High Voltage DC Transmission
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Module No. # 02
Lecture No. # 10
Numerical Problems and converter Charts

Let us start the lecture number 10 of this module that is module number 2. And today, I will discuss about the few numerical problems and also, we draw some wave phase for given inverter operation and then, I will introduce about the converter charts.

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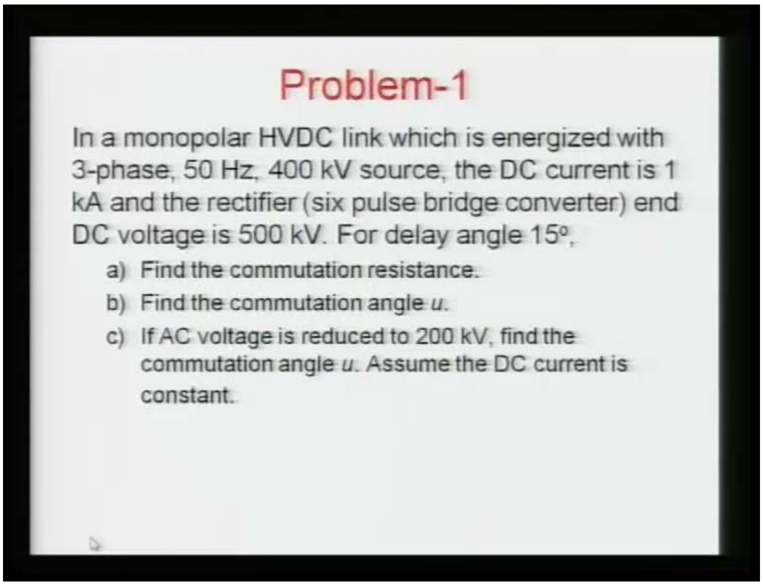

First problem, if you will; let us see some numerical problem, numerical problem number 1. In this, it is said that the monopolar HC DC link which is energized with the 3-phase 50 hertz 400 kilo volt sources, this is AC source, because frequency is given. The DC current is 1 kilo ampere and the rectifier, which is six pulse bridge converter is used and the DC voltage is 500 kilo volt. And for the delaying of 15 degree, you should find the three part that is, a find the commutation resistance; find the commutation angle mu and if the voltage this AC voltage is reduced to 200 kilo volt, what will be the commutation angle u. Assuming that current is same, because the current it can be maintained by the another end of inverter.

This was the so simple problem and if you will see here, simply just you use, relation we derived you know, first we have to see what is this here u, mu is not given to you, but you can use with this starting less than 30 and you can satisfy the equations than it is. Otherwise, you can go for this more than 60 degree, but here you will find here while calculating mu is less than 60.

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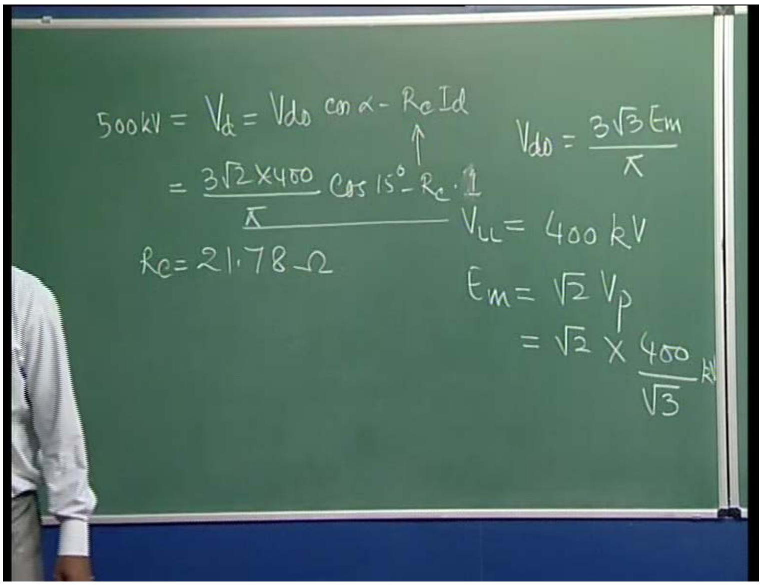

And then, the relation this V output here is your Vdo Cos alpha minus your Rc Id this relation we derived. And you see here, it is asked that, what is the commutation resistance not reactance here, resistance is asked. So, your (( )) is given to you, it is monopolar means, it is only and only one bridge is there, there is no bridge mention means there only one bridge. And this voltage is given to you this is your nothing but your 500 kilo volt. Now, this Vdo is nothing but your Vdo is defined as E m over pi, this we have already derived very well this expression. And now, the question only what is the E m in this case? It is given to you, it is 400 kilo volt ac 50 hertz means, this voltage is your line to line voltage and this voltage is your r m s voltage, nothing said means it is valid. So, this voltage is your V line to line voltage.

Now, here this E m is the phase voltage magnitude. So, here it is your E m, I can write E m it is nothing but under root 2 V phased voltage. So, we can write here, what will be the phase voltage here, under root 2 here, it is your 400 over under root 3 and now, this will be your kilo volt. So, this was expected that you should write E m here in this expression and then, you can write now, what we are going to have here, you can put this value here this under root 3 under root 3 will cancel and we are going to have 3 under root 2 into 400 divided by your pi, cos It is given your 15 degree minus R c. Now, this is Id is 1 remember it all the units should be in kilo, because this is in kilo, this is in kilo, so, 1 is also in kilo so, it is cancelled. So, this is I am using 1, it is not that you are using here 1000 and once, you are going to have this, you are going to get your Rc value and it was so, simple. And your Rc value as per our calculation, it is coming 21.78 so, it is 21.78 ohm. So, this value is now, commutation resistances R, some time it is asked what is the commutation reactance than, you can simply here this Rc value.

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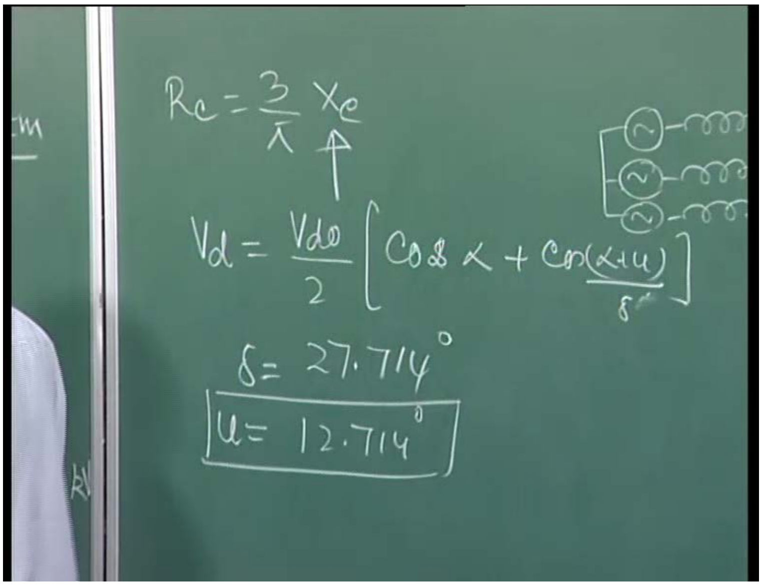

You know, this is Rc is nothing but your 3 by pi X e. So, if sometimes here the reactance is asked so than, you can just we will see in the next problem. Now, to find the commutation angle 2, we have another relation and that relation source that your is your Vdo by 2, here cos alpha plus your cos alpha plus u, you know this equation. Here also, this given to you, this value is here, it is known to you cos alpha, alpha is given to you, here alpha is also given to you, just put the value, only you should be here causes are careful that is to calculates this. And then, here it is this value is normally known as delta and the delta is coming to be as per my calculation, it is coming out to be 27.714. This is angle than, you can calculate what will be mu just subtract 15 you are going to have 12.714 and you can say this is valid, because mu is less than 60 degree just two three valve conduction.

Now, third problem, again it is based on the same, which we are going to use it is said that your, this voltage is reduced to 200 kilo volt, find the commutation angle. Here also the delay angle is not going to change, it is set for this delay angle we have to calculate this. So, here we are going to use only.

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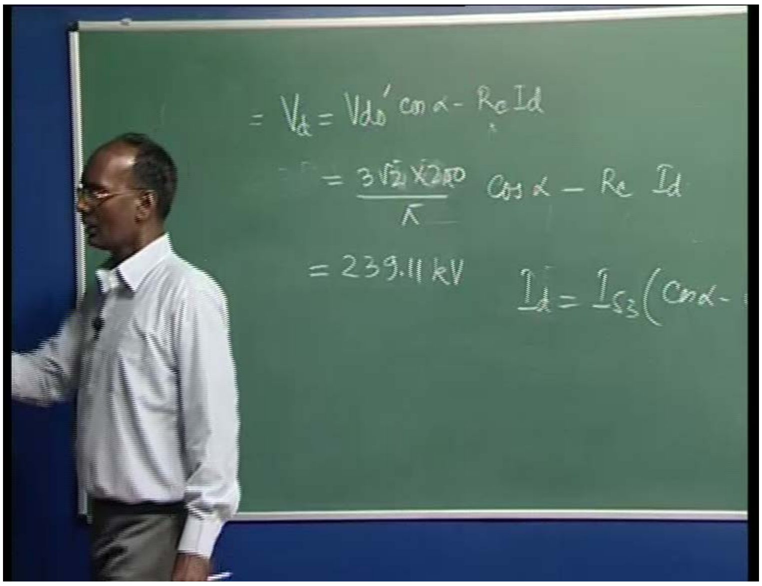

Now, from this expression it is going to be 500 volt, it is not saying, we have to calculate this voltage now, because once your AC voltage is going to dip this voltage will be changed. So, this voltage is not known to you, because this was the valid when we are having the 400 kilo volt. So, once there is AC dip this, because the firing will be same automatically dc output voltage will be changed. So, we have to calculate this what will be your now, with this value, means here it is going to change that I can say prime and this prime correspond with your 3 under root 3 E m by pi and this E m, we used here that we are going to use here, this will be under root 2 into 200 kilo volt. This previous here, we use here 400 now, it is 200 and again your cos alpha that is 15 degree your Rc V calculated, it is not going to change here, it is your Id, Id is also same.

So, if you are going to calculate here, you R going to get some DC voltage. Once you are getting the DC voltages than, here you are going to again just replace here in this equation and then, you can get again the delta from here. Because this is now, calculated from another way, this you can use the Id, the expression for Id you can again get it. If you remember, we derived this Id expression here, it is your is 3 cos alpha minus cos delta. This Id is same, here this value is change, because E m is going to change alpha is known delta you can, because from this two equation itself we derived this so that will be the same. And finally, what we get as per my calculation, here the value is coming out to be here 239, this value is coming 239.11 kilo volt this DC value.

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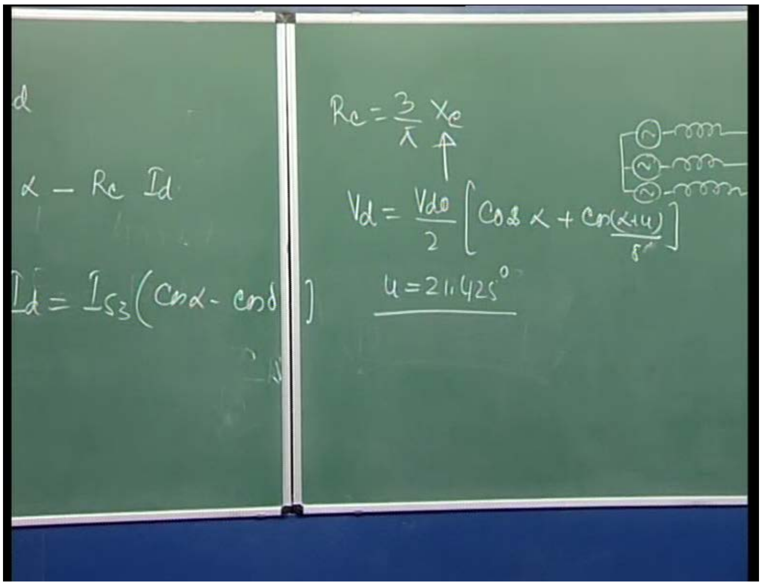

And your mu here, again going to put here, your mu is coming 21.425 degree and you can say now, mu is changed due to the AC voltage. So, this problem was simple only just you have see where to apply and what are the things are given and especially even though earlier also I mention, here about the taking this E m which is here, which is given here the r m s voltage line to line. And also, we will see in the problem third that, some time it is not a monopolar may be bipolar and so, many bridges in series or may be in parallel than, we have to consider those parallel and the series combination.

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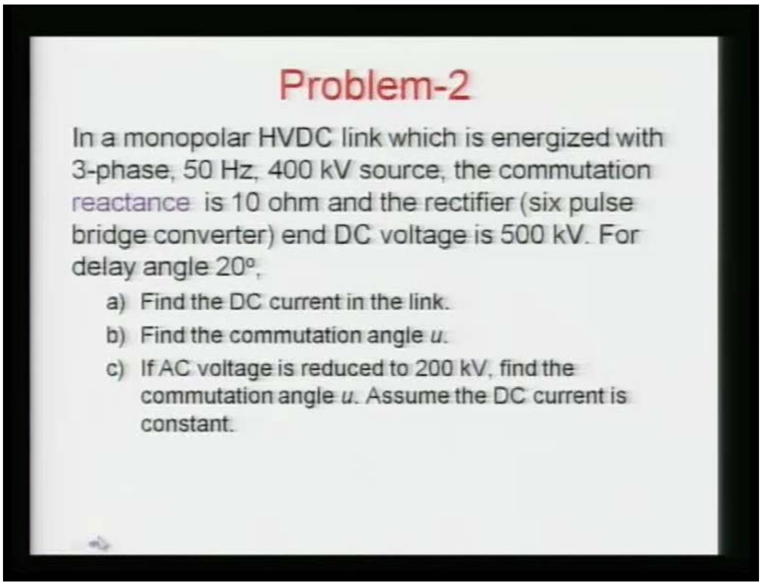

Now, let us see the 2nd problem, second problem is similar to the first problem, only different here, here the commutation reactance is given to you and you have to calculate the current, remaining things are same, because it was asked the previous problem also, mu it was voltage reduces to 2. And then, here instead of this the commutation only some time what is here, people normally escape, it is given the reactance it is not given the resistance means this value x is given to you, not R c.

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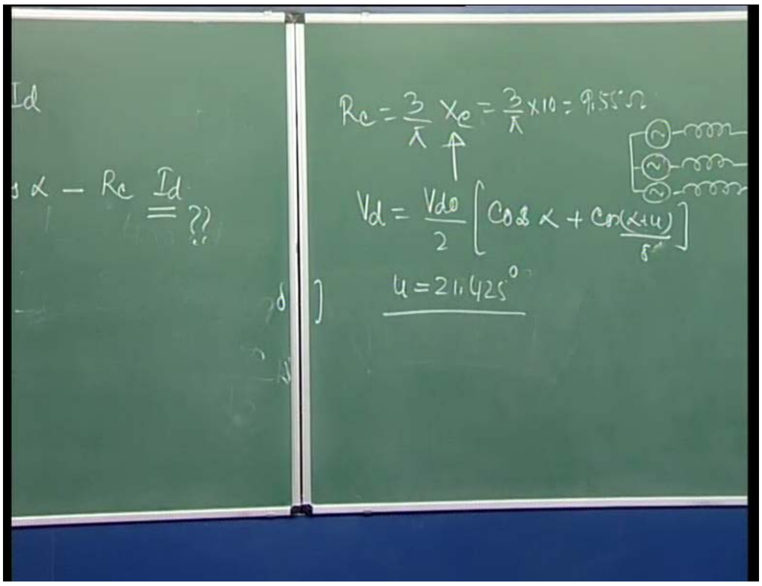

So, here this is given to you your 10 now, you are putting here 3 by pi multiply by 10, it is coming out 9.55 most probably. So, it is slightly different now, if you are going to put this value here, in this expression.

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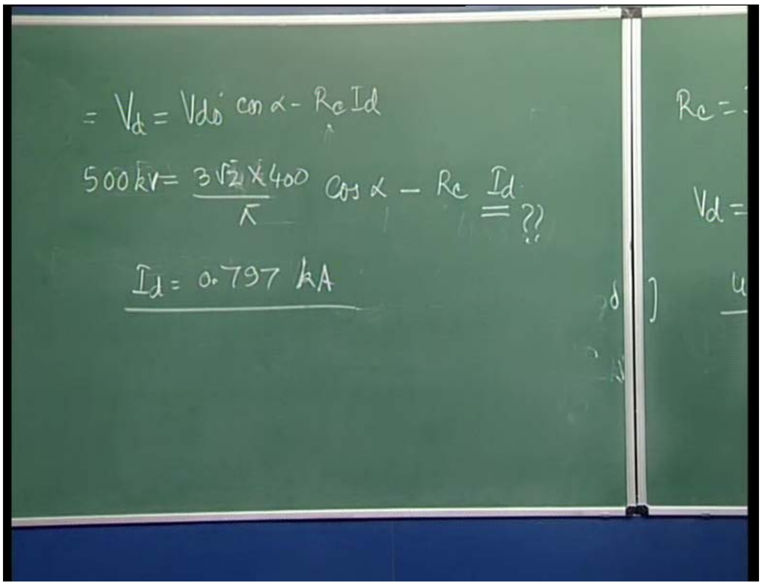

We can see here, it is again your voltage is again 400 volt kV, this is the same expression here now, this is a Rc we are going to get this now, Id we have to determine and this voltage is given to you, it is your 500 kV. So, in this case your Rc is known now, Id is to be determine and this put the value alpha is again given here, alpha is 20 degree delay in this case, put this value Rc here 9.55 Id all the things are known to you and then, you can get. And the Id as per my calculation it is coming out to be 7 point; it is coming out to be Id 0.797 kilo ampere.

Once your done with this, than you can come back here and then, you can calculate here this value delta, because now, this Vd is known, this is given to you, this is given to you, this is you can calculate. Here, you will find even though without calculating the first part you can calculate the second part, because already here is no Rc. So, just this is given to you 500, this value is this value here, by 2 here you have to just put and then, cos alpha is 20 here cos 20 and then, delta you can calculate and this value in this case, it is coming out.

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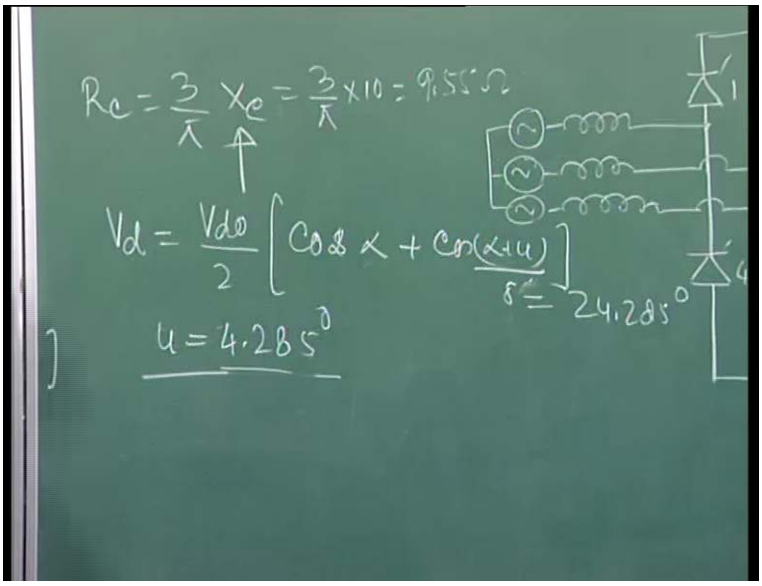

Now, my calculation it is coming, your delta mu is coming 4.285 means, this value is coming to your 24.285 degree so, this was your second part. Now, in third part, again the similar, you have to calculate the DC output voltage for this 20 degree here, again this is same, Rc is now, known to you now, you have to keep this voltage reduces to this 200 means for the same current now.

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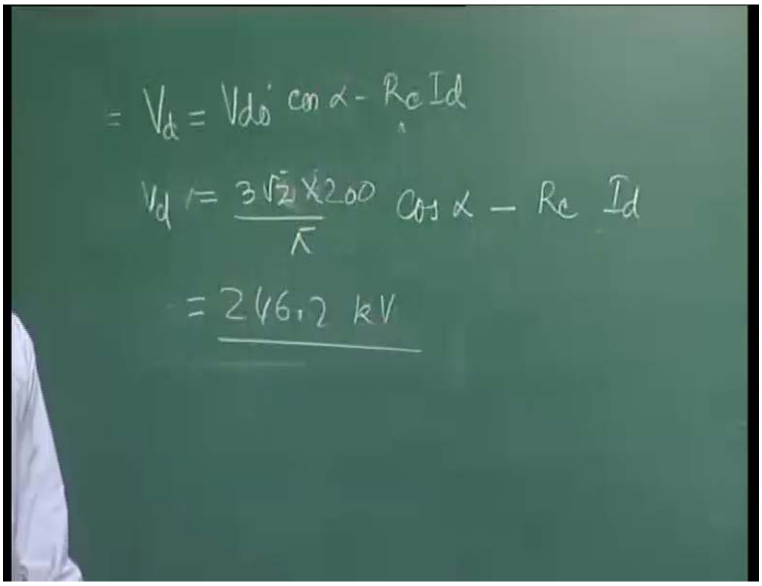

Now, the current is known, this value is going to be change to 200 volt than, you have to calculate what will be this V d, in this case Id is now known. And this value again as per my calculation, it is coming out your 246.2 kilo volt.

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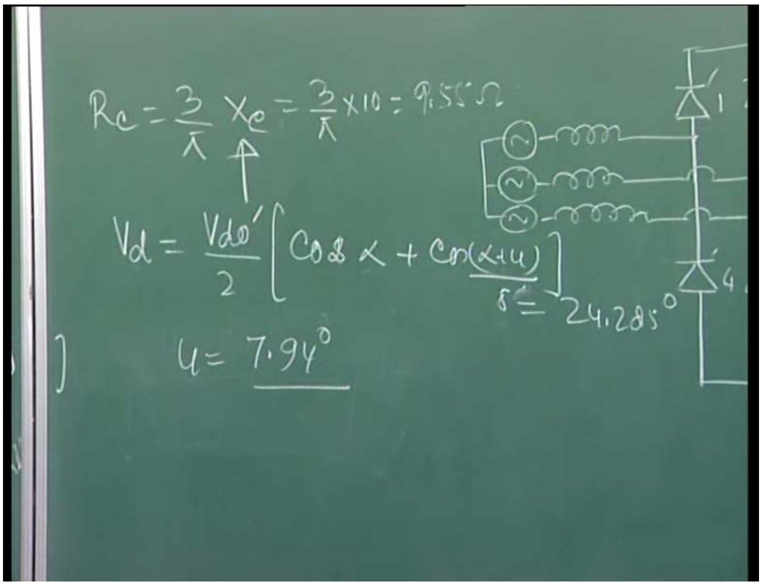

And once, this is known now, again you have to come back here, for this voltage this voltage and here. Now, we have to calculate, what will be in this case it is going to be change with the new voltage that is 200 volt and here it is your value is coming mu is coming to be your 7.94 degree as per my calculation you can check it. So, this is the very simple, only just you have to see how to apply, just you have to read the problem carefully and whatever parts are questions are asked you can just respond accordingly.

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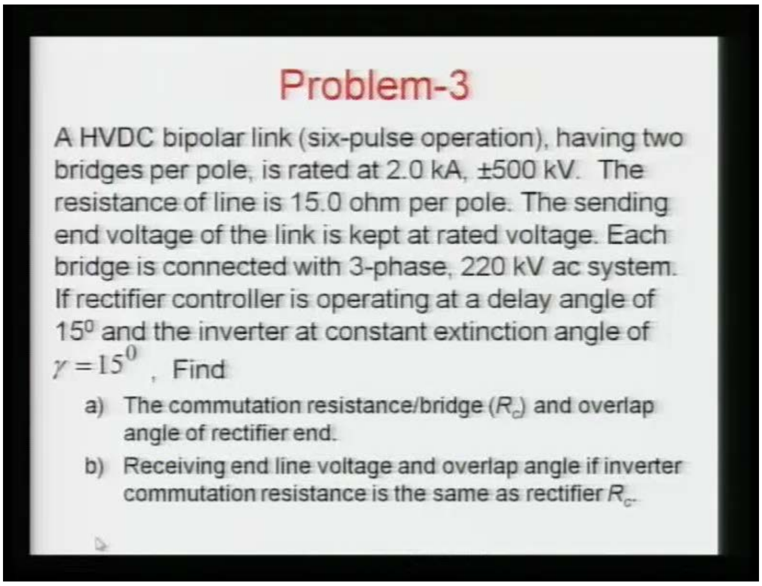

Now, problem number third, this slightly tricky problem, but once again if you will understand what is the meaning of this here, it is very clearly said let us remove them and then, we can go for this problem.

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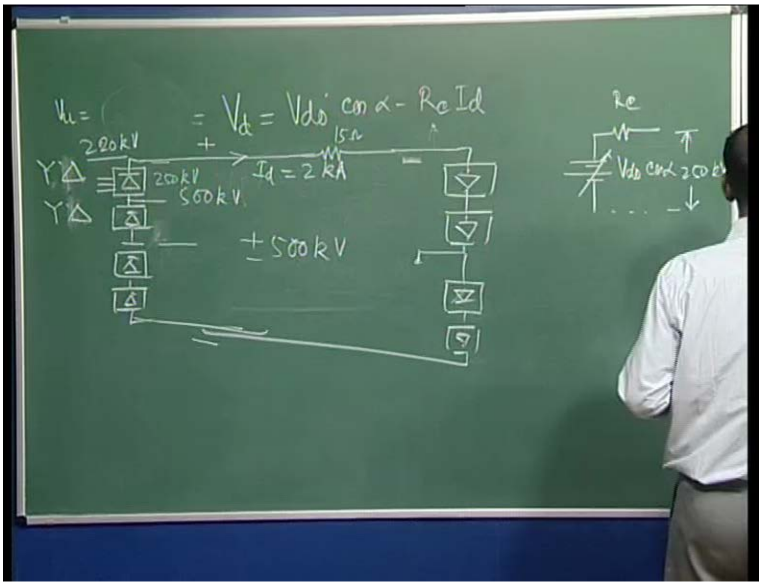

It is said it is bipolar link means, we are having here the two links, one is your past links, one is your negative, that why we are saying plus minus 500 kV means here, there is a some here converters, one is a grounded here and there are it is said two converter, it is said. Means a bipolar links, six pulse operations having the two bridges per pole means here, the one pole is the bipole is the two pole, mean one pole, we are having two bridges and that is a six pulse. So, here we are having one bridge and here, we are having another bridge.

Mind it here, this bridges it is not said whether they are connected this side start delta or something this phase change than, it will be not a six pulses, it will be twelve pulse there. But it is six pulse operation means, both are in the same configuration whether they are here connected in the like here star star. So, this will be also, connected in the star star than, both will be giving the combine effect of your voltage which is coming here 500 that, said directly added and the pulses is again six. If here is a change even though, this is delta in secondary this will be also in delta, because there is a no phase shifts here, because both are in the same phase, here there is same, but here is same.

So, that is why it is written here six pulse operations, inherently it is said that here this are in the same phase here and that is directly added so, this two are giving you six pulse operation now, this voltage.

Now, given to you 500 kilo volt so, the bridges here, this call per piece per pole here, the voltage this means the voltage this and this both are carrying the same voltage. So, the voltage across one here, it is your 250 kilo volt, because it is going to be added to average both are same it is assume both are same although, it is not written, but the two bridges are there normally having same voltages. But here, the current which is flowing it is Id, it will be the same throughout the bridge so, it is your 2 kilo ampere, which is flowing in the DC link.

And it is the resistance of the line is same now, this is having some DC resistance and now, we are having the inverter this side means, again it is inverter of this same similar fashion, this is the grounded and we are having another pole here, this is another pole and bridge of that pole and here this is you can say now, we can just here that is why current is coming here, this is your inverter side. So, this is the diagram which was asked, this resistance is given to you, it is said to be 15 ohm per pole means, this is the resistance of this. Because the total resistance in the circuit will be this plus this for the line and this will be the commutating resistance extra.

Now, the sending end the voltage of the link is kept at the rated voltage, mind it. And each bridge is connected with the 3-phase, 220 kilo volt AC supply system means, this each bridge, it is not each pole, it is each bridge here, we are having the 3-phase that is, 220 kilo volt AC system and it is safe phase. So, this value is again it is your all this is given to you. So, now this is given to you, now come here, if the rectifier controller is operating at the delay angle of 15 degree and the inverter is the extension angle of gamma here 15 degree find this, first it is asking the commutation resistance per bridge Rc and over lapped angle of the rectify end. Now, it is ask for this angle first this side now, this voltage is given to you, because it is said, it is operating; rectifier end is operating at the rated voltage means rated voltage is this one. So, this is a operating at the rated basically voltage this voltage may not be that voltage it may be again, because this is normally controlling your current.

So, from this whole configuration, we have to go for a single here and then, we can define it. Now, first take this one single phase here, it is your and this voltage is here, it is given to you, means now, I can go for this is your whatever voltage this is your Rc of the rectifiers and this voltage is nothing but we are talking here Vdo cos alpha, this is variable and this voltage is your 250 voltage; kilo volt.

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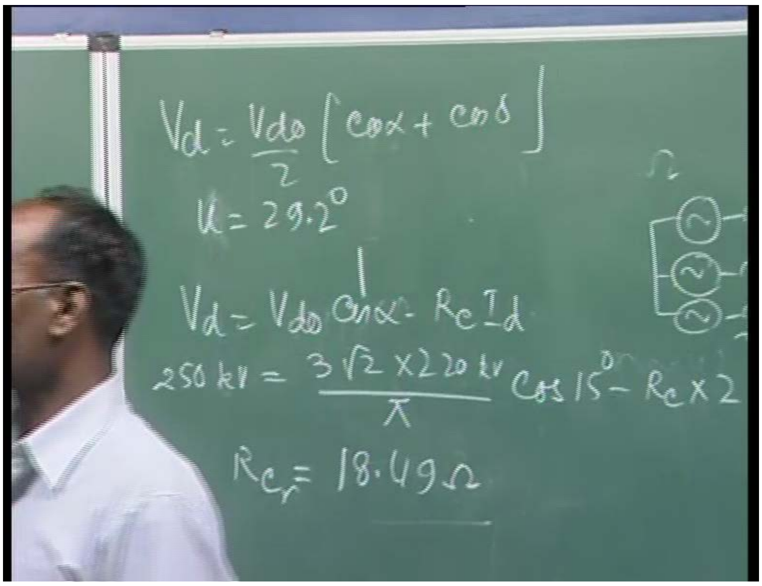

Now, we have to put this value as we know this is expression this is your Vdo cos alpha minus Rc Id this is given to you. Because you know this Rc we want to calculate here rectifier end, this voltage is given to you that is 250, we are again writing in kilo volt so, everything will be in kilo. So, here it is now your 3 under 2 into 220 divided by pi cos, this is the 15 degree minus Rc into 2, because the 2 kilo ampere kilo kilo here, this k, this k here the escalate kV here your kA so, this k is cancelled. And then, from here, you can calculate this Rc value Rc basically, it is of your rectifier and this value as per my calculation it is coming out to be 18.49 ohm.

Now, this is now, with this it is asked that, what will be overlapped angle again, it is a similar to the your example number problem number 1 and 2 you have to put this value again here, you know this, that is the Vdo by 2 cos alpha plus Cos delta here and then, you can calculate (( )). Now, again you can see here in this calculation you do not require even though correct, but you require this value and this should be clearly known. And from this calculation your putting this value here, 15 degree here, delta you want to calculate this value will be the Vdo, you can put from here and the is 250 kilo volt and you will find the delta. As per again my calculation here 209.2 this is basically mu I am calculate mu is 29.2 angle or you can say delta will be nothing but at 15 degree here. So, this was your the part A of this problem.

Now, this B part, we have to be careful, because in the B part it is said that, now we are coming to inverter side and at the inverter side now, you are just see what will be the voltage across here.

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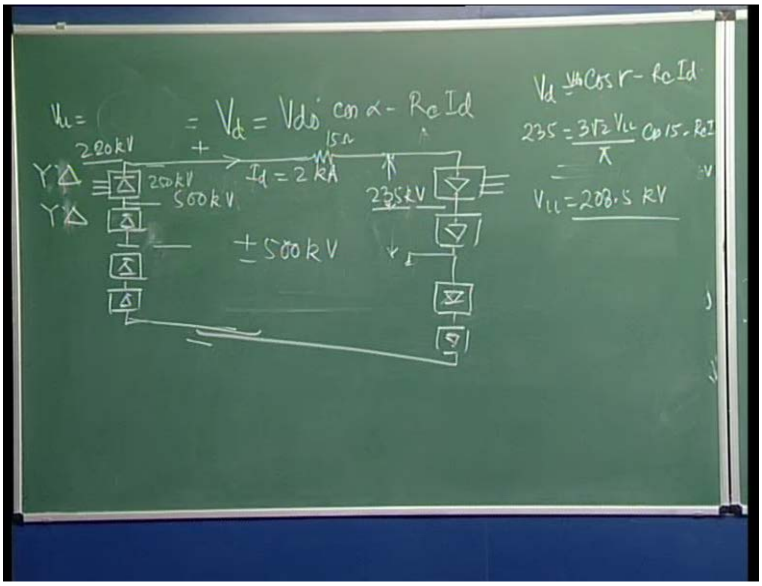

This voltage which is going here, that is going to be dropped. So, this voltage which is going to appear here basically, this voltage total here, we are knowing the 500. So, normally the 500 minus, if we are going to calculate this you are just drop and then, divide by the two bridges mind it. Here slight mistake you can do, you can see this voltage you can take and we are taking this drop and then, we are putting this value that is not valid. Because the drop here is shared by here as well as here it is not only one phase, you can just check it here.

Let us, suppose you are taking this as a bridge of this, drop the Id is given the resistance 30 volt is drop. Now, the question you can say here, it will be 220 kV, you can say this is the 252 ampere is flowing here and then, drop here and here 220 it is not so. Because just think about here, this voltage is 500 minus here 30 that voltage will appearing here, because this is zero potential. So, this value here, the total is going to a 500 minus 30 so, it is 470 volt and this will be shared equally by this bridges and this will be your, how much 235 kilo volt by this bridge.

Now, we in the inverter operation for the single base it is now, it is 235 kilo volt. And now, than you can calculate what; what is sorry. Now, you can calculate what will be your, again with the help of you want to calculate here, we want to calculate this receiving and line voltage, this receiving and line voltage here it is asked the receiving end here we want to know. Mind it, here you can see the receiving end line voltage, we are going for the AC voltage, because this is the receiving end line voltage, you can say this is the DC line voltage you can say this one also, if you are understanding this.

But it was asked what will be here, this voltage. This expression here, we know, this is in terms of this we again can write this here, it is your cos gamma minus Rc Id yes, sorry, here Vdo. You remember here, it is a minus we want for gamma, if the beta you are using it is your past trick, already we define all this equation. So, now it is for this case, we are having this is your 235 kilo volt again and here your 3 root 2, we are going to have the V L L of this side and divided by your pi cos, gamma is given 15 degree minus Rc into Id, Id is given 2 kilo ampere, Rc is given, because same as it is said already we calculated this value and put it here, we will get the V L L here for this side. And this value is going to be is a 208.5 kilo volt, if you write.

So, it was asked the receiving end line voltage basically, it is intention was to ask for the AC line voltage although, you can see the dc line will be of course, the 255 volt. Now, than it was asked what is the overlapped angle? So, again we can use the expression for the overlapped angle in terms of Id and we can use this equation that is your; no, it was asked the overlapped angle, we can remove this first part your.

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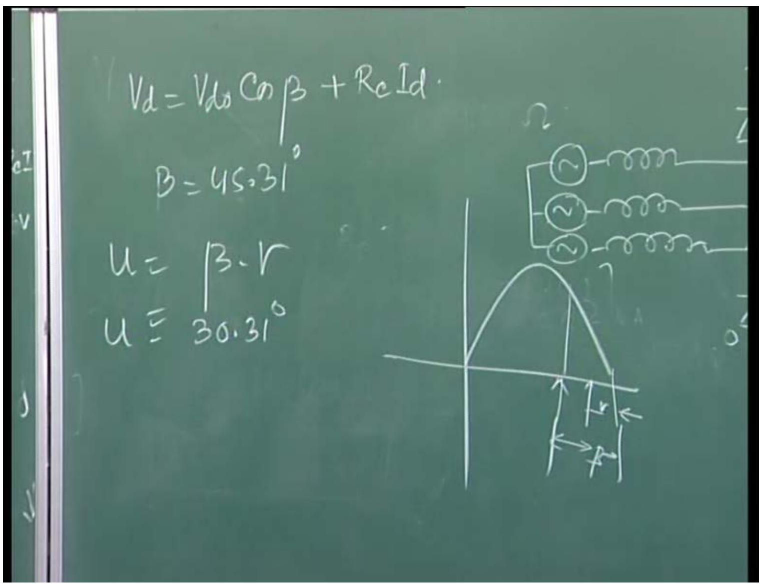

Rectifier operation, this expression, we can write this is your Vdo cos beta, if you can calculate the beta, we can calculate the u. Because you remember here, the gamma is given to you this is your final side of voltage here, this is your beta, this is your gamma, this is your beta from here, so, mu is the beta minus gamma so, you can just simply calculate beta, you can get u. So, here this was your Rc Id and if you will put this value here, everything is known now, the beta you can calculate it is coming to be a 45 point; as per my calculate it is a 45.31 degree just put the value, because here it given to you this is known, this is known, this is to be calculated, this is known, this is also known. And once beta is known than, your mu will be nothing but your beta minus gamma and just 15 you can subtract, it is your 30.31 degree that is your u.

So, only just you have to read the problem carefully and just draw the diagram and then, you can know what is asked and based on that, you can solve the problem.

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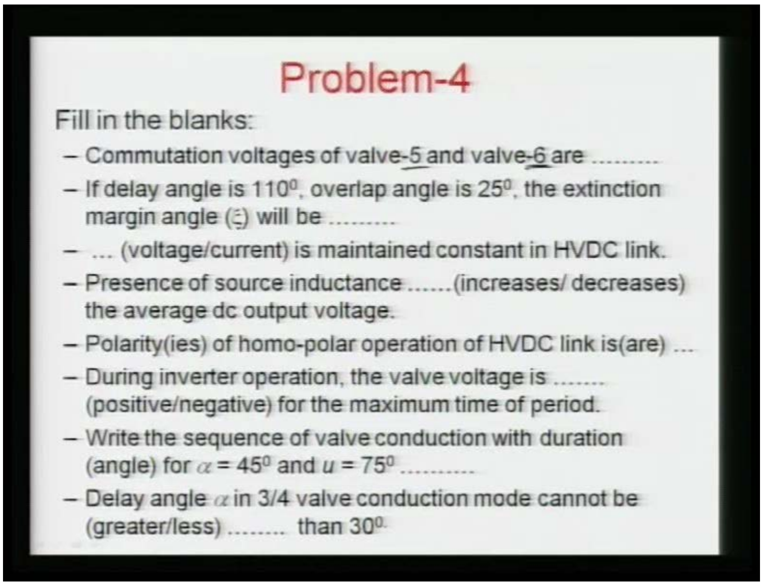

Now, the next problem, it was sometime ask let say, it is asked to you, that you have to write the various values related to this fill in the blanks or choose the values what is given in our inverted brackets here. And it was very simple I think and I did not check, but most probably, you might have done. For example, the first part if you will see here, this is a commutation voltage of valve 5 and valve 6, are asked.

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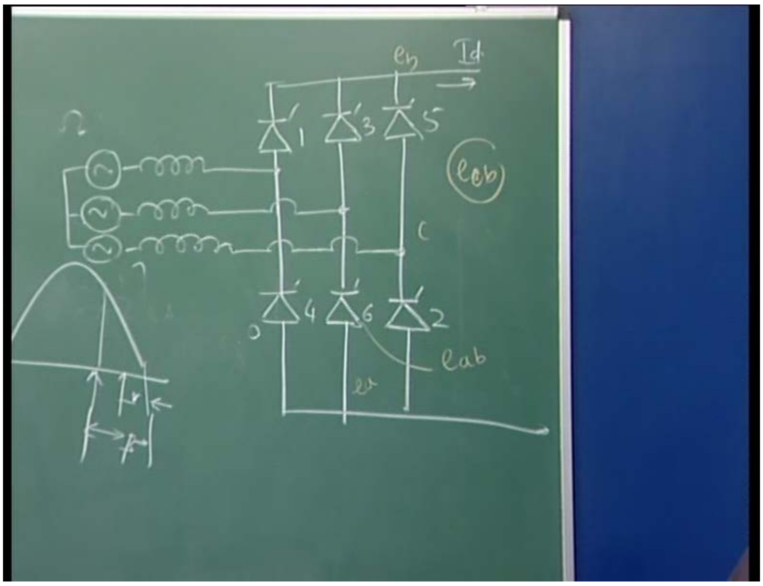

So, from here again I can say, what is the; here is the valve 5 and the commutation voltage means, what was the voltage before it is going to be fired, means once fire 5 is coming means it was 3 and 4 were conducted. So, once 3 and 4 were conducting now, 4 this side here and the 3 here, it is your e b and here, it is your c is always appearing so, this it will be your e c b will be there. So, this will be your; it is correct, it will e c b will be the commutation voltage of valve 5 than, it was asked for 6, 6 means your 5 and 4 and 5 are conducting. So, this is conducting here means, it is your ea this side and always b here means, this will be your ea minus e b that is e a b.

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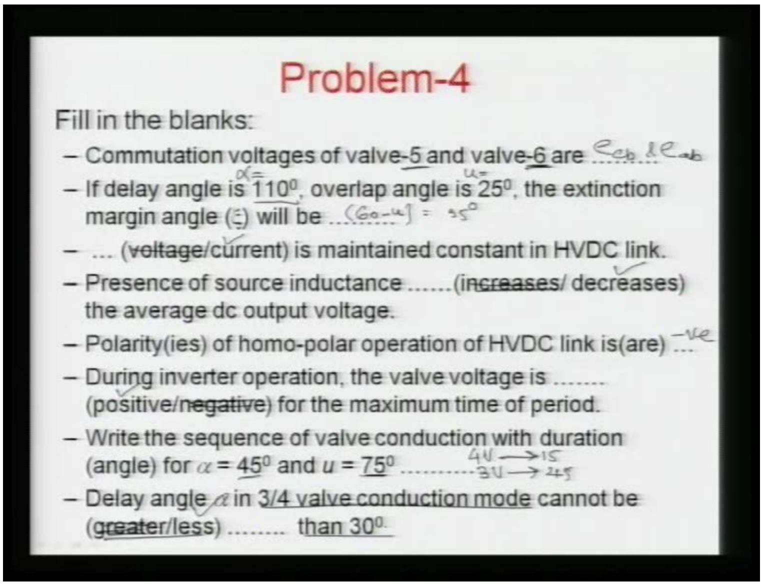

So, it was ask that your answer here, it is your e c b and e you are a b so, it is a commutation voltage of valve you can similarly, calculate whenever it is asked for the different valves. Now, second was asked the; if delay angle is 110 degree means, your alpha is given here this alpha, the overlap angle mu is given to you that is 25 degree, the extension margin angle. Now, you can see here mu is less than 25 degree and your beta if you will see, the beta if you are going to see, how much beta you are getting here? 70 degree, it is the greater than 60 degree. So, here it will be nothing but and also you see the mu is less than 60 degree.

So, in this case your; this your extension margin angle will be nothing but your 60 minus mu and it will be your 35 degree, because it was very simply it was given your 60 minus mu from here only self you can just calculate it. Now, second was asked this whether voltage or current is maintain constant in HC link, I repeat it several time HC link is operating on the constant current mode and voltage is vary to change the power in the link. So, it was the simple it was this was the current is maintain and it was asked to you.
Now, second the presence of source inductance, increases or decreases the average DC output voltage, it will decrease. It will be decreasing, because we all increased, we will see what happens; just see the mu will increase just current and other relation. So, here it will decrease your this and here this is valid.

Now, it was asked the polarities or polarity of homo-polar operation of HC links is rr, because why it is sometime people confuse about if I will say it is r always so, they will certainly understand. So, to confuse about this homo-polar and the bipolar, monopolar here it was r and the polarities are written the scalene. Basically, in homo-polar there is the two polarities so, it will be always polarities of homo-polar operation of HC link or it is both are negative so, it was asked to write. So, here polarities negative and both will be negative, both will be negative it was asked to write both negative you can write.

Now, during the inverter operation valve voltage is passed in a negative for the maximum period of the time, during the inverter operation valve voltage will going to change the next problem, it is most of the time, it is the positive, very few time it is negative so, it was this is wrong and this is your correct. Now, another is called write the sequence of valve voltage conduction duration and with the duration for angle 45 and mu is 75. Now, here mu is more than 60 means, we are going to have three valves and the four valve conduction operation, where some time it is 4 valves sometime 3 valves.

Now, how many times like 4 valve it will be you are mu minus 60. So, 4 valve will be conducting for 15 degree and your 3 valves will be conducting for the remaining 45 degree. And now, you can write the sequence, you know the 5 6 1 than, 5 6 1 2 than, 6 1 2 and so on so far, you have to write the sequence, because the duration of your return means it is clear, when 4 valve are conducting it will 15 degree, when 3 are conducting then, it will be 45 degree.

Now, the delay angle alpha and 3 4 valve conduction mode cannot be greater or less than 30 degree, it cannot be less than 30 degree. I just explain reason, because the voltage across the outgoing valve will be; only it will be positive after 30 degree delay and then, it is will be cannot be less than 30 degree. So, sometimes this very sad question based on your fundamentals of this course of your basically all this are related with the mostly converter and some links operations.

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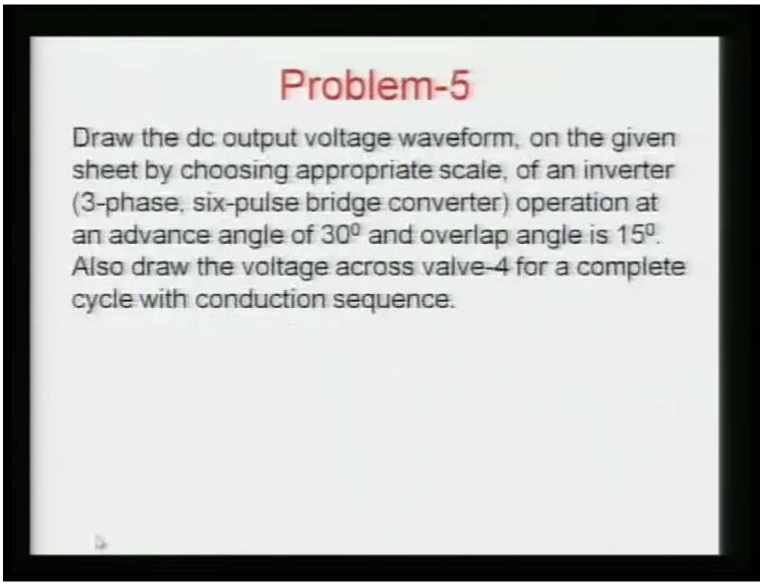

Now, let us, see another problem, which is I explained many many times for all the operations, whether it is the rectifier operation; whether it is inverter operation in both 2 3 valve conduction modes and 3 4 valve conduction modes. No doubt the valve voltage as well as the output voltage for 3 4 conduction phases or 4 valve conduction mode is very simple, but it is slightly tricky once you are going for the inverter operation and which was asked here. You can see in this one, it is given the advance angle and it is not delay angle so, what people slightly I think people do here, simply looking this angle 30 degree they say, it is alpha degree and then, try the rectifier operation which is totally rough, it is advance angle means, beta is given to you and the beta means now, alpha is 150 degree means, you are in the inverter operation.

So, in this problem it is said draw the DC output voltage wave formed; on the given sheet means, it is to make a new form by choosing their appropriate scale, of an inverter 3 6; 3-phase six pulse bridges converter, operation at the advance angle of 30 degree that is a beta here, 30 degree and overlap angle is 15. So, we are sure that mu is less than 60, we are in the 2 or 3 valve connection mode. Also draw the voltage across the valve-4 for the complete cycle with a conduction sequence, it was asked.

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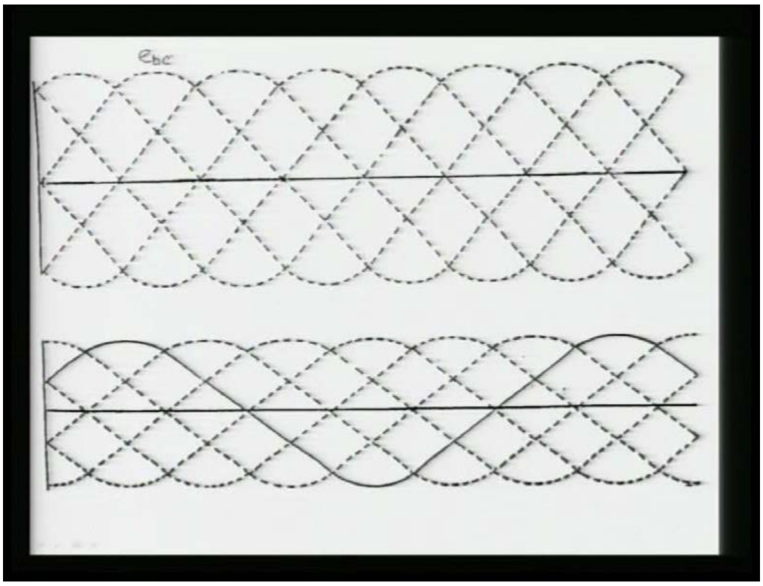

So, to draw this as a sheet is given to you and if it is not given to you than, you have to just draw the various line to line voltage or phase to phase voltage so, you can draw. It was possible to draw here, the phase voltage to of line to line voltage here, upper limb and lower limb, you can draw separately than the difference of this will be this, will be your reflected here. So, it was given to you and based on that, it was asked that, you should draw this valve voltage only here, we just said I just wrote that, this voltage was given to you and it was ebc, it was fixed to you.

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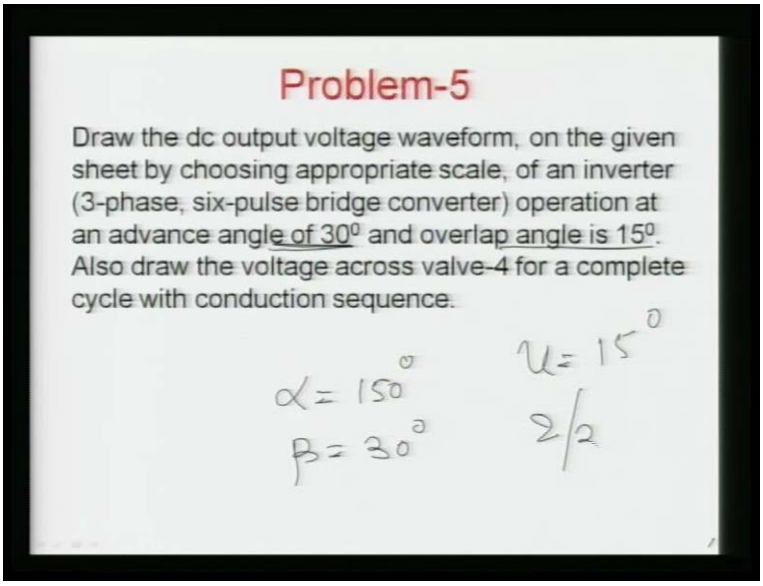

So, let us, draw this DC output voltage for this case, where you are given this your beta is 30 degree and your mu is 15 degree means, you are given alpha equal to 150 degree means, beta is your 30 means, it is this and mu is given your 15 degree means, you are having 2 3 error operation just, you see the angle and you will draw, you will find it is a inverter operation.

So, this is for it is given to you and the sheet you have to draw means, here line to line voltage of this is 0 excess here, is given to you that is ebc. In my lecture always, I took the e b a is the starting voltage, because for the commutation voltage of valve 3, but this time here I have changed and now, we will see what will be the commutation voltage of this valve.

You can see from here also, it is you can see the b c means, b is pass this side it is a b and another side it is a c here, which valve it is, you can see the c is involve means, it will be. may be very possibility of this limb, because c is there or they are conducting before. Now, you see what will be the commutation voltage of this valve, before that, what was conducting the 4 valve there. So, no before this your 6 and 1 are conducting so, this is coming your e b. So, it is your e b here e c so, this minus this so, here it is e b c means, this is the commutation voltage of valve 2. If you are confused do not worry you remember the commutation voltage of valve 3 is e b a, because whole the class, we define and it was there. Now, just mark the line to line voltage so, I just said it is e b c is given to you here.

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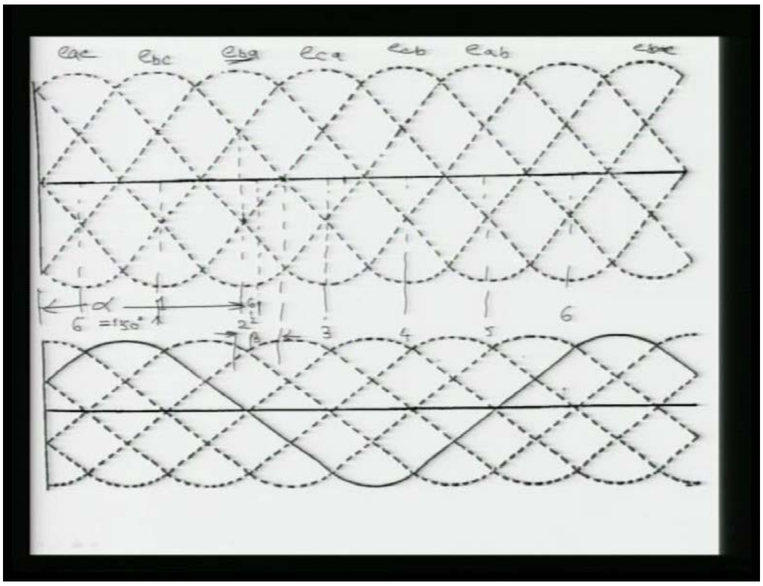

Now, after 20 degree just we can go for here, it is your e c a here it is e a b and; now, after again, we are going to write here, e c it is a here b c. Now, we can see this is a reverse of this so, it is your e b a here this is the reverse of this it is your e a c and this is your e c b. So, now as we know, that e b a this voltage is the commutation voltage of valve 3 this is well known. So, if you are not going here to check which valve is starting, because I have given your 0 axis start from here. So, no problem you can just see it is your e b a here is your commutation voltage of valve 3 means, valve 3 from here it can be fired and the alpha is 50 degree means here is 60 120 and here it is going 180 means, in between here. So, this is your valve 3 is going to fire.

Now, after every 60 here, 2 1 and 6 will be there or you can start there and then, you will come back, because this one cycle is ask. So, I can say here, at this point here, it is your valve 3 is being fired or you can see your e b c here, it was your here, it was your 2 as we see this e b c was your the commutation of voltage of valve 2. So, your alpha here, from I can say from here it is your alpha and this is equal to your 150 degree or I can say your beta from here, here it is your beta degree that is 30 degree.

Now, you can see just every 60 degree, you are going to have another one means here, you are going to have your one here, you are going to have your 6 every 60 degree just move that is here, half of this here your 4 here, you are going to be your 5 here, you are going to be. Once you have mark line to line voltage, once you have mark the instant, where they are going to fired than whole sequence and whole drawing it will be very simple. Now, we can start from anywhere and then, we can draw. Let us, draw from here, am saying this 1 is being fired that why start from here.

You can start by 2, because the e b c is given to you this commutation, commutation voltage of valve 2 here, we are just firing your at this value, we are giving the pulse 2. Now, before that your fix here and 1 conducting and the 2 is given here pulse now, your 6 1 2 are conducting means, just here for few degree 6 1 and 2 are now, conducting and this will be for 15 degree, it is given to you means here, it is a 30 degree means, it will go up to here, it will go up to here the 15 degree of half of this. Now, see what will be the voltage, when your 6 1 and 2 are conducting output voltage see here, 6 is conducting and the 2 this side.

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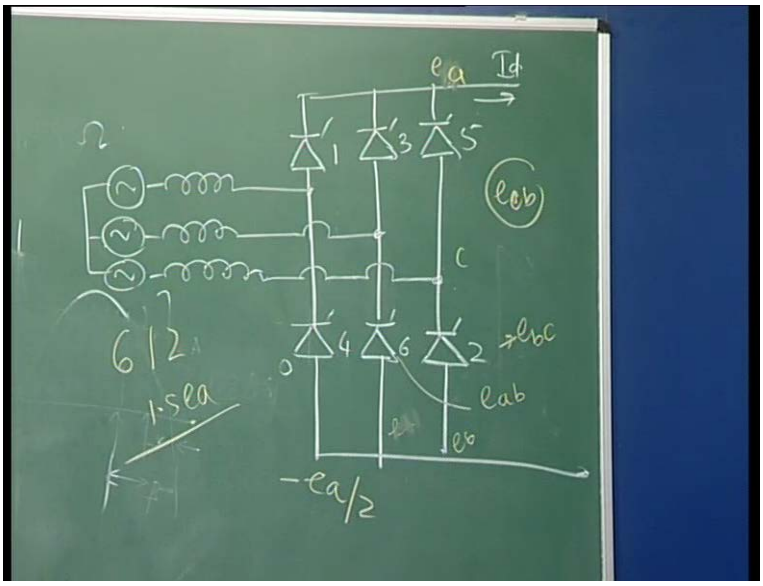

So, this is your e b and this so, it is minus e a by 2 and your 1 here it is your e a. So, this minus, this it is 1.5 e a.

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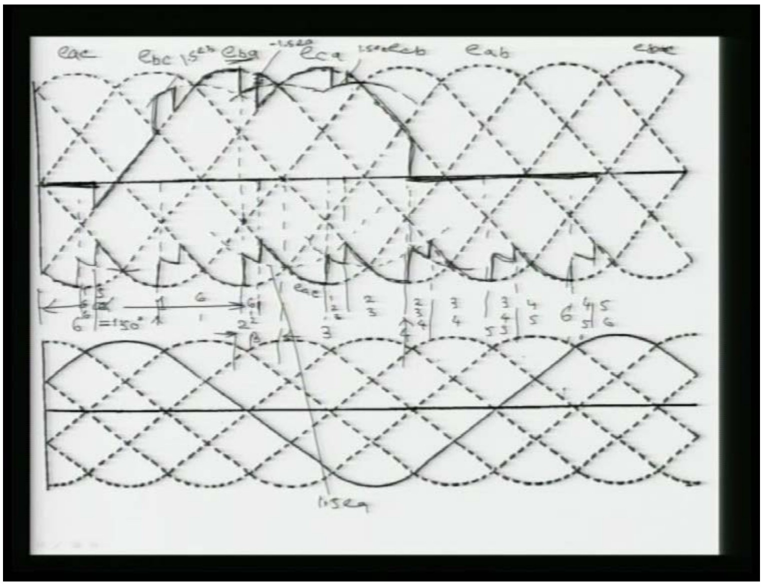

Now, see where the e a, it will find you will see this your minus e a is here, this is your 1.5 e a minus so, it will be the past will be just down here and this will be your this voltage here. Now, what happens here, your output voltage will be this one, because your this is your nothing but I can write here is your 1.5 e a this curve is going, because it is just opposite of this. Now, after mu means, after 15 degree commutation is over between here and here now, we are 1 and 2 and 1 here is your e a and 2 is your e c here, your output voltage is e a c.

Now, we see where is e a c, e a c now, we can see, you see e a c is this curve now, where the e a c, e a c is coming all the way here, here. So, suddenly it will go here and then, it will follow e a c means, in this graph I can draw once, commutation is over means, it is coming to e a c and than, it is following here, up to here next valve this is your e a c. Now, valve 3 is given a pulse means, your 1 2 3 are conducting and than what will be the 1 2 3 means here, it is you're here, it is e c minus e c by 2 and here e c.

So, this minus this is minus 1.5, you see and see where e c and you see this is your c is your positive c is here, this is your 1.5 e c and it is negative. So, it will be coming down here all the way and we are going up to here and here it is coming here, than it will follow up to mu degree. Where it is your 2 3 are conducting than, it will go back and it will follow e b c, because this will be here, your 2 and 3 will be conducting. Because 2 and 3 are conducting here, 3 means b and here is c e b c means, it is following e b c you can say.

So now, it will be following all the way here means, our symmetrical component symmetrically, you will find here this is going to this and we are going to get all the way similar patterns here and we can come back here again this is 6 is given pulse here. So, this output voltage is this and we are going to have here than we are going to have here. So, this is your valve voltage means, you can draw for few here and then, you will find it is repeated, because all the thing, you will be symmetrical here. But, in the case if it is there is miss fire or the commutation failure than, you have to be careful and you have to draw for all the cases. Because here it is said it is normal commutation means here, we are getting this type of voltage and then, you can after going 3 and 4 you can repeat, because it is a symmetrical it will becoming, for every 60 cycle you are getting the same one.

But some time I say here for example, we will see later on if valve 3 guard the pulse, but misfired than means 1 and 2 is continuing to conduct than, we have to follow it and then, at that time each instant you have to see. So, this was your output DC voltage and you can say it is negative means, it is a inverter operation.

Now, it was ask to draw the valve voltage for valve 4 means, this fellow was asked that, what is a voltage this is experiencing in this whole scenario. Now, you can see whenever the 4 will be conducting, the voltage will be 0. So, you can see when 4 is getting pulse here, at this point 4 is getting pulse means, it will be 0 onwards till it will be off. So now, here I can say the; this is your this starting, we can start it is going here shift this fire now, after that 4 5 is conducting now, here 3 4 this duration, you can say what is conducting here, 2 3 4 than 3 4 here 3 4 5 than 4 5 here, it is your 4 5 6 up to certain duration here and then, here it is 5 and 6 means it is off.

So, it is going to be here up to this point, this will be 0 or we can coming this side here means when 6 is going to be fired here and then after that it is your voltage is 0, here we reached the cycle here now, I come back here. Now, in during this period here, we are going to experience the valve 4 will experience some voltage of 0. So, now see it here, here as I said here it is your 5 and 6 are conducting, because it was here 4 5 6 commutation between 4 and 6 is over means 6 is conducting. So, now 5 and 6 are conducting what will be voltage here, once 6 is conducting here, it is your here means, the voltage here it is e b a across that. So, you see where the e b a, e b a is here and this is e b a means here, it will come here and it will follow this voltage.

Till 1 is going to be fired, once 1 is going to be fired here, means before that your 5 and 3 are conducting here, the voltage at this point what is going to change, because this is your e a and this is your e c means, here this voltage is minus e b by 2. And lower 1 was what 6 was conducting so, it is e b so, it is 1.5 e b will be there and it is past, because this e b minus here minus 1.5; 0.5 e b. So, 1.5 you have to see where is that, you will see this is your e b this curve is 1.5 e b positive.

So, what happen it will be going somewhere here, for this duration only mu duration here and then, it will come back again. Because once commutation is over now, you again your and this period, you are having 6 and 1 are conducting. So, again your this is your b and is a, it is no not 6 1 is conducting, it is 6 1 is conducting so, it is e a. So, we are again going to have this e b a and now, it will be not change till you are going to fire second.
So, this will be you are, you are here now, your reaching at this point now, you are giving the pulse to 2. Now, we can see here the commutation between this is going to happen now, it is your minus a by 2 is going, because the e b here e c and than by 2 by this point so, it is going to be this and then, this side, this your e a now, it is minus 1.5 e a.

And now, you can see where is this is your this curve is your already have it opened 5 e a means it is coming here, it will be your up to mu degree and then, it will be going back again once commutation is over, it is going back and then it will again e b a will be there. No it is not. Here, see this we reached here up to this point now, you can see what will be the voltage once commutation is over means we are going to have 1 and 2. Here is a chance now, it is this voltage is going to be e c. So, here it is your e c here to we have to go for e c a and the e c a is from here, it will be going to be here, this is not there. So, it is from here it is coming here and then, it will follow e c a.

Normally, it is always we do the mistake at this point only means, from here whether it will go up or it will go down, because here, the sequence is change it is 1 and 2 are there and 1 and 2 you can see the 2 means c and that is, a always the sides negative side is e a. So, e c a will be there so, it will follow here slowly it will coming here and it will follow there. So, it will continue here till again the next here pulse it is going to be given for 3 once, you are giving 3 here 1 and 3 here again now, the commutation is taking place. Now, this value will be this voltage will be your minus e c by 2 and this side it is your e c so, 1.5 e c will be there and 1.5 e c will be your this this this curve.

So, we are having here now, it will be going for this and but again now, it will be coming all the way here. So, this value is your 1.5 e c once, commutation is over again now, it your 3 2 and 3 are conducting so again you can say, it is hardly matter here the c is coming is there so, it is again e c a. So, it is again following e c a and it is going to be here till again we are going to have the 4th, once 4th giving, we are giving the pulse now, what will happen it will be suddenly 0. So, this was your valve voltage which was asked and to draw for the valve 4 now, you can see it is so, simple.

Only just you have to monitor the which one is conducting, what will be the voltage and you have to be careful about this here, when the 3 valves are conducting. And it was asked to you and this is the problem which this I said, that is you can go ahead with this, it is clear. So, I could not as; in this lecture, I could not explain the converter chart, we will discuss in next lecture. But the problem is very important, because you should be very very careful here, without knowledge of this valve voltages and the output voltage, because some time misses fire some time commutation failure other things. And also, we will see other, how to protect the valve etcetera that is, very very important once you have knowing the exact output voltage of this valve.

So, with this I can stop here, and will next lecture, will discuss about the converter chart, which is very useful that looking at the chart you can say, what is the u; what is alpha; what is the gamma; based on the chart you can know, it without any calculation etcetera. Thank you.