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Soft Computing Techniques ABC, IABC and SFL Optimization Algorithms for 15 Unit Thermal Generating Systems

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Abstract— this paper presents an analysis of Economic Load Dispatch (ELD) problem using various algorithms such as ABC, IABC and SFL algorithm in order to maintain a high degree of economy and reliability of the power system. 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

Electrical power systems are designed and operated to meet the continuous variation of power demand. In power system, minimization of the operation cost is very important. 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[1].

1.1 ECONOMIC LOAD DISPATCH

The Economic Load Dispatch (ELD) can be defined as the process of allocating generation levels to the generating units, so that the system load is supplied entirely and most economically. The definition of economic load dispatch is “The operation of generation facilities to produce energy at the lowest cost to reliably solve consumers, recognizing any operational limits of generation and transmission facilities”. The economic load dispatch (ELD) is one of the most important optimization problems from the viewpoint of power system to derive optimal economy [2, 3]

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

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

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

Economic dispatch including losses:

The fuel cost of generating unit i is expressed as

$$C_i P_i = a_i * P_i^2 + b_i * P_i + c_i$$

$$\Sigma P_i = P_D + P_L$$

Where P_D is the power demand

P_L is the power loss

II. PROPOSED METHODOLOGY

Solution of economic load dispatch problem using optimization algorithm

The objective of Economic Load Dispatch (ELD) for power system consisting of thermal generating units is to find the optimal combination of power generations that minimizes the total generation cost while satisfying the specified equality and inequality constraints. [3].

2.1 OPTIMIZATION ALGORITHMS

The process of optimization lies at the root of engineering, since the classical function of engineer is to design new, better, more efficient, and less expensive systems as well as devise plans and procedures for the improved operation of existing systems.

A. 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 sources. The employed and unemployed foragers are the first two elements, while the third element is the rich food sources close to their hive. The two leading modes of behavior are also described by the model [9, 10].

The model is composed of three important elements

food sources:--its proximity to the nest

--its concentration of energy

--easy of extracting

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.

--its provide information about food source

--it decides direction and distance from nest (food source)

--it shows the profitibality of the source

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%):- 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 [12, 13] it is responsible for finding new food sources.

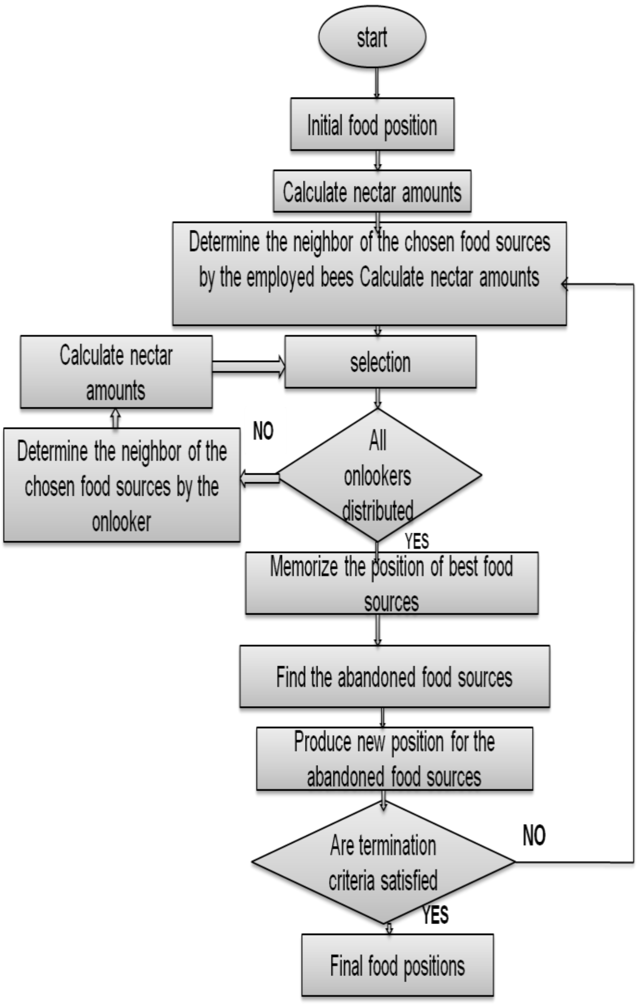
The search cycle of ABC consists of three rules:

(i) Sending the employed bees to a food source and evaluating the nectar quality;

(ii) Onlookers choosing the food sources after obtaining information from employing bees and calculating the nectar quality;

(iii) Determining the scout bees and sending them on to possible food sources

FLOW CHART OF ABC



Main steps of ABC algorithm for ELD problems are as follows:

Step-1: Initialize the population of solutions with in boundaries of the system

$$\mathbf{P} = \mathbf{P_{min}} + \mathbf{rand} * (\mathbf{P_{max}} - \mathbf{P_{min}})$$

Step-2: Calculate the objective function and fitness of each solution. Store the best fitness as *Pbest* solution.

Step-3: A mutant solution is formed using a randomly selected neighbour,

$$\mathbf{P_{k\,mu\,tant}} = \mathbf{P_k(i)} + \{\mathbf{P_J(i)} - \mathbf{P_K(i)}\} * \{\mathbf{2} * \mathbf{rand} - \mathbf{1}\}$$

where *j* is the randomly selected neighbour and *i* is a random parameter

Step-4: Replace$\mathbf{P_{k\,mu\,tant}}$ by$\mathbf{P_k}$if the mutant has higher fitness or lower fuel cost of generation

Step-5: Repeat the above procedure for all the solutions

Step-6: Probability of each solution is calculated as

Probability (*i*) = a*fitness (*i*)/max (fitness) + b

where {a+b =1}

Step-7: The solution *P* is selected if its probability is greater than a random number,

If (rand < probability (*i*))

Solution is accepted for mutation

Else

Go for next solution

Counter is incremented

While (Counter = population/2)

Step-8: Again the best *P* is determined. Replace *P* by random *P* if its trial counter exceeds threshold.

Step-9: Repeat the above for maximum number of iterations.

Step-10: The *Pbest* and F (*Pbest*) are the best solution and global minimum of the objective function.

B. INTERACTIVE ARTIFICIAL BEE COLONY

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. 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 [20] described in the equation (1), the universal gravitations between the onlooker bee and the selected employed bees are exploited [11, 20].

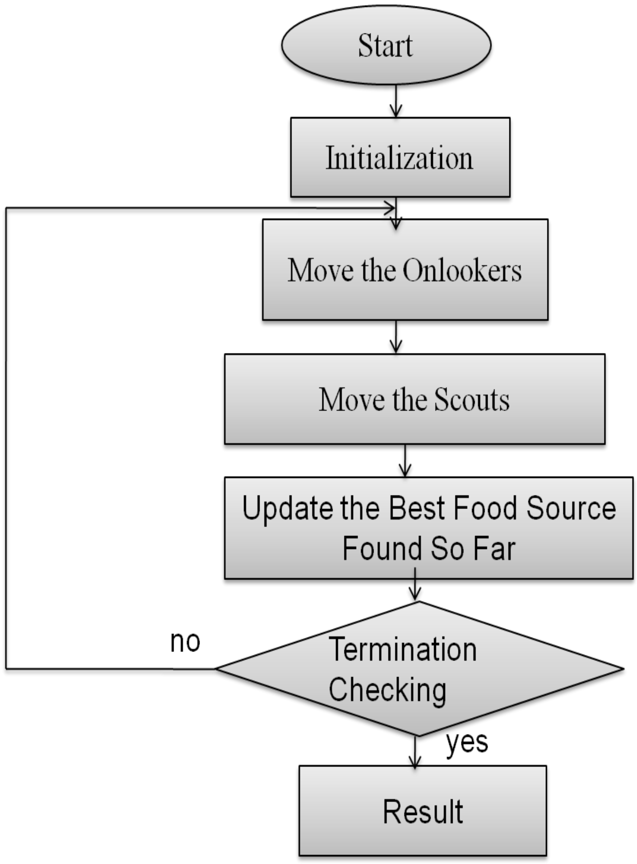
$$F_{12} = G\frac{m_1 m_2}{r_{21}^2}\hat{r}_{21} \qquad (1)$$

In the equation (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).

$$\hat{r}_{21} = \frac{r_2 - r_1}{|r_2 - r_1|} \qquad (2)$$

FLOW CHART OF IABC



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.

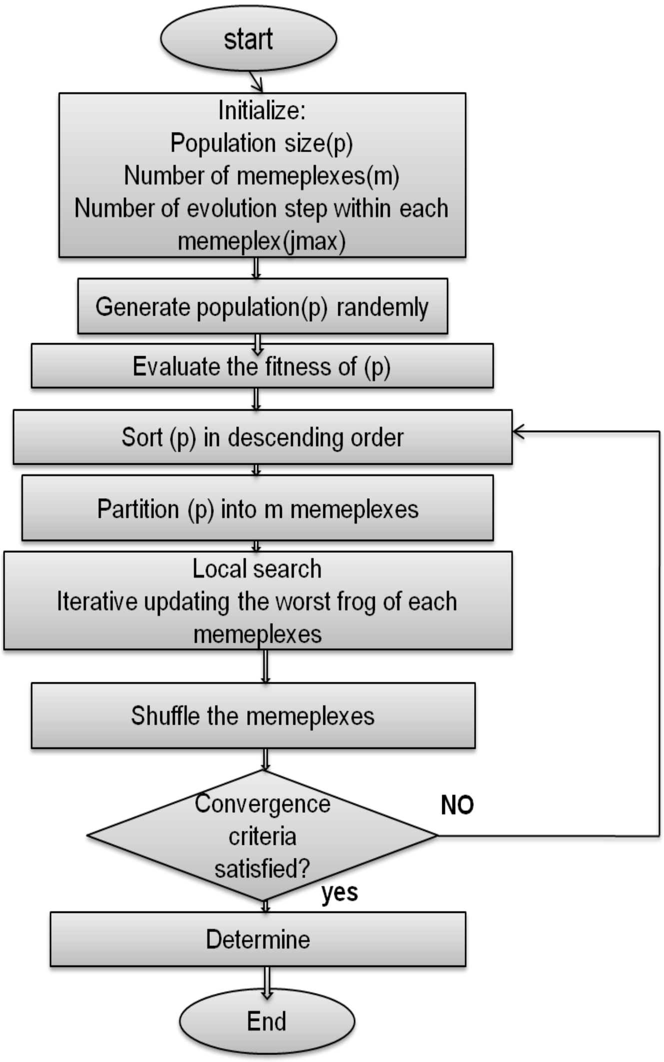
C. SHUFFLED FROG LEAPING ALGORITHM

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 [22, 23].

Implementation of SFLA

The SFLA originally developed as a population-based meta-heuristic by M. Eusuff and K. Lansey in 2003 performed an informed heuristic search using any mathematical function to find a solution of optimization problem It combines the benefits of both the genetic-based memetic algorithm and the social behavior-based PSO algorithm. This algorithm has been inspired by the frog's life as a group when the frogs are in search of food. A shuffling strategy allows for the exchange of information between local groups to move toward a global optimum point. The description and comments of algorithm implementation are presented as follows [23, 24].

FLOW CHART OF SFLA



PROCEDURE OF SHUFFLED FROG LEAPING ALGORITHM

Step1: Generate Initial Population

An initial population of *P* frogs are created randomly for a *S*-dimensional problem. A frog *i* is represented by S variables,

$$F_1 = (f_{i1}, f_{i2}, f_{i3} \ldots\ldots)$$

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

Then the position of worst frog can be improved as follows

$$Bi = rand\,(.)\ x\ (Xb - Xw)$$

$$New\ Xw = old\ Xw + Bi$$

$$-Bmax \leq Bi \geq Bmax$$

Where Rand (.) = Random number between 0 & 1

Bmax =Maximum allowed change in frog's position

If evolution produces better frog it replaces the older frog.

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. I 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. I 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 15 generator systems which are discussed below:--

CASE STUDY: - ECONOMIC LOAD DISPATCH FOR 15 GENERATOR 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 2360 (MW). The results corresponding to ABC, IABC and SFLA are detailed in Table.

COST CHARACTERISTICS OF EACH UNIT

UNIT1:F1=0.000299000000000000*P1^2+10.1000000000000*P1 + 671 Rs/Hr 150 MW < P1 < 445 MW;
UNIT2:F2=0.000183000000000000*P2^2+10.2000000000000*P2 + 574 Rs/Hr 150 MW < P2 < 445 MW;
UNIT3:F3=0.00112600000000000*P3^2+8.80000000000000*P3 +374Rs/Hr 20 MW < P3 < 130 MW;
UNIT4:F4=0.00112600000000000*P4^2+8.80000000000000*P4 +374Rs/Hr 20 MW < P4 < 130 MW;
UNIT5:F5=0.000205000000000000*P5^2+10.4000000000000*P5 +461Rs/Hr 150 MW < P5 < 470 MW;
UNIT6:F6=0.000301000000000000*P6^2+10.1000000000000*P6 +630Rs/Hr 135 MW < P6 < 460 MW;
UNIT7:F7=0.000364000000000000*P1^2+9.80000000000000*P1 +548Rs/Hr 135 MW < P1 < 465 MW;
UNIT8:F8=0.000338000000000000*P2^2+11.2000000000000*P2 +227Rs/Hr 60 MW < P2 < 300 MW;
UNIT9:F9=0.000807000000000000*P3^2+11.2000000000000*P3 +173Rs/Hr 25 MW < P3 < 162 MW;
UNIT10:F10=0.00120300000000000*P4^2+10.7000000000000*P4 +175Rs/Hr 25 MW < P4 < 160 MW;

UNIT11:F11=0.00358600000000000*P5^2+10.2000000000000*P5 +186 Rs/Hr 20 MW < P5 < 80 MW;

UNIT12:F12=0.00551300000000000*P6^2+9.90000000000000*P6 +230Rs/Hr 20 MW < P6 < 80 MW;

UNIT13:F13=0.000371000000000000*P1^2+13.1000000000000*P1 +225Rs/Hr 25 MW < P1 < 85 MW;

UNIT14:F14=0.00192900000000000*P2^2+12.1000000000000*P2 +309 Rs/Hr 15 MW < P2 < 55 MW;

UNIT15:F15=0.00444700000000000*P3^2+12.4000000000000*P3 +323Rs/Hr 15 MW < P3 < 55 MW;

LOSS COEFFICIENT

[0.0000024 0.000045 0.0000034 0.0000078 0.000044 0.000048 0.0000012 0.000024 0.0000098 0.0000065 0.000018 0.000070 0.0000043 0.000054 0.0000709

0.0000032 0.000063 0.0000034 0.0000072 0.000023 0.000031 0.0000017 0.000044 0.0000096 0.0000035 0.000072 0.000043 0.0000049 0.000033 0.0000711

0.0000034 0.000061 0.0000044 0.0000014 0.000052 0.000023 0.0000043 0.000025 0.0000028 0.0000015 0.000048 0.000030 0.0000023 0.000024 0.0000729

0.0000042 0.000042 0.0000031 0.0000022 0.000051 0.000024 0.0000041 0.000051 0.0000023 0.0000032 0.000025 0.000071 0.0000045 0.000012 0.0000032

0.0000070 0.000055 0.0000015 0.0000023 0.000051 0.000012 0.0000062 0.000014 0.0000038 0.0000035 0.000028 0.000040 0.0000013 0.000024 0.0000033

0.0000033 0.000022 0.0000072 0.0000024 0.000012 0.000045 0.0000012 0.000024 0.0000098 0.0000065 0.000018 0.000070 0.0000033 0.000034 0.0000019

0.0000041 0.000045 0.0000034 0.0000078 0.000044 0.000022 0.0000012 0.000024 0.0000098 0.0000065 0.000033 0.000070 0.0000033 0.000054 0.0000039

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0.0000033 0.000041 0.0000034 0.0000078 0.000021 0.000023 0.0000041 0.000024 0.0000098 0.0000065 0.000018 0.000070 0.0000023 0.000054 0.0000029

0.0000024 0.000045 0.0000034 0.0000078 0.000044 0.000048 0.0000012 0.000024 0.0000098 0.0000065 0.000018 0.000070 0.0000043 0.000054 0.0000709

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0.0000033 0.000015 0.0000022 0.0000013 0.000032 0.000013 0.0000012 0.000024 0.0000041 0.0000065 0.000018 0.000070 0.0000022 0.000054 0.0000029

0.0000012 0.000022 0.0000031 0.0000032 0.000019 0.000032 0.0000022 0.000016 0.0000026 0.0000044 0.000049 0.000031 0.0000043 0.000054 0.0000049

0.0000019 0.000033 0.0000037 0.0000017 0.000023 0.000032 0.0000016 0.000061 0.0000024 0.0000044 0.000038 0.000034 0.0000021 0.000032 0.0000039]

RESULT		ABC	IABC	SFL
Power from Generators (MW)	P_1 P_2 P_3 P_4 P_5 P_6 P_7 P_8 P_9 P_{10} P_{11} P_{12} P_{13} P_{14} P_{15}	422.0662 416.3739 130 130 150 419.2787 465 60 25 25 21.25171 41.03168 25 15 15	421.3258 420.1959 130 129.9967 150 416.5438 465 60 25 25 20.99169 40.9483 25 15 15	437.1631 405.4109 118.6364 99.9395 260.9504 326.0192 339.6228 107.2616 25.23464 102.4236 39.1124 27.8193 31.83597 21.7585 16.81413
Power Loss (MW)		0.002179	0.002184	0.002613
System Cost (INR)		**29441.400408**	29448.409916	29663.635355
Computation Time (Sec)		483.071700	117.438547	1805.623861

IV. CONCLUSION AND FUTURE SCOPE

CONCLUSION: In this paper, optimization techniques such as, ABC, IABC, SFLA based economic dispatch of load for generation cost reduction was comparatively investigated sample (15 generator 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 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 here it can be suggested that better result can be obtained by improving the fitness function and penalty factor used in the above programming. In future works we intend to analysis the behavior of the proposed algorithms in other variations of the economic load dispatch problem, for example, in the economic/environmental load dispatch problem and the economic load dispatch problem with security constraints. Study will be helpful to develop the software for real time economic load dispatch problems

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