Power System Protection and Switchgear
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Lecture 07
Current Based Relaying Scheme- II

So in the last class we have discussed regarding the four different types of overcurrent relays. We started with instantaneous over current relay, then time delayed relay then we have discussed the inverse time overcurrent relay and at last we have discussed the inverse definite minimum time overcurrent relay. So with this background of different four different types of overcurrent relay let us solve few numerical.

So, let us consider that there is figure shown here and it is a single line diagram of a portion of power system. So, the one relay is R is connected on this feeder and this relay is a IDMT relay having normal inverse characteristic. The setting range of this relay that is relay R that is 50 percent to two hundred percent of one ampere in steps of 25 percent. So here, one ampere is the relay rated current.

The relay also contain the high set instantaneous unit and it setting range is from 400 percent to 2000 percent of one ampere in steps of hundred percent. The plug setting the time dial setting of this IDMT relay that is given as the hundred percent of one ampere and the TDS is 0.5. The setting range of instantaneous high set unit that is also the set value that is also 1200 percent.

So for two different fault cases say in first case if fault occurs that is shown in this figure and if the magnitude of fault current is 600 ampere then you need to calculate what is the time of operation of relay? And in case second case when the fault occurs and if its magnitude is 1500 ampere then also you need to find out what is the time operation of relay R. So let us solve this example.

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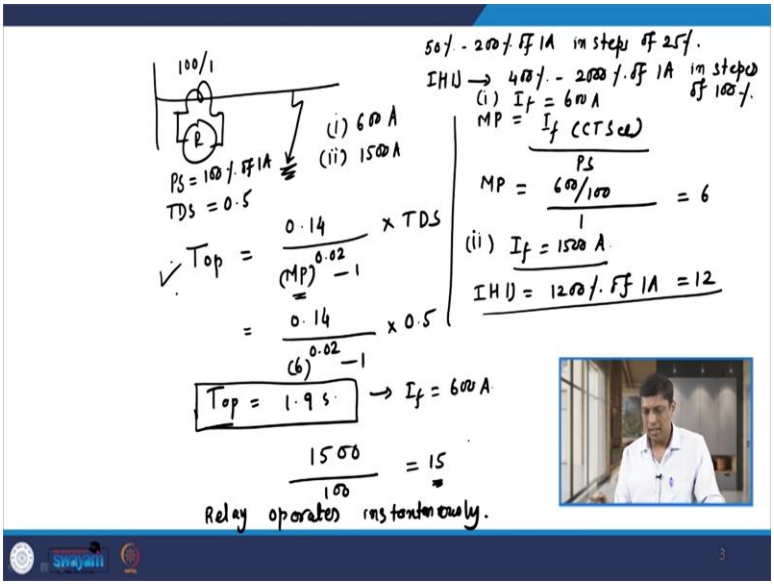

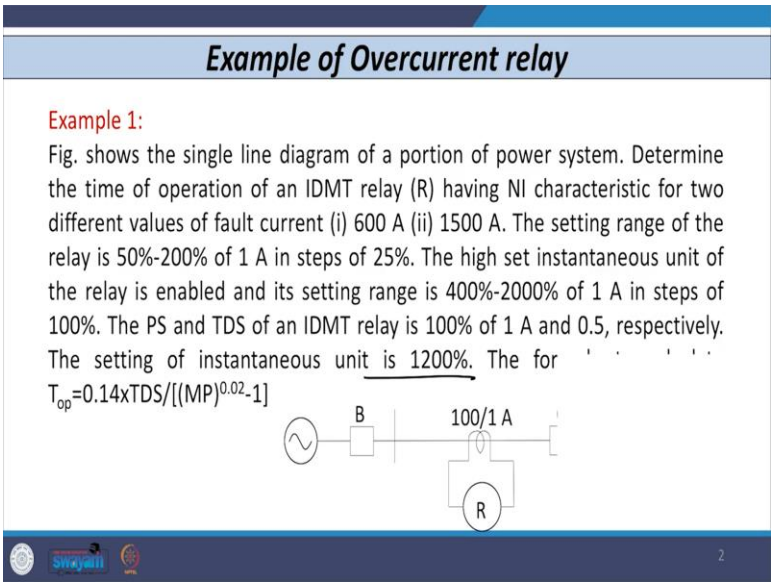

So in this example as I told you the relay R is connected, across the secondary of CT this relay is IDMT overcurrent relay. The CT ratio given that is 100 by 1 and the fault that is going to occur here. And there are two cases in the first case the magnitude of fault current that is given as 600 ampere. And in the second case the magnitude of fault current that is given as 1500 ampere. So we need to plug setting of this relay that is given as 100 percent of 1 ampere that is the relay rated current. And it is TDS value that is given as 0.5, the setting range of this relay are that is from 50 percent to 200 percent of 1 ampere and that is in steps of 25 percent.

The setting range of instantaneous high set unit that is given as 400 percent to 2000 percent of relay rated current that is one ampere and this is in steps of 100 percent. So with this background let us find out the time of operation of relay. So in order to find out the time of operation of relay R we are going to use the formula that is 0.14 divide by multiple of pickup current raise to 0.02 minus 1 into TDS of the relay R. Now, as the TDS of the relay R is given plug setting of the relay is also given.

So we need to find out the multiple of pickup current, so to find out the multiple of pickup current. Let us consider the case one that is say the first case where the current magnitude of fault current that is 600 ampere. So for 600 ampere fault current we know that the multiple of pickup current is given by fault current refer to CT secondary divide by plug setting of relay R. So if I just find out the value of MP multiple of pickup current the fault current is 600 ampere.

Then when it is referred on CT secondary side so it is 600 by CT ratio that is hundred and divide by plug setting of the relay. The plug setting of the relay is given as hundred percent of one ampere, so that is one ampere. So multiple of pickup current that comes out to be 6. So this value if I put this value here then we will have 0.14 divide by 6 raise to 0.02 minus 1 into TDS that is given as 0.5.

So if you solve this then it comes out to be roughly around 1.9 second, so that is time of operation of relay R for the first case when magnitude of fault current that is 600 ampere. So, that is for first case. Now let us consider the second case when the magnitude of fault current that is say 1500 ampere. Now if I look at the fault current value obviously, we can calculate the value of MP whatever it comes out in this case it comes out to be 15.

And you can put the value of 15 here and you can calculate the time of operation of relay for second case. However, the setting of instantaneous high set unit that is also given. So if I look at this example the setting of instantaneous high set unit that is given as 1200 percent. So as the setting of instantaneous high set unit that is given as 1200 percent of rated current that is one ampere so that is comes out to be 12. So, if I find out for the magnitude of fault current that is 1500 ampere then for 1500 ampere if I divide it by CT ratio that is hundred by one then this comes out to be 15.

And as this 15 is greater than this value that is instantaneous high set unit so there is no need to calculation of time of operation of relay using this formula. So we can directly say that in when the if current exceeds this value 12 multiple of pickup current then relay operates instantaneously. So relay operates that is instantaneously, so there is no need of any calculation for the second case we can directly say that as its value 15 that is greater than 12. So relay operates instantaneously.

So that is the case so we have solved both the cases then we can found out the time of operation of relay.

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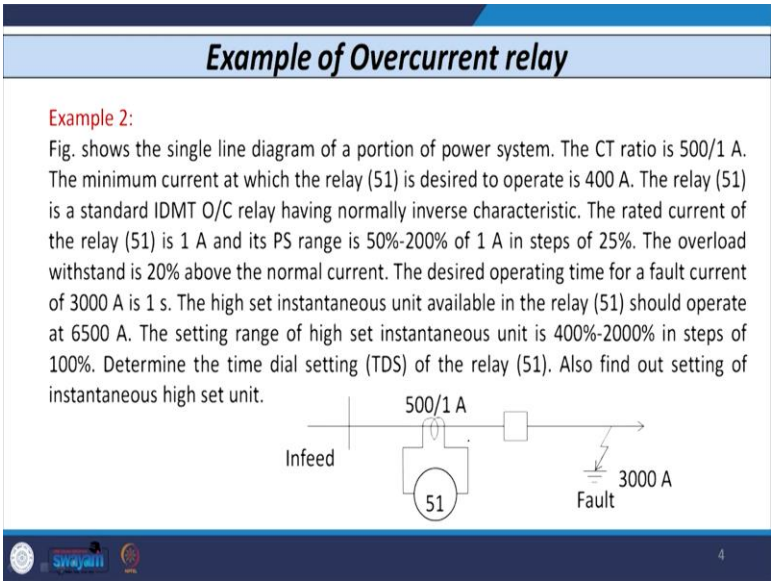

Let us also consider the another, example in which the similar type of figure is given where the relay is given that is known as 51. So let us also solve this example, now what is asked what is given in this example there is a relay that is connected in the feeder the fault current magnitude given that is 3000 ampere the CT ratio given that is 500 by one. The relay that is a overcurrent IDMT overcurrent relay as I told you earlier also the relay is always denoted by standard number.

So the number given to the overcurrent relay is 51 so here it is written 51. So this relay is desire to operate at 400 ampere current, so 400 ampere is the primary side current so equivalently when you transferred with CT ratio 500 by one. So on secondary side relay will operate accordingly.

This relay is a IDMT overcurrent relay having normal inverse characteristic and its rated is given as one ampere.

The plug setting range of this relay is 50 percent to 200 percent of one ampere in sets of 25 percent. The overload withstand capacity that is 20 percent above the normal current or full load current the desired operating time of fault current for 3000 ampere fault current magnitude that is given as one second. So if fault occurs on the feeder with 3000 ampere magnitude then the relay 51 will operates in one second that is meaning.

The high set instantaneous unit available in the relay 51 that should operate at 6500 ampere and the setting range of high set instantaneous unit that is 400 percent to 2000 percent of one ampere in steps of hundred percent. So for this, case we need to determine the time dial setting of relay 51 we need to also find out the what is the setting of instantaneous high set unit because its setting is not given. What is given is it is a value that is 6500 ampere. Now let us solve this example so to solve this example let us consider the same data.

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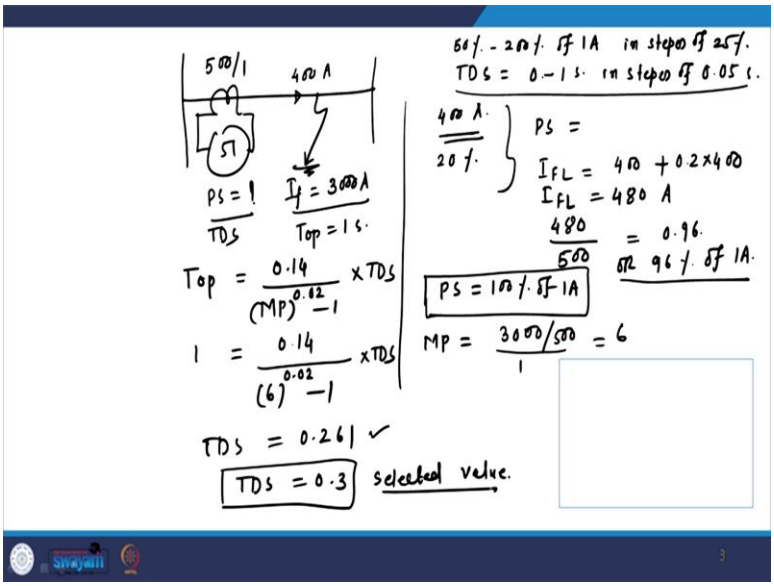

So let us that let us assume that the feeder and here the relay 51 is connected. The CT ratio given that is 500 by one and the fault occurs on this feeder so and the fault current magnitude that is given as 3000 ampere. The relay 51 the setting range is 50 percent to 200 percent of rated current that is one ampere and this is in steps of 25 percent. The time dial setting range of this relay that is 0 to one second in steps of 0.05 second, so this is also given.

Then the, it is also given that the full load current that means this relay 51 is desire to operate at 400 ampere that on primary side so 400 ampere we need to consider. It is also mention that the relay this is also capable to take care of 20 percent overload. So plug setting of this relay that is not given so we need to find out the plug setting as well as we need to find out the time dial setting of the relay. What is given is if fault current fault occurs with a magnitude of 3000 ampere then this relay 51 will operate in one second.

So time of operation of this relay 51 that is also given. So let us first find out the plug setting of the relay, now as I told you earlier the plug setting of any relay that depends on the full load current of the feeder that is carried out by the feeder so with and there is also with allowable percentage of overload. So the plug setting is if we wish to decide than we have to find out what is the full load current it can withstand. So it is mention that it can withstand 400 ampere full load current, plus it can also withstand 20 percent overload on 400 ampere so 20 into 400 that is comes out to be 480. So this the feeder can withstand 480 ampere current on primary side and equivalent current on secondary side.

So if I divide this 480 by CT ratio that is 500 so that comes out to be roughly around 0.96 or in percentage 96 percent. This is of relay rated current on secondary side one ampere so now you can decide the plug setting based on this value. The setting range of this relay is 50 percent to 200 percent of one ampere in steps of 25. So above 96 percent the next step available that is hundred percent, so we can decide the setting of relay that is hundred percent of one ampere. So this is one thing that we can calculate.

Now with this background let us find out what is the TDS of this relay so time of operation of relay that is given by 0.14 divide by multiple of pickup current raise to 0.02 minus 1 into TDS. Now for 3000 ampere fault current the time of operation of relay that is given as one second so that is 1.14. And we need to find out the value of TDS, the multiple of pickup current so multiple of pickup current we can find out as the fault current magnitude is given as 3000 ampere.

So we know that multiple of pickup current is given by fault current referred on CT secondary side so 3000 ampere divide by CT secondary side so CT ratio that is 500 and the whole divide by plug setting of the relay that is hundred percent of one ampere that is one. So we can say that comes out to be 6, so if I put this value here 6 raise to 0.02 minus 1 so we can easily calculate the value of TDS if you calculate it that comes out to be 0.261.

Now as the setting range of this TDS that is given as 0 to one second in steps of 0.05, so above beyond this 0.261 the next available range that is 0.3. So we can select the TDS of relay that is 0.3 that is selected value selected value. So this value we can select, so that is that completes first part. Now in second part you can see that they have mentioned that in the second part. The setting range of instantaneous high set unit is given and the high set instantaneous unit that should operate at 6500 ampere.

So if I consider this 6500 ampere with this current we have to find out what is the setting of instantaneous high set unit. So if I just calculate the instantaneous high set unit.

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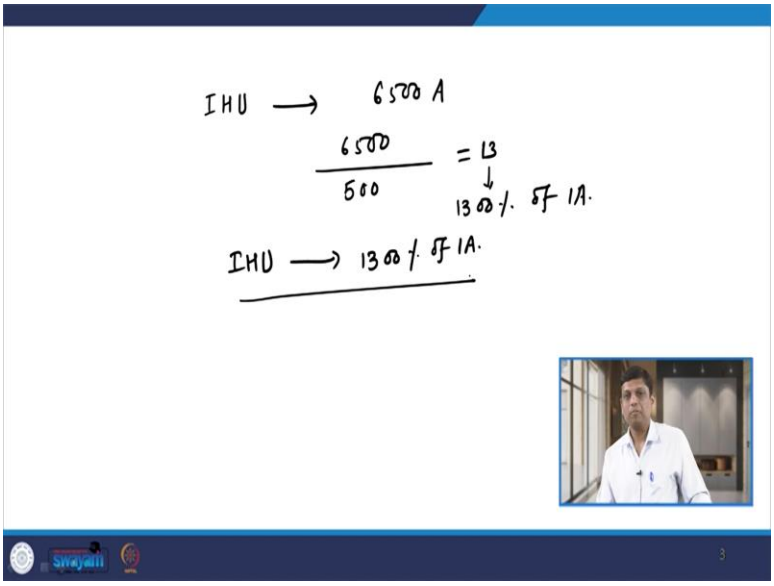

Then the instantaneous high set unit the current given that is 6500 ampere. So if I divide this 6500 ampere with the CT ratio that is 500 by one then I think this comes out to be roughly around 13. So if I consider in percentage that comes out to be 1300 percentage this is of one ampere. So setting range of this instantaneous high set unit that we decide as 1300 percentage of one ampere. So this is also completed, so this completes the second case of the given example.

So we have solved the both the examples and in one first example we have calculated the time of operation of relay. And in the second example we have calculated the time dial setting of the IDMT overcurrent relay. So with this background now let us move further. Now we that let us see what is the discrimination philosophy of the overcurrent relay. So basically, the

discrimination philosophy of overcurrent relay that is given by three different philosophy the first is known as it is based on current.

So that is known as current discrimination of the relay. So we what we do is we have multiple of relays are given and we decide the settings of relay based on current. So current is the coordination criteria coordinating criteria for in this type of philosophy.

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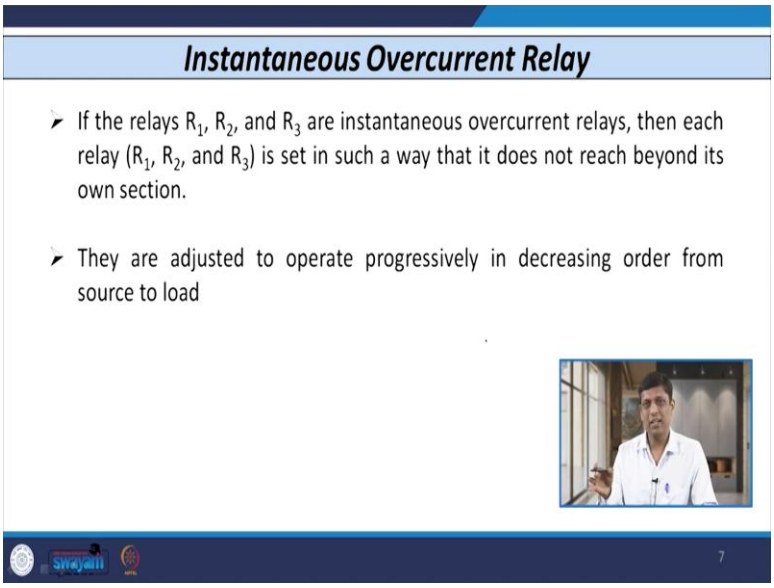

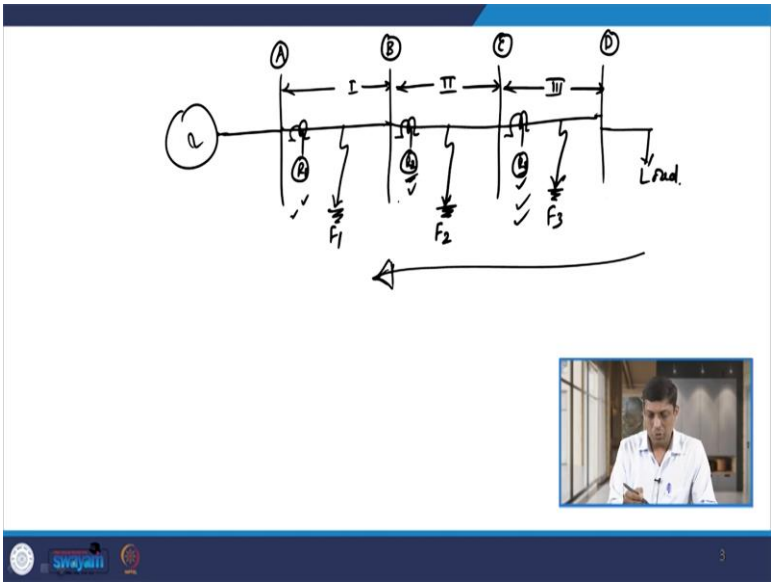

The second type of philosophy that is known as the time discrimination philosophy and here we use time as the coordinating criteria. And the relay we used that is definite time overcurrent relay. The third type of criteria that is the mixture of the first and second that is current time discrimination and in this case we will use both current and time as the coordinating feature. And then we decide the settings of the different relays.

And the relays we use in this case that is the first is the inverse time overcurrent relay and the second we use the IDMT overcurrent relay. Now in means in distribution network most of the utilities they use only the IDMT overcurrent relay. So for all our cases we will consider when we solve the example we consider all the relays are IDMT overcurrent relays. Now let us consider each and every philosophy one by one.

So if I use all the three relays or four relays or multiple relays available in radial structure or radial network. Then let us assume that this relays are instantaneous overcurrent relays so let us assume that the there are three relays are given. So if I assume there is a source and then we have a radial structure network and if I assume that the between bus A and B there is a one section line section or distribution feeder connected. And the relay here let us say this is R 1, same way between bus C and B and C the another relay R 2 is connected and same way between bus C and D the other third relay let us say R 3 that is connected.

So if I consider that this is the feeder section one this is the feeder section two and this is the feeder section three. So in all the three sections we have connected three different relays and

when we are talking about this relay R 1 relay R 2 and relay R 3 of course the load that is connected at this point. So when we have a load on one side and source on other side then we want to decide how this relay coordination of relay R 3, R 2 and R 1 that has to be carried out.

So for this case let us assume that all the three relays R 1, R 2, R 3 are instantaneous overcurrent relays. And this relay operates for fault within its own section that means if I consider this three line sections if any fault occurs in section two let us say F 2 then relay R 2 as to operate other two relays R 1 and R 3 they do not operate. If any fault occurs in say let us say section three say F 3 we have three then relay R 3 has to operate as a primary relay other two relay R 1 and R 2 they do not operate.

Same way if any fault occurs in line section one say F1 then relay R1 has to operate, other two relays R2 and R3 both should not operate because if they operate then that is against the requirement of selectivity criteria of the protection system. So with this background let us consider the relay R1, R2, R3 are all three are instantaneous over current relays. It may possible that let us say if fault occurs in section two that F2 relay R2 has to operate as a primary relay.

But because of some reason if R 2 fails then R 1 has to provide backup, so backup protection that is also required where any primary defense system fails then it is very important. So, with this background all this three relays are instantaneous over current relays and they are adjusted to operate progressively in the order from the let us say the load to source. So, what we the meaning is that if any fault occurs here then the first relay has to operate that is relay R 3.

So we have to coordinate relay R 3 with relay R 2 because relay r two will operate after the operation of relay R 3. Similarly relay R 1 will operate after the operation of relay R 2 and relay R 3, so as we move from load to source so we have to set the first relay which is connected near the load, we have to set first so setting of relay R 3 that has to be decided first. And then, as we move further from our source side then progressively we have to decide the setting of other relay say R 2 R 1 and so on.

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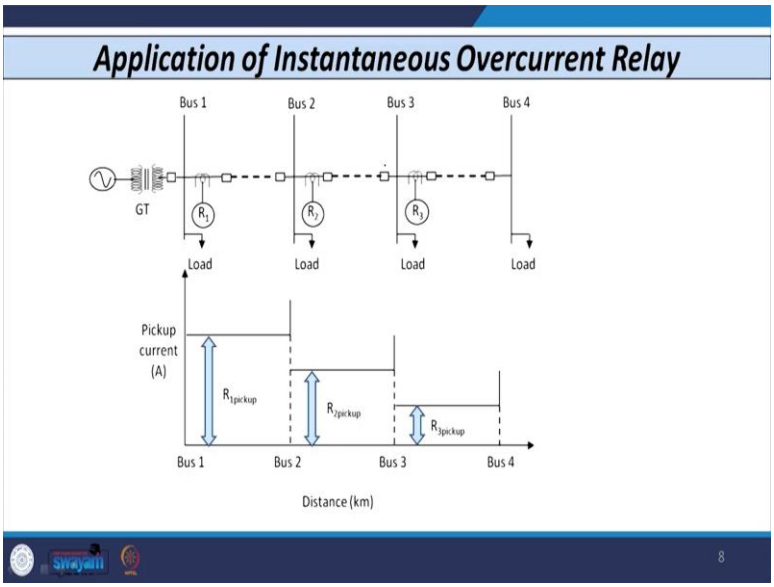

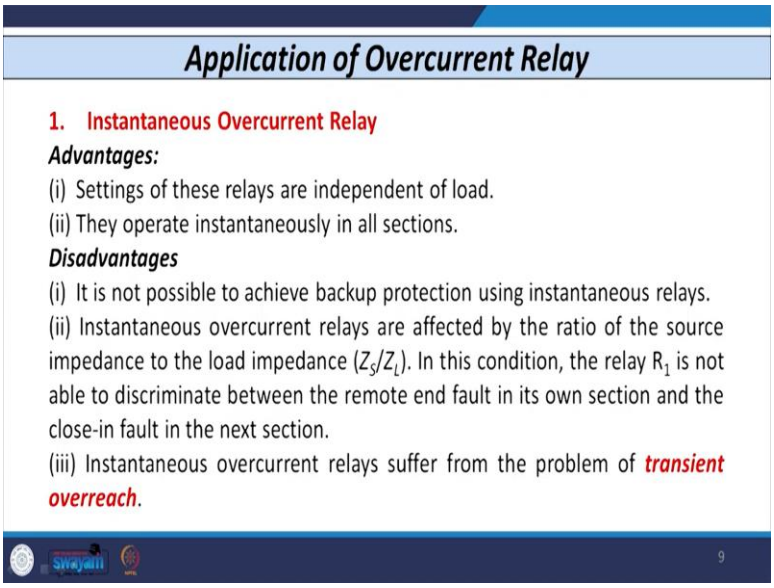

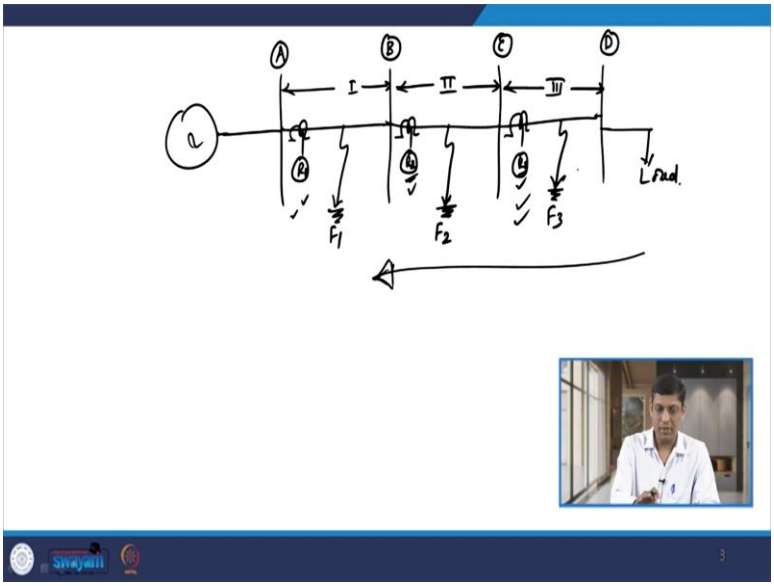

So with background if I consider the same system as I have drawn then the relay R 1, R 2, R 3 all are instantaneous over current relays. So if I want to decide the setting of this relays then as I told you earlier that instantaneous over current relays they have only the current setting they do not have the anytime dial setting. So if this is the case then what we have to do is and as I also told you that we have to set the relay which is connected near the load, the setting of the that relay the in this case R 3 that has to be decided first.

So the pickup of relay R 3 or plug setting of relay r three that is minimum and as we move further towards the source from say R 2 R 1 the pickup of that relay goes on increasing, so as we move from load to source the pickup of relay that increases progressively. So as if I just draw this bus one line below bus two line below bus three line below bus four line if I extend this line then this indicates the bus number, so this is your bus number one, this is your bus number two, this is your bus number three and this is your bus number four.

So pick up of this relay R 1, R 2, R 3 that is given like this, so the pickup of relay R 1 that is highest and pickup of relay R 3 that is the lowest one. So with this background if I move then this instantaneous over current relay has certain advantages and disadvantages, the let us discuss first the what are the advantages of instantaneous over current relay. So the first advantage is setting of this relays are independent of the load that is one thing, that means you can if I just consider the three sections you can carry out the setting independently, so each relay will operate instantaneously.

The second advantage of the instantaneous over current relay that is they operate instantaneously for all the line sections, so that means if any fault occurs in say section three at F 3 R 3 operates instantaneously. Similarly, any fault occurs in section one say at F 1 R 1 operates instantaneously. So this is the all two are the advantages of instantaneous over current relay. Now let us consider the what are the disadvantages of instantaneous over current relay.

So the first disadvantage is it is not possible to achieve backup protection so that what is the meaning, that means if fault occurs at in section three say at F 3, R 3 has to operate as a primary relay and it operates instantaneously. But by due to some reason if R 3 fails to operate as a primary relay then R 2 has to provide backup. So this type of backup protection is not possible if I use all the three relay R 1 R 2 R 3 all are instantaneous over current relays.

Because each relay operates instantaneously and it has only one setting that is current setting it does not have any time dial setting, so that is the first advantage of first disadvantage of instantaneous over current relays. The second disadvantage is instantaneous over current relays are affected by the ratio known as source impedance to the load impedance, so now let us see what is the load impedance and source impedance.

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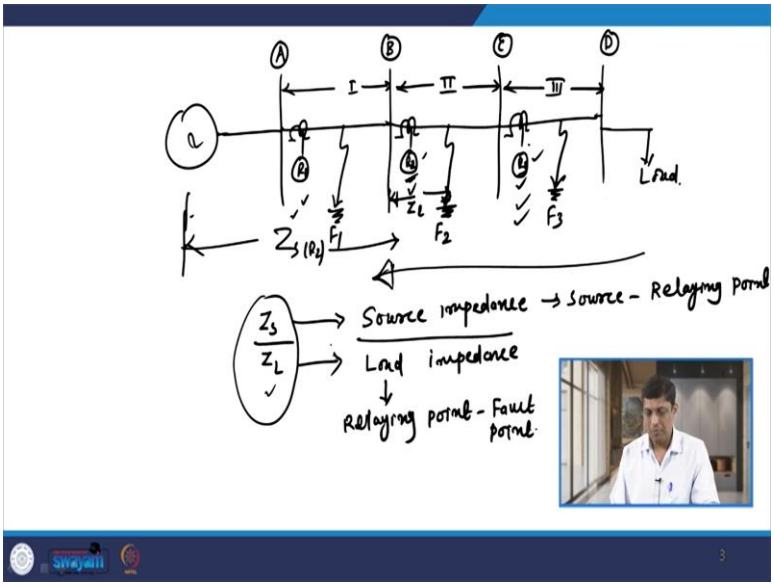

So ZS by ZL, so ZS is known as the source impedance. So source impedance is the impedance from source point to the relaying point, so this is the impedance between source to the relaying point, so this is the source impedance ZS. So if I consider the relay R 2 then for relay R 2 the

source impedance ZS for relay R 2 that is up to this point, up to substation B. What is load impedance ZL, that is known as the load impedance and it is the impedance from relaying point to the fault point.

So from relaying point to the fault point that impedance is known, as the load impedance, so if I consider fault F 2 then for relay R 2 the ZL that is like this. So we are talking about this ZS by ZL ratio. Now if I consider R 1 R 2 R 3 all are instantaneous over current relays then we can say that the ZS by ZL ratio varies depending upon the location of relay. So ZS depends on location of relay and the ZL depends on the location of fault at what location fault occurs accordingly ZL varies.

So as the relay instantaneous over current relay depends on current principle current discrimination philosophy and as current is directly associated with the ratio of impedance so as this ratio changes the current value also changes.

And that is also going to affect the operation of instantaneous over current relay. So what is the effect? If I consider suppose the remote and fault somewhere here at point one in line section one and if I consider a very close fault in line section two say at number two. Then if I consider relay R 1 then due to the effect of this ZS by ZL ratio relay R 1 is not able to provide effective discrimination between remote and fault in section one that is at point one as shown in figure.

And the closing fault in section two that is the fault at point two so it is not possible to discriminate between the remote in fault in one section and closing fault in other section. So this is the main advantage of instantaneous overcurrent relays that they are effected by ZS by ZL ratio that is source impedance to the load impedance ratio.

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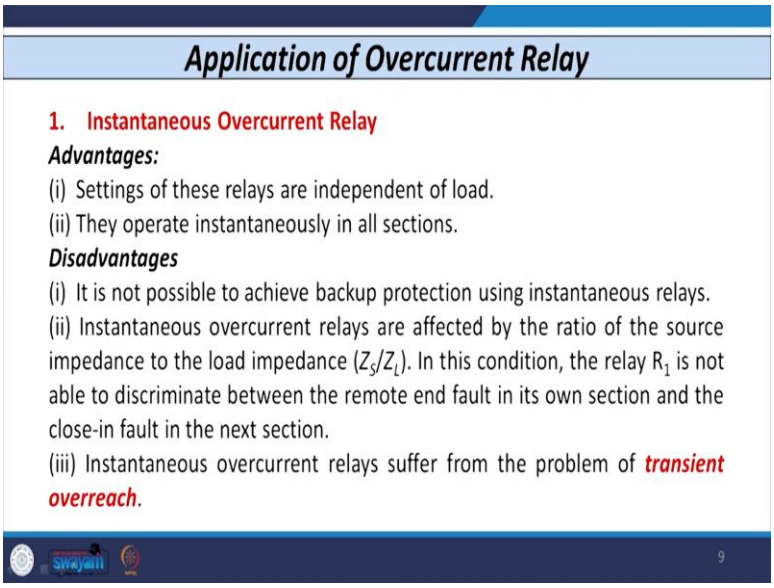

So this is the one of the biggest disadvantage of instantaneous overcurrent relays. Let us discuss the third disadvantage. What is the third disadvantage of instantaneous over current relays so the third disadvantage is this relay all this instantaneous over current relays suffer from the problem of transient over reach. So now, let us discuss what is the transient overreach phenomena.

So transient over reach is defined as it is the tendency of relay to operate instantaneously beyond its own zone of protection. So let us see what the meaning of the transient is over this phenomenon. So if I consider this same section.

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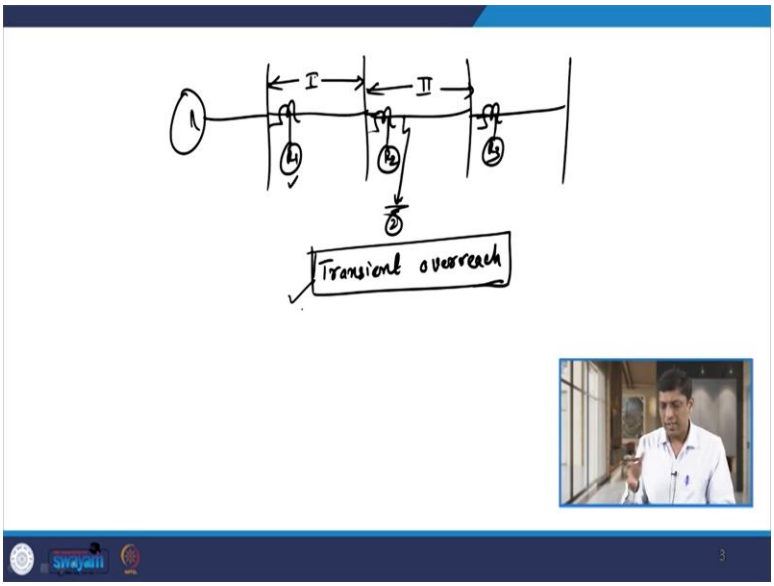

Let us say we have the three line sections and we have the relay same relay R 1 R 2 and R 3 that is connected in three line sections.

Now if I consider say for example fault occurs in line section two very closing fault occurs in line section two here. Then it may possible that the relay R 1 that is located in line section one this relay may operate. This is against the selectivity criteria of the protection because fault is in the section two.

So relay R 2 has to operate instantaneously as a primary relay and R 1 should not operate but in this case by mistake fault occurs in section two very closing fault. And in relay R 1 operates then this type of phenomena that is known as the transient over reach phenomena, Transient over reach phenomena. So transient overreach phenomena is defined as it is the tendency of relay to operate instantaneously beyond its zone of protection. So here the zone of protection of R 1 is only up to section one whereas fault occurs in section two so this fault at two that is the beyond the zone of section of R 1 then also relay R 1 operates so that is known as transient over reaching of relay R 1.

So now how the transient over reach affects how it comes in picture so that we will discuss later on. So in this class we have discussed we started our discussion with two numerical on overcurrent relay and then we have discussed the if I apply the instantaneous over current relays in the radial section or networks then how the what is the behavior of this instantaneous over current relays. What are the advantages and disadvantages of instantaneous overcurrent relays. This transient over reaching phenomena we will discuss later on in the next class. Thank you.