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

Lecture - 26
Load Flow Studies

And will come back.

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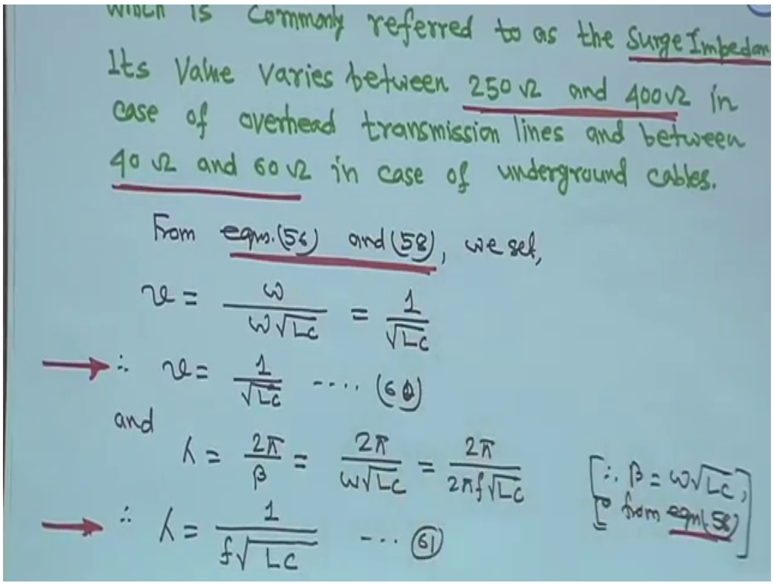

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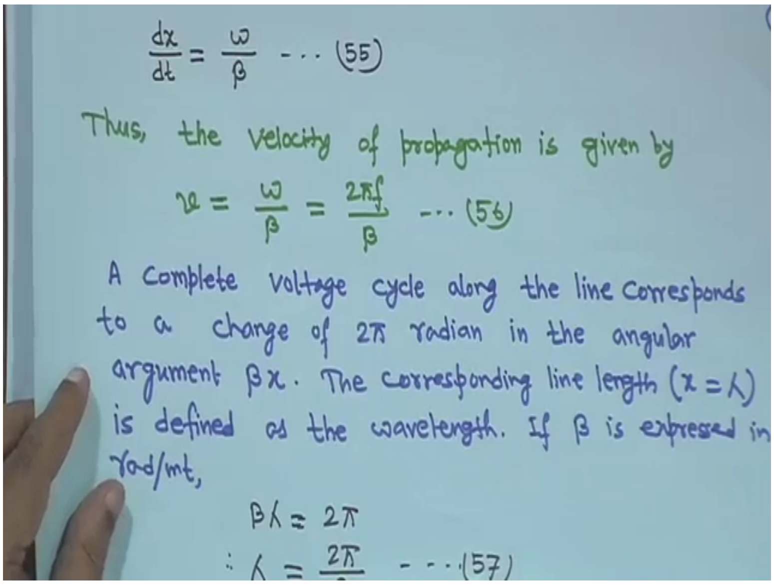

So, now, from equation 56 and 58 right we will get this equation 56 is this one, 2 I f 2 pi f upon beta.

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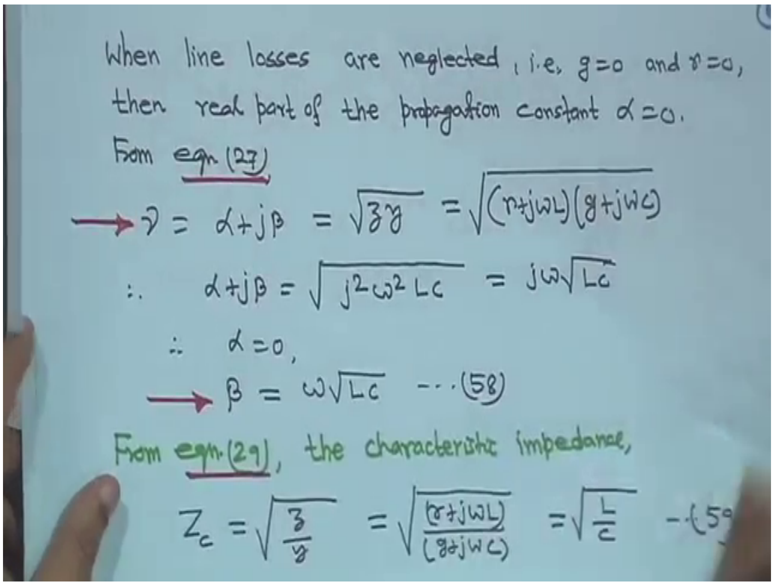

And equation 58 we have seen beta is equal to omega root over l c right. So, therefore, v is equal to omega by beta actually and it is beta is equal to omega root over l c. So, v is equal to 1 upon root over l c right therefore, this is equation we have marked v is equal to 1 upon root over l c 60 equation 60 right. Now lambda is equal to we have seen beta lambda is equal to 2 pi. So, lambda is equal to 2 pi by beta and it is 2 pi and beta is equal to omega root over Lc. So, omega 2 pi f. So, it is 2 pi upon 2 pi f root over Lc. So, 2 pi 2 pi will be cancel and lambda is equal to 1 upon f in to root over l c this is the wave length, this is equation this is the equation of the wave length and this is equation 61 right; now will make some approximation.

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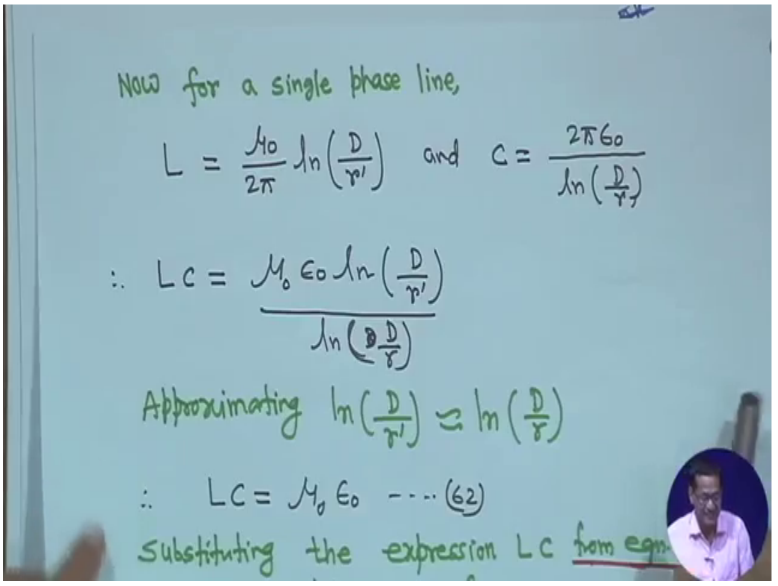

So, now for a single phase line while we are conducting inductance and capacitance, we got l is equal to mu 0 by 2 pi l n D upon r dash right. This we got this we are for the inductance calculation we got this right and capacitance c is equal to 2 pi epsilon 0 l n d upon r this 2 we got. Now multiply this 2 L and c, if you multiply l c is equal to is a mu 0 epsilon 0 l n d upon r dash divided by l n D r, D by r right.

Now will make an approximation that will assume will approximating it that l n D upon r dash the natural of D upon r dash is equal to l n D upon r this is an approximation you are making it an approximation right. If it is so, if this 2 are equal approximately if you so.

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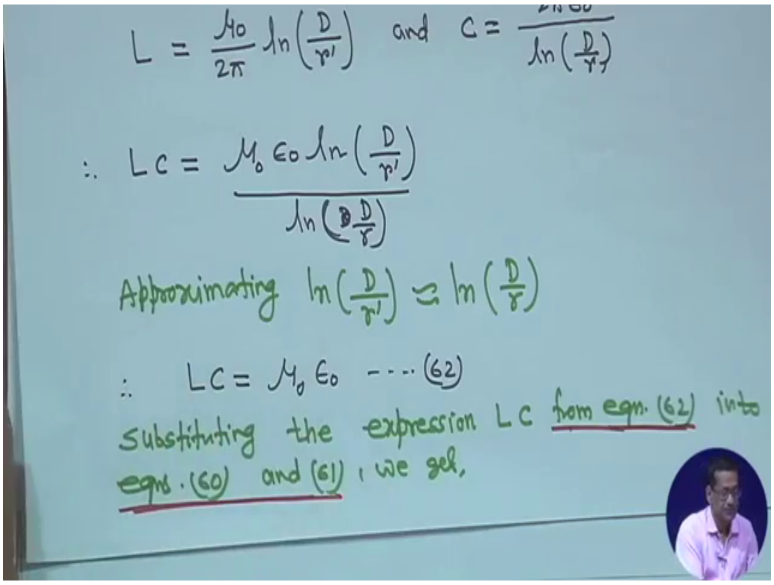

Then L c actually is equal to mu 0 in to epsilon 0 this is equation 62 right. So, if substituting this expression of L c from equation 62 I mean this one in to equation 60 and 61 right; that means, if you substitute this equation in equation 60, that is v is equal to 1 upon root over L c and in 61 by lambda is equal to 1 upon f root over L c, you substitute here right that your L c is equal to root over your what you call sorry mu L c is equal to mu 0 epsilon 0.

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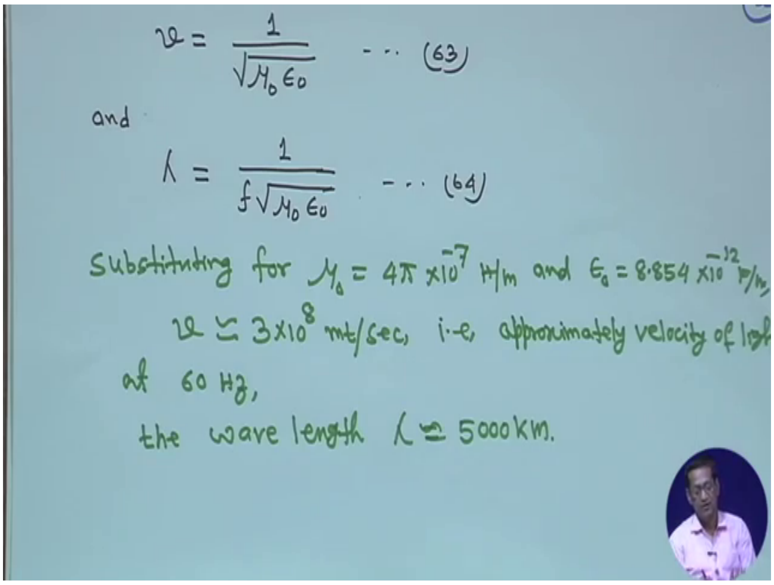

If you if you do so, then mu will become 1 upon root over mu 0 epsilon 0 and lambda will become 1 upon f root over mu 0 epsilon 0 right. So, you know the mu 0 value 4 pi in to 10 to the power minus 7 henry per meter, and you know that epsilon 0 also 8.854 in to 10 to the power minus your 12 farad per meter right. So, approximately v will be 3 in to 10 to the power 8 meter per second, which is approximately the velocity of light at frequency 60 hertz right. So, this is that your velocity and wave length lambda will become 5000 kilo meter. If you put in that second equation here right lambda will become 5000 kilo meter right this is more or less some ideas regarding your velocity your velocity of propagation and your wave length lambda right.

But this is approximate this values are approximate where because you have taken l and d upon r dash approximately is equal to l and d r upon r right, but this will give a good idea about this thing about your v and lambda right.

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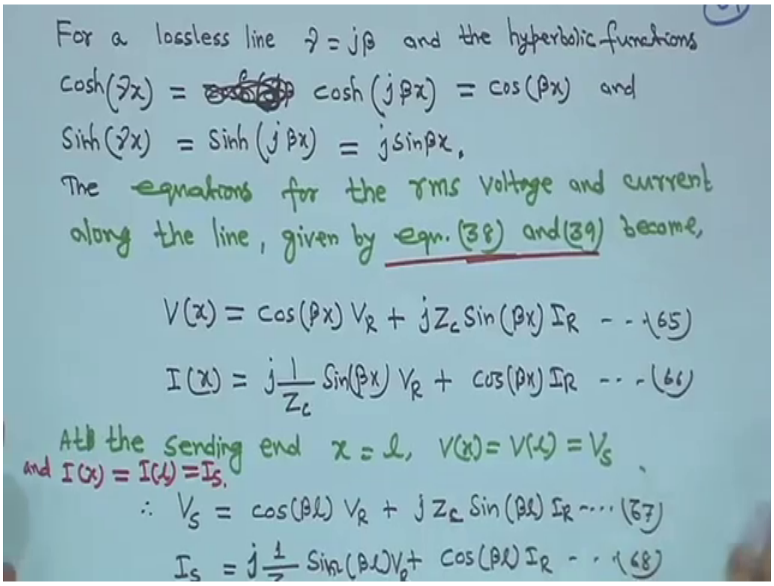

Now, for a loss less line we have seen for a loss less line gamma is equal to velocity of propagation alpha plus j beta. So, alpha is 0. So, for a loss less line gamma is equal to j beta right and the hyperbolic function cos hyperbolic gamma x actually will become that if you substitute gamma is equal to j beta for a loss less line, it will be cos hyperbolic j beta x is equal to nothing, but cos beta x right and sin hyperbolic gamma x is equal to sin hyperbolic j beta x is equal to j sin beta x right.

So, is the simply j sin beta x. So, if you take those expression and put this value definitely, you will get the cos hyperbolic j beta x is equal to cos beta x details are given while developing long transmission line that is why not showing it here I understandable right; the equations for the r m s voltage and current along the line is given by equation your 38 and 39 so equation 38 actually this and 39 this 2 equations rewriting here right. V x is equal to cos in that case instead of cos hyperbolic x, we are putting cos beta x. For a loss less line just now we have written here we have written here cos hyperbolic x for a loss less cos hyperbolic gamma x is equal to basically cos beta x, because alpha is equal to 0 and gamma is simply j beta and cos hyperbolic j beta x is equal to cos beta x.

So, instead of cos hyperbolic we are writing cos beta x V R plus Z c, j Z c rather j Z c sin beta x IR; because sin hyperbolic sin gamma hyperbolic gamma x is equal to sin hyperbolic j beta x is equal to j sin beta x. Similarly here also right this is all this you just replace those hyperbolic term you will get I x is equal to that is equation 38 and 39 in equation 38 you put that because in 39 you put for I x right, then you will get j 1 j 1 upon Z c sin beta x V R plus cos beta x I R this is equation 66 this 165 and this 166 right.

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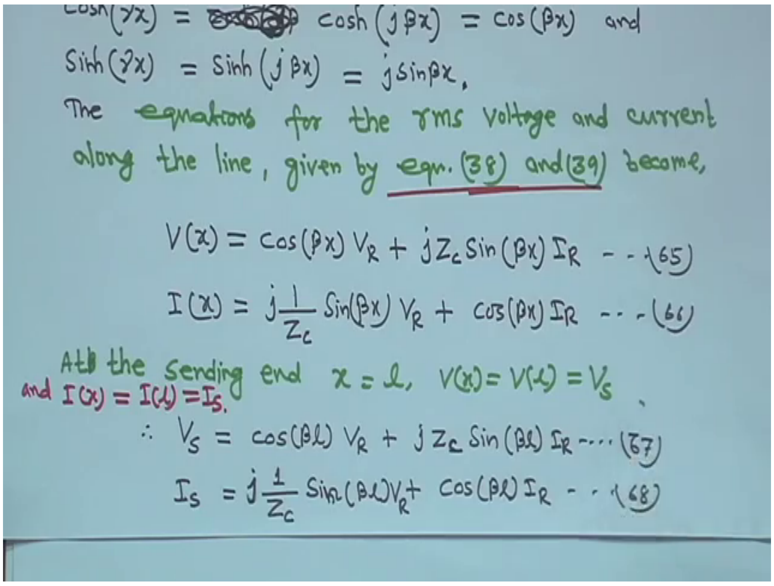

Now, at the sending end because you are made it in the distance from the receiving end to sending end, so at the sending end x is equal to l. So, V x equal to V l is equal to sending end voltage v s right similarly I x is equal to I l is equal to I s right this one. So, sending end voltage can be written as cos beta l V R plus j Z c sin beta l I R this is 67 and I s is equal to j upon Z c sin beta l V R plus cos beta l I R right.

So, actually for quick calculations for a b c d parameters this equation is I think less laborious I mean easier to compute right this equation 67, but 68, but remember this is for a loss less line right. Now that is why I have written for quick calculation it is easier to use 67 and equation 67 and 68 right.

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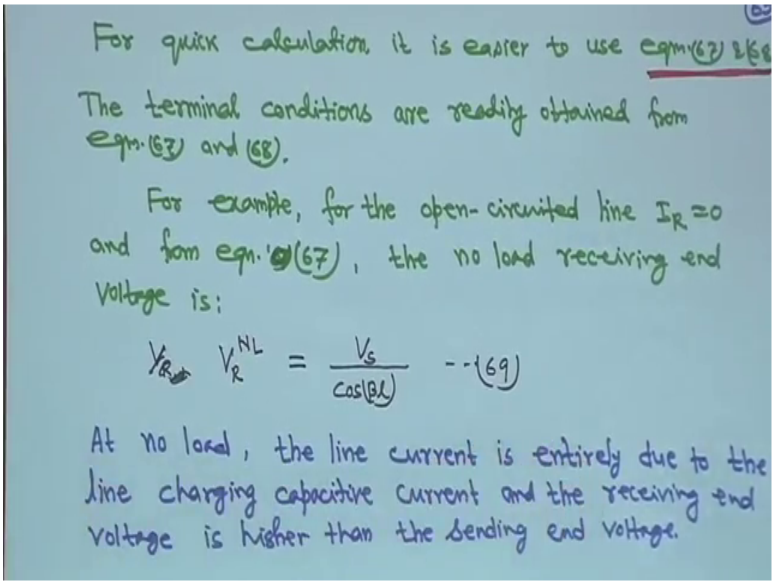

Now, terminal conditions are readily obtained from equation 67 and 68; that means, all this terminal conditions you can easily get it from equation 67 and 68 right. So, for example, for the open circuit line that receiving end current is 0, I R 0 when line is open circuit right and from equation 67 right.

That means, from this equation, equation 67 this equation you put I R is equal to 0 in equation 67 here you put this is for open circuit right if you do so, the no load receiving end voltage will become at that time at the line is open circuit. So, this I mean condition no load condition is that while line is open circuit when I R is equal to 0 right in this equation at no load when I R is equal to 0, V R is equal to V R N L right.

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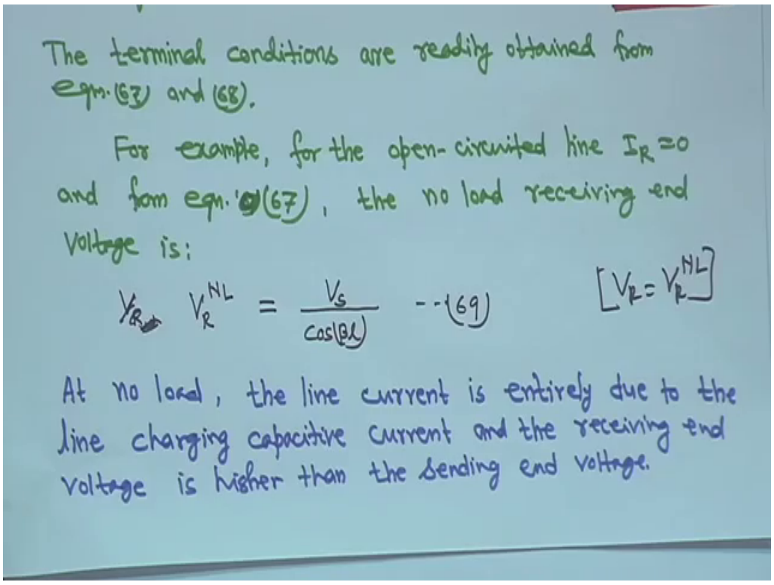

So, when you are telling that when I R is equal to 0; here I am somewhere I am writing that V R is equal to V R no load N L right. So, I am not writing here, but understandable that when open circuit line I R is equal to 0 and V R is equal to V R no load that will be easier to understand therefore, this equation that equation 67, it will become that V s is equal to cosine beta l and V R is equal to V R no load because I R is 0 therefore, V R NL is equal to v s by cosine beta l right. So, that is what I have writing V R n l is equal to V s upon cosine beta l right that is equation 69. So, what does it signify? That at no load condition that receiving end voltage right is greater than the sending an voltage because cosine is less than 1 right.

This is some time this is called Ferranti effect and this is happening because of your charging admittance in the line right. So, no load condition this is happening. So, that is why V R NL is equal to V s upon cos beta l this approximate, but in the same your long line expression also same logic you can use and you will find that V R NL will be greater than the sending end voltage at no load right.

So, that is why at no load the line current is entirely due to the charging capacity capacitive current, and the receiving end voltage is higher than the sending end voltage because when line is no load there is no I said line no line is there is no load connected here right, but charging capacitance are there. So, because of that your what you call this that this receiving no load voltage is becoming higher than the sending end voltage. So, suppose a transmission line this a question to you, suppose if transmission line is your this thing what you call not carrying any power under no load condition right and it is not carrying any power.

Suppose a man standing on the ground with bare feet say with no proper protection or insulation and taking a conductive knot and touching that conductor, what will what will happen to that parcel. I repeat this suppose a line transmission line high tension transmission line was carrying power, but after that that load is disconnected. So, now, this condition whatever will putting that it is that I R is 0 right it is not, but a man standing on the ground right with bare feet say right and taking a conductive rod and touch that conductor that is the line right.

What will happen to that parcel this is a question to you right. Later you can send this when you listening this you send your answer to me right, but here I am not giving that answer right.

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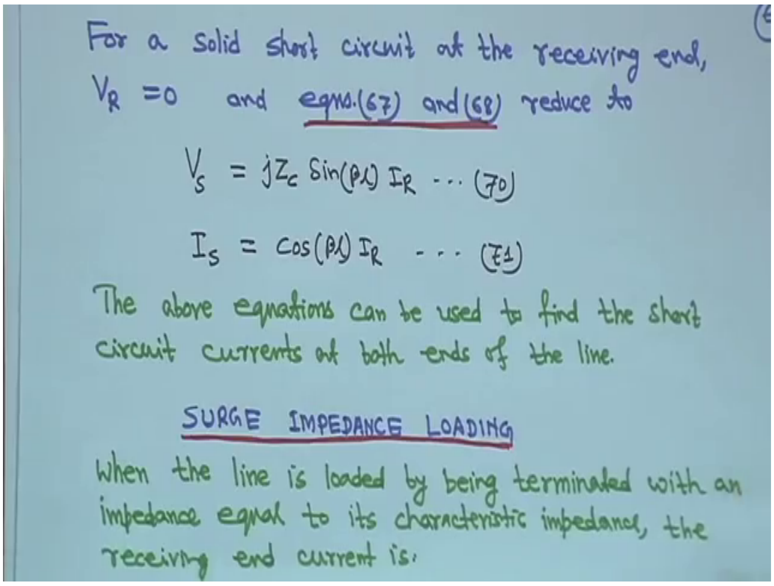

So, this one next for a solid short circuit right for a solid short circuit at the receiving end solid means there is no fault impedance fault will come later right much later. So, for a solid short circuit at the receiving end the V R is equal to 0 right and in equation 67 and 68 that is your this equation 67 and 68 this 2 equation you put that condition that for V R is equal to 0 right. If you do so, then you will get sending end voltage is equal to j Z c sin beta l I R this is equation 70 and I s is equal to cos beta l I R this is equation 71. The above equation actually can views to find the short circuit current at both ends of the line right.

Next is that your surge impedance loading when the line is loaded by being terminated with an impedance equal to its characteristic impedance that is z is equal to Z c is equal to root over l y c right the receiving end current you can define; that means, when a line is loaded by being terminated right with an impedance equal to its characteristic impedance, the receiving end current you be receiving end voltage is V R and it is and that load.

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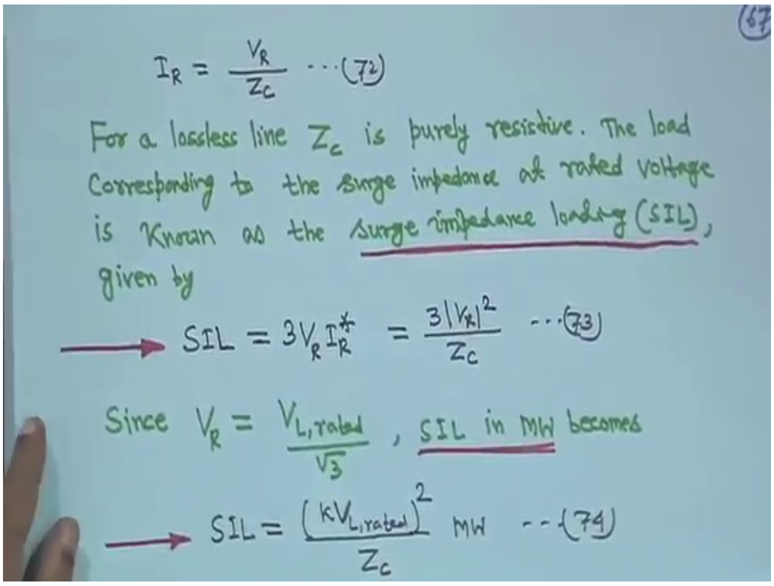

We learn that line is loaded by being terminated with an impedance equal to your characteristic impedance that is Z c; that means I R will be V R upon Z c this is equation 72. The receiving end voltage V R and line is terminated with in your what you call with an impedance equal to Z c.

So, I R will become V R upon Z c this is equation 72 right. Now for a loss less line Z c is purely resistive because you have seen Z c is equal to root over l by c. So, the load the corresponding the surge impedance at rated voltage is known as the surge impedance surge impedance loading that is SIL right. So, this load. So, for Z c is purely the load corresponding to the surge impedance at rated voltage is known as surge impedance loading the loading they SIL and is given by SIL is equal to 3 V R I R conjugate, this we have seen also I have shown you separately how this V R I R conjugate or V R conjugate

I R it come ins right. So, this is 3 V R I R conjugate is equal to this I R is equal to V R upon Z c.

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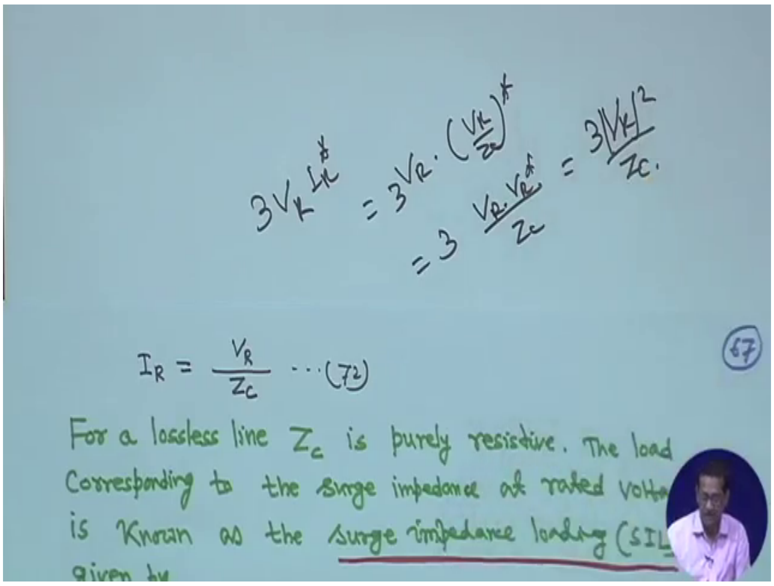

So, this is actually 3 V R I R conjugate right and I R is equal to V R upon Z c. So, it is V R and your V R upon Z c conjugate right multiplied by three. This is 3 V R, V R conjugate and Z c because Z c is a real quantity. So, V R in to V R conjugate it is 3 V R square divided by Z c right. So, that is why you are writing that this one is equal to SIL is equal to 3 in to voltage magnitude V R square upon Z c. This is equation your what you call this thing and V R is your phase voltage that is why this is multiplied by 3 right.

So, since V R is equal to VL rated upon root 3 that is V line rated voltage you are taking here in general. So, SIL in megawatt, it becomes SIL is equal to KVL, KVL rated whole square upon Z c megawatt what we are doing is V R is equal to VL rated upon root 3 we know, but this rated voltage we are actually making it to kilo volt that is why I am writing KVL rated then suppose it is suppose KVL rated means suppose 220.

Then 220 square upon Z c whatever will be there this is kilo volt right this is kilo volt and that is square and this Z c is the ohmic value ohm. So, this is actually megawatt right because it is kilo volt square and this is actually equation 74.

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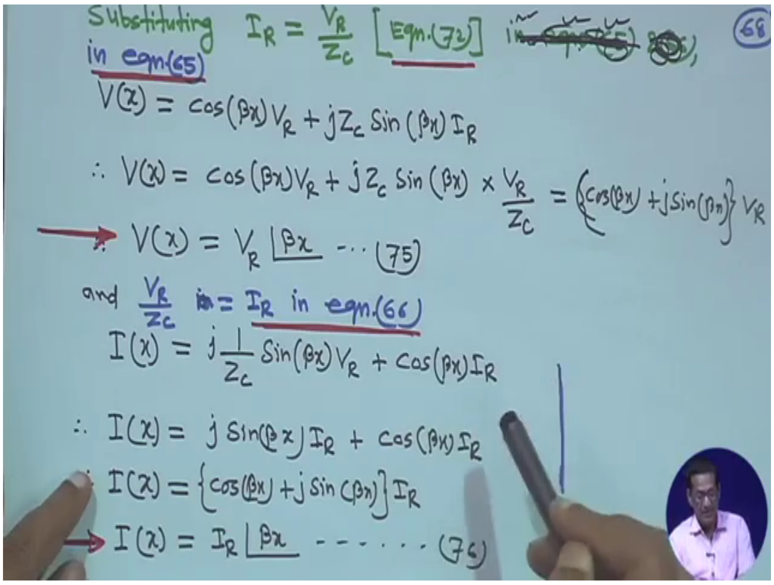

Now, substituting you this is I R is equal to V R upon Z c that is that I that I told you right in equation 65. So, in equation this is actually equation 65 I have rewritten here right. So, cosine beta x V R plus Z c sin beta x I R. Now this I R is equal to V R upon Z c you substitute here I R is equal to V R upon Z c, then Z c Z c will be cancel I have substituted here that this is V R upon Z c. So, Z c Z c will be cancel and it will become actually cosine beta x plus j sin beta x in to V R that means, V x is equal to V R angle beta x this is equation 75.

Similarly that your equation your what you call that in equation see this V R same thing here writing it other way that V R upon Z c is equal to I R you substitute it in equation 66.

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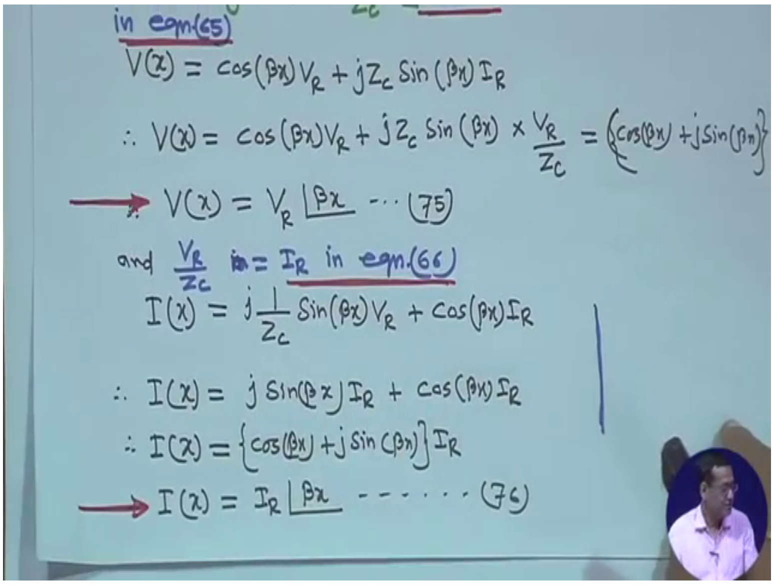

So, equation 66 I am writing here that I x is equal to 1 upon Z c, sin beta x V R plus cos beta x I R right. So, V R upon Z c is equal to I R you substitute. If you do so, that skipping this line same thing just rearranging I x is equal to cosine beta x plus j sin beta x in to I R; that means, I x is equal to I R beta x right; that means, this equation 76, V x is equal to V R angle beta x and here in 76 I x is equal to I R angle beta x.

That means, whatever may be the value of x right that V R and I R at every point of x that v x and V R that value remain same right that whatever at every whatever may be the value at any point of x V x is equal to V R, V R is total independent of x and here also I R total independent of x. So, I x is equal to this I R and V R will not change even x is change right at very at every point this v x and I x both remain same right.

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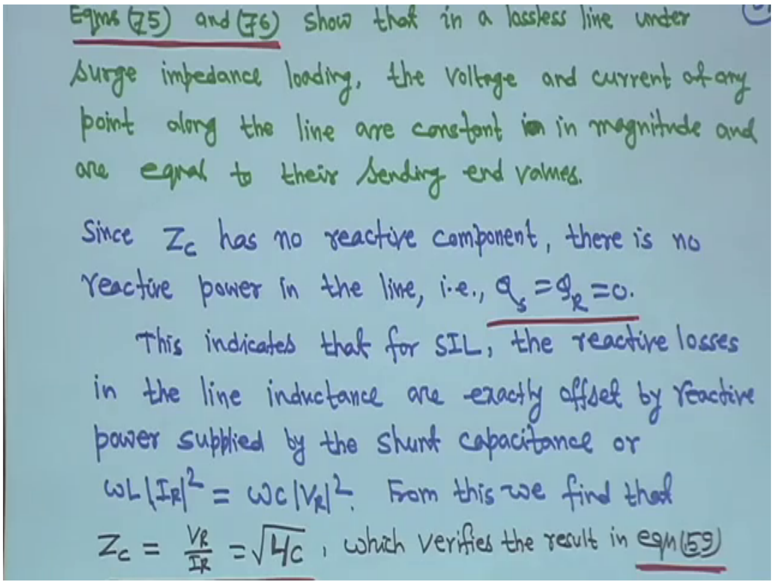

That means it shows that in a loss less line under surge impedance loading, the voltage end current at any point along the line are constant in magnitude and are equal to their sending end values. If you put here x is equal to l; that means, V x means V l is equal to this is the this will be the V s is equal to V R angle beta l and this will become I x is equal to rather I s is equal to I R angle beta l right; that means, and in magnitude and are equal to their sending end values right since Z c.

So, any point you take right. So, the Z c has no reactive component we have seen that Z c is equal to root over l by c. So, there is no reactive component; that means, in the line Q s is equal to Q r is equal to 0 right. Under this condition this indicates for surge impedance loading the reactive losses in the your line inductance, are exactly off set by the reactive power supplied by the shunt capacitance right that is your charging capacitance. So, if it is true then your omega l I R square will become omega c your V R square right if this is true.

So, then your if you use this condition right. So, you will get Z c is equal to V R upon I R if this 2 are equal then it will be root over L by C; that means, that your what I will say right whatever your this thing that this inductance there the line inductance exactly off set by the power supplied by the shunt capacitance; that means, your this one that line inductance is x L is equal to L omega.

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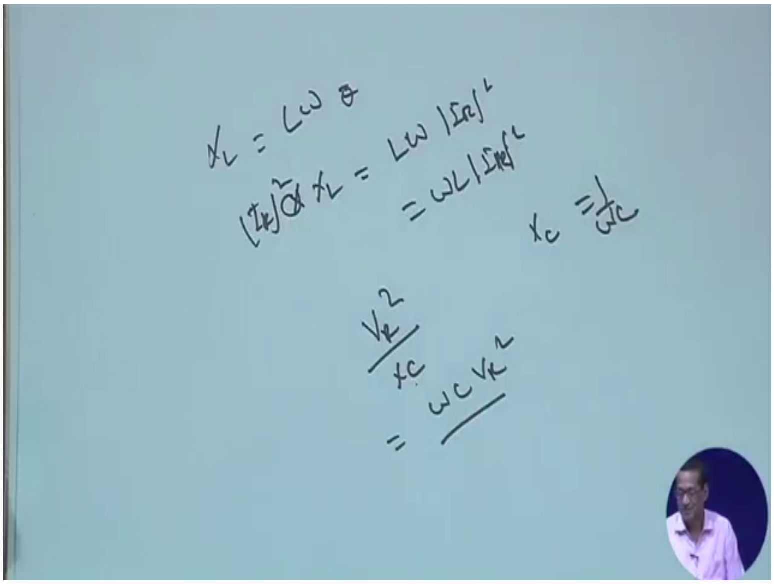

So, that is right; that means, you are what you call I R square in to your I R square x L is equal to l omega I R square.

So, that is why we are writing actually omega L I R square right and that charging admittance is omega c V R square right. So, in that case the power supplied or this reactive power supplied by the charging admittance actually, it is your V R square by x c right and you know x c is equal to 1 upon omega c. So, you substitute here you will become omega c V R square. So, that is why this total your reactive losses supplied by your charging capacitance. So, that is why omega l I square, is equal to omega c V R square from which from which we will get it that Z c is equal to V R upon I R is equal to root over L by c which verifies the result in equation 59.

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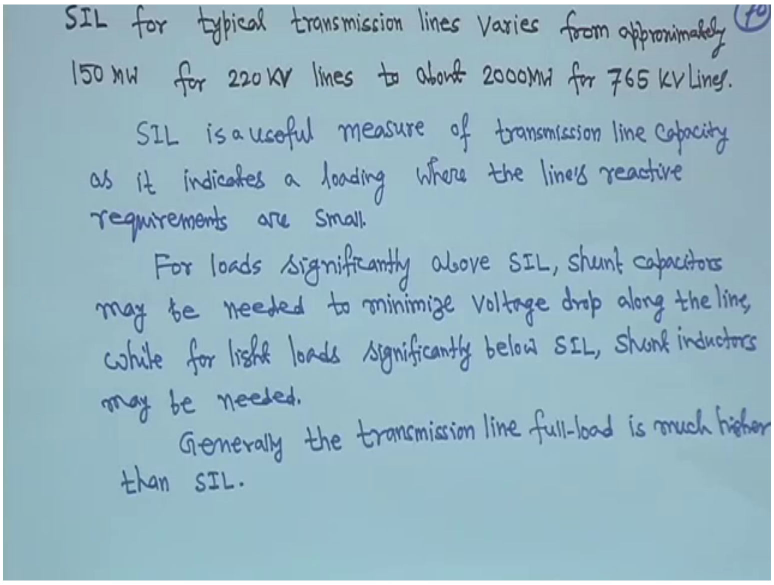

So; that means, when you have your this thing j this kind of condition that there is no reactive power in the line right then what does it mean for surge impedance loading. So that means, for surge impedance first you see for surge impedance loading for a typical transmission line varies approximately from 150 megawatt for 220 k v lines this approximate values, to about 2000 megawatt for 765 kilo volt lines, but generally this line actually of when its operated at the full load or this, that it operates much about the surge surge impedance loading. So, SIL is useful measure of transmission line capacity as it indicates a loading where the lines reactive requirements are small right.

For load significantly above SIL shunt capacitor may be needed to minimize the voltage drop along the line right, generally line operates above this limit right. While for light load significantly below SIL you need basically shunt inductors right. So, if the if it is above the surge impedance loading, then you need shunt capacitor and if it is below the surge impedance shunt impedance loading, then you need shunt inductor right. So, generally the transmission line full load is much higher than the shunt what you call that surge impedance loading.

So, whatever now whatever this thing we have studied for this long transmission line that one is that surge impedance loading, then you have studied velocity of propagation then that wave length lambda right and that physical significance of the your surge impedance loading and the terminal conditions and then we saw that under no load condition that charging this thing what you call receiving end voltage is higher than the sending end voltage this is typical phenomena for a transmission line right this is this happen you do your charging admittance right.

So, these are the things we have studied, but will take a small example of this your what you call velocity of propagation then surge impedance after that will go to for 3 phase your what you call power flow through transmission line right.

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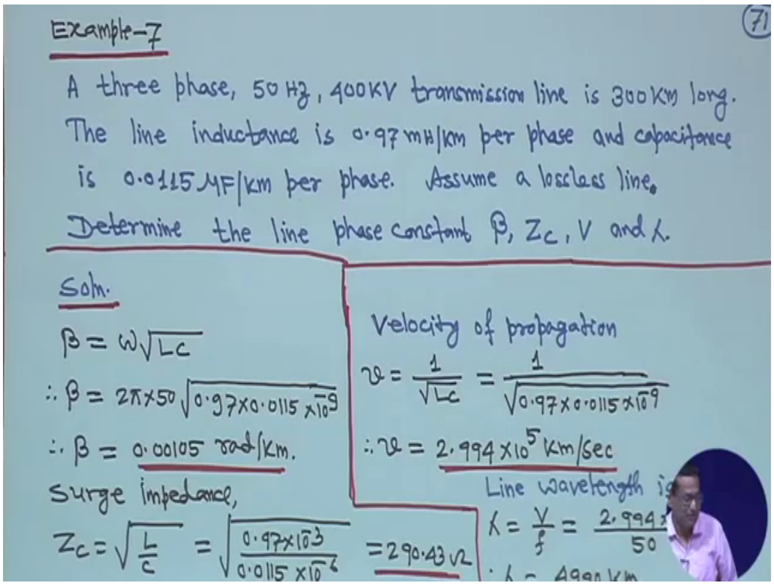

And so, this one we take a small example right that is 3 phase 50 hertz 400 k v transmission line is 300 kilo meter long. The line inductance is 0.97 mili Henry per kilo meter right per phase and capacitance is 0.0115 micro farad per kilo meter per phase

So, assume here you assume a loss less line you have to compute beta, the line beta that is the line phase constant Z c that characteristic impedance or surge impedance v velocity of propagation and lambda the wave length right. So, this thing solution is very simple you know beta is equal to omega root over LC it is 50 has system L is given C is given all you substitute you will get beta is equal to 0.00105 radian per kilo meter right.

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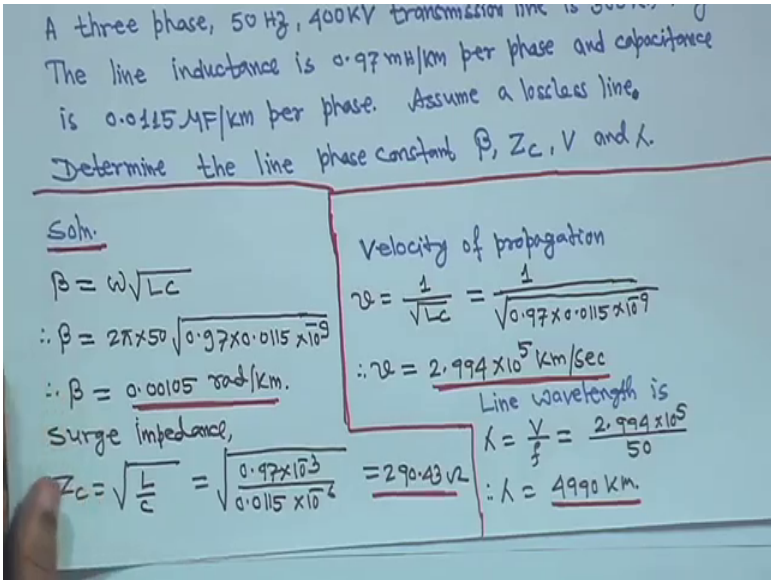

And then surge impedance is Z c root over L by C, L is given C is given. So, it is 290.43 ohm right and velocity of propagation v is equal to 1 upon root over LC. So, L is known C is known you substitute you will get 2.994 in to 10 to the power 5 kilo meter per second right and line wave length lambda is equal to V upon f right. So, is equal to 2.994 we have seen no lambda is equal to you are a 1 upon what you call f root over 1 upon l see that is basically v upon f, because v is competent here.

So, you put the value of b divided by f. So, approximately 4990 990 kilo meter right this is you are the small example for this one, but after this will go for power flow through transmission line right.

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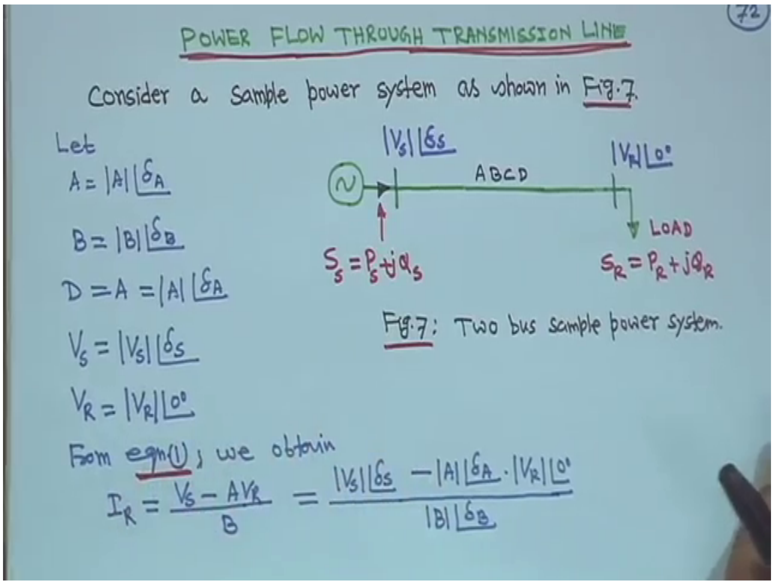

So, in terms of your A B C D parameter; so this one I will get it for you for the receiving end one and sending one I will give you the your final expression, but you can you can derive this right.

So, you consider a sample power system as shown in figure this. So, this side is sending end side. So, power is taken P s plus j q s this side is receiving end side. So, power is p r plus j q r this is load. Sending end voltage is magnitude V s angle delta s receiving end and V R angle 0 degree. So, it is actually your taken as say reference right and this line is represented by A B C D parameter, that is why I am writing here A B C D right and. So, we assume now first let A is equal to magnitude a angle delta a B is equal to magnitude B angle delta B all this thing, D is equal to A is equal to magnitude A angle delta A because throughout that we replace by this thing. Instead of D will write a because A is equal to D right. V s is equal to right magnitude V s angle delta s we have made it here V R is equal to magnitude V R angle 0 we are made it here.

So, from equation one; that means, very first equation right for this topic we have you know V s is equal to A V R plus B I R. So, from here it is coming I R is equal to V s minus A V R upon B right. So, V s V R A B all you substitute in terms of their magnitude and angle right therefore, angle V a this one right magnitude V s angle delta s. So, minus mode A angle delta A minus mode V R angle 0 divided by mode B angle delta B right.

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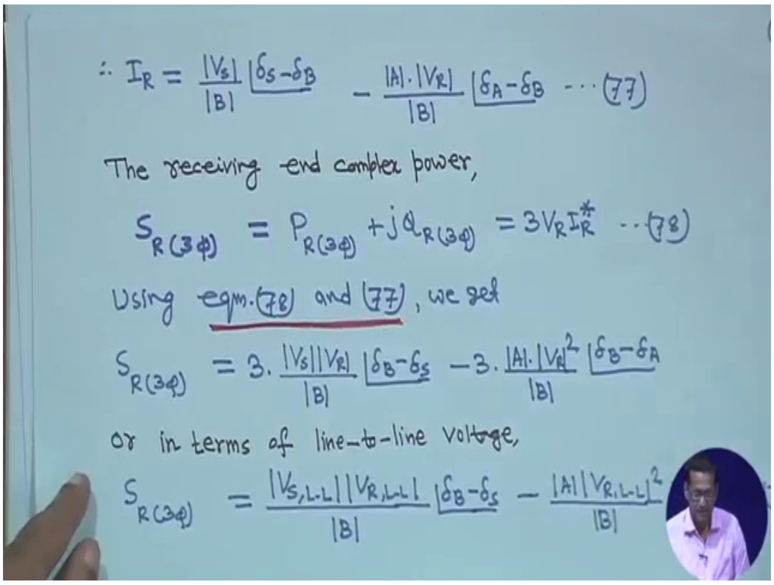

So, in that case this one you all this things you simplify this equation you simplify, then you will get I R is equal to mode V s upon mode B, it will be angle delta s minus delta B minus mode A mode V R by mode B angle delta A minus delta B this is equation 77. We are also same thing we have seen the receiving end complex power SR it is receiving end power 3 phase that is why writing 3 phase.

Is equal to P R 3 phase plus j Q R 3 phase is equal to 3 in to V R, I R conjugate right this is equation 78. Now from equation 78 and 77 this I R is given. So, you have to you find out what is I R conjugate right. So, if you take the conjugate this is I R if you take the conjugate one. So, V s upon b will remain and as it is conjugate. So, this angle will become delta B minus delta S right that is why in this expression it is delta B minus delta s, and for this conjugate this angle also will be delta B minus delta A because of conjugate. So, this angle is delta b minus delta a. So, it is 3 in to mode v s upon V R upon mode B angle delta B minus delta s minus 3 in to mode A mode V R square upon mode B angle delta B minus delta A right.

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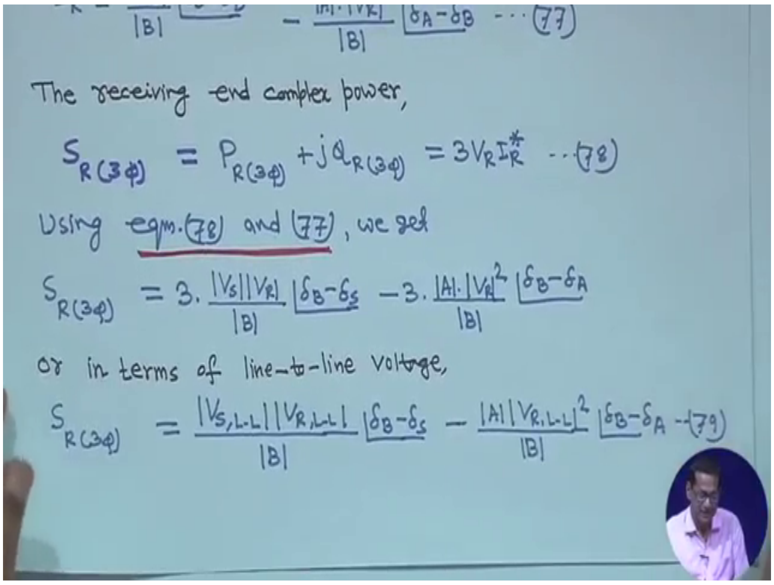

So, in terms of the your what you call this line to line voltage right if you take this line to line voltage.

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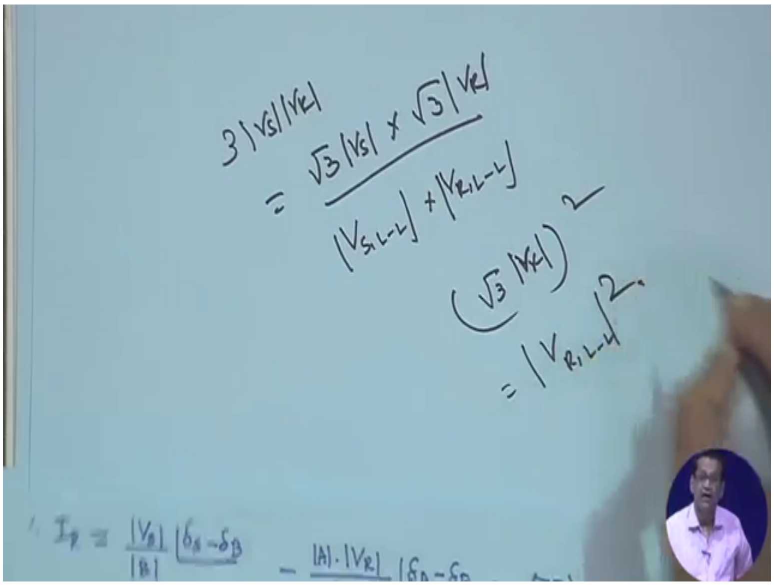

Then we can write this expression it is 3 V s V R; that means, it is 3 V s V R right this one you can write know it is root 3 in to V s into root 3 in to V R right the. So, this one actually will become I have taken here it is V s line to line right in to V R line to line. So, this term is taken that V s magnitude V s line to line V R line to line by mode B angle delta b my delta, delta B minus delta s right. So, this 3 actually written like this and similarly this A V R square right. So, in that case also this this can be written as actually root 3 V R your square because this 3 I take it inside that bracket. So, root 3 V R square V R square.

So, basically this one can be written as V R line to line your square that is why it is written V R line to line square upon mode B angle delta B minus delta A right. We will come back soon.

Thank you.