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TO SOLVE ECONOMIC DISPATCH PROBLEM USING SFLA

P. Sowmya* & Dr. S. P. Umayal**
* PG Scholar, Department Electrical and Electronics Engineering, Muthayammal Engineering College, Rasipuram, Tamilnadu
** Dean of Electrical Engineering, Muthayammal Engineering College, Rasipuram, Tamilnadu

Abstract:

In this paper, a recent evolutionary algorithm called the shuffled frog leaping algorithm is applied for the solution of economic dispatch problem. The practical ED problems have equality and inequality constraints that makes the problem of finding the global optimum difficult using any optimization approaches. The standard SFLA is improved to deal with the equality and inequality constraints in the ED problem. Economic Load Dispatch (ELD) is one of an important optimization tasks and operational decision which provides an economic condition for power systems. This method gives better convergence speed, the quality of solution obtained and solving economic dispatch problems in a practical power system.

Index Terms: Economic Dispatch (ED) & Shuffled Frog Leaping Algorithm (SFLA)

1. Introduction:

Global optimization based on evolutionary algorithms can be used as the important component for many engineering optimization problems. Evolutionary algorithms have yielded promising results for solving nonlinear, non-differentiable and multi-modal optimization problems in the power systems area. The demand can be managed by minimizing the losses, simultaneous increase in generation and the most vital economic operations.

India being a developing nation, the distribution of power from the mix of thermal, hydro and nuclear power station receives the interest of researchers as an optimization problem which is normally known as economic load dispatch. Economic dispatch problem is defined as the process of scheduling the generating units with minimum operating cost such that the generated power will meet the sum of total load demand and transmission loss. In the ideal condition, if the transmission losses are neglected, the total system load can be optimally divided among the various generating plants using the incremental cost criterion. It is unrealistic to neglect the transmission losses particularly when long distance transmission of power is involved.

The algorithm contains elements of local search and global information exchange. The SFLA consists of a set of interacting virtual population of frogs partitioned into different memeplexes. The virtual frogs act as hosts or carriers of memes where a meme is a unit of cultural evolution. The algorithm performs simultaneously an independent local search in each memeplex. The local search is completed using a particle swarm optimization-like method adapted for discrete problems but emphasizing a local search.

More recently, meta-heuristic optimization techniques, have gained an incredible attention as an alternative and Powerful solution algorithm for practical ED problems. SFLA is a population-based optimization technique inspired from the mimic evolution of a set of frogs when searching for food source. The SFLA is a population-based cooperative stochastic search method that mimics natural biological evolution and the social behavior of species. The algorithm has been developed to arrive at near-optimum solutions to complex and large-scale optimization problems which cannot be solved by gradient based mathematical programming techniques. The SFLA consists of a set of interacting virtual population of frogs partitioned into different memeplexes. The shuffled frog leaping algorithm draws its formulation from two other search techniques: the local search of the "particle swarm optimization" technique and the competitiveness mixing of information of the "shuffled complex evolution" technique.

The main goal of the ED problems is to specify the optimal combination of power outputs of all required load demand at minimum total cost and satisfies system constraints. Therefore, the each ED problem can be formulated mathematically as an optimization problem with an objective function and constraints are follows:

$$min: F = \sum_{i=1}^{NG} Fi(PGi)$$

$$= \sum_{i=1}^{NG} (ai(PGi)2 + bi(PGi) + ci)$$

Subject to:

$$\sum_{i=1}^{NG} PGi = Pload + Ploss$$

$$PGimin \leq PGi \leq PGimax$$

For i=1,2……..,NG

2. Shuffled Frog Leaping Algorithm:

The SFLA has been designed as a meta-heuristic to perform an informed heuristic search using a heuristic function (any mathematical function) to seek a solution of a combinatorial optimization problem. It is based on evolution of memes carried by the interactive individuals, and a global exchange of information among themselves. The SFLA is a meta-heuristic optimization method which is based on observing, imitating, and modeling the behavior of a group of frogs when searching for the location that has the maximum amount of available food. SFLA, originally developed by Eusuff and Lansey in 2003, can be used to solve many complex optimization problems, which are nonlinear, non-differentiable, and multi-modal. SFLA has been successfully applied to several engineering optimization problems such as water resource distribution, bridge deck repairs, job-shop scheduling (TSP). The most distinguished benefit of SFLA is its fast convergence speed. The SFLA combines the benefits of the both the genetic-based memetic algorithm (MA) and the social behavior-based PSO algorithm.

The SFLA is drawn from a virtual society of frogs so that individual frogs stand for a set of candidate solution. The term frog in SFLA is equivalent to chromosome in genetic algorithm. Similar to other random base algorithms, this algorithm begins with an initial population of "*N*" frogs *F={X1,X2,...,XN}* which produced randomly within the feasible solution space. In the *S*-dimensional problems (with *S* variables), the *ith* frog's position is described as *Xi=[xi1,xi2,...,xis]T*. A cost function is considered for evaluation of each frog's position. Afterward the fitness of each swarm is computed according to its position and frogs, in whole population, will be arranged in a descending order based on their fitness values. Then, the whole population is partitioned into *m* groups (*m* memeplexes), each of which including *n* frogs (i.e. *F=n×m*). The division is done with the first frog is assigned to the first memeplex, the second frog is assigned to the second memeplex, frog *m* is assigned to the *mth* memeplex and the frog *(m + 1)th* is returned and sent back to the first memeplex, and so on. In memeplex evolution process, the position of frog *ith* (*Di*) is computed according to the different between the frog with the worst fitness (*Xw*) and the frog that has the best fitness (*Xb*) as formulated in. Then, the worst frog jumps toward the best frog and the worst frog's position is updated based on the leaping rule.

A population is a set of individuals. Each individual has an associated fitness value that measures the goodness of the individual. Time is divided into discrete steps called time loops. In the SFLA, the individuals are not so important and the population is seen as hosts of memes, *i.e.* a memetic vector. Each host carries a single meme (consisting of memotype(s)).As noted earlier, memes and memotypes are analogous to genes and chromosomes respectively.In this view, the SFLA does not enumerate the individuals belonging to it; rather, it uses an abstract model, called a virtual population. Consider a group of frogs leaping in a swamp; the swamp has a number of stones at discrete locations on to which the frogs can leap to find the stone that has the maximum amount of available food. The frogs are allowed to communicate with each other, so that they can improve their memes using others' information. Improvement of a meme results in altering an individual frog's position to be optimum by changing the leaping steps (memotype(s)) of each frog. Here, the alteration of memotype(s) is only allowed to be a discrete value by analogy with the frogs and their discrete positions.

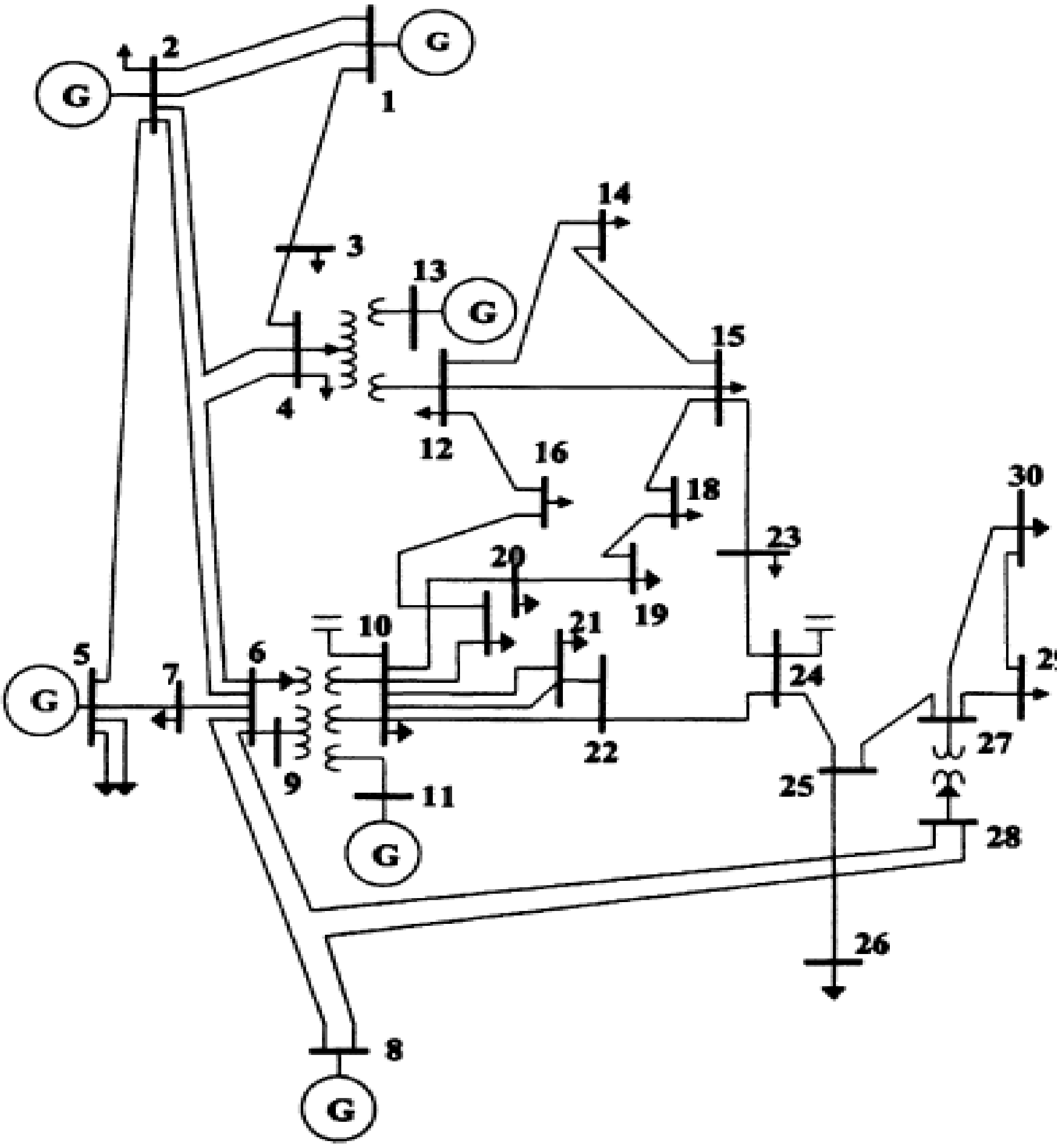

Figure 1: Single line diagram-IEEE 30 bus system

The SFLA is a combination of deterministic and random approaches. The deterministic strategy allows the algorithm to use response surface information effectively to guide the heuristic search as in PSO. The random elements ensure the flexibility and robustness of the search pattern. The search begins with a randomly selected population of frogs covering the entire swamp. The population is partitioned into several parallel communities (memeplexes) that are permitted to evolve independently to search the space in different directions. Within each memeplex, the frogs are infected by other frogs' ideas. Hence they experience a memetic evolution.

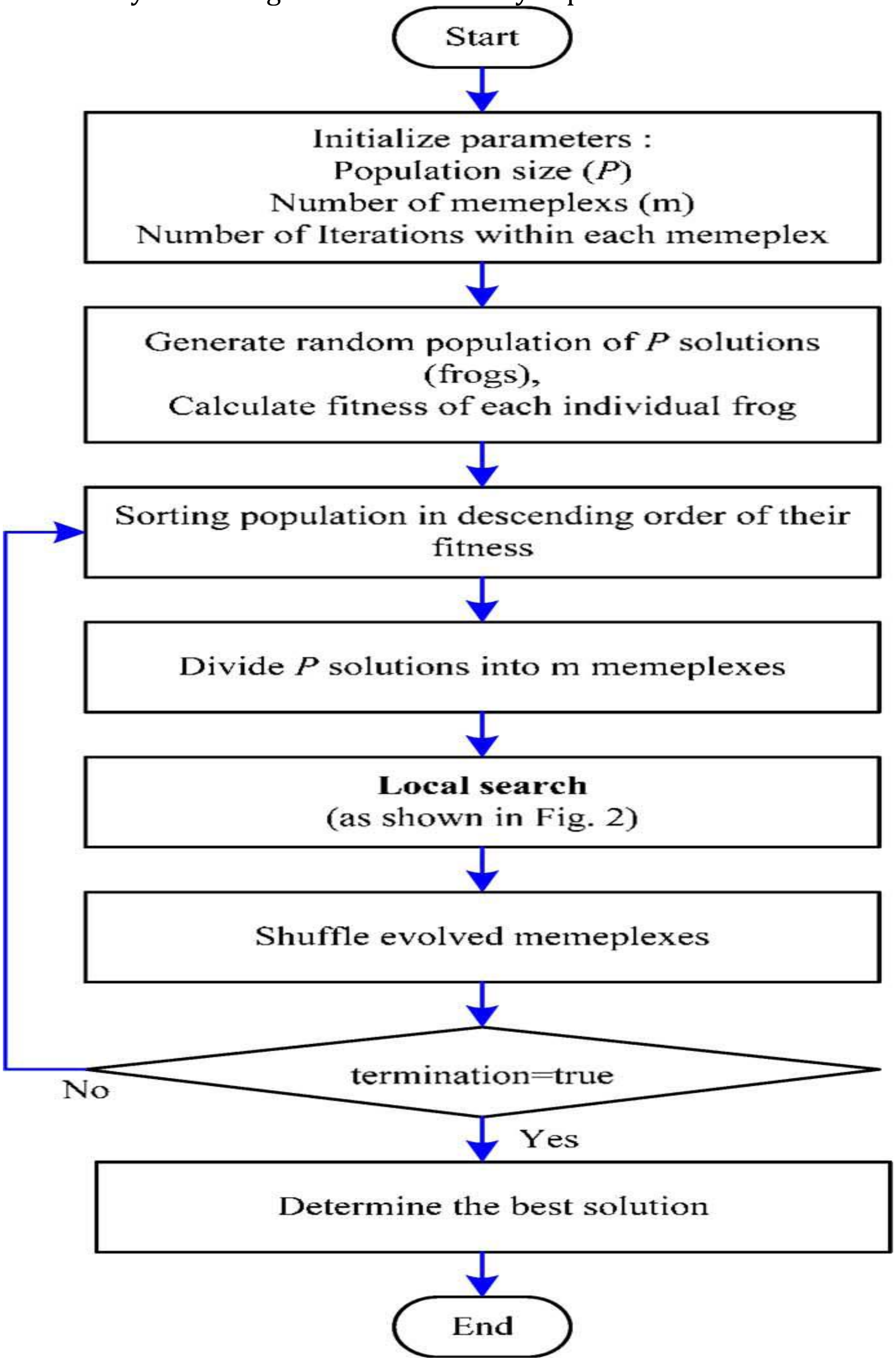

Figure 2: Flowchart for SFLA

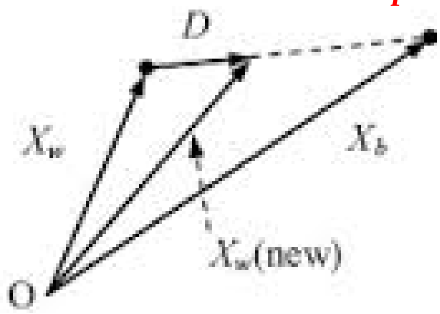

Figure 3: The Original frog leaping rule

Memetic evolution improves the quality of the meme of an individual and enhances the individual frog's performance towards a goal.

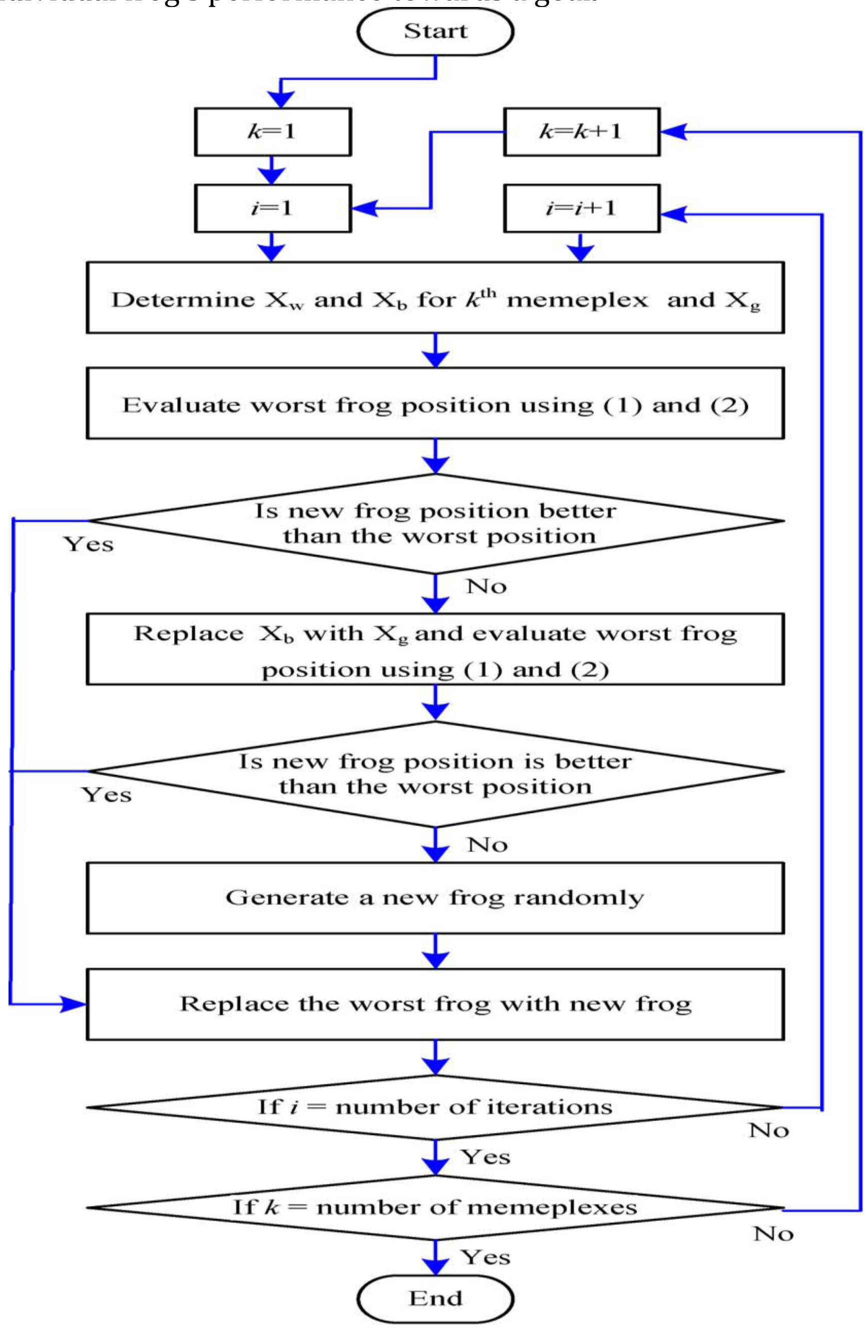

Figure 4: Flow Chart for Local Search

3. Result and Discussion:

Case Study:

The effectiveness of the proposed method is tested on IEEE 30 bus system with generating units. The load demand is 1263MW. As in Genetic programming, the choice of mutation factor, C1 and C2 determines the best solution. After a lot of trials, in this paper C1 are taken as 1.7, C2 as 1.2 and x as 1.The initial parameters for SFLA/IASFLA are given below.

- Population size: 100
- Number of memplex: 10
- Number of iteration for each memeplex: 10

Parameters	Generating units					
	Unit1	Unit2	Unit5	Unit8	Unit11	Unit13
a_i	0.0070	0.0095	0.0090	0.0090	0.0080	0.0075
b_i	7.0	10	8.5	11	10.5	12
c_i	240	200	220	200	220	190
P_{gi}^{max}	100	50	80	50	50	50
P_{gi}^{min}	500	200	300	180	200	120

Table 1: Generating Units Cost Coefficient And Limits

B. Results:

Simulation of Economic Load Dispatch problem is done in Windows 7 OS, 4 GB RAM using MATLAB 2010a. For IEEE 30 bus system, the B-coefficients are calculated using the Newton-Raphson method and they are given by

$$B_{ij}=10^{-3}*\begin{bmatrix} 0.1756 & 0.0744 & 0.0162 & -0.0239 & 0.0090 & -0.0380 \\ 0.0744 & 0.1152 & 0.0420 & -0.0202 & 0.0125 & -0.0424 \\ 0.0162 & 0.0420 & 0.3034 & -0.0196 & 0.0148 & -0.0597 \\ -0.0239 & -0.0202 & -0.0196 & 0.1575 & 0.0681 & -0.0275 \\ -0.0275 & 0.0125 & 0.0148 & 0.0681 & 0.1335 & -0.0317 \\ -0.0380 & -0.0424 & -0.0597 & -0.027 & -0.0317 & 0.1125 \end{bmatrix} MW^{-1}$$

$$B_{io} = (0.002 \quad 0.004 \quad 0.065 \quad 0.08 \quad 0.102 \quad 0.086)$$

$$B_{oo} = [5.5534]MW$$

Table 2: ELD with Losses and Without Valve Point Effect

Methods	Lagrange Method	PSO [4]	GA [4]	Secant method [4]	SFLA
P1(MW)	500.00	447.49	474.80	447.4	395.1450
P2(MW)	200.00	173.32	178.63	173.24	164.1565
P5(MW)	300.00	263.47	262.20	263.38	245.6636
P8(MW)	50.00	139.05	134.28	138.98	150.0000
P11(MW)	200.00	165.47	151.90	165.39	200.0000
P13(MW)	50.00	87.128	74.181	87.052	120.0000
Total loss(MW)	15.5158	12.958	13.021	12.4449	11.9655
Total cost($/hr)	15871.2500	15450	15459	15442.3	15478.353625

Methods	Lagrange Method	SFLA
P1(MW)	500.00	382.9713
P2(MW)	200.00	159.2561
P5(MW)	300.00	262.0745
P8(MW)	50.00	150.0000
P11(MW)	200.00	200.0000
P13(MW)	50.00	120.0000
Elapsed time(Sec)	0.200936	2.091546
Total loss(MW)	15.5158	11.3022
Total cost($/hr)	15678.414343	15284.417459

Table 3: ELD with Losses and Valve Point Effect

4. Conclusion:

This paper presents the application of the SFLA algorithm to the ELD problem. The conventional and other existing meta-heuristic methods suffer from slow convergence. The comparison of the results obtained by the proposed SFLA with Lagrange method and other evolutionary methods for IEEE 30 bus system shows that the proposed method provides an optimum result both in terms of cost and convergence terms. Thus, the SFLA exhibits better performance for solving ELD problem in complex power system.

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