High Voltage DC Transmission

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Module No. # 02

Lecture No. # 09

Analysis of Converter Circuit

So, let us, start lecture number 9 of this module 2 that is, a converter analysis and last turn in lesson 8. We saw that, when u is more than 60 degree then, we are going to have the commutation means is 3 to 4 valve conduction is appearing ,we derived the various currents at that time.

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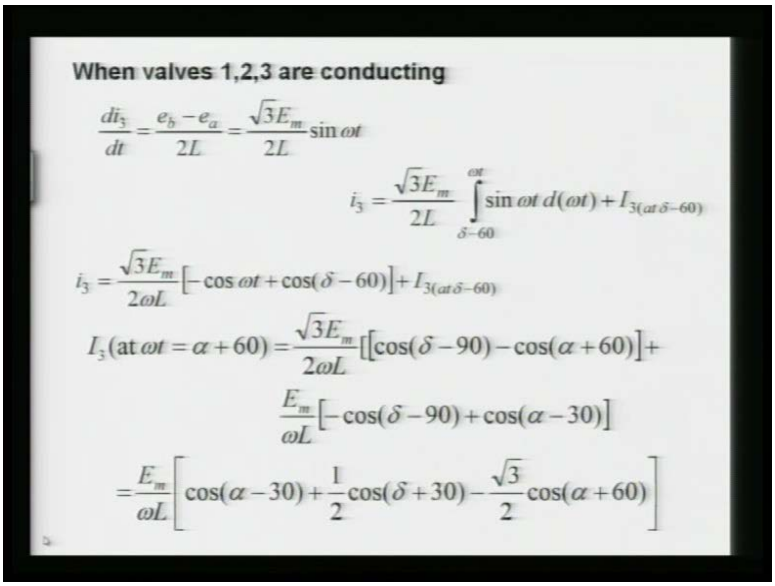

If you remember here we define once your 1 3 1 2 3 are conducting even before here.

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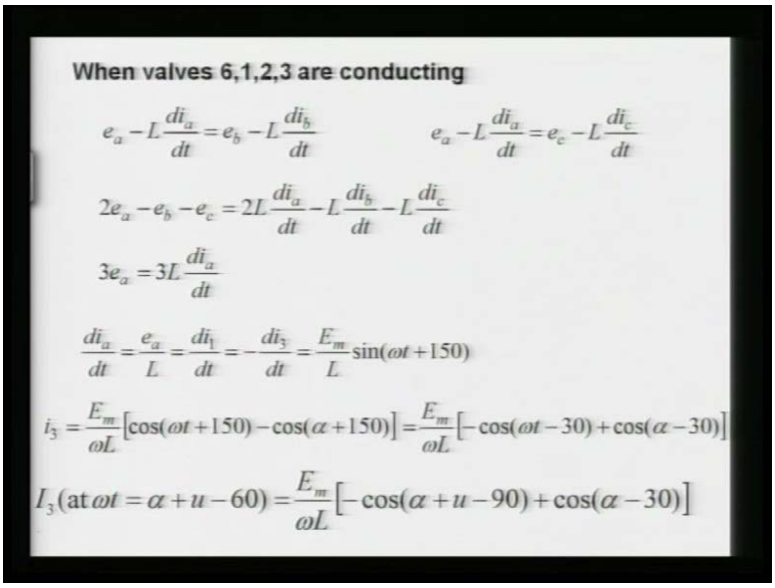

I said your 6 1 2 were conducting and then we give the get pulse to 3, it was conducting we derive the current expression here, now; you can see in terms of here we are getting the currents. Then what happen? The commutation between 6 and 2 will be over 2 will take care then current 1 2 and valve 1 2 3 are conducting and then expression becomes here we derive again and the current equation we wrote here that is, I d at the instant of 1 2 3 valve conduction mode, because at that we are going to give at this point, we are going to give the firing pulse to 4 and now, your 1 2 3 4 are conducting and then we can again here now, here arrived here. So, today I am going to explain here you will see in this 1 2 3 4 are conducting at that time we took here the expression i a rather than i b.

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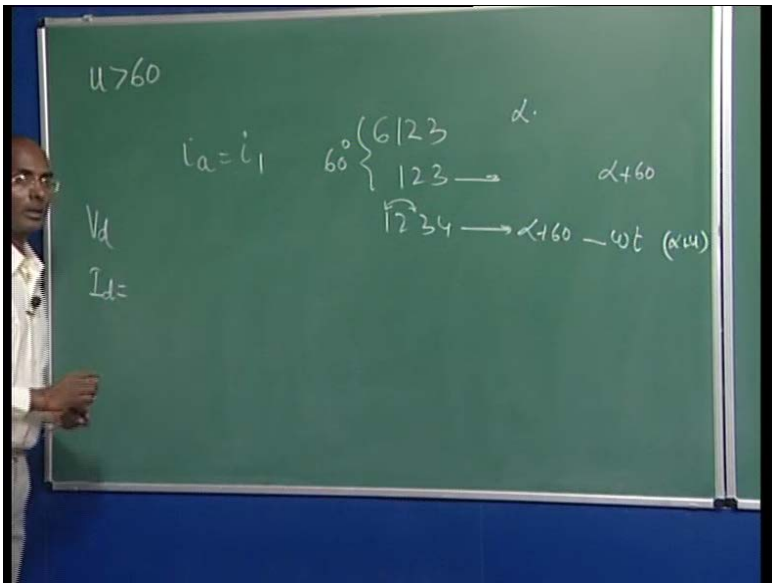

Because that time i 1, i a here it was equal to your i 1, but in this case it is not so, because 1 and 4 are conducting means 1 phase here you can say the current of this 4 here is going and is coming so, this it is not completely i 1 current so, it was not valid. What we did? Now, you can see in upper lime only here this 3 is there no 6 is conducting so, we can say i b is equal to i 3 and we required the expression for i 3. So, here again we applied our a minus this parallel voltage across this phase a here phase b will be equal in that conduction mode here it will be this you can add you are getting a expression here very simple expression that is, your L di 3 upon dt is equal to your this value e b and now, you can integrate for i 3.

You will get this again, we are starting here, this will be the conduction mode, when we are going to start from i plus alpha, plus 60 degree means as I said here your 6 1 2 3 then 1 2 3 here the end period was your alpha plus 60. Here we started alpha means this was your total 60 degree now, your 1 2 3 4 it is your starting your alpha plus 60 to we are writing omega t. That is, why Here you can say alpha plus 6ties 1 integration constant and omega t is appearing here and just it is a integrated here we are getting this value we are adding plus current which was flowing just this conduction was there, so, this is i 3 at alpha plus 60 that from the previous instant is added here and then if simplify you will get at the delta here that is, alpha plus u degree means at end of this conduction we are going to have this I d which will be because now, what will happen this your this commutation between 1 and 3 will be over and now, 3 at this end that is, your alpha here

it is your alpha plus u here it is going to take place and then we are going to have complete I d, because 3 is going conduct so, at end of this is off now, this is these 3 on top only one valve is conducting so, this will be the I d current here so, you can from here you can simplify and you can get this expression.

Now, once again now, we had in this case when we are having this is the case when u is your greater than 60 we got the two expression one for the voltage and another for your I d here also, we want to eliminate the u term because u is varying depending the system condition to condition , but I d is maintain and the V d we are controlling so, we want to write the expression here the V d that is, function of I d like the previous when we define.

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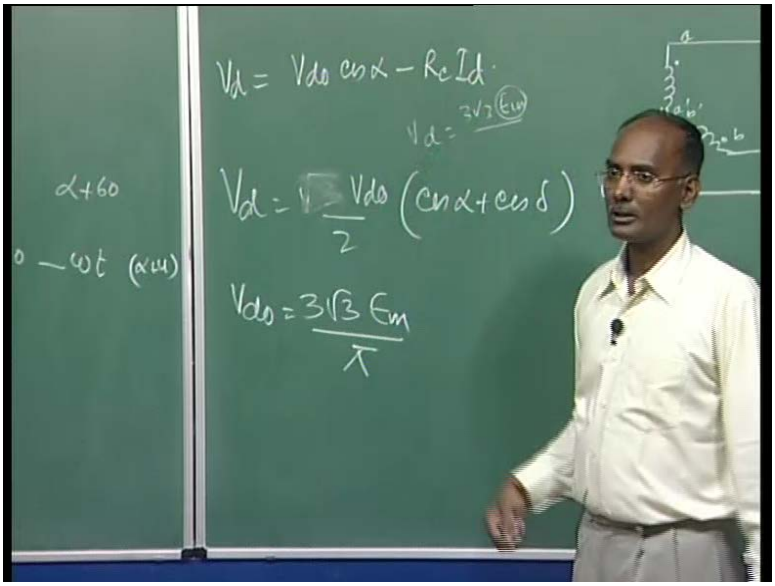

If you remember here it is your V d it was your under root 3 V d o by 2 it was like that here Cos alpha plus Cos delta here it was there it was not under root 3 it was V d o by 2 Cos alpha plus Cos delta it was the case here V d o because it was average all this nothing else here the if you put u is equal to 0. It is getting the 2 Cos alpha and it is cancel it and but no doubt this V d o was your 3 under root 3 E m over pi. So, we want to derive this was it is not in terms of your that it is not in terms of your I d term we can write this 1 also, what was this you remember V d o Cos alpha minus R c I d this we derived from this current at the dense at the instant end and this from here we got this expression this is just like a voltage variator here there is a some drop and there is a that

is, why just it is called equal net commutation reactant. Similarly, here for this case also, we want to derive from this I d and if you remember the voltage equation we derived.

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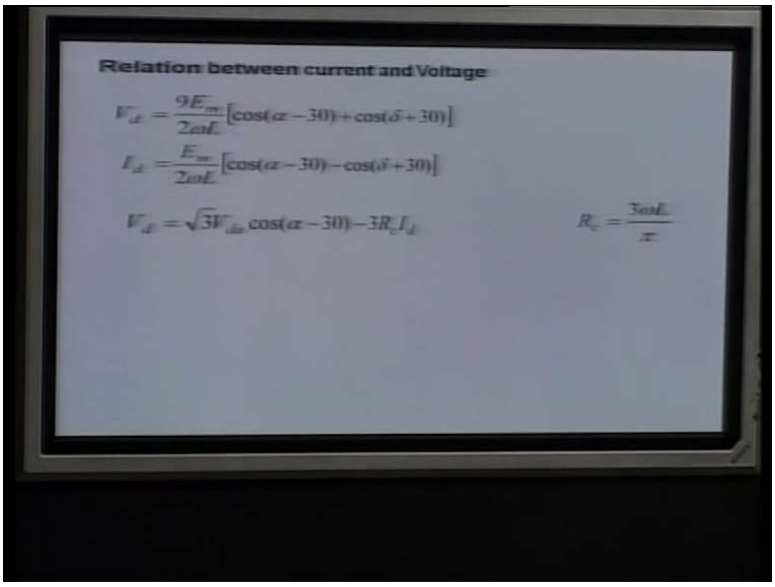

It was you remember anything the V d o was here this expression.

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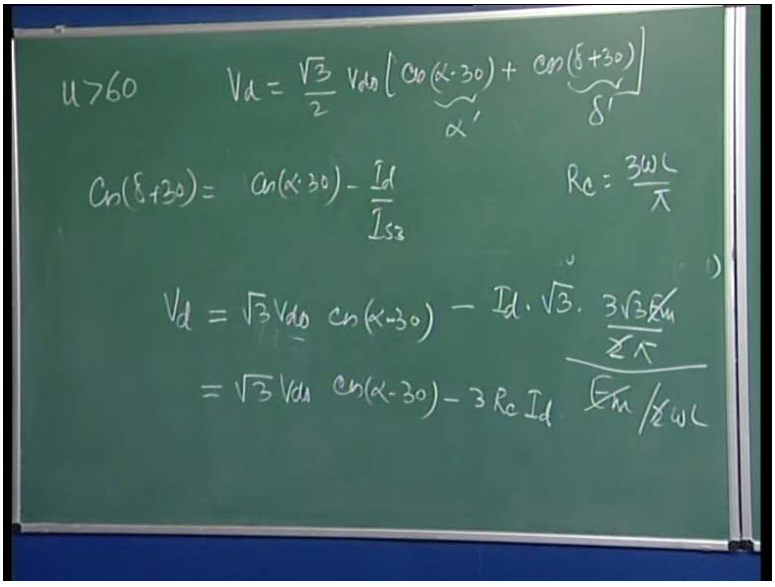

And I wrote at that time here is V d is equal to under root 3 by 2 V d o and it was your Cos alpha minus 30 and here plus your Cos delta plus 30. No doubt this delta is alpha plus u so, normally we say this is your equivalent to alpha prime and this is your I can say it is delta prime. So, we are getting the similar expression to the 2 3 valve conduction

mode this was the case when u was less than 60 so, this is the voltage equation we want to eliminate this because here u is appearing alpha plus u.

We can eliminate from this your I d current and this I d we define just we are slight it was this value so, from here and here you can see inside terms are similar only here the minus of time is coming .So, what we can do? From this expression we can take this Cos delta plus 30 and then we can put it here so, this will be eliminated and then you will have expression like this means, here what we can do we can from the I d I can write your Cos delta plus 30 is equal to your this value I can say it is some constant i s 3 so, it is your yeah Cos alpha minus 30 minus I d by some constant I can say i s 3 I am not using is two because is two used we use there.

So, if you will put this value here here you are going to get now, you can see your V d will be just put it here so, we are going to get under root 3 V d o Cos alpha minus 30. Now, we have to see if you are going to put here now, this value is your I d of course, into we are multiplying this value is your under root 3 and this value is your 3 under root 3 E m by pi and this is already 2 I am putting 2 this is your V d o divide by i s 3 here because I di already I have written here. So, I can write here this is your and this nothing but I wrote here E m by twice omega L. Now, you can see this E m E m is cancelled this 2 is cancelled here and now, we can put it there, so, this whole term we can write it is under root 3 V d o Cos alpha minus 30 minus. Now, you can see 3 I can say R c I d where your R c is nothing , but 3 omega L divided by pi because in the 2 3 valve conduction mode we defined R c here it was this value so, you can see here what we are going to get this now, in this case the R c is a thrice of that mode so, more drop is there one is that alpha cannot be less than 30 degree so, you have to go after the 30 degree here so, this will also, reduce the voltage and there is a more drop in this equivalent commutation resistance here that is, the three times of the previous one here.

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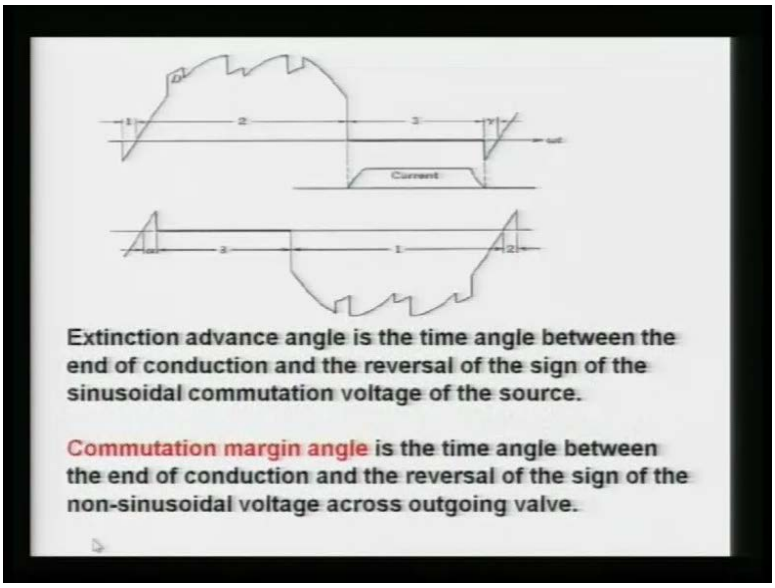

Now, let us, go for again the 2 3 valve conduction mode we will see this extinction angle which I define the gamma and now, this gamma is very very tricky here means you can see the valve voltages this is the case of your inverter. This is a case of rectification and this the case when your u is less than 60 degree now, as I said most of the time in this case the one period, this one where it is here most of the time the voltage is the valve voltage is negative side. What happens? Even though there is any spurious signal this here this cannot conduct even though you are getting giving the gate pulse only the positive here is very small portion but this reverse here most of the time it is the positive and there is a possibility due to the jumps or there is a not complete commutation completed here the valve which was conducting. It will continue to conduct and that is, called the commutation failure.

So, that is, why in the inverter circuit is very very prone to the commutation failure no doubt the misfire can occurs any time we will discuss small operation of all these converters here valves etcetera misfire means you are giving a pulse and it is not conducting means missed but the commutation failure that the pulse is giving the commutation started , but due to the reversal on other thing commutation fails means for example, if the commutation between 1 and 3 is taking place so, the current here started decreasing and this was picking , but due to the reversal of voltage across this there is a possibility here the positive voltage it will pick up the current because here the voltage becomes negative. So, what happens this will be again going back here because and the

commutation may not occur so, and that is, called commutation failure so, this period one here it is as I said we normally we maintain some angle so, that there should be proper deionization proper commutation should take place and this angle is called the gamma angle here.

So, now, if they define here the extinction advance angle sometimes it is also, called the extinction angle and I said it is a gamma and the gamma is this the time angle between the end of conduction. Here this is end of conduction and the reversal of the sin of the sinusoidal commutation voltage of the source here this is reversal here you can say is a going to reverse it so, from this end of conduction of lets go it is a valve 3 and here the sinusoidal voltage which is going to reverse this is the polarity from negative to positive. So, this is define as a gamma now, in the commutation margin angle it is called zeta and this is the time angle between the end of conduction again we are starting here and the reversal of the sign of non-sinusoidal voltage, non-sinusoidal here we are talking means there is a possibility that this can come here we will see the different scenario and then in this case your zeta and your gamma are faket, because here it is going to reverse whether is the sin are non-sinusoidal it is going to reverse, so, their this case gamma and zeta are same , but it is not always true and will see in this figure here.

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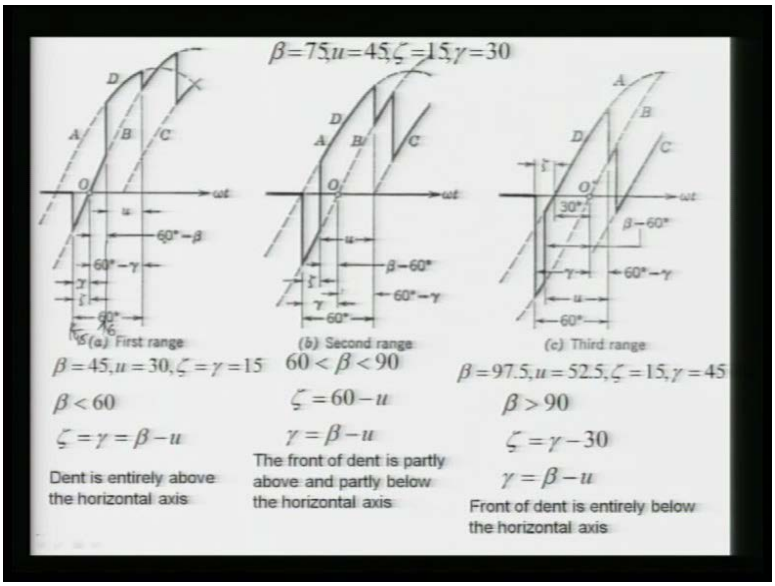

You will see the various configurations various possibilities are there we had the I showed you the previous figure was similar to this you can see it was here the valve 3

was conducting the commutation. This valve 3 was off here and then it was following this voltage and it is going here in this period it was basically the commutation of some of the there is a 2 3 valve 3 valve conduction in this mode. So, then it went with the half of this then again it was commutation was complete that is, why it is u period and then it is going here again and this now, this d that is, the dent if this u period can change. So, what happens this line can you can see this line has come here now there is a possibility even though d line come here and then sinusoidal picked up.

So, these three possibilities are there when we are operating u is less than 60 once again in u greater than 60 these possibilities are not there because the most of the time the valve voltage is 0 only three times it is non-zero and that was nothing but it was half of this that is, a feature voltage 1.5 times of feature voltage. There was no damp we just saw the wave wave say of the valve voltage the only possibility here here in this case in the 2 3 valve conduction mode means u is less then and this is also, true when we are operating in the inverter mode this is the case when we are operating inverter mode in the rectifier mode it does not arise at all because you see the previous figure it is all the time here here you can say this is all the time here it is negative. There is a no possibility of commutation failure here only the possibility because only we are getting this time to get it deionisedor getting it off here we are getting enough time so, this no problem also, we can just see from our say commutation voltage of valve 3.

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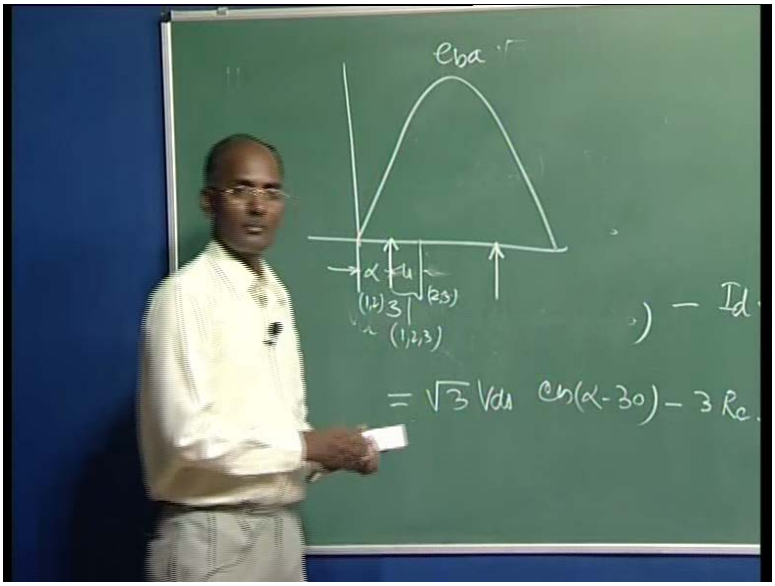

and as I said here we took this commutation voltage of valve 3 is nothing , but your e b a this is a valve 3 commutation voltage. Now, if your valve 4 is here means you are giving a pulse to 3 here this is your alpha you have enough time to this valve to off means it will go no doubt this is alpha and this will conduct and there will be some u period where your this was your before that your 1 and 2 were conducting during this period your 1 2 and 3 are conducting then in between u the commutation is over between 1 and 3 and then again here this period onwards it is your 2 and 3 are conducting. So, you can see even though this angle is enlarging no problem here the voltage you can say here it will be enough time because you will see the negative voltage is appearing here across this valve 3, because once we here the commutation is over you can see still the voltage negative and the fuse negative is there this will be off and even though more time it is taking for the taking off. So, there is no problem here but once you are firing here that is, inverter case means you are just moving delaying your alpha.

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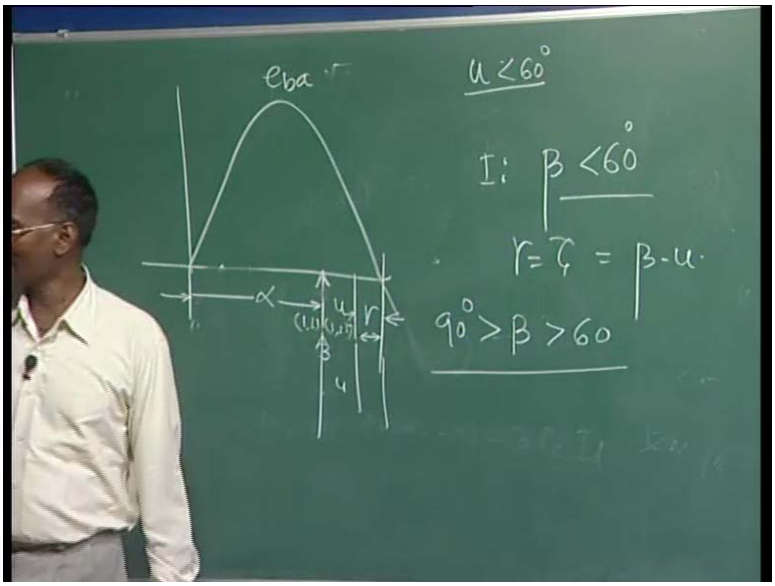

And your alpha is now, more than this then you are giving a pulsed here now, this will take your u degree again here it was 1 and 2 were conducting. Now, 1 2 3 are conducting now, that is, here we are giving some margin because this may enlarge somehow and the commutation may not take proper. So, here you can say now, this voltage reversal is there so, if it is not done here in this period your commutation is not complete possibilities are this is your voltage is going to negative and this again picked up this one can continue conducting and three can again go off means it will take the current and

then again it will be 0 and that will be commutation failure. So, this period in the inverter operation we have the various possibility that is, why it is said that you should maintain this angle gamma at said in the beginning this is the extinction angle you have to give because this may keep on changing because your beta also, is best on some calculation. We will see in the control aspect this beta is decided by what margin you want to make suppose I want to maintain 10 degree here then beta is being calculated why because this voltage can also, change. So, it may take more time if voltage is changed u will be changed so, to maintain this we always to be sure that there should not be any commutation failure in the inverter side. So, we try to maintain this then we calculate based on the voltage at that time and then it will be fired so, there is a your controller will calculate and finally, it will give the gate beta pulse.

So, what happens even though during you have the given the pulse to 3 , but again the voltage change at that time so, that is, why we maintain this angle you believe that in that period it will be the commutation will be the successful , but if there is a fault if there is a very severe condition still we cannot tolerate this and there may be commutation failure so, we will analyze the commutation failure later on and we will found that we will see that this commutation failure is self curing no need to worry about this in one cycle there is a commutation failure next cycle it will take automatic so, it is clear for , but no doubt this commutation fall failure are not allowed because they are going to inject more harmoniction to the system that is, dangerous because our filters are tune for certain harmonic , but once commutation failure happen the output voltage is not symmetric and so, many harmonics are there and that is, not desirable.

So, here we will see now, we are going to here the various possibility and as I said here this is only the case when u is less than 60 because if u is less than 60 then only we are facing problem because if u is more than 60 what happens then we will find most of the time it is 0. The voltage or it is negative there is no dent and that is, a very severe abnormal condition we never allow normally it is 2 3 valve conduction is very very common always because u is there whether is t5 degree 10 degree a 20 degree it will be there and that is, why we are having this scenarios. Now, so, all these three conditions are arising if your beta it depends upon beta basically where you are firing here you are firing here you are firing here and all these possibilities are taking place so, you can see here if your the condition means we are having three different stages and in that stages I

can say in stage one if your beta is less than 60 degree beta is less than 60 degree this is your first case means here the beta is less than 60 degree then we are always having or gamma is equal to your zeta.

Now, what is gamma gamma we define it is your beta angle from here and this is your u so, we are having it is your beta minus u so, you can see if you're maintaining this gamma 10 degree it is always your commutation is successful because we are here this is nor means by this time it is we are having this angle zeta now, if you'll your beta is you can say if beta is more now, you can see this is a very different scenario what happens this is now, coming this side then problem starts arising if you are coming here it is not problem , but the maintain this is also, another problem if you are coming here let us, suppose your beta is itself 170 degree so, gamma is not maintain that even u is something it is coming somewhere else so, that is, going in the different mode so, if your beta is your greater than 60 and it is less than 90 degree then we are arriving at this stage two in this what happens.

Now, for example, I can write at this moment what is going to be fired before that your 3 and 4 will let us, suppose this is the valve output or valve 3 if assume this is the valve output voltage of valve 3 means at this case now, it is coming voltage means it was conducting up to here means there was a commutation between your 3 and 5 means it is over now, here your 4 5 are conducting means I can write here and i slide itself means before that we give some pulse , but here here onwards your 4 and 5 are conducting and this will go up to here when your 6 is being fired once 6 is coming means there is a commutation between the 4 and 6 is taking place.

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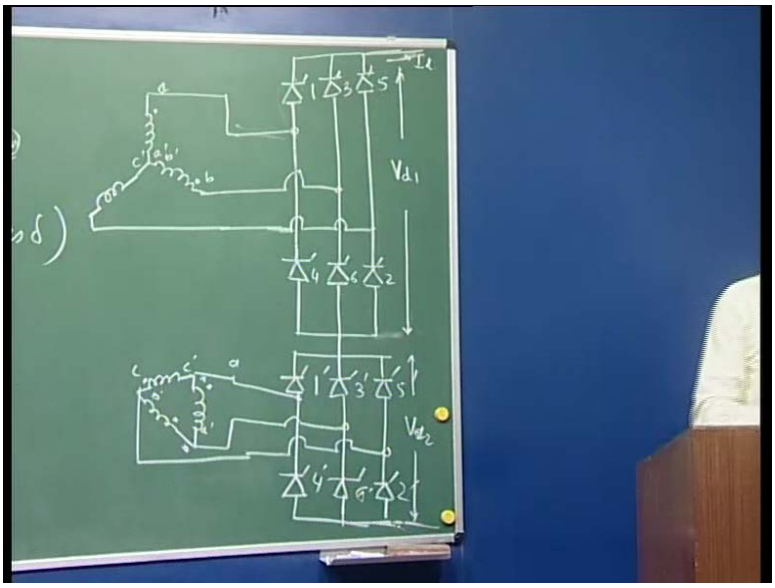

And since this is there here the voltage becomes here is minus e c by 2 so, minus e c by 2 and here it was conducting so, it is 1 point minus 1.5 e c and that is, why no this minus is a minus so, it is a 1 minus 1.5 e c and then that is, why here the it is say coming here it is a following this e c 1.5.

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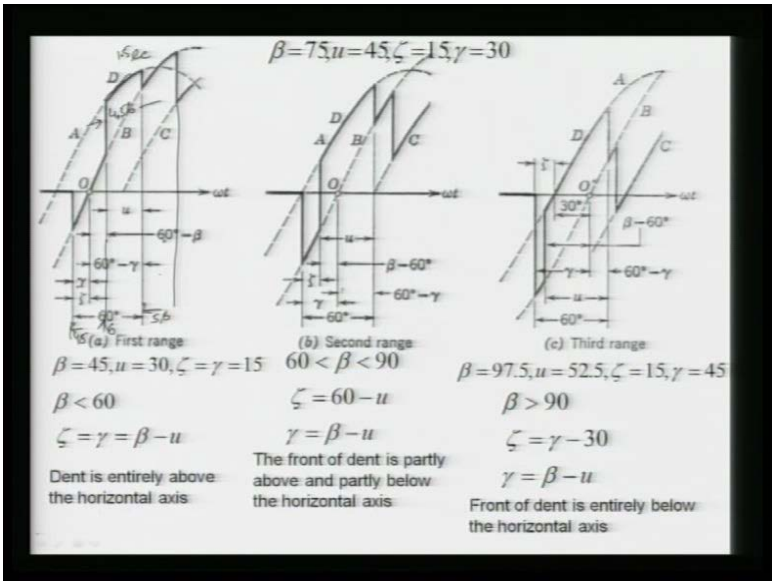

So, this period basically during this your 4 5 and 6 are conducting then here it is off and now, here onwards your this 5 and 6 are conducting and then again we have to there is yeah so, it is keep on same repetition. Now, in this case once your beta is more than 60

degree what happens this dent is going to be larger because you can say for same if the beta is more here here beta is going to be more and u is same then we are going to have a this angle is wider now, what happens now, this is going to shift because always this period when your this period and your firing means next valve firing it is a 60 degree.

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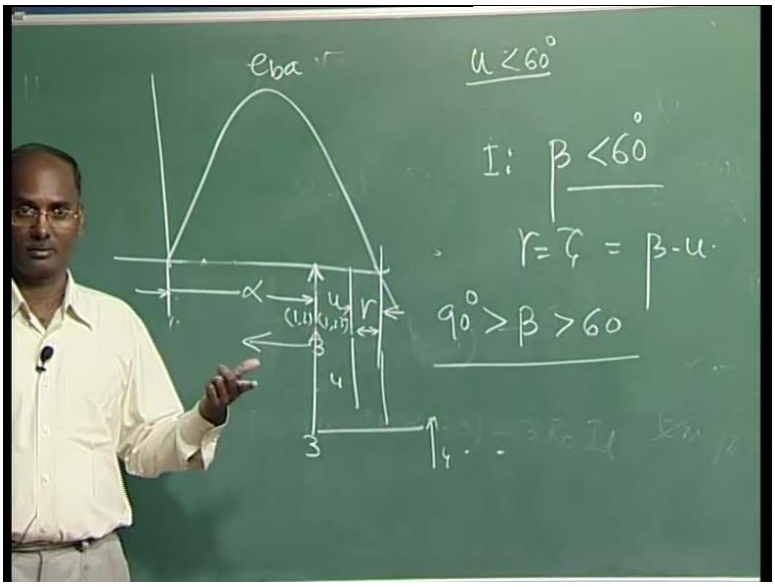

Because always here you are getting 3 valve after 60 degree you are giving valve 4 and so, and so, what happens? this is going to be changed the width is going to change depending on your beta and the basically u as well it is less than that so, this is going to be wider and there is a possibility it is you can say just it is a shifting here and we are having this one at this point. So, as per our definition now, this is the smaller portion is your zeta I said the end of the conduction and then non-sinusoidal reversal of the voltage so, here reversal here so, this is your zeta, but as a gamma definition end of connect conduction here then the sinusoidal voltage of outgoing valve the commutation valve. so, this is your gamma now, you can say zeta is this much now, we have to maintain the zeta what happens if zeta is not there.

Now, voltage becomes positive and again there is a possibility of the commutation failure another possibility you can see if the beta is more than 90 this whole dent is coming below so, in this case what happen your this value is going to be your zeta not this dent this value because here the reversal always we are talking the definition end of connection conduction here and then the reversal of non-sinusoidal voltage here this is

your gamma so, this is a this value is there so, we are having the different flavor different values 3 stages and that is, why here you can say the dent is entirely above the horizontal line this is horizontal your 0 axis. Here the dent is always above in the first stage when your beta is your less than 60 degree if your beta is between 60 and 90 what we are getting? We are getting this dent is basically half of the below and half of the above when this is a here this front of the dent is partly above and partly below this is of front the front is half below half above , but if it a more than 90 degree.

This complete here the front is the complete the below the horizontal angle so, this your zeta is very very important and we if your going your in this mode you should be very very cautious , but normally we operate our inverter in this mode. Why if you are coming this side beta more the power factor becomes very very worst we tried to fire here only in this 1 less than almost 30 degree not more than that so, always we are getting this, but there is a possibility do the fault etcetera you can come this side and the commutation failure may occur. So, here just I said the beta is basically being calculated your controller will calculate because we want to maintain this beta will be calculated something happens here you are landing here either here or here because the calculated beta maybe less than 60 degree or maybe more than 60 degree or maybe 90 degree.

So, that time your all the scenario is going to be disturbed so, this is a very important because the zeta is more important because we have to maintain the zeta rather than gamma , but in the normal case gamma is sufficient because I said we are operating our inverters less than 60 degree to maintain the reactive power support etcetera so, at that case both are same and our commutation is successful.

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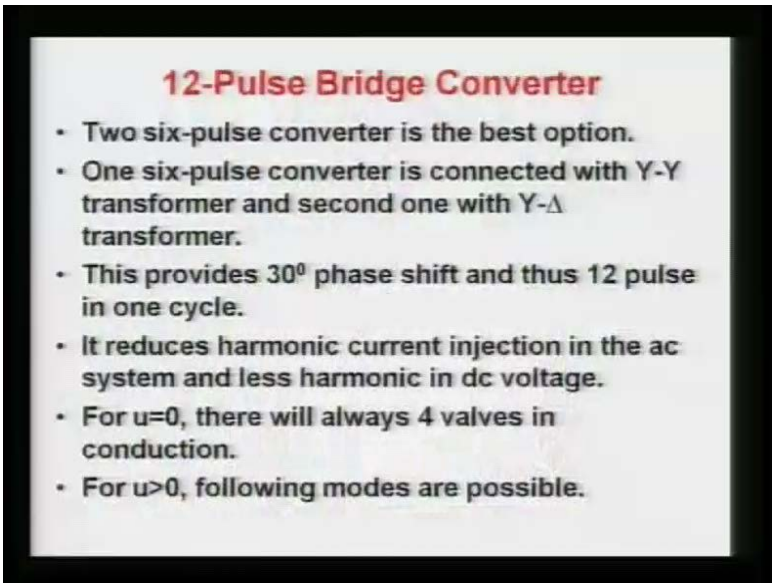

Now, let us, move to our twelfth 12-pulse this is six-pulse is over now, in the 12-pulse as I said there is a so, many configuration are possible but it is very convenient to use the 2 six-pulse bridges and then connect in the series and then output will be your (()) you can have six-phase windings and then you can use your valves in such a fashion that you can get.

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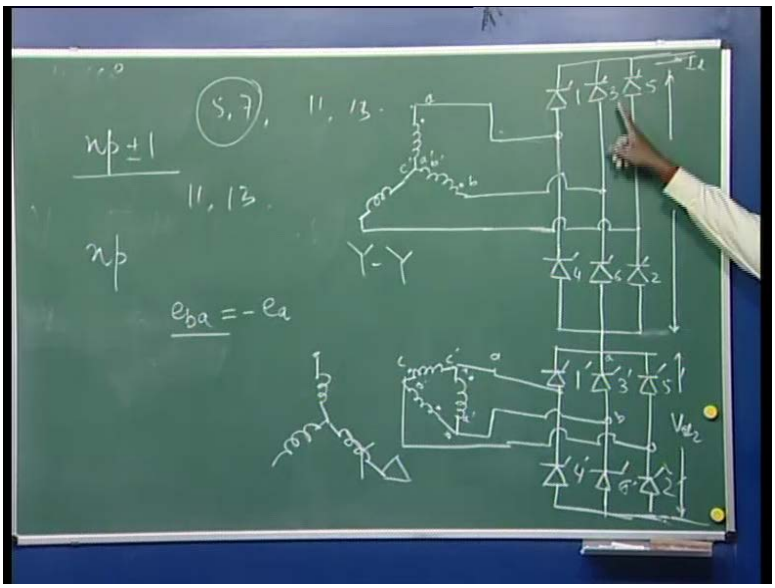

Or you can have this the 2 bridges 6-pulse six-pulse only the difference here the transformer you are using here is a delta delta a star star and here you are using star delta

means secondary of one of the base should be in the delta and the secondary of one will be in your star what happens due to the star and delta here you know, there is a 30 degree. Shift again the 30 degree shift depends upon there is a plus or minus it depends upon the dart polarity if the dart is change here it will be negative if this dart here it will be shifting 30 degree.

Now, to understand this we have drawn for this valve voltage let us, see the what will be the output voltage here (()) of this because here it was this a minus b here it is a b means this is a phase a voltage. Here so, let us, draw the output voltage so, to say here as I already mention here we are going to analyze the 26-pulse bridges one is connected with a transformer star star another is the star delta and they are in series. So, we are getting the 12-pulse here output means both voltages are added together algebraic simply so, they are added and they are used because this provides 30 degree shift. So, 6 and plus 6 in same cycle then it will be the 12-pulse this configuration as I said we are using higher output pulses that we can minimize the a c side harmonicsas well and as well as the d c side harmonics because a c we will see analyze later on here the a c side I said your n p the characteristic harmonics will be this and the d c side it will be your n p p is the number of pulse and n is integer. Now, it the 12 p here you are getting the 12 here 1 so, 2 4 24 and 30 6 1 in the d c side voltage harmonics are there the current harmonics in the a c side it is now, 12 here now, it is 11 11 13 and here you are going to get 23 and 25 or so, we have however if it is 6 it is your 5th and 7th then we are having eleven and thirteen and so, on so, for so, this is going to be cancelled out because the harmoniction repeat here and here they will be consider a c based here where the transformer.

So, let us, see the case when u is 0 and then we have to draw the case for this 1 already we have drawn for this case here I want to show where we have to start now, again we are taking that here one prime and the two prime the valves number are conducting. Now, 3 is going to be fired what will be the voltage across this at that time it will be only conducting when the voltage across this will be positive. So, one here is coming a here it is b means you require e b a is positive what is e b a here see it is nothing , but it is minus e a the phase voltage which is here we are talking here line to line , but this equivalent to the phase voltage here no doubt this phase voltage we are going to transform in such a term ratio that it will be under root 3 times of the phase or voltage of that side this side it is a simple your as is aid star here. here

so, this the transformation we are taking care because magnitude should be same here under root 3 times here and line to line here then we are going to add, but here we are going to get this is minus now, you can see this was our case we are again starting here this e b a it was the case for this case here first phase and we took the third valve commutation voltage is your e b a because one and two were conducting.

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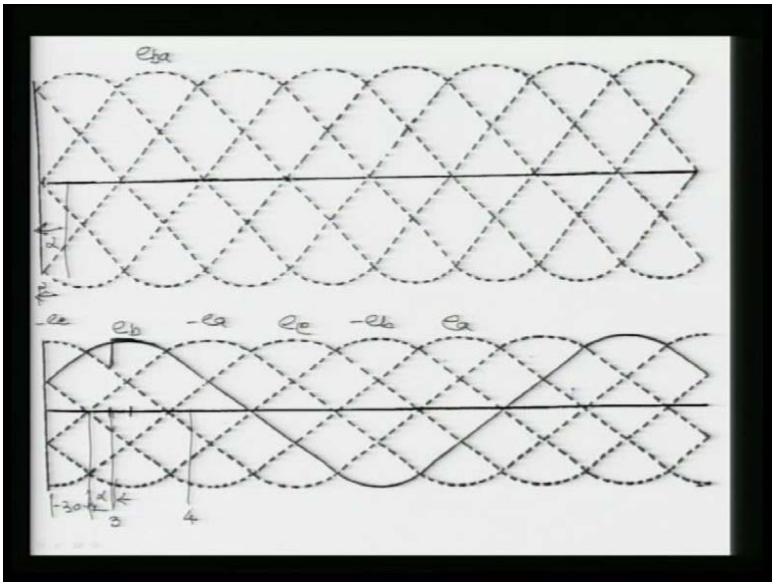

Now, the lower voltage here I am going to draw for this much so, this was your e b it was your e c it was your e a and finally, this was your minus e a this is your minus e b and here we are writing this is your minus e c valve. Now, you can see in this top most figure here means we can start alpha from here any time means we can start here because the voltage across valve 3 in the star star connection 6-pulse converter. Here we can fire and then it will conduct if your redelaying some angle here alpha hardly matter and the voltage will follow and it will conduct coming here now, you can say the voltage across that should be e a minus e a positive because minus e a should be only positive it is going to be here and this degree is your 30 degree and this phase shift is there.

So, your first valve is fired here the same pattern is your alpha degree thus here it will be alpha plus 30 degree you cannot fire because this is cannot conduct because you have to wait here so, the alpha here coming all the way now, alpha start here in this case alpha start 30 degree there and that is, why let us, draw output voltage means here I can say alpha start here your 0 , but in this case here alpha start from here this is your alpha this

is your 30 degree so, if you're going to delay here alpha degree here then you are going to delay here alpha degree here so, only difference due to this is here due to the phaser and 30 degree shift otherwise there's no different so, once you are arrive at certain here that is, now, we are going to start from here this alpha degree now, we can see what with the output voltage for your u is equal to 0 and alpha let us, suppose I can take a 15 degree and then we can draw.

So, let us, see what will be the output voltage here across that I can say V d 2 when we are having the delta here that is, connected with this bridge so, as I said I am going to take alpha is equal to 15 means here I can say we are going to draw u is equal to 0 and alpha is equal to 15 although this u cannot be 0 it can be some value , but for this case we can just take alpha is 0 you can take alpha some value and then there's no difference because already we have seen for this mode so, it will only there will be this period the commutation will occur.

Now, you know, this complete period is 60 degree so, this is your 30 degree means I am going to fire here your I can say 3 is going to get the pulse once 3 is getting pulse here it will conduct because voltage across this valve is going to be positive means minus e a which is positive during that period and it will conduct now, what will be output now, this is 3 2 means 2 and 3 are conducting now, the 2 and 3 means 3 here and the 2 so, see here so, we are getting the e b c here the voltage we are getting e b c will be what is your e b c here this is nothing , but your phase voltage of this is e b because this i said it is a positive polarity so, e b c is positive here.

So, it is your e b no doubt in this case this phaser value is a line to line although you can see here I have drawn the magnitude is less , but it is not so, because the same graphic use for previous case so, is same there otherwise magnitude is same here it is going to be this because it is the turn ratio in such a way that we are getting line to line voltage equivalent to the phase of this side of the transformer it is now, we are going to have the e b now, you can see what is the voltage is going to appear it will be suddenly going here and it will be conducting here so, output voltage is going to be e b because e b is there already we have mark and it is a positive. Now, after 60 degree your valve 4 will get the pulse and this after 60 degree it will be here means your 4 is going to get pulse.

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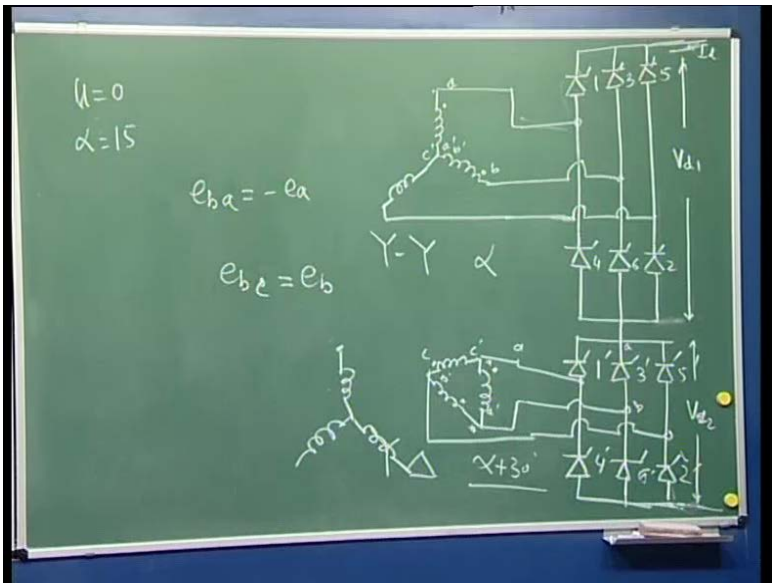

Now, 4 is getting pulse here means commutation is instantaneous we have assumed because u is equal to 0 so, what will happen your which one is conducting 3 and 4 are conducting so, it is e b and a so, it is your output voltage here it is b a so, e b a you see what is e b a e b a it is the negative of this phase so, minus here it is your nothing , but minus e a in this case all these we are talking this case is not with related to this case so, this case is different.

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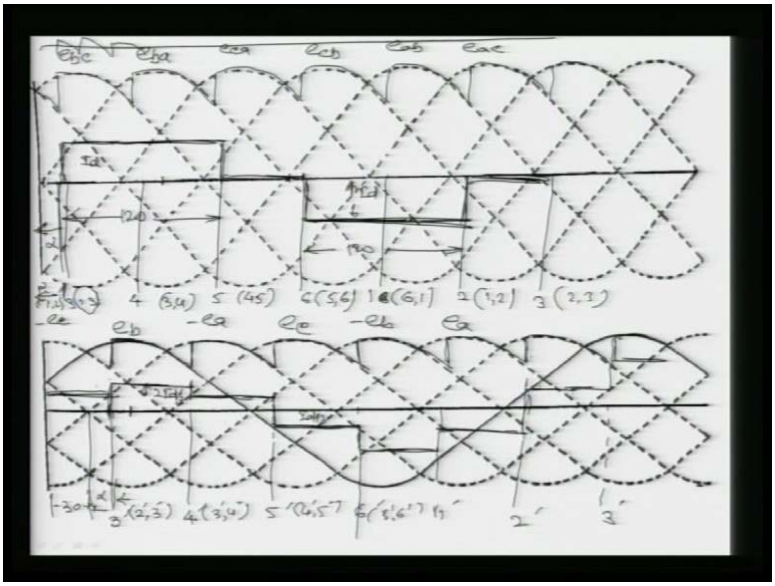

So, here and you can find minus e a is just on the top of this so, it will go up to here and then output voltage will be there and it will follow your here so, again it will be here it will be getting the 5, then it will be getting here 6, then it will be getting here plus 1, then here it will be getting 2 and then again it is your 3 means we are completing the cycle and we will find it is although time we are getting here if your 5th is going to be fired we are going to get this output voltage. So, this will be your output voltage and you can say this is a positive because we are operating in the rectifier mode and here it is all the way here so, this is the just similar to our the previous case and you can say it is here the similar we are the output voltages we are getting.

Now, this here if you are going to draw for this 1 here already we have drawn for the previous case the alpha which we are giving here now, it is going to be your e b c once 3 is going to conduct here the b and the your two e b c will be there and the e b c is nothing but our e b c is this so, here e b a here we can go e c b here it is e a c and this voltage is going to be e c a and this voltage is going to be e a b and so, on so, for so, what happens here now, you are getting here the pulse 3 mind it here it is all the primes means we are talking for this bridge now, I am going for this bridge where those no prime means here three is getting here this basically we are moving ahead because this is 30 this is15 degree. So, this your 4 this is your 5^{th} here your 6 here we are getting so,rry one here it is your two here it is your three and again it is cycling process so, what is happening here it was conducting here output voltage come something here and then we are going to have this output voltage already we draw for this output voltage in the previous class now, you can see here both are the same pattern and the same magnitude here this is looking slightly flatter the reason is that this is a small in size if we will increase this it will be become the same shape because here there's not to the scale to this one because I said it is also, line to line.

Now, this is also, line to line now, you can see the peak of here this is here you can see in the between so, this is going to be superimpose here and we are going to get the 12 pulses output outside and I can simply draw here this is our output voltage will be here this means one here cycle we are going to have the two in one period because it 30 degree shift because it is conducting for 60 period in between the 30 shift. So, we are getting another pulse and then finally, we are getting this total of this here and here and twelfth-pulse we getting in the single one one cycle so, this is your 12 pulse basically the

case this is lower bridge this is upper bridge at together and we will get it even though sometimes you can draw both on the same here no problem because only you have to find where is a this is the b will be here so, but magnitude will be the same here these 1.5 here you have to go for here the line to line and then you can add together.

Now, the another concern here how this harmonics is going to be different in this case we also, draw what will be the current in the phases I am not talking about the valve current I am more concern about the current in the phase because that will create the harmonics so, if we will draw the current pattern here if your now, we can start the which period which 1 are conducting in this period your 3 and 2 and 3 are conducting here 2 and 3 here 3 and 4 because 4 is coming so, it is 3 and 4 here your 4 and 5 here your 5 and 6 and so, on so, for here 6 and 1 are conducting and again we can go for here 1 and 2 are conducting here 2 and 3 are conducting. So, before here your 1 and 2 are conducting now, once the 3 is given pulse here the phase b current will be this it is going to conduct now, let us, draw for only one phase current it will be symmetrical only the shift will be 1 20 degree so, we can start here because 1 3 is getting pulse the current here through this phase a will be some current here I d so, and it will go all along till 3 is there it will go up to 1 20 degree here because the commutation between 3 and 5 is going to be over. This period is your 1 20 degree now, the commutation is over only 5 is taking so, in the period when 4 and 5 you can see this is going here and coming all the way here this both are off on that condition the current here will be 0. So, this will be 0 up to here up to the 6 now, you see once 6 is getting pulse means here the current is going to be at negative side of the phase and it is coming the below here and I can see it will again go for 120 degree because 6 is there so, it is again this value is your id here and it will be going to again 120 degree then here one and two are there mean one here a and the 2 c. So, the b is again 0, it will be again 0 and we are having this current shift so, this is we are getting the current phase b current here similarly, we can draw for phase a phase b c and it will be simply shifting nothing else. Now, let us, see here that is, more tricky in this case again we have the patterns of conduction here because when your 3 is 3 prime now, it is going to fall means your in this more 2 prime and 3 prime are conducting in this case your 3 and 4 primes are conducting here your 4 and 5 primes are conducting and in this case your 5 prime and 6 primes are conducting.

Now, we can start from here now, you see your the case when 2 prime and 3 prime are conducting means, this current which is coming here to where is it 2 and 3 primes here it is your id because the id is going all the way here the same current is flowing here in this I d because this is a series circuit. So, this id is coming so,rry this I d in the coming here this is 3 and 2 is going to return here so, 2 prime and 3 prime conduction here means this I d is going here and this is your id going here through the 2. Now, we will see this is a here this current is 0 at this time at this point you can see this current is coming here now, there is a two path to come here the current one is through this another through all the way here and then here and then it will be going now, this current id is coming here now, you can say here the two impedances are there here the single impedance are there.

It is divided into according to impendence so, here 2 id by 3 and here it will be id by 3 and it will be going and finally, it will be adding because 3 impedances are there so, it is a 2 come here because here half will be there. Now, you can see the current between the phase b now, I am interested to draw the phase b and it is coming out from the positive terminal which also, we talk here the positive terminal. So, this will be the positive 2 id by 3 when this is the period means during this period when the 2 and 3 are there it is not id completely it is slightly less here and this was your 2 id by 3 now, after that 4 is getting pulse mean 3 and 4 are conducting once 3 and 4 are conducting. Now, you see what happens again the current here it is your id which is going in the 3 and 4 now, it coming here the current your id because this is going here and it was coming all the way here where that 4 here now, this is going now, this 0.

Now, we have to see again the direction of currents here one will be coming here because it is returning and another will be here through again here right so, in this case now, you can see it will be id by 3 here 2 id by 3 and here again it is your id by 3 means it is reduce by half of the previous case so, we are going to have here it is half of this and it is going to be here and again you can see the polarity here is the positive coming out from the that polarity. So, it will be positive now, when 4 5 are there 4 and the 5 means here it is going to be here id and 4 this is 0. Now, so, we can again just analyze here what will be the value of this currents so, this is your this current is going to be here so, your 2 id by 3 will be this now, this you can say here it is going to be reverse of this because this current is coming now, this is here and this is coming all the way here because this current is 0.

Now, it is become negative of the previous 1 and again the magnitude is I d by 3 so, we are going to have here this is a same magnitude and here your up to this it will be conducting so, it is your I d by 3 negative side we have drawn and again if we will go further you'll find it is 2 id by here this is your 2 id then again you can have the here id you'll find then you are going to have again here you are going to have this 1 and here so, we are going to have this current here as well so, we are here the current this is a id by 3 2 id by 3 id by 3 minus id by 3 minus 2 id by 3 minus I d by 3 id by 3 positive your 2. So, this is also, a sinusoidal wave shape is there now, if you're adding here now, you can see at the sometime here it is this positive and is a peak so, it is a highest spike positive some portion even the half of this it is added this much only it was 20 degree it is only for 60 60 degree sometimes it is adding complete this peak is added here.

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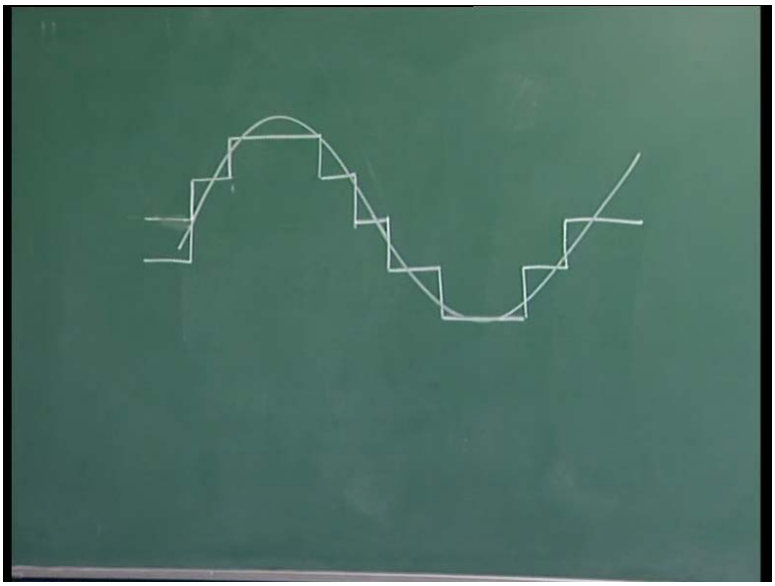

So, it will be peak and if you will go for this adding then what we are getting we are getting this here this period is the highest means this is we are getting this is here and here we are getting the 6-pulses. Again here in the cycle and we will find this will be not there it will be here and you will find this is your perfect sinusoidal this we are going to get the current this is better than the previous one here you can see in this figures we are having the sinusoidal here and the more harmonics are there. Here also, we are having more harmonics so, due to these two additions some of the harmonic is say 5th and 7th are cancel to each other because one will be the positive and another will be the negative

and adding together that will be cancelled out. So, this is basically the twelfth-pulse current and this is only due to the shifting of this is going to take place.

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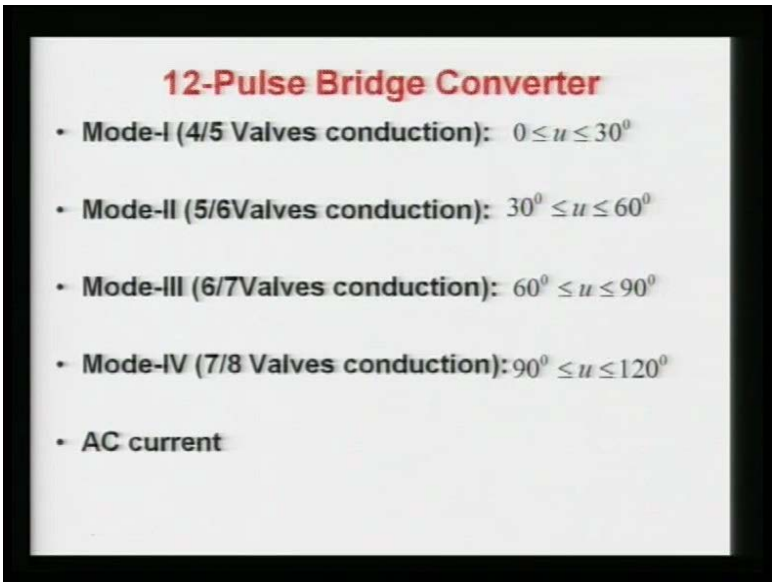

Now, let us, see here in this case now, the previous once we were analyzing only 6-pulse we had basically the two modes.

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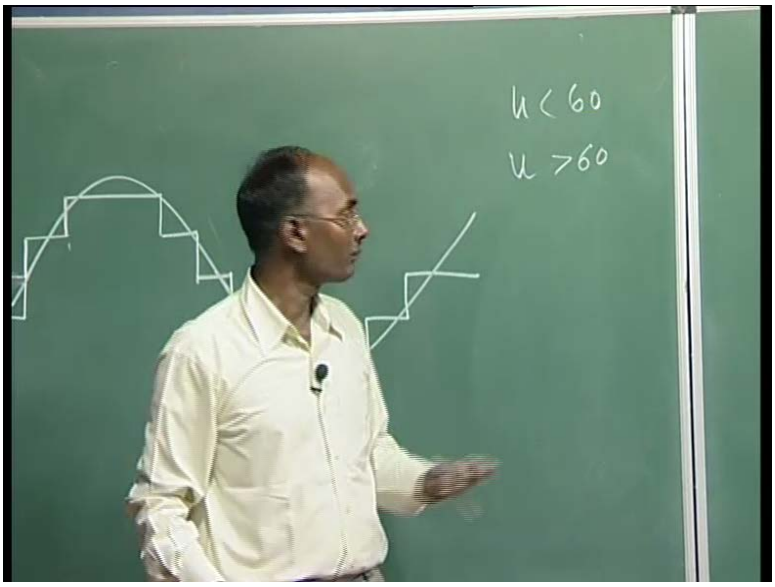

One is if we your u is less than 60 degree or u is greater than 60 degree because in between is another condition .Even though we can define, but when u is 60, but we can differentiate here because here end of this is 3 here starting of this will be thus at the 60 3

we had the two modes. Now, in this case we are having the 4 modes now, instead of u 60 now, u is changing with the 30 because once 30 is there remaining it is 30 shift. So, it is going to act in that way so, when you are having u is less than 30 then you are having 4 and 5 valve conduction means in one bridge it will be the two in another bridge, it will be three sometimes 2. two

Then path will be there of course, and due to this u there'll be some commutation will be occurring in either of bridge so, once u is less than 30 you can see you are here and then if your u is more than that and less than 60 you are going to have 5 6 and so, on so, for and this case when is the dead short circuit again means 8 valve is conducting means 4 valves 4 top on 4 here means is the dead short circuit. So, this is again abnormal condition but here you can say u is less than 30 is also, critical means if it is more than that you are going to have sometimes the 6 valve conduction 3 3 at the same time and the huge voltage reduction is there more over if you will see the current already I explained here to you.

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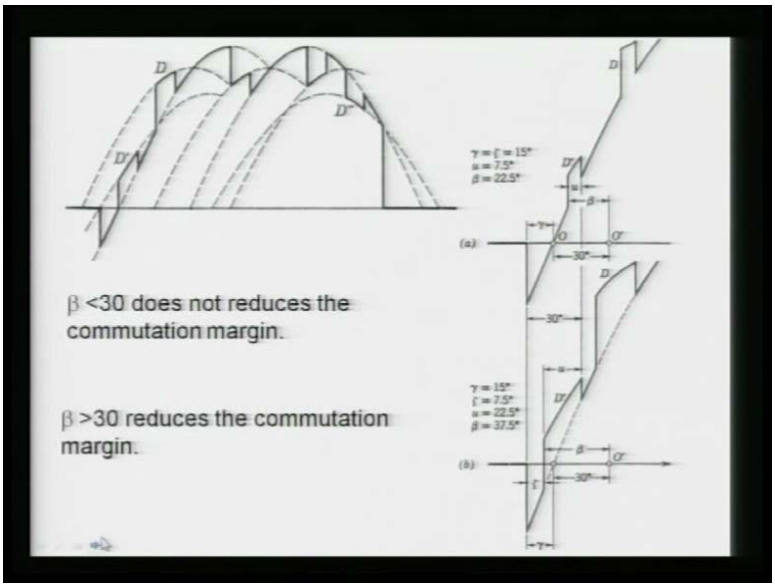

And now, this C D due to this conduction pattern we are having the extra dents here that is, arising for the lower one you see one dent was coming from the top and this was another just deep here it was arising, if the 6-pulses were there now, we are going to add due to that conduction of another effect. We are getting one dent here another here I can say d prime or d double primes are there so, they are going to be added. Now, you can

say if you are operating the twelfth-pulse more now, this is more severe because this is coming earlier to this so, the commutation again becomes very very critical as I said here it can go fall down here very easily and you require u is less than 30 degree.

Here in the 12 mode again, we are very cautious that we should operate your beta here even the beta should be less than 30 degree, if your beta is more than 30 degree in this case as I said here beta is less than 30 degree you are having the gamma is equal to zeta , but if your beta is greater than 30 degree, here you are you see you are here and your gamma is reduced in the figure having zeta so, normally in the12-pulse converter we operate here less than your 30 degree beta in inverter operation. So, with this I can close this the whole wave shape etcetera and the next turn we will just pack about the all these V d and id we will go for the characteristic, this electrical equations purely and then we will see how the operation etcetera can be decided based on the charged. That is, V d and id power power factor etcetera you know, you can say pure electrical we will analyze so, with this I can close this lecture number nine and we will have another lecture on the converter charge on the next turn, thank you.