High Voltage DC Transmission

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Module No. # 03

Lecture No. # 05

HVDC Link Control Characteristics

Welcome to this last lecture of this module 3, that is lecture number 5 and today I will discussed about the energization and the de-energization of the bridges. Here, as I said the bridge means if you are having more than one bridge in any of the HVDC converter station, then you can take one out for it is repair or maintenance work. If it is a only one bridge is there, so you cannot take it out then, you have to shut down complete HVDC link and then you can take it out and you can repair and then you can again put it. So, that procedure will be similar to the start up and start down of the HVDC link completely.

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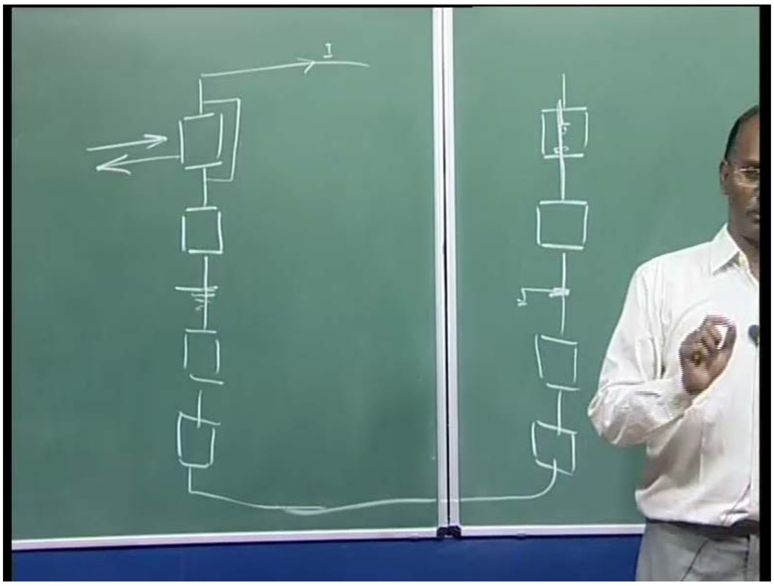

Here, I am talking if you are having let suppose this is one bridge here in one bridge in the one pole here, then one you can take it out and then for that, you know we have to sort this bridge, so that current can bypassed and this is the procedure which I am talking here, the de-energization of this bridge means we are de-energizing this, because we are bypassing here the current completely, and then we can reduce the voltage and we can take it out.

Energization means, I want to once it was there and now, I want to put this bridge inside for the operation then again, we have to shift the current from this bypass valve whatever you on and then, the current could be taken here and you have to open the switch, so that is called energization of this. So here, I am talking the energization of bridge, if you are having more than one converter bridge in a pole. Pole means here, I can say it is monopolar so this will be ground will be return, so it is a two base configuration. If you are having bipolar, then you will have the two here let suppose and then, you are any of this you can take it out.

Only problem that is if you are having for example, if you are taking this out what happens? The voltage across this is going to reduce obvious, because the voltage this is giving 0 voltages only you have sustaining this voltage across this pole. Now, you have to be very careful, the current which was flowing if it is a constant, so this bridge, this pole is giving the different power than this bridge. Similarly, you can see if it is a rectifier and another end is inverter; so inverter end here you are having, let suppose you are having two again, this is if it is a bipolar then you are having here and then, it is here connected. If you are just taking out this what happens? The voltage across this is different than the voltage across this and it is not at wise whole to take this bridge out again without any problem in this bridge.

So what we do? We change because you are maintaining the current because this current will be the same again, voltage here since it is reduced and it is basically, if you are ideally said is half. So, this side what we can do? We can operate these bridges in reduced voltage mode and then, we can maintain the current. So, this side the polarity voltage will be approximately equal to this subjected to the drop in this line, but once again if you are operating these bridges on the lower voltage output what will happen? The active power requirement will go high.

So, again you have to see if you are having the enough support then, you can operate in that mode reduced voltage or again you can bypass this bridge, still no problem you can bypass and only operate one bridge even though there is no need of repairing, but you can bypass and you can keep it for ideal. So, another option that no need to here, we can have the sort one of the leak completely, for example, if you are having one and four here; you can conduct here and the current is coming like this. So, this is giving zero voltage.

So, the various of possibilities are there, but the voltage here should be approximately voltage here, otherwise there will be huge current will flowing in balance because this voltage, this voltage will be you know ground there. If the voltage is not maintaining this, there will be some ground current as well, so this is maintain and normally we do. So here, energization means you are just putting this bridge into the operation and the de-energization means, you are taking this bridge out if you are having more than one bridge then it is possible. In the normal, if you are having only one as I said then, it is a similar you have to shut down your HVDC link and then, you have to go for the repair one. Similarly, if you want to put it for the single bridge operation in HVDC link then, you have to start up and then, you can make it operational already I have discussed with this.

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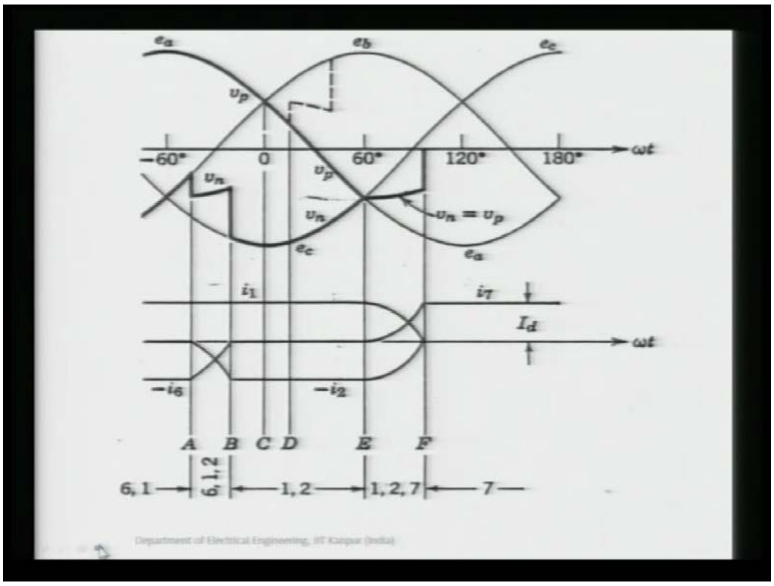

Now, in this first I am going to talk about the de-energization; in the de-energization I said there are two possibilities that either we are having a bypass valve or we can use a pair of valve in the same name and we can make it short circuit.

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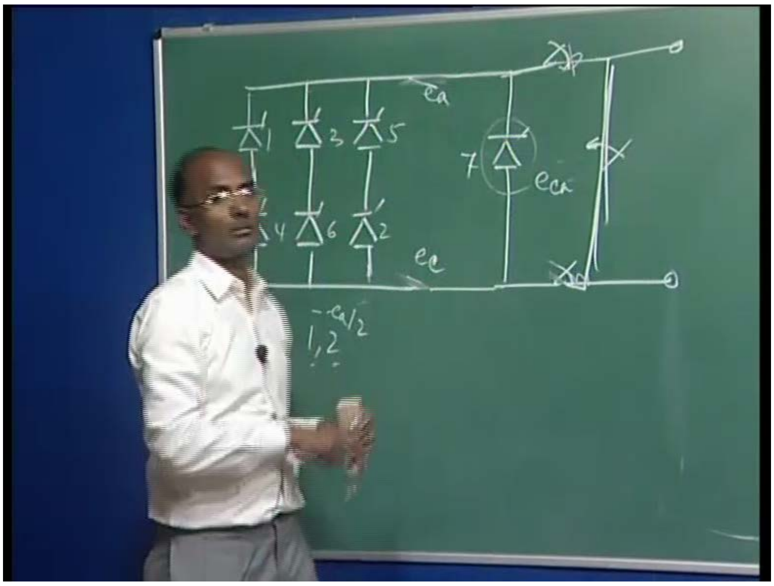

For example here, if this is your 6 pulse converter; this is a all the 6 valves here and we can have a here one option that we can have one bypass, this is called bypass valve. Here is 1 3 5 4 6 2 and this is treated as 7. So, all these are basically the rectifier or g t 0 is switches control switches, I can say.

So, this is your current which was going; this is a portion here so one option that this was operation and this was off; most of the time this is off, only this is used or in conducting when we have to bypass this. Now, one as I said one option that we can use this or even though, there is no need to this use of this. We can use here to in the same leg and this is just like a short circuit; here as a short circuit.

In the early days, when we were using the mercury arc valves, this option was preferable because the arc extension was a very big problem here in this mercury valves. So, that time you were using this, but now it is putting an extra thyristor; extra here elements that will increase the cost. So, already these are there so you can have any here, upper and lower in the same leg; you can conduct it and this will be just working as here, this one so you can reduce. Nowadays, basically it is used in this fashion.

Now, so in this figure here which is shown; now I want to discuss, it is the case when we want to take it out, this bridge means we have to conduct here and this shows that again the conduction pattern is similar. It is you can see here, your valve 6 and 1 are conducting here and the voltage will be as usual 6, 1 means this is e a here the positive side; your negative side it is your 6.

So it is e b; so it is you can see this is your e b. So, it is e b in the lower voltage and this is on top, it is e a was conducting. Now, we gave a pulse to 2 here and there will be commutation take place here between 6 and 2, this will conduct now, after some here the voltage will be again, now this negative voltage will be something different because here it is b and here, it will be minus e a by 2 and you can see this is e a, half of this is I can explain basically with the pen. So, this was basically here, this was half and this is your e a by 2 minus. So, in this commutation period this v n means negative side I say this is a positive side; this is a p; this is your n and then, it is during commutation it is happening.

Now, it was decided, once one and two given the firing pulse two; now, it is decided we want to take it out this bridge means decision can be anywhere, if you join the 6 1 was conducting here and now, I want to take decision then we have to not give the pulse to 2 and we will see whether the voltage across the 7 is positive or not. So, in this figure it is decided now, we are going to give think after the point b. So, this is the similar for in what are the previous valves we are conducting and then, you are thinking means here yours 1 and 2 valves are conducting.

Now, I am deciding I have to bypass this valve bridge; now what will you do? Now, 1 and 2 are conducting the voltage here will be nothing, but your e a c means the voltage across this will only conduct if here it is your e c a will be positive because here the voltage is your e a; here it is your e c. We want e c minus e a that if it is a positive in the case, then you can give the pulse here and it will conduct without any problem. In that case, what will happen? The current from 2 will be shifted to valve 7 and the commutation between 2 and 7 will occur and also, the current from here to here will take place because the current Id was flowing here, now it is taken by here. So, this valve basically is a commutation between 1 and 2 and 1 and 7 and 2 and 7 it is happening.

Now, once at this point we decided that we should this you can say simply block this bridge, I want to bypass this bridge then, we have to watch the voltage e c a should be positive. You can see at this moment, here this is your e c; this is e a is more e c then, e a it is negative just do some subtraction here, it will be negative something coming here. Only at the point, now what happens here? Now you can say; now this is a turn at the point D, the three valves should be given the pulse because we know here, our 6 1 then 1 2 means all they are just getting the pulses, the valves are getting pulses after every 60 degree.

So, this was the case when the d at the point D, it was expected if you are not going to de-energize this base, you have to give the pulse here three and there will be commutation here. So, what we have to do? We have to block this gate pulse of this three, so that it should not conduct means your one and two are continuously conducting. Now, you can see move here, you will find here at this point is a voltage is going to be 0 e c a is going to be 0 and here, it is going to be positive because a is more negative than c.

So, here from this is equal negative; so it will be 0 here and the draw the voltage you will be going (No audio from 11:52 to 12:00) it will conduct ideally, if you are 1 or 2 degrees there so the practically, but ideally if you are giving here pulse it will conduct. So, what will happen if it is going to conduct here now, what will be the voltage? What will be this voltage and this voltage? No doubt, the voltage difference here and here it will be 0 because is a conducting, but if we will ideally say because there is some currents are flowing through this inductor as well, there is some voltage here and here as well. So, the voltage no doubt here and here the difference will be 0, but some voltage here and here it will be appearing till we are not firing, it is completely 0 because the current is coming here means, e a is coming here all the way.

So, what happens? Here once you are giving the pulse to 7, the voltage here is coming your e b by 2, this is your negative side and this is also positive side. So, difference is 0 and once the commutation is over then, it is here it is going to be 0 because this no current is flowing; no voltage is injected here.

Now, so in this period where the commutation is taking place between 2 to 7 and 1 to 7 means current here is completely gone from this side. So, that is why here is the current; here i 1 is coming; here all the way and then, it is going to decrease and your i 7 is taking care here and here also, i 2 is going to be 0 and finally, commutation is over and the current is maintain through this and the voltage become 0 here completely, you can see the voltage here is 0.

So, this is basically a rectifier side now, I want to show you that how this current increases and how this is a current is decreasing and the i 7 is taking complete current. If i 7 is not taking complete current and it is going back then again, this valve will be disconducting and this will continue to conduct. We want the complete transfer of the current from this side to here and then only we can take it out and to taking it out, we are having no doubt the switches here and then we can open and then we can take it out.

Basically, the switches are not here; switches are here; basically here, here and we are having another switch here; what happens if it is a conducting now completely? So, this basically in the beginning it is closed; this is open. In the normal operation here, this is your basically the complete rectifier circuit; this is the your bypass valve, so the current was coming here; earlier here; now after the commutation it is going here and it is going all the way here, because this switch is open. Now once it is conducting, this voltage is 0, so here this switch is will also experience the voltage 0 and then you can close it here.

And once you are closing here, just you can just block this; you can just commutate it off current will be completely taken here without any problem and once the current is taking place here completely, then you can open these switches as well and then, you can completely take it out and then current will be bypassed.

So, this is basically the de-energization of the bridge. Now, I am going to derive that how this current is going to be taken care by valve 7 during this commutation period between 2 and 7.

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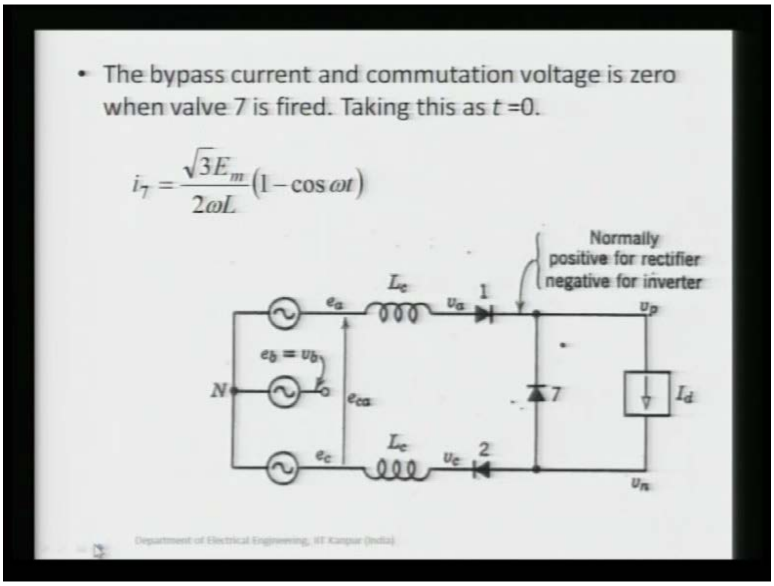

To derive this, you just see this circuit what is happening? As I said 1 and 2 are conducting and at this when e c a is going to be positive, we are giving the pulse to this. Now, I am just writing the equation for this; now before that here I said the voltage will be e b I said this voltage here this is nothing, but half e b; this is minus e b by 2. You can also see from this figure, this is just reverse here and half of the magnitude, this is completely its half.

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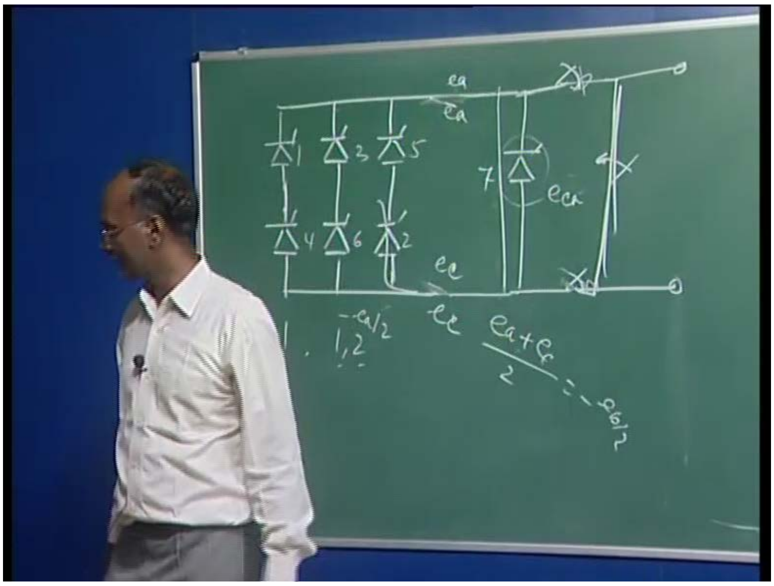

So, this is e b by 2 the reason here, this here is e c; here it is your e a and it is sorted. So, the voltage here and here means voltage at this point will be your e a plus e c by 2 and that is equal to minus e b by 2 both will be the same polarity that is why it is following this one. Once commutation is over there is no current because this is only coming due to the inductor part here, and the voltage source. If the current will be off here, this voltage will be 0 at all because we are not injecting any voltage in the circuit and this will be 0 and that is why, you can say one commutation is over suddenly, the voltage is going to be 0 both this polarity as well as this polarity.

But once it is conducting as you can see this p n will be the same potential because it is a conducting, so there will be difference will be the 0 voltage. Now, so that is why it was e b by 2; now to derive the current that is taken care by the valve 7, we again we can derive the circuit here this voltage will be equal to this voltage, once it is going to conduct. At the time once it is conducting, here you know this is just a parallel power this is short circuit.

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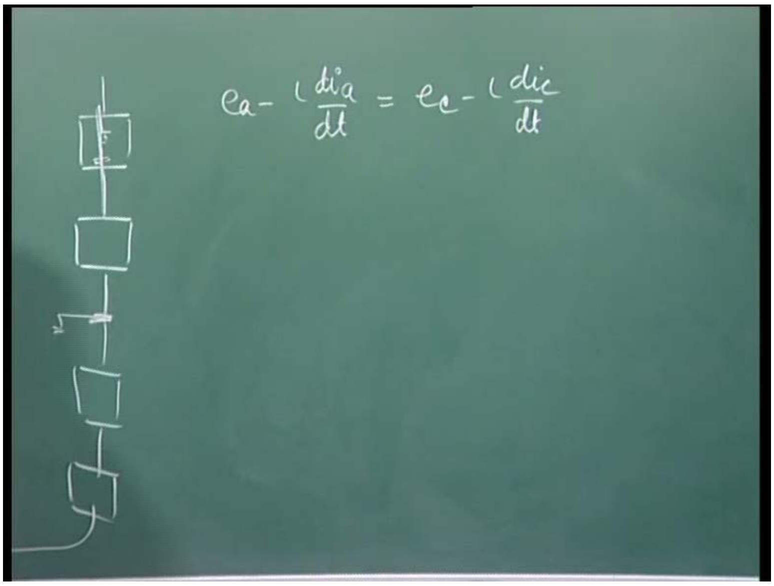

So, we can again write the similar equation as earlier, it is your e a minus l dia by dt here, it is your phase a here draw L c here I have written, you can write L c it is no problem that will be equal to your ec minus l dic by dt.

You remember all the currents we took that it is coming out from here, phase current here coming out; here coming out no doubt, the here current basically going inside, so it is our convention is same and the value will be coming automatically negative. Now, this is I am talking here the current is coming; this is I a c just basically here, now you can see at this point here as well as here, you can apply the Kirchhoff’s law this current whatever is going I 7; here this I 7 will be equal to this minus this what? This is coming we have assume this current direction this.

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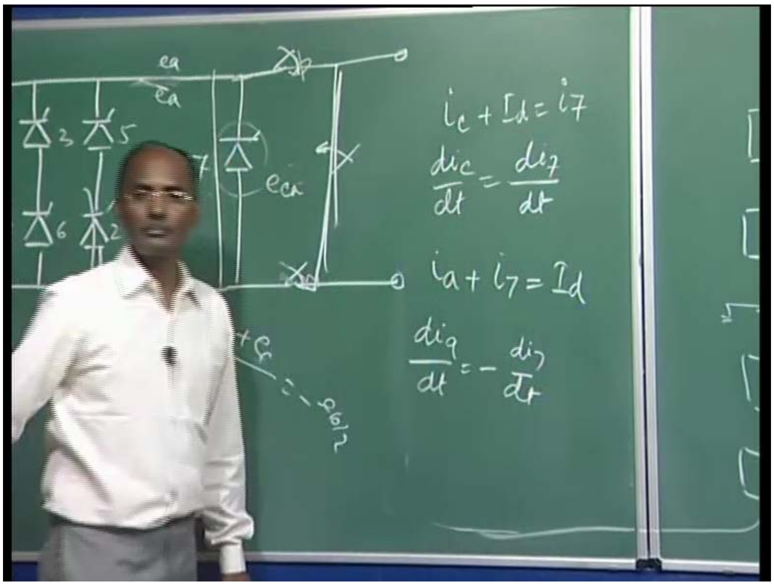

So, this is i c plus I d will be your I 7 means you are here, i c plus I d is equal to your i 7 means if you are differentiating here d i c by d t will be your d i 7 by d t. Here the scenario is different because this current plus this current will be your Id means, your i a plus your i 7 is equal to your I d means I can write d i a by d t will be minus d i 7 by d t because this is a DC current so derivative will be 0.

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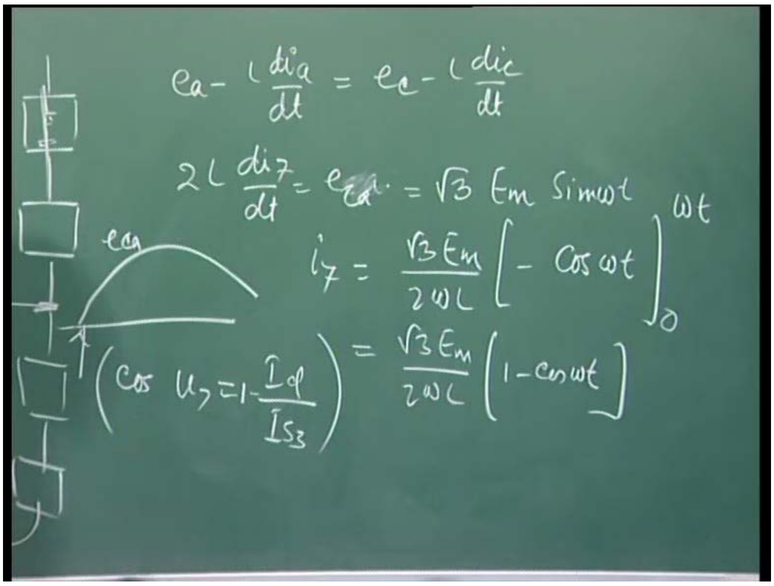

Now, from these two here we can replace this; we are going to have twice L di 7 by dt here e c a and we want a expression in terms of i 7 here, this is a line to line voltage I can write under root 3 E m sin omega t mind it here, I am assuming that it is giving the pulse here, we are taking this is a reference in this case. We are not using alpha and other thing, so we can say this just we are giving at the 0 crossing, this current is going to be here, this is going to conduct. So, I am taking the voltage across this starting the firing angle here it is now, we are firing here at e c a going to be positive, so this is a sinusoidal voltage. Now, here if you will go for the i 7 it is your under root 3 E m twice omega l here, minus you can differentiate this integrate this omega t here 0 because we are giving here the firing pulse and we are writing for your omega t expression and this is nothing, but it is under root 3 E m twice omega L 1 minus COS omega t and that expression is written here.

Now, you can see this magnitude is similar to the magnitude when we derived the 2 3 valve conduction; this magnitude i is three I was talking so that is why, you can see this here the current rise here is a similar to this one. You can see this is a similar to this one means this current is rising; this current is declining because the same current is taking care by this i 7 and once it is completely 0; it is completely I d so this I s 2 current which taking at that time we were talking about the commutation between 3 and 1. So, 3 was rising and 1 was decaying, so the one still it is the same curve and instead here early it was 3 now, it is 7. So, the commutation is taking place and once it is there, so we can get what is the value of this omega t here? That is u 7 I can call, it is again the overlap angle is not this normal overlap angle; it is I can say u 7 when we are just giving the bypass valve.

So, once here during this period you can say here, it is becomes I d, so the omega t you can calculate from here because this is going to be your I d then, that it is nothing, but your u period, this omega t we are starting from 0 to u 7. So, we can write here our cosine of u 7 will be you are I d divided by I s three here and this is coming this side. So, it is 1 minus this. This Id divided by this will be coming this side this will be going that side, so 1 minus Id upon S 3 this will be and that is this period you can calculate that depends upon your the Dc current, that depends upon the voltage at that time E m is involved here and the frequency as well and that is that can be calculated. How much time it will take to commute from 1 to 7 or you can say 2 to 7? And that is why that expression which is written here, already this is i 7 is written now.

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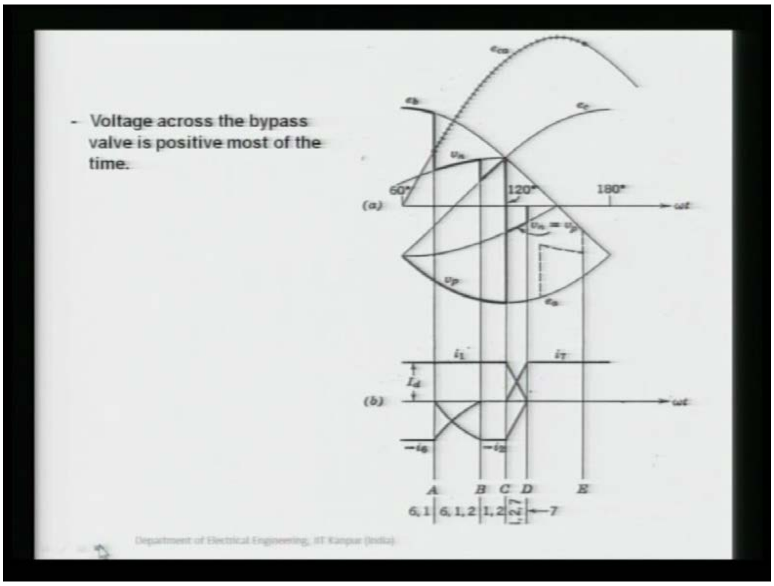

Now, this is very simple in case of rectifier side because this voltage is experiencing negative almost all the time why? Because this voltage is positive; this is negative. So, this valve is experiencing the across this I am talking this minus this is most of the time it is negative, but the reverse is true in the inverter, most of the time this valve is getting the positive already and that is why, here the commutation is very fast and you can commute very quickly without delaying it here.

So, again now let us see here what is happening? In this case also I can say 6 and 1 are conducting then the valve 2 was given a pulse and there was overlap the commutation between 6 and 2 was taking place. Now, here 1 and 2 are conducting, here at this point now 1 and 2 are conducting and I want to the block this bridge means I want to bypass here, it is very well possible you can see at this point what is the voltage? This is the C and this is your e a always positive; this minus this; this is a positive and this is negative.

We are subtracting and the e c a is becoming positive here as well at this point and if you are giving pulse the commutation will takes place, but what normally do? We slightly wait and we wait till the crest of this occurs why? At this point, the voltage across this e c a is the highest. You see this is minus most negative; this is rising, here this after this is also declining this is rising. So, this is you will see it is the peak value here occurring the difference e c a and this time, if you are giving pulse the commutation will be very fast because this will be approximately equal to Id. Because this e m is involved here, so this will be approximately; this u will be 0 means very small value.

No doubt this cannot be very perfect there, so some value will be there and you will be very less that is why, you can see here the 7 is giving pulse and very small duration suddenly, it is going to be commute means current is shifting because the voltage across is most positive. Here, it was rising just even the voltage were very less and it was taking some time because based on this value, if you are giving here it will take less time no doubt, but you are delaying up to this much, so that will be much more time compare to if you are giving here maybe you will be slightly more.

So, this inverter side as it is written, the voltage across the bypass valve is positive most of the time and that is why, you can wherever you can decide here 1 and 2 are there you can give pulse and it will conduct. Same time here, you can see the voltage here is similar 1 and 2 are conducting, you can see this is the overlap period here the v n and there in during this period, again the v n and v p is same; as the previous case this was same during the current is taking place here the commutation, once it is over the voltage become 0 here, you can see coming here and 0. So, this is basically the inverter side when we are taking care.

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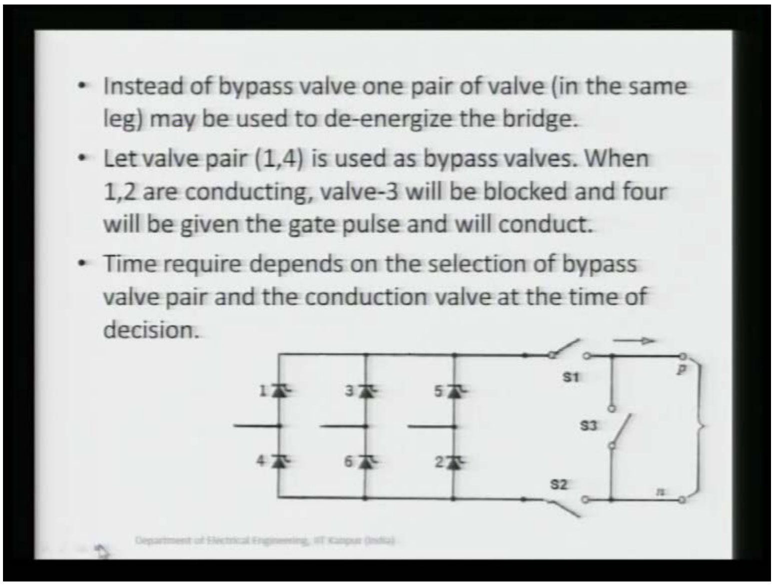

Now, let us see instead of using this bypass valve as I said, it was used in the early days mercury valve arc valves because at that time this to even though change from the current here it was very difficult means taking one a same side because it was not properly conducting. Because due to the arc back another possibility other mal operation of the converter, so this type of arrangement was used, but now since we are having very fast here and the solid state power electronic devices and then we can use one leg instead of having here one bypass valve like this. So in this case, here the instead of a bypass valve one pair of valve in the same leg may be used to de energize the bridge means here, you can sort instead and then, once current is here then the voltage across this is 0 you can close it and once you are closing open this and take it out.

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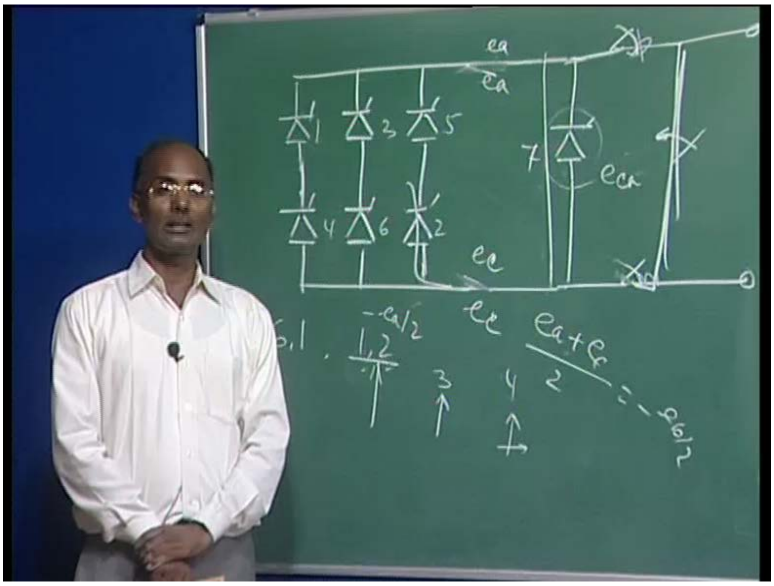

But in this case, making 1 and 4 conducting you have to wait may be longer period why? Because let suppose your case 1 and 2 were conducting and you have decided to bypass this bridge and you want to make 1 and 4 are conducting. Now, what happens after that the chance of 3 will come, then 4 will come because your 1 and 2 were conducting; so now here the 4 will come in that same limb, the time when you have to bypass this then you are coming here, then there will be short circuit and in that case also, even though this you are giving here 1 2 and 4 there is a commutation of the current will take place here, so there is further u degree will be there instead.

In this case, again now your choice is let suppose 3 6 then, you have to wait again several hours, so there is a possibility that you have to wait at least may be 60 degree no it suppose your 2 3 are conducting then it is more. So, 1 and 2 here once conducting and you are deciding the bypass, minimum time is 120 degree; minimum time. Maximum may be again is which is conducting and which one pair you are selecting to bypass it, another problem may occur, this here the blocked and the 4 will be given the gate pulse and it will conduct and then you will have a short circuit.

The time require depends upon the selection of bypass pair and the conduction valves at the time of decision, one problem is that there is a possibility that at this time, if the voltage across the valve 4 is not positive. Especially, this may occurs in the inverter operation, so you we have to see I am not sure we have to check it and if 1 and 2 is are conducting then, we are just blocking this three means you are not giving gate pulse 1 and 2 are conducting and then, we have to come at the 4 and we have to see whether it is the positive or not.

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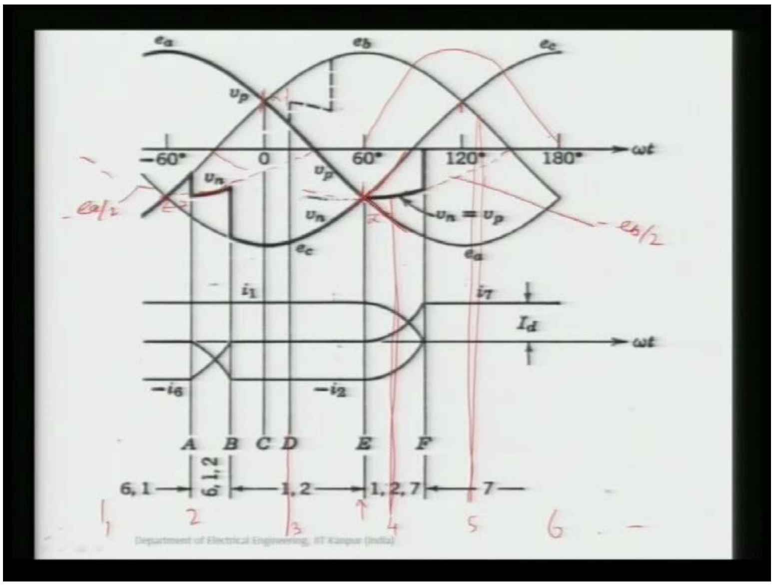

To see this, we can go back to our previous diagram here is a rectifier operation here, this was the basically turn of three here, but we did not give. Now, another turn will come at this point, where this point after just after this 0 crossing here somewhere. It is so no here it will be here; here it is your 4, this is your 3 every 60 degree how to know it? You can see whenever there is a crossing, there is some delay here; this is a delay, there is crossing here; there is delay alpha degree that is the we are delaying here, there is a crossing here, so it will be delayed by alpha degree and then it was turn for the 4.

Here again, it was the at this case it was the 0 here and this was the case of 5; this was a pattern means here, it was your 2 before that it was 1 and on so for. Now, it will be 6 and so on. So, this was the pattern which we were giving the pulse side.

Now let us see, if 3 is bypassed means 3 is not given pulse what will happen? Your 1 and 2 are continuously conducting means we are coming rather than going here in the same graph I am explaining, we are this voltage the lower side, it is going here and this is going here. Now, four commutations here for this what should be the positive voltage this will conduct; now your 2 here this is e c, this 2 is conducting and this is your ea, so e c a should be positive it is similar to your this condition.

And you can see it is positive because before it was positive here, so now it is the 4 here even though we give the seven pulse here, it was positive from here only means you are the voltage e c a is like this. So, it was positive and you will give the gate pulse to 4 it will conduct, so this is the way to analyze here I am just I want to tell you just you have to see the pattern and then, where there is a positive then gate pulse will be there you can just.

So only in this case, here the 3 was blocked and the 4 was given and the voltage across this was positive and it will conduct because you can see it is a see it is more positive than this, so e c a was the commutation voltage here and it is a similar, this 4 is your 7 means same phase same polarity here ac here also, it is ac and now it will conduct.

So, the current from here it will be this commuted and the current will flowing here Id and once it is there, then you can just close this switch and open these two and then you can take it out. Only you have to see in the seven again, in the another side your inverter operation and you have to be see whether it is a possible or not, again the similar pattern you can analyzed.

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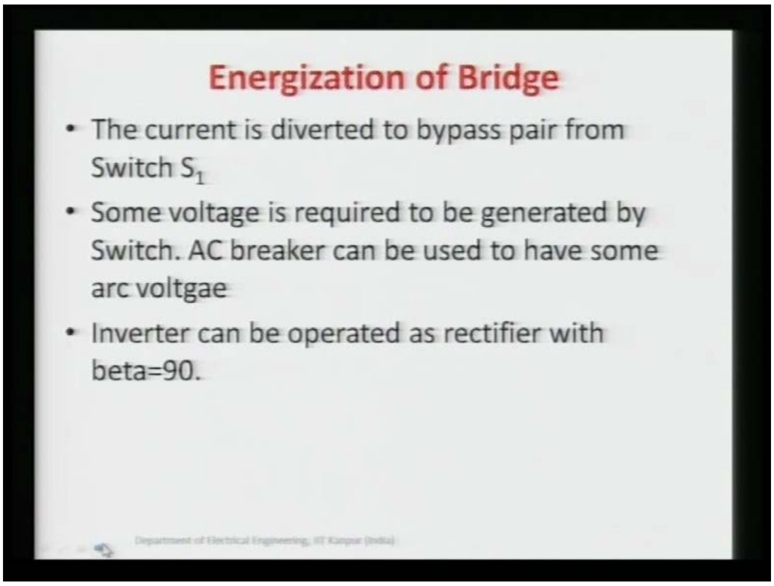

So, this I already discussed now we have to discuss the energization of the bridge how it is going to? So in this case here, in the inverter case as the question arise, that it is the beta it is not alpha and you can see in this case.

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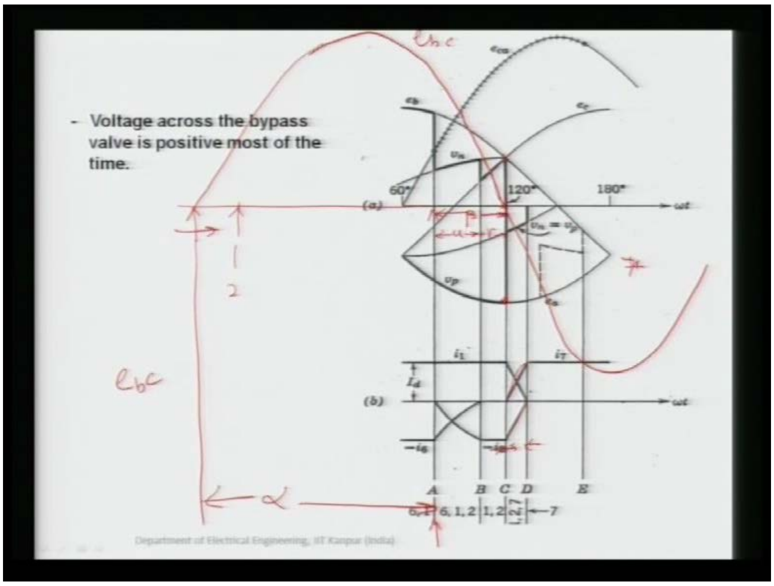

What we are taking this valve 2 which is going to be here fire and the commutation voltage of this is your nothing, but your e b c and the e b c here is 0 means it is going to be like this and this is going to be negative; this is your e b c what happens now? At this point, now your beta is basically this value up to from here in that, this period is your u and this period is normally treated as a gamma.

So, here your beta you can see this is and in rectifier, we are just talking about at this point. The alpha is just we are moving from here alpha and giving firing pulse of two, but in inverter case we are talking here in another side of this e b c that commutation voltage. So, you can see this is your beta, we are talking here or you can say calculate alpha from here then, it is more than 120 degree I pie minus beta here. So, you can see this is your commutation and this will be inverter operation, so now this voltage are showing that is your inverter operation. So, this is now I think clear this is a beta we are talking and giving the firing pulse to these two and subsequent here.

Here, I said why we are going for this? It may be possible that you can again shift somewhere else means your gamma here at this point this is a crossed, so what happens the voltage across the u 7? Here u this the 7 valve is the highest and the commutation will be very fast from your 2 to 7 and that is why, you can see here it is very small angle here, this is that is taking care. So, it is very fast rise almost linear I can say is a small of portion we can linearize it, so this is your inverter operation.

Now, the same facility if you are going for this instead of using this and we are making any of this after 1 and 2 4, we have to see the voltage across this 4 is positive or not and once it is positive you have to give the pulse, it should commutate. Even though here you are delaying some of the time here, it may be the negative because the most of the time the valve voltages here is positive.

So, it is easier when then it will conduct, but only again once you draw you will find the voltage and it will be; it is done basically now it is in modern HVDC link, if you want to bypass it is normally used for same left bridges, because we do not want to incur the extra cost because the bypass is not taking every day, it is if the monthly, may be yearly once there is some problem and also in the beginning I told here it is not only one switch; it is not only thyristor; it is the series of thyristors even though, its voltage also we had some extra thyristor to take care of these eventuality. If we are putting let suppose requirement is ten thyristors to give the required voltage, we are going for the 12 or 13 volt even though one is you can say puncture or some problem still these all bridge will work without any problem.

And whenever you require when load is less or system condition process, then you can take it out because once you are taking it out, you know the voltage is reduced and power carrying capability of the link is going to be reduced by that voltage multiplied by the current rating. So, you are just transmitting less power no doubt about it, so it will be taking the proper time and based on that dismaintenance system.

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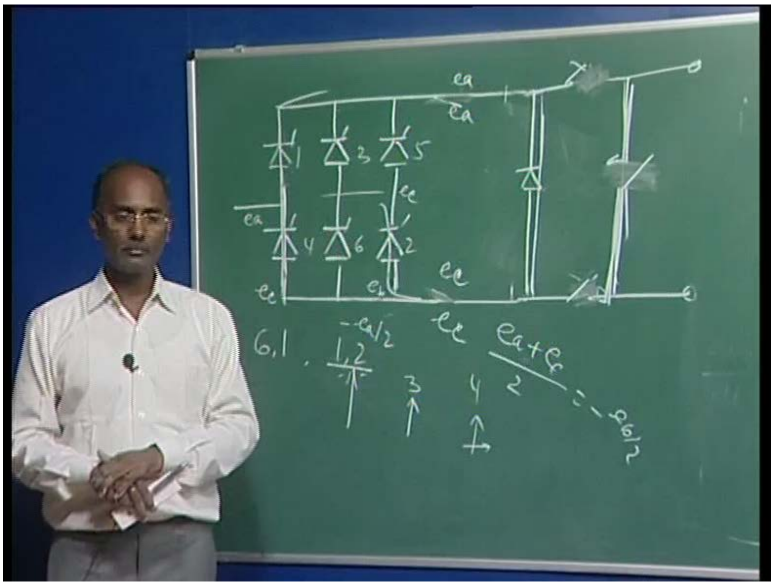

Now to energize this bridge, now the same procedure is adopted here since there was no valves were conducting here and this was your short circuit, it was open; here it was open and this was conducting. What we do? The possibility here, let suppose I am using a bypass valve then, what we were doing. If you are giving the gate pulse to this and you are this is closed, current is flowing voltage is 0; voltage across this 0; this valve will not conduct even just 0 voltage and it will not conduct.

So, what we do? We have to impress some voltage and that what we do? Here, normally we use the ac circuit breaker because if the ac circuit breaker is there, some contact drops will be there and based on that, it will just if you are giving some pulse the voltage will come and then this voltage even the small voltage is suppressed here across this and the gate pulse you are giving this will conduct and once this will conduct then, you can open this.

So, now this is your open and this is taking care of current, now from here we have to come here, in this case the voltage is 0 no doubt, we have to select the pair of valves. Here, it will conduct because the voltage is impress from this side earlier, here once we were talking here they were in off condition and we are just trying to shift here and then we are doing this, so once you are going to do this here, then you have to select the pair of valves you will try to conduct and that time you try to maintain the voltage here 0 that should not be huge voltage here. Otherwise there is short circuit this side you are imposing.

So, we try to here make the voltage 0 means we make alpha is equal to 90 degree approximately, so that the voltage across this should be less and then, the one pair is taking care then you have to off it and then in slowly and slowly you have to raise the voltage build up is otherwise, what will happen if you are impressing high voltage here? What will? There is a huge short circuit current, not only Id huge sort current here because you has dc is short circuited.

So, even though this your rectifier as well as the inverter, once we are going to energize we normally operate even though inverter as a rectifier; rectifier means the voltage 0 very small voltage. Normally, we make beta is equal to 90 degree approximately ninety, so that is also rectifier; this is also rectifier and is just like your energization of HVDC link I discuss we go for 90, 90 degree and then slowly and slowly we reduce the alpha and raise the voltage. Here, the same similar procedure be adopted and once, it has taken care just make it off and then slowly and slowly, you can raise the voltages so that you can just energize this bridge. So, if you are not using this then, it is connected you have to select a pair and they should conduct again the some voltage should be impressed here, otherwise it will not conduct.

So, some auxiliary arrangements are done in this case, that we can have some positive voltage across this and this, so that it can conduct. Here you can see, if e a is there if it is positive this will conduct because this is 0; if this is positive this is 0, it will not conduct. So, we have to do something here, that we can impress suddenly the voltage here as well, somehow so that a pair can be conducting and once it is conducting, then current will be bypassed here and once it is so, then it is you can open it come here. The normal practice we adopt what we do? Instead of going 1 and 4 in the beginning, we try to conduct here, in you know in the sequence order here. Then from there we move here 1 and 4 then current will shifted here and then you can again go back to that mode because how will give this voltage here it is not possible, this ea is positive; this voltage even the going to is just positive, you have to impress some voltage, somehow that it can conduct, make some voltage here injection some arrangement should be done.

Some voltage here may be impressed across this and can be conducting. Otherwise no ideal rearrangement then, you have to go for this conduction mode because e a is positive then e b will be negative and e c will be negative, this will conduct or this will conduct. So, you have to take this 1 and 2 or 6 1 pair is up to you and then, after that one this is conducting then the voltage will be here going to be negative because once is coming here and then, you can fire it. So, the major emphasis here that is we have to make there one leg here, so that we can open this here and then, we can again come back in our sequence order.

During whole process no doubt, you can see that we are no doubt, we are injecting lot of harmonics in the dc side as well as the ac side. Because the currents are changed the pattern, it is not a systematic pattern in the phases and we are so during this time no doubt, we are introducing some uncharacteristic harmonics as well, but here the magnitude is not very significant and since, it is a required, so we have to go for this. There is no other option this short circuit DC side short circuit; you are talking here if you are just.

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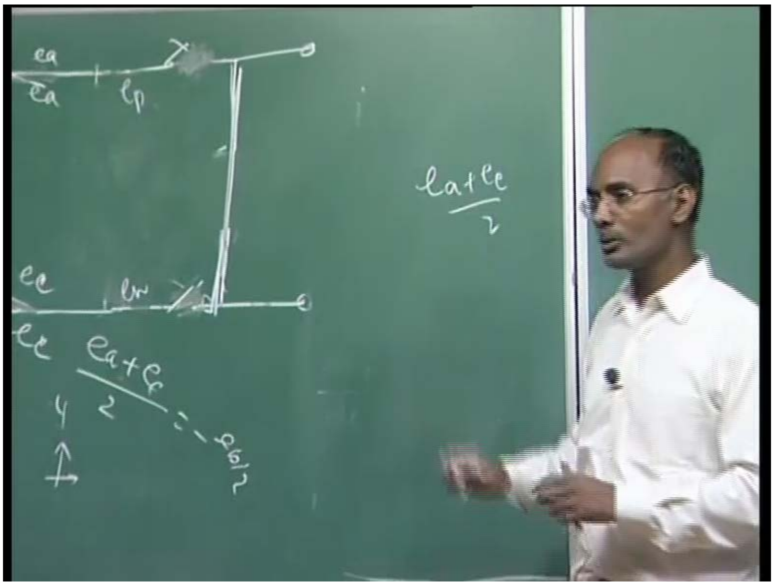

This is no doubt the ac side is going to be there, but the voltages at this angle will the different voltages. The difference will be 0 because is a short circuit, even though in the our energization we saw here this e p and e n are equal, but they are having some magnitude. Once the commutation was over then both were over 0, so this is just like even though every time when there is a commutation is taking place, the two phases there is a line to line fault is occurring in the ac side that is why, the your e always we are ea plus e c by 2 we are doing, so this is in this case also it will be the similar and the commutation will take place.

So, what here again I have written you can say this is similar that is the current is diverted from the bypass pair to the switch one, here basically this is a switch one is to be bypassed and then finally, we have to take care of this. Only here, I want to emphasis the even though the inverter is also operating in the rectifier, the beta is approximately 90 degree and because the voltage should be very less and then, we have to first shift the current and then, we have to raise the voltage and the power rating of this.

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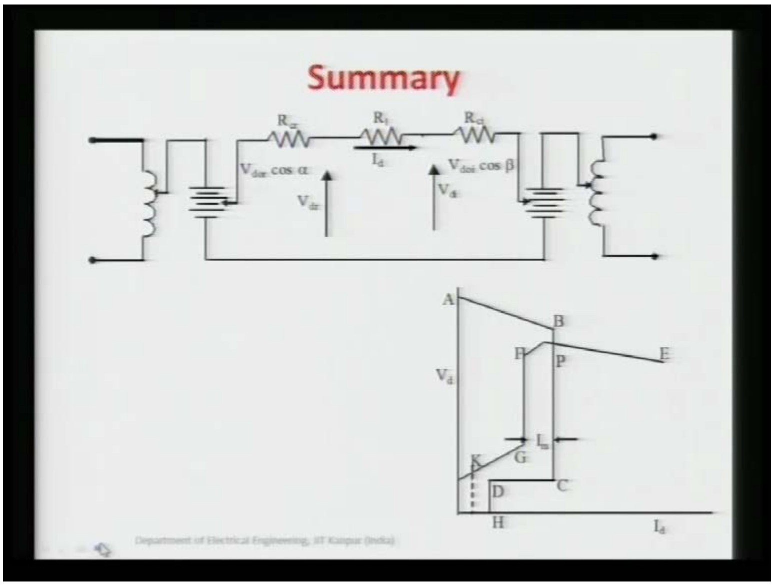

So, this is basically complete energization of these bridges in HVDC link and since, this is the end of this module, now let me summarize what I did in the five lectures. In the beginning, we just develop the equal end circuit, here your rectifier is replaced by variable voltage dc source with the commutation resistance and this is your line resistance; dc resistance basically and this is your inverter side, it can be represented in terms of beta here, it can be also represented in the gamma.

From this, we saw the various possibility of the AC side voltage rise both even though converter side and the your inverter side and based on that, we derive this characteristic for the various reasons. Here, your alpha minimum that is a constant extinction angle

CIA control then, it is a constant current control; here is a constant extinction angle control was there, we introduce another slope here this that is the constant beta control and then, we had another CC that is constant current control of the inverter side. So, this characteristic shows your inverter side characteristic; this shows your rectifier side characteristic. Here in this low voltage operation, it was the your thyristors converter was highly stressed, so to avoid this stress otherwise what will happen? Your thyristors may puncture or they may be damaged.

So, we reduce our operation to the low voltage, low current margin, so the current CC here it was there it was shifted to some another margin, the set value, the current value and here, we are again having going to operate this inverter in the beta mode operation. For the successful commutation otherwise, commutation failure will occur.

So, this was it is called the V d called that is a voltage dependent current order limiter characteristic is introduced especially, during the lower side and same is repeated, if we are your converter becomes inverter and your inverter becomes rectifier. So, it will be repeated in the lower side.

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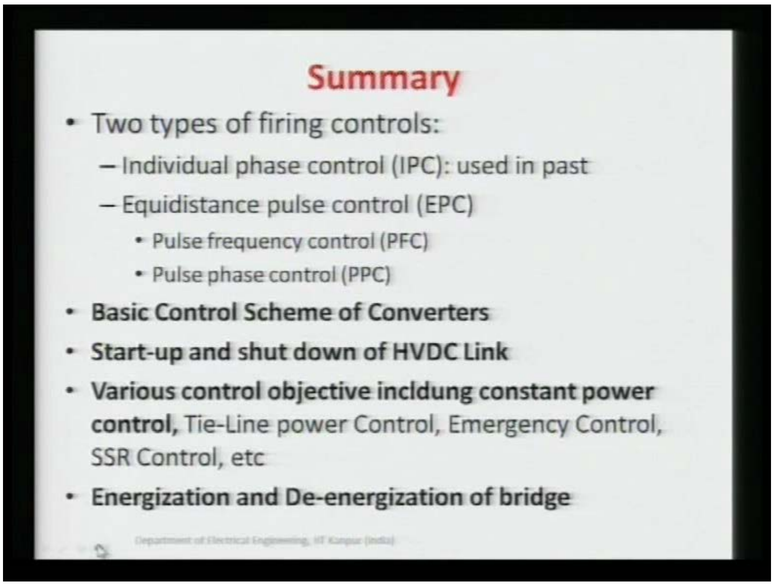

Now, we also discuss the various type of schemes; the control schemes in the principle that is individual phase control or we can go for the equidistance pulse control, in that I discussed your pulse frequency control as well as the pulse phase controls and here, we compare the IPC and EPC. We found is IPC is giving the larger voltage compare to EPC, but it is giving some other problems here, we are introducing so many harmonics and harmonic stability may be instability may come into picture, but this type also EPC the reduced voltage, but there is possibility here that, we can phase the traditional oscillation possibility during the again harmonics injection.

We just I show that is basic control schemes from both rectifier and the inverter sent as well and we saw both CC CIA all the characteristic with the power and VD COL limiters various blocks I shown, then I discussed about the your start up and start down of the HVDC link how this we can start? Once it is you are energizing complete link rather than bridge I am talking here.

So, we how we starting and then, how we can shut down? So that, for any repair or maintenance work or can be done. We also discussed the various control objectives like how to maintain the constant power? How to shift the margin for the constant power, if the voltage has changed then, we have to shift the for constant power; we have to change the voltage and the current margins so that we can maintain the constant power in the link.

I also discussed the tie line power control, emergency control, frequency control and subsequent reservence control as well and we found that it is a feasible and useful for various control schemes; for the various applications and then, at end I discuss the energization and the de-energization of bridge, how we can take it out the bridge for the maintenance and once maintenance is over how we can put it into the service that is a energization part. De-energization means we have to off it and go for the maintenance as well.

So, with this I close this module three and the next module four, we will see the mal operation again of this converter and we will see what is the commutation failure? What is the quenching? What is the misfire? All this possibility, what possibility that we can arise and we will discuss suppose, you are giving a pulse here it is not conducting. So, this is a misfire if it is conducting, but there may the commutation after taking half way, it is coming back again, it is called quenching.

Inverter side, it may be the commutation failure; it is taking current again it is going back, but rectifier side once, it is taking current because the voltage is going to be positive; it will be commutation will be successful, but inverter side there is a possibility the commutation from one to another valve may not be successful and the commutation failure will be there. We will see the commutation failure may be the single commutation failure in one cycle; may be the two cycles, double commutation failure in the same cycle may happen. We will discuss all these in this next module.