High voltage DC Transmission

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Module No. # 02

Lecture No. # 08

Analysis of Converter Circuit (3-4 valves Conduction Mode)

So, let us start the lecture number 8 of this module 2 and today, I will discuss about the 3-4 valve conduction specially we will go for the various valves voltages and the output voltages are both Rectification and inverter operation. Then, we will see the how the commutation currently changing from 1 to 3 for all the 3 periods and then later on we derive expression in terms of DC voltage and the current along with the commutation reactance are resistance.

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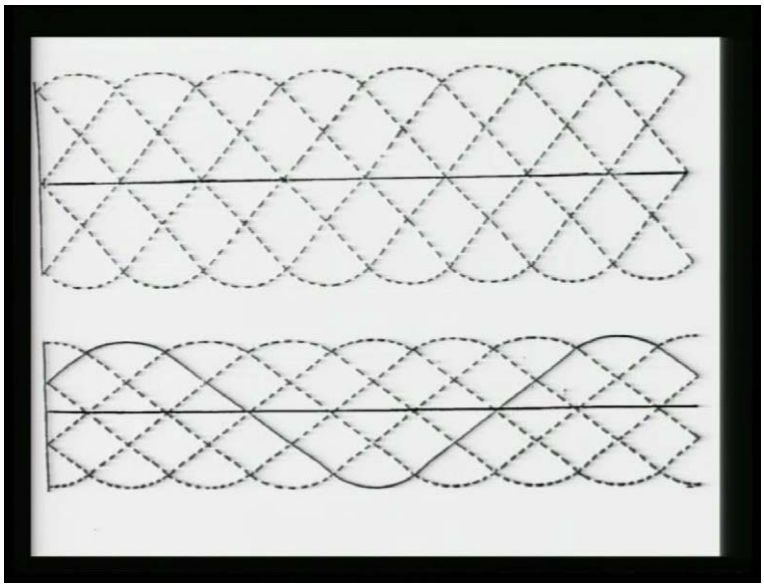

So, the first 1 to draw the valve voltage once your circuit becomes more and more complex means you are going for the 3-4 valve conduction mode or even though you are operating in the 2 3 valves conduction mode, but your alpha is very high and at the same time your this u is also high means you are very near to 2 3 valve conduction mode at

that time the complexity arises. So, it is better to draw a table first and then you will find the table just you can write at what is the Conduction valves.

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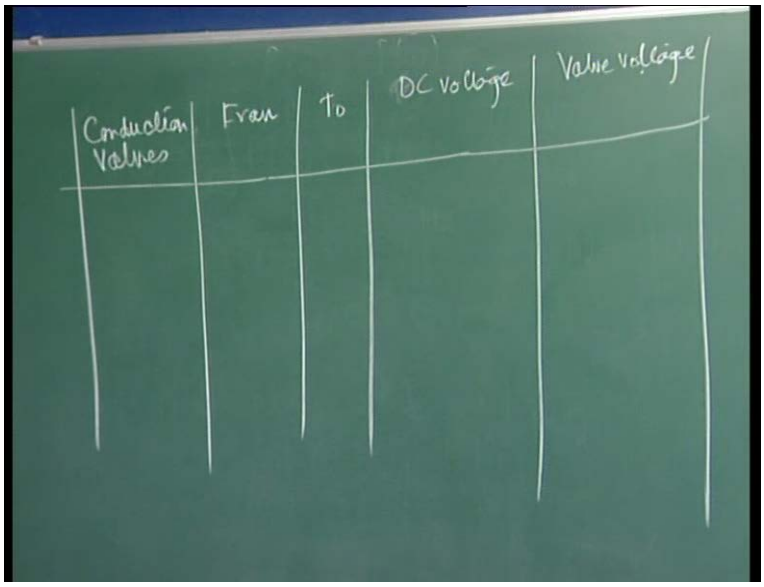

You can write the conduction valves; then you can write the From, To, in angle from then, which angle it will be conducting with period it will from which to which; then, what will be your DC voltage or you can say output DC voltage? Then, if required if you want to draw any valve voltage then you see what will be the valve voltage.

These elements of the table will be very easily and then you have to find and quickly you can mark it. Otherwise, what will happen if you are going for this sinusoidal and then you are saying this is fire and then you going here, there you are again coming back if you are doing any mistakes. So, you will not get the complete output voltage. So, this is valid for all the cases it is whether it is a perfect 2 valves conduction mode or you are going to 2 to 3 valve conduction mode or 3 to 4 conduction mode because, in the 2 to 2 valve conduction mode it was very simple. It drives directly here, but once you are going for 2 3 valve conduction and specially you are going in the inverter operation, even though in 2 3 valve conduction it is required or I can say it is desirable to draw the table and then you find where are you are.

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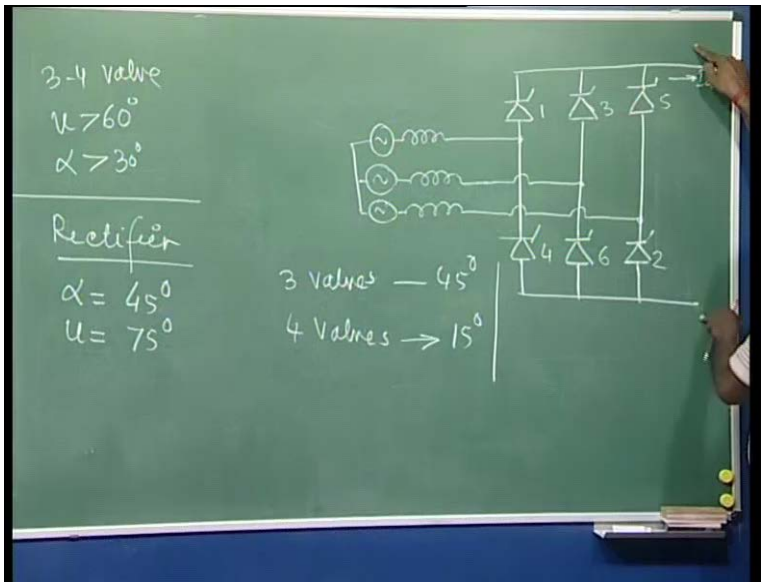

Now, we are here going to discuss again 3 to 4 valve conductions where your u is greater than 60 degree and in this we know alpha should be your greater than these degrees already we proved in the last turn that you must be greater than 30 degree and you're here we are talking about the 3-4 valves conduction mode means your u is greater than 60 degree now, to draw the Rectification operation.

So, first case is I am going to draw for Rectifier and we are going to draw the valve voltage here I want to see it is 3. So, if it is 1 2, whatever just you right this and based on this u can see what would be the voltage. So, you can make this table for complete cycle then go here in the graph and then you can just mark the points and then find the voltages and you can trace it easily now here we are talking about the Rectifier. So, it will be given to you what will be the alpha and what will be your u. So, alpha should be here more than 30 degree. So, let us take alpha is your 45 degree and your u is your 75 degree I making alpha is 45 degree or it is better we can go for the 60 degree also, but let us take this value and then we have to derive.

Now, in this we are going to have a some condition where 3 valves were conducting and sometimes we will have 4 valve where will be conducting now you know what will be the period of this will conduct for u minus 60. So, this will be 15 degree; this u minus 60 15 degree and this pattern is every 60 degree. So, the remaining here it will be your 45 degree. So, we know when about the 3 valves will be coming it will up to 45 degree and

when it is 4 valves then it will go for the 15 degree this is the duration we are taking here the instant we are talking.

Now, here again we are going to start when you are going to give the pulse 2 3you can start from anywhere, but throughout our lecture we have taken the 3 as a just commentating this go image 1 and 2 are conducting in this case 6 1 2 will be conducting and we are giving the gate pulse 2 3 and it is going to conduct. So, in this case also we will start now since I have taken alpha is 45 degree and we are giving the gate pulse 2 3.

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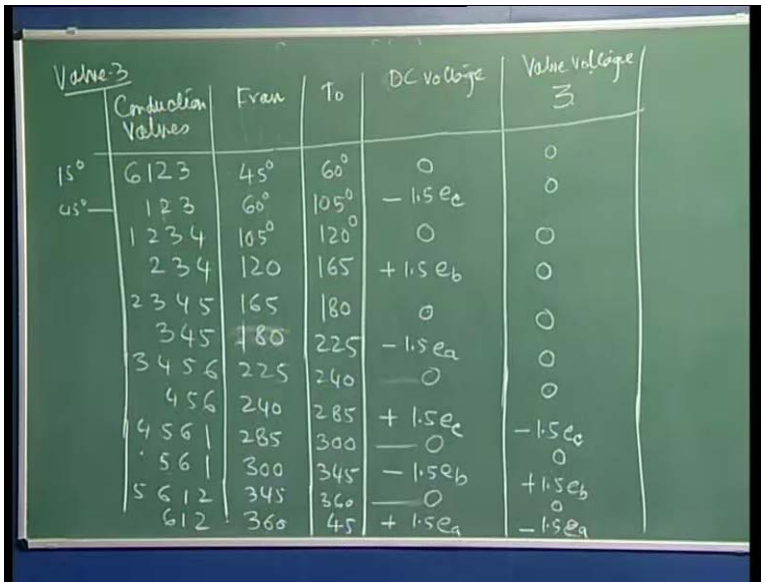

So, here we are starting from 45 degree before that here we are talking the valve 3 is getting pulse. So, this is the case when the valve 3 is getting pulse we are starting from valve 3. So, here now and it will conduct because it is a more than 30 degree. So, here I can say 6 1 2 were conducting earlier.

Now, 3 is going to conduct it is, we are starting from here the 45 degree alpha is direct and here now, earlier the 6 1 2 were there; now the 3 got a pulse and the positive voltage is arising. It will conduct now this will go for 15 degree. So, here it will be up to 60 degree because the 4 valve conduction mode. So, from 45 this and your output voltage will be 0 because always in the 4 valve it is at the DC our circuit and it is 0 valve 3 we are since conducting. So, it will be also 0.

Now, this will go only up to 60; at the 60th instant here, this will be your commutation between 6 and 2 will take place and the 6 will off. Now, 1 2 1 2 3 will be there and now it will go for 45 degree at this here you are going to 105 degree and now, what is the DC voltage in the DC voltage now you have to see what is the DC voltage even though this 1 2 and 3 are conducting it is the similar to even the 2 and 3 valve conduction and the 3 valves were at that time. So, it will be the same voltage and just you can see from this graph simply you can say 1 9 3 at that top. So, it will be a and b here. It will be minus c and this is minus c to 1.5 here minus 1.5 e c will be appearing from there also. You can justify it because, for this at least I can explain 1 and 3 are conducting. So, voltage here a e, here e b. So, the total here minus e c by 2 and this is 2 is here. It is your minus e c by 2 minus e c it is 1.5 e c which I have written here and of course, 3 is conducting it will be 0 now then we can write all the here the patterns tell will arrive again back to here then it will be a complete cycle. So, here now the 4 will get the pulse. So, 1 2 3 4 then we can write 2 3 4 then I can write 2 3 4 5. Then, we will have 3 4 5; then again we are having 3 4 5 6 here we are going to 4 5 6 here 4 5 6 1 here we are going to be 5 6 1 then we are going to 5 6 1 2 and then here 6 1 2 and from here again we are back to here it is.

Now, since the end of this here period will be the starting period of this. Here it will be 105 once again you must be very careful in adding the angles means they are this is a 45 degree. Suppose you are doing any mistake here anywhere here it will be continuously going to be recurring and then finally, you will get something absurd output voltage. So, 105 here now this will go for 15 degree because always it says the duration of this is your 15 degree and this duration is your 45 degree we have already written there. So,. So, now, you add here the 15 degree means 1 20 degree and the voltage will be 0 and here it will be also 0 because 3 is still there.

So, you can now continuously you can write and see what we are going to get. So, here it is 120 then it is your 45. So, 165 I can write 165 here then 15 it is 1 80 here we are going to get 1 we are going to add 45 here. So, it is a 225, sorry, it is 1 80 to we are adding 225 here 225 to add 15 degree and then it will be 2 40 and here from 2 40 to 285 and from 2 80- 5 to here you are adding this is 300 and from here 300 to we are going to here 300 45 and from here 345-50 it is a 360 and where there is any mistake. So, it is 360-45 degree again we are back here or you can add here that is a here 45 degree because this is 0 and again you are going to that. So, we are just coming back and finally, we are getting. You

can see also from if you are doing any mistake you can see if you are not getting 360 degree means there is some problem somewhere.

Now, let us see the voltage it is again how to draw here the 3 valves. So, all the 4th here will be 0. So, I can write here 0 or put voltage we are writing here it will be 0 here 0 here it will be 0.

Now, in 2 3 4 you can see it is a 2 and 4 are the bottom. So, this is a c here a. So, b and this is b. So, here plus 1.5 e b now you can see here this is a 3 and 5. So, it is a minus ea and here. So, it is a minus 1.5 ea. So, here it will be plus you can also see we are getting some symmetricity so plus and minus this is there and you can see it is c b a and again we are going to get the here 4 5. So, it is your 5 is c. So, it is 1.5 e c here minus 1.5 e b and here plus 1.5 e a and then again this is.

To see the valve voltage again now we have to see 3 is here is conducting. So, it will be 0 here these 3 is also there then it is 0 here 3 is there. So, it is 0 here 3 is there then it is again 0 now at this case 3 is off and now we have to see the voltage now here 4 5 6 you see they are conducting means the voltage and 5 is there. So, what will be voltage here you see the 4 and 6 are conducting. So, the voltage here is becoming minus e c by 2 and this side is e c is appearing. So, this voltage minus this; minus 1.5 e c; here it is minus 1.5 e c.

Now, when 5 6 1 are conducting what will be voltage it will be dead short circuit here voltage here will be 0 because whenever the 4 valve is dead short circuits here almost short circuit the voltage here it will be 0. It will be 0 here at this point now we have to see here because the DC short circuit is just you can say this is a b c phases are short circuited all the 3 phases here. So, what will be voltage here there is no voltage it will be 0 now we will see 5 6 1 what will be voltage now the short circuit is removed and 5 6 1 here means here is the e b and here it is your already it is your e b by 2 1.5 e b. So, you can see what we are getting just opposite to this. So, here plus 1.5 e b here 0 here I can say 1.5 e a just check it.

This table is very convenient to draw and this is the best way I can tell you otherwise if you are always you are just you are starting from here without drawing here you are gone.

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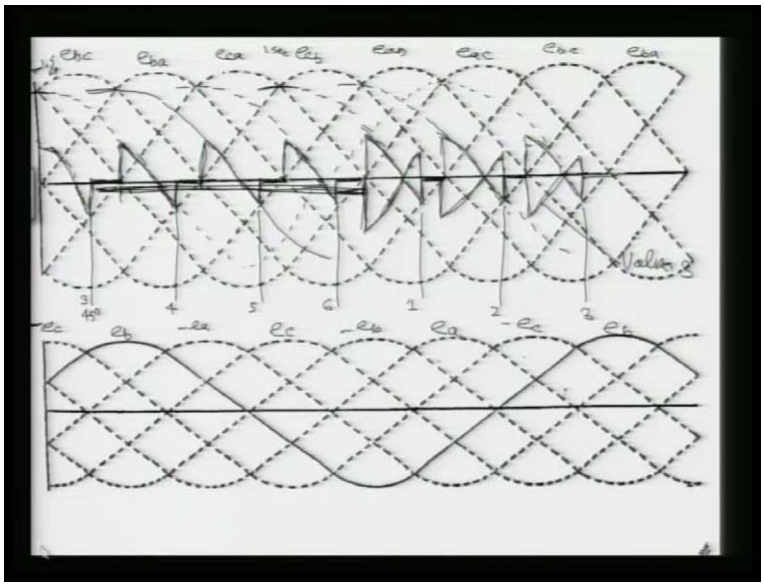

Now, let us see and draw for this case on this graph and where we are getting. So, to draw the output voltage and as well as the voltages at last any of the valve we have to draw the line voltage on the graph and here we are talking since we are starting with this 3. So, the commutation voltage are 3 just it is e b a and then, we have to write other phase or voltages here the line to line again it is c b here it is your e a c and again we are going for e b a here now we can see this is e b a. So, it is your a b just reverse of this here it is your reversal of this. So, e c a here it will be your e b c and the remaining here we are getting here e b c and this is a complete line to line voltage.

Based on this line voltage, we can below on figure can be represented as your phase or voltages and this is your e b this 1 is your e c this 1 is your e a this 1 is your again e b means your this is your minus ea this 1 is your minus e b and this 1 is your minus e c and this curve is your again here it is correct it is correct here and minus ea here we are getting this e c why it is drawn that is just will see the intersection of this 1 is this. So, the voltage here it will be appear 1.5 of e b you can see it is in phase with this here if it is voltage and here it will be we can see is the voltage will be 1.5 e b here.

Now, we have to mark the angles I said alpha is 45 degree and you know this here it is 60. So, in between here it is your 30 and then in between here it is your 45 degree. So, this will be your here I can say it is your 45 degree and here your valve 3 is getting pulse.

Now, after that here you see the output voltage becomes 0. So, we are starting here the output voltage here is going to be 0 far 15 degree and the 15 is up to here. So, it is means this is your 60 this is your just you how can mark and then it is your the output voltage here it is here first it is 0 as already you can see we are drawing here first the output voltage the DC output instantaneous voltage here. So, here it is 0; now we will see after that we are going to search for 1.5 e c that is the minus sign and this will be where is that it is a several way we can find this is the here it is a 1.5 e c you can also see here the minus of we are searching minus here this will be minus sorry no this is a minus you see. So, this will be here it will be coming here all the way to in between there is a 30 degree phase shift and this will go like this. here, now the voltage is going to be this value is your minus 1.5 e c. So, what happen suddenly the voltage will go here and it will follow this 1 when the commutation is basically between 2 and 6 is over.

Suddenly, here it was I said it is your 15 degree it is when the your 6 1 2 3 are conducting. So, after that here commutation of the lower length is gone of. So, it is suddenly following this is a minus 1.5 e c then it will continue and then we have to find another after 60 degree because this will go for 45 degree. So, the 45 degree here this was 30 degree. So, it will go up to here and this is your output voltage up to this period because this is the complete each your 60 degree. So, here it is always this portion we are here is a 60 degree. So, this is 30 degree and this is remaining 15 degree it will conduct. So, it is a 45 degree and it is going to be here as a said 3 valves are there now we are giving pulse to 4.

We can also see from here onwards it is going to be 60 degree and here basically your valve 4 is being given pulse then your output voltage becomes again 0 and here this we are coming here and this will go for 15 degree.

Now, once this will go up to here 15 degree now this is a commutation between your we have reached here 4 is given the commutation between your 1 and 4 it is over and now we are having 2 3-4 and then we have to see the voltage and that voltage is 1.5 e b and you see this 1.5 e b is nothing, but it is going all the way here. So, it will be here it will be coming here the voltage and then it will follow this one and it will again go for 45 degree here till this value.

Where it is we are giving this pulse to 5 and once you are giving this then voltage here become 0 for 15 degree now then again we have to see in this commutation between that is over here the commutation between your 2 and 4 is over we are having 3 4 5 and then already I said this here this we are going to have the voltage output voltage then is output voltage is 1 minus 1.5 ea and this will be your nothing, but here.

So, we are going to have this suddenly and finally, it will go for 45 degree here till this value where we are giving the pulse 6 once pulse 6 is given then we are getting again here this will be 0 for 15 degree and then it will be you can see again we are the voltage here it is your plus e c. So, it will be here and then it is coming to be your this 1 and then again here we are giving pulsed to 1 and then it will be 0 here and again I can see your output voltage will be like this will be here it will be drawn. So, it will be a output voltage here and then again it will be going like this then it is 0 here we are giving the pulse to 2 and then we can comeback this side because of the 2 will be there and then again it will follow here the voltage like this and here the 3 is given the pulse and it is 0. So, you can see it is again we are coming back here 3 where before that it was conducting your this case. So, your voltage was like this and we were getting this output voltage.

This is you can see the symmetrical DC output voltage in the case of Rectifier. So, you can see the 0 and the always you are getting. So, even though this is a simpler than 2 3 valve conduction mode because there are. So, many dents are appearing. So, the voltage slave sheds are even the is here you can say most of the here is the 0 or you are getting 1.5 times of age voltage, but in 2 3 valve conduction even though that pattern. So, many patterns we are getting sometimes dent sometimes even though different types of jerks were there.

Now, to draw here the valve voltage you can say most of the time is 0 why during 3 values it is not 0 otherwise it is 0. So, we can start further drawing the a valve voltage means here I can just draw just below line this will be the valve voltage I can say though it will go up to when your this 4 5 6 means 6 is getting pulse and then still it is going. So, it will be going up to the 6 here and it will be up to this point. So, up to this point the value will be 0.

Then suddenly, here you can see it is the reverse of this here it is negative just below just below. So, whatever you were having here it was this value will be going this. So, you are having this voltage and it is going to follow this 1 and it will go up to this portion and then again it will be 0. So, it is 0 then we are going to have another 1 this is again opposite to this here opposite to do this as means we are going to have here this value again we are getting here and it is going to be 0 and here we are getting here 0 and the finally, this 1. So, this is your valve voltage since here the color we cannot show. So, basically it is here you can say. So, this is your valve valve 3 voltage and the upper portion is your DC output voltage. So, it is a simpler to draw. So, this table is very helpful especially if you are drawing the inverter operation at that time this angle because we are shifting angle far off because this is here we are starting now we are starting at the somewhere here. So, everything mixed up. This was the case for your Rectification operation. Now, here we can go for another one case; we can go for the inverter operation.

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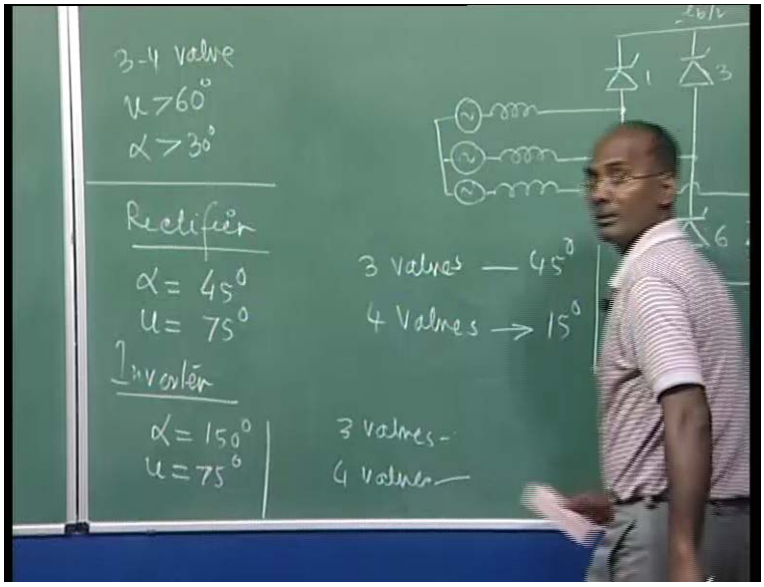

In inverter here I can here in inverter this will get the different shape you can say in the Rectification even though it is the 45 degree and you use this output voltage is the very near to 0, but now if you are going in where some what will happen the voltage going to be more and more negative.

So, in inverter operation let us take alpha is your 1 50 degree and your u is we can keep 75 degree and then we have to start here. Here, this will be changed in this case what happens your 3 valve and 4 valves this is your again 15 degree and this is again it is a 45 degree now we can write clearly this what will be the voltages and what will be your angles we can just draw here in this table and since the pattern will be the same and we are going to draw for 1 cycle. So, this we can keep in tight.

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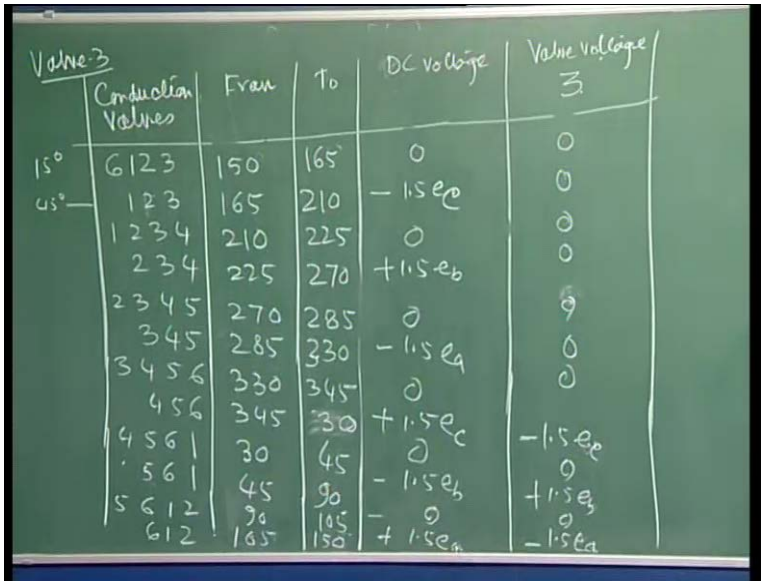

So, now here we are going for alpha 150 degree we are starting from 150 degree and then we are keep on going to add. So, this is 165 what will be output voltage it will be 0 because 4 valve always will be 0. So, it will be 165 then it will be your 2 ten here we are going to have 2 10 to it is 225 then it is 225. So, we are going to have 270 just check it whether we are going in this right direction or not. So, 285 here from 285 plus add 45. So, it is 233 330. So, we are going to 3 30 then 15 3-45 then we are going to have 345 to 3 90 or we can go back and then we can see or here because this is a 360 plus 90 degree. So, I can say simply it is 30 degree because after 360 again we are going to back here. Here, from 30 now we can add this a 45 degree and from 45 to here 45 it is 90 degree and from 90 here is 105 and from 105 we are having 1 50 degree you can see we have reached here again.

So, we can write the output voltage here whenever we are having 4 valve conduction it will be 0 it will be 0 it will be 0 it will be 0 it will be 0 here. Now, when 1 2 and 3 are

conducting then your voltage will be again same voltage because it is not going to change only we will see that voltage will be delayed and the output voltage will be negative side. Here, whatever if we wrote it will be the same here it is what we wrote here it is a plus 1.5 e b here 1.5 e c here minus 1.5 ea here if we wrote 1.5 e c here it is 1.5 e b here plus 1.5 ea and the voltages here this is a 3 we are drawing 0 0 till it will be here it is a 0 now only once we are here then voltage will be here minus 1.5 e c here it Id 0 plus 1.5 it is your e b here 0 minus 1.5 e a. So, with this inverter operation let us draw and you see that we are getting the something different output voltage here it is and let us see for this case as well.

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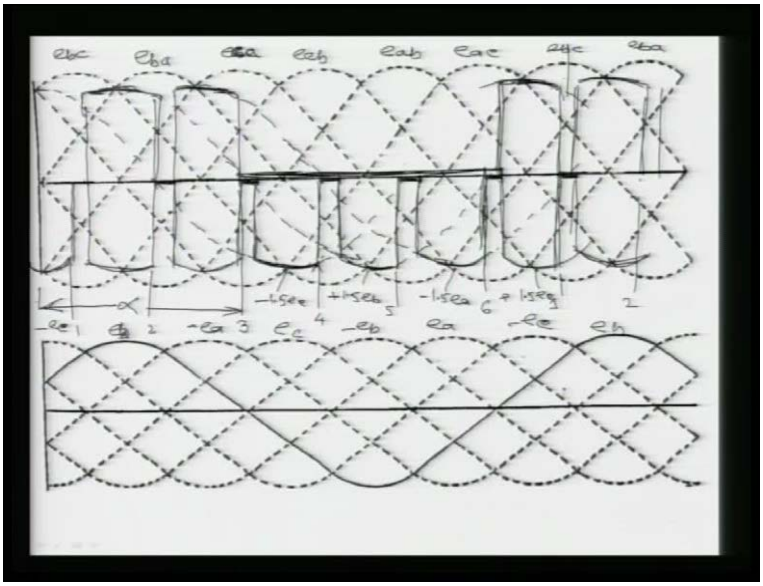

Here, again we have to mark here line to line voltages and the line to voltages here I just I am starting here e b a here I can write e c b here I can write e a c here I can write e b c it is e c e c sorry it is e c a here it is e b c and here it is a b here and here we are getting e b c and here we are getting e b a these are again ea e b sorry here we are getting e c here it is your ea here it is your e b again means here we are getting minus ea; here it is what it is a minus a b; here we are getting minus ac and here this is your minus ac. Once we have mark the figure the below figure we have marking the phase voltages and here we are drawing the line to line voltage and now for this case, we can draw our this inverter output voltage.

We are starting from here again, angle here and we are going up to 1 50 degree alpha is delayed you see your this is your 150 each somewhere here just see here your this is your alpha because we are having this 20 here 60 60 degree this is a complete e b a is the commutation voltage of valve 3 this is 60 this is 60 1 20 and this is a 60 then 1 80 half of this is 30; 150 degree. So, valve 3 is given the gate pulse here and then it will conduct because the voltage across the outgoing valve means this will be positive. So, we are giving here valve 3 voltage once we are giving valve 3 then we have to see where is your 1.5 e c 1.5 e c was somewhere here it was starting and it was here 1.5 here and it is going all the way here.

So, once it is 3 it is given pulse the output voltage will be 0 and it will go for 15 degree here because I said it is a 15 degree here it is 0. So, the 15 here it will go up to this half of this. So, it will be 0 and then it will be once the commutation is over between 6 and 2. So, output voltage will be 1 2 3 and we will going to have our output voltage here suddenly here. So, once the 3 here as I said the gate pulse is given. So, it will conduct at 150 degree because the voltage across this is positive and then it will go up to 15 degrees and the 4 valves are conducting that is 6 1 2 3 and there will be after 15 degree this there is a commutation between 6 and 2 is over then 1 2 3 will be conducting and the output voltage will be here this is your it will go and now it will go for 45 degree now 45 you can see this was the 15 degree here and the 30 degree here. So, it will go up to this portion here where we are giving the pulse to valve 4 and this will be your output voltage.

Now, once we are giving the gate pulse to 4 output becomes 0 and then it will go back again 0 here and this will be 0 for 15 degree then the commutation here is over between your 1 and 3 now the 2 3-4 will be conducting and the output voltage will be suddenly it will be your 1.5 here we are here 1.5 e b and we have to see 1.5 e b the positive one will be your it is going all the way here. So, it will be coming suddenly here and then it will follow this is your and again it will be up to 45 degree when here this is your it will be your gate valve 5 will be given the gate pulse.

Once 5 is there then the 5 4 valves will be conducting that is your 2 3 4 5 and the output voltage will be 0 for 15 degree again here because the 4 valves are there then it will be the commutation is over between your 3 and 5 ah 4 and 2 is over because 2 is going. So, we are having 3 4 5 and the output voltage is 1.5 minus 1.5 a and you will find this is

here and this is your voltage that is going all the way here and we are going to have this 1. So, it will follow suddenly here means this voltage is 1.5 e b that is a plus and this voltage here is minus 1.5 e c and here we are going to have this and this voltage is your 1.5 ea is minus voltage here and then we are giving the gate pulse at this point to your 6 and then this will be 0 here and it will go for 15 degree again. So, we are going to have a very symmetrical pattern in the inverter operation as well and now here the output voltage will be here it will be coming all the way here then it will go up to this where 1 is given gate pulse and then it will be again going to be 0 then the voltage here will be again here.

So, you can see this is your inverter output voltage and you can say mostly it is a negative side similarly we can feel this side also and we are going to have here it will be going up to this then it is going up to this period just we have to mark here and then we will find it is coming all the way here then this is 0 up to this portion and then again we are getting this output voltage here we are also getting this and here we are again getting this output voltage. This is your inverter you can see this is more negative even those alpha you can see here the beta is 30 degree and in 30 degree you can see it is highly negative. So, the inverter voltage is basically increasing, but your Rectifier voltage is decreasing. So, both are same thing and you can see this is your valve output voltage this is not valve this is a DC output voltage of this and valve voltage as I said most of the time it is 0. So, it well be 0 and there whenever it is there it is just output negative of the output voltage. So, I can draw the output voltage valve output voltage here directly and again we can start from here that is a 3 and it is going all the way up to when the 6 is getting pulse means it is going to be 0 here up to this is valve voltage and when even though 2 3-4 6 are conducting it is 0. So, it will be going up to this portion as well.

Now, means I draw up to here when 3 4 5th because 6 is getting pulse and for this duration again this 3 is there because the commutation between 3 and 3 and 5 is over now. So, we have reached up to here now we will find 1.5 e c the positive side here you will find this is your this will be I can again write here what is this value this value is your plus 1.5 ac. So, voltage will be somewhere it is a just reverse up this we are having this is a minus ac you can just see. So, it will be following here and it will be going up to this when it is. So, this is your valve voltage.

Once it is again here it is 0 then we are going to follow another 1 and here again it is your valve voltage it is going and the finally, again it is here 0 then we can come this side because before that here it was 0 now is the 3 here it is your 2 here it is your 1. So, we have gone even though the 6 we will find up to 6 then 1 and we can again the repeat this curly and then will find this what will be the output voltage. We are having the 3 output voltages here and again then we are repeating here because even though 1 is given though 3 is 0. So, 1 is given though 3 is 0 of course,. So, we can get the output voltage even though far here it will be 0 here again. So, means it is 1 here it is your 2. So, you can see your just above 1 we are going to have this output voltage. So, 1 is fire. So, this is 0. So, we are going to have basically this side also we can repeat here it is 0 and then again here we are getting this output voltage.

So, you can say one is starting here means 3 output pulses here in this cycle we are getting means in the complete cycle here again just a one is coming here means we have reached here and then we are having 3 and already here you can see the output voltages are 3 times they are under many time it is all the way 0. So, this is valve voltage which is appearing across the valve 3 similarly you can draw for other as well. Well, now let us go for here to calculate the current in the during the different here you can see the 3 it is going to be different fashions here.

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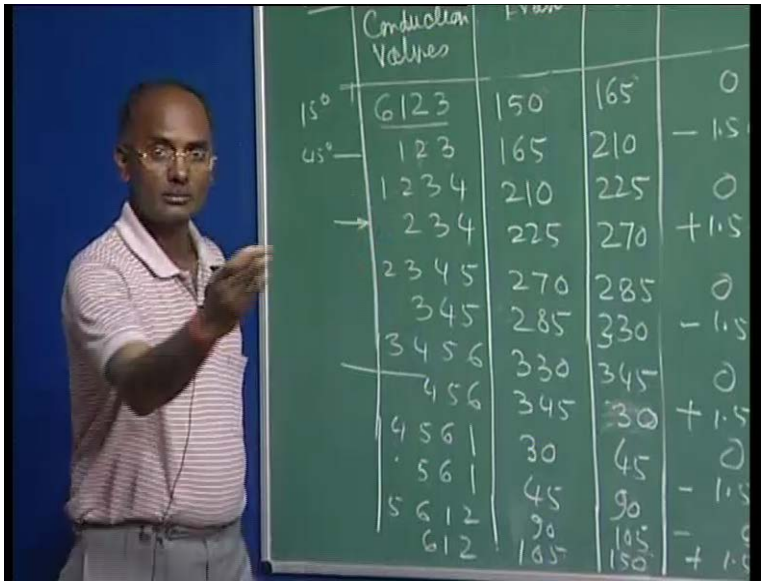

The 3 is coming all the way up to here from starting from here. So, here the commutation between 1 and 3 is taking place here also 1 and 3 here also 1 and 3 and now it is over. So, at this point once it is starting here the current in the 3 is going to be complete id because this 3 is only on the upper limb. So, the complete current the valve 3 is taking. So, we can see they are before that before that here again 1 was carrying the complete current. So, we are having the 3 the modes this condition this condition and this condition where the commutation is taking place means the 3 intervals are where the different scenarios are there and based on that we have to derive this what is the current how from 1 2 3 is shifting in all these 3 no doubt you can see this is going for the 15 degree or again it depends upon what your u and other values and we can just start with this. So, to have this here now I have similarly, here you can see I have written that is your this period now we are not going for any either Rectifier or even your converter Rectification operation or inverter here simply we can now we can see starting with the general expression we are drawing.

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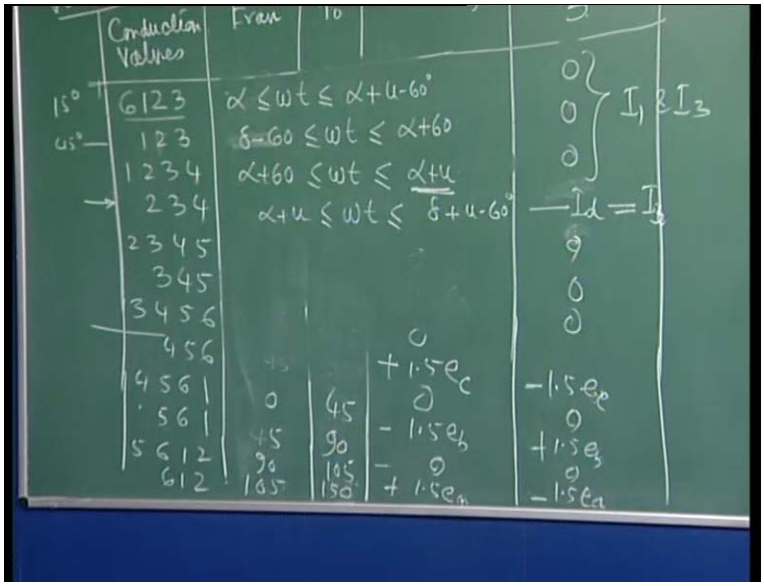

So, I can say this is starting alpha to your omega t to your certain value and this value was you it is a alpha plus u minus 60 degree. So, it is your u minus 60 degree will be there means you can just subtract this minus this that is the degree that is the 15 degree we also calculated So, this will be the phase when 6 1 2 3 will be there. Now, this phase will start your alpha plus u alpha plus u all the time we know it is delta we defined this alpha plus u as a delta. I can write the delta here or you can start with the alpha plus u no

problem. So, it is minus 60 here this will be the current will change and now it will go for alpha plus 60 because the total duration here is the 60 degree.

Now, this phase is your alpha plus 60 omega t here again we are going to have this we are going to add alpha plus u that is all because this period is your u minus just simply add u minus 60. So, this will be alpha plus u and here. Then of course, we are going to have alpha plus u we are again repeating basically and your omega t here this is your you add just delta plus your u minus 60 means our concern here because, this is at this end of this period here this 3 is going to take complete id means here this your complete I d is equal to your I 3 during this 1 it is a shared by I 1 and I 3 I 1 is the valve 1 and the I 3 is valve 3. So, this is the diagram and already the different the commutation period here is written.

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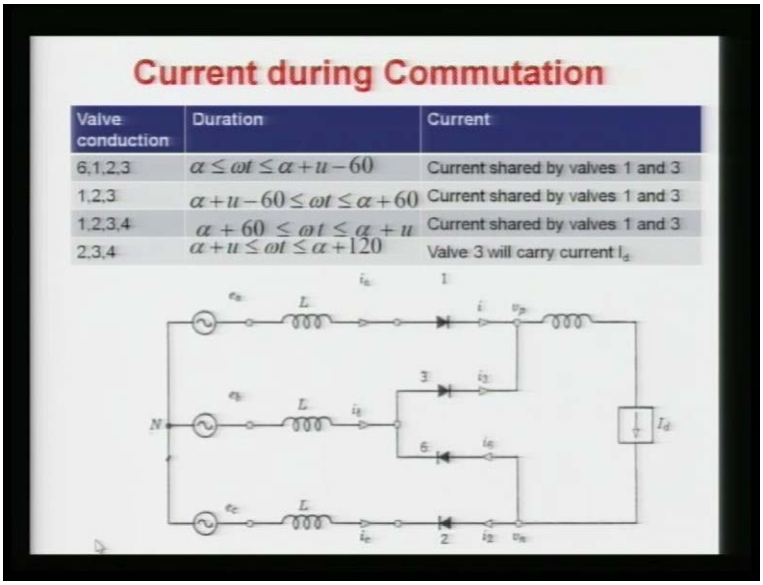

So, who is sharing and this is the case. Now, we are going to analyze this case first means this is the case when you can say your 6 1 2 and 3 are conducting only here you can see the current between this and this here you can apply the Kirchhoff's law. So, this current which is coming here it is and plus this will be this current; however, the current here in the phase will be equal to the valve phase current here the current here will be the negative of this valve 2 current because we are assuming the currents are coming all the phases this i a i b i c. To start with we can from this circuit we can write the voltage equation that is always valid the voltage equation here ea minus L d i upon d t will be

equal to this e b minus L d i b upon d t and this will be equal to this voltage because during this it is 0. So, this is all 3 are the parallel.

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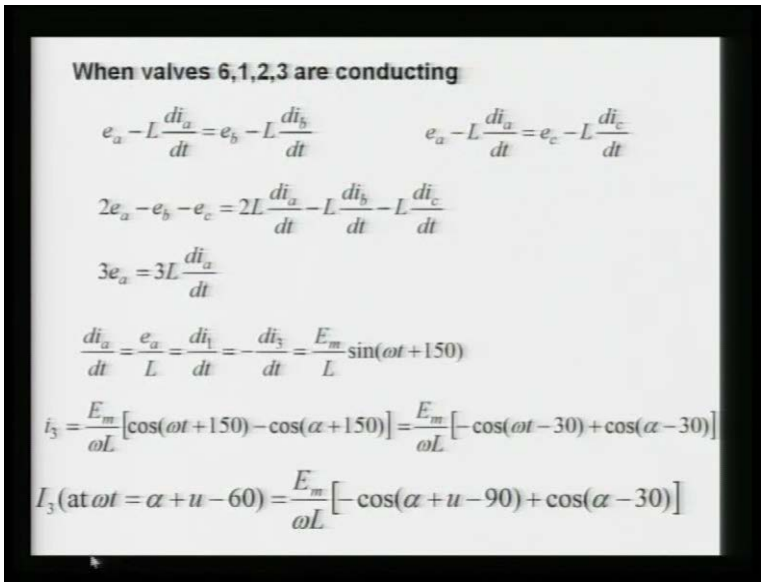

The mathematical equation we can write like this here I wrote the parallel equation here this ea minus L d i a upon d t will be equal to your e b L d i by d b d i b upon d t and similarly we can say the phase a side will be equal to phase c side just add these 2 equations we are going to get this once we are getting this we can substitute here. So, this is equal to your plus ea because minus e b minus e c is plus e b. So, it is 3 here we are adding because it is a 2 L d i by d t here again you are writing you are getting 3 L d i a upon d t and finally, we are getting the d i a d t is equal to nothing, but it is the valve 1 current and we know this valve 1 current and the valve 3 current addition of this is all the time it is I d.

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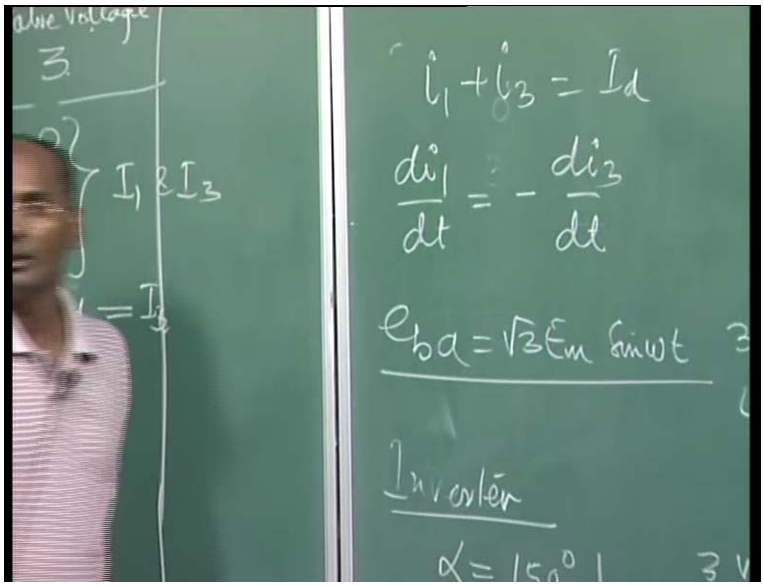

Again here, we can this using this relation that is your i 1 plus i 3 is your I d all the time. So, here again I can say i 1 over d t will be equal to minus d i 3 by d t small quantities I am writing because is a instantaneous right now.

So, here I have written this relation here and this is equal to your e a and e a again we are writing because our reference was e b a based on that here means it is your under root 3 E m sign omega t based on this we can write the voltage e a e a will be this to draw this the voltage sometimes suppose you do not want to remember here.

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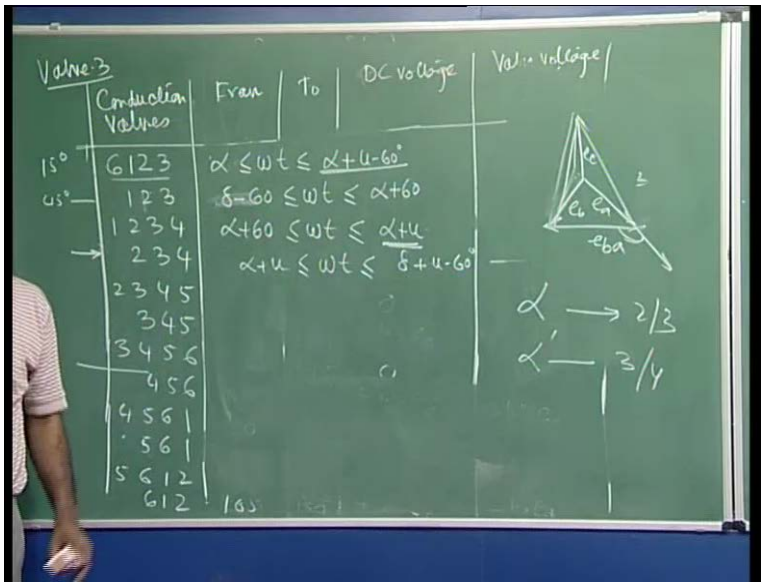

Just I said, we took this is your we are taking this is e this is your e b a if you remember because this is your here simply draw this is your it is not very nice curve, but still we can draw this is your this. So, this is your e b here it is your e c. So, this angle here it is going to extended. So, this angle is 150 degree and that is why it is written omega t 1 50 and since it is a leading. So, it is the pasting because this is just behind with the e b a.

So, I wrote this and now you can write with this expression you can just simply integrate and you can get I 3 now here this I 3 is your expression we are getting now this period is between these period. So, using this period here you can see this is the general expression with omega and now this we can write this expression with omega d we have derived starting from here to your omega d here means you can see simply it is a sign, is integrated. So, it will be cosine with the minus sign but this minus going to be positive. So, it is a Cos omega t plus 1 50 degree minus Cos alpha because we are integrating from alpha to omega t.

So, here we are getting Cos alpha plus 1 50 degree this can be again changed because the 50 is equal and to this you can write there is the minus omega t minus 30 degree. So, here I have written with the minus and this minus becomes positive we can write here in alpha why I am writing here because if you see this output voltage was in terms of Cos alpha minus 30 and also the delta it was plus 30. So, this we will see it is nothing, but alpha prime alpha prime is equivalent when we are going alpha when I am using the 2 3 valve conduction then alpha prime it is your 3-4 valve conduction. So, we are going to have the similar expressions.

So, this is I 3 now at the end of this here this phase now we are coming here. So, end if you are putting value here omega t is equal to this will be the starting current of this. So, that is why here it is written if at omega t is equal to alpha plus u minus 60 here this will be the initial current of this and then we have to integrate for this period. So, here I 3 here at this period just put this value you are going to get this expression. So, this is the case when 1 6 1 2 3 are conducting.

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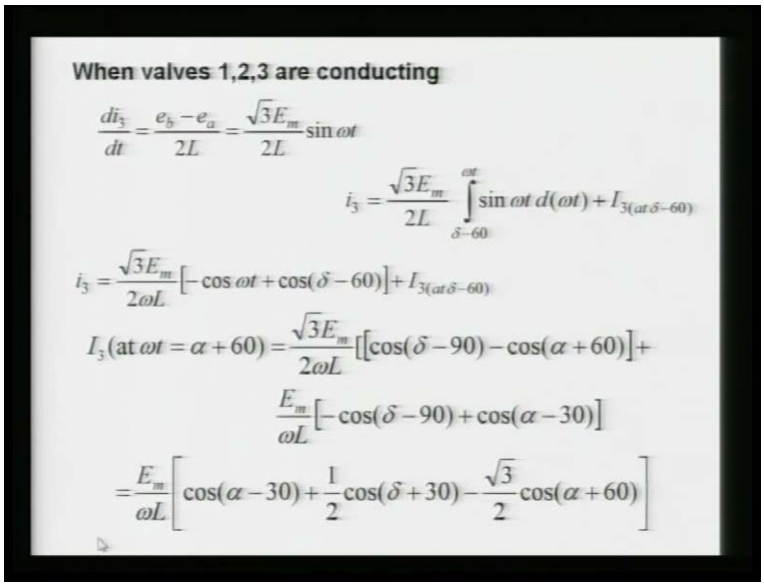

Now, next phase is your here when as a set here 1 2 3 are conducting this is starting from here to here this is the similar when we derived the commutation between 1 and 1 and 3 for the 2 3 valve conduction mode this no change only the period is shifted and the during this period it is following the same expression and we derived here we are getting this say e b a upon 2 L at that case. So, you are going to integrated this I 3 if you are going to get I 3 means you have to integrate from the initial value of this to this some omega t and we are adding plus I 3 because this I 3 here was flowing the beginning. So, the integration the initial current is going to be added. So, this I 3 we are adding and then this is a normal expression for this mode.

So, here if we are simplifying and putting this value from the previous 1 and simplifying here all the way you will find you are going to get the current this and again.

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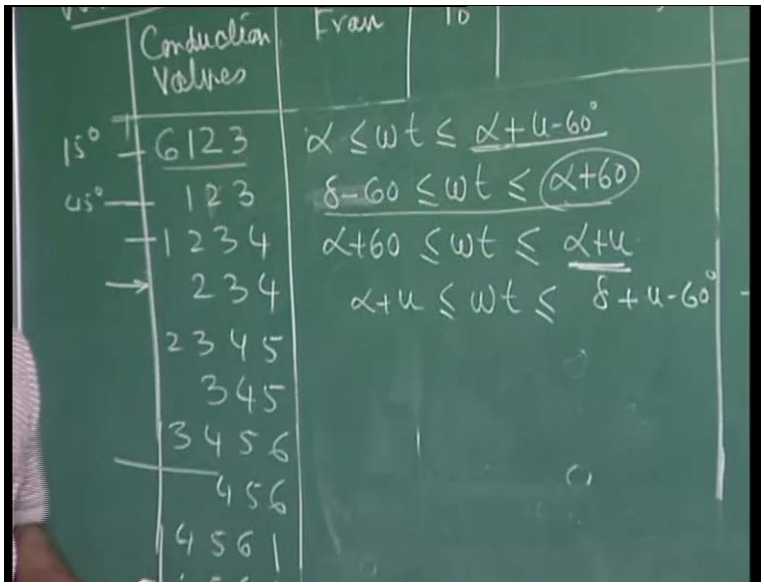

I want to know what will be the current at this value because that will be the initial current for this base. So, the initial current for this will be at this point you just put this value then and add it here you are driving the expression you are adding here after that you are getting that current here that will be the initial current of this phase means we are having the 3 stages the commutation is taking place and if you are putting this value you are going to simplify; you are getting this I 3 at this point.

So, it is you are getting now you can see we are getting alpha Cos alpha minus 30 plus half of the Cos delta plus 30 these are the expressions we were getting in the output voltage as well means is alpha minus 30 and here the delta plus 30. We are getting another term minus under root 3 by 2 Cos alpha plus 60 here in this case and, but here will see the magnitude also change when we are talking in the 2 3 valve conduction mode the commutation here it was basically under root 3 E m upon 2 omega all it was coming.

We will just for next phase here, as I say, it is a initial voltage here and it is 1 2 3 4 are conducting in this case again now you cannot take this expression because if you will see in this case, what is happening?

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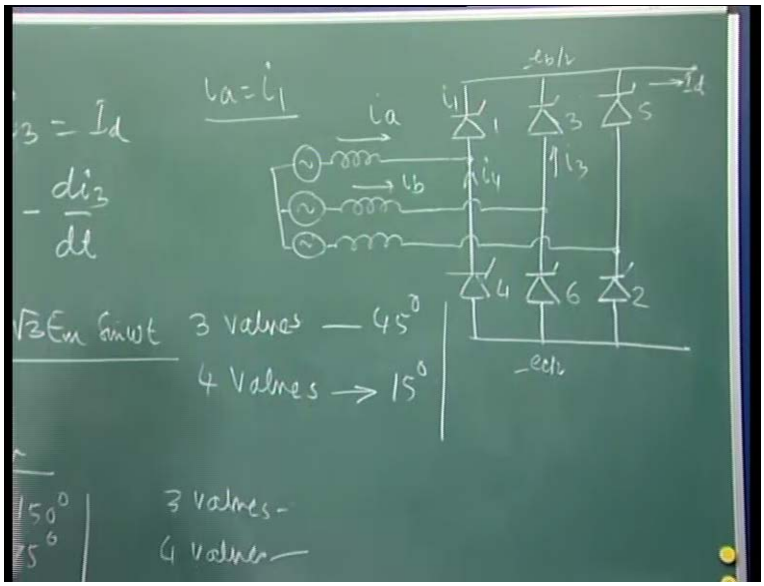

The current here your here this 4 and here a are there sharing means, at that point what is happening, the current which is flowing here is I a it is your I 1. This is also conducting this is giving your I 4 current. So, what happens here? In the previous case, we took this if you remember I a is equal to it was I 1. In that case, it was the case in the first phase here because, it was only 1 was there and thus complete is the phase was current. So, this at that time it was not conducting. So, this current was equal to this current, but now in this phase it is not true here because this is basically the here again Kirchhoff's current law applies.

So, what we will do? We will see which is very clear and you will find this in this case here this your current here I b it is your going to be here I 3 it will be equal because 6 is not conducting. We have to change our formulation that is why earlier we will see I was talking here e a e b here now I have change from e b and e c earlier it was e a. So, what we will do we will derive this expression again on the next in a next lecture and we will derive. Then finally, you will what is the relation between the current and the voltages. Basically, we will find the final current will come; some of this value you can see this is similar to the voltages equation and then from this, we will derive again in terms of commutation resistance and your I d current will see on the next lecture. So, thank you very much.