Power System Dynamics and Control
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Model No. # 01
Lecture No. # 02
Introduction

Welcome to this second lecture on power system dynamics and control. In the previous class, we had focused and discussed one important phenomenon that is the loss of synchronism. We will continue the theme of describing certain stability phenomena in a power system in this particular lecture. So, in this particular lecture, we will cover some other phenomena like voltage in frequency stability. It is a brief over view. The next 40 lectures will actually foc us on all the nitty gritties of this particular phenomenon.

Just recap what we did last time. We discussed the structure of power systems, that is we saw that most of the typical large power system which are there today are synchronous grids, that is they consists of a large number of large synchronous generators interconnected to each other by AC lines.

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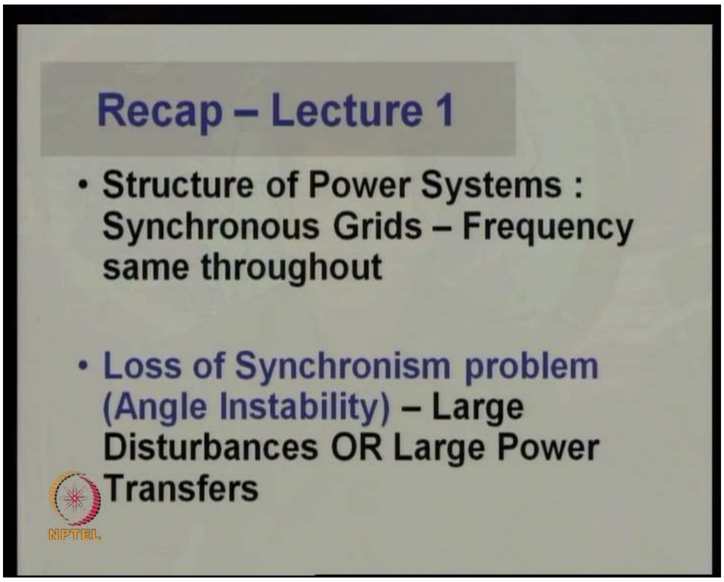

So, once we have inter connection by AC lines, we discuss this that in steady state, we ought to have frequency same throughout. It should be the same throughout the grid. One of the problems, of course, which are likely to face is that although the frequency should be same throughout the grid under some large disturbances or large power transfers, you may have loss of synchronism. So, normally synchronous machines which are connected by AC lines tend to remain in synchronism because of the nature of physical loss which of course, we shall discuss later in this course. Loss of synchronism is an important phenomenon.

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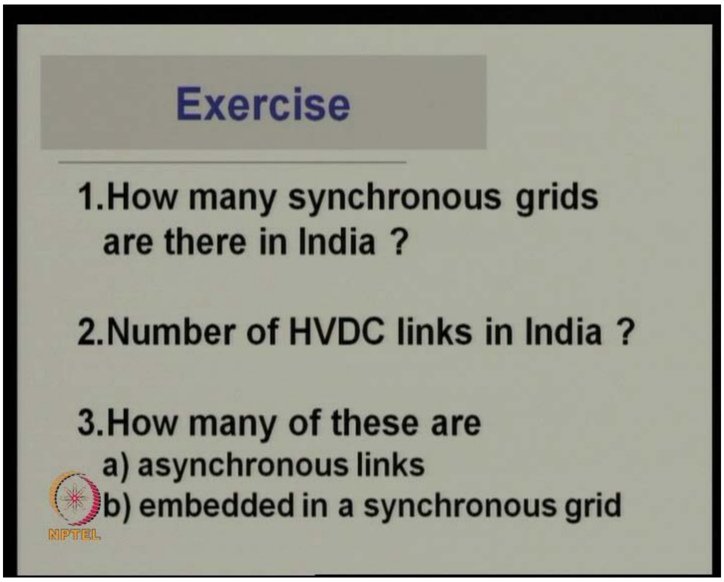

Today, we will learn two other phenomena that is frequency and voltage instability and to do that, we will illustrate a few simple examples. First of all, let us answer the question which you have asked in the previous lecture. How many synchronous grids are there in India or may be in your country, if you are not of India? How many HVDC links are there? How many of these HVDC links are synchronous links embedded in the synchronous grid and how many of them are synchronous links?

So, the answer to this question is as follows. India is at present, that is, in 2009 divided into two synchronous grids. The southern part of the peninsula forms one synchronous grid, that is, the synchronous generators in this part of the system are interconnected to each other by AC lines. The second grid synchronous grid in India is the rest of the system, the rest of the countries actually another synchronous grid.

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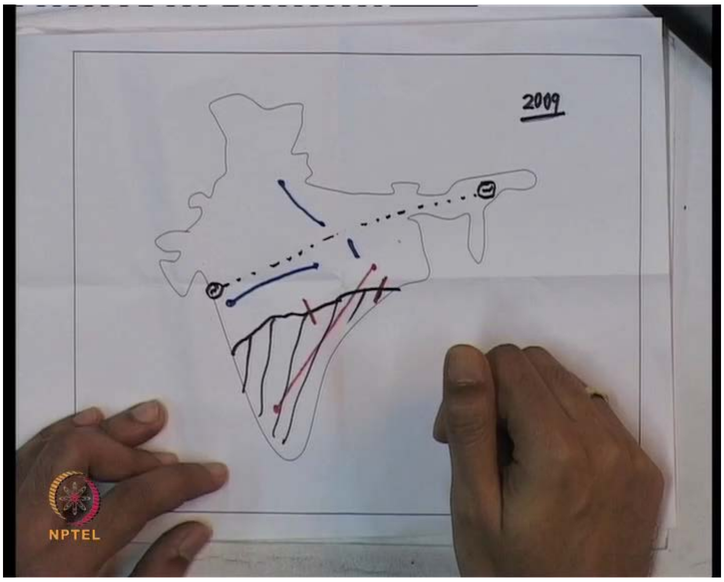

So, if you start off with one generator here, say at Trombay and he follows the AC line paths, you can go to another generator in the same system synchronous grid through only AC line paths. So, all the generators in this northern part of the grid are actually in synchronism in steady state. So, they run at the same electrical speed in steady state. Of course, there are asynchronous links between the southern grid and the other grid. So, for example, there is in HVDC link, long distance HVDC links from one state to the other. Here, it is between Talcher and Kolar. Then, there is another, just here it is very short. It is called a back to back DC links. It is an asynchronous link. There is another here. These are all asynchronous links.

So, these are asynchronous links connecting two synchronous grids. So, these two grids actually can be at different frequencies. Of course, there are HVDC links which are embedded in the AC system. For example, there is a HVDC link within this grid embedded within the AC system. It is a long distance HVDC link. So, there is in fact one here, there is another here. There is a short distance link here. So, this is a Chandrapur Pattga link, this is the Rhendathri link and this is the short link which is actually not used for long distance transmission. These links, although they are present in the synchronous grid, they do not really cause you to have an asynchronous grid.

However, these are asynchronous grids with control power flow. The power flow on these links, DC links does not depend on the phase angle here and here. That is an important thing about interconnects between these two regions. In this region, you have got lot of AC lines in which power flow is of course is a function of the phase angular differences of the voltages at the two ends of the land.

Now, just to illustrate the fact that we have the same frequency prevailing all throughout the grid at a given amount of time, all throughout asynchronous grid, I will just show you the snapshot of the frequencies are reported on the websites of the load dispatch centre's at various locations within the country. In fact, I will show it to at three locations. All these locations are more than 1000 kilometers apart. So, you see this is screen shot of the frequency is reported at various points in the grid at more or less the same time.

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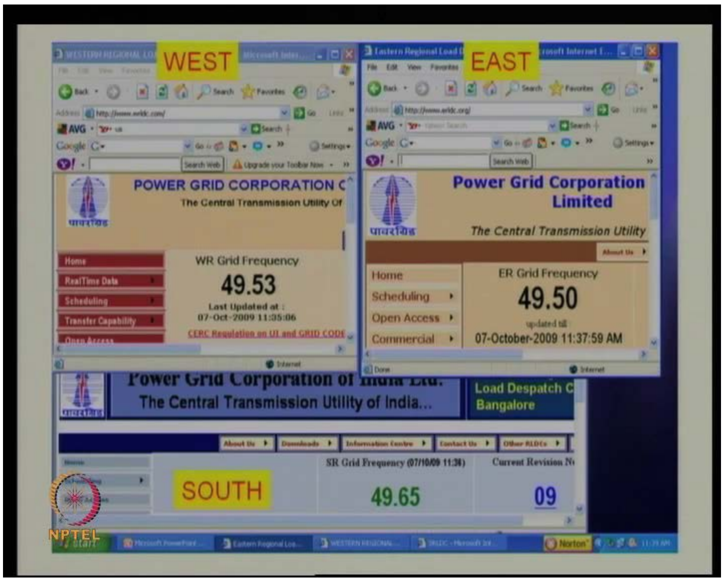

So, the time is approximately 11.35. It is not actually measured at same time everywhere. So, what you see in the west and east, that is at Mumbai and Kolkata, the frequencies are almost the same actually. My statement earlier was that in a synchronous grid, the electrical speeds, flow machines and the frequencies should be the same, but of course, it is not strictly speaking true that two reasons for that at any given moment of time, a power system is subjected to a lot of disturbances. So, actually they could be small disturbances really like I shut of the switch of the bulb here that is disturbance on the system. So, the system is not strictly speaking in steady state at any point of time. They always are small or large disturbances in the system.

So, electrical speed is not exactly the same if you measure them, but another issue which is probably more important at this point of time is that the frequencies are not measured.

It is exactly the same point of time. Also, you may find some differences in frequency as measured in two places. So, although, the western part of the system and eastern part of the system are the part of the synchronous grid of India or synchronous grid of India, you will find the frequency is slightly different from each other.

In fact, if you look at the frequency in the southern part of India, you can look at the slide. You will find as it is different, quite different from what prevails in the west and east which is not a surprise because the southern part of India is different synchronous grid. The normal frequency of both the southern grid and rest of the India grid is actually 50 yards, but you see that the frequency is not exactly 50 yards, it is around 49.5. So, it obviously means, we do not strictly revolve regulating the frequency in India. We allow it to actually change within the band. In a few moments from now, I will also tell you how these frequencies are actually determent and what determines that your frequency is 50 yards. Obviously, it has something to do with the speed of the generators.

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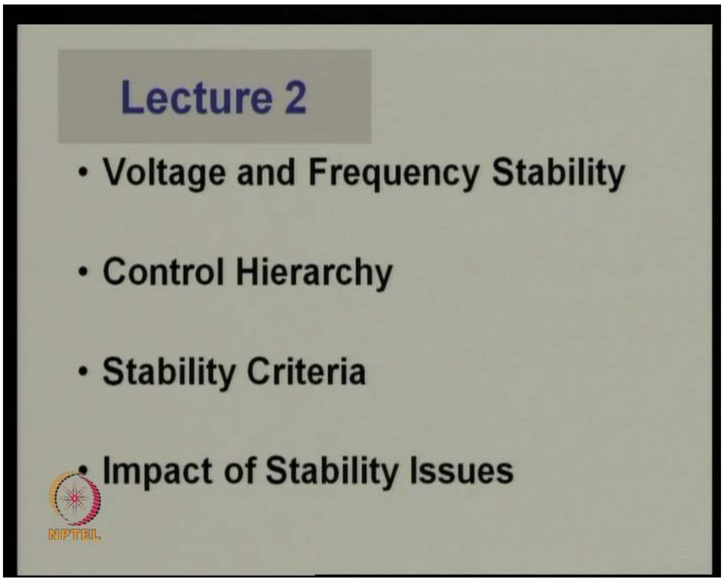

So, let us move on to the topic of today, that is, frequency stability in the grid. So, in this particular lecture, I will be covering the voltage and frequency in stability phenomena, the control hierarchy in a power system because there is a need for you to know what are the typical feedback control systems, what are the manual control actions and so on. Forget about the stability criteria and impact, the stability issues on the power system. So, let us move on to frequency stability. You may have guessed that the frequency of a grid or at least at a particular bus in a simple system like a synchronous generator connected to a load would be depended on the speed of the generator. In fact, the frequency of voltage induced on the center of the synchronous machine depends on the speed of the machine, the electrical speed of the machine.

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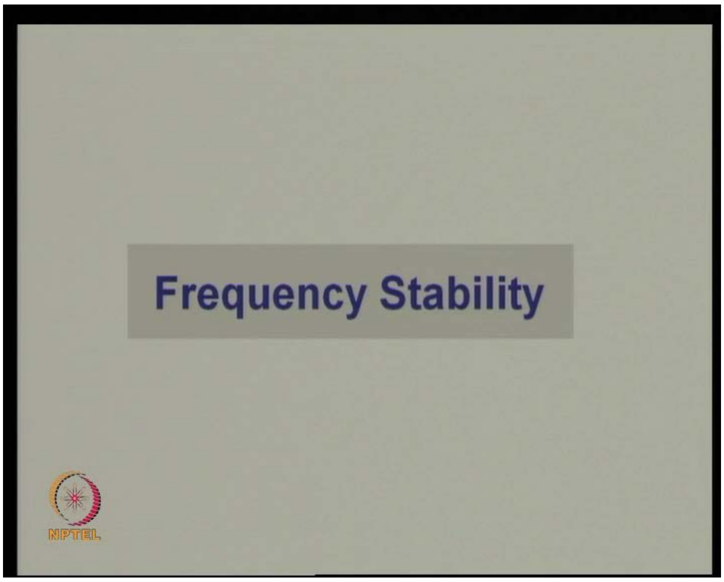

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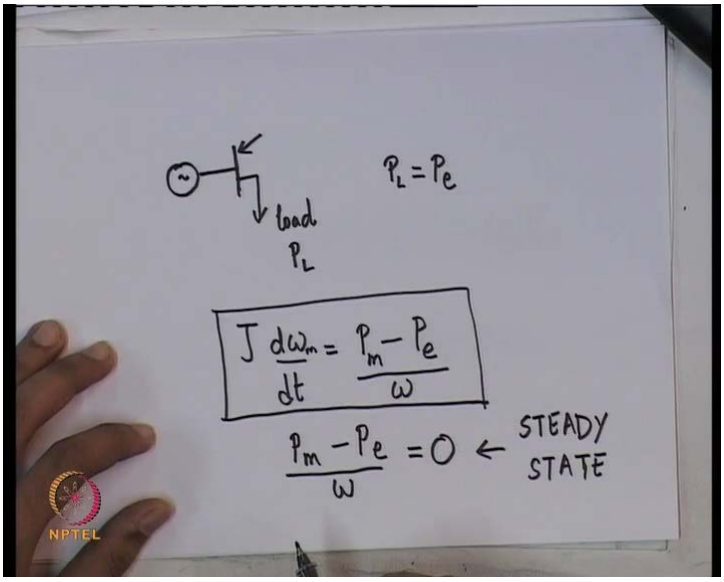

Of course, this particular definition of frequency need to be modified at when one comes to a multi-machine system because then, we will have to talk about local frequency, but let just first talk about the frequency of a simple isolated system. For example, a synchronous generator connected to a load, the frequency of this bus in steady state will be the same as the frequency electrical speed of rotation of this synchronous generator. So, if its 4 pole 1500 r P m machine, it is effectively going to create a e I m f of 50 yards at this bus. At this terminal, the load is connected at this bus and let say, will denote this load power is P L.

Now, what determines the speed of the electrical machine? Well, it is determined by neutrons law. It says that the rate of change of the speed of the machine is equal to is a mechanical speed is equal to the difference of torques, the mechanical torque which is provided by the prime movers and electrical torque, electromagnetic torque which is created by currents torque of the machine. Remember that torque is given by power divided by the angular velocity. The attentive among you would have noticed that there is a minor error here. The torque is given by power divided by the mechanical speed.

So, in this expression, we should have P m minus P e divided by omega m. So, of course, we have corrected it a few minutes later, but it will be good for you to note this down. Once again we should have P m minus P e divided by omega m. So, these are two torques which determines the speed of the machine as per this relationship. Of course, this is the dynamical equation of the machine. If you are in steady state, you will have P m minus P e by omega equals to 0. So, this is only under steady state. So, if actually I have synchronous machine say, which is running on no load, that is P L is equal to O, in that case, we will have P e also equal to 0 because in synchronized steady state if you neglect all losses, P L is equal to P e.

So, what you will have is that if open circuit machine which as P L is equal to 0 suddenly loaded, so this P e is non zero before. When you load it suddenly becomes, sorry it is 0 initially and when you load, it becomes non zero. What is likely to happen is that there will be sudden imbalance in this mechanical input and load. If that happens, the speed will change. For example, if P e is less, then P m you will find the machine. P e is less than P m. The machine will accelerate or if P m is greater than P, the machine will accelerate and vice versa if P e is greater than P m.

So, the speed of the machine is really determined by this equation. Now, the point is if P m minus P e is constant non zero number, the machine will never reaches a steady state because this quantity here will always been non zero. Therefore, machine will either accelerate or decelerate constantly. So, what we really need to do is understand how the system reaches an equilibrium. If you want the system to reach an equilibrium, if it starts off with P m naught equal to P e, for example, initially exact P m is equal to P e and suddenly, I changed the load. So, the P e becomes something different. How does this system reach an equilibrium? The two ways the system could reach an equilibrium to reach at the equilibrium P m minus P e should be equal to 0.

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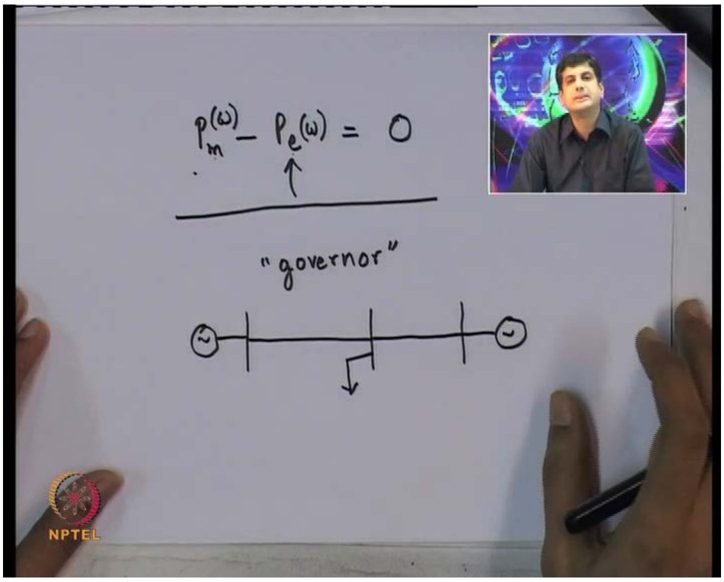

Now, remember that P m and P e can be function of the speed. For example, if P e or the load which you put is that of the fan or a pump, it is a function of frequency. So, actually this is a function of frequency, the mechanical power input to the synchronous machine, the prime mover input also could be made a function of frequency. For example, if I got a system which changes the mechanical power input to machine whenever the load changes or the frequency changes, so both these things could be functions of frequency. So, the final frequency to which a system like this settle down will be determined by the solution of this equation.

So, if you have for example, diesel generator settled at home and we connected to our load of that is in can in incandescent bulbs or fluorescent tubes or fans or pumps, in that case, what we will see is that the diesel generator will have a control system which changes the power when the speed changes. It is called governor, a speed governor. So, this is one of the mechanisms by which you can attain equilibrium. So, this is as far as a single machine and load is concerned, what happens when say we have got two machines, say a system like this two machines synchronous machine supplying a load which is presented at this point.

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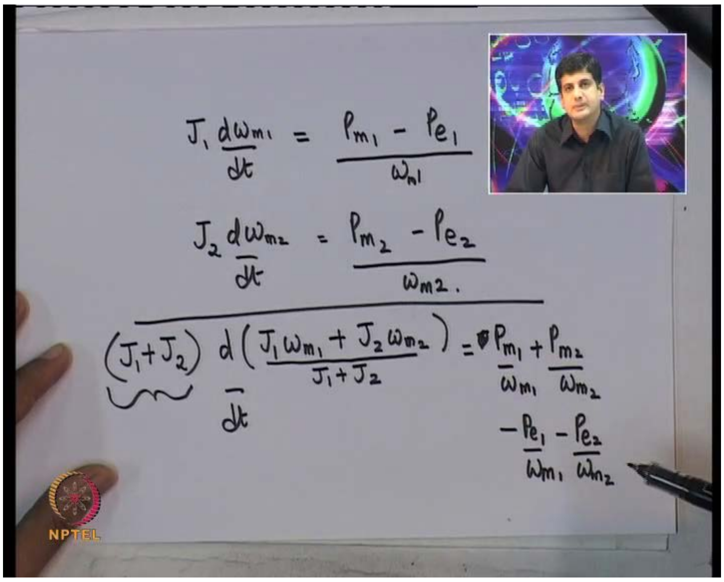

So, what determines the frequency or what ensures the frequency equilibrium under this situation? Now, if you got two machines, you have got two equations for the first machine. Let us say, the same number of poles. So, things will come a bit easier actually. You can use subscribe m 1 I think miss out in the previous equation. This m denotes mechanical speed. Now, what you note here is if I had these two equations, I can write them like this a little bit of algebra which I am skipping. Pay close attention to this. This is a cumulative inertia of this machine. This quantity, can you recognize this quantity? This quantity may be familiar to most students who have done physics course. This is called a center of inertia of the system.

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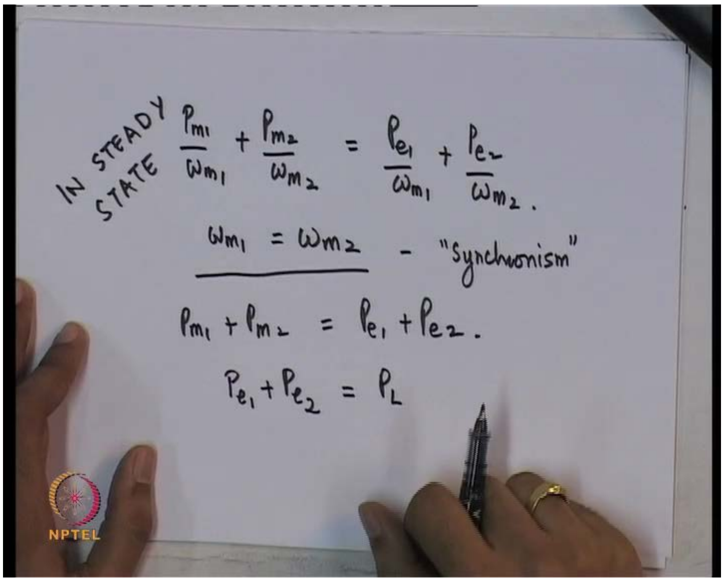

So, the rate of change of center of inertia of the system depends on the cumulative torques on the system. So, if I want this particular system to be in equilibrium, I should have, so what you have here is this. Now, if I am talking of a system which is basically two synchronous machines connected by AC lines and a load here, we must have in steady state. Why this? So, assuming that the machines have the same number of poles, what it means here is that the mechanical speeds have to be equal in steady state. That basically is the synchronism condition. You have seen this in the previous lecture that if the speeds are not equal of the frequency of the two generators, you may have a loss of synchronism phenomena.

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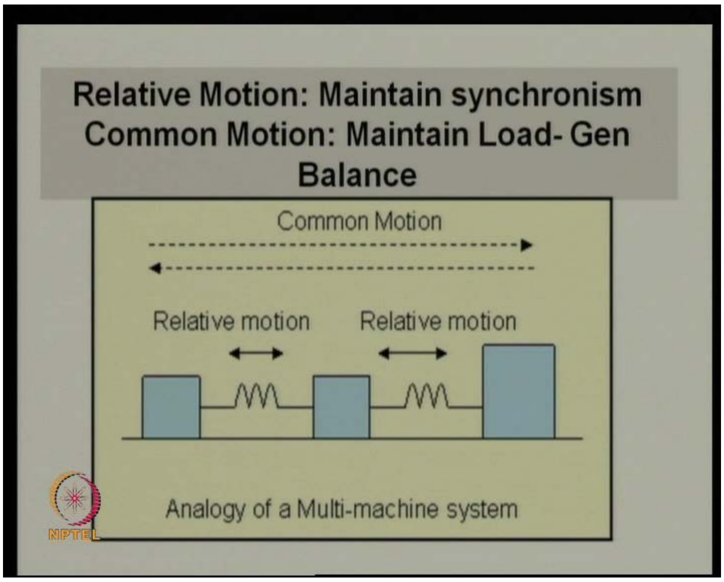

So, what we should have is this. So, which also really means that P m 1 plus P m 2 is equal to P 1 plus P 2. P 1 and P 2 are the electrical power outputs of the two machines. Now, in synchronized steady state and neglecting losses, it is easy to see that the total electrical power output of the machines should be equal to the load power. In the previous lecture, I discussed loss of synchronism. Remember loss of synchronism is when the relative speeds of the machines or the negative frequency are different, buses are not equal. So, you may loss of synchronism. Loss of synchronism is basically something to do with relative speed of the machine, is not something to do with the common motion or the center of the inertia motion.

So, let us in our mind have some kind of clarity regarding this relative motion stability patterns to inner synchronous grid. All machine should be in synchronism. So, that is what it should really you know pattern to where is common motion. This stability of the common motion determines if determined by the load generation balance. So, whatever I meant common motion or whether you have talked about center of inertia motion, I am really referring to the common motion. So, we have to ensure that machine should stay in synchronism in a synchronous grid and the common motion also should be stable. So, we should ensure load generation balance. Others what will happen is you can have a situation where relative motion is stable, but the whole system, the center of the inertia of the system is constantly moving, ok.

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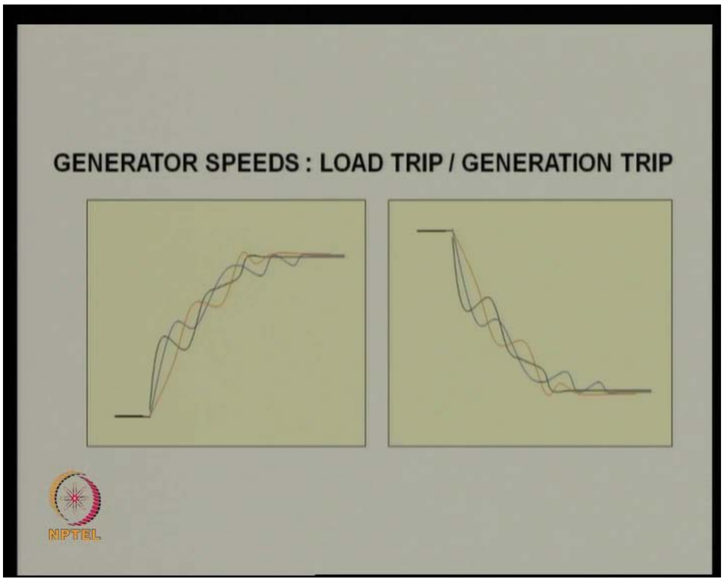

So, what we should ensure is that the center of inertia speed in a synchronous grid should be near about 50 yards. It should be steady at 50 yards or 60 yards in some system. So, what we should have when we have suddenly for example, load trip. If the load trips in a system, they will be a transit in balance between cumulative generation and the cumulative loads. So, if there is a existing load and in gets tripped, then you will find it is imbalance between the total generation and the total load. As a result, the center of the inertia of the system accelerates.

So, if you look at the first figure, that is the figure on your left, you will find that as soon as such a disturbance occurs, there is some relative motion and a system frequency tends to raise and settle to another frequency, but of course, eventually all the machines remain synchronism. So, all the generator speeds tend to become equal. After sometime, they may be some interplay between them exchange power between them, but eventually the system reaches a steady state and which all frequencies are equal, all the generators speeds are equal and the center of the inertia speed equals to the generator speed in steady state.

Now, what ensures that it reaches steady state is something that we have discussed before governor action as well as the load frequency dependents. The fact that load themselves as function as frequency is ensured that eventually you reach an equilibrium, that is if you find a sudden load generation imbalance, the frequency tends to change as soon as there is a change in frequency inherently loads like fans extra change the power outputs. So, frequency fall in fact fans will move just that little bit slower in draw little bit less power. Similarly, you have control systems like governors, which are present on most prime mover systems which effectively increases the power, the prime mover powers in case the frequency goes down and decrease power in case frequency goes up. So, this kind of control system exists on most generator. Of course, the important point is that if you got controller which are aiming to keep frequency constant or near constant, they should be coordinated properly.

So, that is one of the interesting issues which we will discuss sometime later in this course. So, when you have got governors present on many machines, all of them are trying to maintain the frequency at some particular near and keep it almost constant. In that case, you will find that we need to coordinate the governor, so that they share that excess power appropriately. So, that is something which we will learn later. Look at the case in which there is a sudden generation trip. If there is a sudden generation trip, the total generation in the system becomes less than the load at that frequency, but as you will find the frequency, the machines diesel rate, the center of the inertia of the machines which would somewhere here would deeds will decelerate and then, reach and equilibrium based on the governor.

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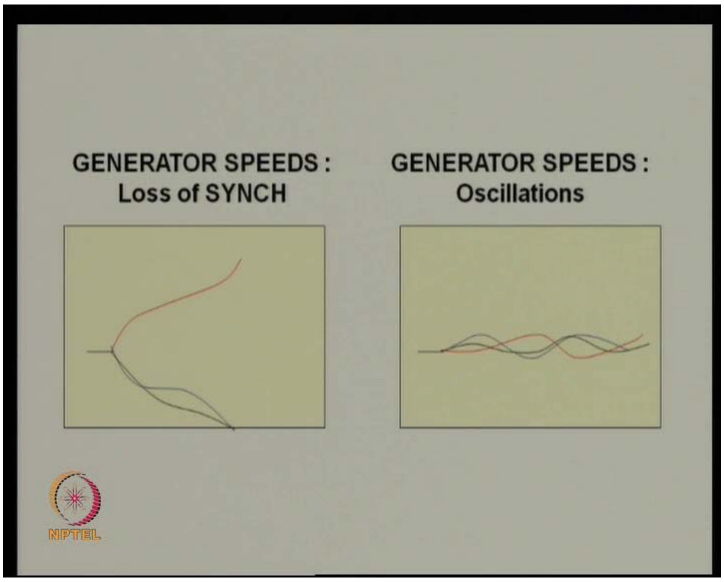

As the load frequency characteristics, it is important to differentiate this center of inertia motion from loss of synchronism if there is a large disturbance. This is what the generators speeds may look like. Here you got one machine whose speed becomes all together different from the frequency of the other machine. So, if you if you got synchronous machine in which synchronous machines are connected by AC lines and there is a large disturbance, you may loss synchronism. So, please differentiate between the center of inertia motion as it is evident from these figures the moment of the center of the inertia motion and the unstable relative motion which is seen in this particular figure.

So, this is the loss synchronism phenomena. Another phenomena which is often seen in the grid because of which could be because of in proper feedback controls or the inadvertent effect of some feedback controls is poorly dam oscillation. Even for small disturbance is sometimes you will find that the system does not settle down quickly to an equilibrium. I mean you will find out just goes on accelerating sometimes. Even this acceleration grows with time in case of certain feedback controllers.

So, these are the things which we will learn in this course, but important point is to differentiate between relative motion and common motion. So, common or a center of inertia motion is dependent on load generation balance and center of phenomena rather than the relative motion. It is rather the loss of synchronism is a phenomena in which relative motion is really important. Now, let us just consider a system like this. You got generator. It has got local load. What another generator? It also got a local load say, this is supplying 1000 mega watts excess no losses for simplicity. This is 500 mega watts. So, this generators actually to over this line exporting this an AC line exporting 500 mega watts. This is say 700 mega watts and this is 200 mega watts.

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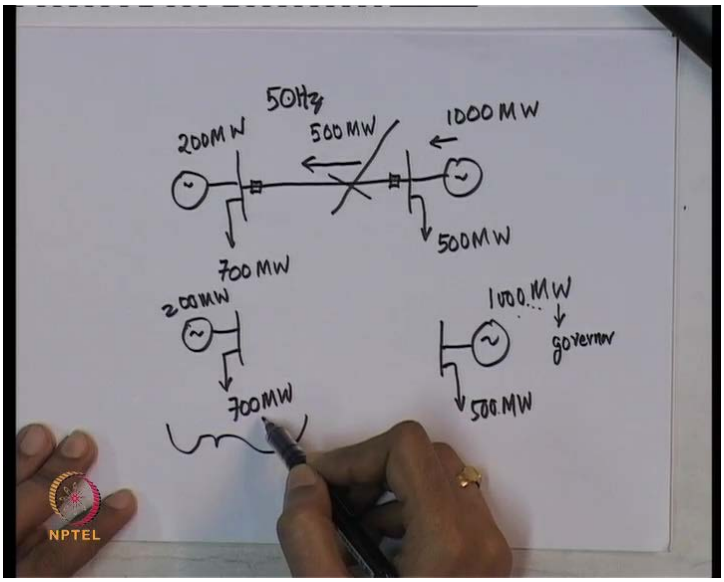

The total load is equal to the total generation. So, the center of inertia is not going to the speed is not going to change. Let us assume, this is a situation which exists at particular time and system is synchronism and in steady state. Now, because of some disturbance or say loss of synchronism, suppose they realize the cut the circuit breaks at two ends of these lines suddenly. So, you have got this line is tripped out. In that case, you have got two systems. Now, you have two separate systems. If the frequency in this system is to remain constant, in that case, the generation load would need to be balanced, but look at the generation at this point of time, it is 1500.

So, the frequency will suddenly shut up. The mechanical power and electrical power on are not the same. So, the frequency is suddenly shut up unless we do something. It will exceed may be 1 or 2 yards above 50 yards which you say, the normal frequency at the beginning of this disturbance parallel to this disturbance. So, it is suddenly shut up by more than a yard. If that happens in this, will suddenly the generator will be tripped out due to over speeding. So, this whole inland will collapse. So, it is important that as soon as inland is formed, immediately some emergency control measures have to be taken to make this generator to reduce this generation. So, you need to have governors. Governor should try to reduce this generation quickly. Similarly, if this under generated inland, you suddenly have a large amount of load and less generation.

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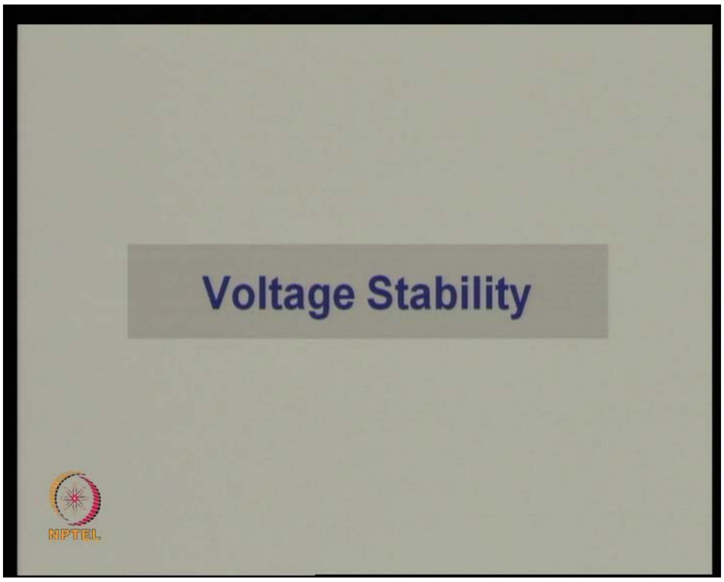

So, what you need to do here is tripped out the load quickly and increase the generation if you can again through governors. So, once you inland, suddenly you are left with carrying differences between the generation and the load. Moving on to another interesting phenomena which has been observed, that is voltage stability. So far, we have been talking about the frequency and relative angle, relative frequency motion of synchronous machines will move on to stability of the voltage magnitude at a particular point in the grid. Now, when does this problem really arrives, that is the question we will ask ourselves? Just having low voltage in steady state does not necessarily mean that you got voltage instability. Normally, if you got system, say a synchronous generator which is supplying some load, let us talk about single synchronous generators, so that we do not have to worry about relative losses synchronism phenomena in this particular system.

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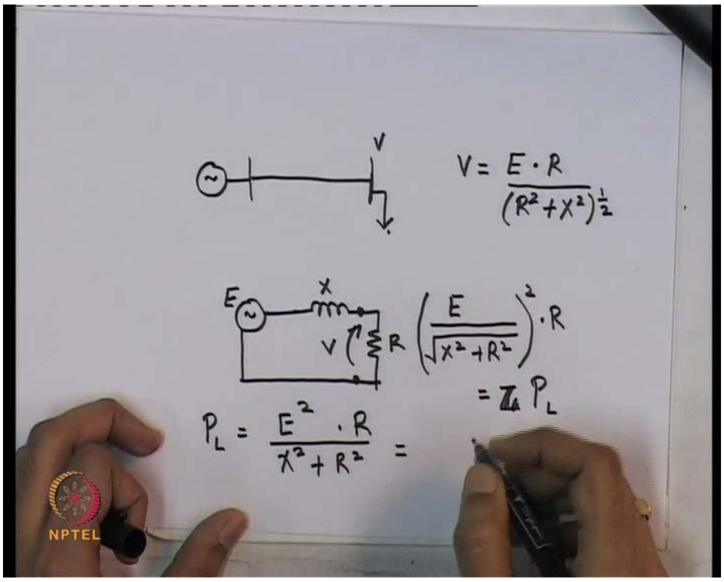

So, just to highlight the problem of voltage stability, just take single machine connected to load. If you got a single machine connected to a load, if we increase the load at this point, typically it is an inductive load most fans and pumps and major loads are inductive nature. They draw basically some reactive power. So, you will find that there is some voltage drop along with line which carries this power to this point. So, one would expect as you increase the load here, the voltage here will keep dropping. Now, this is not necessarily means any kind of instability. For example, just take this even more simplified system.

So, let us take generator connected wired transmission line to simple resistive load, something like this. This is E. Now, normally what is the power at, what is the power drawn by this load? You will find that it is E which is the magnitude. Remember the phase is not plane roll as far as power in this load is concerned. So, we will only talk about the magnitude of the voltage source E divided by the impedance. This is the current. So, square the current multiplied by R that is equal to the power in the load.

Now, you notice that the power is actually a non-linear function of the resistance. So, in fact, P L is equal to I will just simplify this E square upon X square plus R square into R. So, this is the power. So, if I change R, power will change. Another thing is that voltage here, voltage magnitude here will be nothing, but E into R upon this magnitude of the voltage at this point. You can verify that. This is nothing, but V square by R. So, you will get again the same answer if you do E square by R. If I want to increase the power dissipated by the load, so if you got I will just draw it again. If I want to increase the power dissipated by this load, what should I do? Increase R or decrease R. Well, normally one would accept that if I decrease the resistance, one would incregate a larger power output.

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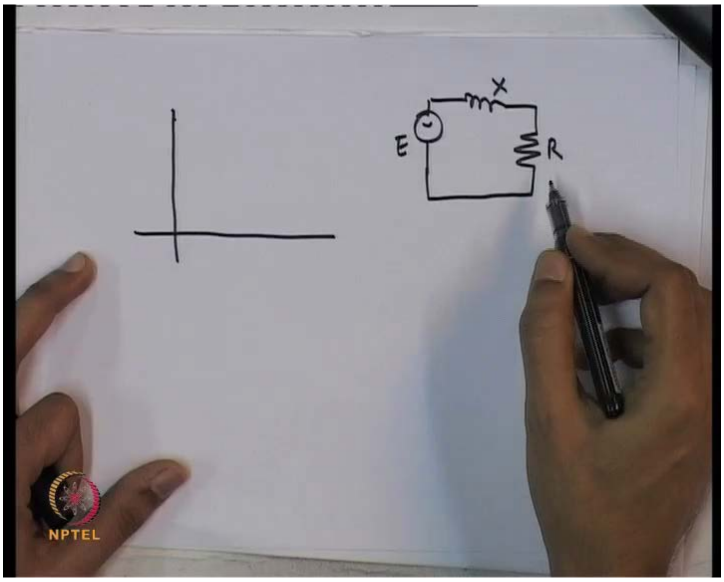

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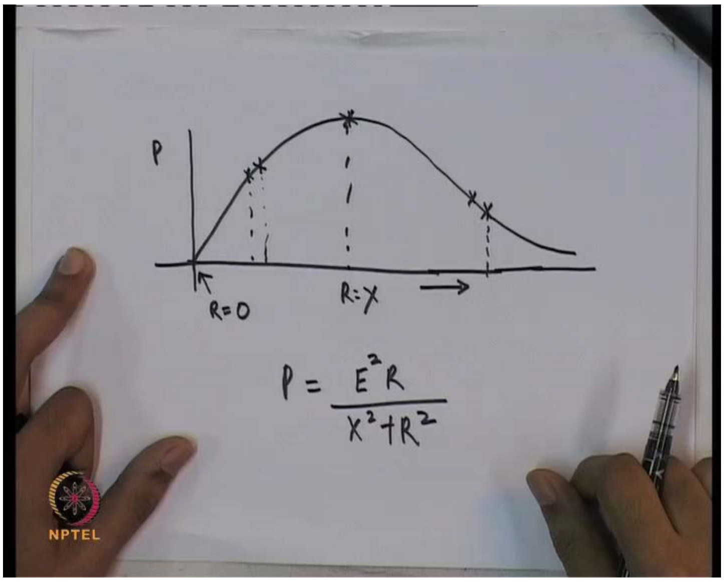

What we will have is power is going to be 0 at R is equal to 0. Do you agree with that? If I increase the resistance and make it close to make it very very large, then also you would expect that the power is again 0. So, what you have is at some point, there is a maximum to this power. So, what is this point? So, P is equal to E square R upon X square plus R square is easy to show that this occurs when R is equal to X. So, the thing is that in case by resistance value is this and I want to increase the power. What should I do? I should decrease the resistance, but if I am here, that strategy will not work because if I try to decrease the resistance, my power actually reduces.

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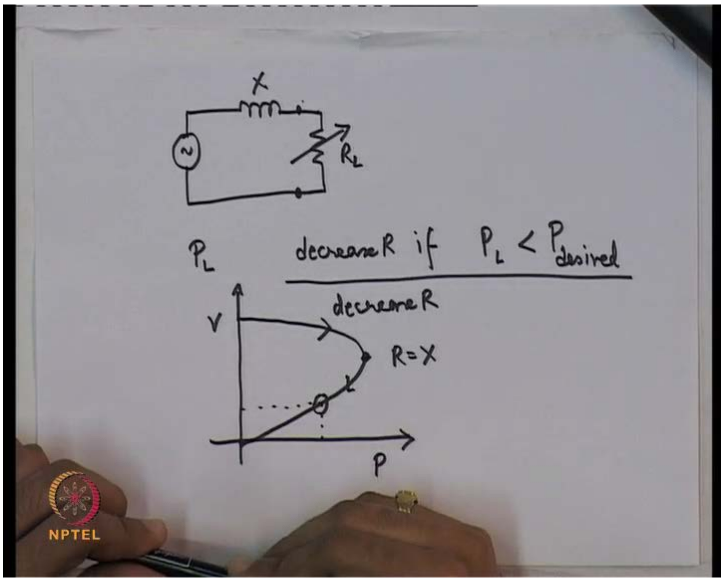

So, in fact, this is the basic origin of problem call voltage instability. So, if you look at say, a load which is constant, but control. Suppose, I use the rule, I am the selfish load. I say whatever be the resist voltage here, I will draw the same amount of power. So, what my rule is? My rule is going to be that I want to get the same amount of power irrespective of what voltage appears here. So, what rule I will follow is decrease R if P L is what, I. This is lesser than what I desired. So, if I use this rule, I may land up into problems if I am at this point in the curve. So, if I reduce the R, in fact my power will reduce. If my power reduces, I again apply the rule. I again reduce the resistance. My power further reduces and you will find there will be driven down the voltage. The power will be actually, it is driven down and resistance value will go on decreasing.

It is not difficult to show this. This is the magnitude of the voltage and the power for this particular system. So, if I actually decrease R, power increases. Voltage also decreases, but actually V square by R still increases. At this point, this is the maximum power point R is equal to X. If I decrease the R, the voltage drop will be much much much faster. In some sense, I would not say use the word faster. You can say that the voltage drops so much that decrease in all does not cause increase in power. So, what may happen is that if you apply this rule, if you got a control system which applies this rule will find that if you go beyond this point, your voltage will be driven downwards.

Typically of course, if voltage goes below certain point, there are some times in many loads under voltage wheelage which will trip out the load or the control action will see at certain point, but point is that you are not achieved much by decreasing resistance. If you are in this part of the course, we actually gone to version the situation. So, this if you have got load which draws power and it changes its resistance or impedance as per the rule, you likely to have instability if you are somewhere beyond this bond. So, this is the basic. You know problem of voltage instability you may ask poor that normally we would design our X to be very small, Y would be normally have an which is an large value. The answer is yes. Normally, your X is not very large and in fact, the possibility of R becoming equal to X is very very remote in a normal system.

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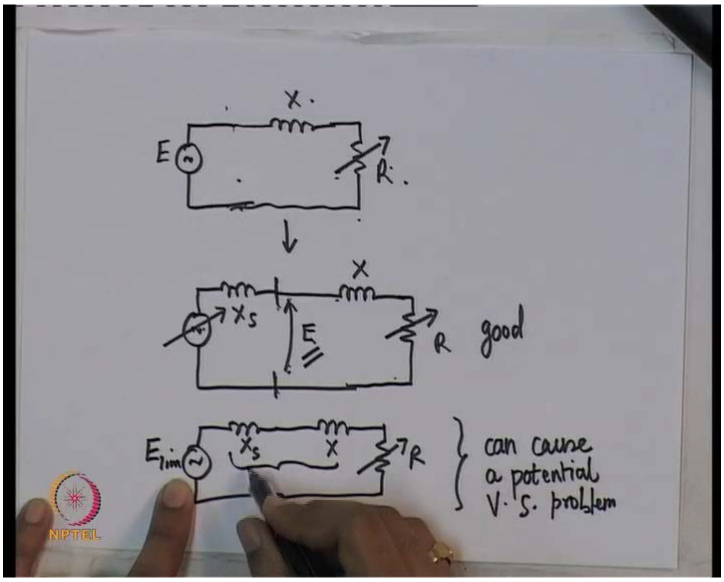

In case you for example, the loss of large amount of transmission line distribution lines, in that case, you may have a system impedance becoming fairly large even more prominent is a situation like this. See this voltage source which are shown here is actually a synchronous generator and I have shown this as an X and this is R actually. In a real system, this is how it looks a synchronous generator is not actually perfect voltage source. It is a voltage source behind the synchronous reactants. So, actually you may ask the question is this figure is not the same as this? Obviously, unless of course, I am intended this to be E, how will I maintain this.

See this figure and figure, convey the same thing if this point here is maintained at voltage E, but the point is that this E is maintained constant. How? By this synchronous generator itself the field voltage of synchronous machine can be controlled, so that the terminal voltage of the machine equals E and nearly, you know almost maintain regulated at E. So, in a normal system, this X is not normally very large. It is never anywhere close to the load resistance, but there is one problem here. This E is not a constant. Strictly speaking, it is regulated, roughly regulated by synchronous machine which as certainly mix. For example, what happens when this synchronous machine hits the field heating limit, that is, I cannot increase the field voltage and there by the field current more than certain limit. Then, this control is lost and I am no longer able to regulate this to E. In that case, it is meaningless to talk of this E as a constant. In fact, this becomes at the limits is an synchronous reactants at the limit. This is how your system is going to look like.

So, this is a constant. This is a large impedance synchronous, reactants of a machine is large. This is the transmission line reactants. Now, this system can be proven to voltage stability because this impedance suddenly very large and this is the constant contrast with this situation, wherein this synchronous machine is able to maintain this E by changing the magnitude of the terminal voltage of the machine, that is by changing. I will repeat the sentence. Contrast this with the situation where E is maintained constant by the synchronous machine by changing the field voltage applied to it. So, this is a good situation in which we are able to maintain this E at a constant value, but once the field voltage hit its limit, you cannot increase the field current beyond the certain limit. Others, it will hit up the field binding.

So, there is a limit to this. If this limit is heat, then suddenly the picture changes. Here, you got very large system impedance behind voltage source which is internal voltage source of this synchronous machine, this practically constant. So, this can cause or potential voltage stability problem because the system impedance suddenly becomes very large. Now, you may ask the question. Of course, I have been talking of load whose resistance changing in control way, that is, it is decreasing the resistance whenever the voltage falls down or the power is less than the desired power. This kind of control rule under certain circumstance may lead you to dropping voltage.

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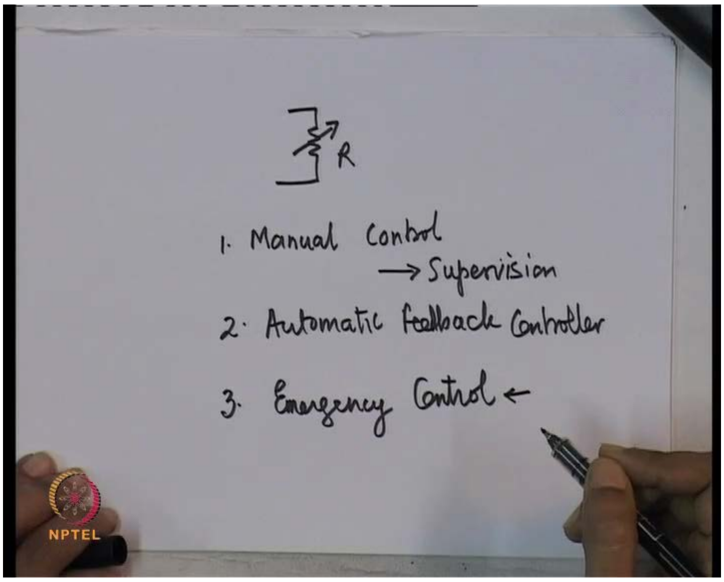

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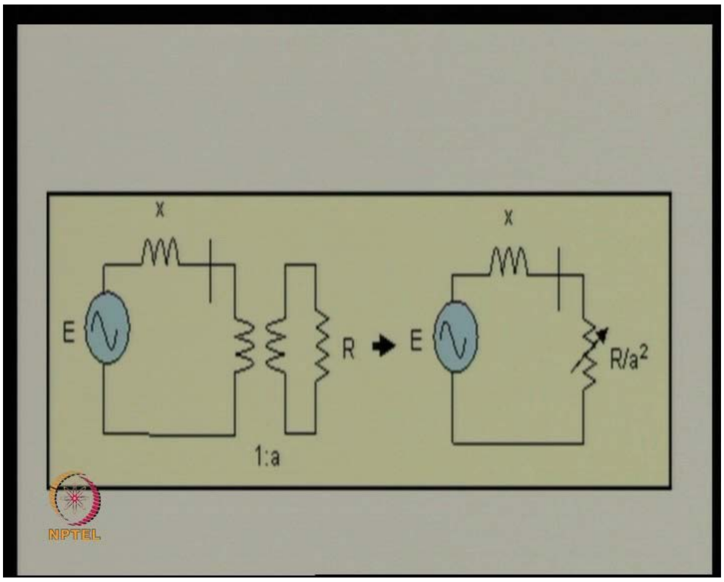

Now, when does this actually occur? For example, do you have control resistance? Well, you can have control resistance, but more typical phenomena with measure the same thing is this one. You have got a load resistance which actually does not change, but it is supplied from a tap changing transformer. The tap of the transformer keeps changing. So, the voltage here drops down. The tap is increased the effective resistance which the system sees in fact is variable. So, although I talked about variable resistance, basically about typical situation is lightly to be like this. Of course, the same issues are here to in fact the same arguments are valid here because this tap is increased whenever the voltage air falls. If the voltage, say falls below one per unit here, you will increase the tap.

If you increase the tap, the voltage here is like you think it will increase; you will increase to 1 per unit near 1 per unit. Therefore, the load power can be maintained the constant, but this of course will not be true if R by a square has exceeded X. So, that is what or other as decreased below X. So, if R by a square decreases below X, any kind of change in a the tap will actually cause decrease in the power.

We will next move on to the other issue, other issues relating to stability. They are mainly caused by feedback control system within the power system in the power grid.

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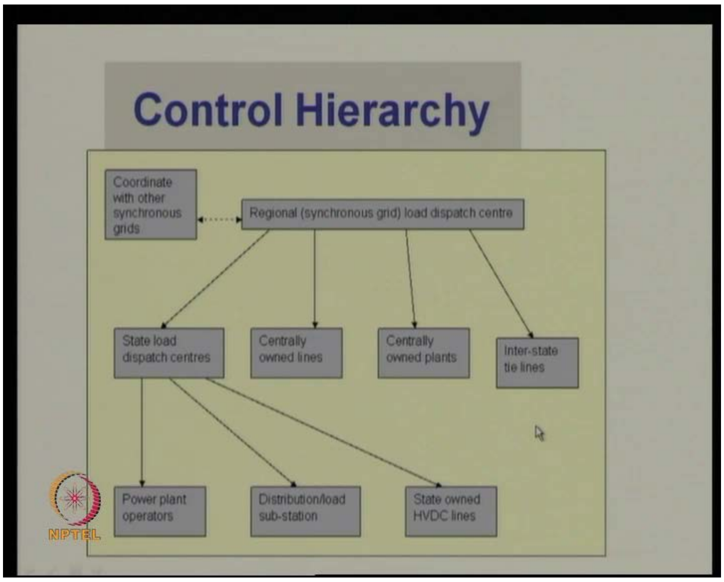

Now, before we look at the control systems which exists in power grid, of course that something will discuss in course later on prime mover controller excitation system controllers. You look at the problem into two ways. There are two kinds of thing which you normally do in a power system. One is manual action, manual control actions based on supervision. The second type is the automatic feedback controllers. These are the typical feedback controllers which you have learned in your control system course. They use typically regulators kind of, they have typical voltage regulators and governors. These are all automatic feedback controllers. The third thing which you will see is emergency controls. Emergency controls are control actions like tripping of load whenever there is a large imbalance of load generation. When in for example, in under generated inland, one can have emergency control scheme, wherein with the frequency falls, you trip out load. So, try to get you know center of inertia of frequency within an inland within certain limits. So, this is called emergency control. In fact, emergency control kind of over laps with in some way with protection system is like recruitment protection system.

Now, if you look at the control hierarchy in power system will find that there is at highest level manual supervision in which you know energy controls system center actually looks at the great monitors. It suggests changes in power flows in certain lines. For example, by adjusting the load engine ration at the two ends of, say a transmission line, so that you are not having the danger of going twin unstable situation. So, this is what is you can say supervise preventive control which manual or a person is load dispassion center does and this may be over you know very long time. This is also feedback control actually. If you look at the control hierarchy in our system in India, you have got regional energy control centers which coordinate with other synchronous grids. For example, the western regional load dispatch center which is in Mumbai coordinates with southern regional load dispatch center. This another synchronous grid, the regional load dispatch center monitors the overall grid.

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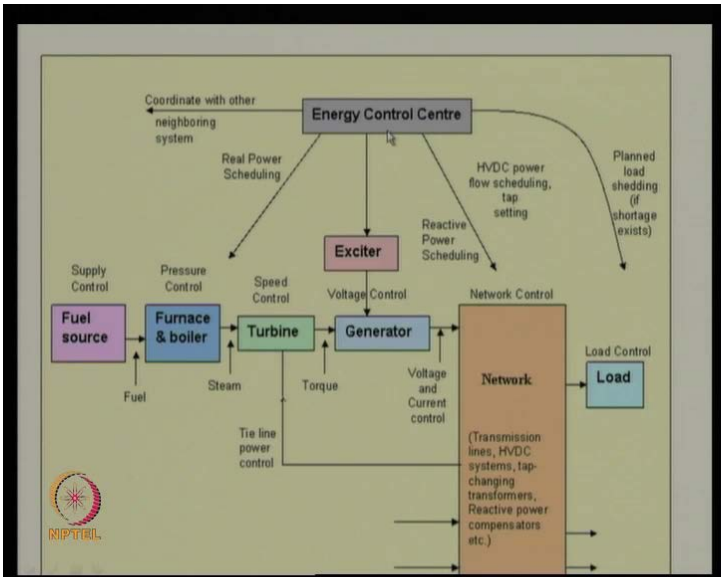

Also, anytime gives instruction to state load dispatch centers. The state load dispatch centers themselves directly communicate with power plant operators load stations and so, on which is in there give restriction. The regional load dispatch center may have a few as such we are under its control. For example, interstate tie lines centrally owned plants and centrally owned lines, so this is basically the manual control hierarchy. However, eventually whatever in a energy control center says, say or state load dispatch centers communicates with power station to reduce its power output, in that case, the power plant operator adjust the prime mover system to reduce the steam input to the tribune and eventually, the generator, the output power reduces because mechanical power eventually reduces. If you reduce the electrical power, output reduces in case reduce the mechanical input to the tribune.

Of course, the energy control center may actually give instruction at slightly higher level. In the sense, they may say reduce the reactive power output of your generator. So, what actually your power plant operator will do is reduce the field voltage. It is not directly you may have what is known as voltage regulator whose reference voltage reduces which eventually reduces the field voltage of the generator and as a result of which, the generator may reduce its reactive power output. Energy controls center may also have control over component which are there in the network. For example, a high voltage DC system, you can control the power out of high voltage DC system or the reactive power out of certain reactive power compensative within the network. The energy control center may also, anytime do a bit of load changing in case there is a severe load generator, there is a severe generation deficit.

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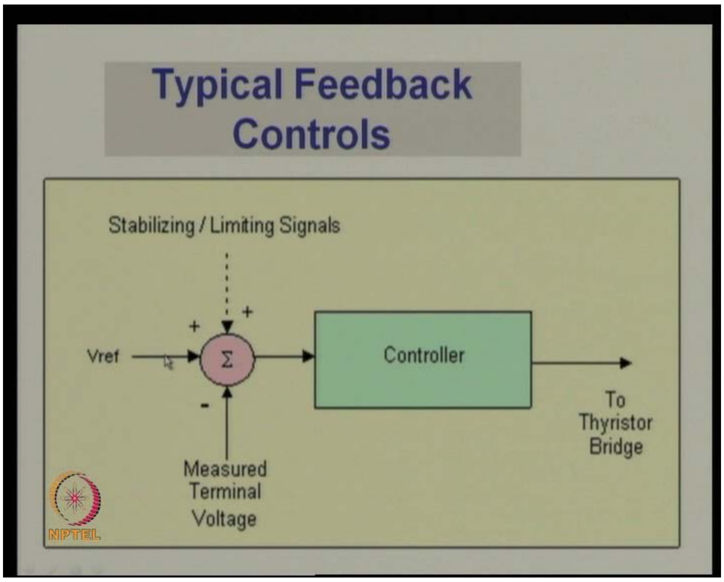

So, remember that eventually at the lowest level, you normally have control system which responds to the scheduling orders of in energy controller, a system operator. You look at a typical control system, the typical control system like voltage regulator of the synchronous generator. What it does is, it compare the measure terminal voltage of generator to the reference value. This is said by the system operator himself. It is passed through a controller which may be professional controller or P I controller and that determines the firing angle of the thyrister bridge bit controls the field voltage which is fit to the field winding often the alternator. Therefore, the terminal voltage is changed. So, Vref is not equal to the terminal voltage. You may find that the controller adjust or changes the final output voltage. In this fashion, you may also have emergency or stabilizing controller which modulate the voltage reference to as improve stability.

So, this is something we will learn later in this course. To come to near the important point in this somewhere, in the close of this lecture, how does stability eventually affect your system operation? Now, if you are near in stability, now of course, this statement itself requires some kind of definition. Then, a system operator tries to take control action so as to reduce a change certain parameter within the power system. For example, you may change the power flow in certain lines. So, stability criteria have to be defined much in advance. For example, a system one would normally like it to operating certain way for example, you would like it to be reliable in the sense that if one power system component is trip, the whole system should not lose synchronism or it should not become unstable.

So, when system is operating a system operator kind of evaluates the stability of the system for certain potential disturbances. For example, he may evaluate that if there is a three phase fall at this bus at this point of time followed by the clearing of the lines in center of the bus will cause this particular disturbance, can cause a loss synchronous will try to take control actions like changing the power flows of the lines which are incident to that bus. This one is possible action. Of course, I am not saying this is the correct action to take, but he can take this kind of actions.

So, whenever he sees that any potential disturbance can cause a loss of stability, he will try to change the operating point. Changing the operating point in power system is done by changing to generation of the load this as economic reconstruction. So, basically stability has got economic reconstruction. So, we cannot, whenever you have system with poorer stability, it is more proven to flout. If you want proven to instability, then you have to pay more in order to get a certain kind of reliability because you will basically try to operate the system which is more which meets a stability criteria and if you do that you may have to actually move to kind of uneconomic schedule of power generation and loads.

So this is something of course, we will try to understand later when we understand preventive control. Even while planning if you find at for typical load generation in scenario system is unstable, a system planner may have to put in some money and build more infrastructure like more transmission lines. So, for that particular projective scenario, the system is table. So, this even in planning which could be a long horizon, a system operator as to taken into account stability issues. In fact, one if for example, if your feedback control in your system are not causing instability, in that case you may even not be able to operate. For example, there have been situation in the past, wherein suddenly you know almost it appears spontaneous a system operator that a system acceleration started building up. You have acceleration in frequency voltage power flows because of the feedback control system which are there in your system. If this occurs, actually in practice it is a very difficult situation because the system operator may not know what to do if you observe spontaneous acceleration smilingly spontaneous acceleration in the grid.

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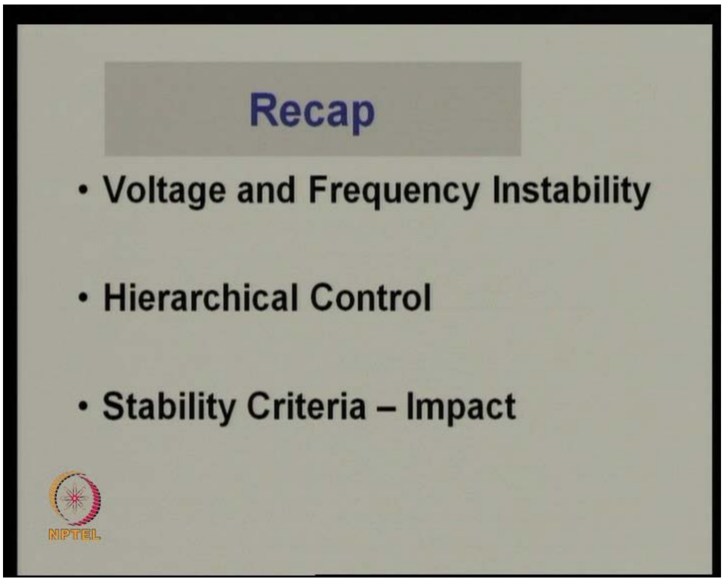

So, design of feedback controllers, appropriate feedback controllers also involve some engineering cause. In fact, if your system is proven to this acceleration are there been observed very often under certain operating conditions, you may have to invest time and engineering effect to design or even you know manufacture proper controllers which will prevent this kind of situation from arising.

So, to recap, they just discussed voltage in frequency instability phenomena by some simple examples. We have discussed hierarchy control and the impact, the stability on power system operation. Of course, our last discussion has been a big brief. We will return back to this topic when we come to emergency and preventive control later in this course in the next lecture. We will really start off with nuts and bolts of this course. The analysis of the dynamical systems till now will been looking in more of an instituted picture of everything. Einstein as said that the most in compressive thing about nature is that it is compressible.

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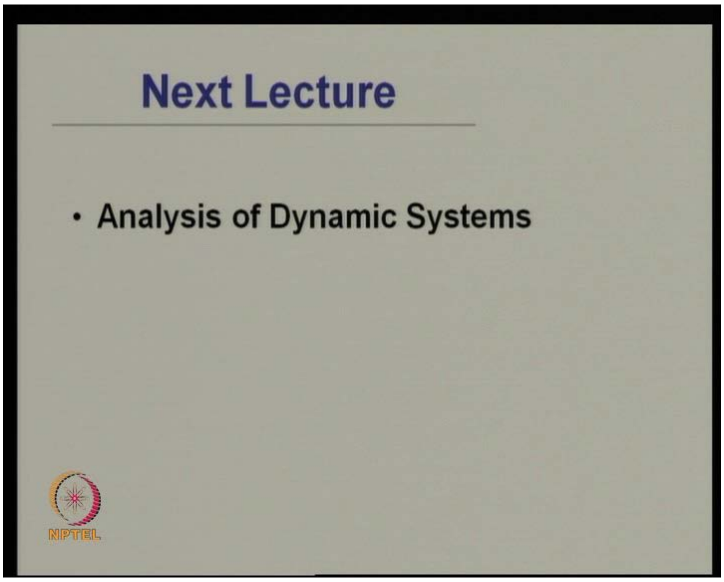

So, although, what we seem to be this course when we are entering into the integrates of this course, what we are set out or cells is to understand the behavior of large gradient and I have mentioned last time, it has lots and lots of elements. The point is that by a systematic in scientific attack to the problem will be actually able to understand these things regressively or at least approximately if not of course, there is no meaning to perfect figure in engineering course, but we will be able to basically from the equation and the modules of the system, we are going to be able to understand all this phenomena quite well. Well enough to design controls for them. Thank you and we will meet in the next lecture.