Moth Flame Optimization Approach for Resolving Electrical ELD Problems

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Abstract:* Major requirement of ELD is to distribute the power among different units so that the load demand of all the units can be fulfilled. In addition to this it is also required to reduce the cost incurred by fuel and power transmission. In this process the load is distributed in such a way that power system utilized in efficient manner and also fulfills the consumer demand in optimum way. Main problem associated with the electric power generation is to schedule the output power units generated in order to fulfill the user's demand of electric power with minimum cost for operation. In this study the solution of Electric Dispatch problems (EDPs) is obtained by implementing Swarm intelligence approach. In this work several optimization algorithm have discussed such as Genetic Algorithm, Lambda Optimization Algorithm and Particle Swarm Optimization. These optimization algorithms can be used as per the requirement of the system. A new mechanism for ELD is developed in this study by using MFO (Moth Flame Optimization) technique. Different optimization algorithms that can be used to resolve the EDP problem GA-API, SDE, TLBO, QOTLBO, KHA and GWO is compared with proposed MFO in this work to assure that the MFO algorithm outperforms among them.

Keywords—Electronic Load Dispatch, Optimization, Moth Flame Optimization, Power Generation, Total Cost.

I. INTRODUCTION

In electrical field the major focus is to enhance the performance of the performed [1] operations efficiently and reliably. The implemented operation in a power system tries to minimize the overall cost and also satisfy the rest of the constraints [2]. This is an aid to optimize the profit. The customer's requirement of load demand should be pleased according to the available power generators and resources. As a conclusion, the ELD [3,4,5] can be defined as a scheduling function for power generators units for meeting the load demand of the customer with the reduced overall operational cost by contentment of the equality and inequality constraints.

Economic Load Dispatch is taken as an optimization issue which produces energy output in accordance with the power generator. It reduces the operational cost of the system. Mathematical representation of this is shown below [6]:

Minimize $f(x)$, the objective function

Subject to $g(x)$ and $h(x) \leq 0$, set of equality and inequality constraints.

In order to decrease the operational cost of power generation system, the ELD optimization plays important role. To do this, output obtained by the output generators is tuned to meet the requirement of the load and to reduce the losses inside the range of power generators and this output [7] is linked to the grid. In order to model the curve indicating the power production cost, the quadratic function can be implemented and this function is subjected [8] to equality and inequality parametric limitations and these constraints are mathematically explained below [9]:

$$F_i p_i = \sum_{i=1}^{n_g} (y_i P_i^2 + \beta_i P_i + \alpha_i) \ldots\ldots..(1)$$

$F_i p_i$, total generation cost

n_g, dispatchable generator nodes

y_i, β_i, α_i, cost coefficients

Subjected to power balance equation of equality constraint:

$$\sum_{i=1}^{n_g} P_i = P_D + P_i \ldots\ldots\ldots(2)$$

P_D, Load demand

P_i, Real power generator

To find out the losses in the system then power flow equation can be implemented. To do this krons loss formulae can be used [10].

$$P_l = \sum_{i=1}^{n_g} \sum_{j=1}^{n_g} P_i B_{ij} P_j + \sum_{i=1}^{n_g} B_{0i} P_i + B_{00} \ldots\ldots..(3)$$

P_l, power transmission loss

For inequality constraint

$$P_{i(min)} \leq P_i \leq P_{i(max)} \ldots\ldots\ldots(4)$$

$P_{i(min)}$, minimum power generation limit

$P_{i(max)}$, maximum power generation limit

Economic load dispatch dilemma can be modeled with an equation which exploit the economic welfare W of a power network and fulfill every the system constraints [11].

$$min_{Ik}(-W) = min_{Ik}\{\textstyle\sum_{k=1}^{n} C_k(I_k)\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(5)$$

In equation (1.5) n defines the number of buses in the system,

I_k is the net power injection at bus

k and $C_k(I_k)$ is the cost function of producing power at bus k. Unconstrained problem is given as in the equation no.5 [12].

Constraints of the system which are required to balance the power as well as its flow on any line so that it should not be exceed its capacity. In the situation of power balance sum of net injections at all the buses ought [13] to be equal to the losses of the power in the branches of the network.

$$\sum_{k=1}^{n} I_k = L(I_1, I_2, \dots, I_{n-1}) \dots\dots\dots\dots\dots\dots(6)$$

In the equation 1.6, L defines power loss which depends on the flows in the network and then net injection shows in the equation [9][10].
Now considered the second constraint which involves capacity constraints having flow on network lines and can be modeled as [14]:

$$F_l(I_1, I_2, \dots\dots, I_{n-1}) \le F_l^{max} \qquad l = 1, \dots, m \dots\dots\dots\dots\dots\dots(7)$$

Where F_l is the flow on branch l and F_l^{max} represents maximum value of the flow allowance.
Above given equation can be combined within to obtain Lagrangian of the optimization problem such as:

$$\mathcal{L} = \sum_{k=1}^{n} C_k(I_k) + \pi[L(I_1, I_2, \dots\dots, I_{n-1}) - \sum_{k=1}^{n} I_k] + \sum_{l=1}^{m} \mu_l[F_l^{max} - F_l(I_1, I_2, \dots\dots, I_{n-1})] \dots\dots\dots\dots\dots\dots(8)$$

Where π and μ are the Lagrangian multipliers of the constraints. The conditions for optimality are then:

$$\frac{\partial \mathcal{L}}{\partial I_k} = 0 \;,\; k = 1,2, \dots, n \dots\dots\dots\dots\dots\dots(9)$$

$$\frac{\partial \mathcal{L}}{\partial \pi_k} = 0 \dots\dots\dots\dots\dots\dots(10)$$

$$\frac{\partial \mathcal{L}}{\partial \mu_l} = 0, \quad l = 1,2, \dots, m \dots\dots\dots\dots\dots\dots(11)$$

$$\mu_l . [F_l^{max} - F_l(I_1, I_2, \dots\dots, I_{n-1})] = 0 \quad \mu_l \ge 0 \qquad k = 1, \dots, n \dots\dots\dots\dots\dots\dots(12)$$

Last condition is helpful in handling the inequality constrained obtained on the line capacity. Computational complexity is higher due to which it can be simplified using a linearised model also known as DC power flow [15].

II. PROBLEM FORMULATION

Electrical power industry restructuring has created highly vibrant and competitive market that altered many aspects of the power industry. Economic Load Dispatch (ELD) is one of the important optimization problems in power systems that have the objective of dividing the power demand among the online generators economically while satisfying various constraints. Economic load dispatch problem is the sub problem of optimal power flow (OPF). The economic load dispatch is defined as the process of allocating generation levels to the generating units, so that the system load is supplied entirely and most economically. For the connection between the two systems it is important that the expenses should be minimized. To describe the production level, each unit in the system is defined, so that the total cost of the system is calculated. The expenses should be less. Economic load dispatch problem is the sub problem of optimal power flow (OPF). The main objective of ELD is to minimize the fuel cost while satisfying the load demand with transmission constraints. So main aim of ELD is to minimize the expense of the system. In traditional work the GWO was implemented for optimizing the results. But in GWO, half of the iterations are devoted to exploration and the other half are dedicated to exploitation, overlooking the impact of right balance between these two to guarantee an accurate approximation of global optimum. Hence there is a requirement to develop a system which can overcome this shortcoming of GWO algorithm.

III. PROPOSED WORK

The objective of the Economic Dispatch Problems (EDPs) of electric power generation is to schedule the committed generating units outputs so as to meet the required load demand at minimum operating cost while satisfying all units and system equality and inequality constraints. The Economic Dispatch Problem is solved by specialized computer software which should honor the operational and system constraints of the available resources and corresponding transmission capabilities. Recently, global optimization approaches inspired by insects or flies and evolutionary computation approaches have proven to be a potential alternative for the optimization of difficult EDPs.
In the proposed work the solution of economic load dispatch will be done by using the MFO (Mouth Flame Optimization). The key advantages are that it can provide very quick convergence at a very initial stage by switching from exploration to exploitation. This makes it an efficient algorithm for applications when a quick solution is needed.

The proposed technique uses the MFO in order to minimize the cost incurred on power generating. The methodology of proposed technique is implemented in following steps:
STEP 1: First step is to load the power generator data. Here data refers to the terms such as generated power, amount of total lost transmission etc. The parameters are generated on the basis of some equations.
STEP 2: Now generate random population by using MFO. In MFO the generation of random population is an important step.
STEP 3: Now calculate the initial fitness value on the basis of the initial random generated population.
STEP 5: Now on the basis of the generated fitness value, apply MFO optimization technique to update the population. .
STEP 6: Evaluate the fitness value gain on the basis of the updated population.
STEP 7: Check if the initially evaluated fitness value is greater than the new fitness value then perform the results evaluation and updation otherwise the control will go to the step 5**.**

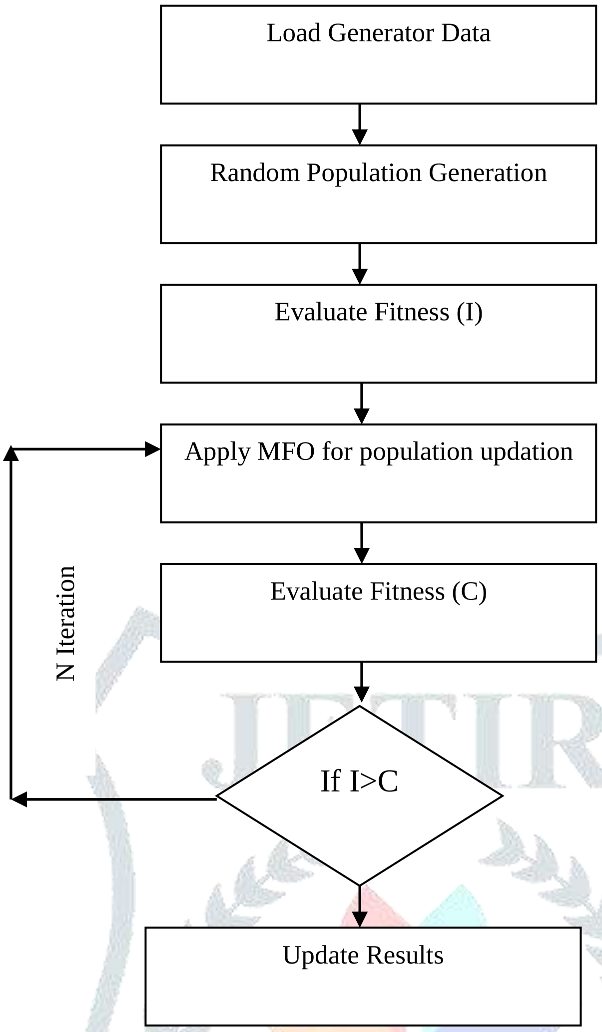

Figure 1 Block Diagram of proposed work

IV. RESULTS

This study implements the MFO (Moth Flame Optimization) optimization technique to resolve the issue of economic load dispatch in electrical power plants. The simulation of the proposed work is done on MATLAB simulation platform. The purpose behind simulation is to generate the results of the proposed work so that the efficiency of the proposed mechanism can be evaluated over traditional techniques. The simulation is performed on various number of generator units and corresponding results are depicted in the form of graphs in this section of the study.

The graph in figure 2 shows the fitness evaluation for corresponding number of iterations. The x axis in the graph shows the number or iterations that ranges from 0 to 100. The y axis calibrates the data in terms of fitness value. On the basis of the graph, it is evaluated that the initially the fitness value is evaluated to be quit high but then suddenly it falls to the 0.

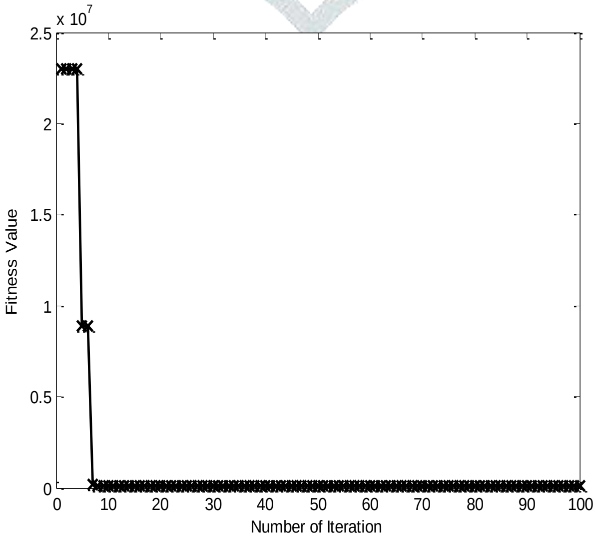

Figure 2 Fitness evaluation

The graph in figure 3 shows the results for proposed work in the terms of generated power by 40 different units. The objective behind evaluation of proposed work over 40 units is to ensure the scalability and robustness of the proposed work. The x axis in the graph shows the data for the generated units and it ranges from 0 to 40 with the interval of 5. It is observed that when the units are 0 then the power generated is also 0 and when the number of units increases the increment in the amount of power generation is also seen. When the number of units reaches to the higher than 25 a sudden fall in power generation is observed. A slight fluctuations have been seen in the curve of power generation which depicts that the power is generated as per the requirements of the units installed.

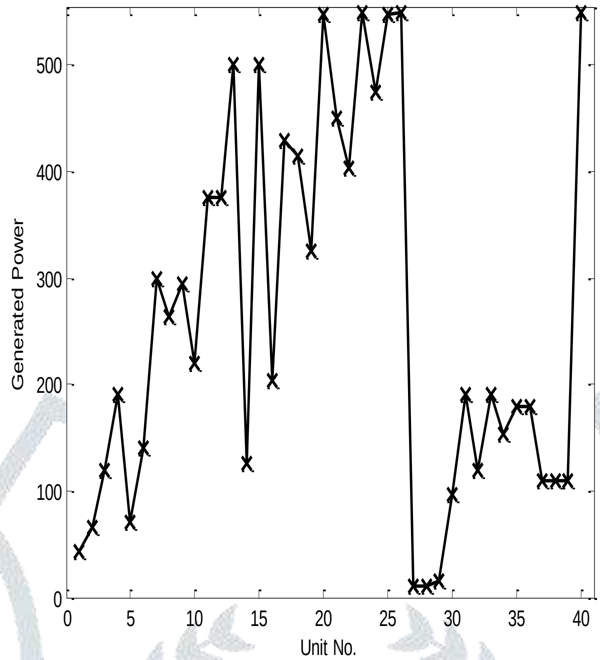

Figure 3 Generated Power Evaluation with respect to 40 units

The graph below shows the comparison analysis of proposed MFO and traditional GA-API mechanism in terms of power generated. The x axis depicts that the experiment is done by considering the 40 power units for the contrast purpose and the data on y axis is calibrated in the terms generated power. The range of the power generation starts from 0 and ends at 600 with an interval of 100.

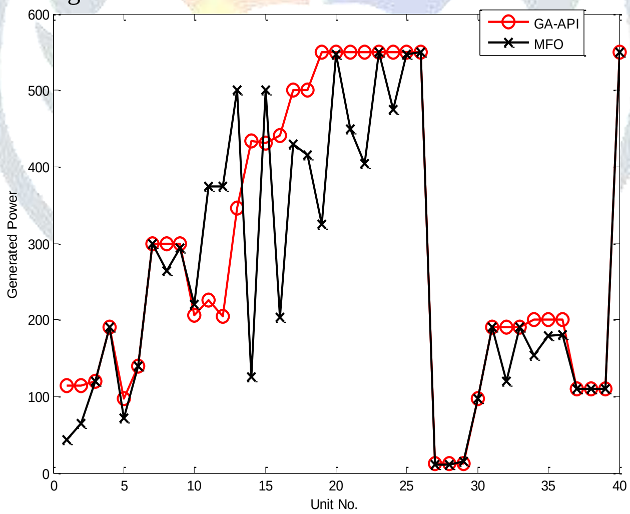

Figure 4 Comparison analysis of generated power for GA-API and MFO.

The curve in red depicts the power generation by GA-API [16] and curve in black shows the power generation by proposed MFO mechanism. The graph explains that when the number of units is 0 the corresponding power generation by MFO technique is 0 whereas for GA-API it is higher than the 100 even in the case of the 0 power units. Thus on the basis of the observations it is concluded that the power generation strategy of proposed MFO technique quite effective and reliable in comparison to the traditional GA-API technique.

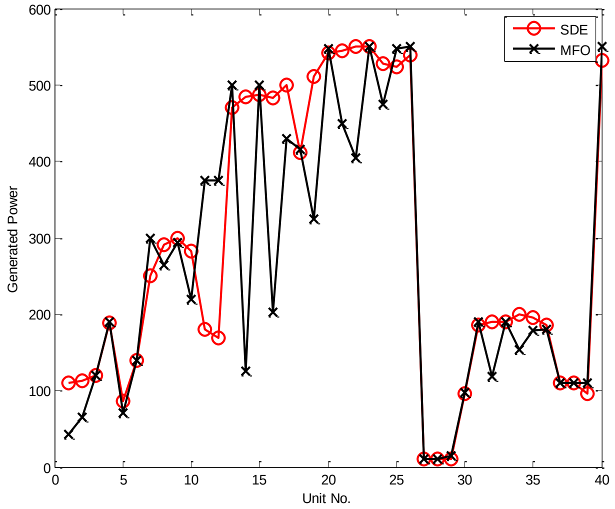

Figure 5 Comparison analysis of generated power for SDE and MFO.

The graph in figure 5 delineates the comparison of proposed MFO and traditional SDE technique. The comparison is done in the terms of generated power corresponding to the 40 power nits. The graph explains that the generated power of SDE [17] mechanism is lower whereas the power generated by the MFO is quite higher and efficient.

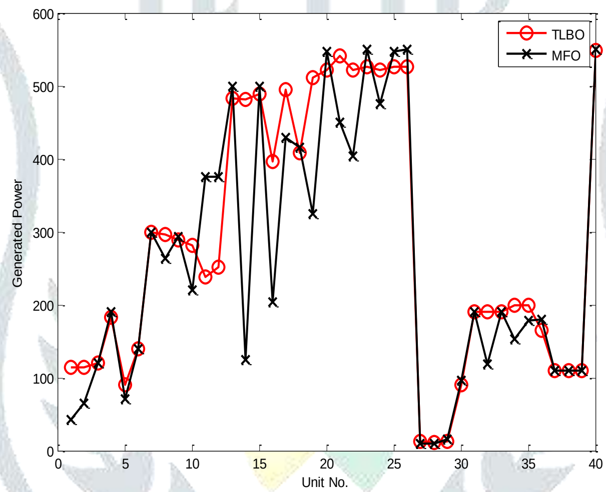

Figure 6 Comparison analysis of generated power for TLBO and MFO.

The graph in figure 6 delineates the comparison analysis of propose work and traditional TLBO [18]. Similarly the graph in figure 7 shows the comparison of proposed and traditional QOTLBO [18] technique. The comparison is done with an objective to prove the proficiency of the proposed work over traditional work. Both of the graphs show that the proposed work outperforms the traditional work in terms of power generation.

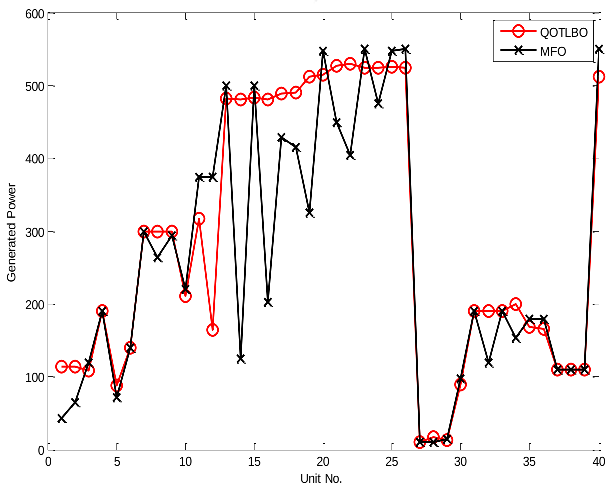

Figure 7 Comparison analysis of generated power for Q OTLBO and MFO.

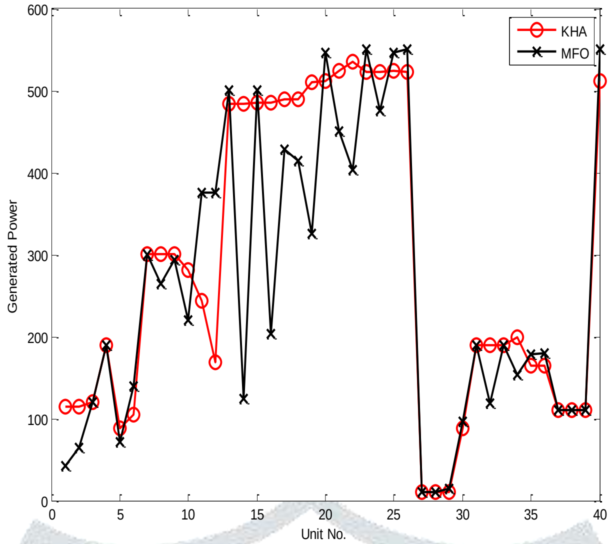

Figure 8 Comparison analysis of generated power for KHA and MFO.

The graph in figure 8 depicts the comparison of proposed MFO and traditional KHA [19] mechanism for resolving the ELD issue in power units. Similarly the graph in figure 9 depicts the comparison of proposed work with GWO [20] technique.

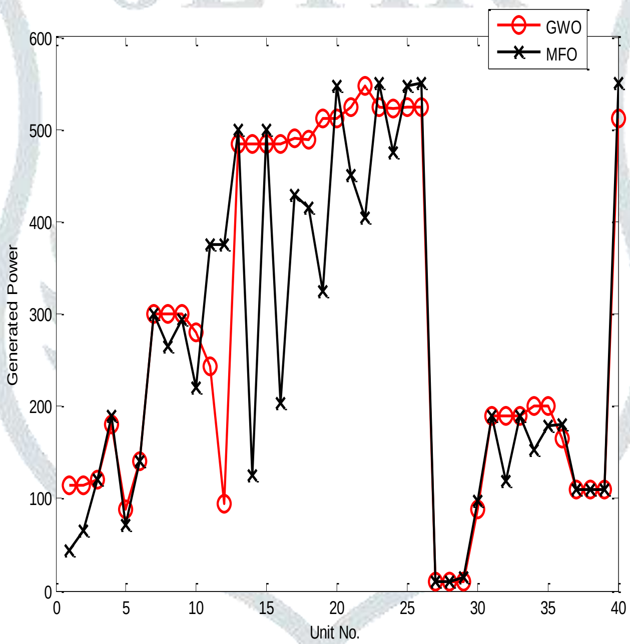

Figure 9 Comparison analysis of generated power for GWO and MFO

The table 1 shows the total cost incurred on power generation systems with respect to the GA-API, SDE, TLBO, QOTLBO, KHA, GWO and MFO technique.

Table 1 Analysis of Total Cost

S. No.	Techniques	Total Cost ($)
1.	GA-API [16]	139864.96
2.	SDE [17]	138157.46
3.	TLBO [18]	137814.17
4.	QOTLBO [18]	137329.86
5.	KHA [19]	136670.37
6.	GWO [20]	136446.85
7.	MFO	109638.238870797

V. CONCLUSION

Economic Load Dispatch is the process known for distributing load in such a way so that economic cost of the power system should be used less and requirement of the consumer fulfilled. Thus in this work different optimization algorithms have been studied which can be used to evaluate proper distribution of load over the power systems. Evaluation has been done between GA-API, SDE, TLBO, QOTLBO, KHA, GWO and proposed MFO which ensures that MFO outperforms among them. Several parameters such as total generation cost and total cost have been discussed. These parameters conclude that MFO is efficient, effective and optimized than other optimization technique. As various optimization algorithms have been evaluated in this thesis where MFO declares as an efficient technique.
In future, more amendments can be done by collaborating the chaotic map search mechanism with present work in order to enhance the procedure of population generation. This will be an aid to consider multiple cases also.

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