Power System Generation, Transmission and Distribution

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Indian Institute of Technology, Delhi

Module No. # 01

Lecture No. # 10

Transmission Line Parameters

Good morning ladies and gentlemen, today we are starting lecture 10 that is on Transmission Line Parameters. Before we go ahead and do transmission line parameters, we had to do a small talk on computers. Now, what is the history of computers in power systems?

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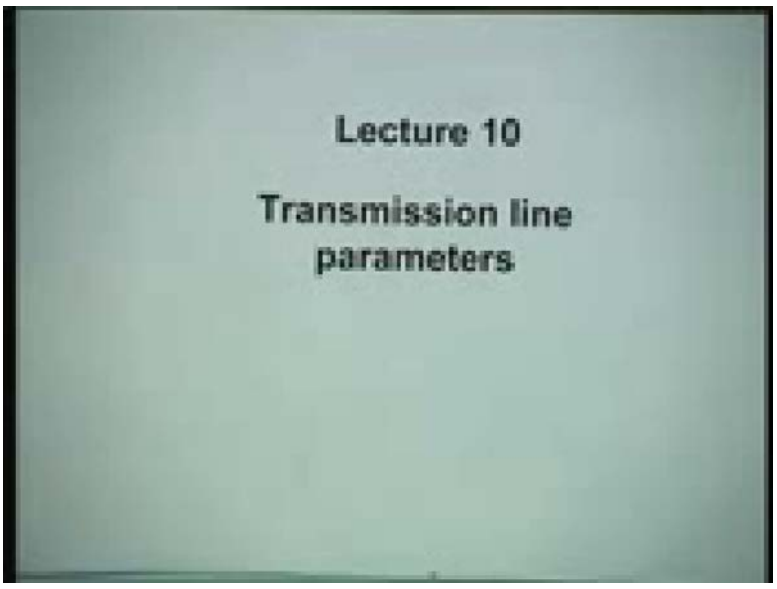

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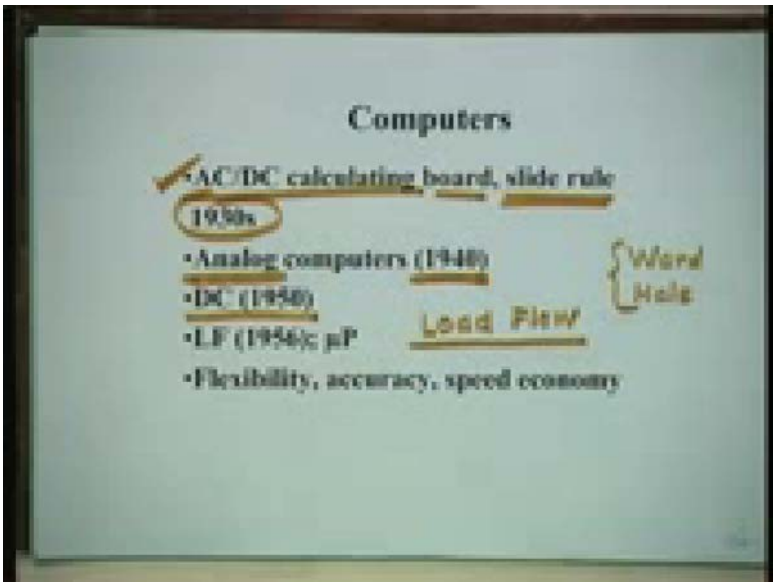

There were A C and D C calculating boards, started do not think that computer is a recent sort of invention; even in 1930s they were computing this, man has to be compute right from the day one and A C and D C calculating boards were used; and then they were replaced by a slide rule, I do not know how many of you aware of slide rule when we did our under graduate B Tech; we used to use slide rule for doing engineering calculation, I still have a slide rule with we if you someone wants to have a go at it, have a dharshan of it you are most welcome.

Then came analog computers, this is an American spelling, but in English spelling is l o u g e there 1940, then came digital computer 1950, I told you about the baby computer 1948, Manchester Umist, the three scientist who invented that the still arrive and there was a golden jubilee celebration in 1998, and which I also participated happened to be there; and the first power system study, which was carried out using digital computer was load flow, I am sure all of you know load flow you must have studied in your under graduate, you will be doing it next semester.

The paper was by Ward and Hale, these were two persons who used digital computer to solve load flow problem, you know what load flow problem is? p q delta v solution of this four parameters. Computers gave what of course, macro processor were also used, computer gave you flexibility, accuracy, speed economy, the slide rule we used to take lot of time, our problems used to be it easier in exam, because of slide rule, because we

used take lot of time and they were approximate, if your eye side is not good your little bit mistake, because you are to use those cursors and things like that.

Then came the mainframe computer, mini computer, micro computer, personal computer of course, now you have laptop, you have the you know the palm top and so on.

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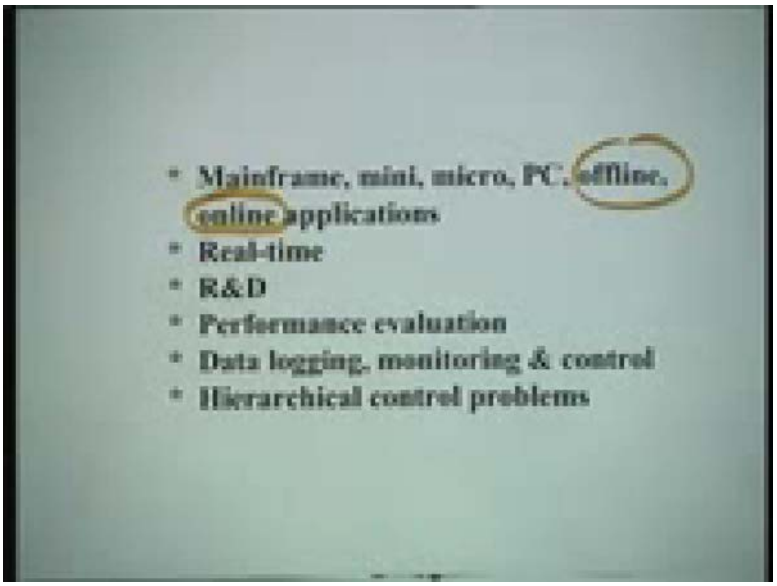

Offline and online application, any problem can be solved offline the same problem can be solved online. The news you here in the various channels they are real time online is not recorded, offline is something which is already done earlier and now it is being beamed, so there is a less likely would of any mistake, now what is going on is online and there is no corruption, there is no retake, there is no set of again doing it, real there is slight difference between real time and online, that is a CSC know computers, so where you should be able to appreciate and some data also comes in real time.

R and D most of the R and D needs computers, performance evaluation also needs computer, now a days all your gate papers J E papers that evaluated at least objective type by you know machine, there is no human beings required. Data logging, monitoring and control is also done by computer whether it is a DST, whether it is a railway, whether it is a power system, whether it is a medical system, you go for any patient in aims all is data will be recorded in the computer. So, data logging then monitoring and control everything is done by computers, hierarchical control problems one after another, as I told you in earlier lectures, first you do forecasting, then you do maintenance, then

unit commitment, then load dispatch of course, sometimes will do state estimation, security, reliability, optimization so on, one after another; what are these problems, which solve in hierarchical way, multilevel way, this is the table which tells you.

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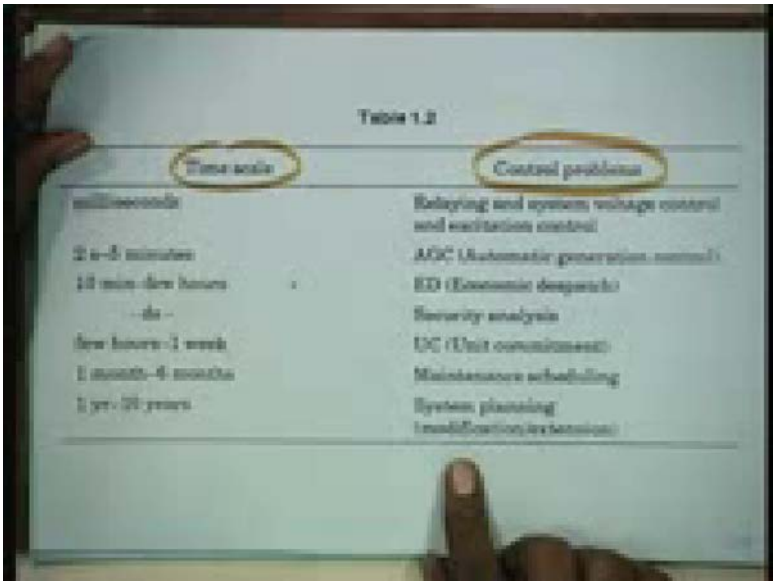

The time scale and it also tells you the control problems; milliseconds, relaying and system voltage control and excitation control, they do not give much time, you have to identify fall in no time, that is why when your studied circuit breakers in your under graduate, you know now they are fast operating fast clearing fault, may be 2 cycles, half cycle, they gone up to half cycle it can be magic within no times, some minimum time has, then 2 seconds to 5 minutes is AGC; you must studied AGC in your under graduate, automatic generation control every 2 seconds to 5 minutes here to run this programmer AGC.

So, that the frequency remains around 50 hertz n plus 9 is 0.5 hertz is in unity 10 minutes to few hours is ED, Economy Dispatch; similarly, for same time you do security analysis few hours and 1 week is unit commitment will be studying all these things in detail next semester, under power system plant that course 860 ESL, 1 month to 6 months is maintenance scheduling, you do not that to maintain in the short term you do not give your car every day to carriage, it will once in a year once in 6 months.

Similarly, power houses are maintain in this frequency and planning is always done up to 10 minutes, going to 10 minutes is no pointing planning for 2050 god knows what

system will be there, who will be there, and what will plan it is very very difficult; who could have throughout by 1990, there will be mobile evaluation in India, planning loads of means modification and extension in the present power system. What are the problems that are being faced currently in powers industry and choices?

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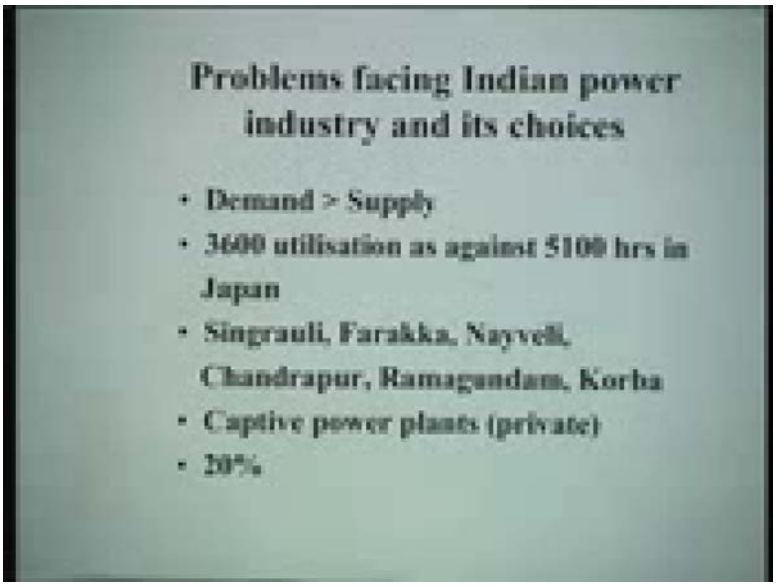

How we can, because everybody say to add 100000 megawatt in 10 minutes, it is not a joke, do you have man power development program corresponding, do you have corresponding coal development program, so it is going to be vast planning in presents and lot of people have to and help developing 100000 megawatt and money of course, that is very important 40000000 per megawatt; 3600 utilization as against 5100 hours in Japan is very pathetic story of course, demand is always more than supply, for in few hours and few states like Uttaranchal, where you have a circulars power, now UDK has no power cut, when it was in UP it is always power cut.

So, that is one advantage of UDK is going into Uttaranchal there is no power cut in , we are able to use our power plants for 3600 hours as against 5100 hours, it is not be restricted to power plant alone, look at the way the government offices work 102 days goes in saturdays, sundays then there are 20 national holidays, districted holidays, 8 casual leave, 15 special casual leave is un leave, then there is a medical leave, so hardly a government servant was work for less than half year, less than 6 months. So, why power

system should be in exception, they also work less than 50 percent, 8760 hours you make it half it is not 3600 hours, so it is very pathetic.

Your spend so much 40000000 per megawatt and your going to use only 3600 hours is very bad as against Japan were 5100 hours. Singrauli, Farakka, Nayveli, Chandrapur, Ramagundam, Korba these are all super thermal power stations; super thermal is any thermal station having more than 2000 megawatt, the captive power plants are only increase that is a private generation, now 20 percent is used to 7 percent before reforms era, now it is 20 percent, and it is likely to go up, more and more privatization. Now, we come to the chapter 2, the book that is the transmission line parameters, of course you must have done it, so will only review it, we are not going to go in detail, since all of you have to take are be electrical.

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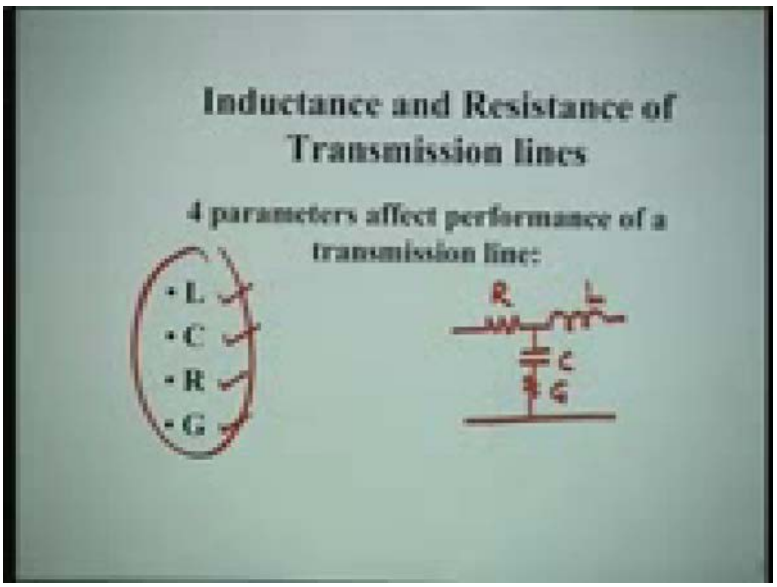

And sure you know the four parameters, inductance, capacitance, resistance, and conductance, in these particular lecture today, we will talk on inductance and resistance which are series parameters right, they are always in series. And capacitance and inductance they are shunt parameters, they affect the performance of transmission line, if you change their values the performance of transmission line will change, and hence it is important, it is imperator to evaluate these four parameters of a given transmission line or while design a transmission, while designing transmission line we should find out, what should be the ideal very low RLCG.

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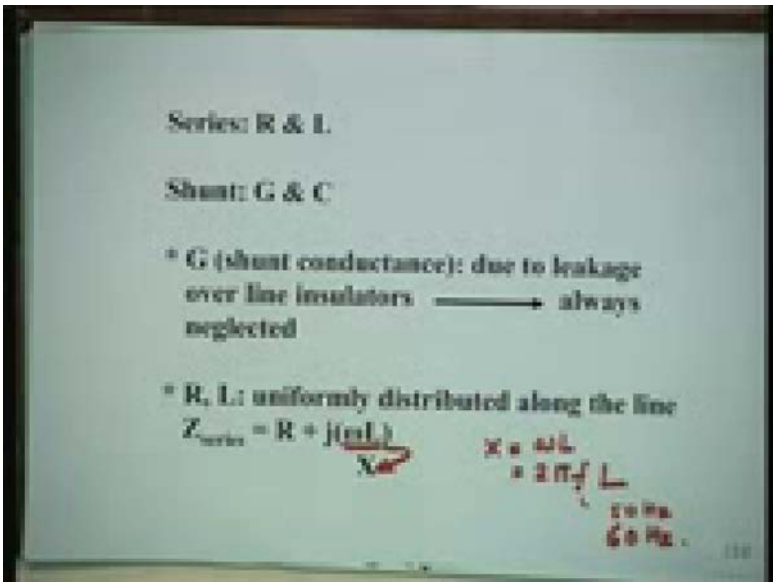

I just now tell totally before few seconds trail you before few seconds, R and L of series parameters G and C are shunt parameters; what is g, we always almost, always neglect G while doing any power system computation, any power system calculation it is there due to leakage over line insulators, we you must know atleast why it is there, and it is unit is Mho, Siemens the opposite of ohm, R and L are uniformly distributed along the line U D L, Z series the figure are drawn in last light is R plus J omega L and J omega, omega L is called X this omega L is nothing but x, x is equal to omega l and omega is nothing but, 2 pi f l f is frequency which is 50 hertz and some countries and 60 hertz in some countries. Since, we we were inheriting UK system or England English system our frequency is 50 hertz, the American system frequency is 60 hertz, the French system it is 60 hertz; out of these 4 L is the most dominant line parameter like UP is the biggest state in India.

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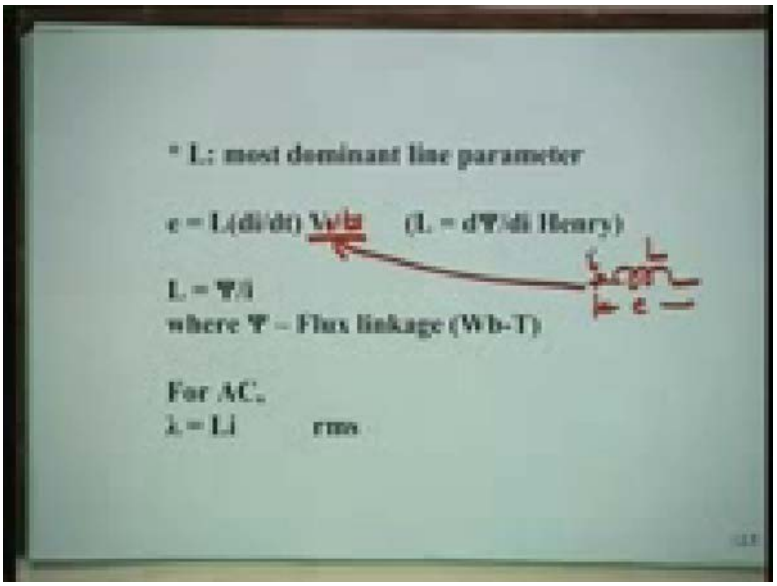

So, L is the most dominant line parameter, you cannot ignite ignored L for anything inductance has got to be computed and you know this law very well e is equal to L d i by d t the voltage across inductance, that is if there is inductance and this voltage e, this is L, this is I, this is related by this, this V is unit volts. So, do not confused as, it is a parameter L d i by d t, L is given by d chi or d lambda by d I, Henry, what is chi, chi is a flux linkage, some people write it lambda also; vapor turns is your physics you must have done all these things in physics of course, in electric engineering for A C when you talk of alternative current lambda is equal to L i.

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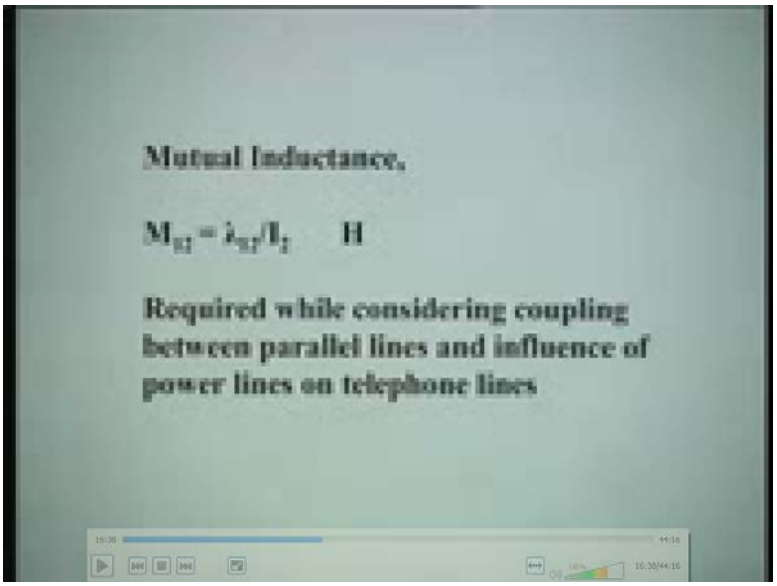

What is mutual inductance? The two coils close current is flowing, so that current flowing in 1 coil also affects the every coil and this mutual inductance is also given in Henry's, which was a unit of inductance to honor a scientist Henry. M 1 2 is equal to lambda 1 2 upon I 2, required while considering coupling between parallel lines and influence of power lines on telephone lines; where do you use it in practice all of you must be knowing that, do not have a single line transmission, we have double circuit transmission line why, that helps you in transmitting more power plus reliability, if very unfortunate if you are then only both the lines will have fault simultaneously, both kidneys will fail very rarely, it is normally one kidney and people can live one another right.

So, similarly one line will only fail at a time, so that you can continue to transmit some power minimum amount of power on remaining line. So, but then there is a mutual infectance, because current is flowing in both similarly, you must have seen while travelling in train or otherwise also the same poles are use for telephone lines to save money. Now, when you have a parallel going the power line as well as telephone line, naturally they have interference, so that mutual inductance and we have to have minimum interferences as in olden days when you do STD or whatever you used to be lot of noise, now it has to gone, now you are talking to New York as if is it city upstairs, so clear.

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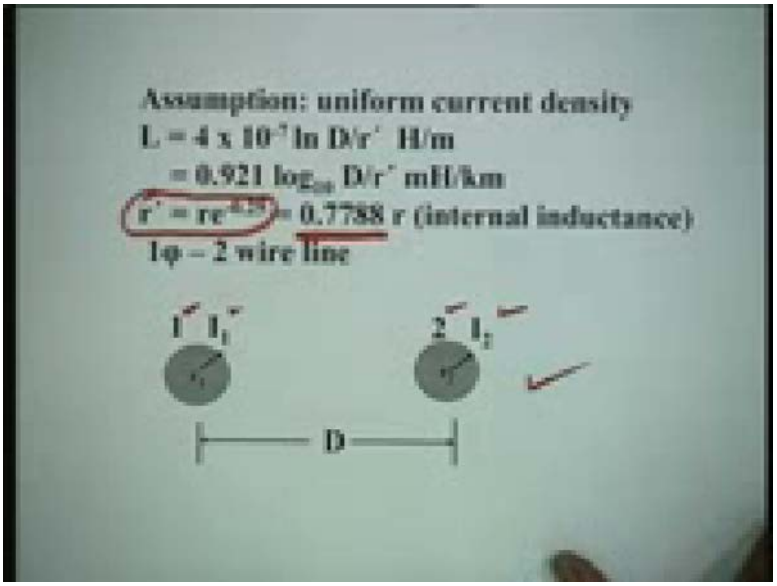

If you assume that there is a uniform current density, then the expression for inductance is 4 into 10 power minus 7 natural log D by r dash, why there is r dash, r is a radius of the conductor, dash means this r multiply by e re power minus 0.25, which is 0.7788 times r in order to consider internal conductance, we as if we consider as if to conductor radius is modified to a smaller value 0.7788 times. Single phase 2 or line the shown here in this figure, the two conductors are separated by distance capital D, conductor 1 is carrying current I 1, conductor 2 is carrying current I 2, radius is r 1 and radius is r 2.

What are the different conductor types, hollow conductor, solid conductor, standard conductor; standard means ACSR, Aluminum Conductor Steel Reinforced. Why do you stand them, so that there is a good grip and mechanically the stronger, what happens there is a central stand of steel and aluminum stands are done alternatively spared across it, how many stands will be there, depends on number of layers; the formulas given here 3 x square minus 3 x plus 1, if there is only one layer then it will come out to be 1.

If x is 1 then this 3 3 will cancel out to get 1, but there are two layers then you will see just check will you get 7 you get 7 lets so on, depending on what power you want to transmit. So, electricity electrically they are in parallel with alternate layers spiral in opposite direction to prevent unwinding, they have spiral in not in same directions, but in opposite directions; so that, they do not come out, no unwinding; you can see the figure in the next slide of this ACSR conductor.

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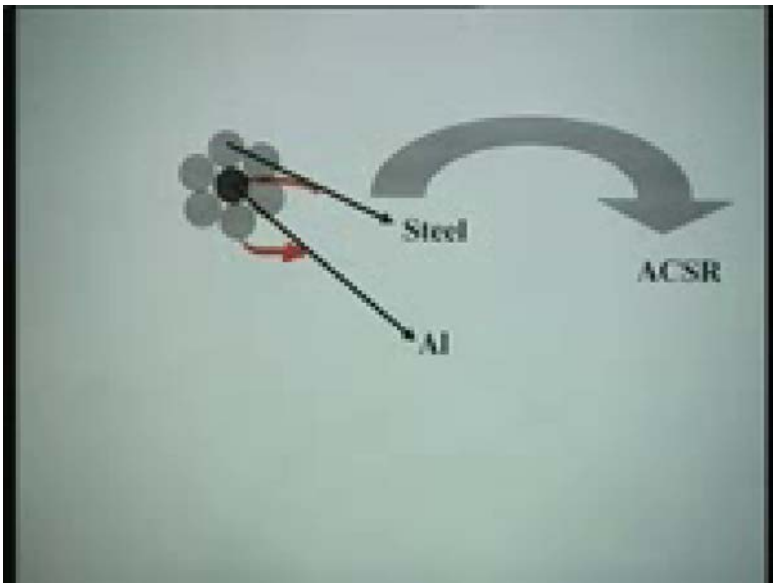

I think this is just we done reverse, this is steel and these are aluminum, this has been prepared by somebody, you not electrical engineer, but you are electrical engineers. So, you will understand this A C aluminum conductor steel reinforced, steel is only one central stack this black point and not so black is shaded ones are aluminum, six are aluminum.

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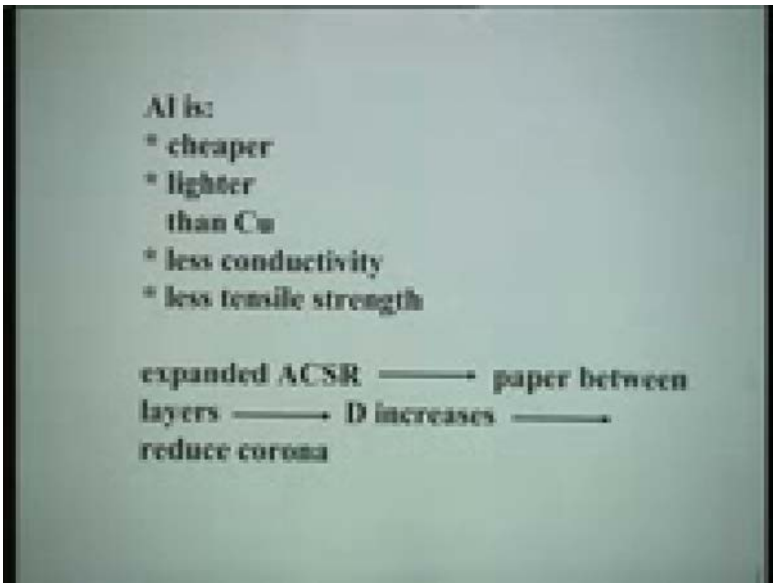

What do you use aluminum, there was a time when you use to use copper

Yes, it is lighted

Cheaper

It is cheaper

Then copper of course, less conductivity it is, we do not worry, less tensile strength, I told you plus and minus whatever you do in life there is always plus and minus. So, there are two minus, two plus points are all availability is better for aluminum in India, we do not had to raise your import bill in hence aluminum is preferred. We keep paper in between layers in expanded is s r, so diameter increases; what happens diameter increases?

Right it reduces the chances of corona you must studied in your under graduate, it is a formic of in violet colour glow around the conductor specially in bad weather conditions,

when it is raining, when it is snowing all these conditions it becomes very easy to corona to form.

Yes also, of course is a using noise also is heard while corona is taking place.

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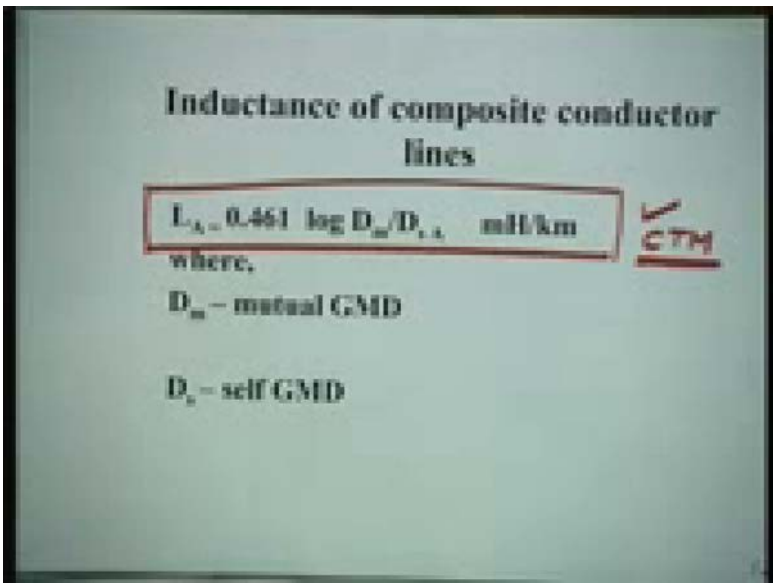

Inductance of composite conductor lines, this is the formula you will have to use again and again, so you should CTM, what is CTM? Committee To Memory, you will be using this formula again and again in transmission line computation, 0.461 log the basic 10 D m by D s e D m is mutual GMD, Geometric Mean Distance D s is the self g m d and the units are mille Henry per kilometer, if you want Henry you can always multiply by tens so minus 3, you make it Henry, if you so particular about Henry.

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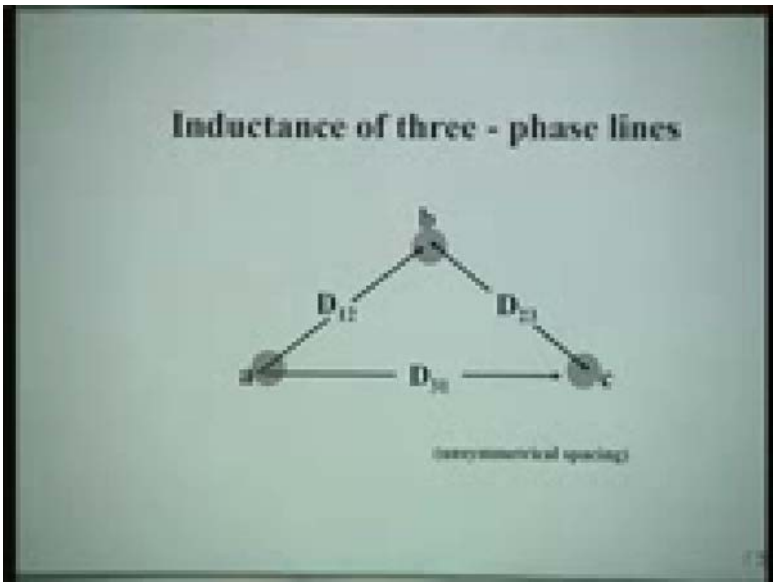

Inductance of three phase lines, look in this diagram spacing is not symmetrical, it is unsymmetrical and that is why D 1 2 is not equal to D 2 3 is not equal to D 3 1 is most general case; the three conductor shown a, b, c order is symmetrical. So, always change a by b, b by c, c by a. In fact, in transposition this, what is done when you learn transposition you might already learn, so no needs to stress much of . So, for this three phase line, they can be in horizontal also, they did not be in triangular form.

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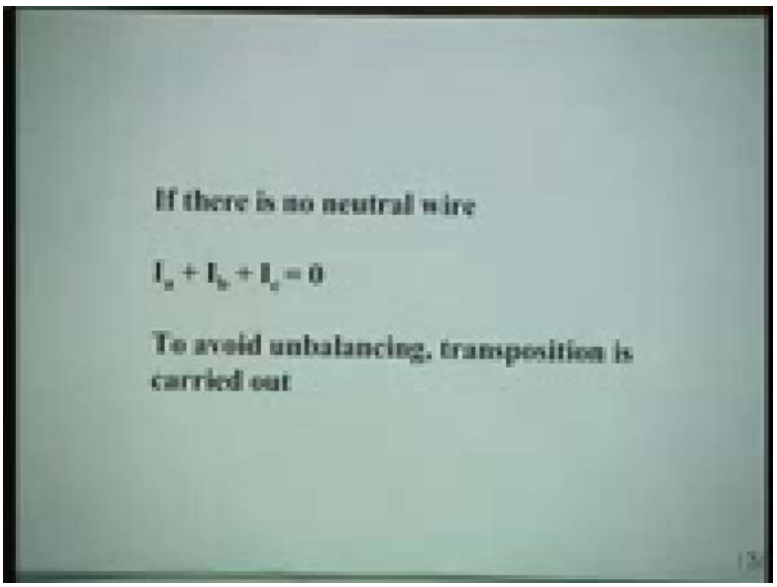

If there is no neutral wire in summation of all the three currents are 0, to avoid unbalancing transposition is carried out, so why transposition is carried out, if they asked

in interview or somewhere is what you have to reply, just show you one transposition cycle this is complete transposition cycle.

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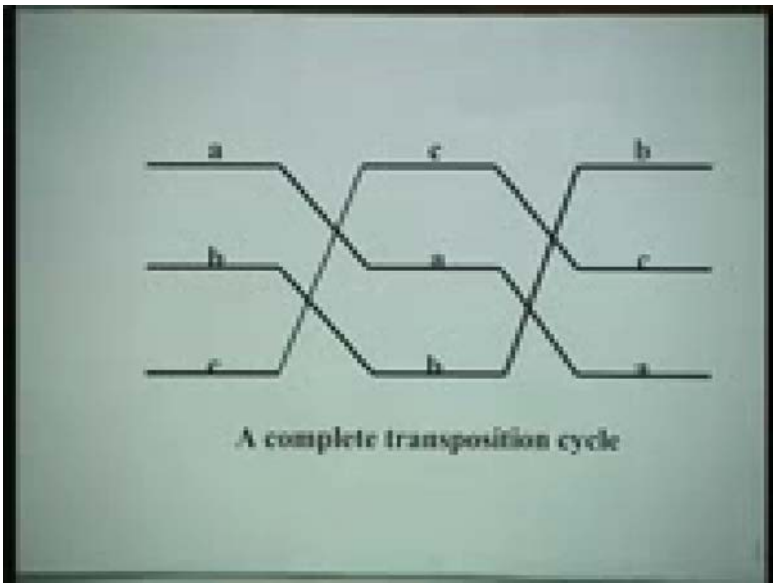

Conductor a after sometime it comes in middle, then it comes below, so unbalancing gets averaged out of course, computation you take average. So, they become big more complex, you must have seen the formulas otherwise please refer to chapter 2 of the book. Any book , red book or the black book which is coming all the 3, chapter 2 is same; this no change even in 3 rd edition there is no change.

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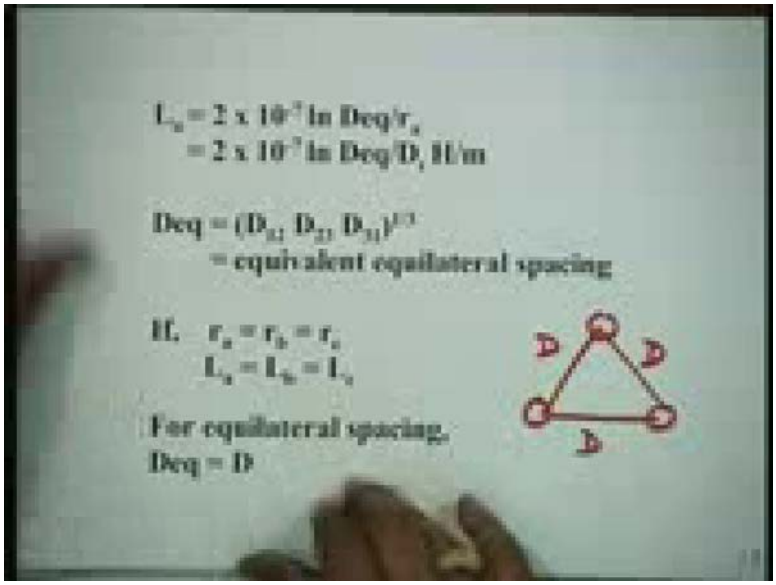

Now, the inductance of phase a is 2 into 10 power minus 7 natural logarithm D equivalent to over r a dash or in a general way it will be D equivalent to be D s self GMT D s is more generator, because it may be bundle conductor which has going to come now next, then D s own be just r it will be under root of you know you know those things, D equivalent in these case is the cube root of D 1 2, D 2 3, D 3 1 and this is called equivalent equilateral spacing.

If all the resistance are same sorry, all radiuses are same or radii I should say and same then all inductances, for equilateral spacing D equivalent get reduced to D, because then there is, they are equilateral all are D, so no D 1 2, no D 2 3, no no D 3 1 in that case D equivalent becomes the cube root of D e q is D itself, the bundle conductor. I seen many students getting confused between ACSR and bundle conductor, when I ask them bundle conductor that draw the diagram of ACSR conductor they get 0 straightaway, is your talking something else, which is not asked.

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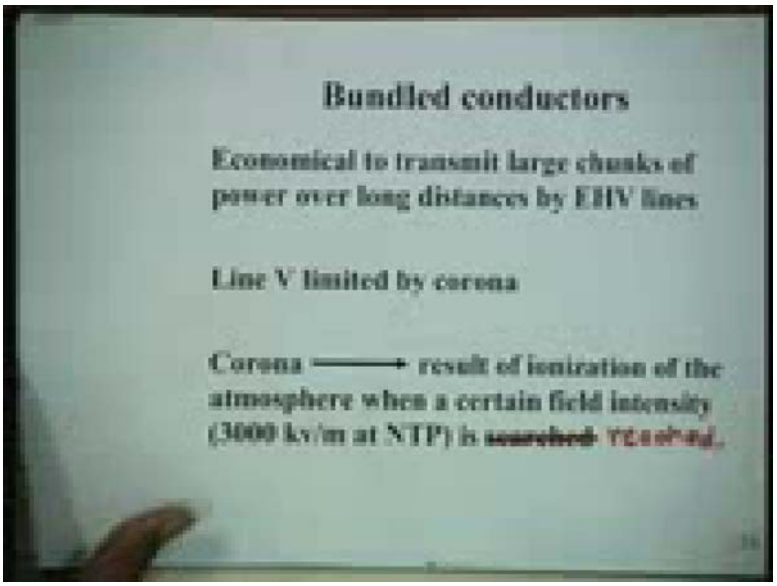

So, bundle conductor is entirely different concept then ACSR conductor, it is economical to transmit large chunks of power over long distances by EHV lines, this we are telling you from very beginning, that is why there is a need of transformer, because generation is always at lower voltage up to 25 k v you cannot to beyond; why, there are cooling problem, there are insulation problems, safety problem, but the transmission is always cheaper, convenient, economical on EHP or UHP line.

So, you need to have a transformer, but line voltage gets limited by corona, just cannot do for million volt, there are problems, there are insulator problems, there is a corona problem, there is safety problems, there are interference problems and so on; so there is a limit there limit the world has gone is 1000 k v or 11 k v not beyond that of course, now there is no question of racing any more power requirement of US, so already maximum. I mean you do every time think by electric power, what else you need electric power for right from the time get up, to time to sleep all your activities consume electricity.

What more electricity you can consume and the population they are not going to increase and know their limiting immigration and know not allowing any buddy to enter, and they do not have marriage institution several problems, so there are no children. So, this no question of power demand going up in those candidates, corona is result of ionization of the atmosphere, when certain field intensity that is 3000 k v per meter at N T P is reached.

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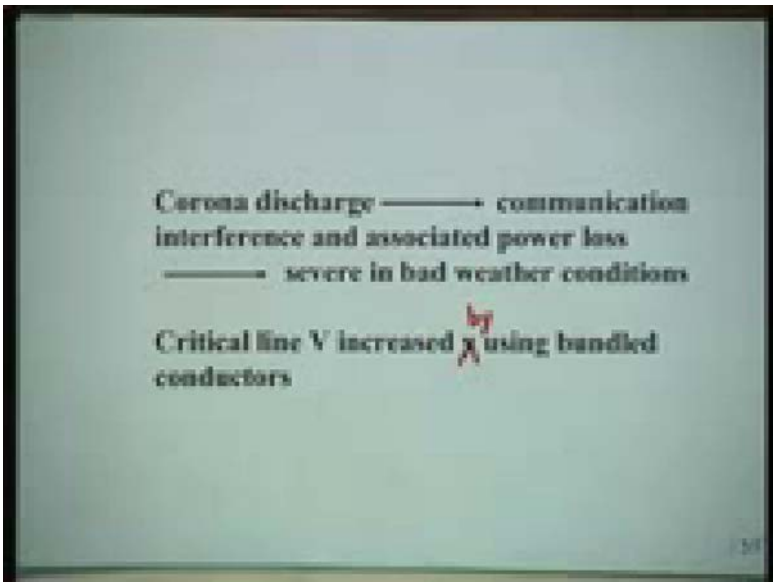

Corona discharge also creates communication into friends and there is a loss do not think I square r loss is the only loss in transmission and there is a peaks formula if you recall that term, which is the used for calculation of corona loss; you can always revise your under graduate notes, if you have any or book and this very severe in bad weather condition as I told, critical line voltage increased by using bundled conductors, so it helps you in avoiding corona.

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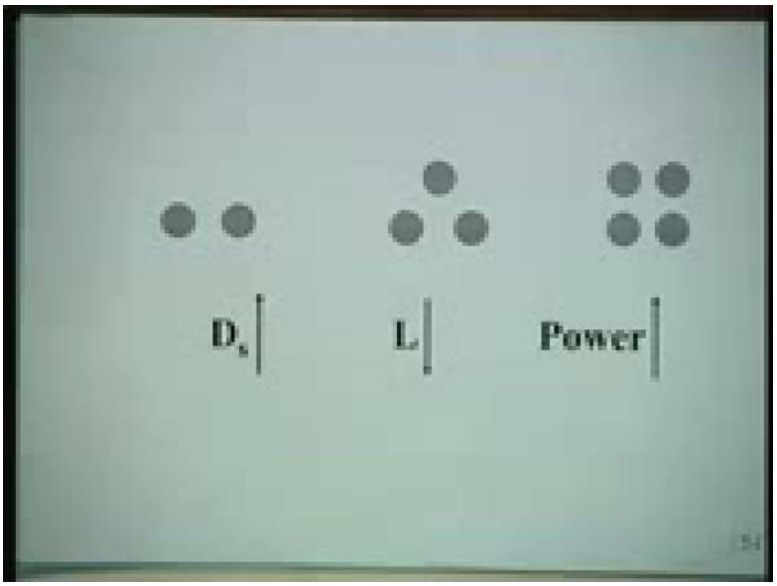

Now, this is what is three types of bundled conductors, the from my side left most figures shows you only two sub conductors for being a bundle, middle figure shows three sub conductors in a equilateral triangular resistance and the third figure from my side right most, that is being formed by using four sub conductors, quadrilateral more than merrier, but money aluminum right, so it depends what is your requirement; the D s goes up with bundle conductor, D s is self GMD D s goes up inductance comes down, has inductance comes down power goes up, that is what you want, we sometimes have generation, but we are unable to transmitter, is transmission lines are not available.

So, in order to develop the whole power system, we are to develop not only generation sector, we have to simultaneously keeping space with generation also develop transmission sector, otherwise if there is no means of power supply available for transmission, that power generation is meaning; let us talks of resistance, we are talk enough of an inductance, because inductance happens to be the most dominant parameters, that is what to be said in the beginning of the lecture.

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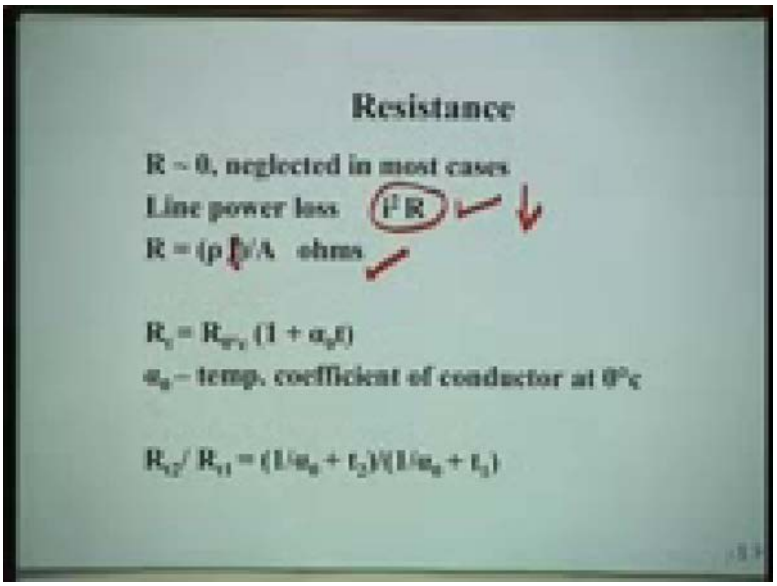

Resistance you must have studied in physics it is nearly 0 in most of the power system studies, we do not consider resistance at all, we ignore it; however, the fact is resistance is very much there, if it is not there they will no i square R losses it will be 0. So, line power loss is very much whether you like it or not and our aim should be to reduce it as much as possible this is the six class expression for resistance rho l upon a, this is unfortunately the l and 1 gets similar, when type it l is length rho is resistivity a is area.

The total units are ohms, if there is a temperature change which is always there all the time, if you see any news channel now the show in live temperatures all the time, is no more only 9 o clock is temperature minimum, maximum any time you can see temperature. So, with more temperature resistance increases alpha 0 is nothing, but temperature co efficient of conductor at 0 degree centigrade, and you can find out at the ratio of the 2 temperatures at 2 different t 1, t 1 and t 2, 25 degree centigrade, 30 degree centigrade, this is some numerical are also being ask anything else is giving you all this data and substitute it and get the values; of course, we wont ask those numerical now, you are post graduate.

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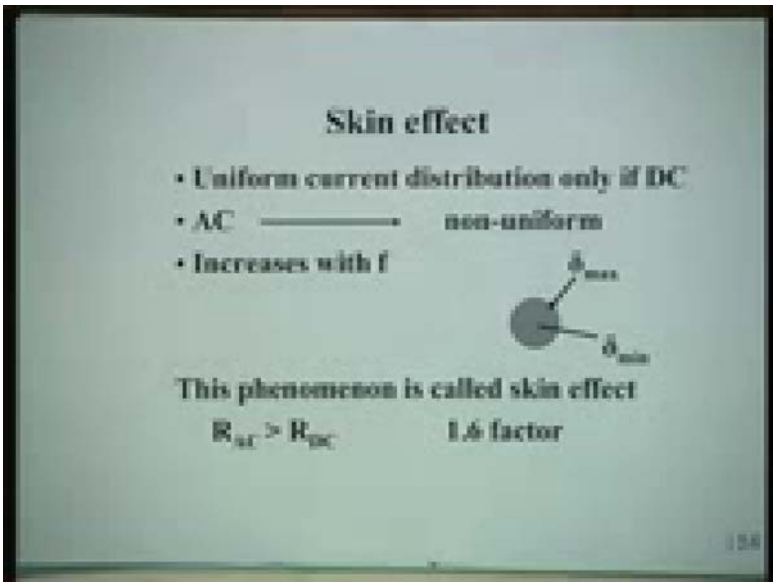

Very important effect of resistance is skin effect, uniform current distribution is only possible in case of direct current DC, in AC and I am sorry unfortunately or fortunately it is non uniform it increases from centre to the as we go towards the surface, and it also increase in frequency. So, delta mean is de centre and the delta max is de surface, delta is normally the current density and p is square meter square, this phenomenon is called skin effect and because of this AC resistance is always more than DC resistance.

So, whenever you are measure the resistance of the anything in laboratory using your simple circuit of battery, elevator, voltmeter and potentiometer, for changing the values of current for taking few readings, otherwise your teacher will get , if you take only one , so all these values must have been multiplied by 1.6 factor which will convert RDC to RAC, RAC is equal to 1.6 times RDC.

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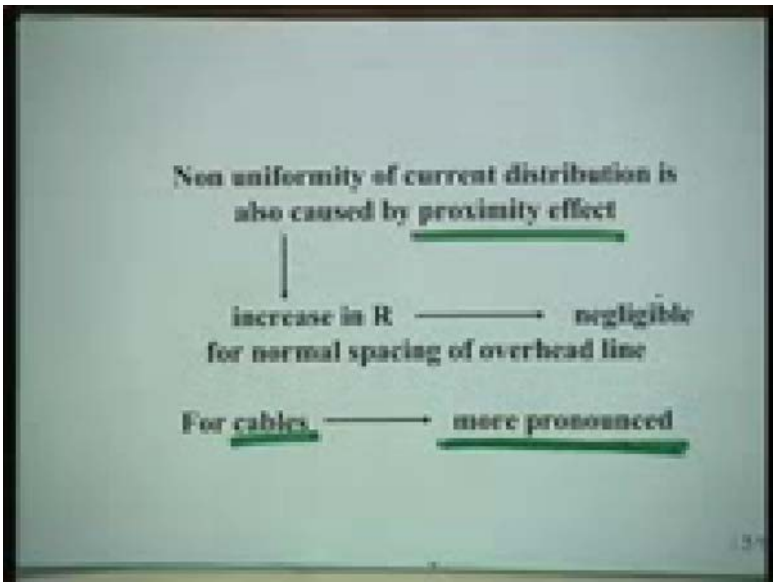

Non uniformity of current distribution is also caused by proximity effect, do not think there is only one skin effect, it has cousin, who are cousin and that cousin is called proximity effect, there is increase in resistance though it is negligible for normal spacing of overhead line, but for cables where this is very close, the effect is more pronounced and you are not supposed ignore proximity effect when you consider cables. You must have studied cables in library there is on very good book cable by v d, w w d y John UK.

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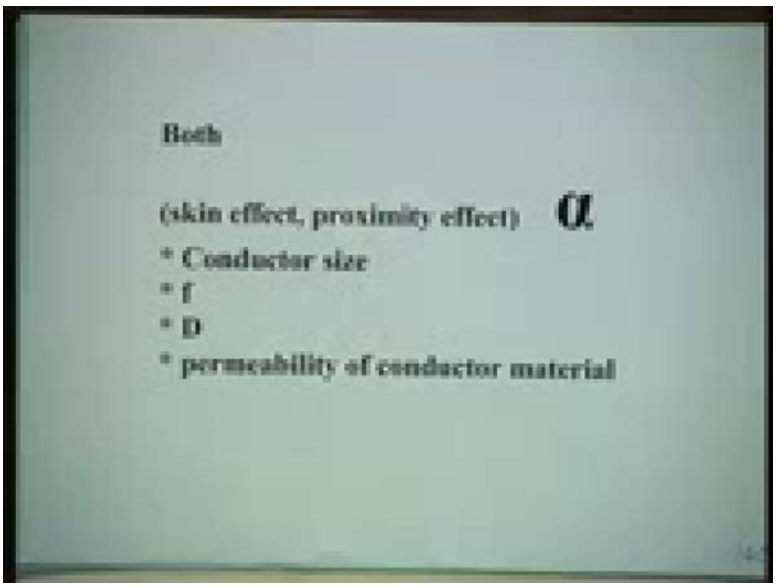

Both skin effect as well as proximity effect depends upon or proportional to the big alpha, is not alpha it is a sign of proportionality, this may be ask in interview, this may be

ask in objective type questions gate exams, depends on four parameters conductor size frequency, diameter, permeability of conductors.

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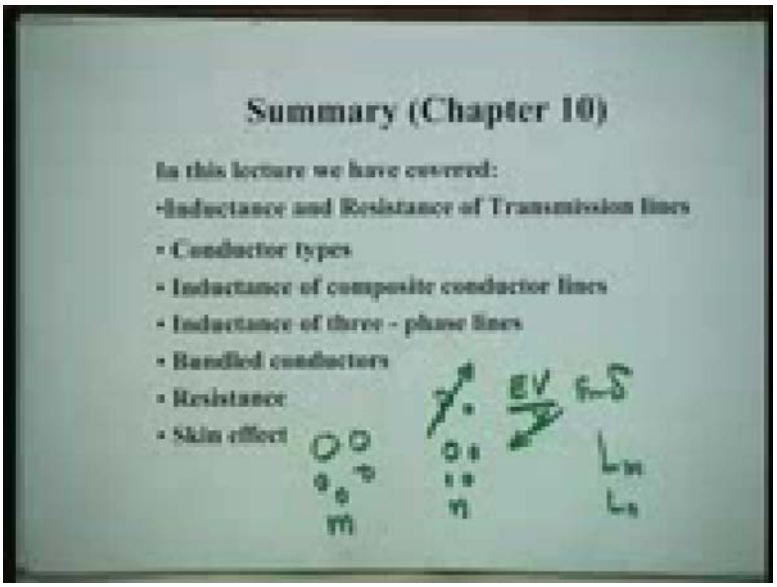

So, what you have done in this lecture, we have covered so for inductance, and resistance of transmission lines, why we are to consider then, which is more important, why we ignore resistance most of the times, why we here to consider inductance all the time, various conductor type, there have been a tables given in many books from where you can directly reinductance and resistance for a given configuration and given type of conductor, the practicing do not have time to calculate the values of inductance and resistance.

In fact, there is a t and d reference book I don not know whether you have seen that, such a big wasting house and that is still a very good book it published in 1950, 50 years back more than 50 years back, then inductance of composite conductance lines, single conductor, single phase, three phase, symmetrical spacing, unsymmetrical spacing, unbundled conductors, bundled conductors, all this things you of course read it, we are just revised it, why bundle conductors are used, how they help you, how they bring down the value of capacitance and sees the bring down the values of capacitance, they bring up the value of power transmit.

Because the…

The bring down inductance to power transmission goes up to x is in the

P is equal to EV by x some delta and if x goes down is goes up, we have to talk about resistance though, we neglect it still, why there is a resistance, what is the formula for resistance, how it varies with temperature, and what are this skill effect and proximity effect. Now, next lecture we doing capacitors, capacitance and conductance we do not have we just ignore. In fact, capacitance is nothing but, a repeat of whatever inductance formulas are slightly different, what makes capacitance different then inductance is consideration of effect of ground, why we ignore the effect ground of inductance, because.

Yes because, there is no set of methods of images etcetera, and it is not a shunt parameter since capacitance is a shunt parameter, it has a connection with ground, inductance has no connection with ground and what happens, how we consider the effect of ground etcetera, how you will see in next lecture, and plus we will talk on fundamental things that is power, complex power, what is operand power, what is the real power or active power or reactive power, how do we change the power factor, what is the excitation control, how excitation make change of leading power to lagging power to unity power factor, without affecting the real power transfer, the real power remains same v i cosine phi. The correspond v i phi will change, but the total product remains still the same, because real power is dictated by load not by excitation, excitation is controlling only the power factor or voltage all these things will be seeing next time, any questions today.

Yes sub sub conductor can be surely, but that bundle conductor is not called

Sir what is the difference between composite conductor and bundle conductor

Composite conductor is entirely different concept, that is there is a phase a and phase b phase a may have n conductors, each one of them may be a bundle conductor. See it is like this, that is seeing the books m conductors and there is a n conductor and then you are calculated L m and L n that particular article you can see that. So, that is I thought since all you done. So, I am not done the whole chapter, we are finished the whole chapter in 1 lecturer; just to revisit that, just to recapitulate, that whatever you are done may be year back also and may be 2 years back.