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MODIFIED PARTICLE SWARM OPTIMIZATION FOR ECONOMIC LOAD DISPATCH WITH TRANSMISSION LOSSES

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A modified particle swarm optimization (PSO) technique is presented in this paper. The proposed method is used to solve the economic power dispatch with transmission losses. The objective is to minimize the total fuel cost of generation. Two standard different study cases are applied to show the effectiveness and efficiency of the proposed technique. The results is compared with the genetic algorithms technique and traditional (PSO) show that the proposed algorithm produces optimal solution in term of computational time and the optimal cost for economic dispatch problem .

Keywords: *Economic Dispatch, Genetic Algorithms, Particle Swarm Optimization.*

1. INTRODUCTION

Engineers always concern the cost of products or services. In a power system, minimizing the operation cost is very important. Economic load dispatch (ELD) is a method to schedule the power generator outputs with respect to the load demands, and to operate the power system most economically. Several conventional and global methods have been applied for solving economic load dispatch (ELD) problems such as lambda iteration, gradient search, Newton's method and dynamic programming [1]. The conventional methods can find good solutions in a fast manner; however they can only be applied to small scale and simple problems. Recently many techniques based on artificial intelligence has been also used for solving ELD problem such as genetic algorithms (GA) [2], simulated annealing (SA) [7], evolutionary programming (EP) [3], particle swarm optimization (PSO) [4] .One of the technique is the Particle swarm optimization (PSO). Early introduced by Kennedy and Eberhart in 1995[5], [6], It was developed through simulation of a simplified social system; it is one of the modern heuristic algorithms based on the analogy of swarm of birds and fish schooling. The PSO technique can generate high-quality solutions within shorter calculation time and stable convergence characteristic than other stochastic methods. Although the PSO seems to be sensitive to the tuning of some weights or parameters, many researches are still in progress for proving its potential in solving complex power system problems.

Due to its simplicity and good performance, PSO has attracted many attentions and have been applied in various Power system optimization problems such as economic dispatch [5], design of PID controller in AVR system [10], reactive power and voltage control [11] and unit commitment [12].

In this paper, a modified PSO method for solving the ELD problem in power system is proposed. The proposed method considers the nonlinear characteristics of a generator such as valve point effect and transmission losses. The feasibility of the proposed method was demonstrated for two different systems [11], [15]. Results obtained show that the proposed approach can obtain more optimum solutions.

2. OVERVIEW OF PARTICLE SWARM OPTIMIZATION AND ITS VARIATION

Natural creatures sometime behave as a Swarm. One of the main streams of artificial life researches is to examine how natural creatures behave as a Swarm and reconfigure the Swarm models inside the computer. Eberhart and Kennedy develop PSO, based on analogy of the Swarm of birds and fish school, each individual exchanges previous experience among themselves [13]. PSO as an optimization tool provides a population based search procedure in which individuals called particles change their position with time. In a PSO system, particles fly around in a multi dimensional search space. During flight each particles adjust its position according its own experience and the experience of the neighboring particles, making use of the best position encountered by itself and its neighbors. In the multidimensional space where the optimal solution is sought, each particle in the swarm is moved toward the optimal point by adding a velocity with its position. The velocity of a particle is influenced by three components, namely, inertial, cognitive, and social. The inertial component simulates the inertial behavior of the bird to fly in the previous direction. The cognitive component models the memory of the bird about its previous best position, and the social component models the memory of the bird about the best position among the particles. The particles move around the multidimensional search space until they find the optimal solution. The modified velocity of each agent can be calculated using the current velocity and the distance from P_{best} and G_{best} as given in the following equation:

$$v_{ij} = \omega v_{ij}^{t-1} + c_1.r_1.\left(P_{bestij}^{t-1} - x_{ij}^{t-1}\right) + c_2.r_2.\left(G_{bestij}^{t-1} - x_{ij}^{t-1}\right) \quad (1)$$

i =1, 2…, N_D ; j=1, 2…, N_{par}

Equation (1) show that, a certain velocity can be calculated, which gradually gets close to P_{best} and G_{best}. The current position (searching point in the solution space), each individual moves from the current position to the next one by the modified velocity in (1) using the following equation:

$$X_{ij}^{t} = X_{ij}^{t-1} + V_{ij}^{t} \quad (2)$$

i =1, 2…, N_D; j=1, 2…, N_{par}

where,

t : Iteration count,

V_{ij} : Dimension *i* of the velocity of particle *j* at iteration *t*,

X_{ij}^{t} : Dimension *i* of the position of particle *j* at iteration *t*,

ω : Inertia weight,
C1, C2 : Acceleration coefficients,
$P_{best\,ij}^{\,t}$: Dimension *i* of the own best position of particle *j* until iteration *t*,
$G_{best\,ij}^{\,t}$: Dimension *i* of the best particle in the swarm at iteration *t*,
ND : Dimension of the optimization problem (Number of decision variables),
Npar : Number of particles in the swarm,
r_1, r_2 : Two separately generated uniformly distributed random numbers in the range [0, 1].

The following weighting function is usually utilized:

$$\omega = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{T_{max}} t \tag{3}$$

where,

$\omega_{max}, \omega_{min}$ Initial and final weights,
T max maximum iteration number
t current iteration number.

A new variation in the classical PSO since P_{besti} is the best solution a particle found so far, it can be considered as the experience a particle acquired in past time. Experience usually helps people learn and accumulate new knowledge. Based on this observation, a new PSO in which the particles explore around its previous best is proposed and therefore the proposed modification in equation (2) is given as:

$$X_{ij}^{\,t} = X_{ij}^{\,t-1} + P_{best\,ij}^{\,t-1} \tag{4}$$

3. ELD PROBLEM FORMULATION

The economic dispatch problem is to simultaneously minimize the overall cost rate and meet the load demand of a power system. The power system model consists of N generating units already connected to the system. The economic dispatch is to determine the optimal share of load demand for each unit in the range of 3 to 5 minutes [1].

The basic ELD becomes a nonconvex optimization problem if the practical operating conditions are included. The basic cost function used is:

Minimize

$$F_T = \sum_{i=1}^{N} F_i(P_i) \tag{5}$$

$$\sum_{i}^{N} F_i(P_i) = \sum_{i=1}^{N} (a_i P_i^2 + b_i P_i + c_i) \tag{6}$$

where,

F_T : Total generation cost ($/hr),
F_i : Cost function of generator i ($/hr)
a_i, b_i, c_i : Cost coefficients of generator i,

P_i : Power of generator i (MW),
N : Number of generators.

1) Active Power Balance Equation:

For power balance, an equality constraint should be satisfied: Total generated power should be the same as total demand plus the total line losses.

$$\sum_{i=1}^{n} P_i = P_{Load} + P_{Loss} \tag{7}$$

Where P_{Load} is the total load in the system (MW) and P_{Loss} is the network loss (MW) that can be calculated by matrix loss formula. However, the transmissions losses considered are governed by the following equation:

$$P_{Loss} = \sum_{i=1}^{m}\sum_{j=1}^{m} P_i B_{ij} P_j + \sum_{i=1}^{m} B_{0i} P_i + B_{00} \tag{8}$$

where,

B_{ij}, B_{0i}, B_{00} are the B-matrix coefficient, P_i is the power in the line.

2) Minimum and Maximum Power Limits:

Generation output of each generator should lie between maximum and minimum limits. The corresponding inequality constraints for each generator are

$$P_{i,\min} \le Pi \le P_{i,\max} \tag{9}$$

where,

$P_{i,\min}$ and $P_{i,\max}$ are the minimum and the maximum output of generator i, respectively.

The current searching process is evaluated using the objective function (f) of the total system cost given by Equation (6). While the evaluation function is:

$$f = 1/F \tag{10}$$

4. SOLVING ELD PROPLEM BY MPSO

Originally, PSO is designed to solve unconstrained Continuous optimization problems with objective variables bounded in a multidimensional hyperspace. However, except the bounded constraint of variables, economic power dispatch problems are basically nonlinear optimization problems with equality constraints as can be seen from (5) and (6). To apply PSO to solve this kind of problems, it requires the constraints to be treated in advance employing some kind of strategies.

The search procedure of the proposed method is shown below.

Step 1: Specify the lower and upper bound generation power of each unit, and calculate Fmax and Fmin. Initialize randomly the individuals of the population according to the limit of each unit including individual dimensions, searching points, and velocities. These initial individuals must be feasible candidate solutions that satisfy the practical operation constraints

Step 2: To each individual Pi of the population, employ the B-coefficient loss formula to calculate the transmission loss P_{Loss}

Step 3: Calculate the evaluation value of each individual in the population using the evaluation function given by equation (10).

Step 4: Compare each individual's evaluation value with its P_{best}. The best evaluation value among P_{best} is denoted as G_{best}.

Step 5: Modify the member velocity of each individual according to (1).

Step 6: If $V_{ij}^{t-1} > V_i^{\max}$, then $V_{ij}^{t-1} = V_i^{\max}$,If $V_{ij}^{t-1} < V_i^{\min}$, then $V_{ij}^{t-1} = V_i^{\min}$.

Step 7: Modify the member position of each individual according to step (3)

Step 8: If the evaluation value of each individual is better than the previous P_{best} , the current value is set to be P_{best} .If the best P_{best} is better than G_{best} , the value is set to be G_{best}.

Step 9: if the number of iterations reaches the maximum, then go to Step 10. Otherwise, go to Step 2.

Step 10: the individual that generates the latest G_{best} is the optimal generation power of each unit with the minimum total generation cost.

5. NUMERICAL EXAMPLES AND RESULTS

To verify the feasibility of the proposed PSO method, two different power systems were tested. In these examples, the transmission losses and valve point effect of units were taken into account in practical application, so the proposed PSO method was compared with an Elitist GA search method and the traditional PSO [9].At each sample system, under the same evaluation function and individual definition, we performed 50 trials using the proposed method to observe the variation during the evolutionary processes and to compare their solution quality, convergence characteristic.

A reasonable B loss coefficients matrix of power system network was employed to draw the transmission line loss and satisfy the transmission capacity constraints. A software program was written in Matlab language to solve this problem.

Case 1: IEEE 30 bus test system:

The system contains six thermal units, 30 buses, and 46 transmission lines [15]. The load demand is 283 MW. The characteristics of the six thermal units are given in table (1). In normal operation, the loss coefficients B with the 100-MVA base capacity are as follows:

$$
\begin{array}{c}
 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6
\end{array}
\begin{array}{c}
\begin{array}{cccccc} \quad 1 \quad & \quad 2 \quad & \quad 3 \quad & \quad 4 \quad & \quad 5 \quad & \quad 6 \quad \end{array} \\
\begin{bmatrix}
0.0017 & 0.0012 & 0.0007 & -0.0001 & -0.0005 & -0.0002 \\
0.0012 & 0.0014 & 0.0009 & 0.0001 & -0.0006 & -0.0001 \\
0.0007 & 0.0009 & 0.0031 & 0.0000 & -0.0010 & -0.0006 \\
-0.0001 & 0.0001 & 0.0000 & 0.0024 & -0.0006 & -0.0008 \\
-0.0005 & -0.0006 & -0.0010 & -0.0006 & 0.0129 & -0.0002 \\
-0.0002 & -0.0001 & -0.0006 & -0.0008 & -0.0002 & 0.0150
\end{bmatrix}
\end{array}
$$

In this case, each individual Pg contains six generators power outputs, such as P_1, P_2, P_3, P_4, P_5, and P_6, which are generated randomly. The dimension of the population is equal to 6 x100 through the evolutionary process of the proposed method.

Table (2) shows the mean, maximum and minimum cost acquired by the proposed method. These results are obtained out of 50 runs for comparison with the results obtained by genetic algorithms and traditional PSO techniques [9]. It is obvious that, in terms of minimum and mean costs, the proposed strategy perform better than genetic algorithms method and traditional PSO. Table (3) lists the optimum dispatch of generator obtained by proposed method. Note that the outputs of the generators are all within the generator's permissible output limit.

Figure (1) shows the search process of the optimal solution through the three algorithms while Fig. (2) describes the performance of GA, PSO and MPSO for solving the ELD problem. It shown that MPSO has the most optimal solution.

Case II: IEEE 57 bus test system:

The system contains 10 controllable active power generations. The load demand is 1271 MW. The characteristics of the 10 thermal units are given in table (4). In normal operation of the system, the loss coefficient B with the 100-MVA base capacity was shown in the Appendix.

In this case, each individual Pg contains 10 generators are generated randomly. The dimension of the population is equal to 10 x100 through the evolutionary process of the proposed method. Table (5) shows the mean, maximum and minimum cost acquired by the proposed method .these results show that the proposed method are feasible and indeed capable of acquiring better solution. The optimal dispatch of generators is listed in table (6) also notes that all generators' outputs are within the permissible limits. It is noticed here that from table (2) the maximum cost for the proposed method is greater than PSO that due to all of the three method have random run and the value which taken is the minimum through the number of runs. Table (3) shows the losses and the total generation cost for each method. From table (3) the generation units for each method is depend on the method itself so, it is clear from table (3) that P1,P2,...,P6 take different values when using equation (8) to calculate the losses for GA method than the other but our objective is to minimize the total generation cost.

Table (1): Generating units capacity and coefficients (6 units)

unit	P_{min}(MW)	P_{max}(MW)	a	b	c	e	f
1	100	500	0.0070	7.0	240	300	0.035
2	50	200	0.0095	10.0	200	200	0.042
3	10	300	0.0090	8.5	220	200	0.042
4	30	150	0.0090	11.0	200	150	0.063
5	10	200	0.0080	10.5	220	150	0.063
6	10	120	0.0075	12.0	190	150	0.063

Table (2): Comparison between both methods (50 trails)

Method	Min. cost	Max. cost	Mean cost	Average cpu time
GA	809.37	910.98	850.12	41.58
PSO	795.12	880.51	846.25	14.89
MPSO	793.22	890.13	845.20	4.26

Table (3): Best solution of 6-unit system

Unit power output	GA method	PSO method	MPSO method
P_1(MW)	174.14	165.12	168.32
P_2(MW)	50.02	60.21	55.25
P_3(MW)	21.19	15.64	14.64
P_4(MW)	24.34	35.61	38.22
P_5(MW)	12.92	15.12	14.45
P_6(MW)	12.00	10.00	11.11
Total power output(MW)	294.61	301.70	301.8
P_{loss} (MW)	11.61	18.7	18.8
Total generation cost ($/h)	809.37	795.12	793.22

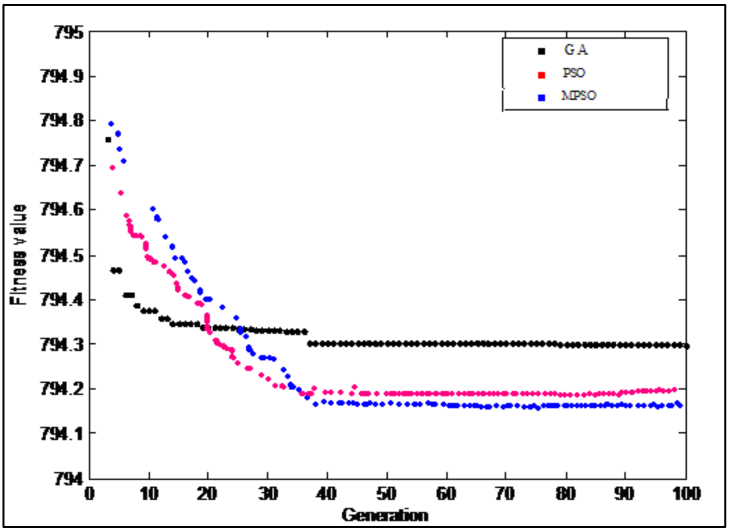

Fig. (1): Search process of the three algorithms of case 1.

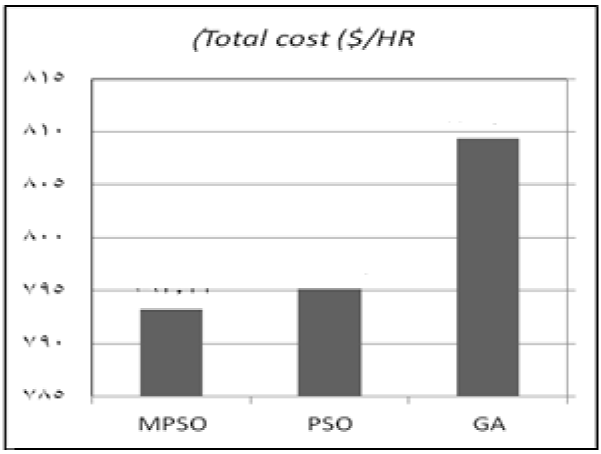

Fig. (2): Performance characteristics of the optimal solution to the case 1.

Table (4): Generating units capacity and coefficients (10-unit)

unit	P_{min}(MW)	P_{max}(MW)	a	b	c	e	f
1	150	455	0.000299	10.1	671	100	0.084
2	150	455	0.000183	10.2	574	100	0.084
3	20	130	0.001126	8.8	374	100	0.084
4	20	130	0.001126	8.8	374	150	0.063
5	150	470	0.000205	10.4	461	120	0.077
6	135	460	0.000301	10.1	630	100	0.084
7	135	465	0.000364	9.8	548	200	0.042
8	60	300	0.000338	11.2	227	200	0.042
9	25	162	0.000807	11.2	173	200	0.042
10	25	160	0.001203	10.7	175	200	0.042

Table (5): Comparison between both methods (50 trails)

Method	Min. cost	Max. cost	Mean cost	Average cpu time
GA	3563.12	3620.25	3590.55	49.31
PSO	3530.25	3630.65	3570.98	26.76
MPSO	3506.28	3615.63	3561.42	10.34

Table (6): Best solution of 15-unit system

Unit power output	GA method	PSO method	MPSO method
P_1(MW)	415.3108	410.1162	455.0000
P_2(MW)	59.7206	47.9729	39.8112
P_3(MW)	14.4250	19.6324	12.7000
P_4(MW)	74.9853	29.9925	24.3310
P_5(MW)	80.2844	51.0681	56.6001
P_6(MW)	46.7902	59.9978	43.3111
P_7(MW)	41.3164	25.5601	33.1601
P_8(MW)	24.7876	98.5699	91.1211
P_9(MW)	13.1445	13.4936	66.0001
P_{10}(MW)	89.2567	101.1142	30.2511
P_{11}(MW)	60.0572	33.9116	24.1401
P_{12}(MW)	49.9998	79.9583	51.6001
P_{13}(MW)	38.7713	25.0042	45.0300
P_{14}(MW)	41.4140	41.4140	23.3000
P_{15}(MW)	22.6445	36.6140	15.0000
Total power output(MW)	1309.27	1303.75	1303.43
P_{loss} (MW)	38.2782	32.4306	32.4306
Total generation cost ($/h)	3563.12	3530.25	3506.28

Figure (3) shows the search process of the optimal solution through the three algorithms while figure (4) describes the performance of GA, PSO and MPSO for solving the ELD problem it shown that MPSO has the most optimal solution. It can be noticed that the cost is decreased from 3563.12 $/hr in GA technique to be 3506.28 $/hr so the effect of our proposed technique has a good improvement in cost that we have a saving nearly to 57 $/hr so that a good effect has been occurred in large power systems.

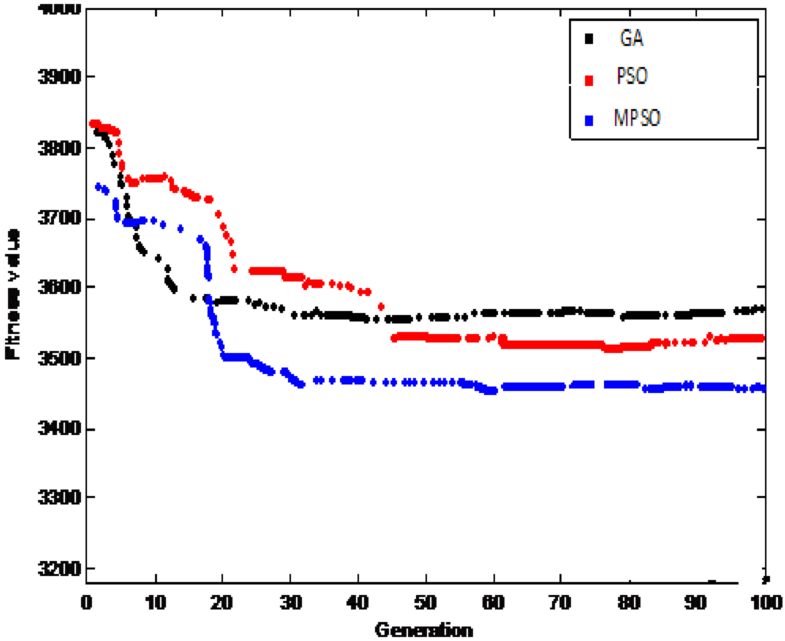

Fig. (3): Search process of the three algorithms of case 2.

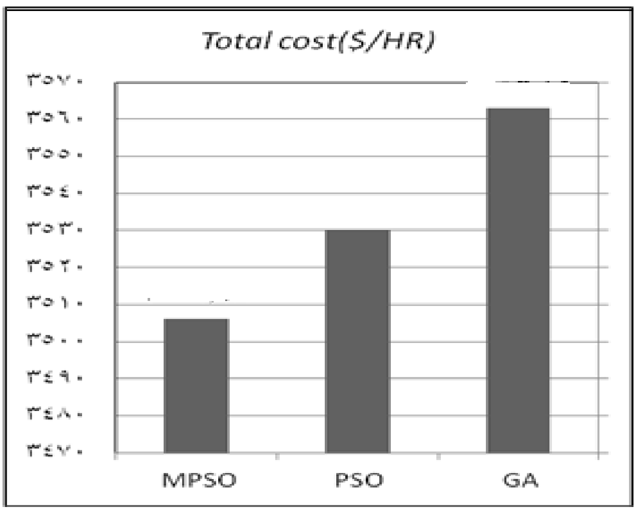

Fig. (4): Performance characteristics of the optimal solution to the case 2

6. CONCLUSION

This paper presents a new approach for solving ELD problem with valve-point effect and transmission line losses based on modified PSO (MPSO) algorithms. The suggested method includes a simple variation in the position equation which is simple concept, and has easy implementation, better effectiveness than previous methods and applicable to large scale systems.

In the study cases the proposed method has been applied to economic dispatch problem with 6 generators and 10 generators for IEEE systems. The results were compared with GA method and traditional PSO method and they showed that the proposed method was indeed capable of obtaining higher quality solution efficiently in ELD problem.

7. APPENDIX

The B loss coefficients matrix of 15-unit system with a base capacity of 100 MVA is shown as follows:

	1	2	3	4	5	6	7	8	9	10
1	0.0147	0.0118	0.0110	0.0015	0.0066	0.0048	0.0080	0.0081	−0.0006	−0.01560
2	0.00118	0.0243	0.0167	−0.0085	0.0077	0.0038	0.0067	0.0063	−0.0005	−0.01380
3	0.0110	0.0167	0.0217	0.0402	0.0094	0.0087	0.0083	0.0083	0.0061	−0.01950
4	0.0015	−0.0085	0.0402	1.8325	0.0265	0.1290	0.0340	0.0423	0.1786	−0.13140
5	0.0066	0.0077	0.0094	0.0265	0.0223	0.0133	0.0077	0.0068	0.0033	−0.01740
6	0.0048	0.0038	0.0087	0.1290	0.0133	0.0549	0.0149	0.0139	0.0175	−0.02970
7	0.0080	0.0067	0.0087	0.0340	0.0077	0.0149	0.0140	0.0118	0.0050	−0.02060
8	0.0081	0.0063	0.0083	0.0423	0.0068	0.0139	0.0139	0.0179	0.0068	−0.02200
9	−0.0006	−0.0005	0.0083	0.1786	0.0033	0.0175	0.0175	0.0068	0.1866	−0.02150
10	−0.0156	−0.0138	−0.0195	−0.1314	−0.0174	−0.0297	−0.0297	−0.0220	−0.0215	0.242400

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استخدام طريقة اسراب الجزيئات المثالية المعدلة لحل مشكلة اقتصاديات القدرة المرسلة بين خطوط القوي الكهربية مع اخذ مفاقيد النقل في الحسابات

تم فى هذا البحث تقديم تقنية اسراب الجزيئات المثالية المعدلة. تستخدم الطريقة المقترحة لحل مشكلة اقتصاديات القدرة المرسلة ومفاقيدها بين خطوط القوي الكهربية. ان الهدف الرئيسى من الدراسة هو تقليل تكاليف الوقود الكلية المستخدمة فى انتاج القدرة الكهربية.حيث تم تطبيق دراستين قياستين مختلفتين لبيان فعالية وكفاءة الطريقة المقترحة.كما تم مقارنة الطريقة المقترحة في هذا البحث مع طريقة الجينات الخوارزمية وطريقة اسراب الجزيئات المثالية التقليدية والتى اظهرت فيها ان الطريقة المقترحة اعطت حل افضل من ناحية الوقت المحتسب وكذلك من حيث تقليل التكاليف.