Power System Protection and Switchgear

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Lecture – 15

Protection of Transmission Lines Using Distance Relays-II

Okay, so in last class we started our discussion with the distance relays, how the distance relay works and how it measures the impedance. So, let us continue our discussion. The next topic is the reach of distance relay. As I have already discussed in the last class that the distance relay measures the impedance from relaying point to the fault point and this impedance is positive sequence impedance. So, on the other hand ground distance relays if we use, then it is based on zero sequence impedance.

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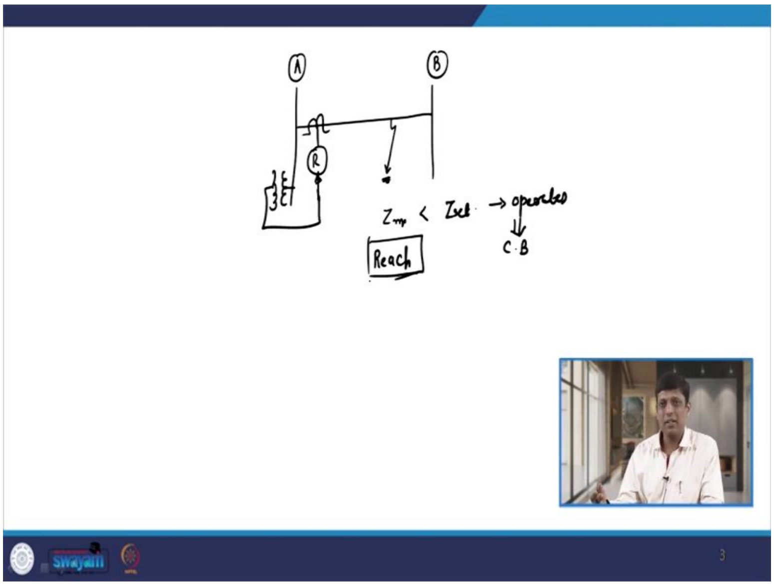

So, whenever any distance relay we put in the circuit then in that case, if I consider, let us say a bus A which is there is a line connected between A and B and we put one distance relay here R, which is also fed by the line PT also. Obviously, whenever fault occurs on the line, the distance relay, just measure the impedance and when the measured impedance is less than some set value of impedance, then relay operates.

So, the distance up to which the distance relay measures the correct value of impedance and provides operation, so further tripping to the circuit breaker. So, that area or portion that is known as, reach of the distance relay. So, reach means nothing but the area up to which the distance relay is capable to sense the fault wherever it occurs on the transmission line.

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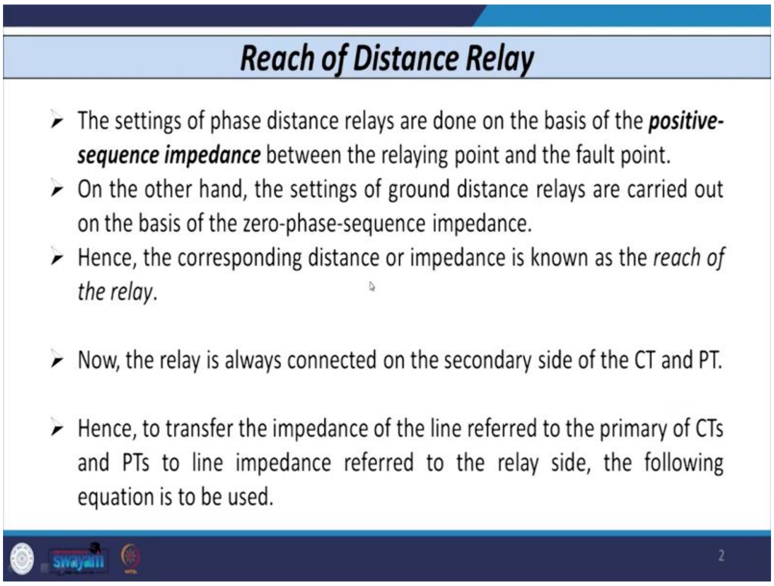

We know that the relay is always connected as I told you on the secondary side of CT and PT or CBT. So, we need to transfer the impedance from primary side to the secondary side because the impedance seen by relay that is different and impedance on the, of the line which is on primary side that is also different. So, if I want to just convert the, this impedance from primary to secondary side, then we need to use the equation.

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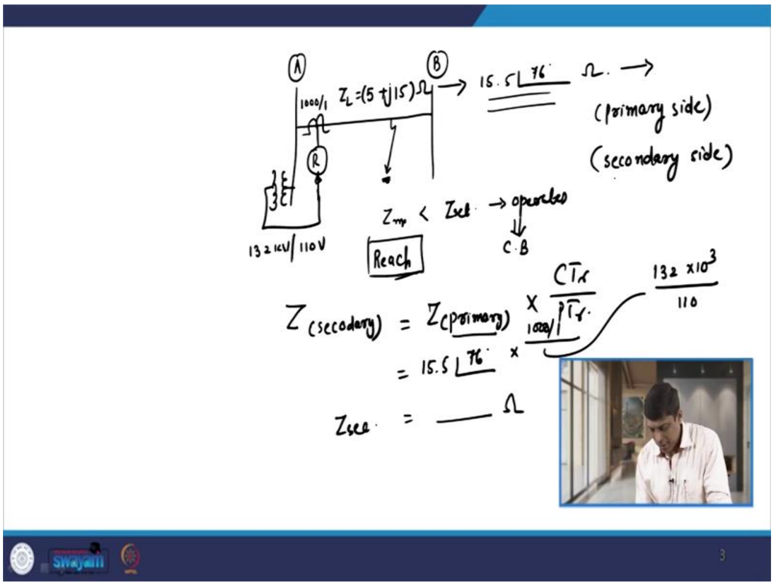

So, for example, let us assume that the, this line has impedance value, say it is 5 plus J 15 Ohm. So, maybe if you convert this value in polar form, it is maybe something 15 point 5 angle (10 in) 15 by 5 so, 10 inverse 3 maybe around roughly 76 degree, this is in Ohm. If the CT ratio is let us say 1000 by 1 ampere and if the PT ratio is let us say 132 kV by 110 volt.

So, then this impedance that is the line impedance, is this is called as the impedance on primary side. Now, whenever we connect the relay, relay whatever and whatever impedance that is seen by relay, that impedance is known as secondary side impedance. So, obviously, we need to convert this impedance so we need to find out what is the impedance seen by relay.

So, the impedance seen by relay if I call it Z secondary right, then as I told you the equation is given by Z secondary equal to Z primary into the ratio of current transformer and potential transformer. So, here we have the Z primary into CT ratio divide by PT ratio. So, this Z primary that is this value 15 point 5 at an angle 76 and into CT ratio so that is 1000 by 1. And whole divided by PT ratio that is 132 kV, so here the value is 132 kV, so 132 into 10 raise to 3 divide by 110 volt.

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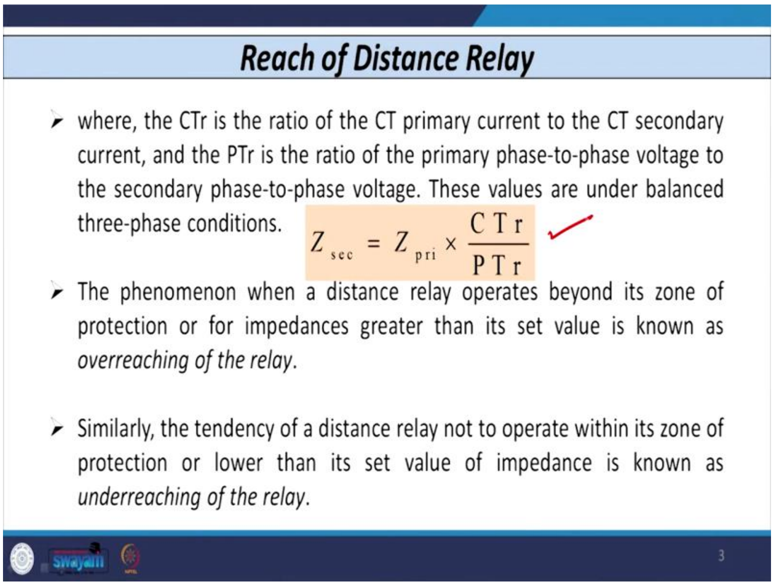

So, whatever final value comes that is also in Ohm but this value is the secondary value that is seen by the distance relay R. So, that means, wherever we solved the example, or whenever we look at into the practical field, then the impedance of the line is given, so impedance seen by relay that can be calculated using, using this equation. So, this is very important as far as the conversion of impedance from primary side to secondary side. So, as we have discussed reach of the relay, so there are two other phenomenas also we need to discuss and that is known as the.

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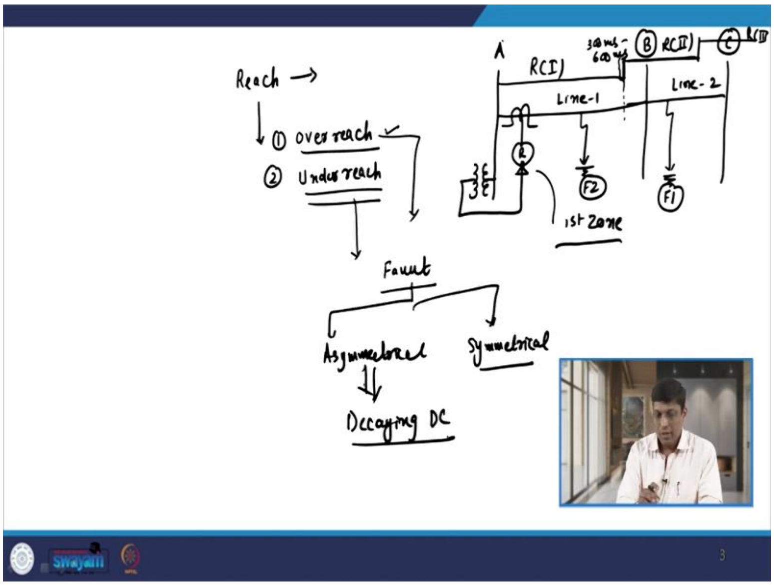

So, we have discussed, what is the reach of the relay. So reach means the area or portion up to which relay is able to sense the fault. Based on this we have another two important definition one is known as overreach, and the other that is known as under reach. So, what do we mean by overreach? So, again let us consider the same example where we have connected a line between A and B, we have another bus C, so we have another line say this is line 1 and this is line 2.

And let us assume that we have a relay R connected which is a distance relay. So, we just give the input from the CT and PT. So, first zone of this distance relay is 80 percent, so this is R1, after some time delay we have a second zone so, this is R2 and so on with some time delay R3. So, now, what do you mean by overreach? If fault occurs somewhere here in line section 2 say at point number 1 F1. So if fault occurs at F1, then obviously relay R will look at this fault in the second zone here.

So, second zone there is a time delay as I told you 300 milliseconds to 600 milliseconds. So, any fault occurs at F1 then relay R does not see this fault in first zone, so the relay does not operate. But due to some reason due to some problem if fault occurs at F1 and relay R looks or sees this fault in first zone right, so first zone. And if relay, and in first zone relay operates instantaneously, so if relay R operates for the fault at F1 instantaneously, then that is known as overreaching of the distance relay.

So, overreaching is defined as it is the tendency of distance relay to operate beyond its zone of protection. So, here in this case in second zone if any fault occurs in first zone then and then relay R has to operate instantaneously. But if any fault occurs beyond first zone and if relay R operates, then that is known as overreaching of the relay. Similarly, let us see what is under reaching of the distance relay. So, under reaching means if fault occurs within, so this is the first zone area. So, if any fault let us say fault occurs at point two F2. So, obviously this fault is in first zone of relay R.

So, relay R has to sense the (fault), this fault and it has to operate. But if relay R does not operate, or if R is not capable to sense the fault at F2, then that is known as under reaching of the relay. So, under reaching of the distance relay is defined as it, as it is the tendency of distance relay to remain in blocking condition or to remain in inoperative condition even though the fault is within its zone of protection, so that is known as under reaching of the relay.

So, now this overreach or under reach, that is mainly because of the fault, so magnitude of fault current. So we have already discussed that fault can be asymmetrical in nature, or it can be symmetrical in nature. So, there are two types, we can classify the fault. So, whenever usually fault occurs it is asymmetrical in nature and this asymmetry depends on decaying DC component, decaying DC component.

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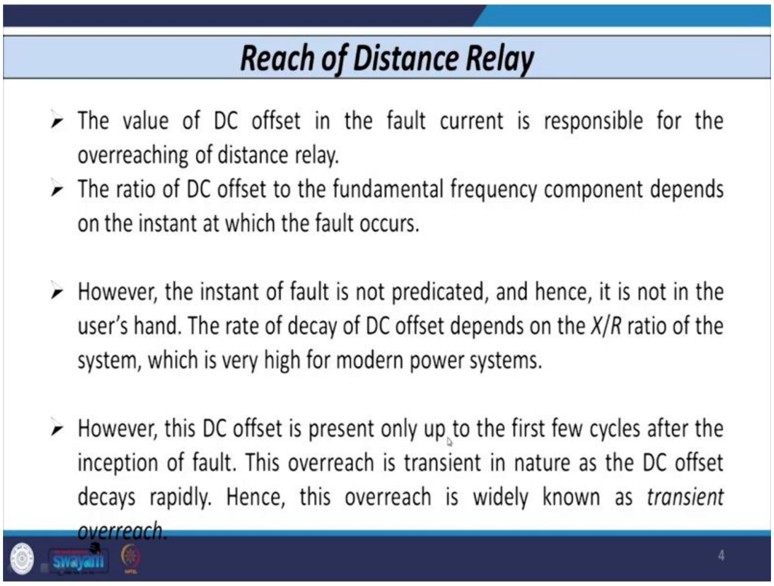

So, this decaying DC component is responsible for the whether relay overreaches or relay operates correctly. So, the value of this decaying DC or DC offset in the fault current that is responsible for this overreaching of the relay. The ratio of DC offset to the fundamental frequency component that depends on the instant at which fault occurs. So, if I (just), if we find out what is the value of DC offset and then if we take what is the fundamental frequency component of, of that value may be current then that depends on the instant at which fault occurs, switching instant we are talking about.

However, the instant of fault we cannot predict so, it is not in the user set and so the rate of the decay or this DC offset at which rate the DC offset decays, that depends on X by R ratio of the system. And for modern system the X by R ratio that is very high. However, the DC offset is present only up to first few cycles 4-5 cycles and this distance relay operates instantaneously only in its first zone. So, it operates in time delayed in second and third zone.

So second and third zone of the distance relay are not affected by this transient overreach or decaying DC component. So, whenever the distance relay overreaches, and if that phenomena last only for first few 4-5 cycles immediately after the occurrence of fault, then this type of phenomena is known as (transient) transient overreaching of the distance relay. So as the transient overreach disappears after few cycles, so, second and third zone of distance relay are not at all affected by transient overreach phenomena.

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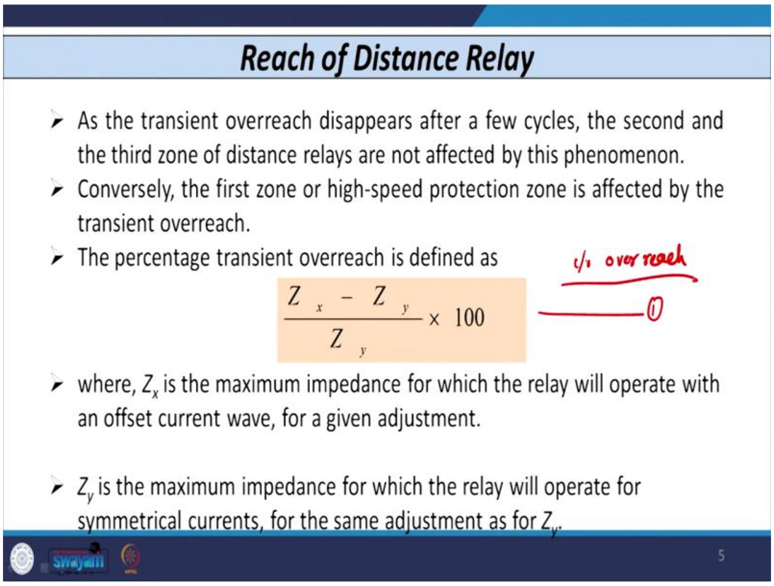

So, how to find out this percentage transient overreach? So that can be obtained using this equation. So, in this equation, you can easily find out the value of percentage overreach that is for any distance relay. So, in this case Z x that is the maximum impedance for which the relay operates with an offset current wave for an (adjacent), for a given adjustment and Z y is the maximum impedance for which the relay operates for symmetrical current for the given adjustment of the value of Z y. So, using this you can easily find out the percentage overreach in any distance relay.

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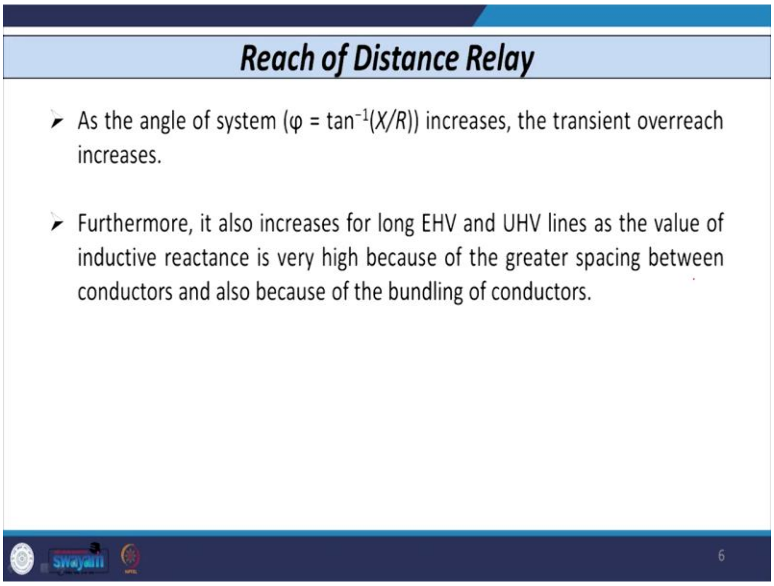

The, it is also true that as the angle phi which is 10 inverse X by R increases, the transient overreach also increases. And for our long UHV and EHV line the inductive reactance is very high, so obviously the spacing between the conductors increases, due to, because of utilization of bundled conductors, so the value of transient overreach also increases. Now, with this background let us see, what are the different types of distance relay characteristic that is available in market.

There are many types of characteristic available as far as distance relay is concerned. So, which type of characteristic we use that depends on the application, suppose if I want to use any distance relay for the protection of short lines, then we have to go for reactance relays. If I want to protect a long EHV transmission lines, then we should go for Mho relay and maybe further quadrilateral or some other type of distance relay characteristic, so it depends again on the application.

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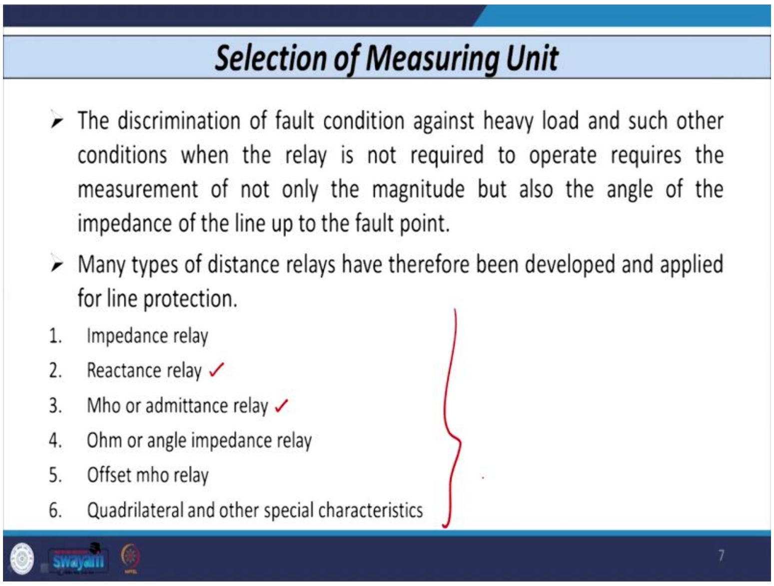

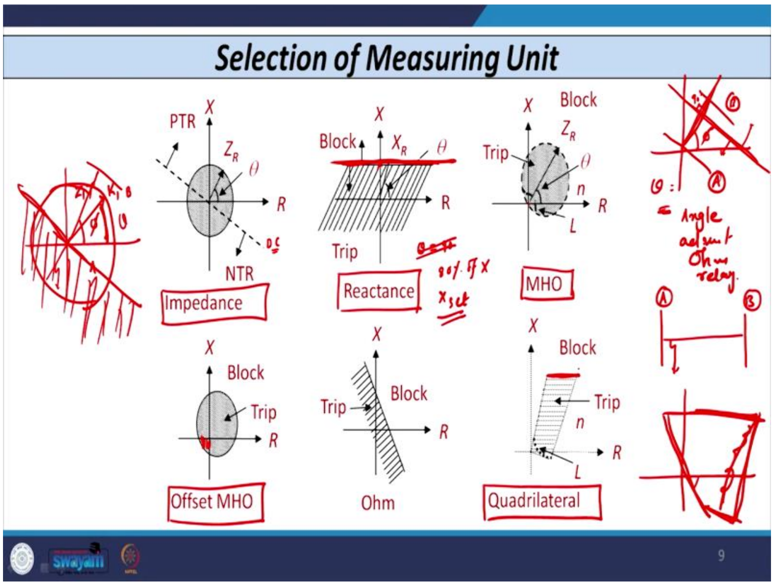

So, let us discuss different types of characteristic. So, usually there are six characteristic, it can be more also, but let us restrict up to six only. So, the first characteristic is known as impedance type distance relay. So, if I use the impedance type distance relay, then this characteristic is shown here, this is the impedance type distance relay characteristic and you can see that there is a circle on the RX plane.

Now, the important point is you can look at, if I just draw on this side the RX plane, then line to be protected or connected between two bus that is somewhere here, this is A and B and this is your line to be protected, this is angle phi. So, if I draw the circle from this point, say this is your 80 percent region, then if I extend this line vector, then any fault occurs on reverse side of this relay or bus, the impedance relay also detects or senses this type of fault.

So, to avoid mal operation of impedance relay on reverse fault, normally in actual field we use the directional unit, so this is nothing but the directional characteristic. So, we have a directional characteristic like this. So, now the relay, that is not going to operate on this side of the region. Now, you can also see here on the impedance characteristic, if any, any value above on this side, you have a positive torque region that is PTR. And any value below this characteristic I told you this side, that is negative torque region.

And you have the angle theta so that it is theta is nothing but this is your Z1, and this is theta that is your K1. So this theta is nothing but your characteristic angle theta of the distance relay. So, this is all about (charac) impedance characteristic. This type of characteristic is not used in the field because whenever you use it, you have to again further use it directional relay along with impedance relay. So, that is the biggest disadvantage of impedance type distance relay. The next type of characteristic that is known as the reactance relay.

So, as the name suggest the reactance relay measures reactance only. So, if fault occurs with any value of fault (imp), fault resistance, then this type of relay that is not affected by that phenomena. We will discuss later on what is the effect of fault resistance on the performance of distance relay. So you can look at here, the characteristic of reactance relay, the characteristic angle theta that is 90 degrees in this case the theta is not there we can say. Now you can look at here, the any value beyond this line, below this line that is this line. So, relay operates. And any value above this line that is relay blocks.

Now, when you consider it measures only (impedance) reactance, so this point this line is nothing but you can say 80 percent of x value or inductive reactance part of the transmission lines. So, whatever primary impedance of the transmission line is given, you take 80 percent of x, that is nothing but this value set value x set of the reactance relay. Reactance relay is normally used for short transmission line, so when we have a feeder whose length is very small, at that time we can use the reactance relay because in that case the fault impedance is very high.

So, if I use reactance relay then there is no effect of fault impedance on the reactance relay. But the biggest disadvantage of reactance relay is, whenever any some other phenomena occurs like power swing, then this relay is very prone for the mal operation and hence, this type of characteristics are not used normally for long protection of long EHV and UHV lines.

So, the third type of characteristic is known as Mho or admittance relay, sometimes it is also known as angle admittance relay.

So, it is basically the modification of reactance relay. So, here reactance relay theta is not there, here the value of theta is there some value. And whenever you want to obtain this type of characteristic so what you do is that in, in such type of characteristic, it is not shown here this characteristic. So, normally what we do? This is the angle admittance relay or sometimes it is also known as Ohm relay. So, in this type of characteristic what we do, if this is the line to be protected between bus A and B, then what we do, this is value is phi, you can obtain with Tan inverse X by R.

So, with this line impedance vector you take the inverse tangent so, whenever you draw any line like this, so, when this angle is 90 degree, this angle is 90 degree, with reference to (line) this is your line impedance vector. So, when this you draw a characteristic like this, then that type of characteristic is known as Ohm relay. So, any value below this relay operates, any value above this relay blocks. Then the next type of characteristic that is known as MHO type characteristic.

MHO type distance relay is widely used in field because you can see it is inherently directional. So no separate directional unit or relay is required and it is also capable to accommodate some value of fault resistance also. So, you can see that if any point that falls under this shaded area that is circle relay operates, otherwise relay blocks. The next characteristic that is known as the offset MHO relay characteristic. So, only difference between MHO and offset MHO is this point which is origin that is slightly shifted below just to accommodate only this much portion.

This is mainly done because whenever the fault occurs very near to the bus, suppose we have a line connected between two bus A and B, and if close in fault occurs somewhere here, then it may possible that your point may fall inside this region. So to avoid that, usually we use offset MHO type characteristic. The function of offset MHO type characteristic that is similar to the MHO type characteristic. So, now, let us consider the another type of characteristic that is known as quadrilateral characteristic.

So, quadrilateral characteristic you can see this portion that is very important. So, in some cases they also consider the quadrilateral characteristic that is of this nature also. Sometimes you may find the quadrilateral characteristic, sorry this is not there. So, quadrilateral characteristic like this, so all this angle that is defined. So, here I have shown only point is that this region or this region, so it is capable to accommodate more value of fault resistance.

So any fault occurs with considerable value of fault resistance, then that is also detected or sensed by quadrilateral type distance relay, that is one thing. So, we have discussed this all six type of distance relay characteristic. And whenever you use any type of characteristic, each characteristic has started with a certain advantages and disadvantages and we have to optimize for a particular operation which type of characteristic we, we want to utilize it.

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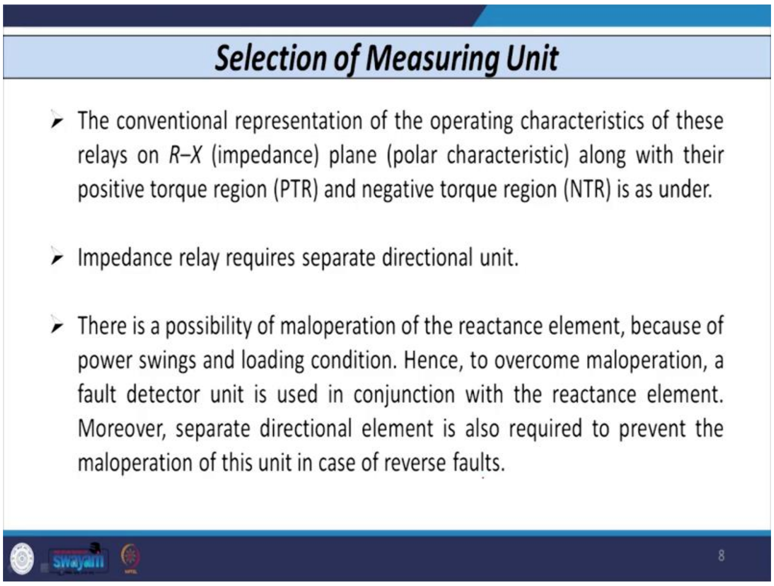

Whenever you use any type of this characteristic, there is a possibility of mal operation of a particular distance element. For example, if I use reactance relay then there are fair chances of mal operation of reactance relay because of power swing and overloading condition, because when you set the third zone setting of the reactance relay or any type of distance relay that is done considering the maximum loading or overload the line can take. And as I told you as you increase loading on the line, the locus that point shifts towards the, towards that region of third zone of the relay.

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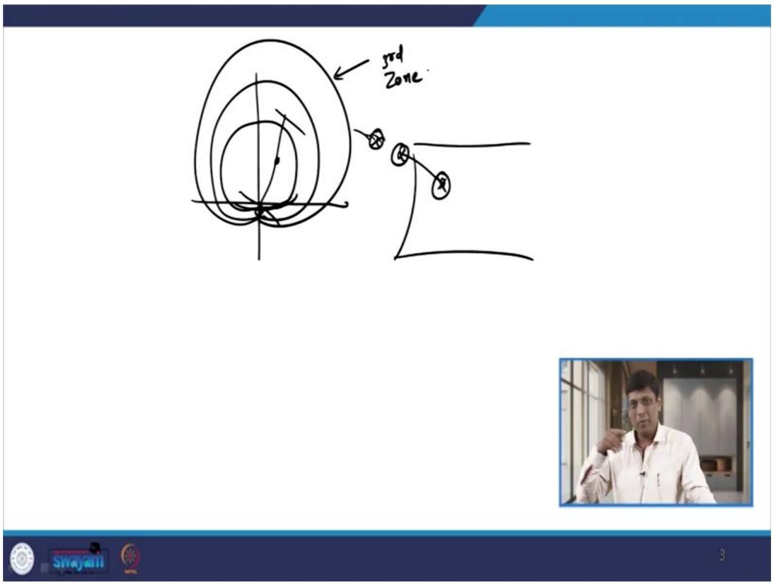

So, for example, if I consider the locus, let us say this is the first zone, we have the second zone and you have the third zone like this, and the load area is somewhere here. So, in normal condition, the fault point is somewhere here. And as you move, as you increase the load on the line, this point will shift like this. In case of fault this point will again shift and move and somewhere settle down here that is fine. But in normal as you increase the load when there is no fault, when overloading of the line occurs, then this point shifts so as you move towards this, this is your third zone of the distance relay. So, third zone setting is always carried out based on the, what maximum overload a particular transmission line can take, so this is one important point, okay.

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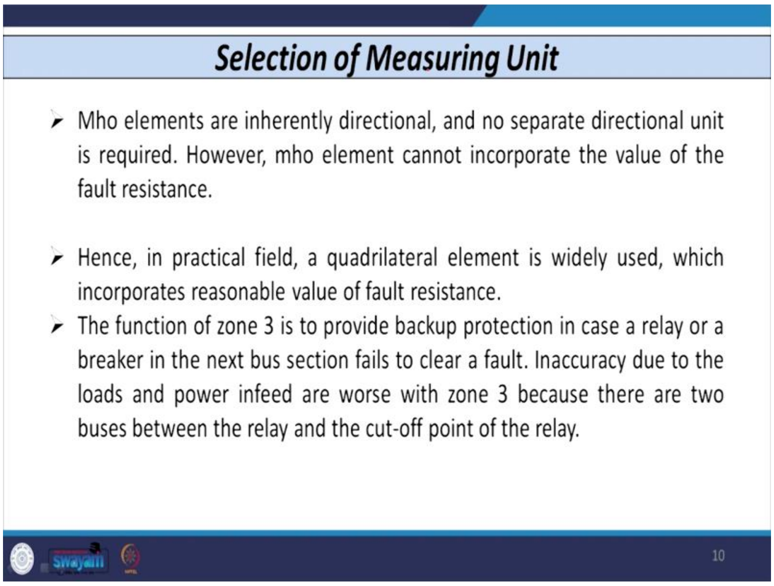

So, as I told you Mho relay is inherently directional and it can also accommodate some marginal value of fault resistance also, so it is used for longer EHV and UHV transmission lines. However, nowadays we know that we are utilizing digital relay and all earlier electromechanical and static type of relays are replaced by digital relays. So, whenever we use digital distance relay in actual field then this relay has different types of characteristic like quadrilateral, elliptical, quadrado.

So, you can configure or develop your any type of characteristic, even user custom design characteristic that is also possible. So, depending upon for what application you are utilizing you can choose a particular characteristic, okay. So, now whenever you consider the reach of the relay, reach of the distance relay, overreaching can cause third zone unit to trip undesirably particularly in case when you have loading or the transmission line is increases or maybe when you connect, a distribution transformer is connected nearby line.

So, in that case whenever you decide the third zone setting of distance relay you need to take care, or you need to consider this point. Moreover, discrimination between fault and overload that is very important. Even discrimination between fault and some abnormal phenomena like power swing that also very important. And your distance relay is capable to discriminate or distinguish between these two phenomena, so that is very important point.

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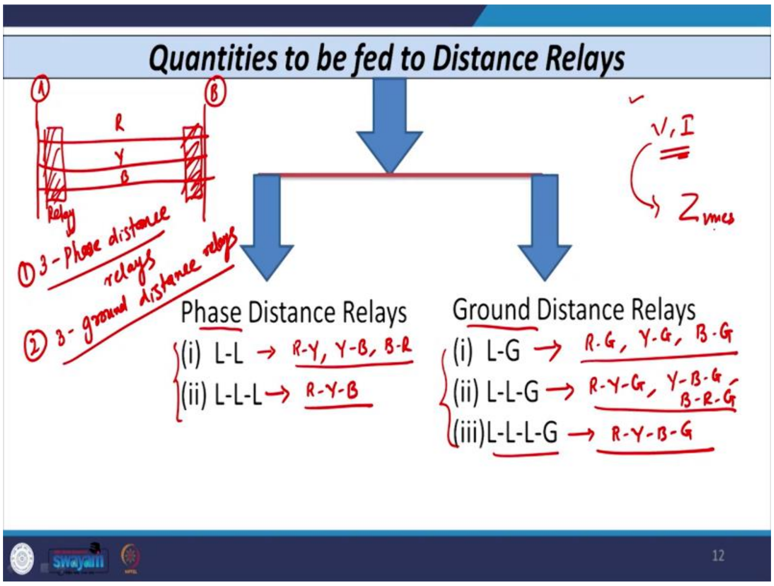

So, after such discussion, now let us discuss that what are the different types of distance relay. So, whenever I consider the distance relay, distance relays are basically classified by two units, one is known as phase type distance relay and another is known as ground type distance relay. So, for example if I have transmission line connected between two bus, let us say A and B and we have the three conductors say R, Y, B and we have the relay located here. This is your relay, supplied by CT secondary and PT secondary.

So, this relay, distance relay, when we talk, it can be phase type relay, distance relay, or it can be ground type distance relay. When I consider phase type distance relay, the phase type distance relay is capable to take care of line to line fault. So it can be R-Y fault, it can be Y-B type fault or it can be B-R type fault. So, any type of this line to line fault either R-Y, Y-B, B-R, the phase distance relay detects and then gives further signal to the circuit breaker.

It is also capable phase type distance relays are also capable to take care or detect triple line fault. So, this is say R-Y-B fault so any type of this phase to phase fault occurs which do not involve ground and phase distance relay that detects and further gives signal to the breaker. So, for this we need, for each phase we need one phase distance relay. So, if I have a relay here on this side at bus A, to protect this single circuit transmission line, then I need three phase distance relay, for each one for each phase.

So three phase distance relays are required to detect or take care of either line to line fault or triple line fault. Similarly, ground distance relay is capable to take care of L-G fault. So, it can be R to ground, it can be Y to ground or it can be B to ground. So, any type of line to ground fault occurs then ground distance relay detects and take care of this and further give signal to the breaker. Similarly, it can also capable to take care of double line to ground fault. So, it can be R-Y to ground, it can be Y-B to ground or it can be B-R to ground.

So, again (six) three line to ground fault, double line to ground faults, the ground distance relay take care of this thing. If triple line to ground fault occurs, which is very rare because it involves some impedance or resistance, then ground distance relay will also take care of this. So for at this point, at bus A if I want to protect single circuit transmission line, then along with three phase distance relays, we also need three ground distance relays.

So that means, if I want to protect single circuit transmission line, then I need total six distance relays, three phase relays and three ground relays at one bus. So, if I use another distance relay, here at bus B, then at bus B also for this relay, again three phase relay, phase distance relays and three ground distance relays, both are required. So total six units are required for, to protect one single circuit transmission line. So six for bus A and six for bus B.

So now when we consider phase relay and ground relay, and as I told you phase relays are meant for phase faults and ground relays are meant for ground faults, then we have to provide some quantity to the phase distance relay and some quantity to the ground distance relay, because here whenever we install the relay, we give input to the relay that is only voltage and current. So, whenever we give voltage and current relay depending upon some calculation, it has to convert it into impedance and that impedance is known as measured value of impedance.

And then it compares this measured value of impedance to the set value and if it is less than that then relay operates otherwise relay blocks. In this class we started our discussion with the reach of the distance relay. We have discussed the under reaching and overreaching of the distance relay, and then we have discussed what are the different distance relay characteristics that is possible or available.

We, finally we conclude that MHO and quadrilateral type of distance and relays are widely used for the protection of long EHV and UHV lines. And then we started our discussion with the different types of distance relay that is phase distance relay and ground distance relay. So, I stop here and then in the next class, we will, I further continue with the phase and ground distance relays. Thank you.