Solution of Economic Load Dispatch problem using Conventional methods and Particle Swarm Optimization

Nikitha M, Pratheksha Jerline L, Aishwarya T, Karthikaikannan D

Abstract: ***Economic load dispatch is the method to find the optimum power output of the generators in a network cost-effectively with adherence to all the constraints. In this paper, the Economic Load Dispatch (ELD) problem has been tested on IEEE 14 Bus System by implementing conventional methods like Classical Coordination method, Gradient method, Modified Coordination method, and Particle Swarm Optimization (PSO). Conventional methodologies provide the solution in the simplest way but it does not handle the constraints effectively. Modified coordination method provides a better solution without the use of B-coefficients and the calculation of penalty factors is much easier because they can be obtained from the already available solution of FDLF involving some computations. PSO also provides a better solution but the initial design parameters are slightly difficult to determine. The performance of all the methods is compared and results reveal that the Modified coordination method proves to be the fastest among other solutions particularly if larger systems are involved.***

Keywords: constraints, loss, optimum, penalty factor.

I. INTRODUCTION

Electricity consumption escalates in every part of the world, so the demand for power is also increasing rapidly in current days. To meet the required demand in an electric power generation system, it is necessary to schedule all the generators effectively. The Economic load dispatch (ELD) is essential and one of the elementary optimization techniques in the operation of the power systems. The ELD problem focuses on minimizing the generation cost of thermal units, total power loss in the system, and the voltage deviations, to maximize the reliability of power supplied to the customers, and to enhance the overall system efficiency satisfying the load demand and operational constraints. Several optimization methods or approaches have been applied through the years for solving the ELD problem such as linear programming (LP), non-linear programming (NLP), and quadratic programming (QP). Amongst them, classical coordination equations method manifests to be the simplest and fastest method but the inability to handle the constraints properly can be overcome by modified coordination equations method.

Revised Manuscript Received on July 29, 2020.

* Correspondence Author

Dr. D. Karthikaikannan*, Department of EEE, SASTRA Deemed to be University, Thanjavur, India. E-mail: karthikaikannan@eee.sastra.edu

Nikitha. M, Department of EEE, SASTRA Deemed to be University, Thanjavur, India. E-mail: mnikitha014@gmail.com.

Pratheksha Jerline. L, Department of EEE, SASTRA Deemed to be University, Thanjavur, India. E-mail: prathekshaashok@gmail.com .

Aishwarya. T, Department of EEE, SASTRA Deemed to be University, Thanjavur, India. E-mail: aishwaryat963@gmail.com

The classical ELD could be made faster by deploying modified coordination equations and the penalty factors could be computed with less effort from the known fast decoupled load flow (FDLF) solution with the use of perturbation technique. The efficient use of modified coordination equations method could be demonstrated by testing them on IEEE 14 Bus System and the numerical results attained are compared with Exact Coordination equations method and Particle Swarm Optimization method. Therefore, the key objectives are to find the optimum power output of the generators considered, total cost of generation and solution time obtained by carrying them out on IEEE 14 Bus System using the conventional methods, modified coordination equation and PSO and to prove which is ideally the best solution amongst them.

II. CLASSICAL COORDINATION EQUATION

A. Without Loss

The Economic Load Dispatch (ELD) of a given system can be solved easily by considering a case where the losses of transmission lines are overlooked. Here P_D is equal to the summation of the generations. The line impedances and the system arrangement are not considered in this method. The main intention of this problem is to find the optimum power generation value at which the total cost of production (Ct) is minimum.

$$C_t = \sum_{i=1}^{n} C_i \quad (1)$$

where,
n = number of buses

$$C_t = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i) \quad (2)$$

This equation is subjected to the equality constraint,

$$\sum_{i=1}^{n} P_i = P_D \quad (3)$$

The constraints are augmented into the function by employing the Lagrange multipliers.

$$\mathcal{L} = C_t + \lambda(P_D - \sum_{i=1}^{n} P_i) \quad (4)$$

The least margin of this unrestrained function is obtained at the point where the partial differentiation of the function to the variables are equal to zero.

$$\frac{\partial \mathcal{L}}{\partial P_i} = 0 \quad (5)$$

and

$$\frac{\partial \mathcal{L}}{\partial \lambda} = 0 \quad (6)$$

We know that,

$$C_t = C_1 + C_2 + C_3 + C_4 + \cdots + C_n \quad (7)$$

Thus, from (5), (6) and (7) the condition for minimum cost of production is found to be,

$$\frac{\partial C_t}{\partial P_i} = \frac{dC_i}{dP_i} = \lambda \;\; ; \; i = 1,2, \ldots n \quad (8)$$

$$\frac{dC_i}{dP_i} = 2a_i P_i + b_i = \lambda \quad (9)$$

and

$\sum_{i=1}^{n} P_i = P_D$ is the equality constraint that is to be imposed on the function. In this method where the losses are neglected and are without generator limits, all the plants are required to work with the same production incremental cost abiding equality constraint.

Thus, the generation of power at each generator bus is found by rearranging (9),

$$P_i = \frac{\lambda - b_i}{2a_i} \quad (10)$$

λ can also be found using an analytical approach by,

$$\sum_{i=1}^{n} \frac{\lambda - b_i}{2a_i} = P_D \quad (11)$$

$$\lambda = \frac{P_D + \sum_{i=1}^{n} \frac{b_i}{2a_i}}{\sum_{i=1}^{n} \frac{1}{2a_i}} \quad (12)$$

This value of λ found is used to find the optimal scheduling of generation [3].

B. With Loss

When distances of transmission are minimal, transmission losses are neglected. However, for a network with longer transmission distances and areas with lower load density, transmission losses are to be accounted which affects the optimum dispatch of generation.

The total cost of generation is,

$$C_t = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i) \quad (13)$$

Constraints enforced are:

(i)Equality constraints:

$$\sum_{i=1}^{n} (P_i) - P_D - P_L = 0 \quad (14)$$

and

(ii)Inequality constraints:

$$P_i^{min} \le P_i \le P_i^{max}$$

where,

P_L = transmission loss of the total system

P_D = demand of the total system

a_i, b_i, c_i = cost coefficient of the i^{th} generating unit

The solution to the optimal P_i procured from the classical co-ordination equations is,

$$\frac{\partial F_i}{\partial P_i}\left[\frac{1}{1 - \frac{\partial P_L}{\partial P_i}}\right] = \lambda \;;\; i = 1,2, \ldots n \quad (15)$$

where,

λ = Lagrange multiplier

F_i = plant i^{th} fuel cost

$\frac{\partial F_i}{\partial P_i}$ = plant i^{th} incremental fuel cost

$\frac{\partial P_L}{\partial P_i}$ = plant i^{th} incremental transmission loss.

The simplest quadratic representation of the transmission loss is

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j \quad (16)$$

The generalized formula is given by,

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_{00} \quad (17)$$

where,

B_{ij} = loss coefficients or B-coefficients [3].

III. LAMBDA ITERATION METHOD

Lambda iteration solves the ELD problem by mapping the value of lambda (marginal cost) to each generator's output (in MW), P_i.

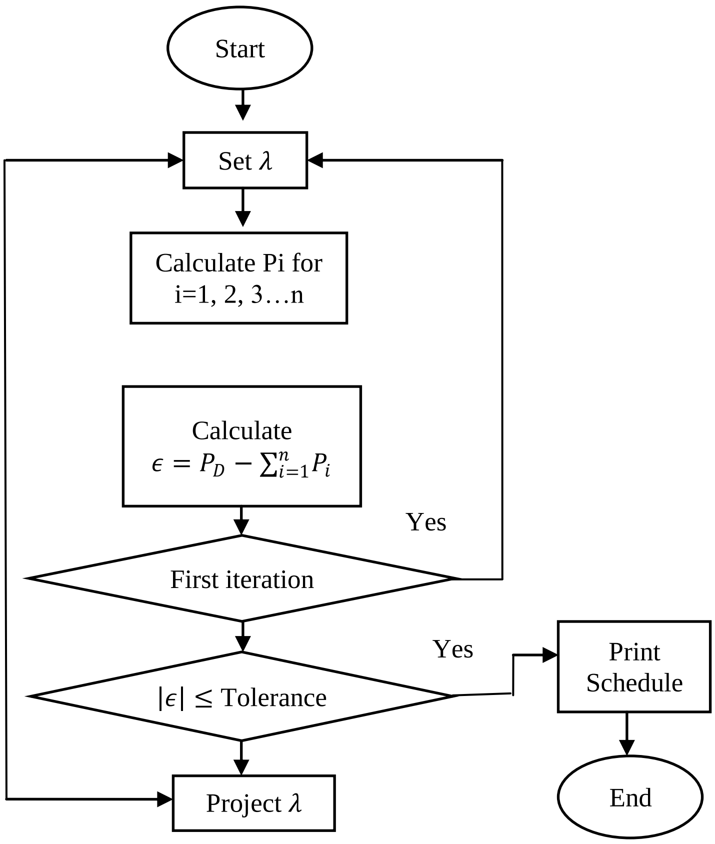

Fig. 1. Algorithm for Lambda iteration method for ELD problem.

The generators collectively produce a total output (in MW) for any value of lambda. This method starts with values of lambda which is assumed and is either more or less than the optimal value.

Retrieval Number: J74750891020/2020©BEIESP
DOI: 10.35940/ijitee.J7475.0891020

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication

The program then iteratively brackets the optimal value. While calculating, the generating limits of each generator is taken into account as a constraint. When the calculated power exceeds the maximum generation of the particular generator, maximum generation value is taken as generator power. When the calculated power is less than the minimum generation of the particular generator, then minimum generation value is taken as generator power [7].

$if\ P_i > P_i^{max}$, then set $P_i = P_i^{max}$

and

$if\ P_i < P_i^{min}$, then set $P_i = P_i^{min}$

The equality constraint taken into consideration is that the sum of all power generation in the generators is equal to the demand power.

$\sum_{i=1}^{n} P_i = P_D$

IV. GRADIENT SEARCH METHOD

For complex cost functions such as,

$$F_T = a_i P_i^2 + b_i P_i + c_i + d_i exp\left(\frac{P_i - e_i}{f_i}\right) \quad (18)$$

Gradient method could be used for evaluation.

$$f = \sum_{i=1}^{n} F_i(P_i) \quad (19)$$

The main objective is to minimize the cost function.

$$\phi = (P_D - \sum_{i=1}^{n} P_i) \quad (20)$$

Equation (20) is the function of the constraint.

Hence to solve the ELD problem taking into consideration of both the objective and constraint, gradient method could be applied to the Lagrange function itself.

The Lagrange function is given by,

$$L = \sum_{i=1}^{n} F_i(P_i) + \lambda\ (P_D - \sum_{i=1}^{n} P_i) \quad (21)$$

And the gradient of this function is

$$\begin{bmatrix} \frac{\partial L}{\partial P_1} \\ \frac{\partial L}{\partial P_2} \\ \frac{\partial L}{\partial P_3} \\ \frac{\partial L}{\partial \lambda} \end{bmatrix} = \begin{bmatrix} \frac{d}{dP_1} F_1(P_1) - \lambda \\ \frac{d}{dP_2} F_2(P_2) - \lambda \\ \frac{dL}{dP_3} F_3(P_3) - \lambda \\ P_D - \sum_{i=1}^{n} P_i \end{bmatrix} \quad (22)$$

The initial values of λ and the generator power values are assumed. The gradient for the Lagrangian function is calculated and updated values of generator power is obtained.

A. Implementation Steps

The solution of eld using gradient method involves the following steps:

1. The load of the system should be specified
   $P_D = \sum_{i=1}^{n} P_i$
2. λ value should be chosen for the initial iteration.
3. By substituting the λ value in the given equation, solve the generation power value.

$$P_i = \frac{\lambda - b_i}{a_i} \quad (23)$$

4. Compare the quantity $(\sum_{i=1}^{n} P_i)$ with P_D and verify if the power is balanced.

$$P_D = \sum_{i=1}^{n} P_i \quad (24)$$

If the power is not balanced and within the tolerance limit, then set the value of λ as,

$$\lambda^{k+1} = \lambda^k + \triangle\lambda^k \quad (25)$$

where,

$$\triangle\lambda^k = \frac{P_D - \sum_{i=1}^{n} P_i^k}{\sum_{i=1}^{n}\left(\frac{1}{a_i}\right)} \quad (26)$$

5. Until final convergence is achieved the cycle is repeated. Finally, the system λ and optimum generation power values are obtained.

V. PARTICLE SWARM OPTIMISATION (PSO) METHOD

PSO optimizes nonlinear function and provides solution with supremacy in minimal time and rapid convergence.

- Assume x to be the position of the particle.
- Assume v to be the velocity of the particle.
- The j_{th} particle in the 'd' dimension is expressed as,
  $x_j = (x_{j1}, x_{j2}, \dots, x_{jd})$
- The position of the j_{th} particle's previous best is noted and denoted as,
  $pbest_j = (pbest_{j1}, pbest_{j2}, \dots, pbest_{jd})$.
- $gbest_d$ is chosen from the best solution of $pbest$.
- The velocity rate of a particle is given by,
  $v_j = (v_{j1}, v_{j2}, \dots, v_{jd})$

The new velocity and position of all the particles can be obtained from $pbest_{jd}$, $gbest_d$ as,

$$v_{jd}^{(t+1)} = \omega.v_{jd}^{(t)} + c_1 * rand() * (pbest_{jd} - x_{jd}^{(t)}) + c_2 * Rand() * (gbest_d - x_{jd}^{(t)}) \quad (27)$$

$$x_{jd}^{(t+1)} = x_{jd}^{(t)} + v_{jd}^{(t+1)}\ ; \quad j = 1,2, \dots n\ \&\ d = 1,2, \dots m \quad (28)$$

where,

n = number of particles in a group

m = number of members in a particle

t = number of iterations

ω = inertia weight factor

c_1, c_2 = acceleration constants

rand (), Rand () = random values distributed uniformly in the range [0,1]

$v_j^{(t)}$ = particle j^{th} velocity at iteration t

$x_j^{(t)}$ = particle j^{th} current position at iteration t

$$V_d^{min} \leq v_{jd}^{(t)} \leq V_d^{max}$$

Here, V^{max} helps in finding the fitness or resolution. This is executed for the space available between the existing position to the destination position. In most cases, the value of V^{max} is assumed to be 10-20% of variable range on that particular dimension [6].
The constants used are the weighting values of the stochastic acceleration whose aim is to approach the position of $pbest$ and $gbest$. Using constants with lower values describes that the particles are drifting far away from the required solution. The high value indicates the rapid and expected movement towards the solution region in pre-destined area. Thus, the values of c_1 and c_2 is taken 1.5 after plentiful experimentations. The balanced value of inertia weight ω provides an expedition in the local and global cases. In every case, the value of ω is taken 0.9 to 0.4 for a period as it decreases linearly.

$$\omega = \omega_{max} - \left[\frac{\omega_{max} - \omega_{min}}{iter_{max}}\right] * iter \tag{29}$$

where,
$iter_{max}$ = maximum number of iterations
$iter$ = current number of iterations

A. *Implementation Steps*

The solution of PSO involves the following steps,

1. The Fitness function (reciprocal of cost of generation) is initialized.
2. Initialize the PSO variables such as Population size, Inertia weight factor(ω), the maximum number of iterations, Acceleration constants (c_1, c_2), error gradients.
3. The cost function, load demand, active power limits of generators, and B-coefficient matrix data are inputted.
4. During the initial execution of the algorithm, randomly allocate numerous active power vectors satisfying generators real power limits.
5. Evaluate the fitness function for each active power vector. To determine $pbest$, the obtained values in the iteration are compared. Similarly, to determine $gbest$, all the fitness function values for the entire population are compared and these values are modified at each iteration.
6. In each iteration, the change in error is verified and $gbest$ value is plotted until it is compassed within the pre-specified range.
7. The final value of $gbest$ obtained is the minimum cost and the optimum solution of the ELD is the vector of the active power.

VI. MODIFIED CO-ORDINATION EQUATION METHOD

When power at the i^{th} bus is perturbed by a minimal value, with P, Q conditions same at the remaining buses excluding slack bus s, the variation in system transmission losses are often expressed as,

$$dP_L = \frac{\partial P_L}{\partial P_i} dP_i + \frac{\partial P_L}{\partial P_s} dP_s \tag{30}$$

Also,

$$dP_L = dP_i + dP_s \tag{31}$$

From the above equations

$$\frac{dP_i}{dP_s} = -\frac{(1 - \partial P_L/\partial P_s)}{(1 - \partial P_L/\partial P_i)} \tag{32}$$

From the classical co-ordination equation

$$\frac{\partial F_i}{\partial P_i}\left[\frac{1}{1 - \frac{\partial P_L}{\partial P_i}}\right] = \lambda = \frac{\partial F_s}{\partial P_s}\left[\frac{1}{1 - \frac{\partial P_L}{\partial P_s}}\right] \tag{33}$$

$$i = 1,2, \ldots n \;\&\; i \neq s$$

where,
s = slack bus

$$\frac{dF_i}{dP_i}\frac{(1 - \partial P_L/\partial P_s)}{(1 - \partial P_L/\partial P_i)} = \frac{dF_s}{dP_s} = \mu(say) \tag{34}$$

$$\frac{dF_i}{dP_i}\left(-\frac{dP_i}{dP_s}\right) = \frac{dF_s}{dP_s} = \mu \tag{35}$$

$$i = 1,2, \ldots n \;\&\; i \neq s$$

For a limiting case,

$$-\frac{dP_i}{dP_s} = -\frac{\delta P_i}{\delta P_s} \tag{36}$$

where,
P_i and P_s are the power in the i^{th} bus and slack bus respectively.
Equation (36) is cited as modified co-ordination equations for power optimization and (dP_i/dP_s) is known as modified penalty factor (PF_i) for the i^{th} plant [5].

A. *CALCULATION OF PENALTY FACTOR*

Considering the first bus as slack, the equations of real power for the FDLF algorithm are,

$$\left[\frac{\triangle P_m}{V_m}\right] = [B'][\triangle \delta_m] \;;\; m = 2, \ldots . n \tag{37}$$

where,
$[\triangle P_m/V_m]$ = mismatch vector of real power
$[\triangle \delta_m]$ = mismatch vector of bus voltage angle
$[B']$ = constant real matrix derived from the Y bus

In the prior iteration of FDLF, $[\triangle P_m/V_m]$, $[\triangle \delta_m]$ values advent to zero and the value of $[B']^{-1}$ remains the same. If there is a minimal disruption at the i^{th} generation, with P, Q conditions consistent at all the buses excluding the slack, then (38) may be rewritten as,

$$\begin{bmatrix} 0 \\ . \\ . \\ \frac{\triangle P_i}{V_i} \\ . \\ . \\ 0 \end{bmatrix} = [B'] \begin{bmatrix} \triangle \delta_2 \\ . \\ . \\ \triangle \delta_i \\ . \\ . \\ \triangle \delta_n \end{bmatrix} \tag{38}$$

or

$$[\triangle \delta_m] = [B']^{-1}\left[\frac{\triangle P_i}{V_i}\right] \tag{39}$$

$[\triangle \delta_m]$ is well procured by multiplying i^{th} column values of known $[B']^{-1}$ with the scalar $\triangle P_i/V_i$. Respective change in power at the slack bus because of the disruption at the i^{th} bus can be constructed as,

$$\triangle P_s = \left[\frac{\partial P_s}{\partial \delta_m}\right]^T [\triangle \delta_m]\ m = 2, \ldots .n \quad (40)$$

From the above equations,

$$\triangle P_s = \left[\frac{\partial P_s}{\partial \delta_m}\right]^T [B']^{-1} \left[\frac{\triangle P_i}{V_i}\right]\ m = 2, \ldots .n \quad (41)$$

$$\left[\frac{\triangle P_s}{\triangle P_i}\right] = \frac{1}{V_i}\left[\frac{\partial P_s}{\partial \delta_m}\right]^T [B'_{icol}]^{-1} \quad (42)$$

where,

$[B'_{icol}]^{-1} = i^{th}$ column of the $[B']^{-1}$ matrix.

The penalty factor $(-\delta P_i/\delta P_s)$ for the i^{th} plant is obtained from (42), after the column vector $[\partial P_s/\partial \delta_m]$ is calculated. This can be procured from the expression of the slack bus as,

$$P_s = V_s V_m \sum_{m=2}^{n} [G_{sm}\cos(\delta_s - \delta_m) + B_{sm}\sin(\delta_s - \delta_m)] \quad (43)$$

$$\frac{\partial P_s}{\partial \delta_m} = V_s V_m [G_{sm}\sin(\delta_s - \delta_m) - B_{sm}\cos(\delta_s - \delta_m)] \quad (44)$$

Penalty factors $(PF_i) = (-\delta P_i/\delta P_s)$ may be calculated from (42) in 2 different ways of assessing $[\partial P_s/\partial \delta_m]$ from (44).

- **$1-\delta, 1-V$ FDLF method:** From final iteration of the FDLF solution, when the convergence of results occurs, calculate $[\partial P_s/\partial \delta_m]$ substituting the values of the most recent voltages and angles.
- **$1-\delta$ method:** The $P-\delta$ equations of the fdlf algorithm are solved till the $[\triangle P/V]$ vector concurs. The most recent voltage angle vector value $[\triangle \delta_m]$ is only considered for calculating $[\partial P_s/\partial \delta_m]$ .The $[\triangle Q/V] = [B''][\triangle V]$ equations remain unsolved and hence voltage magnitudes remain without updating [5].

B. Computational Steps

1) Study the data of the system, cost coefficients of the generators, active power generation limits, etc. Considering bus-1 as slack bus, $Pi^{(0)}$ based on same incremental coefficient is evaluated.

2) Excluding $i = s$, with specified P_i perform FDLF and determine the system's generation at the slack bus and power loss.

Now,

Initialize μ= $a_s\ PGs^{(0)}$ + bs

3) The column vector $\left[{\partial P_s}/{\partial \delta_m}\right]$, $m = 2, \ldots .n$ and $-\delta P_i/\delta P_s$; $i = 2, \ldots .n$ which are the penalty factors are evaluated using the following equation,

$$\Delta P_s/\Delta P_i = \frac{1}{V_i}[\partial P_s/\partial P_m]^T [B'_{icol}]^{-1}$$

where,

$[B'_{icol}]^{-1} = i^{th}$ column $[B']^{-1}$ matrix.

4) (i) By solving the modified coordination equation, new generations are determined excluding the bus at the slack.

(ii) If any variations in 2 generation sets acquired in succeeding iterations is found to be not confined within a predefined tolerance when examined,

- Find the latest slack bus power P_s', latest values for [V] and [δ] by solving P- δ and Q-V equations (or) only P- δ equation of the FDLF solution.
- Update μ´ = (μ+μ´)/2 and again calculate column vector & penalty factors.

where,

μ´ = $a_s\ P_s$ ´+ bs

else,

(iii) Final load flow is performed and the line flow, power of the slack bus, losses of the system and total generation cost are computed and attained results are printed.

VII. RESULTS AND DISCUSSION

The cost function of the generators considered are given below:

$$F_1 = 0.005P_1^2 + 2.45P_1 + 105 \quad \$/hr$$
$$F_2 = 0.005P_1^2 + 3.51P_1 + 44.1 \quad \$/hr$$
$$F_1 = 0.005P_3^2 + 3.89P_1 + 40.6 \quad \$/hr$$

The active power limits of the generators considered are:

$$10 \le P_1 \le 180$$
$$20 \le P_2 \le 80$$
$$20 \le P_3 \le 50$$

Table - I: PSO Method Parameters

Population Size	Maximum No of Iteration	Inertia Weight Factor (w)	Acceleration Constant	
			C1	C2
50	100	0.5	1.5	1.5

IEEE 14 bus system has 3 generators with active power input P_1, P_2, P_3.The approximate solution time is based on the system configuration:

System Type: x64-based PC

Version: 10.0.18363 Build 18363 Processor: Intel® Core™ i5-8250U CPU @1.6Ghz, 1.8Ghz

Table-II: Comparison of the results using Conventional methods, Modified Coordination equation and PSO on IEEE 14 Bus System

Technique applied	Active power output (MW)			Total system loss (MW)	Total cost of generation ($/hr)	Approximate solution time (s)
	P_1	P_2	P_3			
Exact Coordination equation Without Loss	160	68.65	30.65	-	1098.16	0.609065
With loss	160	75.4166	33.6284	12.3076	1139.32	0.623440
Gradient method	160	68.65	30.65	-	1098.16	0.014519
Modified coordination method	176.83	57.921	34.493	9.9440	1139.48	0.230427
PSO Without loss	159.3	80	20	-	1099.47	13.459876 (for 100 iterations)
With Loss	160	70.0862	38.8696	9.6581	1139.02	17.158753 (for 100 iterations)

From the above results obtained we can conclude that the solution time required for modified coordination method is comparatively lower than by using exact coordination method and PSO. The cost of generation obtained for all the cases are nearly equal. Hence Modified Coordination method proves to be the quickest technique amongst other techniques for ELD solution.

A. Convergence Curve for PSO:

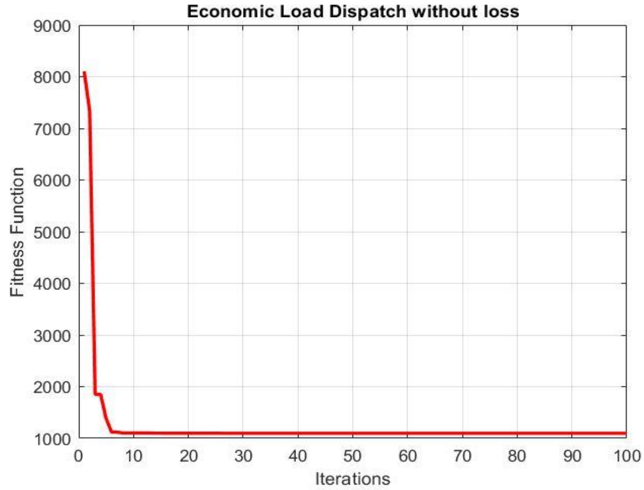

Fig.2. Fitness function curve for ELD without losses

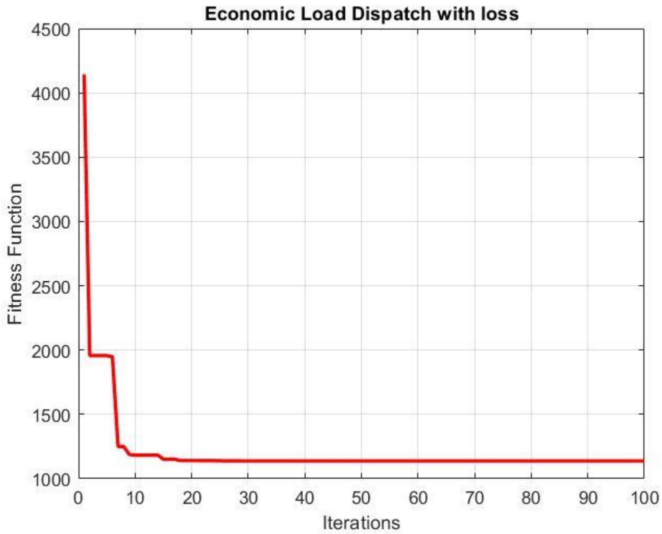

Fig. 3. Fitness function curve for ELD with losses

Figures 2 and 3 shows the convergence of the PSO algorithm as the iteration's advances. The fitness function value gradually increases as the iterations increase. The fitness function is the reciprocal of a cost function which decreases as the number of iterations increases.

VIII. CONCLUSION

In this paper, Economic Load Dispatch is carried out using Conventional methods (Exact Coordination equation, Gradient), Modified Coordination Equation method, and Particle Swarm Optimization method on IEEE 14 Bus System and comparison have been made based on the total cost of generation and solution time. From the results obtained we infer that the solution time of the Modified Coordination method is much faster than conventional methods and PSO.

The total cost of generation obtained for all cases is marginally the same. Moreover, in terms of simplicity, the Modified Coordination method proves to be the best since the computations involved in solving the penalty factors are much easily realized with the available FDLF solutions and it also does not involve designing initial parameters like in the case of PSO. Hence, we conclude that the Modified Coordination equation method is the ideal solution when larger systems are to be considered as it provides the solution at a faster rate particularly for online applications.

REFERENCES

1. Bhowmik P. S, Bose S. P, Rajan D. V, Deb S, "Power Flow Analysis of Power System Using Power Perturbation Method," *IEEE Power Engineering and Automation Conference*, Wuhan, China, September, 2011.
2. M. Gholamghasemi, E. Akbari, M. B. Asadpoor, "A new solution to the non-convex economic load dispatch problems using phasor particle swarm optimization," *Applied Soft Computing Journal*, 2019, pp. 111-124.
3. Hadi Saadat, *Power system analysis*. WCB/McGraw-Hill (USA), 1999, pp. 268-270.
4. D. P. Kothari, I. J. Nagrath, *Modern Power System Analysis*, Tata McGraw-Hill (India), 2003.
5. J. Nanda, L. Hari, M. L. Kothari, and J. Henry, "Extremely fast economic load dispatch algorithm through modified co-ordination equations," *IEE Proceedings C (Generation, Transmission and Distribution)*, 1992, pp. 39-46.
6. M. Sudhakaran, P. Ajay-D-Vimal Raj, and T.G. Palanivelu, "Application of Particle Swarm Optimization for Economic Load Dispatch Problems," *International Conference on Intelligent Systems Applications to Power Systems*, Toki Messe, Niigata, Japan, 2007.
7. Vipandeep Kour, Lakhwinder Singh, "Comparative Analysis of Lambda Iteration Method and Particle Swarm Optimization for Economic Emission Dispatch Problem," *International Journal of Engineering Research & Technology (IJERT)*, 2017.
8. Manoj Mahajan, Shelly Vadhera, "Economic load dispatch of different bus systems using particle swarm optimization," IEEE Fifth Power India Conference, 2012.
9. M. A. Abido, "Environmental/Economic power dispatch using multiobjective evolutionary algorithms," *IEEE Transactions on Power Systems*, vol. 18, no. 4, pp. 1529-1537, 2003.
10. Uma Sharma, Beaulah Moses, "Analysis and optimization of economic load dispatch using soft computing techniques," 2016 International Conference on Electrical, Electronics and Optimization Techniques (ICEEOT)

AUTHORS PROFILE

Nikitha. M B.Tech in Electrical and Electronics Engineering from SASTRA Deemed to be University, Tanjore, India. Her field of interests are Power Systems, Nano Electronics and High Voltage Engineering.

Pratheksha Jerline. L B.Tech in Electrical and Electronics Engineering from SASTRA Deemed to be University, Tanjore, India. Her area of interests are Power Systems, Electrical Machines and Inverter Designing.

Aishwarya. T B.Tech in Electrical and Electronics Engineering from SASTRA Deemed to be University, Tanjore, India. Her area of interests are Power Systems, Power Electronics and Power Plant Engineering.

Dr. D. Karthikaikannan received B.E., degree in Electrical and Electronics Engineering from Madras University in 2002. M.E., from Annamalai University in 2005 and Ph.D from Anna University Chennai. At present, he is working as Assistant Professor in School of Electrical and Electronics Engineering in SASTRA Deemed University, Tanjore. His field of interests are Optimal Power Flow, Generation Control and Power System Restructuring.