Power System Protection and Switchgear
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Lecture 17
Protection of Transmission Lines Using Distance Relays-IV

So, in this lecture we further continue our discussion on distance relays. So, let us start with one example on distance relay.

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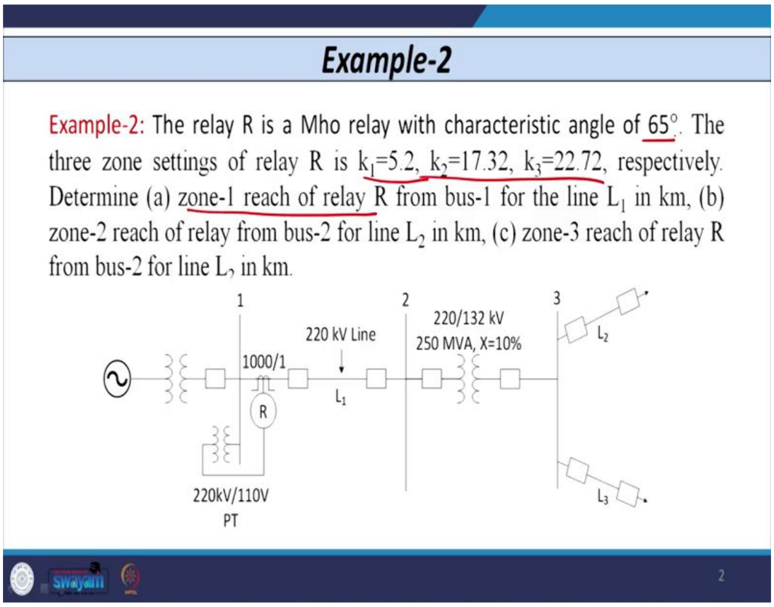

So, the example is given here the relay R is a Mho relay with characteristic angle 65 degree so, here single-line diagram of a portion of power system is given the several three transmission lines are connected one is L1 between bus 1 and 2 another is L2 and L3 from bus 3.

So, the really R is located between at bus 1 so, it is a distance relay having more characteristic with characteristic angle 65 degree the 3 zone settings of distance relay R is given so, k1 k2 and k3 the these three values are given and we need to determine the zone 1 reach of relay R from bus 1 so, what is the reach of relay R from bus 1 for line L1 that we need to determine.

The second b case we need to determine the zone 2 reach of same relay that is R for from this bus, bus 2 or bus 3 because, both are same only the difference is the voltage level so, for zone 2 reach we need to find out it from the for line L2 in kilometre and same way for part c we need to determine the zone 3 reach of relay R again from the same bus for line L2 and that is also in kilometres. So, to solve this example, let us start with the first part that is the, what is the zone 1 reach of this relay so, let us start with zone 1 reach of relay R with value given that is k1, k2, k3 that is given and Theta that is characteristic angle it is also given.

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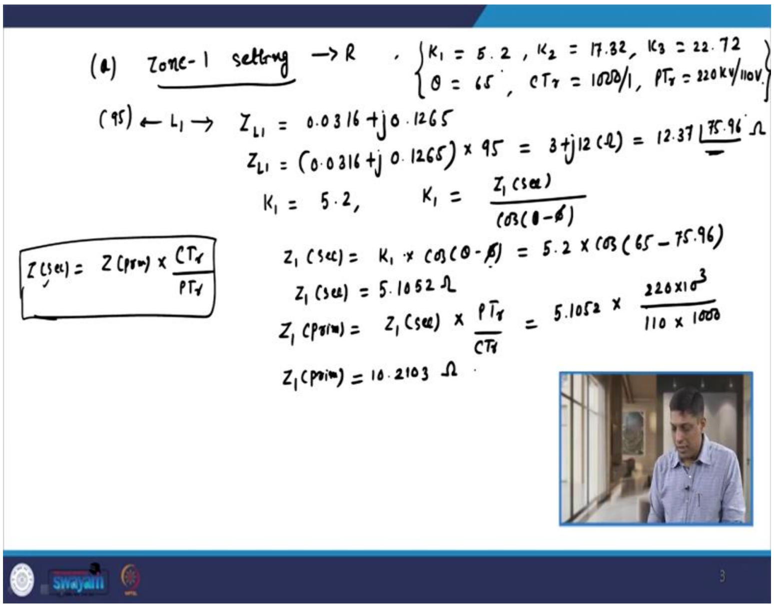

So, let us start with first part that is the a part, so zone 1 setting of relay R so, the value of k1 that is given for this k1 is the zone 1 setting and its value that is given as the 5.2 so, the value of k1 that is given as 5.2 the value of k2 that is given as 17.32 and the value of k3 that is given that is as 22.72 the characteristic angle Theta that is also given that is 65 degree and the CT ratio is also given so, CT ratio is 1000 of oblique 1 ampere and the PT ratio that is also given that is given as 220 kv by 110 volt.

So, this values are already given… and based on this value we need to find out the first zone reach of relay R for line L1 so, we need to find out for line L1 so, let us determine what is the impedance of line L1 let us call it ZL1 so, the value of line L1 that is given as its impedance is given which is 0.0316 plus j 0.1265 and the length of line L1 that is also given which is 95 kilometre long.

So, with this value let us find out the whole impedance of the transmission line so, that is nothing but 0.0316 plus j 0.1265 into line length that is 95 kilometre, so the value if you solve it you will get the value that is 3 plus j 12 this is in Ohm so, if I convert this value in polar form, then it is 12.37 at an angle 75.96 degree this is in Ohm so, the value of ZL1 we have already calculated.

Now, as the value of k1 is given that is 5.2 so, we can find out we know that k1 that is equal to Z1 secondary divide by cos of theta minus phi so, this equation we know so Z1 secondary that is equal to k1 into cos of theta minus phi so, k1 is given as 5.2 into cos of theta is given as 65 degree characteristic angle minus Phi. Now, this Phi is nothing but this value given of ZL1 75.96 degree so, if I solve this value, we have Z1 secondary that is equal to the value comes out to be 5.1052 Ohm so, you can easily find out the value of Z1 secondary.

Now, we know that the Z secondary that is equal to the Z primary into CT ratio divide by PT ratio those, this equation we know we have already discuss this so, using this equation we know the secondary part so, we can easily find out the primary part so, Z1 primary that is equal to Z1 secondary into the reverse PT ratio divide by CT ratio so, that is Z1 secondary that is 5.1052 into PT ratio that is 220 kV by a 110 volts.

So, 220 into 10 raise to 3 divide by 110 volt into CT ratio that is 1000 oblique 1 ampere so, if I solve this we have the Z1 primary that is equal to 10.2103 Ohm so, we have already calculated the primary part so, now what we need to find out?

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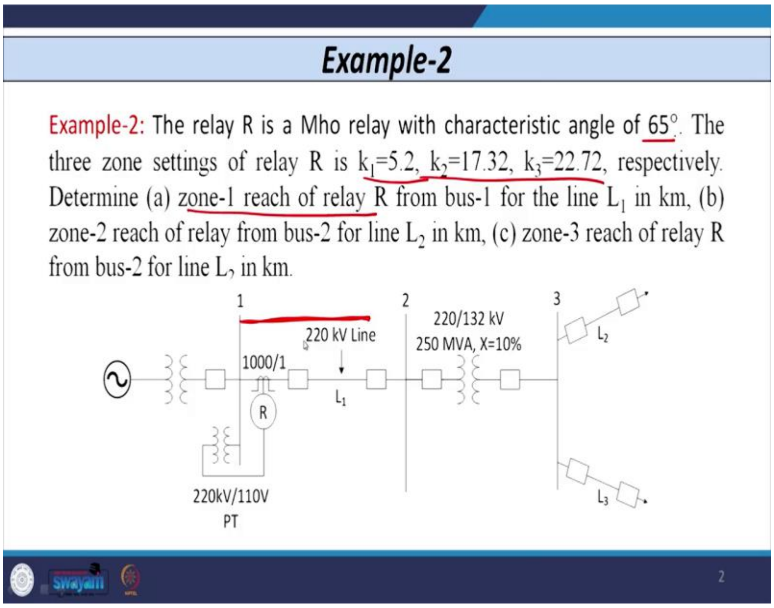

We need to find out the if I just go to the figure we need to find out what is the zone 1 reach of relay R so, as we have already discussed the zone 1 reach of relay R that is normally 80 to 90 percent from bus 1. So, we need to find out up to what this point in terms of kilometres the reach of L1 so, that we need to find out so, if you need to find out then what we have to do is?

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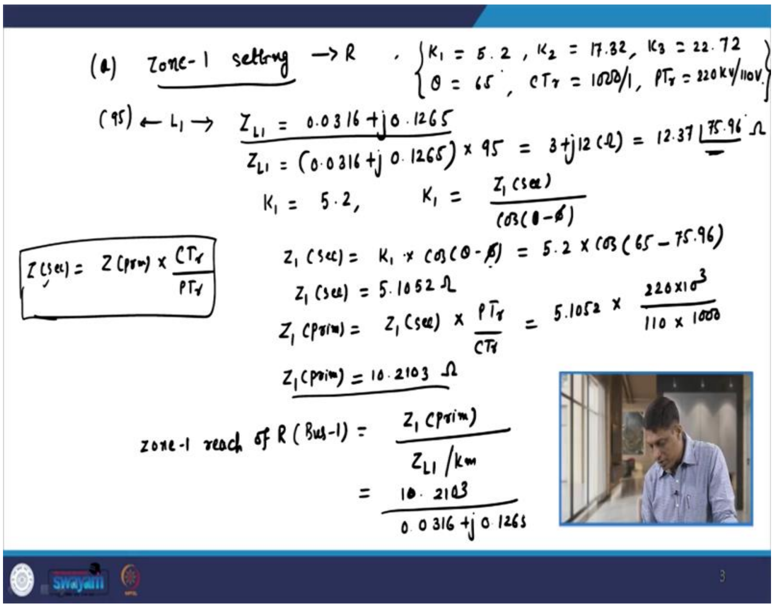

We have already calculated the Z1 primary, so zone 1 reach of relay R from bus 1 so, that is given by your Z1 primary divide ZL1 in per kilometre value so, we know that Z1 primary that is equal to 10.2103 we have already calculated and divide ZL1 per kilometre that is this value so, that is 0.0316 plus j 0.1265.

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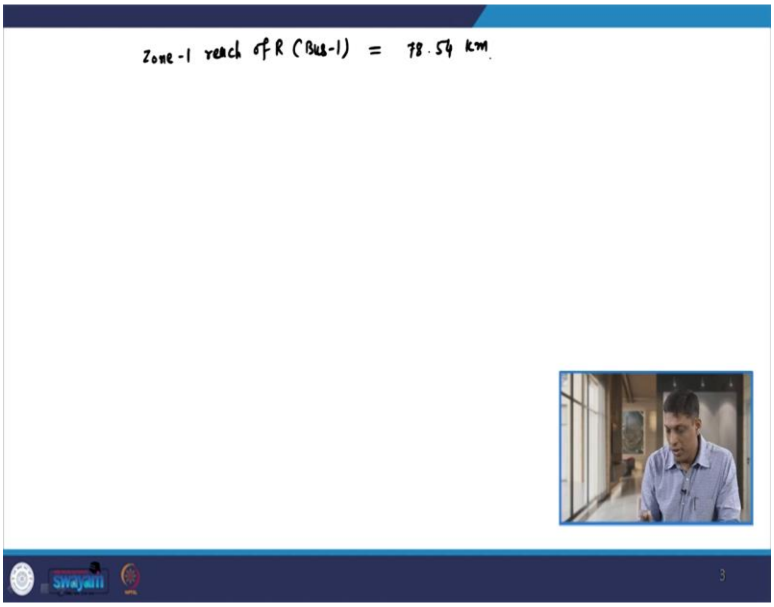

So, if I solve this then the zone 1 reach of relay R from bus 1 that is equal to the value comes out to be 78.54 kilometre.

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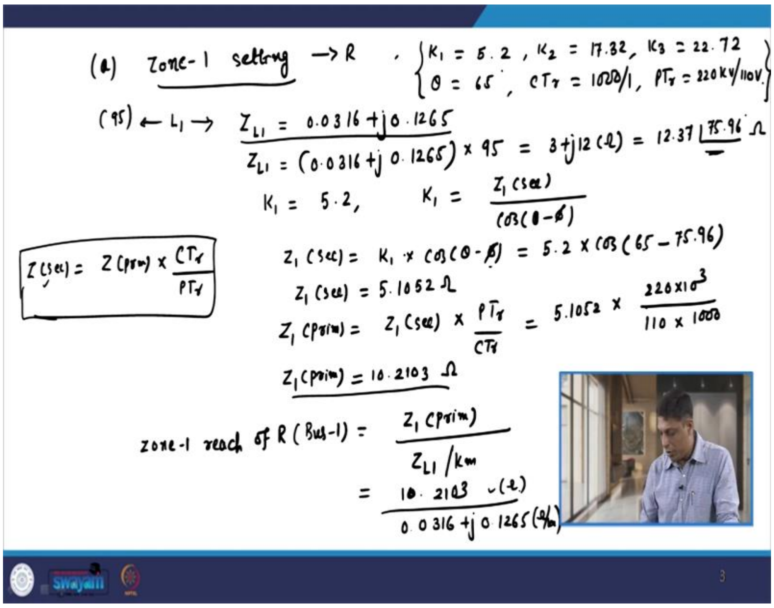

So, you can see that this value that is in this value is given and this value that is in per kilometre basis so, this is also in Ohm and this value is in Ohm per kilometre so, you will get kilometre.

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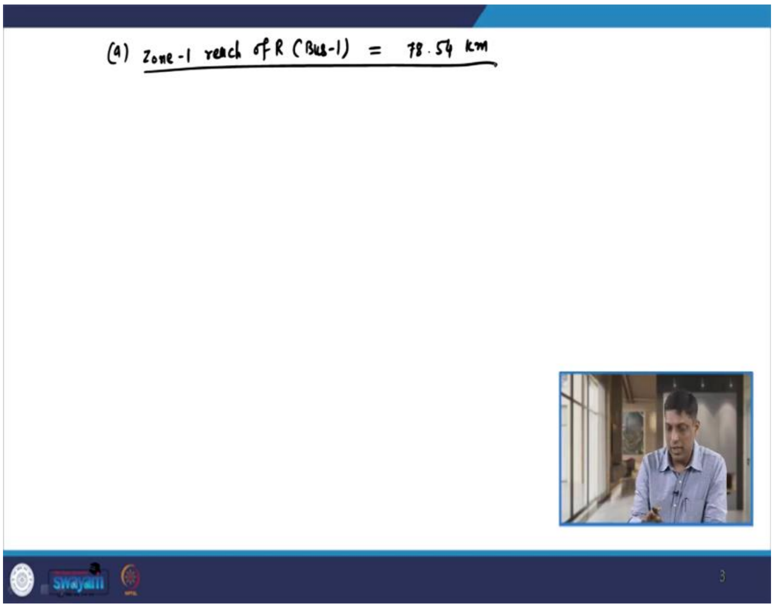

So, the first part that is completed that, what is the zone 1 reach of relay R in terms of kilometres from bus 1 so, that we have completed.

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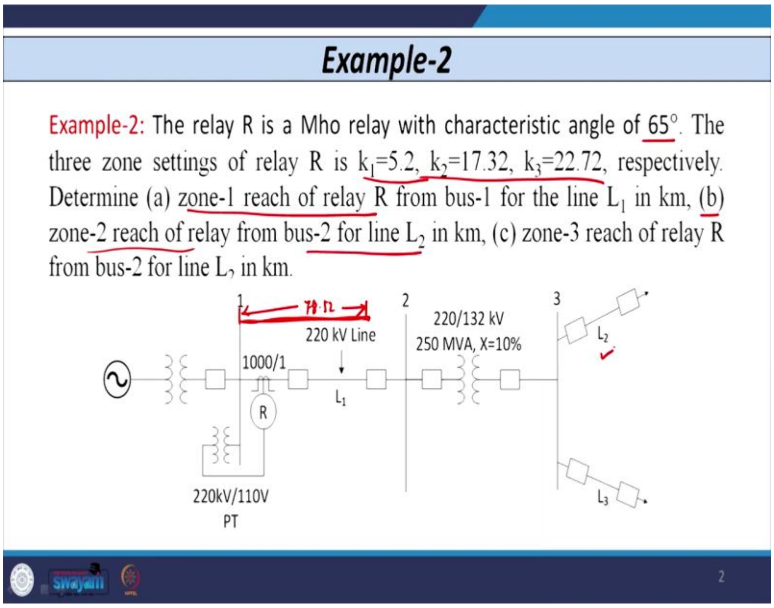

So, you can see that we have this value this length covered by relay R in first zone that is 78.52 kilometre so, that we have calculated. Now, let us consider the second part that is, what is the zone 2 reach of really R from bus 2 for line L2.

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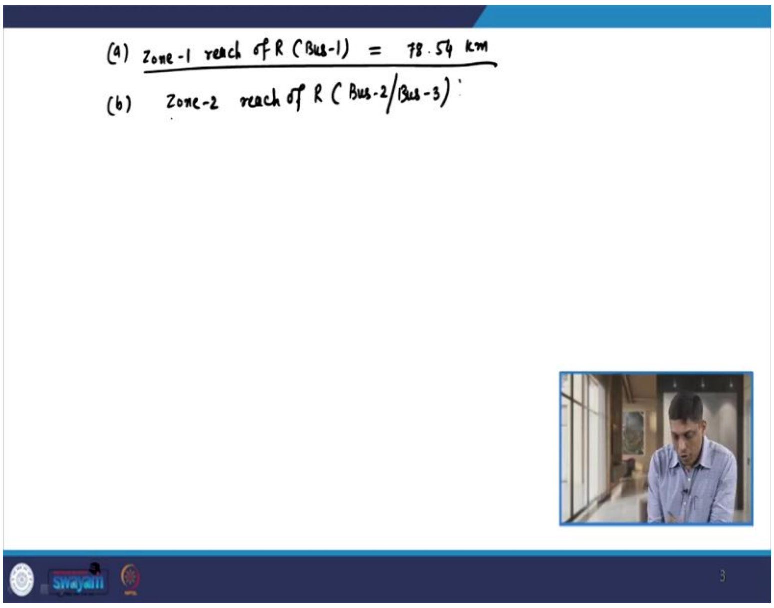

So, let us solve this. so the second part we need to find out the zone 2 reach of relay R and that is from bus 2 or bus 3 both are same because, both buses are in same substation so, let us find out this value.

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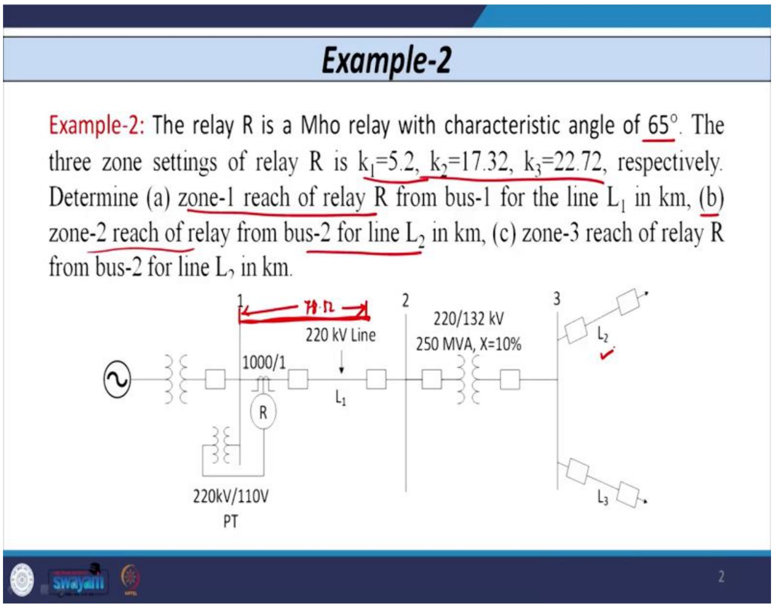

So, zone 2 if, I consider the figure then, the zone 2 of relay R that covers the entire length of line L1 plus the reactance of this transformer so, let us find out what is the total impedance of line L1 plus the reactance of the transformer.

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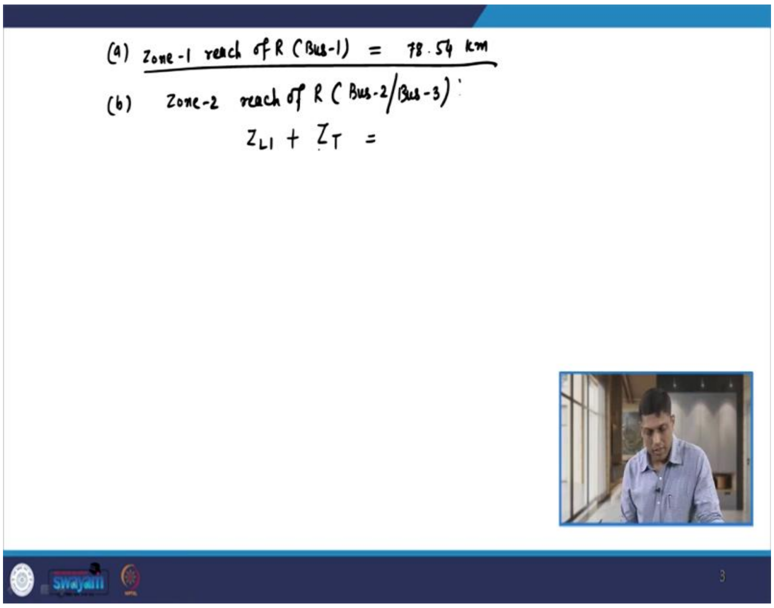

So, let us find out what is the value so, that covers the whole line length so, that is ZL1 entire line length plus the transformer reactants let us call it ZT so, this value the ZL1 total that is we have already calculated.

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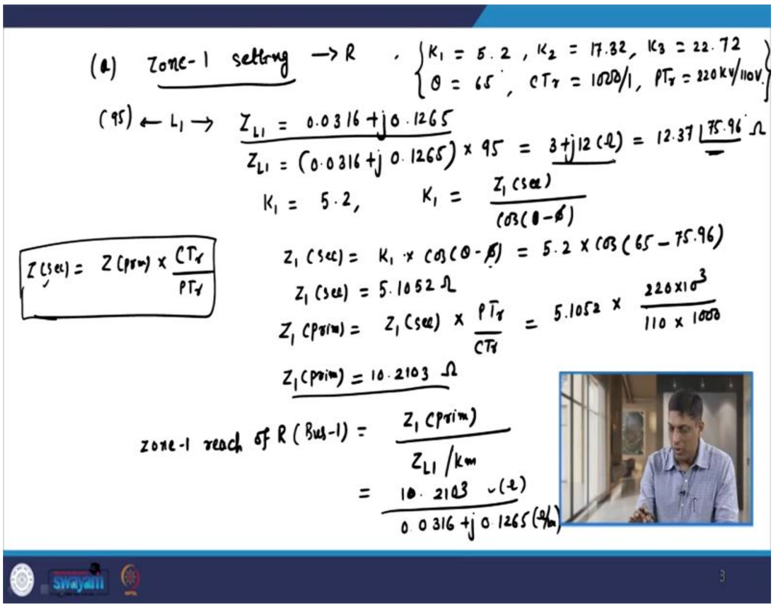

That value is 3 plus j12 Ohm.

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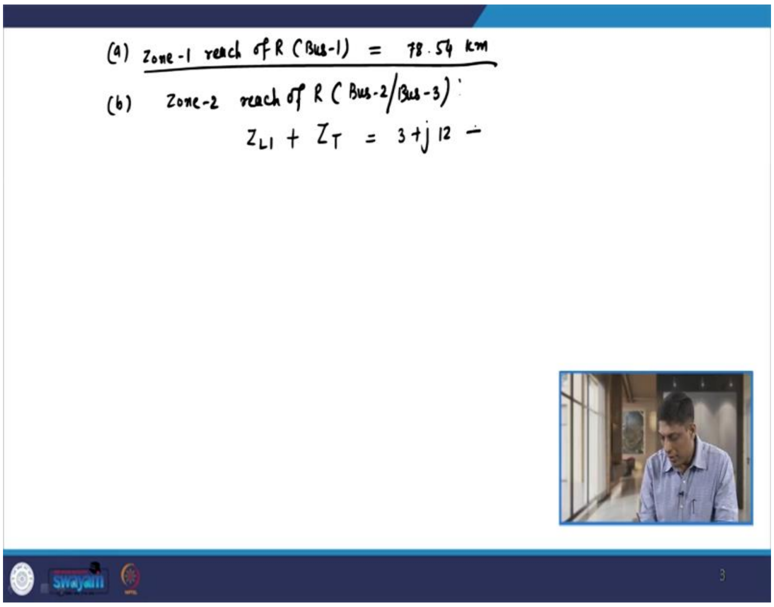

So, this value is 3 plus j12 plus the transformer reactance.

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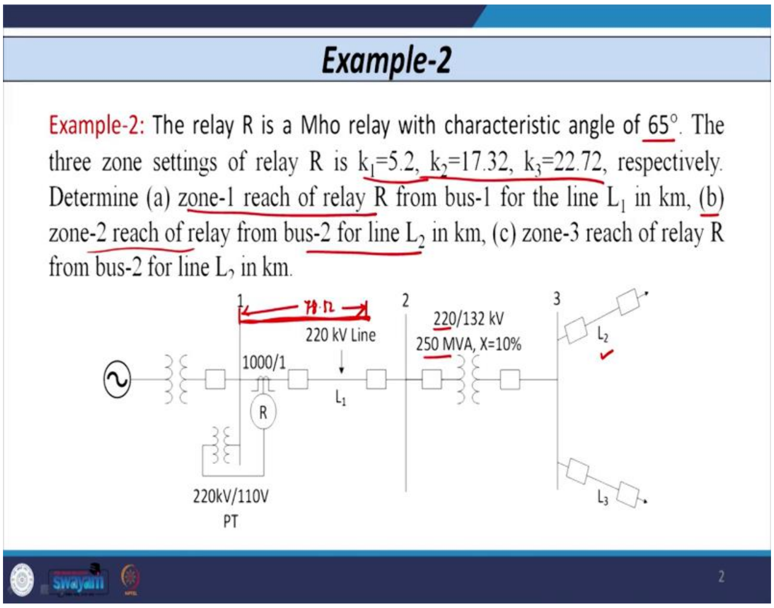

So, here the transformer reactance is given as the 10 percent and the, this line L1 is on 220 kV side so, MVA value is given voltage is given so, we can easily find out the value of reactance of this transformer.

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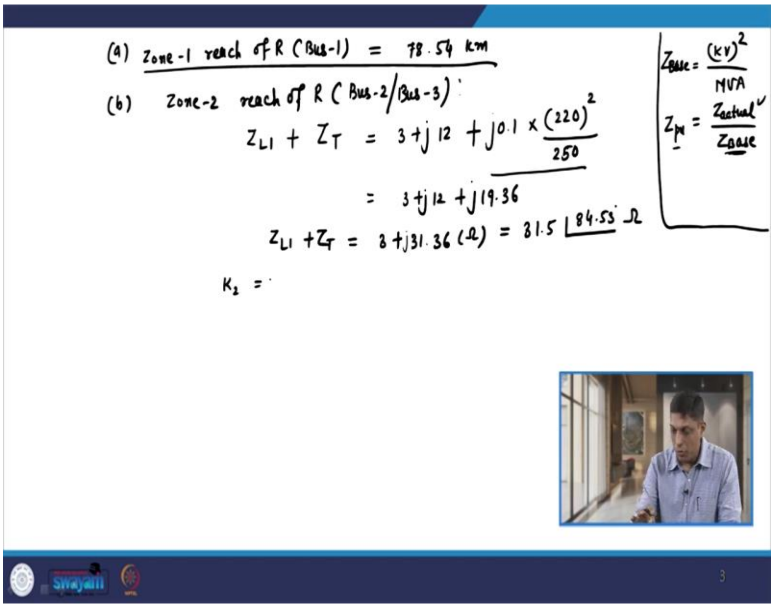

So, that value is nothing but j 10 percent so, 0.1 into equation is kV square divide by MVA so, kV that is 220 kV whole square and MVA value that is 250 so, we know that the when we solve the equation Z per unit any value in per unit that is given as actual value upon base value. So, here this value which we have calculated that is the actual value so, we have multiplied this per unit that is 10 percent or 0.1 which base value which is given by this equation that is kV square upon MVA.

So, if you solve this then that will be 3 plus j12 plus J this value that comes out to be 19.36 Ohm so, ZL1 plus ZT that is equal to 3 plus the value comes out to be 31.36 Ohm or if I convert in polar form then that is 31.5 at an angle 84.53 degree this is also in Ohms so, this we have calculated now the value of k2 is given.

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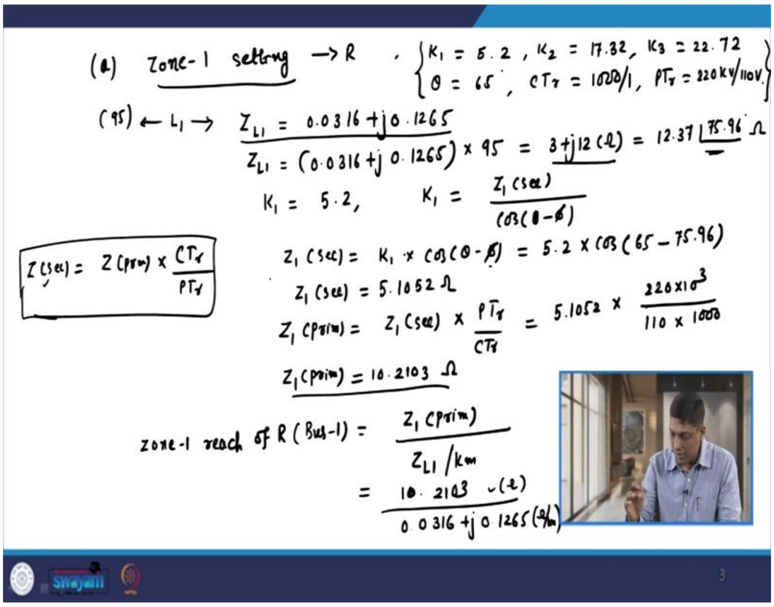

So, the k2 value that is equal to 17.32.

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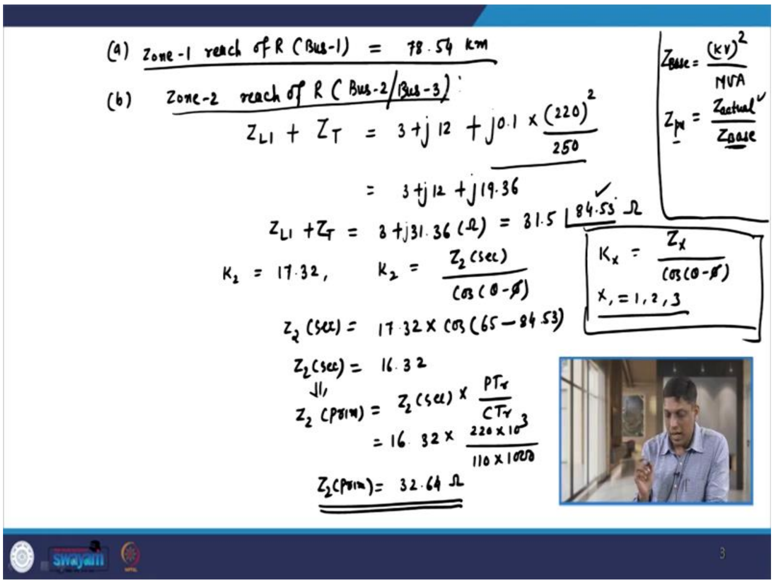

So, k2 is given 17.32 so, we know that k2 is equal to Z2 secondary divide by cos of Theta minus Phi so, this equation you can remember that any value of KX that is equal to Zx divide by cos of Theta minus Phi where X stands for 1, 2 and 3 that indicates the zone value zone setting if you take first then it is k1 Z1 if you take second it is k2 Z2 if you take 3 then it is k3 Z3 so, you can easily find out 3 zone setting equation using this.

So, if I just put the value Z2 secondary that is equal to k2 that is 17.32 into cos of Theta that is 65 degree minus Phi, Phi we have already calculated because of addition of this reactance of transformer the value of Phi changes. So, it is 84.53 so, if you solve this Z2 secondary that comes out to be 16.32 Ohm so, based on this you can easily find out Z2 primary which is equal to Z2 secondary into PT ratio divide by CT ratio.

So, if I put this value 16.32 into PT ratio that is 220 into 10 raised to 3 divide by 110 into 1000 by 1 so, the value is of Z2 primary that comes out to be 32.64 Ohm so, we have calculated the value of Z2 primary now, see we need to find out the zone 2 reach of relay R from bus to or bus 3.

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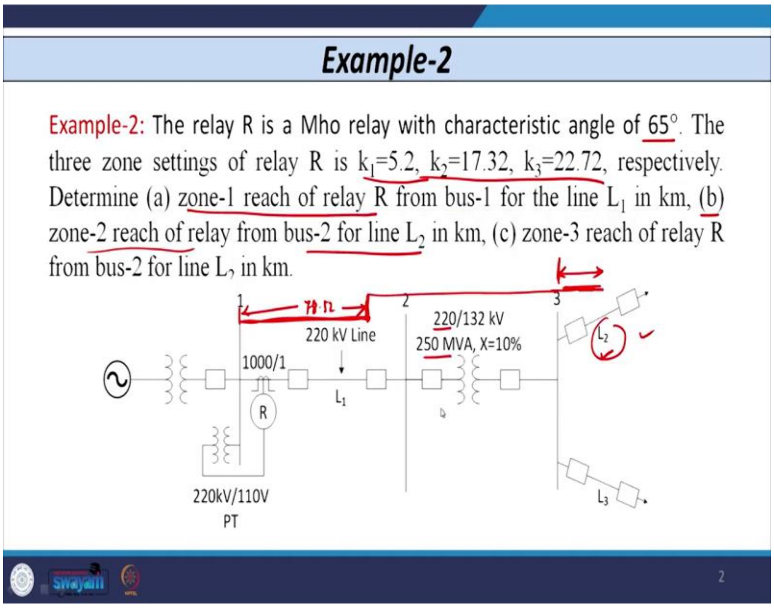

So, if I refer what is the zone 2 reach? Zone 2 reach of in second zone of relay R that starts from here but, after some time delay we need to find out whether for line L2 from this bus up to how much kilometre this reach will enter for line L2 so, this value we need to find out in kilometres. So, for that what we will do we will take the whole Z2 primary value which we have calculated and we subtract it from that we subtract the entire impedance of line L1 that is ZL1 plus reactance of the transformer that is ZT.

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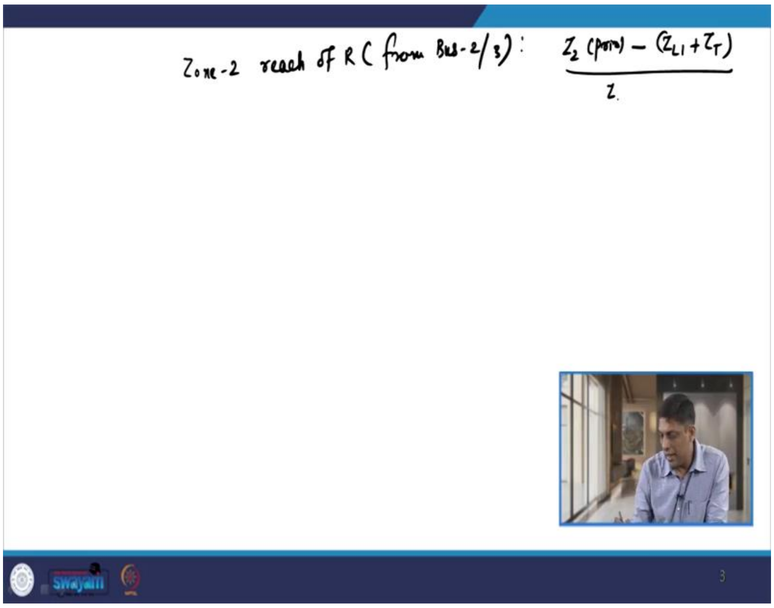

So, if I just find out the zone 2 reach of relay R from bus 2 or 3 both are same so, then that will be equal to Z2 primary minus ZL1 plus ZT so, that we need to subtract so, that we can find out its reach from bus 2 or bus 3 divided by we need to find out the value so, if I just put the value then the value and the in denominator we have just.

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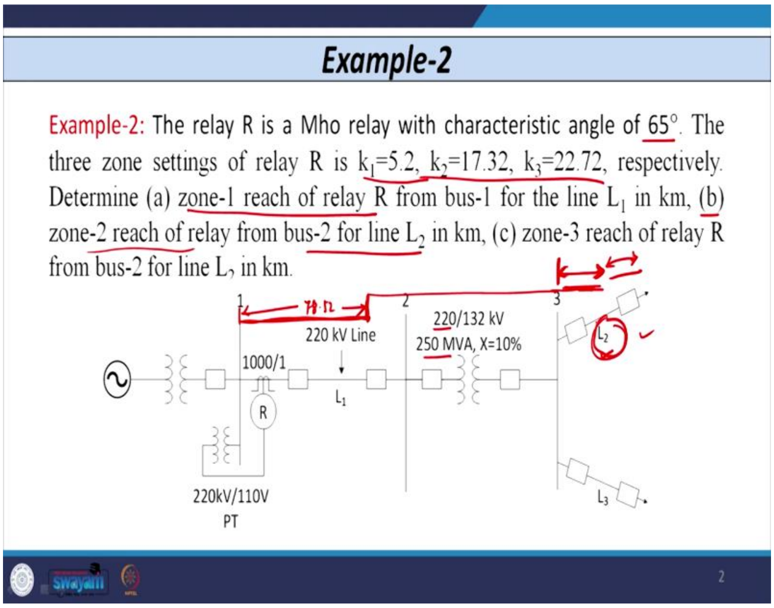

We need to find out zone 2 reach from here this value we have put already put in numerator that is Z2 primary minus ZL1 plus ZT so, that is here and in denominator we have to consider the impedance of line L2 on per kilometre basis.

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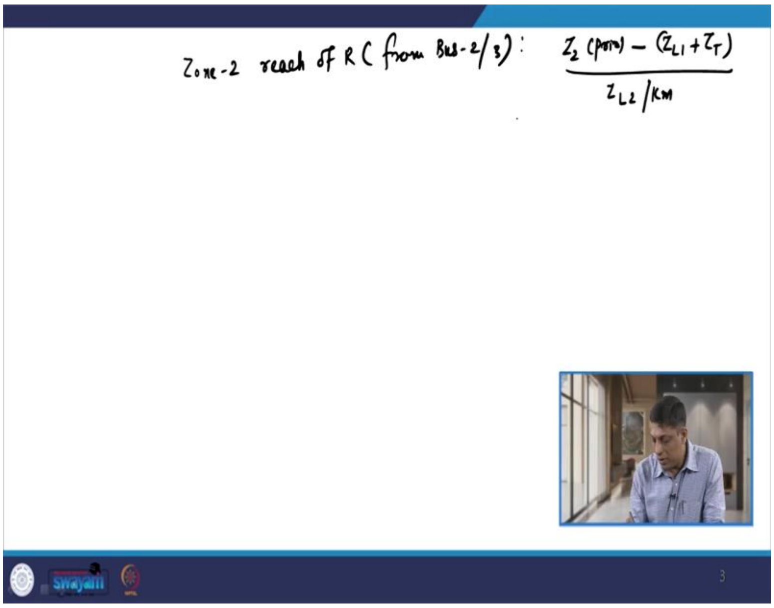

So, if I just this is your ZL2 per kilometre so, if I put this value here Z2 primary.

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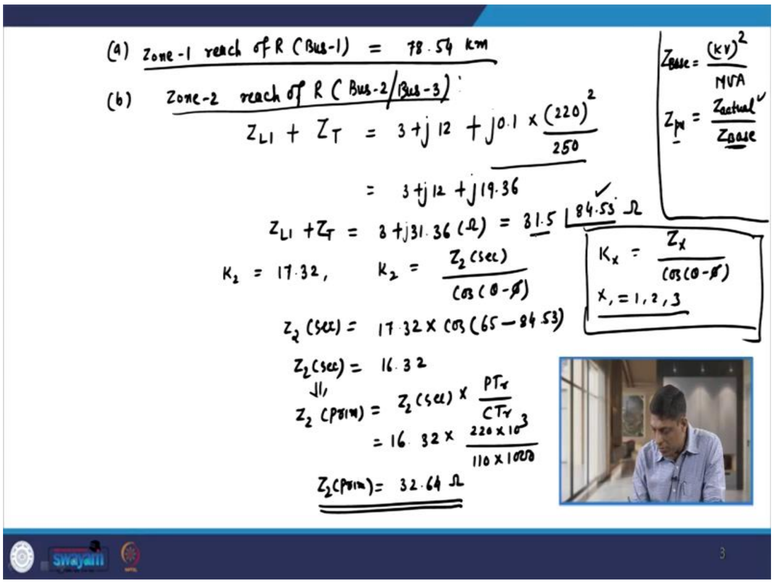

You can see it is 32.64 Ohm so, that is 32.64 minus ZL minus ZL1 plus ZT so, that comes out to be 31.5.

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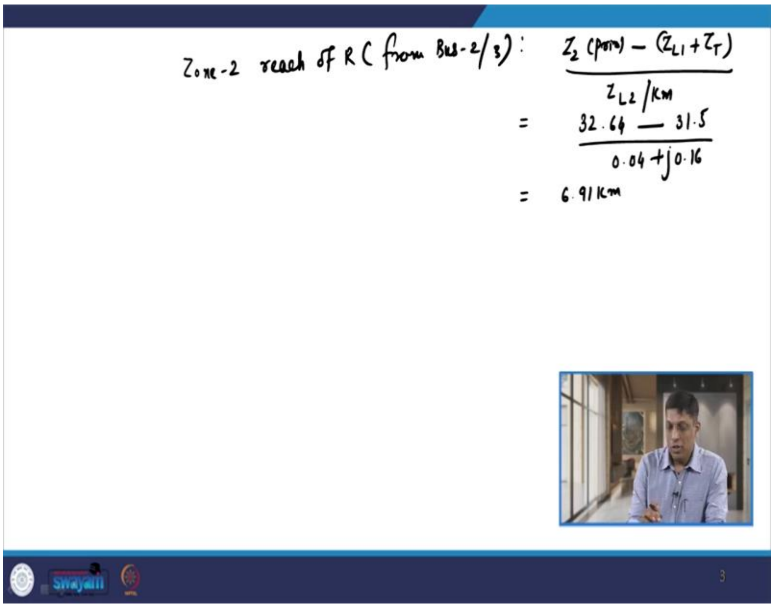

So, this is 31.5 divided by ZL2 per kilometre so, the value of ZL2 per kilometre is 0.04 plus j 0.16 so, if you just solve this you will get the value 6.91 kilometre.

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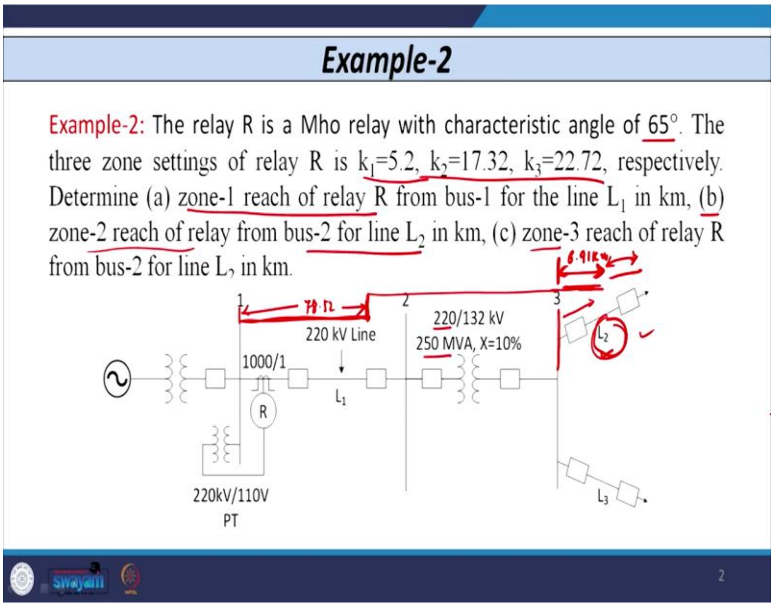

So, if I just look at this figure this value is 6.91 kilometre from this so, from this bus from this point the second zone reach of relay R for line L2 that is only 6.91 kilometre now, let us solve for zone 3 reach of relay R. So, now in order to solve the zone 3 reach for relay R again for same line length that is L2.

So, what we need to do is we need to consider the entire line length of L1 plus reactance of the transformer plus we need to connect the whole impedance of line L2 but, that we need to refer on 220 kV side where the relay is situated because, line L2 is on 132 kV side where as the relay R is situated on 220 kV side.

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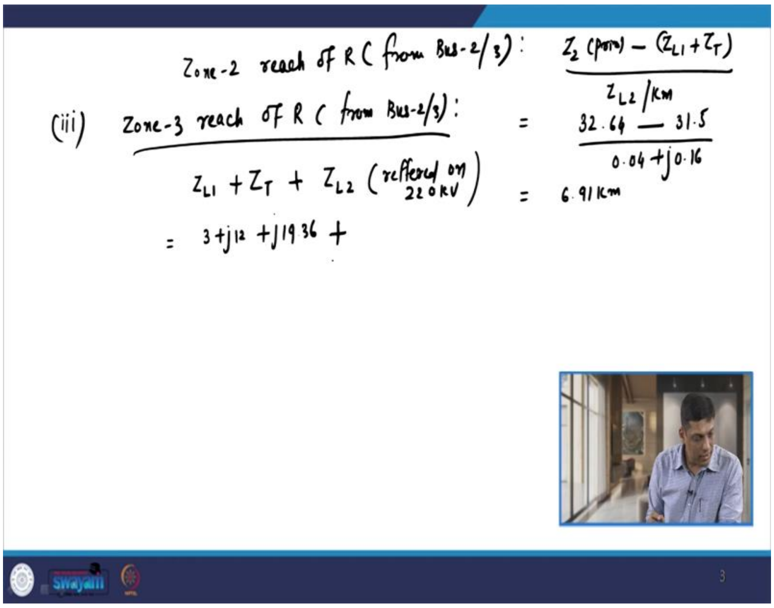

Let us start the third point that is zone 3 reach of relay R from bus 2 or 3 so, for this let us consider the ZL1 plus ZT plus additionally we need to consider ZL2 that is referred on 220 kV side so, that we need to calculate so, if I just add ZL1 that is 3 plus j12 plus ZT that is j 19.36 plus ZL2 so, the value of ZL2 that is 4 plus j 60.

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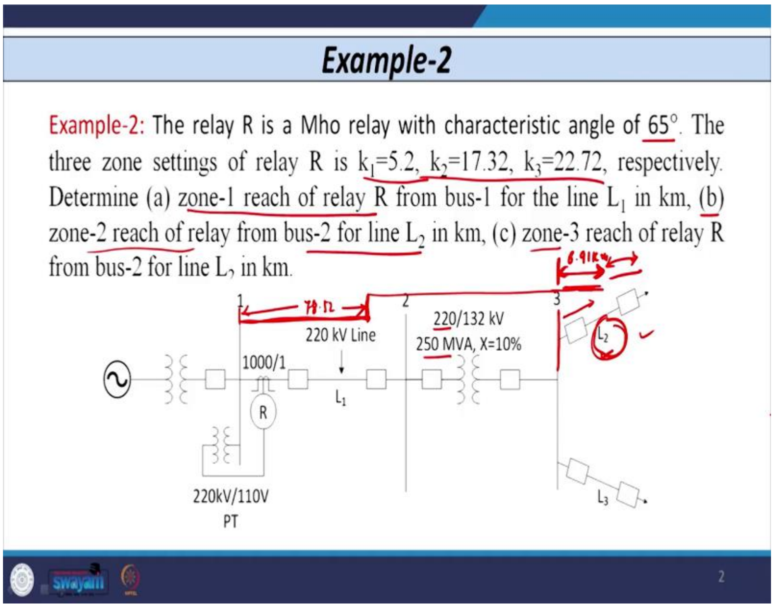

So, if you just look at the figure of this the value of this line impedance for L2 that is given as the 0.0175.

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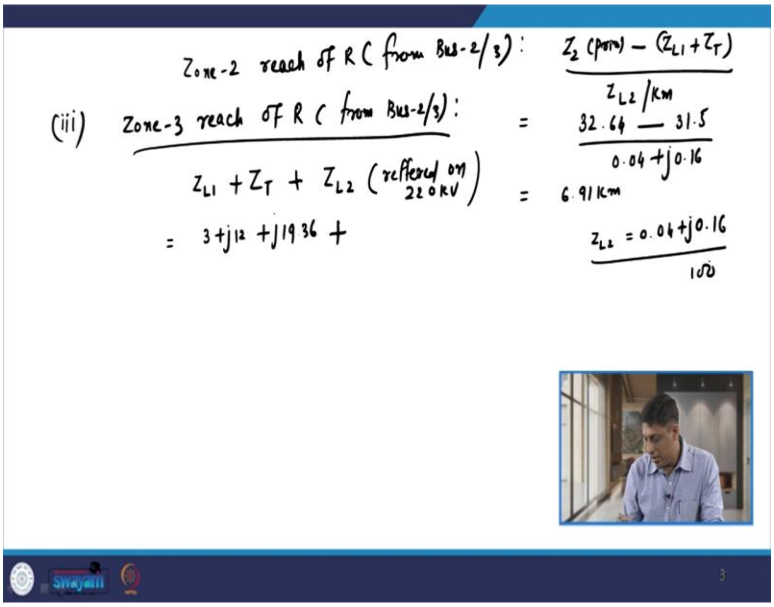

So, the value I am writing this ZL2 that is 0.04 plus j 0.16 and its line length that is 100.

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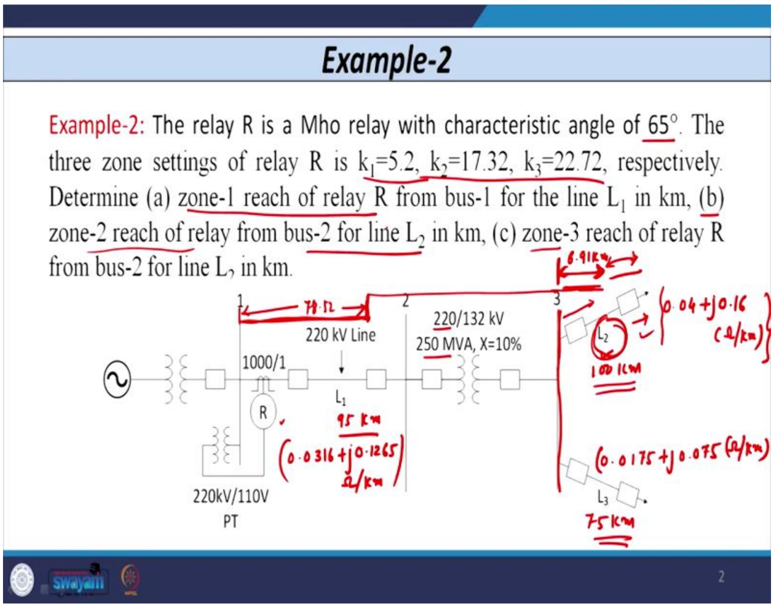

So, if I just write down here the value this value is 0.04 plus j 0.16 and the length of L2 that is 100 kilometre and same way for L3 if I write down its value is 0.0175 plus j 0.075 this is the impedance of this line on in Ohm per kilometre this value is in Ohm per kilometre and this is also in ohm per kilometre and the length of L3 that is 75 kilometre and the length of L1 that is also that is 95 kilometre and we have already know its impedance is 0.0316 plus j that is 0.1265 this is in Ohm per kilometre.

So, now one important point when you consider the zone 3 reach of relay R for line L2 it may possible that in actual field number of lines are emanating from this bus if there are more than two lines or three lines then you have to find out the zone 3 reach of relay R for that line whose line length is highest. So, in this case L2 and L3 the line length of L2 higher than L3 that is why we have considered L2 if line length of L3 is higher than L2 then we had to consider line L3. So, the value on this side is if I consider ZL2 so, ZL2 value if you look at the value that is 0.04 plus 0.j16 into the line length that is 100 so, it comes out to be 4 plus j16.

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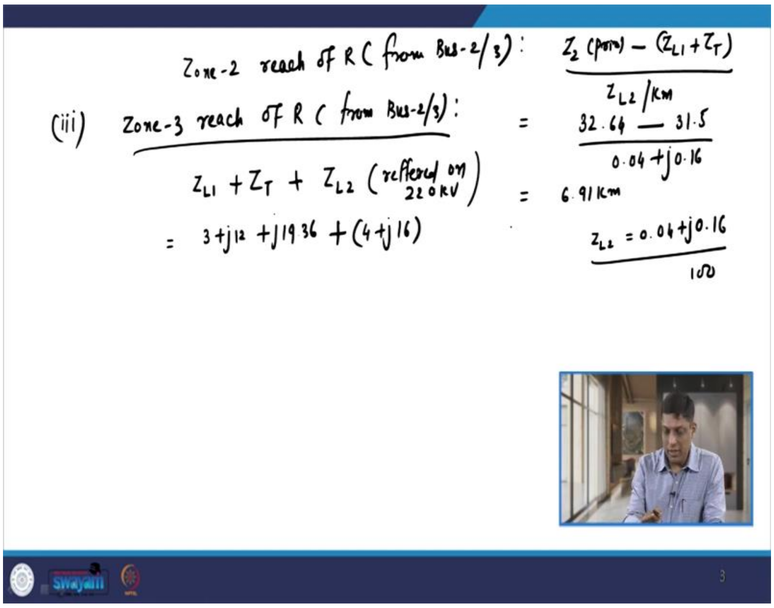

So, if I write down here it is 4 plus j16 and this value we need to referred on the 220 kV side

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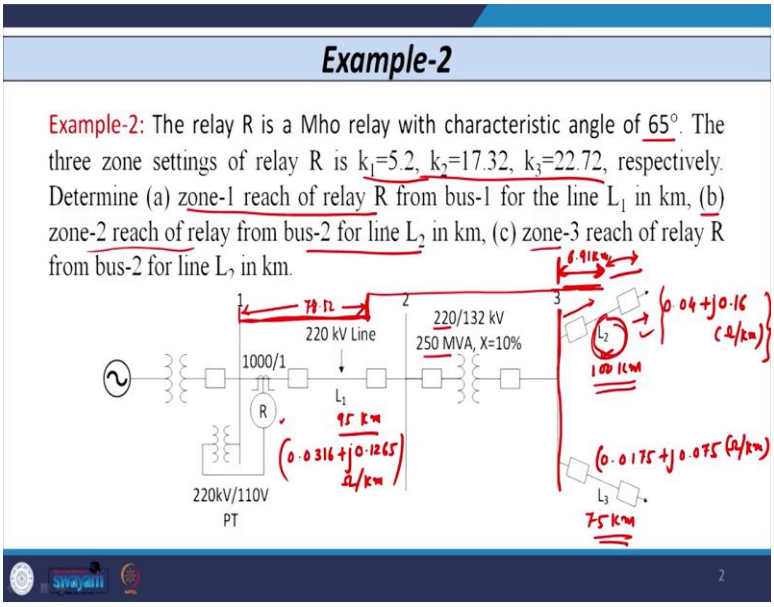

So, it is 220 by 132 whole square.

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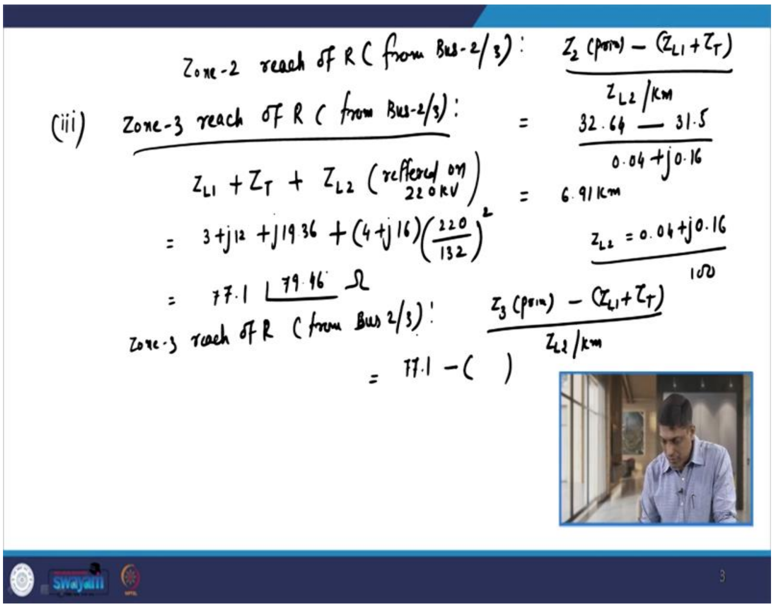

So, this comes out to be 220 by 132 whole square so, if you solve this you will get the final value of this that is 77.1 at an angle 79.46 degree Ohm so, this comes out this value so, if I need to find out now again zone 3 reach of relay R from bus 2 or 3 then what we need to do is we have the Z3 primary minus ZL1 plus ZT that is as it is and divide by we need to find out for line L2 so, it is ZL2 per kilometre so, this value Z3 primary we have already calculated 77.1 minus the ZL1 plus ZT that is the value is how much?

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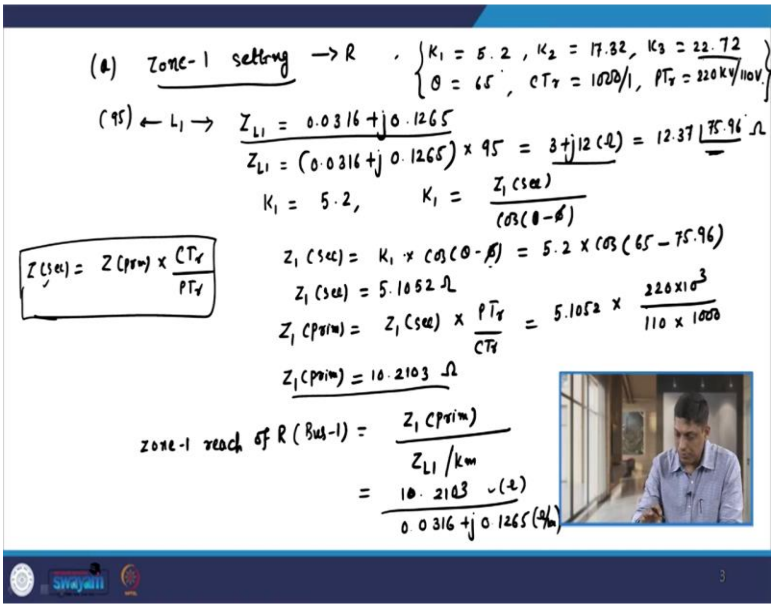

Just a minute. It is 31.5.

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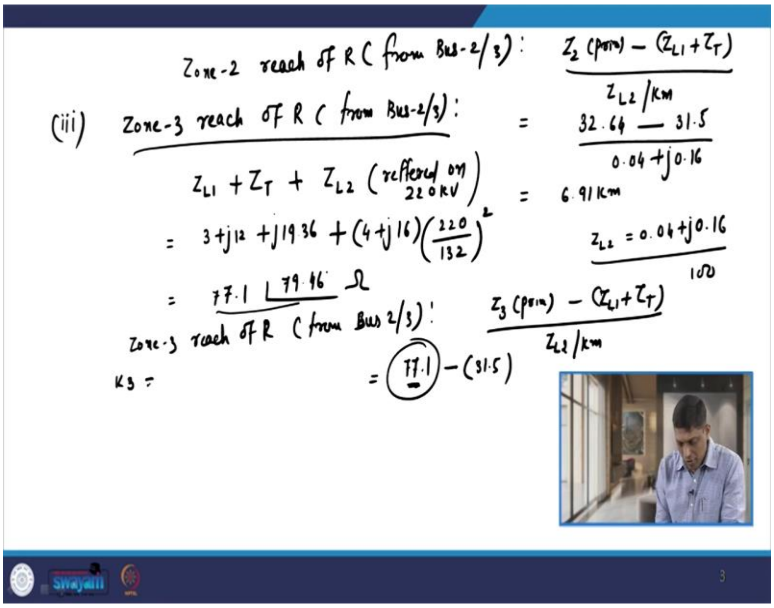

But this value is not there because, whatever value we have calculated here this value, this value is different why? Because, the k3 is given so, the value of k3 is given as what is the value?

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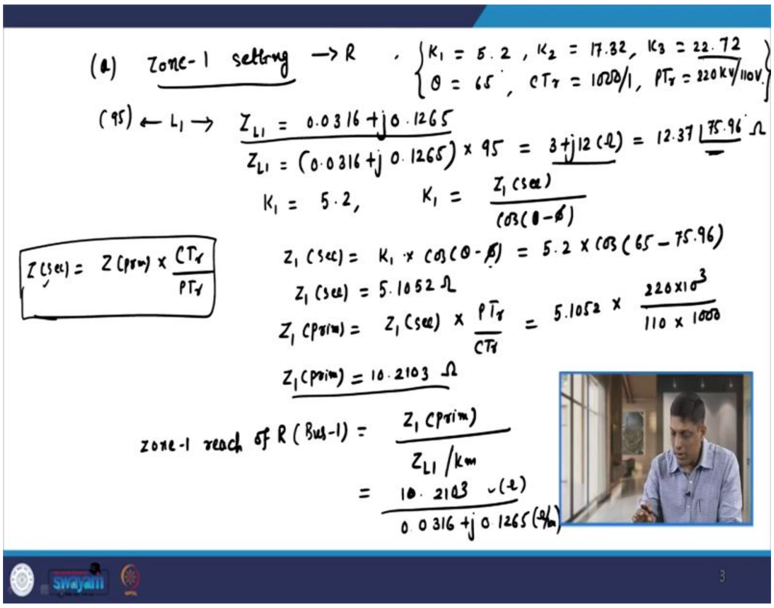

k3 is 22.72.

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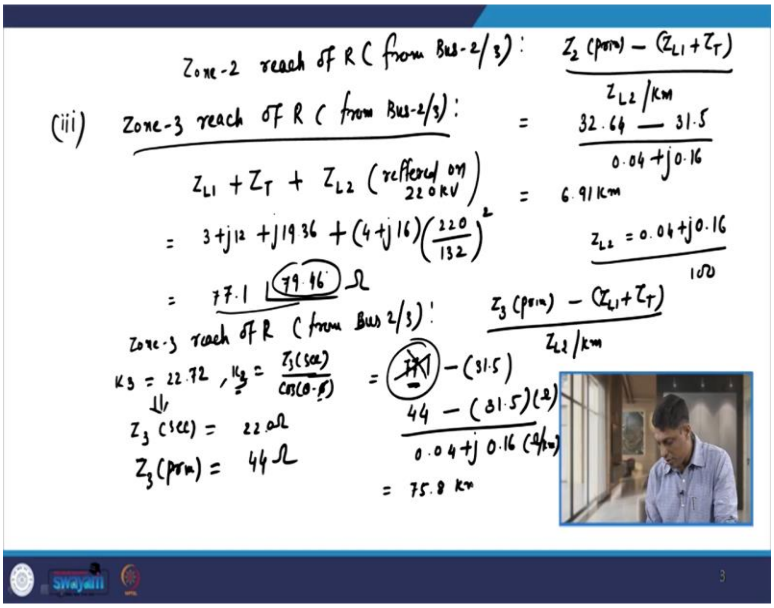

So, if I use that value 22.72 you can find out from this is Z3 secondary using this equation k2 is equal to Z3 secondary divided by cos of theta minus Phi, Phi you need to use that is this value and Theta is as it is 65. So, k3 is given so you can find out Z3 secondary that comes out to be 22 Ohm and if you find out based on this Z3 primary then that comes out to be 44 Ohm almost double because, of PT ratio and CT ratio.

So, the values Z3 primary you need to consider is not this but, that is 44 Ohm minus ZL1 plus ZT that is 31.5 divide ZL2 per kilometre so, that value is 0.04 plus j 0.16 so, this value is in Ohm per kilometre this value is in Ohm so, you will get the value in kilometres so, that comes out to be 75.8 kilometres.

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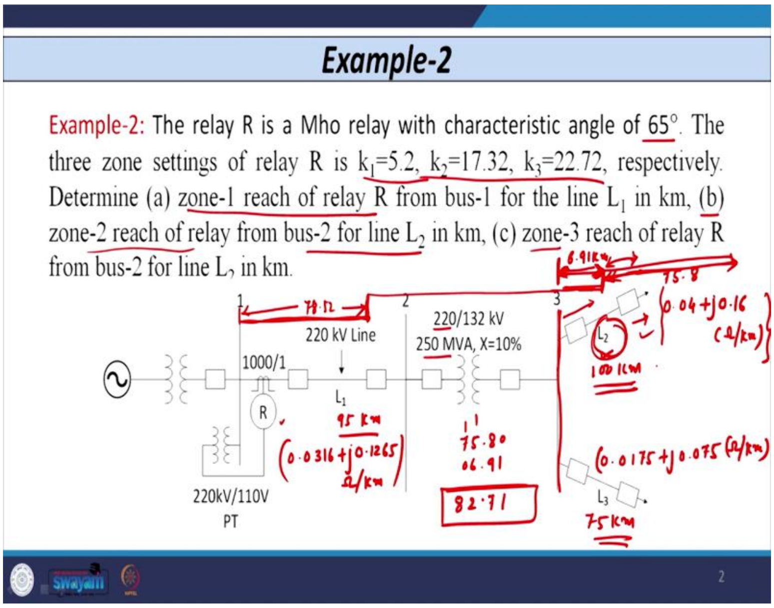

So, if I just refer the figure then the zone 3 reach of this relay R if I consider from here and it will go from this point to you see the length of this line L2 is 100 kilometre so, this will go from this point the 75.8 kilometres. So, this value is 75.8.

So, if I add this 2 that is 75.8 zone 3 reach of relay R for line L2 and 6.91 kilometre that is the zone2 reach of relay R from bus 3 for line L2 then this value comes out to be 82.71 kilometre if you add this and this and the total line length of L2 is 100 kilometres so, out of this the backup provided for line L2 that is 82.71 kilometre so, entire line L2 is not protected.

So, if primary fails for L2 than the some other line will take care but, only up to 82.71 kilometre not beyond that so 100 minus 82.71 kilometre that is again not protected means for that section line section line length section the backup is not available from other relays. So, that is the meaning of this what we have done we have solved one example so, when you solved the example of any distance relay.

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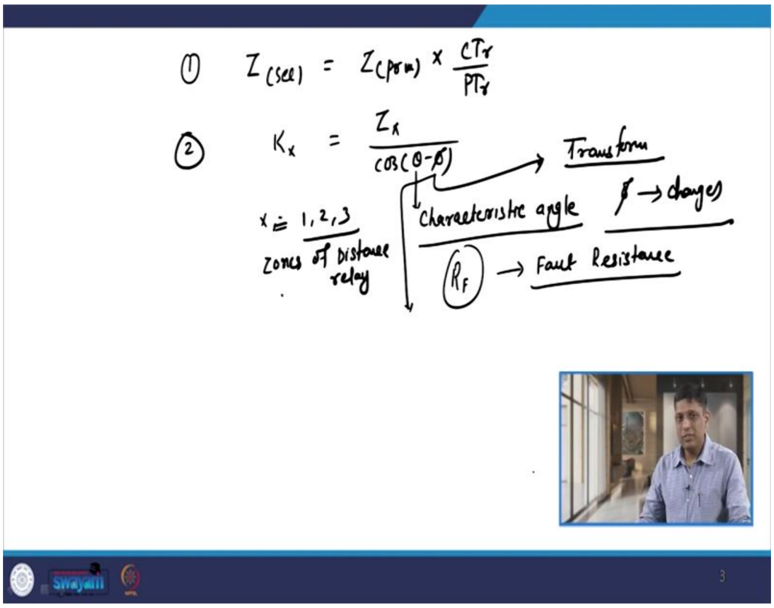

The first equation you need to remember that is this that is the Z secondary that is equal to Z primary into CT ratio oblique PT ratio and the second equation you need to remember that is the value of Kx which is equal to Zx divide by cos of Theta minus Phi this is Phi that changes Theta is your characteristic angle which is already given which depends on what type of characteristic you have used X stands for that is equal to 1 2 and 3 that indicates zones.

So, zones of distance relay so, it can be first zone second zone third zone so, k1, k2, k3 and Phi again that depends on whether if any transformer is involved in that whenever transformer is involved then the value of Phi again changes so, that you need to understand that whenever transformer is connected at any substation and when you add its reactants then the value of Phi always changes.

Again, the value of Phi also changes when you have or when you wish to include the value of RF that is known as Fault Resistance so, whenever you add Fault Resistance in the any line impedance then also the its value changes. So, how let us see how the Phi value of Phi changes so, for that we need to understand the one important point.

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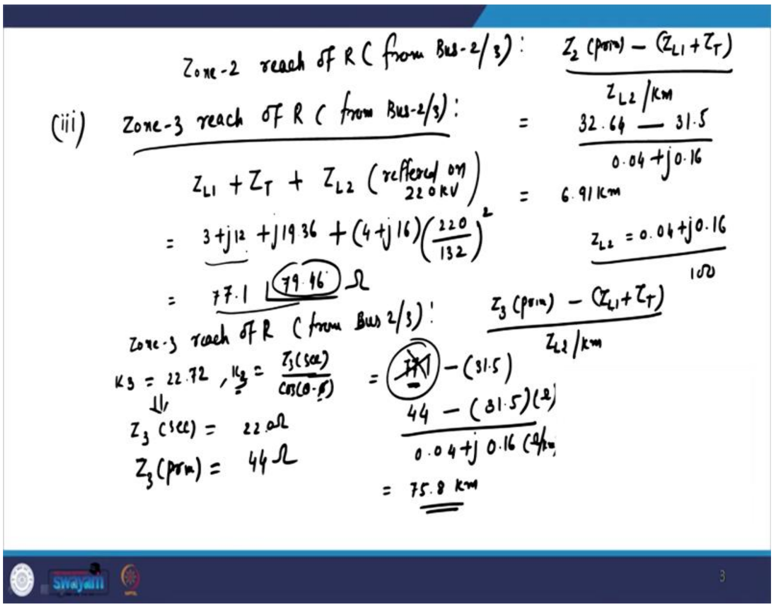

Just take small example say if I consider the same value say the ZL1 is 3 plus j12.

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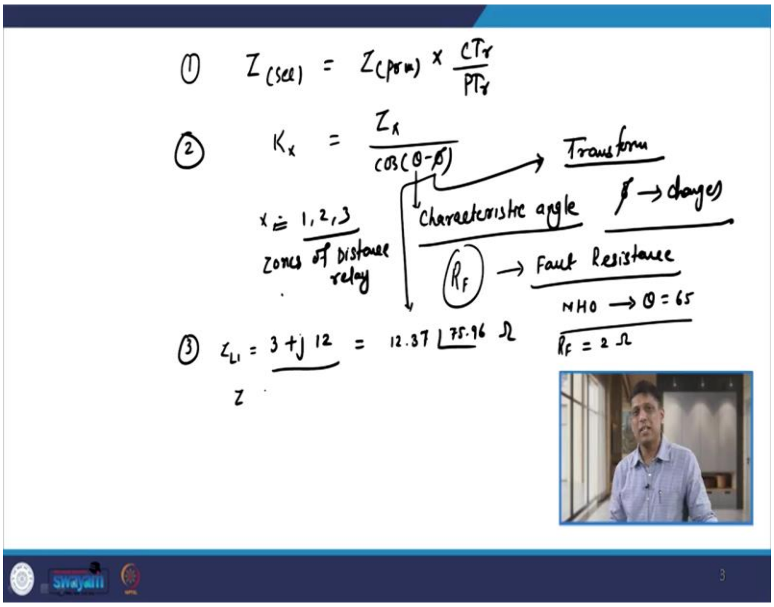

So, if I consider the same value say the line impedance is 3 plus j12 and if I write down in polar form then its value comes out to be roughly around 12.37 angle 75.96 so, it is 12.37 angle is roughly 75.96 Ohm now, if I just suppose specify that the characteristic let us say we are utilizing more characteristic with characteristic angle Theta is equal to 65 degree.

Now, if I specify that suppose this characteristic is also able to include or incorporate Fault Resistance RF that is equal to let us say 2 Ohm so, then for each and every case whenever, I this is your ZL1 so, whenever I calculate the value I need to again calculate the value of my primary impedance and whenever I need to include this primary impedance, we need to also consider the value of RF in that so, for that let us consider the one example.

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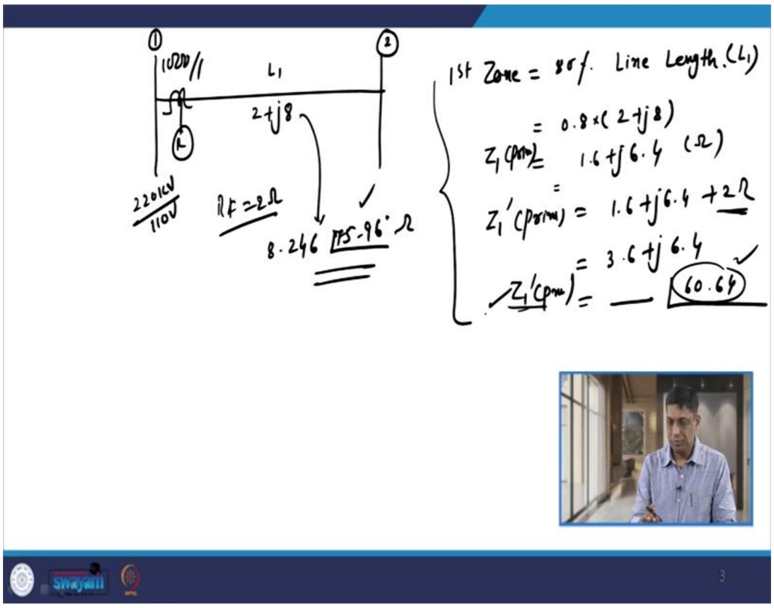

So, suppose the line length is given one line is connected between two bus and suppose so, let us consider just I am, I want to just show you what is the impact of RF so, let consider the line length is 2 plus j8 the relay is located here that is R CT ratio is 1000 by 1 and the PT ratio that is given as the value that is 220 kV by 110 volt.

Now, the first zone of this relay R that is 80 percent of line length so, this is line length let us say this is line L1 so, let us say this is L1 so, if I take this value 80 percent of this then it comes out to be 2 plus j8 so, that comes out to be the value that is the 1.6 plus j 6.4 this is in Ohm.

Now, if I say that this relay is capable to include RF is equal to 2 Ohm then you this is your Z1 primary off course this is primary value because, you have calculated it now, if I say this relay is capable to include the 2 Ohm of resistance then what should I do? I need to find out Z1 dash which is modified primary and that is equal to 1.6 plus j 6.4 Ohm plus 2 Ohm.

So, if I calculate earlier case if I just calculate the value what is the 2 plus j8 value then it is 8.246 the angle is 75.96 Ohm so, in our earlier case the angle is this when I add 2 Ohm Fault

Resistance the value comes out to be the 3.6 plus j6 point 4 so, if I convert it, you have some magnitude and the angle that comes out to be 60.64.

So, you need to consider this Z1 dash primary because, in that case this angle Phi reduce is so, here earlier case it was 75.96 now, it will be 60.64 so, the each and every time if you then you have to add this value in zone1 zone2 and zone3 and then you have to find out modified impedance so, Z1 dash primary Z2 dash primary Z3 dash primary then you can calculate the Z1 dash secondary Z2 dash secondary Z3 dash secondary and similarly you can find out k1 k2 and k3

So, this is just for knowledge that when any Fault Resistance is given that you need to include it in the calculation of impedances so, we have already considered two three examples on distance relay, so I stop here and we will continue our discussion on distance relay in the next class. Thank you.