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Economic Load Dispatch using an Improved Gravitational Search Algorithm Considering valve Point Effect

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Abstract: Economic load dispatch (ELD) is an important optimization task in power plant like thermal plants operation for allocating generation among the committed units such that fuel cost and emission level are optimized while satisfying all operational constraints. It is multi objective optimization problem involving conflicting objectives with both equality and inequality constraints. In this paper, multi-objective differential evolution has been proposed to solve ELD problem. The two objectives i.e. cost and outflow are conflicting in nature we considering both simultaneously to find optimal dispatch. Economic dispatch (ELD) serves to committed generator output scheduling with the predicted demand of load as to optimize both cost and emission simultaneously with fulfilling the operating constraints. It is a multi-objective optimization problem with conflicting objectives because outflow minimization is conflicting with minimum cost of generation. This research paper will propose to solve the problem of Economic Load Dispatch using a novel Gravitational Search Algorithm. Novel or improved gravitational search algorithm because we are using constraint optimization with limit consideration. The meaning is if the solution moves to non feasible space than it is broad back to the feasible space using reflection conditions. The target is to implement a partial search algorithm which will be able to find the optimal capacity of the generating units in multi-generating unit system. The system of different number of generator sets would be taken so that the algorithm is tested for different datasets. The particles are initialized randomly and moved in the search space as they search for the global optimal solution to keeping the particles in the feasible space so that both equality and inequality constraints are not violated. The method for the GSA to work are explain in down which are basis on the optimizing process.

Keywords: Economic Environmental dispatch, Valve Point Effect, Economic Load Dispatch, Gravitational Search Algorithm, multi generating unit.

1. INTRODUCTION

One of the most important functions of modern day in energy management system is Economic load Dispatch (ELD). Its purpose to minimize/reduces the total cost in term of real power generation from thermal plants at various stations while fulfilling the losses and the loads in power transmission system. The dispatching of economical issue includes arrangement by two unique issues. One of these is unit responsibility and pre dispatch issue where it require to choose ideally from the accessible sources are generating to meet the normal load and give a predefined working edge stored above predetermined time period. Second one is the economic dispatch which is online dispatching of economical load where it distributed by the constraints. The generating units of the system having loads which are really parallel with the system such a way to reduce the nearby cost of supply This part of economic dispatch issue that has been talked about in various papers in which the electric systems are inter connected hugely the vitality emergency on the world and continuous rise in cost.

It is necessary to reduce the running charges the electric vitality decreases of fuel utilization for taking care of the specifies demand of load on account of generation of economic dispatch are not improved but rather they are permit to take values again inside of specific points of restrain so that to take care of a specific demand of load with least fuel cost. This implies dispatching of economical load issue is truly an answer of expensive numbers load stream issues and picking the one which optimized as in it needs the base cost which use for long period of life. There are numerous methods developed for understanding the economic/environment load dispatch issues which are classified as traditional and heuristic techniques. In traditional strategy, fuel cost curve is monotonically expanding one and it represented by quadratic capacity. The majority of established optimization methods, for example, lambda iteration technique, Newton Raphson strategy, Gradient or slope technique, Linear programming, Interior point strategy and element programming have been utilized to take care of the essential economic dispatch issue. Because of non curved and nonlinear conduct of ED issue and significant number requirements, established methods can't be execute well in taking care of the ED issues It is clear from this that since aggregate expense is a singular component time period of the sources which can take a quality inside of specific limitations.

1.1. Economic Load Dispatch

It is defined as the generation facilities of the operation to produce energy at the lowest cost and reliable which is serves to consumers, recognizing any operational limits of generation and transmission facilities. Operational limits are acceptable for generation and transmission systems It is a stochastic process and it can occurs in different units like hydro and thermal plants. An important role is plays by economic load dispatch in operation planning and control of modern power system as compare to last few years, a number of approaches has been developed for solving ELD using some programming methods of mathematical. Here we have linear programming methods which are fast and reliable but they have some disadvantages which is approximation of linear cost. Nonlinear programming methods also have a problem of algorithmic complexity and convergence problem. For solving the ELD problems we have to make numerical method more convenient. Modern techniques of optimization have been successfully utilized to solve economic dispatch problems as non smooth.

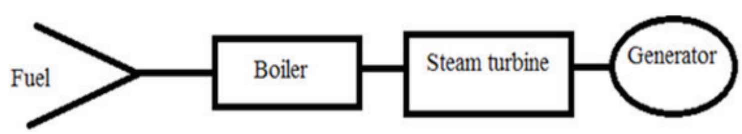

Figure 1: Energy Conversion system

In above figure we are showing the energy conversion diagram of thermal plant. For specification of thermal plants we can model it as transfer function of conversion of energy from fossil fuel to electricity. It generally consists of the boiler, steam turbine and the generator. Fuel is the input of boiler and volume of steam is output. The relationship between input and output can be expressed as convex curve. Total input of the thermal unit could be in form of heat supplied (cal/hr) or may be in form of cost of fuel (Rs./hr) and total output at generator bus will be in form of KW or MW.

1.2. The Economic Load Dispatch Problem with Valve Point Effect

A valve point is the rippling effect added to the generation unit curve when each steam admission valve in a turbine starts to open. This curve posses higher order non linearity and discontinuity which makes the problem of finding the optimum more difficult and increases the number of local minima in the fuel cost function. In turbine valves are used to control the output power of generators opening the valve point effects lead to the sudden increase in loss and cause ripples (wave) in input and output curve and cause cost function non smooth valve point effects is considered in power plants, cost function is taken as non convex (non smooth) due to mechanical effects. Consider the valve point effect sinusoidal functions are added to the quadratic constant function.

As we know that:

$$\sum_{i=1}^{ng} Pg_i = P_d \tag{1}$$

where, Pg_i is power generated and P_d power demand.

$$\sum Pg_i = P_d + P_L \tag{2}$$

Cost of fuel of each power plant:

$$F(Pg_i) = a_i P^2 g_i + b_i Pg_i + C_i \tag{3}$$

F fuel cost and C_i, b_i, a_i factor for fuel cost function of ith unit.

The above expression of cost function is to be modified suitably by valve point effect:

$$F_i(P_i z) = a_i + b_i p_i + c_i P^2 i + |e_i \sin f_i(P_i^{\min} - p_i)| \tag{4}$$

e_i, f_i coefficients of generator i, reflecting the valve point.

1.3. Gravitational Search Algorithm (GSA)

GSA is population search algorithm develop by Rashedi in 2009. The solutions of objects given by GSA population are called agents. These agents are interacts with each other through the gravitation. Performance of each agent in the population is measured by its mass. The base on the law of gravity and mass interact.

Each agent is considered as object and all object move towards other objects with having mass due the gravitational force. The best solution is the solution with the heavier mass. The gravity function 'G' at interation 't' is:

$$G(t) = G_0 e^{-\alpha t/T} \tag{5}$$

G_0 and α are the initialize in the beginning of the search and their values will be reduced during the search 'T' is no of interaction. Object mass obey the law of gravity:

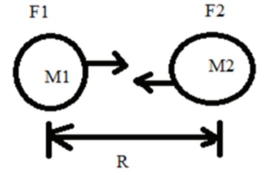

Figure 2: Gravitational Force

The algorithm is intended to improve the performance in global and exploitation capabilities of a population based algorithm. This is based on gravity rules however, but not commonly based on the law of gravity, mass and distance are both integral parts of the law of gravity. The objectives of the Gravitational Search Algorithm to minimize the cost of generation using valve point effects. The population based novel algorithm is based on the law of gravity and mass interactions. The algorithm is comprised of collection of agents that interact with each other through the force of gravity. The agents are considered as objects and their performance is measured by their masses. The gravity force causes a global moment where all objects move towards other objects with heavier masses. The slow moment of heavier masses guarantees the exploitation step of algorithm and corresponds to good solutions. The masses are actually obeying the law of gravity.

$$F = G\,\frac{M_1 M_2}{R^2} \tag{6}$$

$$a = \frac{F}{M} \tag{7}$$

In above equations, F represents the magnitude of the gravitational force, G is gravitational force M1, M2 are the mass of the first and second objects and R is the distance between the two objects. Equation first shows that in the Newton law of gravity, the gravitational force between two objects is directly proportional to their masses and inversely proportional to the square of the distance of the distance between the objects, other shows the Newton's second law which is when a force F, is applied to an object, its acceleration a depends on the force and its mass M.

In GSA agent has four parameters which are position, inertial mass, passive gravitational mass, and active gravitational mass. The position of the mass represents solution of the problem, where the inertial and gravitational masses are determined using fitness function. The algorithm is search by adjusting the inertia and gravitational masses, where each mass presents a solution. Masses are attracted by the heaviest mass. Hence the heaviest mass presents an optimal solution in the search area. The steps are given, All these steps explained above define how the GSA works and the principle diagram of the GSA is illustrated in figure:

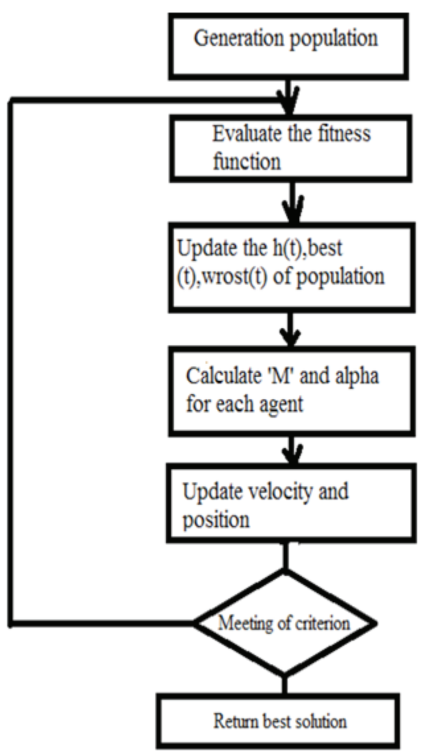

Figure 3: Flow Chart of GSA

(i) **Agents initialization:** The positions of the N number of agents are initialized random

$$\mathrm{X}_i = (x_i^1, x_i^d, ..., x_i^n) \tag{8}$$

X_i^d is the positions of the i_{th} agent in the d_{th} dimension, while n is the space dimension.

(ii) **Fitness evolution and best fitness computation:** For minimization or maximization problems, the fitness evolution is performed by evaluating the best and worst fitness for all agent at each iteration.

Minimization problems:

$$\text{best}(t) = \min \text{fit}\, j(t) \text{ where } j \in \{1, \ldots, \mathrm{N}\} \tag{9}$$

$$\text{worst}(t) = \max \text{fit}\, j(t) \text{ where } j \in \{1, \ldots, \mathrm{N}\} \tag{10}$$

Maximization problems:

$$\text{best}(t) = \max \text{fit}\, j(t) \text{ where } j \in \{1, \ldots, \mathrm{N}\} \tag{11}$$

$$\text{worst}(t) = \min \text{fit}\, j(t) \text{ where } j \in \{1, \ldots, \mathrm{N}\} \tag{12}$$

Fit $j(t)$ represents the fitness value of the j^{th} agent at iteration t, best(t) and worst(t) represents the best and worst fitness at iteration t.

(iii) **Computation of Gravitational Constant (*G*):** Gravitational constant '*G*' is computed at iteration t

$$\mathrm{G}(t) = \mathrm{G}_0 \exp(-\alpha\, t/\mathrm{T}) \tag{13}$$

G_0 and α is initialized at the beginning and will be reduced with time to control the accurate search. Total number of iterations is T.

(iv) **Update the Gravitational and Inertial Masses:** In this step, the gravitational and inertial masses are updated for each agent at iteration as follow:

$$\mathrm{M}_{ai} = M_{pi} = M_{ii} = M_i,\ i = 1, 2, 3, ..., \mathrm{N} \tag{14}$$

$$m(t) = \frac{\text{fit}\, i(t) - \text{wrost}(t)}{\text{best}(t) - \text{wrost}(t)} \tag{15}$$

where, fit $i(t)$ is the fitness of the ith agent at iteration t.

$$\mathrm{M}_i(t) = \frac{m_i(t)}{\sum_{i=1}^{\mathrm{N}} m_i(t)} \tag{16}$$

where, M_{ai} is the active gravitational mass of the i^{th} agent, M_{pi} is the passive gravitational mass of the i^{th} agent, M_{ii} is the inertial mass of the i^{th} agent, $M_1(t)$ is the mass of the i^{th} agent at iteration t.

(v) **Total Force Calculation:** In this step, the total force acting on the i^{th} agent ($F_i^2\ d(t)$) is calculated by

$$F_i^d(t) = \sum_{j \in kbest,\ j \neq i}^{\mathrm{N}} m(t) \tag{17}$$

where, rand_j is a random number between interval [0, 1] and K_{best} is the set of first K agents with the best fitness value having bigger mass. The force acting on the i^{th} mass ($M_i(t)$) from the j^{th} mass ($M_j(t)$) at the specific iteration t is described according to the gravitational theory as follows.

$$F_{ij}^{d}(t) = G(t)\frac{Mpi(t) \times Mqj(t)}{Rij(t) + \varepsilon}(x_j^d(t) - x_i^d(t)) \tag{18}$$

(vi) **Calculation of Acceleration and Velocity:** In this step, the acceleration ($a_i^d(t)$) and velocity ($v_i^d(t)$) of the ith agent at iteration t in d^{th} dimension are calculated through law of gravity and law of motion as follows.

$$a_i^d = \frac{F_i^d(t)}{Mii(t)} \tag{19}$$

where, rand_i is the random number between interval [0,1]

(vii) **Update the Position of Agent:** In this step the next position of the i^{th} agents in d^{th} ($x_i(t+1)$) dimension are updated as follow:

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \tag{20}$$

(viii) **Process Repeat:** In this step, steps from 2 to 7 are repeated until the iterations reach the criteria. In the final iteration, the algorithm returns the value of positions of the corresponding agent at specified dimensions. This value is the global solution of problem of optimization.

2. PROBLEM FORMULATION

Objective economic dispatch is to find optimal combination of generators output powers so as to minimize the total fuel cost while all generating units with satisfaction of operating constraints with meeting the total load demand of power system. Economic load dispatch with optimization results are interesting area to research. In scheduling we also can use these, hence proper algorithm is required for reducing the cost. The ELD is to minimize the total generation unit cost mathematical as the sum of the cost function of each generator.

$$\min F_t = \sum_{i=1}^{N} F_i(P_i)$$

where, F_t is fuel cost for the generator units 'i', N is number of generators, P_i the generation output of i^{th} generator.

(i) The fuel function is usually approximated by a quadratic function as:

$$F_i = a_i \times P_i^2 + b_i \times p_i + C_i$$

a_i, b_i, C_i are the fuel cost coefficients of the i^{th} generator.

(ii) Valve point effects are where input and out curve is non linear. With the valve point effect we are having sine function through which we can modify the above cost function.

$$F_i(P_i) = a_i + b_i p_i + c_i P_i^2 + |e_i \sin f_i(P_i^{\min} - p_i)|$$

e_i, f_i coefficient of generator i, reflecting the valve point.

(iii) Emission function of a generator is defined by quadratic function of output power.

$$E_i(p_i) = d_i P_i^2 + e_i p_i + F_i$$

where, d_i, e_i, f_i are the emission coefficient of unit i.

Hence proper algorithm is required for reducing the cost. The GSA plays a vital/important role for this optimization of these 13 generation units. So, as to get minimum fuel cost at requires demand of power.

3. RESEARCH METHODOLOGY

To minimize the overall cost of different number of generation units using valve point effect with the help of gravitational search algorithm by simulation/MATLAB. Here using improved gravitational search algorithm because considering the constraint optimization with limit considerations which means if the solution moves to space which is non feasible than it broad back to the feasible space using conditions named reflection. The target is to implement partial search algorithm in which optimal capacity of the generating units will found in multi-generating unit system. The system of different number of generator sets would be taken so that the algorithm is tested for different datasets.

(i) To make the programme or we can say that we are simulating different number of generation units to get minimum values of cost function.

(ii) In this we can doing broad back the solution from non feasible to feasible space using reflection conditions.

(iii) To make the generation units less costly for required power to the customers with the help of GSA coding.

(iv) It will give the optimal solution of economic load dispatch with minimum number of iteration.

(c) To get the high performance value to solve non linear functions.

4. RESULTS AND DISCUSSION

The above table data is used for coding in MATLAB, to minimise the cost function of 13 generation units by using GSA algorithm. Where B is the minimum rating of power and C is the maximum rating of power C,D are coefficients E is the different values of α.

Table 1
Data for 13 generator units

	A (no. of units)	*B (pmin)*	*C (pmax)*	*D*	*E*	*F*	*G*	*H*
1.	1	0	680	550	8.1	0.00028	300	0.035
2.	2	0	360	309	8.1	0.00056	200	0.042
3.	3	0	360	307	8.1	0.00056	200	0.042
4.	4	60	180	240	7.74	0.00324	150	0.063
5.	5	60	180	240	7.74	0.00324	150	0.063
6.	6	60	180	240	7.74	0.00324	150	0.063
7.	7	60	180	240	7.74	0.00324	150	0.063
8.	8	60	180	240	7.74	0.00324	150	0.063
9.	9	60	180	240	7.74	0.00324	150	0.063
10.	10	40	120	126	8.6	0.00284	100	0.084
11.	11	40	120	126	8.6	0.00284	100	0.084
12.	12	55	120	126	8.6	0.00284	100	0.084
13.	13	55	120	126	8.6	0.00284	100	0.084

The output power demand and the fitness function or cost function given by convergence graph after simulation:

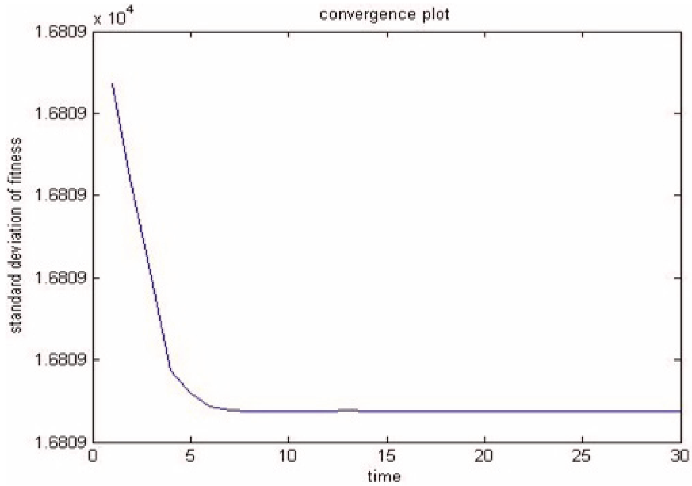

Figure 4: Convergence plot for fitness Vs time

The plot shows the maximum and minimum limits of fitness function considering effect of valve point. First the fitness is high as the iteration process the plot is decreasing and after few no. of iteration it is having constant value.

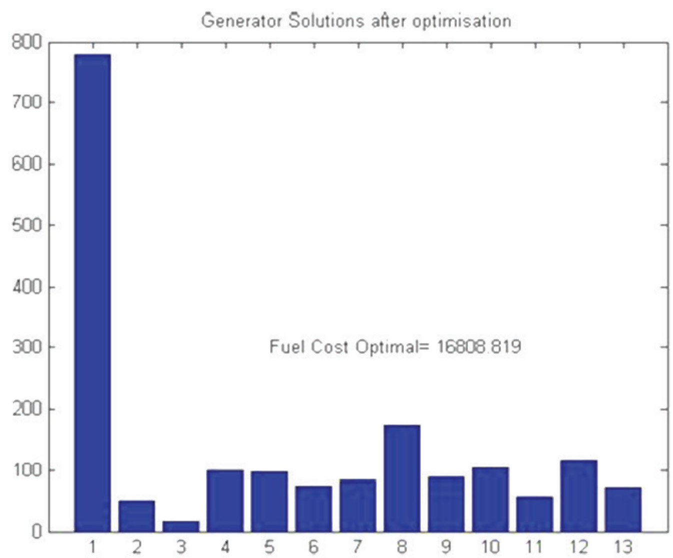

Figure 5: Optimal plot of 13 generating units

As the figure shows the optimal capacity of the generating units of each generator sets it can be observed each unit is within the minimum and maximum limits and follows the equality constraints also.

From the above simulation results we have following observation:

After implemented command in MATLAB for one case of economic load dispatch to access efficiently of the given algorithm has been 13 generation unit (thermal). In this we are using reflection method to convert non feasible solution into feasible solution. The objective function is non convex because valve point effect are taken. The inputs for 13 generation systems are taken. In this the output power 1800 MW. These results the generation cost is minimum.

P_i = 1, ..., 13 units with no transmission loss.

This shows GSA the cost is 16808.819 \$/hr succeed to finding the better solution with less no. of iterations which is 30.

5. CONCLUSION

Different types of calculation or techniques discussed with other basic advancement methods to enhance their execution when connected to EED issues and acquire better results. The multi objectives i.e. cost and emissions are conflicting. We are using the reflection method in which solution becomes feasible. The target is to implement a meta-heuristic algorithm which will be able to discover the power of the generating units which are optimal, in multi-generating unit system. The system of different number of generator sets would be taken so that the algorithm is tested for different datasets. In future, GSA may be the best solution for meeting the demand of coming years in power system optimization to reduce fuel cost. It is a multi target enhancement issue with conflicting destinations objective that emission minimization is conflicting with least cost of generation. The algorithm provides the optimal value of cost for less no. of iteration and can use for any data set it will give best solution for the given problems. In future we can improve this algorithm also can compare this method with existing methods.

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