Power System Dynamics, Control and Monitoring
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Lecture – 41
AGC in deregulated system

So, in the previous lecture we have discussed about discrete integral controller right for AGC.

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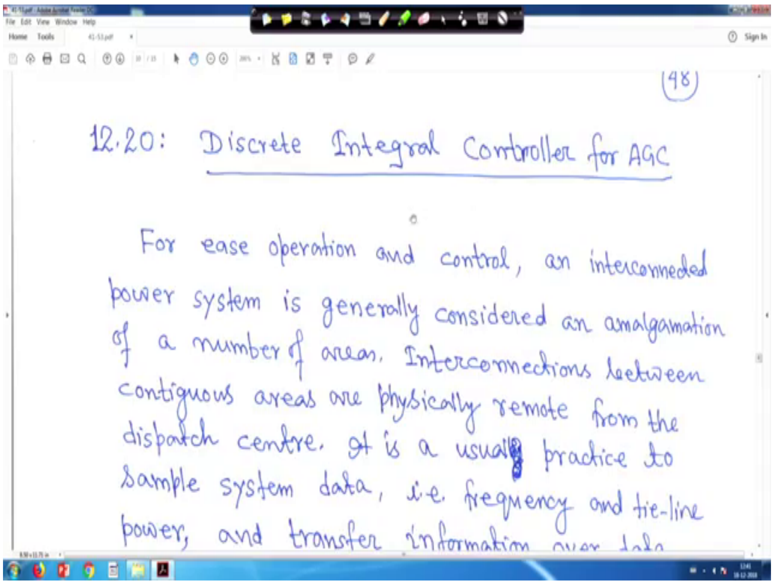

So, this all already we have discussed.

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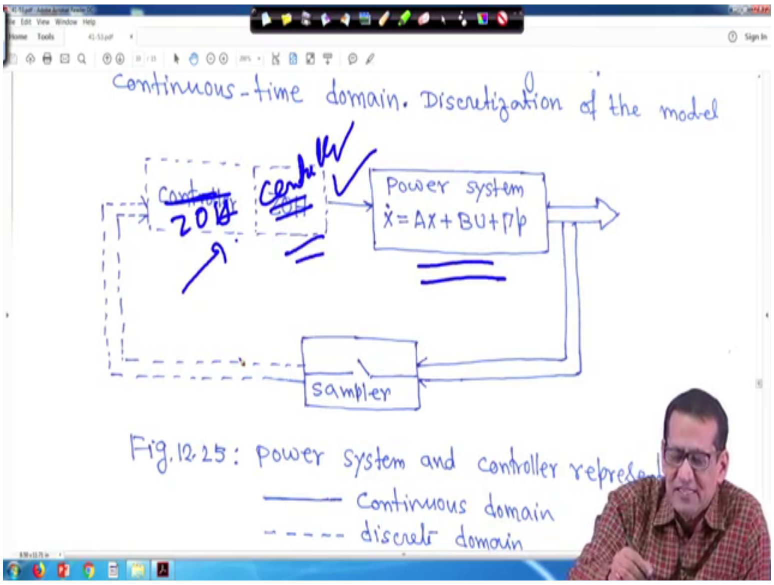

So, this block diagram I told you that power system is in continuous time domain and controller is always in your discrete domain right and this is the sampler and this controller is there 0 order hold is there. So, I told you that ah whenever you will solve I mean I mean nowadays you are putting in the matlab and getting the result, but my suggestion is that if you write the code of your own you have to follow this logic.

So, this is your what you call this is the controller and this is your 0 order hold right. That means, after every sampling instant that suppose it is integral controller that you will be evaluated and it will be hold till next sampling instant comes. And this power system is a continuous system. So, mathematically when you will do it that you have to integrate it you have to follow some numerical methods right. So, that if it is if the logic is like this, then we will come back to this all sampling time other things we have discussed.

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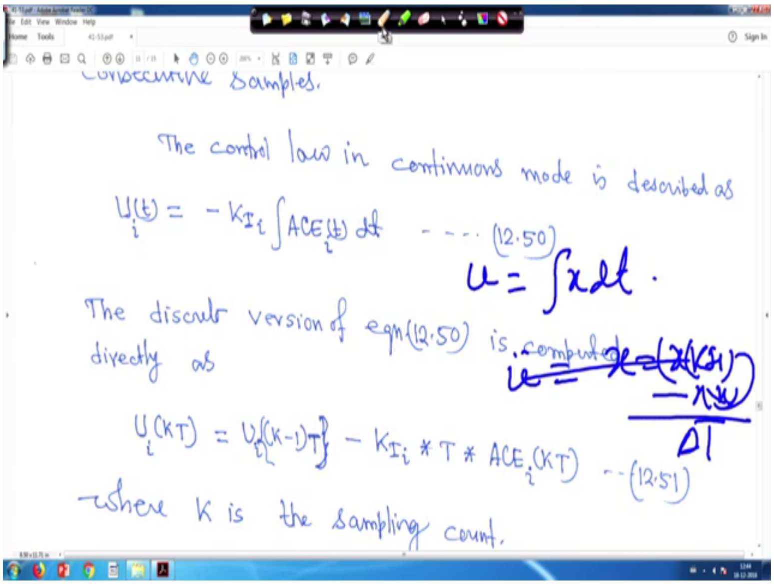

Now, that continuous integral t[me integral your what you call that equation, that continuous mode that control law that U i t for ith are K I integral of ACE i T d t. This is equation say 50 right. Now the discrete version of equation 50 is computed directly as U i K T, K is the sampling instant and T is the sampling time this we write is equal to U i K minus 1 T minus K I i into T into ACE i K T right. So, I mean it is I mean if you I mean it this kind of thing I think you know it that suppose when you find out suppose u is equal to for example, say x d t say right therefore, u dot is equal to forget about other gain anything x dot is equal to actually x.

So, this can be written as x K plus 1 minus x K divided by delta T. This is actually derivation approximate definition of derivative that x K plus 1 minus x K upon delta T right. So, this is. So, whenever you do this whenever you do this and sorry just 1 minute; just 1 minute sorry there is a 1 mistake there is 1 mistake sorry.

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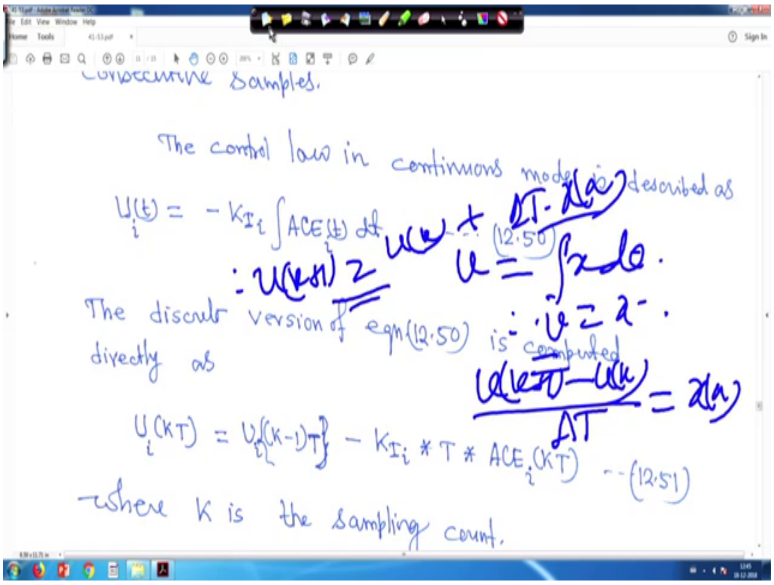

That u is equal to your integration of x d t right therefore, u dot is equal to x. So, this is u dot sorry this side I had thought this is x dot. So, it is actually u K plus 1 minus u K divided by say delta T is equal to x K right; that means, my u K plus 1 is equal to u K right then plus your delta T into x K right. So, this is your; this is your what you call that your integral your that u we can write.

Similarly, when it is U i t you take the derivative of both side then it will be minus K I then ACE i right forget about t therefore, U i t U i your U i dot is equal to minus K I i ACE i mean it will be like this.

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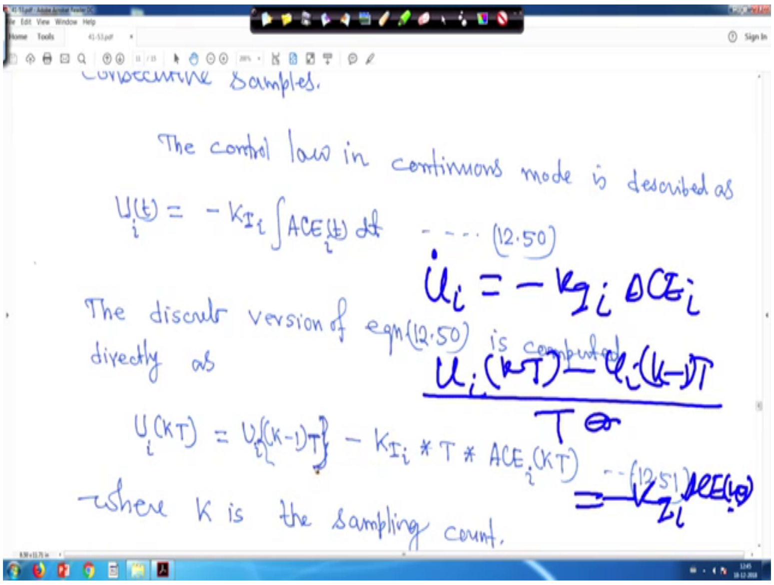

U i dot is equal to minus K I i then ACE i right. But sampling time is T; that means, this one can be written as the way we are writing here say U i K T minus U i your r K minus 1 T divided by T right is equal to your minus K I i ACE K T right. So, just cross multiply and do this. So, this will be your equation that is your U i K T is equal to U i K I minus T minus K I that means every sampling instance say.

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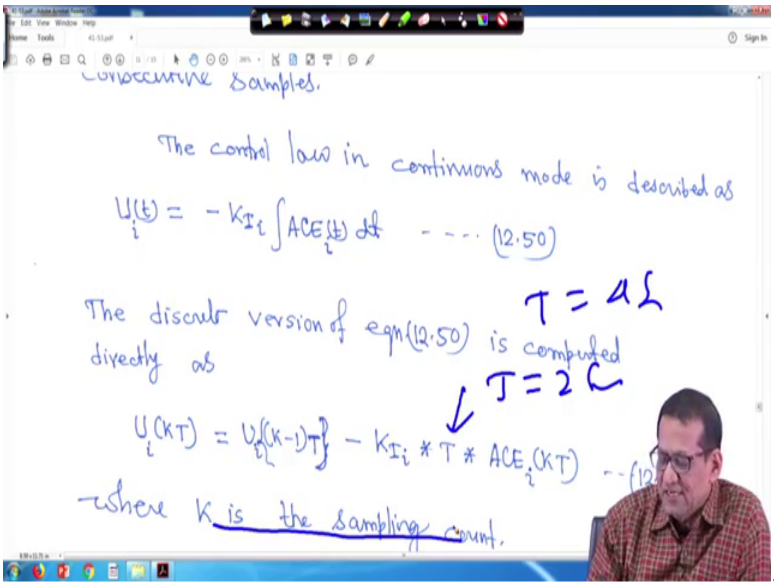

If T is equal to 2 second, you find out what is the value of U till next sampling instance come that is T is equal to 4 second, this signal will be held constant till the next sampling instance come. When T is equal to 4 again you compute till the next sampling instance 6 comes because T is equal to be 6 sampling time is T is equal to 2 second right; where K is the it is given K is the sampling count and T is the your sampling time right.

So, one more thing is there that is your in this block diagram that, now this one controller we have kept first next 0 order hold. So, if you make say other than 0 order hold first say for example, suppose instead of controller say this is 0 order hold and this is my controller. So, how things will look like? So, this is 0 order hold and this is controller. So, in this case what will happen that, this is sampler and suppose ACE will be sampled right in that case what will happen that, ACE will be held constant till the next sampling instant come and this controller now is in continuous time domain right.

It is a continuous controller will be continuous time domain. So, in that case this integration will be in the your what you call in that continuous form and then this system also continuous; that means, in that case that every integrations time whatever you take whatever numerical methods you use right you have to evaluate this one, but this ACE will be evaluated every sampling instant. For example, T is equal to 2, then T is equal to 4 T is equal to 6, but this integration will be continuous right.

So, both the things if you put for example, in matlab and try to see the responses, you will find apart from very closing to the settling time both responses are more or less same right. So, this is your what you call that discrete value that what is the reality actually. So, next is that some exercise.

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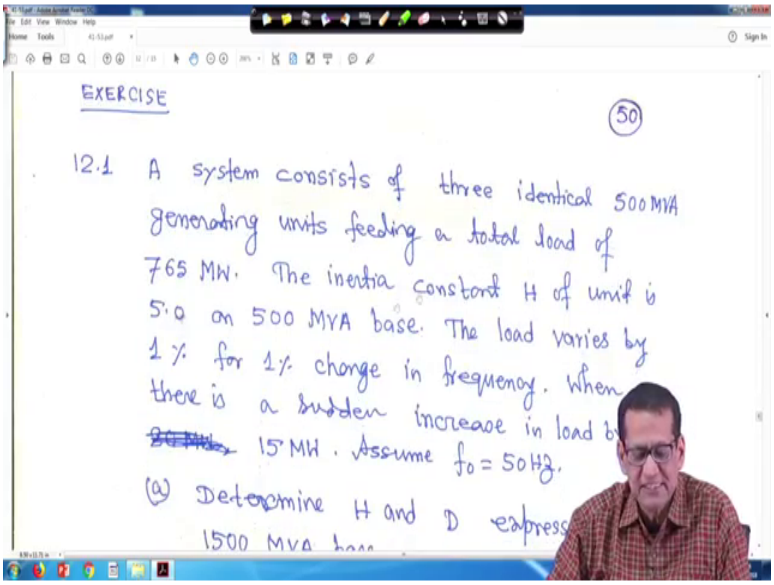

After that again will come to this, this will do it because I have to save some time right. So, first example is that a system consists of 3 identical your 500 MVA generating units feeding a total load of 765 megawatt. The inertia constant H of unit is 5 on 500 MVA base that is 5 second actually right. The load varies by 1 percent for 1 percent change in frequency.

When there is a sudden increase in load by 15 megawatt increase in load means that frequency will decrease assume f 0 is equal to 50 Hertz right.

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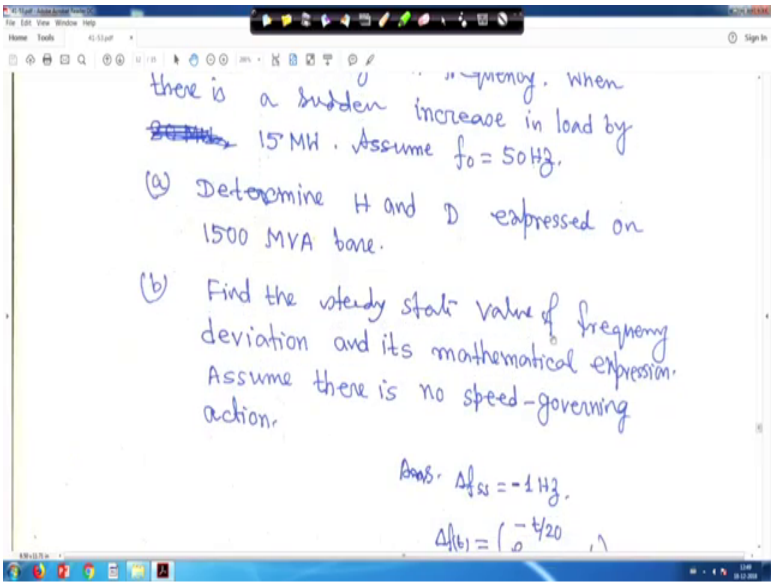

So, you have to determine that h and d expression 1500 MVA base and second one is find the steady state value of frequency deviation and its mathematical expression assume there is no speed governing action. One examples we have seen right. So, you will derive this and this you will find out and this is the actually answer right.

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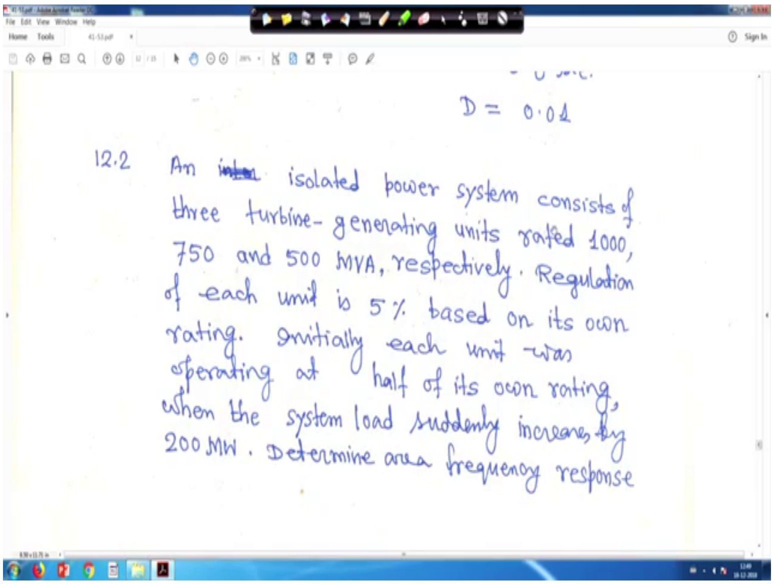

Second thing is, second example is that an isolated power system consists of 3 turbine generating units rated 1750 and 500 MVA respectively. Regulation of each unit is 5 percent based on its own rating initially each unit was operating at half of its own rating, when the system load suddenly increases by 200 megawatt determine the area frequency response.

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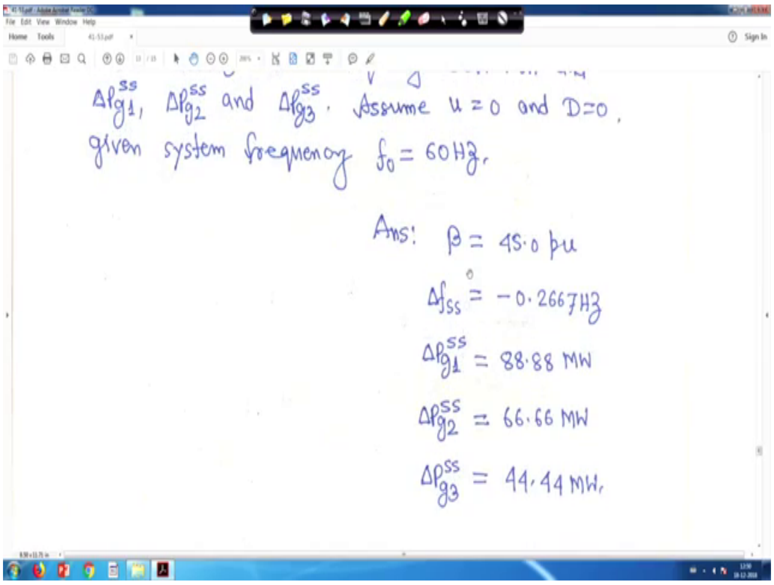

So, answer is given, beta is given right and area frequency response means that beta area frequency response characteristics and all the answers are given.

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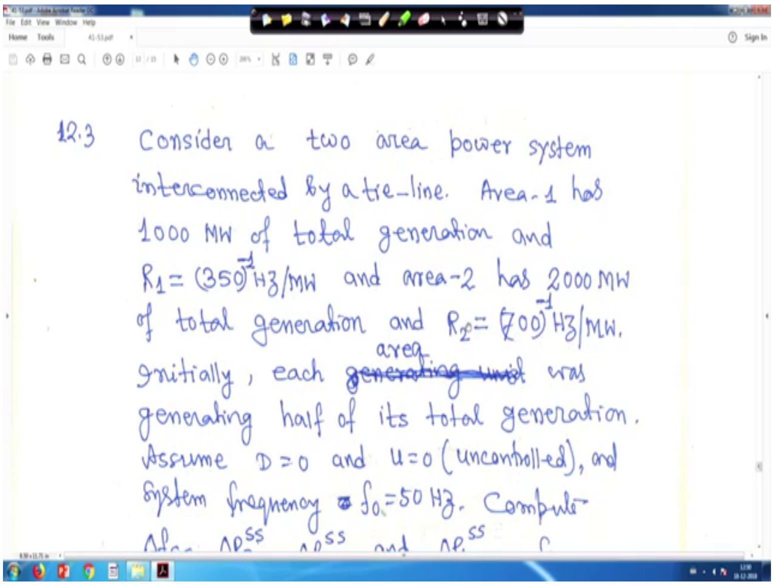

Now, next problem is that you will do it. Consider a 2 area power system interconnected by a tie line. Area 1 has 1000 megawatt of total generation and R 1 is equal to it is 350 inverse that is that is 1 upon 350 Hertz per megawatt and area 2 has 2000 megawatt of total generation R 2 is equal to 700 inverse that is 1 upon 700 Hertz per megawatt right.

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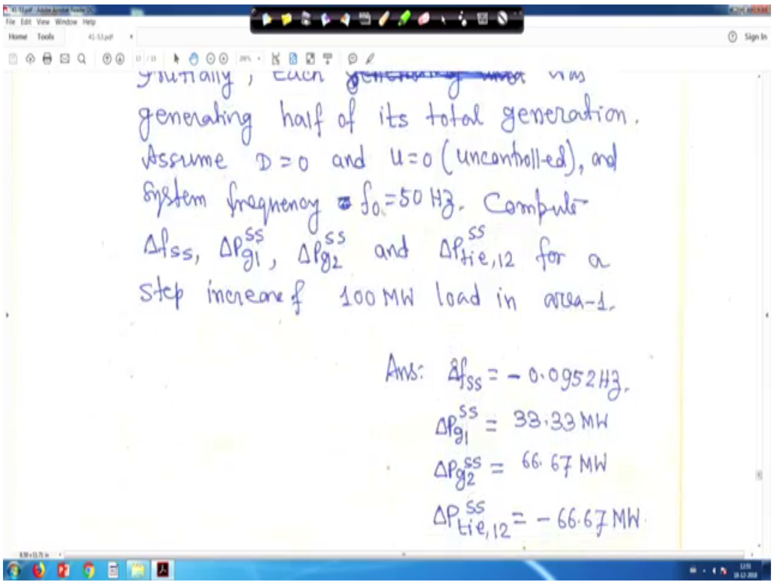

Initially each area was generating half of its total generation. Assume D is equal to 0 and u is equal to 0 that is u is equal to 0 means uncontrolled and D is equal to 0 also you assume and system frequency f 0 is 50 Hertz. Compute all these quantities steady state values of frequency generations and tie power for a step increase of 100 megawatt load in area 1. So, these are the answer right these are the answer.

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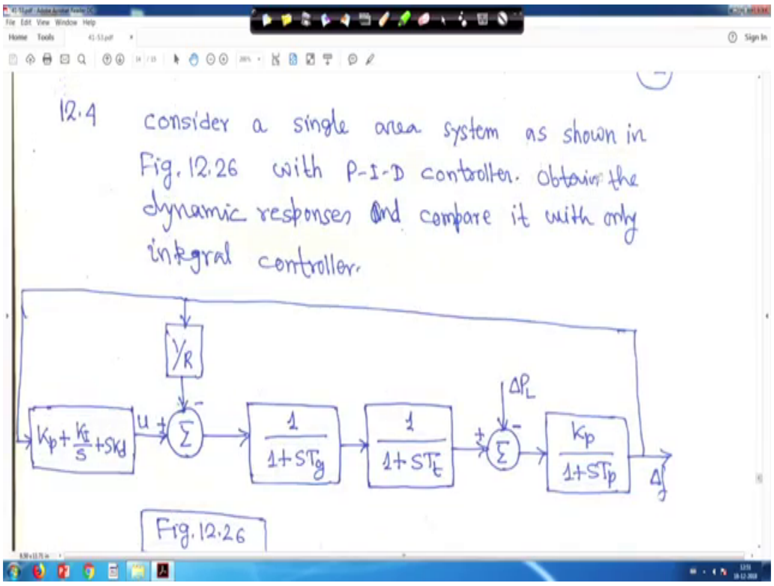

Next one is here the next is you consider a single area system as shown in figure 26, that is a this figure with P-I-D controller obtain the dynamic responses and compare it with only integral controller. So, this is actually stimulation purpose no need just a P-I-D controller is given right. So, in this case how you will actually that matlab that is your matlab Simulink block right matlab Simulink block when you put P-I-D it gives the result it this 1 I can take K p dash because this K p is used here. So, this different K p; so, this is K p dash.

So, this is K p dash plus K I upon S plus S K d that proportional integral derivative. So, in general in general actually this one if you want to this all these values right all these values we say instead of taking this one say minus K p, this is minus K I upon S this is minus s K d in this case you will see that K p K I K d value are will be positive if you put plus it will be minus now question is that how to incorporate for your when you are writing code right how to do this? So, question is that how will do this? So, here just hold on. So, here your this is your K p.

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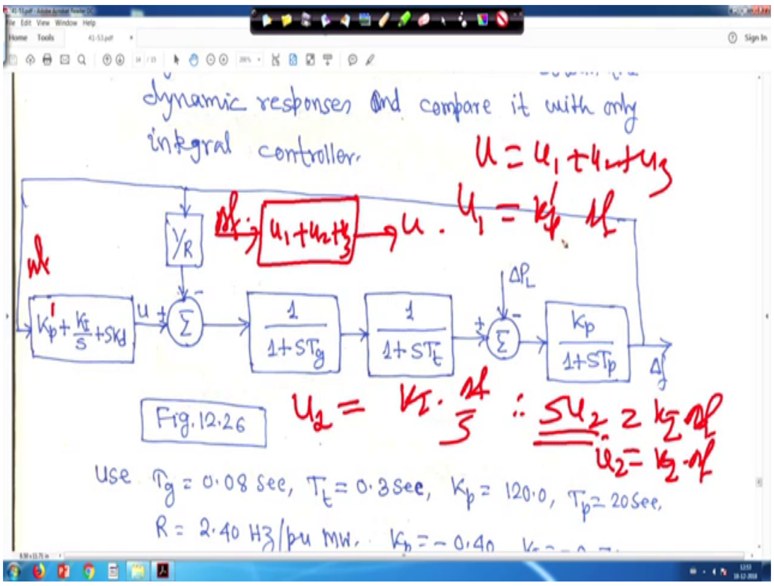

And suppose you have a P-I-D controller; you have a P-I-D controller say this is K p dash plus K I upon S plus S K d say plus is there it does not matter right. So, suppose this input signal for this case it is delta f this input signal is delta f. So, this is actually my delta f right and this is K p we what will do that, we will take 3 part one is u 1 is another is u 2 plus another is u 3 and output is u. So, u is equal to u 1 plus u 2 plus u 3 right. So, what you have to do is and it is multiplied by delta f.

So, u 1 is straight forward, u 1 is equal to K p dash into delta f right this is my u 1. Now u 2 actually u 2 is equal to your this K I into your delta f upon S right. So, if you cross multiply it will be S u 2 is equal to K I into your delta f. So, this is actually derivative u 2 dot that is your u 2 dot is equal to K I into delta f that u 2 dot can be written as. So, this is u 1 is equal to K p dash f.

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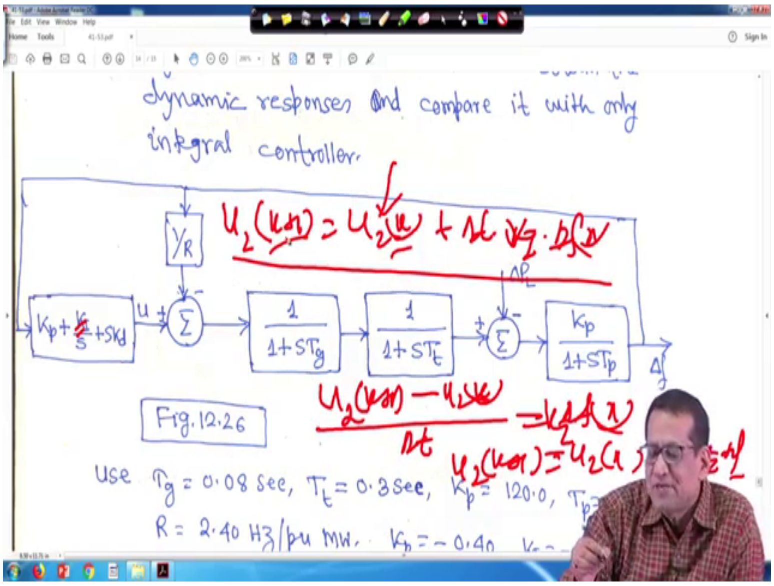

So, u tow dot can be written as say u 2 K plus 1 minus u 2 K that is K is that your what you call that sampling instant divided by say delta t is equal to your delta f K right. That means my u 2 K plus 1 is equal to u 2 K it is actually it was multiplied by K I because this K I term was there. So, K I delta f, so, plus delta t into K I into delta f right; so, this is actually my u 2 K plus 1.

I am rewriting here that is u 2 K plus 1 is equal to u 2 K plus delta T into your K I the integral gain into delta f K this is actually mathematics. So, when you write the code. So, initially this K and other thing nothing is there you have to put in a loop right. And this your what you call when you integrate it. So, initial values of u 2 will be 0 right and accordingly you have to integrate.

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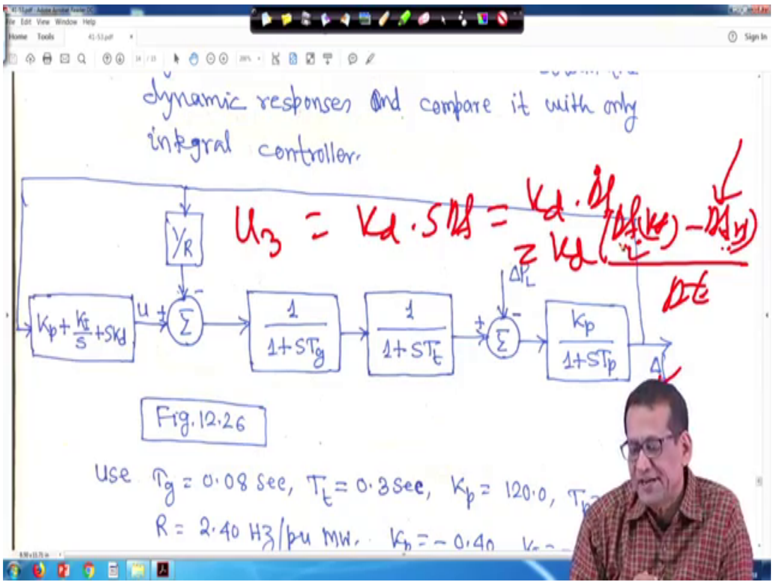

So, this is actually your u 2 similarly for u other part u 3; u 3 is equal to actually K d into S delta f that is nothing, but K d into delta f dot. So, that is nothing, but K d that is delta f K plus 1 minus delta f K divided by delta t this is the derivative. So, initially you to compute this derivative in the when you put in a loop initial value of delta f K is known.

And this one your every time you are going for simulation. So, this will be known this will be known every iteration divided by your integration step (Refer Time: 14:14) that will be your this thing and when you will come to the next iteration, this value this value should be replaced by this value right. So, this way actually you do it and if you look into find the form of your block diagram.

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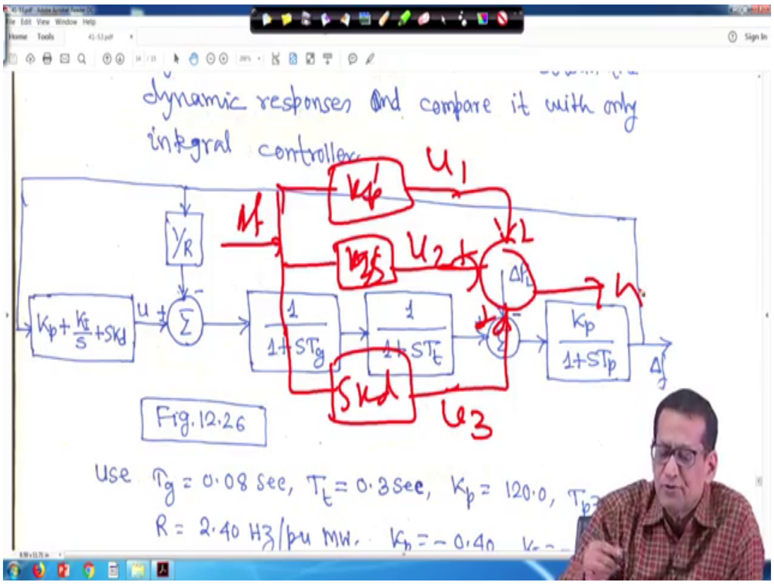

Say this is my delta f then you have to make 3 part; one is K p dash the proportional gain another is K I upon s the integral part right another is that derivative part S K d right and here you have to sum all you have to sum all plus plus. So, this one we took a 1 this one we took u 2 and this 1 u 3 and this is my output u. So, when you write the code all 3 is we have to compute separately, then you have to add then will get the u values right this way you do right.

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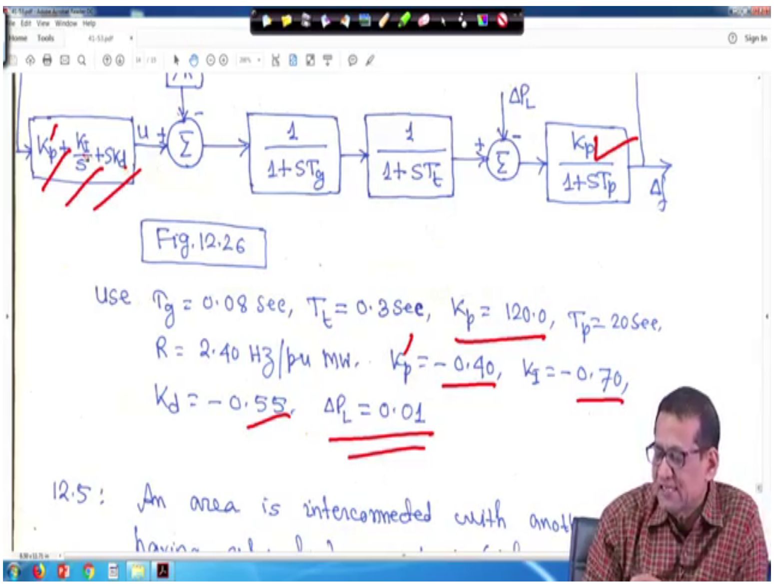

Now just hold on. So, whatever parameters till now we are used earlier also I told you these parameters are given; what I suggest for this one for this kind of thing just you can put in a Simulink and you can see that what is that your what you what is some values of look I told you know, as we have; as we have taken your what you call that your this all plus all plus plus plus in positive all positive that is why K p minus it is K p dash this is actually K p dash. K p dash minus 0.4 K I minus 0.7 and K d minus 0.5 if you take all minus all should be plus and step load input is 0.01 right.

Because this K p; do not be confused with this K this is K p this is K p dash this is proportional gain, this is your derivative gain K d and K I si the integral gain right.

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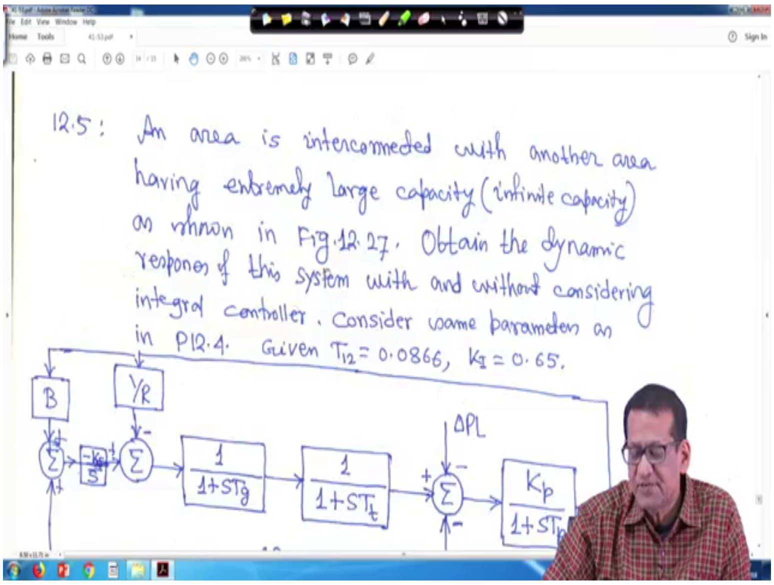

Another one is that suppose an area is interconnected with another area having extremely large capacity, I told you when we are discussing about this after that we will go to deregulation infinite capacity as shown in figure 27.

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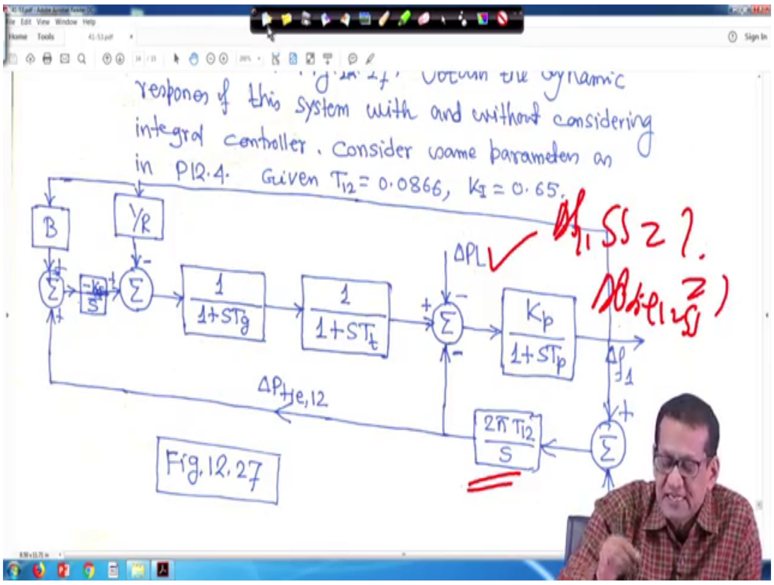

Obtain the dynamic responses of the system with and without considering integral controller. So, this in this problem that as I told you that if the area to capacity is very high, then you will find is there is almost no frequency deviation for a load disturbance in this area.

So; that means, delta f 2 is 0, but tie line should be there it is there. So, in this case I am not asking you to do simulation what you will do is, that you please find out your what you call that your steady state error that is delta f 1 SS is equal to how much and delta p tie 1 2 SS right is how much? This an exercise for you for a step input for a step input delta p l right in terms of delta p f. Now another thing is that regarding your optimisation.

So, different type of performance indices are available for finding out the gain setting of the integral controller or your what you call that P-I-D controller or other type of controllers. So, for in for integral controller say in this case you have 1 delta f and 1 is delta p tie 1 2, but theory also we have delta f 1 delta f 2 delta p tie 1 2, but isolated system we have delta f right. So, whenever we take say for isolated system.

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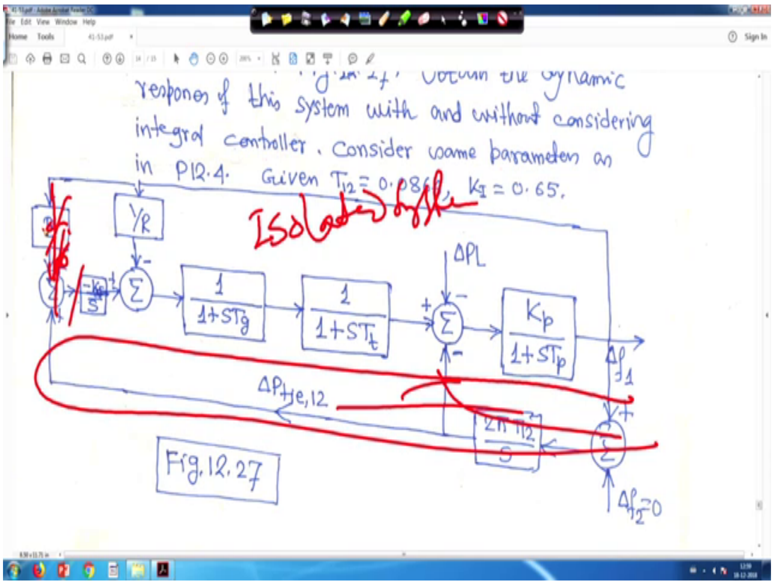

Say when it is isolated system right. So, isolated system actually this thing is not there this part is not there, that we have seen also right only this thing and this part is also not there for isolated isolated system actually directly it will go to your what you call minus K I upon s; b is not there your what you call for isolated system it is simply a direct feedback right.

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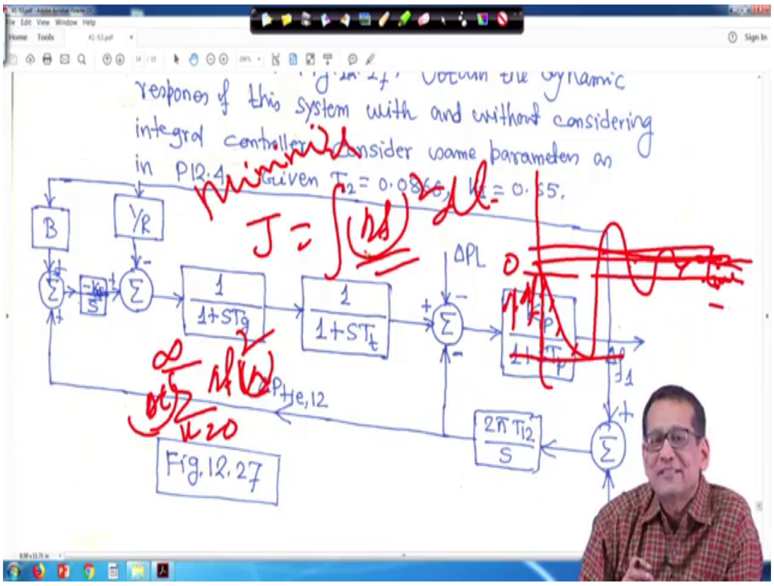

So, for isolated system, your if we take an performance indices say integral of your delta f square d t right it is an integral square error technique if we use, that J that objective function for optimisation you have to go for this objective function say J is equal to delta f square d t and your objective is that you minimise this function you minimise the function J for isolated system only right.

So, generally different other type of performance indices are there, but this in this thing has a some meaning. Meaning is that basically it is in it is written integration of delta f square d t. If you I mean if you go and if that your what you call that delta f deviation for example, suppose this is my 0 this is origin and this is my this axis is my time axis. Suppose response is like this response is like this; like this; like this; like this; right. So, when error is large I mean this is my delta f frequency, when error is large its square will be also large and if error is small its square will be also smaller.

So, this integration 1 if we make it like this say if I make it like this K is equal to 0 to infinity say it delta f K square right; d t I can make it here say this is delta t right because it is multiplying again and again. So, then K 0 I mean descretizing K is equal to 0 to infinity delta f square K right. Now for K is equal to 1 2 3 means it is sampling instant that is your integration time is increasing right. So, in this case what will happen? When it get this value this value this value its value is high. So, its square is higher. So, it means summation that is higher your what you call large error actually we will get more importance

But suppose if you put some threshold here. So, when it is coming in this range say. So, here error is small delta p small its square will be smaller. So, in this addition term its contribution is negligible. That means, the significance of this is that this kind of; this kind of your objective function if analyzes large error heavily and small error lightly; that means, small energy it does not take care, but it takes the large error right. Accordingly if you minimise this objective function to get the K I. So, details are beyond the scope for this course because of your as because we have to think from the point of view of your classroom exercise.

Similarly, for 2 area system also we can take objective function that is J is equal to integration of say del f 1 square plus delta f 2 square plus delta p tie 1 2 square into d t. So, similarly it can be optimized K I K p K your proportional gain integral gain derivative gain or any other form of controller, but you have to follow some optimisation technique most probably soft computing techniques are more suitable for this, but that is beyond the scope right then whole sub computing technique, then I have to tell to do this, but that is beyond the scope.

So, with this that deregulated sorry this conventional AGC part I had to cover because otherwise we will not we will fail to understand that your what you call that your deregulation one right. So, now we will go to the AGC in the structural environment or your deregulated environment right. So, will go to now that AGC in deregulated environment. So, we call that automatic generation control in restructured power system that is deregulator environment.

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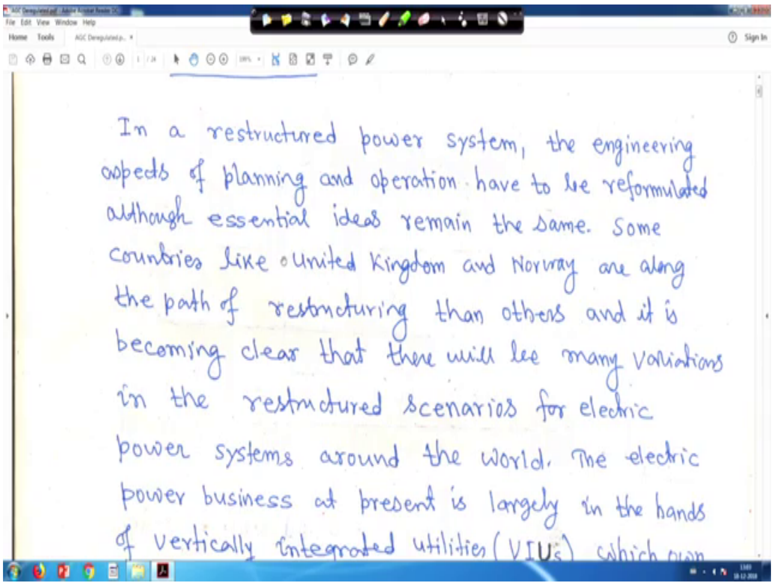

So, first let us see this little bit of introduction. So, in a restructured power system the engineering aspect of planning and operation have to be reformulated although essential ideas remain the same. Look, power generation transmission distribution that power has to be generated and it will go through the transmission to the distribution side.

So, your what you call essential ideas remain same, some countries I mean some countries right there along the path of restructuring than others and it is becoming clear that there will be many variation in the restructure scenarios for electric power systems around the world right.

The electric power business at present is largely in the hands of vertically integrated utilities. The meaning of like this that vertically your integrated utilities the meaning is that.

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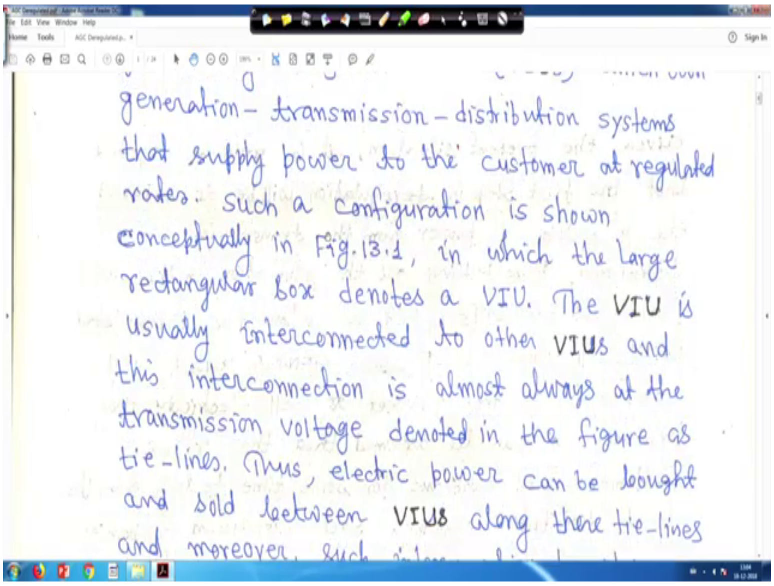

That means suppose you have a power system and you are the owner of generation transmission and distribution all together right. So, that is called actually vertically integrated utilities suppose one utility; utility is owning its generation transmission and distribution right and that supply power to the customer at regulated rates. So, that is your that is we call the conventional thing or vertically your what you call integrated utilities.

Now, such a configuration is shown is conceptually in figure 1. I will come to the figure 1 in which the large rectangular box denotes VIU. The VIU usually interconnected to the other VIUs I will come to that figure and these interconnection is almost always at the transmission voltage denoted in the figure as tie lines right. Thus electric power can be bought and sold between vertical integrated utilities among the your what you call among these tie lines and moreover such interconnection provide greater your reliability.

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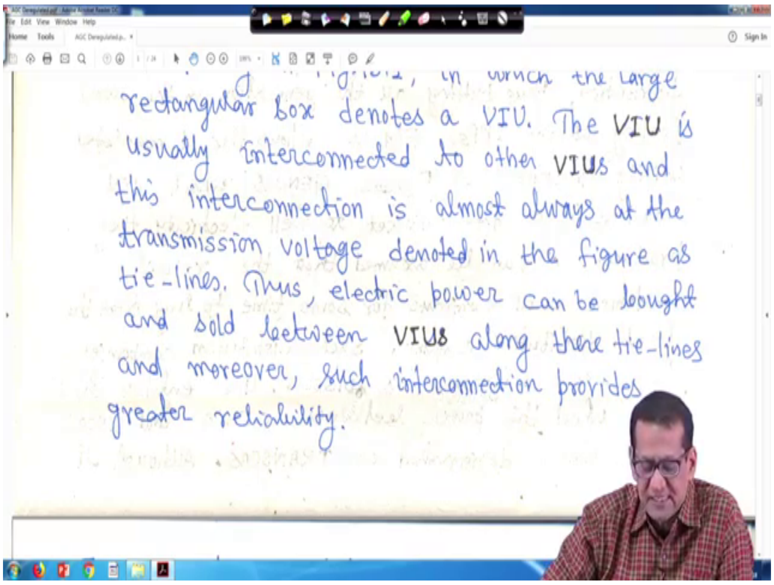

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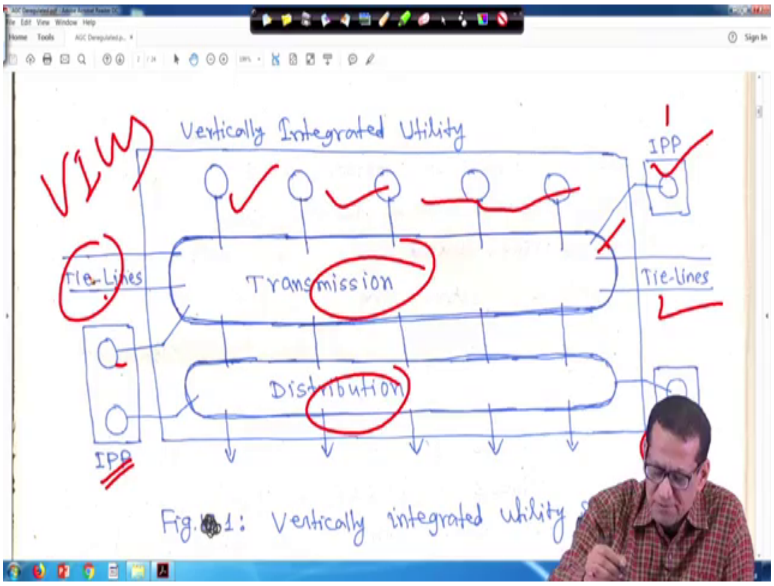

So, now this is actually my VIU the Vertical Integrated Utilities. That means utility is owning everything that is your generation, transmission, distribution this are the generator these are the generators right and then this is a transmission system and then this is a distribution system. Apart from that private parties are there that is IPP that is Independent Power Producer. So, this independent power producers their system maybe directly connected to the transmission system that is a high voltage level, some independent party or the independent power producers their system also maybe connected at the low voltage that is at the distribution level right.

This is also some independent power producers, part of the generators directly connected to the high voltage side it transmission system and some of the power generator generating power at low voltage level, so, directly connected to the distribution system.

So, basically if you own that everything generation transmission and distribution. So, accordingly that power is what you call you are selling to the distribution side including your all sort of consumers. And tie lines are there this tie lines; that means, this power system is interconnected with some other power systems other VIUs right Vertically Integrated Utilities.

And selling and buying actually their purposes are through the your what you call through this tie lines. So, this is actually the conventional power system; that means, that you are the owner of generation, transmission and distribution together right this is the concept of your what you call that your vertically integrated utilities right. Now the concept is changing.

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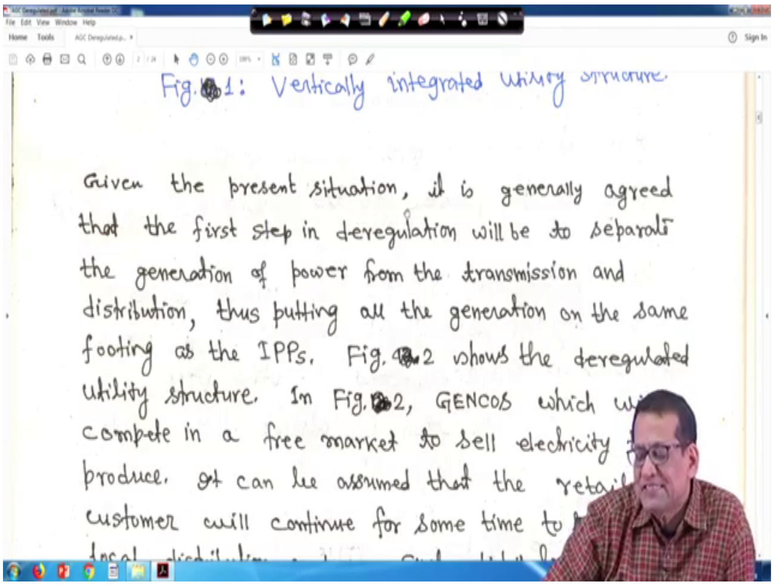

Concept is changing means that suppose given the present situation, it is generally agreed that the first step in deregulation will be separate the generation of power from the transmission and distribution.

That means generation you separate from the transmission and distribution, then putting all the generation on the same footing of the IPPs. IPPs means that is your that is private parties I told you independent power producers; that means, generation all the I mean what you call you separate generation, you separate transmission and separate distribution. So, like independent power producers they are also separate right. So, if you do so, then you will you have a separate 3 different entities; one first generation one for transmission and another for distribution.

So, even IPPs also will come into that generation that is separate right. So, figure I will come later. So, figure 2 shows that deregulated utility structure in figure 2, generation company will can GENCOs right which will compete in a free market to sell electricity they produce. Actually what happen in this case the generation company, transmission company and distribution company 3 companies are there right that power willing will be through the transmission system right.

Now, question is that there must be some separate entity I mean impartial separate entity, that is called your independent your ISO that Independent System Operators right there bidding will be there the generation companies will give bidding that this hour this is the price of the electricity that is the energy right. And power has to power has to flow power willing through the transmission system and you have distribution; you have distribution system so; that means, that is we call generally generation companies will call GENCOs transmission companies we call TRANCOs and distribution companies in short we call DISCOs right.

So, that is distribution companies hence I will tell DISCOs right it has every right to buy power from different GENCOs right suppose there are several are interconnected suppose I am sitting here at Kharagpur, I have some power I have some generating power plant here, I have some distribution companies here right. But I another power plant say somewhere in Bhubaneswar there also you have several generation companies as well as distribution companies.

But if I find the power is cheaper, if I buy it from the generation companies from the Bhubaneswar power plant then I may not buy the power from the generation companies of the Kharagpur. So, this is the flexibility in deregulated power system right. So, that is why that your and that is why we are separating 3 three things; that generation companies, transmission companies and the distribution companies right.

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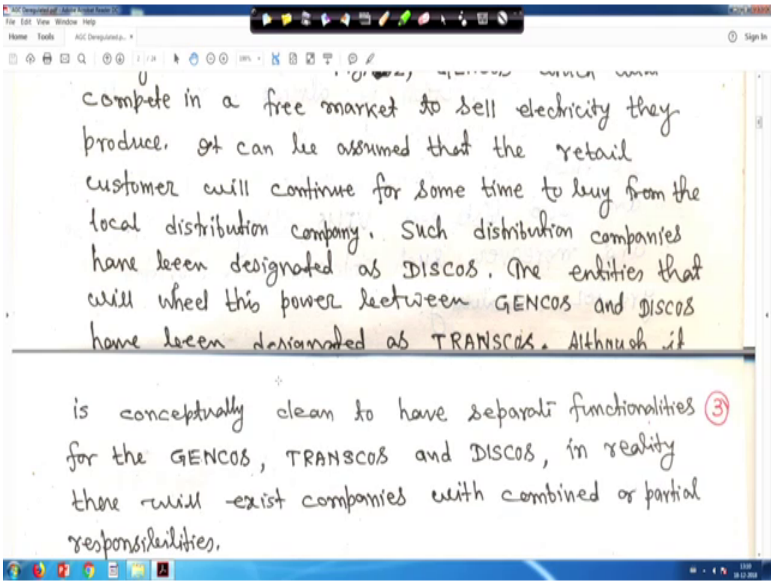

So; that means, your that GENCOs which will compete in a free market to sell electricity they produce. It can be assume that the retail customers will continue for some time to buy from the local distribution company right. Such distribution companies have been designated as DISCOs in short we can distribution companies which in short we call DISCOs right. The entities that will wheel this power between GENCOs and DISCOs have been your designated as TRANSCOs.

So, transmission company we call TRANSCOs right. Although it is conceptually clear to have separate your functionalities for the GENCOs TRANSCOs and DISCOs in reality there will exist company with combined a what you call this your partial responsibilities that is call ISO Independent System Operator.

Thank you very much, we will be back again.