Fuel Cost Reduction for Thermal Power Generator By using G.A, PSO, QPSO with Economic Load Dispatch Problem

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Abstract- *Economic dispatch is the short-term determination of the optimal output of a number of electricity generation facilities, to meet the system load, at the lowest possible cost, subject to transmission and operational constraints. In reality power stations neither are at equal distances from load nor have similar fuel cost functions. Hence for providing cheaper power, load has to be distributed among various power stations in a way which results in lowest cost for generation. For this problem the results are compared for system constraints and minimizing the cost. The economic load dispatch problem is solved for three unit system and six unit system using PSO, G.A, Q PSO with neglecting the losses.. The optimization technique is constantly evolving to provide better and faster results.*

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

1. 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 thermalenergy.

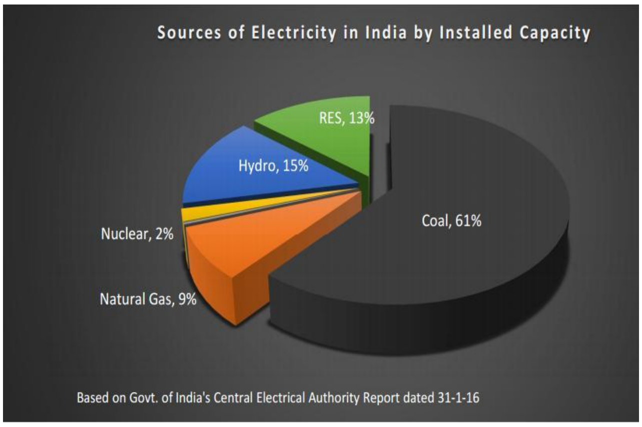

Fig.1 Installed capacity of TNEB in tamilnadu

Thermal energy consumes more fuel cost. So the paper deals with the thermal power plant.

Economic load Dispatch

Economic load dispatch is the problem depends upon the fuel cost. The thermal unit generator fuel cost is high when compared with other generator cost. So it is necessary to include the thermal power plant in the economic load dispatch. The main objective is to serve load at minimum cost. The various cost comparison of the different power plants are being listed below.

ECONOMIC LOAD DISPATCH PROBLEM

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,

$$\min F_i = \sum_{i=1}^{N} F_i(P_i) \quad (1)$$

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

P_i is the reactive output power of the ith generator unit

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

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

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

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

$$P_i^{min} \leq P_i \leq P_i^{max} \quad (i=1,\ldots\ldots,N) \quad (4)$$

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.

2. GENETIC ALGORITHM

The GA is a stochastic global search method that mimics the metaphor of natural biological evolution such as selection, crossover, and mutation GA's work on string structures where string is binary digits which represent a coding of control parameters for a given problem. All parameters of the given problem are coded with strings of bits. The individual bit is called 'gene' and the content of the each gene is called 'allele'. Typically, the genetic algorithms have three phases initialization, evaluation and genetic operation. The fitness function for the maximization problem is

$$f(x) = F(X)$$

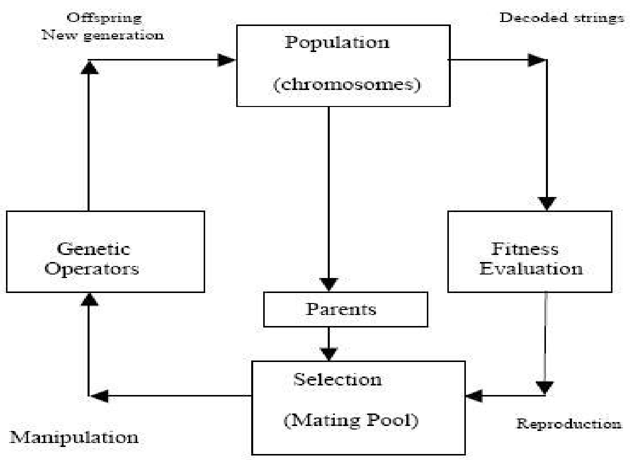

Fig .G.A technique

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

3. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization method is a population based stochastic optimization technique. In this optimization process it provides a population base search by getting the best solution from the problem by taking the particles and moving them into the search space. DrEberhart and Dr.kennedy in 1995 originated this technique in a simple social system. The system starts with a random populations and the optimization takes place when updating the particles. The particles searches the space by following the optimum particles. And the PSO has the position vector(x)and a velocity vector(v).The population is called as swarm and in the swarm each member is called as a particle.

Particle Swarm Optimization is an algorithm capable of optimizing a non-linear and multidimensional problem which usually reaches good solutions anciently while requiring minimal parameterization. The algorithm and its concept of \Particle Swarm Optimization"(PSO) were introduced by James Kennedy and Russel Ebhart in 1995. However, its origins go further backwards since the basic principle of optimization by swarm is inspired in previous attempts at reproducing observed behaviors of animals in their natural habitat, such as bird cocking or schooling, and thus ultimate origins are nature itself. These roots in natural processes of swarms lead to the categorization of the algorithm as one of Swarm Intelligence and Artificial Life.

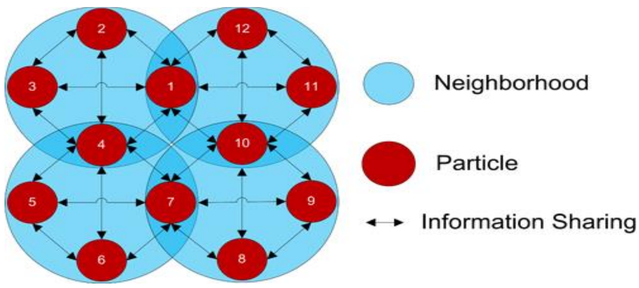

Fig .2PSO technique

Swarm: A set of particles

Particle: A Potential solution or a member of a swarm

i)position

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

ii)velocity

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

Each Particle maintains its previous best position

iii)individual best position

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

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

iv)swarm global position

$$P_g \in R''$$

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

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^tinertia

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

Flow chart of ELD using PSO

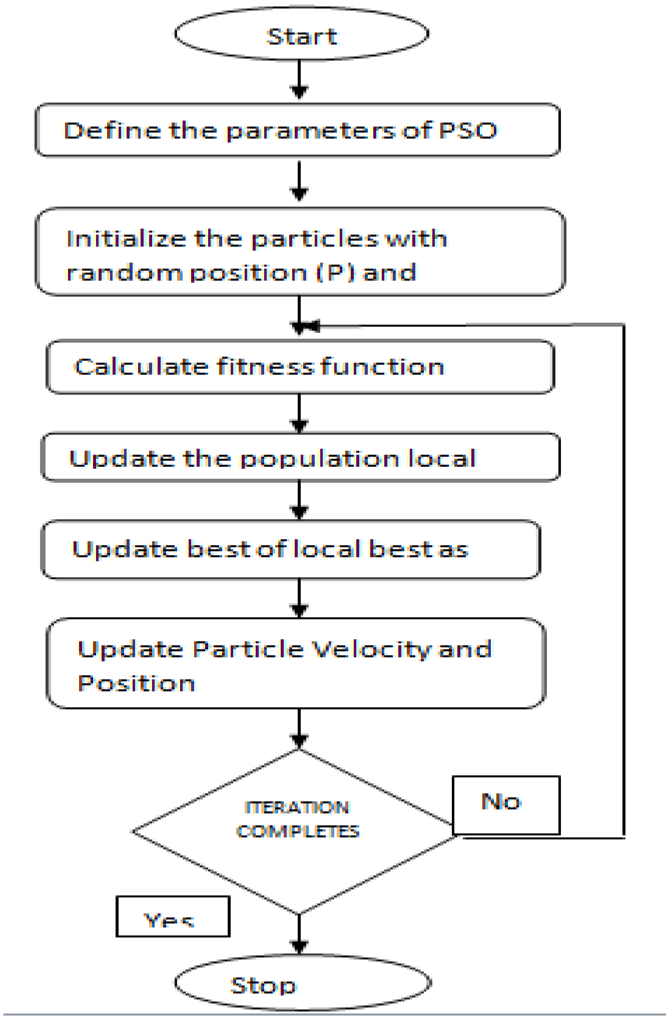

Fig. 3Flow chart of PSO

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 particles was described as the position .

4.Quantum Behaved particle swarm optimization

This optimization technique also similar to the particle swarm optimization. Quantum is nothing but the requirement of the particles with the position vectors. Here the particles moved based on the searching the updated mbest value.

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

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

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

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

$\emptyset$ Acceleration factor

P local attractor

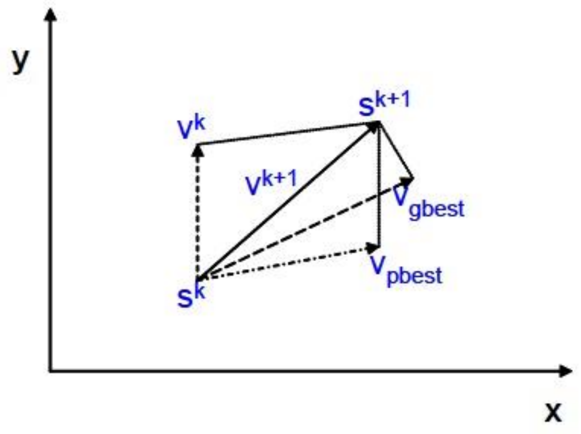

Fig3:Search behavior of QPSO

In QPSO 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

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

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

β 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

$$Mbestj(t) = {}^{1}/_{N} \sum_{i=1}^{N} Pbest_{i,j}\,(t) \qquad (10)$$

N is the number of particles

P is the local attractor

t is the total time taken

Each particle i has two vectors

Psedo code for QPSO

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

Flow chart for ELD using QPSO

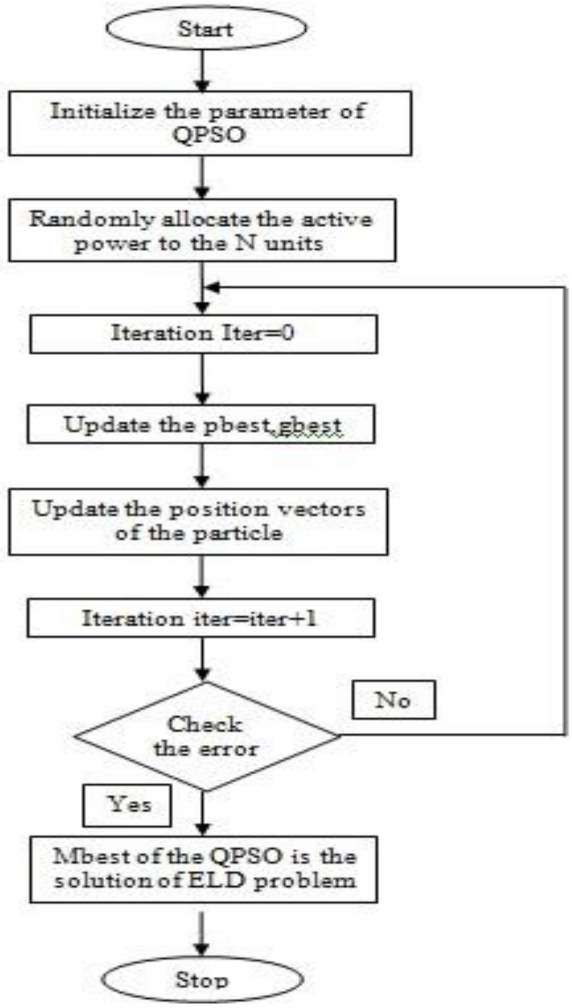

Fig.5 Flow Chart of QPSO

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

ALGROTHIM OF QPSO

1)Initialize population : Random(X_i)

2) Go

3)calculatembest 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)$P = \left(f_{i1} * P_{id} + f_{i2} * P_{gd}\right)/(f_{i1} + f_{i2})$

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 algorithm only the particles going to search the mbest. So the fitness factors are obtained by searching the new particles by the previous best one .According to this formulation the iteration was repeated to the when the fitness value was not obtained.

PROBLEM FORMULATION FOR THREE GENERATOR UNITS

In G.A, PSO and QPSO 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≤P_1≤600 MW

100 MW≤P_2≤400 MW

50 MW≤P_3≤200 MW

The generator demand is set to the four variations. From the above table the results 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	205.30	183.34	61.346	4656.42
2	700	322.72	277.88	99.396	6843.62
3	800	369.68	315.69	114.61	7740.77
4	850	393.16	334.60	122.22	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 (QPSO)

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

PROBLEM FORMULATION FOR SIX GENERATOR UNITS

In G.A,PSO and QPSO 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

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

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

$100\ MW \leq P_1 \leq 600\ MW$

$100\ MW \leq P_2 \leq 400\ MW$

$0\ MW \leq P_3 \leq 200\ MW$

TABLE.4 OUTPUT FOR SIX GENERATOR UNITS (QPSO)

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 (QPSO)

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.6 OUTPUT FOR SIX GENERATOR UNITS (QPSO)

S.NO	DEMAND (MW)	P1	P2	P3	P4	P5	P6	COST Rs/Hr
1	1500	154.74	325.57	375.57	385.57	365.57	335.57	17366.06
2	1800	236.09	299.52	410.92	267.63	369.90	215.92	17488.06
3	2000	247.41	311.05	427.28	415.03	378.87	220.23	19329.53

The generator demand is set to the Six variations. From the above table the results of Economic Load Dispatch problem was obtained using G.A,PSO,QPSO Algorithms.

The Optimum solution was obtained from the Quantum Behaved Particle Swarm (QPSO) search algorithm. When comparing with the PSO and G.A technique. So finally the results obtained for the three and Six thermal unit generators. The fuel cost was reduced up to 3$/Hr and 6$/Hr when comparing to G.A and PSO.

Cost curve for the Economic Load Dispatch using QPSO

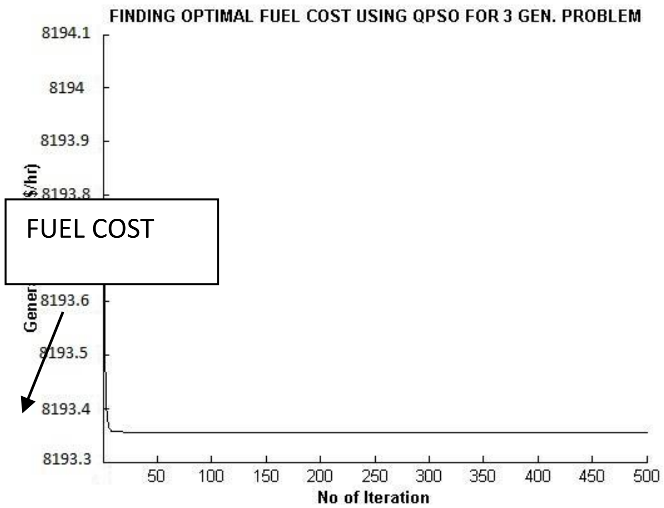

Fig.6 Cost curve for the ELD using QPSO

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

Advantages of QPSO

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

2)Fast convergence

Conclusion

Thus the paper provides the feasible solution for the economic load dispatch problem.In future work the algorithm was implemented to increase the performance of the thermal generator units into six to fifteen units.so this optimization technique can be implemented to the real time application like the metturthermal power station and other thermal power stations in tamilnadu.Hence this paper satisfies the demand with the lowest fuel cost of the generator.

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BIOGRAPHY

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