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EVALUATION OF ECONOMIC LOAD DISPATCH USING ARTIFICIAL COLONY

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Abstract:- ***Economic load dispatch is a crucial optimization task in power system operation for allocating generation among the committed units and also the fuel cost in rupees per hour (Rs/h) are reduced. The economic load dispatch plays a very important role within the operation of power grid. For this operation, six generator system of Satpura Thermal Power Plant has been taken into account. The purpose of the proposed work is to find the optimal value of economic load dispatch in thermal power plant through Ant colony optimization (ACO) in order to solve the economic load dispatch problem.***

Keywords:- Optimization, linear and nonlinear ELD problems, Ant colony optimization, Thermal power plant generation.

1. Introduction

Electricity expanded rapidly throughout the world after invention. Electrical power systems in the world have grown larger and more geographically expansive with many interconnections between neighboring systems. India has also grown in production of electricity. India has recorded impressive rates of economic growth in recent years.

Electrical power sectors play an important role in national economy. Growth in production of electricity has led to its extensive use in all the sectors of economy. The growth in all sectors increases very rapidly and hence the demand of electricity increases in the same ratio. The demand rate of electrical power is very large as compared to generation of power.

Since electrical power system has limited power generation and hence at the same time it is very difficult task to satisfy the demand of all electrical consumers. It is also very difficult task to provide electric power at a reasonable rate of price. So that it is required to reduce the total generation cost of the electrical power plants and fulfill the load demand.

Economic load dispatch is an important optimization task in power system operation for allocating generation among the committed units such that the constraints imposed are satisfied and the energy requirements in terms of British thermal units per hour (Btu/h) or dollar per hour ($/h) or rupees per hour (Rs/h) are minimized. Improvements in scheduling the unit outputs can lead to significant cost savings.

The efficient and optimum economic operation of electric power systems has always occupied an important position in electric power industry. In recent decades, it is becoming very important for utilities to run their power systems with minimum cost while satisfying their customer's demand all the time and trying to make profit. Since the demand is very large and the power generation is limited so it is required to fulfill the load demand using committed generating units in minimum fuel cost.

2. Literature Review

Typically in simulated annealing method, a higher cost feasible solution is accepted with temperature dependent probability, but other solutions are accepted deterministically. **Saber et al. (2005)**presented a new approach to unit commitment problem using absolute stochastic simulated annealing method. In every iteration, a solution is taken with a certain probability. However, all the solutions, both higher and lower cost, are associated with acceptance probabilities. Evolutionary algorithms are heuristic methods that have yielded promising results for solving nonlinear, non-differentiable and multi-modal optimization problems in the power systems area presented by **Abido (2006)**.

Differential evolution is one of the recently developed evolutionary computation techniques presented by **Duvvuru and Swarup (2011)**, to minimize the nonlinear function, which is the total fuel cost of thermal generating units, subject to the usual constraints.
An improved evolutionary search method with binary successive approximation approach presented by **Abido (2003)** used to solve ELD problem in power system by searching the generation of the committed units.

Bhattacharya and Chattopadhyay (2010) presented a biogeography-based optimization algorithm, to solve both convex and non-convex economic load dispatch problems of thermal plants. **Arul et al. (2011)** presented a new evolutionary optimization algorithm to solve economic load dispatch problem with operational constraints using the improved harmony search algorithm. **Swain and Hota (2012)** introduced Gravitational search algorithm applied to economic load dispatch problem with valve point loading and Kron's loss.

A hybrid approach incorporated artificial neural network using back propagation algorithm (BP) and fuzzy logic algorithm (Neuro-Fuzzy hybrid) proposed in **Chauhan at el. (2005)** for the ELD problem to maximize the short- and long-term operations system performance considered generating limits, the transmission line constraints and the limited amounts of the capital available for new units and equipment.

A solution of the dynamic economic dispatch problem using a hybrid approach of Hopfield neural network and quadratic programming introduced by **Abdelaziz et al. (2008)**. The hybrid algorithm is based on using enhanced HNN, to solve the static part of the problem and the QP algorithm for solving the dynamic part of the DED.
Coelho et al. (2008) suggested an alternative hybrid method. The proposed hybrid method combines the

differential evolution, an evolutionary algorithm, with cultural algorithm based on normative and situational knowledge to solve the economic load dispatch associated with the valve point effect.

Quadratic Programming and differential evolution are combined as hybrid algorithm for solving economic load dispatch problem with valve point effect presented by **Coelho and Mariani (2006)**.

A new hybrid system employed hybrid mechanism involving a quantum mechanics inspired particle swarm optimization (PSO) proposed by **Chakraborty et al. (2011)**.

Dorigoet al. (2006) developed Ant Colony Optimization as a viable new approach to stochastic combinatorial optimization. The idea is based on a colony of ants that is able to succeed in a task to find the shortest path between the nest and the food source.

3. Formulation of ELD Problem

The main concern of ELD problem is the minimization of its objective function. For obtaining optimum results of economic load dispatch problem it is needed to formulate proper mathematical model with their constraints. Mathematical model of ELD problem can be formulated in many way as listed in literature such as, Single objective, Multi-objective, Linear model of ELD, Non-linear model, ELD model with emission effect, ELD model with nonconventional sources etc.

The objective of ELD problem for fuel cost is given as

$$\text{Minimize } FC_T = \sum_{i=1}^{N} FC_i(P_i) \quad (1)$$

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

Where, FC_T is the total generation cost; FC_i is the power generation cost function of the i^{th}unit, N is the total number of generating units.

3.1 Constraints

The classical and non-classical models either with smooth or non-smoothed fuel cost functions are subjected to the following equality and inequality constraints.

3.1.1 Power balance constraint

Power balance constraints bring the power system to a principle of equilibrium between total load demand and total power generation since cost function is not affected by the reactive power demand and hence the power balance constraint is applied to the real power balance in the system. Power balance requires the controlled generation of variables P_{Gi} which obeys the constraints equation.

$$\sum_{i=1}^{n} P_i = P_D \quad (3)$$

Where, P_i is the output power of the ith generator and P_D is the load demand.

3.1.2 Power generation capacity constraint

The lower (P_i^{min}) and upper (P_i^{max}) power generation limit of the generating units are directly related to the machine design. Each generator is constrained between its minimum and maximum limits as shown in equation (4)

$$P_i^{min} \le P_i \le P_i^{max} \quad (4)$$

Where P_i^{min} and $P_i^{max}$are the minimum and maximum power outputs respectively of ith generator.

4. ANT COLONY OPTIMIZATION(ACO)

The ant colony optimization is based on the colony of ants cooperates in finding right solutions to difficult discrete optimization problems. Cooperation is a key design component of ACO algorithms. The desire is to allocate the computational sources to a hard and fast of quite easy agents that communicate indirectly with the aid of stigmergy. Good answers are an emergent property of the agent's cooperative interaction. The Ant Colony Optimization (ACO) metaheuristic is proposed by **Dorigo (1992)**. The ant colony optimization metaheuristic can be seen as a higher-level optimization strategy that adopts the basic mechanisms underlying the foraging behavior of ant colonies which are enhanced by artificial intelligence techniques.

In AS, m ants construct trial solutions in parallel by utilizing the random proportional rule. It should be noted that the ants are given memory to store the constructed partial solution. The constructed partial solution sequence is the probability that an ant k adds c_j as the next component in x given by:

$$P(i,j) = \frac{[\tau(i,j)].[\eta(i,j)]\text{^}\beta}{\sum_{g\varepsilon allowed}[\tau(i,g)].[\eta(i,g)]\text{^}\beta} \quad (5)$$

Where τ(i, j) is the pheromone trail of arc(i, j), η(i, j) is the heuristic information of arc(i, j), α and β are the parameters that control the relative importance of pheromone and heuristic respectively.

Pheromone updating

In AS, pheromone evaporation reduces all existing pheromone trails by a factor given by:

$$\tau(i,j) = (1-\rho)\tau(i,j) \quad (6)$$

Where, τ(i, j) is the pheromone trail of arc(i, j) and $0<\rho<1$ is the pheromone evaporation rate.

After pheromone evaporation, all ants deposit pheromone on the arcs they have followed by the value which is given by:

$$\tau(i,j) = \tau(i,j) + \sum_{k=1}^{m} \Delta\tau(i,j) \text{for all i,j} \quad (7)$$

Where $\Delta\tau(i,j)$is the pheromone deposited by ant k on arc(i, j).

5. TEST DATA AND RESULTS

In this study, Satpura Thermal Power Plant (MPPGCL) is considered to investigate the effectiveness of the proposed approach, The data taken into consideration for the analysis of Satpura Thermal Power Plant having six generating unit system in which all units cost coefficients has been shown in Table I. The installed capacity and date of commissioning of the plant is shown in Table II. The results obtained through ACO are compared with PSO methods are tabulated in Table III, has been tested for the load demand of 70 % and 90% of the maximum loading capacity of the plant respectively. The total installed capacity of the plant is 1330MW.

Table I: Cost coefficients of six generating unit data

Units	a_i	b_i	c_i
1	100	200	10
2	120	150	10
3	40	180	20
4	60	100	10
5	40	180	20
6	100	150	10

Table II: Installed capacity, date of commissioning and status of Satpura Thermal Power Station [Data taken from MPPGCL India]

Generating Unit No.	Installed Capacity	Date of commissioning	Status
1	200	July, 1979	Running
2	210	Sep. 1980	Running
3	210	Jan. 1983	Running
4	210	Feb. 1984	Running
5	250	March 2013	Running
6	250	Dec. 2013	Running

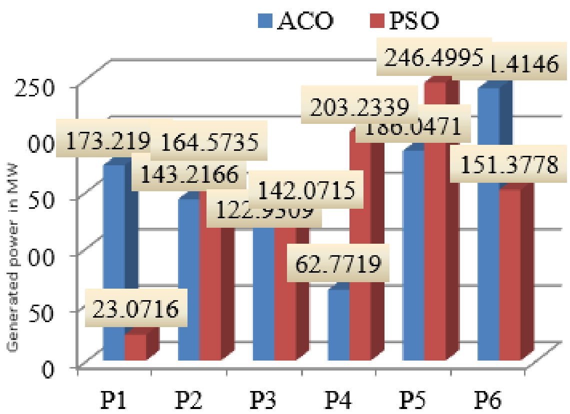

Figure 1: Comparison between ACO and PSO method at 70% of the maximum loading of generator.

Case I

In this case, economic load dispatch problem is solved for Satpura Thermal Power Station at 70% of the maximum loading of generators. Figure1, shows the load demand at different generating units of the generators using the two methods for comparison ACO and PSO.

Table III: Results of 6 generating unit system for the 70 % of maximum demand

Unit Power Output	PSO	ACO
P1(MW)	23.0716	173.2194
P2(MW)	164.5735	143.2166
P3(MW)	142.0715	122.9309
P4(MW)	203.2339	62.7719
P5(MW)	246.4995	186.0471
P6(MW)	151.3778	241.4146
Total Power Output(MW)	931	931
Fuel Cost(Rs/h)	2280019	2276575

Figure 2, shows the convergence characteristic of the ACO for six generator systems at Satpura Thermal Power Station at 70% of the maximum load demand. Figure 3, shows a comparative result of the fuel cost at 70% of the maximum load demand (that is at 931 MW).

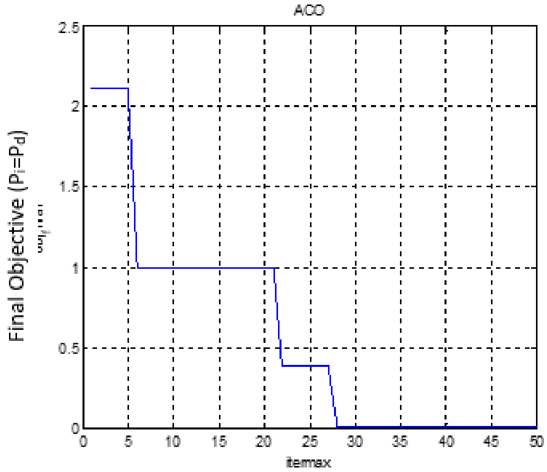

Figure 2. Convergence characteristic of the ACO for six generator system for 70% of the maximum load demand

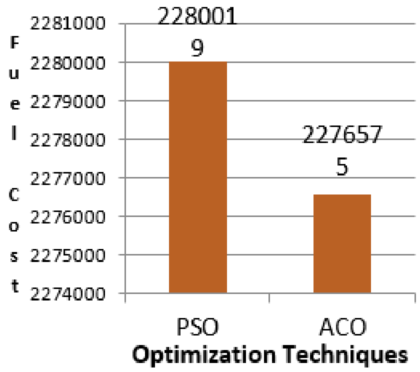

Figure 3: Comparative result of fuel cost of 6 generating units for 70% of load maximum demand

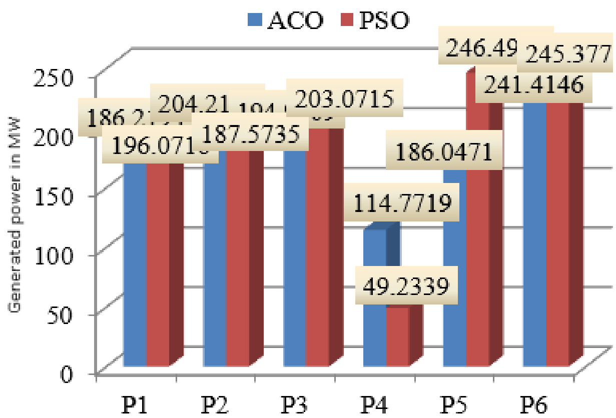

Figure 4: Comparison between ACO and PSO method at 90% of the maximum loading of generator

Table IV: Results of 6 generating unit system for 90% of maximum demand

Unit Power Output	PSO	ACO
P1(MW)	196.0716	186.2194
P2(MW)	187.5735	204.2166
P3(MW)	203.0715	194.9309
P4(MW)	49.2339	114.7719
P5(MW)	246.4995	186.0471
P6(MW)	245.3778	241.4146
Total Power Output (MW)	1127	1127
Total Cost (Rs/h)	3116185	3115690

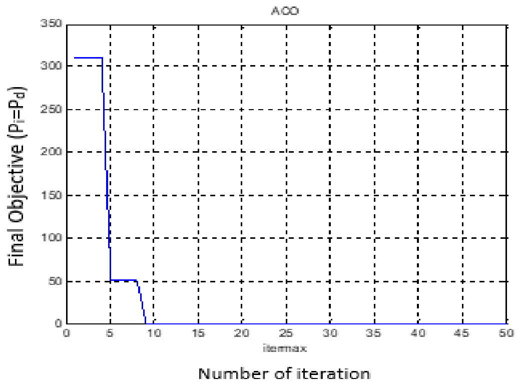

Figure 5: Convergence characteristic of the ACO for six generator system for 90% of the maximum load demand

Case II:

Again in this case, economic load dispatch problem is solved for Satpura Thermal Power Station at 90% of the maximum loading of generators. Figure 4 shows the load demand at different generating units of the generators using the two methods for comparison ACO and PSO. Figure 5 shows the convergence characteristic of the ACO for six generator system at Satpura Thermal Power Station at 90% of the maximum load demand. Figure 6 shows a comparative result of the fuel cost at 90% of the maximum load demand (that is at 665 MW).

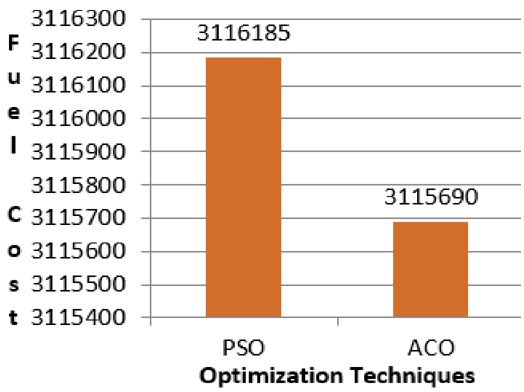

Figure 6: Comparative result of fuel cost of 6 generating units for 90% of load maximum demand.

6. Conclusions

Electrical power sector is running in crisis in terms of unremitting gap between demand and supply. Looking at present strength of India and to achieve target in field of electrical power sector it is necessary to adopt change in form of efficient operation methodology for thermal power plant generation. Thermal power plant located at various parts of India contributes major share in installed power capacity of India. This research is the first effort in state to determine the optimal power generation schedule for thermal power plants. The various aspects of economic load dispatch like cost optimization, minimization of cost, and the cost optimization with equality and inequality constraints are studied. In this work, evolutionary techniques such as, ant colony optimization (ACO) and its results compared by PSO, are formulated and implemented to find the optimum solution of the economic load dispatch problem.

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