High Voltage DC Transmission

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Module No. # 03

Lecture No. # 01

Control of HVDC Link

Welcome to module number three that is lecture first and this lecture must be this lecture this module is devoted to the control of HVDC link. First will see, what are the desired features for the HVDC link then will go for the control characteristic both for the rectifier as well as the inverter end. And will see the various options and various faults, various voltage defects etcetera and then based on that we will derive the exact characteristic for the rectifier as well as your inverter end. Then later stage, we will once we will decide the exact characteristic for the rectifier and inverter, then we will divide we will go for the different type of controllers how that they will work and they will give that performance at the later stage.

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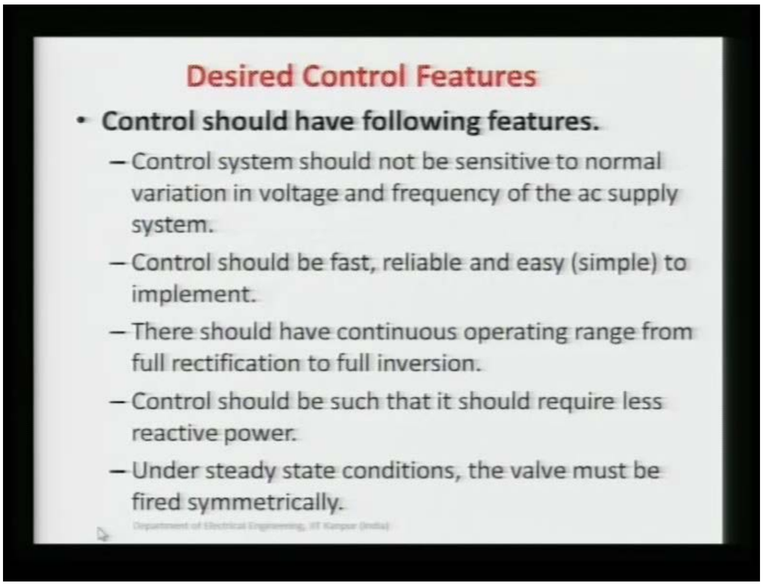

So, to see this desire features here, already I have mentioned several some of them are very common; that is required for any control aspect, any control schemes. For example, that control system should not be sensitive to the normal variation in the voltage and the frequency of the AC system. I mean that, if there is some you know if load is keep on changing the frequency of the system will also change. And then this change is due to the load generation balance whenever, there is a mismatch between the generation and load there will be change in the frequency. Because the energy whatever, the difference is there that is taken by the whatever, the rotating mass in the system it will be transferred. And there by the frequency of the system will fall down or it will rise depending upon the mismatch - means; if your generation is more than load simply then frequency will rise, if your generation is less than your demand frequency will fall.

So, normally, this frequency variation is not much, but still our system it is plus minus sometimes goes up to three percent, but in other countries normally, they maintain at very normal fifty hertz rated well. So, it should not be very sensitive, because if your frequency is changing your controller keep on changing from one mode to another mode here and there, then means, your controller may there be controller unstable means, controller instability may occur that we do not want.

Also, the voltage variation, if the small voltage is varying here the small fluctuations you can say sinusoidal is there, but there are some variations, it should not be much sensitive to that one. No doubt, if the voltage varying is used controller must take care so that it should do it is desired objective. Second feature is very similar for any controller we want that our controller should be fast; it should be reliable and it should be easy to implement. We can divide very complex controller and that time that controller is not useful, because implementation itself is a difficult task.

So, it should be simple as well so that we can easily implement and also it should be reliable means, we should rely on that means there should not be any failure. Otherwise, you know huge power blockage from one end to another end will occur; it should be fast. Even though sometimes we do not want very fast action in several aspect, for example, if a relay is there in AC circuit we want that relay should not be very fast; it should be fast, but not very fast. I mean, if there is a small variation somewhere suppose, current is spike is there and your relay is operating means it will trip the circuit. So, we do not want, but here we want the fast operation, because there will be any fault in the DC link the huge current will flow, because only there is no inductance only resistance is there, huge voltage is there, and there is a short circuit huge current will flow and that many damage the line.

So, HVDC control we require the very fast controller as well. And will see even though, if you are controlling your power electronics device like your converter you are firing here you can control very fast, but there is a option that you have to go for the even though sometimes using OLTC that is a online On load tap changers, if you are doing that that is the mechanical device and that will take time.

But first, we go for your firing of thyristor and based on that, we can do our objective of the control. Third objective is related to the continuous operation range from the full inversion, full rectification to inversion or vice versa what happens? Normally, if you are having a big HVDC link for the bulb for transfer always the direction of power is unidirectional means, if you are transferring huge generator is here, and you are providing the power over the bulk HVDC line and there is a load centre always it is unidirectional.

But as I said, we are having the different type of schemes for HVDC links, it may be your back to back connection, where the power from one region is flowing to another region, and there is a possibility in sometimes it can go back. So, once your rectifier which is a converter working at the sending end power is working is a rectifier, there is a possibility that power reversely there in that line. And this is advantage of HVDC means, it is not only controlling the power, it can reverse the power in the different direction. So, whatever that rectifier operation is there it should also sometimes require to act as a inverter. So, that is why here and it should be continuous, it should not out of change.

So, if you are operating from the rectifier you can go to inverter and then again inverter to rectifier whenever, it is required. So, this is called it should have a continuous operating range, it should not be different here and there. Another, the control your scheme here, we are talking here the control means control of HVDC. The control scheme, which should require the minimum reactive power support as I said, you know normally it requires the 60 percent reactive power due to the delay angle, if your delay angle alpha is delaying the power factor is going to reversion. So, we require the reactive power control.

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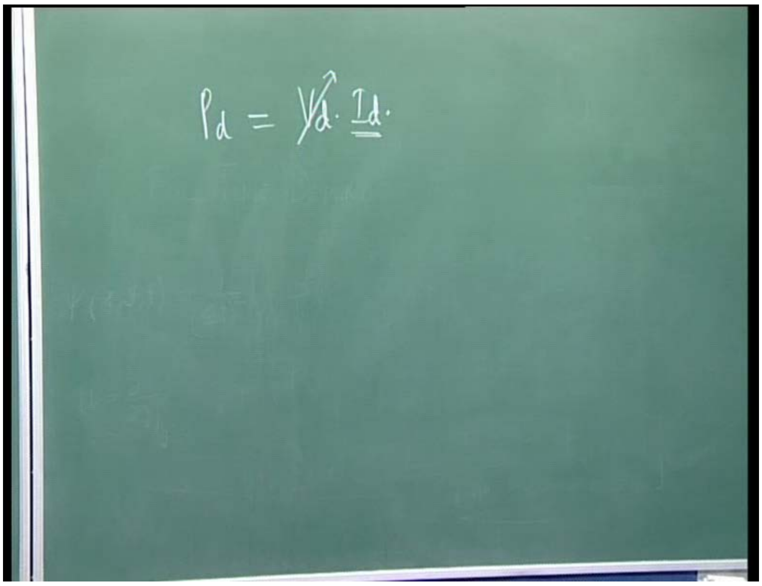

Here we will see, you know this DC power in the link it is nothing but your V d into your I d, if we are talking at the rectifier end, if you are ignoring the losses in the line the V d of the both end almost same. So, this control here, that will see here we are trying to maintain fix and this, we are changing by the rectifier operation. And due to this change, what happens? This V d will be controlled by the delaying your angle means, you delay angle means, if it is you operating rectifier, so you have to change your alpha degree, and if your operating inverter then you have to delay or you have to change your beta. So, once you are doing this then the reactive power requirement is going to change. And therefore, you require huge reactive power support at the both rectifier as well as the inverter end.

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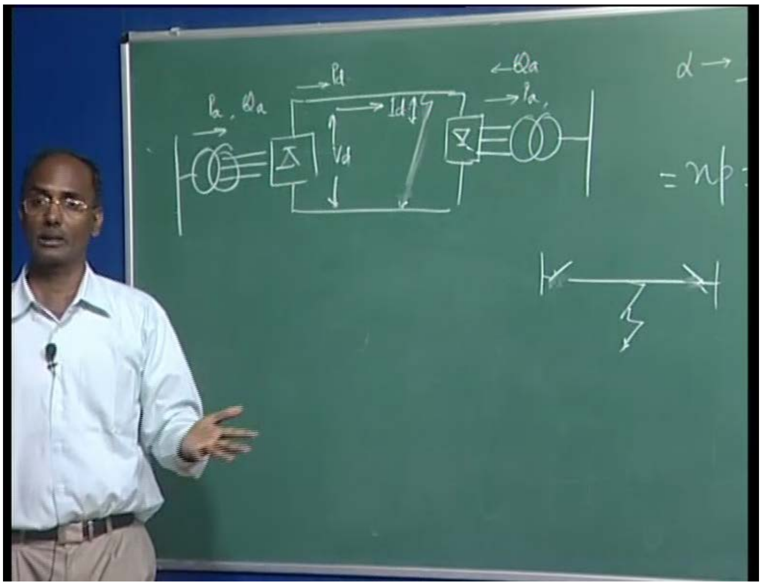

It is always, if you, I can just draw a HVDC link here, I can say simple six pulse link here the three phases is there. And this is your DC link, I can say it is your any link you can assume, here it is a three phase this is HVDC rectifier, if the power is flowing from this end to this one, if power flow is, this is your P d, which is flowing from here. Now, one thing is very here you can see, the power here the reversal is if you are doing this is a negative operation, if the voltage is the reverse, current direction is same, then power is reversed. The option that you can reverse this current and the change the voltage that is also option, but what we do? We prefer that the current in this link should flow in the same direction, it should not change.

We try to change the voltage here, this V d to change the power. So, if V d is 0, P d is 0, but if you want to reverse the power here simply you change this means this will operate, in rectifier this will operate as inverter, this will operate as rectifier then the power flow will be this direction, but the direction of current is still maintaining the same direction. So, it is a unidirectional current always flow whatever, they design. So, normally we talk, if power is flowing from this end to this end as I said, if they you are having huge generation this side and this is your work side, then what happens? Always the power is flowing from this end to this end.

But nowadays we are going to use further bulk back to back connection means, two regions are connected and not very high power is flowing. And, if it is basically based on the need of the different region, so power can flow from this end to this end, this end to this end. So, in this case I want to tell the (( )) power is here how AC power here I am talking this AC here you will also, require the Q at this converter, if it is a rectifier here, it is inverter your here P A C is this one, but your Q a is coming here means, it still consumes reactive power from the system, AC system this is basically, this side we are talking the transformer this is a AC bus here this is AC bus. So, the reactive power basically require, both end and we put.

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Now, you know and already I discuss about the filters, once here will go for the designed of the fill filter will see, we are going to use some of the filter to harmonic to eliminate to mitigate. The harmonic that should not enter this side means, we provide the minimum impedance to ground. And that at the fundamental component, it provides the reactive power means that will work as capacitor, I can say simply effective capacitor although, it is made of inductor and the capacitor together. So, that we can have either tuned filters or may be band pass filters will see the detailed filter design later on.

So, that even though filters provide some of the reactive power, but still we require some reactive power from the source, to minimize this reactive power here the firing angle or here the firing angle can be constant up to certain limit. Normally, what we do your alpha here? Normally, it is 10 to 20 degree, which never go behind the twenty or thirty degree. Because if you are going for more your requirement for reactive power becomes very excessive. Similarly, this side also, that is why here we should have a control scheme in a such a way that we can operate here, even though in this range itself not behind this. So, if you are operating less than that your reactive power requirement will be less.

And that is saying this feature here, another this is say this feature says that, under steady state condition the valve must be fired symmetrically, we are talking about all the valve that we are giving pulses at every sixty degree. So, why it is so, if you are not firing then you may design a controller that may give even though same value, but your symmetrical is not maintained means, your output is not symmetrical and you are generating so many harmonics. So, here due to this symmetrically, fired walls we are minimizing some of the harmonics. And you know you will see later on, if you are not symmetrically, here firing what will happen you are not only getting this harmonic, that is a n p plus minus 1 in the A C side this is now, components that you are getting number of pulse here n is an integer.

So, for six pulse you can say you are getting five seven then you are getting eleven thirteen or so on, if you it is only valid if you are having this symmetrically fired wall, if you are not doing this then you are having all the harmonics components. And inter harmonic components that will be going to your A C system. So, this is also required that we should fire our wall symmetrically. Now, the question arise sometimes that even though you are getting symmetrical, pulses to the valve and one is misfired or even though there is a commutation is taking place and commutation failed. Then in that case, also we are not changing our philosophy, pulses are getting every sixty degrees.

So, that we will see after one cycle this whatever, this misfire are commutation failure is disappeared in the system. No doubt during that cycle, there will be your voltage will be not symmetrical and you are injecting more harmonics, but next cycle it will be admitly cleared. So, main concern here to minimize the harmonics, we have to give the pulses symmetrically to all the valves. Now, some more features here for example, that the control should be such that, it must control the maximum current in the link and limit the fluctuation of current. Here this control say that here, because suppose, if current is excessive flowing in your link in this link the current can vary, if you are varying here what happens this controller may off let.

So, we want that this current should be steady state this fix value and also in the emergency condition, some of the times. Let suppose, voltage has gone down there is a some fault this side, this current should not exceed. So, it should have some maximum limit beyond that it should not go there and controller, should research that it should take care of that for example, even though you can see, if there is a fault here what happen? This current will excess will be, because only very small resistance of the line is there. The huge voltage here, because there is no reactions, no circuit breaker this line will burst.

So, we can maintain anyhow that this limit during any abnormal condition, I am talking it should not increase it is maximum value, it should have certain link means normally, it is not more than twice of this rated current for fraction of minutes, it is not even though for steady state. Now, another is the power should be controlled independently and smoothly, which can be done by the controlling the current end of the voltage. Simultaneously, in the link as I said here to control the power as I said, it is possible that we can control this, we can control this as well together. Here as I am saying the simultaneously means, you should control only one at a time, it is not both you can control this then you can change this so, it is always better to have one control.

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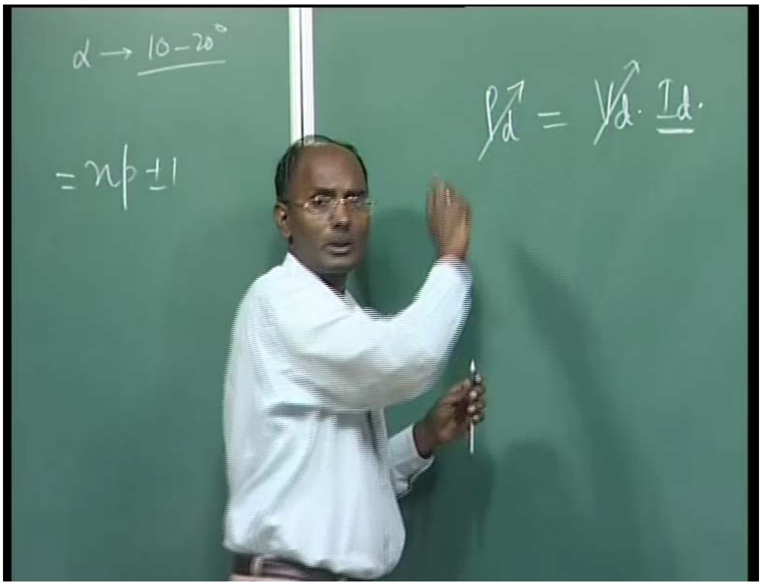

And then take this one means, to control this here it is better either you control this or you control this, to control this not both voltage and current. Because then your controller becomes, very complex and that time may give some unstable solution sometimes. So, in this one what happens we only go for the voltage and we try to maintain the current in the system constant. Another feature we require, because limitation of D C circuit breakers, so for even though. Now, people are doing lot of research in the D C circuit breakers as well as but still in the commercial way on very bulk rating of the current is not available.

So, what happens if there is any fault, we cannot open this line at once, we have one option here to control this we can reduce this voltage automatically current is 0. So, we require that we should operate in such a way your controller should be such that it can even though protect this your converter circuit, as well as. Because in A C circuit what happens here, the circuit breaker is there when a A C circuit here this is line here the circuit breakers, if there is any fault here in the line this will be basically, it is open here from this side, because we have the A C circuit breakers here, we do not have any option.

So, we can use controller for this and this we know that, we have some option to control very fast, because we have the firing angle, if the they can be fired very quickly. And then we can simply try to reduce this voltage 0, this voltage 0 fault will be automatically 0, means that is just like an open circuit. So, that is why here this feature say that, where control scheme should be also such that we can protect the system as well with the help of controllers, not with help of circuit breakers. Now, as I said we are operating here the constant current mode, and changing the voltage.

Now, there is a two option, we can operate at a constant voltage mode, means this is possible it was possible that this is fix we can change this, it is also possible to control the power. Only one quantity is require to because here to control the power, the current you can change and the current direction, if you are reversing then still the power is changed the reversal is possible. So, here we prefer in this control HVDC link that this current is constant, but voltage is varying. Now, then always there is a question why it is so that is why here, I am going to analyze the two options, if you are operating at the constant voltage mode or constant current mode operation, how it is going to vary and differ in the technical data.

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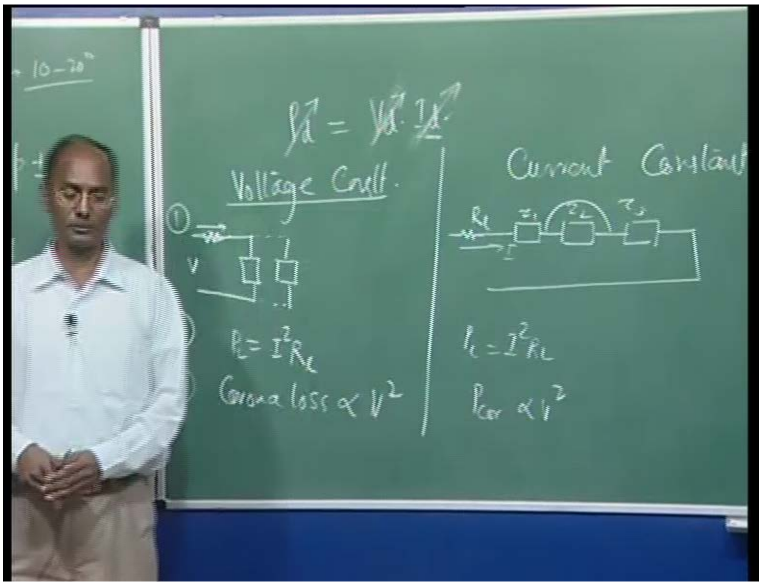

So. We just see here I am writing it is a voltage constant and another is your current. Let us analyze current constant here and we can see, what are the various options are there? You know normally, in the A C circuits always voltage is fix, because all your operators are operating almost same voltage. So, what happens in the voltage constant mode? You had to connect your loads in the parallel of the loads or supply system, means for example, this is your one load, this is your V, if you are having any load you have to connect the parallel to this.

So, what happens the voltage is fix, but the current run here flowing is the deflect. So, all the loads are basically, connected in the parallel in this scheme, here the constant current what we do, we connect all this here the loads in series. So, whatever, the current is flowing: here is the same throughout the this value here the current is different, here is a current is different. Because this depends upon what is the impedance of this load, means what is you can say value of this load impedance here as well. So, the current here is at varying voltage across all these things are same.

So, all the loads are bearing same voltage, different current here all the loads are having same current and the different voltages. Because here the z 1 here z 2 and z 3 are the different of loads, so this is your constant current modes of operation. Now, this is the first characteristic, second characteristic. Let us see about the, if you want to replace any of the load, if you want to replace any of the load, if you want to replace this simply you can take it out without any delay, without any problem. But here you cannot take it out, if you are taking it out here, what happens? The current is 0. So, what we do in this mode we normally, we bypass it and then we take it out. So, it is not easy task, first you have to bypass with the somewhere and then you have to take out, this load or simply bypassing mean itself it is out.

But you have to open here no doubt, if the voltage is there. So, here you can say the bypassing here the simply taking out this scheme still, I can say it is a complex to remove the load in the series circuit. Now, second as I said see about the losses, you know this losses here that is a loss it is here, I am talking about the loss in the line, because loss always occurs in the lines not in the load itself is a loss, because the energy is dissipated. So, we are talking here is there is or let suppose, so this current which is flowing here I. So, it is your I square R whatever, this is let us suppose this R L is the resistance of the line here, if you are having the resistance R L here also the loss will be your I square R L.

Now, see this I is the different, then this I we are taking both I is different this is for the voltage constant mode, this is a constant current mode operation. Now, you can see here the loss, this loss is constant irrespective of your load, irrespective of your voltage here, irrespective of the voltage across the load loss is constant, because current is constant. See here this current is keep on changing that depends upon the loads, if one load is there current will be less, if you are using another load current is again further increase. And so, on. So, for so this I is keep on changing depending upon the minimum loads to the maximum load. So, from here you can see, the loss here is less real power loss compare to here which is fix and constant throughout the operation.

Now, third option we see, there is another loss that is called corona loss, this loss is proportional to your V square. Now, the V of this line is fix, so this loss is constant here, but here we are the voltage is changing, so your corona loss is changing. Although corona loss is not very high, but if you are going for the e h p transmission system, then this loss is significant. Because here this loss is going to be less, means I can say corona loss, it is also here proportional to V square and it is keep on changing. Now, you see another difference here, this R L is more than this R L. The A C resistance, if the same wire you are using, A C resistance is more than your D C resistance due to the skin effect.

So, if this is one ohm it may be 1.2 ohm so this value is till now the loss is also slightly higher, but it is varying here this loss is varying. And also this loss is less in the D C line compared to your A C line, as I said this corona loss is proportional to f plus 25 that is a frequency, so here the frequency is 0. So, this loss is less and also here the voltage is varying. So, this loss is extremely less, even though you are operating at the as I said the bipolar operation, that is a plus minus 500 k v, means you are operating the two lines line to line, to line volt is thousand kilo volt.

So, that case this loss is very significant and it is going to vary means, it is less sometime depending upon the power control. So, the total you will see the losses is not much difference, either you are operating this or you are operating this. But in the most of the practical cases this loss is less, than this loss, if you are operating at the lower voltage this loss is almost 0. Because we require some voltage that is a vcritical voltage, this voltage is minus certain this (()) voltage V minus V O C. So, if it is less than suppose, you are operating let say 400 volt this is 0 corona loss is totally 0.

So, it again that is why here, we are going for HVDC high voltage in these losses are significant, corona loss as well. Now, fourth is that is a very important and this fourth is nothing but related to your fault current means, why we are operating here the constant current, that is related to your constant current here.

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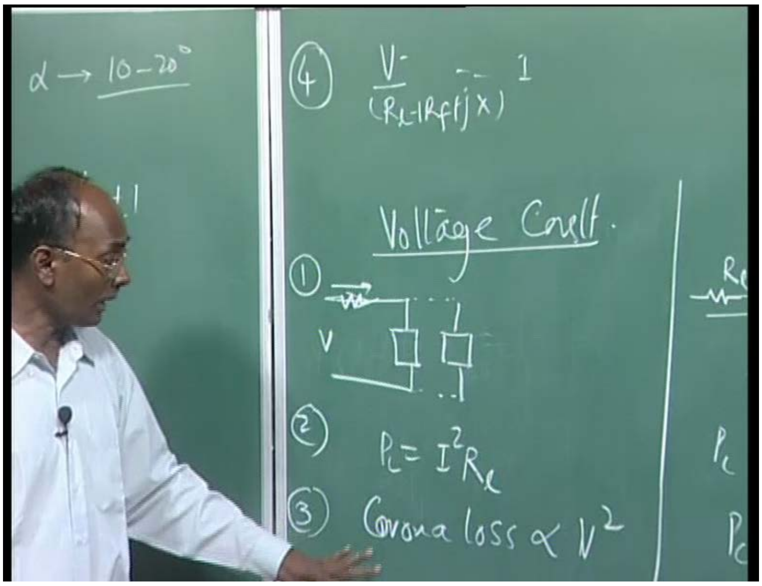

And I can say your fourth option, you see if there is a any fault in the system, what happens? This you have the circuit breaker and you have even though not only resistance, you have reactance of the line as well. And therefore, here your the voltage divided by your this R whatever, you can say this line plus your fault resistance plus your you can say j x whatever, this is the current which is coming this is normally, it is a 5 to 6 times depending upon this what is R f value etcetera. But what happens you have the circuit breaker, it will be automatically tripped, but if you are up here in the constant current mode as a current cannot exceed, that value current is rated current. So, even though there is a fault the current will be here the I d here.

But suppose, we are not operating with the constant here I d what happens? You are operating here as a constant voltage and the varying current. Now, you can see if the fault has occurred here this voltage is constant and this resistance is very small.

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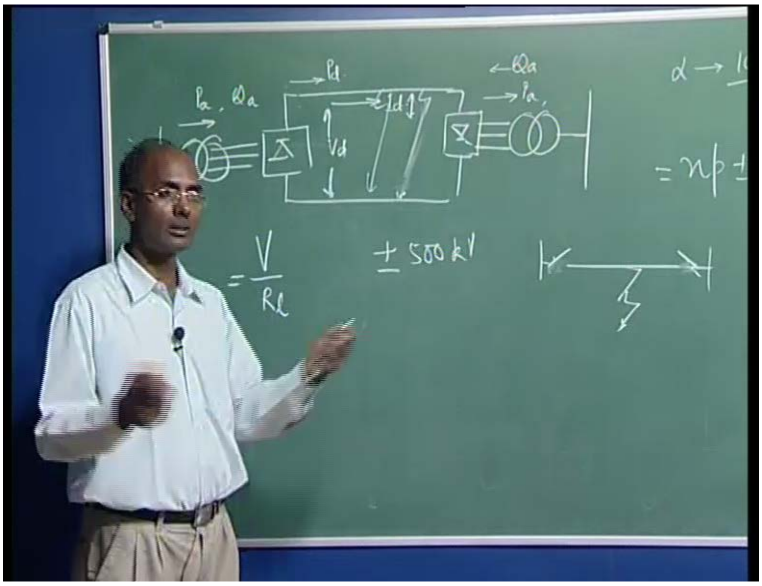

As a D C resistance, no reactance D C and that value your divided by your R l is this current is almost twenty may be, twenty thirty times of the rated current. And then you can imagine, what will happen to the line. So, if you are operating here as a constant voltage varying current here, because you even though your are using any circuit breaker any scheme, but still this is a twenty thirty times current is very very high. And this basically, the reasons here we found the here is not much difference in the loss for e h p lines for high voltage lines, if you will combine together the loss is not much difference, but this impact factor is very high.

Because we want that here there is no circuit breaker and also, only it is the limited the fault current is limited by the fault resistance as well as, your the resistance of the line. So, if you are operating at that constant current mode, no doubt there is a sudden jerk is there, but your controller will work act and finally, the current will be again maintain the same value.

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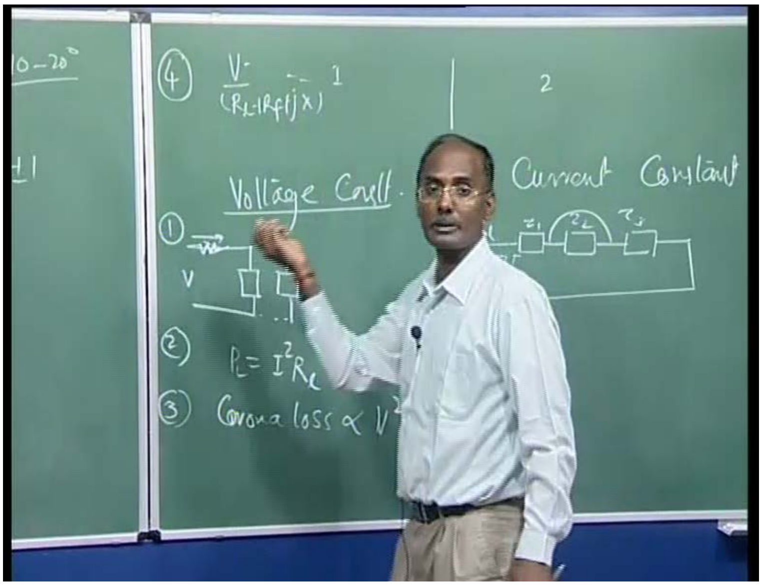

So, normally, here in this case the current, if you are here can go several time here, it can go twice of your rated current. So, this feature basically, advisors that we should operate our HVDC link, in the constant current mode and the varying voltage to control, the power over the line. Now, I hope it is a justified why, we are using the constant current rather than constant voltage, which is practisized in the A C system, here it is a practisized in the D C system.

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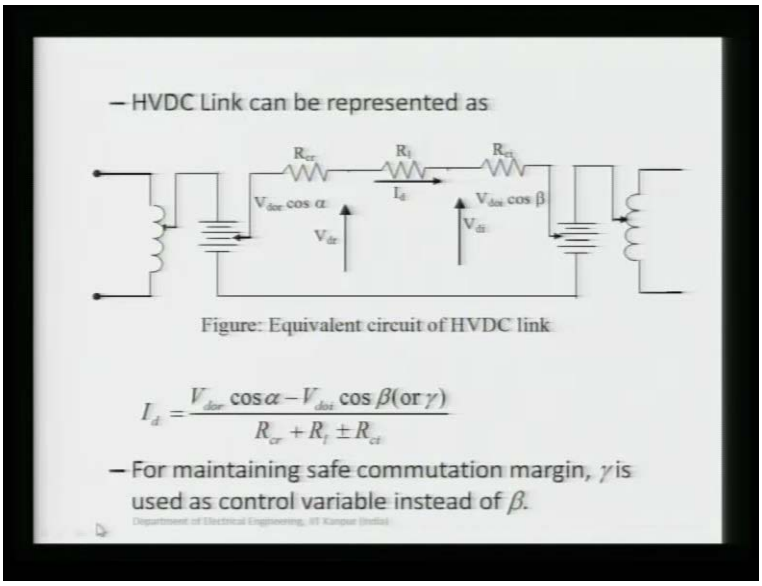

Now, come back to our equivalent converter circuit with the line, if we will see here I already derive this is your rectifier, that is you can say cos here at the V d o R here I have written the cos alpha. And it has a your commutation resistance of R denote your rectifier and I this side denotes your inverter. And this is your V d o I cos beta R c i, and this is your resistance of the line that is R l here, this I d flowing here we are having the transformer this is a equal. And single phase of this of this fourth circuit, we have taken the single phase here this side that A C system, if it is a balance you can take a single phase.

So, this is a complete your equivalent model of rectifier line and the inverter. Now, you can from only from this circuit, we can write the what will be the I d in this link. And that expression here, I have written simply this voltage, minus this voltage divided by the resistance of line commutation, here of the react rectifier and here the inverter commutation resistance. Now, you can see this expression is written here, if you are using beta, if you remember it was the equation was the plus so here it is a plus R c i we are using, if you are using gamma, then it was the R c i was negative. And we are using here the minus 1 so, the bracket quantity, if you are using then it is a minus if you are using path beta then, it is a positive resistance simply is remember we drive the expression for this one.

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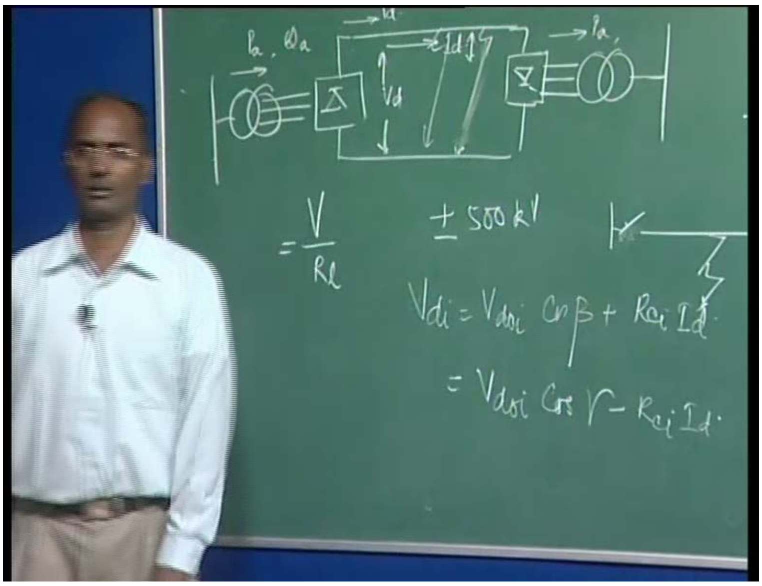

Here, your V d o V d i was your V d o i here cos beta plus here your R c i I d, if you remember this, because you can see this current is flowing this side. So, this voltage plus this voltage your this voltage. So, this is a referral plus, if you are using here the V d o i cos gamma minus R c i I d, if you are using this from here you can just derive it and already we have proof it. Now, this is the equation for the current and based on this equation will analyze, the what should be the characteristic of our controller for both rectifier, as well as the inverter end. Now, as you see this end, we can either operate at the beta mode or gamma mode, it is possible either you can decide the your beta instance or you can maintain the gamma based on your what is the gamma and beta the it is.

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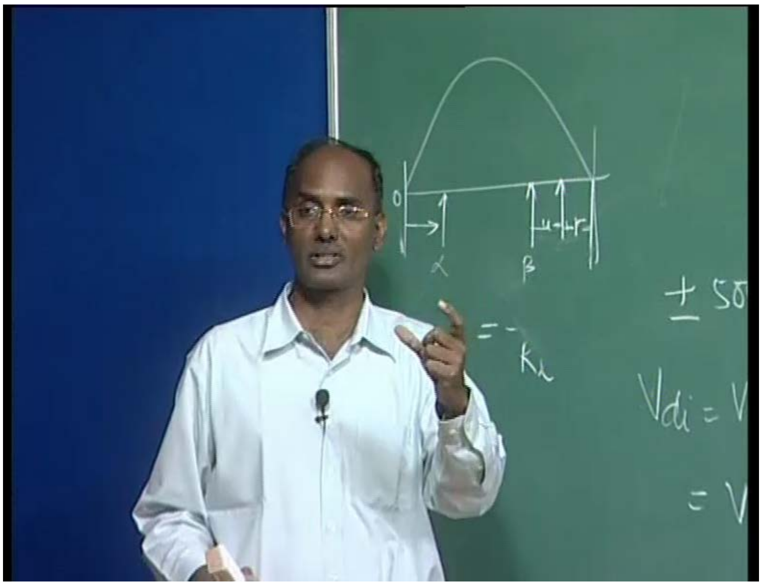

As I have explained here in the inverter operation this is your commutation voltage here, this is from this side, if you are going it is 0 here. And you are firing this is your alpha from here to here and, if you are firing at here this is your beta, that is a and we are measuring from this end, means this beta value is phi minus alpha. So, this your beta where you are talking, then there is a u period and then this is your u period and this is your gamma period. So, either you are denoting again this gamma also, measure from this end and beta is also measure from this end. Because beta is nothing but phi minus alpha. So, this is your alph now so this angle is phi minus alpha this one, so this is your beta degree.

So, either we can operate our inverter by here knowing this value or this value, but it is always preferred to use our inverter end with the gamma control. The reason is here as I said, if you are not maintaining this minimum gamma there is a possibility, that this will be going, when the voltage is reversed means, commutation between the two walls are taking place. And the voltage may reverse without completing the commutation. So, it is always desirable to maintain some angle here may be, ten degree here or 5 to 10 degree. So, that there should not be any commutation failure will see the commutation failure, when we will talk about the mall operation of the converter circuit.

So, it is that is why here it is written for maintaining the safe commutation margin gamma is used as a control variable instead of beta, because once you are using this beta what happens? Then there is a possibility u will change and you cannot maintain the gamma at that time, you may face the commutation failure. But if you are maintaining this based on that you can compute what will be your firing angle, because you have to give the firing pulse to this your valves. So, this is require, but what we are doing, we are trying to maintain this based on that we are calculating the instance will see, how this gamma control is turn, how this beta is calculated controller will calculate. And then it will give the firing pulse and then it will be done.

So, even though while calculating what happens, there is a possibility there is a change in the A C system. So, u may change, so that is why we are maintaining here ten degree, even though there is a some change also take here. So, instead of beta we use this gamma control and this is basically, will see it is called the constant, extension angle control and this angle is maintained minimum value constant. And then there by we control other thing, only problem here in this controller, that due to this negative resistance you see. Now, this is a negative resistance here you can see in this expression, if you are using gamma we are getting here the negative resistance is not a resistance, it is basically effectively due to the inverter operation.

And this resistance, you know negative resistance is very difficult to operate that controller stably. So, it is very very carefully normally this type of controller, it is not we change too much. So, that there should not be any stability problem of the controller at all, this negative will normally, if you are talking or working on the negative resistance it is always possible that operation may not be very smooth. So, what we do, here we try to maintain this gamma will see, these factors will be taken care while deciding the characteristic means, what we are doing, we are not changing the gamma here the gamma is fixed now that is ten degree and then you do of whatever, you want. So, this side only we are trying to maintain the gamma only. And will see whenever, some emergency occurs it will go in the different mode also. And then, when we drive all the characteristics, then it will be clear to you.

Actually, in DC constant current were maintaining and were connecting all the loads in series.

Yeah.

So, then the load should be designed for constant current, they should not this different current.

Yeah, what happens this time of this type of schemes, even though there is no D C loads nowadays means, D C load I mean that we are all the loads are fed with the A C system, here just I was comparing that, if it is possible in the beginning days, when we were having the D C supply only they were connected like this. So, at that time the voltage rating of course, it is changing voltage across this each equipment is changing but you can also see.

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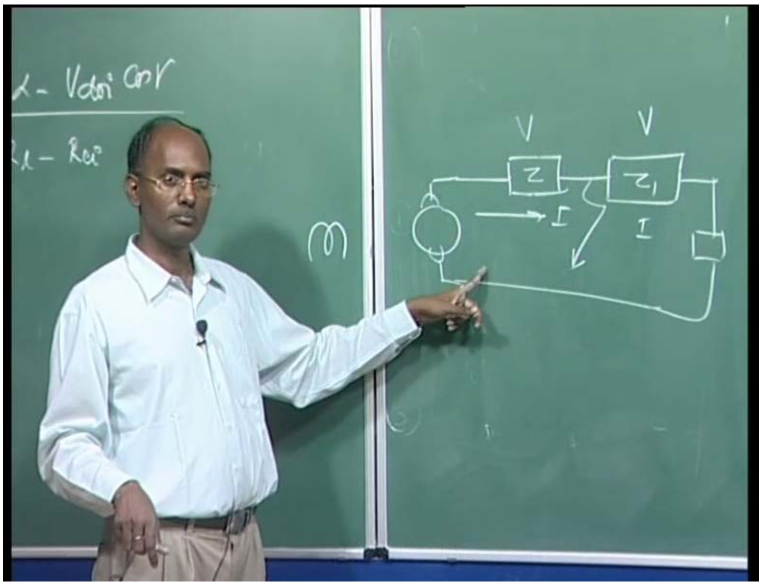

Here, if your let suppose this is your instrument the current is constant here. So, constant current right now, but this impedance is known to you. So, the voltage is also fixed here, so the voltage is also here you can know how much voltage is appearing, because current is constant here, because the impedance is basically, the we measure whether is even though motor load or whether it is your lighting load is travel. So, this is fixed this is now voltage you can calculate based on the gate. So, you can say this voltage or this current almost same thing.

If sir more than one load.

if more than load here what happens this voltage? Now, you can say that the voltage is here, but not this voltage is here we are changing the voltage here. So, this voltage still same, it is not going to change across this voltage, what was even though it is not connected the voltage, again it is going to be same. Because the current this z is a different here, I same and the voltage is this one. So, either we are connecting this load or your load or you are connecting both loads, the volt is you can see and current is not going to change across instrument.

But sir why in the volt, we have to means we have to change the voltage for maintaining the constant current, the current voltage is being changed of the source, how the constant current operation means.

No basically now, the question here, if you are having the some way to control if you are having converters you can control the voltage. This is not practisized in the A C system first thing, it is practisized in the DC system. And on early days normally, people were using this, when only the D C and small loads were there it was not bulking, but in A C always it is a prefer as I again compared with the A C here. The constant voltage and constant current here and found here this is this system is A C system, where the constant voltage scheme is a better than your series one.

So, this was use in the beginning, when the very small small loads and D C generator were there, but now it is so. Now, we are given the D C generators also feeding the same types of parallel load, we are connecting specially, for small voltage loads, your the constant voltage scheme is more efficient more efficient. But if you are operating here in your this is a constant current for high voltage, I said the reason the two reasons losses are not very much effect or more or less similar, no doubt this is a constant voltage loss may give less, but the another thing is said the fault current that is very, very important and based on that we are operate HVDC links on the constant current mode.

Regarding, that type of question that we do not have actually the current source or we have the voltage sources.

No even though, you are having let us suppose, the DC generator you are having.

And DC generator will means, how constant current of constant volt.

Listen here D C generate whatever, the DC generator you are having is a series or seperately excited, the voltage you can change and how the voltage change? This you can change the field and field can change you can measure this current, you can what is your major current, what is your reference current, this can you can change, you can maintain the voltage across the vary.

Sir to maintain the current constant.

Yes.

We maintain we change the field here.

Yeah.

We maintain the so in the case of fault.

Yeah.

Here in the case of fault we current will suddenly go up.

No here the controller is there here, if the fault will rise again, it will try to reduce the flux. So, that voltage will reduce.

So, similar controller was there in the case of constant voltage case also.

No in that case,voltage always fix voltage is not changed.

Yeah sir, but.

Here we are using the A C system, where the voltage is fix it is not change at all.

Controller is maintaining the constant current in the line.

No and when the listen, what you are talking? You are talking about now it is right now A C system or you are talking about this controller both are separate things.

I am talking about that a controller is used to maintain, the constant current.

Where now where.

In this system.

This system is a D C system, where early were there. Now, we do not have this system so in that case here, if you are you said we cannot have the variable voltage earlier, there were no power electronic device, people were using the DC generators. In this scheme, it is a possible that you can change the voltage. And by the here maintaining the current.

I was you were proved that the, because of the fault current we use constant current system.

Yeah.

So, I was saying that fault to maintain, the fault current constant there must be a controller, at the generator side.

No we will come to this controller, how it is decided I did not discuss about this, I said we require the constant maintain current. And now, we will decide what will be the characteristic of this side and this decide will see this, I am going to derive that characteristic, still I did not come on the characteristic.

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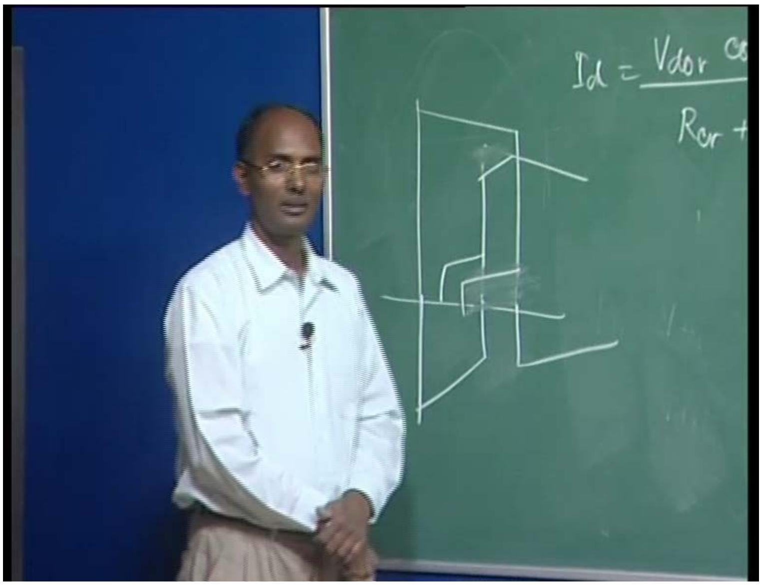

And for your knowledge, will see here this rectifier basically, we are going to have this characteristic is one joule here, we will find this is going to be like this, here if you going like this. And I will come each and every now here again here, I will change here it. Now, it will be this here again, I will change later on one by one here. And we are going to have this characteristic. So, I will give reason for each why I am changing this, so still it your on the before. So, the we will see how the characteristic going to change, you see here is a constant current characteristic here there is also, constant characteristic sometimes, it will be hitting limit it will shift here.

And there, we will just discuss here so my intension was here not to explain much, because I only I explain that, if you are operating the constant voltage or constant current, how much you are going to get means what is your efficiency of the system. And why we are using the constant current in the DC system. Because the main reason, we do not have circuit breaker, only our converter should act and that is why we require the controller, that will work as a just like a fault protection of the your system.

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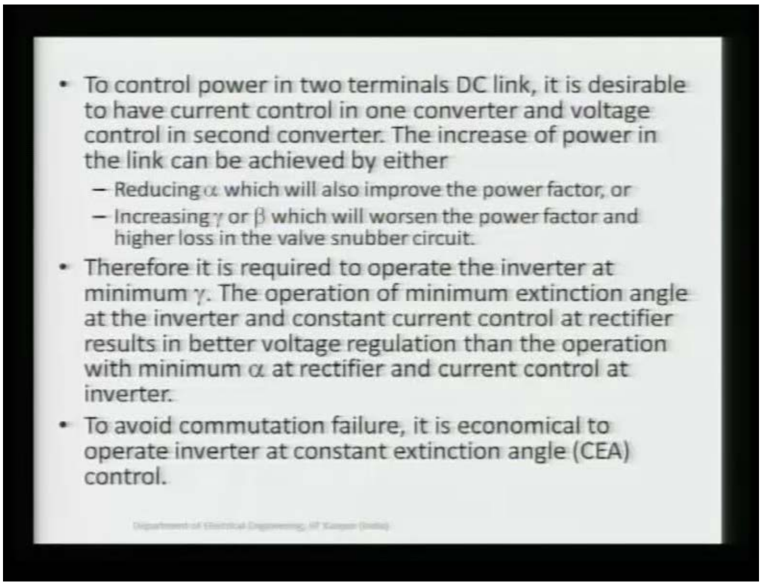

So, we will see and now let us see and we have to drive one by one the characteristic. So, as here already I have written, which I just I discussed you that control the power in the two terminal DC link it is desirable, to have current controller in one converter. And the voltage current, in the second controller, why we want the control should be the different, in the different. Because it is not that every time it is switching here and there, we want that one controller should take the current maintaining the current. And another should control the voltage, so that we can control the power smoothly.

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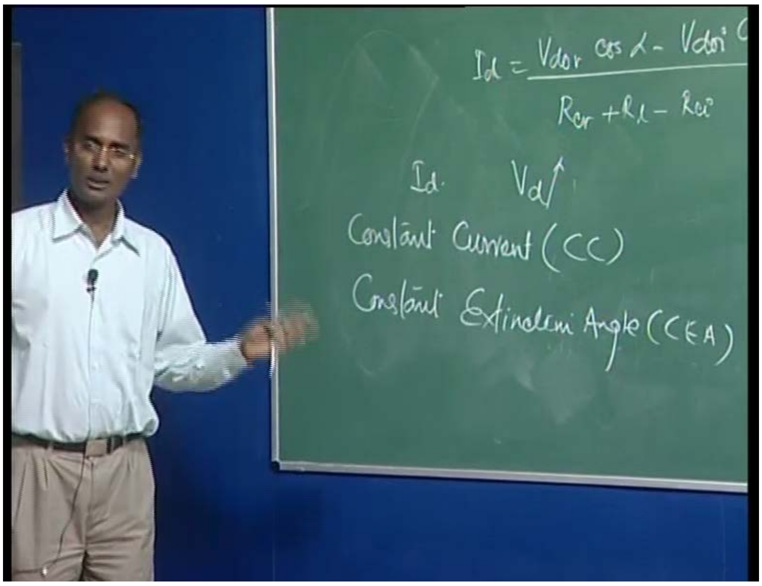

So, because I said we require the fix current, this is fixed, so one has to take care either this side or this side. And we will see from this equation it is required and another side the we require the voltage control. Now, the question is that which will do this, which will control your voltage, option is there will see where, we have to go for the constant current controller, this means maintaining D C current constant means, we will have the constant current control and it is always C C. We also want that this V p our inverter end as I said, due to the commutation failure will come I will drive and will see that, we want the constant extinction angle control and it is called C E A control.

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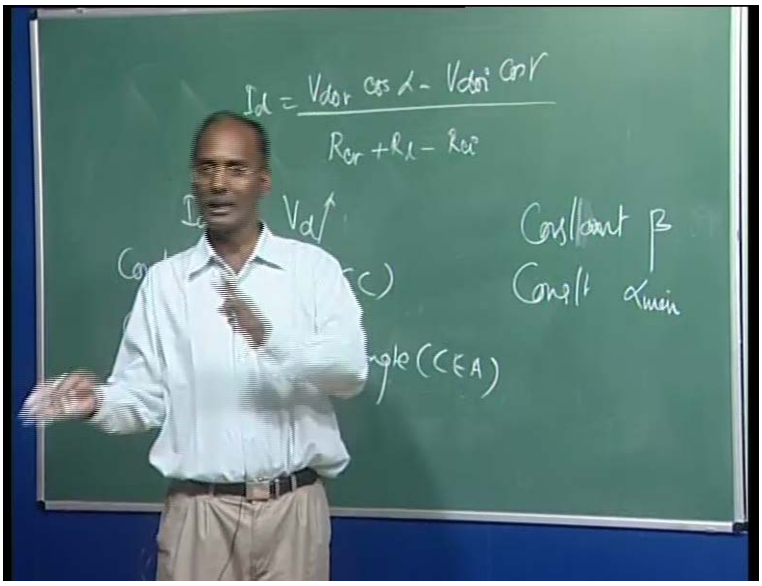

We also find another characteristic is require, that is will see constant beta control, as well and will see constant alpha minimum control, it is also called and it is called the constant ignition angle control, C I A. Will see all the controller why, they are required once we will analyze whole system as well. Now, how this current is maintain the constant now from this equation, you can see here already I have written to increase, the power in the link can be achieved by reducing alpha, which also improve the power factor. And increasing the beta or gamma, which will worsen the power factor and the higher loss in the valve.

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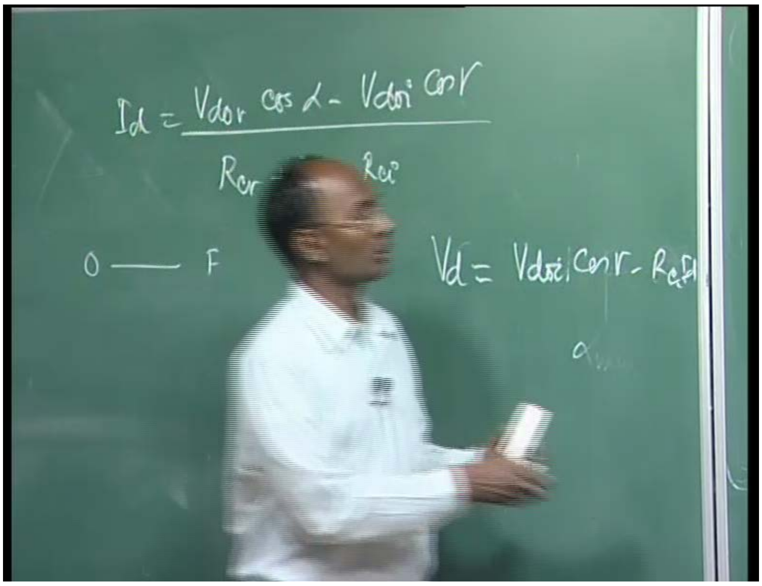

Now, you can see from here, means to this is a constant. Now, we want to control your the V d here this is your V d basically, we are maintaining the current also. And this is a V d, if you are varying here alpha too much for voltage what happen? Suppose, you are varying from 0 to full value this alpha becomes ninety degree approximately, it is again overlap another things you are just taking care. So, that is a different issue, but this if you are going to detoriate much, you are reducing alpha means you are increasing alpha higher what will happen, the power factor is going to be very worse very poor.

So, whatever the power you require may be the more reactive power, you require that time. So, what we do, we try to maintain this mean some value it should not go behind the twenty or twenty-five degree. So, then this side we have to come or we have to use this one this, how we can control this, because we are having the tap changer. So, first we have to go for this, because it is a very fast, if it is exhausting it is limit means your let suppose is a reaching twenty-five degree, then we have to switch we have to try to control here the voltage by this.

Let suppose, this is still exhausted then we can come this side, because this we want to maintain constant, because we do not want to change it here, we can even though go for here for example, this is a minimum value, but we can also increase this value again, if you are increasing this your power factor going to be worsen inverter end. So, you can even though reduce this, but it has a some limiting value. And it should not come and this then option is your inverter end. Now, let us see some of the impact, so based on that as I said here, it is required to operate inverter at the minimum gamma means.

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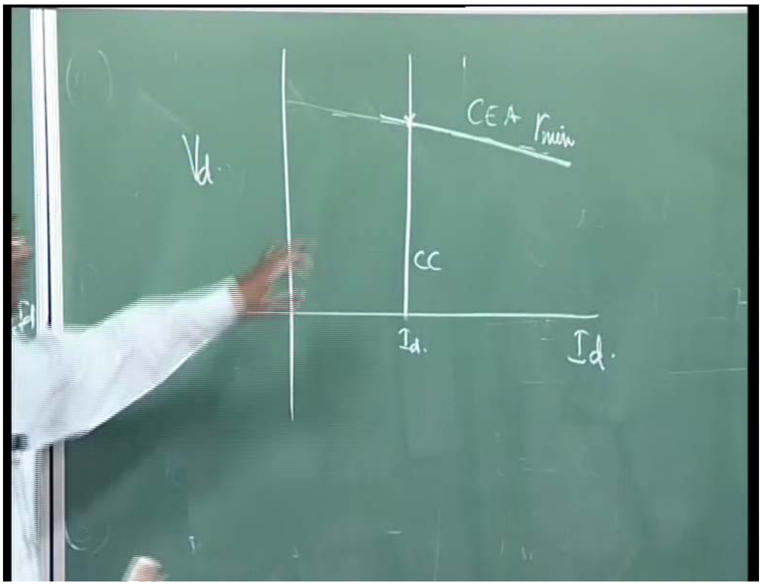

Let us draw the characteristic, of the controller here it is your voltage, here it is your I d, because we want to the characteristic of your whole circuit based on the voltage and current. So, it is we require that this should be there and it should not your this minimum should not be reduced. So, what happens the characteristic will see it is the gamma minimum here, why the equation I wrote, the voltage equation this is you V d here this inverter end. It was your V d V d o i cos gamma minus R c i I d, R c i I d. So, this is the slope of R c i I d, so this is this is a slope here and you can find this is the characteristic this is called C E A.

And this is your inverter end means, it should have a certain limiting value it can reduce the it can the alpha can be larger, but not less than this value. Now, then if it is in this one then, we require another option that there should be control constant. So, this option to maintain the constant, we assign rectifier should take care of this, because this end now, we are fixing this. So, what happens your rectifier here it is your constant current control and this is your I d value of the rated and this is called the C C are constant controller, that is the rectifier storey.

And your intersection here is the your actual operation of your D C link always this controller. And this controller the characteristic will match and then it will be your actual value of operation, because this I d is governed by here this equation voltage and then constant controller here. Now, let us see, if there is a some change and that is why I will go for the characteristic, change later on. Already this things I said, that here rectifier operator constant current control. And the inverter is operating at the C E A mode that is a constant extinction angle control.

And also, I here mention about due to the negative resistance, the stable operation we research keep on changing gamma here, there may be problem. So, normally this is a fix value here. Now, let us see the A C side voltage impact, if there is a fault in the A C side and here and there how it is going to vary. Now, first I will take this case, when the rectifier A C voltage is increasing, rectifier A C voltage increase means this increase, because this is having the rectifier A C side voltage that is a e m. So, if that voltage is changing, means this value will change I am saying, if let us suppose voltage is increased what will happen, if this voltage is increased.

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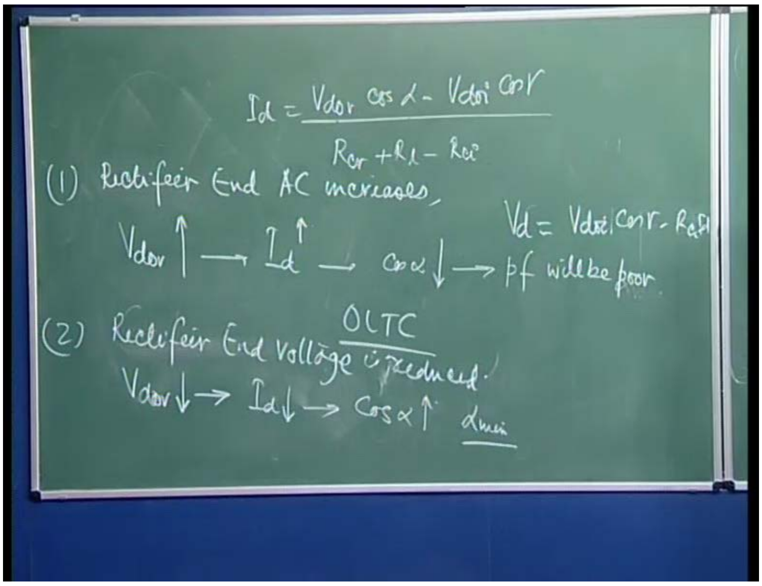

This current will also increase means, here due to the first option this your rectifier end this A C voltage increases, then your V d o r will increase. And this will cause your I d will increase, it obvious this will increase we are not doing anything here and this is divide by this it will increase. So, what will happen your rectifier, which is trying to maintain the current, it will try to change this alpha and it will try to increase the alpha.

So, that this should be reduced, so that multiplication here should again maintain. And the current should be maintain here.

So, what it will do, it will be going for cos alpha here it will be reduce means, alpha is increased. And this will be nothing but what will happen to your system, the power factor will be poor. So, what we have to do, we have to delay this angle alpha further, but we have to stop somewhere. So, that the power factor, because we have the reactive power limitation. So, it is alpha should hit it is maximum value may be twenty-five or twenty- degree. And then we have to stop it, the controller will then still let us suppose, the current is not your rated value what will happen, then our OLTC will come into picture that side. And here our this now OLTC of rectifier will be exercised then and to maintain this one.

Now, the question still arise that, if still it is not maintained we exercise this first, then we exercise this first possibility may be, if huge drop that means A C increase, then what will happen still it is higher. Now, we have to increase this side this we cannot reduce this, because it is a already control extinction angle control mode. So, here we have to do this means, your A C voltage OLTC here has to be changed, no other option. And this will be taking care now, the question you can say still not maintained, because the voltage increase cannot be more than 5 to 10 percent, if it is happening your line will be burst first A C system.

Because voltage is A C voltage let suppose is a 400 k v voltage cannot be more than 420 volt, because there is a other A C system is there that will over voltage. So, that will be even though from here only itself and we can adjust this voltage. Now, you can see this now the same scenario if this voltage is reduced second this rectifier. And voltage is reduce, if this voltage is reduced what will happen? You V d o r will be reduced, it will go down then what will your rectifier will do, it will be your I d will be also reduced. And this will be trying your cos alpha should be increased, if the cos alpha is increased means, we are alpha is reduced.

And we have to say alpha minimum here, means it cannot be reduced at a certain value, because knowingly we maintained 5 degree alpha minimum. So, that all series valve must be fired in that degree that time. So, this alpha minimum is there it will hit this limit. And still it is not maintained then again, OLTC will take care. And still it is not done, then this will be taking care here now, you can see from there.

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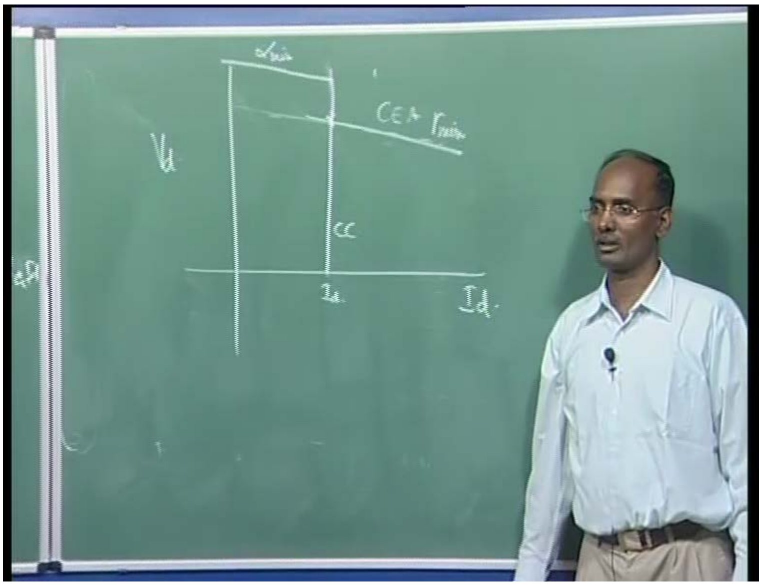

We are having this characteristic here means, we are somewhere it is your value is here. And it is your alpha minimum characteristic is here, means it is not possible here to maintain this means, because this is alpha minimum is hit. Now, this will be stopped that end, it will may be your OLTC will take care suppose, it is still not taking care, then we will see another will take care. So, this is here alpha minimum characteristic is also given here, because it cannot go here. So, that is why here is a C E A here C C here, it is also called C I A that is a constant ignition angle control.

So, with this I can stop here and we will see other effects in the next lecture that, if this side the voltage is changing increasing and decreasing, how this controller is going to act. And thereby we will just change this characteristic and we will see that is basically, required. So, with this I will stop it here and we will meet in the next lecture. And we will see how this control complete characteristic both rectifier and inverter is done. Thank you.