High Voltage DC Transmission

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Module No. #05

Lecture No. #04

HVDC Components Design

So, let us start this lecture number 4 of this module and this will be the last lecture of this module. In this I will be discussing about the reactive power control and the grounding electrode and also I will discuss little bit about this your the DC wires. That is your pole what we are going to use what is the difference between the AC wires and DC wires only I will give the salient features on that.

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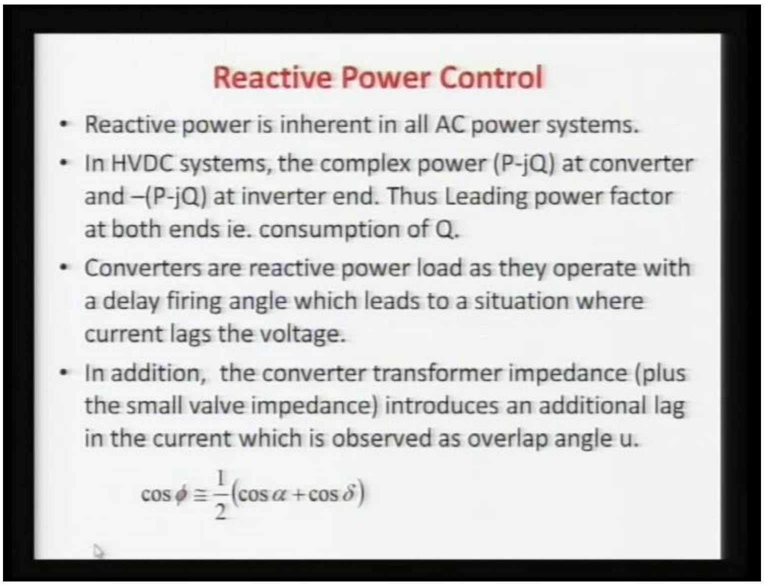

So, starting this the reactive power control already we have seen the converters or even though inverters are consuming reactive power. And the reactive power basically what happens in the converter station we can say it is just like a leading power factor leading in the sense the flow direction of Q will be reverse of the P. So, here this is your, if it is a rectifier and this is your inverter means, I want to say that this is your three phase connection with this so your P here it is flowing in this direction but the Q we require from the system because we have to provide the reactive power support, because it consumes reactive power from the source.

So, it is again your concept what you are just treating means, whether this is also giving reactive power to this the system is giving, but this as a load it is consuming. So, that is why we are saying here? This is your P minus j Q I am writing means, the Q power we have to supply here which is consumed by this one. Similarly, your inverter so, but in principle here it is a leading power factor at the both ends means it is there is a consumption of Q.

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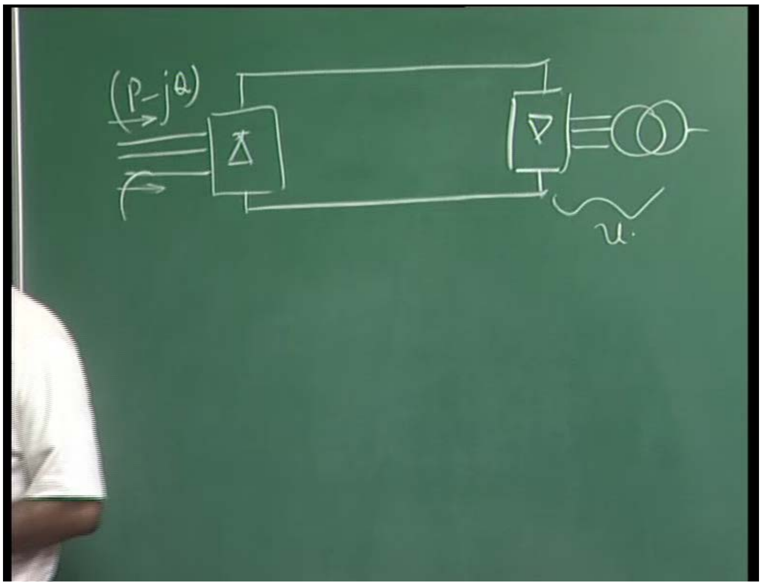

The made culprit who are this consuming the reactive power no doubt, this is your transformer. It is having a reactance and at same time this your valve impedance, along with this is contributing for your reactive power consumption and that is basically reflected in terms of u we have seen that is an overlap angle. Because this overlap angle is basically taken care of this value of reactance as well as whatever, the impedance of your valve it is going to be so that is why it is written here this leads to where the current lags the voltage.

We have also seen here the Cos phi that is a power factor can be approximated. It is very close to your whatever, this is a delay angle Cos alpha plus your Cos delta by 2 this is basically proved in the previous our analysis based on the principle. That we are assuming the P ac is equal to your P dc your converter is lossless. So, it was proved if we are having the delay angle, if we are not having delay angle then this Cos phi is equal to your Cos alpha. And here that is why so this due to this there is some approximation here, because this is not a sudden change so this is very approximate to this power factor.

Now, this power factor here can be also written or you can say, if this is a power factor then we can say our reactive power requirement. Here it will be nothing but your the DC power multiplied by here sorry it is your tan phi. It is not Cos phi, it is a tan phi this is the tan phi of this we have to provide the reactive power just we can proof it also. How it is happening? You can say this Q, this is your P, this is your Q, this is your phi. So, in terms of Q we can write what will be this Q from here itself it is a tan phi. So, the reactive power requirement is basically I can say it is a tan phi into your p. And p is either you can write D C or A C, because this we have proved on this principle and we have assumed this lossless.

So, we can write the p DC so whatever, the DC power there it is power factor is tan phi of this is going to added. Thus, we can also write another relation of overlap angle in terms of here is a function of operating current and the converter transformer leakage reactance. The leakage reactance here is x l and the current here this is a rated current of the link, but if you are not flowing the rated current due to certain reason. Normally, we maintain the current in the link, but if you are operating your link at the half lower depth or somewhere even though less current, then your this u value will be also different. We have seen the u is directly related, what is the current in the DC link?

So, if this is in the per unit these are also in the per unit, we can have this relation this u overlap angle is the Cos inverse here in this fashion. Now, you can see, what is this it is very similar to our expression? Here that is we write here v d this is your v d o here into Cos alpha plus Cos delta by 2. It is related to this in a somehow, because you can see this Cos inverse, if you are taking this if adding this alpha here and taking cosine. So, you are getting from here it is your Cos delta is equal to your Cos alpha minus I d over I d not here into x l.

It is the equation of the current I d, I d is equal to I s 2 into Cos alpha or minus Cos alpha it is similar to the equation of the current. It is similar to the not even the voltage equation it is I d just we have written like this expression. So, this is basically, similar to this means, it depends upon you and this expression that can be seen. Also in order to meet the AC harmonic performance each filter is switched at the certain D C power transmission level known as over loop control. What I want to say that? When your load is increasing in this D C link your filters are normally switched in, in such a way that it can provide the required reactive power support.

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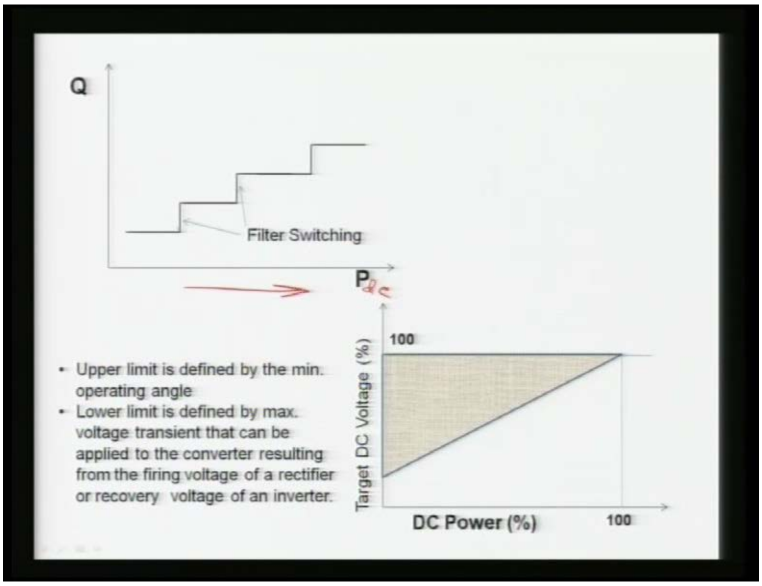

So, the switching instant you can see it is normally, it is here you see this is a curve this is a power your real power is increasing in the this is a D C basically, D C power in the link is increasing. You are keep on switching you know one filter, two filters and three filters accordingly so, that you can provide more and more your reactive power support. Why it is also happening? If the power is increasing the current AC current is also increasing means, your harmonic magnitude is also increasing at that same time. So, if one filter here is there then we can switch another filter here, if more power is flowing of the same magnitude I am talking if the fifth here so, fifth is also here switched in.

So, we are having more flow that it can be that can because the rating of the filters may be a particular current. So, we are adding another parallel so current is shared and but we require more reactive power support also. The reactive power is also increased up to that level. So, the here the filters are switched based on your the power flow normally the variation if it is a long distance power transmission over the D C line the power is normally, maintained at the particular level means. Suppose, it is a fifteen hundred megawatt power it normally flows more than thousand powers. So, then switching is very rare one or two is sufficient.

But if you are starting from 0 and is a huge variation like you are having back to back connection. So, it is every time it can be side that side and keep on changing, then you have to keep on switching even though your filters as well it is if fit here. Now, you can see your operation of the voltage, what happens? As we know to increase the power or the decrease power we prefer to maintain the current. Because we do not want to change u because once u is changing then you are putting more and more reactive power support.

So, we do your voltage change and then you can see if the D C power varies the voltage is changing from the minimum voltage to here it is a maximum voltage. And it is obvious that p D C is here it is equal to your v D C into I D C. So, this we are changing and this is normally kept constant this can also vary depending upon the your change of the this is suppose, is working as inverter. Then we have to change the margin or if the voltage is very low then we have to go for the (( )) area and then we have to reduce the current as well. But the normally, we maintain this current here and voltage. Now, you can see the upper limit here this is a maximum value here is limited by your the delay angle.

Because here this DC here it is nothing but your v d o Cos alpha minus your that component r c I d so this depends what is this maximum value here, if alpha is minimum and that is the control what is a 5 degree or 2 degree accordingly. So, this upper limit is that is why it is written upper limit is defined by the minimum operating delay angle. However, the lower limit how much you can go basically, if the voltage is very much reduced what happens? Here this even though inverter side here this may be the recovery voltage is not sufficient. And this made there is lot of commutation failure and this may not survive.

Here also we see the transient voltage condition that we can go up to this minimum voltage otherwise, if we are switching the here converters more transient will be arising. And that may be problem so that is why? Here it is a practically experience the lower limit is defined by the maximum voltage transient that can be applied to the converter. Basically, we are talking here rectifier resulting from the firing voltage of a rectifier or the recovery voltage of inverter this side the recovery voltage is very important. Because voltage is very small this converter operation is very this inverter operation is very, very difficult. So, this limit minimum limit basically decided by that but upper we know it very well it is a delay angle, again it is your either alpha or beta based on that it is decided.

However, in the switching here this is not only that, that is certain that you have to keep on switching there is also a guidelines that if we are switching a filter here how much voltage, because you are changing the reactor here. The reactive power injection you are feeding here what happens due to this? You have to see how much voltage rises there and that is it is defined, as the step change in the voltage is also seen. You can see here and that is a defined as here means another requirement is imposed on the reactive power control is that A C voltage step change should not exceed specified A C voltage of this voltage.

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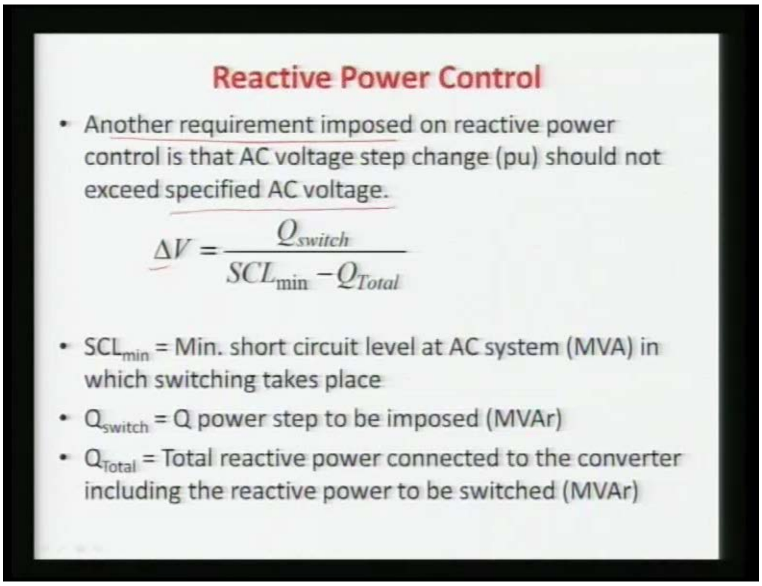

So, it is that is how much reactive power that is a Q a switch here it is a defined, that the reactive power step to be imposed that you are switching this value divided by the short circuit level at that point minus the total reactive power including this, which is going to be switched. So, what is there plus this it is included here and this basically, gives your rise in the voltage at that bus. So, this is also governed, if we are switching here, if voltage is rising then you should wait and you can the previous one will be continue till you are going so this is always calculated.

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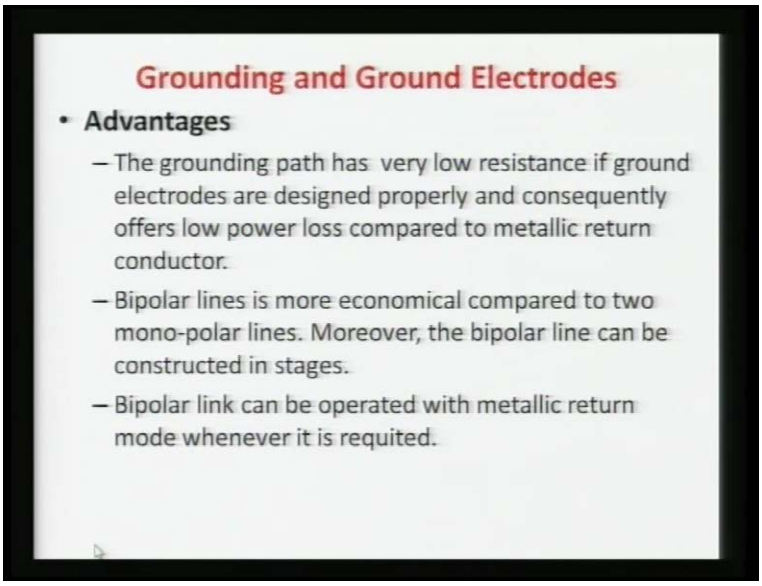

This change step change voltages should not exceed much beyond but because that may create another problem in the operation of the h v D C link. Now, let us come to this your the grounding and the grounding electrodes, already I have discussed about the what are the advantage of the grounding? As you know that we are sharing one wire, if we are operating in the mono-polar operation is obvious. Apart from that here that is grounding path has a very low resistance and, if grounding it is designed properly it is a really very low resistance and it occurs very less loss compared to even though your wire. Because if you are putting a wire metallic wire then the written path is this you just imagine a mono-polar operation this is wire this is your written path.

So, whatever the conductor you are using it has some resistance and this metallic path you are just going here, if you are using this has even though significant resistance. And if you are designing electrode very properly, because this distance is very high although value is very less. So, if you are using ground here even though that resistance is lesser than this metallic resistance and therefore, I square r loss is less so it is said it is less loss. If you are using ground properly ground, otherwise you just put your wire on the ground it will not go.

Another advantage here the bipolar lines is more economical compared to the two mono-polar what I want to say? That we know that is, if we are using the bipolar it is economical in the several sense. Because we are using the this is mono-polar, if we are having here another converter means, we can use here another bridge and this is your, if this is a positive, this is negative and this is your ground. So, the current is flowing no doubt, this ground is not used. Now, the cost of this is always cheaper compared to this mono-polar here why?

Because you are using the grounding system here, here also grounding only one grounding is sufficient for this portion and for this portion and also the converter station is the going to be cheaper. For example, if we are going for one big machine and you are going for a smaller of the same total capacity that will be more expensive is obvious reason. So, this in this no doubt, the grounding is not used bipolar is cheaper. So, and you know this bipolar can operate of a mono-polar, if there is some problem here at the same time this can be even though started in the phase wise. Phase wise means, you have one mono-polar now one pole you are not even though using and you are using ground as a return you can go for the another pole remove this and grounding should be there.

So, it is advantageous in that sense that, if you are installing your device this h v D C link in the phases the bipolar then one pole you can have in the beginning with the help of the ground electrodes. Anywhere, we have to have the ground electrodes, because if there is some problem in any of this pole it should pass through here. So, we can use another one in the stages so that is why here it is said? That it is economical and moreover the bipolar line can be constructed in the stages and that is you can achieve the advantage of this. This bipolar link no doubt, this ground you can use, but it can be even though used as let us suppose, there is some problem in this converter link here what we can do, and if you do not want to use the ground.

Because using the ground it has no doubt, some problems, because there will be some interference another thing. But we can use this wire as well, we had the bypass for all this here the bridges, because once we want to maintain it we had the bypass which is here, we have the bypass which is here as well. So, we can just bypass and we can use this current should flow here rather than this. You can see this construction here in this diagram. How, it is realized here? You can see we want this is a bipolar operation here let us suppose; this is a plus and minus poles are there.

Now, you can see this bridge and this bridge is opened and we are reconnecting this switch d here means here you can see means, current is basically flowing here and it is going here it is going here and coming here. But if you are this breaker, this metallic breaker, this resistance breaker here, if you are closed here there is a possibility that the current will flow here rather than here. Because the resistivity, if the resistance of this path is less than the metallic path here, then it will go here. So, what we do we just, if you want to use this you have to switch open so that the current can pass here.

We use some other some pressure et cetera for opening here. So, this is basically that we can use and we can bypass this completely and you can use this metallic wire if required. But if you do not want to use then suppose, there is a fault in the line there is no other option you have to close this you have to open this and the current will flow here in the half of the bridge.

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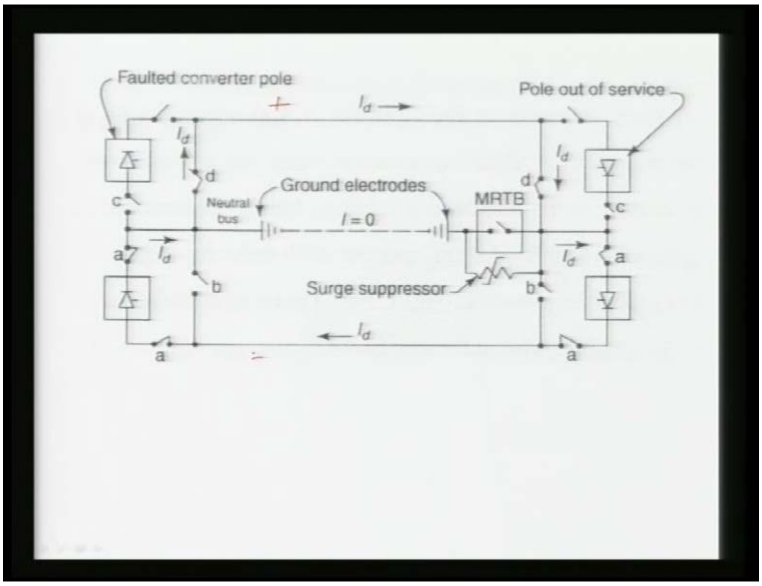

So, this scheme is also there means in the bipolar that is why it is more advantageous, if you want to use the ground wire you can use if the fault is in the line. Then you have to go use the your ground wire here and the ground electrodes are there where the current can flow if required.

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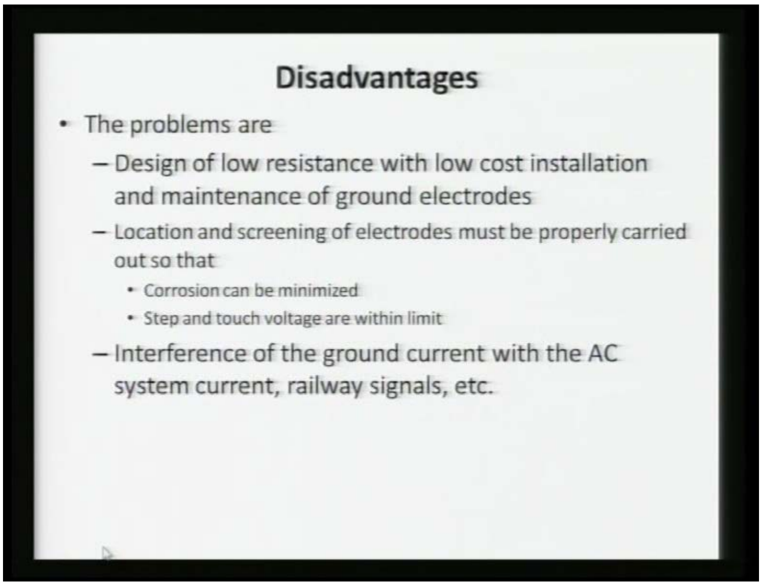

The major disadvantage of this here as we have seen the design of the low resistance with the low cost installation and the maintenance of the grounding electrodes are difficult. The major problem is to design and to get you know it is you have to bury the conductor you have to put lot of chemicals you have to see the soil condition at that place and also you should be very aware the location etcetera is very important. So, that is why the location and screening of the electrode must be properly carried out. So, that we can minimize the corrosion of the even the electrode rods and also other equipments those are grounded there may be some transformer is star connected transformer it is grounded.

So, so many other devices are there may be even the pipes are going some water pipes etcetera are there cables are inside there so lot of problems even though (( )) there may be some current etcetera may induce. So, the corona can be minimized and also the step and the touch step voltage and the touch voltage should be within permission limit. Because if a person who is suppose, some current is flowing in the ground and the person is just stepping in so there is some one meter distance what is the potential? Normally, it is said that 6.5 volt per meter should be the allowable it should be less than that. And the touch voltage is thus potential at that point what will be there it is normally 5 volt per meter is permissible with this.

Another we will see here the what is the touch volt etcetera another problem here that is a interference with the ground current with the other A C system. Because we are having the A C wires, we are having A C substations A C lines are there. That frequency may introduce some current in your D C current as well your thus railway signals are there. That high frequency may be induced in that ground wire and it will raise some potential another thing in that wire in that grounding current.

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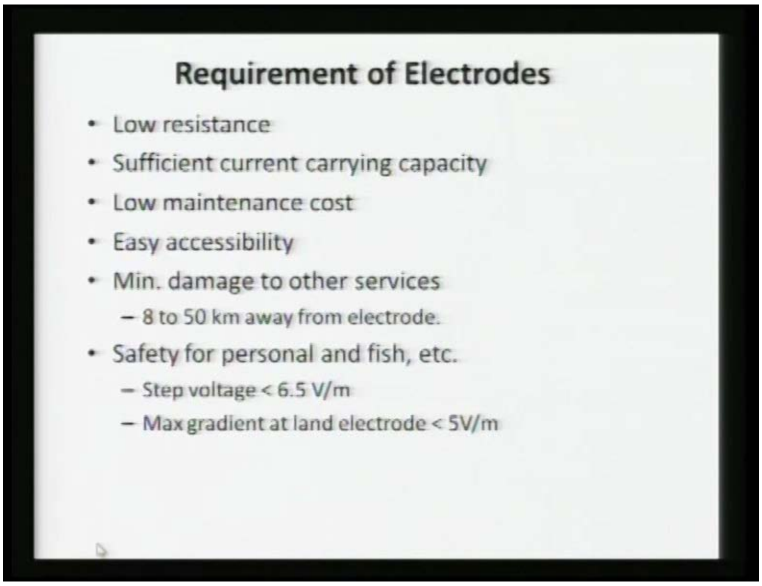

So, it is so many other things also interference is also our concern if current is flowing through the ground. Now, to what is obvious that we require an electrode should have certain property the first and the foremost that it should have the low resistance. Now, here I am talking about the electrodes. Electrodes again can be of two type one is may be your vertical and other may be horizontal what is the vertical and what is horizontal? Here this is your earth your this is electrode inside and you have connected with the some wire here. This is electrode and this is inside this is an electrode this is a horizontal electrode. Normally, it is buried here 1.5 meter to sometimes 10 meter.

Another is called the vertical electrode it is your ground here you are putting a electrode here in the ground here and this is connected here. Then you just free hit here the current will follow because we have to go up to certain level, where this the resistivity of the earth is the main. And this length it may be even though sometimes approximately 50 meters or more than that. So, this is a vertical electrode this is your horizontal electrodes in the that is buried in this ground horizontal how much distance? It is approximately 50 kilometers, 10 to 50 kilometers both sides. Yes even though the location of this is decided how much we are going away we will see it in the next slide. So, we are talking about the electrodes here.

Because the surrounding of this earth where you are putting that is another concern where you are going to put here. Because what is the resistivity of this material is earth of that time, what is the resistivity here as well? So, the total resistance offered by whatever, the current which is flowing here it will be basically this resistance plus the resistance of your earth soil. So, many things so what we do? We design this we even though earth soil is not perfect we put so many chemicals and other things. So, that we can minimize the resistivity and therefore, we can even though area can be more wider so that, we can the current and the current can have a wider path and it has low resistance.

Now, another requirement that it should have the sufficient current carrying capacity, because you know the current, which is we know it is normally this one kilo ampere the current the D C current in the link is seen kilo amperes. So, what we require? Suppose, just kilo ampere huge current is flowing and that is the D C current of course, no doubt, if it is A C current we require more thicker wire. If it is your DC current, because this D C current the uniformly distributed in the electrode so but we require this is the carrying capacity here this should offer the less resistance. Because the normal resistance of which is seen by here to another one. Means, between this point to this point here the resistance is called r earth resistance.

It is your electrode length resistance below the resistance of earth. So, if you are minimizing this you have a very limited control so normally we try to keep it here, because this is certainly it is very less. So, it should have a sufficient current carrying capacity. We will also see if we are not having the sufficient current carrying capacity, then what will happen? Means, the resistance of this electrode is high what happening? The current is flowing there is I square r loss mind it this loss is not dissipated properly. Because it is not exposed to air if a conductor on the top even though there is I square r loss it is just it is dissipated in the air as the freely there is temperature ambient there.

So, it is a release of the energy but here what happens? This is heated then here both sides is the heated and the chemical etcetera what we are putting? Even though resistivity of this soil will change resistance will change. So, we should have even the wider so that is very depth and the very wide wires are even pipes are used for the DC here.

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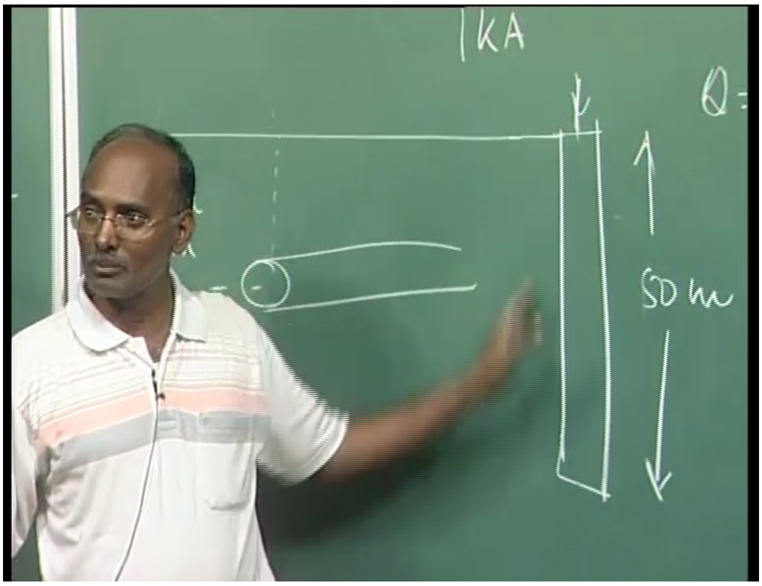

Another condition is the low maintenance cost means, no doubt, the maintenance here what are the maintenance? Because the maintenance here there is required that you have to put some water, some chemicals. So, that if the heats are there here that soil resistivity is changing so you have to maintain this. And also other costs like the joints here there is a corrosion in the pipes etcetera that should be maintained suppose, you want to change it you have to replace so maintenance cost should be also easy less that is also required. Another is the easy accessibility what we do here? This even though, electrodes are not buried in the substation itself.

Because in the, if you are putting in the substation there is a lot of possibility, because other A C equipments are there certainly we will have a lot of problem so, what we do? We try to put this electrodes somewhere on the way, because you can see this is your tower where the conductor. Let us suppose, this is a conductor is going we are having so many towers this is hanged here so it is going. So, what we do here? We go for a neutral wire and at certain this is near to substation your substation is this. So, we go somewhere and then we put the grounding so that this can be there so normally, it is said it is away from 10 to 50 kilometers depending upon we have to see what is the resistivity of the soil at that point.

Because your substation normally near to very near to huge generating station where you have to evacuate the power. So, at that time suppose, you are like in our country if you are having single behind it is very stone another areas. So, it is very difficult so we come here in the plain side where the resistivity is less and we put this grounding electrode there so it is 10 to 15 kilometers away depending upon the size. So, the easy accessibility that you have to see, where you are having the grounding that you can easily access it you can maintain it and you can just inspect it if there is no problem there. So, easy accessibility here related to the location of the grounding. So, it should be easily accessible with the road transport etcetera. So, that you can monitor and maintain the properly that is why? Here this is here written this 8 to 50 kilometer away from this.

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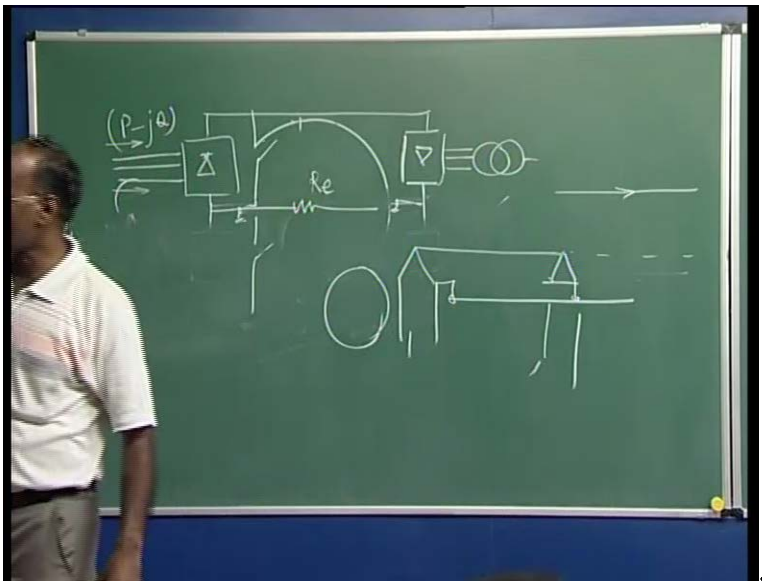

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This is also here the minimum damage to other services means, here if we are putting here there is a most likely that it may damage your other equipments. Because the corrosion here you are having this lightening arresters that is going to grounding earth mites are there so lot of problems are there. So, what we do? We again put some far away so that we can the damage can be minimized. Safety of the personal here of course, that is a touch point, because the current is flowing so, there is some potential gradient because there is a resistance. So, there should be that is why here the step voltage it is set, it is safer limit less than 6.5 volt per meter. A person who is walking is expected one meter distance between the two touch points and also the maximum gradient at the land electrode here at that point. Where it is should be your 5 volt per meter that can be seen here in this diagram here.

You see from here this is electrode, which is buried in this here this is earth. So, this is the potential that is the gradient, which will be burying here it will be like this e is like this. This variation depends upon, which type of rod you are using, you are using the hemisphere, you are using a circular something some ball is inside it is your horizontal. So, this variation basically, is changing in the shape, but say here slope here, but the shape will be almost same here at this center it will be the minimum and the both side here because the fluxes here linking current is going. So, that you will be there and again you will find it is a declining.

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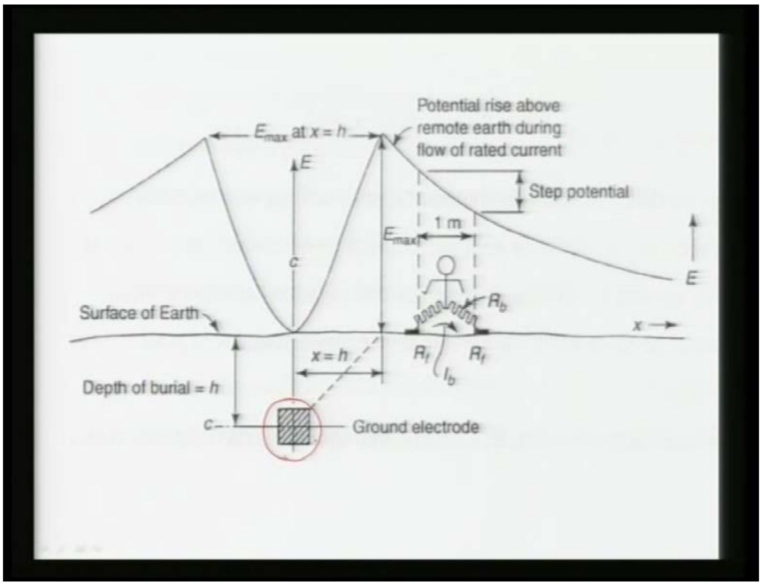

So, this is your field e and this is a x from here to this we will find that this one distance here h, where you will find the highest e max. And this value is basically, coming out to be I think h upon under root 2 this value. This value x here is your h upon under root 2. Now, what is the h? h is basically, the where it is buried, this is h from the ground this is the center of this conductor. So, this value is normally your it is your h by under root 2. So, if it is a more deep this distance will be more here, but and this magnitude also depends upon this. So, if we are going to deeper and deeper this magnitude will be lesser and the it is almost this will be the flat here.

So, that is why we go as deep as possible again we have to see the cost should be minimum. Now, you can see the it is said that the highest touch at this length, this value is this your required this should not be your more than 5 volt per meter. And this step touch you know this is one meter distance between the leg here is normally, it is said. A person who is walking here this that point and this point is approximately one meter and you can say that is why it is written one meter and this is called step voltage. And step voltage is that it should be not more than here.

This is a permissible limit if it is more than that a person can feel a shoe shock. So, this is the potential of a conductor, which is buried inside you can see it is burying both sides in this way although he is not touching the conductor, but only he is walking here he will feel the e the field at the different magnitude surprisingly once he is coming just standing on the ground he is experiencing the 0. You can see if he is coming at very just here this e is 0. But just here at this distance it is more and that can be proved also we will see later on slightly about this.

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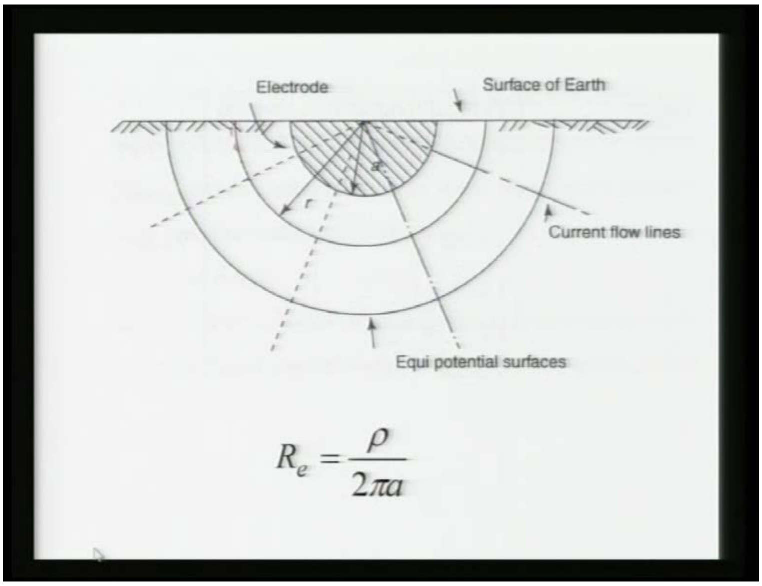

Now, let us see how to calculate the grounding resistance, the grounding resistance here let us suppose, we have a hemisphere conductor half of this it is on the ground this is a conductor we will see once it will go down also later on. But here to see this is your conductor of having hemisphere this and it is radius is a resistance will be this much. How to proof it? We can just calculate this current density the current, which is flowing through this conductor is your I d. So, the current density j is nothing but your I d by your s and this surface area of hemisphere is it is I d it is twice pi r square. Thus, sphere is there it is a 4 pi r square the surface area half of this is 2 pi r square if remember.

Now, so this is your the surface area of hemisphere we are talking half the area is a connector half hemisphere this I want to calculate what will be the potential here the p at this point. Let us calculate first field e, e is nothing but your rho into j then we can calculate the potential difference this is the equipotential surface, because once current is flowing here. So, it will have the equipotential surface of hemisphere like this is obvious and we are assuming here the resistivity of this earth is uniform. There may be different layers of resistivity then it will be the different here if we are having the same resistivity rho. So, it will be the rho will be multiplied by j it will be your e and we can say here it is your rho I d over twice pi r square it is your e.

So, the potential is you know is calculated the negative of work done here from bringing from infinite to at any point r here. So, we can write here this v r it is minus coming from infinite to at any position r e into d r here just small distance here with r into d r here, because coming here some section d r we are taking so just put it here. And if we are putting this value how much you are getting this rho I d twice pi r if you get will go because is one upon this r square. Now, at point e at this point what is e? So, we have to put this a so I can say the v e is your this rho I d over twice pi a that is the maximum basically, that because inside again it is 0 this is a solid conductor. So, is a conductor inside the field will be 0 so the maximum will be here the potential difference.

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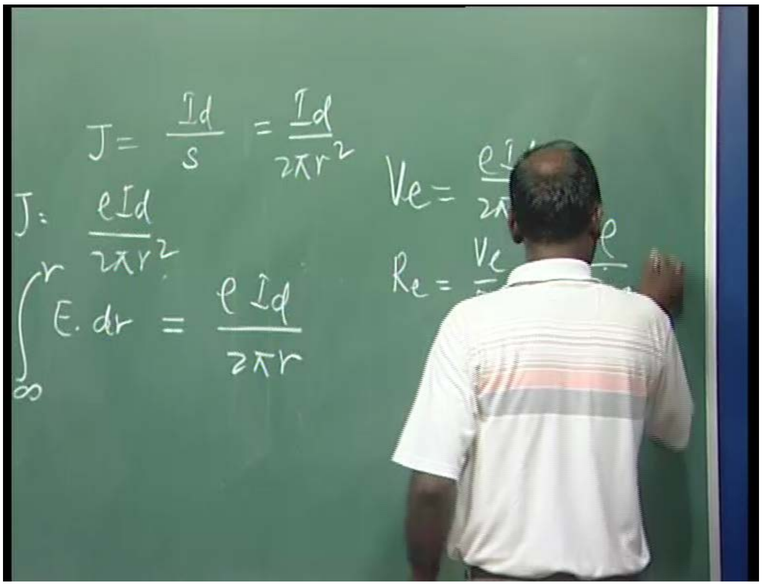

Now, from here what we can do? Now, your r e it is nothing but what is the current going inside this. So, your v into I d is the earth resistance for the hemisphere and then it will be divided by I d means, we are getting twice rho upon this a value this is the case, when we are having the uniform. This is the case of here this uniform resistivity of earth here this sorry here rho and that is why here I have written. So, let us see if your in this case itself if it is not uniform means, if your resistivity is changing and it is changing basically up to certain kilometer the resistivity is different, if we are going deeper and deeper, if we are going in the crest it is very less. So, upper surface is highest if we are going inside, inside out the resistivity is changing. So, if we are going for the different resistivity here what we have to do in calculating? The volt test only the e will be same it is independent of the resistivity.

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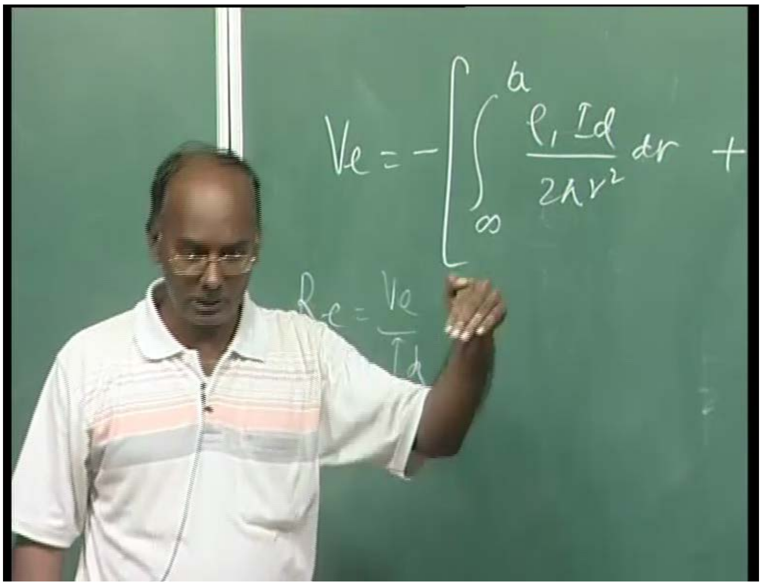

So, your v which you are calculating here it is your minus you are calculating from infinite to here this some distance b where it is a rho one? So, I can say rho 1 here I d divided by your what was the your equation two pi r square into d r plus. Here your b to a you are coming to the conductor and then it is your rho 2 I d over twice pi r square and it is your d r. So, you can calculate this v in this fashion if you are having the different layer of this, if you are having the uniform then this rho will have also with the function of x or you can say function of r. And then you have to calculate accordingly here it will be r so this will be like this.

So, you can calculate and again, then you can calculate your r e accordingly that is v upon your I d will be the earth resistance for the different value. So, either you are having the different resistivity of the earth non-uniform or you are having the one which is changing with the x or r, then you can take that expression and then you have to take care. So, normally it becomes logarithmic if it is a uniformly changing here.

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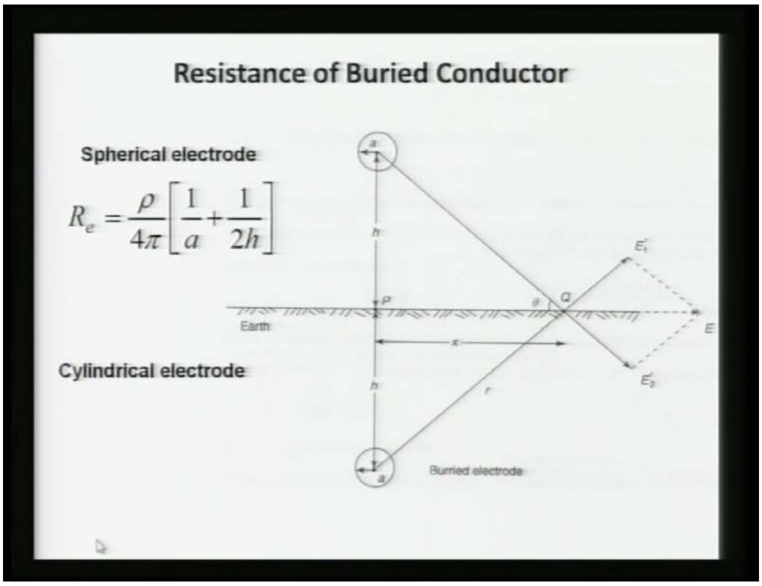

Now, let us come to this if conductor is buried means inside now you can say now conductor is not on the sphere here it is there. Now, what happens? Now, the field here it is in this fashion so, this calculation of the resistance effective resistance is considered as the image of the conductor. But here if the image is not image of charge no doubt, the current is a flow of charge. So, here if this is conductor we are taking this is image so the resistivity of this earth is also taken here it is no doubt, it is seen as in air, but resistivity it is assumed the same resistivity here.

For example, if we are having the three different one so, we take the same resistivity it is not resistivity of the earth. So, this is your h distance of your conductor, which is buried this is a conductor of radius a we are having here. And we are assuming this is a spherical conductor, if it can be a cylindrical it can be spherical. So, it is assumed the spherical now we have a image conductor here and we have to calculate the different point here what is the e? At this point it is it will be cancelled and e will be in the this direction.

So, the total here this potential will be of the two function one will be corresponding to this itself. It will be one upon rho upon 4 pi here one upon a why it is 4 not 2, because it is a full sphere earlier it was a hemisphere. So, it was 2 pi r square now, if it is a sphere is 4 pi r square so your the voltage here that is the v corresponding to that itself it is nothing but your rho over 4 pi a this a is a radius of this sphere. And now due to this the potential here will be now it is a 2 h it is now this is very, very small compared to 2 h so this distance is accounted and this will be your rho upon 2 pi 4 pi into 2 h.

This distance will come into them, because this will be the flux here it is assumed that it is the linking here this conductor here. So, this voltage just like a calculation of inductances and capacitances in the power system you have studied same concept here. So, here that is why 2 h is going to come appear here and you can say resistivity here only the concern here the resistivity of the earth is taken as a uniform. Here although, it is air image we have assumed, but the you have to take the same resistivity, because the aim is we are taking here the current.

So, this will be if we will spherical electrode is there so we have to consider in this way, if you are taking as a cylindrical that becomes very, very complex. You cannot solve very easily like this then you have to use the finite element method etcetera and then you can approximate you can write and then finally, you can get. So, it we will get the very complex that is why here I have let this expression, because we cannot derive. So, easily although it can be derived, but again the derivation will be similar to what we are using? Here we have to use the image conductor if it is a cylindrical, then we have to use the cylindrical they are cylindrical and then you have to calculate accordingly.

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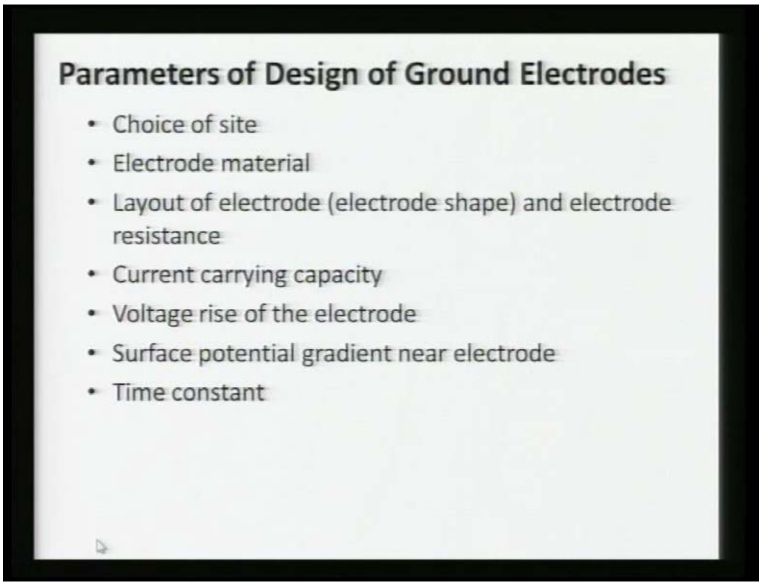

Now, let us see the parameters of what we of the ground electrodes where you are going to put? We saw the characteristic required for the electrodes it should be cheap another things low maintenance etcetera about the low resistance etcetera. But the parameter which are the basically, concerned about the designing of the ground electrode we have to have a very good choice of the site. And as I said the site should be at such place where the resistivity of earth should be small we should have the easy accessible. And also we have to see the cost at that point will be less so, all the parameter related to the choice of the site.

Now, this electrode materials whether you are going to use copper, whether you are going to use aluminum, whether you are going to use iron, what material we are going to use? If you are using copper it is no doubt, the resistance will be very less, but very expensive. And we require the very wider area so you can use even though iron sample with the very large dia and it can solve them but you have to see the cost etcetera. So, the material is also very important that you have to choose. If you are going to more depth inside you can just compromise between the resistances of this electrode plus, because you are going to add the earth resistance along with the total resistance. So, it is again is the very decisive factor in terms of the cost that you are going to put.

Another is the layout as I told that what should be the shape of your electrode means, it is whether they are cylindrical or it is a spherical it is vertical or it is horizontal. So, you have to decide, because if you are going for your this vertical electrode you have to go for 50 meters is very 50 meters more than that. You have to just bury it more than even 100 meters sometimes depending upon again the resistivity of earth. And you have to see the what should be the electrode resistance. So, normally we put so many chemicals along with the electrodes so that to reduce even though there is a surface between the your electrode. And the earth there is some there should not be air bubble etcetera.

Because that will again add the resistivity resistance will be more. So, we put some chemicals so, that we can the flow of current should be uniform we can reduce the resistance as such of electrode. Current carrying capacity already I explained we require huge current carrying capacity so that resistance should be less. The voltage rise of electrodes again this is voltage rise is basically related to your the step touch means, it should not the voltage rise at that time. If the voltage is increasing current is flowing voltage is there that it may create havoc to the personnel.

Here it is also related to the near to the electrode if the potential should not be very high we saw that potential is varying the peak at certain distance and then it is decreasing. So, that magnitude also should not be high in any case otherwise, that may even though your personal may be the safety is not assure. Another is related to your time constant time constant here I mean to say that the thermal time constant. Because if current is flowing in the your electrode there is I square r loss it is even the flowing through the your ground, ground is also heated.

So, and this radiation, because we do not have a proper radiation of no doubt, earth is there water may be there, but even though you are burying here. This resistance there is nothing inside it may be just something there may be cooled out. So, effectively there should not be any thermal time constant means, it should be perfectly that is why you put lot of chemicals to minimize this time constant also to heating etcetera. We can maintain so these are the basically, the parameter design for the ground electrodes. Now, once electrodes are designed then you have to go for your first one here I have to say ground wires.

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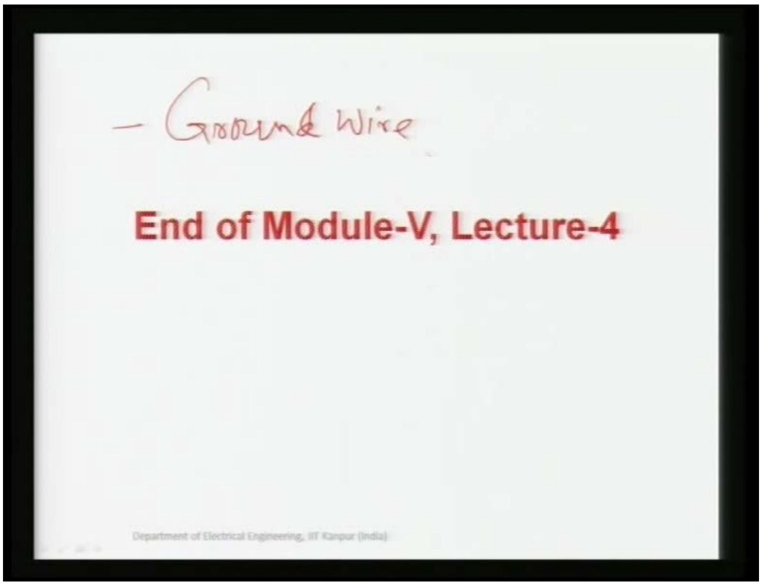

Ground wires as well as we have to talk about the main wire. The design of the main wires you know we are having this is your the go conductor we are having a written conductor.

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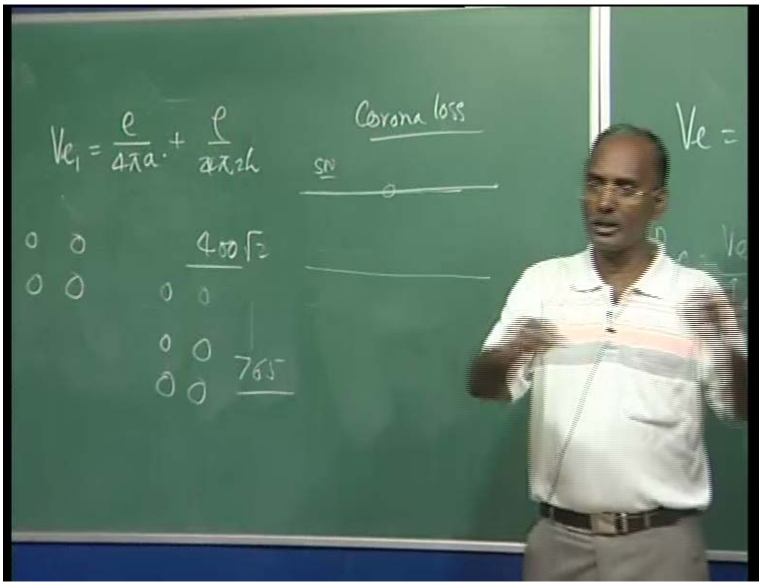

This is a normal wire we can think of this is basically, A C conductor similar to A C conductor these conductors also, because they are operating on high voltage. So, if they are operating high voltage the major concern is your corona loss. No doubt, the corona loss is less in case, of D C line compared to the A C line, but since we are operating 500 600 kilovolt it is more corona loss. So, we have to see the conductor it should be the in good size and the surface here smoothness should also be better. Because your rough surface is there means you are having more field at that point more ionization more corona loss.

So, the conductor here almost designed almost similar like you are having a 400 k v line. 400k v line buried the peak voltage it is multiplied by under root 2. So, it is 650 kilo volts here line so, it is designed here for this peak value this design for the DC value here. So, your insulation etcetera here that is why require less even you are having 400 A C system here your insulation your this voltage etcetera designed for the peak value not the r m s value. Here D C r m s and peak is same so it is that is why it is cheaper? So, required the insulation level is also less, but we always try to minimize the corona loss. So, you will find even though for 500 you will find we use the bundle conductors, because we want to have the more area so that ionization should be less.

So, you will always find if you see the 500 here it is the 4 bundle conductor even though for the 400 you will find only two. So, whenever you pass from here to Delhi you will see the two conductors are passing just over the train it is two wires means it is D C is high voltage tower. And you will find the 4 here means it is a bipolar plus minus 500 in our country. This 400 in the A C we use the 4 conductors for 765 equivalent to this. So, when you are going for higher and higher voltage only concern here is your corona loss there is no skin here, because of D C mind it. But still we here use the standard conductor to provide the maximum strength use the steel wire inside.

So, the line design is almost the same principle at the A C line design there is no inductance calculation capacitance will be there the voltage is there here the ground is there is some straight capacitances are there absolutely that will be there. You can do anything with this even though from one line to another if it is a Bipole. So, we are having 110 volts 1000 volts kilovolt in between that is also capacitance is formed, but again here these are the charge stray. Once it is charged there is no other current is flowing once line is charged it is and capacitance are same unless until current is changing or voltage is changing then the charging current will be the different.

The ground wire here normally, used as I said it is a small wire used over the ground wire it is used for the different reasons it sometimes, because your wires this pole is exposed to air exposed to lightening strokes etcetera. So, on the tower we put say ground wire this ground here we put these all these towers are grounded after not all the towers we go for the alternate few four-five towers are grounded properly. And the wire is flowing so that we can have provide some shielding 30 degree normally, we provide the shielding whatever, the strokes are coming it will be saved by the ground wire and it will be reflected and it will be going to the ground.

But even though, if there is a coming here then a substation also we have the lightening arrester at the both ends. So, that we can this impact of the lightening should not go to the substation and should be going to the grounded somewhere. So, the ground wires here basically used for the protection and also this ground can be used as the return apart sometimes some application. If there is some problem in the your neutral you can use the ground wire so the ground wires are designed properly. So, in this with this I should end in this module this module number 5 in I can summarize in this module especially, we saw this is a your reactive power in this lecture we saw the reactive power and the grounding aspect.

The before that we used filters and harmonic analysis first we did harmonic analysis we saw for the 6 pulse converter we found characteristic harmonics. We also saw the uncharacteristic harmonic then we saw the various tune filtered and we saw the tune filtered design and its impedance etcetera. We saw the in terms of quality factor then we also saw your band pass filter those are also used at certain applications. So, this module that was the 4 lectures was devoted completely for your design basically, the filter and well the grounding wire already the DC reactors. We saw in the previous module in the your module number 4 and the reactors designed et cetera I discussed about how those are designed.

So, with this I can stop it here and in the next module that is module number 6 we will discuss about the A C D C load flow and I hope you are knowing you are A C load flow that is the clear to everybody. Now, we are going to in that this AC is there because we are not going to only calculate the DC system. Because this transmission is always accompanied with the AC system so we are having the A C and D C. So, we have to see this how this D C is going to be incorporated in the A C system. And how we can solve our A C D C load flow along with variables of your D C variables that our D C variables are your angles D C current D C voltage. And the various angles that is a delay angle overlap angle your gamma and your beta so that we will see in this next module. Thank you.