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Minimization of Fuel Cost in Solving the Power Economic Dispatch Problem including Transmission Losses by using Firefly Algorithm

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Abstract:Under normal operating conditions the generation capacity is more than the total load demand and losses. The objective function of this paper is to minimize the fuel cost of the power system for the various loads under consideration by solving the economic dispatch problem (EDP) of real power generation by using Firefly algorithm. The objective is to find the real power scheduling of each generator for an inter connected power system under testing condition to minimize the operating cost of the power plant. Hence the generators power are allowed to vary within the given limits to meet the particular load with minimum fuel cost which is called as optimal power flow problem. This paper compares the optimization techniques such as Particle Swarm Optimization, Modified Particle Swarm Optimization and Firefly algorithm in a 6-unit generating system to show the effectiveness of the Firefly algorithm. Also by using the optimization technique the power losses of the considered power system were reduced.

Keywords—Firefly Algorithm, Particle Swarm Optimization (PSO); Modified Particle Swarm Optimization (MPSO); Economic Dispatch Problem (EDP); FFA

1. INTRODUCTION

An important position in the electric power industry is occupied by economic load dispatch problem (ELDP) of power generating unit. The power output of each plant is determined by ELD where the overall cost of fuel needed to serve the load for the system under consideration has to be minimized [1,2]. Kennedy and Eberhart are the pioneers of PSO algorithm which is based on the analogy of swarm of birds and school of fish [3]. PSO method is proposed for solving economic dispatch problem in power systems [4]. Ramp rate limits, prohibited operating zone and non-smooth cost functions are the various non-linear characteristics of generator were also considered. In order to solve the non-convex economic dispatch problem with a quality control, a hybrid [5] evolutionary programming and tabu search algorithm were used by Lin. A zoom feature is applied during the iterative process. In order to solve the EDP of a system of thermal generating units including the transmission losses [6], dynamic programming iterative process is used. Also the random drift particle swarm optimization (RDPSO) algorithms are used to solve the EDP. This algorithm [7] is inspired by free electron model in metal conductors to employ a novel set of evolution equations thereby enhancing the global

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search ability of algorithm. The EDP problem is to schedule the generating units output to meet the required load demand at minimum operating cost by using PSO [8-9]. Lamda iteration, base point and gradient method are the classical optimization methods which were used to solve economic load dispatch problem [10-11]. The fuel cost along with environmental emission is minimized by using MRPSO algorithm and formulated for multi objective economic dispatch problem [12].

This paper presents the economic dispatch problem with transmission losses for three different cases of demand using FF algorithm. The Firefly Algorithm (FA) is a nature - inspired algorithm which is based on the social flashing behavior of fireflies. A significant advantage of the algorithm is the fact that it uses mainly real random numbers, and it is based on the global communication among the swarming particles i.e., the fireflies, and as a result, it seems more effective multi objective optimization. In this algorithm, the flashing light helps fireflies for finding mates, attracting their potential prey and protecting themselves from their predators.

II. PROBLEM FORMULATION

The economic dispatch problem determines the power output of each online generator. The main objective of economic dispatch problem is to minimize the total fuel cost of the considered system. This can be achieved by adjusting the power output of all the generators connected to the considered power system.

The economic dispatch problem is a constrained optimization problem and it can be mathematically expressed as follows:

$$F_T = \sum_{i=1}^{n} F_i(P_i) = \sum_{i=1}^{n} a_i + b_i P_i + c_i P_i^2 \qquad (1)$$

Where

F_T= Total cost of generation (Rs/hr)

n = Number of generators

P_i = Real power generation of ith generator

f_i= Fuel cost function of ith generator

ai , bi and ci are fuel cost coefficients

(A) DIFFERENT TYPES OF CONSTRAINTS

They are two types of constraints:

- Equality constraints.
- Inequality constraints.

EQUALITY CONSTRAINTS

This is also called as major constraints. These constraints are the nodal power balance equations.

$$P_{g,k} - P_{d,k} - \sum_{m=1}^{N_{bus}} |V_k||V_m||Y_{km}|\cos(\theta_{km} - \delta_k + \delta_m) = 0$$
$$Q_{g,k} - Q_{d,k} - \sum_{m=1}^{N_{bus}} |V_k||V_m||Y_{km}|\sin(\theta_{km} - \delta_k + \delta_m) = 0 \qquad (2)$$

where $P_{g,k}$,$Q_{g,k}$ = active along with reactive power generation at the k^{th} bus, $P_{d,k}$, $Q_{d,k}$ = active as well as reactive power demands at the k^{th} bus, $|V_k|$, $|V_m|$ = voltage magnitudes at the k^{th} and m^{th} buses, δ_k, δ_m= phase angles of the voltage at the k^{th} and m^{th} buses, along with $|Y_{km}|$, $\theta_{k,m}$a = bus admittance magnitude and its angle between the k^{th} and m^{th} buses.

INEQUALITY CONSTRAINTS

This is also called as minor constraints. These constraints arise due to physical along with operational

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limitation of the respective units. For appropriate operation each generator should have a min as well as max permitted output limits.

Generator bus voltage limits:

(3) $V_{Gi}^{\min} \le V_{Gi} \le V_{Gi}^{\max} \quad \forall_i \in NG$

Active power generation limits:

(4) $P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \quad \forall_i \in NG$

Transformers tap setting limits:

(5) $T_i^{\min} \le T_i \le T_i^{\max} \quad \forall_i \in nt$

Capacitor reactive power generation limits:

(6) $Q_{sh_i}^{\min} \le Q_{sh_i} \le Q_{sh_i}^{\max} \quad \forall_i \in nc$

III. MODIFIED PSO

The general PSO is highly depended on its parameter settings. In MPSO the velocity of the particle greatly depends on its inertia weight and acceleration factors. The figure 1 depicts the flowchart of MPSO algorithm.

Algorithm

Step 1: Initialization – Generate 'n' number of particles randomly.

Step 2: Determine the fitness function for all particles.

Step 3: Initialize the Pbest, Gbest, Velocity and Iteration Count.

Step 4: Update the population by using MPSO technique.

i) Inertia Weight factor:

$$W_i^k = W_{\min} + \frac{F_{pbest}^{k-1} \times \left| F_1^{k-1} - F_{pbest}^{k-1} \right|}{F_1^{k-1} \times \left| F_1^{k-1} - F_{gbest}^{k-1} \right|} \quad (6)$$

ii) Modified Acceleration Factor:

The acceleration factor can be calculated to speed up the convergence.

$$C_{1,i}^{k} = \sqrt{\frac{F_i^{k-1}}{F_{pbest}^{k-1}}}$$
$$C_{2,i}^{k} = \sqrt{\frac{F_i^{k-1}}{F_{gbest}^{k-1}}} \quad (7)$$

Step 5: Update the velocity and position of all the particles used in the algorithm.

Step 6: Update P_{best} and g_{best}

Step 7: Check for stopping criteria:

Step 7.1: If 50 iterations are completed; stop the process.

Step 7.2: Else update the iteration count

IV. FIREFLY ALGORITHM

The Firefly Algorithm (FA) is a nature - inspired algorithm which is based on the social flashing behavior of fireflies. A significant advantage of the algorithm is the fact that it uses mainly real random numbers, and it is based on the global communication among the swarming particles i.e., the fireflies, and as a result, it seems more effective multi objective optimization. In this algorithm, the flashing light helps fireflies for finding mates, attracting their potential prey and protecting themselves from their predators. The swarm of fireflies will move to brighter and more attractive locations by the flashing light intensity that associated with the objective function of problem considered in order to obtain efficient optimal solutions. The development of firefly inspired algorithm was based on three idealized rules:

i) Artificial fireflies are unisex so that sex is not an issue for attraction.

ii) Attractiveness is proportional to their flashing brightness which decreases as the distance from the other firefly increases due to the fact that the air absorbs light. Since the most attractive firefly is the brightest one, to which it convinces neighbours moving toward. In

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case of no brighter one, it freely moves any direction
iii) The brightness of the flashing light can be considered as objective function to be optimized.

The main steps of the FA start from initializing a swarm of fireflies, each of which is determined the flashing light intensity.

(A) IMPORTANT DEFINITONS IN FIREFLY ALGORITHM

There are some definitions in FA namely, Distance, Attractiveness and Movement.

(a) Distance:

The distance between any two fireflies *i* and *j* at positions *xi* and *xj*, respectively, can be defined as a Cartesian or Euclidean distance (*rij*) using equation (6.2), where *xi,k* is the *k*th component of the spatial coordinate *xi* of the *i*th firefly and *d* is the number of dimensions.

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d}(x_{i,k} - x_{j,k})^2} \tag{8}$$

(b) Attractiveness:

The calculation of attractiveness function of a firefly is shown in equation (6.3),

$$\beta_{(r)} = \beta_0 \times exp\,(-\gamma r^m),\ \text{with } m \geq 1 \tag{9}$$

(c) Movement:

The movement of a firefly *i* which is attracted by a more attractive (i.e., brighter) firefly *j* is given by the following equation (6.4),

$$x_i = x_i + \beta_0 \times exp\,(-\gamma r_{ij}^2) \times (x_j - x_i) + \alpha\,(rand - \frac{1}{2}) \tag{10}$$

Where the first term is the current position of a firefly, the second term is used for considering a firefly's attractiveness to light intensity seen by adjacent fireflies, and the third term is used for the random movement of a firefly in case there are not any brighter ones. The settings of FA parameters Light absorption coefficient (γ) = 1.0, Randomization parameter (α) = 0.3, Attractiveness value (β_0) = 1.0 and random number (*rand*) generator uniformly distributed in the space [0, 1] = 0.2.

(B) FLOWCHART

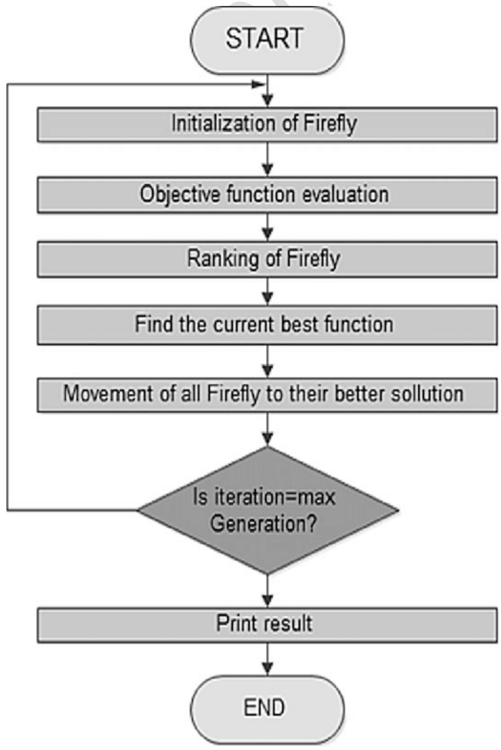

Figure.1 Flow chart of FA

V. RESULTS AND DISCUSSION

To verify the effectiveness of the MPSO algorithm, 6-unit test case is considered. Simulation results of conventional, MPSO and FF algorithm were compared.

A. Case: 6-Units System

A six unit power system is considered. The data of the 6- generating units and coefficients are given in table I. The transmission loss coefficients (B_{ij}) are given in matrix form. The simulation result

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which is inferred from the figure 2-7 shows the effectiveness of the FF algorithm. The table 2 shows the better suited algorithm for the economic load dispatch problem for the different various loads for the system under consideration. The minimized total fuel cost due to FF algorithm is also inferred.

$$B_m = \begin{bmatrix} 0.000218 & 0.000103 & 0.000009 & -.000010 & 0.000002 & 0.000027 \\ 0.000103 & 0.000181 & 0.000004 & -0.000015 & 0.000002 & 0.000030 \\ 0.000009 & 0.000004 & 0.000417 & -.000131 & -.000153 & -.000107 \\ -.000140 & -.000015 & -.000131 & 0.000221 & 0.000094 & 0.000050 \\ 0.000002 & 0.000002 & -.000153 & 0.000094 & 0.000243 & 0.000000 \\ 0.000027 & 0.000030 & -.000107 & 0.000050 & 0.000000 & 0.000358 \end{bmatrix}$$

TABLE I: GENERATING UNIT CAPACITY AND COEFFICIENTS

Unit No.	a	b	c	P min	P max
1	0.15247	38.53973	756.79886	10	125
2	0.10587	46.15916	451.32513	10	150
3	0.02803	40.3965	1049.9977	35	225
4	0.3546	38.30553	1243.5311	35	210
5	0.02111	36.32782	1658.569	130	325
6	0.01799	38.27041	1356.6592	125	315

The test results for the various load change are shown in table II. The values of the power limits of each generator, the coefficients of power loss and the total power load demand are supplied as inputs to the FA algorithm. Each generator's power output and the fuel cost with transmission losses are considered as outputs of the MPSO algorithm.

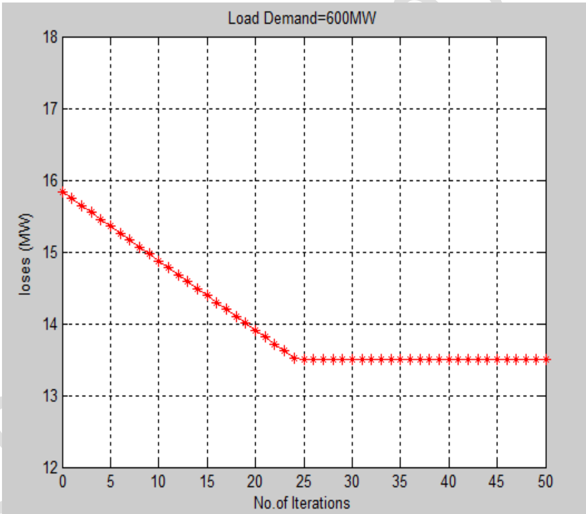

Fig. 2: Minimization of Losses for the load of 600 MW

TABLE 2: POWER OUTPUT OF 6-GENERATOR SYSTEM COMPARISON

	Methods	P1	P2	P3	P4	P5	P6	Fcost()	Ploss(MW)
600	Conv(MPSO)	23.86	10.0	95.63	100.7	202.831	181.197	32094.722	14.2373
600	FA	24.34	10.2	92.54	102.63	206.498	184.334	30976.52	13.2858
700	Conv(MPSO)	28.29	10	118.95	118.67	230.76	212.744	369122.0	19.4318
700	FA	28.85	10.2	121.27	120.91	234.87	216.360	35642.90	18.1227
750	Conv(MPSO)	30.4755	11.226	130.44	127.51	244.46	228.1816	39384.012	22.3107
750	FA	31.68	11.8	135.53	132.33	253.15	235.911	36638.713	19.633

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The load demand of 600 MW is connected with 6-generating power system. By employing optimization algorithms the power losses are reduced for the considered demand. The losses can be reduced by employing the equation4.

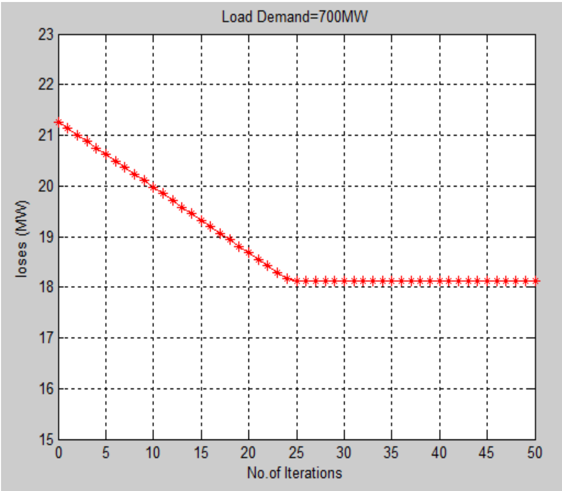

Fig. 3: Minimization of Losses for the load of 700MW

The load demand of 300 MW is connected with 3-generating power system. By employing optimization algorithms the power losses are reduced for the considered demand. The optimization algorithms like MPSO and FA are incorporated with EDP problem to reduce the losses. The simulated output is shown in figure 3.

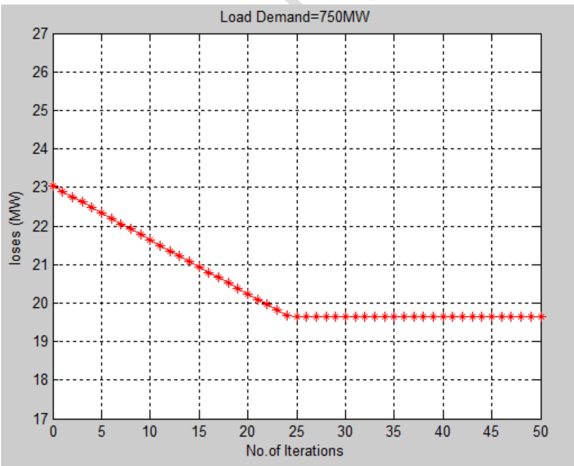

Fig. 4: Minimization of Losses for the load of 750 MW

By employing optimization algorithms the power losses are reduced for the considered 750 MW demand. The optimization algorithms like MPSO and FA are incorporated with EDP problem to reduce the losses. The simulated output is shown in figure 4.

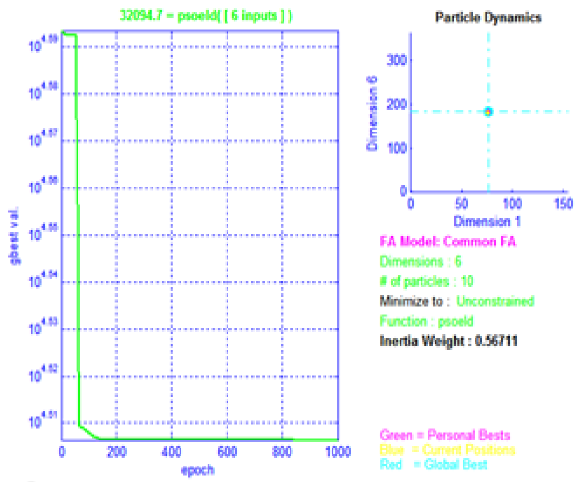

Fig. 5: Minimization of Fuel Cost of 6-Generating Units for the load of 275 MW

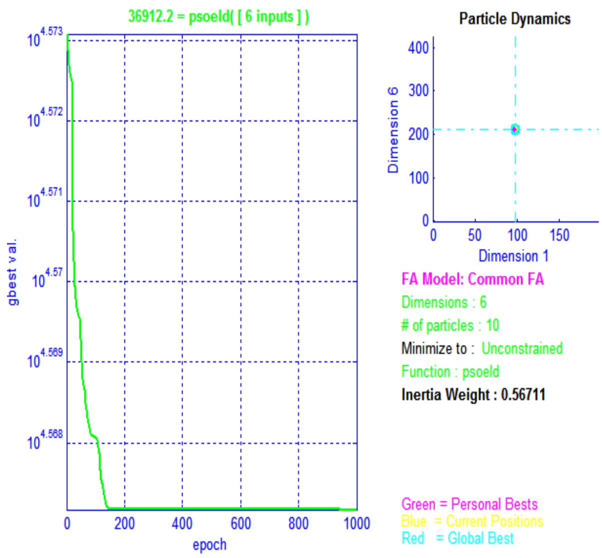

Fig. 6: Minimization of Fuel Cost of 6-Generating Units for the load of 700 MW

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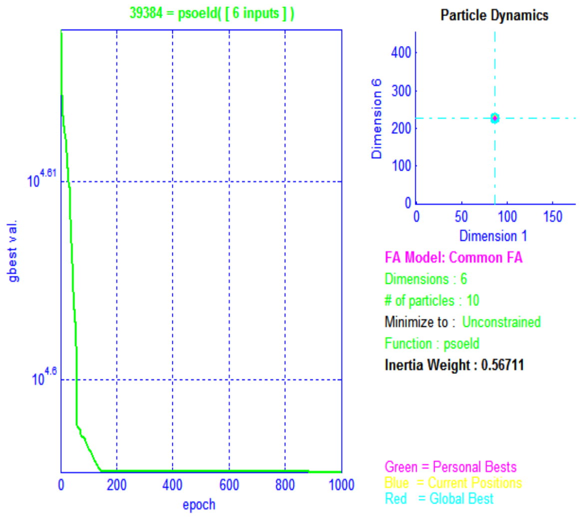

Fig. 7: Minimization of Fuel Cost of 3-Generating Units for the load of 750 MW

By employing optimization algorithms the power losses are reduced for the considered 600 MW, 700 MW and 750 MW demand as shown in the figure 5 to 7. The optimization algorithms like MPSO and FA are incorporated with EDP problem to reduce the fuel cost of the considered power system. Figure 2 to 4 depicts the minimization of losses of a 3-generating unit of various changes in load.

From the simulation results it is inferred that generation output of each unit is obtained and the total cost of generation and transmission losses are reduced by using MPSO and FA optimization techniques when compared with the conventional method. The MPSO algorithm suffers from achieving the global best solution in the possible shortest time. But the FA algorithm provides better accuracy with minimized fuel cost and with faster convergence due to the acceleration factor incorporated in this algorithm. Also the FA algorithm minimizes the transmission losses as well which is observed from figure 5-7.

VI. CONCLUSION

In order to minimize the losses of the system and also to minimize the fuel cost of the generating units of the economic dispatch problem, the optimization techniques like MPSO and Firefly Algorithms (FA) are used. Hence from the above results, it is clear that FA algorithm leads to satisfactory results with faster convergence and better accuracy when compared to conventional method and MPSO algorithm.

VII.REFERNCES

[1] A.J. Wood and B.F. Wollen berg, "Power Generation, Operation and Control", John Wiley and Sons, Newyork,1994.

[2]Hadi Saadat, "Power System Analysis", Tata McGraw Hill Publishing Company, New Delhi,2002.

[3] J. Kennedy and R.C. Eberhart, "Particle Swarm Optimization", Proceedings of IEEE Int. Conference on Neural Networks, vol.4, 1995, pp.1942-1948.

[4] Z.L. Giang,"Particle Swarm Optimization to Solve the Economic Dispatch Considering the Generator Constraints", IEEE Trans. on Power Systems, vol. 18, no.3, 2003, pp.1187-1195.

[5] Whei-Min Lin, Fu-Sheng Cheng and Ming-Tong Tray, "Non Convex Economic Dispatch by Integrated Artificial Intelligence", IEEE Trans. on Power Systems, vol. 16, no.2, 2001, pp.307-311.

[6] Z.X. Liang and J.D. Glover, "A Zoom Feature of Dynamic Programming Solution to Economic

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ISSN NO:0377-9254

Dispatch Including Transmission Losses", IEEE Trans. on Power Systems, vol. 7, no. 2, 1992, pp. 544- 550.
[7] V. Jun Sun, Palade, Xiao-Jun Wu and Wei Fang, "Solving the Power Economic Dispatch Problem with Generator Constraints by Random Drift Particle Swarm Optimization" IEEE Trans. on Industrial Informatics, vol. 10, no. 1, 2013, pp.222-232.
[8] Priyanka Sinha, "Particle Swarm Optimization for Solving Economic Load Dispatch Problem" International Journal of Communication and Computer Technologies", vol. 1, no. 63, 2013, pp.228-233.
[9] Leandro Dos Santos Coetho and Chu-Sheng Lee, "Solving Economic Load Dispatch Problems in Power System using Chaotic and Gaussian Particle Swarm Optimization Approaches", International Journal of Electric Power and Energy Systems, Elsevier, vol. 30, no. 5, 2008, pp. 297-307.
[10] C.L. Chen and S.C. Wang, "Branch and Bound Scheduling for Thermal Generating Units", IEEE Transactions on Energy Conversion, vol. 8, no. 2, 1998, pp.184-189.
[11] K.Y. Lee, Y.M. Park and J.L. Ortiz, "Fuel Cost Minimization for both Real and Reactive Power Dispatches", IEE Proceedings of Generation, Transmission and Distribution, vol. 131, no. 3, 1984, pp.85-93.
[12] Nagendra Singh, Yogendra Kumar, "Multiobjective Economic Load Dispatch Problem Solved by New PSO", Advances in Electrical Engineering, Hindawi Publications, vol. 2015, 2015, pp.1-6.

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