Power System Engineering
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Lecture – 20
Corona

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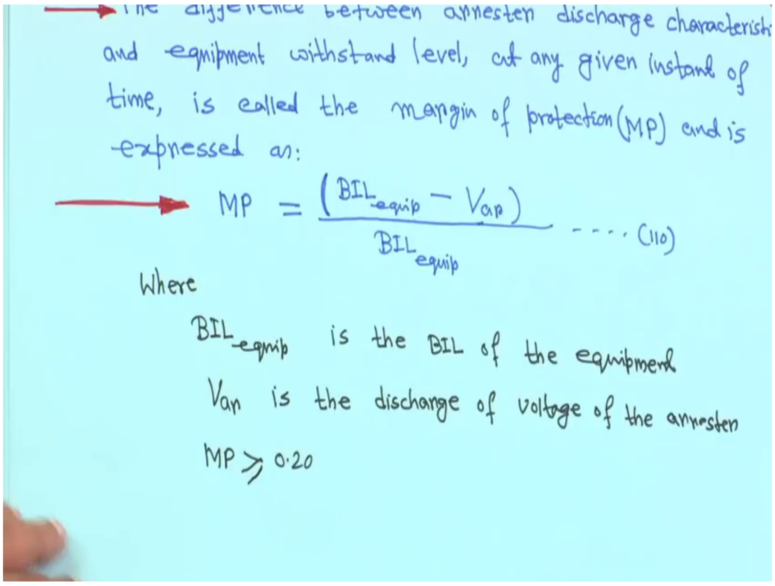

So now, the difference between arrester discharge characteristic and equipment withstand level, at any given instant of time is called the margin of protection and is a his is, your this is actually margin of protection right.

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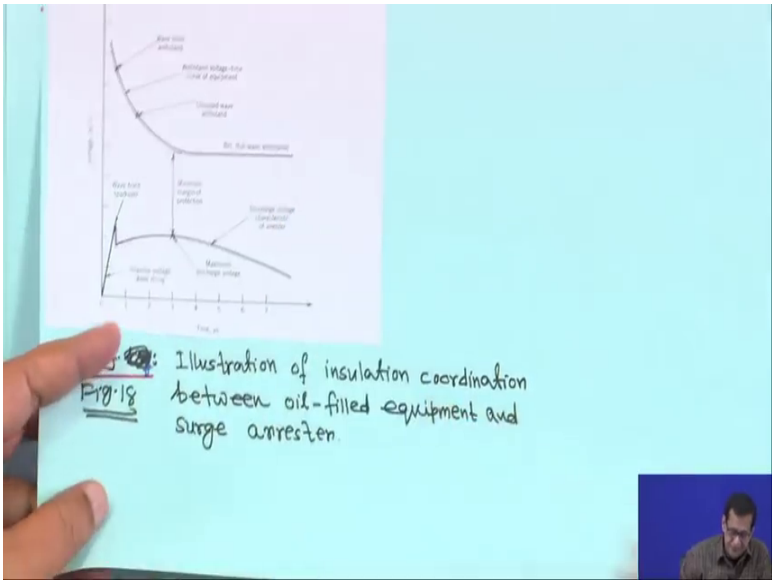

So, it can be expressed as MP, is equal to BIL equipment minus Var divided by BIL equipment, where basic impulse insulation level. So, BIL equipment is the BIL of the equipment, whatever equipment you are testing and, Var is the discharge of voltage of the arrester and generally, MP greater than equal to 0.20; that means, if this value if you make it MP. So, it will be greater than equal to 0.20, this is your what you call that? Your withstand discharge, the difference between arrester discharge and this one, is called the margin of protection, in short, they call MP the margin of protection right.

So, with this that, your transient over voltage and insulation coordination is over right? Next all these things after this whatever will come, first next will come the corona that is, your corona loss right in transmission line. So, after all these thing. So, will find things are very interesting like corona.

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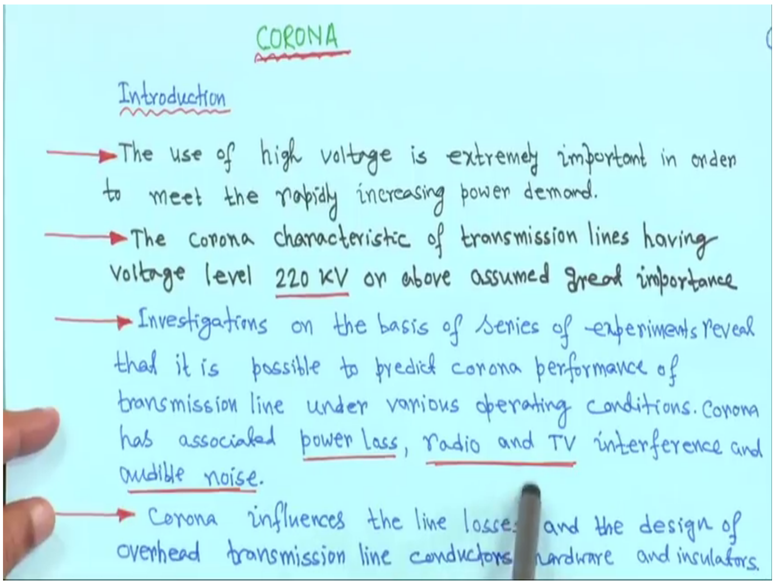

Then sagan tension will come, after that your distinguishing system will come, whatever possible in the classroom that, will we will proceed then lower frequency control and unit commitment, you will find the things are very, very interesting.

So, corona. So, will start from corona loss, generally you know you have some ideas right. So, basic introduction is, the use of high voltage is extremely important right? In order to meet the rapidly increasing power demand, right? So, the corona characteristic of generally, corona happens that line having voltage level 220 KV or above, right? Your assumed great importance, particularly in that your what you call, later I will come to that in the rainy season or you know or any other time also, you can see the corona is happening line 220 KV or above.

So, investigation on the basis of series of experiment reveal, that it is possible to predict corona performance of transmission lines under Various operating conditions. So, at different operating conditions, corona can be predicted, but later we will see that corona loss computation those formula, basically empirical formula. Based on the field test people have, made it over the years and corona actually, has associated power loss due to corona is right, the radio and TV interference and audible noise, right? This is actually corona causing power losses, same time radio and TV interferences and audible noise.

Another thing is that, later will come due to corona that, your voltage and your current wave form become non-sinusoidal right. So, corona place an you know important significant role, particular in power loss thing, but exact evaluation is not possible. But some empirical formulas will be there, from the field test later we will see that. So, and in this chapter also, we need little bit of your knowledge of capacitance chapter, that which we have seen in power system analysis course. So, directly some equation from there I will write, because those equations I will needed instead of telling, but I will refer that thing to that, your capacitance chapter of the power system analysis course, right?

So, corona influences the line losses and the design of overhead transmission line conductors, hardware and insulators. Because you have to consider all set of things, such that your what you call that, your you have to design the transmission line, because corona actually causing transmission line losses.

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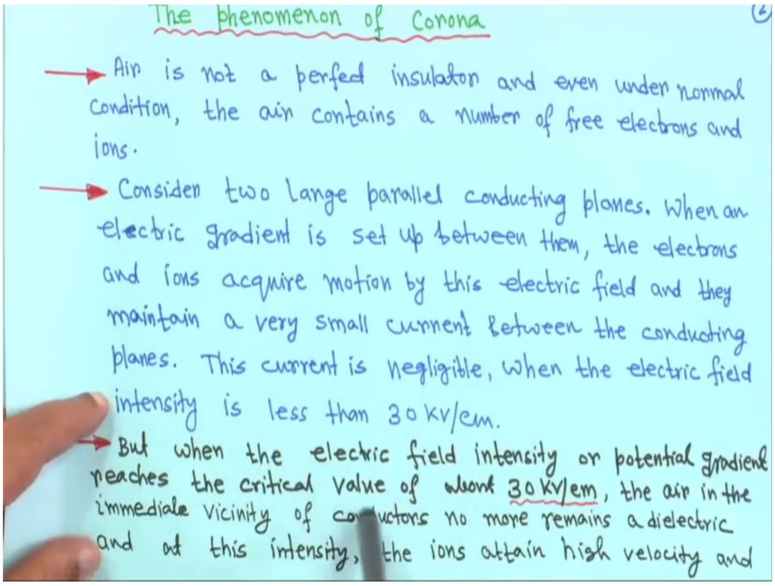

Whatever phenomena here will consider that is for round conductor, that is cylindrical in shape that you say, but suppose if you take you know some kind of logical problem, that suppose instead of round conductor, if you choose the rectangular or square cause section conductor, then how the corona will be formed. These and this is a question to, you answer I will not give that, you would write to me that, instead of round conductor, if you take a conductor having cross sectional is a square or rectangular, what isoever then, how will be the corona loss right?

So now, the phenomenon of corona, basically here is not a perfect insulator that, you know right and even under normal condition, the air contains a number free electrons and ions. Now, if you consider 2 large parallel conducting planes or conducting path, right? If you assume and apply to have voltage occurs this 2; that means, when an electric gradient is set up between them, right? You apply a potentials across them, right? The electrons and ions acquire motion by this electric, because electric field will be created and your electrons and ions, right? Both will acquires speed or motion and, they maintain a very small current between the conducting planes.

So; that means, if you consider 2 electrode and, your applying voltage across this. So, electric field will be you are created and, in that case, what will happen that electrons or ions acquire motion, by this electric field and this maintain, a very small current between the conducting planes. So, between this it will maintain a very small current. So, current is negligible, when the electric field intensity is less than 30 kilovolt per centimeter, but this electric, I mean if this potential gradient is less than 30 KV/cm. So, this current is very small right?

But, when the electric field intensity or potential gradient reaches the critical value say, 30 KV per centimeter therefore, value it have the air in the immediate vicinity of conductors, no more remains say, dielectric at that intensity then when, you reaches to 30 kilometer kv centimeter, the potential gradient, then air surrounding the conductor, will never remain as a dielectric and at this intensity, the ions or your attain high velocity right and striking other neutral electrons, molecule the other right?

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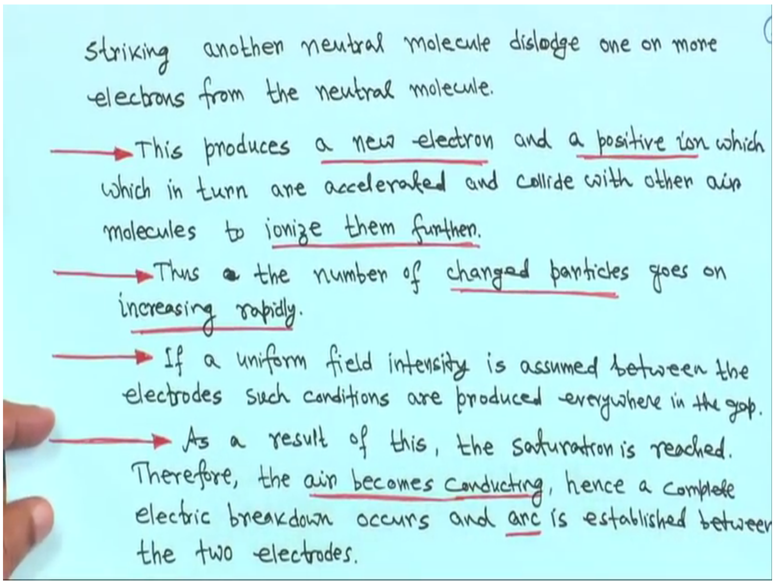

So, in that case what will happen, that your it was striking another neutral molecules and dislodge one and more electrons and the, you're from the neutral molecule; that means, this positive new electron and a positive ion, and this process is a continuous process. So, which are in turn accelerated and collide with other air molecules, to ionize them further. So, it is a continuous process and it will produce, your what you call more you're a new electrons and positives ions, right? Thus, the number of charge particles goes on increasing rapidly, this is true this happens only if the potential gradient around the conductor is the 30 kv centimeter or above.

If a uniform field intensity suppose, if you assume uniform field intensity between the electrodes, just I as well 2 parts right then, such conditions are produced every everywhere in the gap. If it is, if electric field is uniform say, between the 2 parts then at every points such activity, will be your what you call your that uniform field intensity, then between such conditions are produced, everywhere in the gap. Now, as a result of this, the saturation will be reached and therefore, the air becomes conducting, in that case that air will become conducting, hence a complete electric breakdown will be there, and it occurs and arc and is established between the 2 electrodes; that means, basically suppose it is same way will considered.

Suppose, you have a you have 2 electrodes or 2 path, 2 parallel planes, apply the voltage across this 2 and electric field will be created and, if you assume that everywhere that, is electric field intensity is uniform at every point, then there will be a breakdown at this voltage, at the potential gradient 30 kilovolt per centimeter right. So, in that case what will happen, a complete electric breakdown and arc is established between the 2 electrodes.

So, the I think, in those who are doing high voltage laboratories they might have seen, this kind of phenomena for different takes event in the high voltage laboratory, right? Even it is not, only that plane a between 2 sphere also, I mean whatever it is, it will happen and you can see that, if you increase the potential gradient that breakdown will happen, if a high voltage laboratory, if you see that you can see that a through experiment may be, many of you might have seen, in your college in the high voltage laboratory right.

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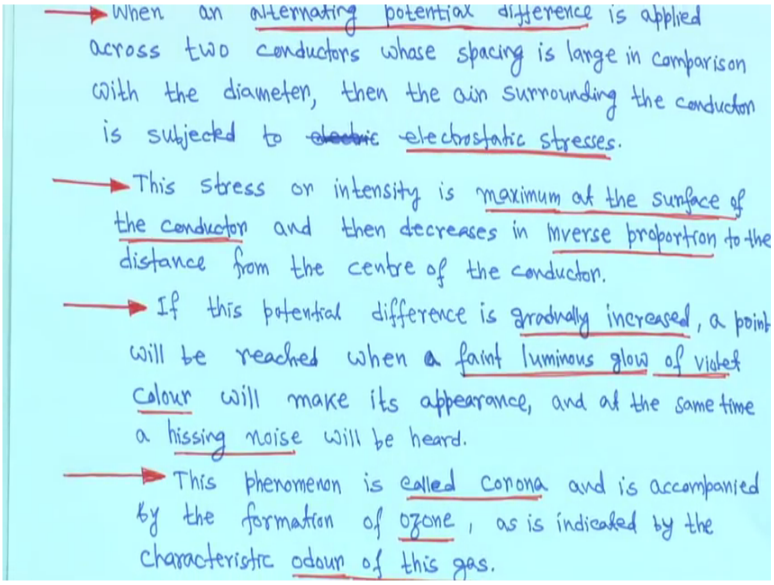

So, when an alternating now, when an alternating potential difference is applied across 2 conductors, like we are thinking about your what you call that overhead transmission line. So, when you apply that, your alternating potential difference that is AC voltage right between 2 conductors, whose spacing is large in comparison to the radios or diameter of the conductor, right? Then the air surrounding the conductor is subject to electrostatic stresses, right? This is known to you.

Now, the stress or intensity is maximum at the surface of the conductor, that we know for the cable studies, for the coming class studying, that cable know electric stresss, we have seen potential gradient, qy q divided by 2 pi epsilon 0 in r, at x is equal to r that stress is maximum right? And decreases inverse proportion of the distance from the centre of the conductor and, if you move along that, it is inversely proportional to the distance, that we know. If the potential difference is gradually increase, I mean if you go on increasing the potential difference, then if a point will be reached, when a faint luminous glow of violet colour will make it is appearance and at the same time, a hissing noise will be heard.

Now, 2 conductors are there, if suppose potential the your difference gradually, if you increase right. So, a point will reach, when you will point that, you know from the your what you call a faint luminous glow of violet colour, will make a appearance that makes it is appearance, that is along the conductor. You can observe, that right? Some luminous glow and violet colour at the same time, a hissing noise will be heard and another thing is that, you will find that, you’re what you call characteristic odour, that is there ozone gas right?

So, this phenomena is called corona and is accompanied, by the formation of ozone, right? This ozone will be formed as is indicated by the characteristic odour of this gas. So, from that you can find out that is, ozone gas form it is smell, you can find out right? So, basically this is your basic philosophy of corona right?

So, question is that, this I do not know whether you might have seen corona or not particularly, 220 KV line, if the you know if of course, it will be around at suppose, in a village suppose high tension line is going on, suppose no light is there as surround you can you can see, that luminous glow around the conductor and rainy season. It will be more visible, I have seen many places that it is happening does not night time it will be visible, day time it also it is happening, but day time you cannot make out all the time, but that, some chattering noise will be there from that noise you can make out that corona, this is due to the corona only. You will find some kind of noise for 220 KV line or, above right? And if we here the noise, that hissing noise then, you can find yes corona is happening.

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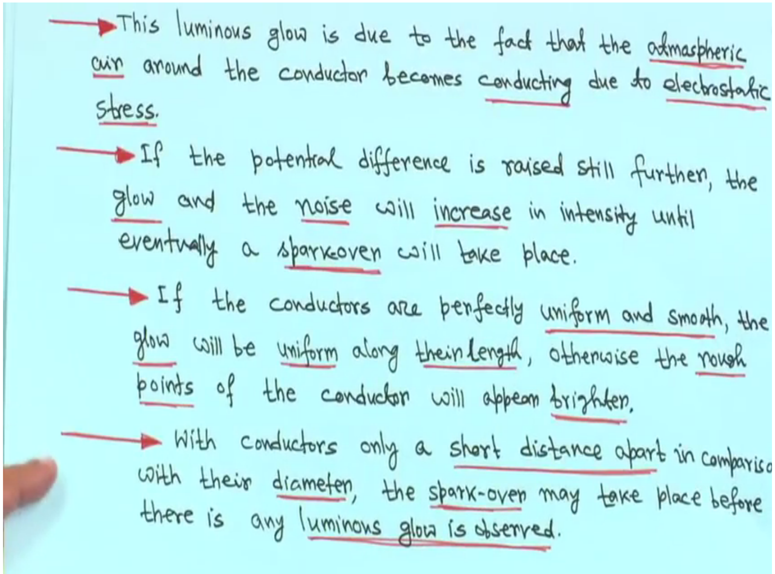

This is common phenomena for transmission system. So, this luminous glow is due to the fact, that the atmospheric air around the conductor becomes conducting, because it is ionize right? Due to the electrostatic stress because, around that conductor that, here your what you call that air around the, becomes conducting right, but potential gradient has to be very high 30 kilovolt per centimeter and above.

So, if the potential difference is raised still further, if you go on increasing the potential difference, then the glow and noise will increase very, very common right, in intensity until, eventually a spark over will take place, right? If you go on increasing this things then, is spark over will take place between the say conductor, but generally for transmission line, the your what you call in laboratory, you can go and increasing, if you have that, your what you call laboratory facilities, but for transmission line in general your what you call the unknown normal operating voltage, it may be 220 KV or above right?

So, there you cannot do that, unless and until some you know abnormal things happens, right? If the conductors are perfectly uniform, now we are assume the conductors smooth right? Around shape conductor, your whatever you are talking about the uniform, your what you call the cylindrical conductor, a circular cross section. But I give you a problem that, if it is not circular, if it is your rectangular or square cross section, then how the corona will be form? Another thing is, if the conductor is not a solid, if it is a hollow conductor then, how that corona will form? These a question to you right?

The glow will be uniform along their length, otherwise the rough points of the conductor will appear brighter, I mean a conductor actually conductor surface is not smooth all the time. So, rough points also will be their, wherever rough points will be there, that your what you call that luminous glow will a be much brighter, then the round then smooth portion of the conductor.

So, with conductors only a short distance apart, in comparison with the diameter the spark over may take place, before there is a any luminous glow is observed; that means, suppose, if the distance between 2 conductors is raise, compare to it is a diameter. Then before it luminous glow, you can observe spark over may take place; that means, if you bring to conductors very close to that, in a potential difference if go on increasing, then spark over will take place, before you can before anything you observe right? I mean luminous glow are anything the spark, over can take place.

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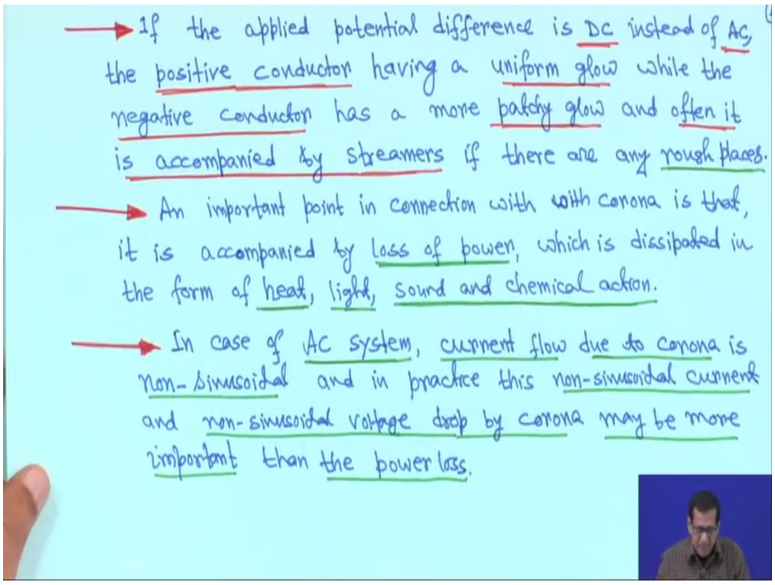

So, if the applied potential difference is a DC, this is a question to you, I will only mention, but answer you should give it to me, if the potential difference is DC instead of AC, suppose you are applying now DC voltage instead of AC the positive conductor having a uniform glow, the positive conductor will have uniform glow while, the negative conductor has a more patchy glow and often it is accompanied by steamers, if there are any rough places, steamer means if rough a thing it is a jumping steamers right.

So, question is that, the positive side if it is a DC, it is uniform where as negative side is a patchy or, if it is a rough surface is there accompanied by steamers, if there are any rough places this is a question to you, that for DC why for positive side is uniform and why negative side is like this right? So, this is a question to you.

So, an important point, in connection with the corona is that, it is accompanied by loss of power, this you know there will be power loss right? So, loss of power which is dissipated in the form of heat, the light sound and chemical action, chemical action means ozone gas, sound means hissing noise, or light means your what you call luminous glow, you have seen and heat means a power loss, is there that heat will be generated right. So, these are these are all sort of, you know outcome from corona right.

Now, in case of AC system of course, all the overhead transmission line apart from hbc line, basically all are ac system current flow, due to corona is non-sinusoidal and in practice this non-sinusoidal current and non-sinusoidal voltage, right? Drop by corona may be, more important than the power loss. So, sometimes it causes problem, but corona also, it contributes significant of the portion of the power loss.

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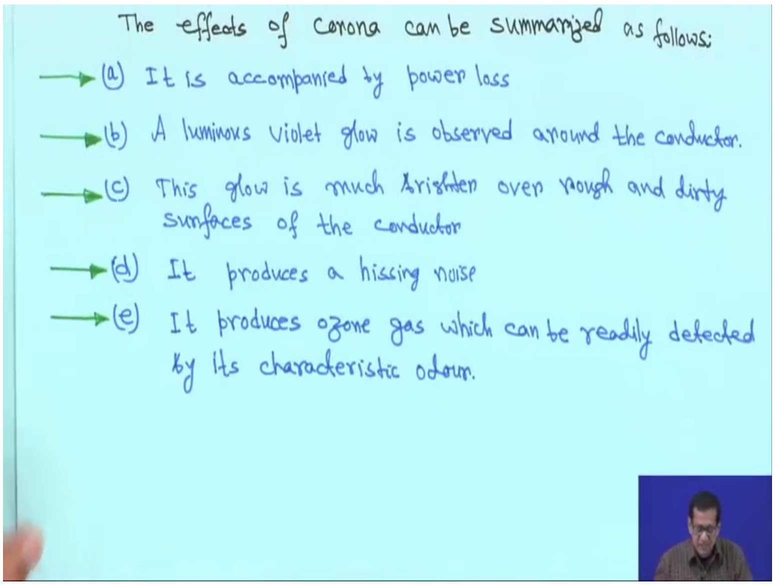

Now, therefore, the effects of corona can be summarized in few point, look it is accompanied by power loss, this is known to you, a luminous violet glow is observed around the conductor, right? This glow is much brighter over rough and dirty surfaces of the conductor other than smooth surface, it produces a hissing noise, it produces ozone gas, which can be readily detected by it is characteristic odour right? So, these are few points can be summarized for corona right?

So, you can that is why I am telling that, try to if you see any overhead line 220 kv or above, you can see this corona things now, with this will come to the potential gradient for single phase line or related to corona.

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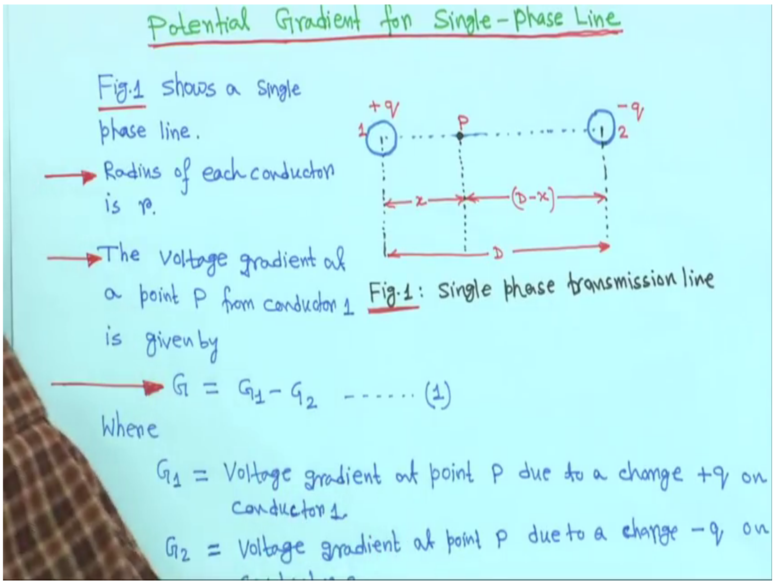

Now, this thing actually potential gradient for single phase line, that again I will refer that, capacitance chapter everything had been done there, for power system analysis course, when will study these are very simple things, but if you want to recall your memories, then please you see that capacitance chapter right?

So, this is a suppose, see it is a single-phase line. So, this is conductor 1, this is conductor 2, this carrying charge plus q. So, hence it is a minus q and take in between some point P, P is the distance from this conductor, that is x and then these total distance between this 2 conductor 1 and 2 is D. So, if it x this will be D minus x. So, there is a single-phase transmission line, say we are considering right?

So, radius of each conductor, you are assume that it is r, both are r and r, if it is different also, that had been also covered in your capacitance chapter, right? So, the voltage gradient at point P from conductor 1 is given by, say from conductor is generally G is equal to capital G is equal to capital G1 minus G2. So, this is equation one say where G1 is voltage gradient, at this point voltage gradient at point P, due to charge plus q on conductor one right. So, this is G1.

Similarly, G2 the voltage gradient at point P, due to charge minus q, right? On conductor 2. So, G is equal to actually G1 minus G2. So, potential gradient right? Now one thing you know potential gradient and in cable chapter, we have seen that it is q upon 2 pi epsilon 0 x, right?

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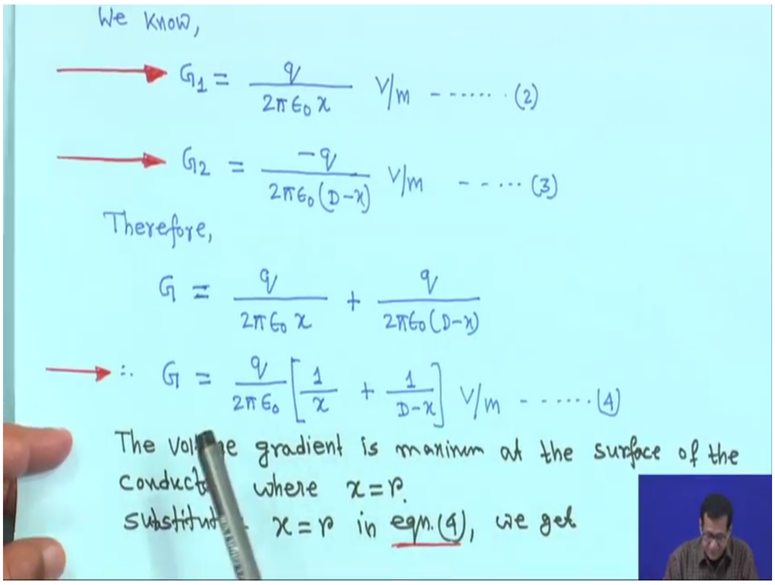

Therefore, your we know that G1 is equal to q, q upon 2 pi epsilon this is volt per meter, right? And G2 is equal to your minus q upon 2 pi epsilon 0, d minus x volt per meter, right? Because this you know G1 is equal to 2 pi epsilon 0, x and for G2 or, for G2 it is minus q divided by 2 pi epsilon 0 d minus x volt per, these are potential gradient right? Potential gradient.

Now, and G is equal to G1 minus G2. So, this G1 and G2 you substitute in this equation in this equation and G2 is minus q upon this thing. So, when you submit G2 is equal to minus q this sign will become plus right? Therefore, your G is equal to q upon 2 pi epsilon 0 x, plus q upon 2 pi epsilon 0 into d minus x, right? Therefore, G is equal to q upon 2 pi epsilon 0, common you take common, it is 1 upon x plus 1 upon d minus x volt per meter.

Now, the voltage gradient is maximum at the surface of the conductor, where x is equal to r, this we have seen for k will also at x is equal to r, the voltage gradient is maximum. Now, if you substitute x is equal to r, in equation you will get suppose, then you will get just one this thing you put x is equal to r here, right? Because it is maximum. So, if you do. So, when in this equation if you put x is equal to r it will be 1 upon r, plus 1 upon d minus r volt per meter. Therefore, it will be your 1 upon r, plus 1 upon d minus r, right since D is large as compared to r right radius.

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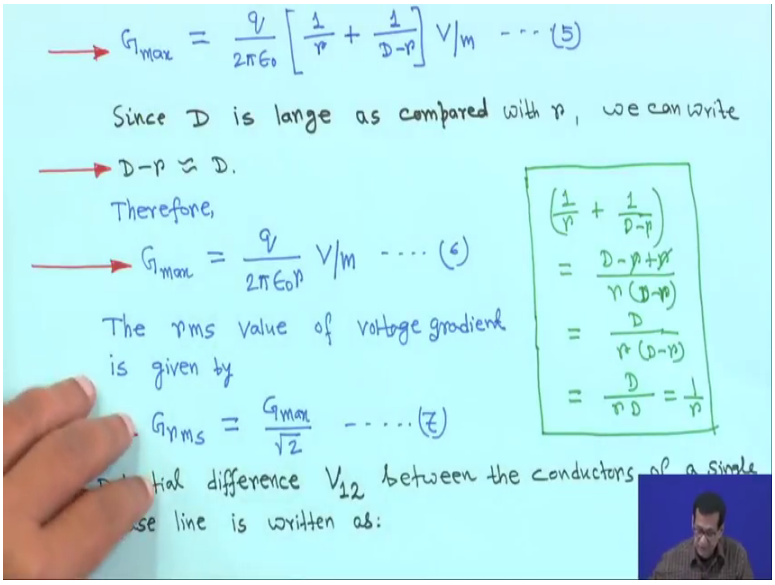

So, we can write D minus r approximately d therefore, we can get G max because our x is equal to r, it will max it will be q upon 2 pi epsilon 0 r volt per meter, these equation can be written as q upon 2 pi epsilon r volt meter.

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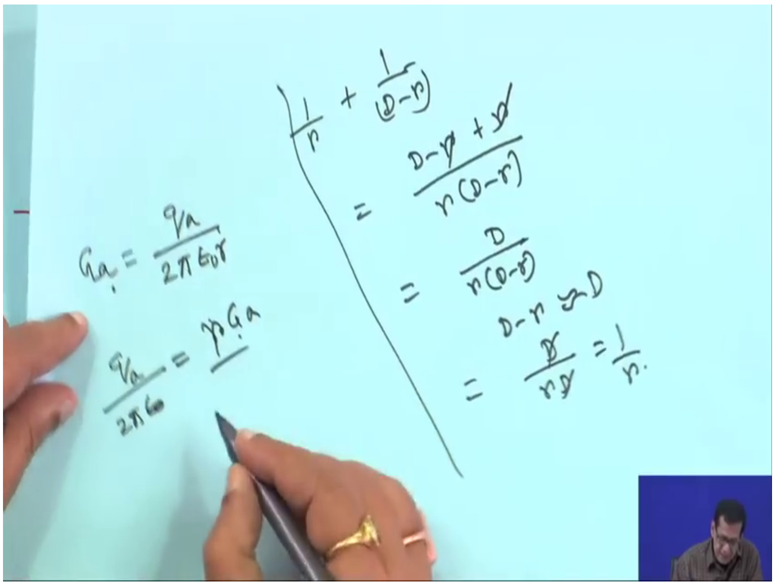

How it is happening? Actually, it is 1 upon r plus 1 upon d minus r, right? Is equal to D minus r right plus r divided by r into D minus r, r r cancel is equal to d upon r then D minus r, but D minus r approximately is equal to D, right? Therefore, it is D upon r D, D D will be cancel, it is 1 upon r, right? That is why that this whole expression this expression approximately is equal to 1 upon r, that is why q upon 2 pi epsilon 0 r right? So, volt per meter here, I have made it here also same thing calculation, I have made it, here right? Therefore, the rms value of voltage gradient is given by, this is maximum value than that is why instead of this G max is equal to q upon 2 pi epsilon 0 volt per meter, the rms value is Grms is equal to G max upon root 2 right?

So, potential difference V12, between the conductors of a single-phase line is written as, this had been for capacitance calculation, these are been derived in the capacitance chapter in power system analysis course.

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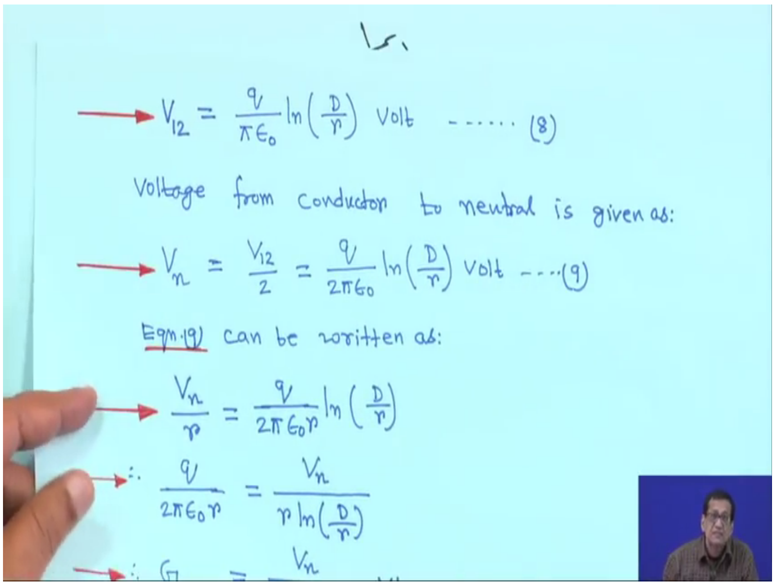

So, directly you we are writing right? Directly you are writing that, your V12 is equal to q upon pi epsilon 0 ln D upon r, refer to that capacitance chapter, power system analysis say, I directly I am not waste in time again doing this, these already has been done and available with you. So, this is q upon pi epsilon 0 ln D upon r volt, this is equation 8.

Now, voltage from conductor to neutral, is given by basically it is single phase line. So, we can make it Vn is equal to suppose, if you have a neutral for example, suppose neutral is available. So, it will be V12 upon 2. So, it will be q upon that it is 2, it was q upon pi epsilon 0, right? Will be q upon 2 pi epsilon 0 ln D upon r volt this is equation 9, right?

So, equation 9, then can these equation 9 can be written as, this these equation actually both side you divided by r, right? Then this one can be written as Vn upon r is equal to q upon 2 pi epsilon 0 r ln D upon r, actually these equation is divided both side by r. Therefore, this q upon 2 pi epsilon 0 r can be written as, this one q upon 2 pi epsilon are is equal to, right? Is equal to it will be Vn divided by r and this ln dD upon r will come here. So, Vn upon r ln D upon r right therefore, this is actually G max because, G max is equal to, your q upon 2 pi epsilon 0 r, this is actually G max from equation 6, q upon 2 pi epsilon 0 r, right? Therefore, your G max is equal to Vn upon r ln D upon r volt meter, this is actually equation 10 right?

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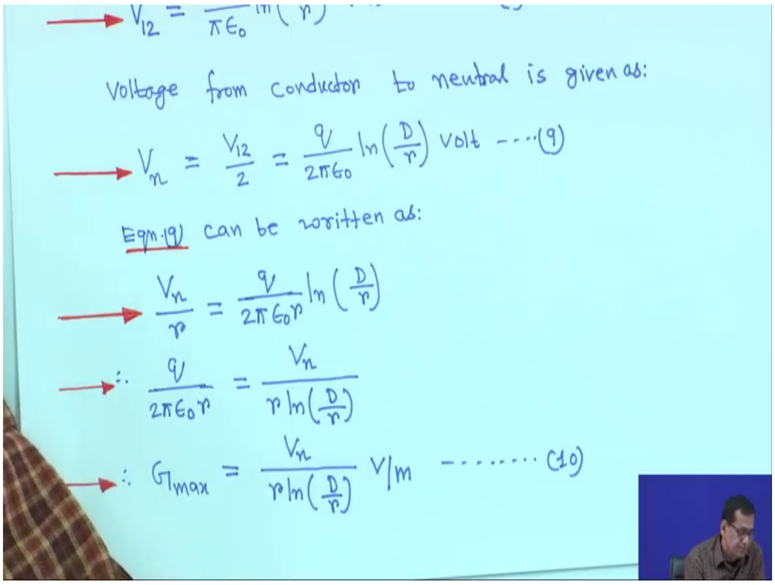

So, from that we can get maximum, your potential gradient that G max will be Vn upon r ln D upon r all right? So, this is for your single-phase line, now for 3 phase line, 3 phase again this derivation again, I will refer to your capacitance chapter all this things derived there, suppose you have a 3-phase line abc 3 conductors are there and distance between the 2 conductance, is for example, ab is dab, bc is dbc and ca is dca.

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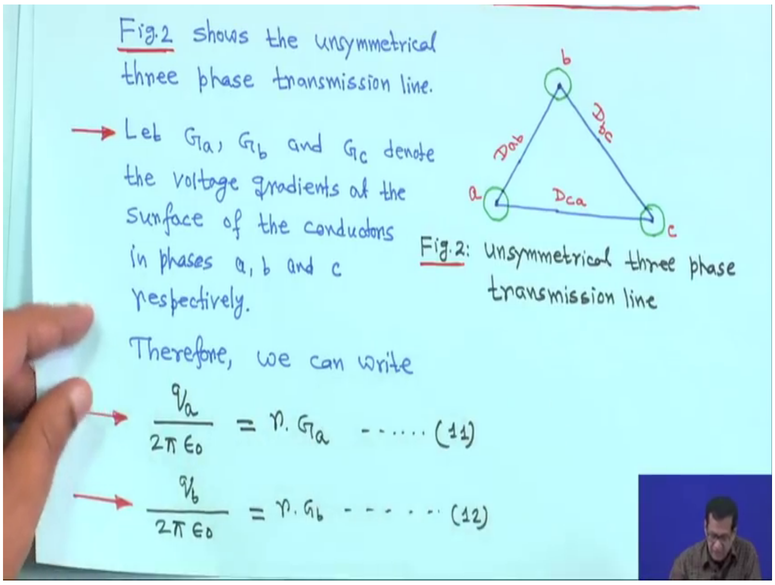

So, it is unsymmetrical 3 phase transmission line, you are not considering symmetrical say, unsymmetrical right and you know that D equivalent is Dab Dbc Dca, whole to the power one third that you know.

So, figure 2 shows the unsymmetrical 3 phase transmission line, this one, right? Now you assume that let, Ga Gb and Gc denote the voltage gradients, at the surface of the conductors in phases ab and c. So, ab and c, Ga Gb Gc right? Are the potential gradient of the conductors abc right therefore, we can write qa upon 2 pi epsilon 0 is equal to r into Ga, basically, you know these one that Ga for example, for phase a Ga is equal to qa divided by 2 pi epsilon 0 r, we are assuming that, radius of all abc 3 conductors are same r you are assuming, that right?

So; that means, Ga you can write for conductor in phase a right? Ga is equal to qa upon 2 pi epsilon 0; that means, we can write qa divided by 2 pi epsilon 0, is equal to r into Ga this one similarly.

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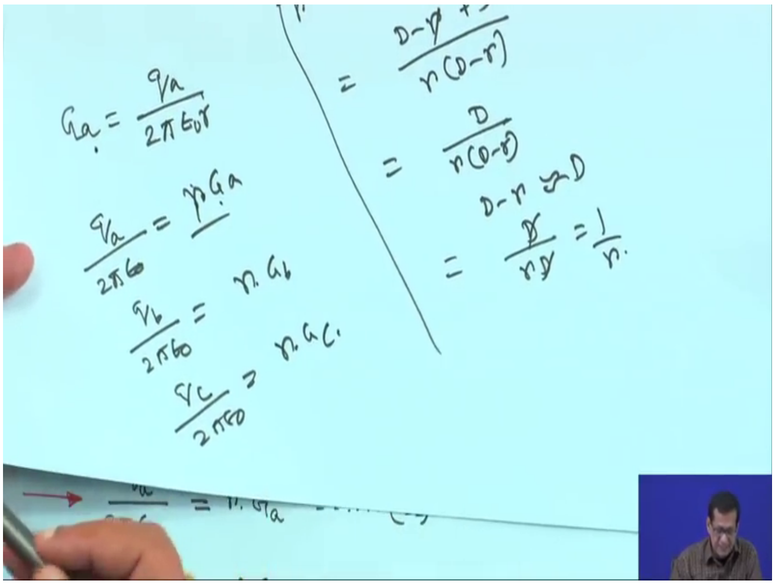

Similarly, you are qb upon 2 pi epsilon 0 is equal to r into Gb, similarly qc upon 2 pi epsilon 0 is equal to r into G right; that means, since therefore, that is why you where writing here that, qa upon 2 pi epsilon 0 is equal to r into Ga, similarly we are writing qb upon 2 pi epsilon 0 is equal to r into Gb this is equation 11 this is equation 12. Therefore, and similarly qc is equal to your qc upon 2 pi epsilon 0 is equal to r into Gc this is equation 13, right?

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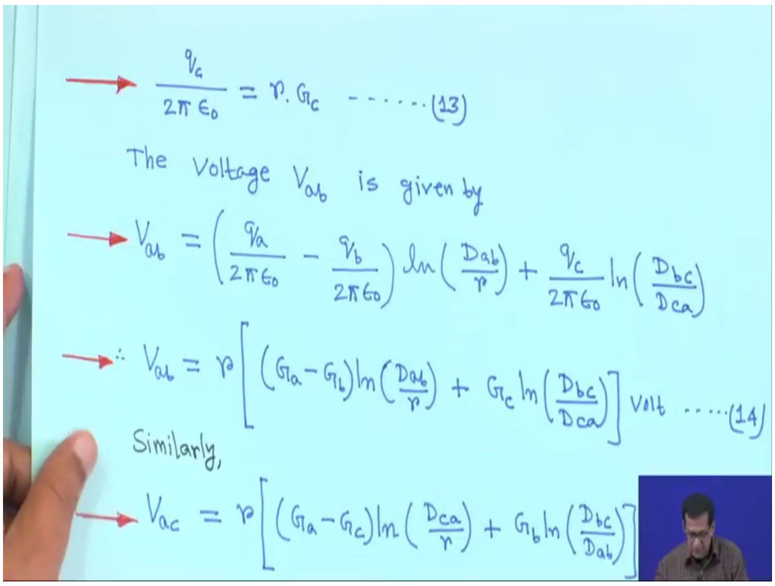

Now, this voltage Vab is given by again from the capacitance chapter, directly I am not deriving it again, but everything is there in that capacitance chapter, all I have done there just have a look again, that is all if you forgotten. So, Vab is equal to qa upon 2 pi epsilon 0 minus qb upon 2 pi epsilon 0 into ln, Dab upon r, plus qc upon 2 pi epsilon 0 ln Dbc upon Dca all right?

So, therefore, this numerator and this thing, you are what you call this Vab is equal to, it is your if you make multiply by r then, it will be Ga minus Gb, I will tell you how it is coming Ga minus Gb, ln Dab upon r plus, Gc ln Dbc upon Dca volt right? Or similarly your Vac also r Ga I will come to that how it is coming, Ga minus Gc ln Dca upon Dr plus Gb ln Dbc upon Dab volt right? So, this is actually equation 15. So, from this how we are coming I will be coming back.

Thank you.