Economic Operation and Control of Power System

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Lecture – 29

A very good morning. Welcome you all to this Economic Operation and Control of Power System Courses on NPTEL platform. Today will be the lecture 29 on Economic Scheduling with Unreserved Load Method and as well as we will talk about Expected Cost Methods. Now in continuation with the previous lecture, the generation requirement for any generating segment are determined by the knowledge of the distribution that is T times Pnx that exists prior to the dispatch that is scheduling of the particular generating segment that is the value of T, P and 0 determines the required hours of operation of a new unit. The area under the distribution which is T times $P_n(x)$ for x between 0 and the rating of the unit loading segment determines the requirement for energy production. The complete area will give me the energy requirement to meet the particular load for a given hour.

Assuming the particular generation segment being dispersed is not perfectly reliable, that means uncertainty being associated, that it is unavailable for some fraction of time it is required and there will be a residual distribution of demands that cannot be served by this particular segment because of its forced outages. Now let us represent the forced outages means the unavailability, the rate for a generation segment C megawatt and the T times Pnx, the distribution of unserved load prior to scheduling the unit. Assume that the unit segment to be scheduled is a complete generating unit with an input output cost characteristic, may less likely:

$$F = F_0 + F_1 P$$

Now if your P is less than C megawatt which is the forced outage segment and greater than 0, then the unit will be required T, P and 0 hours but on average it will be available only 1 minus Q times T$P_n(0)$ hours.

The energy required by the load distribution that could be served by the unit is given by a discrete distribution equal to:

$$E = \int_{X=0}^{x=C} P_n(x)dx = T\sum_{x=0+}^{x=C} P_n(x)\Delta x$$

Now this is a standard algorithm for unserved load method for computing probabilistic production cost and please go through this algorithm which has already been discussed and make sure that you are in a position to solve at least a small numerical problem or at least you can describe your theoretical understanding for a given practical application. Now moving to economic scheduling with the unserved load method, process may be repeated until all units have been scheduled and the residual distribution remain that gives the final distribution of unserved demand. The minimum load cost shown in figure 28.2 since the demands of this production of unit will determine the maximum hours of operation of a given unit.

A general scheduling algorithm may be developed based on these conditions. The procedure shown in the flowchart above or the previous slide is a method for computing the expected production cost for a single time period that is T hours of duration. Now these are the following nomenclatures being used in our content. Now we will move to expected cost method. Now the expected cost technique is both an extension of an idea explored earlier in the discussion of hydrothermal scheduling.

The system composite cost characteristic and the variation in the convolution process used in the probabilistic approach. Using a composite system cost characteristic simplifies the computation of the total system production cost to serve a given load pattern. The expected cost per hour is given by the composite cost characteristic as a function of the power level. Calculating the production cost nearly involves looking up the cost rate determined by the various load levels in the load model. The unserved load techniques starts the convolution procedure with the probability distribution of the load pattern and successfully convoles the generation segment in an order determined by economics in order to compute successive distribution of unserved loads.

Now energy generation and cost of each segment were determined as a step in this procedure. In the expected cost method the order of convolution is reversed. We start by convolving the generation probability densities and calculating the expected cost to serve various level of power generated by the system. Now the total cost are then computed by summing up all the cost to serve each load level in the forecasted load model. Now let us focus on a bit of understanding here.

The expected cost method developed two important functions. The first one, probability density function of a capacity outage of X mega watt that is Pp of X. The expected cost for serving a load of K mega watt. Now in this method what we do the function Px represent the probability that the online generating units have an outage of exactly X mega watt. Keep in mind that the variables X and K defined above refer to the outage and the load magnitude respectively.

The expected cost rate for serving K mega watt of load is identical in its nature to the composite cost characteristic except that it is a statistical expectations that is computed in a fashion that recognizes the probability of random outages of the generation capacity. Thus any generating being scheduled must serve the load amount including any capacity shortages due to both random outages of previously scheduled capacity and demand levels in excess of the previously scheduled capacity. Therefore we required the probability density function of the generation capacity too. The recursive algorithm for developing a new capacity outage density that is:

$$\mathrm{P}_{\mathrm{e}}'(\mathrm{x}) = \mathrm{qP}_{\mathrm{e}}(\mathrm{x}-\mathrm{c}) + \mathrm{pP}_{\mathrm{e}}(\mathrm{x})$$

where, $\mathrm{P}_{\mathrm{e}}(\mathrm{x})$ = prior probability of a capacity outage of x MW

c = capacity of generation segment, 1= forced outage rate, p=1-q

Now X ranges from 0 to the total capacity s previously convolved. We need the initial value of this density function that is S equal to 0 in order to start the recursive computation with no capacity scheduled. These are:

$$\mathrm{P}_{\mathrm{e}}(\mathrm{x}) = 1.0 \text{ for } \mathrm{x} = 0 \text{ and}$$

$$\mathrm{P}_{\mathrm{e}}(\mathrm{x}) = 0 \text{ for all non zero of x}$$

We may develop the algorithm for recursive computation of the expected cost function by considering a simplified case where generators are represented by a single straight line cost characteristic where minimum power level is 0 and the maximum is given by C mega watt. The index I represents the ith unit.

Let us consider P equal to 1 minus Q that is Pi which is 1 minus Qi represent the availability of this unit and FIL is the cost rate rupees per hour when the unit is generated a power of L mega watt. When all units have been scheduled the maximum generation is the value that is:

$$\mathrm{S} = \sum_{i} \mathrm{c(i)}$$

The load that may be supplied is denoted by K mega watt and ranges from 0 to maximum S. Assume that we are in the midst of computing of the expected cost function EC(K). The capacity scheduled to this point is S mega watt.

The new unit to be scheduled that is unit I has a capacity of C of I but any load level below the total capacity previously scheduled that is K is less than or equal to S. Now the new segment will supply the loads that were not served because of the outages of the previously scheduled segments within the range of its capabilities. The generation to be scheduled can only be loaded between its 0 to the maximum C. For a given load level K the loading of new segment is given by L equal to:

$$L = k - (s - x),\ \text{for}\ 0 \leq [k - (s - x)] \leq c$$

$$= 0 \text{ for } [k\text{-}(s\text{-}x)] < 0$$

$$= c \text{ for } [k\text{-}(s\text{-}x)] > 0$$

There will be a feasible set of outages that must be considered.

The increase in the expected cost to serve load level is then given by:

$$EC(k)=EC(s)$$

When the load level K exceed S then your incremental $\Delta EC(k)$ is given by:

$$\Delta EC(k) = p(i) \sum_{\{x\}} P_e(x) F(L) \text{ for } 0 \leq k \leq s$$

So now we came to an end of the expected cost methods and thank you very much for your attention.