

## Module 5 : Real and Reactive Power Scheduling

### Lecture 22 : Real Power Scheduling

#### Merit Order Dispatch

The simplest real power scheduling problem can be formulated by assuming the following:

- The generators which are "committed" are known (the issue of whether to engage a generation unit and for what duration, based on cost and prime mover/energy supply constraints is **not** considered here).
- The cost of generation (per kW-hr) for various generators is a constant.
- There are no inequality constraints considered except for the maximum power output of various generators.
- Power losses are neglected and the only equality constraint to be satisfied is that the *total load is equal to the generation*.

Now, schedule the generation so that the **cost per kW-hr is minimized**.

Let us illustrate the problem and its solution by a simple example:

Suppose there are three generators, say, G1, G2 and G3 with maximum power output of 200 MW, 250 MW and 300 MW respectively.

The cost of energy for the three generators are 2000, 3000 and 2500 Rs/ MW-hr respectively.

The total load of 550 MW is to be shared by the three generators. Find the least cost schedule.

The solution for this problem is easy. We just order the generators as per their cost and utilize the cheapest generator fully. Since the cheapest generator when load fully cannot accomodate all the load demand, the next cheapest generator is utilized to the extent that the load demand is met or upto its maximum output.

Therefore the obvious schedule is:

G1 : 200 MW, G3 : 300 MW and G2 : 50 MW.

The average cost of electricity is  $C = (200 \times 2000 + 300 \times 2500 + 50 \times 3000) / 550 = 2364$  Rs/MW-hr

#### Economic Dispatch

In the previous problem we assumed a constant cost of energy in Rs/MW-hr for the generators irrespective of the power output of generators. In actual practice, there is a fixed and variable cost component. As a result, cost is a function of power generated.

A cost function could have the form:

$$C = 40 \cdot P_1 + 5 \cdot P_1^2 \text{ Rs/hr,}$$

where  $P_1$  is the actual power generated.

Consider two generators with the following cost functions:

$$C_1 = 50 \cdot P_1 + 3 \cdot P_1^2$$

$$C_2 = 50 \cdot P_2 + 2.5 \cdot P_2^2$$

Let us assume that the generators (G1 and G2) do not have any maximum limits. Find the least cost schedule.

Total cost is given by :  $C_1 + C_2$  which is to be minimized.

subject to  $P_1 + P_2 = 550$

We shall soon learn a formal (generalized) mathematical procedure to solve this problem. However we shall try to solve the problem in an informal way now.

Since  $P_1 + P_2 = 550$ ,  $P_1 = 550 - P_2$ . Substituting this in the cost equation we obtain:

$$C = C_1 + C_2 = 50 * P_1 + 3 * P_1^2 + 50 * (550 - P_1) + 2.5 * (550 - P_1)^2$$

This yields,  $C = C_1 + C_2 = (50 * 550 + 2.5 * (550)^2) - 2.5 * 2 * 550 * P_1 + 5.5 * P_1^2 = 783750 - 2750 * P_1 + 5.5 * (P_1)^2$

The cost will be minimum when  $dC/dP_1 = 0$ . Therefore, we obtain  $2750 = 11 * P_1$  which results in  $P_1 = 250$  MW.  $P_2$  consequently is 300 MW.

Total cost is  $C = \text{Rs } 4,40,000$  /hr.

The *price* of electricity for a consumer in Rs per MW-hr is Total Cost / Total Demand =  $C/550 = \text{Rs } 800$  /MW-hr.

It is interesting to note here that  $dC_1/dP_1$  evaluated at  $P_1 = 250$  MW equals Rs 1550 /MW-hr

and  $dC_2/dP_2$  evaluated at  $P_2 = 300$  MW equals Rs 1550 /MW-hr. Both are equal! Is this a coincidence?

## Economic Dispatch : Some Issues

In the previous slide we have not considered several major complicating factors in the economic dispatch, viz, limits on the generator power output, power losses etc. However, even if we are blind to these complications for the time being, we can consider some issues about pricing of power.

In a vertically integrated utility wherein a single entity has full control of all aspects of generation, transmission and distribution, a system operator who performs economic dispatch obtains the actual cost functions of various generators (including fixed and variable costs - and allowing for a certain *regulated* rate of return on investment or profit).

Utilising economic dispatch, the operator tries to minimize costs and thereby minimize the price of electricity for a consumer (consumer may be charged a fixed rate based on estimates of this price over a long period).

Another situation is as follows: generation, transmission and distribution are not a part of the same utility. Generation belongs to several entities and is open to competition. In this situation, actual generation cost need not be available to a system operator. The entities who own the generators, submit their "costs" as a function of power generated. These "costs" are not necessarily the true costs (including the *regulated* rate of return on investment). In other words, the generation owners can decide their own profits! However, if the price of generation is not competitive (i.e. it is too costly), then less power will be scheduled from that generator. Therefore, market forces determine the price of electricity. This, of course will work only if total generation is more than the load demand and other constraints on scheduling (like power flow limits on transmission lines) do not apply.

The overall objective is still the same: to deliver power to a consumer at the minimum price while satisfying various constraints (including serving a given load demand). It is assumed here that all loads buy power at the same price. It may be also possible for independent generators and loads to have independent bilateral contracts at a pre-determined price.

Another assumption is that load demand is given and is independent of the final price which is obtained after the optimization. Actually, load demand can be a function of this price. If the price of electricity is too high some consumers are likely to reduce their demand for power (this is also known as *demand elasticity*).

## Recap

In this lecture you have learnt the following

- How does one schedule generation so as to obtain minimum cost ?
- Two simple examples relating to economic dispatch.
- Some issues in power pricing

Congratulations, you have finished Lecture 22. To view the next lecture select it from the left hand side menu of the page.