A novel approach for solving Optimal Economic load dispatch problem in power system with emissions using Meta Heuristics based Lion Optimization Algorithm

Govind Singh Raghuwanshi[1], Mrs. Dr. Poonam Sinha[2], Mr. Jay Narayan Thakre[3]

[1]Department of I.T., UIT, Barkatullah University, Bhopal (M.P.), India
[2](Professor, Department of Electronics, UIT, Barkatullah University, Bhopal (M.P.), India)
[3](Asst. Professor, Department of I.T., UIT, Barkatullah University, Bhopal (M.P.), India)

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Abstract - *Lion Optimization algorithm simulates the lion pride behavior based on lion pride evolution process and group living. The alarming environmental impacts from the emission produced by the conventional fossil fuel power plants, has converted the classic economic load dispatch that minimizes only the total fuel cost into a multi objective function. The Lion Optimization algorithm strategy is based on mathematical modeling to solve economic, emission and combined economic & emission dispatch problems by a single equivalent objective function. In this work LOA is used for solving economic load dispatch problem and the result produced by LOA algorithm are compared with the result obtained by other optimizing techniques like Particle Swarm Optimization, Genetic Algorithm Optimization, etc. Results shows that LOA has better performance than other bio inspired algorithms on both unimodal and multimodal optimization problem. LOA is robust and it is affected by pride update strategy and brutal competition of individuals*

Key Words: **Economic Emission load Dispatch, Lion Optimization Algorithm, pride, Survival of Fittest.**

1. INTRODUCTION

In today 's world everyone is most concerned about cost he/she is paying for purchase of any commodity as well as environment impact of producing that commodity and thus primary objective in the planning and operation of power systems is not only to provide reliable and quality power to consumers but also at economical cost with less carbon footprints. The increasing energy demand and the decreasing energy resources have made optimization a great necessity in power system operation and planning.

Economic Load Dispatch (ELD) is essentially an optimization scheme of computing the best generation schedule to supply a predetermined load, with minimum cost while satisfying the essential constraints like power balance and generation limits.. Thermal power stations are a major cause of atmospheric pollution, due to the high concentration of pollutants emitted. Currently, with the increasing awareness of environmental pollution caused by burning fossil fuels, controlling the amount of pollutant emission is also a major criterion in the economic dispatch problem. The purpose of Emission Economic Load Dispatch (EELD) is to obtain the optimal generation schedule by minimizing the fuel cost and the emission level simultaneously while satisfying load demand and other operational constraints.

Several deterministic optimization approaches were proposed to solve the traditional ELD problem, including like lambda iteration method, gradient-based method, Bundle method [2], nonlinear programming [3], mixed integer linear programming [4], dynamic programming (DP) [6], linear programming (LP) [7], quadratic programming (QP)[9], Lagrange relaxation method (LR) [8], Newton-based techniques [10], reported in the literature are used to solve economic load dispatch problem but these methods require enormous efforts in terms of computation and workable on ideal systems only with continuous functions.

Many meta-heuristic algorithms have recently shown the efficiency in dealing with many non linear optimization constrained problems for finding the optimal solution in various engineering problems evolutionary programming (EP) [11], simulated annealing (SA) [12], Tabu search (TS) [14], pattern search (PS) [15], Genetic algorithm (GA) [16], Differential evolution (DE) [17], Ant colony optimization [18], Neural network [19], particle swarm optimization (PSO) [20]. In this paper Lion Optimization Algorithm is being proposed to solve constrained engineering problems is proposed by B R Rajkumar [21] and Until now many researches have been carried out to find the solution of optimization problem using LOA like community detection problem by Baber[22] and it was inferred that the LOA is more robust and efficient in determining the optimization.

2. PROBLEM FORMULATION

The mathematical modeling of power generation considers total cost of operation includes the fuel cost, cost of labour, supplies and maintenance. Generally, costs of labour, supplies and maintenance are fixed percentages of incoming fuel costs. The power output of fossil plants is increased sequentially by opening a set of valves to its steam turbine at the inlet. The throttling losses are large when a valve is just opened and small when it is fully opened. The cost is usually approximated by one or more quadratic segments. The present formulation treats the environmental economic dispatch problem as a multi-modal optimization problem which simultaneously optimizes various related objectives as well as satisfying both equality and inequality constraints . The objectives can be incorporated are fuel cost, emission objectives like NOx, SOx, COX and system loss. With these multiple objectives and constraints, the Multi-Objective Environmental

. The total fuel cost in terms of real power output can be expressed with the function

$$F_F(P)=\sum_{j=1}^{N}\left(a_jP_j^2+b_jP_j+c_j\right) \quad (1)$$

The same fuel cost objective of fossil fuel fired generator, considering the valve point effect, is expressed as the sum of the quadratic and a sinusoidal function.

$$F_{FV}(P)=\sum_{j=1}^{N}\left(a_jP_j^2+b_jP_j+c_j+\left|e_j\times\sin\left(f_j\times\left(P_j^{min}-P_j\right)\right)\right|\right) \quad (2)$$

Emission Objective: The atmospheric pollutants such as SOX, NOX and COX caused by fossil fuel fired generators can be modelled separately and are discussed and formulated under division 4.2. These emissions can be expressed as given below:

$$F_S(P)=\sum_{j=1}^{N}\left(\alpha_{sj}+\beta_{sj}P_j+\gamma_{sj}P_j^2\right)$$

$$F_N(P)=\sum_{j=1}^{N}\left(\alpha_{nj}+\beta_{nj}P_j+\gamma_{nj}P_j^2\right)$$

$$F_C(P)=\sum_{j=1}^{N}\left(\alpha_{cj}+\beta_{cj}P_j+\gamma_{cj}P_j^2\right) \quad (3)$$

where Fs is the total SOX emission; Fn is the total NOx emission; Fc is the total COX emission; sj , sj and sj are the SOX emission coefficients of the jth generator; nj , nj and nj are the NOX emission coefficients of the jth generator; cj , cj and cj are the COX emission coefficients of the jth generator.

Problem constraints: The objective functions formulated so far should be optimized while considering the following equality and inequality constraints. The constraints are power balance constraint and generation limit constraints and they are presented below. Power balance constraint: The total generation must supply the demand and compensate the transmission losses in the system. where PD is the total load demand and PL is the total transmission loss.The transmission losses must be taken into account to achieve true economic dispatch. Transmission loss is a function of unit generations. To calculate loss, the B-coefficients methods are used in general (Wood and Wollenberg 1996). This method is commonly used by the power utility industry and the network losses formula is expressed as follows.

$$P_L=\sum_{i=1}^{N}\sum_{j=1}^{N}P_iB_{ij}P_j+\sum_{i=1}^{N}B_{i0}P_i+B_{00} \quad (4)$$

Generator Capacity constraint: The power output of each committed unit must be greater than or equal to the minimum power permitted and must also be less than or equal to the maximum power permitted on that particular unit. This inequality constraint may be framed as shown in the Equation.

$$P_j^{min}\le P_j\le P_j^{max}, \quad for\ j=1,2,\ldots N \quad (5)$$

3. OVERVIEW OF LION OPTIMISATION

The LOA belongs to the Ontogeny category of natural computing in which the adaptation of a special organism to its environment is considered. Lion Optimization Algorithm (LOA), an initial population is formed by a set of randomly generated solutions called Lions. Some of the lions in the initial population (%N) are selected as nomad lions and rest population (resident lions) is randomly partitioned into P subsets called prides. S percent of the pride's members are considered as female and rest are considered as male, while this rate in nomad lions is vice versa.

For each lion, the best obtained solution in passed iterations is called best visited position, and during the optimization process is updated progressively. In LOA, a pride territory is an area that consists of each member best visited position. In each pride, some females which are selected randomly go hunting. Hunters move towards the prey to encircle and catch it. The rest of the females move toward different positions of territory. Male lions in pride, roam in territory. Females in prides mate with one or some resident males. In each pride, young males are excluded from their maternal pride and become nomad when they reach maturity and, their power is less than resident males.

Also, a nomad lion (both male and female) moves randomly in the search space to find a better place (solution). If the strong nomad male invade the resident male, the resident male is driven out of the pride by the nomad lion. The nomad male becomes the resident lion. In the evolution, some resident females immigrate from one pride to another or switch their lifestyles and become nomad and vice versa some nomad female lions join prides. Due to many factors such as lack of food and competition, weakest lion will die or be killed. Above process continues until the stopping condition is satisfied.

4. Implementation of LOA in solving EELD

In this work, the dimension of the problem is the number of generators taking part in the EELD problem. The inequality constraints are transformed to the penalty functions and these penalty functions are added to the objective function to construct the fitness function. In this work, the equality constraints and there active power inequality constraints and the real power inequality constraints are handled during the course of iteration. The EELD problem solved using following algorithm for finding survival of fittest

<u>Algorithm for Lion Optimization (Nomad Coalition)</u>

Define objective function f(x) ,x=(x1,x2,.....)
Initialize the first population of Lion Nomad and Pride randomly within limits
Calculate the firtness of Lion in Pride and Nomad lion
Find the best Lion and assume it part of Pride
While (t<Max Generation)
    For i=1:n
    Select an Male using Roulette wheel
    Get nomad coalition
    If Xe nomad wins
    Kill all the Cubs
    Update the position of Lion in Pride
End for
    Calculate the fitness of all the Male Lions
    Create a nomad coalition if fitter Nomad lion is found
    Update Pride using step one
End while

The Survival fight takes place between one of the two lions of nomad coalition and the pride, despite coalition between nomadic lions is also possible. Instead of engaging nomad coalition for territorial defense, winner take all approach so that only winning nomadic lion Xe _ nomad among the coalition engage in territorial defense. The survival fight result comes in favour of the selected Xe _ nomad

if the following criteria are met
f (Xe _ nomad)< f (X male)
f (X e _ nomad)< f (X m _ cub)
f (X e _ nomad)< f (X f _ cub) .....(7)

Pride is updated by replacing X male by X e_ nomad after removing it from nomad coalition, which happens only when X male is defeated in the territorial defensre. Likely, nomad coalition is updated only when X e_ nomad is defeated. The update process is done by selecting only one X nomad. This approach is used in solving cost minimization problem considering generator constraints with minimization of Emission and Power losses.

5. RESULTS AND DISCUSSIONS

The coding of LOA was written in MATLAB to solve Economic Load Dispatch Problem. The system comprises of 6 generating units. The following are the generators' operating costs in $/h, with Power in MW:

Unit	P_i^{min} (MW)	P_i^{max} (MW)	a_i ($/MW²)	b_i ($/MW)	c_i ($)	α_i ($/MW²)	β_i ($/MW)	γ_i ($)
1	10	125	0.15240	38.53973	756.79886	0.00419	0.32767	13.85932
2	10	150	0.10587	46.15916	451.32513	0.00419	0.32767	13.85932
3	35	225	0.02803	40.39655	1049.9977	0.00683	-0.54551	40.26690
4	35	210	0.03546	38.30553	1243.5311	0.00683	-0.54551	40.26690
5	130	325	0.02111	36.32782	1658.5596	0.00461	-0.51116	42.89553
6	125	315	0.01799	38.27041	1356.6592	0.00461	-0.51116	42.89553

$$B_{ij} = \begin{bmatrix} 0.002022 & -0.000286 & -0.000534 & -0.000565 & -0.000454 & -0.000103 \\ -0.000286 & 0.003243 & 0.000016 & -0.000307 & -0.000422 & -0.000147 \\ -0.000534 & 0.000016 & 0.002085 & 0.000831 & 0.000023 & -0.000270 \\ -0.000565 & -0.000307 & 0.000831 & 0.001129 & 0.000113 & -0.000295 \\ -0.000454 & -0.000422 & 0.000023 & 0.000113 & 0.000460 & -0.000153 \\ -0.000103 & -0.000147 & -0.000270 & -0.000295 & -0.000153 & 0.000898 \end{bmatrix}$$

Table1. Generator data

Unit Output	GA	EPA	BFA	LOA
P1 (MW)	120.16	103.078	105.329	24.9
P2 (MW)	21.36	73.505	76.408	10
P3 (MW)	62.09	91.556	92.920	102.66
P4 (MW)	128.05	110.787	109.834	110.63
P5 (MW)	209.65	187.869	183.192	232.63
P6 (MW)	201.12	174.289	170.013	219
Fuel cost ($/h)	39455.00	39473.433	39433.477	30633
Emission (kg/h)	516.55	467.388	462.716	460
Power losses (MW)	42.44	41.083	37.699	24
Total Capacity (MW)	742.44	741.083	737.699	699.82

Table 2. Comparison of optimization solution using several stochastic algorithms like GA , EPA , BFA with LOA

It is observed that optimal result obtained by LOA is minimum in terms of cost , emission and power losses cases of load compared to other stochastic optimization algorithm methods.

6. CONCLUSIONS

This paper reports an initial study focusing on the use of the Lion Optimization Algorithm for solving EELD problem. Several basic models dealing with the problem of EELD are implemented for a simple case. The LOA algorithm showed superior features including high quality solution, stable convergence characteristics. The solution may be close to that of the conventional method but tends to give better solution in case of higher order systems .The LOA algorithm can be used for solving EELD with renewables in future as the inclusion of renewable energy in the power system will have impact on generation mix, cost, the variability of load seen by other plant, and reserves.

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