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Fuzzy Logic Controlled Based Ant-Lion Optimization Hybridization for Economic Power Dispatch

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ABSTRACT

The demand on the power system rising more rapidly is causing to increase the power system size and capacity. There is a need of interconnection of various generating stations to meet the increased load demand. Economical unit commitment is necessary for plant operation with the advancement in power system integration. The Economical Power Dispatch (EPD) is to find the most favourable combination of generating systems output powers which reduce the fuel cost by satisfying all system constraints. This research involves the fuzzy logic controller (FLC) has been hybridized with Ant-Lion Optimization (ALO) algorithm for EPD. By using this new hybrid technique, minimization of total operating cost by economically dispatch the power to meet the required load and also minimization of system total losses by optimum allocation of DG units were done. Fuel cost function and demand on system are modeled by fuzzy membership functions. The ALO is used to obtain the schedule the committed generating unit's outputs so as to meet the required load demand. This proposed FLC based ALO technique executed with MATLAB software and applied on IEEE-30 system. Effectiveness of this projected algorithm is determined and evaluated with standalone techniques like conventional ALO, ALO-PSO algorithms.

1. INTRODUCTION

The In electric power system it is always very important to find the effective and optimal economical operation. In recent years, to make revenue, it becomes much essential for all utilities run their systems with lowest cost by satisfying customer demand. With the huge increasing demand on the power system and the minimum generating systems availability, and the limitations of supply and the cost of fuel, all the committed units should produce the energy to the demand with the minimum fuel cost.

The main purpose of EPD is to operate and produce the committed unit's power outputs, to meet the required load at low operating cost while satisfying all system constraints [1]. Many researchers have undertaken the EPD problem [2]. The EPD issue involved many different issues like pre-dispatch issue or unit commitment i.e. it is essential to find the best units from the all available units and operate to meet the variable load and other is EPD is economic power dispatch, in which it is necessary to dispatch the load among the committed units in such a way that the total operating cost should be minimum.

In EPD, the energy delivered by committed units is not constant. It is allowed to produce within particular limits to meet particular demand with low consumption of fuel.

For protection of environment based on rules from government, the traditional way of dispatching electrical energy at low cost is not only the solution. The minimization of pollution is also a considerable factor [3]. In order to reduce the level of NO and SO_2, which are delivered from different sources, likes preparing a cleaning scheme for post-combustion. Development of eco-friendly economical dispatch is advisable for the system operation due to ease of apply and need low extra cost. IEEE present operating issues working sets reported regulations for clean environment effect on network operation. Various techniques were projected like Gent [4] in early, provided an economical dispatch approach in 1970 with traditional technique of optimization. Very recently an artificial intelligence [5] and genetic algorithm [6, 7] were applied on the test system to solve this EPD issue. An artificial intelligence-based GA (Genetic Algorithm) has projected themselves as an efficient technique for optimization. In this approach, genetic operators like mutation and crossover has substantial effect on performance.

There has been an increased interest in installing DG at the distribution schemes because of considerable compensations like power loss reduction, cost reduction, environmental friendliness, voltage enhancement, postponement of system upgrades and amassed reliability [8, 9]. Decision about DG placement is taken by their owners and investors, depending on site and primary fuel availability or climatic conditions. The placement should be optimal in order, for maximum user benefit and minimum congestion of DG applied in the network [10, 11]. Although the installation and manipulation of Depending on the number of DGs to be installed, the ODGP issue is categorized as: 1) single DG or 2) multiple DGs installation. Numerous approaches have been described for optimal sitting and sizing of the DG through dissimilar optimization method enlightening technical and economical performances [12-15]. Tools such as deterministic, heuristic and hybrid methods are promising and still sprouting in this field. In addition, abridging assumptions have been utilized to augment the solution performance. Besides power loss reduction, locating a DG may be on the basis of cost reduction. Predictably, the mixed integer linear program, Genetic Algorithm (GA), Tabu Search (TS), Particle Swarm Optimization (PSO) algorithm, direct search algorithm and Ant Colony Optimization (ACO) algorithm are used to investigate the optimal placement and sizing of DG. In those articles while placing the DGs emphasis is provided on the reduction of line loss mostly. Some of those have tried to progress the system voltage also [16-18]. Consequently, the optimization methods should be engaged for deregulation of power industry, permitting for the best apportionment of the DG. In the article, an effective algorithm is proposed to scrutinize the load flow issue and the placement problem of DG.

In the article, an effective algorithm is proposed to scrutinize the load flow issue and the placement problem of DG to minimize test system total losses and economic dispatch of power by optimal scheduling of committed generating units to reduce the total operating cost by satisfying all system constraints.

2. A BRIEF REVIEW: RECENT RESEARCH WORK

Many conventional and latest methods had been used for solving the economic power dispatch issues by considering various objective functions. Different conventional techniques like lambda iterative technique, gradient-based technique, Bundle technique [19], non-linear method [20], mixed integer liner programming method [21], Newton-based method [22] etc., were present in literature for solving this economic power dispatch problem. But these existing methods have some disadvantages and failed to solve economic power dispatch issue. Along with these some population based meta-heuristic methods in literature have proved themselves effective performance. Such as Tabu search [23], Genetic Algorithm [24], Ant-Colony Optimization [25], Particle Swarm Optimization [26], Gravitational Search Algorithm with Fire-Fly [27] etc. These methods also always not guarantee in finding optimal outcome. These heuristic methods are also having their disadvantages slow rate of convergence around global solution, time consuming is high, not easy to tune control parameters, difficult in produce effective memory system, trapping into local optima. ALO technique imitates the catching behaviour of ant lions in general. The updating process is done with the elitism phase of ALO. The proposed hybrid technique improves the ability of global search of objective function which provides the better opportunity to increase the solution space. This also provides the global solution for EPD problem. The effectiveness of proposed technique was evaluated with IEEE-30 sus system with six generators in the system. The outcomes obtained by this proposed method compared with conventional ALO and ALO-PSO methods.

New genetic method based on arithmetic crossover was presented to improve the ELD solution quality. In this research arithmetic crossover, elitism both defines a linear combination of two chromosomes and to produce possible operating consecutive sets mutation used in the GA [28].

The solution for ELD problem was presented with line flow constraints the genetic algorithm application. The major advantage of this GA is that it used only the pay of information; hence it is nature independent of search space like smoothness and convexity [29].

An approach using fuzzy decision tree was presented for ELD problem. In this research an improvement has done in DT approach by fuzzy logic addition to load and unit limits. With this there is an improvement in the convergence rate. The cost of generation obtained is also less than the traditional formulation [30].

One hybrid algorithm was presented to solve the ELD problem is the genetic algorithm with fuzzy logic controller with multi-shunt flexible AC transmission systems, which continuously adjust parameters of mutation and crossover [31].

One new formulation was presented for economic dispatch to solve economic load dispatch problem. By reducing the variable numbers and by removing constraints of equality and inequality the new formulation has done. This transformed the constrained non-linear programming into unconstrained one. This new unconstrained formulation objective function is reduced by Hooke-Jeeves' approach [32].

An effective optimization approach was presented to solve ELD problem based on genetic algorithm with continuous and non-smooth cost function by considering various constraints. The presented algorithm effectiveness finds out on various systems with system losses of thermal power plant [33].

Four evolutionary algorithms study was presented for ELD problem solvation, they are particle swarm optimization, genetic algorithm, ant-colony optimization and bacteria foraging optimization. This research is carried on IEEE-30 test system [34].

3. MATHEMATICAL FORMULATION FOR OBJECTIVE FUNCTION

The purpose of the economic dispatch is to schedule the outputs of all available generation units in the power system such that the fuel cost is minimized while system constraints are satisfied.

The objective function of an EPD problem is to:

$$\min imize\ F_{\cos t} = \sum_{j=1}^{N_g} F_j(P_j) \tag{1}$$

The fitness function for the selected objective function is:

$$F_j(P_j) = a_j + b_j P_j + c_j P_j^2 \tag{2}$$

a_j, b_j and c_j represent the cost coefficients of the j^{th} generating unit.

$F_j(P_j)$ represents the cost function of the j^{th} generating units (in \$/h).

P_j represents the real output of the j^{th} generating units (in MW).

N_g is the total number of generators in the power system.

Subjected to the following generator constraints:

$$\sum_{j=1}^{N_g} P_j = P_D + P_L \tag{3}$$

4. PROPOSED EFFICIENT TECHNIQUE FOR ECONOMICAL POWER DISPATCH

In this research, the one hybridization method is presented to solve the EPD issue. To analyse the generating unit's outputs from the committed generating units, the objective function is defined for IEEE-30 mesh configuration network. By using this new hybrid technique, minimization of cost function by economically dispatch the power to meet the required load and also minimization of system total losses. For this, the test system bus data, line data, committed generating unit's capacities, minimum and maximum generation capacities, are considered as the input for this new proposed hybrid approach. The total working procedure this new proposed hybrid approach for EPD is demonstrated in Figure 1.

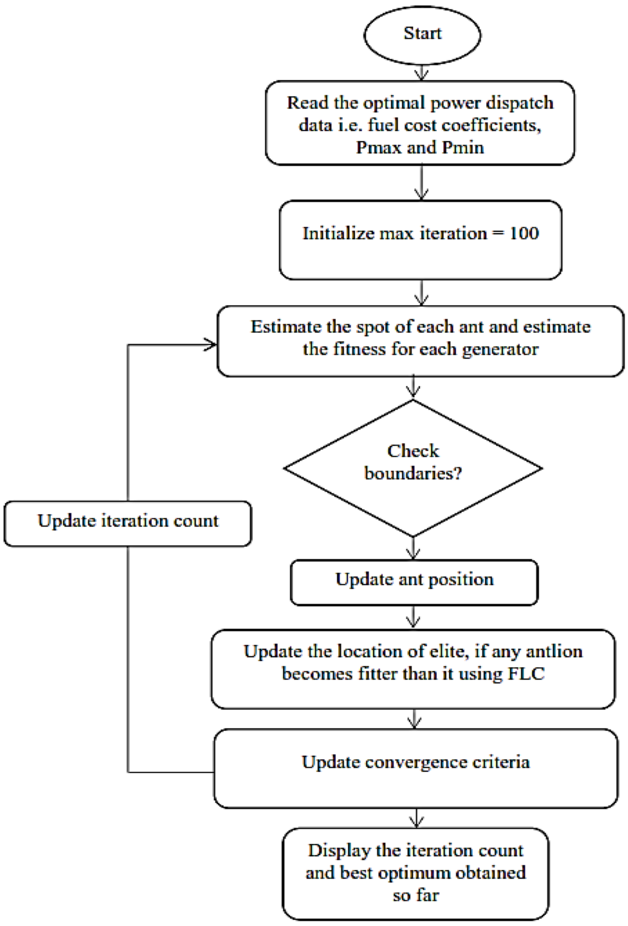

Figure 1. New hybrid technique flow chart

4.1 Fuzzy logic controller using Mamdani

For this new hybrid approach using Fuzzy Logic controller for inference the system using Mamdani type. The Loss sensitivity Factor (LSF) and the node voltages are considered as the input to the FLC and the fitness evaluation is considered as the output of the FLC.

Triangle membership functions are considered to construct the membership function plots.

Figure 2 shows that the node voltage triangle membership function plot and the low, medium and high are considered as membership function and this is ranging from 0 - 1.

Figure 3 shows that the LSF triangle membership function plot and the low, medium and high are considered as membership function and this is ranging from 0.9 - 1.1.

Figure 4 shows that the fitness triangle membership function plot and the low, medium and high are considered as membership function and this is ranging from 0 - 1.

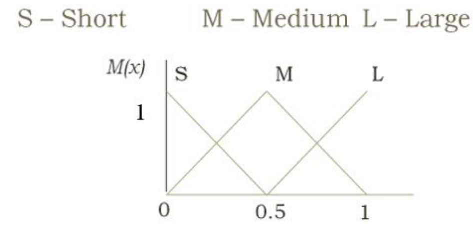

Figure 2. Membership function plot for p.u. Nodal Voltage

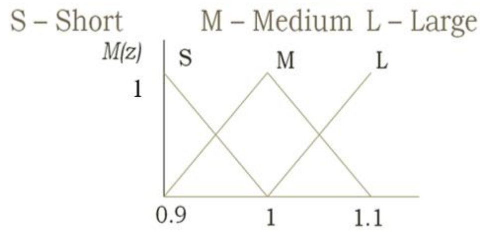

Figure 3. Membership function plot for Loss Sensitivity Factor (LSF)

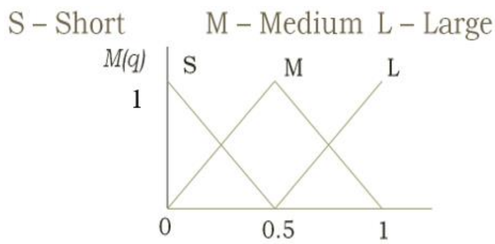

Figure 4. Membership function for fitness

Table 1 represents the rule base for fitness.

Table 1. Decision matrix for determining fitness rule base

LSF\Voltage	S	M	L
S	S	S	M
M	S	M	M
L	M	M	L

The ALO for training dataset

The ALO approach is used for optimal training dataset is briefly described by following section.

The random placements of the ant's and ant-Lion's

The random location of the ant's and Ant-Lion's are represented in $M_{ant\text{-}lion}$, M_{ant} [35].

$$M_{ant-lion} = \begin{pmatrix} AL_{1,1} & AL_{1,2} & \cdots & AL_{1,n} \\ AL_{2,1} & AL_{2,2} & \cdots & AL_{2,d} \\ \vdots & \vdots & \vdots & \vdots \\ AL_{n,1} & AL_{n,2} & \cdots & AL_{n,d} \end{pmatrix}$$

$$M_{ant} = \begin{pmatrix} A_{1,1} & A_{1,2} & \cdots & A_{1,n} \\ A_{2,1} & A_{2,2} & \cdots & A_{2,d} \\ \vdots & \vdots & \vdots & \vdots \\ A_{n,1} & A_{n,2} & \cdots & A_{n,d} \end{pmatrix} \tag{4}$$

Fitness function of all ant-lion's and ant's has been given in the matrix M_{OAL}, M_{OA} [36] and function f is given as,

$$M_{OAL} = \begin{pmatrix} f\left(\left[AL_{1,1}, AL_{1,2}, \ldots, AL_{1,n}\right]\right) \\ f\left(\left[AL_{2,1}, AL_{2,2}, \ldots, AL_{2,d}\right]\right) \\ \vdots \\ f\left(\left[AL_{n,1}, AL_{n,2}, \ldots, AL_{n,d}\right]\right) \end{pmatrix} \quad (5)$$

$$M_{OA} = \begin{pmatrix} f\left(\left[A_{1,1}, A_{1,2}, \ldots, A_{1,n}\right]\right) \\ f\left(\left[A_{2,1}, A_{2,2}, \ldots, A_{2,d}\right]\right) \\ \vdots \\ f\left(\left[A_{n,1}, A_{n,2}, \ldots, A_{n,d}\right]\right) \end{pmatrix} \quad (6)$$

Ant's Movement randomly

For search of pray total ants permitted to move randomly. The movement of ant's is shown by (7),

$$X(t) = \begin{bmatrix} 0, cumsum(2r(t_1)-1), cumsum(2r(t_2)-1), \\ \ldots, cumsum(2r(t_n)-1) \end{bmatrix} \quad (7)$$

where, *cumsum* represents the total sum, *n* represents total ants, *t* represents step random walk, and random generation represents with *r(t)*, production of random number between [0,1] with uniform distribution,

$$r(t) = \begin{cases} 1 \; if \;\; rand \; > \; 0.5 \\ 0 \; if \;\; rand \; \le \; 0.5 \end{cases} \quad (8)$$

Updating the position of ant's as,

$$X_i^t = \frac{(X_i^t - p_i)(s_i - r_i^t)}{s_i^t - p_i} + r_t \quad (9)$$

Here, q_i and p_i are max and min values of ant's walk randomly, r^t_i and s^t_i signifies min and max m^{th} variable at t^{th} iteration.

Ants trapping

Random walk of ant's is changed by traps, which are developed by ant lion's given by:

$$c_m^t = Ant \text{ - } lion_n^t + c^t \quad (10)$$

$$d_m^t = Ant \text{ - } lion_n^t + d^t \quad (11)$$

Trap construction

The ALO algorithm is for ant-lion's selection by roulette wheel operator depends on ant-lion fitness.

Ants sliding into pits

Sliding of ant's into traps characterized by,

$$c^t = \frac{c^t}{I} \quad (12)$$

$$d^t = \frac{d^t}{I} \quad (13)$$

Here, $I = 10^{w\,t/s}$, *t* is current iteration, *S* is the max iterations and w is a constant, and its value is given by,

$$w = \begin{cases} 2 & if \;\; t \; > \; 0.1S \\ 3 & if \;\; t \; > \; 0.5S \\ 4 & if \;\; t \; > \; 0.75S \\ 5 & if \;\; t \; > \; 0.9S \\ 6 & if \;\; t \; > \; 0.95S \end{cases} \quad (14)$$

Prey catching and pit reconstruction

To catch the new ants, now ant-lions update their current location,

$$Ant-lion_n^t = Ant_m^t \quad if \; f(Ant_m^t) > f(Ant\text{-}lion_j^t) \quad (15)$$

Elitism

Every ant is estimated to associate with an ant-lion using roulette wheel as,

$$Ant^t = \frac{R_A^t + R_B^t}{2} \quad (16)$$

5. OUTCOMES AND DISCUSSIONS

In this section of the paper, the entire work is explained in a precise manner. The standard IEEE-30 bus system as in Figure 5 [37] is used as a test system and the results are evaluated. The test system consists of 30 buses of which 6 generating buses are present including slack bus and remaining 24 are load buses. 41 lines, 4 tap changing transformers, and 9 shunt capacitors are present in this test case. MATLAB software is used to run NR power flow.

In this research, All the outcomes using various methods of algorithms are reported in Tables 2 to 4. The Comparison Analysis using various methods illustrated in Figures 6 to 8. This proposed FLC hybrid method has been tested for solving IEEE-30 bus. The response of proposed FLC hybrid method is also evaluated with outcomes of ALO and ALO-PSO techniques.

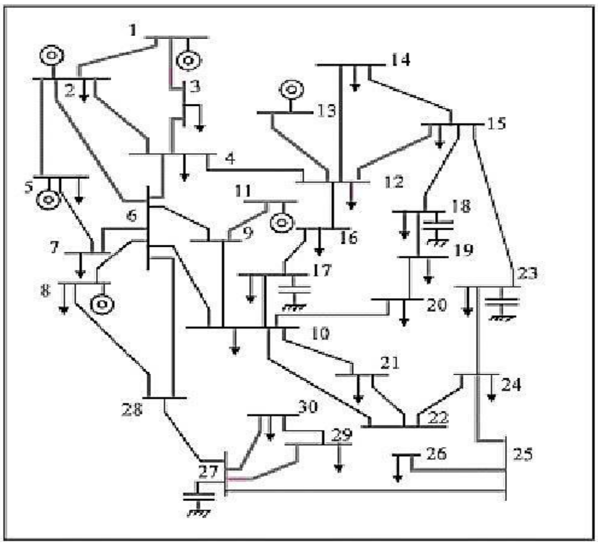

Figure 5. Single line diagram of IEEE-30 Bus System

Table 2. Comparative analysis for Optimal Dispatch and Total Cost without loss before DG placement

S.no	Bus No	GA in MW [38]	PSO in MW [39]	ALO in MW	ALO-PSO in MW	ALO-FLC in MW
1	1	137.99	143.35	142.88	178.62	186.73
2	2	64.4	51.19	51.28	41.68	37.79
3	5	15	22.98	30.03	17.53	19.67
4	8	18.32	27.69	21.66	13.14	10
5	11	16.53	18.97	19.88	13.01	10.29
6	13	39.95	19.78	17.64	19.30	18.90
Total Generation		283.4	283.4	283.4	283.4	283.4
Time		2.52 Sec	2.41 Sec	2.14 Sec	2.01 Sec	1.8 Sec
Fuel Cost		$793.60	$787.77	$799.93	$778.58	$776.74

Table 3. Comparative analysis for Optimal Dispatch and Total Cost with loss before DG placement

S.no	Bus No	GA in MW	PSO in MW	ALO in MW	ALO-PSO in MW	ALO-FLC in MW
1	1	140.91	146.27	184.32	183.71	197.28
2	2	67.32	54.11	47.74	55.93	49.56
3	5	17.92	25.9	20.71	18.37	18.77
4	8	21.24	30.61	14.08	10.21	10.00
5	11	19.45	21.89	17.56	12.10	11.21
6	13	42.87	22.7	16.48	20.57	14.08
Total Generation		300.92	300.92	300.92	300.92	300.92
Time		2.65 Sec	2.45 Sec	2.15 Sec	2 Sec	1.81 Sec
Fuel Cost		$854.59	$848.40	$838.19	$837.60	$833.41

Table 4. Comparative analysis for Optimal Dispatch and Total Cost with loss after DG [38] placement

S.no	Bus No	GA in MW	PSO in MW	ALO in MW	ALO-PSO in MW	ALO-FLC in MW
1	1	138.32	143.68	184.01	166.50	178.34
2	2	64.73	51.52	37.171	47.915	38.384
3	5	15.33	22.31	21.011	23.105	24.334
4	8	18.65	28.02	12.041	18.185	10.734
5	11	16.86	19.30	12.361	16.185	13.954
6	13	40.28	20.11	18.801	13.505	19.654
Total Generation		285.4	285.4	285.4	285.4	285.4
Time		2.13 Sec	1.9 Sec	2.13 Sec	1.9 Sec	1.6 Sec
Fuel Cost		$812.82	$805.47	$812.82	$805.47	$798.40

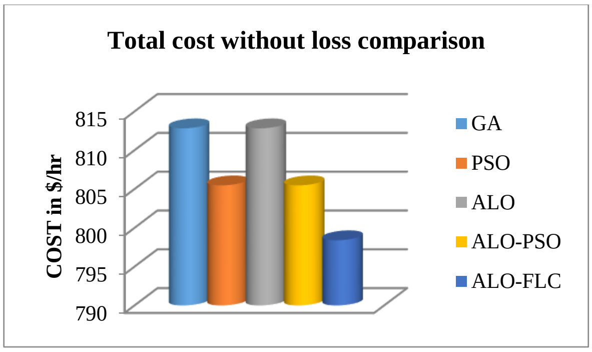

Figure 6. Comparative analysis for Optimal Dispatch and Total Cost without loss before DG placement [39]

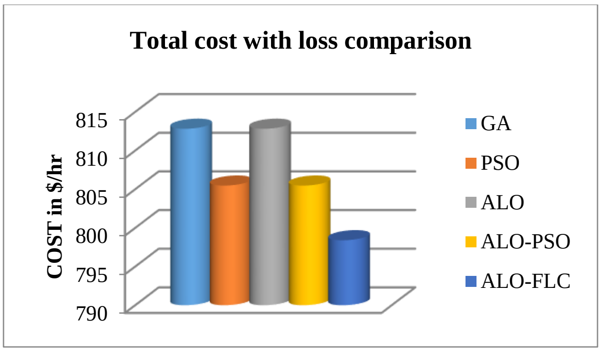

Figure 7. Comparative analysis for Optimal Dispatch and Total Cost with loss before DG placement

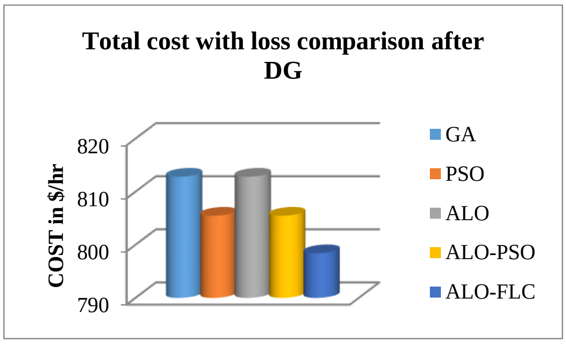

Figure 8. Comparative analysis for Optimal Dispatch and Total Cost with loss after DG placement

6. CONCLUSION

An efficient method is proposed in this research to solve an EPD problem in IEEE-30 bus system. Initially, NR method was considered for optimal load flow issues. In addition, the expressed optimal load flow problems have been fixed while satisfying system inequality and equality constraints. Proposed FLC hybrid technique was verified for its efficiency by initializing the iteration process with a decent principal value and reaches an absolute best value in a smaller number of iterations. Hence, it is decided that the final improvement in cost minimization, scheduling all committed generating units in an optimal way to minimize the total operating cost.

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NOMENCLATURE

F_{cost}	cost Function
a_i, b_i, c_i	cost coefficients
P_i	real output
N_g	total number of generators
cumsum	total sum
n	total ants
t	random walk
r(t)	random generation

Subscripts

EPD	Economic Power Dispatch
FLC	Fuzzy Logic Controller
ALO	Ant-Lion Optimization
LSF	Loss sensitivity Factor
S	Short
M	Medium
L	Large