Economic Operation and Control of Power System

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Week - 06

Lecture - 26

A very good morning, welcome you all to the NPTEL course on Economics Operation and Control of Power Systems. Today we will be talking about Production Cost Models, lecture 26. Now one of the most important part of economic operation of power system is to optimize the overall cost of generation and also we need to meet the load requirement not only for an hour but also for a day, for a week, for a year and it's a continuous process. You all must have learned nicely about economic dispatch with and without losses as well as unit commitment solutions. So the conclusion at this point is that we need to schedule the generations means you have to identify the unit and once the unit is known to you what would be the output of that unit so that the overall combination is equal to your load after getting losses. You must have also revised on thermal generation or thermal scheduling as well as hydrothermal scheduling for better understanding of both hydrothermal operation for meeting the required loads.

Now one important question here before you that when you have to solve this optimal solution or economic dispatch or unit commitment one of the most critical variable is your production cost model. So based on the production cost, the cost characteristic AP square plus BP plus C or AP plus B the value of ABC or the coefficients or the constants are very important which normally decides your magnitude of power outputs, the scheduling based on unit commitment and so and so. So my question here is it not important to have a accurate and exact production cost model to arrive to a solution which is acceptable and optimal. So today we'll be focusing on how those production cost models are created and simulated so that you may be in a position to conclude your generation outputs effectively and efficiently.

Now production cost models are computational models designed to calculate a generation system production cost, requirement for energy imports, availability of energy for cell to other systems and fuel consumption. Now very importantly the cost of fuel, the cost of coal or the cost of gas is keep on changing around the year. So you may not be able to conclude that this cost characteristic is fitting to my particular resources around the year. But we cannot create production cost models for every half an hour or every hour. So you need to have a cost model which is overly fitting into your annual averaging production cost model.

So they are widely used throughout the electricity utility industry as an aid in long range system planning, full budgeting and in system operation. The primary function of computing future system energy cost is accomplished by using computer models of expected load patterns and simulating the operation of the generation system to meet the loads. Now let us get into a digital simulation of the generation system involves representation of generating unit efficiency characteristics that we have already discussed in the past, input output curves, fuel cost per unit of energy supply because you might have seen initially I told you that this is the kind of characteristic and non-linear characteristics you know AP square plus BP plus C. Sometime it is linear, sometime it is quadratic and those characteristics are being not available to you for a given site or a plan that need to be generated. So our focus is how to generate that characteristic which is the art of your optimizing process.

Now the system operating policies with regard to scheduling of unit operation, the economic dispatching of groups of unit that are online, contracts for the purpose, purchases and sales of both energy and power capabilities. Now when hydroelectric plants are a part of the power system, we have seen the production cost simulation will involve models of the policies used to operate these plants. The first production cost model were deterministic in that the status of all units and energy resources was assumed to be known and the load is a single estimate but practically assuming a load which is fixed which is not true because let us say I am assuming the load is 100 megawatt tomorrow at 5 p.m. which is not necessarily true.

Now the production cost programs involve modeling of all the generation characteristics and many of the controls discussed previously including fuel cost and supply, economic dispatch, unit commitment as well as hydrothermal coordination. They also involve modeling, effects of transactions, deterministic programs incorporate the generation scheduling techniques in some sort of simulation models. In the most detail of this, the online unit commitment program might be used in an offline study mode. Now these are used in studying issues that are related to system operations such as I told you for the purchase of power, sales of power, decision making during your transactions, transmission access issues and near-term decisions regarding operation control as well as demand management. Now stochastic production cost models are usually used for longer-range studies that do not involve near-term operational consideration and if you see a practical load model, the consumption model, they are not so stationary, they are variable.

So stochastic models are being accommodated in most of the algorithms used in the field or industries. In these problem areas, the risk of certain random generating unit failures because let's say I have scheduled the unit number, one is operational between two hours during 6 to 8 p.m. generating 100 megawatt, it's fine, it's my calculation, my optimal solution but it may so happen suddenly the system may not be in operation and as you know, even if I that means in doing 100 hours or 100 days, one day we have to give for maintenance, am I right? So that is one interesting part we need to consider because the classical algorithms do assume that the generation is available to you around the year, there is no maintenance, loads are accurately forecasted and they are not practically true and random variations or random deviations of the load from the mean forecast are considered as probability distributions. So stochastic production cost models and probability load forecasting models are considered to be an important area that you can consider for your future research and maybe project to work in this field.

The original purpose of these production cost programs was preliminary, primarily computation of future system operation cost. In recent years, these models have been used to study such diverse area as the possible effect of load management, the impact of fuel storage, issues related to non-utility generation and the reliability of future systems. You must have heard that during the recent war in Europe, most of the country were talking about the gas issues because you are dependent on certain input ingredients such as gas for your power generation. So when the energy becomes cheaper, then everyone try to buy those and then you cannot consume within a day that you need to store it. So then the kind of model we have created for your cost characteristic is not going to work during the recent war zone or maybe your collaboration with other countries.

So from time to time, the cost characteristic is going to change. So my intention here that the cost characteristic of a power unit or power plant is not going to be a smooth characteristic or a fixed characteristic, but it is time dependent, it keeps on changing over a period of time. Now if you look into the block diagram for a single area energy production cost program used for planning, so what we do actually, we initialize the system and then probably we go for understanding what is the annual maintenance schedule and then annual load model. So that means you assume randomly the unit is going to fail 0.1% or 0.5% or 0.05%, whatever it is. And based on that, you understand that this unit is going to fail and then you get the load model and then modify the loads to account for hydropower plant schedule and interchange contracts and schedule and dispatch pump storage, hydro and thermal power plants and then you plan what would be your production cost considering long term planning characteristics. So because you need to have the water model, you need to have the rain model, you need to have the hydropower output model, then you have to have the gas model, coal model, load model, maintenance schedule of thermal power plants, hydropower plant and then you get an overall solution, okay this is how my next one year is going to be with the existing infrastructure or the generation available to me. Now the universal block diagram that has recently been shown to you, the organization of a typical energy production cost program, the computation simulates the system operation on a chronological basis with system data input being altered at the start of each interval.

These programs must be able to recognize and take into account in some fashion the need for scheduled maintenance outages. What I wanted to highlight here, you all have solved numerical problems for economic dispatch for a particular hour, you all have solved unit commitment for a day or maybe a week but now the question is you have to introduce the maintenance outages of those power plants during your calculation for economic dispatch as well as unit commitment. Now logic may be incorporated in this type of program to simulate the maintenance outage allocation procedure actually used as well as to process maintenance schedules that are input to your given program. Now expansion planning because you need to plan your whole one year ahead strategy, expansion planning and fuel budgeting. Now here I like to just deviate a little bit, why you need to have a long term planning, why short term planning such as one day or one week is not enough? Because just imagine the hydropower plants, the amount of water available to you, it's a continuous input is there but those resources you have to utilize within a year because once your water is being discharged then that year is gone.

So you need to plan that at what given point of time, how much water will be available to me and how much need to be discharged. So how much energy will be available to me from hydro. So the rest of the energy must come from thermal and what would be the thermal cost characteristic and what is the resources that is coal and gas cost will help me to understand your cost characteristic of thermal power plant. So if you see it is not such a simple problem the way it has been presented, though to make you understand we make the problem quite easier as for the under-graduate program is concerned or the post-graduate program is concerned but for industry level this problem becomes too complicated for a long term planning, taking hydrothermal into account, the cost variation, load variation, everything into account become a very very interesting problem. So the research scholars those who are listening to this talk can consider as one of a potential PhD topic for your future.

Load models used in studying operational issues involve the next few hours, days or weeks and are usually chronological load cycles. A load duration curve expresses the period of time, say the number of hours, maybe one hour or two hours, 24 hours in a fixed interval, day, week, month or year that the load is expected to equal or exceed a given megawatt value. It is usually plotted with the load on the vertical axis and the time. So all the time you get a load characteristic, okay, on the horizontal axis. So you have time, you have load.

Now the scheduling of unit maintenance outages may involve time interval as short as a day or as long as a year. One plant is not operational, minimum could be a day and maximum could be a week, month and even up to a year. The requirements for economic data such as units, plant and system consumption and fuel cost are usually on a monthly basis because we do not make it too short or don't reimagine something going to happen for a year. Then these time interval requirements conflict as they often do. You plant something but it doesn't support your thought process.

The load model must be created in the model for the smallest sub-interval involved in the simulation. So you operate it, plant it properly for a long duration but simulate in a shorter span to get accurate solutions. Production cost programs may be found in many control centers as part of the overall application program, central operating system to have production cost programs. They simulate, they give you direction, their friend, plant number one, operate your plant with X megawatt of output, plant number two with Y megawatt of output. So they keep on changing their decision from time to time through a simulation output.

So these production cost models are usually intended to produce shorter term computations of production cost that is just for few hours or maximum per week in order to facilitate negotiation for energy or power, interchange or to compute cost savings in order to allocate economic benefits among pooled companies. Probably there are a lot of transactions happening and probably there are some agreement happening and to get into detail I can say this market oriented economic dispatch problem then probably there are so many dynamics that you take care that could be a bidding process. One may say I like to buy the energy for X rupees, the other may say I'm interested to buy for 2 X rupees. So then your cost characteristic impact those decisions because you as your owner try to optimize your solution but the market may behave differently. So we are not talking about anything market year for your better understanding.

We are talking about a conventional central decision making on my energy output of given power plants considering the outages and cost functions and loads being variable dynamic changing over a period of time. In either application the production cost simulation is used to evaluate cost under two or more assumptions. For example in interchange negotiation the system operators can evaluate the cost of producing energy on the system versus the cost of purchasing it. So how much they buy the ingredient and what is the cost of production and in the United States, power pool where units owned by several different utilities are dispersed by the control centers. Now the dynamics of the market operation is different.

There are so many market models so it's out of scope. So there is another course called energy markets. So we are not talking about this but this course will certainly help you to understand more about energy market in real time operations. It is usually necessary to compute the production cost or the saving due to pool operations. So we need to understand there is a market so people are ready to buy energy, people are ready to you know sell energy and you have a market system and you see how much you save by paying some money to the generations and getting money from the load consumers and the net saving can also be worked out in a pooled operation model.

That is each seller, each seller of energy is paid for the cost of producing the energy sold and may be given one half the production cost saving of the system received with energy. Now one way of determining these savings is to simulate the production cost of each system supplying just its own load. In fact in at least one US pool this is called own load dispatch. This computed production cost can be compared with actual cost to arrive at the charges of transferring those energies. Now we are not considering anything related to transmission system charges etc.

We are just considering the energy cost at production level. Okay there are other costs like transmission usage cost, losses you know the cost keep on changing. So you produce with one dollar or one rupees per hour and by the time it is available to the consumer probably it is three to four to five times because of other costs are included over a period of time. But now our focus is only at generation point of view. The models used are deterministic and typically use the actual load pattern that occurred during the period under study.

Scheduling computations frequently are performed with models that are similar to those used for real time operational control. Production cost computations are also needed in fuel budgeting. You need to understand how much you have to pay for your you know fuel in any form. This involves making computations to forecast the needs for future.

Fuel supply at specific plant sites. Arrangements for fuel supplies vary greatly among utilities. If there are ten utilities depending upon the location just an example if your thermal power plant is very close to a coal site then certainly your cost of fuel will be much cheaper than it is being transported to thousand miles or 500 miles along distance all right. So this is very standard. So it also the cost of fuel is not same for all utilities or all power plants when they procure it. In some instances the utility may control the mining of coal or the production and transportation of natural gas in other it may contract for fuel to be delivered to it.

So the cost of fuel is very very difficult to predict. In many cases the utility will have made a long term agreement maybe a cost rupees x for one year so that you are not indulging to various Indian prices of the market behaviors with a fuel supply for the fuel needed for a specific plant. Examples our mine mouth coal plants or nuclear units in still other cases the utility may have to obtain fuel supplies on an open or a spot market means they go to market bid it and then earn it okay. So whatever price are prevailing at that time. So just imagine if your fuel cost is keep on varying then your generation cost characteristic is also keep on varying and if your generation cost characteristic is keep on varying then your economic dispersed solution and unit commitment solution has to change with different characteristics.

So the solution that you have obtained with a given cost characteristic is not going to remain same with different fuel costs okay and hence it is important to have a fuel cost characteristic which is robust takes care of all the fluctuations and variations from time to time so that your solution become more accurate. This requires a forecast of specific quantities and large quantities of fuel at a given future rates. Now fuel budgeting models are usually very detailed we are not going to focus too much on that but I just wanted to make you understand that they are the quantities which are variable in nature. So your solution depends on those accuracies okay. So deterministic or probabilistic production cost simulations may be used for these applications in some cases where the emphasis is on the scheduling of fuel resources, transportation and fuel storage, the production cost computation might be one part of a larger linear programming model.

In these cases the load might be modeled by the expected energy demand in a week because I am getting into the probability in a week, month or a season scheduling of generation would be done using a linear model of the input output characteristics. The operating center production cost need may have a seven day time origin weekly. The fuel budgeting time span may be one to five years because you just have a long term contract and in case of mine mouth plant studies extend out to predict or extend to the expected life of a plant. System expansion studies usually encompasses a minimum of 10 years and it may extend up to 30 years in future. It is this difference in time origin that makes different models and approaches suitable for a different problem.

So depending upon the case study your algorithm, your models may be designed because you cannot have a model which can take everything okay. So depending upon your requirement you use a model whether you are focusing on variable load models or you are considering the outage models or you are considering the price fuel cost variation models. So depending upon your own requirement you can have your own algorithms to study. So with this we stop here.

Thank you very much for your kind attention. Thank you.