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# Particle Swarm Optimization Applied To Economic Load Dispatch Problem

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## Abstract

*The economic load dispatch problem is one of the major optimization problems in the electric power system. The main objective of this problem is to reduce or minimize the total operational cost of the system fulfilling the load demand within the limit of constraints. In this work, a more general heuristic method known as Particle swarm optimization (PSO) is applied to solve the economic load dispatch problem in electric power system. IEEE-14 bus system for 3-unit is considered to test the algorithm with cost function. This method is simple, direct, relatively new, modern, reliable and powerful optimization method that has been empirically shown to perform well on many of these optimization problems. It is widely used to give the global optimum solution in a complex search space. The mat lab programs were developed to solve the Economic load dispatch problem for 3-unit system using PSO and conventional method i.e. Lambda iteration method. These methods are applied to solve for both the cases i.e. the problem including transmission losses and without including transmission losses. Finally, the proposed PSO method results were compared with conventional method (i.e. lambda iteration method) to show the effectiveness of PSO and were found that PSO is superior then the conventional method.*

**Keywords:** Economic Local Dispatch; Unit Commitment; Particle Swarm Optimization;

## Introduction

In modern world electric power system, there are many problems such as optimal power flow, Economic Load Dispatch (ELD), Unit Commitment (UC) etc. the economic load dispatch problem is one of the major problem in the power system. The objective is to fulfill the load demand by reducing the cost and satisfying the environmental constraints. Over the years many techniques have been applied to solve the ELD problems such as conventional methods and non-conventional technique have been used to solve the ELD problems. Conventional methods have simple mathematical models and high search speed but they are failed or unable to solve many complex problems due to local optimum solution and facing difficulties to locate the global optimal solution. Recently, the interest have been focused on the other method based on artificial intelligence to solve the economic load dispatch problem, these are Particle Swarm Optimization, Artificial Bee Colony, Genetic Algorithm, Neural Networks, Evolutionary Programming and many more.

Particle Swarm Optimization (PSO) provide the better solution, they generally provide a fast and reasonable solution (sub optimal or near global optimal). Each method has their own advantages. This

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work proposes particle swarm optimization (PSO) to solve ELD in the electrical power systems, which are population, based probabilistic search optimization algorithms and can be applied to real world problem.

## Problem Formulation

The main objective of ELD is to minimize the total fuel cost of unit and also reduces the transmission losses with increased output and satisfying all the constraints. The objective function of ELD is defined as:

$$Min\ C = \sum_{i=1}^{N} C_i(P_{Gi}) \quad (1)$$

$$= \sum_{i=1}^{N} \alpha_i + \beta_i(P)_i + \gamma_i(P)_i^2 + \cdots \quad (2)$$

Where, $C_i(P_{Gi})$ is cost function, $\alpha_i$, $\beta_i$, $\gamma_i$ is cost coefficient of i generator, Pi is the power generated by the i unit and n is the no. of generators.

The minimization subjected to the following generator constraints:

$$P_{pmin} \leq P_p \leq P_{pmax} \quad (3)$$

Were, $P_{pmin}$ and$P_{pmax}$ is the minimum and maximum power output.
The transmission loss can be calculated by using the following equation given below:

$$P_L = \sum_m \sum_n P_m B_{mn} P_n \quad (4)$$

Were, $B_{mn}$ is the element of loss coefficient matrix B.

## Overview of Particle Swarm Optimization

Particle swarm optimization (PSO) is stated as a population based optimization technique developed by Russell Eberhat and James Kennedy in 1995, inspired by the most social behavior of birds that is the bird flocking or fish schooling. In this technique each solution is a bird in the search space we call it particle all of particles have values which are evaluated by the fitness to be optimized and have velocities which direct flying of the particle. PSO initialized with group of random particles or solution and then searches for optima by updating generations. In every iteration each particle is updated by following two best values. After finding the two best values, the particle updates its velocity and position with following equation given below:

$$V_i^{k+1} = wV_i^k + C_1 rand_1 \times \left(pbest_i - C_i^k\right) + C_2 rand_2 \times \left(gbest_i - C_i^k\right) \quad (5)$$

Where,

$V_i^{k+1}$= velocity of agent i at iteration k, $V_i^k$=velocity of agent $i$ at iteration $k$, $\boldsymbol{\omega}$ = weighting function, $C_i^k$= current position of agent i at iteration k, $C_1$ **and** $C_2$ = weighting Factors, $rand_1$ *and* $rand_2$= random number functions between 0.0 to 1.0, $pbest_i$= personal best of agent $i$ and $gbest_i$ =best value of agent $i$ within whole group.

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The weighting function is defined as which is used in equation:

$$w = w_{max} - \left(\frac{w_{max} - w_{min}}{iter_{max}}\right) iter \quad (6)$$

Where,

$w_{min}$ =final Weight, $w_{max}$ =initial Weight, $iter_{max}$ =maximum Iteration Number, $\boldsymbol{iter}$=current iteration number.

The current position (in the swarm) can be modified by the following equation:

$$C_i^{k+1} = C_i^k + V_i^{k+1} \quad (7)$$

## Algorithm of Particle Swarm Optimization to Solve ELD Problem

Steps of Implementation Of PSO For ELD

1. Initialize the fitness function.
2. Initialize the parameters of particle swarm optimization that are population size, C1, C2, inertia max and minimum value etc.
3. Input the cost function its maximum minimum limits, the total load demand and its loss coefficient matrix.
4. At the first step set of solution should be check for equality constraints and the equality constraints are checked
5. The value of fitness function is calculated and all the values obtained in iterations are compared to obtain the pbest value. After that the pbest values are comparing to get the gbest value. At every step these values are updated.
6. Update the velocity and the position of particles.
7. The value of gbest is plotted.
8. This final value of global best is the value of minimum cost and represents the optimal solution of economic load dispatch.

The flow chart for the proposed algorithm is given below in fig.1

## Result and Discussions

To verify the feasibility and effectiveness of the particle swarm optimization three generating units system have been tested. Result of particle swarm optimization is then comparing with the conventional method. The loss matrix $B_{mn}$ we have used is given below

$$B_{mn} = \begin{matrix} \mathbf{1.36255 \times 10^{-4}} & \mathbf{1.75300 \times 10^{-5}} & \mathbf{1.83940 \times 10^{-4}} \\ \mathbf{1.75400 \times 10^{-5}} & \mathbf{1.54480 \times 10^{-4}} & \mathbf{2.82765 \times 10^{-5}} \\ \mathbf{1.83940 \times 10^{-4}} & \mathbf{2.82765 \times 10^{-4}} & \mathbf{1.61470 \times 10^{-3}} \end{matrix}$$

By using the proposed PSO techniques and conventional method the results obtained are shown in tables given below. The test results in the table for three unit systems are for the load changing from 190, 215 and 240 MW. The algorithm applied for the two different considerations with transmission losses and without transmission losses. And shows that PSO is superior to the conventional method.

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The results for different load demand (190, 125, 240MW) for without considering transmission losses are given in the table (1), (2) and (3).

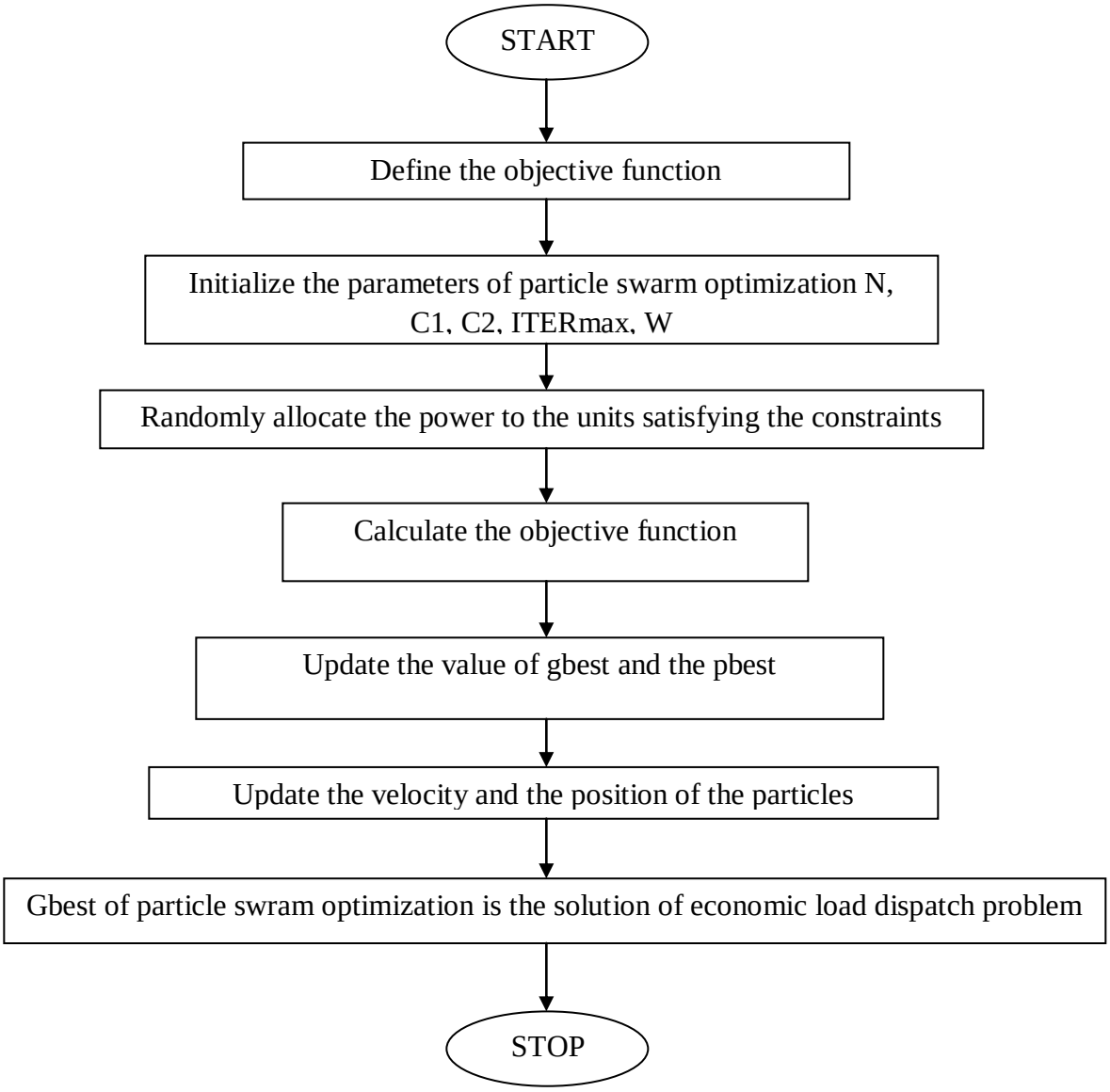


*Fig.1 flow chart of proposed algorithm of PSO*

Table 1 comparison of cost in different methods with the load demand of 190

| Generated output(MW) | Proposed PSO Algorithm | Conventional Method |
|---|---|---|
| P1 | 50.00 | 143.9936 |
| P2 | 5.00 | 11.0256 |
| P3 | 135.00 | 34.9807 |

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| | | |
|---|---|---|
| Fuel Cost | 2051.8 | 2320.5021 |
| Load Demand | **190** | **190** |

Table 2 comparison of cost in different methods with the load demand of 215

| **Generated output(MW)** | **Proposed PSO Algorithm** | **Conventional Method** |
|---|---|---|
| P1 | 64.5734 | 153.0836 |
| P2 | 13.6084 | 18.8683 |
| P3 | 136.8182 | 43.0481 |
| Fuel Cost | 2258.9 | 2576.050 |
| Load Demand | **215** | **215** |

Table 3 comparison of cost in different methods with the load demand of 240

| **Generated output(MW)** | **Proposed PSO Algorithm** | **Conventional Method** |
|---|---|---|
| P1 | 71.4176 | 162.1736 |
| P2 | 31.7650 | 26.7110 |
| P3 | 136.8174 | 51.1155 |
| Fuel Cost | 2465.6 | 2839.996 |
| Load Demand | **240** | **240** |

The figure (2), (3), (4) given below shows the minimum value of the optimal solution obtained by the particle swarm optimization for without considering transmission losses. The plot is plotted between the fitness function along with number of iteration taken in the algorithm of PSO.

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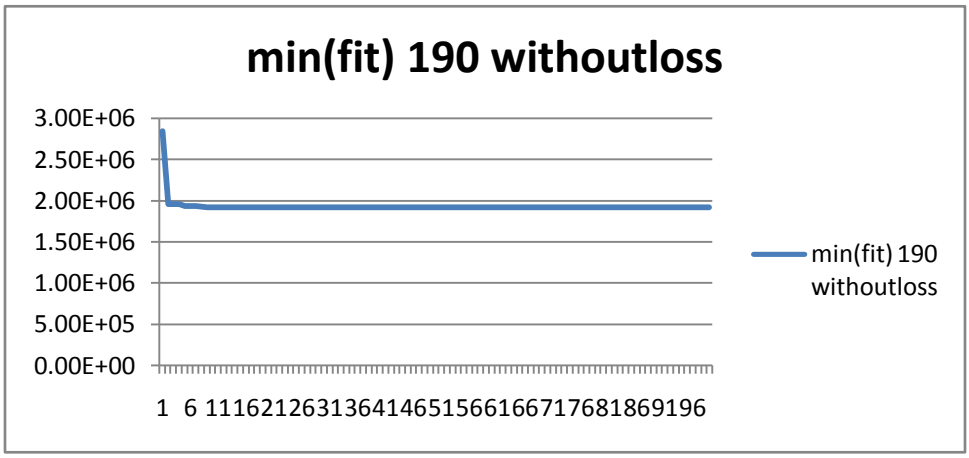


Fig.2 minimum fitness function plot for particle swarm optimization for 190 load demand

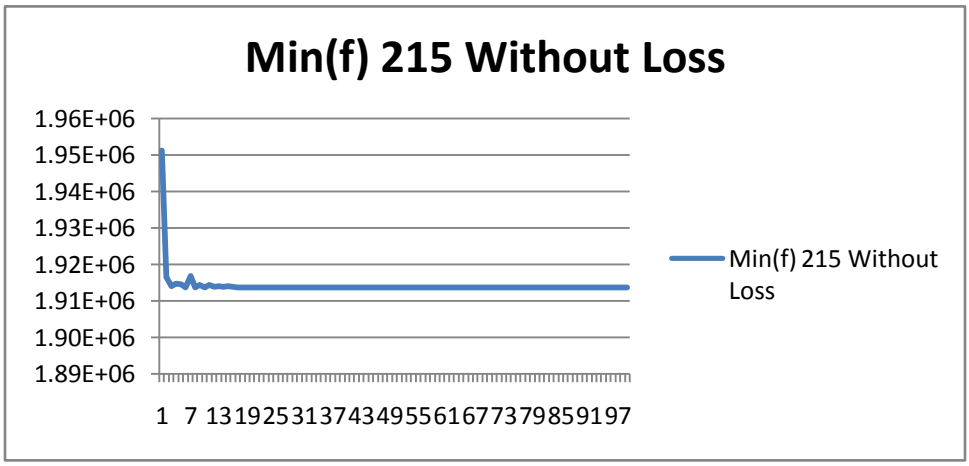


Fig.3 minimum fitness function plot for particle swarm optimization for 215 load demand

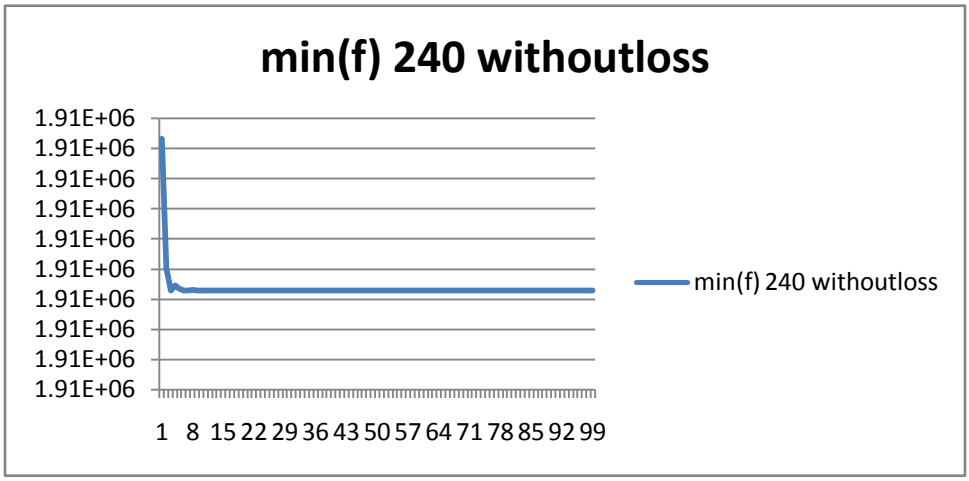


Fig.4 minimum fitness function plot for particle swarm optimization for 240 load demand

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The comparison of both the methods that have been applied to solve the ELD problem with transmission line losses have been given in the table (4), (5) and (6) for different load demand (190, 125, 240MW).

Table5.8 comparison of particle swarm optimization method and lambda iteration method for 190 load demand

| Generated output(MW) | Proposed PSO Algorithm | Conventional Method |
|---|---|---|
| P1 | 50.2138 | 143.8125 |
| P2 | 6.3358 | 35.70524 |
| P3 | 136.880 | 14.94276 |
| Transmission Loss | 3.3682 | 4.5121 |
| Fuel Cost | 2079.7 | 2372.5356 |
| Load Demand | **190** | **190** |

Table5.9 comparison of particle swarm optimization method and lambda iteration method for 215 load demand

| Generated output(MW) | Proposed PSO Algorithm | Conventional Method |
|---|---|---|
| P1 | 59.9129 | 165.16102 |
| P2 | 23.0922 | 40.06988 |
| P3 | 136.8211 | 14.89231 |
| Transmission Loss | 4.8262 | 5.6688 |
| Fuel Cost | 2298.5 | 2642.6023 |
| Load Demand | **215** | **215** |

Table5.10 comparison of particle swarm optimization method and lambda iteration method for 240 load demand

| Generated output(MW) | Proposed PSO Algorithm | Conventional Method |
|---|---|---|
| P1 | 72.9955 | 177.8229 |
| P2 | 36.6513 | 53.86336 |
| P3 | 136.8192 | 14.762 |
| Transmission Loss | 6.4660 | 6.6575 |

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| | | |
|---|---|---|
| Fuel Cost | 2519.0 | 2916.7885 |
| Load Demand | **240** | **240** |

The figure (5), (6), (7) given below shows the minimum value of the optimal solution obtained by the particle swarm optimization for considering transmission losses. The plot is plotted between the fitness function along with number of iteration taken in the algorithm of PSO.

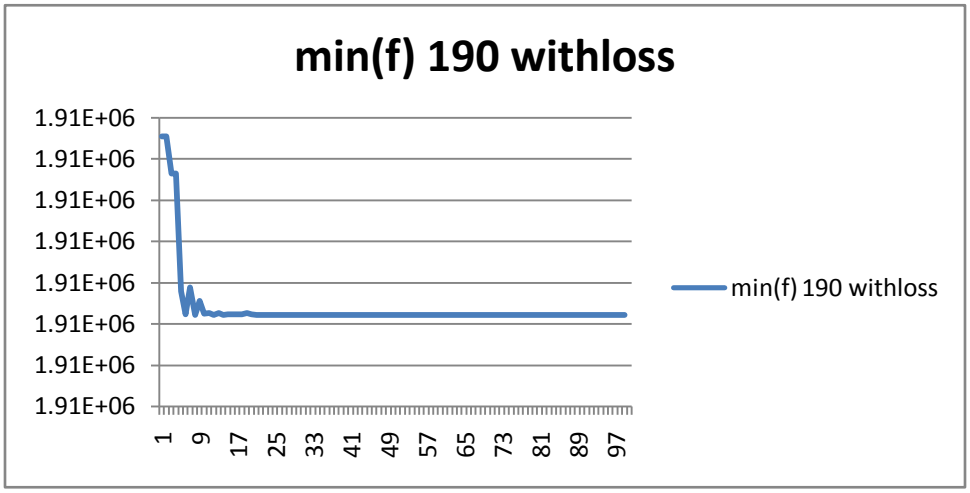


Fig.5 minimum fitness function plot for particle swarm optimization for 190 load demand

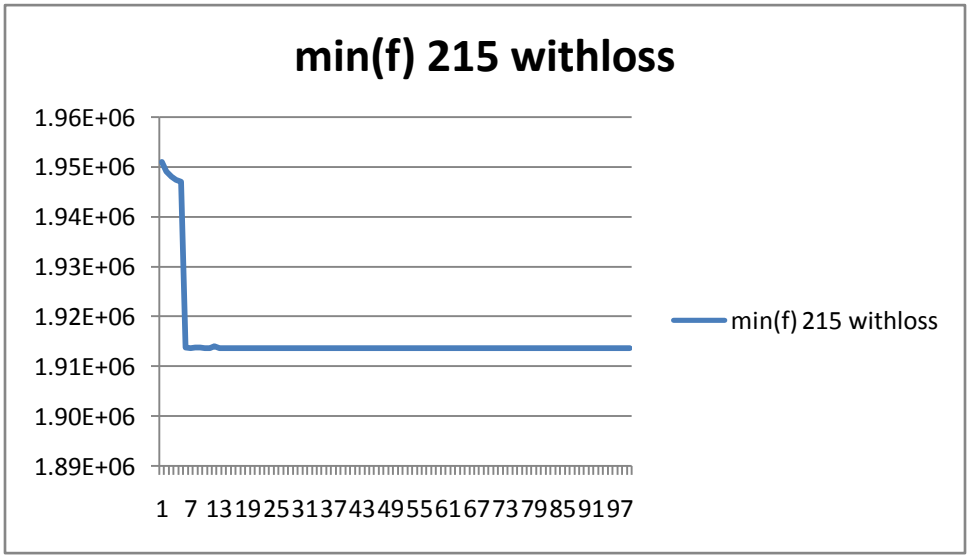


Fig.6 minimum fitness function plot for particle swarm optimization for 215 load demand

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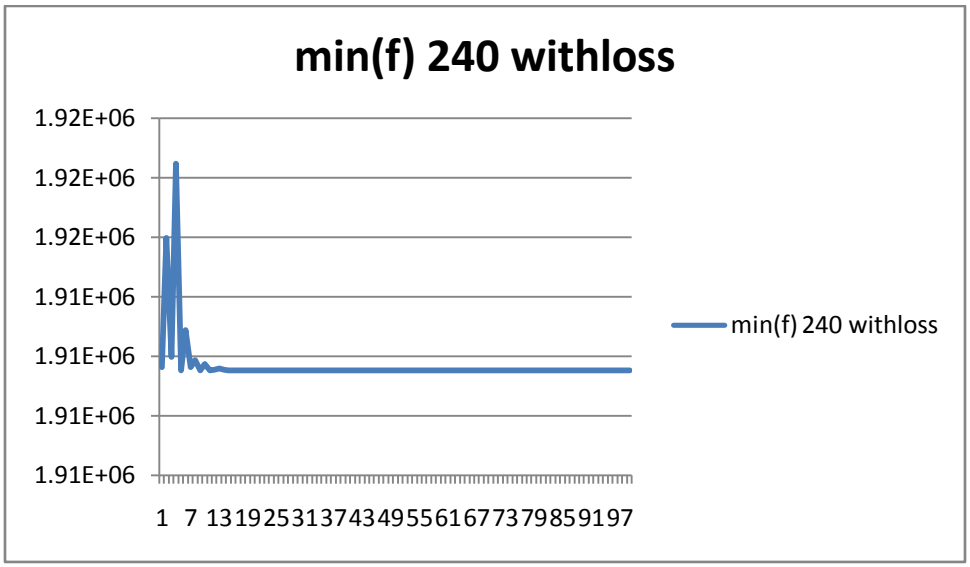


Fig.7 minimum fitness function plot for particle swarm optimization for 240 load demand

## Conclusion

In this work overview of economic load dispatch problems and its solution methodology is discussed. Implementation is done using the mat lab programs to solve Economic load dispatch problem for three-unit system through lambda iteration method and particle swarm optimization. From the results when compared we concluded that the particle swarm optimization technique is successful technique to solve the economic load dispatch problem.

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