Power System Protection and Switchgear
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Lecture 09
Current Based Relaying Scheme- IV

So, in the last class we have discussed regarding the instantaneous Overcurrent relay and definite time minimum delay relay. So, now in this class we start our discussion with the inverse time overcurrent relay.

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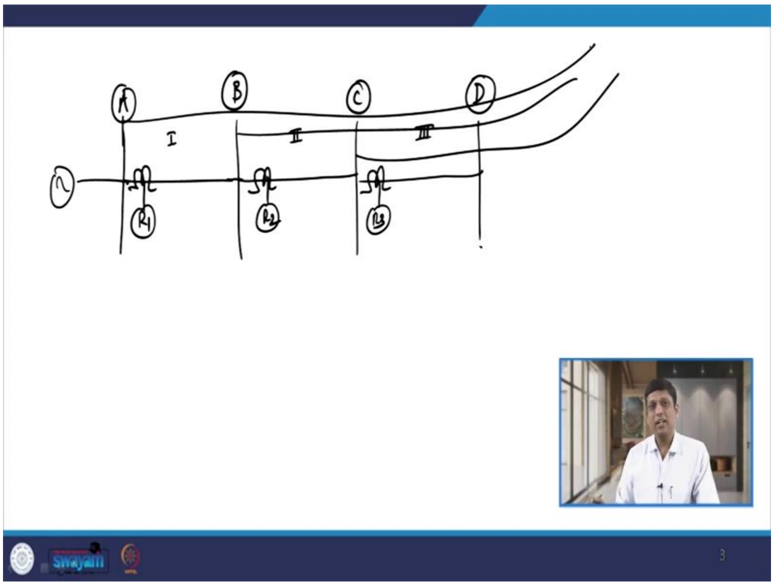

As I told you earlier in the class that if I consider the multi-section radial feeder network which contains let us say, the 3 sections, these sections are connected between the bus A, B, C and D and we have a relay in section 1 let us say R 1, relay in section 2, it is R 2 and relay in section 3 that is R 3. So, this is your first section, this is second section and this is third section.

So, with this case all the 3 relays R 1, R 2, R 3 are inverse time overcurrent relay, then we can plot the characteristic of this inverse time overcurrent relay like this. So, for R 2 we can plot the characteristic like this and for R 1 we can plot the characteristics like this. So, those 3 relays R 1, R 2, R 3 are inverse time Overcurrent relay.

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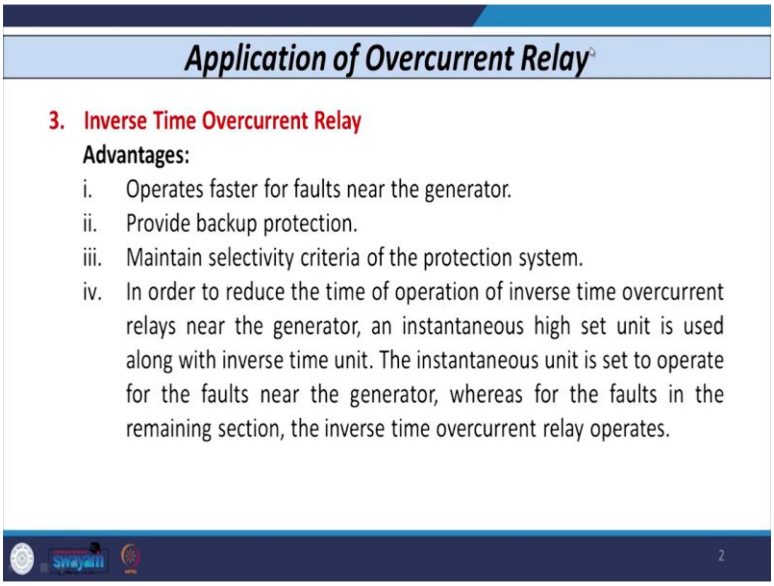

So, there are certain advantages of inverse time Overcurrent delay. The very first advantage is this relay operates faster for faults near to the generator.

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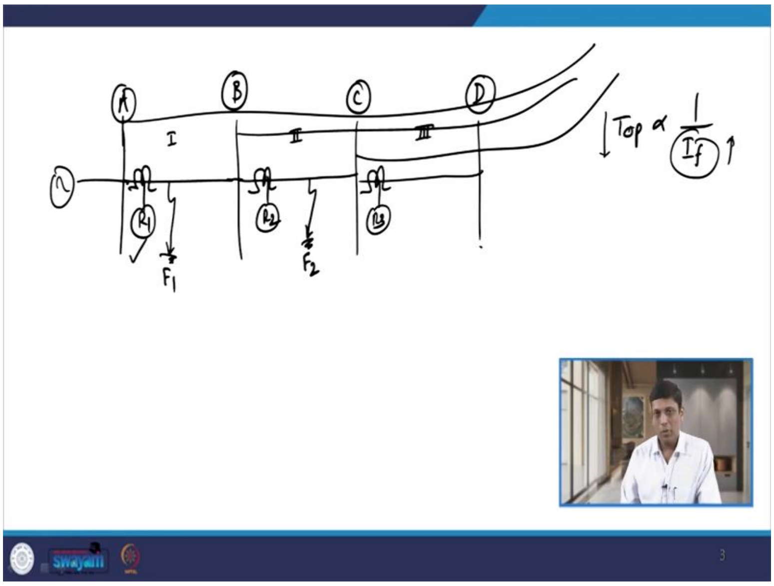

So, as I told you that if any fault occurs in section 1, let us say here at F 1 then if R 1 is a defining minimum time delay relay, then this fault clears with delayed time delay because the name itself of definite minimum time delay is that it operates after some pre-set value of time. So, if I use instead of that inverse time overcurrent relay, then time of operation of this inverse time overcurrent relay that is inversely proportional to the magnitude of fault current. So, as fault occurs in section 1 at F 1 then the magnitude of fault current is very high. So, the time of operation of this relay that is very small. So, this is the main advantage of inverse time overcurrent relay.

The second advantage is that this relay provides backup protection. So, again if any fault occurs in Section 2, let us say at F 2, R2 relay act as a primary relay and it has to sense this fault. If R 2 fails due to some reason, then R 1 has to provide backup. So, this type of backup that is possible if I use all the 3 relays are inverse time overcurrent relay. The third advantage is it maintains stability for the protection system.

So, this type of relay remains stable for any external fault situation and the very important fourth point is that if I want to further reduce the time of operation of this inverse time Overcurrent relay, then I can also connect instantaneous high set unit with the inverse time Overcurrent relay.

So, for small or medium range of magnitude of fault current, this type of relay follows inverse time overcurrent principle and for very high magnitude of fault current, the instantaneous high unit detects such type of fault and operates instantaneously. So, both this type of operation that is possible in the 1 relay itself.

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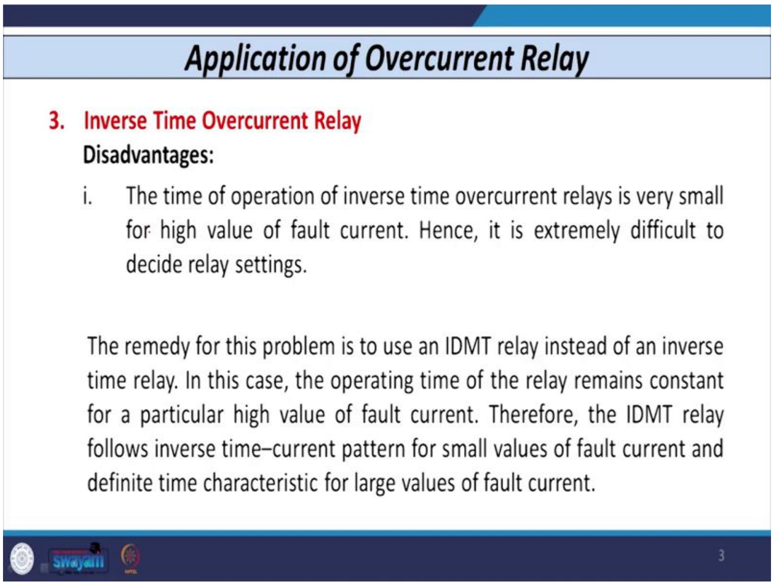

With this background, let us discuss what are the disadvantages of inverse time overcurrent relay. So, very first disadvantage of inverse time overcurrent relay is that the time of operation of inverse time Overcurrent relay is very small for high magnitude of fault current.

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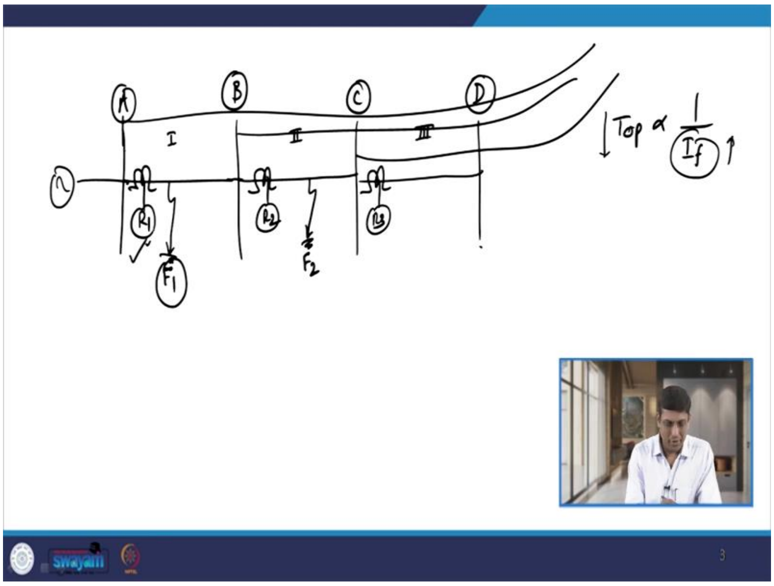

So, if I consider the same example in this multi-section radial network if fault occurs at F 1 the relay R 1 has to sense this and whenever R 1 senses the fault, then the time of operation of this relay is very small. So, again it is very difficult to decide the setting of the relay. So, there are as I told you earlier, that this relay has 2 types of settings; one is plug setting and another is time dial setting. So, the remedy of this problem is I have to use the inverse definite minimum time delay relay instead of inverse time overcurrent relay. So, this is IDMT relay is a combination of inverse time overcurrent relay and definite minimum time delay relay.

So, for low magnitude of fault current the relay acts as a universal time overcurrent relay, so time of operation is inversely proportional to the magnitude of fault current and for very high magnitude or fault current the relay acts as a defined minimum time delay relay. So, this is how the IDMT relay works.

The next disadvantage of inverse time overcurrent relay is in case of multi-section radial feeder network particularly when the source impedance is greater than the load impedance, then it is very difficult to decide the setting of the relay due to insignificant difference between the magnitude of fault current in one section with respect to the magnitude of fault current in other section. So, for example, to understand this let us consider the again the same multi section radial feeder network.

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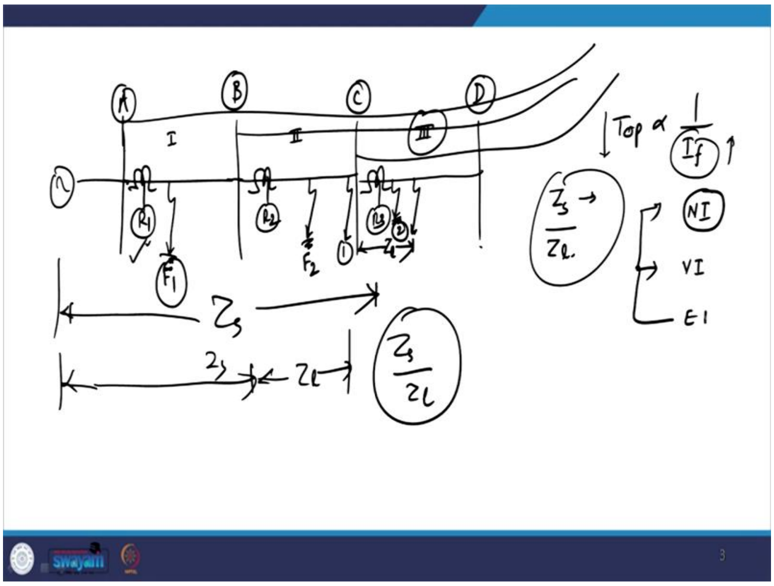

Here there are 3 sections. So, if I consider the third section, then for third section the value of Zs that is the source impedance which is the impedance from source to the relaying point that is something like this. So, Zs for relay R 3 is this much and if any fault occurs somewhere here, let us say this point, then the Z l is very small that is only here. So, if I take ratio of Zs by Z l in this case, we will get one value. And if I consider let us say fault somewhere here, this type of fault is known as the remote end fault for line section 2. So, in this case also the value of Z s that is something like this and the value of Z l that is like this.

So, if I take this ratio, Zs by Z l and this ratio and this ratio for any fault in close in fault in section 3. So, this close in fault in section 3 and remote end fault in section 1 there is insignificant difference in the magnitude of fault current. So, this ratio is also not that much different so, it is very difficult to decide the setting of inverse time overcurrent relay if I use normal inverse characteristic. So other remedy is, I have to use either very inverse characteristics or I have to use the extremely inverse characteristic to avoid this situation.

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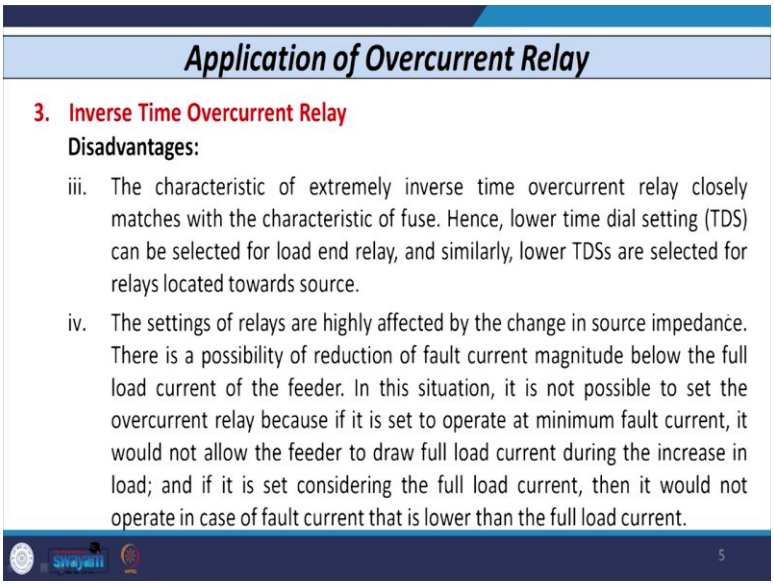

So, that is another disadvantage of this type of inverse type of overcurrent relay. So, the third disadvantage of inverse overcurrent relay, whenever we want to decide the characteristic of relay, then its characteristics should be exactly match with the characteristics of the particular protective device which we have connected near the load.

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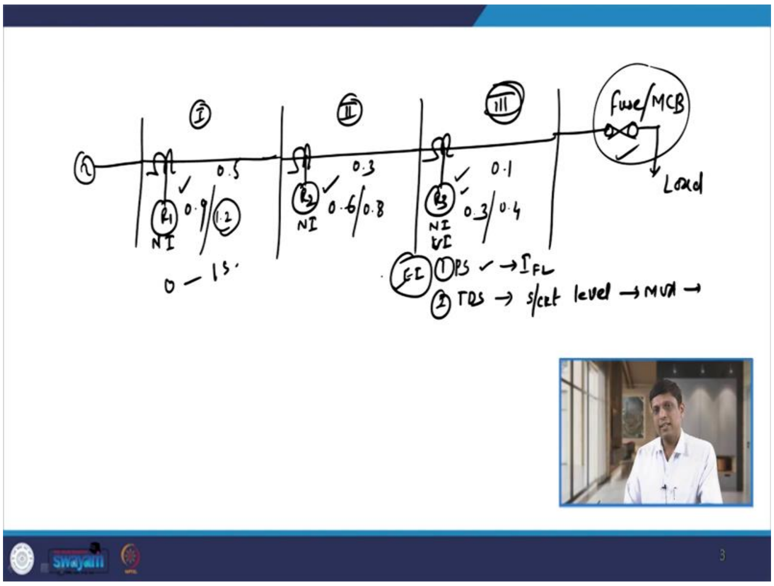

So for example, if I consider the similar type of network, same multi section radial feeder network, let us say it contains the 3 sections; section 1, section 2 and section 3. And let us say we have 3 relay R1, R 2 and R 3 in each section 1, 2 and 3 respectively. Now, suppose I use all the 3 relays R 1, R 2, R 3 R inverse time overcurrent relay, having normal inverse characteristics. So, characteristic of all the 3 relays that is normal inverse. If I want to decide the time settings of this relay, as I told you earlier there are 2 settings, 1 is the plug setting and the other is the time dial setting.

Plug setting is based on the magnitude of current full load current physically and the time dial setting depends on the magnitude of or short circuit level. Usually this level is given in MBA. So based on this you calculate the fault current and then you decide the time dial setting of the relay.

Suppose that the time dial setting of relay R 3, that is let us say 0.3. Now normally, when we decide the time dial setting of multi-section radial network, then here the load is there. So, let us say we have a load connected here and we have a fuse or MCB connected with this node for protection of load against short circuit.

So, I have to coordinate relay R 3 with the characteristic of fuse. So, first I decide the time dial setting of relay R 3 as this R 3 is very near to the load and then we have to move the source and then we have to decide the TDS of R 2, let us say it is 0.6 and then we have to decide the TDS of R 1 let us say it is 0.9.

Now, if due to some change in the network suppose, I need to change the TDS of relay R 3 that is 0.4. So, obviously TDS of R 2 that also changes let us say it becomes 0.8. And similarly the TDS of R 1 also changes and it becomes the let us say 1.2. But 1.2 is not possible because the range of TDS is only from 0 to 1 second.

So, here it is very difficult to decide the time dial setting of this relay if I use normal inverse characteristic. So, instead of that the remedy or solution is, I have to use the very inverse or I have to use the extremely inverse characteristic. Out of very inverse and extremely inverse I use extremely inverse characteristic because it exactly matches with the characteristic of fuse or MCB.

So, if I use this then we can select the TDS of the relay which is located near the load and in this case R 3, its TDS comes out to be very small let us say 0.1, as we move further towards the source, the TDS of R 2 can be 0.3 and TDS of R 1 that can be 0.5. So, lower time dial settings can be selected if I use the extremely inverse characteristic that is exactly match with the characteristic of fuse or MCB.

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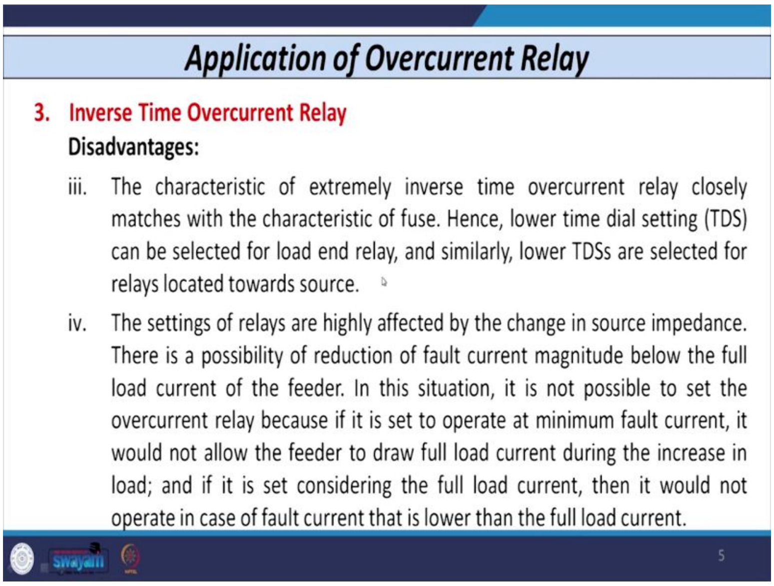

So, that is the third disadvantage of inverse overcurrent relay and we can also resolve this issue if I use the extremely inverse overcurrent relay. Let us further proceed, the fourth disadvantage of this inverse time overcurrent relay is the setting of this inverse time overcurrent relays are highly affected by varying generating conditions.

So, varying generating conditions, we know that in power station, we do not use a single generator, but we have a multiple or group of generators and all are connected in parallel. So, depending upon the requirement of load either single generator is connected or operating or multiple generators are connected or operating.

And based on the requirement of load whether it is high or low, the number of generators connected in the network that is also switched on or switched off. So, when such condition exists, it is very difficult to decide the setting of this inverse time overcurrent relay, because the source impedance changes. So, suppose when we have let us say the multiple generators are connected, the effective or equivalent source impedance that is lowest and when only single generator is connected then the overall or equivalent source impedance that is highest.

So, when the equivalent impedance is lowest or highest based on that the magnitude of current changes and hence the operation of inverse time overcurrent relay that is also affected.

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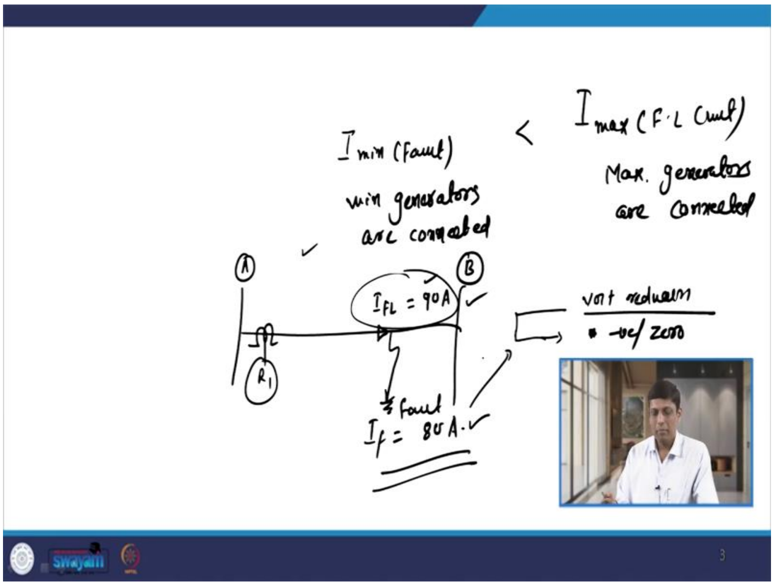

So, the practical problem is, it may be possible that sometimes when I use number of generators connected in parallel, then it may be possible that the minimum value of fault current. So, I minimum fault when minimum number of generators are connected, when minimum number of generators are connected this is less than the maximum value of full load current when maximum number of generators are connected.

So, when such situation exists, we have a minimum value of fault current when minimum generators are connected it, may be less than the maximum full load current when maximum number of generators are connected in the system. When such situation exists it is very difficult to decide the setting of inverse time Overcurrent relay, let us understand this with an example.

Let us say we have a feeder connected between 2 bus A and B and let us say we have a relay R 1 connected on this feeder. Say full load current of this feeder is let us assume that it is 90 ampere. Now, in certain exists and whenever fault occurs somewhere here at this point, the magnitude of fault current, let us say it is 80 amperes.

So, when such situation exists it is very difficult to decide the setting of inverse time overcurrent relay, because if I decide the setting based on minimum fault current 80 amperes, it operates if current exceeds 80 ampere, so it does not allow the feeder to take full load current and if I decide the relay setting was not this full load current that is 90 ampere then relay does not operate or it is not able to detect the minimum fault current with the magnitude of 80 ampere which is lower than the full load current of the feeder.

So, it is very difficult to decide the setting in this case if I use inverse time overcurrent relay. And again the question comes in mind that even though the magnitude of fault current here it is lower than full load current, this is harmful to the feeder because whenever fault occurs and if that fault is asymmetrical in nature, then it may lead to generate one thing, voltage reduces.

So, whatever equipment you have connected, the performance of those equipment that is affected, and second it will also lead to degeneration of negative sequence and 0 sequence if fault is asymmetrical in nature. So, that is why even though the magnitude of fault current is lower than the full load current of the feeder it is harmful and we need to detect it by some means.

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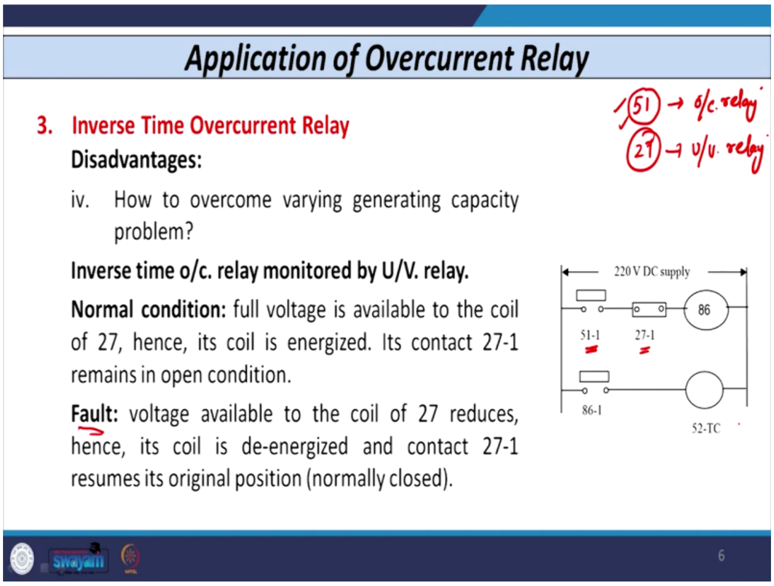

So to avoid this, the solution of this this thing is we have to use the overcurrent relay that is monitored by under voltage relay. So if I use such things, then the overcurrent relay that is denoted by the number that is known as 51. So 51 is your overcurrent relay. It is coil off overcurrent relay, and 51-1 that is the contact of the overcurrent relay.

So, to resolve this issue, what we do is that the magnitude of fault current is lower than the full load current. So, we set the relay based on the minimum magnitude of fault current. So, if I consider the earlier case we set the relay based on this 80 ampere that is the minimum fault current.

So, when the feeder takes full load current, obviously current exceeds the plug setting or pickup value so relay 51 operates. When left 51 operates its contacts that closes that is 51-1 closes and further action will take place. But now, when this condition is normal, when there is no fault when feeder takes full load current, I have also connected the another contact that is 27-1. So, 27 is the coil of under voltage relay and 27-1 that is the contact of under voltage relay. It is a normally closed contact, so when full voltage is available to the coil of 27 in this case the coil is energized and the contact of this relay 27 that is 27-1 which remains in open condition. So, even though se set the relay based on minimum fault current and when there is no fault during normal condition and when it takes full load current even though 51-1 closes, there is no tripping of the circuit because 27-1 that is in open condition.

Now, in case of fault the other condition, the 51-1 relay coil is energized so 51-1 already closes. Whenever fault occurs the voltage reduces and when it reduces below some value, this coil of under voltage relay 27 that is de-energize. So, the relay contact of this 27 that is 27-1 remains at or hold its original position that is normally closed, 51-1 closes this 27-1 is already closed so it energizes the coil of auxiliary relay 86 which further closes the contact of auxiliary relay 86 and hence the final trip coil of circuit breaker that is energized.

So, this is how we can avoid the problem that is faced by inverse time overcurrent relay that is varying generating condition problem, so this is how we can avoid it.

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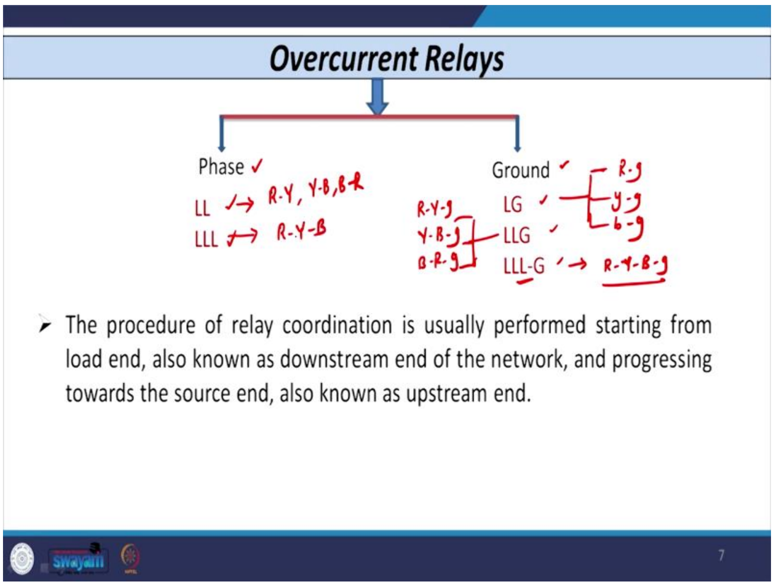

So, after that let us consider that how the coordination of overcurrent relay that is carried out. So, we know that we have over current relay, so over current relay there are 2 types of over current relay; one is known as the phase relay and the another is known as the ground relay. Phase overcurrent relays are those relays which are responsible for detection or operation in case when line to line fault occurs or triple line fault occurs. So, both are phase faults so, whenever any phase fault occurs, phase overcurrent relay detects that fault and it gives signal to the circuit breaker.

Similarly, ground overcurrent relays are those relays which are responsible for detection of any type of fault that involves ground. So, line to ground fault, double line to ground fault and triple line to ground fault are the different types of ground faults. So, when I consider line to ground fault, again there are 3 types of line to ground faults R to ground, Y to ground and B to ground.

Similarly, when I consider the double line to ground fault again there are 3 types of faults; R-Y to ground then Y-B to ground and then we have B-R to ground. So, there are 3 types of line double line to ground fault and then we consider the triple line to ground fault that is R-Y-B and ground fault.

Same way on the other side if I consider phase overcurrent relays than double line fault that means either we have R-Y fault or we have the Y-B fault or we have the B-R fault, there are 3 different faults. And when we consider triple L fault we have the R-Y and B fault. So, the overcurrent relay either phase overcurrent relay or ground overcurrent relay it has to detect phase fault or ground fault.

So, we have 2 different types of ground overcurrent relay; phase relay that is responsible for detection of phase faults, and ground relay that is responsible for detection of ground faults. So, the procedure of relay coordination, coordination means we have to decide setting of the other relay with reference to the setting of the previous relay or the any other relay located near the load end that procedure is known as coordination of relay.

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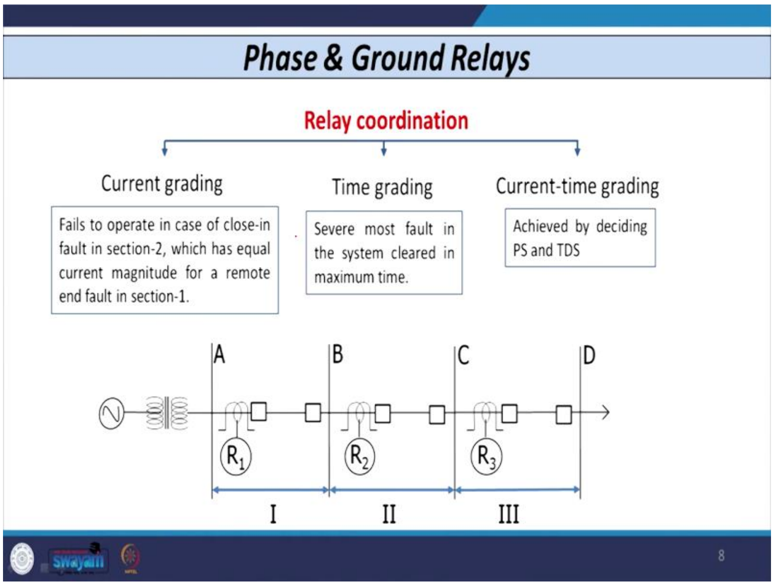

When we carry out coordination of relay when we follow we have to follow some procedure and we always start the setting of those relays which are located near the load end this this is also known as downstream end of the network. And as we move further towards the source end also known as the upstream end of the network, we have to progressively decide the setting of other relays.

So, let us see how the coordination of relays that is carried out. So, there are basically 3 methods of coordination of phase and ground overcurrent relays, the first is the coordination based on current quantity, the second is the based on coordination of time quantity and third is the coordination based on the current and time both the quantities.

So, when I consider the coordination based on current that is known as current reading procedure and this type of procedure normally fail to operate when we have a closing fault in one section, which has the equal magnitude for the remote end in the other section.

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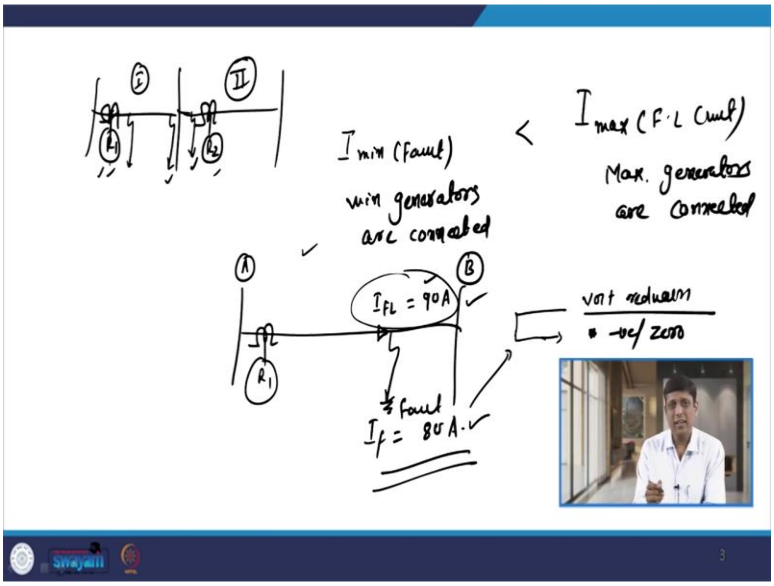

So, if I consider suppose the 2 section network here, let us say this is section 1 and section 2 So, any close in fault occurs in section 2 and any remote end fault occurs in section 1 the magnitude of these 2 are almost equal. So, again, it is very difficult to carry out coordination of relay based on current only. The second type of coordination procedure that is known as time grading. So, we carry out the coordination of relays based on the time however, this method also usually not used in the field because the severe most fault that is cleared by very long time delay and the best example is, we use here the relay.

Let us say we have a relay R 1 and relay R 2 in section 1 and 2, if I use both coordination of these two relay based on time grading procedure, then any fault occurs here, this relay R 1 operates very late. So, the severe most fault that is cleared by very time delay so that is why the time grading method that is also not used in actual practice when we carry out coordination of relay with other relays.

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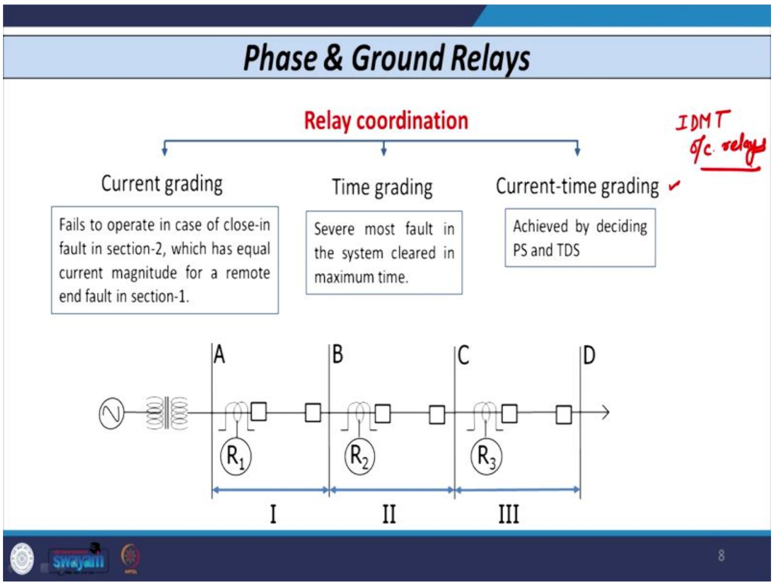

So, the method which is actually used in the field for coordination of relays that is based on both current and time grading, and the relays which we used in actual field, those relays all are usually IDMT overcurrent relays. So, all the relays are IDMT overcurrent relays, which is a combination of inverse time Overcurrent relay and definite minimum time relay.

So, usually when we use current time reading method for coordination of relays, we first calculate the plug setting of all the relays and then we calculate the time dial setting of all the relays based on certain procedure. So let us see how what are the procedures or rules for deciding the plug setting and time dial setting of relays.

So coordination is nothing but we need to decide the plug setting and time dial setting of relay located near the load. And then as we move further towards the source, we need to decide the plug setting and time dial setting of other relays with reference to the relay which is located near the load end. So, let us see what are the different rules for deciding the plug setting and time dial setting of the face and ground relays.

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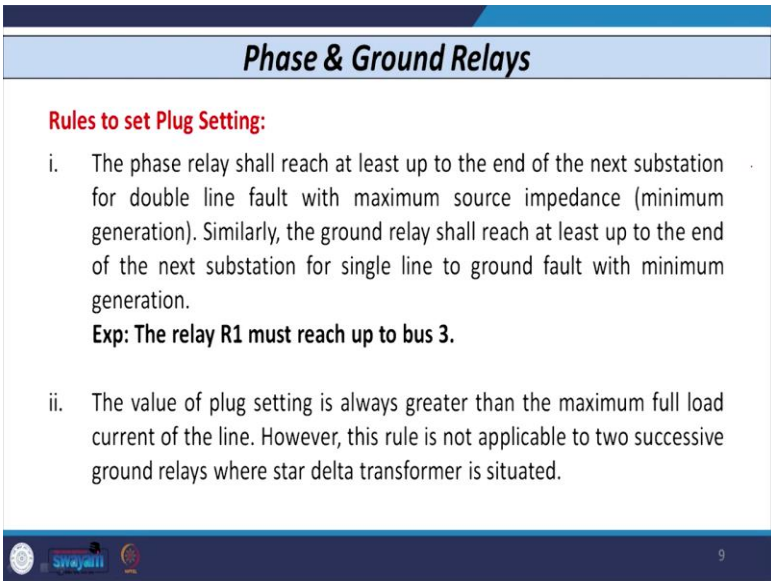

So, if I consider first the rules for deciding the plug setting of ground relay as well as phase relays both. Then the first rule is that the phase relay shall reach at least up to the end of next substation for double line fault with minimum generation, same way the ground relay has to reach up to the end of the section for L-G fault with minimum generation.

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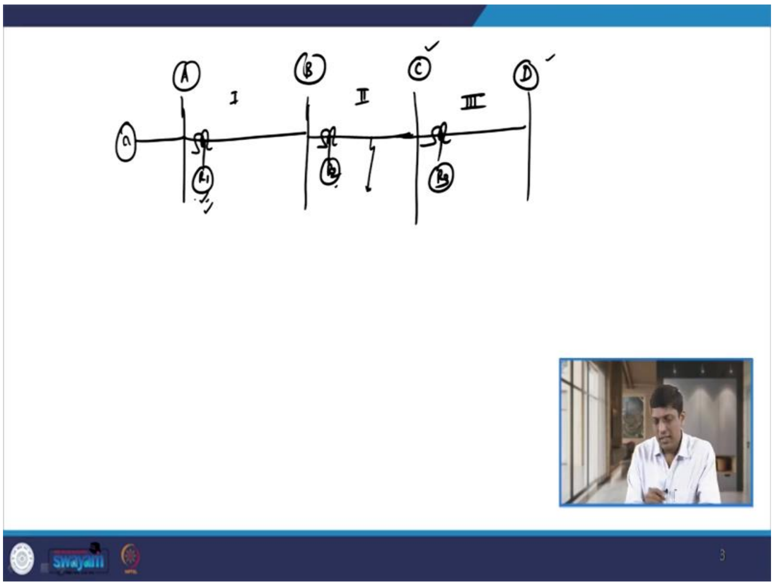

So the meaning of this is that if I consider the same multi-section radial network, let us say we have a network like this 3 section network. So we have here four buses A, B, C and D and let us say we have 3 sections; section 1, section 2 and section 3. And in each section we have a relay R 1 relay R 2 and relay R 3. So, the meaning of first rule that is plug setting, the reach of the relay shall reach at least up to the end of next section. So, reach of relay R 1 that has to reach up to bus substation C, reach of R 2 that has to reach up to substation D. So, if I use R 1 as a phase relay, then its reach should reach for double line fault and if I use R 1 as a ground relay then it’s reach should reach up to for L-G fault.

Why it's reach should be up to substation, let us say if I consider R 1, whether it is phase relay or ground relay, its reach should go up to substation C, why C? Because if any fault occurs in this section, if relay R 2 fails, then R 1 has to provide backup that is why it's reach that should go up to the substation C and the same concept is applicable for other relays. So, that is the meaning of the first rule to decide the plug setting of the relay.

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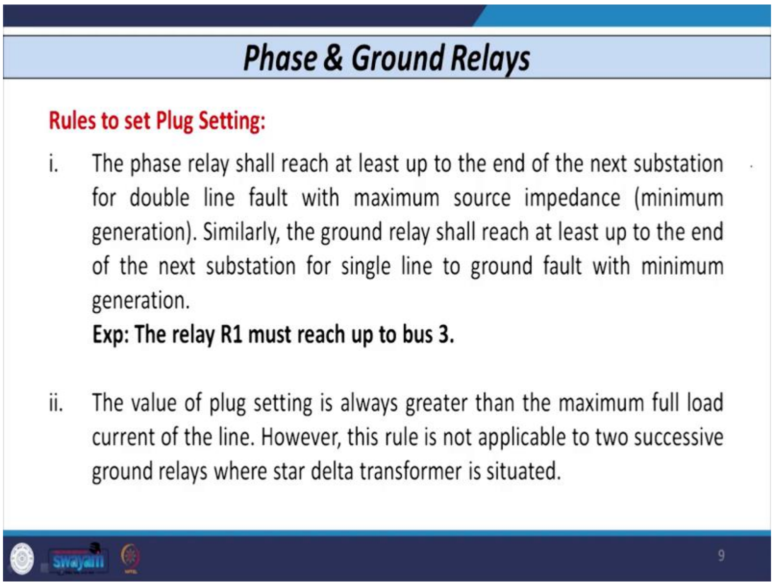

The next rule is the value of clock setting is always greater than the maximum full load current. So, whenever we decide the plug setting of any IDMT relay, we have to decide based on the what is the full load current that can carry by the feeder. So if any additional percentage overload is mentioned then that also we need to consider while we are deciding the plug setting up the relays. However, this rule is not applicable for ground overcurrent relay when 2 successive ground overcurrent relay are connected and in between that there is a Star-Delta transformer is situated.

So we will see later on why this rule is not applicable. This is not applicable because phase relays are connected across the secondary of line sets whereas ground relays are connected in the residential circuit of 3 line sets, when we connect the ground relay in the residual circuit of three line sets, then this current is not reflected in the residual circuit. That is why while deciding the plug setting of phase relays, we have to consider its plug setting based on full load current of the feeder and for ground relay it is not applicable.

So, let us see what is the third rule for deciding the plug setting. When we decide the plug setting of whether ground or phase overcurrent relay with reference to some other relay, the pickup of the relay has to vary from 105 percent to 130 percent of the plug setting of the previous relay.

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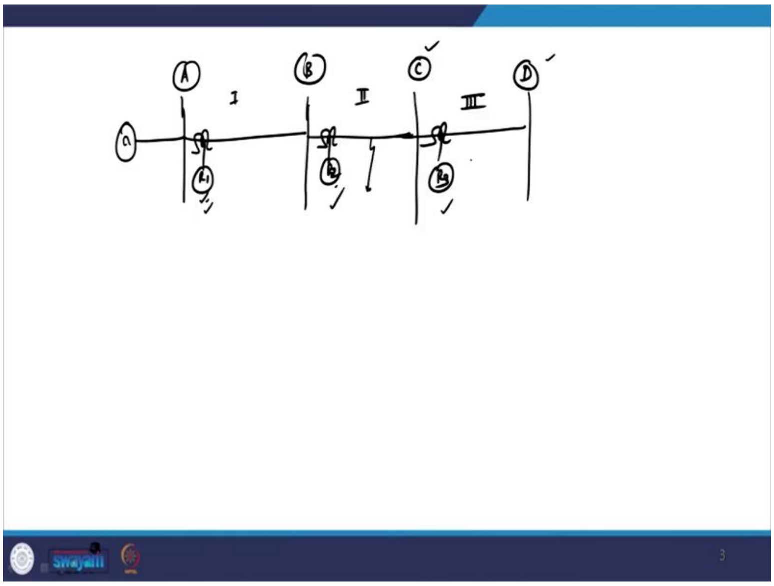

So if I consider the same feeder network say here, let us consider relay 2 and relay 3 which is in section 2 and 3.

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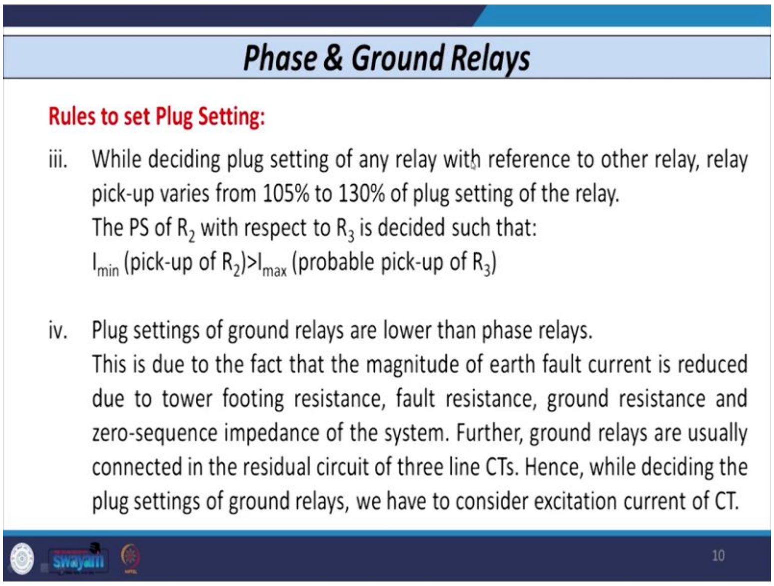

So when you consider these 2 relay, then the plug setting of R 2 that has to be decided with reference to plug setting of R 3, so, you have to decide this setting such that minimum value of pickup current of R 2 that is always greater than the maximal probable pickup current of relay R 3 so that there should not be any mal operation of relay R 2 for any fault that occurs in line section 3, because if I consider if any fault occurs in this section then R 3 has to operate, R 2 does not operate. So, if we reach that then the pickup of relay R 2 that has to be decided by this rule.

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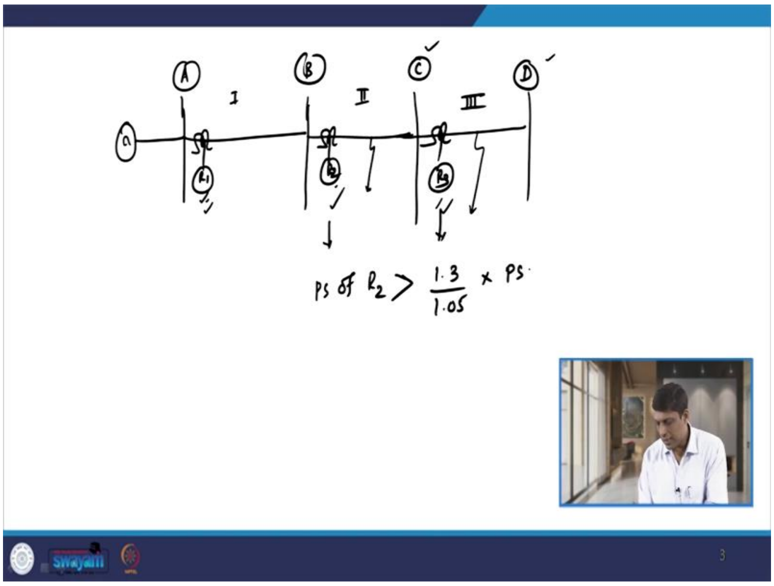

So, when we decide the pickup of relay 2, then pickup of R 2 is decided based on R 3. So, plug setting of R 2 that is always greater than the 1.3 upon 1.05 into plug setting of relay R 3.

So, this rule we need to remember when we decide the plug setting have two relays. Now here, 1.3 comes from 130 percent and 1.05 comes from 105 percent of the pickup variation. Same way, if I consider plug setting of relay R 1 then it has to be greater than the 1.3 upon 1.25 into plug setting of R 2. So, as we move progressively from load end towards the source end, accordingly we have to decide the plug setting or pickup of this IDMT overcurrent relay based on this equation. So, this is the third rule to decide the plug setting of phase relay and ground relay.

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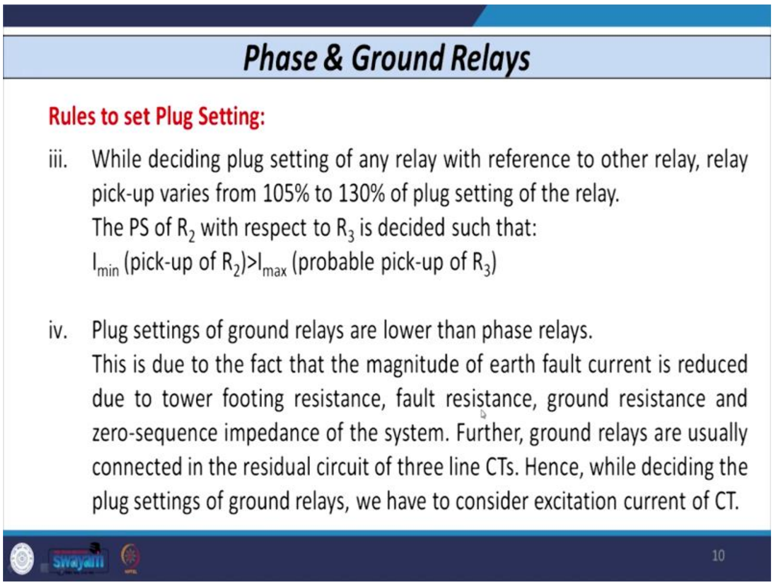

So, in this lecture, we started with the what are the advantages of inverse time overcurrent relay and then we have also discussed there are four main disadvantage of the inverse time Overcurrent relay, the very important one that is the setting is affected due to varying generating conditions. And then we started our discussion with what are the rules to decide the coordination or setting of the plug setting and time dial setting or phase and ground relays. So the next rule that is fourth rule to decide the plug setting of the phase and ground relay that we will discuss in the next class. Thank you.