DESIGN AND SIMULATION OF HYBRID ECONOMIC AND EMISSION DISPATCH PROBLEM USING IMPROVED PARTICLE SWARM OPTIMIZATION

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ABSTRACT: *-ELD is a tool for scheduling generator set output based on specified load demand to operate the power system most economically, or in other words, we can say that the main goal of economic load scheduling is to optimize all system constraints. At the same time, all kinds of generator sets have been distributed at the lowest possible operating cost. The input/output characteristics of modern units are inherently highly non-linear (with valve point effects, rate limiting, etc.) and have multiple local minimum points in the cost function. In this regard, random search algorithms such as (GA), (ES), (EP), (PSO) it can be proved that (SA) is very effective in solving highly nonlinear ELD problems, and there is no limit to the shape of the cost curve.(GA) is a soft computing technique used to find exact or approximate solutions to optimization and search problems. Genetic algorithms are classified as global search heuristics. An algorithm to get the best solution to the optimization problem. The individual's performance is assessed by the fitness function i.e. objective function and considering the minimization problem, in this case, particles with lower values have more performance. The best experience for each particle in the iteration is stored in its memory, called Personal Best (Pbest). The optimal value of Pbest's (minimum) in the iteration determines the global best value (Gbest).*

Keywords- Economic Load Dispatch (ELD),Genetic Algorithms (GA), Evolutionary Strategies (ES), Evolutionary Programming (EP), Particle Swarm Optimization (PSO)

1. INTRODUCTION

We can define economic load scheduling (ELD) as the process of assigning load levels to generator sets so that system loads are fully and economically delivered. In interconnected power systems, costs must be minimized. The production level of each generator set is defined by the economic load distribution, so the total cost of generating and transmitting electricity is the least likely for a given load plan. The purpose of economic load scheduling is to minimize the total cost of generating electricity.The situation becomes more complicated when utility companies try to address transmission line losses and seasonal fluctuations associated with hydropower plants.There are many conventional techniques that can be used to solve the problem of economic load distribution, such as Lambda iteration, Newton-Raphson and Lagrangian multiplier. The entire interconnection network is controlled by the load dispatch center. The MW power generation for each grid is allocated by the load dispatch center, depending on the primary MW demand for that area. The job of the load control center is to maintain the power exchange between different areas and system frequencies at the required values. There are many alternatives for scheduling generation. In interconnected power systems, the primary goal is to find the actual and reactive power schedules for each individual power plant in such a way as to minimize operating costs. This is known as the "economic load scheduling" (ELD) issue. The objective function is also called the cost function. These objective functions can bring economic costs, system security or other goals. The loss factor is called the B factor. The main purpose of the economic load scheduling problem is to minimize the total cost of generating actual power.

The components that make up operating costs include fuel costs, labor costs, maintenance costs, and supplies. The throttling loss is large when the valve is just opened, and the throttle flow is small when fully opened.

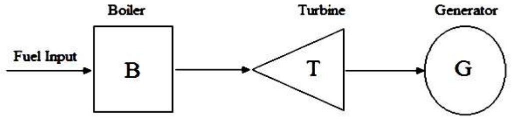
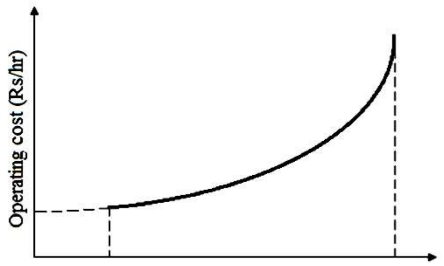


Figure 2.1 Simple Model of Fossil Plant

Figure 2.1 shows a simple model of the purpose of fossil plant scheduling. The cost is usually approximated by one or more secondary segments. The operating costs of the plant are shown in Figure 2.2. Therefore, the fuel cost curve in active power generation is in the form of a quadratic curve, as follows:

$$F(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i Rs/hr \quad (2.1)$$

Where a_i, b_i, c_i is the cost factor of the i-th unitF (P_{gi}) is the total cost of generation P_{gi} is the generation of the i-generation plant



Fi(Pgi)
Pgimin Output Power (MW) Pgimax
Figure 2.2 Operating Cost of Fossil Fired Plant

The fuel cost curve has many discontinuities,these occur when the output power is extended by using additional boilers, steam condensers, or other equipment. The is the minimum loading limit below which the operating device is uneconomical (or technically not feasible) and is the maximum output limit due to its rating.

II. ECONOMIC LOAD DISPATCH

Assuming that there is an N_G generator in one station and an active power load demand is given, the actual amount of power generate by each generator must be allocated in order to minimize the total cost. Therefore, the optimization problem can be expressed as:

Minimize:

$$F(P_{gi}) = \sum_{i=1}^{NG} F_i(P_{gi}) \quad (2.2a)$$

Subject to the energy balance equation

$$\sum_{i=1}^{NG} P_{gi} = P_D \quad (2.2b)$$

the inequality constraints

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \quad i = 1, 2,,, NG \quad (2.2c)$$

Where, P_{gi} is the decision variable, that is, the actual power generation P_d is the real power demand NG is the number of power plants $P_{gi}^{\min}$ Is the lower limit of the actual power generation, $P_{gi}^{\max}$ Is the allowable upper limit of actual power generation, F_i (P_{gi}) is the operating fuel cost of the i-th plant, given by the quadratic equation

$$F(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i Rs/hr \quad (2.2d)$$

The above problem is a constrained optimization problem. Use a Lagrangian multiplier where the function is minimized (or maximized) by using this method; the enhancement function is defined as

$$L(P_{gi}, \lambda) = F(P_{gi}) + \lambda (P_D - \sum_{i-1}^{NG} P_{gi}) \quad (2.3)$$

Where is Lagrange multiplier, The partial derivative of the Lagrangian function defined by L=L (Pgi,) must be zero for each parameter.

$$\frac{\partial L(P_{gi}, \lambda)}{\partial P_{gi}} = \frac{\partial F(P_{gi})}{\partial P_{gi}} - \lambda = 0 \quad (i= 1, 2,,,.. NG) \quad (2.4)$$

And

$$\frac{\partial L(P_{gi}, \lambda)}{\partial P_{gi}} = P_D - \sum_{i=1}^{NG} P_{gi} = 0 \quad (2.5)$$

From equation 3.4 we get,

$$\frac{\partial F(P_{gi})}{\partial P_{gi}} = \lambda \quad (i=1, 2,.. NG) \quad (2.6)$$

Where $\partial F(P_{gi}) / \partial P_{gi}$ is the incremental fuel cost of the *i*th generator.

$$\frac{\partial F(P_{gi})}{\partial P_{gi}} = 2a_i P_{gi} + b_i \quad (2.7)$$

Substituting the increment cost in (2.6) this equations becomes

$$2a_i P_{gi} + b_i = \lambda \quad (2.8)$$

Rearranging equation (2.8) to get P_{gi}

$$P_{gi} = \frac{\lambda - b_i}{2a_i} \quad (2.9)$$

Substituting the value of Pgi in eq. (2.5), we get

$$\sum_{i=1}^{NG} \frac{\lambda - b_i}{2a_i} = P_D$$

or

$$\lambda = \frac{P_D + \sum_{i-1}^{NG} \frac{b_i}{2a_i}}{\sum_{i-1}^{NG} \frac{1}{2a_i}} \quad (2.10)$$

With the economic load scheduling problem with transmission power loss PL, the objective function is therefore expressed as: Minimize

$$F(P_{gi}) = \sum_{i=1}^{NG} F_i(P_{gi}) \quad (2.11a)$$

$$F_i(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i Rs / hr \quad (2.11b)$$

Subject to (i) the energy balance equation

$$\sum_{i=1}^{NG} P_{gi} = P_D + P_L \quad (2.11c)$$

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \quad (i= 1, 2,,\ldots\ldots. NG) \quad (2.11d)$$

In general form the loss formula using B-coefficient is

$$P_L = \sum_{i=1}^{NG} \sum_{j=1}^{NG} P_{gi} B_{ij} P_{gi} \quad (2.12)$$

Where P_{gi} and P_{gj} are the real power generation of the i-*th* and j-*th* buses, respectively. B_{ij} is the loss factor or B coefficient At Eq. (2.12) the transmission loss formula is called the George formula.

$$L(P_{gi}, \lambda) = F(P_{gi}) + \lambda (P_D + P_L - \sum_{i-1}^{NG} P_{gi}) \quad (2.13)$$

Used for minimize enhancements,

$$\frac{\partial L(P_{gi}, \lambda)}{\partial P_{gi}} = 0 \quad (2.14a)$$

$$\frac{\partial L(P_{gi}, \lambda)}{\partial \lambda} = 0 \quad (2.14b)$$

$$\frac{\partial F_i(P_{gi})}{\partial P_{gi}} = \frac{\partial F(P_{gi})}{\partial P_{gi}} \quad (i=1,2,\ldots\ldots NG) \quad (2.15)$$

The condition given by (2.14), results as

$$\frac{\partial L(P_{gi}, \lambda)}{\partial P_{gi}} = \frac{\partial F(P_{gi})}{\partial P_{gi}} + \lambda \left(\frac{\partial P_L}{\partial P_{gi}} - 1 \right) = 0$$

$$\frac{\partial F(P_{gi})}{\partial P_{gi}} = \lambda\left(1 - \frac{\partial P_L}{\partial P_{gi}}\right)$$ (i=1,2,,,,NG) (2.17)

We can say that

$$\frac{\partial F(P_{gi})}{\partial P_{gi}} + \lambda\left(\frac{\partial P_L}{\partial P_{gi}}\right) = \lambda$$ (2.18)

Where $\frac{\partial F(P_{gi})}{\partial P_{gi}}$ is increment fuel cost (IC) $\frac{\partial P_L}{\partial P_{gi}}$ is called incremental transmission loss (ITL) i and is associated with the ith generation unit. Rearrange (2.18) results

$$\frac{\frac{\partial F(P_g)}{\partial P_g}}{1 - \frac{\partial P_L}{\partial P_{gi}}} = \lambda$$ (i=1,2,,,,NG) (2.19)

$$\left(\frac{1}{1 - \frac{\partial P_L}{\partial P_{gi}}}\right)\frac{\partial F(P_{gi})}{\partial P_{gi}} = \lambda$$ (i=1,2,,,,NG) (2.20)

$$L_i\left(\frac{\partial F(P_{gi})}{\partial P_{gi}}\right) = \lambda$$ (i=1,2,,,,NG) (2.21)

L*i* is called the penalty factor for the i-*th* plant.

$$L_i = \frac{1}{1 - \frac{\partial P_L}{\partial P_{gi}}}$$ (2.22)

Equation (2.13) shows that the minimum cost can be obtained when the incremental cost of each plant is multiplied by its penalty factor for all plants. Equation (2.20) is also written in another form

$$(IC) = \lambda[1 - ITL]_i$$ (i=1,2,,,,NG) (2.23)

This equation is called the exact coordination equation. Therefore, it can be clearly seen from the formula (2.23) that in order to solve the economic load distribution problem.The B-factorthis method is sufficient for dealing with loss coordination in economic dispatch of loads between plants. The general form of the loss formula using the B-factor is given in (2.22) the simplified formula the identification $B_{ij}=B_{ji}$,

$$\frac{\partial P_L}{\partial P_{gi}} = \sum_{i=1}^{NG} 2B_{ij}P_{gi}$$ (2.24)

$$\frac{dF_i(P_{gi})}{dP_{gi}} = 2a_iP_{gi} + b_i$$ (2.25)

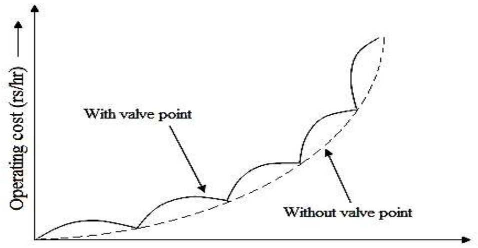
$$2a_iP_{gi} + b_i + \lambda\sum_{i=1}^{NG} 2B_{ij}P_{gi} = \lambda$$ (i=1,2,,,,NG) (2.26)

$$(2a_i + 2\lambda B_{gi})P_{gi} = -\lambda\sum_{\substack{i=1\\ j\neq i}}^{NG} 2B_{ij}P_{gi} - b_i + \lambda$$ (i=1,2,,,,NG) (2.27)

$$P_{gi} = \frac{1 - \frac{b_i}{\lambda} - \sum\sum_{\substack{i=1\\ j\neq i}}^{NG} 2B_{ij}P_{gi}}{\frac{2a_i}{\lambda} + 2B_{ij}}$$ (i=1,2,,,,NG) (2.28)

$$F(P_i)=\sum_{i=1}^{NG}(a_iP_i^2+b_iP_i+c_i+d_i*\sin\{e_i*(P_i^{\min}-P_i)\})$$
(2.29)

For any particular value of □, the above equation can be solved iteratively by assuming the initial value of P*gi*.ELD is considered to be one of the key functions of power system operation. However, due to the valve point load in fossil fuel combustion equipment, the actual input-output characteristics show high order nonlinearities and discontinuities. The valve point loading effect has been modeled as a repetitive rectifying sine function, as shown in Figure 2.3.



Power Output Pi

Figure 2.3 Operating Cost Characteristics with Valve Point Load

The valve point effect introduces ripple into the heat curve.Mathematically, the economic load scheduling problem considering valve point loading is defined as:

Minimize operating costs

$$F(P_i)=\sum_{i=1}^{NG}(a_iP_i^2+b_iP_i+c_i+d_i*\sin\{e_i*(P_i^{\min}-P_i)\})$$
(2.29)

Where a*i*, b*i*, c*i*, d*i*, e are the cost coefficients of the first unit.

Subject to: (i) the energy balance equation is given by the equation. (2.11c) and (ii) the inequality constraint is given by the equation. (2.11d)

III. COMBINED ECONOMIC EMISSION DISPATCH

The function of fuel cost is simulated and approximated as a Cubic curve, whose total expression ($ / h) is for a period of time T and many generators N are given by:

$minF_T = \sum_{i=1}^{n} F_i(P_i)$ The economic dispatch problem can be defined mathematically as an objective with two constraints:

$$F_{ci}(P_i) = a_iP_i^3 + b_iP_i^3 + c_iP_i + d_i$$

Subject to the two constraints:

$$\sum_{i=1}^{N} P_i = D + L$$

$$P_{imin} \le P_i \le P_{imax}$$

Where P_i: power output (MW) of the i-th generator; F_T: Total fuel cost ($ / h); F_i (P_i): fuel cost per unit i ($ / h); D: Total demand (MW); L: transmission loss (MW);P_{imin}, P_{imax}large power limit of unit i (MW); and N: total the number of service units. Toxic gas released by thermal units Burning fossil fuel sources such as sulfur dioxide, nitrogen oxides and carbon dioxide Can contribute to minimizing the world alone Emissions pass:

$$E_{SO2i}(P_i) = a_{SO2}\,P_i^3 + b_{SO2}\,P_i^2 + c_{SO2}\,P_i + d_{SO2}$$
$$E_{NOxi}(P_i) = a_{NOxi}P_i^3 + b_{NOxi}P_i^2 + c_{NOxi}P_i + d_{NOxi}$$
$$E_{CO2i}(P_i) = a_{CO2}\,P_i^3 + b_{CO2}\,P_i^2 + c_{CO2}\,P_i + d_{CO2i}$$

In this work, we integrated the price penalty factor hi (maximum fuel cost / maximum emissions per gas) Emission equation

$[F_{Ti}(P_i) = F_{Ci}(P_i) + h_{SO2i}E_{SO2i}(P_i) + \cdots h_{NOxi}E_{NOxi}(P_i) + h_{CO2}\,E_{CO2}\,(P_i)$

Where h_{SO2}, h_{NOx} and h_{CO2} are price penalties SO_2, NO_x and CO_2 are mixed with emissions Cost and normal fuel costs.

$$h_{SO2} = \frac{F_{Ci}(P_{Maxi})}{E_{SO2}\,(P_{MAXi})}$$
$$h_{NOxi} = \frac{F_{Ci}(P_{MAXi})}{E_{NOxi}(P_{MAXi})}$$
$$h_{CO2} = \frac{F_{Ci}(P_{MAXi})}{E_{CO2i}(P_{MAXi})}$$

Comprehensive economic emission scheduling problem is a problem Combination of economic load scheduling and emissions Dispatch problems. In this paper, the cubic criterion function is Use CEED instead of quadratic function to represent CEED problem. Cube standard functions have been found more effectively resists nonlinearity of actual power system. Economic scheduling problems can defined as:

$F(P) = \sum_{i=1}^{n} a_i P_i^3 + b_i P_i^2 + c_i P_i + d_i$ Where $F(P_i)$ is the power generation cost of the generator set ($/ hour) output power is P_i; a_i, b_i, c_i and d_i are costs Generate the coefficient i of the unit. Emission scheduling issues can also be defined as cubes Standard functions with four transmit coefficients as:

$$E(P) = \sum_{i=1}^{n} e_i P_i^3 + f_i P_i^2 + g_i P_i + h_i$$

Where E (P_i) is the emission (in kilograms per hour) and Pi is the power Generated by unit i, and e_i, f_i, g_i and hi are transmitted coefficient. Minimize the goal of generating electricity costs Pollutant emissions can be converted into a single Use the target of the price penalty factor. Maximum/maximum fine Factors in this study were considered to address CEED issues. The CEED problem with the maximum/maximum penalty factor can be described as

$OF = F_T = \sum_{i=1}^{n} F(P_i) + \sum_{i=1}^{n} h_{iMAX/MIN} E(P_i)$ Where OF represents the objective function (CEED) and FT refers to Total cost and $h_{imax/min}$ are maximum/maximum penalty factors Generator set can define maximum/maximum penalty factor Such as

$$h_{imax/min} = \sum_{i=1}^{n} F(P_{imax}) / \sum_{i=1}^{n} E(P_{imax})$$

Where $P_{i,\,max}$ refers to the maximum power (in MW) can be generated by the generating unit i. The goal of this paper is to minimize power generation costs. And the emission of pollutant gases, i.e. the total cost Meet all other constraints. In the power generation system, need to have many equal and unequal constraints considered to optimize the actual situation system. Power balance and generator limit constraints the two most important constraints are considered here jobs. The total output power (megawatts) must be met Total load demand (in megawatts) Therefore, the total output power must Equal to the sum of total load demand and total load Power loss (MW). It can be defined as

$$P = \sum_{i-1}^{n} P_i = P_D + P_L$$

Where P_i, P_D and P_L are total generated power, total load demand and total loss, respectively.Each power generation unit in the power generation system has its upper and lower limits. Generate unit output Must be within this limit to work properly. This one Constraint can be defined as

$$P_{imin} \le P_i \le P_{imax}$$

Where $P_{imin}$and P_{imax} denote the minimum and maximum limits, respectively, of generating unit i.

IV. QUANTOM PSO BASED COMBINED DISPATCH

PSO provides population based Search program, in which individuals are called partial icles change, their position over time. In the PSO system, Particles fly around in a multidimensional search space. Each particle adjusts its position according to it during flight Own experience and experience Adjacent particles, using the best position It is encountered by itself and its neighbors. Optimal in multidimensional space seeking a solution to move every particle in the group Get the best point by adding speed position. Particle speed is affected three components, namely inertia, cognitive and society. The inertial component simulates the inertial behavior of birds flying in the previous direction. The Cognitive components mimic the memory of birds about its best location and social the component simulates the memory of birds the best location in some of the icles. Particle movement around the multidimensional search space until they find the best solution. Modification speed of each can use current speed and calculation agent the distance to Pbest and Gbest is as follows.

$$V_i^{k+1} = W \times V_i^k + C_1 \times r_1 \times (Pbest_i^k - X_i^k) + C_2 \times r_2 \times (Gbest^k - X_i^k)$$

Where, V_i^kThe speed of individual i when iterating k, X_i^k Individual i is in the position of iteration k, W inertial weight C1 , C2 acceleration factor, $Pbest_i^k$The best position of individual i in iteration k, $Gbest^k$ Group's best position until iteration k r1 , r2 Random number between 0 and 1. Accelerate during this speed update the coefficients C1, C2 and the inertia weight W are Predefined and r1, r2 are randomly generated uniformly The number is in the range [0, 1]. In general, inertia the weight W is set according to the following equation:

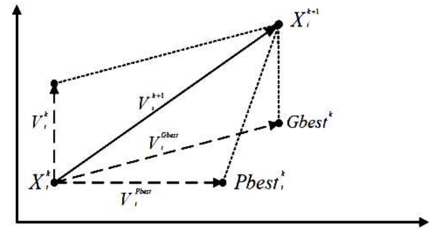


Fig 3.1 the search mechanism of PSO

The modified velocity equation (6) is given by:

$$V_i^{K+1} = K.\left(W.V_i^k + C_1 G_d()\left(Pbest_i^k - X_i^k\right) + C_2 C_d()\left(Gbest^k - X_i^k\right)\right)$$

$$K = \frac{2}{\left|2 - \varphi - \sqrt{\varphi^2 - 4\varphi}\right|}$$

Where $\varphi = C_1 + C_2, \varphi > 4$

The convergence characteristic of the system can be controlled byφ. Contraction factor method (CFA) φ must be greater than 4.0 to guarantee stability. But as φ Increase Factor K is reduced, diversification is reduced, Produces a slower reaction. Usually when Using shrinkage factors, φSet to 4.1 (ie C_1, C_2 = Therefore, the constant multiplier K is 0.729.QPSO, proposed and developed by Sun et al., is the expansion of PSO in the field of quantum computing. The concept of qubits and revolving doors is here to introduce the improvement of demographic characteristics Diversity. Qubit and angle Represents the state of the particle rather than the position and the particle velocity completed in the basic PSO. Thereby, QPSO has powerful search capabilities and powerful search capabilities Fast convergence feature. The basic difference between a qubit and a classical bit is the latter can stay at the same time Superposition of two different quantum states,

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

In the above equation, $\alpha$and $\beta$are complex numbers that satisfy the equation

$$|\alpha|^2 + |\beta|^2 = 1$$

The rotation state is represented by | 0> and the rotation state is It is represented by | 1>. As can be seen from (1), a qubit is Represents two information states (| 0> and | 1>) simultaneously. This superposition state can also expressed as

$$|\psi\rangle = \sin\theta|0\rangle + \cos\theta\,|1\rangle$$

Where the phase of the qubit is represented by□□□□the relation among □□□□and □□□The relation among □□□□and□□□can be defined as the position of the particle in QPSO can be described as□□□□arctan□□□ $x_{id} = p_{id} \pm \frac{L}{2}\ln\left(\frac{1}{u}\right)$

Where x_{id} is the position of the ith particle and p_{id} is local The attractor of particle i is located between pbest and gbest and u is a uniformly distributed random number in the range [0,1]. The value of L can be used following equation

$$L = 2\alpha|x_{id} - p_{id}|$$

Where □□is the only parameter of QPSO, which can be calculated using the following equation

$$\alpha = (1 - 0.5).\frac{t_{max} - t}{t_{max}} + 0.5$$

And the local attractor p can be represented as below

$$p = \varphi.pbest + (1 - \varphi).gbest$$

Where φ refers to a uniformly distributed random number. The range of φ is [0, 1]. Figure 1 depicts a flow chart of the QPSO. In the first step, Algorithm parameters, such as population size, particles initialize the dimension and the maximum number of iterations. The second step is to evaluate the fitness of each particle and Record pbest and gbest.

IV. RESULTS

The research work done in this dissertation is associated with the minimization of fuel cost and emission dispatch while maintain the network constraints with consideration and non-consideration of valve point effect.

The problems addressed in this research work are as follows-

- Formulation of economic load dispatch for different test systems.
- Implementing economic load dispatch problem considering valve point effect for different test systems.
- Implementation of economic load dispatch problem using modified particle swarm optimization for valve point effect for different test systems.

- Implementation of combined emission and economic load dispatch using improved cost function and quantum particle swarm optimization.

This system consists of 13 generating units and the input data of 13-generator system are given in Table . In order to validate the proposed Modifed-PSO method, it is tested with 13-unit system having non-convex solution spaces. The 13-unit system consists of thirteen generators with valve-point loading effects and have a total load demands of 1800 MW and 2520 MW, respectively output.

Table 1
Result for 13 Generator System Valve Point Effect

Unitpoweroutput	**NN-EPSO[20]**	**MPSO**
P 1	490.0000	269.263671702325
P 2	189.0000	150.750185936561
P 3	214.0000	224.858126186401
P 4	160.0000	112.081379788931
P 5	90.0000	157.271376553459
P 6	120.0000	158.473867494880
P 7	103.0000	106.176428015040
P 8	88.0000	158.919165718706
P 9	104.0000	159.451200806129
P 10	13.0000	77.5031323538038
P 11	58.0000	101.999849738940
P 12	66.0000	92.4841327770156
P 13	55.0000	92.7117782526324
Total Power Output (MW)	1800	1800
Total Generation Cost ($/h)	18442.5931	**18100.145**

V. CONCLUSION

This research focuses on calculation and stimulation of economic load dispatch problem under different operating conditions. It also provided the solution involving valve point effect and losses for different test systems. Therefore, three aims were constructed. First, constructed the mathematical model of economic and emission load dispatch with cubical cost functions under valve point effect and non-valve point effect with and without losses. Second one is to solve numerical results of economic load dispatch with modified quantum particle swarm optimization. The third one is comparative analysis of simulated results with existing soft computing problems.
This research mainly studied the improved quantum PSO method. It is used to provide the solution involving numerical analysis. The modified PSO method requires less number of iterations to reach convergence, and is more accurate and not sensitive to the factors.

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