ECONOMIC LOAD DISPATCH USING SIMULATED ANNEALING ALGORITHM

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Abstract - *Economic load dispatch is the process of allocating the required load demand between the available generating units such that the cost of operation is minimized. There have been many algorithms proposed for economic dispatch such as genetic algorithm, particle swarm optimization, and differential evolution. Out of which a simulated annealing (SA) was found to be one of the best methods that is discussed in this paper. Simulated Annealing (SA) algorithm for optimization inspired by the process of annealing in thermodynamics to solve economic load dispatch (ELD) problems. The proposed approach is found to provide the optimal results while working with operating constraints in the ELD and valve point loading effects. In this paper the efficiency for the three (3) generators and forty (40) generators is tested by MAT Lab coding. Also it is further extended for fifty (50) generators.*

Key Words: *Thermodynamics, Simulated Annealing, Economic load dispatch*

1. INTRODUCTION

Economic operation is very important for a power system to get profits on the capital invested. Operational economics involving power generation and delivery can be sub divided into two parts: minimization of power production cost called economic load dispatch and minimization of transmission losses. Thus in general, economic dispatch is the method of determining the most efficient, low-cost and reliable operation of a power system by dispatching the available electricity generation resources to supply the load on the system. The primary objective of economic load dispatch is to minimize the total cost of the generation while honoring the operational constraints of the available generation resources. The objective of ELD in a power system is to discover the best possible combination of power output for all generating units which will minimize the total fuel cost as well as satisfying the load and operational constraints. The ELD problem is extremely complex to work out because of its large dimension, a non- linear objective function and various constraints. Several analyses on the ELD has been carried till now suitable improvements in the unit output scheduling can contribute to significant cost savings.

Therefore the simulated annealing (SA) is the proposed way so as to estimate the efficiency of the generators. So that the load that is to be shared to the generators in an economic way resulting in the reduction of economic load dispatch problems. The proposed approach is found to provide optimal results while working with the operating constraints in the ELD and valve point loading effects. In order to prove the robustness of the algorithm it is investigated on different standard test cases consisting of 3, 40, 50 generating unit systems.

2 ECONOMIC LOAD DISPATCH FORMULATIONS

As we mentioned before, the objective of ELD problem is to minimize the total generation cost with a specific period of operation so as to accomplish optimal generation dispatch among their generation units. They simultaneously meet the system load demand and the other generator optional constraints.

The objective function to the generation cost can be approximated described as a quadratic function as follows:

$$F_{cost} = \min(\sum_{i=1}^{N} F_i(\mathrm{P}_i)) = \min(\sum_{i=1}^{N} a_i P_i^2 + b_i P_i + c_i)$$

Where in the equation 'P_i' is the real power output of 'i^{th}' generator and a_i, b_i, c_i are the cost coefficients of the generator cost function and $F_i(P_i)$ is the corresponding cost function. N is the number of the generating units. The ELD problem consists of minimizing F_{cost} subjected to the following two constraints.

2.1 GENERATION CAPACITY CONSTRAINTS:

For normal system operations, the real power output of each generating unit should be restricted by its upper limit and lower limits as follows:

$$P_i^{\min} \le P_i \le P_i^{\max}$$

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Where $P_i^{\min}$ and $P_i^{\max}$ are the minimum and maximum power generated by the i^{th} generator respectively.

2.2 POWER BALANCE CONSTRAINTS:

The total power generation must cover the total demand and the real power loss in the transmission lines. The relation can be described as follows.

$$\sum_{i=1}^{N} P_i = P_D + P_L$$

Where P_D , P_L is the total system load loss, and in addition, the transmission loss P_L is expressed using B co-efficients.

3.OPTIMIZATION USING SIMULATED ANNEALING:

3.1ANALOGY TO SIMULATED ANNEALING:

The simulated annealing algorithm was originally inspired from the process of annealing in the metal works. Annealing involves heating and cooling a material to alter its physical properties due the changes in the internal structure. As the metal cools its new structure becomes fixed, consequently causing the metal to retain its newly obtained properties. There is a significant co-relation between the terminology of thermodynamics annealing process and the combinatorial optimization as the following figure shows:

Thermodynamic Annealing	Simulated Annealing
System State	Feasible Solutions
Energy	Cost
Change of State	Neighbouring Solutions
Temperature	Control Parameters
Frozen State	Heuristic Solutions

3.2 CRITICAL PARAMETERS OF SA ALGORITHM:

There are four control parameters in the simulated annealing process:

- Initial Temperature
- Final Temperature
- Temperature Decrement Rate
- Iteration parameter

Firstly, in simulated annealing we will keep a temperature variable to simulate the heating process. We initially set it as initial temperature and then let it slowly cool down as the algorithm runs. At the beginning, initial temperature should be set at a higher value, and then thus the algorithm will be allowed with more frequency to accept the solutions that are worse than our current solution. This gives the algorithm the ability to jump out of any of the local optimum value; it finds itself in early on N execution.
cooling process is what makes the simulated annealing algorithm remarkably effective at finding a value close to optimal value when dealing with the large problems which contain numerous local optimum values. And the stopping criterion is set as final temperature.

Thirdly, as initial and final temperatures have predefined values, it is also important to find a different method of transition from the beginning to the end as well as the maximum price happened at each temperature value which is implemented as iteration parameter. And there are two mainly and widely used decrement method:

1. T (t) =d/log(t)
2. T (t+1) =aT(t)

Where in the first method, d is a positive method and in second, a is a constant close to 1, whose effective range is 0.8 ~ 0.99.

4. ADVANTAGES OF SIMULATED ANNEALING:

When there is a large number of local optimal values which are available in the system, then it increases the complexity of finding the optimal point. So the main task in the optimization is to achieve fast convergence as well as good exploration capacity. Apart from the above there are a few advantages of simulated annealing. They are as follows:

i. Simulated Annealing doesn't need large memory for computations

ii. It is quite robust with respective to non-quadratic surfaces

Simulated algorithm has very limited assumptions when solving optimization problem

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SA ALGORITHM IMPLEMENTATION:

According to the content introduced in the above, we consider the SA algorithm as the following:

SIMULATED ANNEALING ALGORITHM

1. Choose an initial temperature T, final temperature T`, a decrement parameter b and the iteration values C_i.
2. Set he iteration counter C to zero (0).
3. Generate an initial solution S_i randomly and compute its cost function F_{cost} (S_i).
4. Generate an adjacent solution S_j randomly and compute its cost function F_{cost} (S_j).
5. If $F_{\cos t}(S_j) \le F_{\cos t}(S_i)$ then accept the new solution, if $F_{\cos t}(S_j) > F_{\cos t}(S_i)$ then let $\Delta S = F_{\cos t}(S_j) - F_{\cos t}(S_i)$, generate a random number $\omega \in (0,1)$ and accept it if $e^{-\Delta S/T} \ge \omega$. If there is an accepted new solution, replace the initial one with the new.
6. Decrease the temperature T (t)=b*T(t-1).
7. If $T \le T^{'}$ then Algorithm ends. If $T \ge T^{'}$ then turn back to step 4 and repeat.

RESULTS:

The proposed SA based approach has been developed and implemented by using the MATLAB software. In order to investigate the robustness of the proposed method we experimented with three standard test cases. They are 3, 40 and 50 unit systems with a varying percentage of the maximum power as demand and large system consisting of 50 generating units.

Set up	P_{min}	P_{max}	a_i	b_i	c_i
Unit 1	36	114	0.0069	6.73	94.705
Unit 2	36	114	0.0069	6.73	94.705
Unit 3	60	120	0.0203	7.07	309.54
Unit 4	80	190	0.0094	8.18	369.54
Unit 5	47	97	0.0114	5.35	148.89
Unit 6	68	140	0.0114	8.05	222.33
Unit 7	110	300	0.0036	8.03	287.71
Unit 8	135	300	0.0049	6.99	391.98
Unit 9	135	300	0.0057	6.6	455.76
Unit 10	130	300	0.0061	12.9	722.82
Unit 11	94	375	0.0052	12.9	635.2
Unit 12	94	375	0.0057	12.8	654.69
Unit 13	125	500	0.0042	12.5	913.4
Unit 14	125	500	0.0075	8.84	1760.4
Unit 15	125	500	0.0071	9.15	1728.3
Unit 16	125	500	0.0071	9.15	1728.3
Unit 17	220	500	0.0031	7.97	647.83
Unit 18	220	500	0.0031	7.97	647.83
Unit 19	242	550	0.0031	797	647.83
Unit 20	242	550	0.0031	7.97	647.83
Unit 21	254	550	0.003	6.63	785.96
Unit 22	254	550	0.003	6.63	785.96
Unit 23	254	550	0.0028	6.66	795.93
Unit 24	254	550	0.0028	6.66	794.53
Unit 25	254	550	0.0028	7.1	801.32
Unit 26	254	550	0.0028	7.1	801.32
Unit 27	10	150	0.5212	3.33	1055.1
Unit 28	10	150	0.5212	3.33	1055.1
Unit 29	10	150	0.5212	3.33	1055.1
Unit 30	47	97	0.0114	5.35	148.89
Unit 31	60	190	0.0016	6.43	222.92
Unit 32	60	190	0.0016	6.43	222.92
Unit 33	60	190	0.0016	6.43	222.92
Unit 34	90	200	0.0001	8.62	116.58
Unit 35	90	200	0.0001	8.62	116.58
Unit 36	90	200	0.0001	8.62	116.58
Unit 37	25	110	0.0161	5.88	307.45
Unit 38	25	110	0.0161	5.88	307.45
Unit 39	25	110	0.0161	5.88	307.45
Unit 40	242	550	0.0031	7.97	647.83
Unit 41	10	150	0.5212	3.33	1055.1
Unit 42	10	150	0.5212	3.33	1055.1
Unit 43	47	97	0.0114	5.35	148.89
Unit 44	47	97	0.0114	5.35	148.89
Unit 45	47	97	0.0114	5.35	148.89
Unit 46	25	110	0.0161	5.88	307.45
Unit 47	25	110	0.0161	5.88	307.45
Unit 48	36	114	0.0069	6.73	94.705
Unit 49	50	200	0.0048	7.97	78
Unit 50	50	200	0.0048	7.97	78

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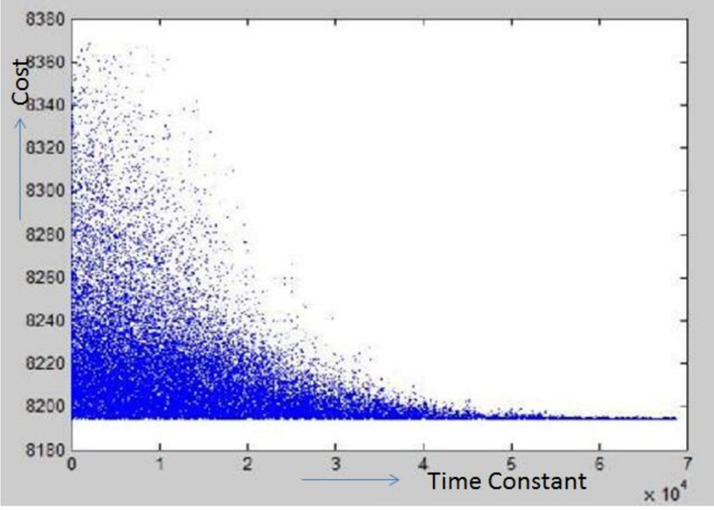

NOMENCLATURE:

F_{cost} : Total power production cost

$F_i(P_i)$: Fuel cost corresponding to the i^{th} generator for output power P_i.

a_i, b_i , c_i : Cost coefficient of i^{th} generator

P_i : Real power output (MW) of the i^{th} generator corresponding to time period t.

P_D : power demand.

P_L : power loss

P_i^{max} : Upper bound for the power outputs of the i^{th} generator unit.

P_i^{min} : Lower bound for the power outputs of the i^{th} generator unit.

CONCLUSION:

This paper has proposed the SA algorithm for the ELD problems, a stochastic optimization technique based on the process of annealing in thermodynamics is presented. In this work we have investigated the potential of the SA algorithm in solving particularly non smooth cost functions of the generators without considering the losses. The ELD problem has become a very important issue with the depleting reserves of coal and the increasing fuel prices. An appropriate planning and scheduling of the available generating units may save millions of dollars per year in production cost. First this study was carried out to determine the optimal values of the tuning parameters of the SA and the best set of parameters were fixed for the rest of the studies. The selection of the optimum combination of the parameters for the SA algorithm is an essential task, since the success of the algorithm depends on it. The feasibility of the proposed method for solving ELD problem is verified using 3, 40, 50 generator test systems. The outcome of the analysis supports the claim that the proposed method was found to provide the better solutions that are optimal.

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BIOGRAPHIES

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