COMPARATIVE ANALYSIS OF MODERN OPTIMIZATION TECHNIQUES TO REDUCE OVERALL GENERATION COST FOR THERMAL GENERATING SYSTEMS

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ABSTRACT

This paper presents the analysis of modern optimization algorithms to solve Economic Load Dispatch (ELD) problem in thermal generating system. The optimization of systems and processes is very important to the efficiency and economics of many science and engineering domains. Optimization problems are solved by using rigorous or approximate mathematical search techniques The primary objectives of this paper is to develop flexible and extensible computational framework as MATLAB environment for implementing the various algorithms such as ABC ,IABC and SFL to solve economic load dispatch problem and analysis the Performance of various optimization algorithms on the basis of power generation(MW),computational time(sec) ,minimum generation cost(INR) and power loss(MW).

Keywords: - Economic load dispatch, Optimization, Artificial Bee Colony Algorithm, Interactive Artificial Bee Colony Algorithm, Shuffled Frog Leaping Algorithm

I. INTRODUCTION

The economic load dispatch plays an important role in the operation of power system, and several models by using different techniques have been used to solve these problems. Several traditional approaches, like lambda-iteration and gradient method are utilized to find out the optimal solution of non-linear problem More recently, the soft computing techniques have received more attention and were used in a number of successful and practical applications. The purpose of this work is to find out the advantages of application of the evolutionary computing technique. In this work, data has been taken from the published work in which loss coefficients are also given with the max-min power limit and cost function. All the techniques are implemented in MATLAB environment. This formulates the economic load dispatch (ELD) problem for finding the optimal combination of the output power of all the online generating units that minimizes the total fuel cost, while satisfying an equality constraint and a set of inequality constraints[1,2].

1.1 Thermal Power Plant

A thermal power plant is a plant wherein prime-mover is propelled by steam. Water is the main working fluid. Water is heated in order to circulate with energy which expanded at the steam turbine to produce work at the shaft of the generator. Then it passes by the turbine into the condenser and then pushed to feed the boiler where it again heated up[3].

For generalization, thermal power plants can be considered as a transfer function of energy from

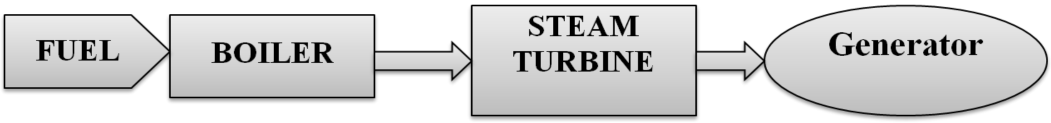

Figure 1.1: Energy conversion diagram of a thermal power plant

The thermal unit scheme usually consists of the boiler, the vapor turbine, and the generator. The input of the boiler is fuel, and the yield is the capacity of steam. The relationship of the input and output can be expressed as a convex bend .The input of the turbine-generator unit is the volume of vapor and the yield is electrical power, the general input-output attribute of the whole generation unit can be got by blending exactly the input-output attribute of the boiler and the input-output attribute of the turbine-generator unit. It is a known as convex curve.

1.2 Economic Load Dispatch

Economic Load Dispatch (ELD) is a method to schedule the power generator outputs with respect to the load demands, and to operate the power system most economically, or in other words, we can say that main objective of economic load dispatch is to allocate the optimal power generation from different units at the lowest cost possible while meeting all system constraints. The Economic Load Dispatch (ELD) difficulty is one of the fundamental matters in power system operation This formulates the economic load dispatch (ELD) problem for finding the optimal combination of the output power of all the online generating units that minimizes the total fuel cost, while satisfying an equality constraint and a set of inequality constraints[4].

The objective of Economic Load Dispatch is to minimize the overall cost i.e.

Minimize

$$C_t = \Sigma c_i p_i$$

The fuel cost of generating unit i is expressed as

$$C_i P_i = a_i * P_i^2 + b_i * P_i + c_i \text{ Rs/hr}$$

Economic dispatch including losses:

$$\Sigma P_i = P_D + P_L$$

Where a_i, b_i , c_i are cost coefficients for unit i,

C_t= total cost of generation

Pi = power generation of ith unit plant

P_D is the power demand

P_L is the power loss

II. PROPOSED METHODOLOGY

2.1 Optimization Algorithms

The proposed works are described here firstly analysis the all previous approaches in the field of economic load dispatch then we have formulated the economic load dispatch including losses using MATLAB environment, create a 3 generator and 6 generator problem and implemented the three optimization techniques such as Artificial Bee Colony, Interactive Artificial Bee colony and Shuffled Frog Leaping Algorithms and find out the result then analysis and compare this optimized result on the basis of power generation, minimum generation cost ,power losses and computational time[5,6].

2.1.1 Artificial Bee Colony

The ABC algorithm is a swarm based, meta-heuristic method based on the model first proposed by [30] on the foraging behavior of honey bee colonies. The model is composed of three important elements: employed and unemployed foragers, and food The model is composed of three important elements sources. The employed and unemployed foragers are the first two elements, while the third element is the rich food sources close to their hive[7,8]..

The model is composed of three important elements

food sources:--its proximity to the nest it shows the concentration of energy, the position of a food source signifies the position of a promising solution to the optimization problem, whereas the value of nectar of a food source represents the fitness cost (quality) of the associated solution.

Employed foragers: (50%):

In ABC system, artificial bees fly around in a multidimensional search space and the employed bees choose food sources depending on the experience of themselves.

Unemployed bees:

The onlooker bees (50%):- . It gets the information of food sources from the employed bees in the hive and select one of the food source to gathers the nectar.

Scout bees (5-10%):- It is responsible for finding new food sources. Scout bees fly and choose the food sources randomly without using experience. Each food source chosen represents a possible solution to the problem under consideration. The nectar amount of the food source represents the quality or fitness of the solution.

Exchange of Information among bees

- The exchange of information among bees is the most important occurrence in the formation of collective knowledge.
- The most important part of the hive with respect to exchanging information is the dancing area
- Communication among bees related to the quality of food sources takes place in the dancing area.
- This dance is called a Waggle dance.
- Employed foragers share their information with a probability proportional to the profitability of the food source, and the sharing of this information through waggle dancing is longer in duration.
- An onlooker on the dance floor, probably she can watch numerous dances and decides to employ herself at the most profitable source.

There is a greater probability of onlookers choosing more profitable sources since more information is circulated about the more profitable sources[9]

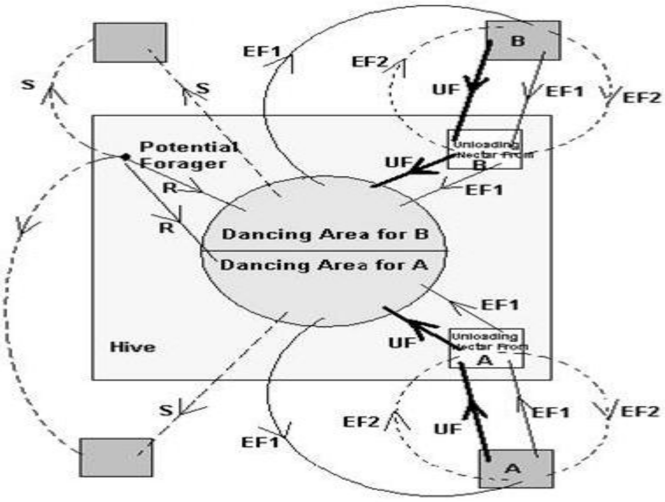

Fig 2.1:-*The behavior of honey bee foraging for nectar*

2.1.2 Interactive Artificial Bee Colony

In this research, a multi-objective Interactive Artificial Bee Colony (IABC) is proposed to solve the economic power dispatch problem. This newly technique makes ABC technique, more flexible and powerful**.** In general, the ABC algorithm works well on finding the better solution of the object function. However, the original design of the onlooker bee's movement only considers the relation between the employed bee, which is selected by the roulette wheel selection, and the one selected randomly[10,11].

Therefore, it is not strong enough to maximize the exploitation capacity. The Interactive Artificial Bee Colony algorithm is proposed based on the structure of ABC algorithm. By using the Newtonian law of universal gravitation [32] described in the equation (2.1), the universal gravitations between the onlooker bee and the selected employed bees are exploited[17,18].

$$F_{12} = G\frac{m_1 m_2}{r_{21}^2}\hat{r}_{21} \quad (2.1)$$

In the equation (2.1), F_{12} denotes the gravitational force heads from the object 1 tothe object 2, G is the universal gravitational constant, m_1 and m_2 are the masses of theobjects, r_{21} represents the separation between the objects, and $\hat{r}_{21}$ denotes the unit vectorin the equation (2.2).

$$\hat{r}_{21} = \frac{r_2 - r_1}{|r_2 - r_1|} \quad (2.2)$$

The process of the IABC can be defined in 5 steps:

Step 1. Initialization: Spray n_e percentage of the populations into the solution spacerandomly, and then calculate their fitness values, which are namedas the nectar amounts, where necharacterizes the ratio of employed bees to the total population. Once these populations are positioned into the solution space, they are named as the employed bees.

Step 2. Move the Onlookers: Calculate the probability of selecting a food, select a food source to move to by roulette wheel selection for every onlooker bees and then determine the nectar amounts of them.

Step 3. Move the Scouts: If the fitness values of the employed bees do not be improved by a continuous predetermined number of iterations, which is called "$Limit$",those food sources are abandoned and these bees (employed) become the scouts. Then the scouts move**.**

Step 4. **Update the Best Food Source Found So Far**: Remember the best fitness value and the position, which are determined by the bees.

Step 5. Termination Checking: Ascertain if the amount of the iterations fulfills the termination status. If the termination condition is persuaded, terminate the program and output the results; else proceed back to the Step 2.

2.1.3 Shuffled Frog Leaping Algorithm

Shuffled Frog Leaping Algorithm (SFLA) is a heuristic search algorithm presented for the first time by Yusuf and Lanes in 2003. The main purpose of this algorithm is achieving a method to solve complicated optimization problems without any use of traditional mathematical optimization tools. the SFL algorithm is combination of "meme-based genetic algorithm or Mimetic Algorithm" and "Particle Swarm Optimization (PSO)". This algorithm has been inspired from mimetic evolution of a group of frogs when seeking for food. In this technique, a solution to a given problem is presented in the form of a string, called “frog” which has been considered as a control vector[19,20].

Procedure Of Shuffled Frog Leaping Algorithm

Step1: Generate Initial Population

An initial population of *P* frogs are created randomly for an *S*-dimensional problem. A frog *i* is represented by S variables, $\boldsymbol{F_1 = (f_{i1}, f_{i2}, f_{i3} \ldots\ldots)}$

Step 2: Evaluate the fitness

Calculate fitness value of each frog according to the given problem. Then Record the best frog position in the entire population.

Step 3: Sorting

The frogs are arranged in a descending order according to their fitness.

Step 4: Partition into memeplexes

the P frogs are partitioned into m memeplexes, each containing n frogs **(P = m × n).**

In this procedure, the first frog moves to the first memeplex, the second frog moves to the second memeplex and the mth frog moves to the mth memeplex, then (m + 1)th frog goes back to the first memeplex and so on.

Step 5: Memeplex Evolution

In each memeplex, the frogs with the best and the worst fitness are determined and named as Xb and Xw, respectively. Also, the position of frog with the global best fitness among the memeplexes is identified as Xg

Step 6: Shuffling

After a defined number of memeplex evolution steps, all frogs of memeplexes are collected, and sorted in descending order based on their fitness. Step 5 divides frogs into different memeplexes again and then step 6 is performed.

Step 7: Check Terminal Condition

If the defined convergence criteria are satisfied or the output does not change for a specific number of iterations, the program will be terminated and the results will be printed, and the rest of the program goes to Step 4

III. RESULD AND DISCUSSION

In this section, the results of ELD after the implementation of proposed ABC,IABC and SFL methods are discussed. we have developed model for solving the Economic Load Dispatch problem using the proposed method in MATLAB R2009b. The main objective is to minimize the cost of generation of plants using various optimization algorithms. We have used Artificial Bee Colony Algorithm, Interactive Artificial Bee Colony Algorithm and Shuffled Frog Leaping Algorithm for resolving ELD problem. The performance is evaluated with considering losses using 3 generator and 6 generator systems which are discussed below:-

CASE STUDY 1:-ECONOMIC LOAD DISPATCH FOR 3 UNIT THERMAL GENERATING SYSTEM

In this case study the loss coefficients, fuel cost and maximum and minimum power limits are given below.

The power demand is considered to be 585 (MW). The results corresponding to ABC,IABC and SFLA are detailed in below.

COST CHARECTERESTICS

UNIT 1 : F1 = 0.00156*P1^2 + 7.92*P1 + 561 Rs/Hr 100 <= P1 <= 600 MW
UNIT 2 : F2 = 0.00194*P2^2 + 7.85*P2 + 310 Rs/Hr 100 <= P2 <= 400 MW
UNIT 3 : F3 = 0.00482*P3^2 + 7.97*P3 + 78 Rs/Hr 50 <= P3<= 200 MW

Loss Coefficient matrix

[0.0000750 0.0000050 0.0000075
0.0000050 0.0000150 0.0000100
0.0000075 0.0000100 0.0000450]

RESULT		ABC	IABC	SFL
Power from Generators (MW)	P_1	233.2524	233.2556	233.2524
	P_2	267.8646	267.8597	267.8645
	P_3	90.84041	90.84218	90.84043
Power Loss (MW)		6.957403	6.968032	6.979407
System Cost (INR)		**5886.940886**	5897.940886	5902.940886
Computation Time (Sec)		27.253742	16.832191	344.345349

CASE STUDY 2:-ECONOMIC LOAD DISPATCH FOR 6 UNIT THERMAL GENERATING SYSTEM

In this case study the loss coefficients, fuel cost and maximum and minimum power limits are given below.

The power demand is considered to be 700 (MW). The results corresponding to ABC,IABC and SFLA are detailed in below.

COST CHARECTERESTICS

UNIT 1 : F1 = 0.15240*P1^2 + 38.53973*P1 +756.79886 Rs/Hr 10 MW < P1 < 125 MW;
UNIT 2 : F2 = 0.10587*P2^2 + 46.15916*P2 +451.32513 Rs/Hr 10 MW < P2 < 150 MW;
UNIT 3 : F3 = 0.02803*P3^2 + 40.39655*P3 +1049.9977 Rs/Hr 35 MW < P3 < 225 MW;
UNIT 4 : F4 = 0.03546*P4^2 + 38.30553*P4 +1243.5311 Rs/Hr 35 MW < P4 < 210 MW;
UNIT 5 : F5 = 0.02111*P5^2 + 36.32782*P5 +1658.5596 Rs/Hr 130 MW < P5 < 325 MW;
UNIT 6 : F6 = 0.01799*P6^2 + 38.27041*P6 +1356.6592 Rs/Hr 125 MW < P6 < 315 MW;

Loss Coefficient matrix

0.000140	0.000017	0.000015	0.000019	0.000026	0.000022;
0.000017	0.000060	0.000013	0.000016	0.000015	0.000020;
0.000015	0.000013	0.000065	0.000017	0.000024	0.000019;
0.000019	0.000016	0.000017	0.000071	0.000030	0.000025;
0.000026	0.000015	0.000024	0.000030	0.000069	0.000032;
0.000022	0.000020	0.000019	0.000025	0.000032	0.000085

RESULT		ABC	IABC	SFL
Power from Generators (MW)	P_1	28.30266	28.31833	27.68066
	P_2	10	10	15.8924
	P_3	118.9581	119.6222	118.7095
	P_4	118.6729	117.9694	118.6574
	P_5	230.765	230.4953	229.5668
	P_6	212.733	213.0226	208.7124
Power Loss (MW)		19.411575	19.427783	19.519205
System Cost (INR)		**36912.147812**	36924.183417	36939.068072
Computation Time (Sec)		738.969706	660.444032	1678.393601

IV. CONCLUSION AND FUTURE SCOPE

CONCLUSION: In this paper, the formulation and implementation of solution methods to obtain the optimum solution of Economic Load Dispatch problem using soft computing techniques such as, ABC, IABC, SFLA based economic were comparatively investigated for 3 unit and 6 unit thermal generating system. The results obtained were satisfactory for all approaches but it was shown that the ABC performed better as compared to other procedures for the minimum generation cost viewpoints. ABC shows less power loss as compared to IABC and SFLA but IABC takes minimum computational time. Results will be in terms of the best optimized solution, Computational time, Better convergence towards the solution etc. Study will be helpful to develop the software for real time economic load dispatch problems

FUTURE SCOPE:-A future recommendation can be made for above proposed methods to solve ELD problems as the use of new efficient operators to control and enhance the efficiency of instantaneous population for better and fast convergence. Here it can be suggested that better result can be obtained by improving the fitness function and penalty factor used in the above programming. Direction of research work can still be developed by improving methodologies used for parent selection and fitness function. Further, the optimization result can also be improved by using hybrid artificial intelligence technique. Hydro –thermal-nuclear power scheduling can also be improved

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