Power System Protection and Switchgear
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Lecture -13
Current Based Relaying Scheme - 8

So, last time we have discussed regarding the directional relay, how the directional relay operates, what is the characteristic of directional relay and then we have also discussed, how we can introduce the maximum torque angle or the characteristic angle theta in the torque equation.

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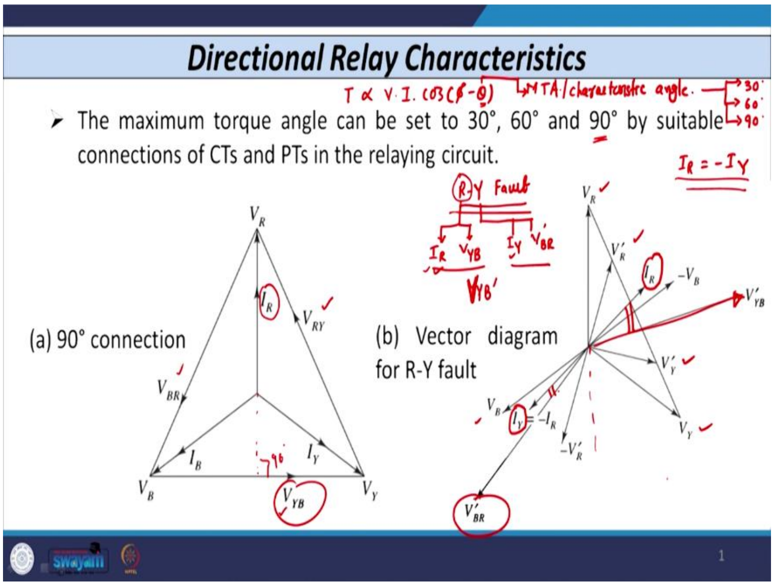

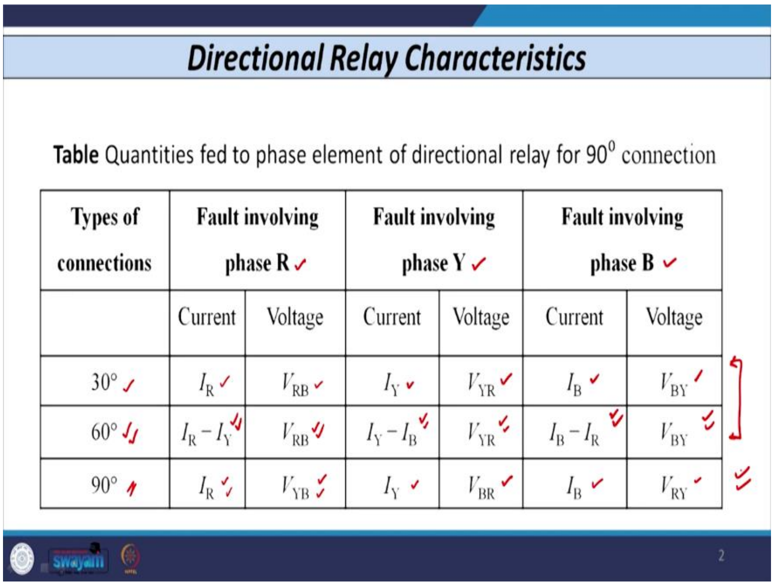

Types of connections	Fault involving phase R		Fault involving phase Y		Fault involving phase B	
	Current	Voltage	Current	Voltage	Current	Voltage
30°	I_R	V_{RB}	I_Y	V_{YR}	I_B	V_{BY}
60°	$I_R - I_Y$	V_{RB}	$I_Y - I_B$	V_{YR}	$I_B - I_R$	V_{BY}
90°	I_R	V_{YB}	I_Y	V_{BR}	I_B	V_{RY}

So, we have discussed that the torque equation T that is proportional to V into I into cos of Phi minus theta, where theta that is nothing but your maximum torque angle. This Phi depends on power factor angle, so it is obtained by 10 inverse X by R, where X and R is the parameters of transmission line. So, we are talking about the theta which is known as maximum torque angle. Sometimes it is also known as characteristic angle

So, I told you that whenever fault occurs the value of Phi varies from 70 to 90 degree. So, in order to achieve the maximum torque, so that relay operates for all fault conditions, we have to adjust the theta, and that we can carry out by adjusting or connecting the CT and PT, such that we can change the value of theta. And I told you this theta, that can be changed either we can set 30 degree, we can set 60 degree or we can set the 90 degree.

So, universally if I set 30, 60 and 90 degree, then the quantities that we need to feed to the directional relay, as I told you directional relay is a two input relay. So, we have to give the current input and voltage input from the CT secondary and PT secondary. So, for different conditions like 30 degree, 60 degree and 90 degree for each phase, that is R phase, Y phase and B phase, we have to give or the current and voltage to the input to the directional relay.

So, if I use 30 degree connection then for R phase I have to give IR current and for the voltage we have to give VRB. Similarly, for Y phase and B phase, we have to give IY and VYR and IB and VBY. If I use 60 degree connection, then for 60 degree, I have to give the current that is, IR R phase, IR minus IY and the voltage that is VRB. Whereas in Y phase we have to give IY minus IB and for voltage, we have to give VYB. And accordingly we have to give for the B phase.

However, if I use 30 or 60 degree any of this two connections, then for certain faults condition the relay may produce very low torque. So, to rectify that in actual practical field, they use the 90 degree connection. So, for R phase they have to give IR current and the voltage they have to give that is the VYB. So here you can assume that, if fault is in R phase then, we have to give the IR phase current.

So, the magnitude of current is very high in R phase. And for voltage we have to give the other two phases not including R. So, we have to give VY and B phase voltage, similarly for Y phase also, we have to give IY current and the voltage other than Y phase that is VBR and similarly for B phase, we have to give IB current and the voltage other than B phase that is VRY. So, by giving this values for each phase R, Y, B, if I consider the some fault condition, let us say RY fault occurs.

So in case of RY fault, let us see how the torque is produced by the directional relay. So, as I told you there are RY faults or two phases are involved, one is R phase and another is Y phase. So in R phase, we have to give the quantity that is IR and the voltage we have to give that is, VYB other than R phase voltage. Similarly for Y phase, we have to give IY current and we have to give the voltage other than Y phase, so that is VBR.

So, let us check for this values how the vector diagram behaves. So, you can see that on here, we have drawn the vector diagram considering that IR, IY, IB, all are displaced by 120 degree and the voltage at this point is VR, VY, VB. So we have the VRY voltage VYB voltage and we have the VBR voltage. So, for R phase as we are giving IR current and VYB. So, you can see that the current IR is here and the voltage VYB that is here.

So, if I just plot the angle between this IR and VYB that comes out to be 90 degree. That is why this connection, is known as 90 degree connection, same way for other phases. So, in case of RY fault, if I draw the vector diagram considering voltages as reference, so we have VR, VY and VB voltages all are displaced at by (one went) 120 degree. Now whenever fault occurs, RY fault, so R phase and Y phase voltage reduces.

So, VR becomes VR dash and your VY that becomes the VY dash. So, this two voltages reduces the current IR that is, now in case of RY fault, we have the condition that is IR is equal to minus IY, and IB is equal to 0 as the magnitude of B phase current, that is very small compared to other two faulted phases, so we can neglect it. So the IR current that lacks the voltage VR dash or VR, now we call VR dash by some angle.

And similarly you can see that the voltage that is IY is exactly opposite of this IR, so IY that comes out here and the angle between IY and VY or VY dash that is also very high, because I told you whenever fault occurs, the value of Phi that varies from 70 to 90 degree. So, we have to give the IR current, so we have the IR current here. And then we have to give the VYB, so VYB is nothing but your VYB dash. So voltage VYB dash, so that is VY minus VB dash. So, VY voltage you have here. So we have the, the minus VB dash voltage is here.

So, if I have the VY voltage here and VB, minus VB dash here, so you have the voltage VYB dash that is this value. So, this is your V dash YB and angle between V dash YB and IR, that is this angle. So, you can see that they are, if you give this quantity to the relay, then relay will produce maximum torque. Same way for other Y phase, the IY is the current, so you have the IY current here and you have the VB V dash BR, so it is nothing but the you have the VB minus VR dash so VB is here, minus VR dash that is, that comes out somewhere here.

And if you plot, you have the value V dash BR. So, angle between V dash BR and IY, that is this angle, which is very small. So, the torque produced by the relay that is very high. So, by utilizing 90 degree connection and accordingly if I give the input to the relay phase wise, this value that is the last row, then we can say that the directional relay produces maximum torque and there is no mal operation of relay.

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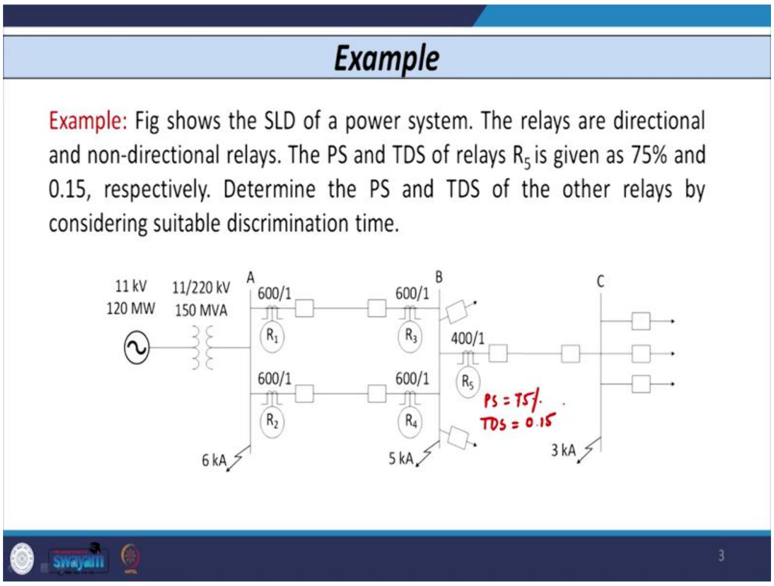

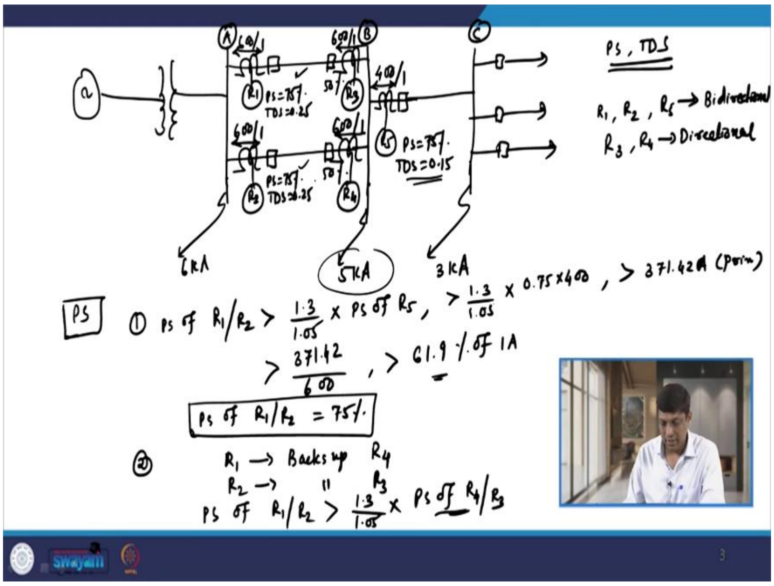

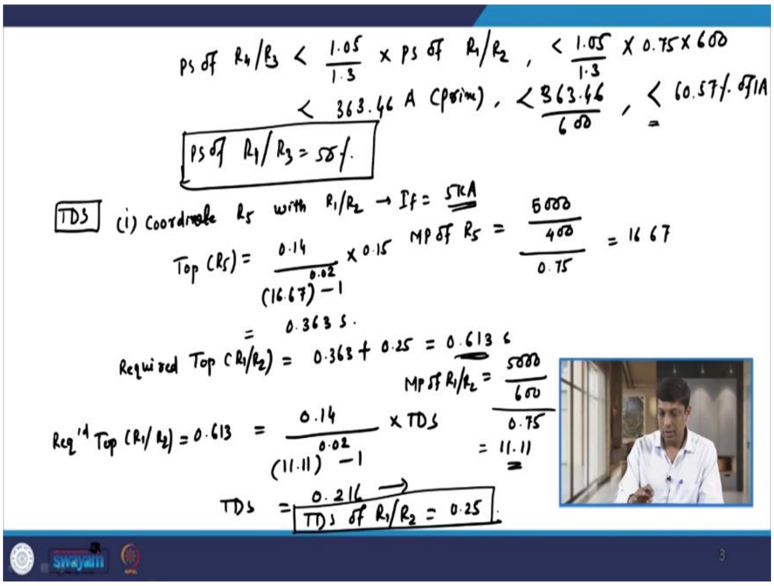

So, let us solve one example based on the directional relay. So, let us consider that the figure is given here. So, there are five relays shown in this figure. So, this relays can be directional or it can be bi-directional. So, we have to determine the plug setting and time dial setting of the relays. The plug setting of relay R5 that is given as 75 percent. So, this plug setting is given as 75 percent and the TDS of relay R5 that is given as point 15.

So, this values are given and based on this we have to find out the plug setting and the time dial setting of relay R1, R2, R3 and R4. Now for this, let us consider that the, the system is like this. So, if I just draw this, this system again. So, then we can say that the, the system is we have the generator, then we have the transformer and then we have the parallel feeder. So, this two feeders are connected here at bus B and we have the four relays located here on this parallel feeder.

So, this relays are R1, R2, R3 and R4 and the CT ratio of all this relays are 600 by 1. The fault level at bus A that is given as 6 kilo ampere, the fault level at bus B that is given as 5 kilo ampere. And then we have the another relay that is located here, that is relay R5 whose CT ratio is given as 400 by 1. Its plug setting is given as 75 percent and its TDS value is given as point 15. There is another bus C, so we have the different lines emanating from this bus.

The fault level at bus C that is also given that is 3 kilo ampere. And we need to find out the plug setting and time dial setting of all this relays. So, we have a breaker here also and we have a breaker, this side also. So, now let us determine the plug setting and time dial setting of the relays R1, R2, R3 and R4. Now before we start calculating plug setting and time dial setting of relays, four relays R1 to R4, we need to first identify which relays are directional and which relays are bi-directional.

So, obviously relay R1 and R2 this two are bi-directional relay. So, I indicate with double arrow like this. The relays R3 and R4 both are directional relay, because there are fair chances of reversal of fault current. So, I indicate with this arrow the arrow that is away from the bus B. So, R3 and R4 both are directional and relay R5, that is again bi-directional relay, so, I indicate by double arrow. So, now let us decide, so we have the relay R1, relay R2 and relay R5, this three relays are bi-directional.

And we have the relay R3 and relay R4, this two are directional relays. So, now let us start discussing how we can find out the plug setting of this relays. Now see plug setting of relay R5 is given as 75 percent of 400 ampere or 1 ampere secondary side. So, R1 and R2 we have to coordinate with relay R5, because R3 and R4 are directional. So, obviously this R5 which is a bi-directional relay that needs to be coordinated with relay R1 and R2.

So, setting of R1 and R2, both are same because we assume that CT ratio are also same and the, whatever load capacity by this line as well as this line, that is both are equal. So, let us find out plug setting of relay R1 or R2 that is greater than 1 point 3, 1 point 05 into plug setting of R5. So, if I just put the value 1 point 3, 1 point 05 into plug setting of R5 that is 75 percent. So, point 75 into 400, so if you calculate the value comes out to be 371 point 42 ampere this is on primary side. So, this is primary side of R1, R2.

So, if I just divide by this value 600, so we have the secondary value that is 371 point 42 divide by 600, so the value on secondary side comes out to be in percentage 61 point 9 percent of 1 ampere. So, the higher value, higher range above this that is 75 percent. So, plug setting of R1 or R2 that is selected as 75 percent of 1 ampere, so, this we have calculated. So, both this value, this is plug setting is 75 percent and this plug setting is also 75 percent.

Now, let us calculate the plug setting of R3 and R4. So, as I told you that R3 and R4 both are directional relay and when we have discussed the parallel feeder, I told you that R1 backs up relay R4, so R1 will provide backup for relay R4 and similarly R2 that will provide backup to relay R3. So, obviously time of operation of R1 and R2 that is higher than the relay R3 and R4 or in another way, time of operation of R3 and R4 is lower than the time of operation of R1 and R2.

So, I can write down the plug setting of R1 and R2 that is greater than 1point 3 1 point 05 into plug setting of R1 backs up R4, so I am writing R4 first and then R3. So if I just change this value, if I write down in terms of R4 and R3, then we have the plug setting of R4, R3, that is less than 1 point 05, 1 point 3 into plug setting of R1 and R2. So, if I put the value here 1 point 05 by 1 point 3 plug setting of R1 and R2 we have already decided, it is 75 percent of 600 ampere. So, we can write down it is point 75 into 600.

So, if I calculate this value primary side that comes out to be 363 point 46 ampere, this is on primary side. If I divide with the (ratio) CT ratio of R4 and R3, then this value 363 point 46 divide by 600, so that comes out to be in percentage, that is 60 point 57 percent of 1 ampere. So, as it is less than, so we have to change, decide the setting next range below this. So, the below this value available that is 50 percent, so we can decide the plug setting of R4 and R3, that is equal to 50 percent of 1 ampere.

So, this we have decided the setting of R3 and R4, that is 50 percent, so that we can note down. Now, let us decide the time dial setting. So, as I told you that earlier case that the time dial setting of relay R5 is given that is point 15. So, we have to coordinate relay R5 with relay R1 and R2 because all these three relays are bi-directional relays. And we have to coordinate this R5 with R1 and R2 for a fault level of 5 kilo ampere. So, let us coordinate, relay R5 with relay R1 and R2, so that is first thing.

So, for this with IF is equal to 5 kilo ampere. So, let us find out first the multiple of pick up current of relay R5. So, this is based on the 5000 ampere current divide by CT ratio of R5 that is 400, you can see here. The CT ratio of R5 is 400 and the plug setting is 75 percent. So, whole divided by point 75, so that comes out to be the value 16 point 67. So, if I use this value MP of R5, then we can find out time of operation of relay R5 that is equal to point 14 divide by MP that is 16 point 67 raise to point 02 minus 1 into TDS, TDS of R5 that is given as point 15.

So, I can put the value point 15. So, this value if you solve that comes out to be point 363 second. So, required Top of R1 oblique R2 that is equal to point 363 plus point 25 that is the minimum discoordination time between two successive relays R5 and R1 or R2. So, that comes out to be point 613 second. So, now let us find out what is the MP of R1 oblique R2 for the same magnitude of fault current that is 5 kilo ampere.

So, for 5 kilo ampere that is 5000 ampere divide by CT ratio of R1 and R2. So, CT ratio of R1 and R2 is 600 by 1 and its plug setting is 75 percent. So that is 600 divide by point 75. So, this value comes out to be 11 point 11. So, if I use this value here then we have the required time of operation of R1 oblique R2 that is equal to, we have calculated point 613 second that is equal to point 14 divide by MP that is 11 point 11 raise to point 02 minus 1 into TDS.

So, if you solve this you have the value of TDS that comes out to be point 216, so we can select the TDS of R1 oblique R2 that is the next higher range available that is point 25. So, we have decided the plug setting of R1 and R2 that is point 25. So, we can write down the TDS here that is point 25 and TDS here that is also point 25. Now, what is remaining is we need to now find out the plug setting of R3 and, sorry we have already calculated plug setting of R3 and R4, so now we need to calculate the time dial setting of R3 and R4.

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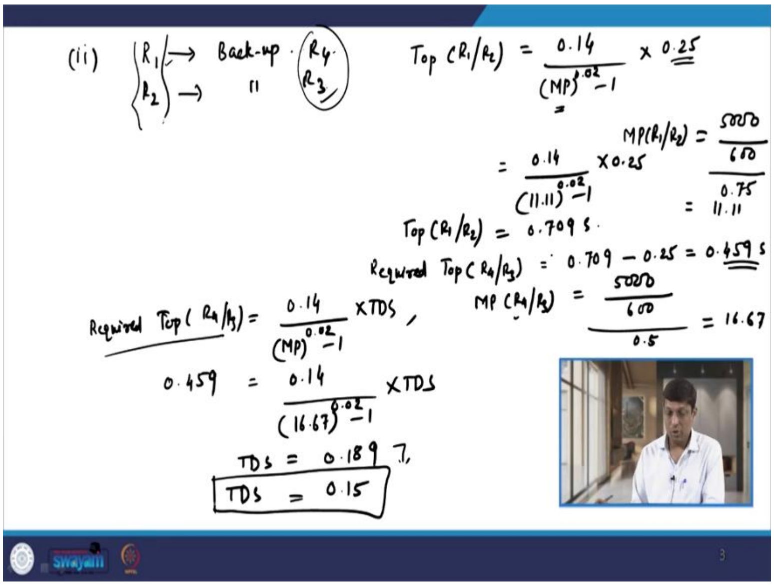

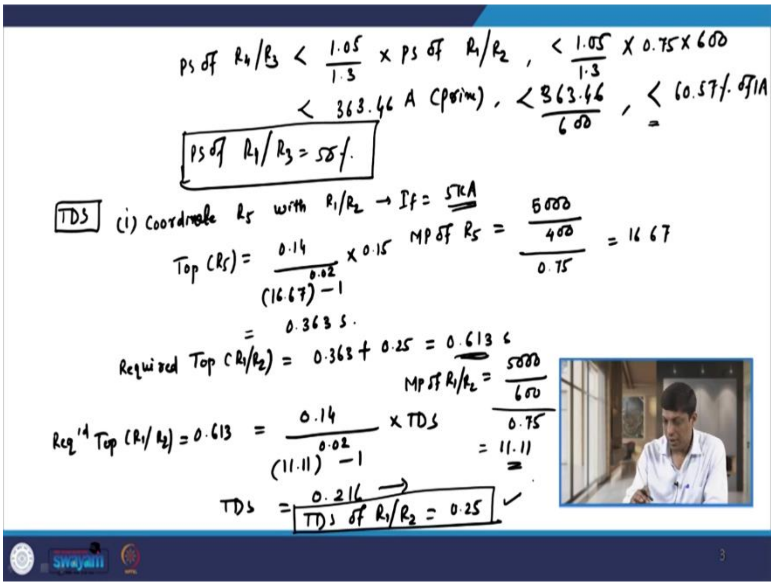

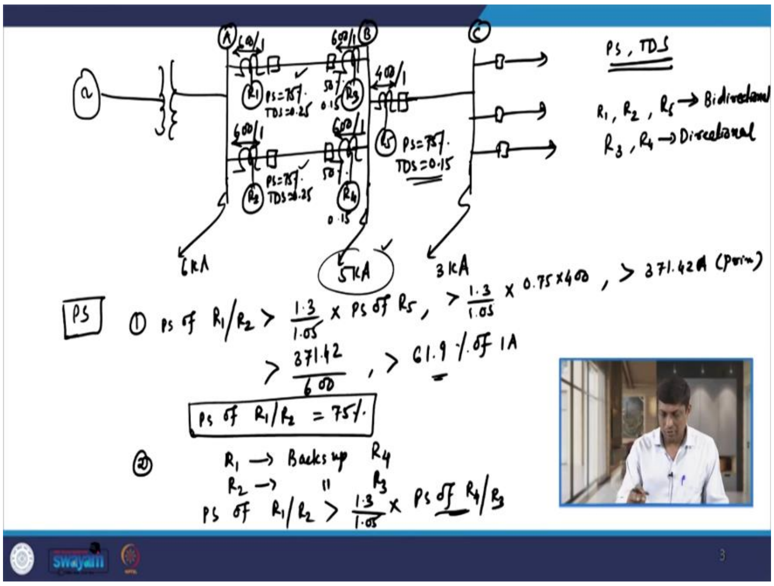

So, let us coordinate here, I told you that R1 provide backup to relay R4. And R2 will provide backup to relay R3. So, obviously time of operation of relay R3 and R4 that is lower than the time of operation of relay R1 and R2. So, let us first find out what is the time of operation of relay R1 oblique R2 using this equation point 14 MP raise to point 02 minus 1 into TDS. TDS of R1 and R2 we have already calculated that is point 25. So now we consider this value as point 25. Now we again, the question is what is the value of MP for R1 and R2.

So, for that as we are coordinating the relay R1 with R4 and the relay R2 with R3, we have to consider the same fault level. That is 5 kilo ampere and we need to calculate the MP of R1 and R2. So that is 5000 ampere divided by this CT ratio of R1 and R2 that is 600, divide by its plug setting that is point 75. So, if you calculate this, then that value comes out to be the 11 point 11 we have already calculated.

So, if I put this value here point 14, 11 point 11 raise to point 02 minus 1 into point 25. So, then this value comes out to be the point 709 second. So, this is the time of operation of relay R1 and R2 for fault current 5 kilo ampere with time dial setting point 25. Now as I told you that R1 provides backup to relay R4 and R2 provides backup to relay R3. So, obviously time of operation of relay R4 and R3 that is lower than R1 and R2.

So, we can write down the required time of operation of relay R4 or R3 that is equal to point 709 that is the time of operation of R1 and R2, minus point 25, we have to subtract it. So the, if you calculate the value comes out to be point 459 second. So now we can easily find out the required Top of R4 oblique R3 that is equal to point 14 divide by MP raise to point 02 minus 1 into TDS. So, we need to find out the multiple of pick up current of R4 oblique R3, so that is for same fault current 5000 ampere divide by CT ratio of R4, R3 that is 600 whole divided by plug setting R4 and or R3, that is 50 percent, so point 5.

So, if you solve this the value comes out to be 16 point 67. So, if I use this value here point 14 divide by 16 point 67 raise to point 02 minus 1 into TDS. And this value required Top of R4, R3, we have already calculated that is point 459 second. So, if you solve this the value of TDS, that comes out to be point 189, so we can select lower value, lower than this set (is) available in setting range, so we can select point 15.

So, we have already calculated the TDS of R4, R3 that comes out to be point 15. This is also point 15. So, with this background we have already calculated the, what is the value of plug setting and time dial setting of relays that is R1, R2, R3 and R4. So, in this example, we have consider both bi-directional relays as well as directional relays. So, with this background, now I let us stop here, and next time this come we will discuss the next philosophy that is distant relying scheme.

So, in this lecture what we have discussed, we have discussed the directional relay, how it operates, what are the different connections of directional relay to be carried out that is 30, 60 and 90 degree in order to set the value of maximum torque angle theta. And then we have solved one example, which includes both bi-directional relay and direction relay. So, I stop and next time we will discuss the next chapter, that is the protection of transmission line using distance relays. Thank you.