

High Voltage DC Transmission
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Module No. #03

Lecture No. #04

HVDC Link Control (Contd...)

So, today's lecture that is lecture number 4 of this module and now we will just categorize and will see the various type of control that is feasible for the H V D C link. We discuss about the constant current controller and also we discussed the characteristics in the previous lectures.

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CEA Control

- Knowing commutation voltage and γ_{\min} , one can find β

$$2L \frac{di_3}{dt} = e_b - e_a = \sqrt{3}E_m \sin \omega t$$

$$2L \int_0^{I_d} di_3 = \sqrt{3}E_m \int_{t_1}^{t_2} \sin \omega t dt \quad \begin{matrix} t_1 = \alpha / \omega \\ t_2 = (\pi - \gamma_{\min}) / \omega \end{matrix}$$

$$2LI_d = -\frac{\sqrt{3}E_m}{\omega} [\cos \omega t]_{\alpha/\omega}^{(\pi - \gamma_{\min})/\omega}$$

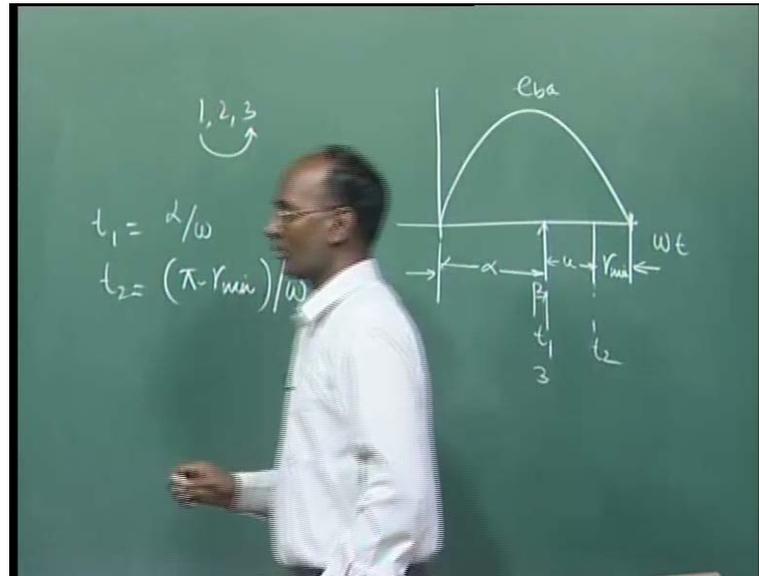
$$-\cos \alpha = \cos \gamma_{\min} - \frac{2\omega L}{\sqrt{3}E_m} I_d = \cos \beta$$

- β depends on ω , L , I_d , E_m and these are measured continuously.

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Now, here I will just discuss how the C E A control is accomplished. The C E A control as I said we have to maintain the gamma minimum angle. So, that the commutation failure can be avoided especially in the inverter because the commutation failure is a only possible in the inverter because the rectifier we are having the valve voltage most of the time it is negative. So, the commutation failure may not occur.

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So, we know this we have to in the C E A control we are maintaining this is your commutation voltage of any valve and if I am writing this for the valve 3 it is a e b a and this is the zero crossing and basically we are maintaining this period that is a gamma minimum. So, that the commutation can be successful even at the during time of after firing at the during time of the firing if u is changing. So, we should land off and there should be successful of your commutation. So, based on this we are just calculating the angle beta where this inverter is to be fired and we are calculating at that time what will be the value of u.

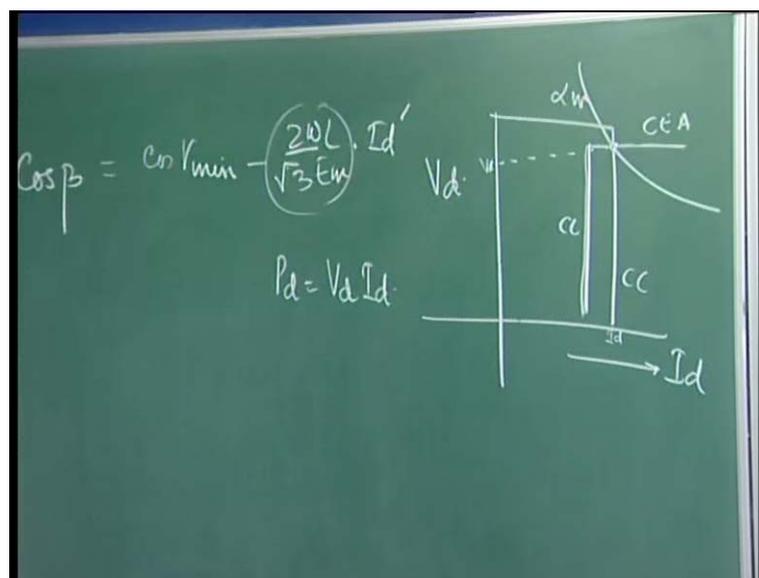
So, for the known value here u we can maintaining this, we can calculate the beta instant the beta instant and then we can give the firing pulse. Now, in this condition here you can just write, because here we are talking about the two three valve conduction mode and this expression we already derived if remember. Here, we are talking that earlier one and two valves were conducting and three is given pulse. So, in that case your valve 1, 2 and 3 are conducting. So, the current which will be basically there will be the commutation from 1 to 3 the current earlier it was idle here now it is going to be taken by the three current and we derived this expression that is a $2 L \frac{di}{dt} = e_{ba}$. Taking this our convention of your this, this is a sinusoidal that we are taking zero axis here this is voltage.

And you can calculate the current here you can integrate here what will be the value. The instant that is at t_1 here it is your this value is your t_1 and this value is your t_2 . We are giving the firing instant here, where, the valve three is going to ignite. And it will ignite because the voltage across this valve is positive and if here the ignition is successful then it is a t_1 instant and then it is going to be off 1 is going to off here means 3 is taking complete current of this link. So, the t_1 will be basically nothing, but, if you are measuring from here.

So, this is basically nothing but, your alpha. So, t_1 I can write it is nothing but, your alpha divided by omega. Because this axis is your omega t. So, this omega t here at this point is alpha. So, it is a t_1 instant we can just calculate. Similarly, the t_2 instant here it will be the pi minus this angle. So, I can write here the pi minus gamma minimum divided by your omega. So now, we know that is at this instant your I_3 was 0 and at this instant I_3 becomes your I_d .

So, you can solve this equation here just you integrate from 0 to I_d for I_3 and this is from t_1 to t_2 where we already defined here and if you are just integrating this you are going to get this expression. And finally, we are getting this expression means we can write our cos beta that we want. From this expression we are getting the cos alpha and the cos alpha here alpha is basically nothing, but, your pie minus beta.

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So, we are going to have this equation means we are getting your $\cos \gamma$ minimum minus your this value that is $2 \omega L$ divided by under root $3 E_m$ into your I_d . Basically, this value is nothing but, your I_s if you remember this was the base value earlier and if you divide here because that value was under root $3 E_m$ divided by $2 \omega L$. So, it is same we are getting here.

Now, this β basically we are fix this value is known at the time of firing this value is known I is known e_m is measured and I_d is also measured. So, we can calculate the β . Only the problem once you have a given the β here this γ , because before the firing this γ here this I_d is assumed as a constant, but, it may not so, because that may change during that time.

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CEA Control

- For precise control, I_d is replaced by I_d'

$$I_d' = I_d + \Delta I_d$$

- ΔI_d is to take care of change of I_d during the interval u .

Transition of CEA to CC

- In the event of sudden system disturbance due to inverter end ac voltage rise or dip in dc voltage, the dc link current decreases. If current amplifier of rectifier saturated, the firing pulse of inverter will increase γ and inverter will take over the CC control.

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So, this I_d is basically replaced by your this I_d plus some α here as I said. This I_d is now replaced by I_d' we are adding some small that is a magnitude of this ΔI_d some percentage of this in that equation here, so that that can take care of any change due to the u interval. So, this is basically decided based on the practical condition what how much it is going to change.

So, this I_d is now going to replace by this I_d' . And some percentage this is a basically depends on the converter link what is the distance excreta everything and is based on that experience this value is added. Now, another here as I said there is a possibility if your inverter which is operating as a constant extension angle control, due

to the some severe voltage trip at the inverter end this may shift to the constant control. So, already we defined the characteristic here, this is your alpha minimum here C C constant current here and this is your this is the C C. So, this is your C E A. So, this is your inverter. So, it was operating here.

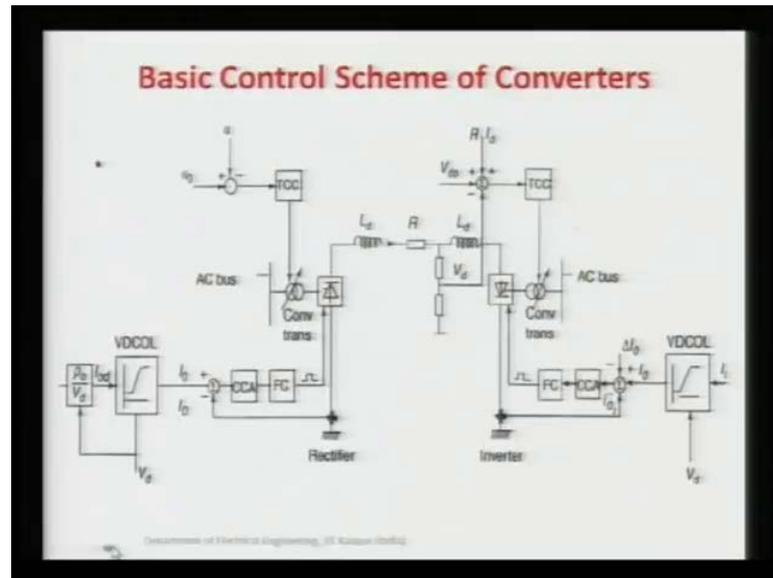
If there is a certain trip here you may land up somewhere here that you should take care. So, we should have a smooth transition from here to here. Then how we manage this? How it is going to be changed here? So, that is here in the event of the certain system disturbance due to the end this a c end inverter voltage rise or the dip in the d c voltage. So, what will happen if the voltage going to rise inverter end then your I_d is going to reduce or due to some problem here means there is a some voltage dip in that one d c link also, that is may cause your current should be here is a decrease and then what happens this side your controller is saturated current controller is saturated that it has to be shifted here.

So, what we do we gamma here basically increase it. And then it will be sifted here and the control. So, normally what we do first we change here gamma minimum, increase the gamma minimum and then we shift to constant current controller and this would be operating. We will see again even for maintaining the constant power how this characteristic from here to here and here to here is going to change. Suppose, right now what will happen in this condition, this is your operating point. And your power characteristic (()) it will be this characteristic.

Why? Because we know this P_d is nothing but, your V_d into I_d in per unit. This is your I_d , this is your V_d . So, the power characteristic will be for a given here this intersection will be operation and the power which will be flowing in the link will be this value this characteristic. Means this current multiplied by this voltage.

So, this is your voltage and this is a current here I_d here this one V_d . And now, we will see if suppose, it is operating here in this mode due to the certain problem, now you can see if suppose, this has gone down. Now, the power is also changed in the link. So, we will see how it is going to shift how we can change. So, that we can maintain the constant power control in the HVDC in this link we will see in the few slides. Before this this is the complete.

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If you will see this figure here, we are having the rectifier this is the rectifier, this is your inverter and this is your length. It has a resistance, it has a smoothing reactants both side or you can have a half so it is no problem. So, this is your rectifier and this is your inverter. Here you see the firing pulse is generated to fire it. Here also in the inverter side we are giving the firing pulse to ignite it here.

We are having extra here I have written the T C C. This is the transformer track changer control. Till now, I was discussing here because this is only alpha control in the rectifier, but, to achieve the V d curve here as I said here this characteristic will go here and this will be basically the constant voltage and then finally, here. This characteristic is modified when the inverter voltage has gone suddenly very low. So, this controller from here the characteristic will be totally sifted here and in this case we are operating at very less power in the circuit.

We cannot maintain if the voltage has gone down suddenly very low. Your converter station will be stressed highly. So, that is why it we reduced power and finally, we operate here in this zone. And this is called V d curve means voltage dependent current order limiter. Means the voltage has gone down your current order is changed and finally, we operate in this zone. To take care of this we measure the voltage of the link you see here. Thus we measure here the voltage and we know how much power is

flowing in the how much power you have set it. So, this divided by this means you are getting some current if voltage has gone down very less this current value will increase.

Once this value will increase based on that you VDCOL will see where you are going to operate means this will limit your I d current. Because, this current is going to decide here if it is heating this value or this in between or less based on it will be decided.

And then your I d is set I naught is set whether you want to set this here or you want to set here. So, this will be giving information this reference current will be decided if it is VDCOL is not constraining here, it will be your actual I d, if it in this zone. Otherwise it will set and then finally, we have to change the firing angle and we have to operate this here.

So, this VDCOL here that limiter is also added. Now, you can see there is another signal coming from outside. Basically that is nothing but, it is based on the power how much you are setting, if you want to increasing manually power how much to increase another here you have to add it here. Because this P naught and other power is coming here all the way. This P naught basically coming here V d only coming from here. So, this P naught basically how much you are setting in this that is deciding your current.

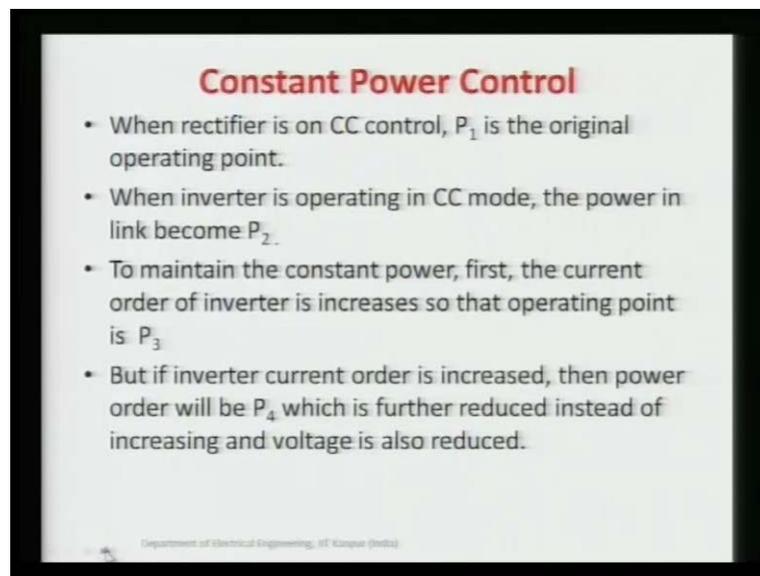
So, this reference is decided and then it is measuring the current here and if there is a some difference then your here the current control amplifier is there, it is amplifying the signal and then firing control angle is here it is calculated and then it is coming here all the way. So, this is basically your control characteristic of your rectifier side it is taking care.

However, this as I said if the voltage is changing very suddenly, because we have the limitation of alpha, because we have the alpha minimum as well here, may be one or two or five degree and also we do not want operate alpha at the larger because, it require more reactive power. So, what happens this will be here it will be set and this will be checking. What is your reference set of alpha and what is a current alpha? If there is a some mismatch, then it will start this type changer will be there and it will be trying to change your converter registration rectifier end it will be the tapping will be changed, to control again the current will be this.

Because this alpha is decided by current and this is also changing the voltage which is a current is there. So, there is a complete impact here and finally, the current will be maintained in this side. Reverse is also true here, you can say the VDCOL here also we need and then it is coming all the way here. And finally, we are here the gamma is beta is calculated and we are firing this inverter based on gamma minimum angle control C E A control and the beta is coming here. Here this T C this control is basically the so many aspects are there because this side this fellow is maintaining the voltage. Because, the inverter end is the voltage control this is your current control.

So, it is current is taking here when residing here also is no doubt the current is taken for this controlling because the current also require. But, this we are comparing the voltage plus the drop in the circuit here, how much this because this voltage and this voltage here drop and then finally, if there is any change with this voltage then we are changing here. This V d o is the reference, how much voltage we are going then suddenly we are changing here. So, it is your transformer type inverter side it is changed. So, this is complete control as such the both rectifier as well as the inverter side.

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Constant Power Control

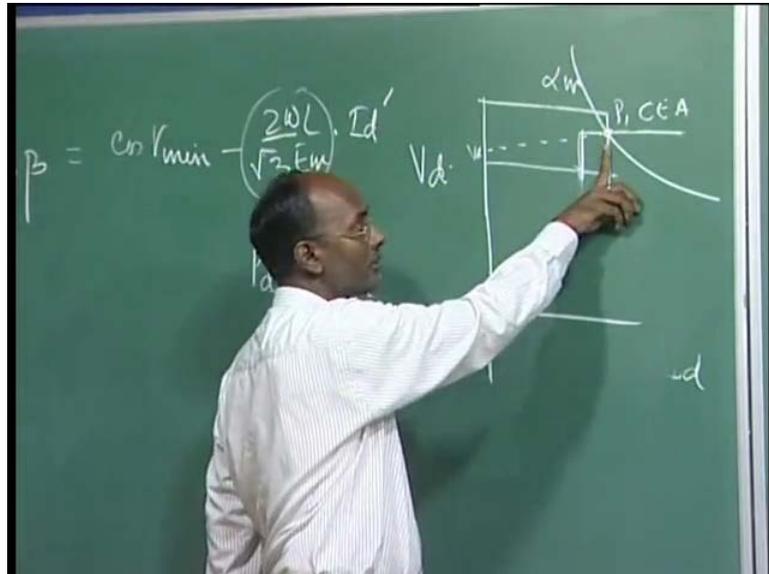
- When rectifier is on CC control, P_1 is the original operating point.
- When inverter is operating in CC mode, the power in link become P_2 .
- To maintain the constant power, first, the current order of inverter is increases so that operating point is P_3 .
- But if inverter current order is increased, then power order will be P_4 which is further reduced instead of increasing and voltage is also reduced.

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Now, let us see I think since we are starting here it is let us see the power control first. Then we will see how this even though your converter hold HVDC link, when there was no power how it is going to be started and how we can down it. Because it is not powerful suddenly you can just start full current and you can just load this HVDC link.

So, to understand this constant power control again I will come here and you see your actual operating power I can just remove here.

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This is your P 1 point I can say here. You can see when rectifier is on C C control P 1 is the original operating point here that is a control of this one here. Because, this is your rectifier C C, this is your C E A and this is your operating point.

When the inverter is operating in the C C mode the power in the link becomes P 2 means what happens here this is your P 2, because due to some problem here there is some voltage here has gone down. And now it is now operating in the C C and this is now operating in the voltage control. So, this is your P 2 and again if you draw this here this characteristic this will be like this. Now, what happens you can say this power is less than this power. Because this is more V d and I d both more here the I d is also less and the V d is also less.

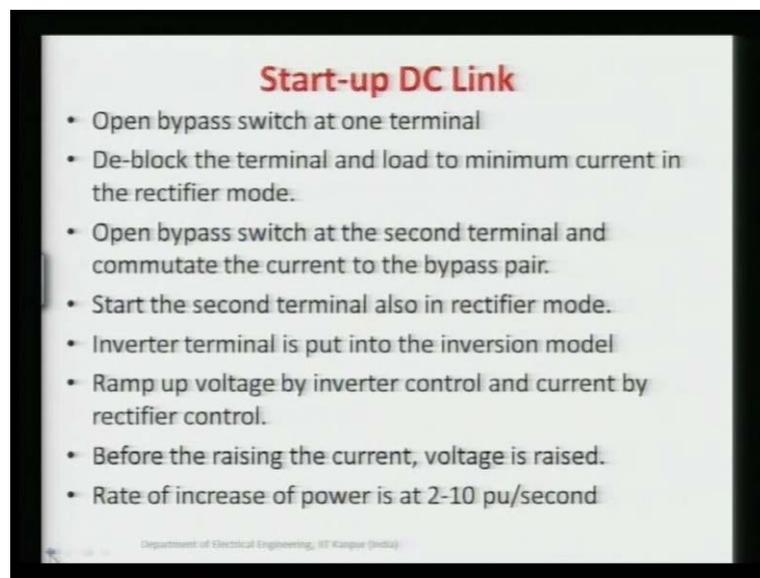
Now, to maintain the constant power, there is a two option that we can increase the current this one current here. So, that we can have because you know what happens here if this is your here we can just increase here and this intersection can be there. So one option that we can increase this current or we can increase this current. First see we want to increase this current order of your rectifier end. So, the first the current of the inverter is increases so that operating point is P 3. Here it is not a inverter it is basically the

axis. Because this is your beta control. You are just doing the beta control here you are coming here and then you are getting the P 4 intersection it will be set your operating point suddenly.

Because whenever, your inverter characteristic and the rectifier characteristic are intersecting each other that will be your operating point. So, it will be intersecting here and now you can see in this case you are increasing the current order, but the same time here the voltage is also reduced and the power is also less. Because this power is very **very** less than even your P 3 here P this P naught value. So, it is advisable that it is better to shift this characteristic means current order of the rectifier, so that we can get the suitable operating points P 3 and we can maintain the power that is a constant power.

So, whenever the power is changed because there is a power controllers are there. The power is basically I_d which is decided while I_d is calculated if the power setting your constant power operation mode. Because your reference I_d is changed now and it has become this value. So, your controller will take action and I_d reference value is changed and now we are operating here rather than here.

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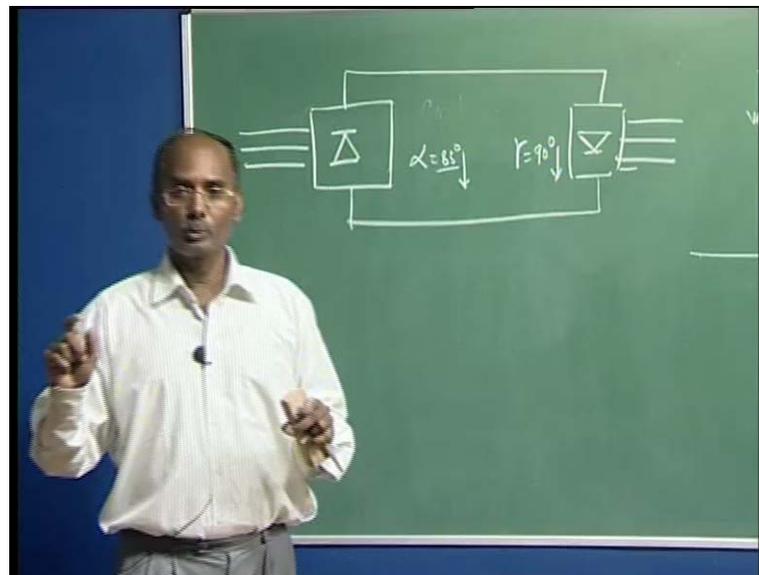


Now, another concern here that is how we can start or stop our link? How we can go ahead with this? So, in general this HVDC link can be started by the two methods one is called using the long pulse gate pulse that is, if you are given the gate pulse for valve for

120 degree or you are giving 60 degree. So, if you are talking about the short pulse there is 60 degree and if you taking long pulse it is 120 degree. Why it is 120 by 60?

Because if we will see if you are giving 60 degree after that even though that is required the pulse should be there it is not there then you will get the valve will be not on. It depends on what is the voltage across this. So, if you are talking about the long gate firing pulses, it is very simple. Because here what we have to do you have to de block the inverter around this 90 degree. What does it mean? We are having this is your just I will explain with this example.

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This is your rectifier. This is your inverter. Let us suppose it is here the monopolar operation whatever you can see. Now what we do here it is set d block means earlier it was not doing anything. Now we are just giving the fire impulse to this and especially we are maintaining the gamma is 90 degree. If you are giving the 90 approximately 90 degree, what will happen? The voltage across this will be zero. You are just turning d blocking here you are giving here 90 degree and it will be on.

Now, in this case here now you have to de-block this rectifier and give alpha is 85 degree we are not giving 90 degree, because there will be some u. Once this is on there is no current is flowing here. So, u is not applicable at all. Because it is simply it is a $V_d \cos \gamma$. So, the gamma is 90 it is V_d is 0. Now, if you are going to give here 90 degree what happens due to u even this voltage may be negative.

So, what we do we try to give some positive voltage we try to ignite somewhere around 85 degree or so. And still this voltage is very very small. So, now you are just starting this as a valve, now your voltage is here and now the current will start flowing small amount of current will flow, because this is zero this is very small voltage approximately zero some current will be flowing. Now, what we do? We then increase the voltage. What we will have? We have to decrease this slowly and slowly.

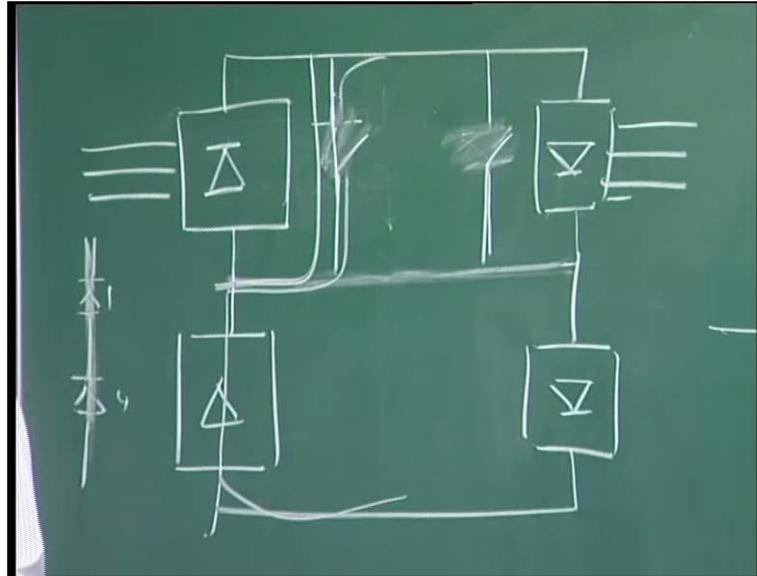
But again in this case now the question is that we can increase the current together we can increase the voltage together. But, it is preferable that we have to raise the voltage first then increase the current. Because, if you are increasing the voltage, why it is so? It is possible that you can just change this value keep it this current will increase. But, we do not want this. Because, what happens the current once it is flowing if there is some problem of insulation anything there is huge short circuit will be there.

So, we try to increase the voltage and see the line is okay or not even though the small amount of current is flowing. Once it is sustaining that voltage if there will be some flash over here and there in the towers and insulators here and there then you can just check it and then you can stop it again very easily without because the current was very less. So, what we do we try to ramp already here it is you can see the ramp up voltage by inverter control and current by the rectifier we have to increase, but, what we do first we increase the voltage to have the minimum current here. Means you have to increase the voltage means ramp. Then, you have to load this link by maintaining the current.

So, basically this is the starting over a D C link is done if you are using the long gate pulse. This 120 will arise long pulse because here you are starting at that time there is a huge possibility of the commutation failure. Because if the 90 you are using here that (()) the voltage across that valve may be negative. Because we saw that the voltage valve voltage here in the inverter operation is most of the time it is negative.

So to avoid this if it is at 60 you are having 120 this pair will operate. So, there will be no problem, but if you are going for the short gate pulse firing here, so the current extinction here as I said in the inverter operation is a problem because the forward bias is not in the conduction mode in the inverter side. So, the sequence of in this case will be first open the bypass switch at one terminal.

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Basically what happens all these here the converters they are having a bypass valve here or we are having bypass switch. This is a valve means what happens if there is any problem, this is basically equipped with this. This is used especially suppose you want to take it out. What happens suppose you are having another valve? This is your converter circuit, this is let us suppose we are having another here we will explain this in more detail.

Now, you want to take this bridge out for the maintenance purpose, what happens? Without creating any problem we want some current should flow like here then you can take it out. You cannot suddenly here take it out this valve then it is a current is zero and also it is not possible that simply just put it here short circuit and then it will be taking out. Still it is very difficult because there will be huge transients and huge problem will be there.

So, either we use here bypass valve or we use bypass switch. Switch means here simply here the opening are closed. In that case you cannot open and close if the current is flowing. So, what we have to do we have to create some voltage across this is zero then only you can close. Otherwise huge here sparking will be there. You know it is just like a circuit breaker. Here if the voltage is there in between these two connecting huge spark because the gradient will be there potential and this air will be ionization there will be spark will directly damage it.

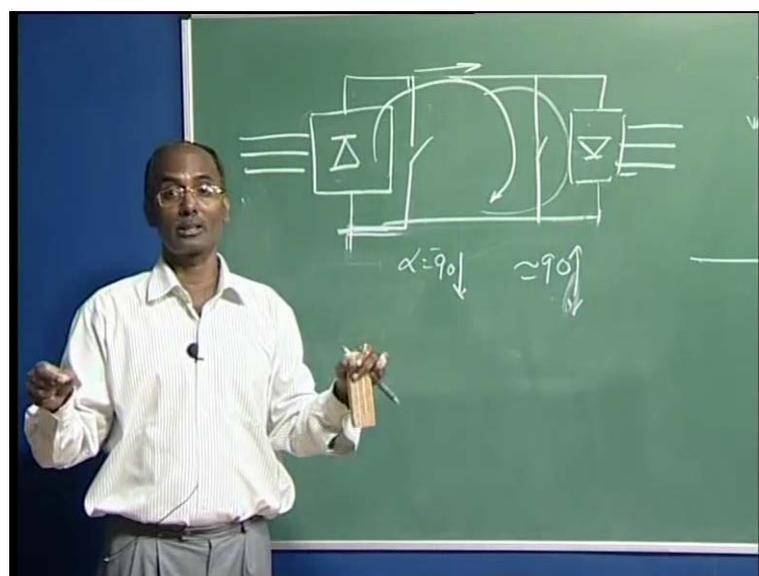
So, what in that case we do here already we use one pair of valve as the bypass valves. Because, here we are having you can say this is one and this is your four. If both are conducting here the voltage across this become zero. And, once this is there this current is flowing at that time you can close it here and then you can open here and the current will be flowing without any problem.

So, we use either bypass valves or we use bypass switches if you are using this concept then those switches are used, if you are using this valves then valves are also used. But, this will increase the extra cost, because you are maintaining (()) are more expensive than a switch. Because in this case also you may require switches. So, here the open the bypass switch at one terminal, means this is a switch because earlier it was open means now you have to open it, now it is ready to conduct a current.

So, de block the terminal means terminal was blocked. Now you have to give block means just there is no firing pulse all the gate pulses are blocked. Now you start giving the gate pulses to the valves. So, de block the terminal and load to the minimum current in the rectifier mode. Now, you have to use here suppose you are using this one. So, you have to operate this as a rectifier this is switch is close step we are not opening this one. This is still there and then that current you have to flow here.

So, one which is you are just de blocking you operate this as a rectifier or if you are using this you are use this as a rectifier. So, if you are taking this as a first one let us see.

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So, what we did we open this, this was already closed and we are taking here only the monopolar operation for simplicity. Now, you are just de blocking this means you start giving the pulses. Now it will be conducting the pattern again it will follow as a 6112 this pattern always symmetry will be there.

So, we are generating some voltage small voltage here and the current will start flowing here. So, this current is very minimum current. So, what we do now? This switch we have to open and the same time we have to de block first de block and then open the switch this current will start flowing here. Now, bypass the second terminal and the commutate the current by the bypass pair, then start the second terminal also in the rectifier mode means another one is also in the rectifier mode means here the voltage here is just opposing in the additive here because you are connecting in this way.

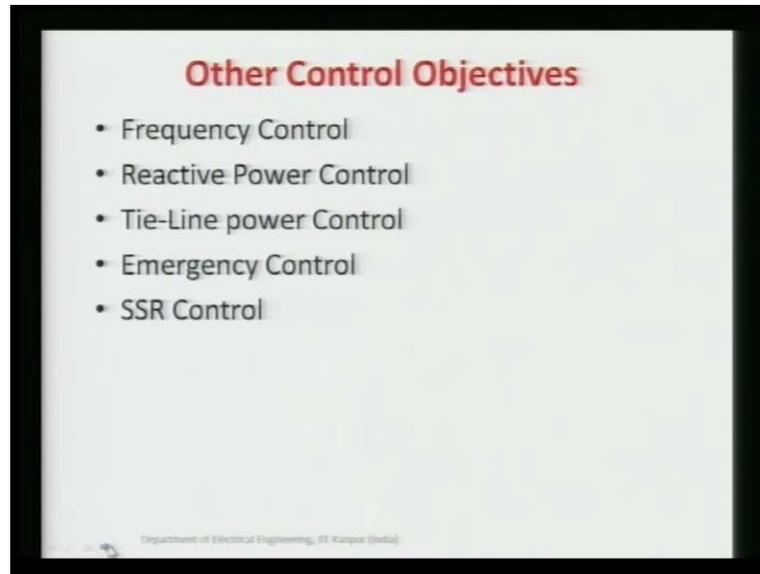
So, this is also additive. So, the current will be flowing even though for a small voltage. Rectifier mode the inverter terminal is now put in to the inverter. Now, you have to change your angle in such a way if it is a you know in beginning both are operating as a rectifier, because we do not want to use an inverter in the beginning because the short gate pulse there is a commutation problem.

So, to start with you have to flow the current and both should operate as a rectifier it is possible. Because the voltage mismatch will be there and the current will be flowing here. Then, you have to change the firing angle this angle this is let us suppose you are operating here is 90 approximately here also approximately 90. Now, this angle alpha should increase means the beta should reduce and this should reduce here and this rectifier this is inverter and this is basically the procedure and finally, it will be taking complete current and the voltage.

So, once you have started this is rectifier (()) inverter, now we have to increase the voltage and then you can just load this link into your HVDC. Normally what happens here while the raising the power increase is not beyond the 2 to 10 per unit per second this is possible that suddenly you can just here from ninety you can go for zero, it is not possible because if you are doing this huge current and even the smoothing reactors are there huge voltage drop across the line will be there dI/dt now it is through the inductor will be there and that is very dangerous for the HVDC link.

So, it is advisable that you should operate 2 to 10 per unit power rate of change basically is not power rate of change per second.

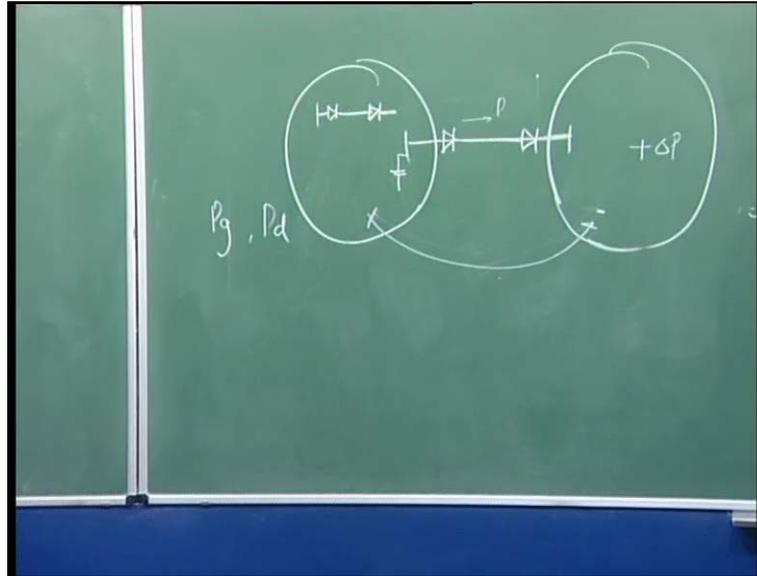
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So, already I discussed this one. Now, other control objectives of this whole HVDC link that we can control the frequency up to limited extent. We can control the reactive power again up to limited extent, we can control the tie line power with the full power it is up to you. You can control you can use this HVDC link for emergency control as well and we can also use for the sub synchronous resonance control. To control the frequency here we know that the system frequency if it is a c system the frequency is a directly related with your load generation balanced.

If your generation is more load is less frequency will rise, if your generation is less and load is more, then frequency will fall, because it will utilize your rotating energy that is a kinetic energy in the system. But, it is also possible if the two areas are there and they are connected with the HVDC link. So, you can feed from one area power to another area power to change the frequency of that area as we can utilize this controller. But, if it is a complete in the integrated system means then it is not possible.

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So, the frequency control is only possible if the two ac system this is a ac system. Here we are having another ac system or you can say area and now it is connected with here HVDC link. Then you can control the frequency of any area by here power flowing in this area are taken from this area. But, if you are having here ac line and you are having the dc here in between somewhere, you cannot do the frequency control at all. Because that is then always it is your this generators and your demand will set your frequency. So, with this if you are having the here some connection then you can inject more power into system or you can withdraw more power means basically what you are doing? You are this bus is just like a generation or load bus.

And therefore, you can control the frequency of either this area or this area. So, only it is possible especially like we are having back to back connection then we can flow more. But even though let us suppose we are having a dc here dc link and you are having another ac link here. In this case also your ac line this there. So, if you are controlling the power here in this you will go back here to maintain the frequency of the system. So, that is why here the frequency control I am saying with the help of HVDC link is the limited application. It is only true if the two different systems are connected by the dc, if this is also dc it is possible. But, if it is connected in ac system inside your dc is built you cannot control the system frequency at all, because frequency is related with your generational power.

So, this is your frequency control. Now, another I can discuss here your reactive power control. Reactive power control is also basically in this fashion you know the converters are consuming reactive power. Both inverter as well as the rectifier they require huge reactive power and here we are having some capacitor banks and other things. In the reactive power control I mean to say that, here with the help of firing angle, if let us suppose the voltage of the bus is going to very high, you can fire this α is a very large value reactive power requirement of this converter is going to be more. So, it can consume more reactive power from here. But, it is not advisable, we never do unless until really you are in the emergency.

Because, if you are changing this α then here also γ should be changed accordingly to maintain the power here. And then it will be absorbing the reactive power from the system more and more. So, you can do this reactive power control up to the limited extent and especially in the really critical conditions when your system may be, let us suppose voltage stability conditions and other things arising then you can utilize, but, still normal practice we never do the reactive power control with the HVDC link.

So, next control possible is the tie line power control. That is a very simple and really it is useful. Especially we do when we are taking about the back to back control. Basically this is nothing, but the two areas here again we are having the HVDC link here it may be the long distance transmission HVDC line or it may be short distance that is a back to back connection means, they are both converter inverter stations are very near to each other and only our intention is to control power from one region to another region or from here to here then it is possible.

So, you can say the tie line power here we can control from this from one area to another area. And here even though you can say the tie line power control I want to say there is a possibility this area is having the deficit or you have a surplus of power. But, if you are setting the power here reference here your P it will be still injecting the power there. Means you can even though force it.

Here let us suppose it has the this P is higher in this zone and this is also injecting this means frequency of this system will go up. So, it depends normally based on this here this area and this area agreement if the power is now is the more here then that can be coming this side or this side. So, we can control very effectively this your tie line power

in the two area even though this area is connected by a c line some other point, but, still we want to control somewhere here as well.

Because, this power this line may be very big sometimes or very small voltage connection here we will require long distance power as well. So, the tie-line power control no doubt this in HVDC is one of the major objectives that is if you are having back to back connection means it is one area another area they are controlling to each other. Tie line means the two areas are connected. So, the two area here I can say and especially it is a back to back connection.

Now, another is your emergency control. Emergency control basically what happens sometime here this is the shift for the certain power even though inside is not only the area. It is let us suppose inside you are having this HVDC control your system some of the lines are tripping and this is set at certain power let us suppose even though 1500 let us suppose it is rating is there. There is a possibility that we can load this line even the more than this 1500 for few minutes. Because, if a line is some line is let us suppose tripped what happens one line tripping make if your cascade tripping due to the over loading of other lines. Because, this power is not going to change even though tripping of any other lines here, because here this is a operating as a constant power mode.

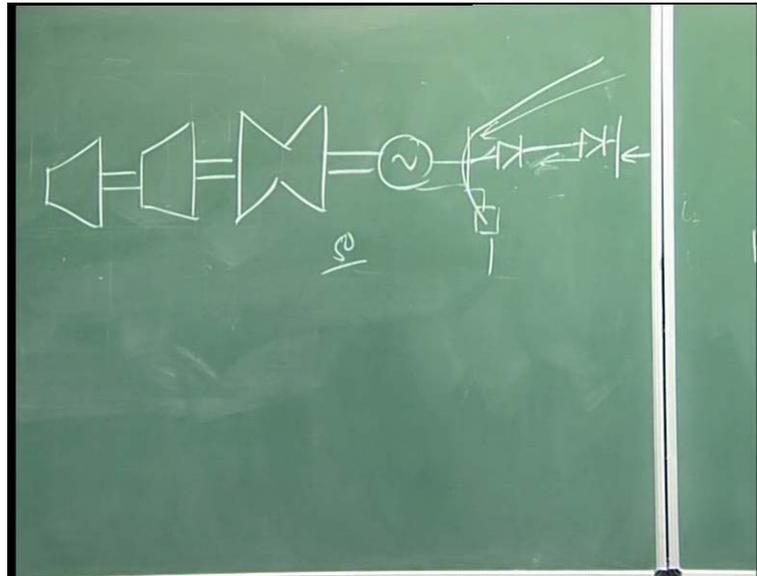
So, this will be flowing as it is. But, if there is a some lines are going to overload momentarily we can increase this power for few minutes and then we can just synchronize or we can reduce our power levels generation and load balance in a such a way that our no line should be overloaded even the outage of your lines. So, in the emergency we can operate if this now at time this 1500 setting is no more required, we want to maintain the stability of the grid first and then therefore, we can do it here.

And this is very very useful especially in the emergency conditions. It is really working very effectively. So, the emergency control means the control which is it is used for some other purpose. It was used to flow huge amount of power from here or here to here. But, during the disturbance abnormal conditions the objective is changed to stabilize both of the system or the same system because we can elevate the overloading or operating conditions in the normal limit.

So, that is your emergency control another here is your S S R control it can do S S R again I was explaining even though on the in the previous lecture, that this phenomena

normally happens when you are having this your power plant thermal power plants you are having the huge turbines like your high pressure, intermediate pressure of low pressure turbines and then your generator is connected then you are having so many critical frequencies.

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So, in this case let us suppose your this is your turbine high pressure turbine that is connected with you i p and then we are having l p, that is low pressure turbine and then we are having your synchronous generator and now here we are having some HVDC link.

What happens if you are putting this one here, this may if your frequency which was entering here from another area, it will not go inside. Because due to the d c. Here means of course, you are having this is a inverter here, means if it is a entering some frequency which is in the system it will block here. So, it will even though control sometimes that it will not go inside to the generator winding that current harmonics and therefore, there will be no S S R problem.

You know S S R problem is a sub-synchronous it is called means sub-synchronous is your 50 hertz means that frequency is less than 50 hertz. But, I am sure you people have not heard the super synchronous resonance. Because, they are designed in such a way here the frequency of the critical frequency always less than 50 hertz. So, even though

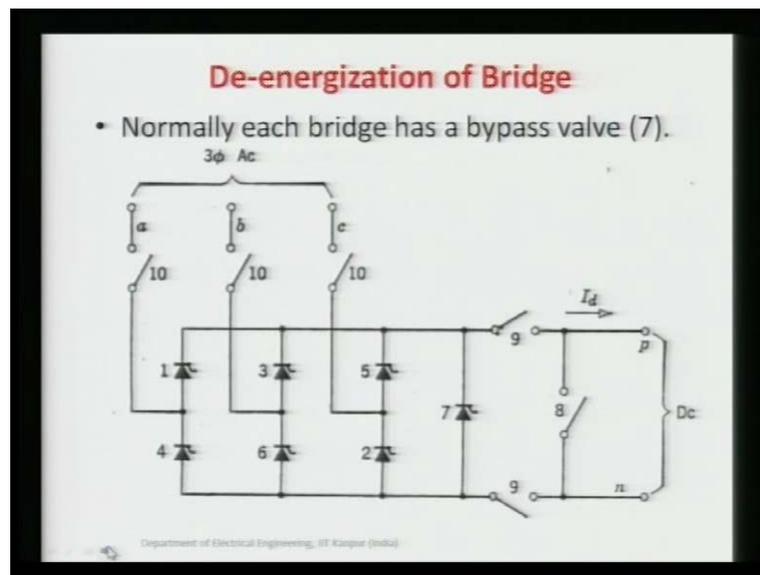
you are having the higher frequencies here, if those are entering here that will be not having the any this troctional oscillation concept.

So, that is we never bother about super synchronous. Means if frequency is more than 50 hertz that is a multiple of frequency intra harmonics and your integer harmonics. So, that will not affect that term. Because if less than this will be entering here then we make these critical frequency may synchronize and may be matches and then huge troctional oscillation or troctional torque will be developed and this (()) may be broken.

So, this can also do if it is used in this way in several specific purpose. It is not necessary that we can use like this. Because we may have some a c lines also, so here this may enter in this way or if you are having the a c line and the d c line and then you are having some filters here for those then it may go down it may not enter here.

So, that possibility is there. So, if your filters are here that may go down here due to the HVDC link. But, it is not always because we are using the filters here only for the characteristic harmonics. So, this 50 hertz less than that we are not bothering at all, so it will go inside. So, this is your S S R control that it can do up to certain extent if it is properly designed.

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Now, the major question here that suppose you want to take out the bridge or you are putting in the surveys and it is very common phenomena if your some of the valve is

damaged that should be taken away and then you have to repair it. It is not possible that inside you can do it properly if it is energized. Means taking away means you can bypass this or then you can do whatever you want to do here. Maybe there is a failure of the cooling's of this tharisters or g d o(s), then you have to repair. So, in all the maintenance purposes excreta you have to isolate your bridge and then you have to take care.

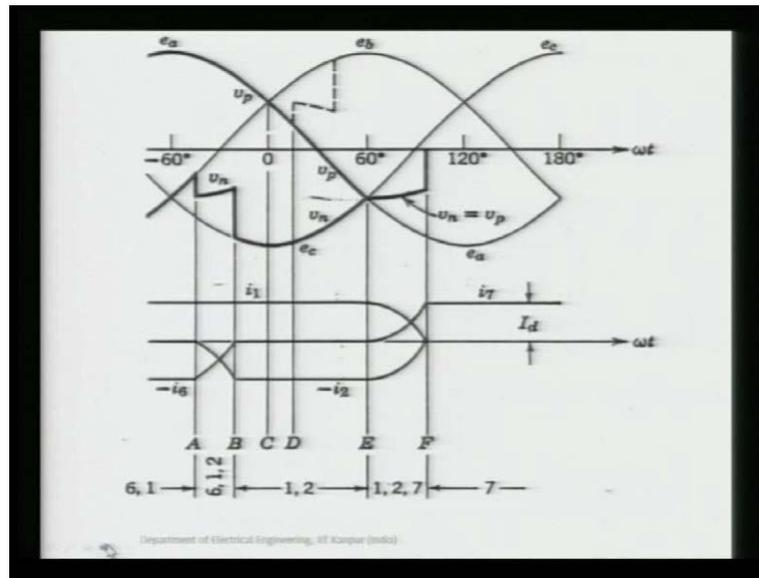
As I said it is not so easily that you can open the switch and take it out and close this switch current will be flowing here. Because it will introduce choose harmonics both a c side and the d c side and it may choose damage your even though bridge circuit as well.

So, we adopt very procedural procedure way here as I explained there is a possibility that we can have here a valve, that is called the bypass valve. And or we can have only the here switches, then we have to use one of the here circuit used as a bypass. You can see this is a conduction means is a short circuit. So, if you are conducting anyhow 2 and 5 together then it will be short circuit the same purpose. Similarly, is there so, either you are using this here bypass valve or you can use the pair of here the valve in the same leg. So, both options are there only in that case what happens you have to wait a larger time here if you are using this one. Because you do not know when you are going to decide it.

So, let us suppose you are operating at let us suppose your 3 and 2 and 3 are operating and you want to make this as a or this bridge as a bypass pair. So, then 2 3 then 3 four 4 5 6 1 then 1 is coming here then you can then wait for 3 then go for 2 then 3 then 4 will be coming then it will be short circuit. Means it will require sometime maybe from 120 degree to 180 degree, means what is the instant work decision it depends upon you can also choose this pair you can also choose this pair.

So, first we will see if you are having a bypass valve. How it is going to be operated so that the current here which was flowing here earlier through these valves either this or another will be here means one from top one from below and then we are having this I d current here.

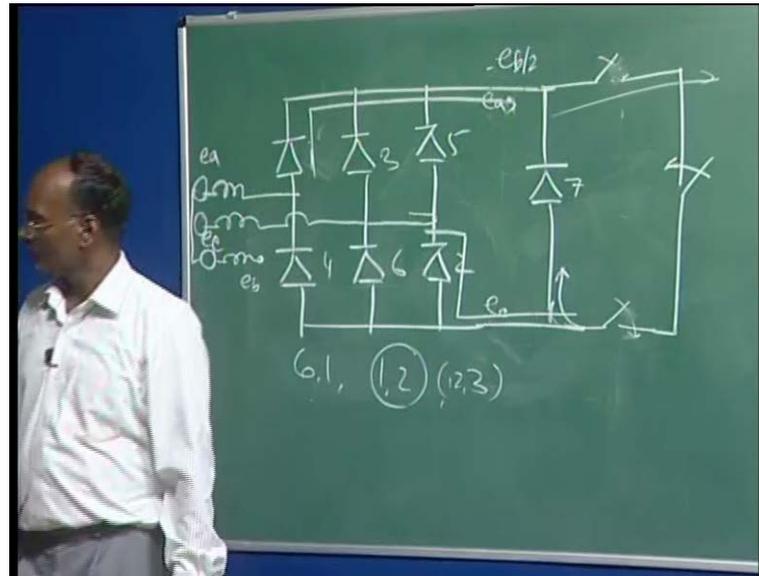
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To see this, now let us see the rectifier circuit. And I am taking the same configuration six pulse bridge converter here I say that the 6 1 is conducting the pair of valves 6 1 from here. Now then 2 is given fired and now it is a conducting here. You can see this is the rectifier we are talking. Now, this is 2 is fired here, now the possibility that is here we can give the command to 3 at this point.

You see it here 6 1 2 is the commutation is between your 6 and 2 is taking place. Because here we are giving the firing pulse 2, here we can give because you can see the voltage is going to be positive. Now, this 6 1 2 due to the u period and now here this is a conducting your portion this e this. Now, 1 2 is let us suppose it is conducting now we have decided to bypass it means you want to take.

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So, what happens we have to give the fire impulse to 7. Means this is your to understand this, **this** is your 6 pulse bridge converter. Here we are using this valve and this is your I d, this is your 7 this 1 4 3 5 6 2. Now, once your 1 and 2 are conducting what will be the voltage here. 1 it is e a, 2 it is e c. Voltage across this should be positive to get it fired. Means voltage we require here e c a should be positive, if it is negative it will not conduct.

Now you can see what happens. Here 1 and 2 are conducting you can see what is the voltage? This is your C this is here it is negative. Because is C E A this minus this is still negative. So, if even though you are giving the pulse here it will not conduct. So, what you have to do you have to wait. Now, you can see after this now this was the d point was the point where 3 was given a pulse in our sequence it was your 6 1 then 1 2 now it is conducting, now 3 is going to come.

So, what we will do we will block this pulse. We will do not want that this should conduct. If this conducting here again, this voltage across this will be negative. So, what will happen here at this point the d was coming means your valve 3 was coming we stop the block get pulse of this one. Then, this 1 and 2 is continue to conduct.

Now, you can see at the point here when e c and e a is going to be this means at this point e c e c a is zero, now it is going to be positive this point onwards. So, we waited till here now seven we give the pulse and once we are giving the pulse it will conduct. Now,

before that the current was flowing here and it was going like this. Through this winding it was going means here it was your this, this is not conducting here and your voltages were there. This is e_a here is e_c and this was here e_b . Now, what is happening? This current which was flowing here now there is going to be a commutation between 1 and 7, 2 and 7. Because, this current is now is basically in fact, we are having the commutation between 2 and 7.

Because the current which was flowing here I_d is now earlier it was flowing here, now it is going to be shifted here. And it will take some period some time when it will be basically the complete transfer of the current from here to here it will take place and this current will become this side it will be zero. You can see here this is i_1 here when we are giving the pulse this i_1 is going to decrease, i_2 here zero here this is i_2 is also going to decrease and your this current i_7 which we get the pulse it is going to take care and it is going to be I_d . Once it is there I_d is taking full current, now what happens this is a short circuit. This is the short circuit here means this current is complete taken now you can open this one without any problem you can take it out this one.

Now, here there is no switch. So, what we do we put the switch here. This is your switch, this is the switch here we are having a switch here. So, what happens earlier? It was closed and the current was flowing now here. Now, this voltage is zero. Now, we can connect this **this** is a both are short circuit now you can open here the current will be totally diverted because the voltage across this is zero. So, you can open this now and you can take it complete base together means even including this.

You can see here how the voltage is going to change during this period that there is a some voltage the positive side here this and this going is to be same. Because the voltage across is zero. What is happening? This c and this e_a is going to be zero. This voltage here as here means this voltage is nothing but, the addition of these two voltage it is your e_b by 2 minus. We already proved here this voltage e_a plus e_c by 2 will be minus e_b by 2. You can see this is here e_b by 2 minus and this will be the same this will be the same and that is why the output voltage is zero.

So, you can say output voltage it was following here it is continuing here it was coming all the way here. Once whenever you are giving this here it is following this e_b by 2 till the commutation is finished and it will be zero.

And then finally, it is going to be this. Because once this current is zero here this voltage will be zero and this is the circuit. So, basically on the next turn next lecture we will see how this current is going to change from here and there, and then we will see how it is a different in the inverter circuit once we are using the bypass power. Then we will see if you are going to take this pair how we are going to take out again using if you are not having this bypass valve, we are having this only switches, we are using one pair how one what will be the sequence and when we can take it out in this one.

So, this is basically the de energization, then we will talk about the energization reverse process we have to put in again into the service after repair then how what will be the sequence and the procedure will be formed? So, with this I can stop it here and in the next lecture we will see the complete again the derivation of the current commutation here and also the inverter de energization then we will see the energization then this control aspect will be the (()) thank you.