**CHAPTER 1**

**INTRODUCTION**

**1.1 GENERAL**

Economic Load Dispatch (ELD) is an important function in power system planning and Operation. ELD solutions are found by solving the conventional load flow equations while at the same time minimizing fuel costs. The resulting optimization problem has nonlinear constraints from the load flow nodal equations and simple bound constraints on the variables from the load bus voltage magnitudes. The operation cost in power systems needs to be minimized at each time via Economic Dispatch (ED). In practical power system operation conditions, many thermal generating units.

The operation cost in power systems can be minimized at each hour by economic dispatch (ED). In practical conditions of power system operation, the fuel cost function of thermal generating units those are supplied with multiple fuel sources like coal, natural gas and oil may be segmented as piecewise quadratic cost functions for representing different fuel types. The ED with piecewise fuel cost functions is to minimize fuel cost among the available fuels for each generating unit satisfying load demand and generation limits. This is a non-convex optimization problem due to containing discontinuous objective with many local optima. Therefore, the solution methods dealing with this problem has to search in a large search space for finding an optimal solution. One approach for solving the ED with units having multiple fuel options is to linearize the segments and solve them by traditional methods.

However, the solution quality obtained by the method is not high due to the linearization of the fuel cost functions. A better approach to the problem is to retain the assumption of piecewise quadratic cost functions and solve them such as hierarchical approach based the numerical method. Generally, the major problem with the numerical methods for solving this problem is their exponentially growing time for larger systems. In addition to the conventional methods, the artificial intelligence based methods are also widely applied for solving the problem.

**1.2 METHODS TO SOLVE ELD**

Lambda iteration Method

Neural Network based Technique

**1.2.1 Lambda iteration method**

The lambda iteration method is one of the methods used in solving the system lambda and optimal power dispatch of generators. Other methods include gradient method and Newton method. Lambda is the variable introduced in solving constraint optimization problem and called a Lagrange multiplier. It is important to note that lambda can be solve at hand by solving systems of equations. Lambda iteration is introduced for the sake of computing lambda and other associated variables using a computer.

Unlike usual iteration methods like gauss seidel and newton-raphson, lambda iteration is somewhat different. In gauss seidel method, for example, the next value of the unknown variables can be solve using an equation, which is usually, a function of itself. In lambda interation method, the unknown variable, lambda, gets its next value based on intuition. That is, there is no equation that computes the next iteration of lambda. It is projected by interpolating the best possible value until a spicified mismatch has been reached.

DISADVANTAGES:

* Conventional method is an iterative technique.
* Time consuming and not suitable for online applications.

**1.2.2 Artificial neural network**

An Artificial Neural Network (ANN) is a mathematical model that tries to simulate the structure and functionalities of biological neural networks. Basic building block of every artificial neural network is artificial neuron, that is, a simple mathematical model (function). Such a model has three simple sets of rules: multiplication, summation and activation. At the entrance of artificial neuron the inputs are weighted what means that every input value is multiplied with individual weight. In the middle section of artificial neuron is sum function that sums all weighted inputs and bias. At the exit of artificial neuron the sum of previously weighted inputs and bias is passing trough activation function that is also called transfer function.

ADVANTAGES:

* It can map non-linear data for any degree of accuracy.
* It is computationally less rigorous as compared to conventional method.
* Can be used on-line applications.
  1. **LITERATURE SURVEY**

1. B.Kar et al, K.K.Mandal Economic dispatch by ANN with Back prop algorithm**.**

**A** multi layered feed forward Artificial Neural Network(ANN) trained by Back-propagation algorithm is used to solve the problem of Economic and Emission dispatch. The system of generation associates with thermal generators .Equality constraints on power balance as well as inequality constraints on generation capacity limits of generators and transmission limits are also considered.

2. S.Panta et al (2007) Optimal ED for Power Generation using ANN.

Optimal Economic dispatch of electrical power plants by using back-propagation neural networks. The method of economic dispatch for generating units at different loads must have total fuel cost at the minimum point. There are many conventional methods that can use to solve economic dispatch problem such as Lambda iteration method and Newton Raphson Method, to find the optimal economic dispatch from time to time.

3. Chao –Ming Huang and Fu-Lu Wang (2007) proposed Radial basis neural network for ELD.

Conventionally electric power plants are operated based on minimizing operational constraints while meeting diverse system constraints. To speed up the computation effect, an adaptive learning algorithm is used for online dispatch of power from different generating stations.

* 1. **INFERENCE FROM THE LITERATURE**

Thus from the literature survey, it has understood that NN has good potential for ELD problems and it is an active area of research. This is the motivation to carry out project in this area.

**1.5 PROPOSED OBJECTIVES**

1. To propose ANN for ELD problems.
2. To investigate various types of neural architectures and learning algorithms for ELD.
3. To compare their performance in terms of accuracy, compactness and complexity.
4. To identify suitable ANN for ELD.
5. To validate results extensively using various BUS systems.

**CHAPTER 2**

**ELD USING CONVENTIONAL METHOD**

**2.1 ECONOMIC DISPATCH**

The operation of generation facilities to produce energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities.

Most electric power systems dispatch their own generating units and their own purchased power in a way that may be said to meet this definition.

The factors influencing power generation at minimum cost are :

1. operating efficiencies of generators
2. fuel cost and transmission losses

Objective function

The ED problem is formulated using Lagrange dynamics. The objective of the optimization problem is to minimize the total fuel generation cost function, so that the objective function is

) 2.1

where FT is the total generation fuel cost and it is given by FT = F1+ F2+ F3+ . . . + Fng,

Fi is the generation cost of each unit i,

Pi is the power generated by each unit i and

ng is the number of generating units.

The objective function for the ELD reflects the costs associated with generating power in the system. The quadratic cost model is used. The objective function for the entire power system can then be written as the sum of the quadratic cost model for each generator:

2.2

where ai, bi and ci are the fuel cost coefficients of the generating unit i.

**2.2 OPERATION CONSTRAINTS**

The operation constraints are classified into two groups. The first group is related to the design specifications of the generating units and the other physical constraints such as generation capacity, line maximum power flow, generation ramp limits, prohibited operation zones and spinning reserve. The second group defines an upper level of operation control such as unit commitment and other management plans. Here, only constraints related to the scope of the work are considered. The power plants are not located at the same distance from the center of loads and their fuel costs are different. In economic dispatch only real power scheduling of each power plant in such way as to minimize the operating cost.

**2.2.1 Equality constraints**

The generation-demand equality constraint, implies that the sum of the generated power is equal to the total load demand plus the transmission losses so that Pi.

2.3

where is the total active load demand, PLosses is the transmission losses.

The transmission losses is given in terms of Kron’s loss formula is

2.4

where , and are the transmission network power losses coefficients.

The B-loss coefficients represent the transmission line loss.

**2.2.2 Inequality constraints**

Each generating unit has minimum and maximum generation capacities so that

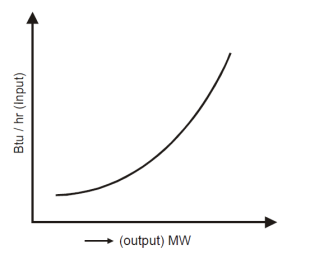
2.5

where and are the designed minimum and maximum generated power capacities of each unit i, respectively.

**2.3 PERFORMANCE CURVES**

**2.3.1 input-output curve**

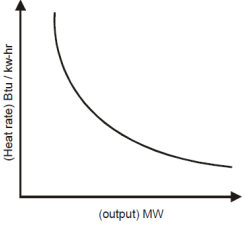
This is the fundamental curve for a thermal plant and is a plot of the input in British thermal units (Btu) per hour versus the power output of the plant in MW as shown in Figure 2.1



**Figure 2.1** **Input-output curve**

**2.3.2 Heat rate curve**

The heat rate is the ratio of fuel input in Btu to energy output in KWh. It is the slope of the input – output curve at any point. The reciprocal of heat – rate is called fuel – efficiency. The heat rate curve is a plot of heat rate versus output in MW. A typical plot is shown in Figure 2.2



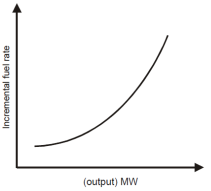
**Figure 2.2 Heat rate curve**

**2.3.3 Incremental fuel rate curve**

The incremental fuel rate is equal to a small change in input divided by the corresponding change in output.

2.6

The unit is again Btu / KWh. A plot of incremental fuel rate versus the output is shown in Figure 2.3



**Figure 2.3 Incremental fuel rate curve**

**2.4 THE LAMBDA ITERATION METHOD OF SOLVING OPTIMAL POWER DISPATCH**

The discussion on how to set up and solve the optimal power dispatch and system lambda using lambda iteration method. To make the concept simple and explainable through words without using illustrations and equations, we simply neglect the effect of power losses in the formulation.

Setting up the equations:

1. Formulate the Lagrange function. Lagrange function is simply the objective function, in this case - minimize the fuel cost, plus the equality constraint - total power generated equals the total load, multiplied by lambda, plus the inequality constraint which will contain the multiplier mu.
2. Find the partial derivatives of the lagrange function with respect to each power generation and lambda.
3. After doing the calculus, you should come up with an equation of power generations as a function of lambda.

**2.5 ITERATION METHOD**

Before going to the iteration process, we will first assume that there is no violation of power generation limit. Using this assumption the power generation or dispatch will now only a function of lambda because mu’s are zero if there is no violation of power dispatch limit.

Step 1: Set any value of lambda.  
Step 2: Solve for the value of power generation or dispatch using the equation of power that we have formulated earlier.  
Step 3: Compute the mismatch or the absolute value of the difference between the actual load and the sum of the computed power generations.

If the sum of the power generation is too large compared with the actual load, try so set another value of lambda that, depending on the equations for power, lower the sum of the power generations compared with the load.

Using this technique, you will have an idea on what the value of lambda that is that will make the total power generations equal to the system load and thereby solved the optimal power dispatch. This is how the iteration goes. You will have to project, through interpolation, the value of lambda.

If a violation of generation limit has occurred. That limit will be automatically the dispatch power of that generator and what we only need to solve is the dispatch of other generators. In this case, the lambda of that generator that violates its limit is not equal to the system lambda.

**2.6 SIMULATION AND RESULTS**

Two test bus systems are considered in this thesis. They are simple 3 bus system and complex 26 bus system. The Lambda iteration method is used to solve ELD for the chosen Bus Systems.

**2.6.1 Case study 1**

ITERATION METHOD FOR THREE BUS SYSTEM:

For a three bus system the cost functions as given below are

C1=200+7.0P1+0.008 P12 (10MW ≤ P1 ≤ 85MW)

C2=180+6.3P2+0.009 P22 (10MW ≤ P2 ≤ 80MW)

C3=140+6.8P3+0.007 P32 (10MW ≤ P3 ≤ 70MW)

With PL=0.000218 P12+0.000228P22+0.000179P32

Determine the optimal dispatch of generation for different power demands?

Inputs are taken as power demand and outputs are generation and losses (P1, P2, P3 and losses)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PD (MW) | 150 | 160 | 170 | 180 | 190 | 200 |
| P1 (MW) | 35.099 | 38.44 | 41.8 | 45.17 | 48.6 | 51.95 |
| P2 (MW) | 64.13 | 67.11 | 70.1 | 73.08 | 76.12 | 79.09 |
| P3 (MW) | 52.47 | 56.33 | 60.22 | 64.089 | 68.033 | 71.89 |
| PL (MW) | 1.699 | 1.916 | 2.15 | 2.397 | 2.671 | 2.93 |

**Table 2.1 Optimal dispatch for different power demands for a 3 bus system**

**2.6.2 Case study 2**

For 26 bus systems with 6 generating units

C1=240+7.0 P1+0.007 P12  (100MW ≤ P1 ≤ 500MW)

C2=200+10 P2+0.0095 P22 (50MW ≤ P2 ≤ 200MW)

C3=220+8.5 P3+0.009 P32 (50MW ≤ P3 ≤ 300MW)

C4=200+11 P4+0.009 P42  (50MW ≤ P4 ≤ 150MW)

C5=220+10.5 P5+0.008 P52  (50MW ≤ P5 ≤ 200MW)

C6=190+12 P6+0.0075 P62 (50MW ≤ P6 ≤ 120MW)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PD (MW) | 1150 | 1200 | 1250 | 1300 | 1350 |
| P1 (MW) | 414.9 | 424.5 | 433.96 | 442.9 | 463.04 |
| P2 (MW) | 156.63 | 163.9 | 171.14 | 178.5 | 188.81 |
| P3 (MW) | 248.5 | 256.2 | 264.2 | 272.1 | 283.2 |
| P4 (MW) | 112.6 | 120.5 | 128.32 | 136.3 | 147.98 |
| P5 (MW) | 159.36 | 168.3 | 177.17 | 186.3 | 198.84 |
| P6 (MW) | 68.68 | 78.06 | 87.4 | 97.06 | 111.05 |
| PL (MW) | 10.72 | 11.7 | 12.31 | 13.41 | 14.95 |
| COST ($/Hr) | 13936.6 | 14601.1 | 15268.3 | 15949.4 | 17022.4 |

**Table 2.2 Optimal dispatch for different power demands for a 26 bus system**

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