.H.GA-EVOA providing the best result.

Table 9 compares the costs of variable loads in a 15-unit network. The charges are as follows: 2500.

The first test of optimization, Figure 9, shows the convergence characteristic of M.H.GA-EVOA in search of the optimum cost for three generating system for $P_0=3727$MW. It was clearly shown from the figure that the solution is converged to a high quality solution at early iterations (50 iterations) and that there is no rapid change in the fuel cost function value after 70 iterations.

![Fig. 9. Convergence characteristic of M.H.GA-EVOA for Algerian network for $P_0=3727$MW.](image1)

![Fig. 10. Convergence characteristic of C.H.GA-EVOA for Algerian network for $P_0=3727$MW.](image2)
The convergence characteristic of C.H.GA-EVOA in the search for the optimal cost for a 15 generating unit system with \( P_D = 3727 \text{MW} \) is shown in Figure 10. The graphic clearly shows that the solution is converged to a high quality solution at an early iteration (45 iterations) and that the fuel cost function value does not vary rapidly after 100 iterations. Clearly, show that M.H.GA-EVOA reduced the cost regardless of the load.

Table 9 where the charges are successively as 3000, 3727, 4500, 4800, 5500, 5000, 4100, and 3200 MW. The suggested techniques EVOA, GA, C.H.GA-EVOA, and M.H.GA-EVOA are compared in this study. The results in Table 9 clearly show that M.H.GA-EVOA reduced the cost regardless of the load.

**B-electrical network with solar energy production unit**

This application is interested in the economic dispatching solution with the integration of a solar units.

We note that the solar units (Table 10) are located in Algeria so that these solar units operate and generate around 266.1 MW, and connected to the Algerian power system [42, 43].

In this test system, we have applied the methods EVOA, GA, C.H.GA-EVOA and M.H.GA-EVOA in order to improve the function total cost. The application is made on 9 different loads.

### Table 10. Renewable energy units installed in Algeria

| Renewable Energy unit | Power installed (MW) |
|-----------------------|----------------------|
| Oued Nechou PV (Ghardaia) | 1.1 |
| Sedrel Leghzel (Naâma) | 20 |
| Oued El kebrit (Souk Ahra) | 15 |
| Ain Skhoua (Saida) | 30 |
| Ain El Bel (Djelfa) 1 et 2 | 53 |
| Lekhneq (Laghouat) 1 et 2 | 60 |
| Telagh (Sidi-Bel-Abbes) | 12 |
| Labiodh-Sidi Chikh (El-Bayadh) | 23 |
| El Hджira (Ouargla) | 30 |
| Ain El Mell (M’Sila) | 20 |
| Oued El Ma (Batna) | 02 |

The obtained findings show that the suggested approaches have a certain interest in terms of dependable convergence toward a global optimum and decreased overall cost reduction. When compared to EVOA, GA, C.H.GA-EVOA, and other approaches, the M.H.GA-EVOA method converges faster.

Table 11 compares the best fuel cost results derived from the suggested techniques EVOA, GA, C.H.GA-EVOA, and M.H.GA-EVOA, as well as other optimization algorithms, showing that the proposed methods EVOA, GA, C.H.GA-EVOA, and M.H.GA-EVOA clearly minimized the cost. When compared to other optimization methods, the M.H.GA-EVOA provides a rather excellent answer for the 3727 MW power requirement.

Figure 11 depicts the M.H.GA-EVOA convergence characteristic in the search for the best cost for a 26-generator system with \( PD = 3727 \text{MW} \). The figure clearly shows that the solution is converged to a high quality solution at early iterations (18 iterations) and that the fuel cost function value does not vary rapidly after 70 iterations.
approaches have a certain interest in terms of software is tested on nine different loads. and M.H.GA iterations.
iterations (18 iterations) and that there is no rapid convergence toward a global optimum and decreased overall cost reduction. When
iterations (28 iterations) is converged to a high quality solution at early
cost ($/h) 17567.1261 17989.8154 18277.2698 18630.8913

Table 11. Comparison of proposed methods for Algerian network connected to solar units

| Unit (MW) | M.H.GA-EVOA | C.H.GA-EVOA | EVOA | GA |
|-----------|-------------|-------------|------|----|
| Pg 4      | 407.8376    | 595.6580    | 593.5651 | 509.9105 |
| Pg 5      | 564.6554    | 255.1066    | 365.6622 | 291.1171 |
| Pg 11     | 67.8266     | 88.8250     | 44.6844 | 73.8813 |
| Pg 15     | 137.6606    | 197.2694    | 225.7023 | 95.9382 |
| Pg 17     | 379.4056    | 440.1205    | 528.2573 | 404.1019 |
| Pg 19     | 162.3120    | 167.9163    | 89.0690 | 291.1748 |
| Pg 52     | 140.0823    | 260.1457    | 178.6339 | 154.3353 |
| Pg 22     | 129.2858    | 188.0164    | 131.1582 | 185.3904 |
| Pg 80     | 247.5282    | 126.7413    | 78.2766 | 222.8013 |
| Pg 83     | 209.5447    | 151.6242    | 261.1066 | 238.4779 |
| Pg 98     | 144.5444    | 172.6281    | 114.9896 | 256.0692 |
| Pg 100    | 600         | 577.8229    | 600    | 600    |
| Pg 101    | 199.7370    | 169.6443    | 198.1409 | 200    |
| Pg 109    | 73.2989     | 84.4052     | 75.0135 | 10     |
| Pg 111    | 98.6178     | 86.4112     | 78.0783 | 29.2773 |
| PV (Ghardaia) | 1.1     | 1.1         | 1.1    | 1.1    |
| PV (Naïma) | 20        | 20          | 20     | 20     |
| PV (Souk Ahras) | 15   | 15          | 15     | 15     |
| PV (Saida) | 30        | 30          | 30     | 30     |
| PV (Djelfa 1 et 2) | 53 | 53         | 53     | 53     |
| PV (Laghouat 1 et 2) | 60     | 60         | 60     | 60     |
| PV (Sidi-Bel-Abbes) | 12    | 12         | 12     | 12     |
| PV (El-Bayadh) | 23    | 23          | 23     | 23     |
| PV (Ouargla) | 30        | 30          | 30     | 30     |
| PV (M’Sila) | 20        | 20          | 20     | 20     |
| PV (Batna) | 02        | 02          | 02     | 02     |
| Total output | 3828.4376 | 3828.4358 | 3828.4387 | 3828.5757 |
| $/h) 101.4376 | 101.4358 | 3828.4387 | 3828.5757 |

Table 12. Economic dispatch results of variable loads for 15 units system connected 11 solar units.

| Total Load | Method | M.H.GA-EVOA | C.H.GA-EVOA | EVOA | GA |
|------------|--------|-------------|-------------|------|----|
| Total output | cost ($/h) | Total output | cost ($/h) | Total output | cost ($/h) | Total output | cost ($/h) |
| 2500       | 2557.4992 | 8807.8791 | 2557.4948 | 8902.6914 | 2557.5099 | 9104.9572 | 2557.4954 | 9231.3657 |
| 3000       | 3070.1346 | 11643.7079 | 3070.1069 | 11965.4191 | 3070.1021 | 12158.3196 | 3070.1084 | 12414.2895 |
| 3727       | 3828.4376 | 17567.1260 | 3828.4358 | 17989.8154 | 3828.4387 | 18277.2698 | 3828.5757 | 18630.8912 |
| 4500       | 4655.1971 | 25248.0293 | 4655.1944 | 26181.7111 | 4655.2050 | 26428.3932 | 4655.2053 | 26828.5993 |
| 4800       | 4982.6792 | 29051.5304 | 4982.7098 | 30345.5475 | 4982.7652 | 30430.5097 | 4982.7136 | 31171.9672 |
| 5500       | 5773.8139 | 39938.5054 | 5773.8327 | 40065.7755 | 5773.8229 | 41253.8359 | 5773.8326 | 42537.7766 |
| 5000       | 5204.8244 | 32819.9047 | 5204.7926 | 33155.7217 | 5204.8230 | 33382.6388 | 5204.8144 | 33589.2335 |
| 4100       | 4225.1666 | 21710.7576 | 4225.1935 | 22028.6917 | 4225.1683 | 22192.3119 | 4225.1928 | 22416.4079 |
| 3200       | 2557.5033 | 8648.5321 | 2557.4978 | 8745.0599 | 2557.4977 | 9072.6609 | 2557.5158 | 8889.6479 |

iterations compared to EVOA, GA, C.H.GA-EVOA, and other approaches, the M.H.GA-EVOA method converges faster.
Figure 12 shows the convergence characteristic of C.H.GA-EVOA in search of the optimum cost for 26 generators unit system for $P_0=3727$MW. It was clearly shown from the figure that the solution is converged to a high quality solution at early iterations (28 iterations) and that there is no rapid change in the fuel cost function value after 70 iterations.
The results of the metaheuristic approaches used (GA), (EVOA) are of particular relevance in terms of dependable convergence toward loss minimization and total cost minimization. The capacity of metaheuristic strategies to reach the optimal value of the cost of production is demonstrated by a comparison of results acquired from metaheuristic techniques. The most successful approach is always the EVOA method.

The results show that when the electrical network is connected to renewable energy production units, the cost function is better reduced.

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