High Voltage DC Transmission

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Module No. # 03
Lecture No. # 03
HVDC Link Control Schemes

So, welcome to lecture number three and this lecture, I will discussed the various control schemes those are nowadays used for HVDC control. In the last term, we saw that we are having the approximately three characteristic.

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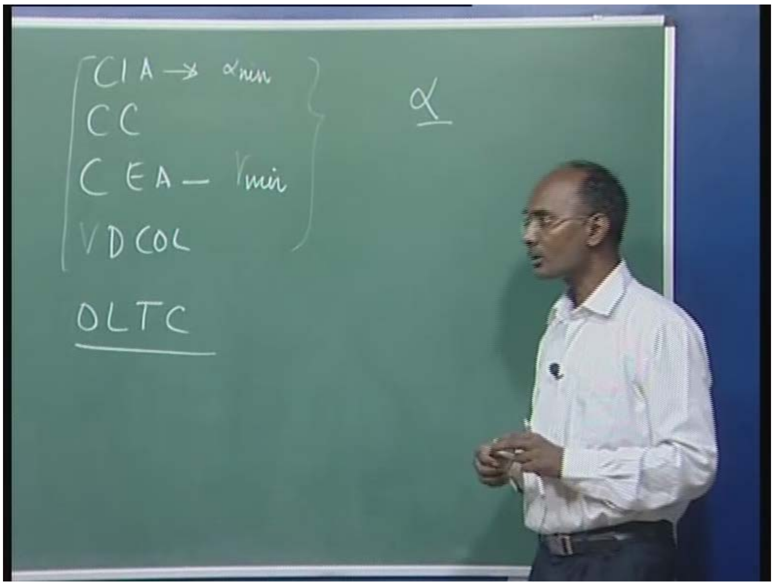

One is we are having the CC, another we are having the CEA control if it is working as the inverter mode, then we are having this VD COL - this if the voltage is very less, and also we had this your that is called CIA that is a constant extinction angle control. So, any end of the inverter HVDC link, how I can say converter circuit, we are having the four different parts that is a to be characterize and we have to use the control schemes for all these characteristic. This is valid for your rectifier end and also it is valid for your inverter end because whenever the power reverse be there, your rectifier should go in this mode as well, so this is your four characteristic will be there.

This is nothing, but here you will say it is your alpha minimum control means, it is just hitting the limit. Here, this is your almost we are going to operate at gamma minimum control. The basic here the constant control here, we have to see, but here in this control once you are measuring this maintaining this minimum your beta is calculated. So, in overall I can say in whole control schemes, we are very much concern about the firing angle of the converters means, we want your alpha means how this pulses are going to generated? And these pulses basically are giving given to converter circuits and finally, we are getting the D C output.

So, here as it is written the operation of CC or CEA, here where we are deciding basically the gate pulses of valves that is at very closely related and we will see the various schemes. Now, we require how to generate alpha to take care of the constant current control or the constant extinction angle control or we are going to have the C I A control. No doubt, we have another scheme here because if this controls are exhausted; we are also going to use the OLTC that is on load type changer control, it is also exercise specially in the extreme conditions. So, this is your mechanical and whenever these are hitting up the limit, we can go for the OLTC operation of rectifier end or we are going for your inverter end.

In the literature we are having here, I am going to talk about the first firing angles control that is why, here it is written the firing angle whether is rectifier or it is inverter, we had to have this alpha if it is less than this 90 degree then, it is rectifier more than that it is inverter.

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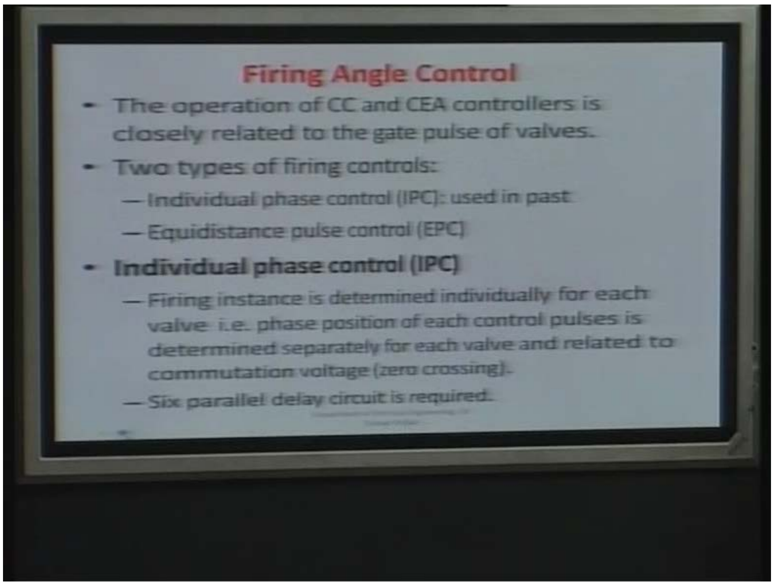

So, there are the two schemes are popularly used that is called the individual phase control that is IPC. This scheme was use in the early days when we were using the mercury arc valves, so it was use that is why it written it was use in the past, but the most of the modern HVDC control stations.

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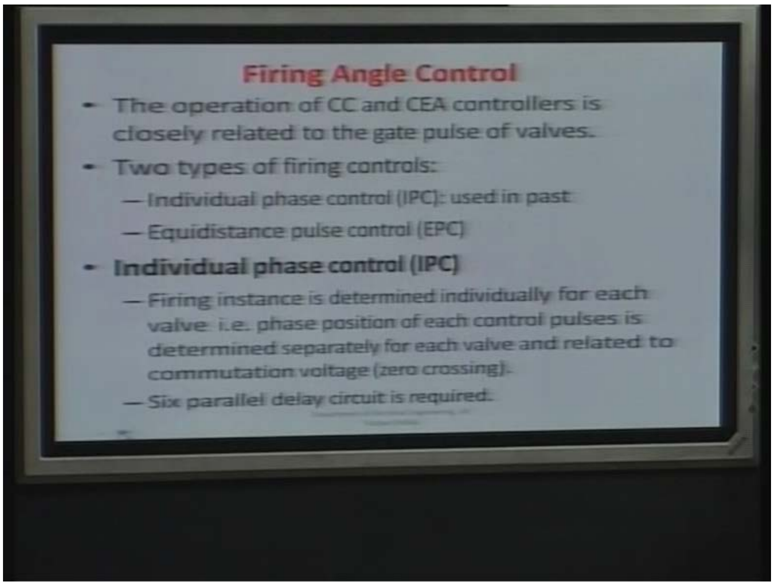

They are using the equidistance pulse control, but we had to know what is the IPC and EPC difference? What are the advantage and disadvantage? So, I will also discuss here this IPC scheme as well.

To start with let us go for this individual phase control as it is name, we are controlling the if it is a six- pulse your converter circuit; we are having the six valves each valve is getting individual pulses I mean that no doubt, converter circuit the gate pulses are given the individually, but what happens here? We are deciding the gate pulses based on the scenario or condition of the network A C side or the D C side each one is getting. Here in the equidistance pulse as it is name, you are deciding the firing alpha and this 60 degree is given to everybody means.

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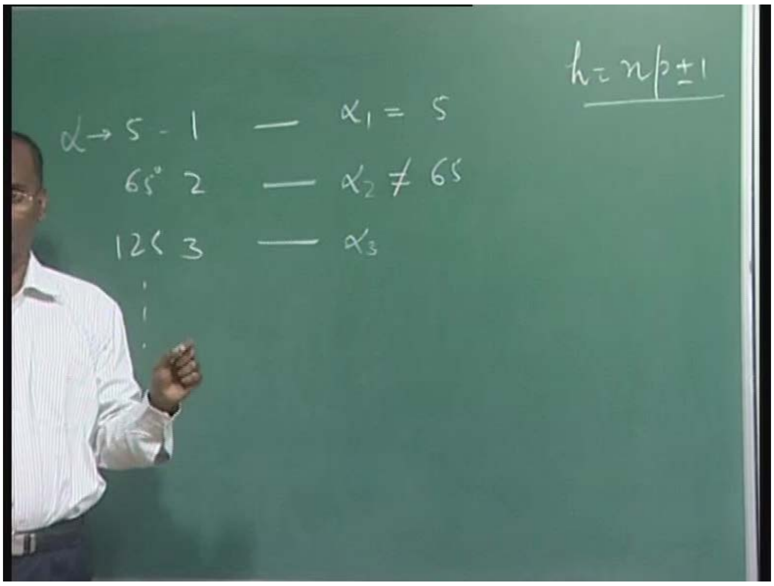

I mean that if alpha is decided here, let suppose it is there 5 degree then and it is given to your valve 1 then you are similarly, your valve 2 will get after 60 degree mean that is a 65 degree distance and so on and so forth. So here, you can say the distance is equidistance I can say here 3, it is just add here 125 and so on and so forth, so it is called equidistance and EPC control. In IPC it is not so, we are calculating this alpha; here we are calculating alpha 1; we are calculating alpha 2; here we are calculating alpha 3 individually.

So, what is happening? With this you can say, we are having the symmetricity in your output because again we are maintaining the 60 degree for each pulses, here it may not so. If there is no error in current or whatever the controller you are going to do, let us suppose I am talking about the current controller means we are talking; we are just measuring the current; we are comparing the reference and if there is a it is equal so this alpha is fix; it is not going to change. If there is a mismatch, then alpha should be changed and then, if you are using this, then it will be decided what should be the alpha for at that instant, which is incoming valve? And it will be again 60, it is a given to the entire valve.

Here, it is calculated individually and therefore, what happens? There is a possibility this is coming to be your 5; it may not be here 65; it is may not; it may be; it may not and therefore, what happens? You know your D C output voltage. You can imagine about your current, so we are going to have a various type of harmonics, it is not characteristic harmonic I discussed, here your n p plus minus 1; here we are going to have other than these. These are generated when we talked about what is the symmetricity is there in the current.

So, we are going to have some other harmonics in the system and that is why, it is not also good. So, we will compare so I here, I am going to discuss first, the individual phase control and as it is written here, the firing instant is determined individually for each valve, that is the phase position of each control pulses is determined separately. That is alpha 1 to alpha 6 for each valve and it is related to the commutation voltage; again the commutation voltage here what happens? This is your commutation voltage of let suppose valve 3, it is your e b a so it is the zero crossing; it is to be known.

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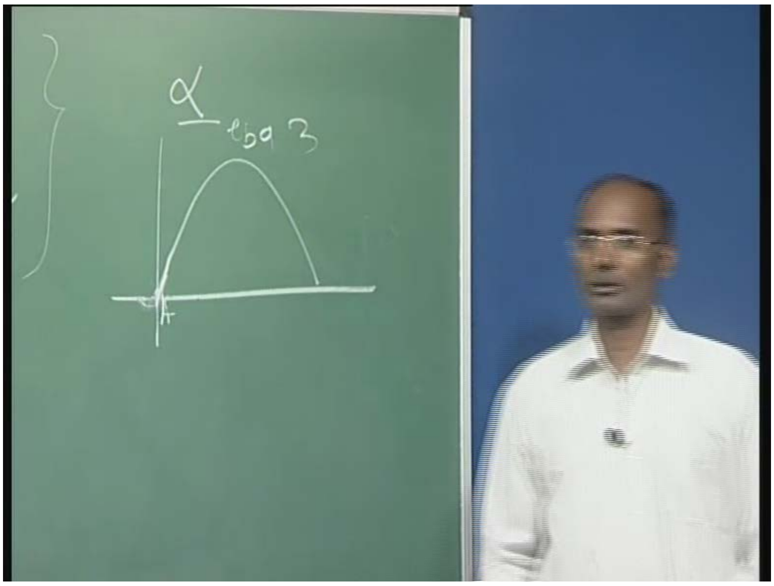

So, also there is a problem if you are using the zero crossing due to some distortion; due to some fault. This zero crossing may shift at that time, there is a possibility this is here and what happens? Now your zero crossing is shifted and therefore, your alpha is checked. So this is also one of the problem here in the individual phase control because it start here the commutation voltage; it is measuring from your A C circuit and zero crossing is started checked here and once it is there, that alpha start from here, but let us talk about the ideal case because we will see later on, this is basically limitation of this scheme. So, we are talking here; we are having the perfect zeros crossing here because our supply system is balance; we are believing it.

So, here we require this individual since, we are calculating the alpha 1 to alpha 6; we require the individual phase delay circuits. However here, it is very easy if we were having this one alpha control; you can have a ring counter 6 pulse wind counter; you give this command; you are getting the individual sixty displays six outputs, but from one counter. Basically this is what is a counter? It is nothing, but is voltage control oscillator circuit, so once you are giving the pulse, then 6 displaced circuits will be available to you and that can be given individually here to the phases because it is an equidistance placed. Here, we require individual for each circuit delay circuit.

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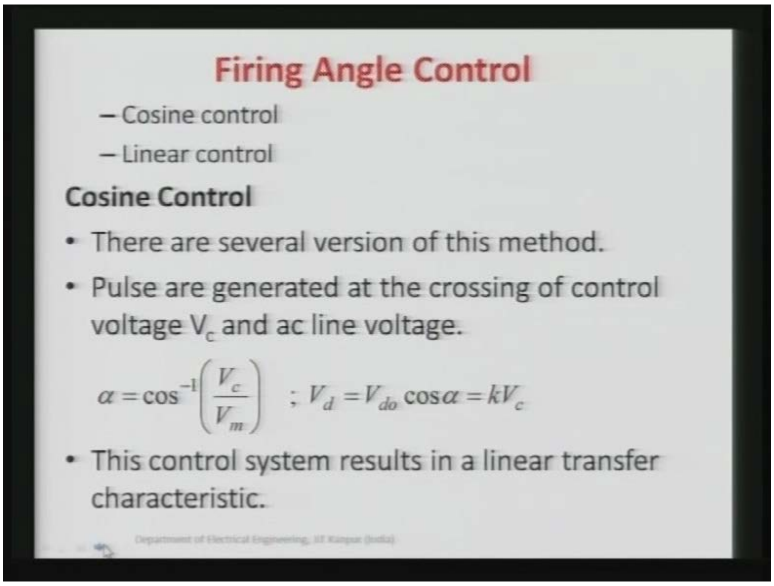

Now, so in IPC that is individual phase control, there are so many schemes so many versions of this control was there, most popularly there is a two control here that is the cosine control, another is a linear control. Now in the cosine control, if you will see here the pulses are generated at the crossing of control voltage V c and your ac line voltage what happens? Here we generate some cosine wave and then, we equate with your control voltage what is control voltage? Control voltage is the voltage generated due to the error in the miss match of your control, a measure value with your reference value.

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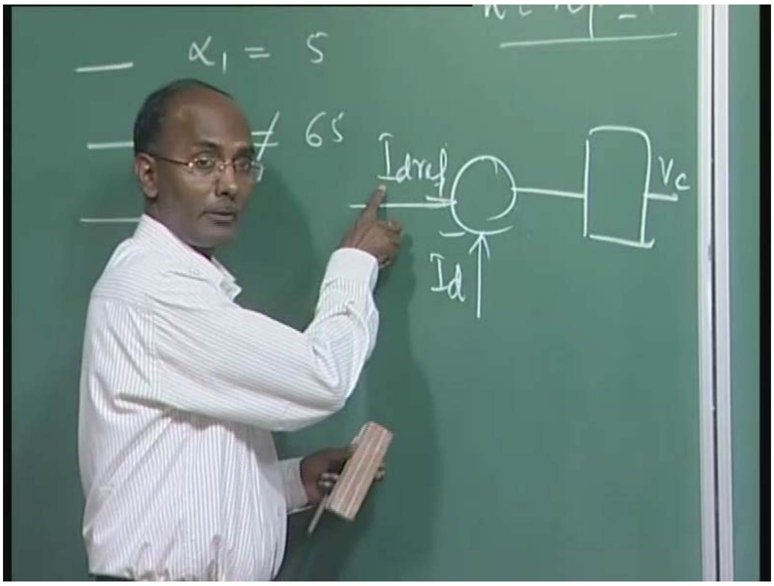

If you are talking your CC then, it is your let suppose here, it is your I d reference setting and then, you are measuring here I d; here plus minus whatever you are getting here this current difference; here there will be some circuit we are getting here V c. So, the control voltage is directly related with the difference to this quantity which you are controlling, if you are controlling your CC.

If you are controlling constant extinction angle then, extinction angle is compared with your gamma minimum reference is this what is the gamma? And then, we are checking there. So, the voltage control here the V c is basically obtain from the some circuit with your require; with your actual, the difference between these two. So, what happens here in the cosine? Here this is your reference; this is omega.

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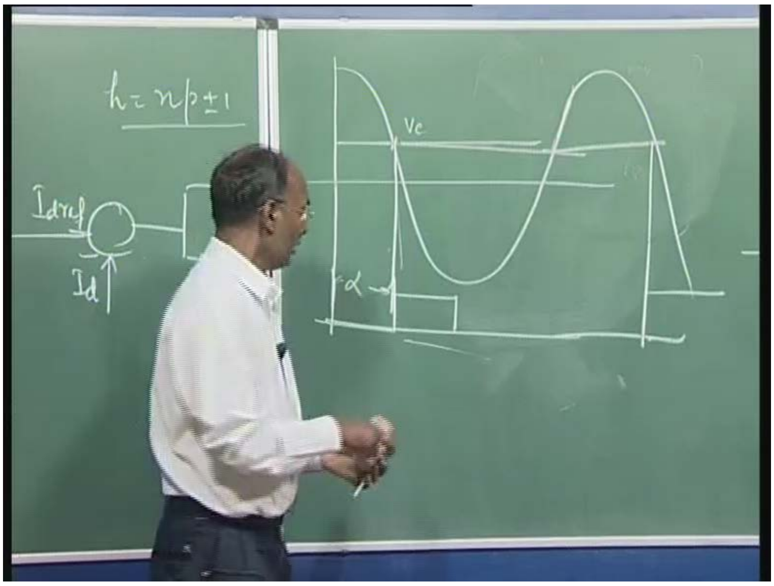

And let us suppose, this is your cosine wave and what happens your V c, if your V c here is compared this is the V c signal there is a some change; if V c is 0, so your firing pulse is here may be omega, here we can generate it. Now, this cosine again I can say is a inverted cosine or a regulars cosine which can be also use, means this can be reversed here and then, we can the shift your alpha V c from here or here. So, we can have the various versions here and basically, your alpha once this is zero crossing of V c here, we can say your alpha is this value and the pulse is generated.

So this is your pulse, once here the V c is equal to your cosine of the wave. So, your alpha this value is measure from zero crossing, here not zero crossing is the cosine of maximum value. So, this is your alpha then what happen? The pulse will be generated and again here, it is going to be this is another pulse for valve one because it is now, it is 180 degree, here the 2 pi is there because this one will be coming here, again after 365 degree. So, this is let suppose you are talking for the valve one, so this voltage cosine is compared with your control voltage and wherever it is equal to this, pulse is generated and now, the pulse again the duration is 60 degree, it can give the sum even the smaller magnitude till your valve is fired.

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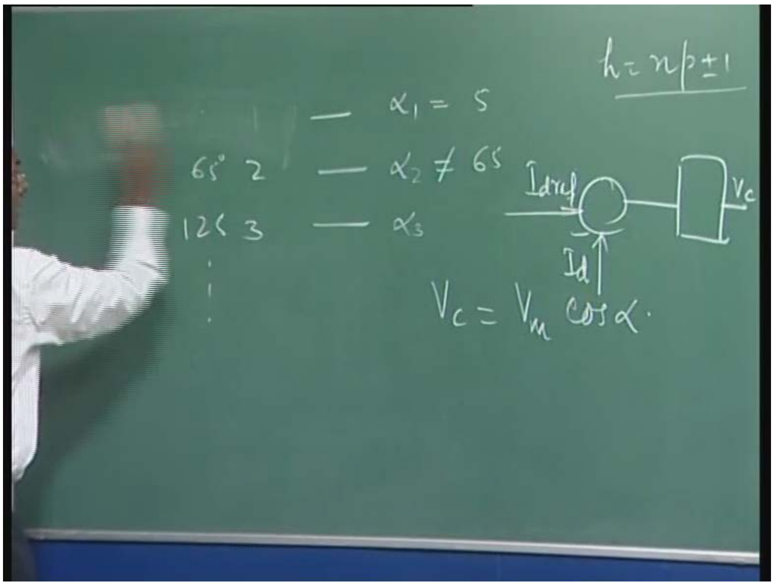

Now from this equation, we can see that your alpha here or you can say the V c is equal to your V m COS alpha because at this alpha value here, the value of this voltage will be this is a cosine curve cosine omega t. So, here is I can say V m COS alpha or you can say alpha will be nothing, but you are the V c upon V m COS inverse from here, we can get it. Now this cosine control; now you can say why we are taking cosine? It is very advantageous because we know however this voltage equation the output voltage; it is a function of cosine so it is a COS alpha.

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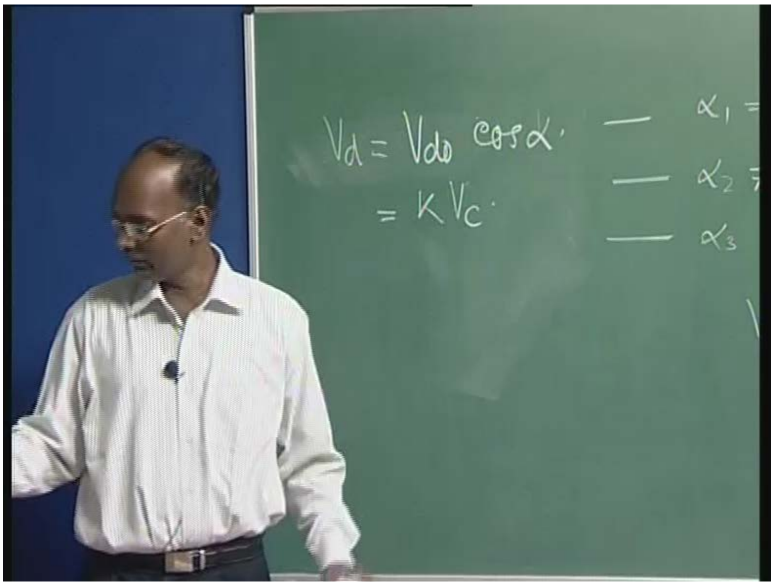

Now here from COS alpha if you are putting, we are going to get some constant of this V c, so our output voltage here is you can see it is a proportional to it is control here, this value V c . So, you can see this control scheme results in a linear transformation is giving a linear transformation characteristic; it is a linear one. Now, if you are going for another control that is a linear if you are going to use instead of cosine in that, we are going to compare.

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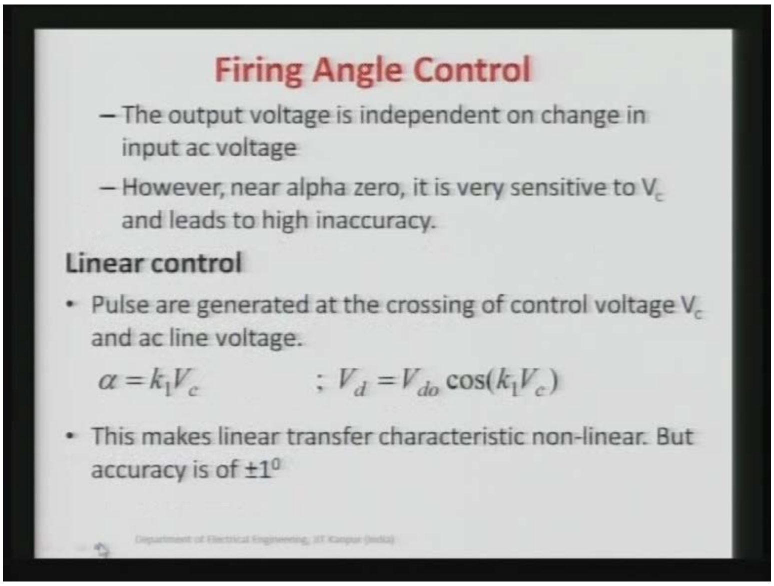

In this one linear, here you can say alpha is directly proportional to your low voltage control if you are taking, but you are this voltage equation becomes non-linear. Only problem here is that you can see the output voltage is independent on the change in the ac input voltage this is advantage. Here your output voltage is independent of change in here, the ac voltage E m etc. So it is advantage, but here this is very, very difficult when alpha is zero, it is very sensitive to V c. You can see at here if you will see it is error is very, very high because even the small value of V c suppose you are here, it is you can see, if V c is change alpha is drastically changed is a cosine wave characteristic. Here it is almostly near in this trough, but in this trough you can see fine here the sensitivity is very high.

So, even though that small error in the, I can just I explain here this is your V c, if there is a small change here, you can see in the how much change in the degree is changed. So, the error here you can say due this V c change it gives high inaccuracy, especially when alpha is zero at this point. So, this is the drawback of cosine, but it is a linear one is a independent of voltage this equation is there is no E m involve here, in the linear if the transformation is no doubt it is a non-linear, but the error here it is within one degree and these two schemes were basically use in the I just again said, that it is a in the old mercury valves and now, they are not use due to the problem that here, they are we are not going to control the individual one by controlling the individual here, we are going to introduce so many other problems like a inter harmonics and other harmonics in uncharacteristic harmonics not here, this one and this may even though lead sometimes harmonics instability it to your controller.

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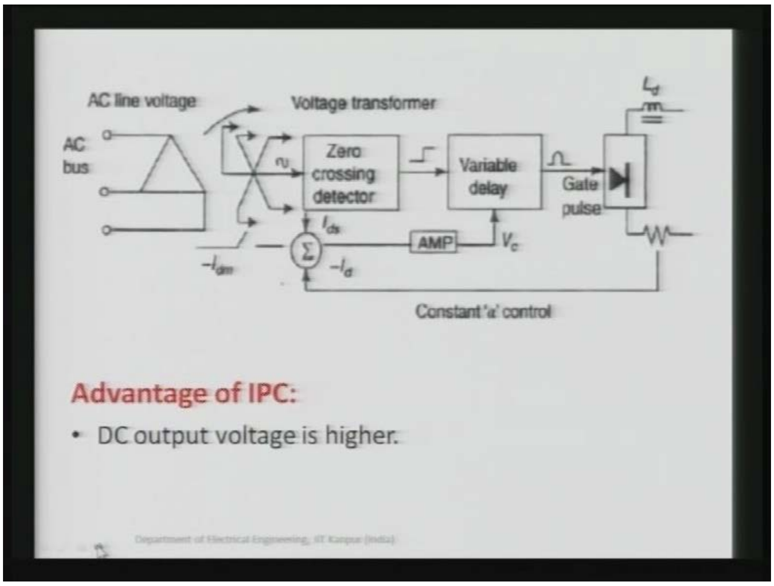

So to compare here, but advantage just you can see here how it is going to be done? You see there this here, the different the phases is all the six are there; here we are taking this is only one phase and then, we are calculating the zero detector this were is zero crossing and your current here, this is a measure current and this current is compared basically; here this a switch is all set if you are shifting from rectifier to inverter then the margin is changed.

So, it is open it is rectifier this is there and wide amplifier we are getting some V c. So, this V c as I said we are getting here, now this V c from here 0 crossing; here you can say your zero crossing is starting. In this case basically, the our as a measurement here is a from zero crossing from here; so once it is zero then, we are going to invert to take the cosine wave means once it is measuring zero here, then cosine is generated here. So, it is still measuring the zero crossing here and then with this V c, we are getting the gate pulse for the individual; we are generating either cosine wave or we are using pure linear circuit. In the linear circuit what with how it is varying.

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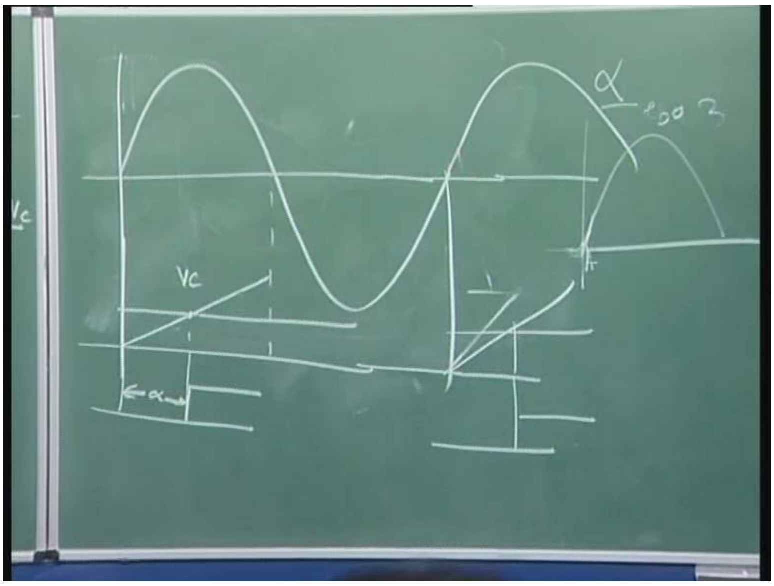

Let us see the characteristic here, in the linear circuit it is a simple ac sinusoidal and this is your ac wave, here we did never use the cosine; here your this value, we are changing here with this one linearly and your V c, this is your V c and this is your basically at this point the pulse is generated and this is your alpha, means once it is zero crossing is detected, then we use a linear generator here for this complete cycle and wherever this V c is intersecting, that is going to generate the pulse. So, that is why here in the circuit I wrote here, this is your V c is your K into alpha basically. This is alpha here; this is changing alpha is zero; this is some slope we are generating, some constant and this is your characteristic.

So based on here, your V c is directly proportional to alpha; when V c is zero? Alpha is zero. Similarly, for the another cycle here this is again we are going to have this and this is your V c and we are generating the pulse here; so this is a pulse for this again this pulse is for 360 degree ahead this is for valve one. Similarly, we can have for the valve two and so on and so forth.

So, this is a linear because you can see this is we are using the V c and this linear circuit earlier, we were using cosine with your V c comparing together; so in the linear; this is linear, this alpha this on slope and then we are comparing, and we are getting the alpha and this alpha you can put and you can get this, what will be the your output voltage. The major advantage of this scheme is it gives the highest voltage.

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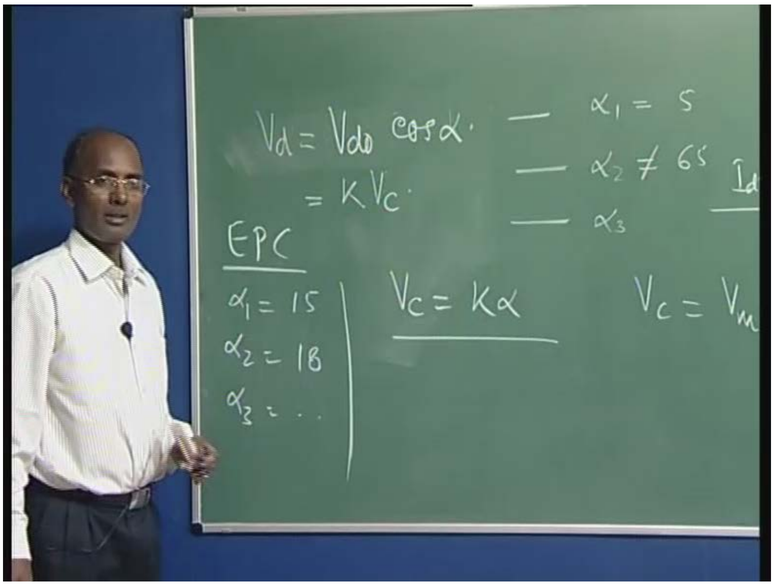

For example, now the question why it gives the highest voltage? In this EPC, all the valves are getting the pulses of the 60 duration. Let us suppose, if we had to change alpha; we had to let us suppose increase the alpha; if you are increasing this alpha let us suppose for alpha 1, it was 15 degree; alpha 2 you are going to have 18 degree; alpha 3 may be something degree here, means you are individually calculating for all this here in IPC. IPC means for individual phase control, we are calculating alpha for all the valves individually.

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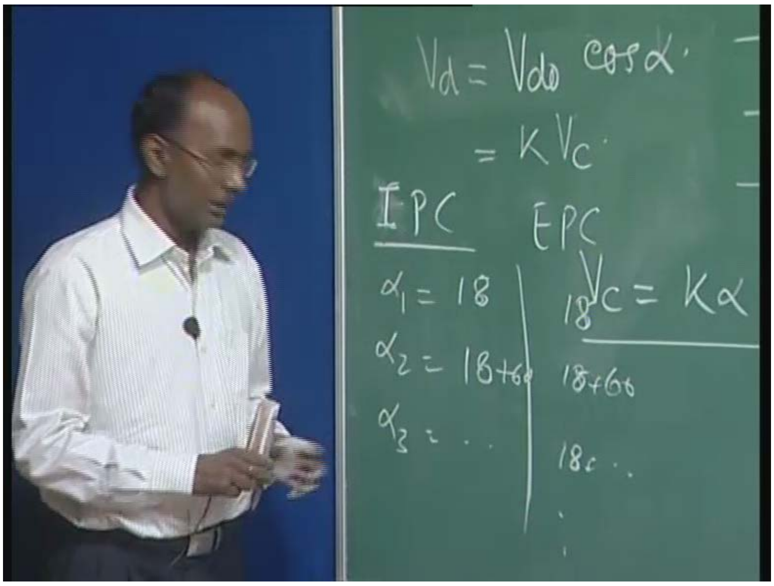

So, this will be the alpha 2 will be of course plus 60 no doubt, means we are just if you are measuring from here instant from 0. So, this is fire at 15 degree than 60 plus 18 means this firing instant of that from we are calculating is this 18 degree. So, what happens and in EPC what we are doing? It is 15; it is 15 plus 60; it is 15 plus 60 and so on and so forth. Sometimes what happens even though is let us suppose for here you are calculating 18 degree and remaining are 15 degree; it will be again 18 degree and so on and so forth.

Here if it is reduced, suppose you have fired at 18 later on the voltage is controlled or current is maintained, now your angle here it has come to original value means if your current V c is there changed what happens? Your alpha will be changed. Now, it depends upon whether your current is increased or decreased that can be visualize by again that writing that equation.

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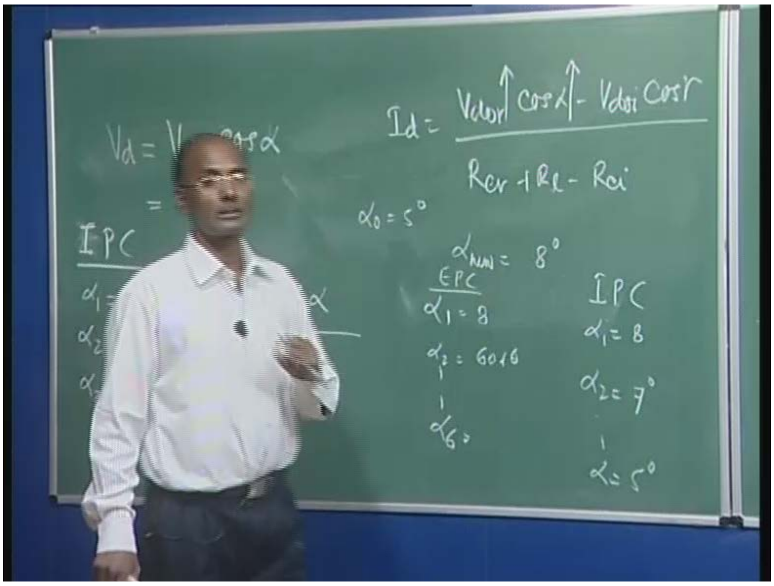

Let us proof this how this voltage in this case output voltage will be more, we have this equation; this is Id; this is your V d o r COS alpha minus your V d o I COS gamma, here R c r plus R l minus here R c I, I hope this equation is here correct. Now, let us say your due to this voltage increase; here or this voltage is increased, if your voltage is increase what will happen? This value should reduce means alpha should increase. Once alpha is increase let suppose in beginning alpha naught was 5 degree. Now due to this increase; now alpha new should be let suppose 8 degree or 10 degree whatever some value has to be increased to maintain the current.

Once it was just calculated at that time this alpha 1 to alpha 6, we are giving at the 8 degree; here it is 8 degree plus alpha 2 we are getting 60 plus 8 in the case of EPC, equidistance because 60, 60 it will be displaced. Now, if you are using IPC here, no doubt this alpha one here is 8 degree, once this is fired now what happens? This value is now going to be reduced, so the error is also going to reduce.

Once the time is coming for alpha 2, if this value is going to reduce so that time here, you will find this degree may be 7 degree because it is the error is going to a minimize and finally, may be you can again in the same cycle you have gone here to 5 degree. Now, you can see if you calculate the voltage here, it is less because more alpha here; it is less alpha sometimes here means average output voltage, in this case will be higher compared to your EPC. So, this is advantage of this, but it has a greater problem with its characteristic harmonics, uncharacteristic harmonic that is going to be generated.

Here due to this, we are having the unsymmetricity in the output voltage and also the currents are we are having many harmonics.

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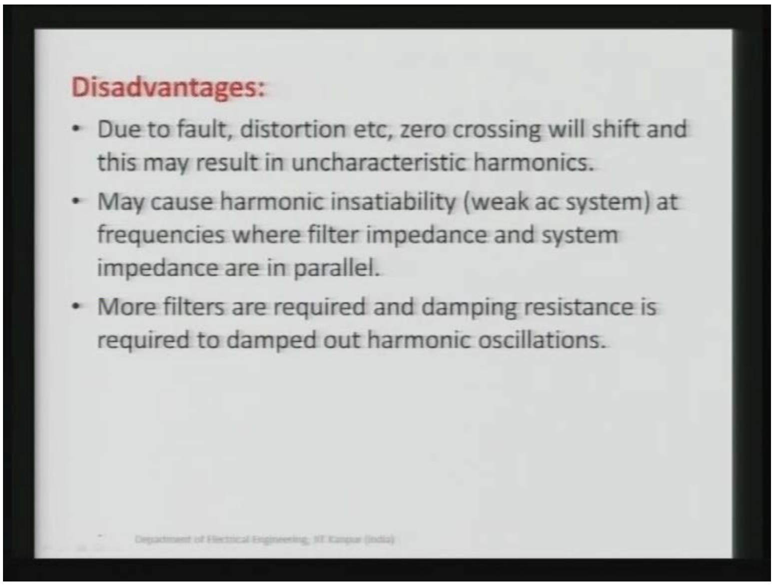

So, the major disadvantage I can say here the harmonic, but some other disadvantages like due to the fault distortion etcetera, the zero crossing is one of the big problem because this based on the zero crossing whether it is a linear circuit; it is directly using here zero crossing and this is generated based on the zero crossing and even though in the cosine wave, if zero crossing comes we generate a cosine reference angle reference voltage will shift and this may result in uncharacteristic harmonics here as well, means your this h n p plus or minus 1 here, this is your characteristic harmonics h, but here uncharacteristic harmonics we are talking other than these and that is why, here it may cause the harmonic instability especially in the weak A C system.

Now, the weak A C system means if there is a small fluctuation, it may be the severally effecting your voltage and magnitude strong system means when the drawing the power the voltage and frequency is almost unchanged. So, weak here system if there is a small problem load increase or something voltage will change very fluctuating.

So, weak A C system at the frequency where the filters impedance and the system impedance in the parallel, what happens? There is a some resonance and the harmonics insulating may occurs therefore, what we do to avoid this? We have to use more filters not only here 5 th and 7 th for the 6 th pulse are 11 th and 13. We have to go for some other harmonics filter as well and also, we have to put some damping resistance to damped out the harmonics oscillation in the circuit. So, these are the major problem and nowadays that is why, these are not used in our modern HVDC link.

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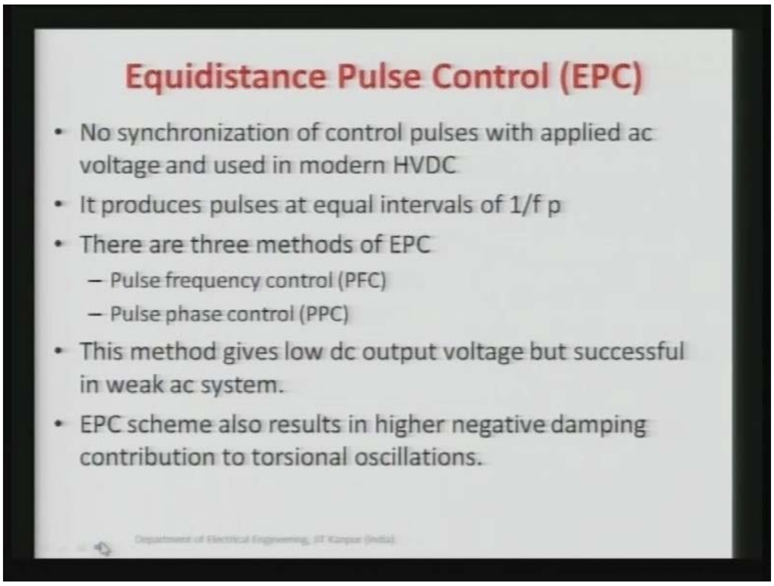

So, let us go to our this equidistance pulse control and let us see, how it is visualize and what is a main concept behind this scheme. Here as said no synchronization of control pulses with applied ac voltage. There is no synchronization here, because here all are you can say the different values are calculated; here you are calculating only once remaining are this pulse are generated without any problem and that is why, it is used in the modern HVDC links.

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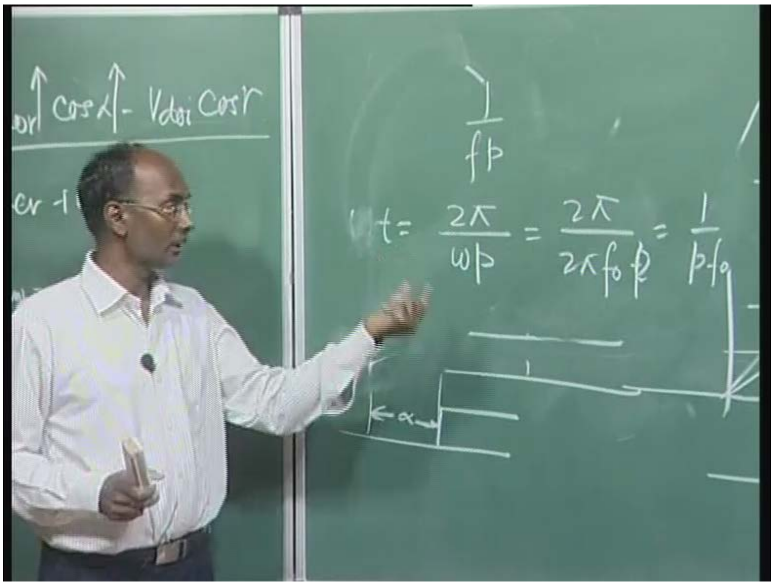

It produces the pulses at equal interval of here that is you are, the pulse here it is your 1 over f p means interval of the time duration of these pulse. How come? You know this is omega t, if it is a six- pulse you are talking, so omega t is 360 degree; you are going to have the sixth pulses so the duration of each pulse here, we are going to have that is how much? 2 pi by this is in if you are talking in radiant here; it is not degree in it is 2 pi, it is a 2 pi divided by p. Duration of each pulse we are talking here, this is a p is number of pulses, in the 2 pi if it is 6, so it is 60, 60 degree.

Now, your t will be here omega and I can write the twice pi 2 pi f, this is normal frequency and we this is p and we are getting here p plus p into f naught. So, the duration of each pulses here, that depends upon here f naught and the p that is here I have written means once you are calculating the firing instant then that here that difference that is a 1 upon f into 1 upon p into f naught, it will be the distances automatically calculated. So, here it is threes schemes methods are written basically, there is a some modification of this method, it is pulse period control is very similar to the pulse here in these schemes so that is why, here I wrote the three methods, but now here I am going to only discuss the two commonly use method here for this equidistance pulse control.

First one is your pulse frequency control that is a PFC and another is your pulse phase control that is called PPC, though third was basically it was the pulse period control which I am not going to discuss and it is almost slight modification of even though there also we will find some modification people have done to again achieve over the better objective.

In this method, as already we describe and here I just I tried to convince you that this method gives low dc output voltage, but it is successful even though in weak ac system means there is instability problem is avoided, but no doubt we will find here it is say EPC schemes also results in higher negative damping contribution specially to torsional oscillation; the torsional oscillation specially arises when if you are having some thermal power plants.

If you are having some of the harmonics which is entering to the mechanical system there is a some oscillation in an torsional torque will be there due to that matching frequency and that torsional normally it is called sometimes we call it sub synchronize resonance in the ac system. What is this? To know this, it is the if you are having a thermal power plant, you know it is big masses are there means we are having our, if we will see the thermal power plant.

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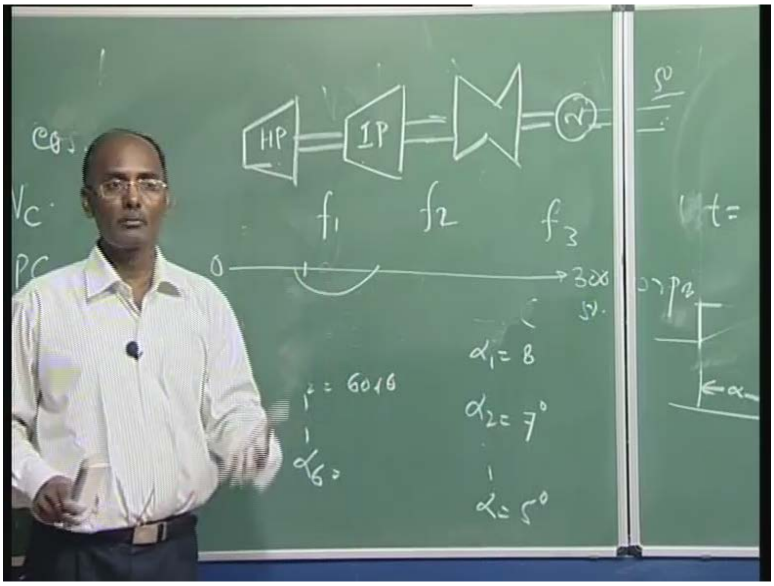

This is your high pressure turbine, although it is high pressure, but the size is small. On the same shaft, we may have our intermediate pressure turbine; on the same shaft here we may have low pressure turbine and then we are having our big synchronization data. So, all these three, one, two, three these are the mechanical here our electrical system start, but still this is a mechanical system because is a rotating mass, huge bigger even though very heavy rotter along with the you know turbine blades here, what? No that is even though some here, even though rotary for excitation of this also that is a some machine some weight is there that is even though excitations system and also even though they are on the rotter itself and nuclear inertia is changed.

But these three here they work just like a spring mass, you know whenever you are connecting two masses with the some shaft and the shaft is not of having the is infinite stiffness coefficient. So, what happens? They are just like a spring, so each here will having one critical frequency, if we will calculate this is a whole system you will find one frequency here f 1; one frequency between this and one frequency here between the cycle say 2 and 3. These frequencies are specially lesser than 50 hertz, if you will if you are having here the 50 hertz system; you will find these values are starting from 2 hertz 2 hertz 250 hertz in between.

So, any frequency which is let suppose you are having HVDC link here connected at this pulse and that harmonics is entering here in this system, the rotter which is rotating there is induced E M F and that torque here is matching with these frequency then, what will happen? The huge torque oscillations will torsional torque will be develop in opposite direction and that may cause damage to your shaft.

So, this is called your torsional oscillation, if it is this frequency is matching whatever the frequency entering to the system, even though if you will see in the actual power plant; even though they are just starting synchronizing this machine they never stop at this frequencies. Now, what do you mean by frequency? It is basically rotation you know the 50 hertz is 3000 r p m.

So, for this frequency you know what is the speed of machine where you have to not stop, so since we are starting from 0 no doubt, here up to 3000 these frequency this is r p m means this is your 50 hertz. So, starting from your 0 to the 50 hertz certainly, this frequency will lie here. So, the operator for the power plant once this frequency is coming, they never stop they suddenly just move the machine to this from here to here, if they can stop here there is a huge oscillation or there say you know vibration of the shaft remember machine may go off because they are on the volt and huge torque will be developed.

So, these are the basically critical frequency just I wanted to tell what is the torsional oscillation because if it is happening here then the frequencies matching huge torque is developed and that torque may even though damage to your shaft. So, this problem only occurs if you are having a power plant near to that one, otherwise it has no problem because it has a negative damping.

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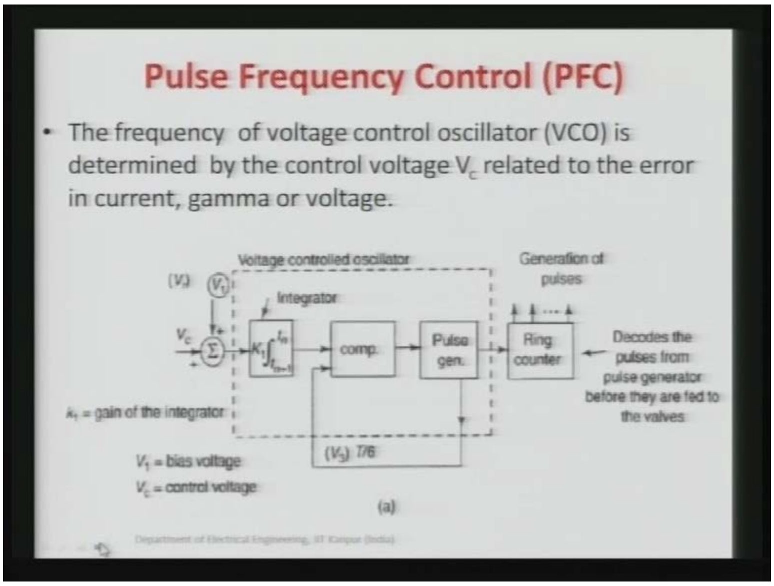

Now, let us start with now the first part that is a pulse frequency control the PFC and how it is going to generated? Here the frequency of the control voltage control oscillator, we require a oscillator- circuit; we had to have your V c means you are giving this control voltage and based on that, your this is you can say this is whole scheme is your voltage control oscillator. Voltage control oscillator is nothing, but it is a comprise of a integrator; it will have a comparator and then it will have a pulse generator and once it is generating then it is giving to your ring counter and it is shifting sixty degree automatically because it is the equidistance once alpha is calculated here, then for one it is alpha; for two is alpha plus sixty; for three it is one twenty plus alpha and so on and so forth. So, this is a ring counter and it is given to the individual valves to this here.

So, the frequency of the voltage control oscillator V c o is determined by the control voltage; control voltage V c here is basically arised due to the mismatch; arised due to the difference between the you are set point and your actual point. If it is a current, then current mismatch means what is your reference setting and what is actual current flow in the link, if there is a difference V c will be some value, if otherwise this will be zero. So, this is your voltage control oscillator which is generating and we will see here, we are using some gain to stabilize it that gain is also important and we are using some biasing signal here, to we will see this biasing V 1 is also important if this V 1 is 0 this is unstable system.

So, from here if you are having V 1 and V c; here that is sum together then, we are integrating here and then we are comparing with the V 3. V 3 is a basically a signal that is t by 6 because is a 6- pulse converter, we are giving and this is some voltage; it is a divided in that one and that is a compared just I will come to that and then once it is compared and then, at that instant when both will be equal this value and this value is equal the pulse is generated because always comparator means is comparing two signals once is zero then, the signal is generated and we will see here in the next slide.

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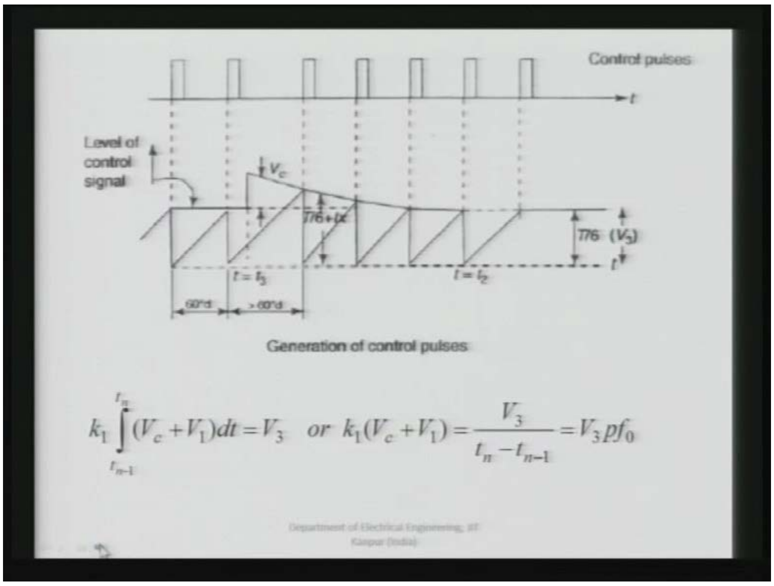

So, the mathematics equation that we can write here as I said this is your integration here, this term is equal to V 3 and finally, we can say the k 1 the V c plus this we can this is a dt between this t n minus 1 instant to t n because we are talking the next instant here to here, the t n minus 1 to n and we can write here, the V 3 t n minus t n t n minus 1 and finally, we can say V 3 into the p f because this is the duration, t n minus 1 to t n is the duration of the pulse and already we derived here, this duration here basically this is nothing, but it is your t n minus t n minus 1. So, this is duration of the pulse and this is 1 upon p f and if you are putting this here this value 1 upon p f is the p f here, that is gone means p is your pulse number, f naught is your base frequency and V 3 is a voltage which is that is going to be compared, so we are getting this expression. In this case, you can see it is a directly related to your this f naught; f naught is your the base frequency, but it does not correspond to your actual operating frequency.

We are calculating this instanted with the base f naught; f naught intermediate the f naught can also change means that frequency of the system means we talking 50 hertz f naught means it is 50 hertz, but the frequency of the system can change here, it is not taking account of that. So for that, we can have some modification, but before that here, we can just discuss about how this pulses are shifted or it is going to be generated. So, let us see this figure; in this figure how the pulses are generated? Here this is your V 3 which is going to be compared and this is the V c is here, you can see the V c is some change here, there is no V c. V c is 0 what happens in this your voltage control oscillator it is ramp circuit is generated. The ramp circuit is generated here and then when V 3 is coming here it is the pulse is generated here.

So, in the normal case when the V c is 0, we are getting you can say the 60 degree here, this pulse and finally, here we were getting like this, but if there is error in your whatever the controller you are using for current controller or c a controller here, the V c will have some let us suppose some positive value what happens? This has increase because we are adding here with this V 3 because V 1 is added; V 1 is the bias circuit which is integrated that is basically their ramp circuit.

So you are adding here, now you can see it is going to be here integrated and this is a it is going to be at this point; it is going to be generated here, basically this is the V 3 and V 3 is equal to here the V 1 and it is going to cut here and the pulse is generated is more than 60 degree because the V c is more means what happens your current is more you have to delay it, for let us suppose you are using the CC.

So, in this case here your this value the t 6 plus some t x is going to be added this is V 3 and then, we are comparing here and the pulse is generated and similarly, then again we are having the 60 if it is a decreasing exponential here, your alpha is change accordingly and the firing you can say this is the control pulses, normally here is the shifted and we are believing once this is shifted, the current in this value which going to get delayed and it will be going to reduce because even the one alpha is delayed output voltage is going to be changed and once output is voltage is going to change, here your current the whatever the mismatch it will be going to adjusted. So, it will be decreasing and finally, again we are getting here.

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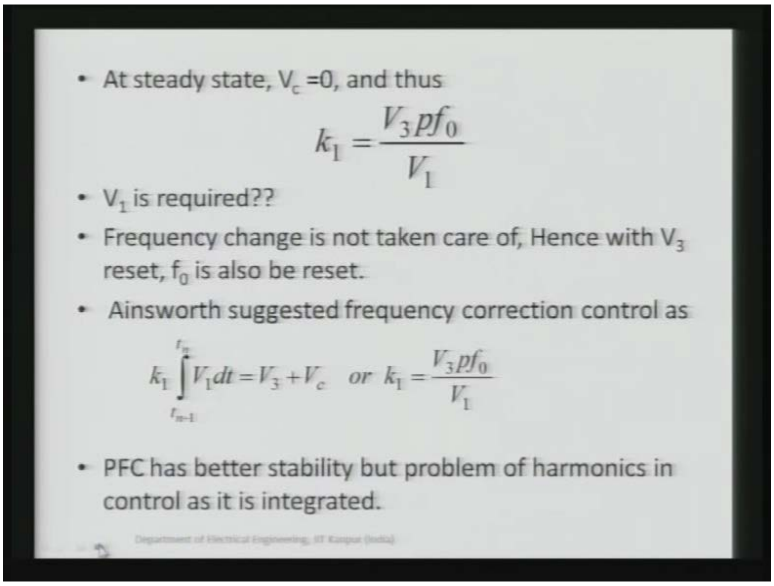

It will be more clear here, from let us see why we are going to have the V 1 circuit; V 1 at the biased element, from this equation we can now you can see here, if in steady state condition your V c is 0 then from the previous equation, we can find this k 1 is your V 3 p f naught upon V 1. Now if this V 1 is very small, let us suppose your bias is very small what happens in the steady state? This k 1 value is very, very high means you require very huge gain and if this V 3 here, V 1 is 0 this is becomes infinite.

So, you cannot have without this your V 1; if the V 1 you are not using directly you are using your V 3, V c and you are comparing with the V 3 your circuit will be unstable. So, that biased is required that can be proof from here because this value is almost every time most of the time it is 0 unless, until there is a change in the your settings or your actual value. So, this gain is which is you require very high gain you require infinite is not feasible means that is your controller is not satisfactory, so in this case, we require some biased voltage and that is basically added with your V c and then, we are integrating it that is why, here I question why the V 1 is required at all why not directly we are from V 3; we can use this. In the next we will see, we are not going to have the even the V 1 in this fashion, directly your voltage pulses are generated proportional to your V c. In the pulse phase control, you are the pulses are directly related with your V c it is not related to the V 1 the problem here again, I am going to discuss the frequency change is not taking care of in this case because f naught is there, it is normal frequency and hence, with the V 3 if you are resting this you have this should be also be reset means what happens? Your ramp is there, you have to reset here that one also because this is 50 - 50 hertz means this is a your f naught if you are using the 50 hertz, your ramp which is calculated for the sixty for the six- pulse because one cycle it is a 360, if the frequency is change now this period is also going to change.

So, once this is reset means you have to reset this again and then, you have to measure the frequency f naught and then you have to use it, so after one cycle means for one cycle you cannot do once you are using f naught; it is f naught and then next cycle you have to measure the frequency and then you can change it only to here to the have the frequency correction, this here this ainsworth suggested the frequency correction control where this is we are not in this one what happens? The harmonics is not integrated. In this frequency control what he has changed? You can see the change is compared to the previous one here your V c is not integrated means what here suggested this is your V 1 circuit here.

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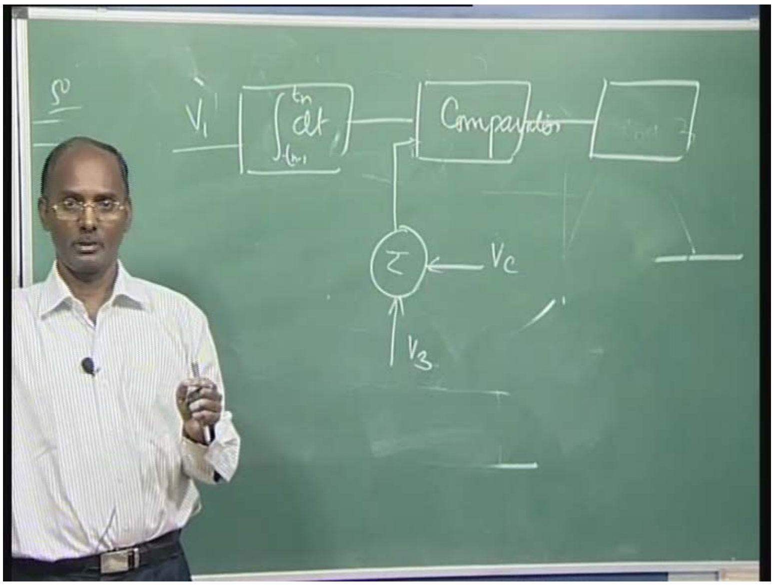

This is your integrated dt, here your this comparator is there; it is your comparator and then we are having your the pulse division circuit, here your this is your V c and we are having your V 3. They are just added together and then, this is compared here. Now the difference you can see what happens? Earlier we were adding V 1 and in the V 1 and V c here and then we are we are integrating here again, here is a t n minus 1 to t n and now we are comparing here.

So, in this case what happens? You can this integration value is equal to your V 3 plus V V c. The advantage of this if there is a some fluctuation in the V c here, it is going to be integrated here and that may cause your some instability problem that is why, here it is called this scheme is better stability because here, the control is not integrated this control value the V c. So, he said why not we can add here and then we can compare because this, if there is some fluctuation here that will be taken care that will not that will not reflect here because it is not integrated. Integration means if there is error it is keep on adding, so with this we can derive here equation and you can say the k 1 is here again, we require V 1 the bias circuit is require voltage because both are same and the same logic applies, but only here the advantage in this correction here, your this V c is not integrated and the V c can be change with the frequency here.

In the earlier, if you are using the V c what happens? If frequency every time is changing it is integration create lot of problem, but here whenever the V c you are using; the V c can be corrected based under frequency correction as well, because it is not going to be integrated and then, we can use the frequency correction here in the V c. So, this is some modification of the previous one, that is your pulse frequency control and it is basically the most popularly used control scheme.

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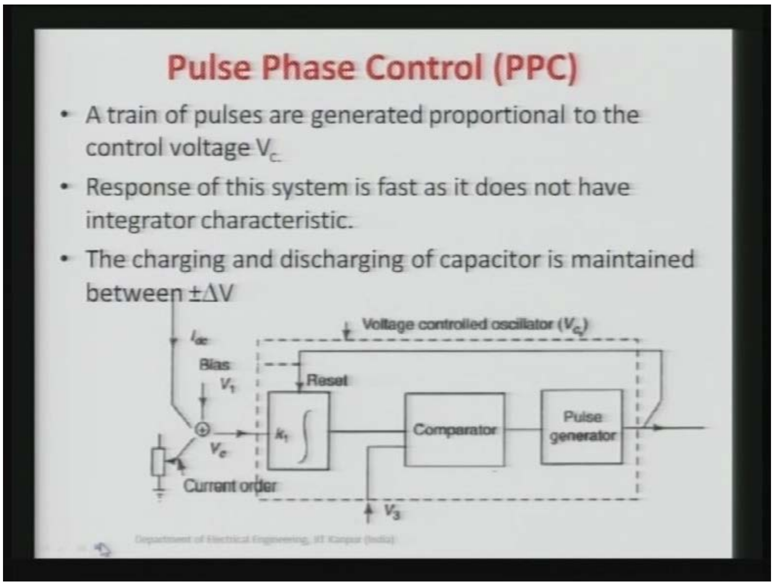

Now, another one is called the pulse phase control, here in this scheme the trains of pulses are generated and that is directly proportional to your control V c. The in this case, it is very fast because here the integrator characteristic is not used, now you can see here the integrator is there, but this integrator is only to generate the ramp. We had to have a ramp some charging and discharging is taken care, here the charging and discharging normally we use a capacitor, then charge and discharge, so that we can generate some voltage here for use of your comparison purpose to see this. Let us see this diagram and then it will be more clear.

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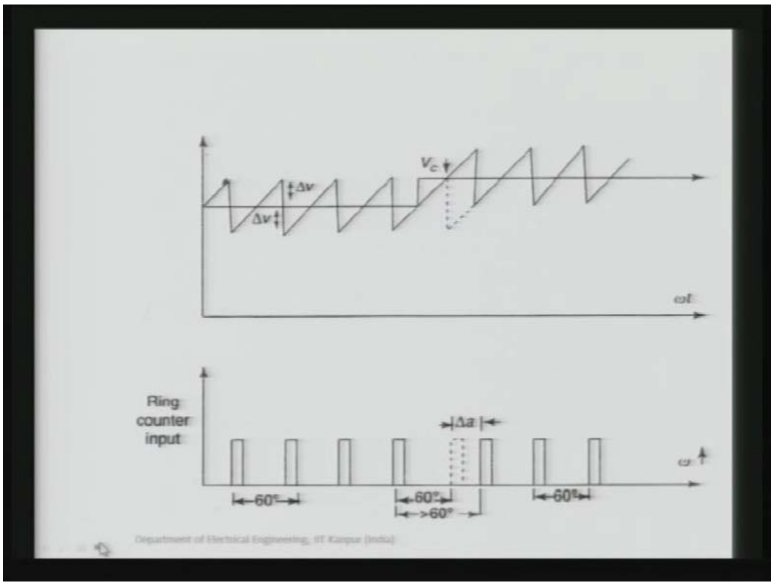

See it here, what happens? You are the plus and minus the voltage on the reference here, we are having the ramp, this is integrator which was use; here it is just you can see at this point the pulses are generated where this is equal to your positive one. This one value this is charging here we are having.

Now, let us suppose your voltage is increased; voltage means control voltage I am talking due to again this voltage will change due to the mismatch in the error. So, once let suppose this is increase it was 0 here, this voltage is at V c. Now, what happens? Now you can say the charging is more increase here and this point, it is going to set and this is the delay here you can say this change in this alpha. Now, it is coming here because the pulses are generated here; earlier it was expected to generate here, but due to this change now we are having this plus and plus minus going to be here and then, we are having so this is a delayed here, more than 60 degree and then again in this case, you can say now this again 60, 60. It is going to be there and it is equidistance sequencing means only this is a shift here, once we find which is there and we believe that it will take care. Let us suppose if the later duration it is reduce then, this will be further reduce here.

So, here it is very fast and as there is no integrator; integrator here is a ramp circuit generator that is very, very fast; it is we are not integrating our control voltage as all, we are not controlling the bias voltage at all. Only we are generating the charging and discharging may be capacitors and how you can say the pulses are generated and with the circuit, so here that is why, this is a circuit here also we are using the control voltage oscillator and again, once the pulses are here coming out and this is we are going to use your ring counter to generate for remaining and then, we can give for the remaining valves of this rectifier circuit.

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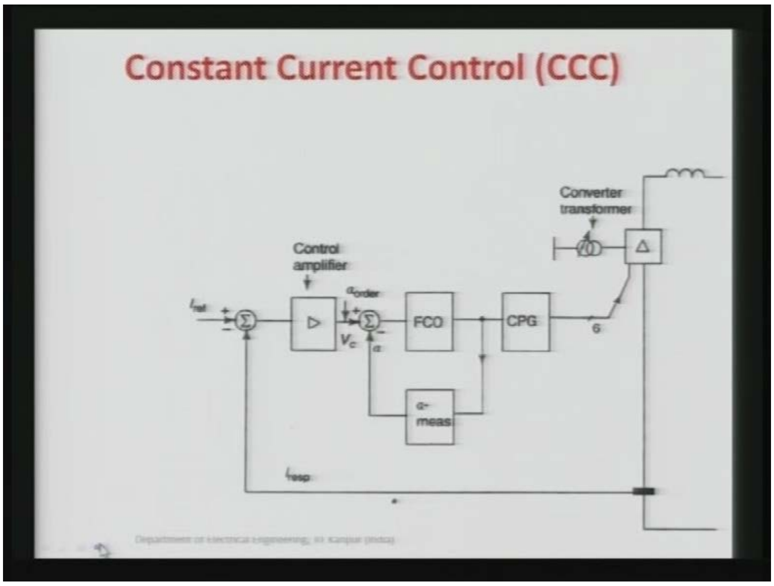

Now, here let us go for your see how hold control philosophy is realized because these are the schemes which I explain that it is to generate your alphas, simply nothing else I said we are generating the pulses for the valves and objective is to control either current or to control your constant extinction angle. So, you can see this is what we are doing here; we are measuring the current of this. Let us suppose, this is your rectifier end; rectifier is basically used to control the current, it has to maintain the current in this link constant current and this is measuring the current here and it is a comparing with the reference value as usual here whatever this error is there, we are just using some current controller amplifier because this error may be very less.

So, we have to use some here, first order some transfer function for this controller and then, we are getting some voltage here. This voltage basically generating your alpha; once this alpha is generated here, either block is not written because there is the V c u is there; alpha one is there. We are right now measuring what is the alpha? Because what was this alpha it is generating here, alpha what was alpha if there is a change then, again, we can changes status otherwise we can make it constant.

So, this is this controller your FCU is basically is checking your current measurement of alpha then, it is of what is the V c that created. If there is no then, no need to go for there the change in the firing pulse, it will be the same; If it is there then, it will try to increase slowly because alpha must be shifted sudden change it is not possible, we have to alpha shift slowly and then it is because that is why, here the some transfer function will be there and then, it is generating the pulses for remaining 6 as well as that same time equidistance and then, it is given to here and once it is giving your current again, it is measured and it is basically, whole circuit is so this is basically the loop for your constant current control.

So, if this is your rectifier which is maintaining constant current then, the current will be checked; if it is going in this your extinction angle control means inverter zone or you are talking about inverter control.

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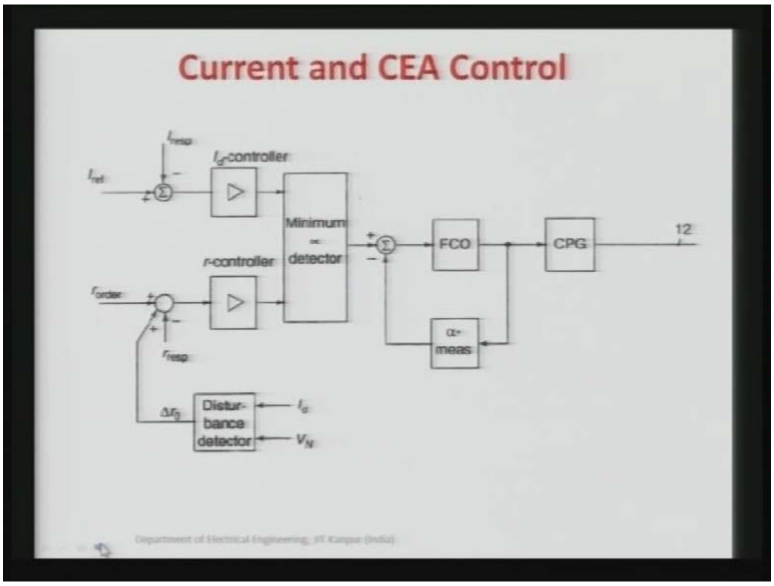

You see how it is (No audio from 51:10 to 51:18) here what I have done? Here I just added another block; here we had all this things as usual; here it was like this only. In the previous one the constant current controller if you are using simply without any extinction angle control this will work; this will; if you are using this will work; if you are using this will work both will not work together. As we know, that is either it will work in the constant current or it will work as CEA.

So, this we saw, it now if you are just changing in the CEA; this will be here coming back and we are calculating the here, it is not r; it is a gamma, basically gamma not. What is the minimum value? It is comparing with your, what you have generated and then, again this controller will try to adjust your gamma and finally, it is coming for all the inverter and voltages. So, this is basically the CEA and the CC control together in that control loop later on, we will also see it is not only individual; we will see the whole comprehensive controllers including your CC; including your CEA. We will also see how the VD COL also going to be implemented and when it is going to be bypass? When it is going correct? So the control philosophy of any HVDC converter station is very, very complex, it is not so simple that is we are writing the block diagram because in actual realization of each block require a huge smaller circuit to get it fast accurate and there is no noise here and there we can have it.

So, in the next lecture; we will talk about the various controller like was suppose you want to control the power, how this current and the CEA angles controls are going to be visualized and will also see the complete your sending end and receiving end converter stations; how the control the all other controls are clubbed together or basically implemented.