Power System Protection And Switchgear
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Lecture-16
Protection of Transmission Lines Using Distance Relays-III.

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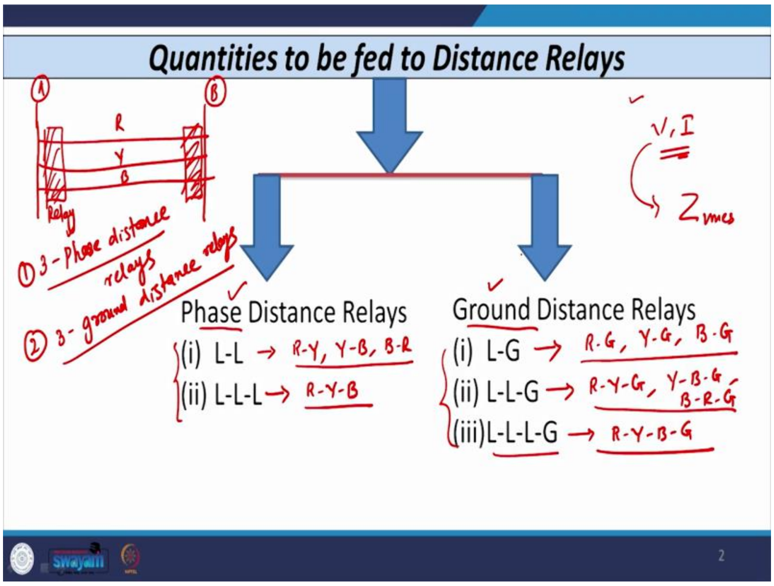

Okay, so, let us continue our discussion with the quantities to be fed to the distance. So, as I told you earlier that there are mainly two types of distance relay, one is known as the phase distance relay and the other is known as the ground distance relay. Now, when we consider the phase distance relay and ground distance relay, relay has to measure some value of impedance.

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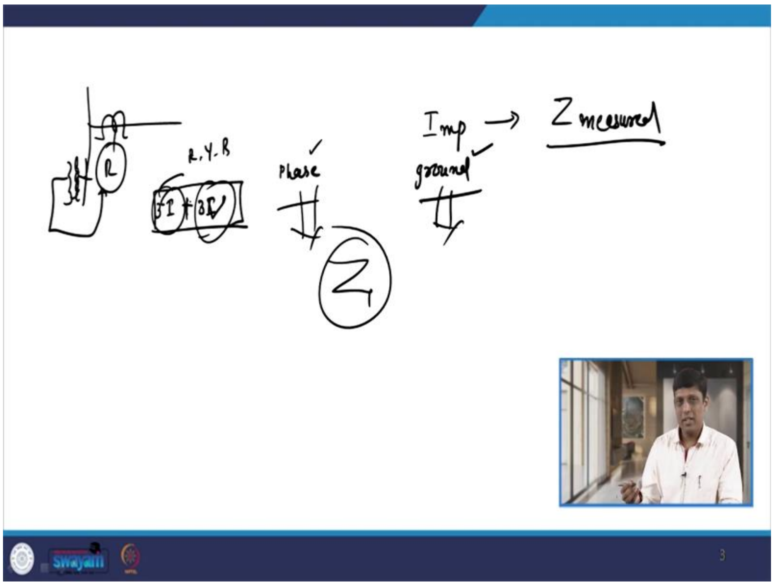

So, whenever the relay measures the impedance, that impedance is known as measured value of impedance that is measured by distance relay. Now, whenever we consider the phase distance relay and whenever we consider the ground distance relay, each and every time whatever quantity we feed to the relay, because whenever I as I told you, relay is connected somewhere here on secondary side and we are also giving the input from the PT secondary also to the relay. So, relay will receive 3 currents and 3 voltage.

So, this 3 currents that is for RYB and 3 voltage that is of each phase. So, it receives 3 current and 3 voltage. So, whenever we talk about either phase relay or ground distance relay, it has to measure only the positive sequence impedance from relaying point to the fault point. So, what value we give, means value means the value of current and value of voltage to the distance relay, so that, it for each and every type of fault, it measures the correct value of impedance from relaying point to the fault point.

So, our next discussion that is related to the what value or what quantity we fed or provide to the distance relay. Obviously, quantity means voltage and current, such that it always measures the positive sequence impedance or the correct value of impedance from relaying point to the fault point.

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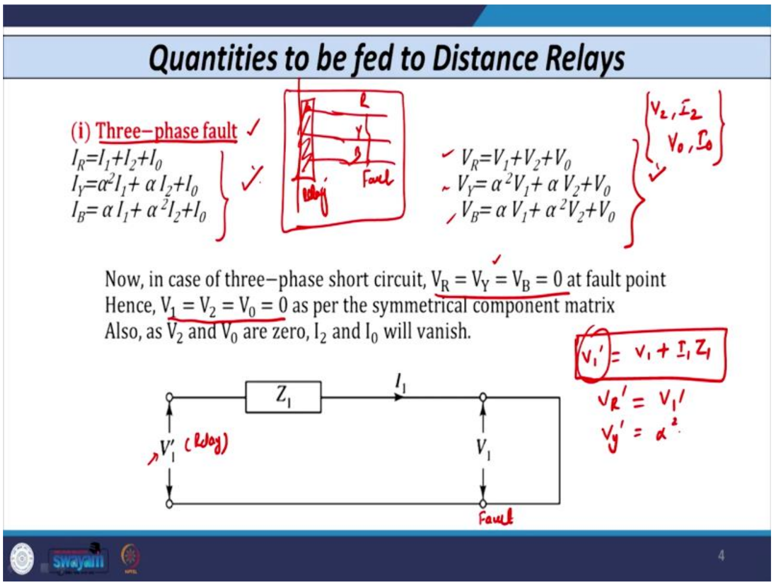

So, let us start our discussion with one by one each type of fault. So, let us consider first the three phase fault, and let us see what quantity we need to fed to the distance relay. Before we start our discussion, the two equations are very important that is related to the sequence components of currents and voltages. So, we know that the R phase, Y phase and B phase are the 3 phases. So, IR is equal to I1 plus I2 plus I0 whereas IY is equal to a square or alpha square I1 plus alpha I2 plus I0 and similarly, Ib is equal to alpha I1 plus alpha square I2 plus I0.

Same way, we have the VR, V1 plus V2 plus V0, VY alpha square V1 plus alpha V2 plus V0, and VB is equal to alpha V1 plus alpha square V2 plus V0. So, these three are the fundamental equations which we will utilize for derivation of all types of faults. So, now, let us start with three phase fault. Now, whenever three phase fault occurs, if I assume three conductors and whenever three phase fault occurs, let us say this is RYB phase.

The relay is located somewhere here and this is the fault point. Relay is located in this bus there is a bus here and this is your relay. So, whenever fault occurs the three voltages R phase, Y phase and B phase all are 0. So, VR is equal to VY is equal to VB equal to 0 at the fault point. If this is the, this is true, then the all the 3 sequence voltages V1, V2, V0 that is also equal and 0. So, with this background and moreover whenever the triple line fault occurs, it is basically a symmetrical fault or balanced fault.

So, it contains only positive sequence voltage and current, it does not contain negative sequence voltage and current. So, V2 and I2 that is also not there, 0 and similarly V0 and I0 this is also not there, when triple line fault occurs. So, if I just draw the circuit based on this, this diagram, then we have this voltage, that is voltage at the relaying point. So this is the voltage available at the relaying point, Z1 is the impedance of the line from this point to the fault point, this is your fault point.

And V1 is the voltage at the fault point. So, voltage available at the relaying point V1 dash that is nothing but the V1 plus I1 into Z1 as only positive sequence current exist in case of triple line fault. What is the each phase voltage available or given to the relay, that is VR dash VY dash and VB dash. So, that we can find out using these three equation, VR dash, that is equal to what, that is equal to V1 dash this value, that is this value.

And V1 dash is nothing but V1 plus I1 Z1. Similarly, what is VY dash VY dash is nothing but alpha square V1 dash. And similarly VB dash, that is nothing but the alpha V1 dash. So, we have the three voltages at the relaying point VR, VY, VB, instead of that we have VR dash, VY dash, VB dash because whenever fault occurs the voltage slightly reduces.

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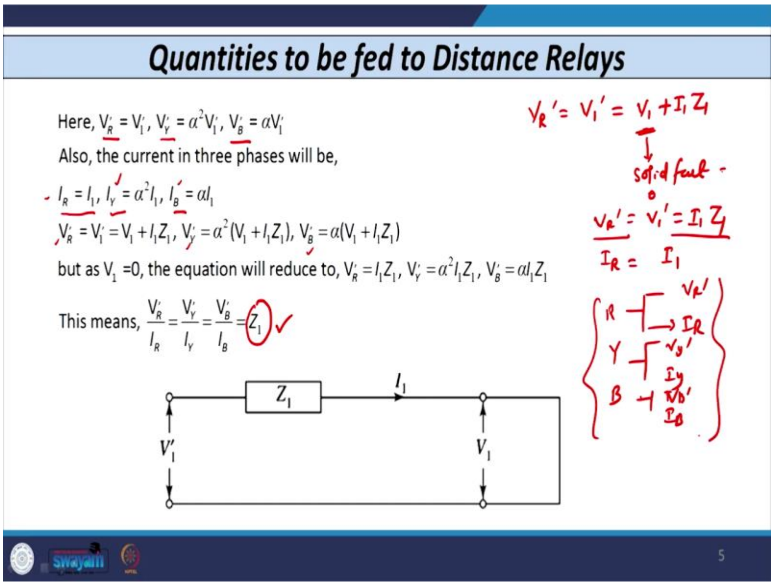

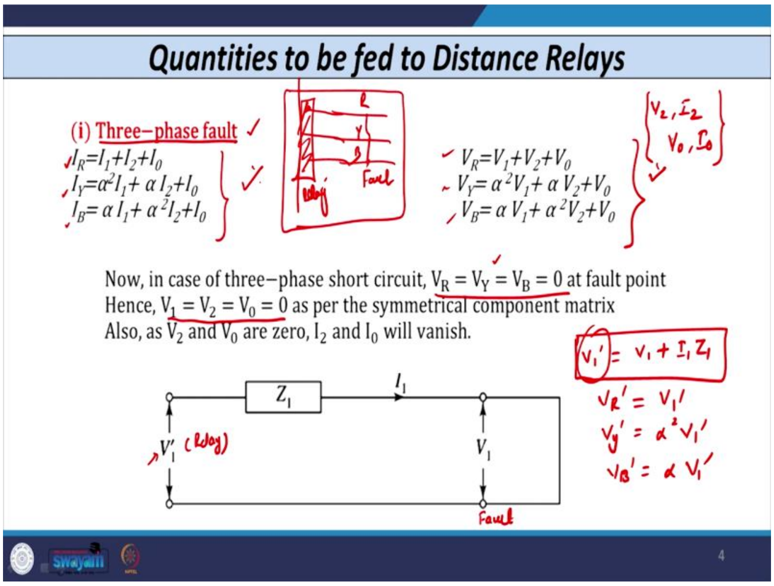

So, as I told you the three voltages VR dash VY dash and VB dash, that can be obtained. So, now we need the three currents IR, IY and IB. So, IR that is equal to I1 because in earlier case if I consider this equation then IR is equal to I1 because I2 and I0 both are 0. Similarly, IY is equal to alpha square I1, again I2 and I0 is 0, and similarly IB is equal to alpha I1. So we have IR, we have IY and we have IB.

So, with this background, now we have VR dash and we have IR, we have VY dash and we have IY and we have VB dash and we have IB. So, if I take the ratio of VR dash by IR, so, our VR dash is V1 dash that is nothing but, so, if I just write down, VR dash that is equal to V1 dash, which is equal to V1 plus I1 Z1. Now, this V1 is a 0 at, voltage at the fault point, that is 0 if we assume it is a solid fault. So, this is 0, this part is 0.

So, we have VR dash, that is equal to V1 dash that is equal to I1 Z1. And what is IR, IR is equal to again we have the only I1. So, if I take ratio of this two, then we have I1 Z1 divide by I1 So, ultimately we obtain the value of Z1, which is the impedance VZ or seen by the relay from relaying point to the fault point. Same way for other two phases. Now, we have three phases RYB.

So, for R phase we are giving the voltage VR dash and IR to the relay, Y phase similarly VY dash and IY, and B phase we have VB dash and IB. So, if I give this quantity to the relay, if three phase fault occurs then relay will measure correct value of impedance that is the Z1. But again we have to ensure that if line to line fault occurs and if we give same quantity, then also relay has to measure the correct value of impedance that is Z1. So, let us discuss the same thing for line to line fault or phase to phase fault.

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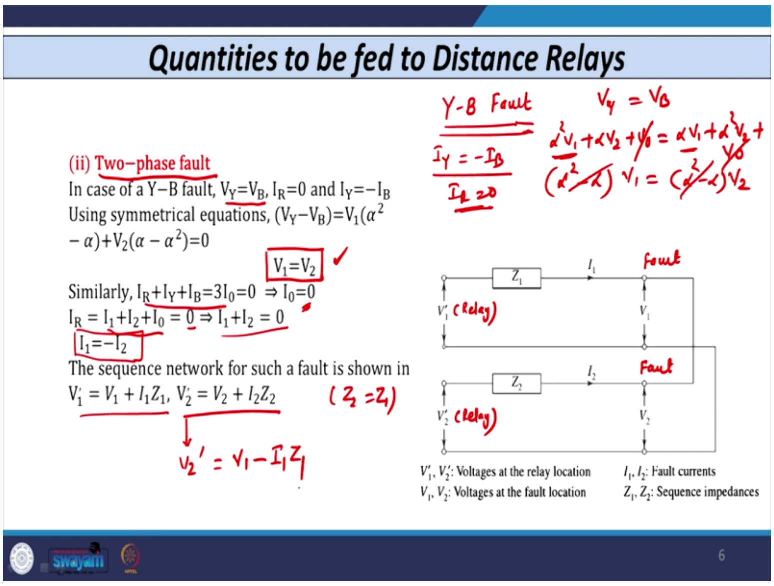

So, if I consider two phase fault, then we know that, let us consider the YB fault for example. So, if I consider the YB fault, then we know that in case of YB fault the voltages of Y phase and B phase are same. So, VY is equal to VB. So, if I just put VY that is equal to VB and if I put the equation of VY here, what is the equation of VY, equation of VY is this equation, VY is equal to alpha square V1 plus alpha V2 plus V0.

So, if I put this value here, that is alpha square V1 plus alpha V2 plus V0 that is equal to VB, what is VB, that is alpha V1 plus alpha square V2 plus V0. And if I equate it V0 and V0 gets cancelled. So, I have finally, the equation of this value V1 and this. So, we have alpha square minus alpha into V1 that is equal to on this side alpha square minus alpha that is equal toVv2. So, we have finally V1 that is equal to V2.

So, consider phase to phase fault, say YB fault, then V1 is equal to V2, that means, the sequence two sequence voltage is positive and negative, both are equal at the fault point. Similar way the, if YB fault occurs then the R phase current is 0 because its magnitude is very small compared to the Y phase and B phase. And IY, Y phase current that is equal to minus IB, this is also true and IR is equal to also 0.

So if this is the case then we have the IR plus IY plus IB that is equal to 3I0, so I0 that is equal to 0. That means if any phase to phase fault occurs, the 0 sequence current does not exist. If 0 sequence current does not exist, then (V) if I0 is 0, then V0 is also 0. So as I told you, IR is 0. So, if I put in the equation IR is equal to I1 plus I2 plus I0, so then I1 plus I2 plus I0 equal to 0. As I0 is already 0, so I1 plus I2 is equal to 0. So we have I1 that is equal to minus I2.

So if I draw the sequence network, you can see that for at the fault point, this is the fault point. At the fault point, this is also fault point, we have V1 is equal to V2 positive sequence voltage is equal to negative sequence voltage. And we have I1 that is equal to minus I2. So, that is also correct in this case. So, what is V1 dash voltage, this is the voltage at the relaying point. So, V1 dash is equal to again V1 plus I1 Z1, voltage drop across this. Similarly, V2 dash, that is equal to voltage across the relaying point.

So, that is equal to V2 plus I2 Z2. Now, as I told you V1 is equal to V2. So, this V2 dash that is equal to, V2 is equal to V1 plus I2 is equal to what minus I1. So, minus I1 and Z2, we know that for transmission line positive sequence impedance is equal to negative sequence impedance, so Z2 is equal to Z1. So, we can easily write down this equation as like this. So, V1 dash is equal to V1 plus I1 Z1 and V2 dash that is equal to V1 minus I1 Z1.

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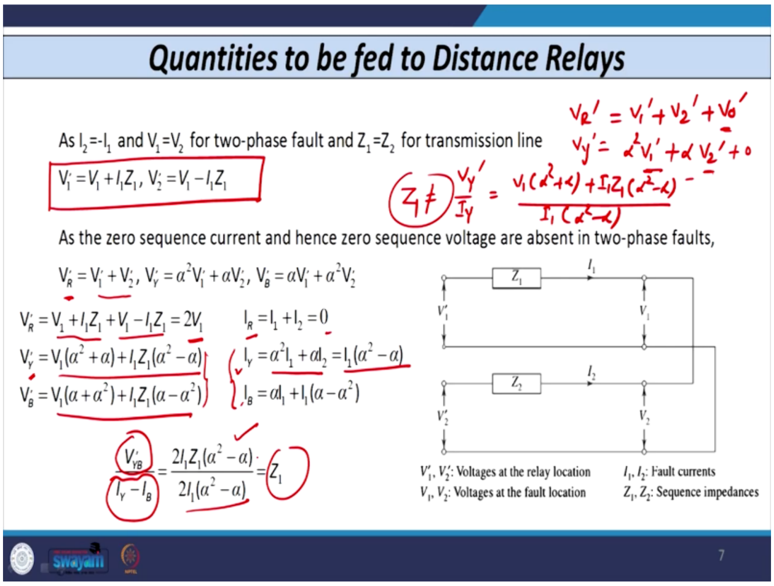

So, if I use these two equations that is shown here, then we can easily find out what is the voltage given to the relay, that is each phase R phase, Y phase B phase. So, let us find out what is the voltage given for R phase. So, that is nothing but the VR dash. So, VR dash is given here, what is VR dash, what is VR, VR is equal to V1 plus V2 plus V0. So, VR dash that is equal to what V1 dash plus V2 dash plus V0 dash. So, we know that V0 is 0 because I0 is 0. So, we have VR dash that is equal to V1 dash plus V2 dash.

And you know V1 dash is equal to V1 plus I1 Z1. So, you can put this value here. So, VR dash is equal to V1 plus I1 Z1, plus V2 dash that is equal to V1 minus I1 Z1. So, you have VR dash is equal to 2 V1. IR is 0 because we have considered fault in Y and B phase, so IR is 0. So, IR is 0 here. Same way for Y phase if I consider then Y phase VY dash is equal to what? So, VY dash that is equal to alpha square V1 dash plus alpha V2 dash plus V0 dash V0 dash is 0.

So, we have here VY dash is equal to what is that alpha square V1 dash. So, V1 dash is V1 plus I1 Z1. So, you can put it here. Similarly, you have alpha V2 dash is equal to V1 minus I1 Z1. So, if you put here the value of V1 dash and V2 dash, then you have the final equation like this, that is V1 alpha square plus alpha plus I1 Z1 alpha square minus alpha. Same way you can find out this value, VB dash because VY is equal to VB.

So, this is also same, only the difference is this value. What about IY and IB? So, if I consider IY, then IY is equal to, we know that the equation of IR, IR is equal to I1 plus I2 plus I0, IY is equal to alpha square I1 plus alpha I2 plus I0. So, IY is equal to alpha square I1 plus alpha I2. Now, we know that the here the value is I2 is equal to minus I1.

So, if I put it here I2 is equal to minus I1 and take I1 common then we have I1 into alpha square minus alpha that is equal to IY. So, if I take the ratio of VY dash divide by IY this value, VY dash divided by IY then you have VY dash, that is equal to this value V1 into alpha square plus alpha plus I1 Z1 into alpha square minus alpha divided by, what is IY, IY is equal to I1 into alpha square minus alpha.

So, if I take this ratio, I am not going to get the value of Z1. So, that means if I give or if I fed same quantity which I fed earlier for three phase fault, in that case even though it gives or measures correct value of impedance that is Z1, positive sequence impedance from relaying point to the fault point, same quantity if I fed for two phase or phase to phase fault, then we do not get the value that is known as the positive sequence impedance.

So, obviously, we need to feed some other quantity, such that for either phase to phase or triple line fault, it correctly, relay will correctly measure the correct value of positive sequence impedance from relaying point to the fault point. So, we have to give the quantity that is, this is the voltage VYB dash and we have to give the current that is IY minus IB.

So, if I give this value, then we know that VYB dash that is equal to VY dash minus VB dash. So, you have to take the difference of this two, if you take it, you will have this value. And if I take the difference of IY minus IB this two difference then you will get the value that is this value. And if you take ratio, then you will get the value Z1.

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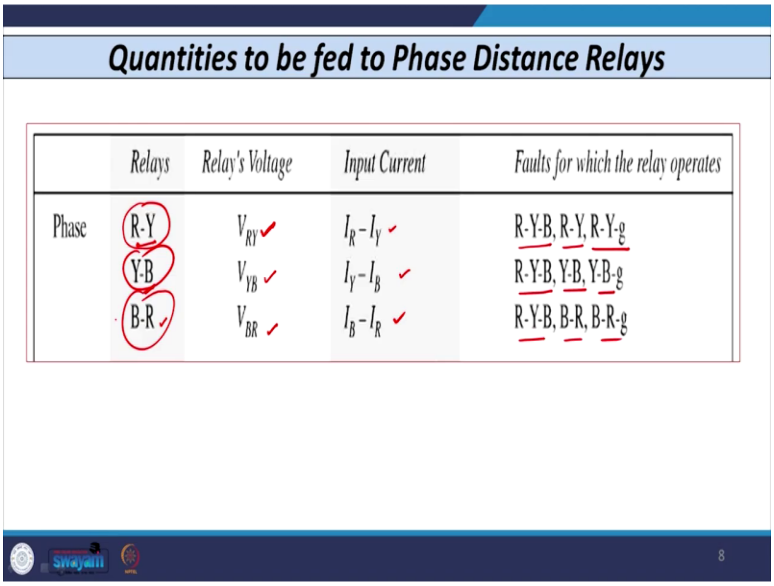

So, if I fed the quantity to the phase relay unit for RY phase, so, if I fed the voltage that is VRY and current that is IR minus IB, then relay will measure correct value of impedance that is Z1 from relaying point to the fault point. So, similarly for YB fault, we have to give VYB as the voltage and IY minus IB that is the current. And similarly for BR phase we have to give VBR voltage and IB minus IR that is the current.

So, you can see that if RY fault occurs, then R phase and Y phase voltage we are giving and same R phase and Y phase current of difference we are providing or giving to the relay. So, phase (relay), phase distance relays, if I consider then that is RYB triple line fault, RY fault, RYG fault this unit that is phase distance unit operates. Similarly, for RYB fault, YB and YBG fault, YB unit will operate and RYB, BR, BRG fault BR unit will operate. So, we need three phase distance relays to protect or against the double line and triple line fault.

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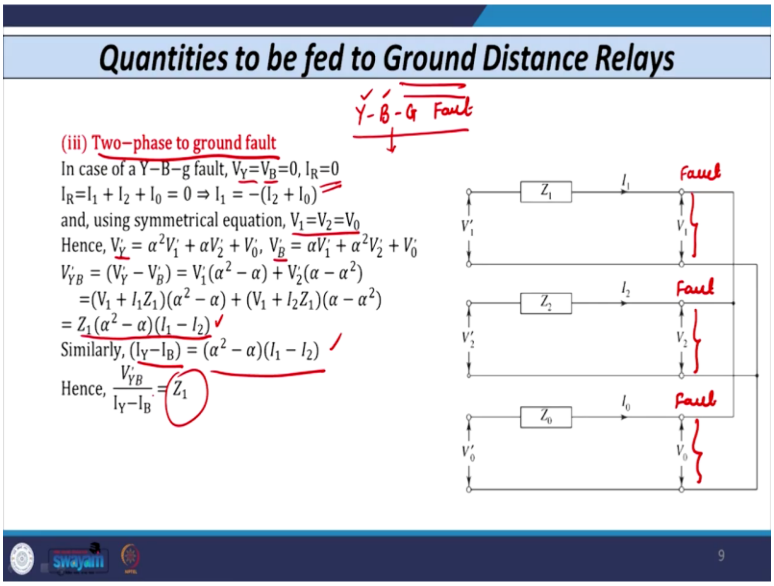

So now, let us consider the ground distance relay. So, if I consider the ground distance relay, which is meant for line to ground fault, double line to ground fault or triple line to ground fault. So, in that case let us consider two different faults, two phase to ground and single line to ground. So, let us consider two phase to ground fault. So, let us consider the same fault that is YB ground fault.

Earlier we have consider YB fault when we consider phase to phase fault here we consider YB ground fault. So, again VY that is equal to VB in this case also. So, as we have VY is equal to VB, so we have V1 is equal to V2 also. There is no, R phase is not involved so, IR is equal to 0, in this case also. So, as IR is equal to I1 plus I2 plus I0 and IR is 0, so, we have I1 that is equal to minus of I2 plus I0. And we do have V1, V2 and V0 all the 3 are equal. So, all the three sequence voltages positive, negative and 0 sequence, at the fault point are equal.

So, this is the fault point. So, here at the fault point all the three voltages V1 that is this value, V2 and V0 all the three are equal. Now, if I consider VY dash, then VY dash and VB dash equation, because Y and V both phases are involved. So, we have VY dash is equal to alpha square V1 plus alpha V2 plus V0 dash and similarly, VB dash is equal to alpha V1 dash alpha square V2 dash and V0 dash.

So, if I calculate VYB dash, taking difference of this VY dash and VB dash and if I solve it then I will get this value finally, that is Z1 into alpha square minus alpha into I1 minus I2. Similarly, if I give IY minus IB then the value we have that is this and if I take ratio of this two, then definitely we will get the value that is Z1 which is positive sequence impedance. So, relay will measure correct value of impedance.

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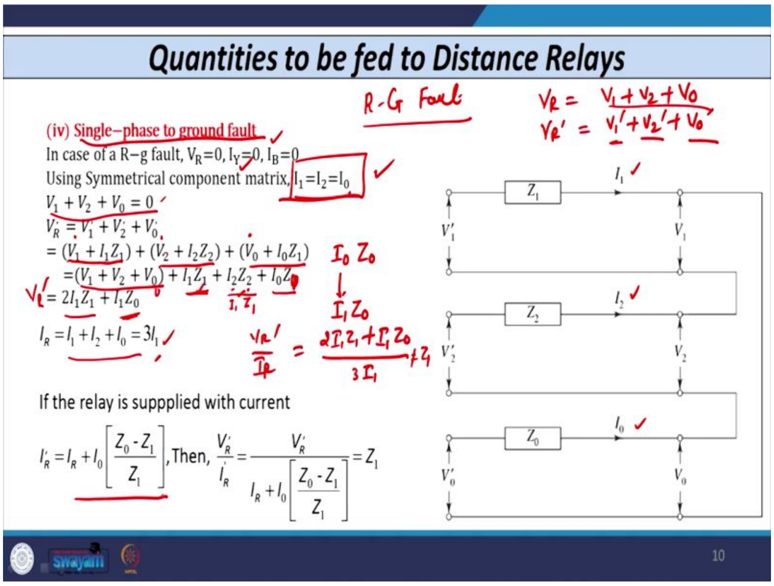

Same way if I consider, single line to ground fault, let us consider R to ground fault. So, then what quantity we need to fed to the distance relay? Now, as we know whenever single line to ground fault occurs, all the three sequence currents positive, negative and 0 sequence current are equal, the sequence network in case of single line to ground fault are connected in series. So, this 3 values I1, I2 and I0 all are equal that you can see from here, I1, I2 and I0 that all are equal.

Now, as fault is RG fault, so the other 2 phases Y and B phase the current is very small compared to R phase. So, IY and IB both are 0 that we can assume. And as the fault is in R phase, so VR that phase voltage that is also 0. So, as we know that the V1 plus V2 plus V0 is equal to 0. So, VR dash voltage at the relaying point that is given by V1 plus V2 dash plus V0 dash. So, this we have obtained VR is equal to V1 plus V2 plus V0.

So, the VR dash that is the voltage at the relaying point that is given by V1 dash plus V2 dash plus V0 dash. Now what is V1 dash, V1 dash is nothing but that is equal to V1 plus I1 Z1, so this value, V2 dash that is equal to V2 plus I2 Z2 and V0 dash that is nothing but the V0 plus I0 Z0. Now we know that the value of this I1, I2 and I0 all are equal, so we can put the value I2 is equal to I1 so we can put it here I1, Z2 is equal to also Z1.

Similarly, we can put it here, the I0 that is equal to I1 also we can put. So if I add this to V1 plus V2 plus V0 this value, this value and this value, we will have this plus we have I1 Z1, this value, I2 Z2 And I0 Z0. So, if I consider this value V1 plus V2 plus V0 that is 0 because we have already considered it, it is 0, because VR, R phase voltage is 0. So, VR is equal to V1 plus V2 plus V0. So, this value is 0. So, this we can put as 0.

I1 Z1, that is there, I2 Z2 now, I1 is equal to I2 is equal to I0. So, this I2 can, we can replace with I1. Z2 is equal to Z1 because positive sequence impedance is equal to negative sequence impedance. So, this is nothing but your I1 and this is nothing but your Z1. So this 2 becomes 2 I1 Z1 and this is nothing but your I0 Z0, this is this term is I0 Z0. So I0 that is equal to I1, so it is basically I1 Z0, so that term that is here. So this we have to give to the relay that is VR dash. Now what is IR, IR is equal to I1 plus I2 plus I0, that is 3 I1 because all the 3 values are equal.

So, we can put we have 3 I1. So, if I give this value to the relay that is VR dash by IR dash, this value, VR dash by IR. So, VR dash is 2 I1 Z1 plus I1 Z0 and IR that is equal to 3 I1 then we do not get the value Z1. So, obviously, we have to give some another, we have to feed some another quantity. So, if I feed the relay with this quantity that is IR plus I0 into Z0 minus Z1 upon Z1, then relay will measure correct value of impedance. Let us see how relay will measure the correct value of impedance. So for that we are providing the relay VR dash is equal to 2 I1 Z1 plus I1 Z0.

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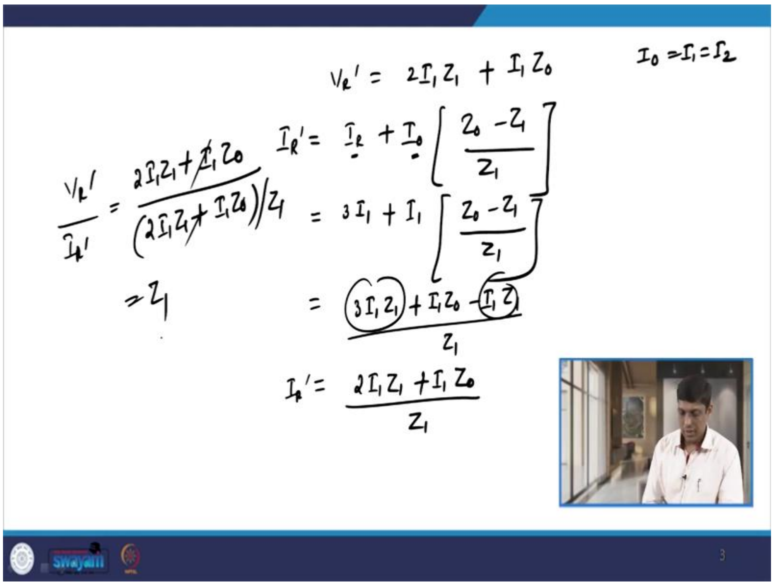

So if I consider, what is VR dash, VR dash that is equal to 2 I1 Z1 plus I1 into Z0. And what is, what IR we are providing, we are providing the value of IR that is, to the R phase relay IR dash is equal to IR plus I0. So, we provide IR dash that is equal to IR plus I0 into Z0 minus

Z1 upon Z1. So, if I give this value, let us see how VR dash by IR dash or IR that will give Z1. So, here IR, what is IR we can say that IR is equal to 3 I1. So, we can definitely write down this value, that is 3 I1 plus, what is I0, I0 is equal to I1, because I0 is equal to I1 is equal to I2.

So, we can write this as I1 and we have Z0 minus Z1 upon Z1. So, we have the 3 I1 Z1 plus we have I1 Z0 minus I1 Z1 divided by Z1. So, we have this value and this value, so 2 I1 Z1 plus I1 Z0 by Z1. So this is the current we need to give to the relay. So if I take the ratio of VR dash by IR dash, VR dash is 2 I1 Z1 plus I1 Z0 and IR dash that is equal to 2 I1 Z1 plus I1 Z0 divide by Z1. So then we will have the value that is Z1. So if I give this quantity to the relay, then relay will measure correct value of impedance.

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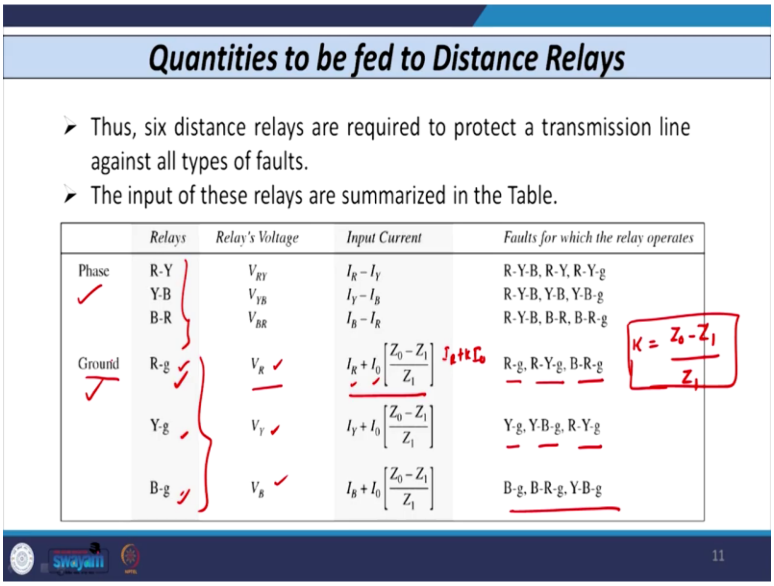

So let us see if I consider the ground distance relay. Then for R phase, we have to give the R phase voltage and we have to give the current as IR plus I0 into Z0 minus Z1 upon Z1. So, this Z0 minus Z1 upon Z1, that is known as the zero sequence compensation factor and it is given by the term k. So, k is nothing but Z0 minus Z1 upon Z1. So, you can also replace this value with k. So, we have to give IR plus k I0 that is the input to the R phase, Y phase we have to give Y phase voltage and IY plus k I0 and B phase we have to give B phase voltage and IB plus k I0.

So, if I give this input VR and this current that is IR plus k I0, then the unit operate that is RG, RYG fault and BRG fault, this unit will operate. Similarly for YG, YBG and YRG, Y phase unit will operate and same way for other three types of fault B phase unit will operate.

So, that means, three units are required for phase distance relay and three units are required for ground distance relays. So, total six units are required to protect one single circuit transmission line at particular bus.

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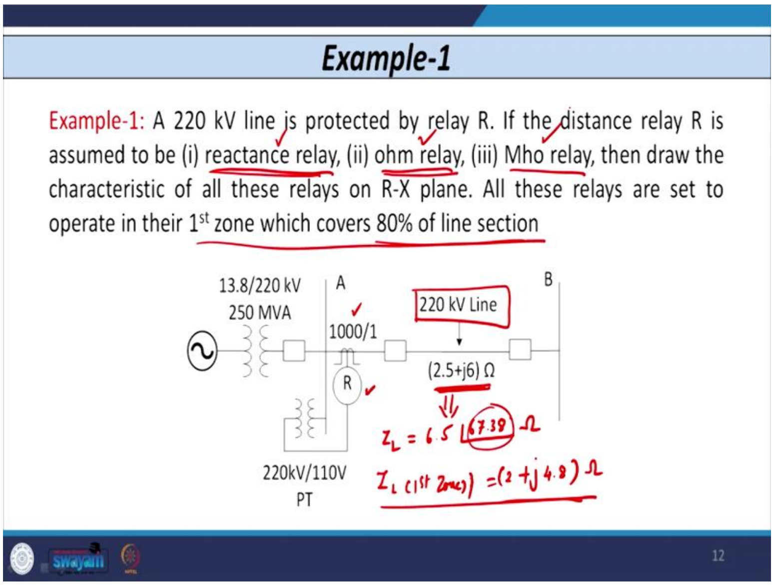

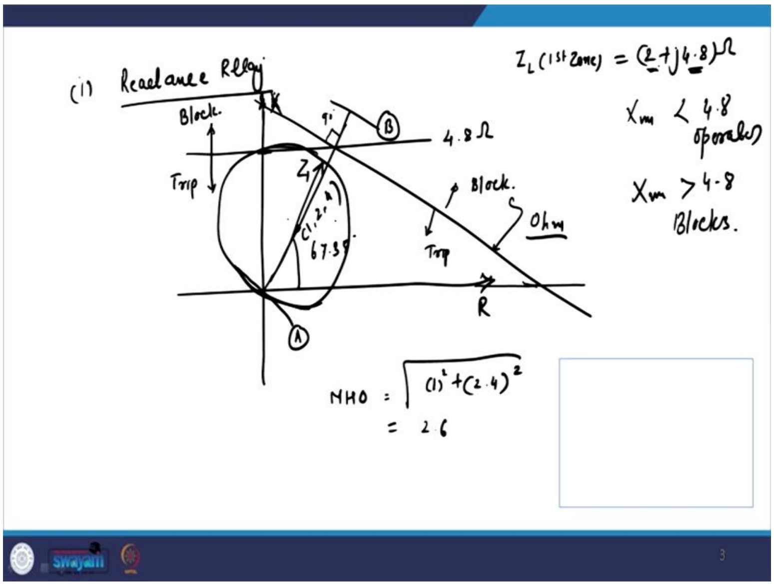

So, with this background, let us solve one example. So, here the 220 kV line is given, the impedance of this line is given as 2 point 5 plus j6 ohms. And this line is protected by the relay R, R is a distance relay. Now, this relay R is a reactance relay, it can be a ohm relay or angle impedance relay, or it can be a Mho relay. So, 3 characteristics are available for distance relay R.

So, we have to draw this relay characteristic on R-X plane. The CT ratio is given as 1000 by 1 and the PT ratio is given as 220 kV by 110 volt. And one more thing all these relays means all types of relay characteristic reactance ohm and Mho, the relay has to operate in its first zone which covers 80 percent of the line section. So, with this background, let us solve the example. So, line impedance that is given as the 2 point 5 plus j6 ohm.

So, if I convert this value in polar form, then it comes out to be 6 point 5 at an angle of 67 point 38 degree, this is in ohm. So, this is your line impedance. Now as it is given that the first zone of the relay of any type of characteristic that covers 80 percent. So, if I take 80 percent of this value, then we have the first zone impedance, ZL first zone that is equal to what 80 percent of this so, that is 2 ohm plus j, 80 percent of this that is 4 point 8 ohm.

So, we have the value we have taken 80 percent of this. So, we have the impedance in first zone. So, now, let us draw the characteristic of the relay. So, first we draw the characteristic of reactance relay. So, if I draw the characteristic of reactance relay, the value is 2 plus j 4 point 8. So, if I just take the value of first zone, I just write down it is 2 plus j 4 point 8 ohm. So, if I first take the reactance relay, then as I told you, reactance relay measures the reactance of the line.

So, reactance of the line that is 4 point 8 ohm. So, whenever I draw the characteristic then I have to draw the characteristic of, this is R and this is your X. So, whenever I draw, this point is nothing but your 4 point 8 ohm. So, any value below this reactance wherever will give trip, any value about this the relay will block. So, the measured impedance reactance is less than 4 point 8 ohm, relay operates. Whenever this value measured reactance is greater than 4 point 8, relay blocks.

Now, the second point that is regarding the ohm relay. So, as I told you ohm relay is the angle of admittance relay. So, we have to draw a tangent with the line. So, if I just tell you the, if I take the angle the angle is 67 point 38. So, the line to be protected, that has to be drawn from here, this value and this angle is you have 67 point 38. This is your line to be protected bus A and this is bus B.

So, whenever you draw a angle from here this point, such that the, this angle is 90 degree, then this characteristic is known as ohm characteristic or angle admittance characteristic. So, any value below this, relay trips, or any value on this side, the relay block. Now, let us see the third point that is the Mho relay. Now, as I told you, the Mho relay is a relay having circular characteristic.

So, what is the radius of the Mho relay that can be calculated by the, if I consider Mho relay here, then if I draw the Mho relay, the Mho relay that is given by like this. So, this is your Z1 at an angle 67 point 3. So, Mho relay radius that is given by square root of half of this value plus the half of this value that is 2 point 4. So, if I take square root of square of half of this value and square of this, so, this value comes out to be 2 point 6.

So, 2 point 6 that would be the circle of this relay. And what is the point the point is here 1 and 2 point 4. So, this is how the Mho relay works and we can draw the characteristic of Mho relay. So, here the other values are mentioned. So, we have discussed this and we have draw the characteristic of 3 different relay, that is ohm, ohm relay, reactance relay and Mho relay.

So, in this class, we have discussed the quantities to be fed to the distance relay and we have seen that for phase relays and ground relays we have to give different voltage and current quantity, then and then relay is capable to measure correct value of impedance, that is positive sequence impedance from relaying point to the fault point. And then we have solved one example. I stop here and in the next class, we will solve some more examples. Thank you.