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SOLVING ECONOMIC LOAD DISPATCH WITH RELIABILITY INDICATORS

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Abstract: Due to the great importance of reliable indicators in electrical operating systems in all its different parts, it has been considered the most important factors in the design and maintenance of the electrical system, especially during its operation. The main reason for attention to reliability indicators relates to interruptions in the power system that are provided to consumers. The introduction of reliable indicators to solving an economic load dispatch (ELD) issue increases the possibility of providing customers with a required load with the highest degree of reliability. The ELD issue has been solved with reliability indicators. This means that the ELD problem with reliability is combined into one problem called combined the economic load dispatch with reliability (CELDR). Solving the above problem lowers the fuel cost while increasing the reliability of the generators while preparing the required load. The exchange market algorithm (EMA), in this work, has been implemented in a system of 26 generating units to solve the CELDR issue.considering system reliability, inequality, and equality constraints. The results obtained show the direct effect of using reliability indicators in solving the above problem, where the best results were obtained using the EMA algorithm to solve the mentioned problem, compared to other algorithms.

Keywords: *Economic Load Dispatch ,Reliability, Optimization Algorithm, Uninterrupted Power.*

1. Introduction

Reliability, known as the measure of the power system's ability to perform designated functions at the conditions which designed to operate within it. So that, Reliability simply means efficient power delivery to all consumers [1]. The power system should be primarily planned to provide economical and reliable energy to customers. The rate of energy saving is measured by consumers with a minimum interruption through the concept of reliability. The main purpose of the reliability study is to reduce economic and other losses due to power outages [2]. Every shutdown of the power system gives the impression of making reliability indicators more important. Some of the reliability indicators such as, expected energy that's not supplied {EENS},the loss of the load probability {LOLP},and the forced outage rate {FOR},are explained in [3-5].The generation, distribution and transmission, are three important sections of a power system. Since the power generation section of power plants plays an important, sensitive and costly role, it is necessary to choose the best power plant outputs by calculating reliability indicators. In this work, reliability indicators in the power generation units are calculated by looking at the ELD problem. In the CELDR

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problem, the ideal goal is to reduce fuel costs and increase the reliability of providing consumers with electricity,while having to adhere to restrictions of all kinds. The target function in the above problem is represented by one function using the optimization process [6].

The operational characteristics of the generating units are inconsistent (not converging), which means that the above problem solution cannot be achieved by traditional methods, such as the gradient method, interior point mode, linear programming, lambda iteration method, dynamic programming, and Newton’s method [7-8]. For example, the dynamic programming way {DP} solve any kind of issue, but it is not successful with dimensions [9-10]. So, in the last period, some techniques have been used as: the Genetic Algorithm {GA} [11], Differential Evolution method {DE} [12-13], the Particle Swarm Optimization {PSO} method [14-15],Biogeography Based Optimization {BBO} [16-18], Grey Wolf Optimizer [19-20], Symbiotic Organisms Search [21-22], Backtracking Search Algorithm [23-24], Interior Search Algorithm [25], Whale Optimization Algorithm [26], Mine Blast Algorithm [27], Exchange Market Algorithm [28-29], etc, developed to solving these issues. The EMA algorithm was applied to a system of 26 generating units to provide a solution to the CELDR problem to reduce fuel cost and increase reliability by linking the two variables to one target function.

Exchange market algorithm as a new, robust and powerful method, that it was suggested by the professors E. Babaei ,and N. Ghorbani in the year 2014 [30]. The idea of EMA is inspired by the exchange market where shares are bought and sold by supervisors. EMA has been suggested to solve continual improvement issues. This algorithm is a population algorithm based on the financial exchange market where the number of shares in this market is chosen by the members. At EMA, there are two market modes available for every iteration of the program, the first is a normal market; EMA attracts individuals towards mighty members, and the second is a changing market; where the EMA searches for unknown points.

At EMA, individual fitness is calculated after any market position. After that, they are arranged according to their fitness, and they are placed in various groups. Further study of EMA's high ability to find the best global point in [28-30], In this work, EMA is implemented to solve the CELDR issue. The results obtained from the EMA demonstrated the durability and ability of this method in solving these issues.

Parts of this paper are as follows; part 2: describes the problem; part 3: explains EMA algorithm; part 4: shows a solution of the CELDR issue by EMA; part 5: implement the EMA to test the system and the results obtained; and part 6: shows the conclusions.

2. Problem Formulation

2.1. The Target Function in Proposed Issue

The solution to the CELDR problem is to reduce the cost of fuel consumed in generation services while increasing reliability [6]. This means that the reduction equation contains two unrelated variables that must be reduced together as follows::

$$Minmizing: F = [F_{FC}, EENS] \tag{1}$$

$$[P_G] = [P_1, P_2, \dots, P_n]^T \tag{2}$$

Subjected to: $h(P_i)=0$ and $g(P_i) \leq 0$

n :number of generating units, P_i :active power of i^{th} unit, $h(Pi)$: an equality restriction, and $g(Pi)$: an inequality restriction. F : fitness function which should be reduced.

F_{FC} : the cost of fuel for the generation unit, and $EENS$: an expected energy of the system that not supplied. The functions of the above problem will be explained simply, before it is combined with the target function to become only one

2.2. The Economic Load Dispatch Issue

The aim of an ELD issue is to reduce a total cost of the system, taking into account system restrictions. Details of the mentioned problem are mentioned with some limitations in [12] and [16]. In general, the simplified cost of the fuel function per generation unit is as follows:

$$F_{FC} = \sum_{i=1}^{n} F_i(P_i) \quad (3)$$

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \quad (4)$$

Where, F_i: a cost function of an i^{th} generation unit, F_{FC} is the total generation fuel cost, a_i, b_i ,and c_i are the cost coefficients of the i^{th} generation unit, n is the last power generation unit number and P_i is the output power of the i^{th} power generation unit.

In ELD problem without considering power losses of transmission line. In this case, it is necessary that The energy generated is equal to the load demand, as follows:

$$\sum_{i=1}^{n} P_i = P_{load} \quad (5)$$

The power output of any power unit must comply with this limitation:

$$P_{i,min} \leq P_i \leq P_{i,max} \quad (6)$$

$P_{i,max}$ and $P_{i,min}$: the highest and lowest power amounts of an i^{th} power unit, sequentially.

2.3. The Reliability Issue

A goal of the CELDR issue is to choose the optimum power for the generators in a manner that reduces the EENS and fuel cost for the system. Probability of reducing the generation of any generator unit equals the value of the forced outage. There are so many power units, with different forced outages, that any of the power units is based on the forced outage. It is important to find a relationship between the value of the forced outages and the power generated in each generation unit, which any unit that has the minimum forced outage, has the highest participation in reliable quality, and produces the maximum portion of power that the system needs. Calculating the EENS per unit of power, depending on {FOR}, and the power of any unit as follows: [6]:

$$EENS_i = FOR_i \times T \times P_i \text{ (MWh)} \quad (7)$$

$$EENS = \sum_{i=1}^{n} EENS_i \quad \text{(MWh)} \quad (8)$$

Where, P_i: the i^{th} unit of power generating in in {MW}. T: represents a period in hours, n :represented the number of the last power generation unit. From (7) in a fixed amount of EENS, it is more powerful produced by a generating unit, that have minimum FOR value. The equations (7) and (8) are used to calculate EENS in power release systems and the energy market [6] [31].

2.4. Combination of ELD, and EENS in The Target Function

The CELDR problem consists of two different parts (independent parts). Because the EENS and ELD in the terms of MWh,and (\$/h) respectively, and the optimal number for each function is numbered with a different set of values, the coding method per unit [32] have been used for combination multi-objective functions to a single objective function. In per-unit method, it should be easy to point out that the percentage of any job applies to an objective job of the problem. The combined target function and final state of the CELDR issue, as follows [32]:

$$Minimize\ (F = \gamma \times F_{FC,pu} + \mu \times EENS_{pu})\text{(pu)} \quad (9)$$

Where, $F_{FC,pu}$: the cost of fuel in per unit form, and equal to:

$$F_{FC,pu} = \frac{F_{FC}}{F_{FC,max}} \text{ (pu)} \qquad (10)$$

$$F_{FC,max} = \sum_{i=1}^{n} a_i + b_i P_{i,max} + c_i P^2{}_{i,max} \text{ (\$/h)} \qquad (11)$$

Where, $EENS_{pu}$: the EENS in per unit form ,and equal to:

$$EENS_{pu} = \frac{EENS}{EENS_{max}} \text{ (pu)} \qquad (12)$$

Where, the followings are valid:

$$EENS_{max} = \sum_{i=1}^{n} FOR_i \times T \times P_{i,max} \text{ (MWh)} \qquad (13)$$

The parameters γ and μ : associated with the percentage of any fuel cost and EENS in the target function , and the sum of these coefficients must be equal to 1 [32].

3. The Exchange Market Algorithm

EMA is appropriate to solve an optimization issue, a data for explaining it is represented in [30], and it is mentioned briefly in this paper. Two search operators at EMA, and the same number of pipette operators in it. This feature enables it to search on an ideal point as well as in a large area at one time. At EMA, any member is a solution to the problem. In the EMA method, there are a limited number of stocks, { the shares number represents generation unit number}, any member will buy the some of them {the output power of any units}, and try to gain a maximum benefit { earnings reduce objective functionality }, at the final of any duration of time, the validity of the total good shares will be determined

There are two types of market conditions in the EMA. After any recurrence, stockbrokers are verified and the stockbroker will be categorized according to the value of their holdings. In any market mode, the members with low, middle, and high ranks, will be sorted as group1, group2, and group3, respectively [30].

3.1. Balanced mode in EMA

In this state, a market is balanced and does not experience any oscillation and algorithm is trying to absorb members towards elite stockbrokers and search for the optimum points via the following issues: without regard to other risks, using the accumulated experience of the elite stock market, and consider urgent cases. Any individual in this position is categorized according to a number of any kind of share they possess, and their fitness value. Finally, after sorting population, they should be arranged to: (group1; group2; and group 3) respectively, and they will be changed, its shares based on the policy of the group as follows [30].

3.1.1. Group1 members of higher rank

In this group a member is the best solutions for the problems or an elite stockbroker, that are necessary to remain unchanged.

3.1.2. Group2 members of a meaner rank

Members of this group use stock market success experiences. These members change a number of shares, according to (14) to get more profits.

$$pop_j{}^{group(2)} = r \times pop_{1,i}{}^{group1} + (1 - r) \times pop_{2,i}{}^{group1} \qquad (14)$$

$j=1,2,3,..,n_j$, $i=1,2,3,..,ni$ &, n_i :the n^{th} member of the group1, n_j : the n^{th} shareholder of the group2, and r :the random number between [0, 1]. $pop_{1,i}{}^{group1}$ and $pop_{2,i}{}^{group1}$:a member of the group1 , and $pop_j{}^{group2}$: a j^{th} member of the group2.

3.1.3. Group3 members of lower rank

Group members get more profits by changing the number of shares, according to equations (15-16):

$$s_k = 2 \times r_1 \times \left(pop_{i,1}{}^{group(1)} - pop_k{}^{group(3)}\right) + \left(pop_{i,2}{}^{group(1)} - pop_k{}^{group(3)}\right) \qquad (15)$$

$$pop_k{}^{group(3),new} = pop_k{}^{group(3)} + 0.8 \times s_k \qquad (16)$$

Where $k=1,2,3,....,nk$, r_1 and r_2: a random number between [0 1] n_k : n^{th} member of a group3, $Pop_k{}^{group(3)}$: the k^{th} member, and s_k : the variations of share of the k^{th} member of a group3.

3.2. Oscillation mode in EMA

After assessing the members and ranking them according to their physical fitness, the members begin trading stocks. The fitness of each member will be regarded, they should be sorted as a member of (group1, group2,and group3), respectively, and will be changed, their shares based on the policy of the group as follows [30]:

3.2.1. Group1 members of higher rank

Members of the group1, include an elite stockbroker, or that has had a good answer to the issue. The members of group1 lead the market, and to preserve that rank, they don’t change these shares and don’t enter the risk.

3.2.2. Group2 members of meaner rank

Based on this group’s policy, the total stocks caught by members tend to be fixed, as the number of some stocks decreases and some other increases, provided that the total is fixed. Firstly, the amount of shares caught by any member increases, according to equation (17):

$$\Delta n_{t1} = n_{t1} - \delta + (2 \times r \times \mu \times \eta_1) \qquad (17)$$

$$\mu = \left(\frac{t_{pop}}{n_{pop}}\right) \qquad (18)$$

$$n_{t1} = \sum_{i=1}^{n} \left|s_{ty}\right| \; y=1,2,3,...n \qquad (19)$$

$$\eta_1 = n_{t1} \times g_1 \qquad (20)$$

$$g_1{}^k = g_{1,max} - \frac{g_{1,max} - g_{1,min}}{iter_{max}} \times k \qquad (21)$$

Where Δn_{t1}: the number of shares must be added to several shares, n_{t1}: all shares of the t^{th} member, before the share changes are applied. δ: information on the exchange market, s_{ty}: shares of the t^{th} member,. η_1: level of risk related to any member of group2, r : a random number, t_{pop} : the amount of a t^{th} shareholder. In (18), n_{pop}: final number of the member in a market, and μ : the constant parameter of any member, r : as above, t_{pop} : a t^{th} member number in the market.In(20), g_1 : The market value of a common risk that decreases if the number of iterations increases.In (21), $iter_{max}$: a last number of iterations, k : a number of iteration program, $g_{1,min}$ and $g_{1,max}$ represented the lowest and highest risk on the market, respectively.

After increasing the members' shares, each shareholder will buy and sell shares in equal quantities, making the total number is fixed. It is necessary for each member to reduce their shares byΔn_{t2}. Δn_{t2} of any member equal to:

$$\Delta n_{t2} = n_{t2} - \delta \qquad (22)$$

Where Δn_{t2} : a number of the shares must be decreased from several shares,and n_{t2} : The sum of the value of shares of a t^{th} member after the share differences are applied.

3.2.3. Group3 members of lower rank

In this group, the percentage of risk of the members varies with limiting their physical fitness. Group 3 unlike Group 2, the size of member stocks must change after any trade. In this group, any member sells or buys a quantity of shares. Shareholders change many of his shares, according to (23):

$$\Delta n_{t3} = (4 \times r_s \times \mu \times \eta_2) \quad (23)$$

$$r_s = (0.5 - rand) \quad (24)$$

$$\eta_2 = n_{t1} \times g_2 \quad (25)$$

$$g_2{}^k = g_{2,max} - \frac{g_{2,max} - g_{2,min}}{iter_{max}} \times k \quad (26)$$

Where Δn_{t3} : The value of the stocks that must added to the shares of any shareholder, r_s : the random number between [-0.5 0.5], μ : a constant parameter for any shareholder , and η_2 : The indicated risk parameter for any member of Group 3. In (26), g_2 : variable risk for a group 3 market, and $g_{2,\min}$ and $g_{2,\max}$ related to the lowest and highest amounts of a risk in the market, and are the parameters of the EMA.

4. The Implementation of EMA

The CELDR issue is solved using EMA according to the following points:

1. Set initial values and distribute shares to members.
2. Determine the fitness of members, according to (9), rank and sort members in 3 groups. (Starting normal position).
3. The differences in shares apply to Group 2 members according to (14).
4. The differences in shares apply to Group 3 members in the balance market, according to (16).
5. Redefining the fitness of members, in accordance with (9), arranging members and sorting them into 3 groups. (Start the oscillation position).
6. Trading in the stocks of group 2 shareholders in a volatile position, according to (17).
7. Trading in the stocks of group 3 shareholders in a volatile position, according to (23).
8. Repeating the point 2, until the program criterion is satisfied ,all a number of the program iterations.

After finishing the program applies the optimal values of the shareholders, which cause the objective function in per unit form minimization in (3), (10), (13), to obtain system optimum fuel cost in ($/hr), and system's EENS in term (MWh). Figure 1 shows an EMA application flowchart to solve the CELDR problem.

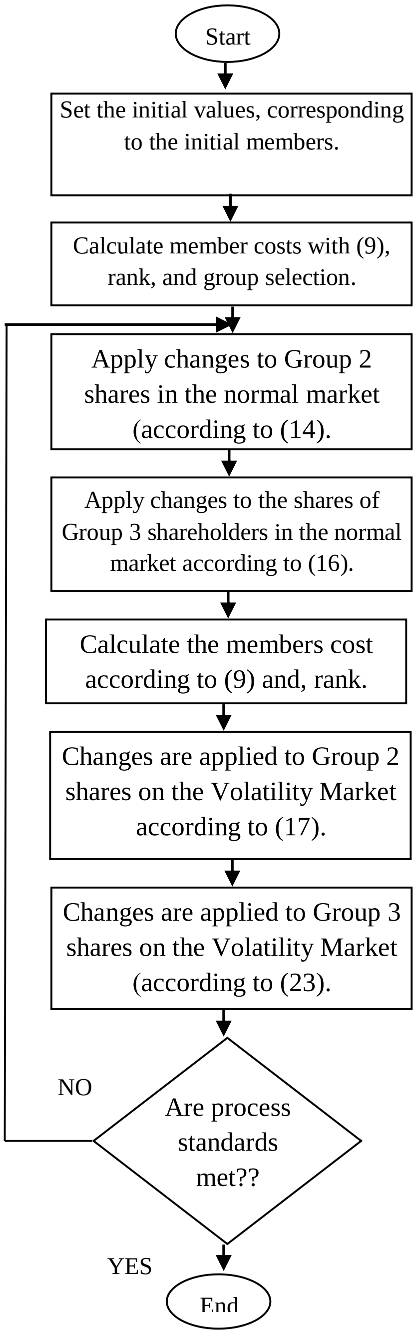

Figure 1. The EMA application flowchart to solve CELDR problem

5. Numerical Experimentations

In this work, EMA is implemented to solve the CELDR issue on a large system consisting of 26 generating units taking into account the ELD and the reliability index (EENS). (MATLAB) version 7.01 is used to simulate programs.A configuration system is the Pentium 4, which is a 3.2 GHz processor, and 2 GB RAM. For all tests, CELDR is arranged for only one hour. In any CELDR case study, fifty tests were applied to compare answer quality and affinity properties The iteration and the size of the population of the proposed EMA, set to 5000 and 100, respectively. The penalty factor for solving this problem in the form of per unit is set to 0.07, and without use it is set to 100. An obtained results by proposing EMA method is compared with the results of the PSO - SIF technique [6].

In solving CELDR problems through the proposed EMA method, the individual number for the 1st, 2nd, and 3rd groups in the normal market are set to (25, 25 and 50%) of the primary population, and the fluctuating market positioning pattern is set to (25, 60 and 15%) of the primary population [30]. The necessary adjustable parameters for the proposed algorithm are risk factors for the second and third groups in a volatile market situation whose optimum value is shown for each problem in Table 1.

Table 1. EMA risk factors to solve CELDR issue

Risk value	g_1 [min , max]	g_2 [min ,max]
26 generating units	[0.0001,0.05]	[0.0005,0.005]

5.1. System testing 26 units

The tests were applied to a system consisting of twenty-six units taking into account fuel cost and reliability level. The total demand of the system is (2430) MW. Unit generation data are available at [33]. The reliability data shown in Table 2 is taken from [34]. The test is applied in three parts; reduce EENS, reduce fuel cost, reduce EENS level and fuel cost. The results obtained by EMA are compared with the PSO-SIF results method as shown in Table 3. In the PSO-SIF, selecting optimal values for δ_1 and δ_2 are very important in the result of the accuracy of the results obtained, therefore, they are chosen based on several tests previously performed In this case study δ_1 and δ_2 are set to 0.04 and 0.03, respectively [6].

Table 2. *FOR* values of a 26 generator [6]

NO. Of Units	*FOR*	NO. Of Units	*FOR*	NO. Of Units	*FOR*
G1	0.12	G 10	0.02	G 19	0.02
G 2	0.12	G 11	0.02	G 20	0.02
G 3	0.08	G 12	0.04	G 21	0.02
G 4	0.04	G 13	0.04	G 22	0.02
G 5	0.04	G 14	0.04	G 23	0.1
G 6	0.04	G 15	0.05	G 24	0.1
G 7	0.04	G 16	0.05	G 25	0.1
G 8	0.02	G 17	0.05	G 26	0.1
G 9	0.02	G 18	0.02		

Table 3. Results of CELDR in a 26 generator system Problem

NO. Of Units	F_{FC} Minimization		EENS Minimization		EENS & F_{FC} Minimization	
	(PSO-SIF) [6]	(EMA)	(PSO-SIF) [6]	(EMA)	(PSO-SIF) [6]	(EMA)
1	399.9995	400.0000	100.0003	100.0000	288.8665	288.9972

UNIT (MW) Unit (MW)	Minimization of F_{FC}		Minimization of EENS		Minimization of EENS & F_{FC}	
	PSO-SIF[6]	EMA	PSO-SIF[6]	EMA	PSO-SIF[6]	EMA
16	68.9500	68.9500	197.0000	197.0000	69.0070	68.9500
17	68.9500	68.9500	197.0000	197.0000	68.9500	68.9500
18	2.4000	2.4000	12.0000	12.0000	11.9763	11.9611
19	2.4000	2.4000	12.0000	12.0000	11.9606	11.9172
20	2.4000	2.4000	12.0000	12.0000	11.8017	11.9594
21	2.4000	2.4001	12.0000	12.0000	11.9391	11.8438
22	2.4000	2.4000	12.0000	12.0000	11.9969	11.6308
23	4.0000	4.0000	4.1195	4.0000	4.0000	4.0000
24	4.0000	4.0000	4.0155	4.0000	4.0005	4.0000
25	4.0000	4.0000	4.0491	4.0000	4.0000	4.0000
26	4.0000	4.0000	4.0681	4.0000	4.0000	4.0000
TP	2430.0000	2430.0000	2430.0000	2430.0000	2430.0000	2430.0000
Fuel ost($/h)	33630.0528	33630.01655	42212.3306	42205.7964	36269.9568	36262.5896
EENS MWh	171.9084	171.9084	126.3550	126.34999	152.8301	152.8694
F (p.u)	0.674581	0.6745809	0.614477	0.6144531	0.7342839	0.734281
Time (Sec)	0.0061	0.0055	0.0061	0.0055	0.0081	0.0067
2	399.9981	400.0000	100.0000	100.0000	284.5642	284.8432
3	350.0000	350.0000	338.7472	339.0000	349.9972	350.0000
4	155.0000	155.0000	155.0000	155.0000	154.9999	155.0000
5	155.0000	155.0000	155.0000	155.0000	154.9997	155.0000
6	154.9998	155.0000	155.0000	155.0000	154.9999	155.0000
7	155.0000	155.0000	155.0000	155.0000	154.9999	154.9973
8	75.9998	75.9999	76.0000	76.0000	75.9971	76.0000
9	75.9992	76.0000	76.0000	76.0000	75.9961	76.0000
10	75.9999	76.0000	76.0000	76.0000	75.9998	76.0000
11	75.9975	76.0000	76.0000	76.0000	75.9995	76.0000
12	47.7311	47.7900	100.0000	100.0000	99.9982	100.0000
13	40.4191	40.2948	100.0000	100.0000	99.9985	100.0000
14	33.0057	33.0652	100.0000	100.0000	99.9994	100.0000
15*	68.9500	68.9500	197.0000	197.0000	68.9513	68.9500

* To be continue

In the case 1, The CELDR was resolved to reduce the system's fuel cost, without regard to system reliability. In this case, the fuel cost obtained for a system by EMA and PSO-SIF methods is 33630.01655 ($/h) and 33630.0528 respectively, This result is minimal, among other cases, and EENS in this test for EMA and PSO-SIF algorithms is 171.9084MW, this is the worst case and the largest compared to the other. Figure 2 shows the results obtained by

EMA compared to the PSO-SIF algorithm for case1.

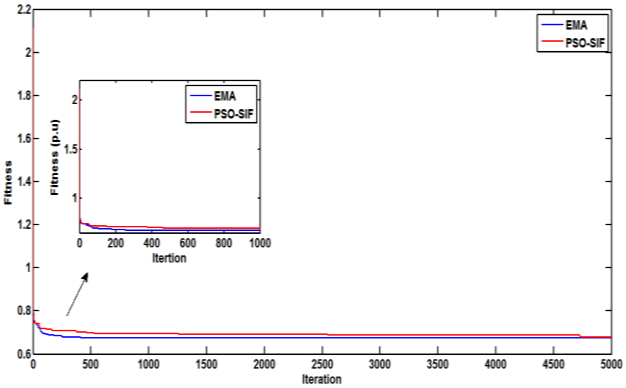

Figure 2. Convergence Characteristics of The (EMA& PSO-SIF) in solving CELDR problems for 26 unit system considering fuel cost (FFC) only.

In the case 2, the goal is to system's EENS minimization considering no system fuel cost. In this case the obtained system EENS by EMA and PSO-SIF methods is 126.34999 and 126.3550 MWh, respectively, this result is minimal, among other cases,and the obtained related system's fuel cost by EMA and PSO-SIF methods are 42205.7964 and 42212.3306 $/h, respectively, this is the worst case and the largest with respect to the other cases. Figure 3 shows the results obtained by EMA compared to the PSO-SIF algorithm for case two.

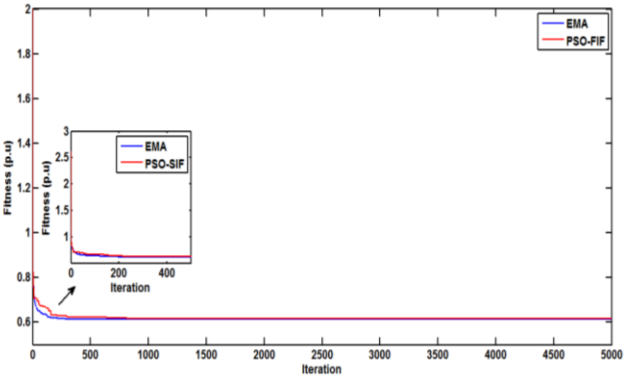

Figure 3. Convergence Characteristics of the (EMA& PSO-SIF) in solving CELDR problems for 26 unit system considering the reliability level (EENS) only.

In the case study 3, both EENS and the fuel cost system are reduced. In this case the EMA method could find minimum fitness value, 0.734281 pu that is minimum than obtained fitness value by the PSO - SIF method that is 0.7342839 pu. In this state the obtained related fuel cost and EENS by EMA method is 36262.5896 ($/h) and 152.8694 (MWh), respectively. Figure 4 shows the results obtained by EMA compared to the PSO-SIF algorithm for case3.

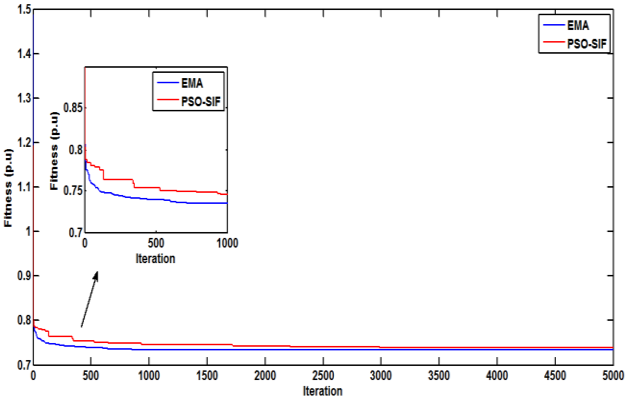

Figure 4. Convergence characteristics of the (EMA& PSO-SIF) in solving CELDR problems for 26 unit system considering reliability level and fuel cost (F).

In obtained results by EMA method, it is clear that as the ratio of impact on the reliability of the target function of the system increases, the value of EENS decreases proportionally, and as the ratio of the impact of fuel cost on the target function decreases, its value increases proportionally. This process was achieved with an increase in the system's impact reliability ratio, and a lower fuel cost impact ratio. In the case 3, the value of EENS decreases compared to Case 1 by 19.039 MWh , and the cost of fuel increases compared to the first case by 2632.57 $/h.

6. Conclusions

This effort suggested an EMA to solve the CELDR issue as follows:

1) Since the proposed algorithm has two searchers, it has been able to reach the optimal point as quickly as possible, because research is carried out in large areas, resulting in unknown points, while research with limited areas produces points near the optimal points.

2) This algorithm also contains two absorption factors for persons to bring the good member, which causes the algorithm to organize and generate random numbers in a good way. Taking into account the maximum power of the EMA method to find the optimal point, EMA is implemented to solve CELDR problems with operational constraints.

3) The ideal solution to the ELD problem is to ensure high reliability with low fuel cost for generating units. These two factors must be combined into a single goal function despite their contradiction. For combining these functions in the objective function, per-unit coding method has been used which that, any function is used in the form of per unit and the base is the maximum value of this parameter.

4) it is clear that as the ratio of impact on the reliability of the target function of the system increases, the value of EENS decreases proportionally, and as the ratio of the impact of fuel cost on the target function decreases, its value increases proportionally.

5) The obtained results of solving multi-objective CELDR problem by EMA method demonstrate the large potential of the EMA method compared to the optimization methods.

Conflict of interest

The authors (Falah A.Athab & Wafaa S. Majeed) should mention that the publication of this article cause no conflict of interest.

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