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Design and Implementation of Power System Optomization Using Particles Swarm Algorithms for Addressing the Economic Dispatch Problem

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***Abstract*—**This research is aimed to design a power system using particle swarm algorithm (PSA) and test its efficiency on a standard IEEE bus bar system. The algorithm has been modified for power generating system and successfully demonstrates and provides optimization results for six generating units .

Reducion in fuel cost by distributing load among the generating units in inter connected bus bar system is the core area of this research. The losses in power transmission as well as generation are also minimized. Moreover, the PSA coding was executed using MATLAB and the graphs are shown for comparison with other optimization techniques. The results obtained using PSA were compared with other optimization techniques and PSA was found comparatively better than other techniques.

PSA has been found to be reliable for power system optimization and hence suitable for practical purposes.

***Keywords*—** Particle Swarm Algorithm (PSA) , Economic Load Dispatch, Bus Bar System,

I. INTRODUCTION

Designers , sellers and consumers, all are interested in the cost of the services or the end-products they receive. Of those services, electricity is one of the most crucial and on it almost all of our technological innovations, luxuries and requirements are dependent. Minimizing the cost of electricity generation and provision to common consumers is the center of focus. Electrical engineers are required to come up with more and more efficient solutions in the electrical industry. Due to advancement in ever growing electricity grids and networks have made the need of more man power and working hours and has affected the overall electricity prices. Therefore, it is required to reduce the cost of electricity generation. In the field of power generation and efficient operation, the most prominent problem is the Economic Load Dispatch (ELD) problem.

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In this problem, the main emphasis is on the reduction of operating costs of electricity generation. For this purpose, mathematical and optimization algorithms have been developed over the years to decrease the cost of electrical power generation. PSA is one of the prominent optimization technique among them which has been utilized here in this research to optimize the electrical power generation. The paper is organized as follows.

Section I comprises of general introduction. Section II is about Particle swarm algorithm. Section III discuss methdology to deal with economic load dispatch problem. Section IV have implementation of Particle swart algorithm for addressing the echnomic load dispatch. Experimentation setup , result simulation and comparison with other relevant research is discussed in section V. Conclusion is in section VI.

II. PARTICLE SWARM ALGORITHM

Particle swarm optimization is an algorithm for solving complex mathematical problems which are deemed as non polynomial hard (NP-Hard) by the mathematicians. Such problems cannot be solved efficiently within a finite time by a computing device. Therefore alternate solutions for solving them are being researched every other day. PSA has its fair share of solving such problem in the field of science where it has been inspired from the natural behavior of birds flocking on food sources and better habitats. Originally PSA was developed by Eberhart and Kennedy in 1995. It has proven to be one of the best optimization algorithms over time. [4]-[7]

The concept of the algorithm is to use a set of variables called as particles to search a problem's solution space defined by the constraints of the problem in search of a global minima or maxima depending on the problem type. At each new turn of the algorithm's running sequence, the speed at which the variable particles move in the search space called velocity, is updated according to a predefined technique based on the position of the particle itself. The best position for a particle is defined by a function input by the user into the algorithm and is called as the fitness function. This function is used to define the best position for a particle mathematically and hence all the particles initiated by the algorithm search that best position which is later on called as the optimal solution of the problem. These set of particles are called as a swarm and hence the named as Particle Swarm Optimization [13].

In the application area of conventional real world problems pertaining to data analysis, most algorithms fail to provide an answer due to the non-linearity of the problem and the inflexibility in the problem formulation from data. This is called noisy data set in mathematics. In noisy data, the data points are not interrelated and the mathematical rules that define that data set are very hard to find out using normal algorithms. In this case, particle swarm optimization algorithm proves to be the best candidate for the said purpose and successfully finds out an optimum solution for the data set which would have otherwise been improbable. PSO can be successfully applied to power system problems on which various papers have been published in research journals.

Advantages of PSA

Pros of using PSA for optimization problems are summarized as follows:

- Relatively easy to implement.
- Fewer variables to input and adjust
- Compared with GA, it has a memory function where it remembers previous states of all the swarm particles.
- Mathematically, PSA is more efficient than most algorithms due to diversity in searching the solution space. Hence it is easier to get global maxima or minima rather than a local maxima or minima as is the case in GA. [8-9].

III. METHODOLOGY TO DEAL WITH ECONOMIC LOAD DISPATCH (ELD) PROBLEM

Mathematically the ELD problems can be represented using the following ways:

1. Single Objective
2. Multi-Objective

In this work, I have targeted the single objective function formulation and applied PSA on it.

Details are following.

A. *Single Objective Formulation*

The single objective representation of the problem can be expressed mathematically as a polynomial function of 2nd order regarding the total generated power by the units, as shown below: [14]-[17]

$$Min\ FT = \sum_{I=1}^{N} F_i(P_i)$$

When subjected to

$$\sum_{i=1}^{n} P_{gi} = p_d + p_{loss}$$

and

$$P_{Gmin} < P < P_{Gmax}$$

The cost function representing the output power w.r.t the fuel intake in terms of PKR/hr for generating unit "i" can be expressed mathematically as:

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

Here F represents the total cost of power generation units whereas a, b and c are cost coefficients and i represent the total number of generators. ELD without Network Losses

Input Output parameters of a set of generating units G_1, G_2, G_3 ... Are F_1, F_2, F_3 ...whereas the total real system load is represented by P_D. The target is the minimization of the total cost of production in terms of fuel consumption F in the presence of constraint. The constraint in this case is that the received load by the system must be compensated equally by the generated power as expressed mathematically below: [1]-[3]

$$F = F_1(P_{G1}) + \cdots F_N(P_{GN}) = \sum_{I=1}^{N} F_I(P_I)$$

Subjected to the constraint:

$$\sum_{i=1}^{n} p_{gi} = p_d$$

The mathematical solution proposed in literature for this type of constrained problem is the Lagrange Multiplier method. It is mathematically expressed as:

$$Min\ F = f + \lambda(p_d - \sum_{i=1}^{n} p_i)$$

i.e. an undetermined variable is multiplied by the objective function and is added to the constrained function results in the Lagrange function. The undetermined variable is called as the Lagrange multiplier and is represented by λ [4][2][1][17][9][13]

The derivative of the LaGrange function is taken w.r.t. each of the independent variable in the equation and is set to zero [1][3] . i.e,

$$\frac{\delta L}{\delta P_{Gi}} = \frac{\delta F}{\delta P_{Gi}} - \lambda = 0\ for\ i = 1,2,\dots,N$$

$$\frac{\delta F}{\delta P_{Gi}} = \lambda\ for\ i = 1,2,\dots,N$$

Since the generating unit can produce power relevant to the fuel intake, therefore, power can be a function of fuel intake or fuel intake can be a function of power produced, so the equation above can be rewritten as:

$$\frac{dF_I}{dP_{GI}} = \frac{dF_2}{dP_{G2}} = \cdots = \frac{dF_N}{dP_{GI}} = \lambda$$

and so, the per unit of power fuel cost is given by:

$$\lambda = \frac{dF_I}{dP_{GI}} = b_i + a_i P_{GI}$$

Now for a system of N generating units let us assume:

$$F = F_I(P_{GI}) + F_2(P_{G2}) + \cdots F_N(P_{GN}) = \sum_{I=1}^{N} F_I P_I$$

This equation gives us the cumulative cost of fuel for the entire power production of the system where the fuel costs of the individual units are represented by F_I, F_2 … F_N. The total input of power to the network in megawatts is given by the following equation:

$$P_{G1} + P_{G2} + \cdots + P_{GN} = \sum_{I=1}^{N} P_{GI}$$

Here P_{G1}, P_{G2} … are power produced by the individual generating units which are provided to the network. The minimum value of the cost function F is constrained by the following constraint as described previously:

$$\sum_{i=1}^{n} p_{gi} = p_d$$

And now rewritten in the following form:

$$p_d + p_{loss} - \sum_{i=1}^{n} p_i = 0$$

Now the Lagrange multiplier method for obtaining the total fuel cost is shown below:

$$F = (f_1 + f_2 + \cdots + f_N) + \lambda(P_L + P_D + \sum_{I=1}^{N} P_{Gi}$$

This equation is called as the lagrangian and λ is the incremental cost multiplier when transmission losses are considered. Units of f, P, F and λ are PKR/hr, MW, PKR/hr and PKR/MWhr respectively. Now the same equation can be transformed to an equation in which constrains are removed. Such that:

$$\frac{\delta F}{\delta P_{GI}} = \frac{\delta f_i}{\delta P_{Gi}} + \lambda\left(\frac{\delta P_L}{\delta P_{Gi}} - 1\right) = 0$$

Or

$$\frac{\delta F}{\delta P_{GI}} + \lambda\left(\frac{\delta P_L}{\delta P_{Gi}} - 1\right) = 0$$

Or

$$\lambda = \frac{\left\{\frac{1}{1-\frac{\delta P_L}{\delta P_{Gi}}}\right\} dF_I}{dP_{GI}}$$

Or

$$\lambda = \frac{L_I dF_I}{dP_{GI}} \ where\ L_1 = \frac{1}{1-\frac{\delta P_L}{\delta P_{Gi}}} = penalty\ factor$$

The penalty factor tells us about the relation between the PGI and transmission losses for a single unit. For a generating system with N generators with outputs of $P_{G1}, P_{G2}, \ldots P_{GN}$ the penalty factors $L_1, L_2, \ldots\ L_N$ must be equal. It also shows that:

$$\frac{L_1 dF_I}{dP_{GI}} = \frac{L_2 dF_2}{dP_{G2}} = \cdots = \frac{L_I dF_N}{dP_{GN}}$$

IV. IMPLEMENTATION OF PSA

The implementation of PSA to ELD is described as follows:

1. The swarm is initialized randomly according to the upper and lower limits of power generation of each generating unit in the power plant.

2. Then the transmission power loss is calculated for the individual population of the generating units for a given time unit using the following formula

$$P_l = \sum_{i=0}^{n}\sum_{i=1}^{N} P_{Gi} B_{ij} P_{ij} + \sum_{i=1}^{N} B_{Oi} P_I + B_{OO}$$

3. The fuel cost of production for each generating unit is calculated using the following equation.

$$F_i p_i = ca_i + b_i p_i + a p_i^2$$

4. Also, the price factor is found out by:

$$\lambda = \frac{df_i}{dp_i} = a_i p_{gi} + b_i$$

5. Then the objective function is found out for each iteration of the algorithm as follows:

$$F_i = ca_i + b_i p_i + a p_i^2 + \lambda(p_l + p_d - \sum_{i=1}^{n} p_{gi})$$

6. Then the best value of the current iteration is compared with the previously stored best values of the swarm to find out the global best value of the total iterations as expressed mathematically below:

$$p_{best,i}^{t+1} = \begin{cases} p_{best,i}^{t}\ if\ f(x_i^{t+1}) > p_{best,i}^{t} \\ x_i^{t+1} if\ (x_i^{t+1}) \le p_{best,i}^{t} \end{cases}$$

7. New speeds and locations of particles are provided to the swarm using the following relations:
   $g_{best} = min\{p_{best,i}^{t}\}$ *where* $i \in [1, \ldots\ldots n]$
   $v_{ij}^{t+1} = wv_{ij}^{t} + c_1 r_{1j}(p_{best,i}^{t} - x_{ij}^{t+1}) + c_2 r_{2j}(g_{best} - x_{ij}^{t})$
   where $w = w_{max} - [((w_{max} - w_{min})/ iter_{max}))^* iter]$
   $P^{t+1}_{ij} = v_{ij}^{t+1} + P^{t}_{ij}$
   Where w -is the inertia weighting factor
   W_{max} - maximum value of weighting factor
   W_{min} - minimum value of weighting factor
   $iter_{max}$ - maximum number of iterations
   iter - current number of iteration. [17]

8. Personal best is updated when the given local best is better than the previously saved local best value and similar analogy can be applied for the update of global best positions "gbest"

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9. If the iterations have completed according to the number fed into the algorithm as the "iter" then the results are listed and graphs are plotted otherwise the algorithm is repeated from step 3 until maximum iteration number is reached. The whole process is shown Fig.1 below

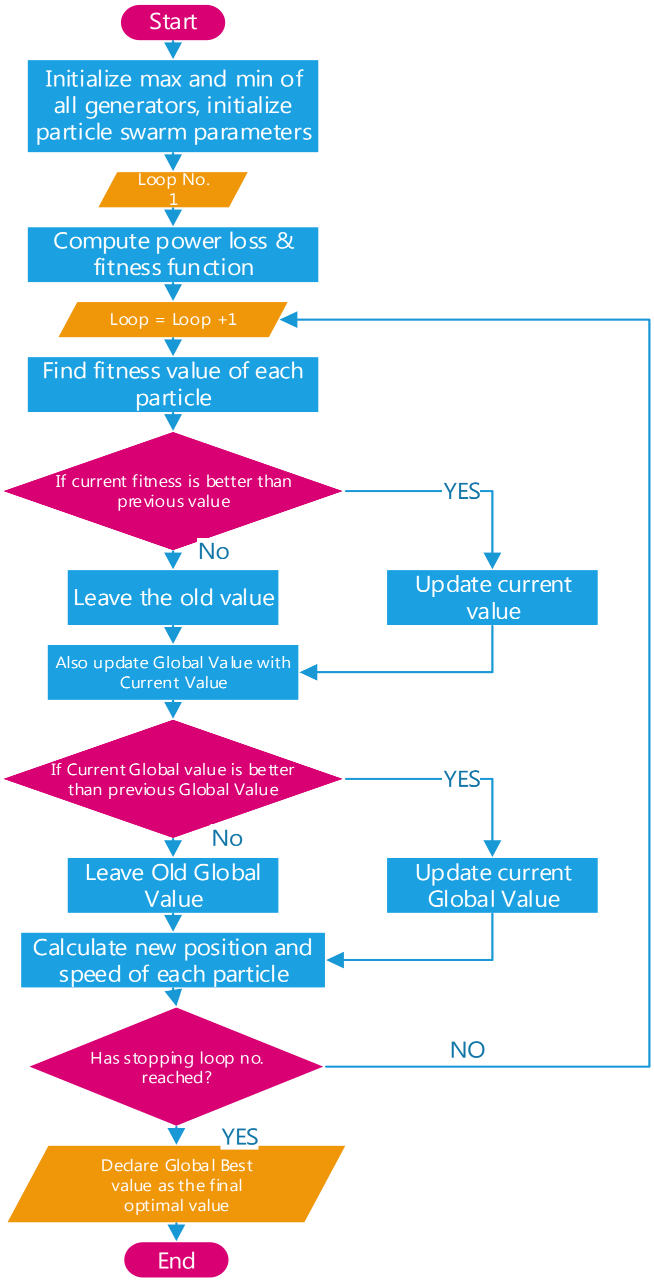

Figure 1. Flow Chart of PSA

V. EXPERIMENTATION EXPERIMENTAL SETUP AND SIMULATION RESULTS

As a test of the implementation, IEEE-30 bus bar system is taken which is a standard in all optimization problems. The diagram is presented below:

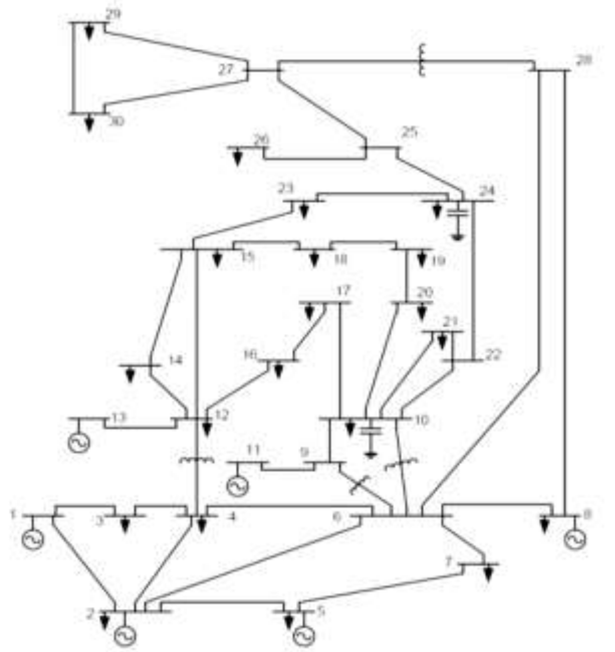

Figure 2. IEEE Standard Bus Bar.

The initial conditions and testing parameters as shown in the table 1.

TABLE 1: INITIAL CONDITIONS AND TESTING PARAMETERS

Unit	$a_i\left(\frac{MW}{PKR}\right)$	$b_i\left(\frac{MW}{PKR}\right)$	$c_i(PKR)$	$P_{imin}(MW)$	$P_{imax}(MW)$
1	0.0152	3.853	7567.9	10	125
2	0.0105	4.639	4513.2	10	150
3	0.0028	4.039	10499.9	35	225
4	0.0035	3.832	12435.3	35	210
5	0.0021	3.632	16585.5	130	325
6	0.0017	3.827	13566.5	125	315

A. PSA parameters used in this research paper are given in table 2.

TABLE 2: PARAMETERS OF PSA

Power Demand	800 MW
Population Size	20
Max Iterations	1500
Inertia Weight (w)	0.9,0.4
Acceleration Constants	C1=C2=2
Convergence Criteria	0.000001

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TABLE 3: B-COEFFICIENT MATRIX FOR 800 MW AND GIVEN 6 GENERATING UNITS.

0.00014	0.000017	0.000015	0.000019	0.000026	0.000022
0.000017	0.00006	0.000013	0.000016	0.000015	0.00002
0.000015	0.000013	0.000065	0.000017	0.000024	0.000019
0.000019	0.000016	0.000017	0.000071	0.00003	0.000025
0.000026	0.000015	0.000024	0.00003	0.000069	0.000032
0.000022	0.00002	0.000019	0.000025	0.000032	0.000085

B. Simulation:

The simulation was run for 800MW power demand, using MATLAB 2016 version on the computing machine with features: Processor Intel (R) Core (TM) i-3- 4005U CPU @ 2.40 GHz, installed memory (RAM) 4.00 GB, 64 bit operating with 64x based processor.

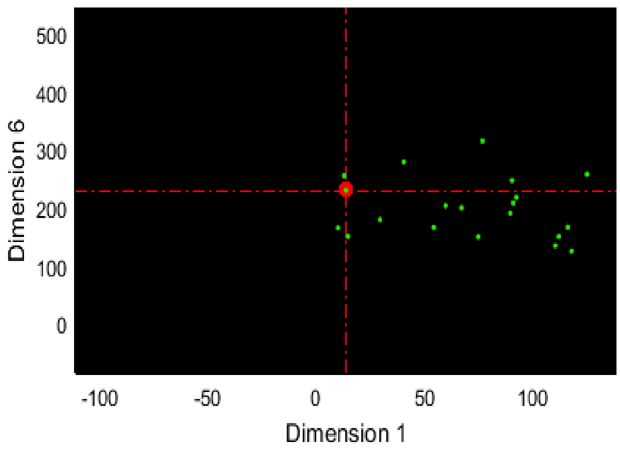

Figure 3: Initial Swarm Position for 800 MW Power demand after first 10 Iterations

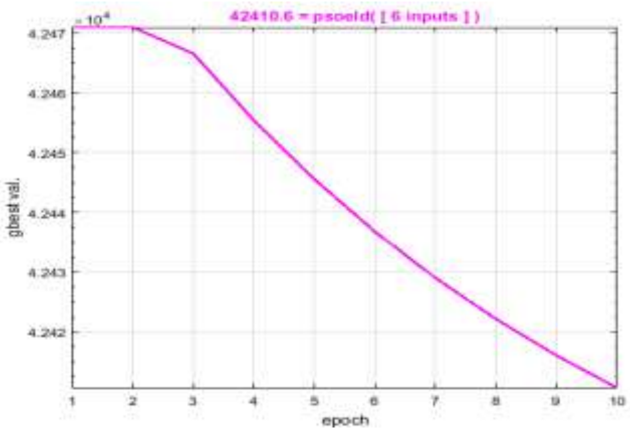

Figure 4. Graph & Cost Function's Value for 800 MW Power demand after First 10 Iterations

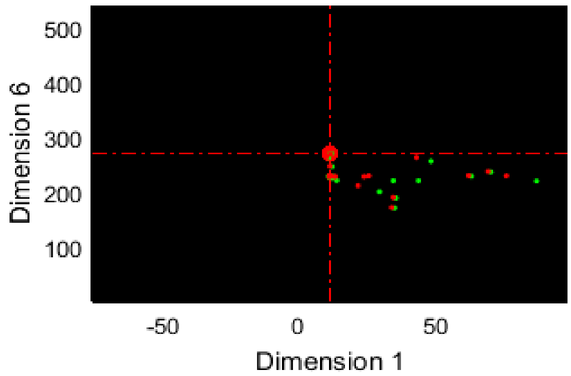

Figure 5: Position of Swarm after 50 Iterations

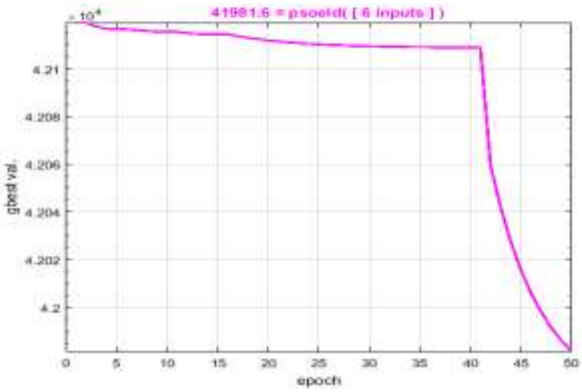

Figure 6 : Graph & Cost Function's after 50 Iterations

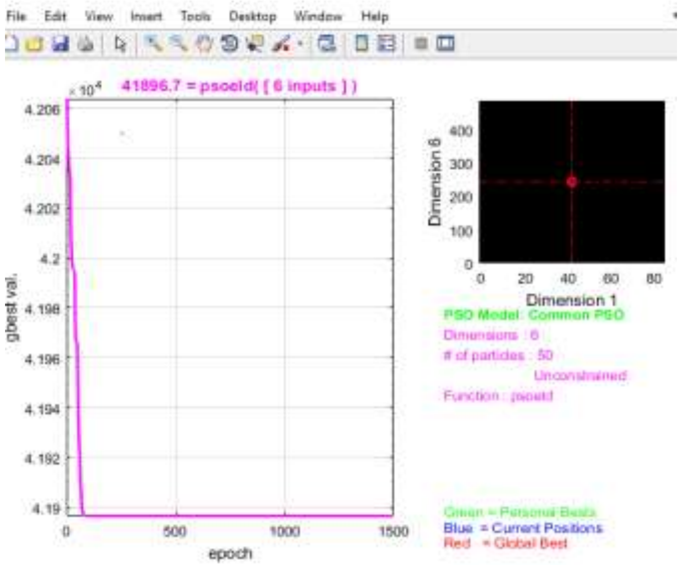

Figure 7: Graph & Cost Function's Value for 800 MW Power demand after 1500 Iterations

RESULTS:

The simulation results for 800MW power demand obtsined from PSA was compared with so far best results of GA [10] in table 4.

TABLE 4: COST COMPARISON FOR POWER DEMAND OF 800MW FOR A 6-UNIT GENERATING PLANT

Power generated by Units	GA [10]	This Method - PSA
P1	32.5	41.84
P2	12.4	14.48
P3	140.51	141.5
P4	136.2	136.0
P5	258.28	257.6
P6	245.3	243.0
Cumulative Power	825.19	834.42
Losses	25.44	25.33
Cost PKR/hr	41925.28	41896.71

VI. CONCLUSION

In this research the PSA was applied for the power system optimization on a standard bus bar of IEEE. The results were found comparatively better than so far best results obtained from other optimization algorithms, i.e. Genetic Algorithm.

REFERENCES

[1] J. John j. Greinger. & William D. Steveson, Power System Analysis, singapore: Mc Graw Hill, 1994, pp. 531-562.

[2] D. K. &. I. Nagrath, Modern Power System Analysis, New Delhi: Tata Mc Graw Hill, 2003, pp. 258-280.

[3] J. Zhu, Optimization of Power System Operation, Hoboken, New Jersy: John Wiley & Son.inc, 2009.

[4] S. S. &. V. V. V. Karthikeyan, "A New Approach To The Solution of Economic Load Dispatch Using Particle Swarm Optimization with Simulated Annealing," International Journal on Computational Science& Application (IJCSA), vol. 3, no. 3, pp. 37-41, June 3 2013.

[5] Mohn Faazi, Othman,Rubiyan,Mayzuki Khalid, "Solving Economic Load DispatchUsing Particle Swarm Optimization," Journal of Theoritical &Applied InformationTechnology, vol. 46, no. 2, pp. 526-535, 31st-Dec-2012.

[6] S. SARANGI, "Particle Swarm Optimization Apllied To Economic load Dispatch," a thesis submitted in partial fulfillment of the requirements for the degree ofmaster of technology in power control and drives , 2009.

[7] S. Talukder, "Mathematical Modelling and Applicationsof Particle Swarm Optimization," Master's Thesis Mathematical Modelling and Simulation, Feb 2011.

[8] D. V.Selvi, "Comparative Analysis of Ant Colonyand Particle Swarm Optimization Techniques," International Journal of Computer Applications , vol. 5, no. 4, pp. 1-5, August 2010.

[9] Y. Saber, "Economic dispatch using particle swarm optimization with bacterial foraging effect," Electrical Power and Energy Systems, vol. 34 , p. 38–46, 2012.

[10] SUREKHA P, Dr.S.SUMATHI , "Solving Economic Load Dispatch problems using Differential Evolution with Opposition Based Learning", WSEAS TRANSACTIONS on INFORMATION SCIENCE and APPLICATIONS ; Issue 1, Volume 9, January 2012

[11] H. M. D. ,. M. P. &. B. K. P. Kamlesh Kumai Vishwakama, "Simulated Annealing For Solving Economic LOad Dispatch Problem with Valve Point Loading Dispatch Problem," International Journal of Engineering, Science & Technology, vol. 4, no. 4, pp. 60-72, 2012

[12] N. A. R. ,. A. B. H. M. Mohd Noor Abbullah, "Efficient Evolution Particle Swarm Optimization Approach For Non Convex Economic Load Dispatch Problem," vol. 89, no. 2a, pp. 139-143, 2013.

[13] V. P. R. Amita Mahor, "Economic dispatch using particle swarm optimization: A review," in Renewable and Sustainable Energy Reviews , India, 2009.

[14] J. S. &. A. Mohan, "Particle Swarm Optimizatiom Approach for Economic Load Dispatch," International Journal of Engineering Research & Appplication, vol. 3, no. 1, pp. 013-022, 2013.

[15] "Solution of Economic Load Dispatch Problems by a Novel," International Journal on Electrical Engineering and Informatics ,, vol. Volume 3, no. 1, pp. 26-36, 2011.

[16] [17]. International Journal on Computational Sciences Applications (IJCSA) Vol.3, No.3, June 2013.

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