

Economic Operation and Control of Power System

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Lecture - 27

Very good morning, welcome you all to the course on Economic Operation and Control of Power System. And we will continue with the same production cost models where we stopped during our previous lecture. So, when we look into the production cost programs, we will get into details. We talked about why production cost programs are important and what are those variables impact your production cost model and hence decision making through economic dispatch and unit commitment solutions. Now, if you see this table, you could see that there are many variables such as load models, interval considered, economic dispatch, long range planning, fuel budgeting, operations planning, weekly schedules and pool savings. Now, what happens depending upon the variables that you consider for your simulation, you may have to adopt one particular algorithm.

So, this table very clearly says that if you go for a particular algorithm, for example, weekly schedule, then probably you need to have those variables. So, first one if you see total energy or load durations available to you, season or year is known to you and block loading is known to you, then probably you can carry out long range planning. And if you have load duration months or weeks, incremental loading is known to you, then you can carry out long range planning, budget failing, operation planning and so on and so forth. So, the types of production cost programs shown in the earlier table utilizes chronological load patterns or load cycles and deterministic scheduling methods.

Our computer implementation of the economic dispatch techniques and unit commitment methods explored previously. I have already discussed about it that your assumptions, your program of production cost will help to arrive to an accurate solutions related to both economic dispatch and unit commitments. Since production cost and fuel consumption are computed repetitively means regularly, assuming that the load cycles are known for an extended period into the future and that the availability of every unit can be predicted with 100 percent certainty for each sub interval of that future period. In models using probabilistic representations of the future loads and generating unit availability, the expected value of production cost and fuel consumption are computed without the assumption of the perfectly known future. There are other type of production cost

program that are known by various names, some includes different ways of categorizing the programs, models or computational method that are used.

Now, the one of the very, very important application to me is Monte Carlo application. For example, there are Monte Carlo probabilistic simulations that are detailed deterministic programs with the added future that unit outages and deviations of loads from those forecast are incorporated by the use of synthetic sampling techniques. Once again, I request all my fourth year, final year undergraduates or second year master students can take this as a project problem for your research. Random numbers are generated at regular time interval and used to develop sample results from the appropriate probability distribution characteristics. These numbers determine the status of a unit, whether it is 1, 0, 0, 1, operating at full capability on force outages or coming back into a state where it is available if it was previously not available.

The magnitude of the load deviation from the magnitude forecasted because you forecast a particular load, but in the reality when you carry out your simulation, the load will be slightly different. So, the magnitude of the load deviation from the magnitude that you forecasted may also be determined by a random number using a forecasted error probability density function. So, you can know what about the percentage of error that you can see or foresee for a given forecasting scenario. Other programs might combine some of the approximate generation scheduling techniques with load models that separate the week into weekdays and weekend days. For example, you have a week data model, you can say no, I would like to have two models, one is for weekdays and another model for weekends because the behavior of the consumer patterns, the load forecasting during the week and weekends they are different.

A Friday evening in United States may be slightly different or maybe a Diwali day in India may be slightly different and we consider only four weeks per year and one for each session. So, each season we can consider one day and get its understanding and then you repeat for that whole. So, instead of getting to 365 days probably you can have random choices of 4 to 5 days in 4 different seasons. In these so called quick and dirty models, the weekly cost and fuel consumption are multiplied by appropriate scaling factor to compute the total seasonal values. On the other end of the complexity scale, there are programs which consider the dispatch of several interconnected areas and utilize power flow constraints caused by the transmission interconnections to restrict inter area interchange levels, optimal power flow programs could be used in the same fiction.

Now, the problem you see we started with a very simple low dispatch with losses, without losses, unit commitment and then we thought of power production cost programs and algorithms, load variations, outage variations, you know anything. But now we are making the problem quite complicated even by considering inter area power exchanges, optimal power flow, losses, transmission exchanges, many more. So far, networks have

only been represented in production cost programs by very, very simplified models such as using penalty factors as we have discussed it can give you a standard model using a DC power flow and or using a transportation network system. But AC power flow are usually useful for security constraint, economic dispatch, unit commitment and purchase cell analysis. Optimal power flow may be used to study transmission power and reactive power flow pattern to develop prices for the use of transmission system.

Now, very, very important, I told you during my previous lecture that the transmission system may also play an important role to decide your energy cost. Once you decide or arrive to a cost from the generation model, then when you get into the transmission, the cost will vary because some of your cost which has been injected to the transmission system will be much more when it is exited or when you cater to the particular load consumer. Because the transmission system will also consume some percentage of your power in the form of losses. Now, if the loss is going to be 20 percent, then if the cost is 10 rupees, okay, at the entry level, so output level, it will be more than 20 percent, okay, the cost will be more than 10 rupees. So, what we wanted to highlight here, if you consider the transmission models even in your production cost programs, then the real and reactive power flow will decide the cost of real power as well as reactive powers.

In the complex deterministic programs, the load may be represented by chronological arranged load cycle patterns and these patterns consist of hourly or biaurly loads that might be calculated using typical daily load cycle. Patterns for working days, weekdays and holidays throughout the period can be determined. The development of these typical patterns from historical data is an art, it is not easy. Using them to develop forecast of future load cycle is straightforward once the overall load forecast is developed. So, now what do you need to do? You need to understand the consumers, you need to understand the load, you need to understand the fuel, you need to understand your outages, you need to understand your linear programming, you need to understand your computer programming and finally you arrive with a box which can give you a wonderful solution to optimize your generation outputs.

Now, we will try to have one more approach, production costing using a load duration characteristic. So, if you the load characteristics are available to me, probably I can try my level best to have a approximate or simple production costing algorithm can be developed. I will tell you what exactly it is. Now, let us have a look into your load characteristic. So, what is load characteristic? You plot load in the y-axis and the x-axis actually it is versus time.

So, the load is keep on changing from hour to hour and then you can have a probability density function. So, this is how the product probability density function will look like and this is my load and this is my, I mean the probability load which is equal to my L megawatt, but which can also be extended where probability load equals or greater than L

megawatt, then the characteristic will be plotted like this and this is my load and this is going to be the with time. So, what you are saying basically, this many times your load is more than a particular level, this many times the load is more than a particular level, this many times the load is more than a particular level or time. So, it is basically my cumulative distribution function and the first one is you my density function. So, this is probability density function and this is cumulative distribution function of the load with respect to my required distance, whether the load is equal to my generation that is megawatt level or it is less or more can be identified from those density and cumulative functions.

Now, just to get into little bit more in detail, so what you are saying here, so for example, this is my load, so what you are saying this many times or this many percentage times, my probability of unit load is equal to L megawatt and I am saying the probability of unit load is equal to L megawatt. So, if you plot it in a distributed fashion, so the density function will you know, uniformly consider all options is possible to me, it is 10 megawatt, 20 megawatt, 30 megawatt everywhere you have a value. Now, in this case, in the second cumulative distribution function what you are saying, the probability load equal or more than L megawatt. So, what is this point? This point is a load which is nothing but my peak load, am I right? That is the maximum load. So, you could see that very, very minimum times it is equal or more than the peak.

So, that is what you are giving a lesser weightages and probably you keep on giving higher weightages to other load sector. So, peak will be for a duration of minimum time period and off peak and other loads will be for a larger duration. So, this is my cumulative characteristic which tells me or makes me understand that how many times my generation is equal or more than the load in a given period of time. In representing future loads, sometimes it is satisfactory to specify only the total energy generation for a period. This is satisfactory if only total fuel consumption and production cost are of interest and neither capacity limitations nor chronological effects are important.

If capacity limitations are more concerned, a load duration curve might be used. Figure number 27-1 shows an expected load pattern in your first A and a histogram of load for a given time period in B and the load duration curve constructed from it in the figure C. Now, in practical developments, the density and the distribution function, both B and C that I have shown you earlier, may be developed as histograms where each load level L denotes a range of loads. That is, these last two curves are expressed in both hours and per unit probability versus the megawatt load.

Now, the figure 27.2 which talks about this is my load versus the hours load equal or exceed L. So, I think I want to just how many, this is T, x-axis is my time period, y-axis is my demand. So, how many hours the load equal to or more than 1500? How many

hours the load is equal or more than 1300 mega watt? How many hours the load is more than or equal to 800 mega watt? These durations that you can calculate in these characteristics. Figure 27.2 shows the more conventional representation of a load duration curve where the probability has been multiplied by the period length to show the number of hours that the load equals or exceeds a given level.

L mega watt, it is conventional in deterministic production cost analysis to show this curve with the load on the vertical axis. In the probabilistic calculations, the form shown in figure 27.1c is used and in the process, one can also develop an algorithm where the cost characteristic of each and every power plant is known to me and I do have the previous characteristic load versus time and then I can blindly assign those generators based on the characteristic that is available to me which are those power plants we used for peak hours and which are those power plants we use for the base loads. So for example, the previous diagram from this characteristic itself, I know that I need some power plant to be used in this area and some power plants may be used in this area. So certainly, the costly plant, costly generation plants will come to this zone and the economic power plants will come to this zone.

So let us get into a very beautiful example for our better understanding. Now figure 27.3 is very important. So in the simulation of economic dispatch procedures, with this type of load model, thermal units may be block loaded. This means the units on the system are ordered in some fashion and are assumed to be fully loaded or loaded up to the limitation of the load duration curve.

Please try to understand. If you have a thermal power plant, normally we do not shut down a thermal power plant until and unless it needs outages or maintenance or the coal is not available to me. Because when you shut down a thermal power plant, probably the cooling will take a couple of days and the energy which are being developed or generated will be simply wasted. So most of the classical nuclear power plants, thermal power plants, they are all my base loads. We do not really keep them, you know, allow them to be switched on and off frequently because a big plant, it is not easy. For them to start a thermal power plant will take hours and days and weeks.

So we all know that. So those power plants will run round the year until and unless there is a maintenance. So probably, so that is what they are saying that if you have any number of generating units, you order them, which generating unit has to be operated in the first, second, third, fourth, fifth. And accordingly from this characteristic that is available to you, you can put them at different blocks. So figure 27.3 shows this procedure for a system where the internal peak load is 1700 megawatt.

Why 1700 megawatt? So probably you can see this point is assumed to be 1700 megawatt from this characteristic. Now the units are considered to be loaded in a

sequence determined by the average cost at full load in some price per megawatt hour for each unit you can calculate. And you could see there are some unit type 1, 2, 3, 4, 5, there are so many power plants, but different cost characteristics available to me and they need to be loaded. The amount of energy generated by each unit is equal to the area under the load duration curve. So you have a unit of X megawatt operated for Y hour.

So that means your XY megawatt hour and that area of that power plant must fit into your required area of these characteristics. So this area is also megawatt hour for me and I have a unit so I will fit those blocks. So one unit will fit up to this area and the rest will fit into this area. So that means this block is covered for me. So then I will go for the second block, then third block, fourth block, fifth block.

So it's a kind of a very smooth simple way of handling your solutions. Now the same example let us expand. So what you have done we have different units, unit number 1, 2 and you can use the standard textbook from which we have taken this example is Wood A Wollenberg and where you have 2 millipoints the 800 megawatt capacity, Mohawk 1, 2, Bravo 1, 2, 3 and 8 gas turbines of 400 megawatts. So if you see there are totally 820 megawatt is available to me and that need to be accommodated in this characteristic. So what you have done the first 800 used, then the next 300 used, next 200 used, next 120, 75, 25, 20 all 3 used and the rest 400 available to me but I need only 280 for an example because 800, 300, 1100, 200, 1300, 1420.

So for 1700 minus 1420 is 280. So I need 280 out of 400. So that 280 megawatt must come from the last plant and that will be assigned to this zone for my peak. So what has happened now? The last power plant is a gas turbine. So gas turbine are not necessarily to be a base engine, the reason being you can switch on and switch off any given part of time. So if you have a digital generator to be used to cater a load of a particular unit, so you can only bring them during the peak hours or emergencies not all the time.

So gas turbine here is handling your peak energy requirement for meeting 1700 megawatt. So that means I got a schedule also. So what is my schedule? 800, 300, 200, 75, 25, 20 and 280. So that is the solution.

No mathematics, nothing. It is a history, experience, cost is known to me, arrange them in a descending order or ascending order and then you pick it up. Now besides representing the thermal generating plants, the various production cost programs must also simulate the effects of hydroelectric plants with and without water storage. That is also important. The effects for energy and capacity purchase and sales and pump storage hydroelectric plants also can play an important role in decision-making. The action of all these reserves in a modified load to be served by the array of thermal power plants, the scheduling of the thermal plants should be simulated to consider the security practices

and policies of the power system as well as to simulate to some appropriate degree the economic dispatch procedures used on the system to control the unit output levels.

More complex production cost programs used to cover shorter time period may duplicate the logic and procedures used in the control of the unit. The most complex involve the procedure discussed in the previous three chapters on unit commitment and hydrothermal scheduling. These programs will usually use hourly forecast of energy, that is hourly integrated load forecast and thermal generating units model that include incremental cost functions, startup cost, shut down cost and various other operating constraints. With this we stop here. So what you have done exactly, we learned what are the challenges associated with production cost modeling and how they can be accurately designed and modeled to have a wonderful and accurate clear cut solutions for economic dispatch and unit commitment solutions. Thank you very much.