Power System Operations and Control
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Module - 01
Lecture - 03

Welcome to lecture number three of module first, and this is also last lecture of this module one. We have seen in module one of lecture one that what is the evolution of the power system, and then we went on looking at the milestones. And finally, we saw the interconnections; that is very very important and the present day power system is highly complex, and it is highly interconnected power system. In lecture two, we saw that there are various power system operation and control design criteria's and which also we saw the various states of the power system such as your normal states, alert state, restorative state and your extremis or emergency state as well.

In this lecture, we will see the various control functions of energy management centers; along with we will also see the various control hierarchy that is applied in the power system.

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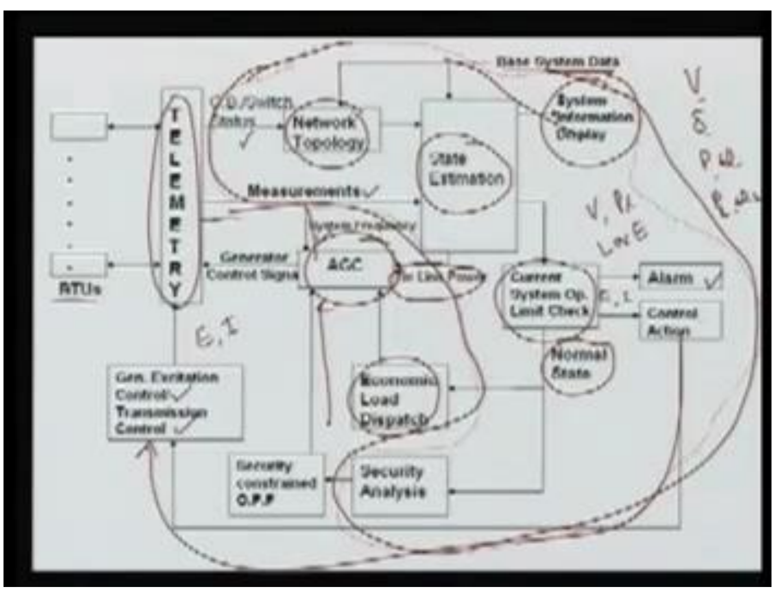

Here this is block diagram of the various functions of modern energy management systems. First, we will see here we start with the RTUs. RTUs are nothing but the remote terminal units by which we measure the power system data from the field and this data; it means this RTU gives information to this various modules and through the telemetry. So, this is the telemetry, and the RTUs are the large number in the power system; they are spread all over the world.

And they give the various information such that they will give the various measurements, they will give circuit breaker switch and the status, and with this information, we do the various other functions, like we can form the network topology here. This network topology that requires this base system data that is the intact system information; at the same time, what is the circuit breaker status of the various element in the power system? The circuit breaker status of the transmission lines, transformers, as well as other circuit breaker status; they are coming through the telemetry data. And then finally, we can have the network topology.

It means what is the present network information network diagram? Based on that, this information basically use in your state estimation. State estimation is slightly different than the power flow steady, and you know the states of the power system are nothing but your voltage and the angle at all the buses. This is the angle; it is not a power factor angle, it is the best voltage magnitude angle. And this v is the magnitude of the bus voltages.

With the help of these two information at each bus, we can determine all the power system quantities such as your real power flow, your reactive power flow and also we can determine the power losses that are the real power loss and same time we can go for this reactive power loss as well. So, that is why we call the states of the power system. We also determine this voltage angle in power flow analysis, but in that, we normally solve the power balance equations, and we get the solutions at the voltage and angle in terms of that.

However, in the state estimation, the number of equations is loss; however, in the load flow, the number of equations is equal to the number of unknowns. So, we get the unique solution at particular condition. In the state estimation we assume, since, we are measuring the data from the RTUs and they are coming through that communication channels that is through the telemetry information. And these measurements data will have some errors some noises. So, with the help of the various measurements, we normally obtain the voltage and angle; that is the best estimate. Means here in the state estimation, we do nothing; it is thus this error reduction.

We have to eliminate the errors as much as possible, so that whatever the information we are getting in terms of voltage and delta; we can say that is the exact information. And based on that, we do other online security analysis as well as the economic dispatch; it means energy management functions we perform. This state estimation also if you have determined the voltage and angles, then it can give the various system information. Information in the sense that it will give the voltage magnitude; it can give the limit violations; it can give your line flow limits.

Means all the information we can display, and that can be displayed on the computer CRTs and anywhere on the display instruments. This state estimation now the information which we have to write now that is used to check the current operating states of the system. Now the present power system that is we are measuring the data which is coming through this RTU through this network topology and the state estimation. Here the current system operating limits can be checked; it means we can have our system as already we have discussed in the previous lecture, what are the various states of the power system.

It means here we can see whether out voltage, whether your this power flow limits are satisfying, and at same time, we have to go for the load constraints, or sometimes it is called the equality constraints. Means here in the operating limits, we check our equality constraints and the inequality constraints i. Now there are different scenario exists. If we are having, there is no violation in the equality as well as the inequality constraints, then we can say our system is normal state. If it is not so, means our system may be in emergency state or it may be in the restorative state or it may be extremis condition, where both equality and inequality are not satisfying. So, then we have to take the control action accordingly.

So, information here if it is in normal state, then we have to do other functions; if it is not in the normal state, then we have to give some alert signal as well, so that the operators can be attentive, and they can take corrective or preventive measures. At the same time, the control actions can be applied at the various points which are required to move the system into the normal state of the power system. Now if your system is in your normal state, then we can perform the security analysis, and then we can also perform the economic low dispatch, and then this information the economic dispatch here, it will pass to the automatic generation control of the power system.

Here basically with the AGC, we control the output of generators. For AGC, we require the various information. Those information that is the first one is the system frequency that is measured from here from the system from RTUs, and also we require the tie line power flows. Because our system may be connected with other neighboring system, so the tie line power flows are also required in the AGC. So, we require the tie line power flow; we require our present setting of the generators, and also we require the security constraints with OPF in this, then finally we solve our automatic generation control.

This automatic generation control will give some signal to the generators through again it will go to the telemetry communication, because this whole process. It is not necessary this process is sitting at the generating station. It may be somewhere else. This is normally in the state load dispatch centers, and this information like your generator settings will pass through the various generators. And then finally, we can give this signal and then we can control; we can achieve our desired outputs.

Other here the control actions if your system is not in normal state, then there is no option; you have to directly control here the various control to bring your system in the normal state. That is we have to go for the generation excitation control; we have to go to the transmission control, so that we can satisfy our equality and your inequality constraints. That is we have to bring our power system in the normal state.

whole this process; here if we will see this complete which is with the red line here, it is nothing but it is called security monitoring and assessment function.

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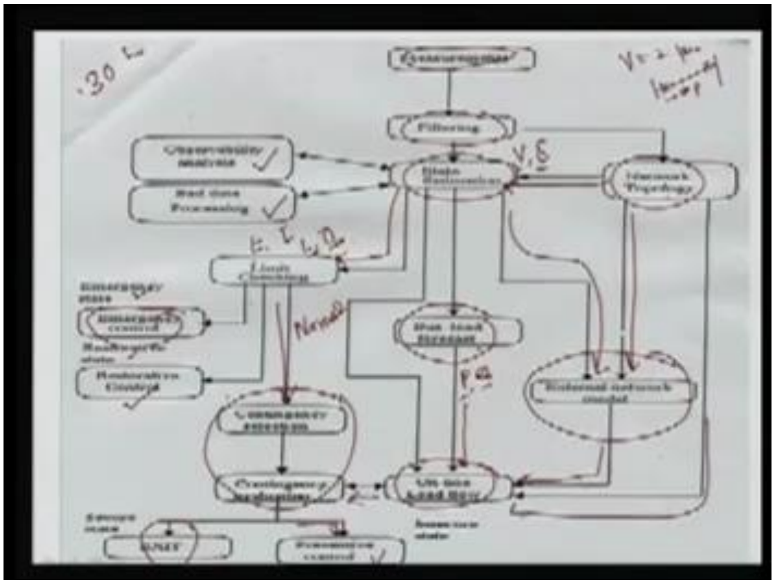

Now you can see here that is in detail what we do in this security monitoring and assessment function of a modern energy management system. Here again if we will see here the data's are measured from these RTUs. We are getting the measured data. These measured data, normally, will have the bad data. Bad data may be of two type; some data that by looking at the data information, you can directly say that this information is wrong.

For example, suppose you are measuring a bus voltage at any point; it is two per unit. This shows that your power system it is running; it is not possible that your voltage magnitude is two per unit. Similarly, you can see another information. Suppose, your transmission line here, this is giving your circuit breaker here status both end; it is saying that it is a circuit breaker is open, and also it is saying that there is some power flow in this line which is not possible.

So, both information are contradict to each other. So, based on this information, we can filter out some of the absurd measurement data's, and that is called the filtering of this measure data. Still, we have some errors in the measurement, due to the communication links, due to the measurement unit itself, due to your CTs and PTs, and those errors we have to minimize in your state estimation function here. This filtering data will give some information for the network topology. Network topology is nothing but we want, what is your intact power system right now; what are the various elements those are now in existing and the power is flowing over those lines.

So, this network topology requires the status of circuit breakers, and then this information can come here; from after filtering, we can just this network topology we can form. And this network topology will be utilized in this state estimation. Again as I explained that the state estimation is nothing but we have to determine this voltage estimate as well as voltage angle estimate. Now again in the state estimation is a broad process. Here we do sort of analysis; that first one is called the observability analysis, and another is called the bad data processing. In the state estimation, the bad data processing means we try to eliminate the bad data's; there is so many ways in mathematics behind that.

And also we analyze that the observability analysis we perform by which we can say we can estimate our states accurately or not. So, after doing the state estimation, we get lot of information. First as I said, we are getting voltage and angle and by which we can check the operating limits. Limits here your equality constraints and your inequality constraints; it means here we can also called the load constraints or your operating constraints. If these constraints are violating, let us suppose your operating constraints; for example, it is let us suppose it is voltage, then we can say it is we are in the normal state.

So, your operating limit that is your constraints that is your load constraints as well as the operating constraints, then based on that, we have to decide where our power system is. Means your power system may be in the normal state; here it is normal state, then you have to perform contingency analysis. Here this whole process is called contingency analysis. If your system is not in normal state, it may be either in your emergency control here, or it may be in restorative state. So, then you have to perform this restorative control, and if it is in emergency state, then you have to apply this emergency control to bring your system first in the normal state. Then you can go for the contingency analysis or the security analysis.

So, it is very important that the security analysis or contingency analysis; this block is called the contingency or security analysis. It is only performed if your present operating system is in normal state; otherwise, if it is not in normal state, then we have to take corrective action or the preventive corrective action, so that we can bring your power system in the normal state. Now you can also see this now in contingency analysis, we require several other information. Those are from the state estimation, we get this load forecast. Normally, whole this process measurement to all these calculation, etcetera; it is performed in half an hour interval.

So, every half an hour, we are getting data from the RTUs, and finally, we are doing all these process, and again after half an hour, we are getting the new set of data. In this half an hour, what happens? Your load which is kept on changing that will be varying. So, we require the load forecast during that period, so that we can have exact information about the system state within this half an hour. So, we require some bus data bus load forecast.

And after getting the load forecast means we get the P and the Q at the various buses, then that is used in online load flow. So, this is in this online load flow, here we also require the system states; we require the network topology here and your other information from the state, so that we can form the external network. As I said, your power system may be connected with other neighboring system. So, we have to it is not possible to go for analysis for all the system. So, it is convenient to form that external network with one or two nodes, and then that is called the external network model; we have to model in such a way that it will not hamper your power system studies.

So, with this information that is required for your online load flow; we know in the load flow analysis, we require the real power and reactive power information’s at the buses. And at the same time, we require the network topology; here that is coming, and we require the external network, and then we can run the load flow that is used in the contingency evaluation process. Here in this contingency analysis, we will study in the later modules and it is already I will discuss one or two lecture on this issue. Now in this contingency analysis process, your system may be secure or insecure; as I said in the contingency analysis security analysis, always we think if any new contingency will occur whether your present power system for that contingency, it is well prepared or not.

Means your present power system is able to sustain able to remain in the normal state following any probable contingency that may occur in future, then we can say our power system is secure. So, if it is secure state, then you have to go for here you can come out and then you can go for this optimal power flow at this and then so on. If your power system is in insecure state, then you have to go for some preventive action. And at the same time, you can apply security constraints, optimal power dispatch, because here you are going to control something. You are going to change the setting up; some of the outputs of the generators may be the elements of the power system.

At the same time, it is possible that we can set our generator in such a fashion that we can achieve the minimum cost operation and then it is called security constraints optimal power dispatch. So, we saw that the various security monitoring and assessment functions, and we also saw that there is various here these functions those are requiring some software’s.

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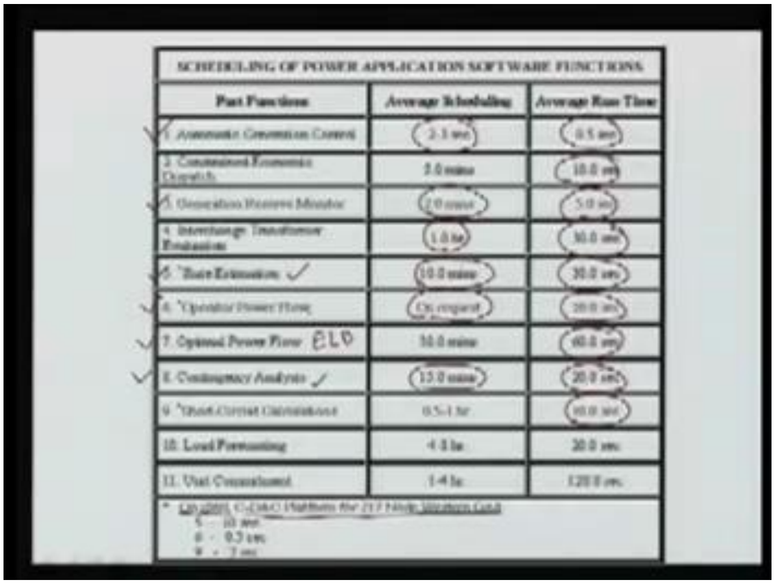

SCHEDULING OF POWER APPLICATION SOFTWARE FUNCTIONS		
Part Functions	Average Scheduling	Average Run Time
1. Automatic Generation Control	2-3 sec	0.5 sec
2. Constrained Economic Dispatch	5.0 mins	10.0 sec
3. Generation Reserve Monitor	2.0 mins	5.0 sec
4. Interchange Transformer Evaluation	1.0 hr	30.0 sec
5. *State Estimation	10.0 mins	30.0 sec
6. *Operator Power Flow	On request	20.0 sec
7. Optimal Power Flow ELD	30.0 mins	60.0 sec
8. Contingency Analysis	15.0 mins	20.0 sec
9. *Short-Circuit Calculations	0.5-1 hr	10.0 sec
10. Load Forecasting	4-8 hr	20.0 sec
11. Unit Commitment	1-4 hr	120.0 sec

* [illegible] C-DAC Platform for 217 Node Western Grid
5 - 10 sec
6 - 0.3 sec
9 - 7 sec

So, the scheduling of the power application software functions, you can see here it is the various functions that the first one is your automatic generation control. And it is the average time that is computed on I 86 CDAC platform of 217 nodes of western grid. The automatic generation control functions the average scheduling time is 2 to 3 second scheduling time; however, the ever re average st run time for this software is required 0.5 second. At the same time, we require the constraints economic dispatch; it is also called the optimal power flow study that requires 10 seconds of the run time. This is basically the CPU time; however, the average scheduling time requires two minutes, because we have to change the settings of generators, etcetera. So, that requires the fraction of minutes.

We go for these other power application software function; that is the generation reserve monitoring. That is also requires here 5 seconds for your average runtime; interchange transformer evaluation, there is an ITC evaluation. It may go for the 1 hour this average scheduling time and average runtime for this is almost 30 second. Another that is the very important function of energy management is that is your state estimation. As again I want to say you the state estimation is the process where we estimate the states of the power system accurately in any noisy or erroneous environment. So, for that, we go for those several various large number of information we measure that, and that is passed through your telemetry, and finally, it is coming to your state estimator.

In state estimator, we have some computer software. Try to evaluate the exact state of the power system. The average scheduling time for this is your 10 minutes, but it is average run time requires at least 30 second. Other function is your optimal power flow; it is normally done on the request basis. If it is required, then only it is done, but it is a computational time requires at least 10 seconds that is the CPU time. There is no elapse time; here it is CPU that is the computational time. So, it is an operator's power flow which is every time it is required whenever basically required that is asked and then it is there.

Here again in the operator's power flow, there is a two type of power flow; one is your offline, another is your online. Online power flow is normally performed in the contingency analysis process; however, this offline is whenever required you can do this study. So, it is 10 second if it is a big system. In this optimal power flow also, it is known as economic load dispatch, and it requires 60 seconds; it depends upon again system to system. If your system is very large, its time may increase. Your contingency analysis, you know the contingency analysis is having several parts. One is contingency evaluation, contingency selection and then contingency ranking.

Here basically, evaluation is the last part. So, the contingency definition, contingency ranking and then we go for the contingency evaluation. So, all these three process included in the contingency analysis, and this requires at least 20 second for the average runtime, but here for the average scheduling time is 15 minutes. We also require the short circuit calculation, and again it depends upon the system to system, and that calculation requires here 10 second. Load forecasting, again the load forecasting can be done in the different fashion.

Load forecasting can be of different type, whether it is long term, medium term or short term load forecasting. Again this short term load forecasting can be categorized at the various intervals. It may be for one day, it may be hourly; it may be even though half hourly.

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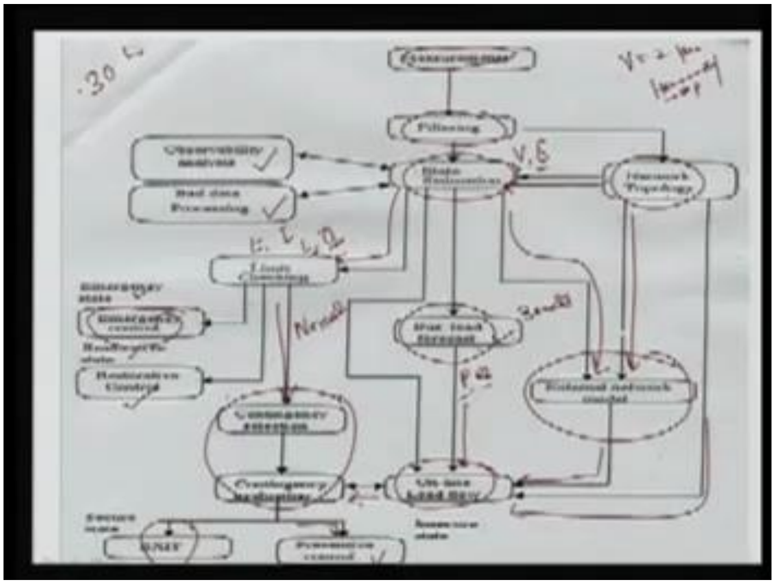

We saw in the previous section; sorry, here we saw this. We require the load forecasting, then this load forecasting within 30 minutes; however, other load forecasting here functions may require half an hour, so that the operator can schedule the generating station accordingly.

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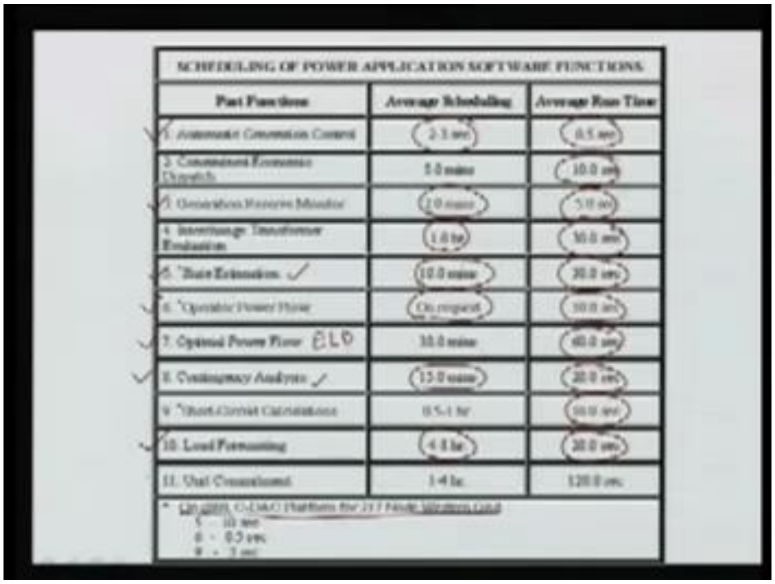

So, it may require 4 to 8 hour for the average scheduling, but computational time is very fast requirements that is the 20 second. We also go for the unit commitment; unit commitment that is turning on a unit that is generating unit or it is shutting it off. So, lighting on of any generating units may require several hours. Again it depends on what is the state of your generator means if it is a cold role or it is hot role. In cold role if it is a thermal coal base power plant, then it may require 7 to 8 hours. However, in hot role, it may require 3 to 4 hours.

So, this unit commitment that we have to arrange, we have to commit the units, so that we can achieve our economic operation; at the same time, we can also go for the maintenance scheduling of the generators, so that we can plan accordingly. So these are the various computer power application software functions and their average time.

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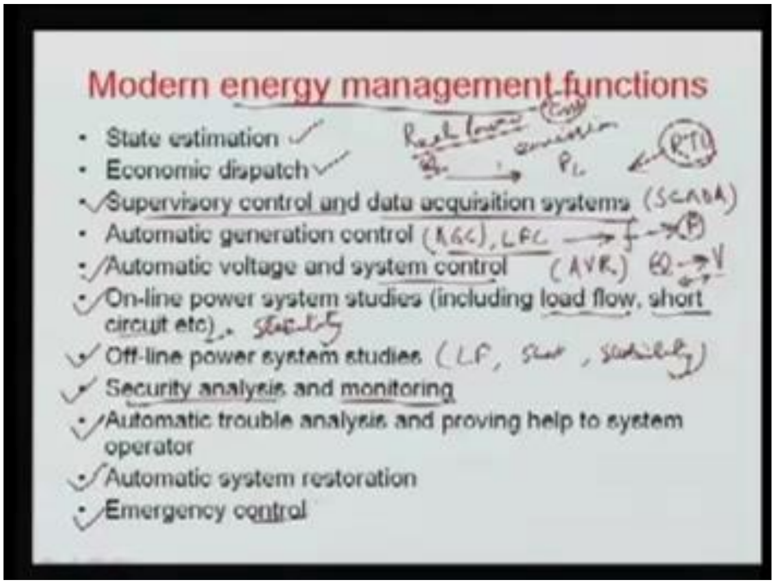

Now I can summarize here the various management function means your energy management functions EMS. First, that is very important is your state estimation, then we have a software related to economic dispatch. Here in the economic dispatch, there are various types of economic dispatch programs that it may be your real power dispatch; it may be your reactive power dispatch; it may be your emission. Nowadays, this is also very important, that we have to operate our power system in such a way that they should emit less environmental those are polluting environment you can say pollutants.

So, we can go for the minimum emission dispatch; we can go for the reactive power dispatch. In the reactive power dispatch, normally, what we do? We try to minimize the system loss the real power loss; however, in the real power dispatch, normally it is called the economic dispatch where we try to go for the cost minimizes in the cost of all the generating units that in total. Another we require function that is your supervisory control and data acquisition system. This is also known as SCADA that is very important. So, this is SCADA; this is supervisory control as well as the data acquisition system; we know the data we have to get it from the field from the various units of the elements of the power system those are spread all over your geographical area.

So, we have to measure those data, and once these data's are measured, then we have to transmit these data to your energy control function center, where we can process it. And then from there, we can go for some supervisory control. Here the SCADA is nowadays very important. Any measuring units like your RTU that is remote terminal units; it measures the data. At the same time, some of the functions it can do the supervisory control as well and then other information, it can send to the energy management function.

Another function is called AGC means automatic generation control; it is also known as the load frequency control, automatic generation control, load frequency control. It is sometimes called primary, secondary and tertiary control of the generating units, and we will see this automatic generation control much in detail in later modules. Here what we try to do? We try to see, we try to set the power generations of the generating units, so that we can maintain the frequency of power system. So, this is your AGC. Another is your automatic voltage and the system control; sometimes, it is called automatic voltage regulator or automatic voltage control.

In any generating power system, we have the two rules. A generator is equipped with excitation system; that excitation system controls the voltage of the power system of the terminal of the generator voltage and also it sets the reactive power output. In the AGC as I said, we control the frequency of the system, and this frequency is global in nature. Means the frequency of whole system is the same; however, the voltage at the individual node individual point is different. So, automatic voltage control means we have to control the excitation of the generators, so that we can achieve our system voltage profile and thereby we can generate the reactive power.

We always know this here this reactive power is directly related to your voltage, whereas your frequency is directly related to your real power. So, if you are changing your real power of a generator means you are changing the frequency of the system, whereas if you are changing the reactive power of the system means you are changing the terminal voltage by vice versa. Means you can change the terminal voltage thereby the reactive power output of that generator will be changed. So, in the automatic voltage control, we control the voltage of your generating units; at the same time, the system control is not the generator control.

It may be the service station control; it may be we can use other devices in the power system to provide the reactive power support, so that we can maintain our voltage in the desired limit. Other energy management function is your online power system studies. We require the various studies like your load flow; that is very very common and very frequently used. Another is your short circuit calculation; we also sometimes require the stability studies. So, these are your online studies those are performed whenever they are required.

Another energy management function is your offline power system studies. These are also the studies similar to your online, but they are done offline. Means there is no need to every time online we have to go for, because it is a very time consuming process here calculation of short circuit, stability and the load flow. So, some of the studies we can perform offline, so that we can see the system performance, etcetera, for our analysis and you can say other monitoring purposes. So, these are also including your load flow, your short circuit and your stability studies. Another energy management function that is very important is your security analysis and the monitoring.

Already in the previous slide, I explained you the security analysis and monitoring functions; we start from the measurement. Here you can see, this is your security monitoring and assessment function which starts from the measurement and then we take the various control actions and then we operate our power system in secure manner. So, this is your security analysis and the monitoring functions. Another is your automatic trouble analysis and the proving help to the system operator. We require various system analysis modules, so that we can analyze the troubles of the power system. And the same time, that will be very very useful for the system operator to manage the power system in efficient, secure and the reliable manner.

So, these analyses are required, so that we can analyze. For example, if there is some voltage dip somewhere in the power system; based on that dip that information is coming to your energy management system, it is now your duty to know why this dip has occurred; it may have the different even the problem later on. So, this automatic trouble analysis may give you information what was the problem, where was the problem and how to mitigate that problem. So, that will be very very important for the operating your system in the efficient, secure and the reliable manner.

Another is your automatic system restoration. We know there are some parts of the system may be out due to the various faults, due to the various other contingencies in the system. So, we require the system restoration process; again you know if suppose your system is completely in black out, what will happen? Then you have to light up your generators, because in the black out means the generator has gone, transmission lines have tripped. So, you have to start from one end, so that you can synchronize your grid as quickly as possible. This is the main aim of the system operators that the system must be restored as minimum time possible.

For that, we must require the automatic system restoration procedures; because it is a manual it may require large time. And during that interval, you are not supplying electricity to your customer; that is a huge loss of the revenue and also huge loss of the customers. So, automatic system restoration procedures are applied, and again it depends up on the various system to system; it is not unique. So, it must be there are some guidelines; at the same time, there are some procedures. Based on that, you can restore your power system in very efficient manner.

Another that is very important of your energy management function is your emergency control. It is not always possible to run power system in the normal state, because there are so many events that are out of your control. For example, if you are having a transmission line, there is some lightening stroke over that line; what will happen? There is huge energy is flowing on the transmission line, and there may be possibility that that line will be tripped, and that may lead to the cascade tripping of the several lines as well as your generators.

So, in that it is a fraction of time, fraction of minutes; in that, you have to take some actions, so that you can restore your system. Main intention of this electricity operators that we have to provide the supply with the less interruption to our customers. So, we require the emergency control functions whenever there will be problem even though in generator station or in the substation station. Wherever there is a problem, we have to use the emergency control, so that it should not lead to the cascade tripping, and that is called the collapse of the system.

So, the emergency controls are always there in the power system whether it is a generating station or it is normal substation, so that operator can take those actions to maintain the complete system or the part of the system, so that he can supply power in an economical, secure and uninterruptible way, okay.

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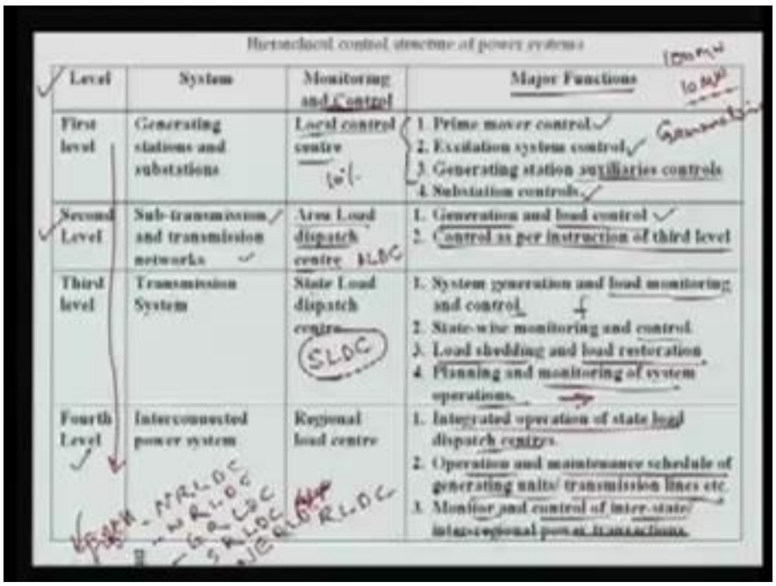

Hierarchical control structure of power systems

Level	System	Monitoring and Control	Major Functions
First level	Generating stations and substations	Local control centre	1. Prime mover control 2. Excitation system control 3. Generating station auxiliaries controls 4. Substation controls
Second Level	Sub-transmission and transmission networks	Area Load dispatch centre	1. Generation and load control 2. Control as per instruction of third level
Third level	Transmission System	State Load dispatch centre	1. System generation and load monitoring and control 2. State-wise monitoring and control 3. Load shedding and load restoration 4. Planning and monitoring of system operations
Fourth Level	Interconnected power system	Regional load centre	1. Integrated operation of state load dispatch centres 2. Operation and maintenance schedule of generating units/ transmission lines etc 3. Monitor and control of inter-state/ inter-regional power transactions

Now let us see the various hierarchical control structures of the power system means how we operate. As we saw, the power system is very bulky; bulky in the sense that we have the various substations. We have various smaller and smaller units, and they must operate in the coordinated fashion, because it is not possible. Electricity is one of that this electron once they are flowing, they cannot be stopped in the intermediate lines. So, once the power is generated, it must be going to the customers; means we cannot store the electricity in the bulk amount of power.

So, the various control hierarchical structure process are adopted to provide smooth and the reliable power supply to the customers. The first level this is here you can see this table where we have given here the various level; what are the various systems, monitoring and control here what we are going to monitor, and the major functions of those levels. This hierarchical control structure of power system is known as bottom to top control hierarchy; means the level first one is your bottom point, and then it is keep on moving to the fourth level or we can say higher levels.

So, in first level, it is nothing but your generating stations and the service station controls, and it is also called the local control centers. For example, if you are having a generating plant, there may be one or two or several units, then you should have first one unit if it is there then, there will be one control of unit for that individual unit. If you are having several such types of units, then all these units will have one coordinated unit, so that there will be any problem it can be sorted out locally. For example, you can see there is some problem in this BFP boiler feed pump of a thermal power station. So, that problem is the local problem; it is nothing with this central dispatch centre.

So, that problem must be sorted out with the local control structure itself. What are the various problems in that control; it must be taken care by these local operators, and that is called your local control centre. Similarly, we have the various substation; substations may be it is 400 KV service station; it may be 220 KV substation; it may be 132 KV substation and so on and so forth. Now again if we will see what is this substation; why we call it the 400 KV or 220 or 132 KV? Basically, it is the maximum voltage possible at that substation is basically the rating of that voltage of that substation.

For example, if you are having a substation, there is a transformer. Means some of the lines if they are coming at the 400 KV, they are even though outside if they are going 220 or 33 KV. That substation is called the 400 KV. Means the highest voltage possible in that substation means if we are having any equipment that is sustaining that highest possible voltage, then we say that voltage is the rating of the substation.

Whenever you pass through any street, any road, any substation, you will find it is written like 33 KV substation; it is written 132 KV substation, may be 220, may be 400, and nowadays you can also find 800 KV substation.

800 KV lines are already constructed in our country, and it is very near to us; that is one of service station. It is from Anpara - Unnao line that is the design at the 800 KV. So, you will find 800 KV substation means we have some of the equipments there. I am not saying all because some of the instruments, some apparatus there will be having the lower voltage. So, highest possible voltage is the 800 KV, then we call 800 KV substation. So, in that service station, we have the various controls, and those controls are for the proper operation of those units.

So, the major functions of the first level control are it is a prime over control of generating unit here for the generating unit we are talking. The excitation control of generating unit we will discuss the prime over control as well as the excitation control later on in other modules of this course. We have the generating station auxiliaries control; you know in any generating station, we have a lot of auxiliaries. Auxiliaries mean we have to have several auxiliaries for generating a single megawatt of power. For example, you know in the thermal power station, we have the boiler feed pump; we have the condensate pump, condensers; we have the PF primary air fan; we have the FD fans; we have ID fans; we have coal mills, ball mills. So, several units several motors and they are equipped with various individual control units.

So, here we require the various control functions they are in that unit itself, and that must be performed, and that comes under the first level of control of the power system. So, all these three the first one to three is related to your generating plant controls. Means you have the prime mover means you have to control the prime mover; what is the prime mover of your generating station? It is the turbine, and turbine gets energy in terms of steam from your boiler. So, we have to control and here normally it is called the governor control.

Governors are there. So, they try to increase the output of the turbine, and finally, it is coming to your alternator, and it gives the output accordingly. Excitation control as I said, it is nothing but we have to set the voltage of the generating unit's terminal voltage, so that we can generate the required amount of reactive power. And the other auxiliaries the various auxiliaries are used in the generating power station; just I want to tell you in the thermal power station, the 10 percent of the rating of a thermal unit is consumed for the auxiliary itself. Means if you have a 100 megawatts unit means you require 10 megawatt power that is required and that is consumed in the auxiliaries of the generator itself.

So, it is 10 percent; however, in hydro, it is less than 1 percent. It is very small percent because the auxiliaries are very very less in the hydro. However, in the thermal, it is very high; thermal may be in the nuclear also, it is very high consumption for the auxiliaries. So, we required the auxiliary controls for those things. In the substation that is nothing but it is a transformers. They are the transformers; they are the lightning arrestor; they are reactors. So, so many elements are there in the substation, and those must be controlled locally; if they are controlled locally, then it is called the first level control.

Second level control, now let us see. In the second level control, it is related to the area load dispatch centers, and normally, it is called ALDC. So, whole state whole region is divided into the several ALDC centers. For example, in UP, it was the four area low dispatch centers and Panki is presently one of them. So, in the area load dispatch centers, what we monitor? We monitor the sub transmission system and the transmission network means we can manage the load. So, the major functions of ALDC are your generation and the load control means here we control the generation so that we can meet the demand.

At the same time here in the load control, we have to go for the load control as well, so that we can merge generation and load together so that we can maintain the frequency and we can operate our system smoothly. And also they get controlled as per instruction of third level. Now this is the third level control means it is a state load dispatch centers, they give some information. For example, there is some line between let us suppose one station to another station, and they are getting the information, now trip this line.

So sitting in the control room, they can trip that line. Again the requirement why this line is to be tripped; again it comes from your third level; so, the third level control that is nothing but your state load dispatch center, and it is also called SLDC. So, in each state, for example, in UP, we have one that is one state. So, we have one state load dispatch center that is situated in Lucknow that is in Shakti bhavan itself. So, this state load dispatch centers looks after overall operation and management of your states of UP itself. So, the major functions are your system generation and the load monitoring and the control.

They monitor what are the generation of the power system, how much they are going to generate, how much they generate in the next hours or so on and so forth and how the load will be monitored. Means they have to supply power to the load; if they are unable, then they are going to set the load accordingly, so that the load and generation can be balanced. Basically, here in our state, since, always we are suffering from the crisis of power. So, they are going to see the load management, because the generation are normally generating is your maximum level. So, we are basically controlling the load, so that we can match your generation as well as the load to maintain the frequency of the system.

So, they normally look at the frequency; if the frequency is 50 hertz, they say they are very happy. If the frequency falls down, they are very much worried, and they we will go for the load shedding so that they can improve the frequency of the system. So, it is functions regarding this state wise monitoring and controls. They also monitor all the things, and they get all the information, and that is used for the current operating scenario and also for the post operating scenario, they get all the information. And those information are very much required for the post operation as well as the present operating condition.

So, here already I have said this load setting and the load restoration. If your system is some part of our completely system is in black out, then you have to restore the system, and that policy is decided from the SLDC itself in that state. So, they plan some restorative plans, and based on that, we keep on connecting the various elements of power system so that we can provide the electricity in much less time. This SLDC is also responsible for planning and monitoring of the system operations for the future planning; means future planning is not planning for after four five years. It is planning for a day, planning for a month or so on, so forth, and they monitor all the power system quantities, and then that information is used for your electricity board officials.

Here they should also follow the instructions received from the higher level; higher level means here for them it is fourth level, and they get the information from the fourth level to change their generator setting, to change the load setting, to change the transmission line status. Means outage or intact system, and based on that, they give this information to the various levels means level number two or level number first accordingly. So, they are the base heart of individual state; they get information from this fourth level. And that information is passed on to the second and first level for smooth operation of the power system.

Now let us come to the fourth level. Fourth level basically the interconnected power system; as we know we have various regions like we are living in the northern regional electricity board region, NREB normally we call it. In that the several states like UP, Uttaranchal, Haryana, Punjab, Chandigarh, Himachal Pradesh, Jammu and Kashmir; they are interconnected. So, each state is having one state load dispatch center. So, we require some coordinated control for all these states and then it called regional load dispatch center; this is RLDC. So, we have the several RLDC that is depending upon the region.

So, we have NRLDC that is the northern regional load dispatch center, we have western region load dispatch center, we have eastern region load dispatch center, we have southern region load dispatch center and then we have another one that is north eastern regional load dispatch centers. So, we have the various regional level load dispatch centers; their functions are to integrate operation of the state load dispatch center. So, as I said, it is the integrating body. It gets information from the various states, and then finally, based on looking the various constraints, they give the information to the various state level load dispatch centers.

So, the other functions are operation and the maintenance of schedule of the generating units, transmission lines, etcetera. So, various transmission lines presently they are the inter regional transmission lines, interstate transmission line. So, their operation, maintenance, etcetera, they normally monitor. They also monitor the control of the interstate and inter regional power transactions. As I said, all these states are connected. So, we have the one regional load dispatch center. So, there will be some power transfer, and that power transfer is monitored by these regional load dispatch center.

Now in India, we are going to have our national grid we are talking. Now all these regional load dispatch centers means all the states are going to be connected. Most of them are already connected like northern is connected with western; western is going to be connected with the southern. So, whole this India is going to be having one grid, and that is called national grid.

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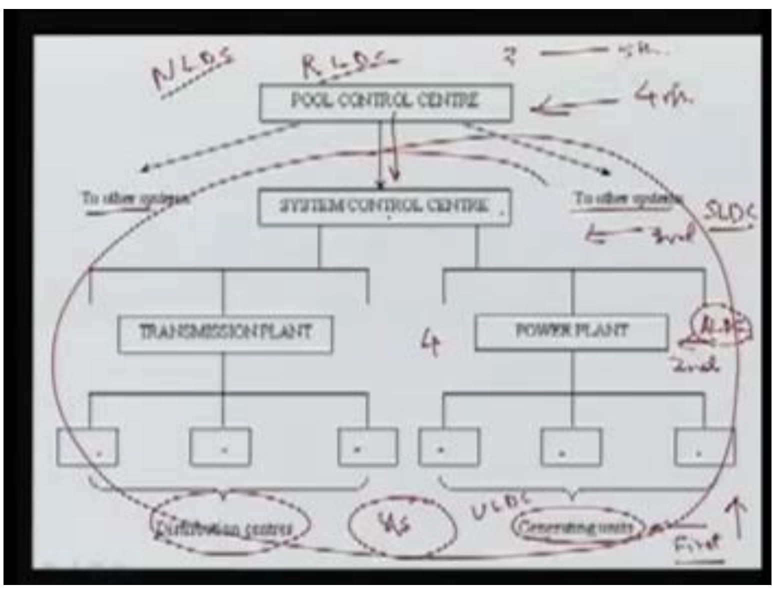

So, we will have another level later that is your fifth level control and that is called your national grid and then if that will be materialized, then our structure will be the different one. Here you can see all the levels. So, this is your first level; this is your second level; this is your third level which I explained, and this is your fourth level, and we are going to have the fifth level. And we start from as I said from bottom to top. So, this is your generating units control; this is your distribution centre control. At the same time, we may have some transmission substation controls here.

So, all these are coming at the first level of the control. To recap, here these are the various generating plants, here the various distribution centers, and the same time we have the various transmission substation centers. Now we have now the second level of control; that is here it is called ALDC. So, this is area load dispatch center control; they control the power plant in that respective. They get the information from the state load dispatch center; it is your SLDC state load dispatch center, and it is one in each state. And here in UP we have in Lucknow, and this ALDC will be several in the numbers. Presently, we have the four ALDC in our UP. So, they control the transmission plants, their transmission substation and your power plants.

And finally, they get information from the control centers; that is the state load dispatch center. And that is these load dispatch centers the various will be there for all the states; they get from the region or you can say the pool control center. It is also called regional load dispatch center as already seen. And as I said, we are going to have this whole national and that is called your national load dispatch center that will be the top, and it is the supreme authority. So, here the power that it will save that is all these units must follow the instructions from their hierarchy. Means here this unit will get information from ALDC or even though they can get information directly from the state load dispatch center, and they have to follow that; they have to do the action accordingly.

So, this state is one state, and they are going to monitor. Normally, here the RLDC, they never interfere in the individual operation of these load dispatch centers. Here you are the first level or the area load or basically this is called unit load dispatch center of individual substation. They normally here NREB that is coming to the state level, and then they provide the information to the various units. So, this is your control hierarchy of your power system.

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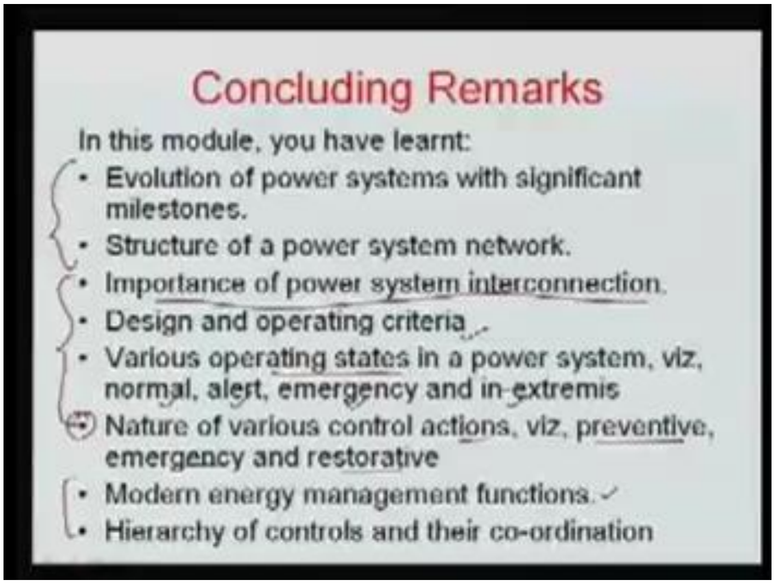

Now let us come to the recap of this module three. Now in this module one, I had three lectures. First lecture was basically devoted the first two points; that is the evolution of the power system with the significant milestones. We saw that our present day power system is highly complex, and it is integrated with both ac and dc transmission systems. However, the generation and the distribution or you can say utilization is the mainly AC. Now again nowadays you can see now the DC use; for example, for use of the computers, we use the DC power again inside that.

So, we convert from AC to DC again for the various purposes. We also saw the structure of the power system that we have generating stations at the different voltage levels, then we have the generating transformers. Those generating transformers lift the voltage at the desired level and then we have the interconnected power system comprises of different voltage level; that is both EHV as well as the high voltage transmission lines. Then we have the various type of other units like the small units those are normally inside the distribution system, and then we can give the power supply to the various users at the higher voltage, lower voltage as well as the medium voltage, and finally, our customers they are getting.

So, this power system structure that we follow from the generating stations, we must carry power over the GTs, then the transmission line, then distribution wires, and finally, it must reach to our customers. In the second module, what I just explained you; I explained these three points. This point is basically common in your second as well as third lecture, but in the lecture two, the importance of various power system interconnections was explained. We saw what is the advantage of interconnection power system.

Interconnected power system has several advantages; at the same time, it has some problem, but the modern energy management system, those are very much automated. And based on that, we can remove the various complexity of the interconnected power system. We also saw the design and operating criteria, and I elaborated there were the five design and operating criteria. First, I said the power quality; I said power system should be secure, it should be reliable, it should be economical, and it should be stable as well, because we must supply power in the stable and the efficient manner.

So, the various design and operating criteria I explained. I explained the power quality issues those are very much emerging right now. And I also explained various operating states in the power system for the security analysis; for the secure operation of power system I explained the normal state, the alert state, emergency state, restorative state as well as the extremis. We saw the various state models starting from the Dy Liacco three state model, then we saw Fyens and Carlson five state model and then very exhaustive model given by Bean state et al and we saw that in the lecture two. We also saw thus in lecture two some of the part, the nature of the various control actions like your preventive, emergency and the restorative controls, so that we can operate our power system in the normal state or you can say we can operate our system in the secure way.

In the today's lecture, just I discussed the two major points. One is your modern energy management functions and second one, the hierarchy of control and their coordination. In the modern energy management functions, we saw the various functions starting from the measurement of the data; that is RTU, SCADA functions that is we are measuring the data; finally, we are transferring the data over the telemetry unit. And it is finally coming to the state estimators where we estimate the state and thereby we analyze the current state of the power system.

If it is in some normal state, then we can go for some other actions; if it is not in the normal state, then we have to take some preventive some corrective actions for the emergency as well as the restorative controls and we display alarm as well. And then if it is in normal state, then we can go for the security analysis, economic dispatch and then we go for the AGC, etcetera. So, I explained the various modern energy management functions along with what is the approximate execution time for the various functions as well.

And the last which I explained the hierarchy of controls and their coordination, I gave the various control levels starting from bottom to the top in the state; that is in each state, we had the three level control. First one is the unit level control, then we went for the area level control, and finally, it is the state level control. Now we have the fourth level controls that is the region level controls means regional electricity boards are there, and the various states are interconnected and their roles and responsibilities were explained.

Now again we are going to have the national level that is the fifth level control. Once all these REBs regional electricity boards were will be interconnected, then we can have the complete power system fifth level control. So, in India, right now we have the four level control and then we are planning to the fifth level control as well. So, it is at end now you have understood the power system, their structure, operating and designing criteria and their control hierarchy.

Thank you.