**Power System Dynamics, Control and Monitoring**
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**Lecture – 01**
**Power System stability**

Welcome to this another course that your Power System Dynamics Control and Monitoring. So, before starting this course, of course say that your little bit I would like to tell that whenever you are teaching this course you just I would like to tell that you have; at least you have studied electrical machines as well as power system analysis for you know for under graduate student. Those who have already read machines particular synchronize machines and your what you call this power system analysis you will find things are very very comfortable, right. And, for post graduate student analysis call as they can or if they want they can opt it, right. And, apart from that in various colleges that many faculties are there if they if they (Refer Time: 01:12) this thing they can also go through this lecture, right.

So, basically this is power system dynamics and control it is slightly different then other courses. Although you will see that what you call that half of the portion or even more it will be mainly your modelling and other thing for synchronous machines. So, apart from that for this course you will study transient stability analysis for multi machine system and your automatic generation control and deregulator environment. And at the same time we will see the state estimations. If time permits I will see little bit some little bit more thing if you can add.

So, only thing is that this course those who are aware of this syllabus and other thing in various colleges, right so, I will see that you know this your what you call assignments or questions whatsoever that it can be solved in a classroom; that way I have planned, right. And, and just see how is it; and mostly whatever I will show you it is basically I have scanned my class note and based on that we will study that and you will find that things are little different. But, only for undergraduate students first I would like to tell that you have covered if you have competed electrical machines as well as power system analysis then you are welcome and you will find things are very very comfortable for you, right an fizzy and resource caller also can and teachers also I will all faculties of various colleges also I will encourage it. Just go through this, right.

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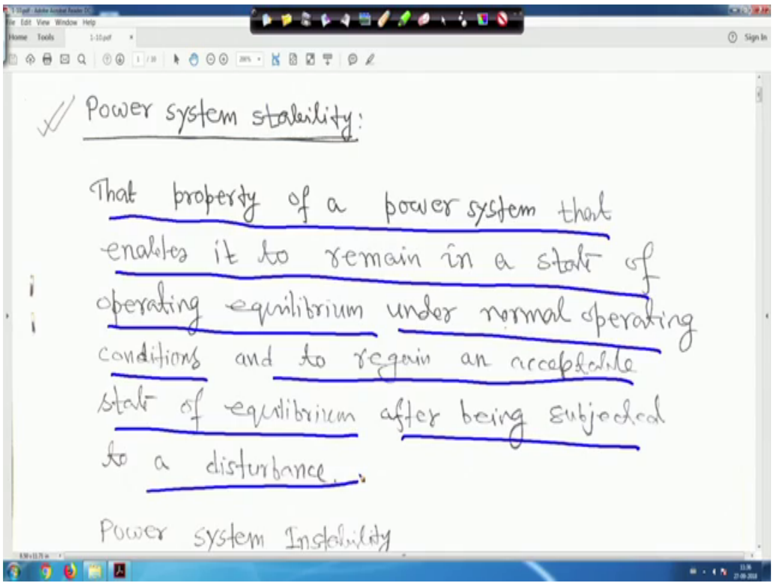


So first thing is that dynamics and control, right; so first thing is that whenever we study that power system dynamics and control the first what we will see that power system what you call that power system stability, right. So, in that case the definition of the stability, right: so it is something like this. The property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions, right and to regain an acceptable state of equilibrium after being subjected to a disturbance, right.

This is will be find as a power system stability. That means, if it is subjected to some disturbances, right then naturally, but it will remain, it will come back to it is original equilibrium point or may be in the vicinity of the equilibrium point then system should be your what you call power system will be remains stable, right.

So, that is that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance. That means, acceptable equilibrium acceptable state of equilibrium means that it will be very close to it is previous equilibrium point right, and it will remain stable. So, that is what to you call we define as power system stability, ok. So, just let me clear this.

Now, next is your power system instability, right.

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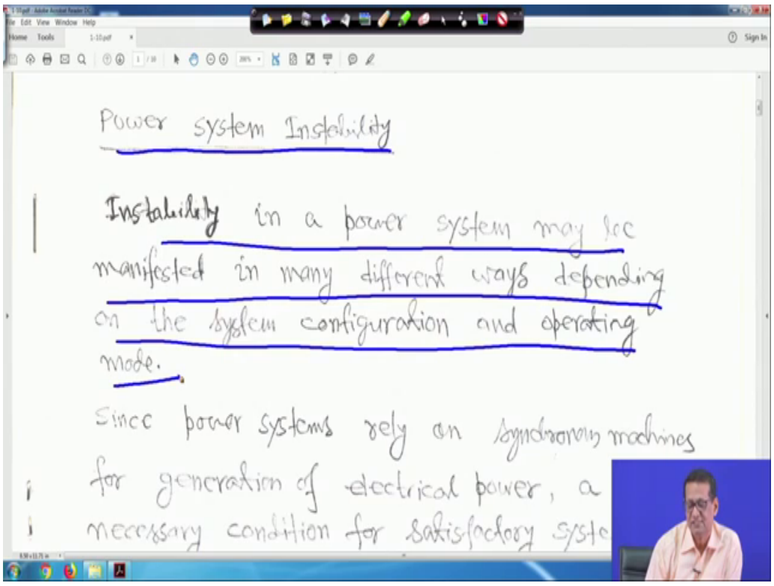


So, another one is power system instability initially first two – three hours lecture this will scan from a your what you call from photocopy. So, that is I will slightly frame after that things will be alright, right. So, now question is that next is power system instability, right. So, instability in a power system may be manifested in many different ways it depending on the system configuration and operating mode, right. So, basically in power system you will find a power generating plan basically they are synchronize machine or synchronize generator, right. So, let me clear it let me move it up mathematics will come little later, right.

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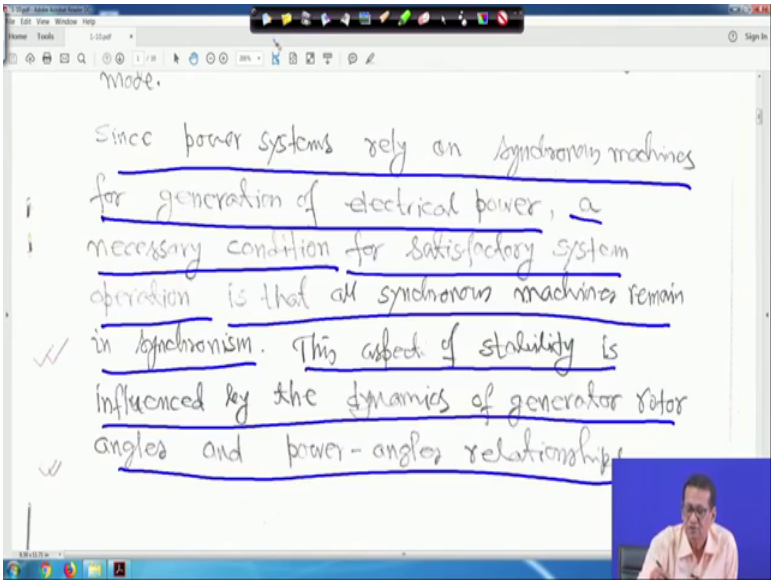


So, in power system since power system rely on synchronous machine for generation of electrical power; that is synchronous generator, right, a necessary condition a necessary condition for satisfactory system operation, right. This is satisfactory system operation is that all synchronous machine remain in synchronism, right. So, they should not be fall they should not be fall out of step, right. So, all will be your remain in synchronism this aspect of stability is influenced by the dynamics of generator rotor angles and power angle relationship, right.

So, your derivation other things later we will see.

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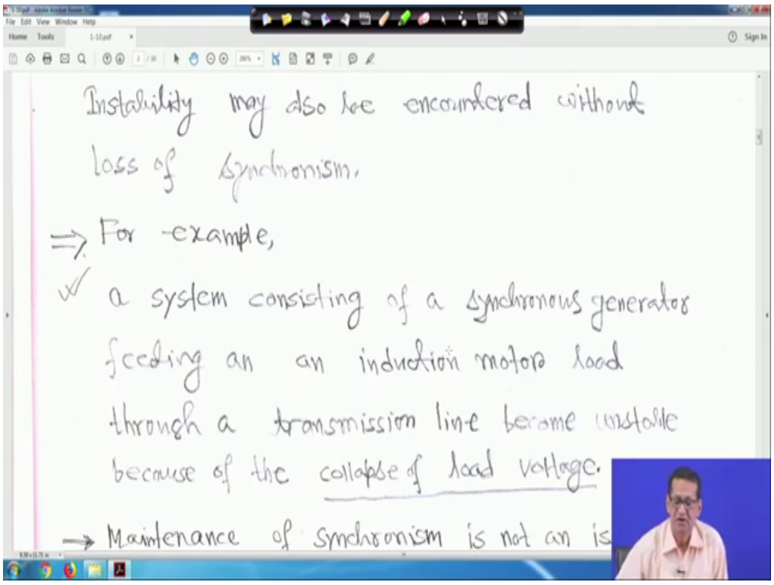


So, instability may also be encountered without loss of synchronism. If it is what you call if machine synchronous machine is fall out of step, then what you call there will be loss of your synchronism, loss of your stability, right. So, because all the machines they swing a new machine; that means, they are what you call that is your they are in coherent group; that means, they are increase or decrease of the speed same, right.

But if one of the machine fall out of step; I will loss synchronism that instability may happen. For example, a system consisting of synchronous generator feeding an induction motor load through a transmission line becomes unstable, because of the collapse of the load voltage, right. So, that is previously saw that loss of your what you call that your synchronism.

The second thing is that is system consist of suppose synchronize generator facing an just one minute here an is written twice, right just hold on an is written twice, feeding an induction motor load through a transmission line become your unstable, because of the collapse of the load voltage. So, this is also another kind of unstable system can occur, right. So, maintenance of synchronism is not an issue in this instant, right. If you want of maintain the power system stable that all the machine should stay unison they should be in synchronism right, but in this case synchronism is not an issue, right. So, instead the concern is the stability and control of voltage, right. This is another example of instability.

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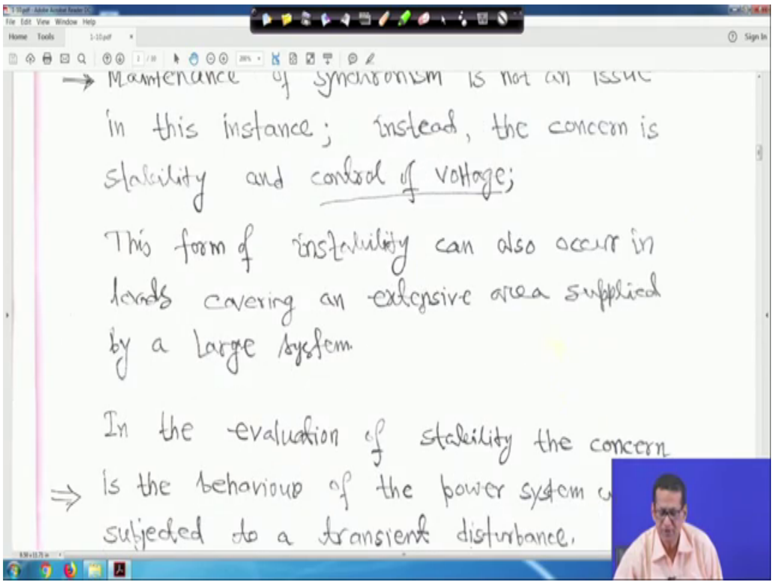


So, this form of instability can also occur in loads covering an what you call extensive area supplied by a large system, right. So, that means, one thing is that your power system rely on synchronous generator or generation of electric power, a necessary condition for satisfactory system operation is that synchronous machine remain in synchronism, right. This aspect of stability is influenced by the dynamics of generator rotor angles and power angles relationship. If any machine for it is out of state then it will be unstable.

An another example is given that is synchronous machine feeding and induction motor load, right and if there is a collapse of load voltage then what you call unstable condition may arise, right.

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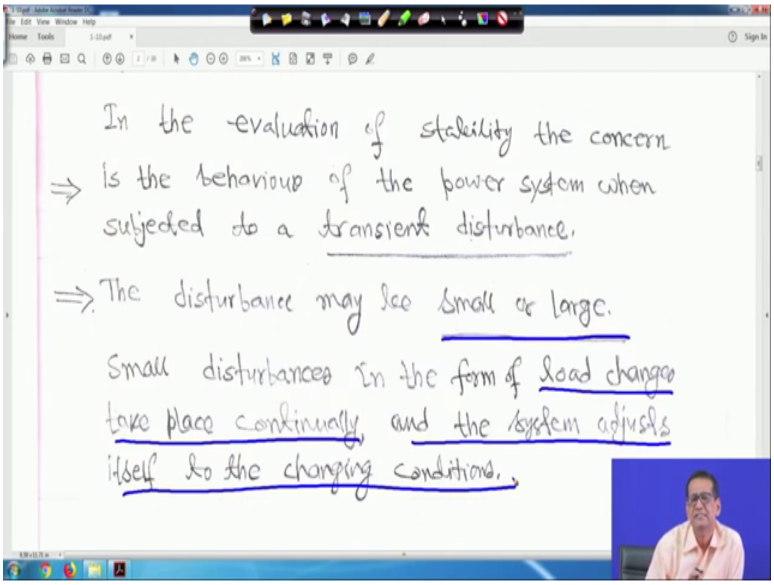


So, another thing is in the evolution of stability the concern is the behaviour of the power system when subjected to a transient disturbance. The disturbance may be small or may be large, right. So, this disturbance it may be small disturbance or a very large disturbance small disturbance is in the form of your load changes take place continuously right and the system your what you call adjust itself to the changing conditions, right. If actually in the power system you will find small disturbance are always there because loads are switched on-off, on-off. This kind of disturbance is there, it is not ideally stable, right.

So, question is that that you have to what you call some disturbance is there, but system is stable, right. So, here before moving further I will put a question, right and you answer when you will go through this your video lecture at the time you put the answer in the forum the question is suppose, suppose you are staying in the hostel right and you are sleeping, but you are stable right or in a what you call in your TV hall, right. They are perhaps you are watching TV some cricket match or soccer match at that time you are also watching everything, but you are stable, right. When you are walking on the street and gossiping with your friends you are also stable, right, when you are coming to your institute and attending the classes you are also stable, when you are going to the library and reading books you are also stable, right.

So, you are sleeping you are stable, you are watching TV you are stable, right, you are you are reading books in the library was stable, you are attending the classes you are stable and you are walking with your friends, right, and gossiping on the street, whatsoever which one you like most, right. This is a question to you. I want a good answer among all these things, right. So anyway, that is what you call that continuously some disturbance is happening, but power system remains stable, right.

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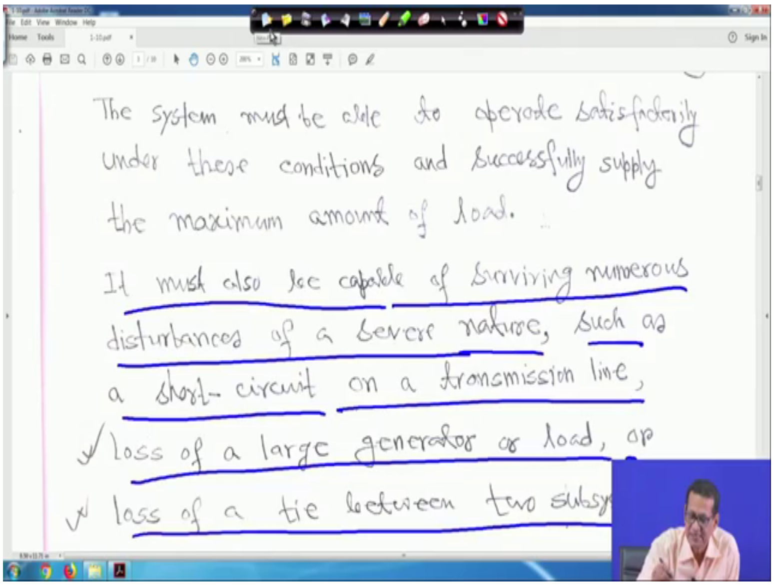


So, because load loads are switched on and off, right. So, system must be able to operate satisfactory under these conditions and successfully supply the maximum amount of load, right. It must also capable of what you call that it must also it must also be capable of your surviving numerous disturbances of a severe nature such as a short-circuit on a transmission line, right. So, loss of a large generator or load or a loss of a tie between substation; just hold on, let me clear it let move it, then I will tell you.

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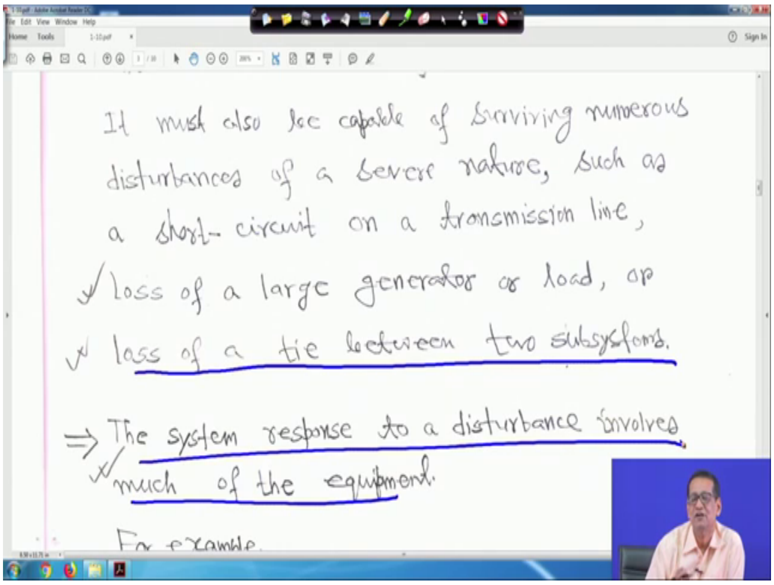


So, I mean if it happens that what you call if large disturbance happen of a severe nature such as short circuit on a transmission line or loss of large generator or a load or loss of the tie between two substation. That means, actually what happened this one your this one that your loss of a tie, just hold on, that loss of a tie between two substation that mean I mean two substations and loss of a timing that is 3-phase transmission line it is a tie line, right if all of a sudden that power goes off, right. So, all these things so, in that case that your what you call that I mean this kind of problem will give you your what you call unstable system operation, right.

So, the system response to a disturbance involve much of what you call the equipment, because whenever any fault or any such things happen you have your what you call. So, many your what you components in a power system and all will be effected because of this I mean this kind of the large disturbances, right.

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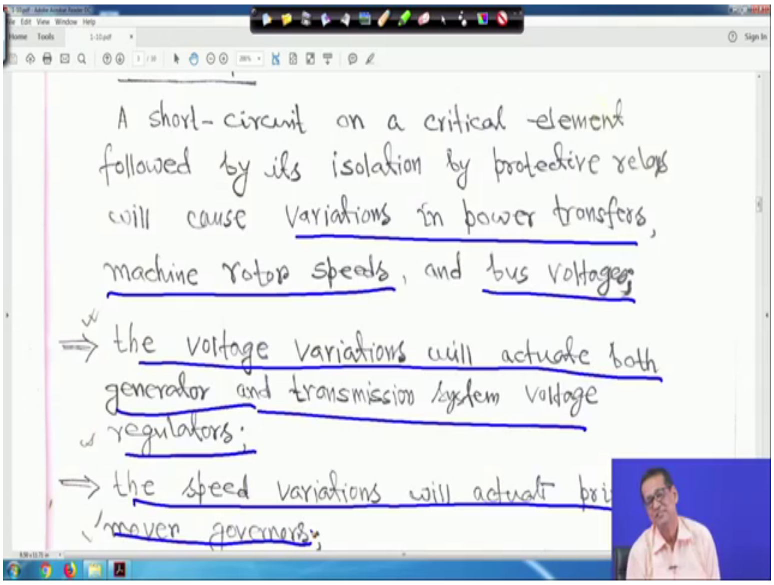


For example, for example, a short circuit on a critical element followed by it is your isolation by protective relays will cause variations in power transfer what you call machine rotor speed and bus voltages. That means, what you call it will there will be variation in power transfer, then it will change also machine rotor speed, and also the bus voltages, right.

So, the voltage variations will actuate both generator and transmission system voltage regulators, right because if volt happen many components are there. So, although relay is there to isolate the system, but all these things will be effected, right. And, speed variations will actuate your prime over governors. Prime over means for say for example, for thermal power plant it is turbine, sorry because turbine and generators they are coupled together, right.

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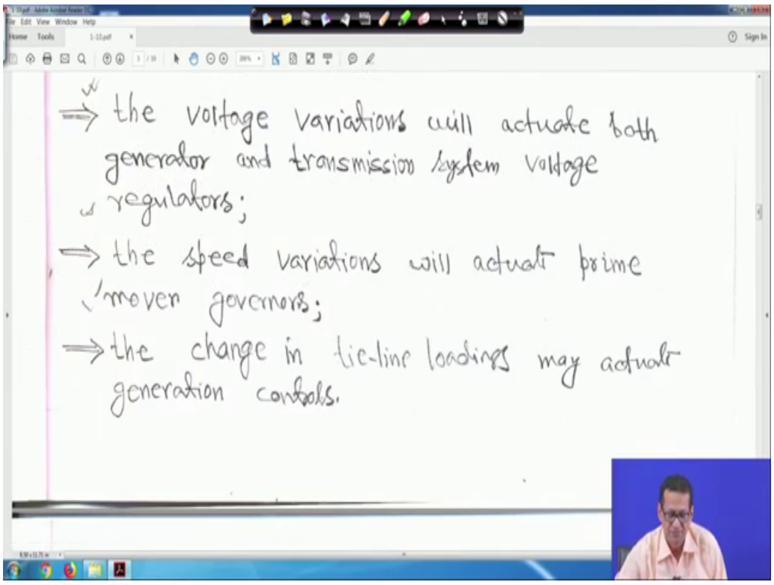


So therefore, this speed variation will actuate prime over governors and the change in tie line loadings may actuate your generation control, because whenever you will study that your automatic generation control in deregulated environment we will see that two power system was interconnected by tie lines. Tie lines means it is 3-phase transmission line, right.

So, all these things will be your what you call actually be affected, right.

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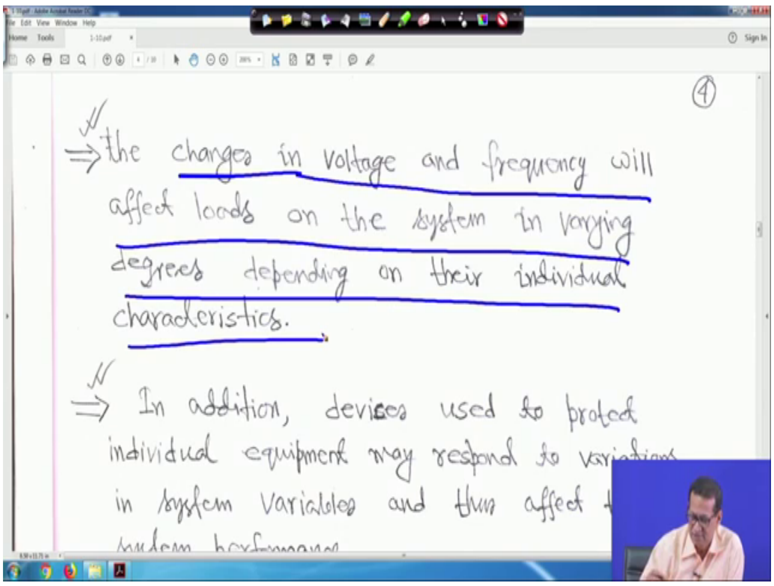

So, in therefore, the changes in voltage and frequency will affect loads on the system in varying degrees depending on their individual characteristics, right. So, the idea is that your here we are making it that the changes in voltage and frequency will affect loads or the system in varying degrees depending on their individual characteristic, because load you will if you were aware of it the loads will find may be sensitive to the may different type of loads are there.

So, many load are sensitive if the voltage magnitude as well as the system frequency. So, based on that that will also affected, right in your; just hold on, let me go up.

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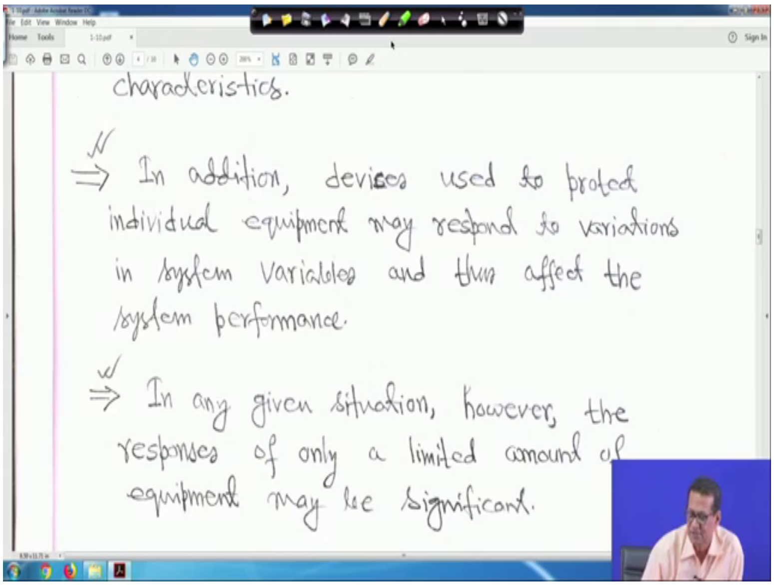


In addition devices used to protect individual equipment may respond to variation in system variables and thus affect the system performance. That means, if some kind of short circuit happens many things actually will be affected, right. In any given situation however, the responses of only a limited amount of equipment may be significant because all these things generally will not be consider, but a limited your what you call amount of equipment may be significant not all, right.

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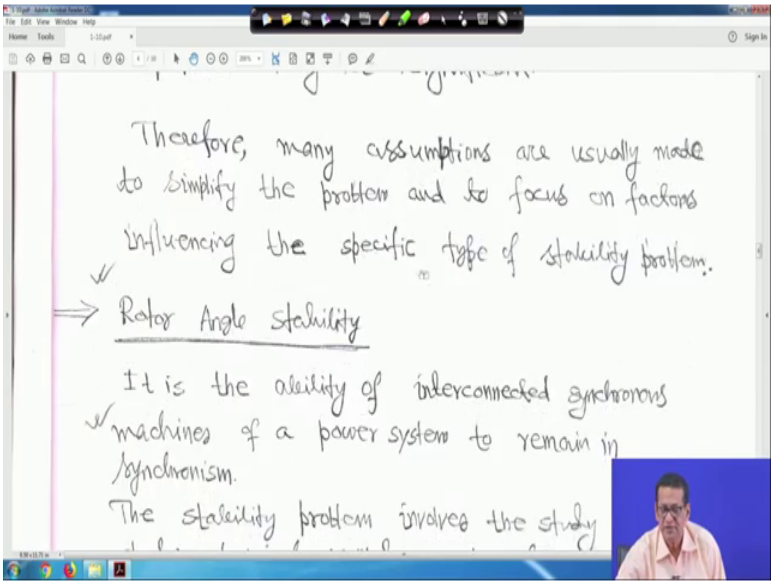


So therefore, many assumption assumptions are usually what you call made to simplify the problem, and to focus on what you call factors influencing the specific type of your stability problem, right. So, as a whole we need not consider as a whole all the things, but only those things will be affected more, right.

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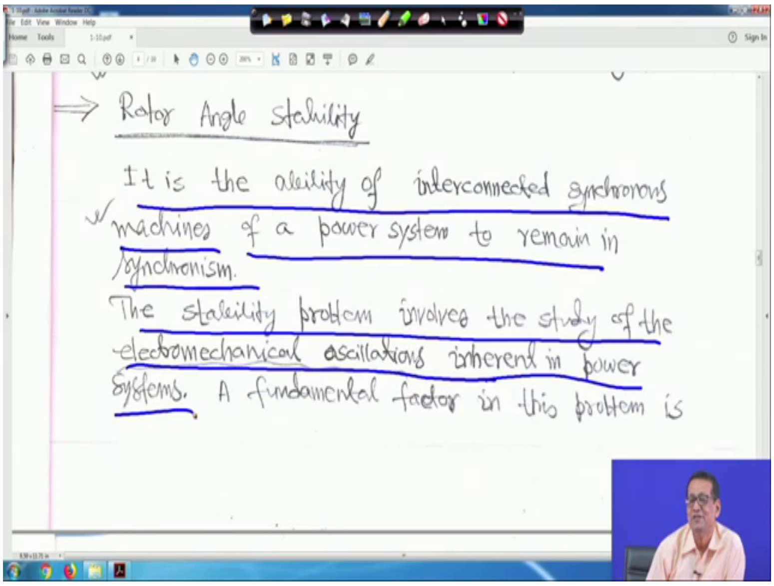


So, next we will come to that rotor angle stability. So, this is a your this is actually it is the ability of interconnected synchronous machines of a power system to remain in synchronism; that is rotor angle stability. The stability problem involve the study of the electromechanical oscillations inherent in power system, right.

So, this is actually later that we will see many things first we will see slowly, and slowly it will take time means how to develop the synchronous machine model, right. And then we will your see that your participation factor also because different modes are there, right. So, those things those things also we will identify right some Eigen values, Eigen properties all will be required. And, at the end of this course if time permits then I will come to the excitation system of synchronous machine various excitation system, if times permits, right

Because those excitation of excite us it will take time, right. This I have decided if everything goes fine if I get two – three hours more at the end then only I will come to that, but otherwise I have to skip it, right.

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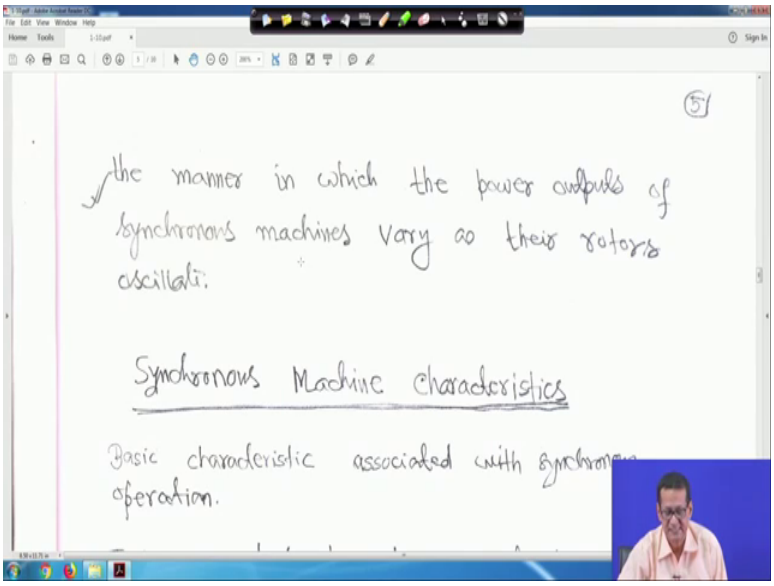


So, the fundamental factors actually in this problem is the manner in which the power outputs of synchronous machines vary as their rotors your what you call oscillates, right.

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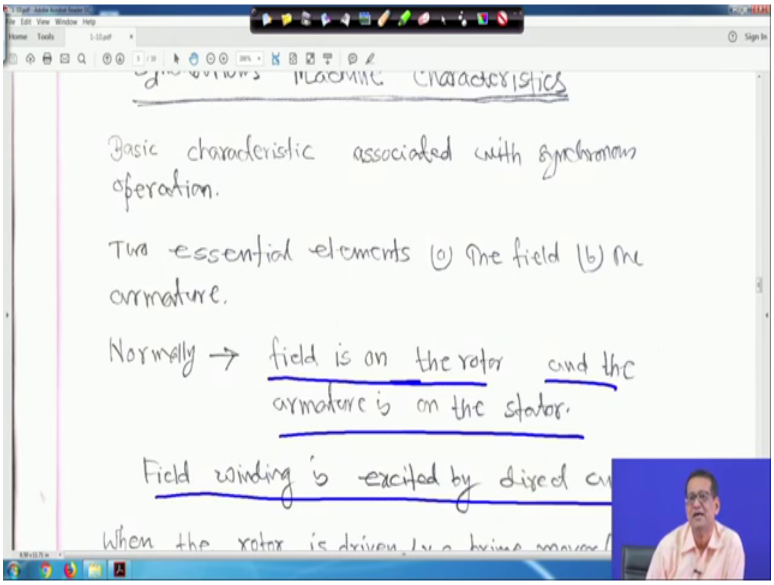


Now, synchronous machine characteristics; basic characteristic associated with synchronous operation the essential elements the field and the armature; I told you that because we have already studied electrical machines that we have to see that your field and the armature. Normally the your what you call the field actually is on the rotor the field is on the your rotor and the armature is on the stator for synchronous machine, right and field winding is excited by direct current.

So, how is this field excited is excited by direct current, what is this mechanism? If I find time then at the at the your what you call at the end of this course if I find couple of hours time then I will definitely try to tell you, right. Actually we read many things in the book also revised excited another thing. But whatever little bit I have learn from those who are in really in the power station what they have told about this your what you call that excitation of synchronous machine if time permits I will tell you what you call at the end of this course couple of hours if I get extra, right.

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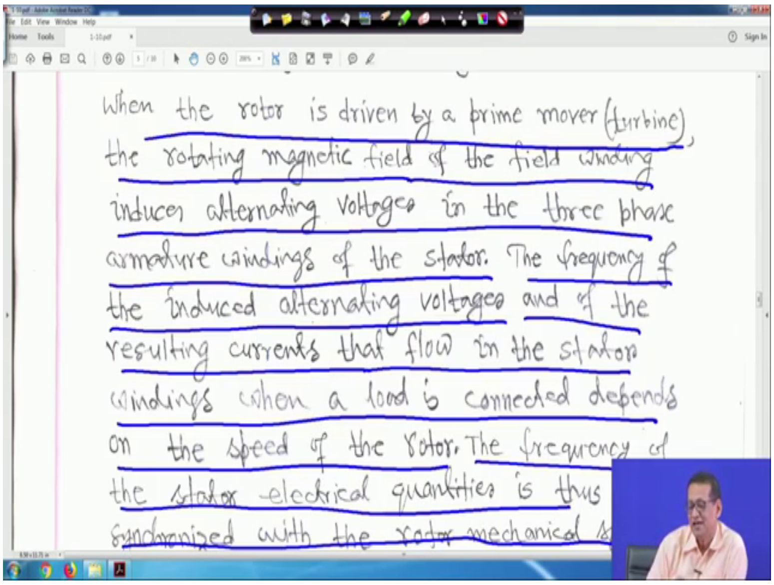


So, when the rotor is driven by a prime mover prime mover means it is a turbine, right; when the rotor is driven by a prime mover that is turbine, turbine and synchronous generator they are coupled together, right. the rotating magnetic field of the field winding inducers alternating voltages in the three-phase armature windings of the stator, right, because armature is on the stator and field is on the rotor for synchronous machine, right.

The frequency of the induced alternating voltages and the resulting currents that flow in the stator windings when a load is connected depends on the speed of the rotor, right. Therefore, the frequency of the stator electrical quantities is the synchronized with the rotor mechanical speed hence the name is synchronous machine, right.

So, question is that that when the that is why underline once again that when the rotor is driven by a prime mover prime mover means the turbine and generator coupled together. But let me tell you there will be no gear mechanism in between this turbine there is no geared direct directly it is coupled, right. If rotating magnetic field of the field winding induces alternating voltages in the three-phase armature windings of the stator.

The frequency of the induced alternating voltages and of the resulting currents that flow in the stator windings when a load is connected depends on the speed of the rotor. The frequency of the stator electrical quantities is synchronize if the rotor mechanical speed, right. So, just hold on, right.

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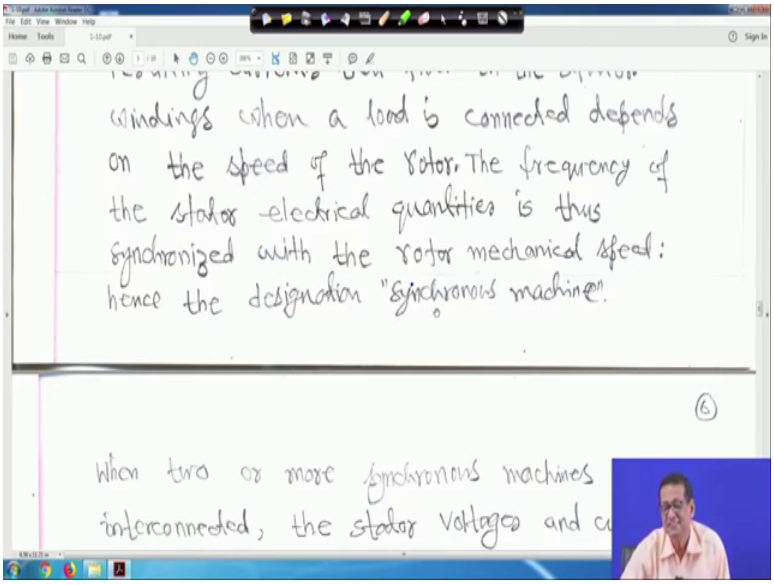


So, hence the designation is synchronous machine, right. So, or otherwise it is constant speed machine, right. So, that is why it is called your synchronous machine.

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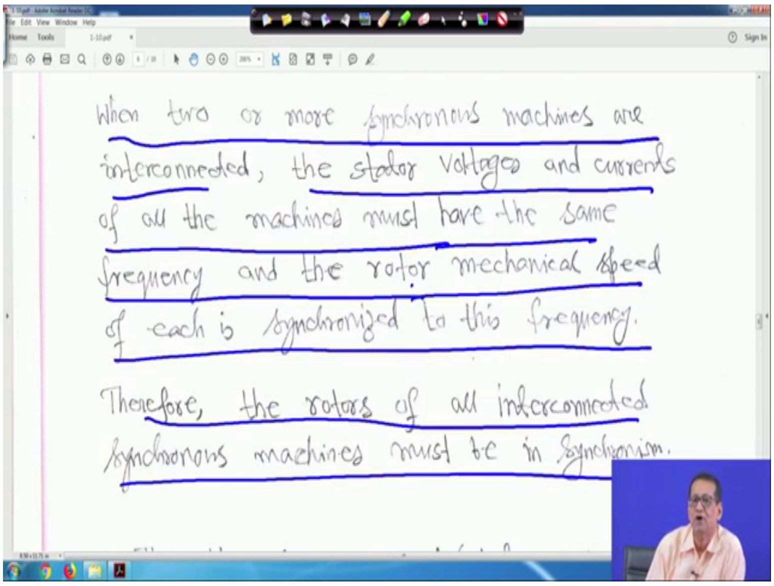


When two or more synchronous machines are interconnected right when two or just hold on when two or more synchronous machines are interconnected. The stator voltages and currents of all the machines must have the same frequency and the rotor mechanical speed of each is synchronized to this frequency, right. Therefore, the rotors of all interconnected synchronous machines must be in synchronism, right. They are I mean in general they are will be in coherent group, right they are increase or decrease speed will remain speed, right. So, all will be in synchronism. But, all the time due to some small disturbance the speed is slightly varying it is changing very little this way that way, plus minus, this way it is varying, right, but they will never lose the synchronism or they will never fall out of step, right.

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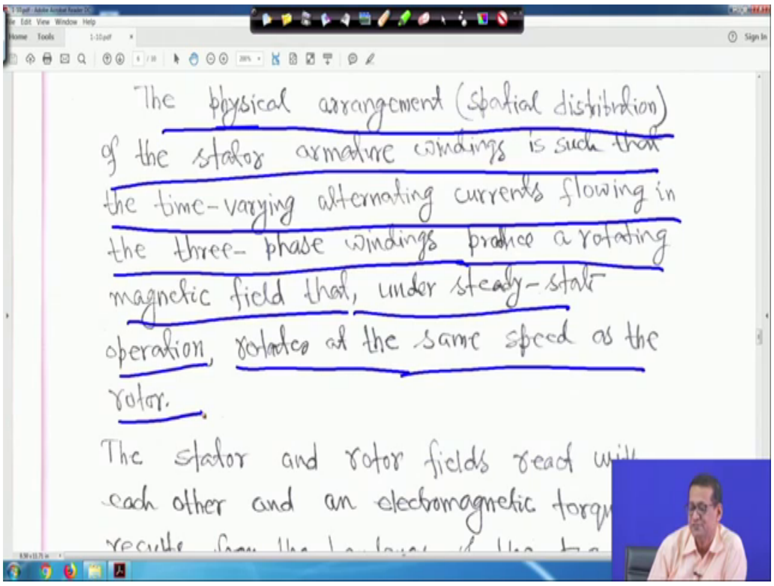


So, the physical arrangement that is your just hold on the physical arrangement that is the spatial distribution of the stator armature winding is such that the time varying alternating currents flowing in the three-phase windings, right what you call produce a rotating magnetic field that under steady state operation rotates at the same speed as the rotor, right. Therefore, the physical arrangement that is spatial distribution of the stator armature winding is such that the time varying alternating currents flowing in the three-phase winding, right is produce a rotating magnetic field that under steady state operation rotates at the same speed as the rotor. Just hold on.

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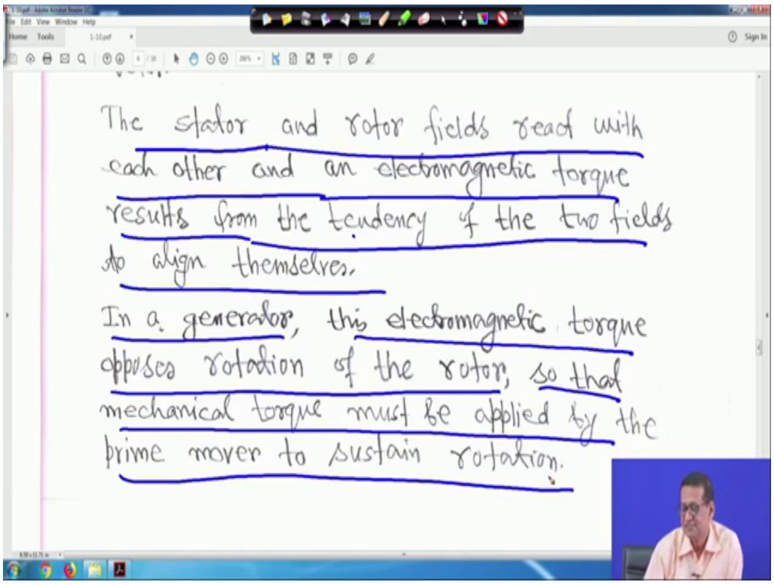


The stator and rotor fields with each just hold on the stator and rotor field react with each other, and an electromagnetic torque results from the tendency of the two fields to align themselves, right.

Now, in a generator that is in a generator this electromagnetic torque opposes rotation of the rotor, right. So that the mechanical torque must be applied by the prime mover to sustain rotation prime mover means the turbine, right. Therefore, in a generator of the electromagnetic torque opposes rotation of the rotor, so that the mechanical torque must be applied by the prime mover to sustain rotation. For example, that your single machine infinite bus system right some you have studied that your transient stability analysis, just see those diagram and how thing mechanical and electrical torque some rotation and some direction is given clockwise anticlockwise right t a minus t e, right.

So, this is the idea.

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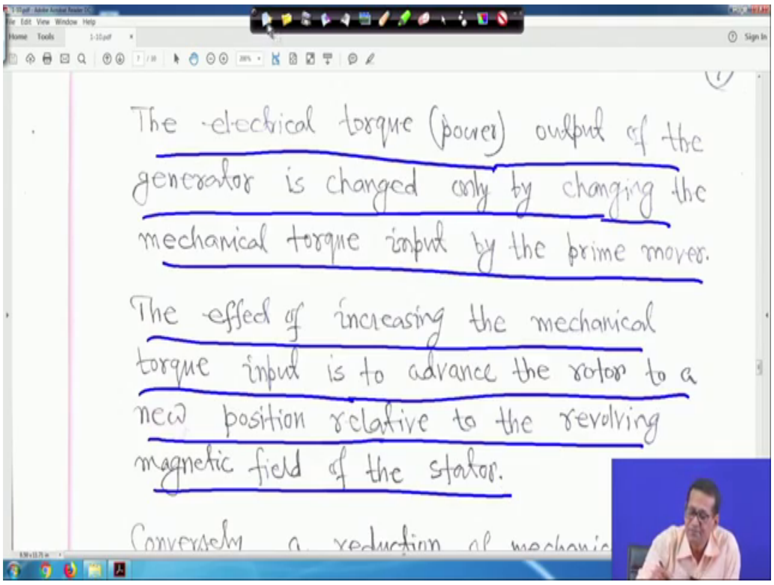


So, some the electrical torque I have writing in bracket in power. Later we will see that in power unit values; we will see that torque and power is same when you will neglect the your; what you call that losses we will find that torque per unit values torque and power same. In this course we will also study power unit system for synchronous machines that will be slightly per unit same for whether power system and this, but here slightly different you will find, right. Later we will see that then that and cover that one also we will take some time.

So, the electrical torque that is why I am writing in power you assume what you call per unit output of the generator is changed only by changing the mechanical torque input by the prime mover. This is single machine infinite bus, something some something we have studied also, right. So, the effect of increasing the mechanical torque input is to advance the rotor to a new position relative to the revolving magnetic field of the stator, right.

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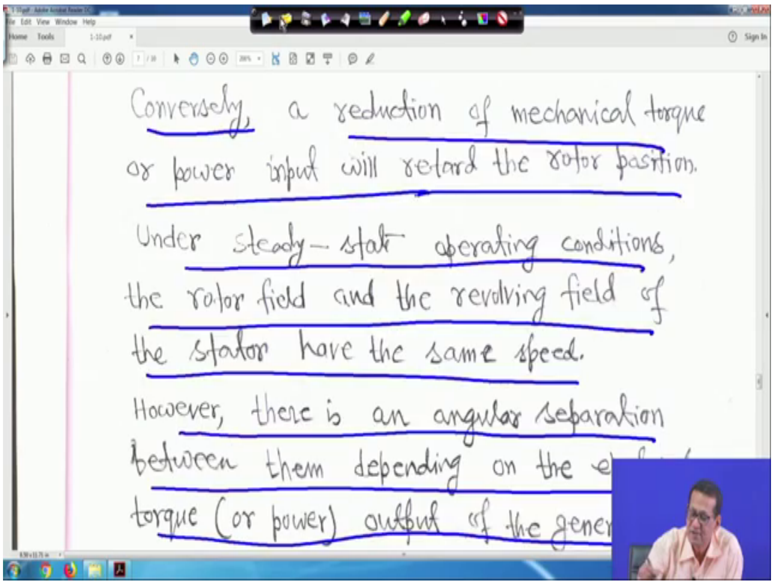


So, now conversely, a reduction of mechanical torque, conversely a reduction of mechanical torque or power input will be will retard the rotor position I mean deceleration, right. So, under steady state operating condition the rotor field and the revolving field of the stator have the same speed, right. So, where when it is steady state operating condition rotor field and the revolving your and the revolving field of the stator they have the same speed. However, there is an angular separation between them depending on the electrical torque output of the generator, right.

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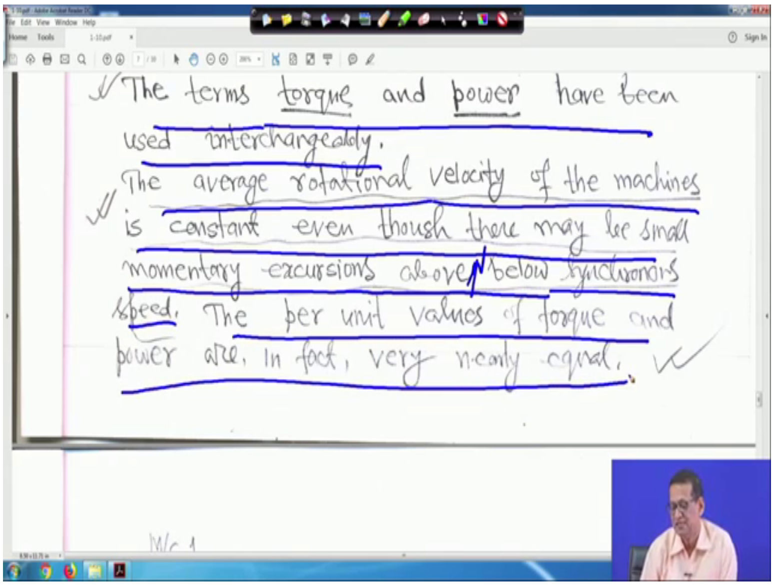

The terms torque and power have been used interchangeably, right. So, just hold on. So, the terms torque and power have been used interchangeably, right. Now, the average rotational velocity of the machines is constant even though there may be small momentary excursions above or below synchronous speed, right. It is above or below right synchronous speed per unit value of torque and power are in fact, very nearly equal; that means, because machine lose is negligible, right. Later we will see if lose we ignore then you will find in per unit values power and torque will be remain same, that will prove, that will prove later because this course actually have full of mathematics only, right. I mean you will later you will see that full of mathematics that is why I told that we will set the assignment questions such a fashion such that you can answer in the class room, but it is a full of mathematics, right.

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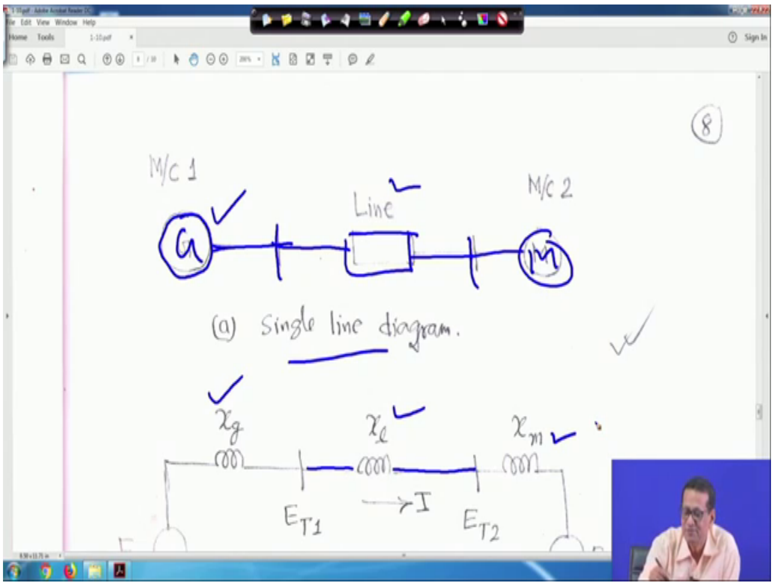


Now, for example, these diagram; this is actually later after one or two hours lecture later we will find things are ok; this is actually scanned from a photocopy, right. So, this is my generate suppose this is one generator this is machine 1, right this is my generator I am just redrawing it for you once again. This is one this is my this is transmission line impedance, this is line and this is your a motor is there, this is machine to a motor is there, this is a single line diagram, right. Suppose, now if you take the generator for above resistance only reactants generator reactance is a x g, line reactance is x l, right make it a these thing right like reactance is x l and motor reactance is x m, right and terminal just let me let me move little bit up.

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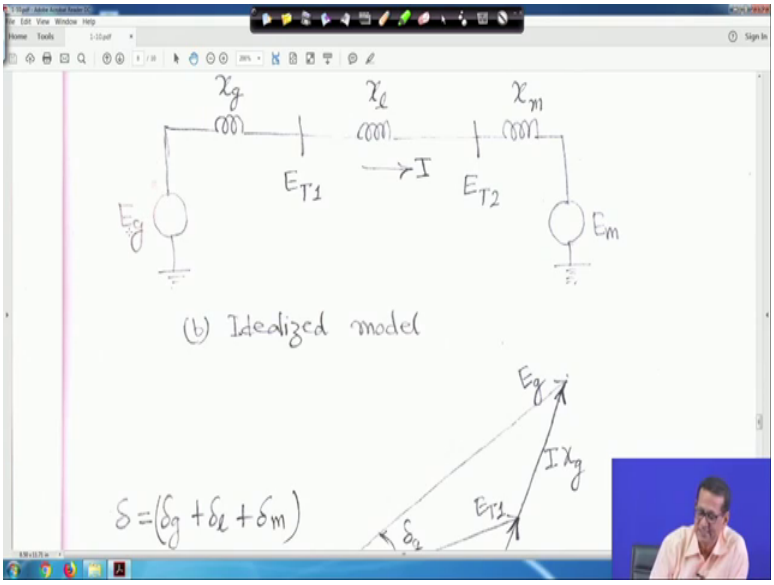


Just make it further right this one. So, in this case what you call and this motor reactants x m and here the voltage is E T 1 and here the voltage is E T 2, right. And this is your idealized model, because resistance we have consider and this is your generator voltage E g and this is E m motor side.

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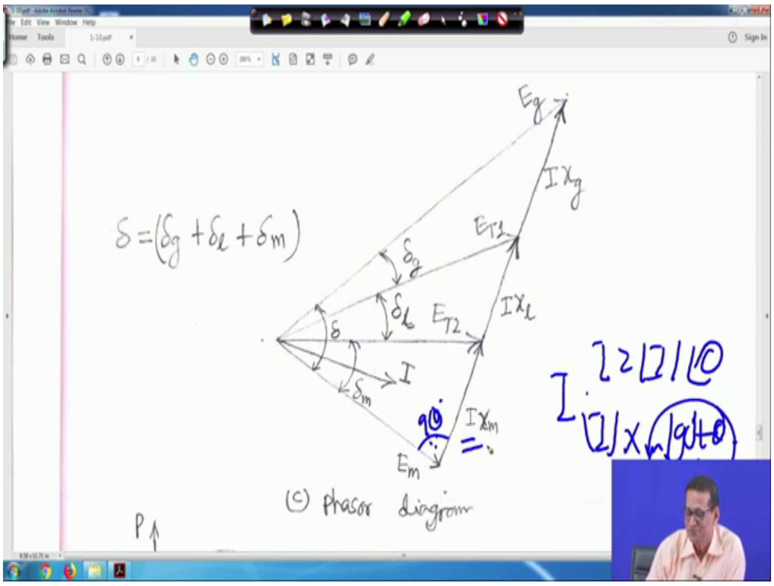


Now, if you draw your the phasor diagram, right so, what we have taken we have taken say E T 2, E T 2 as a reference suppose this is your reference E T 2 as a reference, right. This is my E T 2, right, this is my E T 2. Now, we assuming that your current it showing

I this is the current I it is lagging current say current is lagging right this current is I, right. Now, if you say what you call E T 2, E T 2 will be what? E T 2 will be E m plus j x m. So, E T 2 is equal to this is my this is my E m this is my this is my E m, E T 2 is equal to E m plus your j I x m. So, this angle actually 90 degree, right. So, E T 2 is equal to and this is the current right, this is I x m.

Now, next is your E T 1 it will come, just let me clear it. If you come to this diagram again the E T 1 will be j x l plus E T 2 because this is my E T 1. So, if current is showing in this direction E T 1 will be E T 2 plus j x l. So, look at that that E T 1 will be E T 2 plus j your I your what you call I into j x l, sorry I into j x l, right; so here also I into x m and here also I into your j x l, right.

And, one thing is there, one just one correction is there it is actually I is I is actually lagging. So, what you call this angle your what you call it may not be your what you call 90 degree because I also have some angle I previously I wrote 90 degree it cannot be 90 degree because I also has some angle. If I angle 0, then it is 90 degree otherwise if I is equal to your magnitude of I angle theta and this is j x m, so, basically it will be magnitude of I say into x m, then angle your what you call 90 degree plus theta as current is lagging so, theta will be your negative. So, in that case it will be your less than 90 degree. So, only 90 degree is possible if I what you call your angle 0 degree, but it is not right, it is lagging from this one. So, it cannot be 90 degree right I over looked at one.

So, question is your what you call this one now E T 1 will be I into j x m E T 2 that is why E T 1 is equal to E T 2 into I into your j x l, right and similarly your next one is your then E g will be I into j x g plus E T 1. Therefore, E g is equal to your E T 1 plus I into j your x g, right. So, this way you have to draw, but if I is known, angle is known, x g value is known and then we can find out the exact angle and this is the phasor diagram, right. So, for this system and you step by step if you make it then things are very simple, right.

So now, delta will be the total angle delta between your E g and your E m, right. It will be delta m plus your delta l plus delta g; so delta g plus delta l plus delta. This is the angle between E g and E m this is the phasor diagram, right.

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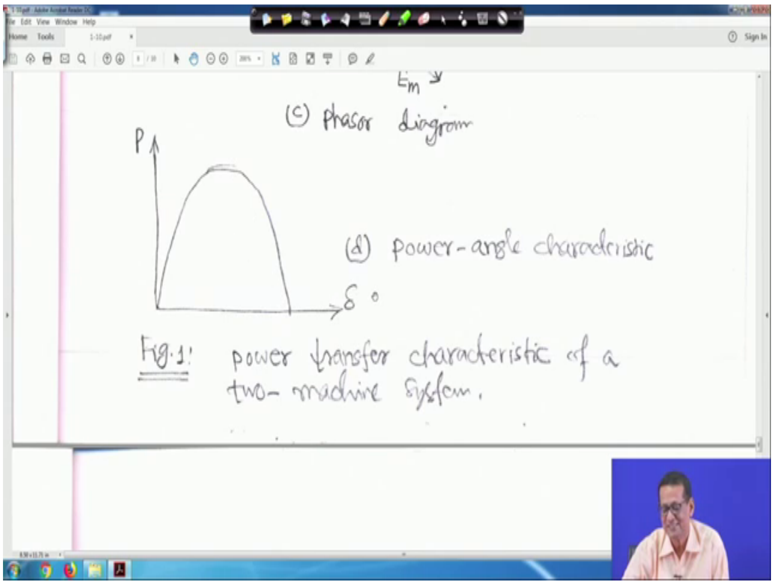


And, power angle characteristic you know from your power system analysis studies or missing these things. So, this is my your what you call P versus delta curve, right; P-angle characteristic.

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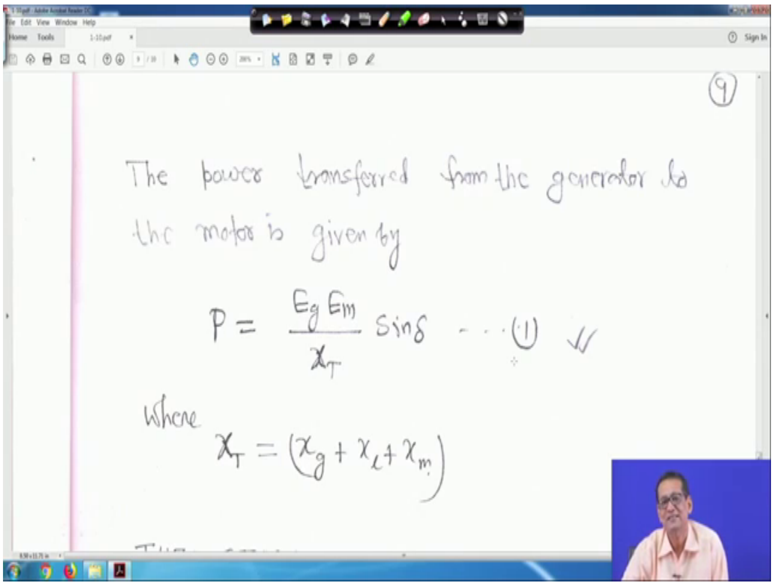


And, therefore, the power transfer from the generator to the motor is given by P is equal to E g E m upon x T sin delta, right. This we know, we have studied already in these thing and x T will be sum of all the reactants. And this is equation 1.

Thank you very much. We will be back again.