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OPTIMAL POWER SYSTEM ANALYSIS USING MATLAB

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Abstract:

Power disaster is one of the most important issues of concern all over the world today. The production is not enough to meet the demands of customers. Under these conditions the power system should be efficient in Economic Load Dispatch which minimizes the total generating price. This Work shows the optimal system Operation using MATLAB. The Optimal economic operation of their electric networks while considering the challenges of increasing fuel costs and increasing demand for electricity. The economic dispatch (ED) occupies significant position in a power system's operation and control. The purpose 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 proposed method will be tested in a 3 unit system using MATLAB.

Key Words: Economic Load Dispatch (ELD), Economic Dispatch (ED) & Optimal Power Flow (OPF)

1. Introduction:

The Optimal Power system is the backbone of power system analysis and design. Power systems need to be operated economically to make electrical energy cost-effective to the customer in the face of constantly increasing prices of fuel, wages, salaries, etc. New generator- turbine units added to steam power plant operate more efficiently than other older units. The contribution of newer units to the generation of power will have to be more. In the operation of power systems, the contribution from each load and from each unit within a plant must be such that the cost of electrical energy produced is a minimum [1]. Scheduling is the process of allocation of generation among different generation units. Economic scheduling is a cost-effective mode of allocation of generation among the different units in such a way that the overall cost of generation should be minimum [3]. This can also be termed as an optimal dispatch. The Optimization problem is to assign the total load demand on the station PD among the 'n' no. of generating units in an best way to decrease the overall cost of generation. Let PG1, PG2, PG3,……..,PGn be the power generated by each individual unit to supply a load demand of PD. To formulate this problem, it is necessary to know the 'input-output characteristics of each unit'.

2. Load Dispatching:

The operation of a modern power system has become very complex. It is necessary to maintain frequency and voltage within limits in addition to ensuring reliability of power supply and for maintaining the frequency and voltage within limits it is essential to match the generation of active and reactive power with the load demand. For ensuring reliability of power system it is necessary to put additional generation capacity into the system in the event of outage of generating equipment at some station. Over and above it is also necessary to ensure the cost of electric supply to the minimum. The total interconnected network is controlled by the load dispatch centre. The load dispatch centre allocates the MW generation to each grid depending upon the prevailing MW demand in that area.[4] Each load dispatch centre controls load and frequency of its own by matching generation in various generating stations with total required MW demand plus MW losses. Therefore, the task of load control centre is to keep the exchange of power between various zones and system frequency at desired values.

2.1 Generator Operating Cost:

The total cost of operation includes the fuel cost, cost of labour, supplies and maintenance. Generally, costs of labour, supplies and maintenance are fixed percentages of incoming fuel costs. The operating cost of the plant has the form shown in Figure 2.1For dispatching purposes, this cost is usually approximated by one or more quadratic segments. So, the fuel cost curve in the active power generation, takes up a quadratic form, given as:

$$F(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \text{ Rs/hr}$$

Where,

a_i, b_i ,c_i are cost coefficients for i^{th} unit
$F(P_{gi})$ is the total cost of generation
P_{gi} is the generation of i^{th} unit

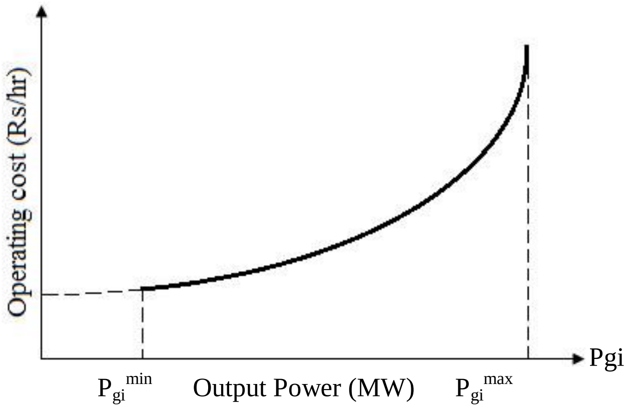

Figure 2.1: Operating Cost Curve

The P_{gi}^{min} is the minimum loading limit below which, operating the unit proves to be uneconomical (or may be technically infeasible) and $P_{gi}^{max}$is the maximum output limit.

3. Optimal Power Flow:

3.1 DC Optimal Power Flow (DC-OPF):

ELD is the simplest planning method and it is used for long-term planning purposes. Most of the system constraints are not considered in ELD. The OPF problem seeks to control generation/consumption to optimize certain objectives such as minimizing the generation cost or power loss in the network. Each load or generation point of power system is called a "bus" and different buses are connected together with transmission lines. Indeed the transmission lines have resistance and reactance which cause power loss. Considering all the system parameters, the optimization constraints are non-linear equations. To clarify different power system parameters, a simple 3 bus system. Two types of power exist in power system, Active power and Reactive power. Active power relates to the resistive loads like electric heaters, lamps, and etc. Reactive lodes are related to motors and rotational loads. Transmission line parameters include resistance and inductance. Transmission line resistance results in active power loss and inductance result in reactive power loss. Nonlinear AC-OPF problems are approximated by linearized DC-OPF problems to obtain real power solutions. In DC-OPF, we ignore the line resistances and reactive power flow in the system. Since the transmission line resistances are considered to be zero, all the voltage magnitudes throughout power system are equal to the nominal voltage of the system. The voltages are only different in phase angles.

3.2 AC Optimal Power Flow (AC-OPF):

The AC-OPF is at the soul of power system operation; it is being done by system operator and is solved form every day for day-ahead markets, every hour, and even every 5 minutes. Optimal power flow is sometimes referred to as security-constrained ED. In DC-OPF, assumes all voltage magnitudes are fixed; indeed, DC-OPF is a linearized form of a full AC-OPF.

4. Problem Formulation:

The simplest ELD problem is the case when transmission line losses are neglected. Due to this the total demand P_D is the sum of all generations. A cost function $F_i(P_{gi})$ is assumed to be known for each plant [2]. The problem is to find the real power generation, P_{gi} for each plant such that the total operating cost $F(P_{gi})$ is minimum and the generation remains within the lower generation P_{gi}^{min} and upper generation P_{gi}^{max}. Suppose there is a station with NG generators committed and the active power load demand P_D is given, the real power generation P_{gi} for each generator has to be allocated so as to minimize the total cost.[5] The optimization problem can be therefore be stated as

$$\text{Minimize:}\quad F(P_{gi}) = \sum_{i=1}^{NG} F_i(P_{gi})$$

4.1 Equality Constraints:

The energy balance equation $\sum_{i=1}^{NG} P_{gi} = P_D$

4.2 Inequality Constraints:

The inequality constraints $P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max}$ (i=1,2,…………….,NG)

Where,

Pgi is the decision variable, i.e. real power generation at bus i
PD is the real power demand
Ng is the number of generation plants
Pgimin is the lower permissible limit of real power generation

Pgimax is the upper permissible limit of real power generation
Fi(Pgi) is the operating fuel cost of the ith plant and is given by the quadratic equation
Fi(Pgi) =aiPgi2 + biPgi + ci Rs/hr (1)

The above constrained optimization problem is converted into an unconstrained optimization problem. Lagrange multiplier is used in which a function is minimized (or maximized) with side conditions in the form of equality constraints. Using the method an augmented function is defined as

$$L(P_{gi},\lambda)=F(P_{gi})+\lambda(P_D-\sum_{i=1}^{NG}P_{gi})$$

Where λ is the Lagrange multiplier (LM)

A necessary condition for a function F(Pgi) , subject to energy balance constraint to have a relative minimum at point Pgi* is that the partial derivative of the Lagrange function defined by L = L(Pgi , λ)with respect to each of its arguments must be zero. So, the necessary conditions for the optimization problem are

$$\frac{\partial L(P_{gi,}\lambda)}{\partial P_{gi}}=\frac{\partial F(P_{gi})}{\partial P_{gi}}-\lambda=0 \qquad (i=1,2,\ldots\ldots\ldots\ldots..,NG) \qquad (2)$$

And

$$\frac{\partial L(P_{gi,}\lambda)}{\partial \lambda}=P_D-\sum_{i=1}^{NG}P_{gi}=0 \qquad (3)$$

From equation (2)

$$\frac{\partial F(P_{gi})}{\partial P_{gi}}=\lambda \qquad (i=1,2,\ldots\ldots\ldots\ldots\ldots,NG) \qquad (4)$$

Where $\frac{\partial F(P_{gi})}{\partial P_{gi}}$ is the incremental fuel cost of the ith generator.

Optimal loading of generators corresponds to the equal incremental cost point of all the generators. Equation (4), called the coordination equations numbering NG are solved simultaneously with the load demand to yield a solution for Lagrange multiplier λ and the optimal generation of NG generators. Considering the cost function given by Eq. (1), the incremental cost can be defined as

$$\frac{\partial F(P_{gi})}{\partial P_{gi}}=2a_iP_{gi}+b_i \qquad (5)$$

Substituting the incremental cost into equation (4), this equation becomes

$$2a_iP_{gi}+b_i=\lambda \qquad (6)$$

Rearranging Eq. (6) to get Pgi

$$P_{gi}=\frac{\lambda-b_i}{2a_i} \qquad (i=1,2,\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.NG) \qquad (7)$$

Substituting the value of Pgi in Eq. (3), we get

$$\sum_{i=1}^{NG}\frac{\lambda-b_i}{2a_i}=P_D$$

or

$$\lambda=\frac{P_D+\sum_{i=1}^{NG}\frac{b_i}{2a_i}}{\sum_{i=1}^{NG}\frac{1}{2a_i}}$$

5. Results:

The Optimal Generation at each node is formulated by using the ELD. In first stage determine the Optimal Generation at each unit and in the next stage incremental fuel cost and total generation cost is determined. This method is tested on 3 unit system.

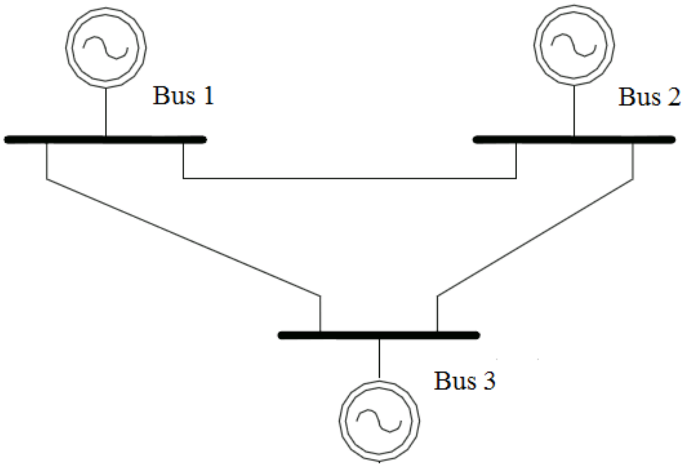

Figure 5.1 Three unit system

The 3 unit system contains of three generators shown in figure 5.1. The highest Optimal Generation is at bus number 3 which is 359.2727 MW. The Optimal cost and optimal generation is shown in Table 5.1 and Table 5.2 respectively.

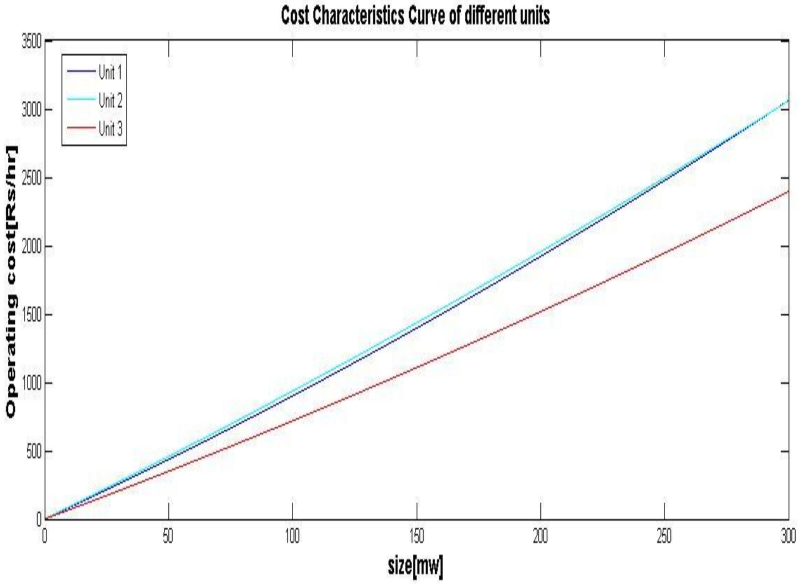

Figure 5.2 Cost Characteristic curve of 3 unit system

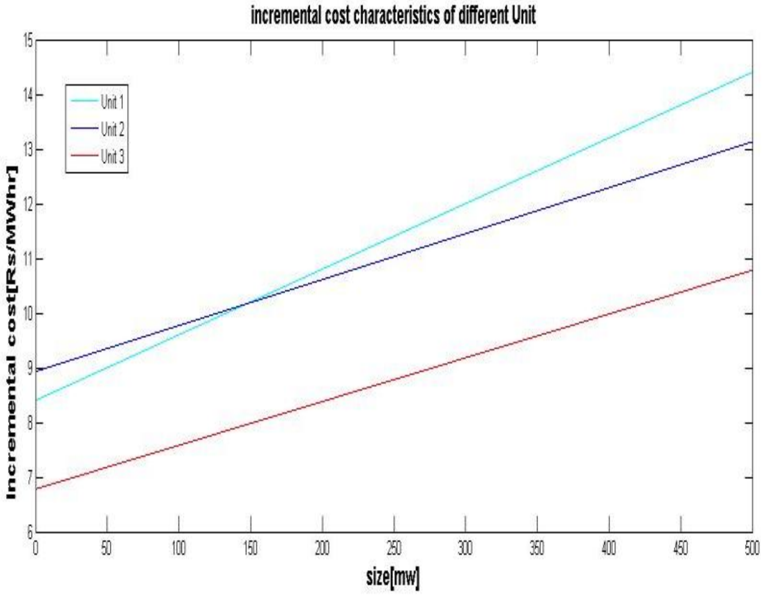

Figure 5.3 Incremental cost curve of 3 unit system

Generating Unit	Optimal Generation (MW) At PD= 550 MW	Optimal Generation (MW) At PD= 820 MW
1	104.5152	173.2424
2	86.2121	184.3939
3	359.2727	462.3636

Table 5.1: Optimal Generation Scheduling

Cost at PD = 550 MW		Cost at PD = 820 MW	
Incremental Fuel Cost (Rs./MWhr)	9.6542	Incremental Fuel Cost (Rs./MWhr)	10.4789
Total Generation Cost (Rs./hr)	6346.70	Total Generation Cost (Rs./hr)	9064.70

Table 5.2 Optimal cost at different demand

6. Conclusion:

In this paper Optimal Generation at each node is formulated by using the ELD. In first stage determine the Optimal Generation at each unit and in the next stage incremental fuel cost and total generation cost is determined. This method is tested on 3 unit system.

7. Future Scope:

An exhaustive investigation is required to study the effect of ELD. In future, to solve the ED problem with the most problematic line flow constraints, PSO Algorithm will be used which leads to more optimized solution. For handling the line flow constraints, in addition to the various optimization techniques, the Newton Raphson method (NR) will be used as well as for handling the security constraints also. Furthermore, the generating cost will be minimized and the maximize the power generation will be targeted.

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