Power System Engineering
Prof. Debrapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 10
Cables (Contd.)

Next is, please a when again we will come to this cable chapter only.

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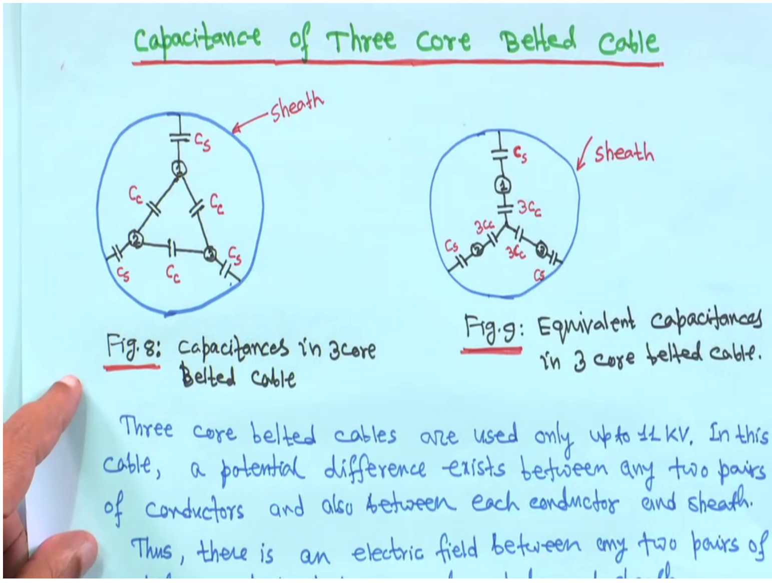

So, next is that your capacitance of 3 code belted cables right. So, what you will do here that this is the blue colors circular one this is the sheath right and you have a conductor I have mark is conductor 1 conductor 2 and conductor 3. So, the 3 core cable so from everything is uniform. So, conductor 1 to sheath conductor 2 to sheath and conductor 3 to sheath, all the thing capacitance is C s right, so but basic I mean technically as a sheath means is a common point everywhere it is a common point connected and between each conductor that capacitance is C c 1 to 2, 2 to 3 and 3 to 1 and also it acts as a it is like a delta connection, this delta connection and it is capacitance is C c suffix C c transfer core right.

So, this is what you call 3 core belted cable, now if you convert this delta connection capacitance to the star connection then it will become this is a star version 1, this is neutral say if you convert into star. So, it will be 3 C c, 3 C c and 3 C c because, it is a capacitance you can do yourself, also I think I did not show you that transformation from delta to star such that it will be 3 C c, just hold on let me show you that just as.

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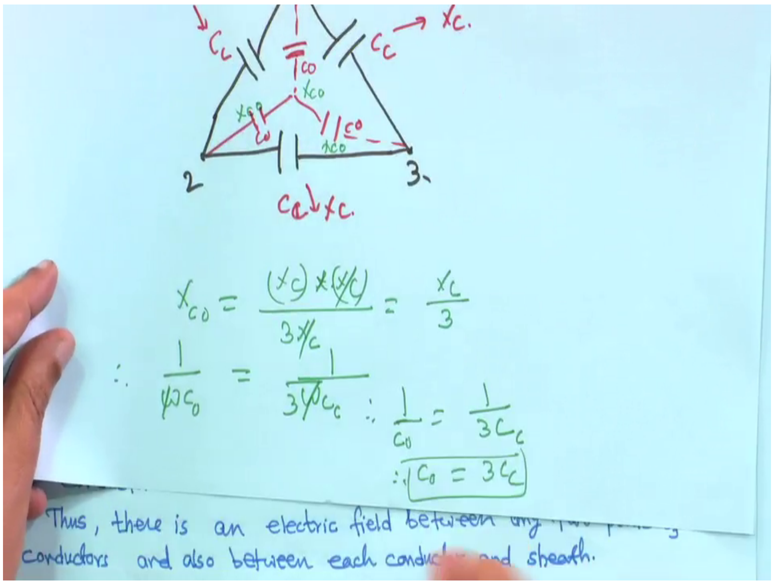

Suppose this is your capacitor this is delta connection right and this is your, this point is 1 and this is 2 and this point is your 3 right, this is 3 conductor their capacitance is this is C c and this is your C c right, so if I convert to star right.

If I convert it to star, then what will be the value say star conversion say for the this is actually I showed you this is 3 C c, how 3 C c is coming this is C 0. This is C 0 and this is C 0, right. So, when is this C c means you for example, suppose you take it is reactant X c reactant X c this is X c and this is X c right. Therefore when you convert delta to star write and it is equivalent to here, when you convert into converting it to star then this 1 reactance is X c 0 here also X c 0 here also X c 0 say right. So, when that means you can write the way you do delta to star transformation X c 0 is equal to product of these 2 things, that is your X c into X c make it like this because it is X c into X c divided by summation of all 3. So, it will be 3 into X c, X c will be cancel. So, 1 X c will be there that is your X c by 3 right, this one will be cancel so X c by 3.

Now X c 0 you can write it is 1 upon omega C 0 is equal to x you can write X c is equal to 1 upon omega C and this 3 so omega will be cancel; that means, your 1 upon C 0 is equal to 1 upon 3 c. That means, actually it is C c right your, it is C c, that means, C 0 will be C c C 0 will be 3 C c right. So, that is why this when it is a your this thing it is a delta to start transformation right, it will become your I think this you know it, but still for brush up your memories right so C 0 will be 3 C c.

So, that is why we are writing that you are this C s will be there, now C s will be in series with 3 C c. So, this is C s plus your sorry this 3 C c and C s in series connection, this is also 3 C c and series connection this also 3 C c and C s connection, this is your what you call sheath there is a common point, now we will come to this is your capacitance in 3 your code belted cable and this 1 equivalent capacitance right of this 1, that equivalent capacitance is 3 core belted cable. Now some description is there so whatever this thing I have told you, now 3 core belted cables are used only up to 11 kv right, in this cable a potential difference exist between any 2 pairs of conductors.

So, actually your potential difference may happen because, in between any 2 conductors therefore and also between the conductor and sheath. Therefore, there will be electric field right; thus there is an electric field between any 2 conductors as well as between any conductor and the sheath. Hence, the your what you call capacitance exist because of that electric field right. Thus, there is an electric field between any 2 pairs of conductors and also between each conductor and sheath and that is why this capacitance are considered.

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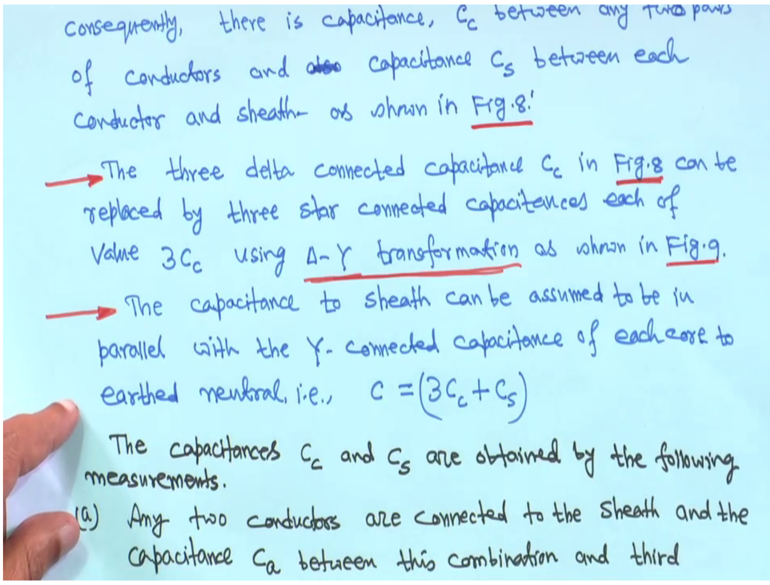

So, consequently there is a capacitance C c that I showed you that this capacitance is C c right, between any 2 pairs of conductor and capacitance C s between each conductor and the sheath right as shown in figure 8 and this equivalent is shown in figure 9 when it is delta to star transformation right.

Therefore the 3 delta connected capacitance C c in figure 8 can be replaced by 3 star connected capacitance each of 3 C c, I have already showed you using star delta transformation as shown in figure 9 this already I have done it for you and have shown it right. The capacitance to sheath can be assumed to be in parallel with star connected capacitance of each core to earthed neutral, that is C will be equivalent to 3 C c plus C s right.

So, capacitance to this is the thing the capacitance to sheath right can be assumed to be; I mean that capacitance your what you call capacitance to sheath can be assumed to be in parallel with star connected capacitance of each core to earth neutral, that is in that case your equivalent will be C c, Should be equal to 3 C c plus C s right. So that means the capacitance C c and C s are obtained by the following measurement, I mean you can you can measure you can measure it also right. So, my question is that look each your this 3 C c this capacitor is there, then this C s is there and that your with y connected capacitance; each core to earthed neutral is C is equal to 3 C c plus C s this you can simply do it of your own also right.

So, capacitances C c and C s are obtained by the following measurement, here you have to understand little bit any 2 conductors are connected to the sheath right and the capacitance Ca between this combination and the third conductor can be measured right. So, what you can do is right.

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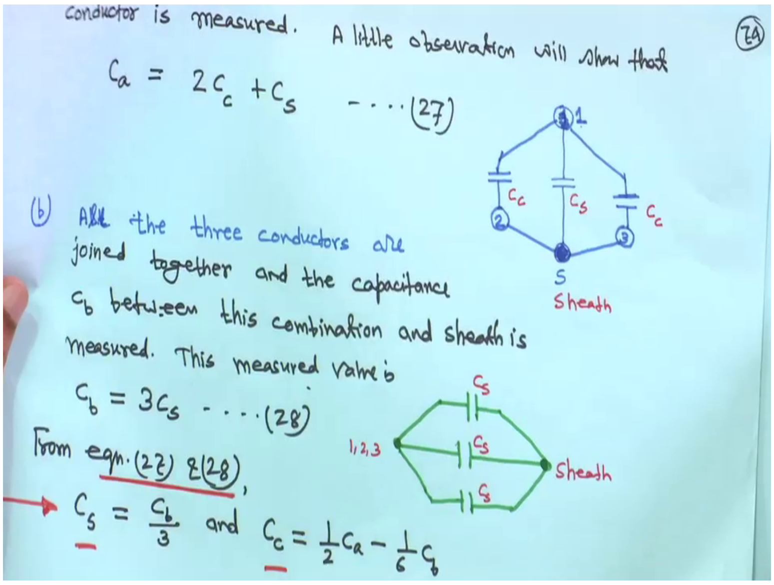

So, what it is telling that any 2 conductors are connected to the sheath, suppose any 2 conductor; what you call there are 1 2 3; three conductors are there. So, any 2 conductor this is sheath, it is taking as a your what you call this is actually it is a sheath it is a common point right because, it is a common if this 1 nothing is there in between that it is a common point.

So, in this case that 2 and 3 this conductor at directly I mean just for your understanding, I am showing that like this is sheath 3 is connected to the sheath and 2 is also connected to the sheath it is S stands for sheath right. So, any 2 conductors are connected to the sheath so it is connected, now the capacitance Ca between this combination and the third conductor is measure, I mean you combine this and between the third conductor say here it is 1 you measure.

So, a little observation will show that Ca will be 2 C c plus C s right. So, in that case if you I mean your equivalent circuit of this 1, I am just showing you just hold on.

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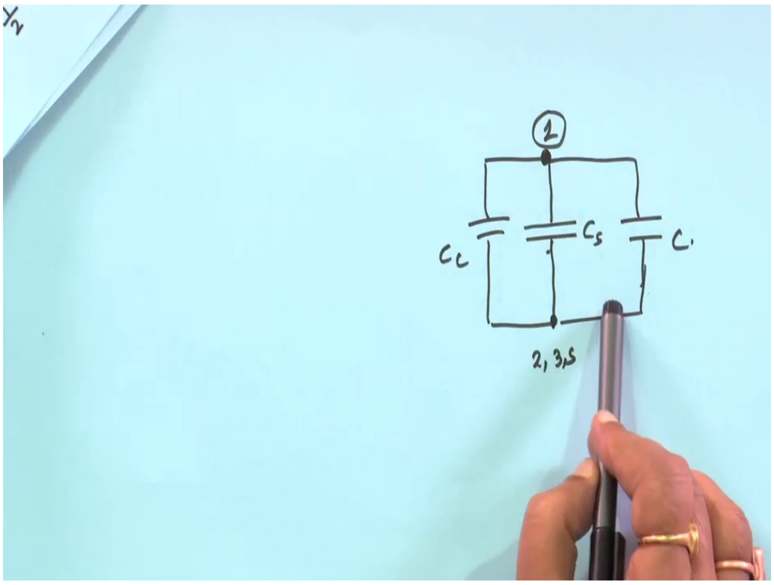

This is actually it is a common point. So, this is your conductor 1, this is actually conductor 1 right so these 3 are common point. So, what 1 can do is this is your C s this is C s right, so when I combined this 3 points; so this is another this point is 2 this is 3 this is s this point and here you are what you call this is another point 1.

So, 1 to this side it is C c it is C c and this side also it is C c right, so these 3 are in parallel capacitance are in parallel means it is your that mean 2 C c plus C s, therefore Ca is equal to 2 C c plus C s this is equation 27. So, this equivalent 1 I have drawn it for you. So, this point is a common point it is for conductor 2 3 and C these all are joint together, that is why I am writing this common point 2 3 and s same diagram I am putting here right, another second thing is this is 1, so this will give you 2 C c plus C s right.

So, another thing is that means, between this 2 you are trying to find out I mean between this 2 point we are trying to find out what is the equivalent capacitance between this 2 point, that mean this 2 point this 1 and this common 2 point; that means, Ca is equal to this 1 similarly part b nuts. Next thing all the 3 conductors are joint together you join 1 2 3 all the conductor together, you bunch it together right, a join together and the capacitance Cb between this combination and sheath is measured. So, this all conductors are bunching together and between sheath right. So, sheath is a common point and all are bunch together therefore, it will be C s all 3 are will be in parallel, if you bunch it together right.

This 1 you suppose you by what you call you bunch all the 3 conductors together right. So, what will happen this 1 this conductor 1 2 3 you bunch it together. So, what will happen if you this 1 bunch it together they will common point to C s and this sheath is a common point also. So, there will be 2 point and that is why this; what you call this only that is conductor to C that capacitance will be there C s. So, naturally then if you measure between this 2 point, then it will be Cb is equal to 3 C s that is equation 28.

So, this value is known because your measure this value is known therefore, C s you directly you will get is Cb by 3. So, C s is equal to Cb by 3 and if you substitute C s is equal to Cb by 3 in this equation, you substitute then you will get C c is equal to half Ca minus 1 upon 6 Cb because, Ca and Cb are known through measurement, therefore C c and C s both can be obtained or can be computed right, from this measure value you can solve for C s and C c; I hope you have understood this right.

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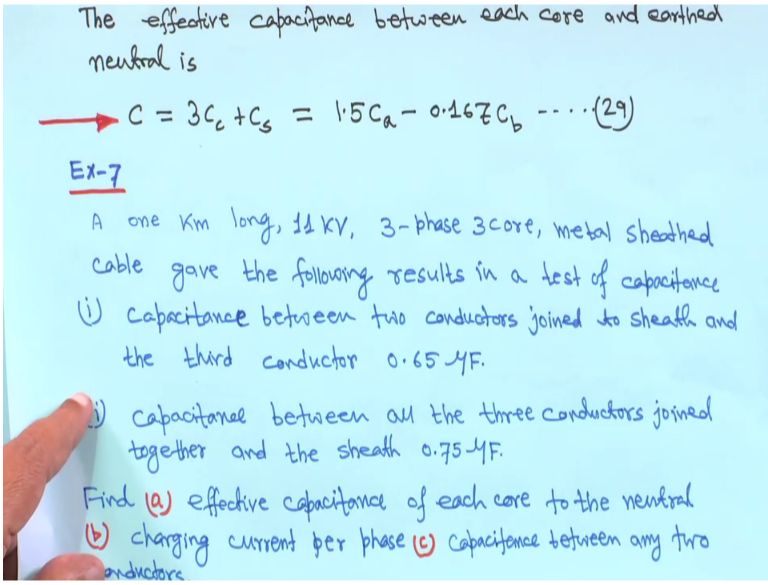

Therefore, that effective capacitance, the effective capacitance between each core and earthed neutral is C is equal to 3 C c plus C s this we have seen.

So, to substitutes C c and C s value all this things in terms of Ca and Cb it will be 1.5 Ca minus 0.167 Cb, I think it is becoming 1 by 6 3 by 2 Ca minus 1 upon 6 Cb that is 0.167

approximation this is equation 29 right, this is your what you call this is your 3 core belted cable and it is used up to your 11kv and as it is a 3 core belted cable. So, that potential difference occurs between the conductors as well as between each conductor and sheath.

Therefore because of that electric fields will be there and hence that your what you call that your capacitance between the conductor as well as between each conductor sheath exist right. So, let me tell you through measurement all these 3 a Cb can be you can obtain and you can compute. So, next is we will come to an example 7 say it is given you 1 kilometer long cable.

11kv 3 phase 3 core metal sheath cable gave the following results in a test of capacitance right, 1 what we get capacitance between 2 conductors joined to sheath and the third conductor is 0.65 microfarad, just now we have seen that core to conductor join to the sheath and that point and the third conductor that capacitance is 0.65 microfarad this is measure, number 2 capacitance between all the 3 conductors joined together and the sheath it is 0.75 microfarad all the conductor joined together and your what you call you have got this for your what you call 0.75 microfarad right; then you have to calculate find effective capacitance of each core to the neutral charging current per phase and capacitance between any 2 conductors right.

So, how we will do this it is given that capacitance between what you call that 2 conductors joined to sheath and the third conductor is 0.65 microfarad.

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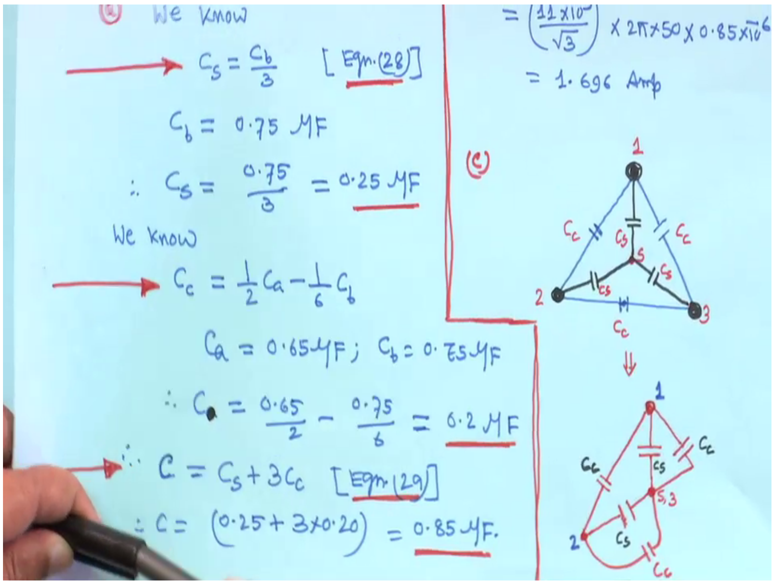

Now, this we know that C s is equal to Cb by 3 do not see this 1, no need to see this 1 you look at that C s is equal to Cb by 3 from equation 28, Cb is given 0.75 microfarad therefore, C s will be Cb by 3. So, 0.7 by 3 0.75 by 3 that is your 0.25 microfarad and we know also C or C c is equal to half Ca minus 1, I mean this equation is actually your C c is equal not this 1, C c is equal to half C minus 1 upon 6 Cb this equation you have derive.

So, we know that C c is equal to half Ca minus 1 upon 6 C b. So, Ca is given 0.65 microfarad right Cb also data it is given 0.75 microfarad, therefore Ca is 0.65 by 2 C c a your what you call that your this thing Ca is given Cb is given it is actually C right. So, C is equal to 0.65 by 2 minus 0.75 by 6 is equal to 0.2 microfarad right, therefore C is equal to C s plus 3 C c this is equation 29 C s is 0.25 and plus 3 into 0.2. So, 0.85 microfarad right now b is the charging current, charging this thing has been ask to determined right.

So, you have to find out that, your charging current per phase. So, charging current per phase is voltage is 11kv phase voltage eleven by root 3 and it is it is changing to kv to volt. So, that is multiplied by ten to the power 3000, then omega that is 2 pi a into your 0.85 into 10 to the power minus 6 right. So, then because this is 0.85 microfarad, it is here 0.85 microfarad C therefore it is your omega C v.

So, C is equal to 0.85 into ten to the power of minus 6 right, therefore it is coming about 1.696 ampere, now last 1 it says that capacitance between any 2 conductors, you take any

2 conductors and find out what is the capacitance you take between any 2 conductors, now if you try to find out the capacitance between any 2 conductors; that means, suppose we want to find out this is the connection we want to find out that 1 to between any 2 conductor 1 to 2, suppose you want to find out right across this you have to find out. So, this is what you call this is sheath and this is conductor 3. So, we want to find out 1 2 3 what we have done it here then 3 and s, what you call you join together that dry. So, in this case look 1 to s is C s right, similarly 1 to your 3 that is your 3 and s right it is your C c, similarly 1 to 2 is your C c and similarly your 2 to your s, that is your 2 to s is equal to your C s and 2 to 3 that is your 2 to 3.

I mean if you join s and 3 how many elements will be left out, if you join this 1 2 3 4 5, 5 elements are left. So, if you join this together 2s it is C s will be there and 3 and s will be common point. So, 2 to 3 or 2 to s again it is C c. So, this is some kind of thing you have to find out the capacitance between any 2 conductors. So, what we are doing is this third conductor and sheaths are joined together. So, that is this circuit this circuit can be drawn in little simplest manner right that is you have to find out capacitance between 1 and 2.

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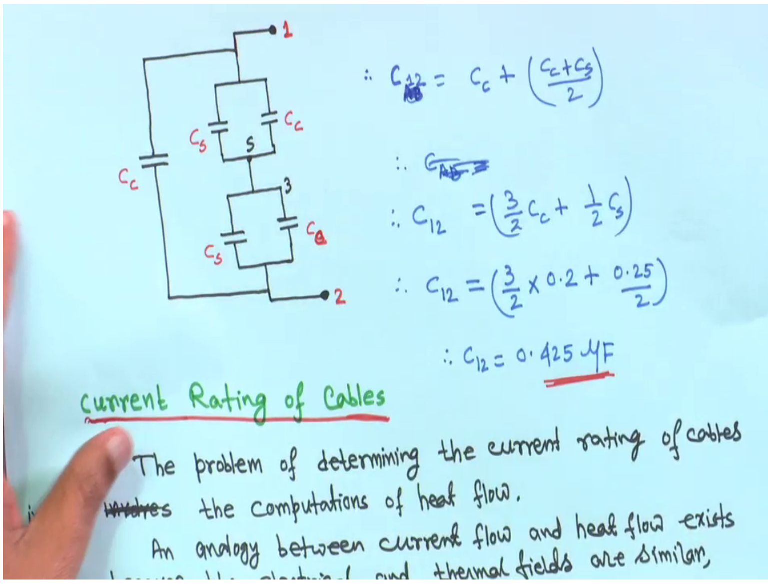

So, this is 1 and 2 right between 1 and 2 C c it is there and s and 3 is a common point, where just to show it differently that is why s and 3 is a separate where is a common point.

So, between s your what you call between 1 and s right, it is 2 capacitance are there C c and C s similarly between 2 and s or 2 are 3 so ever common points C s and C c will be there, so this circuit can be drawn like this right. So, in that case directly you can find out what is C 1 2 you have to find out C 1 2 so C c right, C c plus these 2 are in what you call these 2 C s and C c are in parallel. So, it will be C s plus C c here also it will be C s plus C c there in parallel and this term and this C s plus C c and are in series therefore, it should be C 1 2 should be C c plus C c plus C s upon 2. So, C 1 2 will be 3 by 2 C c plus half C s. So, C c is given you have got it 0.2 microfarad and C s is 0.25.

So, C 1 2 substitute you will get C 1 2 is equal to 0.425 microfarad. I think, I hope you have understood the little bit practice is necessary, little bit observation from that you can make out this 1 right.

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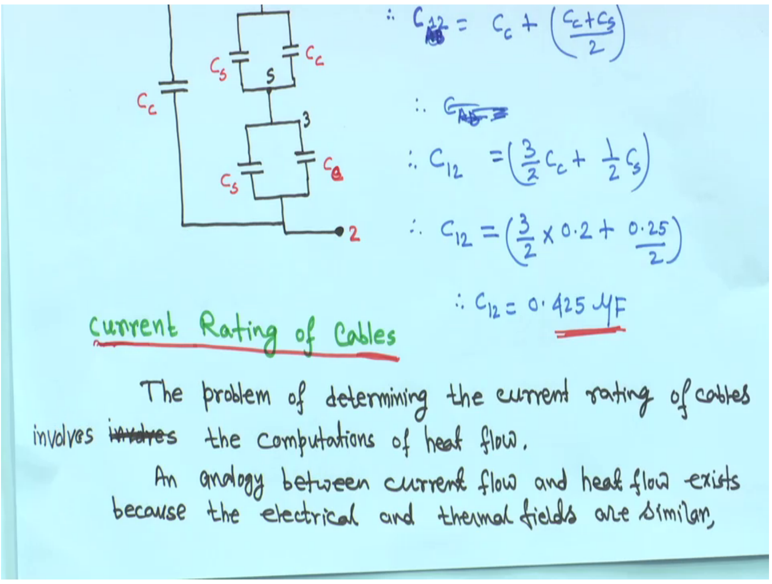

Next is that current rating of cables right, this is very important factor from the point of view selecting the current rating of the cables, the problem of determine the current rating of cables involves the computation of heat flow you have to consider many things, an analogy between current flow and heat flow exists between the electrical and thermal fields are similar; that means, your this is actually analogous to this. So, between current flow and heat flow exists because the electrical and thermal fields are similar right.

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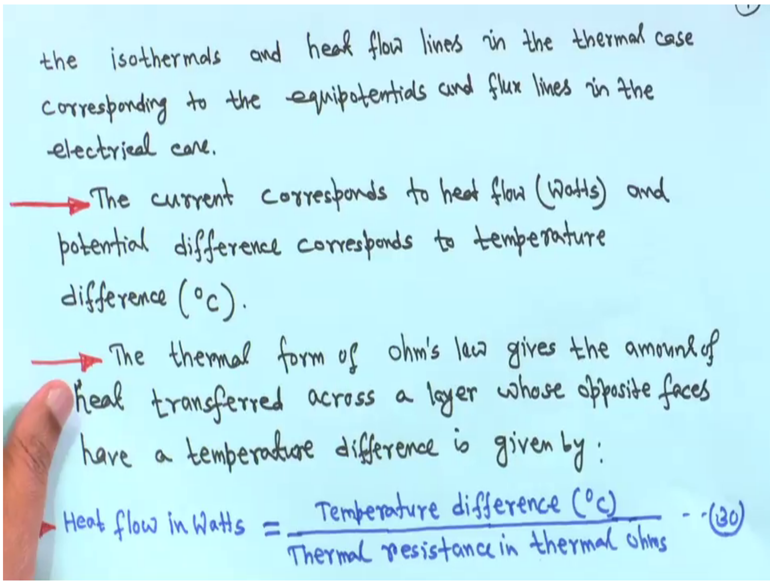

That means just hold on; that means the isothermals and heat flow lines in the thermal case corresponding to the equipotentials and flux lines in the electrical case. So, this is just based on this analogy only we try to find out, the current corresponding to heat flow we will be represent in terms of watts and potential difference corresponding to temperature difference degree centigrade analogous to each other; the thermal form of ohms law gives the your amount of heat transferred across a layer whose opposite faces have a temperature difference is given, there it is a voltage difference here it is temperature difference.

So, heat flow in watts it is temperature difference in bracket it is in degree centigrade divided by thermal resistance in thermal ohms, this is in this equation 30 right. Heat flow there will current flow in watts I is equal to a potential difference is the e upon r say here also heat flow your writing. So, current flow in watts temperature difference degree centigrade by thermal resistance in thermal ohms right.

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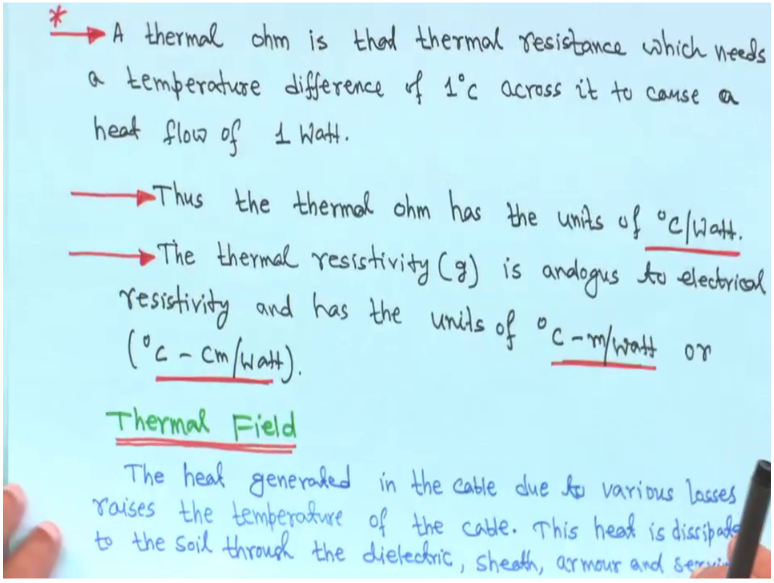

Therefore a thermal ohm is that thermal resistance which needs a temperature difference of 1 degree Celsius, similar to the resistance ohms law occurs across it to cause a heat flow of 1 watt same thing right, if you change it to the ohms law in the electrical quantity it will be just analogous to a it will instead of temperature difference if you go for voltage and in the in the heat flow of 1 watt if you go for current then meaning is same only we have to write again and again thermal ohm, thus the thermal ohm has the units of degree centigrade per watt right and in the case of your what you call that thermal ohm and in the case of electrical thing it is ohm right.

That it is ohm or in other way your v is equal to Ir, so I is equal to v I r. So, it is volt your what you call it is v by I it is volt per ampere and here it is degree centigrade.

The volt is analogous as it to your degree centigrade, an ampere is analogous to thermal heat flow that is in watt right; the thermal resistivity g we are considering thermal resistivity g is analogous to electrical resistivity and has the units degree centigrade meter per watt or degree centigrade centimeter per watt, meter you can transfer into centimeter also. So, degree centigrade meter per watt or degree centigrade centimeter per watt right.

Next is thermal field the heat generate in the cable due to various losses right, the heat generate in the cable due to various losses raises the temperature of the cable there are many factors, this heat is dissipated to the soil through the dielectric is there sheath is there armour is there serving right. So, this heat will be dissipated right.

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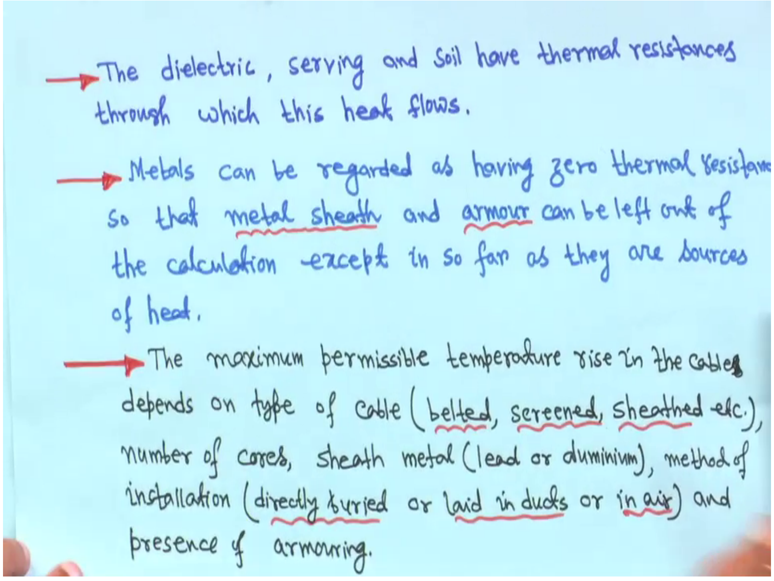

So, the dielectric serving and soil have thermal resistances through which this heat flows, so dielectric serving and soil all have thermal resistance resistances through which this heat flows. So, metals can be regarded as having 0 thermal resistance, for metal we will not consider we will consider they have no thermal, what you call no thermal resistance for the metal right. So, that metal sheath and armour can be left out of the calculation except in so far as they are sources of heat. So, we will left out metals sheath and armour as per as thermal resistances cable your right.

The maximum permissible temperature rise in the cable right, depends on type of cable that what type of cable you are using belted screened or sheathed etcetera number of cores. So, many factors are there sheath metal lead or aluminum you are using or not, method of installation directly buried or laid in the ducts or in the air it may be in the open cable can be in the open air also, it may be directly furied also or it may be taken thought a ducts right and presence of your armouring so many factors are associated with maximum permissible temperature right.

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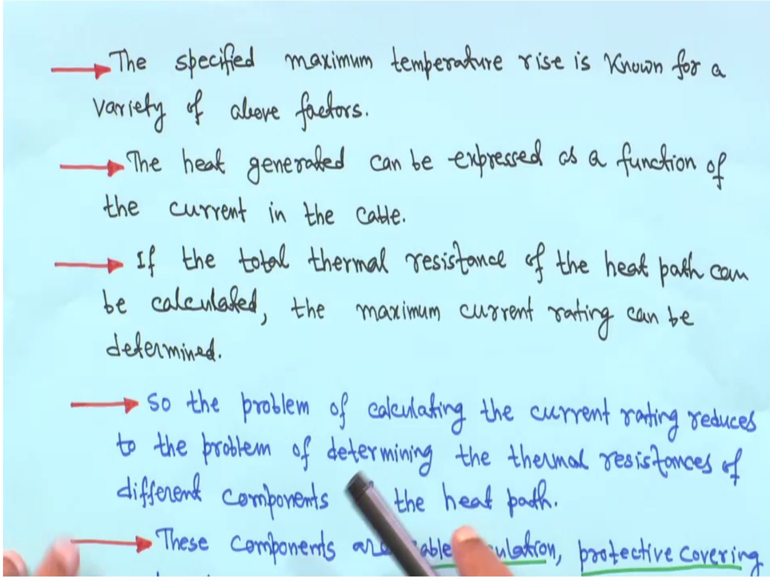

Then the specified maximum temperature rise is known for a variety of above factors, the heat generated can be expressed as a function of the current in the cable; if the total thermal resistance of the heat path can be calculated the maximum current rating can be determine right. So, when we will take an example then you will know how so many factors are there. So, the problem of calculating the current rating reduces the problem of determining the thermal resistances of the different components of the heat path, these components are cable insulation, protective covering and soil. For all these things you have to consider while determining the current rating of the cable.

Thank you very much. We will be back again.