Power System Protection and Switchgear
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Lecture No. 14
Protection of Transmission Lines Using Distance Relays-I

So, today we will discuss the distance protection that is to how the transmission line is protected using Distance Relays.

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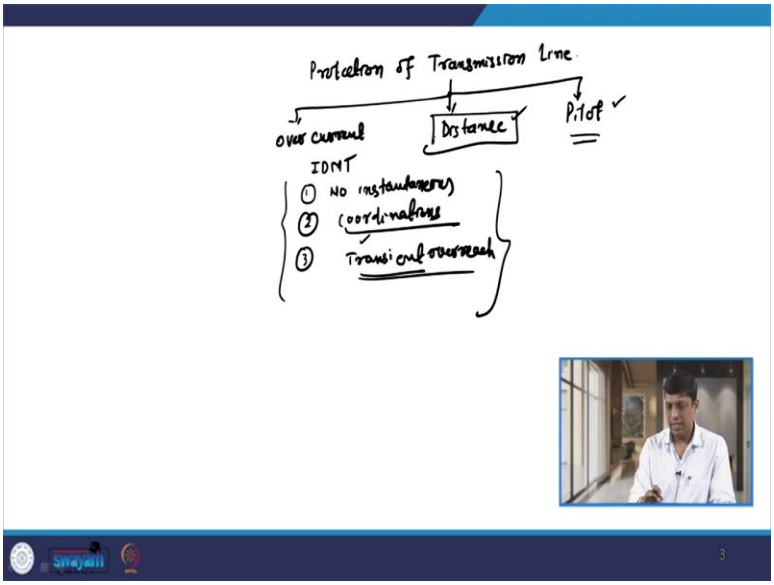

So, we know that if I consider the protection of transmission line then the it is protected by one is known as by current that is over current relay. The other we have that is the Distance relay and the other we have that is the Pilot relays. If I use over current relays, as we have discussed in earlier classes so, we can use any type of relays usually we use IDMT Inverse Definite Minimum Time relays, but there are certain disadvantages.

The first disadvantage of current base relaying scheme is we cannot have the instantaneous operation throughout the entire line. So, no instantaneous operation throughout the entire line that is not possible use if I use over current relays, the second is the coordination. Coordination of over current relays, that is very difficult if I use the

interconnected system and we have say, more than sufficient relays like 10 relays, 15 relays 20 relays then in coordination is very difficult.

And the third thing is the problem of transient overreach. So, the over current relays all over current relays are affected by the phenomena known as transient overreach. So, it is the tendency of relay to operate beyond its you know protection that is known as over (())(02:12) and as this phenomena is transient in nature, it happens or occurs in first few cycles 3, 4, 5 cycles that is why it is known as transient.

So, because of this reason, we have to use another type of philosophy that is let us have distance or we have pilot if I use the pilot based relaying scheme then that needs communication channel. So, that is very costly. So, we have to use the distance relaying scheme.

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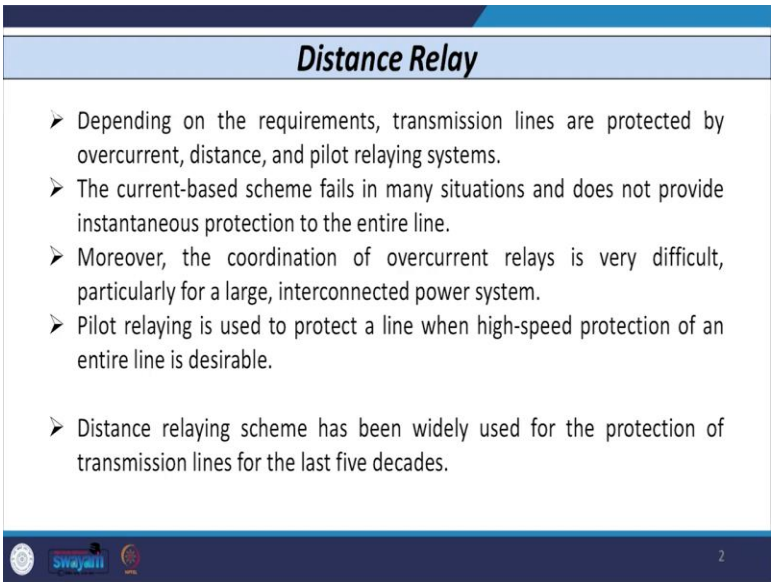

So, distance relays are widely used over 63 percent of the total lines are protected by distance relays. A main advantage of distance relaying scheme is that it does not require any communication channel. So, the same as we used the over current relays, we can also utilize the distance relays.

Now, let us see how the distance relay works. So, the operation of distance relay is mainly based on the impedance measurement. So, basically distance relay measures the impedance from relaying point to the fault point. So, if I use the one simple network,

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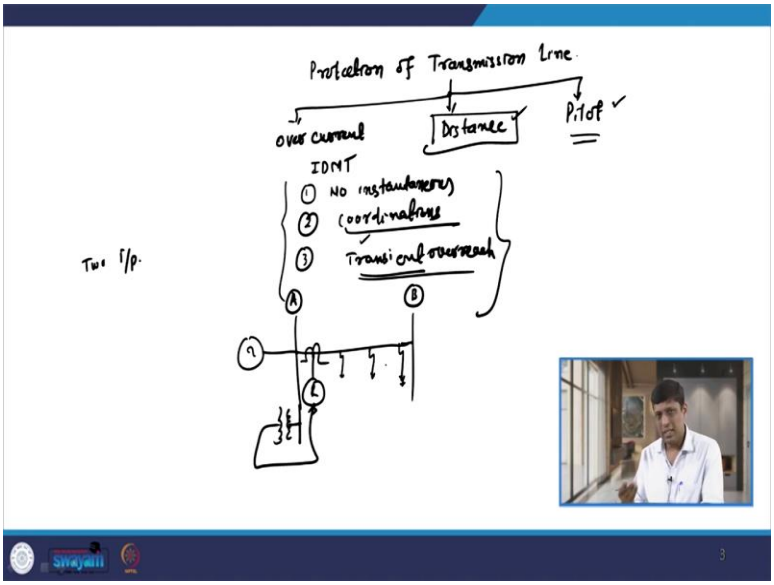

Suppose we have a network like this where the line is connected between bus A and B and if I use the relay here, then the distance relay again it is a two input relay. So, we have to give the input from the CT secondary as well as the PT secondary also. So, the relay which here we connect it receives two supply, one from CT secondary and other from PT secondary that is bus PT.

So, this relay measures the impedance anywhere so, a fault occur somewhere here then the relay measures the impedance if fault occurs somewhere here than also it measures the impedance a fault occurs somewhere here It measures the impedance.

So, impedance of the line that is proportional to the length of the line as the location of fault changes impedance also changes. So, that is why it is known as impedance relay or as impedance is proportional to distance. So, it is known as distance relays.

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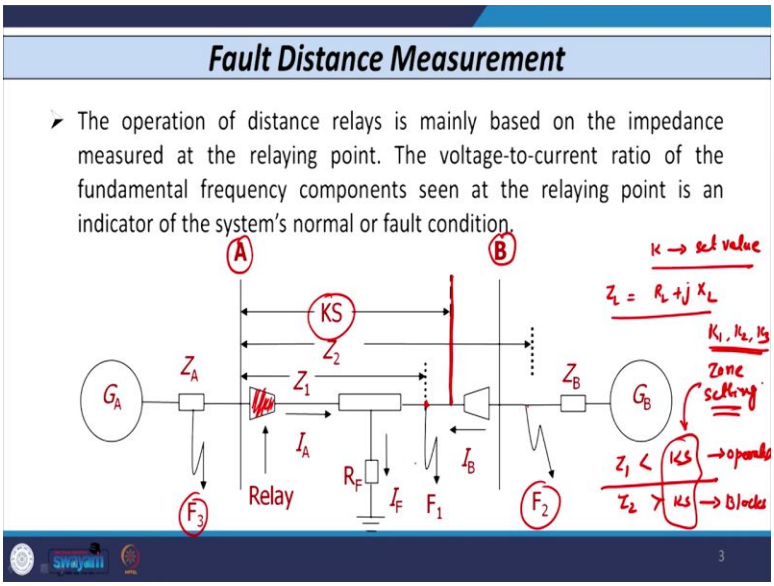

So, basically the distance relay measures the ratio of voltage and current of the fundamental frequency component seen at the relaying point. So, if it measures and then it compares with some set value or threshold value as as we discussed in case of over current relay, it measures the current and if current exceeds some value threshold value pickup value flux setting then relay operates.

So, same way in case of distance relay also distance relay measures the impedance of the light where it is protected or installed and it compares with some threshold value here it is known as set value.

So, here the value or threshold that is known as the set value. So, set value is nothing but the value that is your K sometimes it is indicated by K. So, K we can call it as set value this is nothing but the threshold. So, let us consider a line connected between bus A and bus B. So, we have a two bus where line is connected the impedance of this line is let us say it is ZL which is nothing but the RL plus j XL. So, this is the impedance of this line.

Now, as the relay is located here, so, this is your relay let us say R as I show in an earlier case. So, it receives input from CT secondary as well as PT secondary from the bus. Now, this relay measures the impedance. So, suppose if fault occurs somewhere here. So, this value initially we set as the set value that is indicated by KS. So, this is your

threshold. So, whenever a fault occurs on the left hand side of this value that is threshold anywhere let us say one example, say fault occur somewhere here at F1.

So, relay measures the impedance that is Z1 in this case, and it compares this Z1 with the set value of impedance if this value is less than the set value than relay operates if this value so, in this case relay operates and if suppose if fault occurs somewhere here at F2, then the measured impedance by the relay is Z2. So, this Z2 is obviously greater than the set value of impedance, so, relay does not operates that means a relay blocks.

So, operation are blocking of the relay that is based on the set value of impedance right that is known as normally zone setting of the relay This is known as zone setting of the relay. This is normally indicated by K usually in practical field. So, we have K1, K2 and K3. So, these 3 are the 3 zone settings of distance relay, one indicates the first zone, second indicates the second zone, third indicates the third zone of distance relay.

And sometimes it may possible that a fault occurs on the reverse side of this relay, this relay are then the measured impedance that is not positive it is negative It is usually falls in third quadrant, so, relay that is not going to measure the correct value it measures negative impedance and hence the relay does not operate.

So, if I just plot or represent this distance relay, the relay itself and the system along with this fault point F1, F2, F3, then we can show it on the one diagram that is known as RX diagram.

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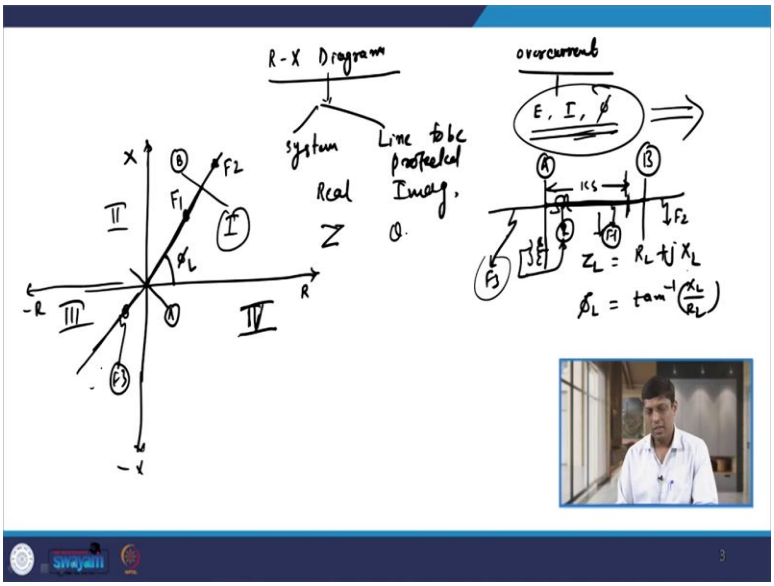

So, let us see now what the RX diagram is. So, RX diagram, what is RX diagram? So, now, in case of an earlier relays that is the over current based relays, if I consider over current relays then it has only the quantity known as the voltage current and the angle between voltage and current that is 5. So, 3 quantities are there and we can represent this using some characteristic type of operation versus the multiple of pickup current.

But here, if, in this case over current relays were we 3 quantities, we cannot represent the system as well as the line itself on this same plane. So, if I want to represent the system as well as the line vector or line to be protected on the same plane, then we have to use the RX diagram. So, basically it measures the real part and imaginary part of impedance and sometimes also known as Z an angle theta. So, if I just plot this, then we can represent it. So, if I consider the RX diagram, so this is R value positive and this is the X value, we have the negative R here and we have the negative X here.

So, if I want to just represent a line connected between two bus A and B. Then we can represent this point origin shows the bus A. So, if I just write down this is your bus A and if I draw this diagram, then this is your bus B. So, this is the line which we need to protect connected between these two bus A and B if this line has an impedance let us say ZL, which is RL plus jXL, then if I just find out phi L which is tan inverse this XL by RL, then this phi L is nothing but your this phi L.

So, you can just represent this now, the characteristic of the relay can be of any type. We can say we will see later on discuss that we have the impedance relay and different types of relay. So, whenever if I just say the fault occur somewhere here, let us say this is the your set value KS. So, if fault occurs less than this value here, say F1 then have F1, obviously, will be settled down somewhere here.

So, this is your F1 point a fault occurs somewhere here F2 which is beyond KS. So, then you have the value of F2 somewhere here and if I have a reverse fault because your relay is located here, which has the input from CT and PT both and if fault occurs somewhere here at F3 reverse side, then the it is located somewhere here this is your F3 point.

So, in earlier F1 and F2 case the impedance is in first quadrant, this is your first quadrant, second, third and fourth quadrant. So, in earlier two cases F1 and F2, it is in first quadrant but as it is less than the set value than relay operates whereas in F3 case, it is in third quadrant so relay measures negative impedance.

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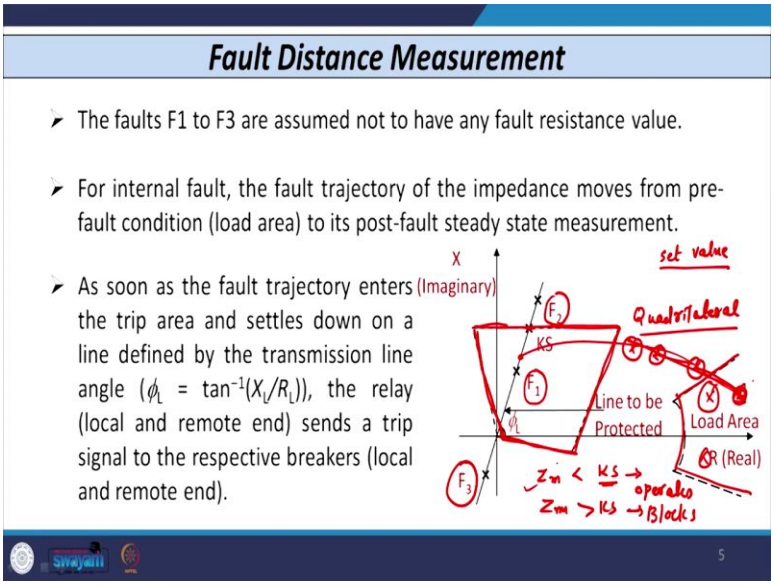

So, same way as I told you here, I have shown this line with F1 we have the F1 point, we have the F2 point and we have the F3. So, if I just tell you what is this KS this is your KS that is, the set value and on this set value I have shown with some characteristic right this

is the characteristic of the relay and this type of characteristic is known as quadrilateral characteristic of the distance relay.

So, if anywhere on this characteristic if measured impedance of the relay is inside this area, then relay operates so, that means, when the measured impedance is less than the set value, then the point falls inside this region and relay operates. So, relay operates. And if reverse is the case measured impedance is greater than set value that the point is outside this region.

So, the relay does not operate and relay blocks the operation. Now, initially when there is no fault in normal condition, the point is located somewhere here, this point is known as the load area. So, a point that is anywhere located somewhere here as you increase the loading on the line, this point will again shift from this point to it comes here further if you increase the load the point will move near to this region.

So, as you increase the loading on the line, this point will shift from this original point this region from this region. So, you have to see that that is why you cannot overload the line beyond certain limit otherwise this point will enter in this region and relay may (())(14:01) operate. So, this is very important point.

So, whenever fault occurs in case of fault somewhere in the here on this point F1, then what will happen earlier the point is somewhere here in at this point during no load condition or maybe pre fault condition, when system is working in normal condition the point is here and wherever fault occurs this point will tragic a trajectory will move from this to somewhere here and it settle down somewhere here. So, as the measured impedance is less than the set value, relay operates. So, this is the background of the distance relay.

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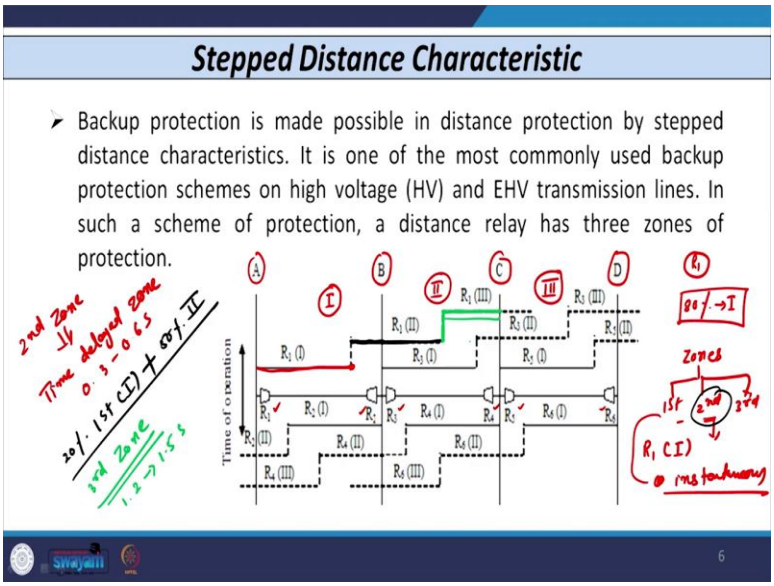

Now, let us see how the backup is possible for the distance relay. So, in order to understand the backup protection of distance relay, let us discuss let us consider the 4 buses. That is bus A, bus B, bus C and bus D and let us discuss the line is corrected between bus A and B, bus B and C and bus C and D. So, 3 lines are connected 3 line sections are there basically and for each line section so if I consider the line section one here, this is your first line section, this is your second line section, and this is your third line section.

So, in each line section 1, 2 and 3, we have two relays, R1 and R2. We have another two relays R3 and R4 and R5 and R6 for each line section. So, the first zone of relay R1 that will reach up to 80 percent of the line section one. So, let us talk about relay R1 only first. So, the distance relay has basically 3 zones that is known as the so zone of distance relays. That is basically first zone, second zone and the third zone.

So, first zone of distance relay R1 that covers 80 percent of the line from bus A. So, if I just draw 80 percent from bus A, so, this region is the first zone of distance relay R1. So, it is indicated by R1 that is really R1 and first zone that is first. So, if any fault occurs in this region, then relay operates instantaneously. So, first zone the operation is instantaneous.

So, without any time delay really operates instantaneously. Now, in second zone which is a time delayed zone, second zone is a so, if I write here second zone, that is your time delayed zone. So, the delay time that is of the order of 0.3 to 0.6 seconds, so, 300 to 600 milliseconds. So, from this point, if any fault occurs in this region, let us say this is 80 percent.

So, this is 20 percent region here any point on this side if any fault occurs in this 80 percent region here somewhere here. So, then the distance relay sees this fault in second zone and the distance relay operates after some time delay. So, reach of the second zone distance relay that will cover this remaining 20 percent and it will also extend towards the next section adjoining section that is section 2 here. So, it will cover up to 50 percent.

So, second zone will cover 20 percent of the first section. So, that is first plus 50 percent of adjoining section, that is second. So, this is the zone 2 of the second zone of the distance really whereas the first zone as I told you, the first zone that covers the just 80 percent of the first line section, that is this one.

So, this is all about the second zone of the distance relay. Now, if I consider the third zone of distance relay, then the third zone that will act as a backup. So, if any failure occurs, then the distance relay, if primary relay fails that distance relay then third zone operates and provides backup.

So, this indicates the delay in third zone. So, delaying third zone that is roughly around 1.2 to 1.5 seconds. So, 1200 to 1500 milliseconds and the remaining 50 percent of adjoining line section that is covered by relay in third zone. So, that is why I have written R1 third, so R1 third indicate third zone of relay R1. R1 2 indicate the second zone of relay, R1 and R1 1 indicates the first zone of relay R1.

So, we have first zone so, it will cover remaining 50 percent of the this adjoining line section. So, if I just want to show this first zone, second zone, third zone on the characteristic area, then I can say that we have on the RX diagram.

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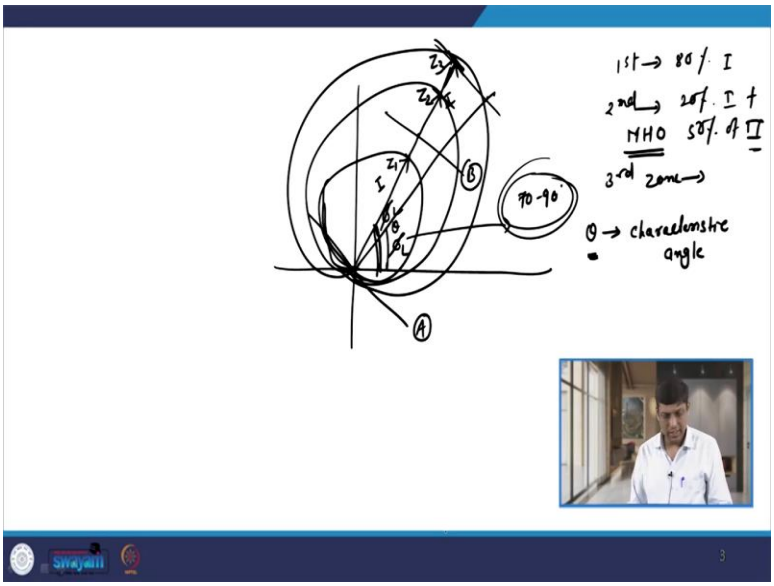

So, if I just draw on the RX diagram, this is bus A, we have the line this is bus B. So, first zone of the distance really that covers 80 percent of the first line section. So, this is our first line section, this angle is fi L. So, if I just draw let us consider the MHO relay characteristic. So, if I draw 80 (per) take 80 percent of first line section, then the distance relay characteristic that comes like this. So, this covers 80 percent of the line section.

Now, we have another adjoining line section. So, this is second line section. So, the second zone of distance relay that covers the remaining 20 percent of first zone plus 50 percent of second zone, second line section, so, it starts again from here and you take 50percent of this. So, that covers this much region. So, this is your basically you have Z1 and you have Z2.

And the third zone of distance relay that covers the remaining 50 percent of the line section. So, again it covers so, this is your remaining 50 percent so, basically it covers this region. So, this value you have the Z3. So, now I as I told you in case of directional relay which is also a two input relay or distance relay is also a two input relay So, we have to introduce the angle theta, which is known as characteristic angle.

So, this characteristic angle as same as maximum torque angle in case of directional relay. So, this this phi L varies from 70 to 90 degree as I told you in case of directional

really also. So, whenever fault occurs the value of phi L is very high. So, the torque produce that is Vi cos phi minus theta. So, this theta we need to set up roughly around this value.

So, this we can set using the characteristic angle like this. So, we have the characteristic angle theta for each zone, and it is same for all the 3 zones. So, we have the theta and we have the phi L also here, this is phi L, this one is your phi L and the other one is your theta. So, this is all about the 3 zone settings of distance relay.

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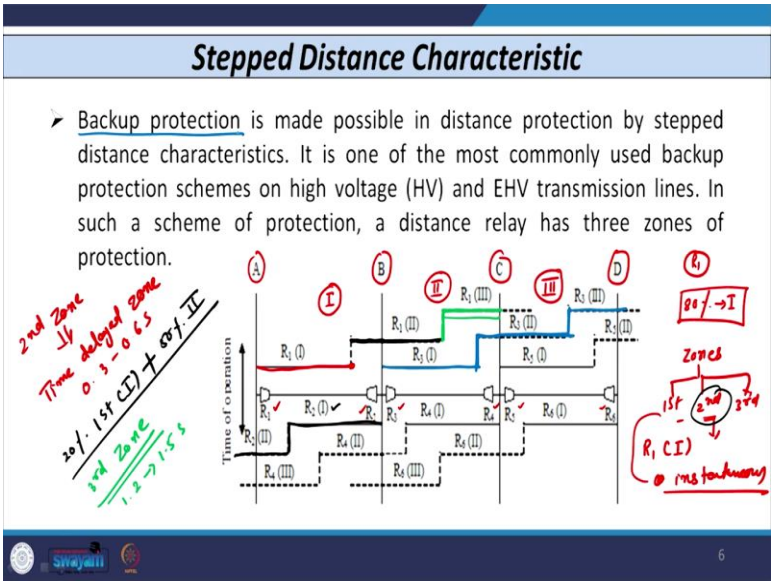

If I just tell you if I consider the second relay R2, then the first zone of second delay are two that is 80 percent from bus B, this side. So, this is R2 one is the first zone of relay R2 the second zone there is a time delay of 300 to 600 millisecond. And then second zone starts covers remaining 20 percent and 50 percent of adjoining line section.

Same way if I consider the relay R3. Suppose, here in this case, then the relay R3 that covers the first zone here 80 percent from bus B so, R3 one, then you have the time delay here that is 300 to 600 then you have the remaining 20 percent plus 50 percent of adjoining that is second zone of R3 so R3 second. Then again time delay, and then you have the third zone of relay R3 same way you can draw the characteristic and the

different 3 step distance characteristic of other relays that is R5, R4 then R2 all that you can find out or draw the characteristic.

So, using this step distance characteristic the important point is, we can achieve the backup protection. So, if we wish to achieve backup protection in case of distance relay, we can achieve the backup protection by 3, 2 different by extending or adding the two different zones that is zone 2 and zone 3. So, each distance relay has 3 zones, zone 1, zone 2, zone 3.

Similarly other distance relays shown here R2 to R6 they have also the 3 zones. So as it is 3 zones the characteristic is known as step distance characteristic and we can achieve the backup for all the utilizing this third zone and second zone of distance relay.

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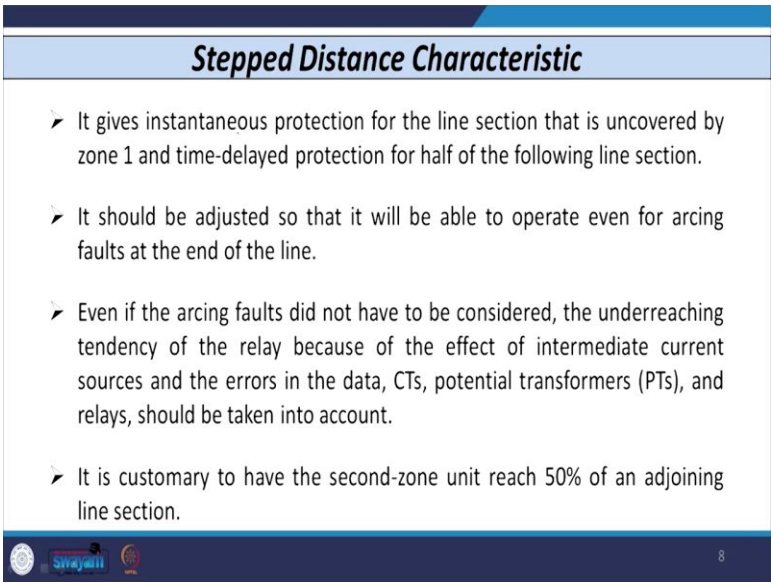

Now, sometimes it may possible that as I told you that there are 3 zones of distance relay and in zone 1 relay distance relay operates instantaneously whereas in zone 2 and zone 3 relay operates after some time delay. So, to understand this we have to draw the control circuit of the distance relay.

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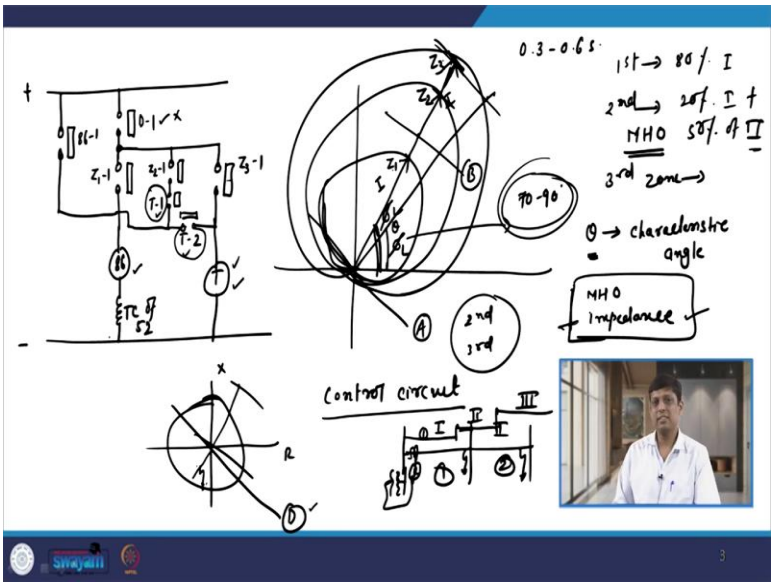

So, let us see how to draw the control circuit of distance relay. So, if I just draw the control circuit of distance relay, then we have the positive terminal and we have the negative terminal here and then we have the one unit that is of directional unit let us say it is D1 and then we have the unit of let us say it is Z1 1 and then we have the relay 86 which is the coil of auxiliary relay which is connected to trip coil of 52 that is circuit breaker.

We have the hold on path also provided by this 86 relay that is 86 1 and that is connected here. And then we have from this point we have the unit connected that is one unit that is known as the Z3 1 and then we have the another unit that is known as the Z2 1 that is somewhere here. So, it is your Z2 1 and then this Z2 1 is connected with one contact that is known as T that is connected here. That is T1 and the other contact that is connected here.

So, the another contact that is connected here and we have the another timer contact that is connected here, that is T2. So, this is the control circuit of the distance relay. So, here you can see that the T that is the coil of timer 86 is the coil of auxiliary relay, we have the 3 zones as I told you Z1, Z2, Z3. So, Z1 1, Z2 1, Z3 1 are the contacts of zone 1, zone 2, zone 3 that is, the Z1, Z2 and Z3.

Two contacts off timers are there that is, T1 and T2 are the two contacts off timer and 86 1 that is the contacts of relay 86. D1 one is the contact of the directional unit.

Now sometimes we can utilize the different types of characteristics in case of distance relay, we will see later on what are the different types of characteristic. So, we have the MHO type characteristic we have the impedance type characteristic. So, we have different types of characteristic of distance relay. If I use MHO relay then this unit that is not required because MHO relay is inherently directional.

So, if fault occurs on reverse side as I told you then this relay does not operate, but if I use impedance relay, then it is not an inherently directional unit. So, if I draw just the on RX plain just the characteristic of impedance relay then it is like this. So, and the line protected is somewhere here. So, if any reverse fault occurs somewhere here as it is inside this characteristic, so, impedance really operates. So, for that what I have to do is I need a directional unit here D. So, the contact of directional unit is have shown here but if I use MHO relay, which is inherently directional like this here, then this contact is not required.

So in if fault occurs in the posture of relay then Z1 one operates so this contact closes and it gives energizes the coil of auxiliary relay 86, which further energizes the trip coil of circuit breaker and circuit breaker becomes open if fault occurs in second zone and third zone then in both the cases as you see you can see that second zone characteristic and compasses the first your third your characteristic encompasses all first and second zone.

So, if any fault occurs in second and third zone that means if I have the two sections like this section two and section one and if I have a relay here connected distance relay then first zone covers 80 percent that is first zone, the second zone covers remaining 20 percent and 50 percent of adjoining line and then third zone.

So, this is second zone this is third zone, this is second section this is first section. So, if any fault occurs in either here second zone or in third zone somewhere here, then the Z2 1 and Z3 1 both will operate simultaneously. So, these two contacts becomes closed and hence the coil off timer is energized. Now whenever coil off timer is energized, the timer

has two contacts one is T1 and the another is T2. So, T1 will trip after some time delay. So, as I told you the time delay in second zone is 0.3 to 0.6 seconds.

So, after this time delay this timer will trip and further tripping is given. So, from this side Z2 one is closed, Z3 one is closed timer T coil is energized. So, this becomes close. So, the tripping is given like this and in another case if fault is in third zone, then after the some time delay this contact T2, T2 that will close and hence the again the tripping is given from like this tipping is given and hence the trip coil of circuit breaker is energized and circuit breaker becomes open.

So, this is how the timer circuit of the 3 different zones of distance relay works. This is known as the control circuit of distance relay.

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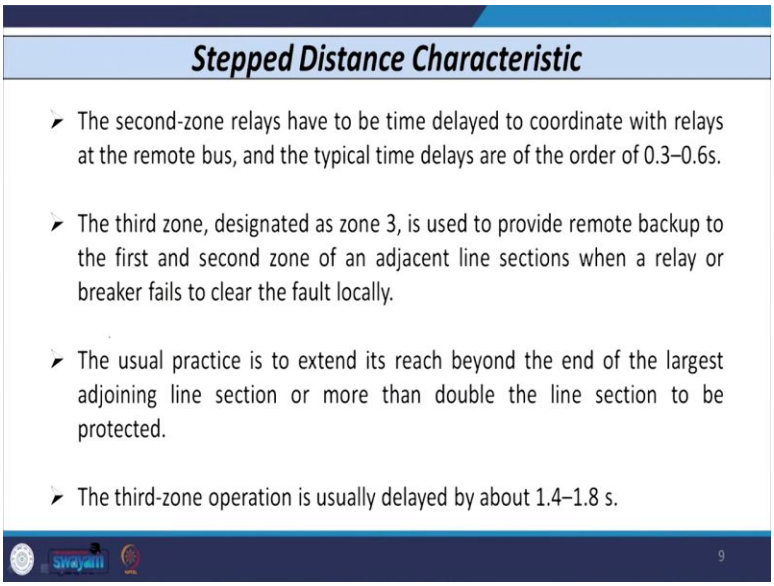

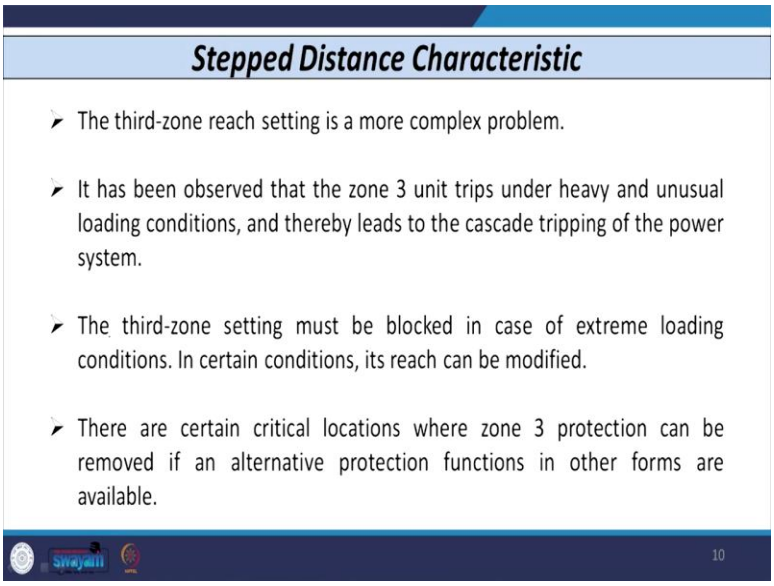

So, as I told you in step distance relay, that there are 3 different zones of distance relay and zone, first zone is instantaneous in nature, whereas, the second and third zone are time delayed zone with some value.

So, in this class we started our discussion with the distance relay, how the distance relay works, what are the different types of characteristic. Then we have discussed the stepped distance characteristic of distance relay. And finally, we have discussed the control circuit of distance relay. So, I stop here and in the next class continue our discussion on the reach of distance relay. Thank you