High Voltage DC Transmission
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Module No. # 04
Lecture No. # 04
Analysis of Converter Circuit

So, welcome, to this lecture number four of this module and this will be the last lecture of this module. In this lecture I will discuss the various dampers those are used to avoid the voltage oscillations, current oscillations and also, me times line current oscillations which I will discuss here.

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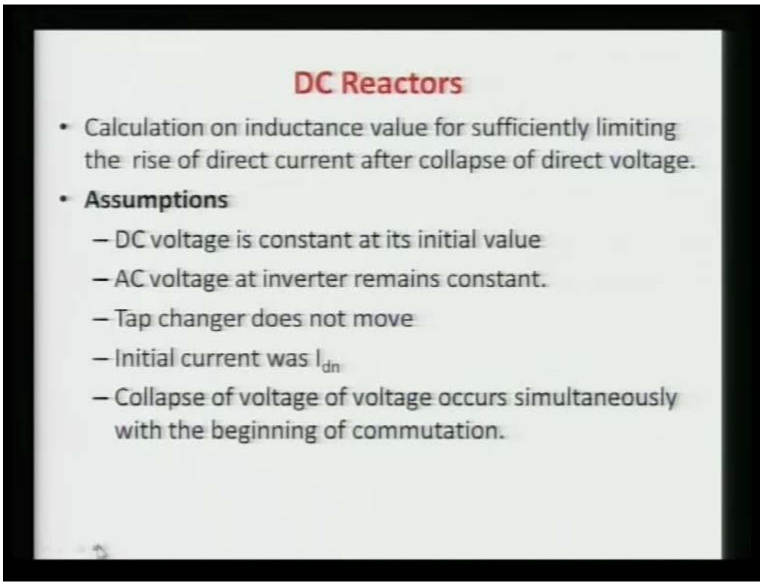

Last time I was discussing about the DC reactor and we can calculate what should be the value of this inductance value that is a DC smoothing reactor. So, that we can avoid the commutation failure I will give one example, in this class based on a several assumptions. And a assumptions are that the DC voltage is constant at it is initial value across the inverter side, this voltage AC voltage at inverter terminal remains constant tap changer does not move means, there is no tap changing is occurring initial current was I d n and the collapse of the voltage. I am talking the DC voltage occurs simultaneously with the beginning of the commutation.

I mean to say that you know this is a inverter side this is a commutation voltage of valve three, where we are just giving here a signal the beta that is (( )) with the certain here the margin here, I can say gamma. So, at this point when we are assuming all these assumptions that once a beta is calculated and the beta can be calculated is the expression. If you remember this was your using I d here IS2 here Cos beta minus Cos gamma are reverse one. Because this value is less than this it will be Cos gamma minus Cos beta. So, with this expression normally, for the given value of this we can calculate the beta.

So, once beta here is calculated we are assuming that the inverter side AC voltage means, your Em is your constant it is throughout at this point it is said that the DC current before that firing it was the constant in the link. Now, here once you are firing now there is a collapse of the DC voltage in the line and what will happen? The current will rise and current will rise here and this will lead to your another value of gamma and that will lead to your commutation failure. So, here this it is said the initial current here, it was the normal current I d n n denotes the normal current, which was flowing in the DC link.

So, it is a constant here initially I d n from here to here once it is going to here, it is changing and you are assuming is a linearly changing. And AC voltage which I said here the inverter side AC is not changing, why because the this calculation and other calculation we are going to assume this is a constant because this is nothing, but your IS2. Sometimes I was using I s 3 also, but the meaning is same her,e under root 3 Em divided by twice omega l. So, l is constant frequency of the system is constant and Em is we are assuming constant means this value is constant.

And your DC voltage is a constant at is here the DC voltage is constant now, the DC voltage is going to at this the last assumption is that, the voltage collapse is occurring here when it is going to just conductor beginning of the commutation. Here the commutation is going to start between the valves. So, with this assumption now, I want to derive what should be the value of l d that is smoothing reactor so, that we can avoid the commutation failure. And for this here see what we do? Normally, here I can say now, I d n is the normal current, which was flowing in the beginning this was calculated your n and this was your n it was the normal n here I am talking this is your n value.

Means, we are firing at this it is a commutation what is going to take if the DC current is constant there is no voltage collapse it will be here concluded and it will be n value. So for this value given value we can calculate here, beta n what will be the normal value here? You can calculate here, we were always calculating the beta n. Because we are operating in the c a mode this value we are just deciding what will be the c a? And this value will be the minimum value here, that is sometimes we fix it, it is called gamma m. This minimum value means, we cannot go beyond this because commutation will not occur failure will occur. So, we can go up to this point beyond that commutation failure will occur so; this is a some value always this minimum value is let us suppose 5 degree or 10 degree.

So, always it happen we fire in a such a way that we can commutation is over before valve before this. Now, since there is a some voltage collapse current will increase this value will exceed and once it is crossing or here the possibility of the commutation failure will occur in the inverter side I am talking now. So, it is as I said here, our current is at this value your current is your I d n now, the collapse is going to happen now, this value here it is your I d n we are assuming that it can go up to here. The current is rising and the u will increase it will be not commutate here; with this value here it will the beta is calculated for this one.

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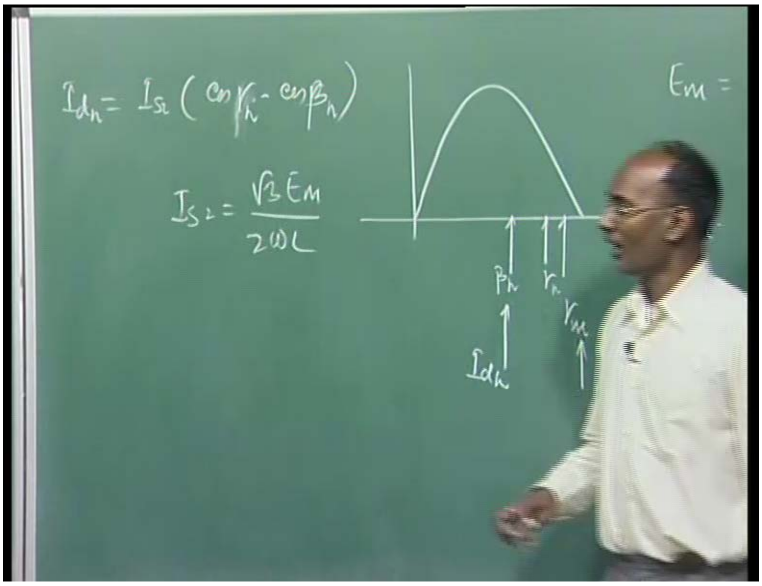

If I d is a constant, but it is changing so it will be exceeding and here some this current and there will be some change in your I d current here. At this m value here gamma m and it is assumed that the current is linearly increasing so, we can say you know this d I here d n not d n we can say any current, which is changing here that is here I can say I d n if it is very small d t it will be nothing, but your this is a l 1 upon l d change in the d v over d t or change in the time. You know the change in the voltage is a l d I by d t this concept we are just checking the linear one, because the time duration is very very small it is in the less than millisecond.

So, from here we can say this l d that is a inductance that is required, because the voltage is going to collapse let us suppose, is zero this inductance value must take care of if this value is taking so this will be continuing and there will be no commutation failure so this principle is adopted. So, this l d here we can say it is we can write here it is your change in here voltage here, into your d t divided by your change in I d. Here I think it is not this here it is only v d because change in the v d is your l d I by d t it is not d t so, this is this value there.

So, this is your inductance value we can calculate where what is your delta t? Delta t is the time from here to here from here to here; we are assuming this is a delta time. Where the commutation should be finished without avoiding the commutation failure that is why it is written here, beta n minus here gamma m it is not gamma n divided by here this omega and this value will come.

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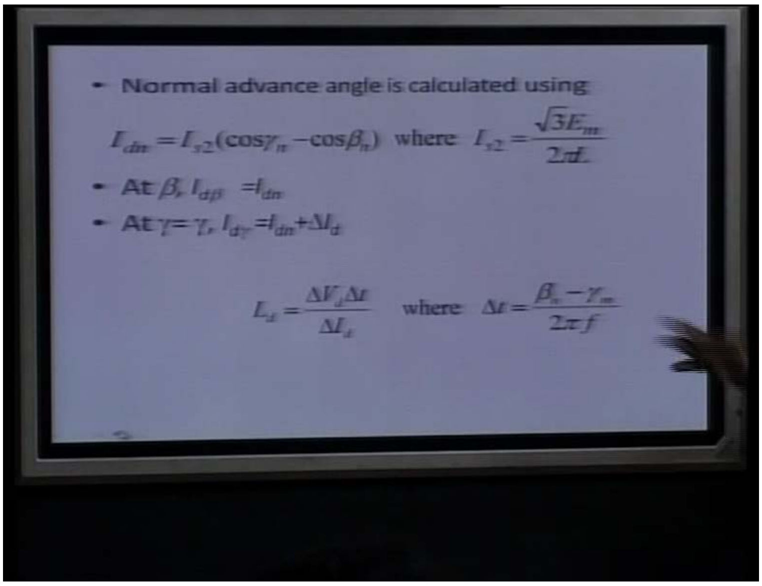

If we are taking this as a in radian then it is in radian otherwise we have to here you have to 2 pie you have to write 360degree. If you are using the beta chain degree, then instead of here omega 2 pie you have to write 3 60 otherwise it will be if you are (( )) in,

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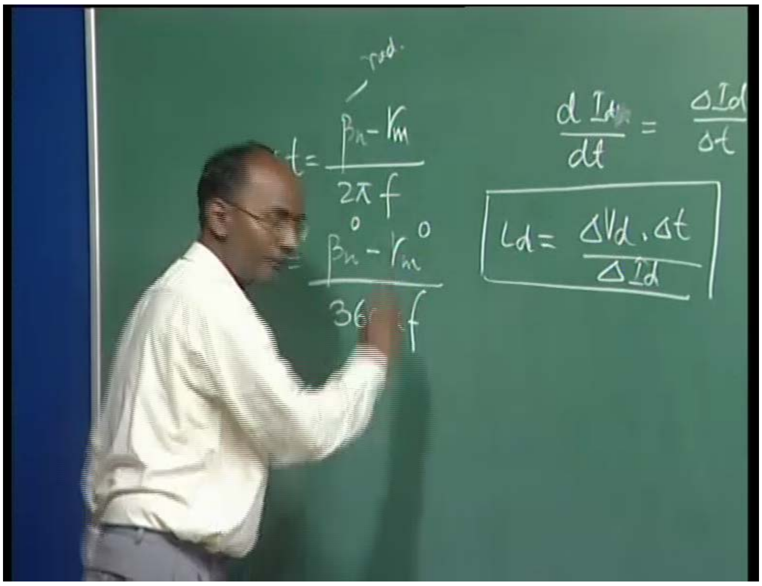

radian it will be 2 pie. So, this will be divided by 2 pie f, f is the frequency of the system where these values are in radians. If you are using in this angle so this beta n now I can write angle gamma m angle here, I am writing the angle here 3 60 into your f. Now, to see this I will show you one example here and this example here it says, that this example you just you can see how we can we can calculate. This is that, that your the this v d the link voltage or pole it is 200k v it is given to you it is also, given here your the rated current I d n it is your 1.8 kilo ampere.

It is also, given your s 2 here, it is 10 kilo ampere frequency here it is given to you it is 60 hertz and your gamma n is given it is operating at 10 degree and gamma m is given it can go up to 5 degree here. And then you have to calculate the value of l based on that here so, that we can avoid the commutation failure. This the v d this link voltage this 200 kilo volt operating per pole here, this current is the DC current which was flowing before this voltage collapse. This is the value here, it is based on calculated this value and it is given to you instead of giving Em nano mega and l values here it is 10 kilo appear.

And now, the frequency of this system is 60 because we are going to use here this is operating the AC side system. And gamma n is this value where it is a normally, if there is no voltage collapse your gamma n it should be commutation should be over by this degree. But we can go up to 5 degree normally if it is 10 degree so it is 15 degree also, but it is given to you now we want to calculate. Now, from here the beta n is not given to you and beta n we can calculate from this expression means, it is given here this value is your 1.8 here into 10 because this is a kilo kilo so it will be cancel here, your Cos 10 degree minus Cos beta n.

So, your beta n will be that can be calculated as per my calculation it is coming out to be 36.4 degree. Now, if this is known now we want here in this expression this change in I d now, you can see what is happening? To calculate the change in I d which is very important this expression, which we are writing when there was a no collapse we can write this expression here, as here I d n d beta plus I d gamma by 2. What is happening? If the DC current is constant weather at this value or this value is the same. So, we can say this I d n this I d n divided by 2 is I d n this I am going to write here IS2 now here Cos gamma. Here I am going to write m value because we are going to change it is certain which is changing up to gamma m here your Cos beta n.

We are taking the average here because is linearly increasing the current so, this why just (( )) taking at the beta instant and the gamma instant taking average that is a I d it is going to be I d, no this is the gamma here at this value. Basically, the gamma n is there, but now we are going to take here that is approximately here this is going to change here. What I am going to say here? This at the beta n the current is your I d n at the gamma m I am going to take here that is your I d n plus change in your I d so, this value here is n and here we are talking m. Now, if will you add this which equation this equation what I am doing here? If just assume there is your no change in I d. So, what we can show here this I d n?

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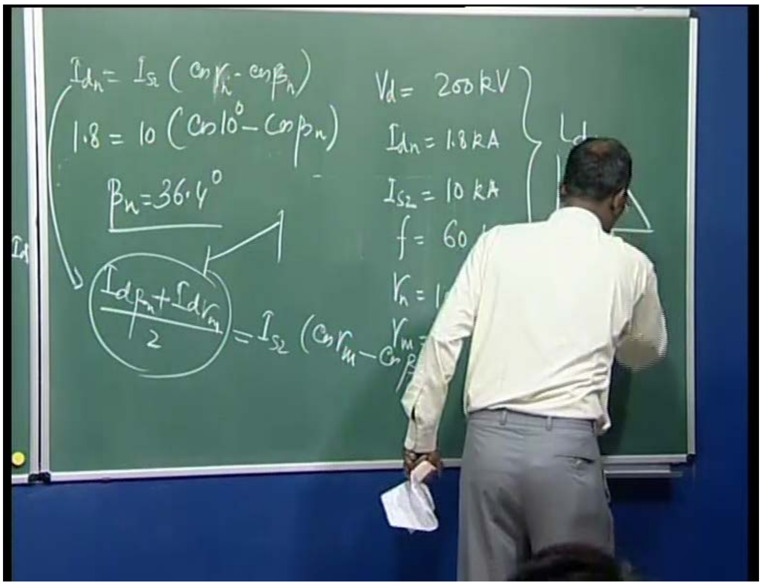

At this n and this value delta n it will be the same means, we can write at this value. Where we are drawing? The expression here at this value beta here n and whether any value here gamma m or this gamma n this I d was the constant. So, this value was I d n here also I d n so we can write within somewhere, that it is a average of these two current which is a if is a small variation is there. So, this expression here directly I am writing with this value in the normal case here what is happening? We are having this is I d n, because this is equal this is equal and then both are divide by 2 means same value here.

Now, as per this expression what I am going to do? Here we are just writing this your I beta n here is your I d n, because at that time this was the current now, your I gamma n here is going to be this current. Because the current is in changing here due to the voltage collapse when there was nothing it was not collapsing this was zero. And this duration is very small we can take the linear increase. So, from here you just add it, it is your I beta n plus I gamma n m is equal to here twice I d n plus your I d here, if I can divide by 2 here by 2 here by 2 here.

This expression here we can put it here so, the change of current which is a linearly we are assuming it is your I d n it is nothing, but your twice IS2 Cos your gamma m minus your Cos beta n minus twice of your I d n. Similarly, this is two here we are just putting this value and this we putting that side so, going the here and divide multiplied by 2. So, we are going to get this means this current change due to this value now here is a gamma m rather gamma n, because we are assuming (( )) value is changing it is said that voltage is collapsed. So that is why the current is increasing and the current increase is a linear one so, I d can be calculated from this expression.

Now, you can just use this value here 2 into your 10 here Cos 5 degree minus Cos here 36.4 degree minus twice into 1.8. I put this value here I d n the normal current before the collapse it was 1.5 kilo ampere twice here the beta n we calculated here and the gamma m is given to you is a 5 degree if is going commutation failure will be happening so it should be over by this period. Now, from here if you will calculate and this value is coming to be here 0.2277 kilo ampere means, current is going to be 0.2277 kilo ampere is going to happen.

Now, this is now known now in this expression this is given to you this is said it is going to be zero collapse voltage earlier it was operating at the 200 kilovolt voltage is collapsed to zero. The maximum fall will be zero it cannot be negative so, we are just considering the extreme condition so this change in the voltage is 200 k v. So, and then we have to calculate here this value from here delta t. Now, I can remove this and we can put this value now what will be the delta t for this one? Here it is your delta t will be 36.4 minus 5 degree divided by 3 60 into your 60 this will be some millisecond it will be 10 to power I think minus 3 second and this value as per my calculation.

It is coming out to be 1.1 0.45 here 1.454 second since it is in degree so I am using here there 60 means this expression I am using and here 60 hertz if it is system is there. Now, here your l d I can write here 200 this is in the kilovolt so, it is 10 power 3 multiplied by here 1.454 into 10 power minus 3 divided by this value is your 2277 into 10 power 3 kilo ampere and this value will be your h. And as per my calculation here, this value is coming out 3 1 2 5 hennery so, if can put this value of 1.3 2 3 1 2 5 hennery then.

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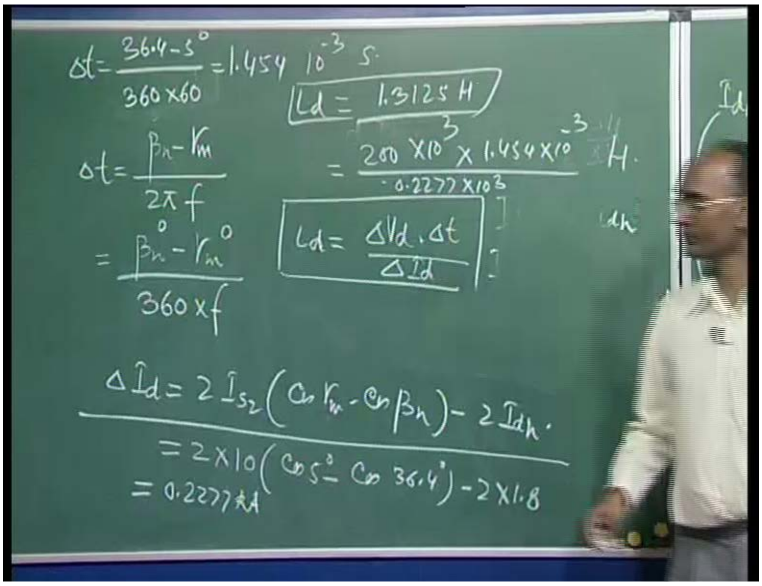

We can avoid the commutation failure even the voltage collapse to the 0 in the DC side assuming that your AC side voltage is constant inverter AC side voltage and the current is linearly, increasing and for given this value of your gamma m the 5 degree. So, here it is now, you can see this very high value of smoothing reactors is required to avoid the collapse. The collapse cannot be even the only due to the AC side it can be due to some other reason. The collapse can be we have converter side can be a fall can be anything with the DC side voltage can collapse so, we are assuming this AC side because the AC side voltage is not a radial system it is a interconnected by some AC system.

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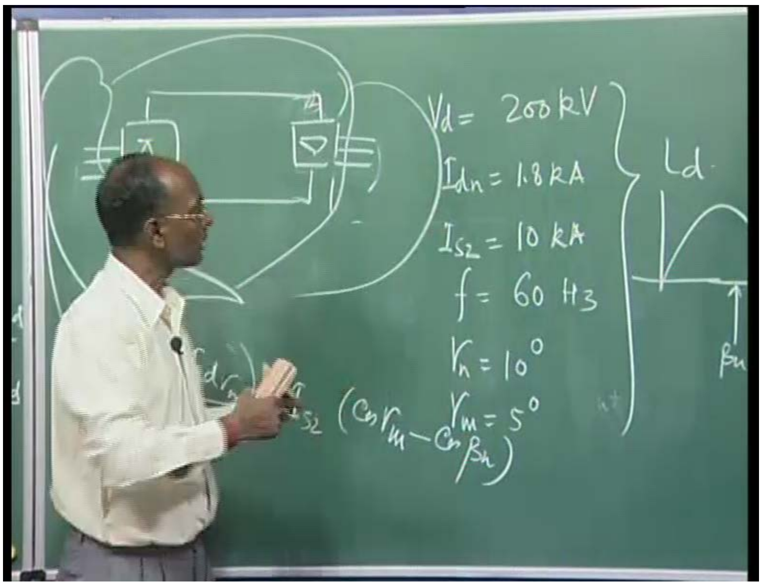

As well means, you can assume here how is a system is working? This is your converter circuit rectifier this is your DC link this is your inverter here, this is your three phase here three phase this is basically, complete system which is here AC system is there. So, all the both side you cannot make this voltage zero here, because this is voltage is governed by some other AC system as well so, it is assumed no doubt this Cos may be voltage collapse due to this here, if the three phase short circuit here voltage will be zero. But there is so many other condition this voltage can be zero due to this side due to the short circuit some other problem.

So, we are saying here the there is a voltage collapse l sometimes, your bypassed valve is fired here there is a bypassed valve it is fired it is voltage zero, but here the voltage is minus. So, this is a condition that is why it is all calculation which I am making assumption that your Em is constant. If Em is going to reduce what will happen? Let us suppose your I s three here, which is a constant this value is going to also reduce it. Once it is going to reduce you can see what is going to happen here, this value is going to reduce once it is going to reduce this is going to be further reduce.

And once it is reducing means, current change is less and current is current is change is less commutation failure will not occur, because the commutation current increases only trying because current is increasing and then it is leading to another side. So, if that is that is why it is the worst case calculation we are doing otherwise what will happen? This value will be certainly you can see this IS2 is change let us suppose, you have to change your value and then you can calculate no doubt about it. So, accordingly here instead of 10 it will go down this current change will be also reduce and therefore, your commutation will be consider in that value.

L d at that it will be increase inductance high inductance value will be there, but this inductance value here it will be increase this voltage is zero this is t this is I d if I d is less basically, this naturally here this l d value will increase. We require the higher inductance and then how it is going to affect even though let us suppose there is no change to this is zero. So, l d is infinite what is meaning of l d infinite? You do not need anything basically, so here basically this is a the case the I d will be of course, zero if this value is less you know the designing of the small inductance is a difficult than the larger inductance.

Here the size if you are going for the mile here and the winding the number of turns excreta, because N Square upon r is the inductance value. So, here these numbers of turns are reluctance you are required what is a reluctance value approximately, we can say this what is the reluctance value? This l is proportional to your n square over the reluctance value here l equal to here so for the given terms here the reluctance value.

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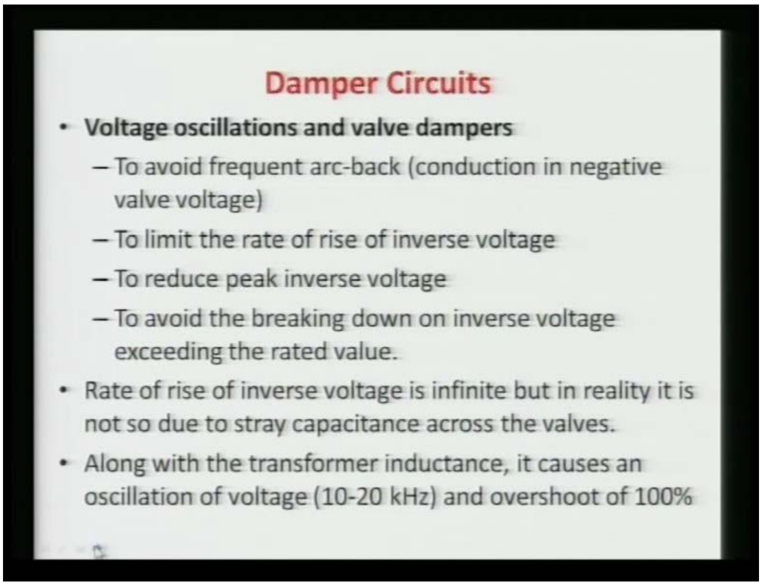

If we are going for hertz this value will be smaller, smaller means any small value we can use are or you can say (( )) any magnetic material you can use. But only I can say if the current is not increasing means that is no sense of calculating this means there will be there will be not a commutation failure at all. If the huge change you have to go for this because the voltage rise will be very high. Now, move to another protection schemes of the valves that is a call the damper circuits, the damper circuits basically there is a three types of a damper circuits are used. One is the damper circuit that is due to the voltage oscillation another we will see due to the current oscillations and another is called due to the line oscillations line current basically oscillation.

Why it happens? Now, just you can imagine before this valve is going to conduct it was having some voltage for example, let us see this diagram you see here. At this point once you are delaying it this is the valve voltage of any valve here if you are firing at the zero degree the voltage across that valve is zero. Means, here you can clear this value it is just if commutation voltage is increasing means that said this value it is zero, but once you are delaying the voltage across this is going to be positive and more and more positive. And once you are igniting it suddenly it will become zero now, you can imagine there is a some voltage before and there may be some stray capacitance between the valve because one is here the some polarity another is some another polarity.

So, there is some capacitance will be fall and due to this capacitance one you are keep on increasing and you are firing here. This capacitance along with the transformer here that will be coming in the series and that will be the voltage oscillation. So, this is basically due to this voltage across the valve once the capacitor is charge it is going to discharge through your once it is a fired. The capacitance which was across the valve here, it was a just voltage was there and the capacitance here some fixes this you do not worry this I will talk later this is basically damper circuit we are putting.

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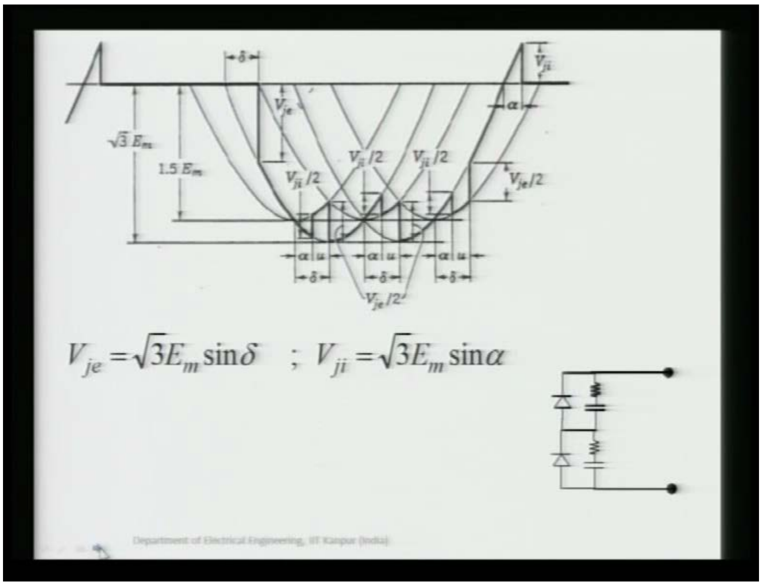

So, here the some voltage across this is appearing and now, this is now fired now the charge which was here it was the positive here at this cross that it will be charge here. And due to this there is some voltage here going to appear across this even though there is some inductance here also, again this stray capacitance is larger it is not only across this here the inductance of the transformer is also there. So, the capacitance here also there from the another side of the transformer and this will be some here, due to the once it is a conducting so, me discharge here of the voltage is going to rise and that is called the voltage oscillation no doubt this value of stray capacitance is very small.

And the frequency of the oscillation will be very high, but magnitude will be less we will see much more detail here. So, now I am talking about the voltage oscillation and to minimize this we can use some damper circuit means that oscillation if is passed through some somewhere, some resistance circuit then this oscillation will be damped out as usual and it will go in the resistance. And the resistance will be this loss and finally, it will be damped out the major problem in the voltage oscillation is there is a possibility that it can be the arc arc-back may occur means, it can conduct in the negative polarities here.

So, if you are using the valve dampers then it can avoid the frequent arc-back the basically, conduction in the negative voltage side it also, damper circuit limit the rate of rise of inverse voltage. It reduces the peak inverse voltage in the mercury arc valves as well and it avoids the breaking down of the inverse voltage exceeding the rated value. We saw here in the ideal case the voltage ride is sudden in the valve voltage, which I explained you here in this here you see whenever, you are just there is a voltages here sudden jumps sudden jumps whenever, there is a conduction of any valve is taking place the (( )) are there.

But in the practically it is not happening, because there will be some capacitance some inductance some circuit stray capacitances and this your inductance was there and this rise here rate of rise is infinite. Because in zero second the voltage is changing so, certain d v by d t divided by zero it is infinite, but practically it is not infinite it has some limited value, but it is very high no doubt and it is very high. So, we can use some damper circuit so, that we can minimize this because at this point there is a jump and possibility of in the inverse voltage it may conduct.

So, what happens if it is conducting in the inverse voltage here? That is called arc-back arc -back is there also, there is a possibility here at this point the voltage across this is there and due to this oscillation we will see the current oscillation will be also, there at that time. So, there is a possibility of the misfire this is a here and current is going to reduce due to the that oscillation of the current in the valve due to the charging here.

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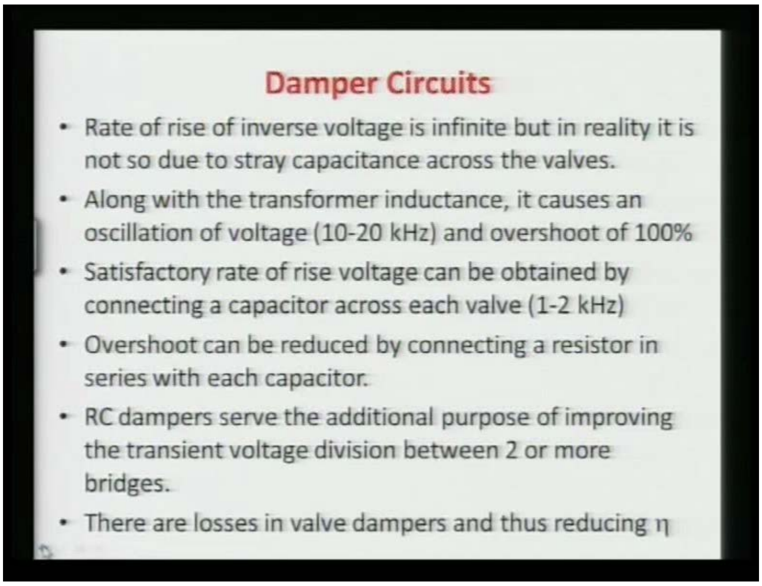

So, these are the jumps and these jumps are very dangerous. So, we have to use some damper circuit so that we can minimize the oscillations and also we can this sharp edges we can reduce it. Now, you can see what will be this voltage? This voltage we can simply before that action we can just see some theory here, as I said this oscillation of voltage you can see 10 to 20 kilohertz. Why because? These stray capacitances are very less and frequency you know this is one upon l c l and c both are very small and therefore, it is this value is frequency is very high. So, it is in kilohertz and, but the problem here the overshoot is sometimes cent percent 100 percent so, voltage is going to be double.

And even though it is a short duration it may cause damage or it may cause the your valve should conduct in the negative direction so, that is why it is said here the arc-back here it is possibility here the arc-back may happen due to the even though stray capacitances. But if you are using this dampers than it is going to minimize this now, you can see here so rate of rise of inverse voltage is finite, but in reality it is not so due to the stray capacitance as I said across the valve, because the capacitance is formed. Because the voltage is appearing and once voltage from the two terminals conducting terminals are there and then some capacitance will be automatically because air is as a medium it is formed.

And already I said here this value satisfactory rate of rise voltage can be obtained by connecting a capacitor across each valve. If you are capacitor suitable value of capacitor then we can reduce to one to two kilohertz and, but the overshoot you cannot reduce overshoot is 100 percent and to minimize. This you have to connect a resistance in series with a capacitance then your overshoot means, damping the overshoot we also reduce. So, that is why we connect resistance here in series with the each capacitors and this is called your r c damper or it is also called your the valve dampers. Because we are using across the valves, another advantage of this the dampers circuit if you are using the damper circuit across each valve.

If there is any transient across this voltage this is going to share across other valves as well. For example, here you see here if there is any transient occurring across this this voltage is going to here and is going to divide by this circuit here. So, it is not only limited to that valve it is going to divided in other valves as well and it is a safer valve if any transient occurring across any valve. So, this is also that is why it is said here it is going to safe curve is division between the two or more bridges where the valves are there it will be just going to be shared.

But only problem here that is if you are using some resistance it is going to be loss and thereby the efficiency of the system, because the loss is coming from the you are AC. Wherever, this r is there and even though (( )) stray chargers it is going to dissipated in the resistance and finally, the efficiency will be reduced. And that is a again it depends upon their design what is the value of r how much it is a stray capacitance are formed and based on that this efficiencies are calculated. Now, in this circuit I want to see there is a two voltages that is a very is to be calculated one is this voltage.

This is the voltage when the valve is going to be off, if you are trying to draw the valve voltage for valve three at this point from here to here it is going to be off and this value is delta means, what is happening? Your this value here I just I should explain here. You can see this is here at this value some alpha is delayed and then your u p rate is there here once commutation is over then this valve three is off and your fifth is taking care this is a three to five commutation if you will say. So, this value if you see what is this value? The magnitude you can say this magnitude is nothing, but under root three times Sin delta, because this is a Sin curve this is here it is a Sin curve no doubt this I am talking magnitude no doubt is a negative side

I am talking how much jump is there. What is this value of magnitude? Here it is I can say V je, v j I am talking the j x valve at the extension of this valve means, one it is going to be off I is use here when it is going to ignite. So, this value you can say this is a Sin curve so this value is from here zero if you are taking this is a x is a zero so this value will be Sin delta and this is your line to line voltage. So, under root three times Em is appearing and this is your voltage. Now, this voltage you can see it is your commutation voltage here starting at this 0.0 and we are going to fire here, this is alpha degree delay and this is a sinusoidal so this value your will be under root 3 Em Sin alpha.

So, this magnitude here we are talking this is your this value and this value here I am talking this is this value. So, these are the highest voltages those are going to occur, but we will see some other voltages like in between here this is another voltage jump here, another voltage jump here we are having another voltage jump here as well and we are having here as well as here. So, we can also see why this value will be here? It will be the equal to this value and these three here, here and here they are equal in the value and it will be, because at this time the valve is going to extension some valve will be is going to extension. So, this value will be your V je by 2 how we will prove it?

Another is your whenever you are going to ignite any valve here like this like your this and like your this it is equal to your v this is not this is a by 2 you will be this v j I by 2 will be there it is for this term. And we will see why it is so and how to calculate this value why it is half? Why not full and we will just see from this diagram we will calculate got it? But here we are saying simple r c circuit not that nothing, but some other circuit will have the that is also because it will increase the back peak inverse voltage capability of the that (( )). Now, I want to calculate what will be this value here let us calculate at this value first this value here.

Now, this value that we can see you see this is a one curve here means, this value is at this point this minus this we if you can get means, we can write this value what is the instant here? Starting as a this as a 0 this magnitude here at this point it is your under root 3 Em by 2. If it is a peak one, but it not a peak value it may be before also, it may be after also, what we will do? Here I just I want to write this value here I can say a and here it is a b it is clear a so, at this voltage a will be your under root 3 Em Sin now, what is this period from here to here? Here to here basically at this point is 60 it is your 60 plus delta.

Because this is 60 because we are firing here so it is 60 plus delta because this delta here it is a 60 plus delta will be there. Now, minus I want to write this if this voltage we are saying it is your 1.5 Em this value it is written here maximum is 1.5 here this peak. Now, it is Sin you see how much value we are going to at this point here? You see first we are taking this as 0 minded it is 0 somewhere, here so this is basically the 30 degree shift because this is 30 degree where line to line this is a phase voltage so this is 30 degree shift.

This plus it is 60 plus delta simply this is a 30 degree shifted, because we are here taking at this point as a basis so this is your value. Now, this value is 1.5 Em here Cos delta, because 60 plus 30 is 90 and 90 plus delta is your a Cos here and just expand this value so this value you are going to have under root 3 Cos Em here Sin, Sin 60 into Cos delta plus under root 3 Em Cos 60 into Sin delta.

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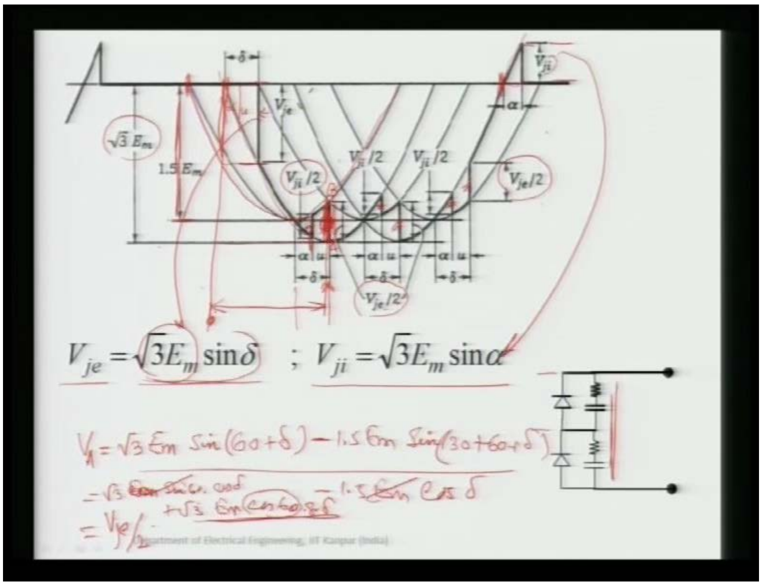

Now, you will find here the this value and this value here is going to be cancel, because Sin 60 here under root 3 under root 3 by 2 so I under root 3 and it will goes 1.5 here it will be cancel here. So, we are having this value only and this value here Cos 60 is half so we are going and this value you can say this so, we can say this value is your V je divided by so, your all this values here. Whenever it is going to extension here this is the highest value and other values are here this and this are of half of this, this proved?

Similarly, we can see if this is a v j I all this values this side this is small wherever you are going to ignite this and this will be of half similar concept can be applied.

So, you can again you can see your I can write for any value here you can take for this just it is a plus alpha degree here. So, this value your I can write now I am writing for here is looking I am talking here at this at this alpha value here what is this value? So, yeah 60 plus alpha here of this peak this highest value that is under root 3 Em Sin alpha plus 60 minus this 1.5 Em again 30 plus 90 plus alpha. And you will again then prove it you will find it is a half of this value so, at extension no doubt this value looks it depends on how much alpha you are delaying if alpha is larger than larger you will find this value is increasing.

But if your delta is more this value will be always larger here, because this is a alpha plus your value is u. so, this will be always larger than this you are delaying this, this is also delayed and then this symbol value. So, they each jumps are very very critical when your valve any of the valve is going to be extension. So, this side when it a extension here here and of course, of the same valve here the voltage is going to change. And these are the critical conditions and using this r c damper circuit here you can see we are using r here and c and this is also, called your valve dampers, because they are connected across the valves.

Now, another here we use that is a anode dampers we call it. In anode dampers here if the ignition of the valve is delayed a positive voltage is build-up across it which collapse when it is ignited. Again same concept is there, but it is since it is then it will be discharged through the valve so, current oscillation is there. So, in that case here there was some capacitance was there and it will be not oscillating unless until you have some stray inductance. In that voltage circuit we were taking the inductance of the transformer that side and voltage was appearing. So, voltage can oscillate current also oscillate so here basically, current is once it is conducting it was charged and then it is going to discharge here through this and the current is going to be added on your I d DC current.

So, it will be sometime negative sometime positive what happens? Sometimes current is going to be very negative is this value is very high discharging so the current becomes here zero. So, you are just giving a firing pulse it is igniting, but it will misfire means, it go and it will be you can say or quenching may happen so this is basically happening the stray capacitances and if there is some inductance stray's are there then. Now, this value is again very very small the stray capacitance are very high sufficient amount, but the inductance is this stray experience a very very less. So, what happen? It is oscillation you can say it can go in the megahertz is very high value.

So, it is start here that was 10 to 20 now it is 20 to 10 megahertz, due to this because this inductance value is very very small. So, and you know this is a lightly damped because there is no resistance involve here normally, the resistance here stray resistance are very very small so it is very lightly damped and it is going to be very high value here detrimental. So, what this does due to this the current once it is a oscillating high harmonics so, that may effects. Your radio interference nearby the communication signals it will be effected then there is a possibility of arc-back of outgoing and the misfire of the same valve. So, these are the detrimental effect of this current oscillation and then we use the damping circuit and that is called anode dampers.

And anode dampers you can see what we do? We use some sort of circuit here like we use a some circuit here you can see we are using here the some damper circuit. See this figure what is happening? This you see here it is written this the power frequency of the valve current here this is changing here the valve which is I d which is flowing across this. Why this is looking linear? Normally, if you will see the current increasing in any valve it is going be like this, but we are talking here in the mile second so, very small value so this is a just like a linear circuit it is shown to you here.

Due to oscillation here you can see this very high value of oscillation is added and here if you are not using any induct ant here. If you are not using any inductor in series with the valve then here you are getting a very high oscillation. But if you are using the anode reactor here we are using anode reactor here what happens you can see the current is going to be this frequency is reduced drastically so what happens? Now, your current discharge is going to be here this circuit just remove this r r will be used later on to avoid the mode loss so that we can release the energy.

So, if you are using this then your frequency going to be this to simplify this this figure is now translated here. You can see this is a linear circuit as a d here and if you are not using any resistor here then your oscillation is your b with anode reactors basically, this is a reactor. This is just like it is rising and this current this is oscillating which current is taking care by this valve and on that it is oscillating. So, this is basically current which is taken by let us suppose I 3 over this a is due to this once, it is ignited and the it is going to be here like this. So, this is you can say is a likely damp and this magnitude is not reducing very less reduction is there because there is no resistance in this circuit.

Some resistance offered by this valve may be there and that is a very small value. Now, if you are using so what we here it is suggested? We can put we cannot put a resistance in series of this valve; because huge current is flowing we cannot put here resistance because this is a stray value we do not know where is a connection. Because these are the stray value it is not a physical inductance it is not a physical capacitance, it is a firm between the two points here. So, this you are using inductors to damp out here frequency is ready here changed from here very high value now, we are going to less value.

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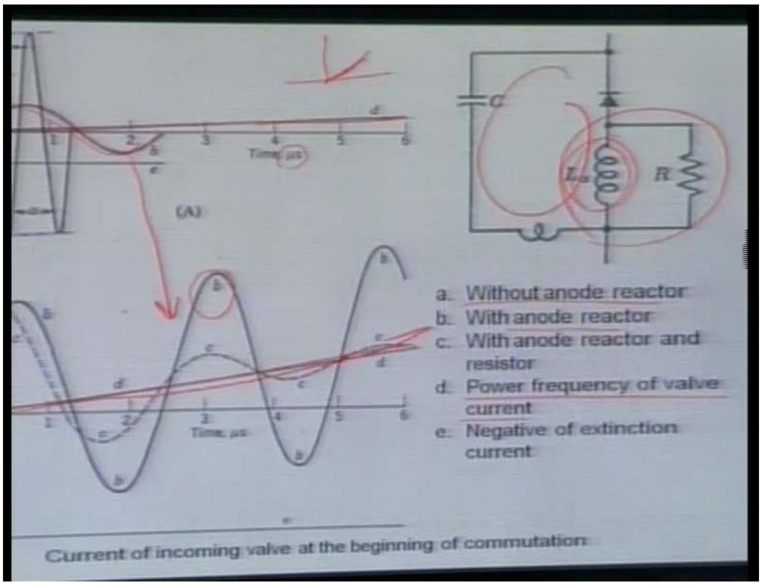

So, if across this if you are using here resistor because whenever, the voltage is going to be here voltage across this is coming and the loss will be coming here. And now you can see it is going to be critically damped and this is called your anode damper because you can say it is connected anode across this valve (( )).

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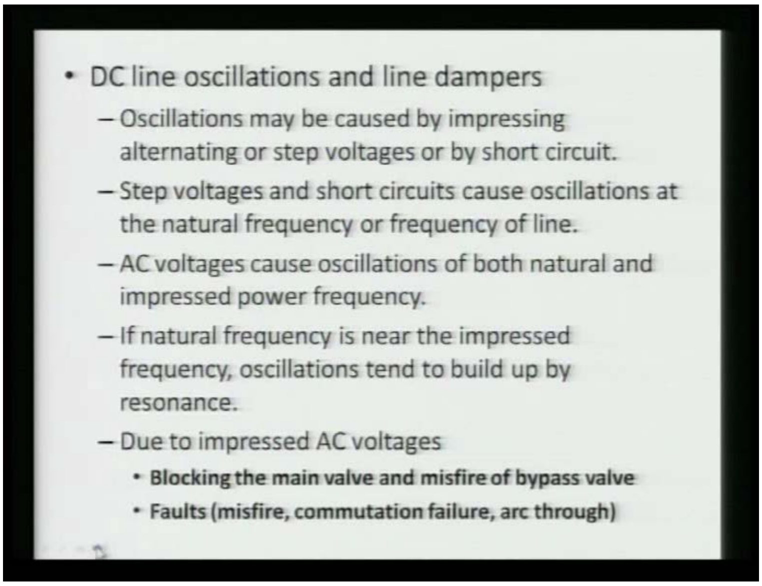

And since damper means you are having some damper circuit that is you should have r that said m power. So, we are using l and r this is a reactor and here resistor in combine together and this we are getting here. So, this is your anode dampers are used to avoid the oscillations excreta in this circuit. Another damper we used that is call the DC line oscillation or we call it the line dampers why it is happening? Now, already you are having a smoothing reactor in series with I d and the two poles are even the one poles having the zero potential and high potential capacitance will be formed.

So, due to this there is a some oscillation, because the stray capacitance is formed already inductance you are having in the DC line and then there is a some oscillation will be happening and this is called the you can say and this is basically the due to the different reason. If the DC current is constant then, there will be no oscillation why because this DC inductance is zero for this DC and this capacitance will be there. Whenever the voltage changing the DC voltage either step voltage or something then this here, this voltage across the inductance is going to change energy stored across the inductance is going to change.

And once it is going to change it must be exchange through the capacitors, because inductance l I square energy you must know if I is constant this energy is stored in the inductor capacitors is charged at a same here. The voltage whatever, the voltage is there and there is no exchange of the energy. If you are changing here the voltage capacitance voltage is change stored energy is going to change so, is change means is this energy must be discharge through some other device. And this is your inductor and once it is going to discharge through the inductor then there is a exchange of energy. When there is a exchange of energy means, you are having oscillation always oscillations occurs if you are having the two type of storage devices.

If you are having simple capacitors three will be no oscillation at all. So, you must have a inductor and capacitor combination for the oscillation so that is why we every time we were discussing the inductor and capacitance. So, there is a possibility that voltage is changing there is a possibility is current is changing, if current is changing mind it voltage is constant. So, capacitance energy is constant here inductance energy is changing due to the current then then we again oscillation. And again if your voltage is changing current even though constant than again it is going to change because your capacitance energy is going to change or both are changing so it is happening.

So, that is why the three cause if your voltage is changing alternative side here this voltage DC output will change or there is some step voltages arising due to some other misfire or fire another thing then this may also go there. And if it is a short circuit the current is changing then these are the three causes of the line oscillation. Now, here that a different the possibility why it can happen? Now, the voltage change basically it was the block if your main valve is blocked or misfire the bypass valve excreta fault is there. So, it is a you know these 3 conditions AC voltage changing then it is reflected during the DC side or step change due to the bypassing of the valve or due to the misfire meets a commutation failure. Always there is a step change in the DC output side or even the DC short circuit current.

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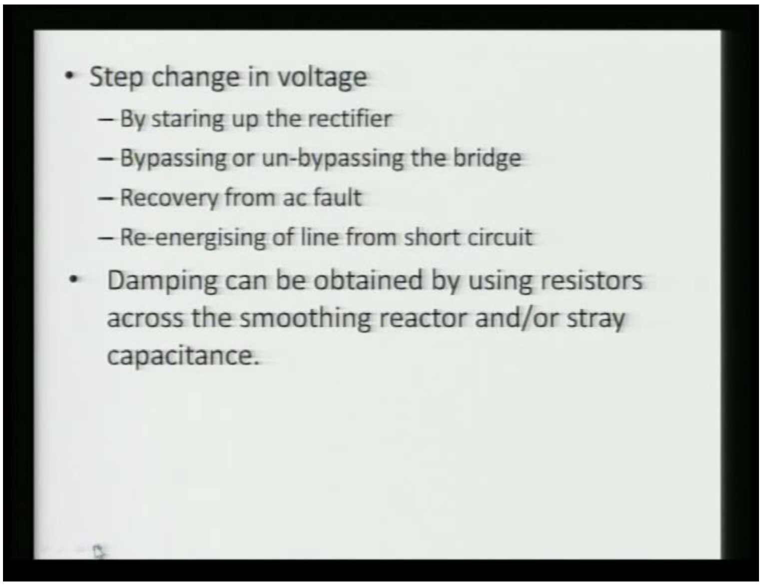

So, these basically the conditions may arise and that is a giving your oscillation in your line here. So, that is why the voltage change here if you are starting the rectifier or bypassing or un-bypassing the bridge the recovery of the AC fault. These are the various basically; causes that is the step change will be there. So, how we do? The damping can be obtained by using resistors across the smoothing reactor and or the stray capacitances means, here you can see this is your smoothing reactor this is your stray capacitance.

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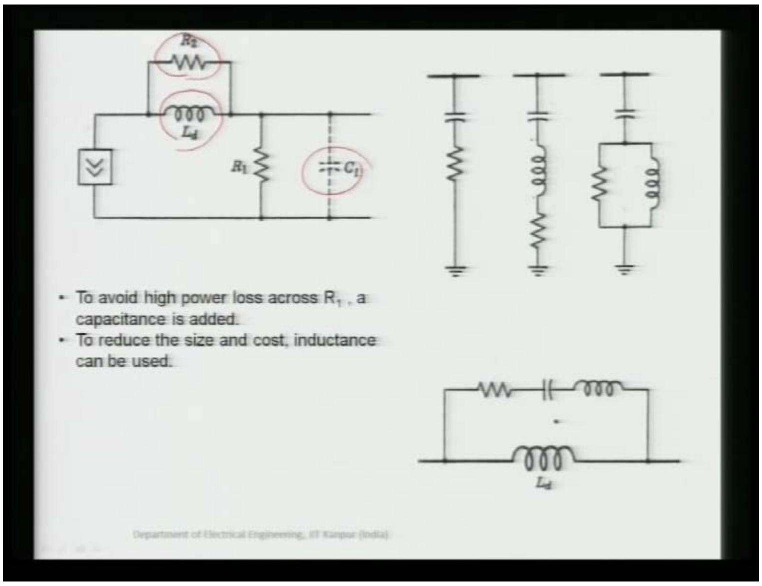

So, to avoid the damp to reduce the damping here or you can say provide the damping means, you do not want the oscillation here, we can use some resistance here parallel to this or we can use the resistance across this. So, what happens if it is a discharge it will try to discharge here itself? If there is some energy here it will try to flow in this one circuit loop itself and it is a dissipated in the air and this be there. But the major problem here you can see if you are using this r huge voltage across this resistance is there and even the normal condition. This loss is there in the normal if the DC is constant and then it is still there is a huge voltage and the resistance the huge loss is there.

So, what we put? We put a capacitor here if it is a constant DC there will be no current whenever there is a some oscillation then this will provide as a filter and it will be oscillating here. So, here this is a r c damper that is called the line r c damper we are using the lines here this is a line and then we have the grounding in here. So, this is a r c damper here we use the capacitance, but the cost of this capacitance is very high and the loss to avoid this. If you can use the inductor here then here you can minimize the cost of these quality capacitors. And here if you are using this then this is called your l c r dampers, in this condition what remains some harmonics current if you are using here this c then it can also flow.

Similarly, if you will see here resistance if you are putting across the resistance here always there is some change this even though there is a no line oscillation, but due to the some small change here that is not available there is some loss here. Because the current slightly changing here the huge voltage here arising and that is going to be there so, what we do? We again we put here capacitor in series so that in normal condition if a small value is there so that should not be discharged and we put the inductor in series to avoid minimize the cost of this capacitor.

So, that is why to here to reduce the size and cost inductance are used so, you can say here l c r damper here, here also we are l c r damper some people propose here in putting in the instead of series we can put in the parallel this is another tuning of the capacitors that can be used. So, this is your line dampers are used to avoid the discharge of this your the line oscillations. So, at the end here in whole this module what I discuss?

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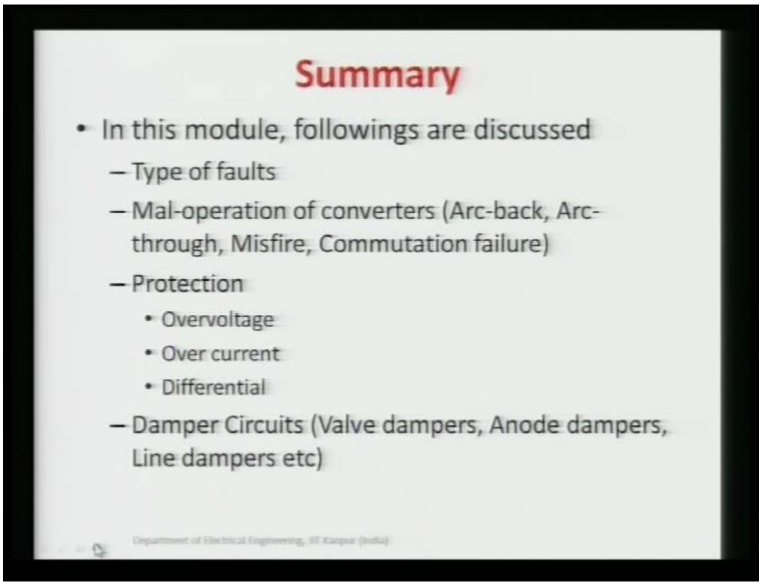

I want to summarize here in this module we discuss the following things we discuss the various types of faults, including even though AC your voltages AC over current fault etcetera.

Then we talked about the mal-operation of converters including your arc-back arc-through misfire and more detail and the commutation failure in inverter (( )). Because the commutation failure is a very common and all these faults will lead to your commutation failure in the inverter side. But the rectifier side these misfire arc-back and the your arc-through fire for we discuss with the voltage we have save and we saw how it is going to happen. Then I discussed the various protection schemes how means, we can use the over voltage protections we also, use the over current protection that is done by the valves itself control here.

The over voltage we are using overvoltage protection as well and then we also, saw we are using the differential protection to check the pole current dissimilarities. And I gave here complete layout how the protection schemes for overvoltage as well as your over current and differential protections are used the converter stations. Then at the last lecture I just discuss the various damper circuits and including your valve dampers basically, valve damper anode damper and also the dampers those are used for the line oscillations here.

That is called your line dampers here so, this whole module was basically related to your false and protection and the mal-operation of converter circuits. With this I can end this module number four and we will see module number five the different aspects. Thank you.