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Economic Load Dispatch

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Abstract: ELD or Economic load dispatch is an online process of allocating generating among the available generating units to minimize the total generating cost and satisfy the equality and inequality constraint. ELD means the real and reactive power of the generator vary within the certain limits and fulfils theload demand with less fuel cost. There are some traditional methods for = 1; 2; :::;N) isgiven as Vi=[Vi;1; Vi;2; :::; Vi;D]. The index ivaries from solving ELD include lambda irritation method, Newton-Raphson method, Gradient method, etc. All these traditional algorithms need the incremental fuel cost curves of the generators to be increasing monotonically or piece-wise linear. But in practice the input-output characteristics of a generator are highly non-linear leading to a challenging non-convex optimization problem. Methods like artificial intelligence, DP (dynamic programming), GA (genetic algorithms), and PSO (particle swarm optimization), ALO (ant-lion optimization), solve non convex optimization problems in an efficient manner and obtain a fast and near global and optimum solution. In this project ELD problem has been solved using Lambda-Iterative technique, ALO (ant-lion Optimization) and PSO (Particle Swarm Optimization) and the results have been compared. All the analyses have been made in MATLAB environment
Keywords: ELD (Economic load dispatch); ALO(Ant-lion optimization) ;transmission loss; PSO (particleswarm optimization

I. INTRODUCTION

Economic load dispatch (ELD) is an constraint based optimization problem in power systems that have the objective of dividing the total power demand among the online participating generators economically while satisfying the essential constraints. The conventional methods include the lambda iteration methods [1, 2], base point an participation factors, etc. Among these methods lambda iteration is the most common method because of ease of implementation. The ELD is nonconvex optimization problem required rigorous efforts to solve by traditional methods. Moreover, evolutionary and behavioural random search algorithms such as genetic algorithm (GA) [3], particleswarm optimization (PSO) [4] have been implemented on the ELD problem. GAs does possess some weaknesses leading to larger computation time premature convergence [5]. Particle swarm optimization (PSO) is considered one of the evolutionary computational algorithmwhich is depend on intelligence of the swarm. It is proposed by Kennedy and Eberhart (1995a; 1995b)where it has been simulated from the artificial livings research. Also, it is a population based optimizer.The PSO mechanism is started by randomly initializing a set of potential solutions, then the searchfor the optimum is performed repetitively. In PSO algorithm, the optimal position is found by follow the best particles. Generally, these approaches have hitches in finding an overall optimum, usually offering local optimum point only.

II. PARTICLE SWARM OPTIMIZATION: ALGORITHM

Particle swarm optimization (PSO) is inspired by social and cooperative behavior displayed by various species to _ll their needs in the search space. The algorithm is guided by personal experience (Pbest),overall experience (Gbest) and the present movement of the particles to decide their next positions inthe search space. Further, the experiences are accelerated by two factors c1 and c2, and two random numbers generated between [0, 1] whereas the present movement is multiplied by an inertia factor varying between [wmin;wmax]. The initial population (swarm) of size N and dimension D is denoted as X = [X1,X2,...,XN]T ,where 0T0 denotes the transpose operator. Each individual (particle) Xi (i = 1; 2; :::;N) is given asXi=[Xi;1;Xi;2;:::;Xi;D]. Also, the initial velocity of the population is denoted as V =[V1,V2,...,VN] T .Thus, the velocity of each particle Xi (i
1 to N whereasthe index j varies from 1 to D. The detailed algorithms of various methodsaredescribedbelowforcompleteness. V k+1

i;j = w _ V k
i;j + c1 _ r1 _ (Pbestk i;j Xk
i;j) + c2 _ r2 _ (Gbestkj Xk
i;j) (1) Xk+1
i;j = Xk i;j + V k+1
i;j (2)
In eqn. (1) Pbestk

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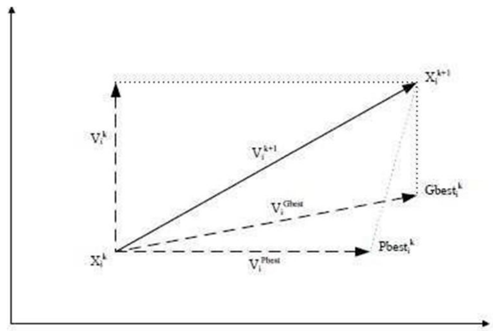
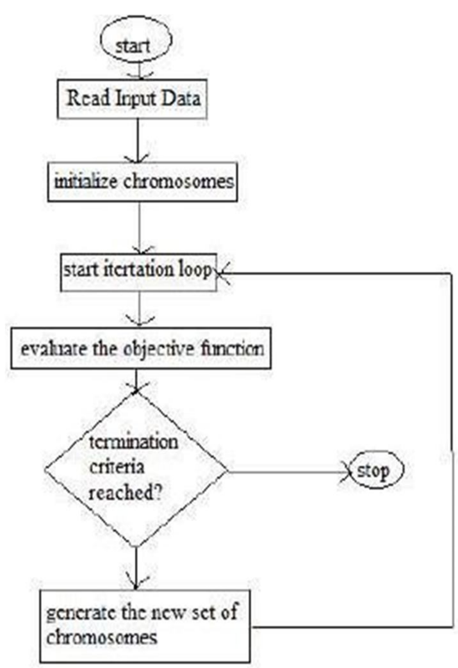
i;j represents personal best jth component of ith individual, whereas Gbestkjrepresents jth component of the best individual of population upto iteration k.



III. METHODOLOGY

1) *Step-1:* Read the input data(generator data and the corresponding constraints).
2) *Step-2:* Define maximum and minimum velocities and initialize the velocities for all the particles in the search space defined
3) *Step-3:* calculate the losses from the coefficients and calculate the difference in generation and demand plus losses from the random population chosen and check whether it is greater than your required error(termination criteria).
4) *Step-4:* if error is more than required calculate the new generation limits by using Xnew=Xold-(error/nunits) and calculate the error with new limits and repeat the loop until the difference is under required criteria
5) *Step-5:* calculate the cost of generation and emission rate for all the units and also maximum and minimum cost and emissions of units
6) *Step6:* calculate the penalty price factors from the formula h=max cost/max emission
7) *Step-7:* formulate the multi objective function to be optimized and obtain the fitness functions of the particles.
8) *Step-8:* obtain local fit and local cost and local best generation
9) *Step9:* calculate the weight from the max and min weights and hence update the velocities of all the particles chosen
10) *Step-10:* calculate new generation limits and hence update the limits for all the particles.
11) *Step-11:* find the losses and check the equality constraints at every iteration until error is under required level and repeat the loop until the maximum iteration limit.



Two MATLAB script _les (*. m _le) are needed to fully write the codes. In the _rst _le, the objectivefunction is de_ned, whereas in the second _le, the main PSO program is developed [6].Now, this problem will be solved by using the PSO algorithm. The objective function _le and main program _le can be written as follows:

Objective function _leThe problem de_ned in the last section can be expressed in MATLAB script _le (*.m) as follows:

```
function f=ofun(x)

c0=[];

% objective function (minimization)
of=10*(x(1)-1)^2+20*(x(2)-2)^2+30*(x(3)-3)^2;

% constraints (all constraints must be converted into <=0 type)
% if there is no constraints then comments all c0 lines below
c0(1)=x(1)+x(2)+x(3)-5;     % <=0 type constraints
c0(2)=x(1)^2+2*x(2)-x(3);   % <=0 type constraints

% defining penalty for each constraint
for i=1:length(c0)
    if c0(i)>0
        c(i)=1;
    else
        c(i)=0;
    end
end

penalty=10000; % penalty on each constraint violation

f=of+penalty*sum(c); % fitness function
```

Save the above codes as ofun.m. The "ofun.m" _le de_nes the problem discussed above. In main program _le this function will be called again and again as per the requirement.

IV. ANT LION OPTIMIZATION

Ant Lion Optimizer (ALO)[7] is a novel nature-inspired algorithm proposed by SeyedaliMirjalili in 2015.The ALO algorithm mimics the hunting mechanism of ant lions in nature. Five main steps of hunting prey such as the random walk of ants building traps, entrapment of ants in traps, catching preys, and re-building traps are implemented. Ant lions (doodlebugs) belong to class of net winged insects. The lifecycle of ant lions includes two main phases: larvae and adult. A natural total lifespan can take up to 3 years, which mostly occurs in larvae (only 3–5 weeks for adulthood). Ant lions undergo metamorphosis in a cocoon to become adult. They mostly hunt in larvae and the adulthood period is for reproduction. An ant lion larvae digs a cone-shaped pit in sand by moving along a circular path and throwing out sands with its massive jaw.After digging the trap, the larvae hides underneath the bottom of the cone and waits for insects (preferably ant) to be trapped in the pit. The edge of the cone is sharp enough for insects to fall to the bottom of the trap easily.

V. PROBLEM FORMULATION

The objective function of the OLD problem is to minimize the total generation cost while satisfying the different constraints, when the necessary load demand of a power system is being supplied. The objective function to be minimized is given by the following equation:

$$F(P_g) = \sum_{i=1}^{n} (a_i P_{gi}^2 + b_i P_{gi} + c_i) \qquad \ldots (1)$$

The total fuel cost has to be minimized with the following constraints

A. Power Balance Constraint

The total generation by all the generators must be equal to the total power demand and system's real power loss.

$$\sum_{i=1}^{n} P_{gi} - P_d - P_l \qquad \ldots\ldots (2)$$

B. Generator Limit Constraint

The real power generation of each generator is to be controlled within its particular lower and upper operating limits.

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \; \mathrm{I} = 1, 2, \ldots, ng \qquad \ldots..(3)$$

Random walks of ants: Random walks are all based on the Eq.4

$$X(t) = [0, cumsum(2r(t_1) - 1), cumsum(2r(t_2) - 1), \ldots\ldots, cumsum(2r(t_n) - 1)] \qquad \ldots..(4)$$

Where cumsum calculates the cumulative sum, n is the maximum number of iteration, t shows the step of random walk and r(t) is a stochastic function defined as follows:

$$r(t) = \begin{cases} 1 & if\ rand > 0.5 \\ 0 & if\ rand \leq 0.5 \end{cases} \qquad \ldots\ldots(5)$$

however, above Eq. cannot be directly used for updating position of ants. In order to keep the random walks inside the search space, they are normalized using the following equation (min–max normalization):

$$X_i^t = \frac{(X_i^t - a_i) \times (d_i - c_i^t)}{(d_i^t - a_i)} + c_i \qquad \ldots\ldots(6)$$

Where ai is the minimum of random walk of ith variable, bi is the maximum of random walk in ith variable, c th is the minimum of ith variable at tth iteration, and d t indicates the maximum of ith variable at Ithiteration.

Trapping in ant lion's pits: random walks of ants are affected by antlions traps. In order to mathematically model this assumption, the following equations are proposed**:**

where is the minimumof all variablesat tth iteration, indicates the vector including themaximumof allvariablesattth iteration, is the minimum of all variables for ith ant, is the maximum of all variables for ith ant, and Antliont j shows the position of the selected j- thantlion at tthiteration

1) *Building Trap:* In order to model the ant-lions's hunting capability, a roulette wheel is employed. The ALO algorithm is required to utilize a roulette wheel operator for selecting ant lions based of their fitness during optimization. This mechanism gives high chances to the fitter ant lions for catching ants.
2) *Sliding ants Towards Ant Lion:* With the mechanisms proposed so far, ant lions are able to build traps proportional to their fitness and ants are required to move randomly. However, ant lions shoot sands outwards the center of the pit once they realize that an ant is in the trap. This behavior slides down the trapped ant that is trying to escape. For mathematically modelling this behavior, the radius of ants' random walks hyper-sphere is decreased adaptively. The following equations are proposed in this regard: = …(9) = …(10) where I is a ratio, ct is the minimum of all variables at t-th iteration, and dt indicates the vector including the maximum of all variables at t-th iteration.
3) *Catching Prey and re-building the Pit:* The final stage of hunt is when an ant reaches the bottom of the pit and is caught in the antlion's jaw. After this stage, the antlion pulls the ant inside the sand and consumes its body. For mimicking this process, it is assumed that catching prey occur when ants becomes fitter (goes inside sand) than its corresponding antlion. An antlion is then required to update its position to the latest position of the hunted ant to enhance its chance of catching new prey. The following equation is proposed in this regard: = > …(11) where t shows the current iteration, Antliont j shows the position of selected j-thantlion at t-th iteration, and Antti indicates the position of i-th ant at t-th iteration.
4) *Elitism:* Elitism is an important characteristic of evolutionary algorithms that allows them to maintain the best solution(s) obtained at any stage of optimization process. Since the elite is the fittest antlion, it should be able to affect the movements of all the ants during iterations. Therefore, it is assumed that every ant randomly walks around a selected antlion by the roulette wheel and the elite simultaneously as follows: = + 2 … (12) where is the random walk around the antlion selected by the roulette wheel at t-th iteration, is the random walk around the elite at t-th iteration, and indicates the position of i^{th} ant at t^{th} iteration.

VI. CONCLUSION

In this paper, the concepts of particle swarm optimization have been discussed in a very simple way.
Further, its algorithm has been developed. Also, PSO programming codesin MATLAB environmenthave been given and an example has been solved successfully whichdemonstrate the e_ectiveness of the algorithm. The following conclusions can be drawn from this work:

A. The MATLAB codes discussed here can be extended to solveany typeof optimization problem ofany size.
B. Any equality constraint needs to convert into corresponding two inequality constraints.
C. The codes discussed here are generalized for solvingany optimization problem with inequalityconstraints of anysize.

The objective function of the OLD problem is to minimize the total generation cost while satisfying the different constraints, when the necessary load demand of a power system is being supplied
ALO has been used to solve the OLD problems in three different test cases for exploring its optimization potential, where the objective function was limited within power ranges of the generating units and transmission losses were also taken into account. The iterations performed for each test case are 500 and number of search agents (population) taken in both test cases is 30.

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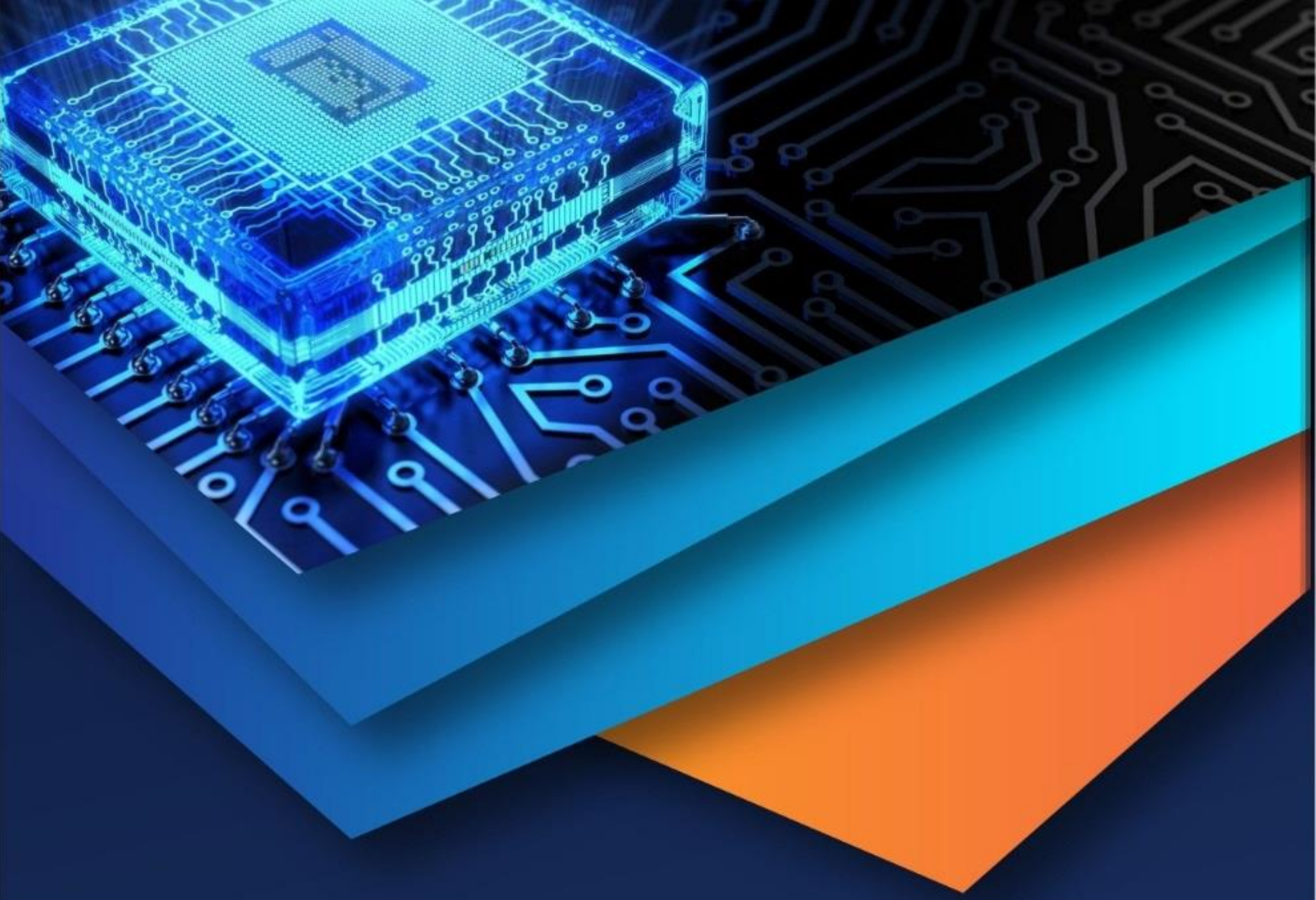

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