# Fuel Cost Reduction for Thermal Power Generator with Economic Load Dispatch Problem using SFLA

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**Abstract**

*Economic load dispatch problem with multiple fuel cost options is one of the major problems in a power system. The thermal plant fuel cost is highly non-linear, because of the load demand and discontinuities for the power generation. This makes the EDP problem a non-linear constrained optimization problem. In the traditional EDP problem, each generator's cost function is represented by a single quadratic polynomial equation which can be solved by using numerical programming based techniques such as gradient-based method, lambda iteration method. In this paper is to minimize the fuel cost of the power system for the various load conditions by solving the EDP of the real power generation by using SFLA optimization algorithm. This paper compares the optimization techniques such as PSO, MPSO in a 3-unit generating system. The EDP is to determine the optimal combination of power outputs of all generating units to minimize the total fuel cost while satisfying the load demand and operational constraints. The comparisons of results show that the proposed SFLA algorithm provides the less cost of the fuel cost and the quality solution of the power generation. The proposed methodology emerges as robust optimization techniques for solving the ELD problem for different size power system.*

**Keywords** : *Optimal power flow (OPF), Economic load dispatch (ELD), Genetic Algorithm (G.A), particle swarm optimization (PSO), Quantum behaved particle swarm optimization (SFLA).*

## I. INTRODUCTION

Nowadays in the power system, the power generation to the demand is the major problem. The purpose of this paper is dealing with the thermal power plant. At present the tamilnadu has the present demand as 91,642 million units in 2015-2016 as per TNEB record. The power demand has increased to 14% compared to the previous year. In future the government has planned to produce the power by using the wind energy, hydro-electric energy and thermal energy. Thermal energy consumes more fuel cost. So the paper deals with the thermal power plant.

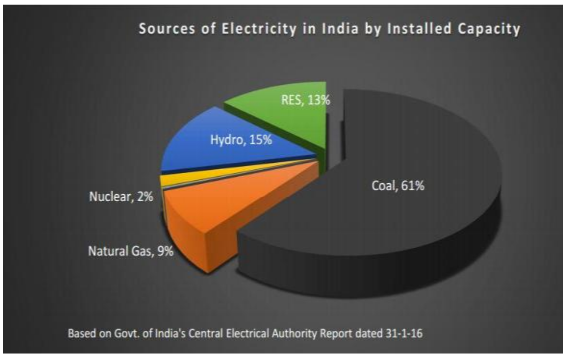



**Fig.1 Installed Capacity of TNEB in Tamilnadu**

## II. ECONOMIC LOAD DISPATCH PROBLEM

Economic magnetize hasten is the question hang upon the kindling cost. The warm one dynamo fuel cost is high when compared with other generator cost. So it is indispensable to include the warm influence sapling in the frugal load hasten. The main objective is to serve freight at minimum expense. The different pain illustration of the separate influence plants are being enrolled below.

### A. *Objective Functions*

The objective of the Economic load dispatch problem is to reduce the fuel cost including operating constraints. The fuel cost function can be represented as,

$$minF_i = \sum_{i=1}^{N} F_i(P_i) \qquad (1)$$

$F_{i(P_i)}$ is The cost function of the generator

$P_i$ is the reactive output power of the i[th] generator unit

The non-linear function of the economic load dispatch problem was,

$$F_i(P_i) = a_i p_i^2 + b_i p_i + c_i \qquad (2)$$

Here $a_i, b_i, c_i$ are the cost co-effecients of the generator.

### B. *Constraints Power Balance Constraints*

It is expressed as

$$\sum_{i-1}^{N} P_i = P_d + P_l \qquad (3)$$

(3)

The system generator has the load and the demand losses. So the generator cost is minimized .so the equation should be satisfies the demand.

$P_d$ System demand

$P_l$ System load

### C. *Generator Limits*

$P_i^{min} \le P_i \le P_i^{max}$ (i=1…, N) (4)

$P_i^{min}$ Minimum power produced by the generator

$P_i^{max}$ Maximum power produced by the generator

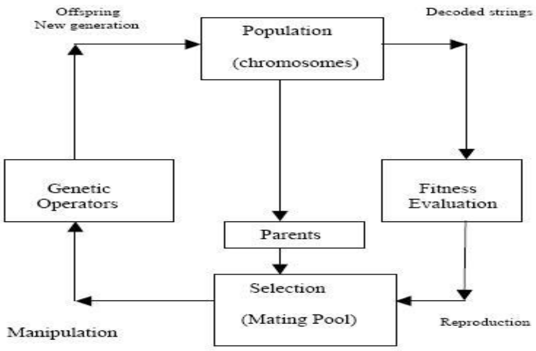
Here as per the equation no (4) the load must be satisfied with the demand. So only the paper proceeds with the economic load dispatch problem to reduce the fuel cost.

## III. GENETIC ALGORITHM

The GA is a random complete search course that mimics the metaphor of natural biological evolution such as choice, crossover, and change GA's work on string construction where chain is binary digits which personate a coding of control parameters for a disposed question. All parameters of the assumed problem are coded with concatenation of particle. The individual little is appeal to 'gene' and the contented of the each gene is called 'allele'. Typically, the hereditary algorithms have three state' initialization, valuation and hereditary transformation

The fitness function for the maximization problem is

$f(x) = F(X)$




- STEP1: Create a Random Initial State
- STEP2: Evaluate Fitness
- STEP3: Reproduce
- STEP 4: Next Generation

## IV. PARTICLE SWARM OPTIMIZATION

The GA is a random whole investigate career that imitated the metaphor of illegitimate biologic maneuver such as choice, crossover, and alter GA's composition on string construction where bond is dyadic digits which mask a digest of government parameters for a affectioned question. All parameters of the assumed problem are coded with series of particle. The individual little is accusation to 'gene' and the willing of the each gene is called 'allelomorph'. Typically, the ancestral algorithms have three state' initialization, valuation and patrimonial transfigurement

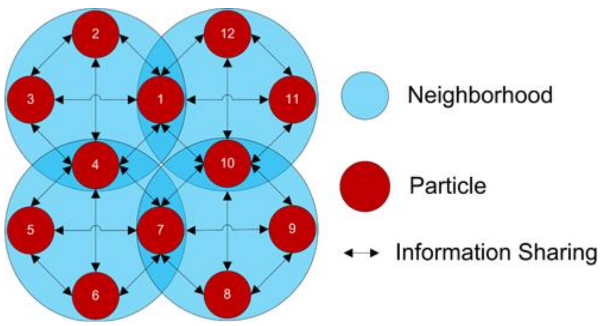



**Fig .2PSO technique**

*Swarm*: A set of particles

*Particle:* A Potential solution or a member of a swarm

*i) Position*

$$X_i = (X_{i1}, X_{i2}, \dots, X_{in}) \in R'' \qquad (5)$$

*ii)Velocity*

$$V_i = (V_{i1}, V_{i2}, \dots, V_{in}) \in R'' \qquad (6)$$

Each Particle maintains its previous best position

*iii) Individual best position*

$$P_i = (P_{i1}, P_{i2}, \dots, P_{in}) \in R''$$

$$Pbest = f(P_i) \qquad (7)$$

*iv) Swarm global position*

$$P_g \in R''$$

$$gbest = f(P_g) \qquad (8)$$

*v) Original velocity updating equation*

$$V_i^{t+1} = V_i^t + \emptyset_1.r_1(P_i - X_i^t) + \emptyset_2.r_2(P_g - X_i^t)$$

$V_i^t$ Inertia

$\emptyset_1.r_1(P_i - X_i^t)$ Cognitive component

$\emptyset_2.r_2(P_g - X_i^t)$ Social component

A single particle (which can be seen as a potential solution to the problem) can determine \how good" its current position is. It benets not only from its problem space exploration knowledge but also from the knowledge obtained and shared by the other particles.

A stochastic factor in each particle's velocity makes them move through unknown problem space regions. This property combined with a good initial distribution of the swarm

### *A. Flow chart of ELD using PSO*

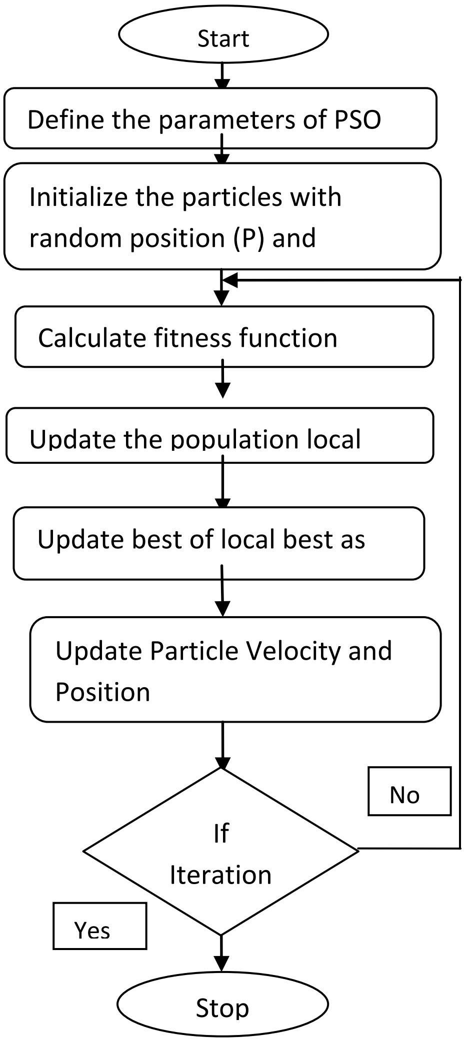



**Fig. 3Flow chart of PSO**

The flow chart presents the solution to the economic dispatch problem using PSO to search the optimal solution of the each generating unit. The population was described as the swarm and the particle was described as the position.

## V. SHUFFLED FROG LEAPING OPTIMIZATION

This optimization technique also similar to the particle swarm optimization

Each particle converges to its local attractor. It means the best of its own particle.

$$P_i = (P_{i1}, P_{i2}, \dots, P_{in})$$

$$P_{i,j} = \emptyset . pbest_{i,j} + (1 - \emptyset). gbest_{i,j} \quad (9)$$

$$\emptyset = (0,1)$$

$\emptyset$ Acceleration factor

P local attractor

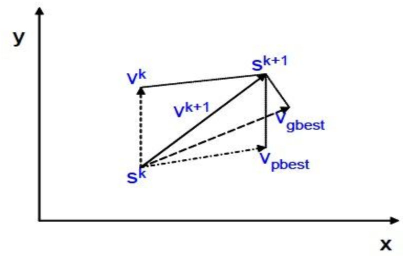



**Fig3: Search Behavior of SFLA**

In SFLA each particle has only position vector and does not have any velocity vector. So its convergence speed of the searching process has been high when comparing to the PSO.

During evaluation the particles update their position according to their best fitness values.

Using montecarlo method the particles moving according to this equation

$$x(t+1) = p + \beta * |mbest - x(t)| * \ln\left(\frac{l}{u}\right) \; if \; k \geq 0.5$$

$$x(t+1) = p - \beta * |mbest - x(t)| * \ln\left(\frac{l}{u}\right) \; if \; k < 0.5$$

$\beta$ It is the contraction expansion co-efficient which can be turned to control the speed of the algorithm.

L and u are the random variables distributed uniformly with the range of (0,1).

Mbest is the mean best position of the position which is calculated by

$$Mbestj(t) = \frac{1}{N} \sum_{i=1}^{N} Pbest_{i,j}\,(t) \quad (10)$$

N is the number of particles

P is the local attractor

t is the total time taken

Each particle i has two vectors

*Pseudo code for SFLA*

*Begin*

While FES<=MAX.FES

Go

Update the position (9)

Calculate the fitness value

FES++

End for

Update the pbest,gbest and mbest using (10)

End while

End

### *A. Flow chart for ELD using SFLA*

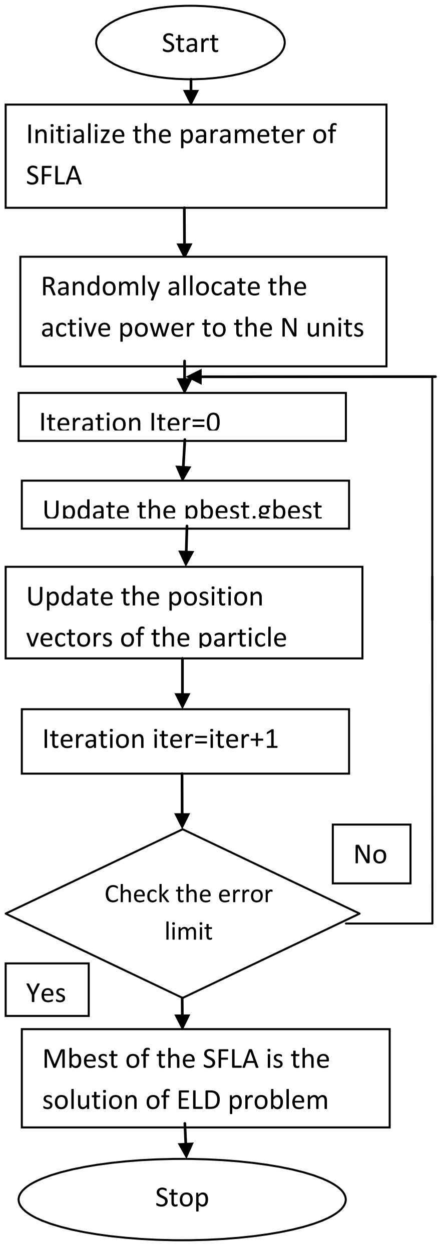



**Fig.5 Flow Chart of SFLA**

This optimization technique provides the low fuel cost for the Thermal generator comparing the results with PSO.

*ALGROTHIM OF SFLA*

1) Initialize population: Random ($X_i$)
2) Go
3) Calculate mbest using equation (10)
4) for i=1 to population size M
5) if $f X_i < f(P_i)$ then $P_i = X_i$
6) $pg = min(P_i)$
7) for d=1 to dimension D
8) $f_i = rand(0,1)$
9) $P = (f_{i1} * P_{id} + f_{i2} * P_{gd})/(f_{i1} + f_{i2})$
10) L=$\propto * abs(mbest - d - X_{id}$
11) u=rand(0,1)
12) if rand (0,1)>0.5
13) $X_{id} = P - l * ln\, {}^{l}/_{u}$
14) Else
15) $X_{id} = P + l * ln\, {}^{l}/_{u}$
16) Until termination criteria is met

Based on this algorithmic rule only the particles going to inquire the mbest. So the fitness factors are obtained by scrutinous the novel particles by the anterior best one. According to this formulation the iteration was repetition to the when the finess value was not procure.

## VI. PROBLEM FORMULATION FOR THREE GENERATOR UNITS

In G.A, PSO and SFLA techniques we applied here for the three generator units. In all the case the transmission losses are neglected. All the simulations are done in the MATLAB R2010a environment

The Three generators considered are having different characteristics their fuel cost function characteristics are given by the following equations

$$F_1 = 0.00156P_1^2 + 7.92P_1 + 561\$/Hr$$
$$F_2 = 0.00194P_2^2 + 7.85P_2 + 310\$/Hr$$
$$F_3 = 0.00482P_3^2 + 7.97P_3 + 78\$/Hr$$

The operating limits of minimum and maximum power also different. The unit operating ranges for the power generation for $i^{th}$ units are given below

$$100\ MW \le P_1 \le 600\ MW$$
$$100\ MW \le P_2 \le 400\ MW$$
$$50\ MW \le P_3 \le 200\ MW$$

The generator demand is set to the four variations. From the above table the result of Economic Load Dispatch problem was obtained using Genetic Algorithm.

**Table.1 : Output For Three Generator Units (G.A)**

| S.NO | DEMAND | P1 | P2 | P3 | COST(Rs /Hr) |
|---|---|---|---|---|---|
| 1 | 450 | 205.307 | 183.345 | 61.346 | 4656.42 |
| 2 | 700 | 322.721 | 277.881 | 99.396 | 6843.62 |
| 3 | 800 | 369.687 | 315.696 | 114.616 | 7740.77 |
| 4 | 850 | 393.169 | 334.603 | 122.226 | 8196.35 |

**Table.2 : Output For Three Generator Units (Pso)**

| S.NO | DEMAND | P1 | P2 | P3 | COST(Rs/Hr) |
|---|---|---|---|---|---|
| 1 | 450 | 203.125 | 177.240 | 69.635 | 4654.18 |
| 2 | 700 | 324.457 | 278.960 | 96.583 | 6840.61 |
| 3 | 800 | 372.453 | 312.258 | 115.289 | 7739.23 |
| 4 | 850 | 381.917 | 327.841 | 140.242 | 8195.79 |

**Table.3 : Output For Three Generator Units (Sfla)**

| S.NO | DEMAND | P1 | P2 | P3 | COST(Rs/Hr) |
|---|---|---|---|---|---|
| 1 | 450 | 205.307 | 183.345 | 61.346 | 4653.42 |
| 2 | 700 | 322.721 | 277.881 | 99.396 | 6840.62 |
| 3 | 800 | 369.687 | 315.696 | 114.616 | 7737.77 |
| 4 | 850 | 393.169 | 334.603 | 122.226 | 8194.35 |

## VII. PROBLEM FORMULATION FOR SIX GENERATOR UNITS

In G.A, PSO and SFLA techniques we busy here for the three dynamo one. In all the circumstances the transmission losses are indifference. All the simulations are done in the MATLAB R2010a surrounding The Three generators contemplate are possession separate characteristics their fuel charge function characteristics are given by the succeeding equations

$$F_1 = 0.002035P_1^2 + 7.43P_1 + 85.63\$/Hr$$
$$F_2 = 0.003866P_2^2 + 6.41P_2 + 303.77\$/Hr$$
$$F_3 = 0.002182P_3^2 + 7.42P_3 + 847.14\$/Hr$$
$$F_1 = 0.001345P_1^2 + 8.30P_1 + 274.22\$/Hr$$
$$F_2 = 0.002182P_2^2 + 7.42P_2 + 847.14\$/Hr$$
$$F_3 = 0.005963P_3^2 + 6.91P_3 + 202.02\$/Hr$$

The operating limits of minimum and maximum power also different. The unit operating ranges for the power generation for $i^{th}$ units are given below

$$100\ MW \le P_1 \le 600\ MW$$
$$100\ MW \le P_2 \le 400\ MW$$
$$0\ MW \le P_3 \le 200\ MW$$

**Table.4 : Output For Six Generator Units (Sfla)**

| S.NO | DEMAND (MW) | P1 | P2 | P3 | P4 | P5 | P6 | COST Rs/Hr |
|---|---|---|---|---|---|---|---|---|
| 1 | 1500 | 156.82 | 320.37 | 321.93 | 236.25 | 312.93 | 151.70 | 14772.6 |
| 2 | 1800 | 233.24 | 297.88 | 414.43 | 264.63 | 374.63 | 215.19 | 17493.1 |
| 3 | 2000 | 245.82 | 319.20 | 420.95 | 411.46 | 386.97 | 215.60 | 19338.1 |

**Table.5 : Output For Six Generator Units (Sfla)**

| S.NO | DEMAND (MW) | P1 | P2 | P3 | P4 | P5 | P6 | COST Rs/Hr |
|---|---|---|---|---|---|---|---|---|
| 1 | 1500 | 156.82 | 320.37 | 321.93 | 236.25 | 312.93 | 151.70 | 14772.6 |
| 2 | 1800 | 233.24 | 297.88 | 414.43 | 264.63 | 374.63 | 215.19 | 17493.1 |
| 3 | 2000 | 245.82 | 319.20 | 420.95 | 411.46 | 386.97 | 215.60 | 19338.1 |

The dynamo demand is set to the six variations. From the above slab the terminate of Economic Load Dispatch proposition was keep using G.A, PSO, and SFLA Algorithms. The Optimum solution was obtained from the Quantum Behaved Particle Swarm (SFLA) seek algorithmic rule. When comparison with the PSO and G.Atechnique.So finally the arise keep for the three and Six hot unit generators.The kindling expense was diminish upto 3$/Hr and 6$/Hr when comparing to G.A and PSO.

## VIII. COST CURVE FOR THE ECONOMIC LOAD DISPATCH USING SFLA

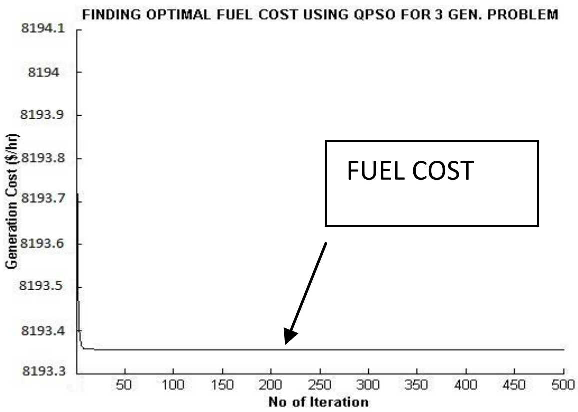



**Fig.6 Cost curve for the ELD using SFLA**

For the X axis there the no of iterations totally taken. Here the iterations totally taken are 500.In Y axis the fuel cost of the thermal generator.

### *A. Advantages of Sfla*

1) The speed of the algorithm can be controlled by the parameter β

2) Fast convergence

## IX. CONCLUSION

Thus the paper foresee the feasible solution for the frugal magnetize kill proposition. In future fabric the algorithmic rule was implemented to increase the act of the thermal generator one into six to fifteen one. So this optimization technique can be instrument to the real opportunity application like the mettur warm power situation and other warm power location in tamilnadu. Hence this paper satisfies the demand with the lowest fuel suffering of the generator.

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