**Economic Operation and Control of Power System**

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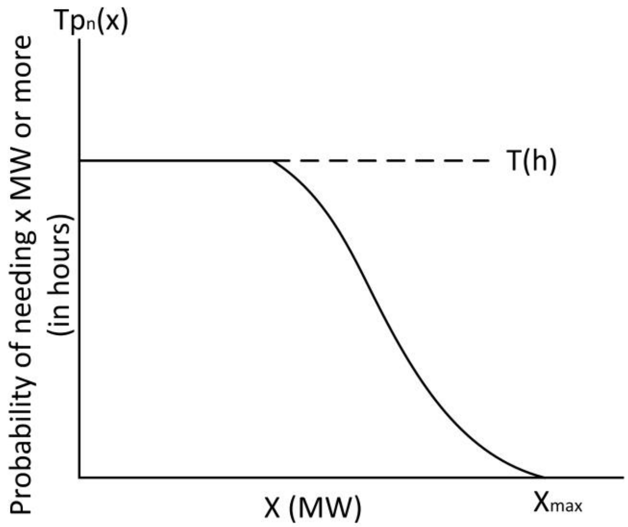
**Week - 06**

**Lecture – 30**

Very good morning. Welcome you all to this NPTEL course on Economic Operation and Control of Power Systems and we are discussing lecture number 30, where we will be talking about certain practical problem applications based on our earlier understanding on economic dispatch. And probability theory. Now to understand more on outages, unrealistic load characteristics, probabilistic and expected economic dispatch solutions, we have to consider one example to make it easy for us to understand applications of expected cost methods as well as unserved cost methods. The example here illustrates the simplicity of the basic computation of the scheduling technique used in this type of probabilistic production cost program, where the load is modeled using a discrete tabular format. Now there are detailed complications, extensions and exceptions that arise in the practical implementation of any production cost techniques.

We have gone through two different production cost techniques and let us see how this can be applicable to a practical problem in real life. Now let us focus on figure and it very clearly shows the probability of needing the probability of needing X megawatt or more versus the load. Now here you can see that the time for example, if the load is going to be very, very high, then the probability of needing X megawatt or hour or more become very, very less. Now if the load is going to be less, the load is going to be less, then the probability of having or needing X megawatt or more will be naturally for a long duration.

Now the characteristic of load curve if you see, only for a lesser duration, we need peak energy and most of the time we need base energy. So this characteristic perhaps very clearly says that if your megawatt requirement increases, that means the duration for the maximum period will be less. Am I right? So consider figure 30.1




which shows the cumulative load distribution that is a low duration curve treated as a cumulative probability distribution for an interval of T hours, for an interval of T hours. Now this characteristic one can even place it in this way or one can place in this way.

It depends whether you place X versus probability Now assume an order list of loading segments as shown in the following table for the unit number 3, 1 and 4 are to be committed initially so that the sum of their capacities at full load output equals or exceeds the peak load plus capacity required for spin reserve. So, through those units we have to commit in such a manner that the meeting my load plus the spinning reserve at a given point of time. Now you could see this is my unit number 3, unit number 1, unit number 4 and the P minimum which is 0, P maximum 20, 0 and 20 and 0 and 40 and these are the cost characteristic rupees per hour is known to me and the outages rate is now being considered. In the previous applications we never considered the outages but in this problem we are assuming that 5%, 2% outages probably maybe there. The initial availability rate is when the outages is going to be 5% then the availability is 95% if the outages is 2% then the availability is going to be 98% and so and so forth.

Now moving further there is one more interesting thing we have to Now next unit number 1, 3, 4 which has a incremental cost characteristic that is rupees per mega hour where the P minimum is going to be 20 plus and the P maximum is going to be 60 plus and similarly it is 20 to 50 and 40 to 50. Now you may be worried actually why this P max is keep on changing because there are two way of understanding. I can talk about unit number 1 which is minimum 0, maximum 20 and when I go for actually unit number 1, 2 numbers, 2 numbers of unit number 1 then the minimum is going to be 20 and the maximum is going to be 60. Similarly if you go for unit number 3, 2 numbers then it is 20 to 50 and the unit number 4, 2 numbers it is 40 to 50. So these are the ranges which are keep on changing when the number of units are more naturally the maximum limit is going to change and as well as the cost function either it could be a cost characteristic rupees per hour and either it could be an incremental cost characteristic and we can have outages rate with reference to incremental cost characteristics or we can have outages rate with respect to simple cost characteristics.

Now if you assume that two segments for each of these three units this committed total of 160 megawatt. If you go back as you could see the last three components 1, 3 and 4 60 plus 50 plus 50 that you can maximum achieve 160 megawatt at a given point of time. Now assume such a table 30.1 that includes all the units available in that sub interval the cost data for per hour and either it could be an incremental cost characteristic and we can have outages rate with reference to incremental cost characteristics or we can have outages rate with respect to simple cost characteristics. Now if you assume that two segments for each of these three units this committed total of 160 megawatt.

If you go back as you could see the last three components 1, 3 and 4 60 plus 50 plus 50 that you can maximum achieve 160 megawatt at a given point of time. Now assume such a table 30.1 that includes all the units available in that sub interval the cost data for first three loading segments are the total cost per hour at a minimum loading level of 20 plus 20 plus 40. So first three units for the first interval has been assigned to 20, 20, 40 megawatt as you have seen you could see 20, 20 and 40 right respectively and the remaining cost data are the incremental cost in rupees per megawatt hour for the particular segment. So first are the unit cost characteristics and last three are the incremental cost characteristics.

Table is also arranged in order list of loading segments where each segment is loaded generation and cost are computed and the cumulative load distribution function is convolved with that segment. There are two problems presented by this data that have not been discussed previously in our lectures. First the minimum loading section of the initially committed unit must be loaded at the minimum load points means they have to be loaded at 20, 20 or 40. For instance the minimum load of unit 4 is 40 megawatt which means it cannot satisfy load less than 40 megawatt at any given point of time. Second each unit has more than one loading segment.

Each unit has more than one loading segment that means 1, 3, 4, first 20, 20, 40 and then actually 60, 50, 50. The loading of the unit second loading segment by considering the probability distribution of unserved load after the first segment of the unit has been scheduled would violate the combinatorial probability rules that have been used to develop the scheduling algorithm since the unserved load distribution include events where the first unit was out of service. That means that is the loading of a second or later section is not statistically independent of the availability of the previously scheduled section of the particular unit. Means each one is dependent on the previous availability. If the previous fails then the second calculation also need to change.

Both these concerns requires further exploration in order to avoid the commitment of known error in the procedure. Means you have a statistical or strategy for your commitment you have done it load is being met but if something happens in between due to failure or outages then certainly your solution is not going to work properly. The situation with block loaded units or a non-zero minimum loading limit is easily handled. Suppose the unserved load distribution prior to loading such a block loaded segment is TPn(x) and the unit data are:

q = unavailability rate, per unit

p = l – q

c = capacity of segment

By block loading it is meant that the output of this particular segment is limited to exactly C megawatt. That is the non-zero minimum loading limit may be handled in a similar fashion. The convolution of this segment with T P and X now must be handled in two different parts. For load demand below the minimum output the unit is completely unavailable the way we have explained if the load is less than 40 megawatt so certainly this unit is not available for you. The load demand below the minimum output C the unit is completely unavailable for X greater than C the unit may be loaded to C megawatt. The algorithm for combining the mutually exclusive events where X or more megawatt of load remain unserved must now be performed in segments depending upon the load the load level X such that X is greater than or equal to C.

The new unserved load distribution is:

$$\mathrm{P}_{\mathrm{n}}'(\mathrm{x}) = \mathrm{q}\mathrm{P}_{\mathrm{n}}(\mathrm{x}) + \mathrm{p}\mathrm{P}_{\mathrm{n}}(\mathrm{x}+\mathrm{c})$$

that is my question number one where the period length T has been omitted for some loads X less than or equal to C. Now the unit cannot operate to supply the load because it is less than its requirement. Let P N X devote the probability density of load X in discrete form that is:

$$\mathrm{P}_{\mathrm{n}}(\mathrm{x}) = \mathrm{P}_{\mathrm{n}}(\mathrm{x}) - \mathrm{P}_{\mathrm{n}}(\mathrm{x}+ MW_{step})$$

where MWstep = uniform interval in tabulation of Pn(x). For loads equal to or greater than c, the probability of exactly x MW after the unit has been scheduled is

$$\mathrm{P}_{\mathrm{n}}'(\mathrm{x}) = \mathrm{q}\mathrm{P}_{\mathrm{n}}(\mathrm{x}) + \mathrm{p}\mathrm{P}_{\mathrm{n}}(\mathrm{x}+\mathrm{c})$$

Now these three questions are very very important for me to simulate any probabilistic based economic response solutions.

Now For loads less than c (i.e., $0 \leq x \leq c$),

$$P_n'(x) = P_n(x) + pP_n(x + c)$$

For convenience in computation, let

$$P_n(x) = (q + p)P_n(x)$$

for $0 \leq x < c$. Then for this same load range

$$P_n'(x) = qP_n(x) + pP_n(x + c) + pP_n(x)$$

Next, the new unserved load energy distribution may be found by integration of the density function from the maximum load to the load in question. For discrete representations and for $x \geq c$,

$$P_n'(x) = qP_n(x) + pP_n(x + c)$$

For loads less than c; that is, $0 \leq x \leq c$,

$$P_n'(x) = qP_n(x) + pP_n(x + c) + p[P_n(x) - P_n(c)]$$

that is how actually you have to determine different expressions and apply to a given problem.

So my conclusion here that whenever you apply economic dispatch solutions under a probabilistic environment you have to understand equation number 30.1 to 30.8 and the practical problems can be solved using a probabilistic environment and I am very sure that you all will attempt to solve a simple problem using equation number 30.1 to 30.8 and try to understand how the numerical problems with different load energy distribution can be obtained for a given practical application. Thank you very much.