Power System Analysis
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Lecture - 24
Characteristic and Performance of Transmission Lines (Contd.)

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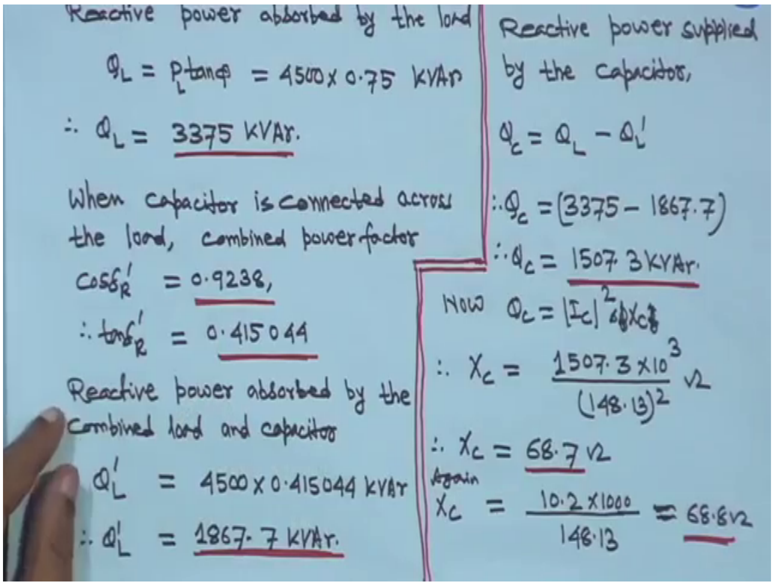

So, that means, not only the capacitance you have to find out actually how much hour supplied by the capacitor right and this 68 to verify the result that is cross checking here it is coming 68.8 and here it is coming 68 this is nothing, but the only decimal places if you take all the all the calculations previously up to 4 decimal places like right everywhere here. For example, I have taken only up to only 1 digit after decimal places if you take little bit more I mean 3 or 4 decimal places you will find that this 2 are equal almost equal right exact will on get because of the numerical that your because of so many decimal places if we put then very close to that, but it is this source that your that calculation is correct and X; that means, from this diagram.

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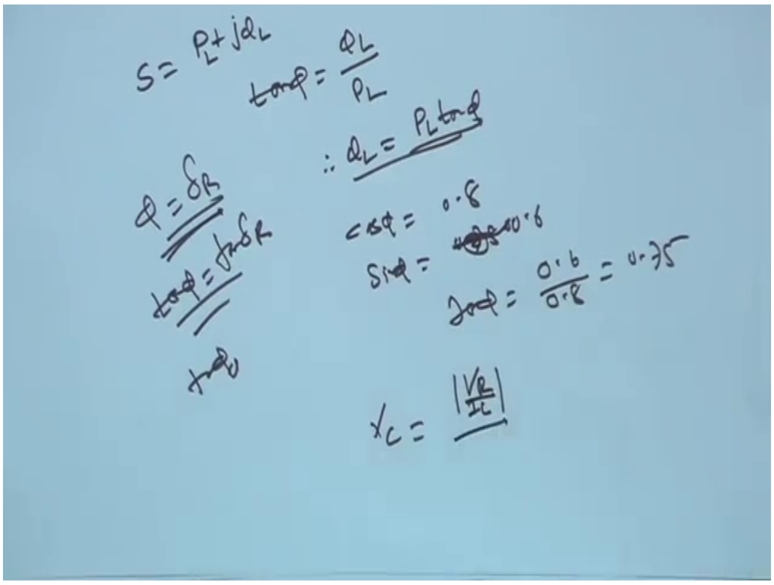

If you look at the diagram that X C is equal to basically V R by I c right. So, that is use that that thing that x is equal to V R upon I c that here we have used that V R upon I c; I c you are it was j c j 148.13 is magnitude. So, from that you can calculate you can see that your results are correct. So, mainly not the capacitor you have this is your power your all of you are (Refer Time: 01:42) engineering and studying power system you have to see that how much power actually supplied by the shunt capacitor right and that that means.

So, this is hopefully this part is understandable right now efficiency; efficiency in the case a transmission line output by output plus losses output is 4500 kilo watt.

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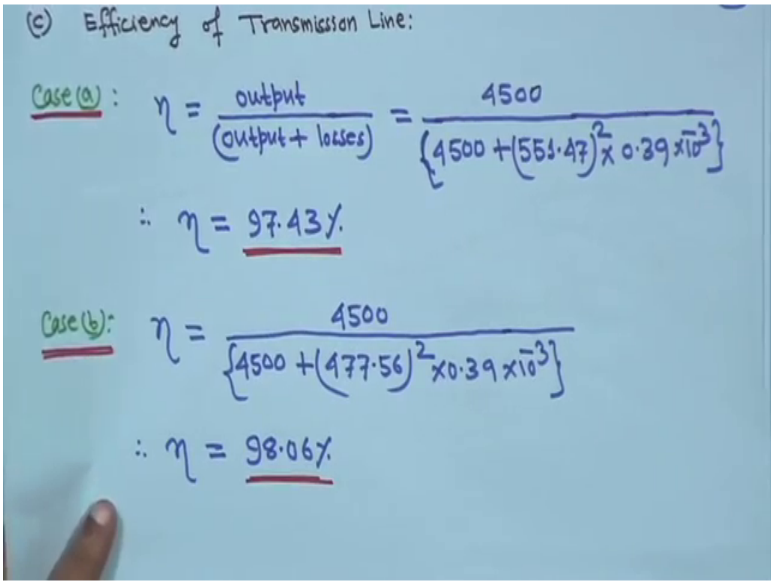

We are keeping in kilo watt only right we are keeping in kilo watt only. So, 4500 then I square R 5 first case 551.47 square in to 0.39, this is what divided by 1000 that is why in to 10 to the power minus 3. So, this is also kilo watt this term is also kilo watt this is kilo watt this. So, efficiency 97.43 percent and when you connect the shunt capacitor, so, it is at the time current was 477.56 in to 0.39 and it is converted to kilo watt, so, multiplied by 10 to the power minus 3. So, it is 98.06 percent; that means, when you connect the shunt capacitor that transmission line efficiency improves to some extent right. So, that is that is the idea. So, this is this say numerical we consider for the single phase transmission line right.

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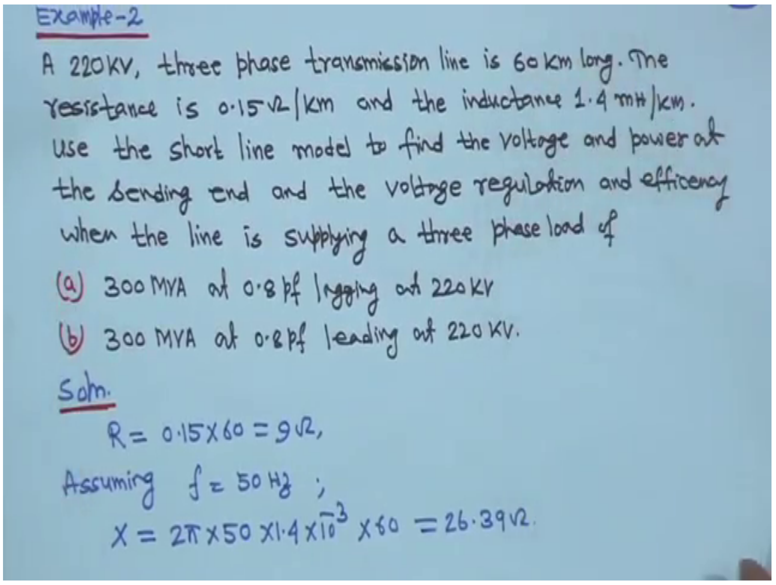

Now, we consider a 3 phase example this is example 2. So, will consider your 3 phase transmission line right; so, for this when you are studying all this what I have decided that first all theories then 5 6 7 examples right again theories such that also all varieties of problem such that you know.

You will understand as a whole that how things are given right. So, we have here also you have taken 5 or 6 examples. So, such that things will be more or less clear to you right the second 1 is that a 220 KV 3 phase transmission line is 60 kilometer long right the resistance is 0.15 ohm per kilo meter and the inductance 1.4 mili Henry per hour kilo meter. So, use the short line model to find the voltage and power at the sending end and the voltage regulation and efficiency when the line is supplying a 3 phase load of that a 300 MVA at 0.8 power factor lagging at 220 KV and another 1 is 300 MVA at 0.8 power factor leading at 220 KV right.

So, you have to find out basically that sending end power voltage and power at the sending end and voltage regulation and efficiency. So, how to find out that R is equal to 60 kilo meter long. So, it is a short line. So, no need to consider charging at a charging admittance. So, R is equal to 0.15 in to 60. So, 60 kilo meter long. So, and it is 5.15 ohm per kilo meter. So, 9 ohm f is 50 hertz right as nowhere it is mention the frequency is not mentioned. So, I have taken the frequency 50 hertz right and x is equal to then 2 pi your what you call 2 pi f right and your induct your this thing inductance is given L is given

1.0 omega l. So, 1.4 mili Henry per kilo meter, so, 1.4 in to 10 to the power minus 3 in to 60 kilo meter per length that is 26.39 ohm right.

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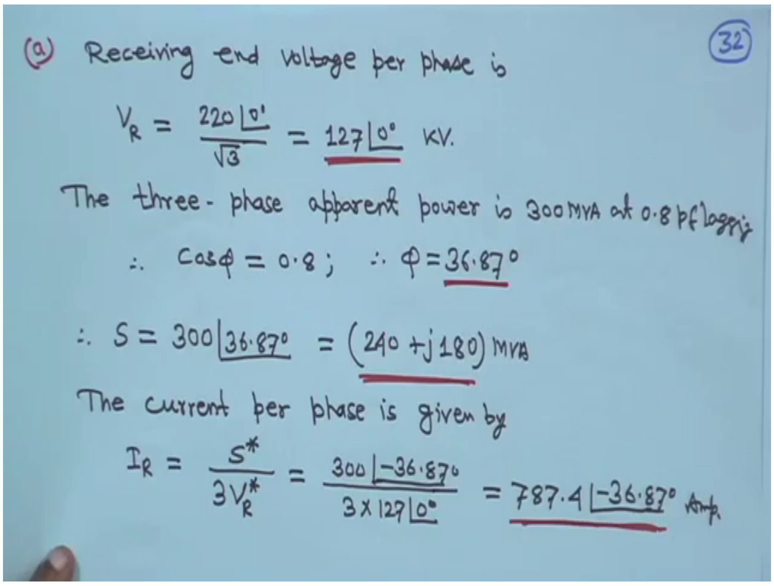

Now, part a just hold on. So, receiving end voltage per phase that V R is equal to all listen whether it is a 3 phase when you solve that see you will use the relationship sending end and receiving end voltage you will convert this thing all in per phase basis right so, that that you should know. So, V R is equal to 220 angle 0 up on root 3. So, 127 angle 0 degree kilo volt this is the reference we have taken right the 3 phase apparent power is 300 MVA at 0.8 power factor lagging because it is given 300 MVA of 0.8 power factor lagging at 220 KV means line to line voltage.

So, power phase power you have to this thing right. So, that will come that is that will come later. So, cos phi is 0.8; so, phi is equal to 36.87 degree. Now first you write S is equal to 300 and it is P plus j q. So, angle 36.87 degree right is equal to 240 plus j 180, listen one thing that when you are writing current at that time it is minus, but when you write power it is actually it is actually convention that it should be P plus j q means that you have to write that this indicate this plus angle with power indicates lagging I think you at beginning.

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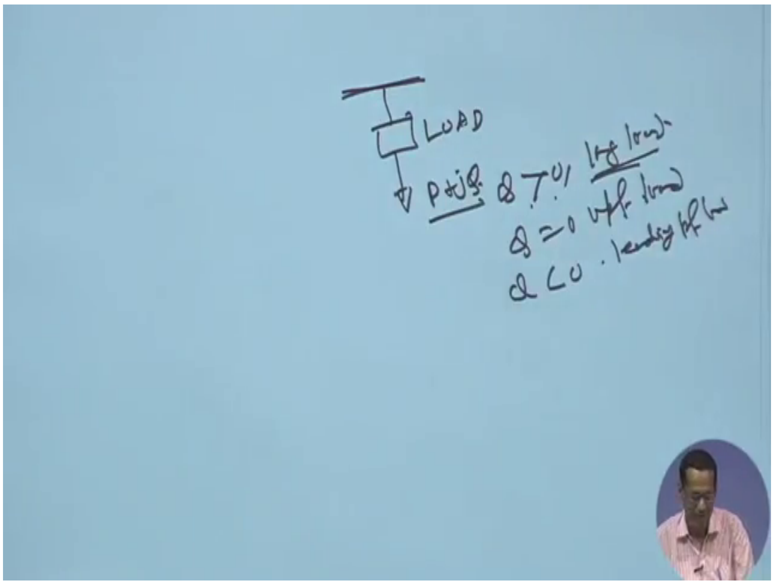

I think might have told you that if somehow load is connected if somehow load is connected right say this is your load and if it is P plus j q load is consuming power if q greater than 0, it is called lagging load right if q equal to 0 it is unity power factor load right and if q less than 0 that is negative it is leading power factor load right.

So, this is the convention so, generated just opposite because generating in power right. So, when q greater than 0 that is q is positive; that means, it is lagging load that is why here 240 plus j 180. So, q is your what you call positive. So, it is a lagging load right. So, do not put negative if you put negative it will be mistake it will be leading load then right. So, this is the convention when q if you make load consume power P plus j q if q greater than 0 it is lagging load if q is equal to 0 it is unity power factor load and if q is negative that is less than 0 it will be in leading power factor load.

So, in that case it is strange that this is lagging power factor load 0.8 power factor lagging. So, that is why 300 angle 36.87 degree that is equal to 240 plus j 180 and bracket we are writing MVA because this is megawatt this is mega bar when you combine this you can write MVA right hope it is understandable next is. So, I hope you understood right. So, no do not put minus here minus then it will mistake right lagging load means it that 2 parts will be positive right now the current per phase is given by that I R is equal to S conjugate up on 3 V R conjugate that we have seen also right now per phase current per phase we are making it that is why this your what you call this is 3 phase power 300 that is why 3 we have divided it by 3 right here it is 3. So, S conjugate up on V R conjugate.

This thing for example, for example, I hope you will be knowing this right for example, this conjugate business. So, will come at the time of load flow studies of course, after completing all this transmission line characteristic performance and characteristic will come to the load flow, but question is that this conjugate thing should be clear.

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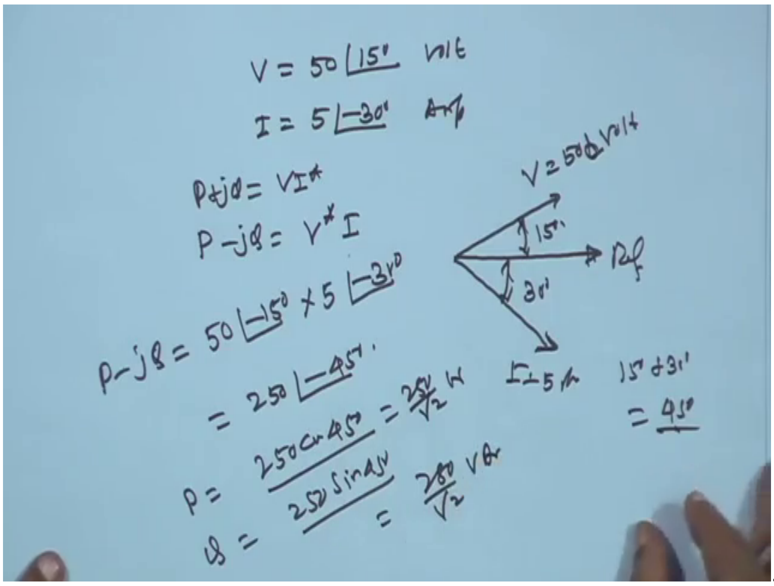

For example for example, suppose you have given you have been given just for your understanding suppose you have been given V is equal to say 50 angle say 15 degree volt right it is leading and say suppose I is equal to given say some 5 angle minus 30 degree ampere suppose this is given to you now you have to find out P and q. Now how to find out. So, take a reference line right take a reference line and from that your this is your V is equal to say 50 this is 50 volt and this is your 15 degree right and this side this is the current this is the current I is equal to 5 ampere current.

This is your reference line and this side current that current is 30 degree then what is the angle between voltage and current it is 15 degree plus 30 degree is equal to 45 degree right. That means, that that conjugate term comes that itself right that is why when we write that your when we write P minus j q is equal to V conjugate I or sometime or otherwise we are writing P plus j q is equal to V I conjugate right, but generally in our power system studies we follow V conjugate I for is the your is the your mathematical derivation right.

So, P minus j q is equal to V conjugate I this conjugate actually to capture the power factor is to capture the angle between voltage and current that is the power factor angle. So, that is why it is 45 degree that is why P minus j q is equal to V conjugate i; that means, P minus j q that your V conjugate V is equal to your given 50; 15 angle 15 degree. So, conjugate will be 50 angle minus means conjugate minus 15 degree in to 5 angle minus 30 degree is equal to 250 angle minus 45 degree; that means, P is equal to 250 cos 45 degree and q is equal to 250 sin 45 degree because this 250 cosine 45 degree minus j 250 sin 45 degree. So, P will become 250 cos 45 250 that is 250 by root 2 say what and this is 250 by root 2 say R right.

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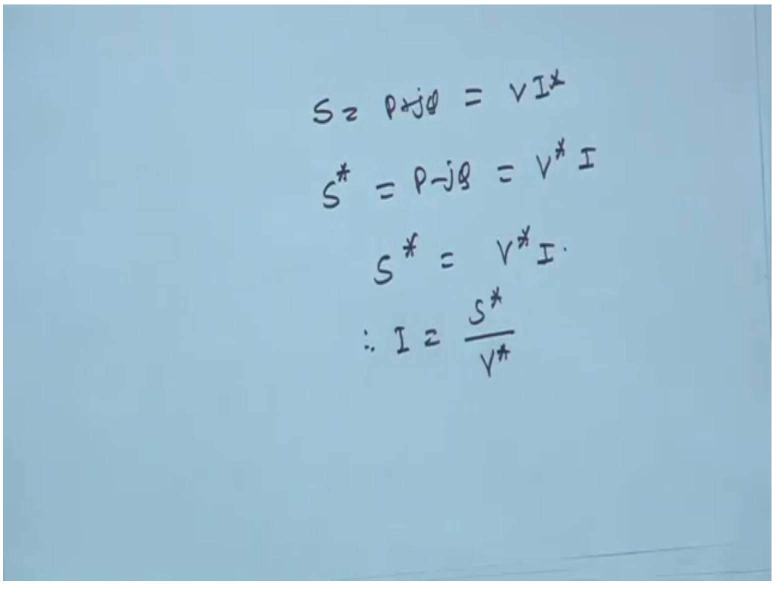

That is why this conjugate business come that P minus j q is equal to V conjugate I right that is why here P minus when we are taking; that means, just look; that means, we are taking actually P plus j q that is S that is your V I conjugate right and now if you take conjugate on both side then S conjugate is equal to P minus j q is equal to V conjugate I; that means, your S conjugate is equal to V conjugate I right; that means, your I is equal to S conjugate up on V conjugate right. So, that is why you are writing that this thing I R is equal to S conjugate up on V R conjugate this 3 comes because of the per phase.

If it is per phase then 3 will not be there, but 3 phase it is right that is why S conjugate up on V R conjugate it is right I hope you have understood this right if you have understood this one this concept then everything will be clear right. So, this is the reference line accordingly you draw some reference line you have to take and see what is the angle between voltage and current that is power factor angle. So, this conjugate comes to capture the power factor angle actually; that means the angle between voltage and current right. So, that is why after this. So, substitute your S conjugate that is 300 angle minus 36.87 degree and the 3 in to V r; V R is equal to that 127 angle 0 degree k v, so, its conjugate also same thing the 127 angle 0. So, it comes actually 787.4 angle minus 36.87 degree ampere right this is the current receiving end current right.

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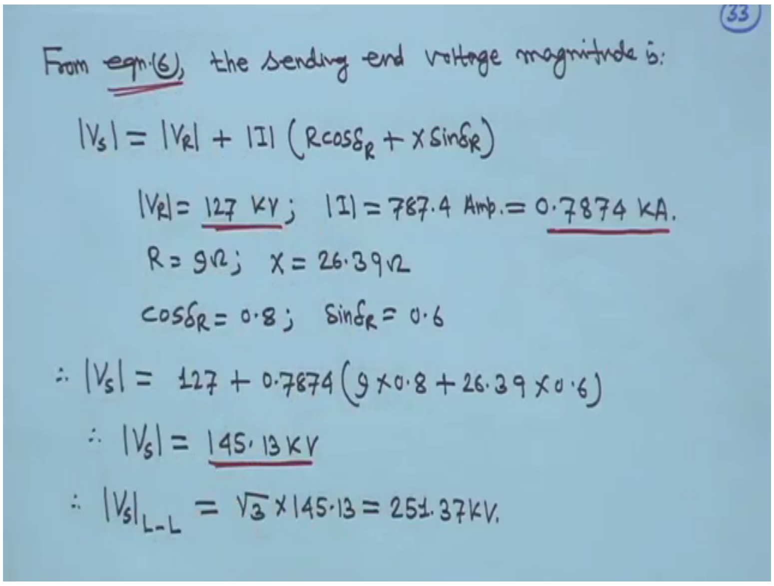

Now, from equation 6 this is the relationship from equation 6 right. So, from equation 6 the sending end voltage magnitude is V S is equal to magnitude V S is equal to V R plus magnitude I in bracket R cosine delta R plus x sin delta R bracket close right. So, V R is known 127 KV magnitude; magnitude of I is 787.4 ampere you convert it to kilo ampere 0.7874 kilo ampere right because we keep here all this things in your what you call KV R is equal to 9 ohm x is equal to 26.39 ohm this are that parameters given all you have computed. So, cosine delta R is 0.8 and sin delta R is equal to 0.6 right.

So, V S is equal to V R we are kept it in kilo volt plus this; your this current that you have kept it in kilo ampere right we have converted to kilo ampere; so, 0.7874 in bracket all this quantity. So, it is coming magnitude of V S coming 145.13 kilo volt KV therefore, V S this is line to line right. So, L dash L I have made line to line is equal to root 3 in to 145.13 that is 251.37 KV this is the sending end voltage right.

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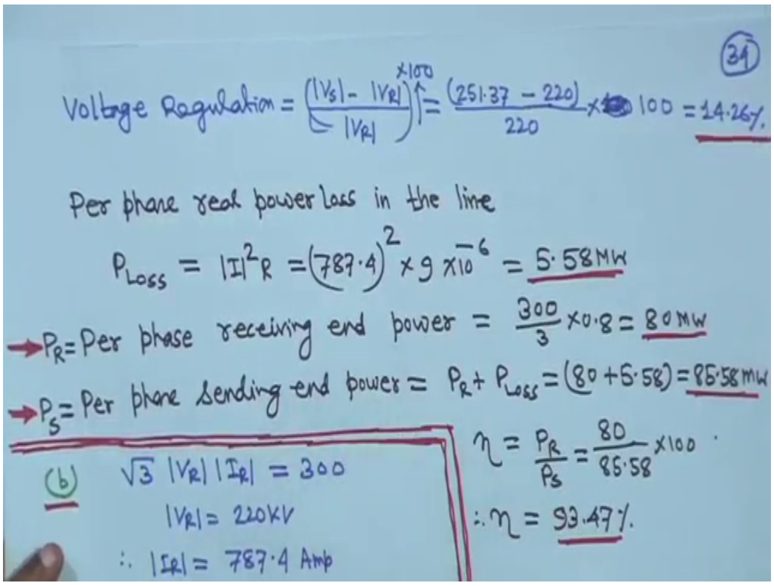

Therefore, voltage regulation is equal to V S minus V R I miss this 100. So, I am here it is multiplied by 100 actually right divided by V R. So, you substitute V S magnitude V R and this you voltage regulation calculation you can use 3 phase you can convert it to per phase also answer will remain same if you divide by root 3 this 1 divided by root 3. This one also will be divide by root 3, this 1 also divided by root 3. So, it will be your same answer in to 100 you will get 14.26 percent only my request to you that all this calculations I have made it if you find any calculation anything you calculated error or anywhere you should when you use you should mail to me right and now power loss is equal to current square in to R magnitude I square current magnitude I square in to R I mean this is; that means, 787.4 square in to 9 R in to 10 to the power minus 6 means you have converted to megawatt right.

This is what divided by 10 to the power 6 in to 10 to the power minus 6. So, we have converted to megawatt it is this will become 5.58 megawatt right therefore, P R that is per phase receiving end power is equal to this is 300 MVA. So, per phase is 300 MVA is 3 phase, so, divided by 3, so, per phase in to cos phi 0.8, so, 80 megawatt right. Similarly P S per phase sending end power is equal to receive per phase receiving power plus P loss. So, 80 plus 5.58 that is 85.58 megawatt right therefore, your what you call efficiency do not come to this side this is part b efficiency is equal to P R up on P S that is 80 up on 85.58, so, 93.48 percent. This is output this is this is a receiving end power means output and sending end power means input, so, 80 up on 85.58 in to 100, so, 93.48 percent this efficiency.

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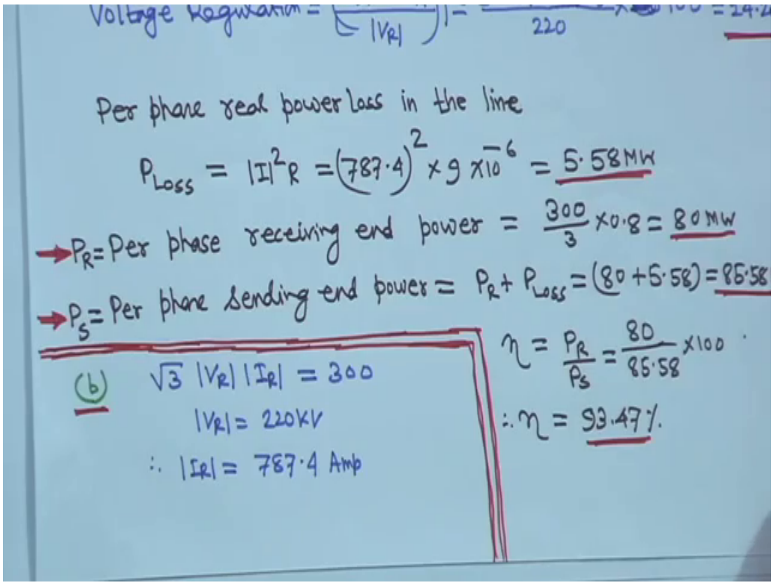

Now, part b part b actually root 3 V R I R is equal to 300 this 3 phase ampere. So, my V R is 220 KV I R 787.4 ampere right. So, you can calculate from equation 6 from equation 6 the sending end voltage magnitude is your this is the relationship V S is equal to V R plus I again and again not uttering that mode or magnitude understandable I in to R cos delta R plus X sin delta R. So, substitute all this your per phase values right.

So, for your magnitude of V R is given magnitude of I is given k ampere we have converted R x known cosine known sin known. So, you will get your; what you call sorry, sorry, here it is second round this is this is sorry, this is your next one.

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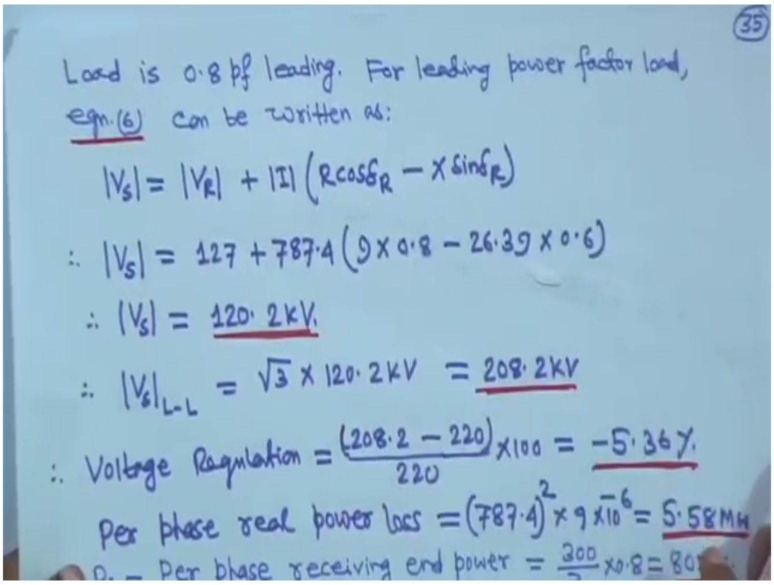

Next one is your sorry, this is actually this is the previous one sorry. So, this is root 3 V R I 300 V R is equal to 220 KV. So, I R is this one right, now it is load is 0.8 factor power factor leading right. So, previous page is keep right leading for leading power factor load equation 6 can be written as. So, as a leading power factor I told you this sign will be minus right. So, rest will remains same. So, V S is equal to this 127 plus this 1. So, magnitude V S is 120.2 KV this is your phase voltage right line to new turn therefore, V S line to line is equal to root 3 in to 120.2 KV that is 208.2 KV right.

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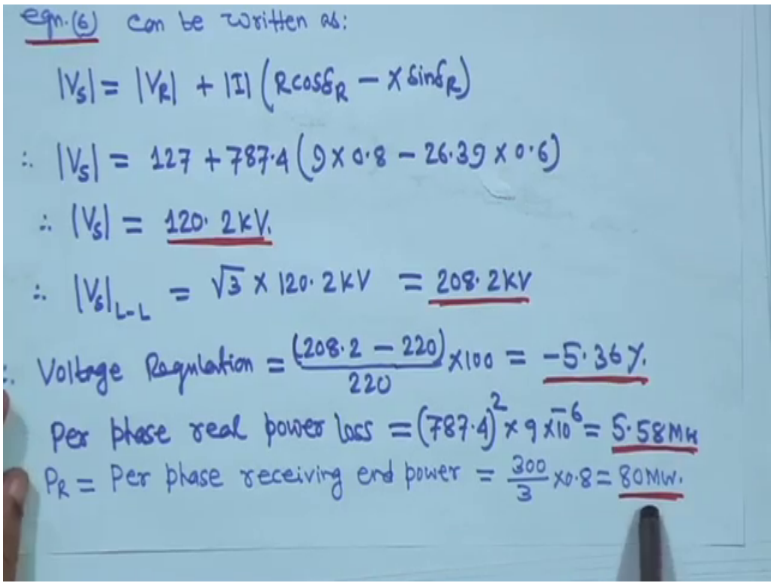

So, voltage regulation is sending end voltage minus this is your 220 to 100. So, minus 55.36; that means, for leading power factor regulation is negative; that means, you can find out the receiving end voltage actually greater than the sending end voltage from the receiving end whatever power factor we have chosen and per phase real power loss is equal to 787.4 square in to 9 in to 10 to the power minus 6 that is 5.58 megawatt right.

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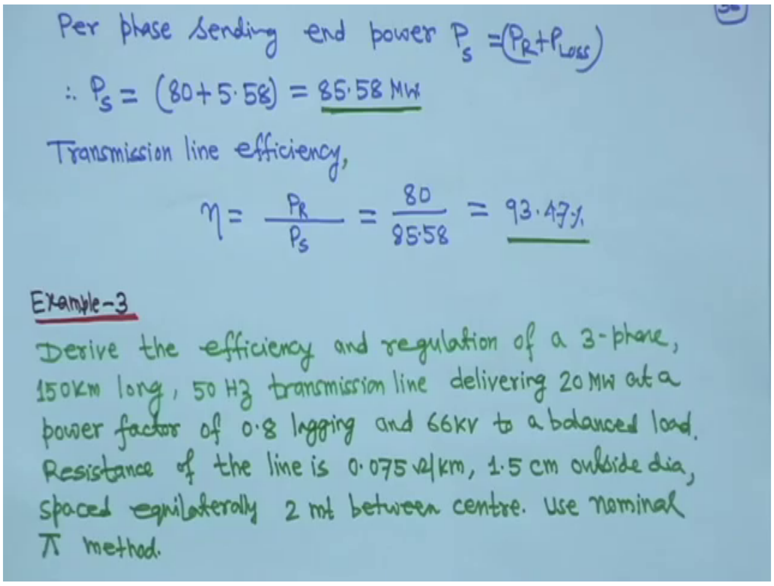

That is P R is equal to per phase receiving end power that is 80 megawatt right therefore, per phase sending end power P S is equal to P R plus P loss easily you can compute. So, P S is equal to this much and efficiency is equal to P R up on P S that is 80 up on 855.58, so, 93.48 percent right. So, this is for that your what you call efficiency right. So, for leading power factor you can see that it is not always, but in this case that regulation is negative right.

So, next example; so, derive the efficiency and regulation of a 3 phase 150 kilo meter long 50 hertz transmission line delivering 20 megawatt at a power factor of 0.8 lagging and 66 KV to a balanced load resistance of the line is 0.075 ohm per kilo meter 1.57 outside dia spaced equilateral equilaterally 2 meter between center use nominal pi method; that means, you have to compute here inductance capacitance those formulas are needed right. So, this is the problem given right. So, as you listen to this recording thing right if little bit of making calculation around a little bit or error in the classrooms students can correct right everything. So, everything we can rectify, but in this case that is why I am telling if there is any error any mistake you find calculation of this dia you please inform right because it is recorded. So, that is why this problem you come to this that R is equal to convert everything is given. So, it will become eleven point 2 5 ohm.

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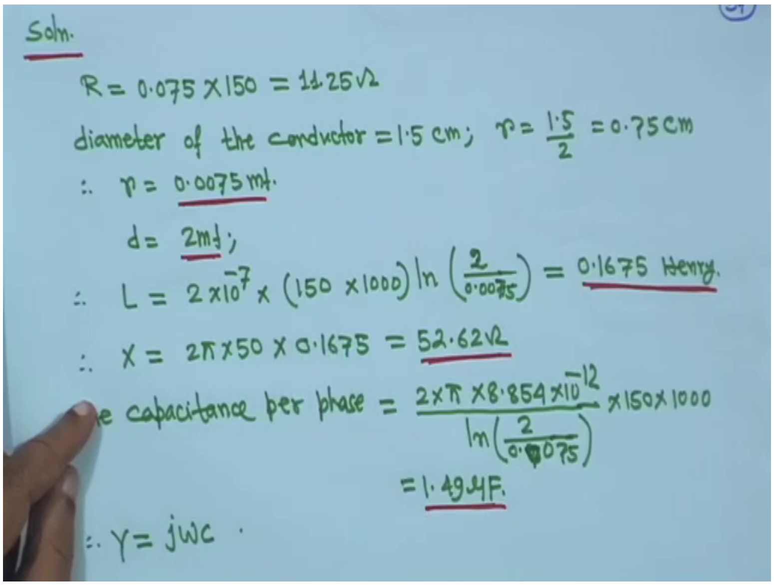

Because this data is given diameter of the conductor is 1.5 centimeter. So, radius is equal to 0.75 centimeter. So, R is equal to 0.0075 meter distance 2 meter equally right. So, this formula already derived for inductance chapter. So, L is equal to 2 in to 10 to the power minus 7 in to you make it to 150 kilo meters. So, 150 into 1000 meter right natural log L n 2 that is the equilateral; what you call it is given here that is your what you call outside dia spaced equilaterally 2 meter between center right. So, it is d is equal to 2 meter d is equal to 2 meter. So, d up on your; what you call this 0.0075 right. So, that is coming 0.1675 Henry. So, and this 1 x is equal to 2 pi in to then you find out in to L is this much, so, 52.62 ohm.

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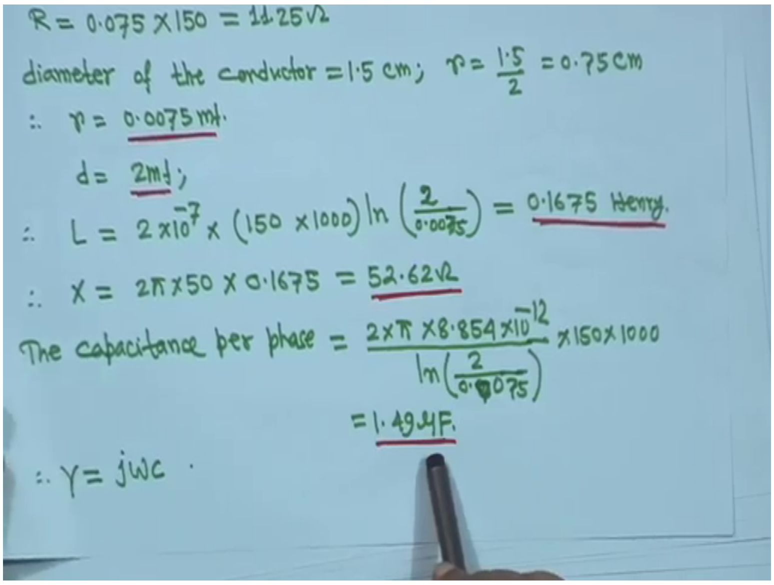

Similarly, it is 150 kilo meters line long line. So, you have to consider charging capacitance. So, directly that go to the capacitance your chapter it is 2 pi and 0s. So, 2 pi 8.854 in to the power minus 12 farad per meter this 1 and 0 divided by natural log L n 2 up on 0.0075 this is 0.0075; 0.0075 in to 150 in to 1000 it comes 1.49 micro farad after calculation and your admittance Y is equal to charging admittance Y is equal to j omega c.

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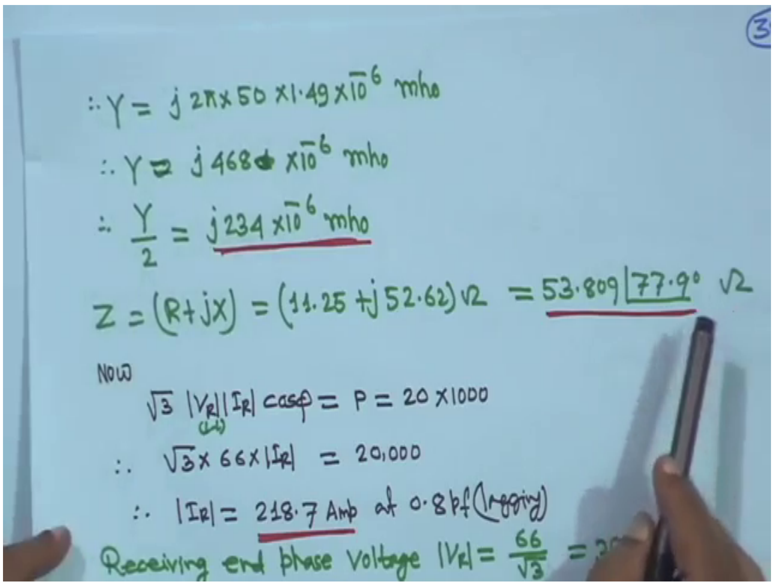

So; that means, Y is equal to 50 hertz. So, j 2 pi f in to 1.449 it is micro farad. So, 10 to the power minus 6 it is more I am not writing Siemens here I am making everywhere I am putting mho right.

So, Y is equal to j 4 68 in to 10 to the power minus 6 mho right therefore, Y by 2 is equal to j 234 in to 10 to the power minus 6 mho.

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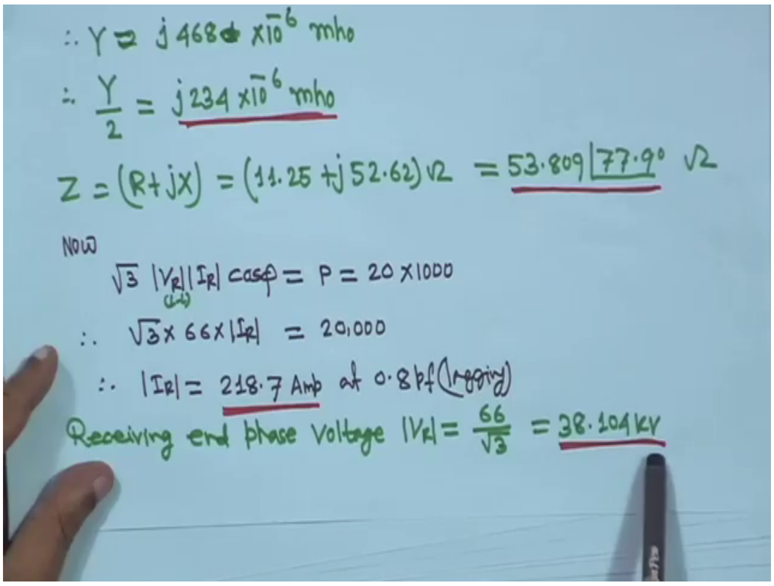

Now, Z is equal to R plus j x R is this much this is x. So, 53.809 angle 70; 70.9 degree ohm, now root 3 V R this is line to line I marked it by green when I will making it I missed it that is why root 3 V R line to line I R cos phi is equal to P is equal to 20 in to 1000 right so; that means, root 3 in to 66 into I R magnitude is got 20000. So, from which we get I R is equal to 2 18.7 ampere at 0.8 power factor lagging right. So, receiving end voltage V R will be per phase 66 by root 338.104 KV, this is the receiving end voltage V R right therefore, from equation 15 right.

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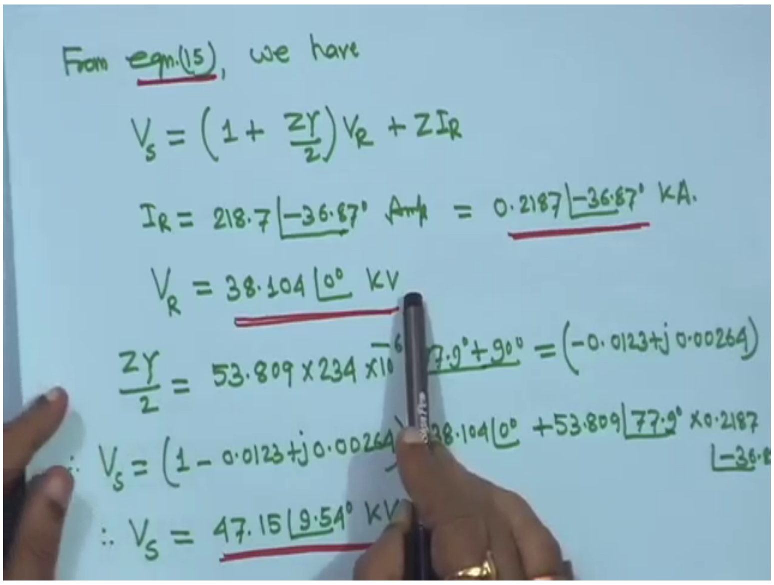

From equation 15 just hold on you know that V S is equal to 1 plus Z Y up on 2 V R plus Z I R right. So, I R is known current is lagging 2 18.7 angle minus 36.87 degree ampere. So, converted to kilo ampere 0.2187 and this is the angle kilo ampere. So, V R is equal to this is 38.104 angle 0 degree KV.

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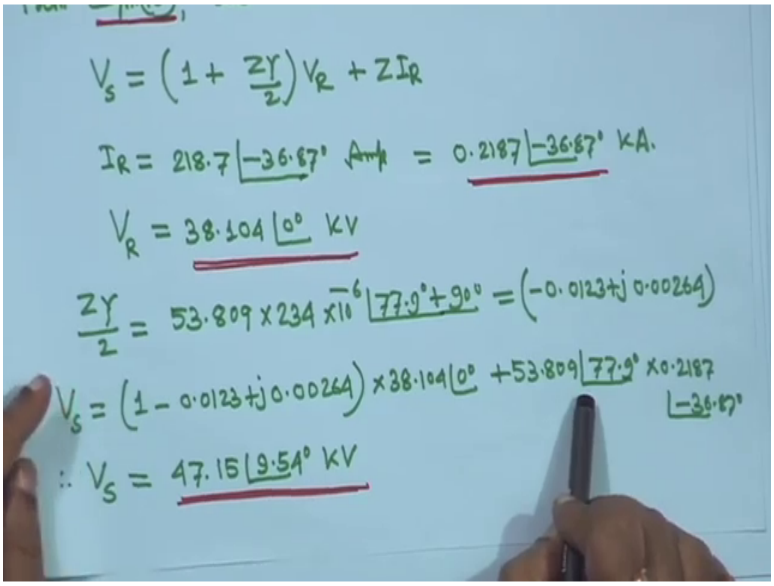

So, Z and Y both here computed. So, Z Y by 2 you make it because 1 plus Z Y by 2 2 Z Y by 2 compute it will be this one right minus 0.0123 plus j 0.00264 therefore, V S is equal to this is 1; 1 minus Z Y by 2 because it is coming 1 plus your Z Y by 2. So, Z Y your; it is coming this much. So, 1 minus 0.0123 plus j 0.00264 multiply by your V R which is 38.104 angle 0 degree plus Z in to I R. So, this is Z and this is your I R though this kilo ampere. So, this one you become also this stop will become kilo volt. So, it is coming V S is equal to 47.15 angle 9.54 degree kilo volt this is your V S right.

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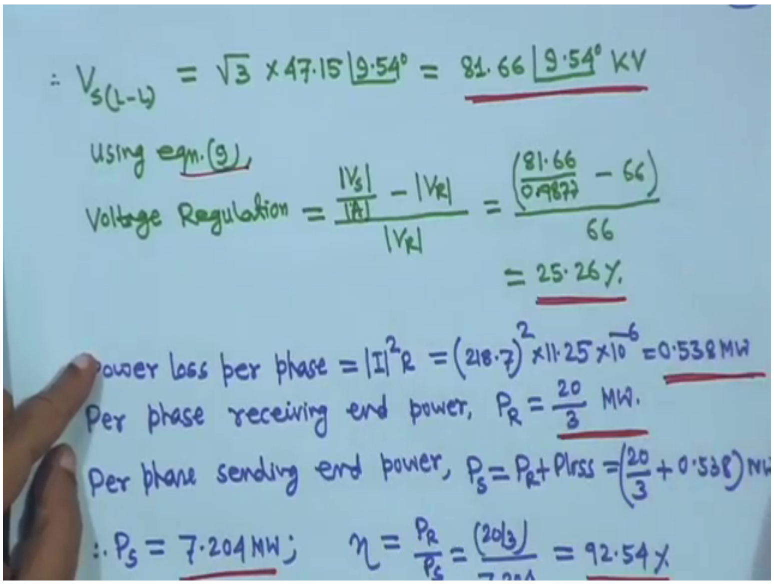

Therefore V S line to line is equal to root 3 in to 47.15 angle 9.54 degree. So, it is 81.66, it is 8.0 angle 9.54 degree KV. So, using equation 9 right when your charging capacitance has not considered at that time V S minus V R upon V r, but at the same time we have derived that equation; equation 9 where because for the short line a is equal to 1, but here it is not. So, using equation 9 only it is mode V S up on mode a minus mod V R up on mode V R right. So, a mode a you can easily calculate your this thing this is actually a is equal to a is equal to 1 plus Z Y by 2. So, this term actually compute and by this is actually you are a this term this the bracket term this term is a.

So, you compute. So, that that model mode of this is 0.9877 right minus 66 divided by 66, so, 25.26 percent that is the voltage regulation.

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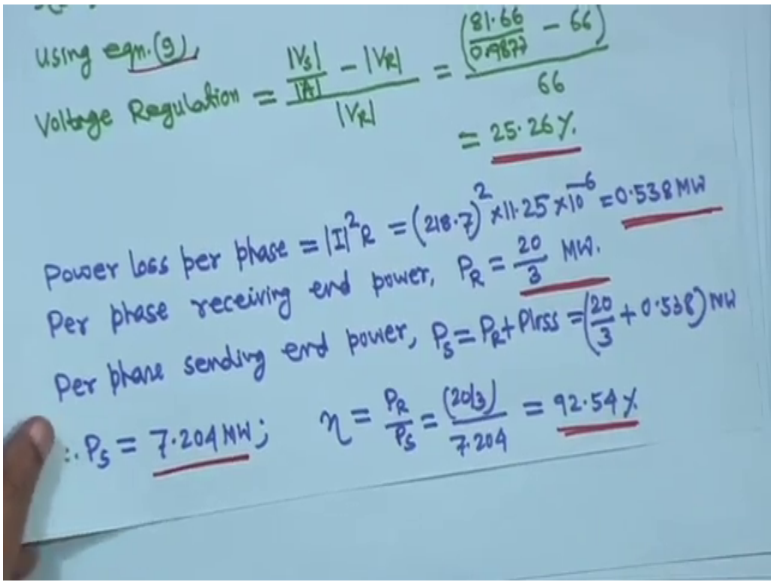

Now, power loss per phase is equal to magnitude I square R. So, substitute all the value and convert it to megawatt. So, that is why multiplied by 10 to the power minus 6. So, 0.538 megawatt, so, per phase receiving end power 20 upon 3 megawatt and per phase sending end power is equal to receiving end power plus loss 20 by 3 plus 0.538 megawatt. So, P S is 7.20 efficiency is equal to P R upon P S. So, 20 upon 3 divided by 7.204 is equal to 92.54 percent right this is your; what you call efficiency right.

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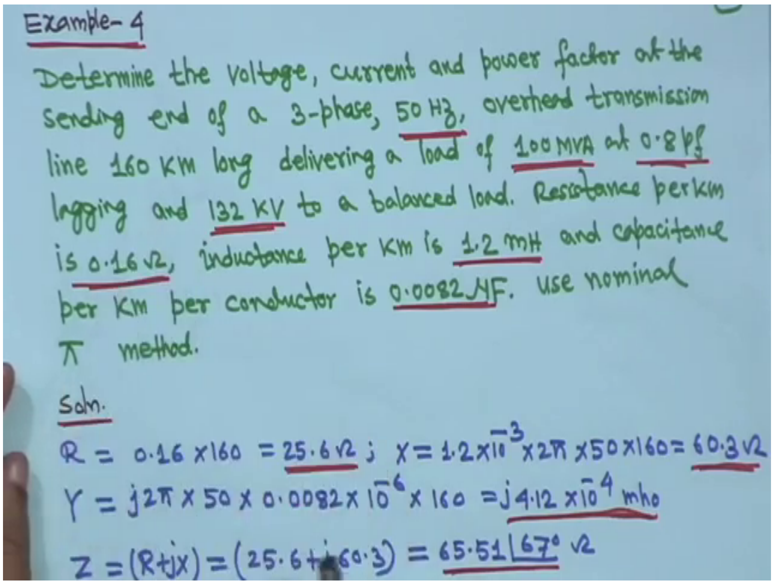

Next 2 example is that determine the voltage current and power factor at the sending end of a 3 phase it is another type of problem 50 hertz overhead transmission line 160 kilo meter long delivering a load of 100 MVA at 0.8 power factor lagging and 132 KV to a balanced load right resistance per kilo meter is given 0.16 ohm and inductance per kilo meter is given 1.2 milli Henry and capacitance per kilo meter per conductor is 0.0072 micro farad you have to use nominal pi method because line is 160 kilo meter long right.

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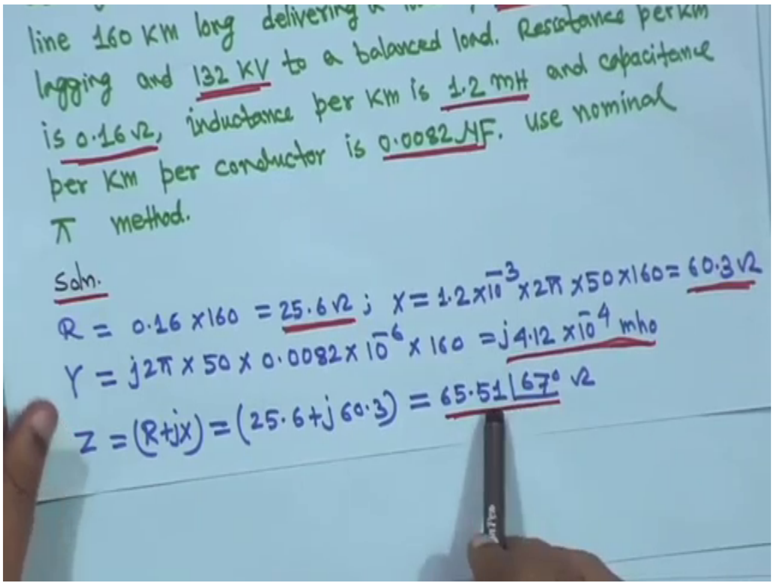

So, in this case you calculate R it will become 25.6 ohm x you calculate it will become 60.3 ohm now all this thing are repeating because understandable now Y is equal to calculate your this your 0.0072 micro farad is given and it is 50 hertz your what you call frequency. So, length line length is 160 kilo meter. So, you will get j 4.12 in to 10 to the power minus 4 mho I am not using Siemens using mho right and Z is equal to R plus j x. So, this is your impudence of the line angle is 67 degree right.

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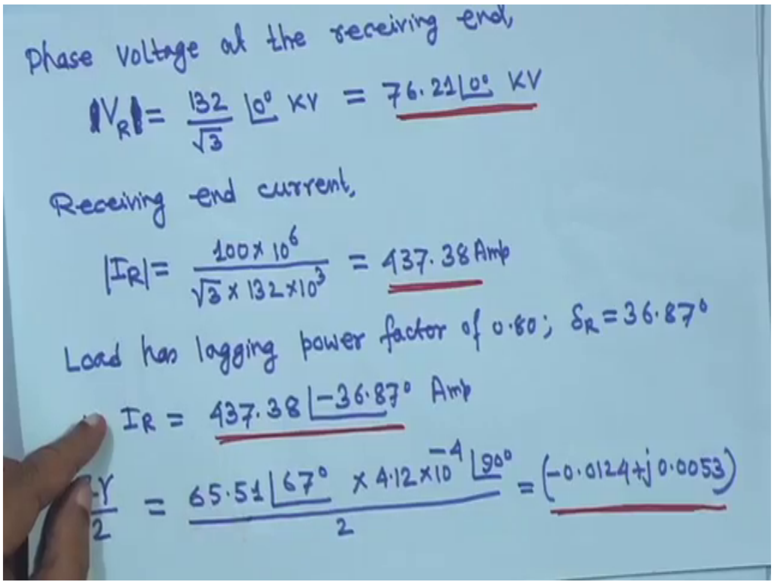

Now, phase voltage at the receiving end V R is equal to 132 by root 3. So, 76.21 angle 0 degree KV because this is given right receiving end current I R is equal to your basically it is your what you call it is keeping MVA. So, this side your what you call this side also. So, it is I R root 3 this one this is your; it is given 100 MVA. So, it is making your making it volt ampere and this is 132 in to 10 to the power 3. So, kilo volt is made volt. So, I R is equal to this 1 divided root 3 in to 132 10 to 10 to the power 3 that is coming 437.38 ampere right other way also you can calculate no problem right.

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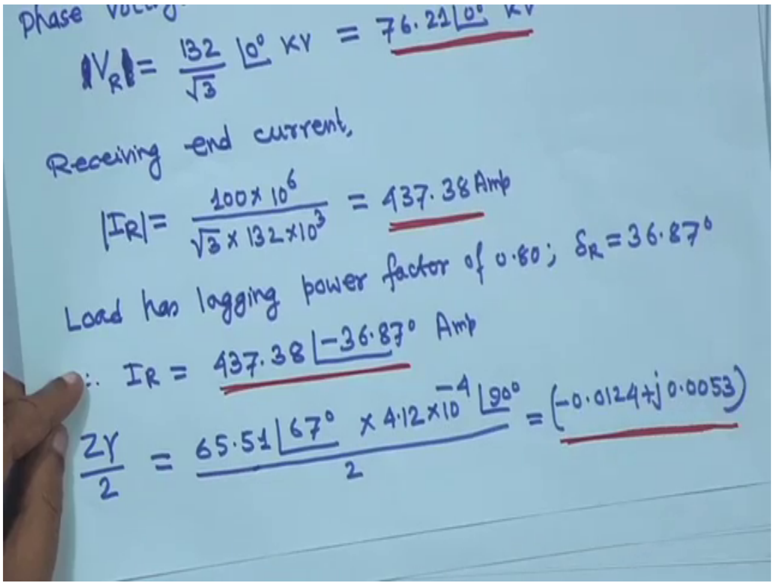

So, load has lagging power factor that is delta R is 36.87 degree because it is 0.8 therefore, current I R is equal to 437.38 angle minus 36.87 degree ampere. So, it is your what you call it is your a b c d parameter you have to calculate. So, first a is equal to 1 plus Z Y upon 2 first you compute Z Y by 2 put all this value you will get this value right.

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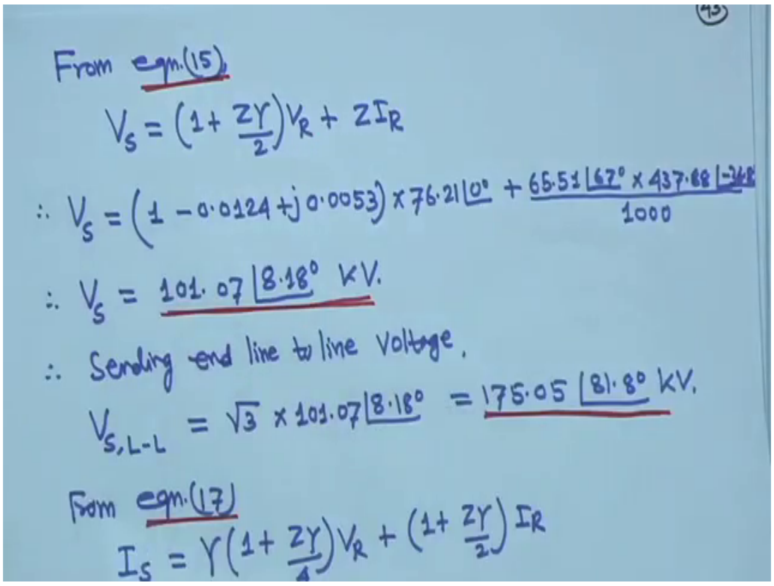

Then from equation 15 from equation 15 V S is equal to 1 plus Z Y by 2 V R plus Z I R right substitute all this right all these this current this is actually volt divided by 1000 that is it that is it has been made kilo volt right. So, and because this is in kilo volt 76.21 angle 0 is kilo volt. So, that is why this is volt because this is in ampere and this is divided by 1000. So, V S is equal to 101.07 angle 8.18 degree 1 8 degree, sorry 0.18 degree kilo volt right. So, sending end line voltage multiply this 1 by root 3 it is 170.05 and this is the angle right this is actually it is actually my writing mistake it is actually 8.18 degree right.

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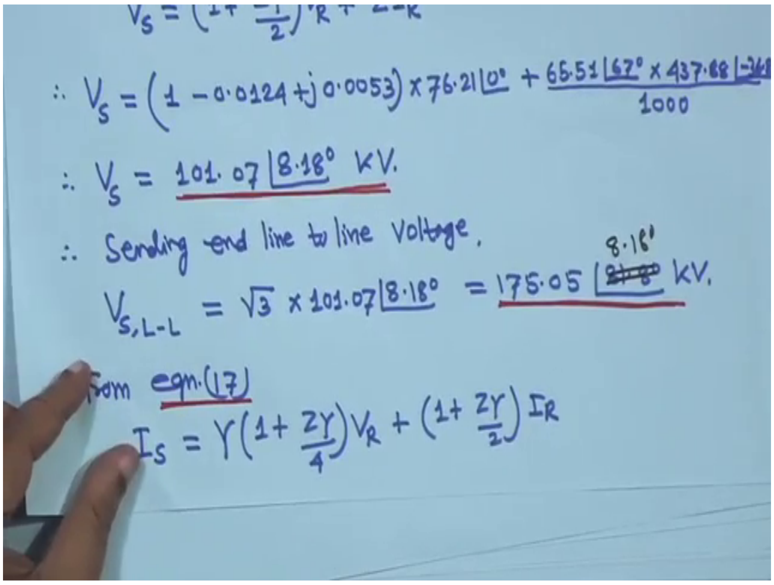

And from equation seventeen you calculate I S your c b R plus d I R all this things you this thing what you call this thing all you compute right. So, I have only computed directly right.

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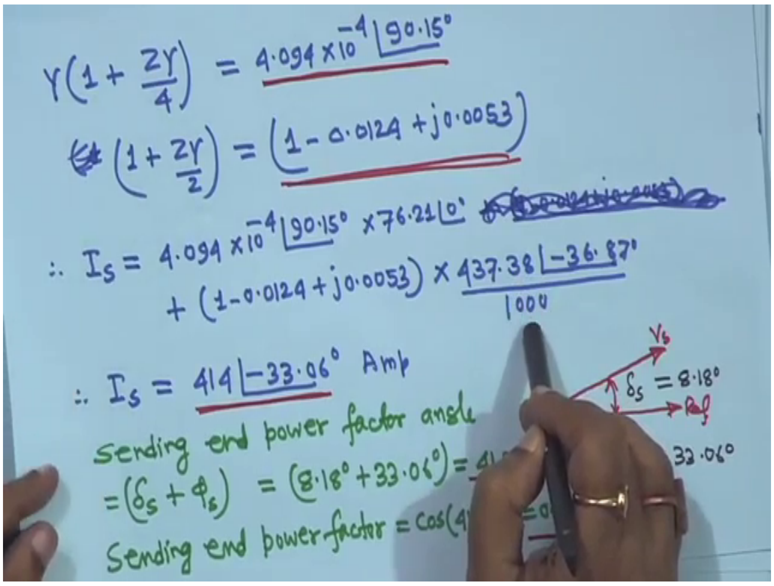

So, if you compute all it will become this value 4.094 in to 10 to the power minus 4 this 1 and 1 plus Z Y 2 will become like this right then you substitute in that expression all this thing you substitute only this one you divided by 1000 make it kilo ampere, so, divided by 1000 right because this voltage is actually in kilo volt right.

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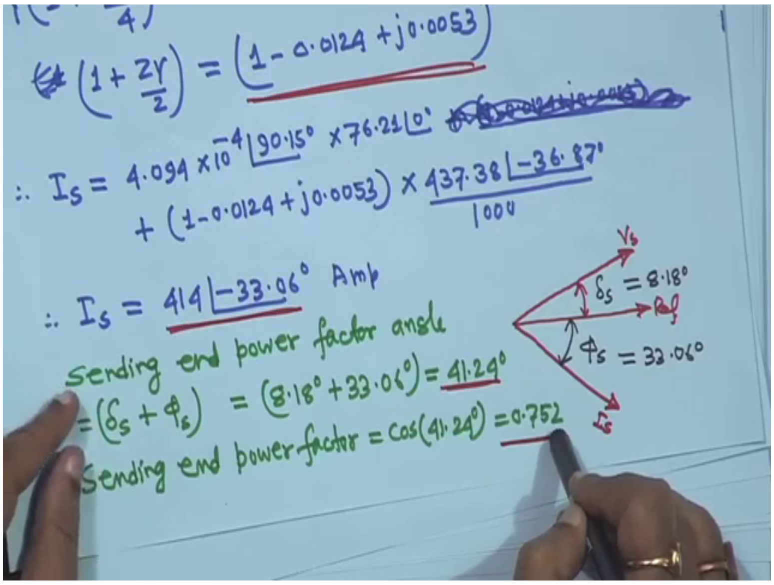

So, you will get 414 angle minus 33.06 ampere right. So, now, this is your reference line this is the voltage sending end voltage its angle is 8.18 degree and this is the current this is minus 33.06. So, this is your 33.06. So, you have to find out the power factor of the sending your sending end. So, angle between sending end voltage and sending end current is 8.18 plus 33.06. So, that is why I am writing 8.18 plus 33.06. So, sending end power factor angle is 41.24 degree if you make it like these and draw it there will be no mistake. So, sending end power factor cosine 41.24 degree. So, that is 0.752 right.

Thank you.