Power System Protection and Switchgear
Professor Bhaveshkumar Bhalja
Department of Electrical Engineering
Indian Institute of Technology, Roorkee
Lecture 10
Current Based Relaying Scheme-V

So let us continue our discussion, with the what are the rules to decide the plug setting of overcurrent relay that is phase relay and ground relays. So, the fourth rule that is the plug setting of ground relays are always lower than the phase relays. This is due to the fact that the magnitude of the earth fault current that is always lower than the magnitude of current when phase fault occurs. This is basically due to the involvement of the fault resistance in the earth circuit that involves the arc resistance.

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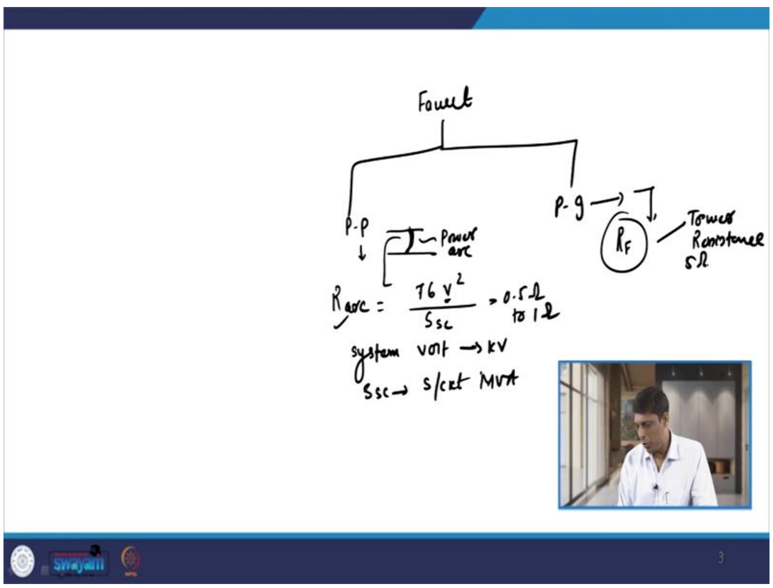

So if I consider just the fault value here, fault current, then we have a phase to phase fault and we have a phase to ground fault. So whenever phase to phase fault occurs between two conductors, when this conductor touches, phase to phase fault occurs. So between these two there is only a arc known as power arc. So when power arc is there, the value of arc resistance you can obtain with the equation; it is an empirical formula: 76 v square by Ssc; where v is the system voltage, system voltage in kV and, Ssc that is the short-circuit fault MVA at the location of fault.

So using that you can decide the arc resistance and usually it comes out to be 0.5 to 1 ohm. So this is fixed. But, when you have a phase to ground fault, then the involvement of this phase to ground fault that involves the fault resistance Rf, so that that contains the tower resistance. So, tower resistance that is usually varies from 5 ohm to 50 ohm. So that is also there.

And if I consider for the other involvement of resistance, then in that also contains zero sequence impedance of the system, if fault involves the fault is in symmetrical in nature. So, that is why the magnitude of fault, earth fault current that is always lower than the magnitude of fault current in case of phase to phase fault.

The other reason is that ground relays are always connected in the residual circuit of three lines CT. So, when we decide the plug setting of ground relays, we need to consider the excitation current of the city. Whereas we when we decide the plug setting of the phase relays and there is no need to consider the excitation current of the line CTs. So, this is very important rule as far as the plug setting is concerned.

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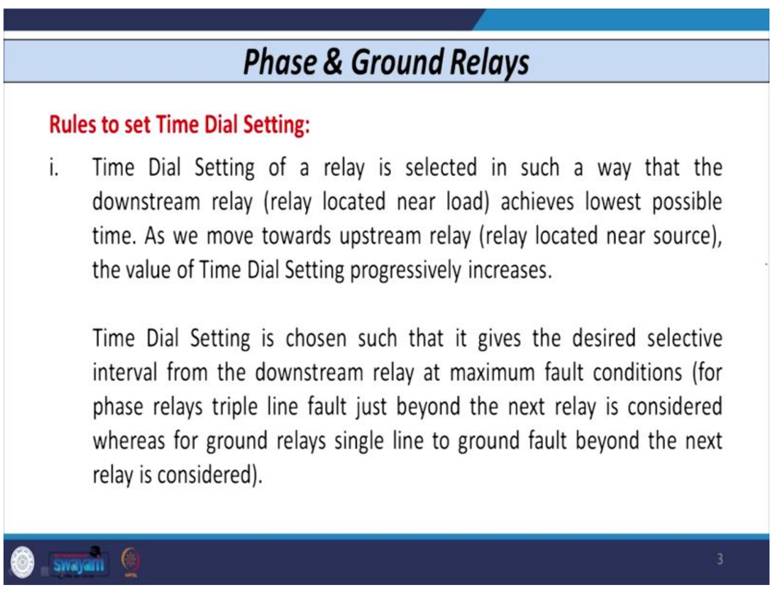

So similarly, let us discuss what are the rules to decide the time dial setting of the phase and ground relays? So time dial setting of phase and ground relay that is selected such that the whenever any relay which is located near the load, that achieves the lowest possible time. And, as we move further from downstream relay to the upstream relay, the time dial setting or its value increases.

So, time dial setting is chosen such that it gives the desired selective time interval between the downstream relay for maximum fault conditions. For phase relays, it is triple line fault and for ground relay it is line to ground fault. So what is the meaning of this?

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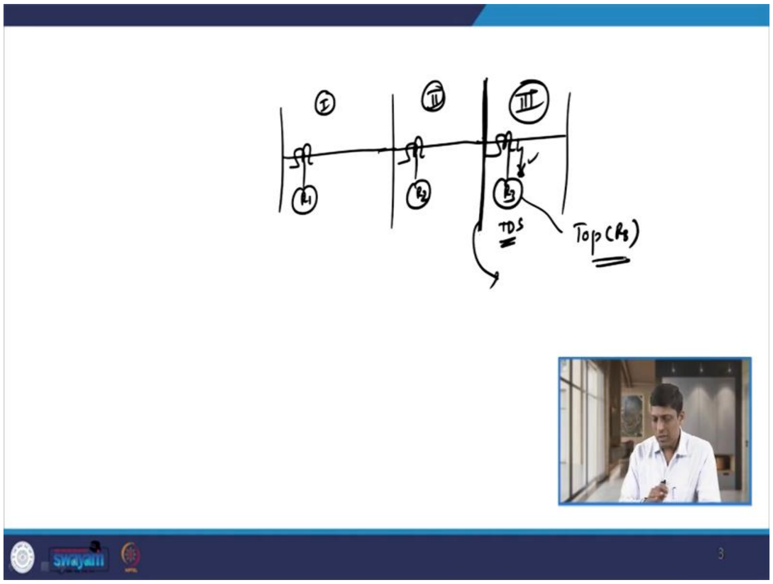

The meaning is that let us say we have a multi-section radial feeder network. So this is section I, section II and section III. And let us consider we have the relay R1, R2, and R3 connected in section I, section II and section III respectively.

Now when we decide the time dial setting of relay R3, then we have to consider some fault condition and usually fault condition we consider that is the fault immediately after the relaying point. Now, if I consider this fault, the fault MVA is not available for this case. So what we do? We consider normally the fault MVA at this bus.

So for this bus, we calculate the time of operation of relay R3, right? For maximum fault current conditions. And then based on this, we decide or we calculate the time of operation of relay R2. So this is the meaning of that thing.

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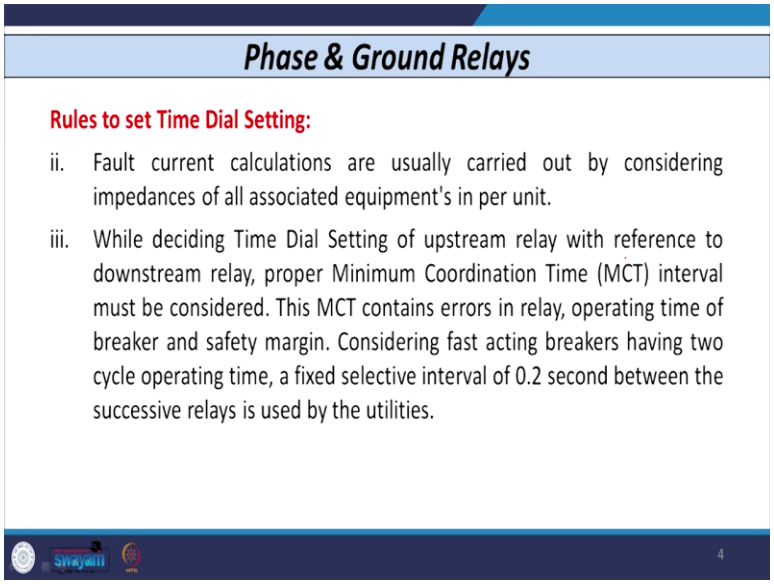

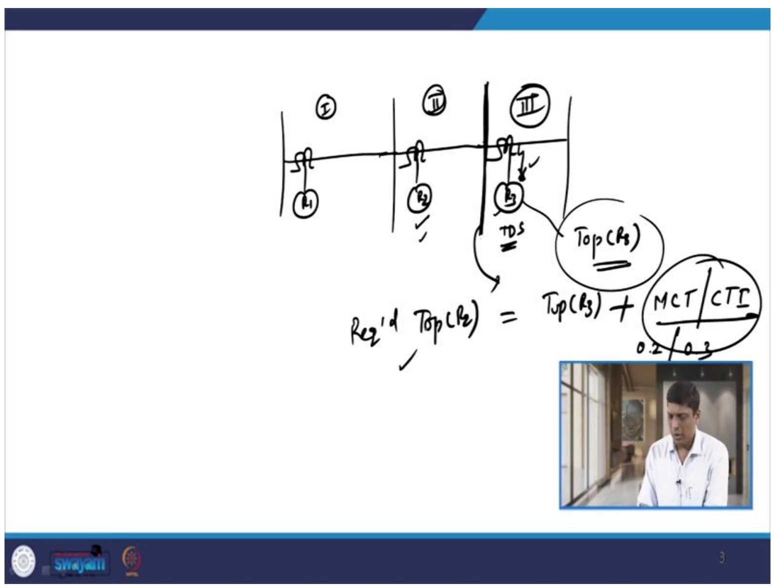

So, when we decide the time dial setting of one relay with reference to other relay, we have to consider some margin, that margin is known as Minimum Coordination Margin (MCT) or sometimes it is also known as CTI, Coordination Time Interval.

So same example, if I consider when we consider the coordination of relay R2 and R3, we have to calculate time of operation of relay R3. Then, the time of operation or required time of operation of relay R2 that has to be equal to time of operation of relay R3 plus some minimum coordination time interval or coordination time interval, CTI.

Now, this MCT that depends on many parameters, it depends on the for example, what are the errors in the CT or what are the errors in the relay plus some safety margin. So based on that, if we consider all these things then the minimum coordination time interval that can be considered in the range of 0.2 to 0.3 seconds.

So, here in this case we need to add either 0.2 seconds or 0.3 seconds or in between any value in between these two and then we have to decide the time of operation of relay R2. And similarly, further we need to decide the time of operation of relay R1. So this is very important point as far as the time dial setting is concerned.

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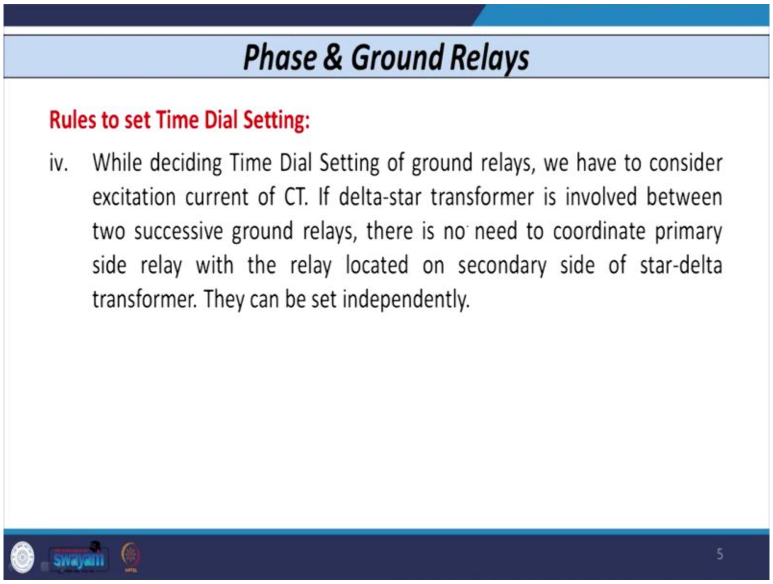

The next rule is while deciding the time dial setting of ground relay, we need to consider the excitation current of CT, as I told you earlier. However, when we consider the two successive ground relay and if there is a star-delta transformer involved between these two successive ground relay, then there is no need to consider anything; no rule is required. You can set both the relay independently. Even you can set instantaneous operations also for both the relays. This we will discuss later on that why there is no need for any such rule when star-delta transformer is involved.

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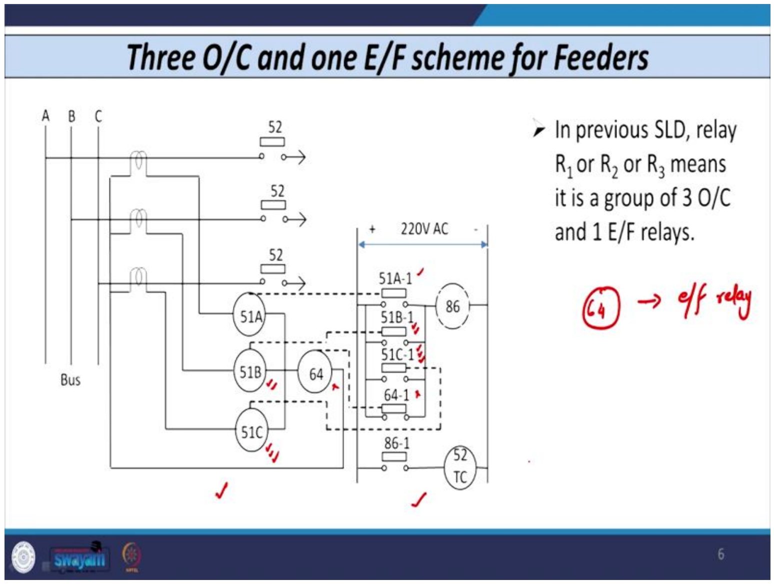

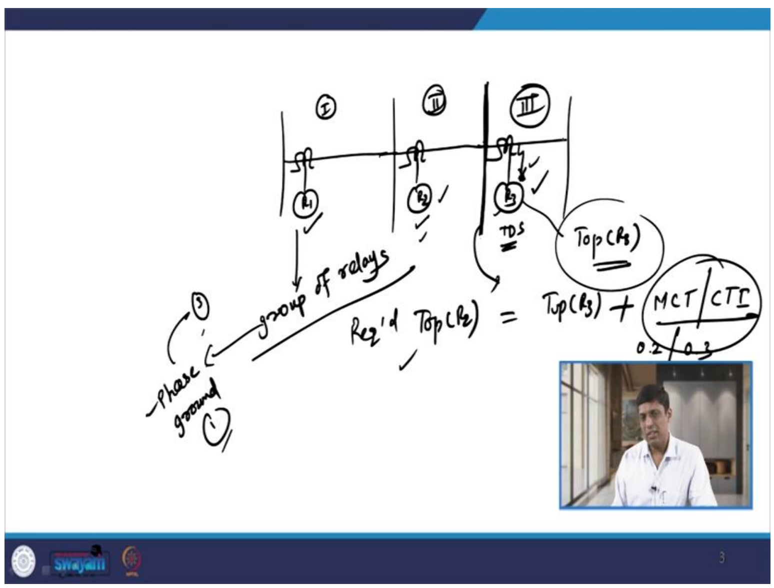

So with this background, let us consider the three overcurrent and one earth fault scheme used for the feeders. Now, what is the meaning of this? So if I consider relay R1 here then this R1 is nothing but the group of relays. So, this R1 means a group of relays means we have a phase overcurrent relay and it also have a ground overcurrent relay.

So, we have normally three units of phase relays and we have one unit of ground relays. So, when you have three units of phase relay and one unit of ground relay then it is known as three overcurrent one earth fault scheme. So, three overcurrent means three units of phase relays and earth fault means one unit of ground relay. Similarly, when you consider R2, R2 means also group of relays. So it has three phase relays and one ground relay. Similarly, R3 also group of relays- three overcurrent one ground relay.

So, if I consider the network for this, then we have let us say the three conductors are there are R-Y-B or A-B-C and we have a three relay connected in each phase. So, in R phase we have a 51 A, in Y phase we have a 51 B connected, and in B phase we have 51 C connected. So, three phase relays are connected in each phase. And in the residual circuit, we have a one ground relay unit. Its number is given by 64. So, 64 is the number given for earth fault relay, earth fault overcurrent relay.

So here we have a power circuit and we do have a control circuit like this. So 51 A unit has its contact, 51 A-1; 51 B unit has its contact that is 51 B-1; and similarly 51 C unit has its contact that is 51 C-1. So same way we have a 64 relay. So 64 relay has its contact that is 64-1. And we have 86, that is auxiliary relay coil, and its contact is 86-1. And then we have a 52 TC that is the trip coil of circuit breaker.

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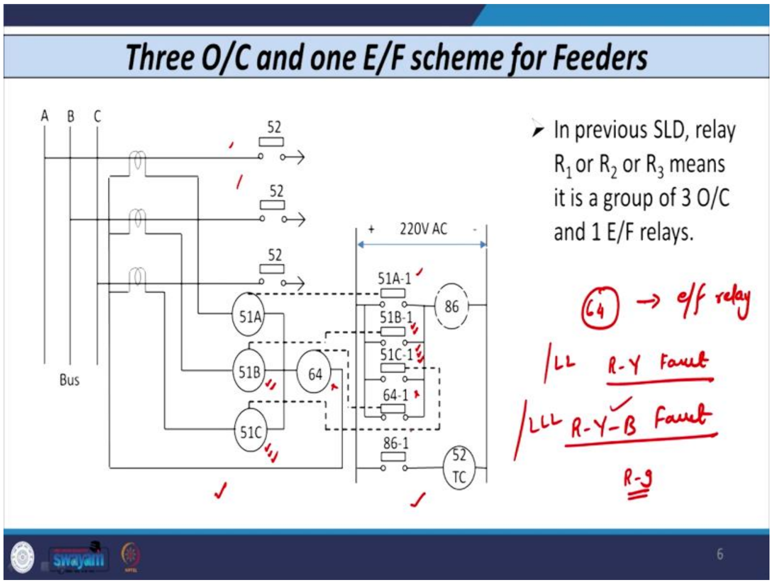

So now let us see how the three overcurrent one earth fault scheme works. Let us say normal condition or when there is a double line fault or triple line fault, then how and what the relay works? So when we consider such type of fault, let us say the phase fault. Then in case of phase fault, say in this circuit let us consider the R-Y fault occurs.

So in R-Y fault is a line two line fault, so obviously phase relay has to operate; it has to detect it. Ground relay should not operate. So whenever in R phase and B phase, the current accordingly increases in primary same way in secondary also it is reflected. So two units are connected: 51 A and 51 B. These two are energized and it gives signal to its contact 51 A-1 and 51 B-1.

So both A-1 and B-1will close it which energizes the coil of auxiliary relay, 86. And further its contact 86-1 trips and which is going to energize the trip coil of circuit breaker that is, 52 TC. So this is how the three overcurrent one earth fault scheme works. If suppose, R-Y-B fault occurs which is a again triple line fault, then the three units 51 A, 51 B, 51 C; all are energized and it their contacts: 51 A-1, B-1, C1 all arc closes and further tripping event is initiated.

Now, in case of LL fault or in case of triple L (LLL) fault, no current that flows through the ground unit that is 64 because it is a balance condition. In case of involvement of fault in ground; let us say the R2 ground fault occurs, then what happens? The unit that is 64, the current in the residual circuit increases and its contact that is 64-1 trips and which is going to energize the 86 and further the tripping is initiated. So in each case each relay that operates or that is responsible for the operation of one particular or different types of fault.

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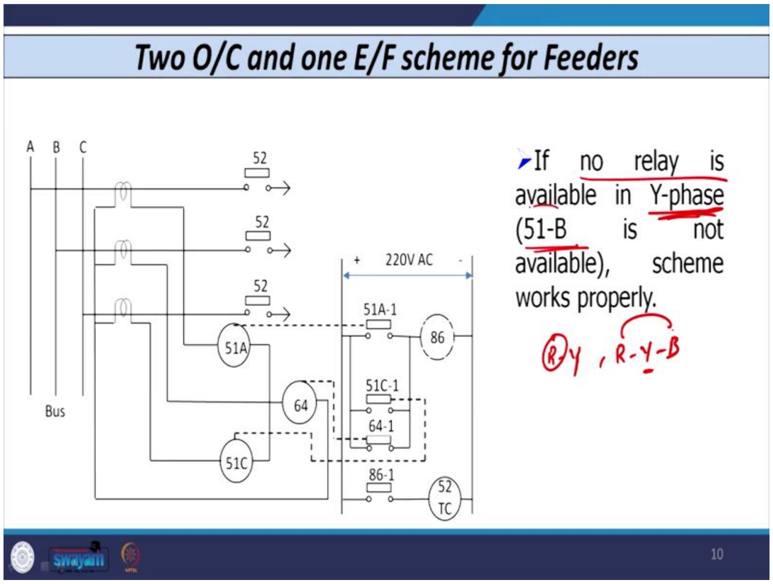

Now, sometimes it may be possible that suppose in this circuit, let us say I have removed the one unit. Then this scheme that becomes two overcurrent and one earth fault scheme. So, let us say there is no relay available in the 51 Y phase. That is 51 B, I have removed compared to the previous three overcurrent one earth fault scheme.

So now you can see that if any fault occurs, let us say if R-Y fault occurs, though there is no unit in Y phase but in R phase we have a unit 51 A. So, 51 A operates and the further tripping is given. If R-Y B fault occurs, then also if there is no unit in y phase, but we have a unit in R and B phase, so the 51 A and 51 C operates and further tripping is initiated. Same way you can consider for the faults involving ground that is line to ground, double line to ground, and triple line to ground. If I remove any one unit out of three phase unit, then the same scheme works perfectly well.

The only thing happens, only one disadvantage of this scheme is that whenever we have a star-delta transformer involved means any distribution feeder is feeding to the transformer, then there can be a possibility of delayed time of operation. Let us consider this with an example.

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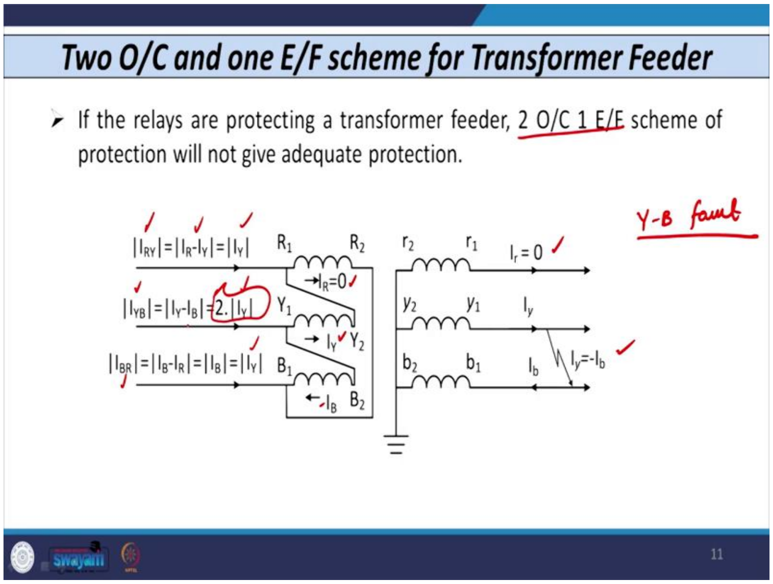

So, again you consider that in Y phase, there is no unit, we have removed the 51 B from the Y phase. Now let us consider one star-delta transformer and let us assume that we use two overcurrent one earth fault scheme, so there is no unit in Y phase.

Let us say the Y-B fault occurs in this case on the secondary side of the transformer. So on star side, say Y-B fault occurs here. So, in case of Y-B the current Iy that is equal to minus Ib and there is no current. Ideally, very small current in the R phase; so Ir that is equal to 0 and Iy that is equal to minus Ib.

If this is the case, then the current in on the other side, delta side the IR, the capital IR is 0, the capital IY that flows here and capital IB that flows that is exactly opposite of IY. So, if I again calculate IRY which is a difference of IR minus IY, so as IR is 0 so we have magnitude wise only IY. If I consider IYB which is a difference of IY minus IB. So we have IY and IB both are in opposition. So the current is 2IY. And similarly if I consider IBR which is a difference of IB minus IR, then again IR is 0 so we have only IY.

So you can see that fault occurs, Y-B fault occurs. We have removed the unit, phase unit from Y phase and in Y phase we have a magnitude of current that is two times the normal current, right? So two times magnitude of IY current, that current flows or available in Y phase in which we have removed the unit.

So there are chances of delayed operation in this case, and our objective is to achieve the instantaneous operation as soon as fault or any short-circuit occurs. So, this is not possible if I consider the two overcurrent and one earth fault scheme of instead three overcurrent and one earth fault scheme for the protection of the radial network. So, this is very important difference between the three overcurrent and one earth fault scheme and two overcurrent and one earth fault scheme.

So with this background, we have discussed the plug rules for deciding the plug setting and the ground setting of the phase and ground relays. We have also discussed the three overcurrent one earth fault scheme and two overcurrent and one earth fault scheme. So, now let us solve one example. This example is basically for deciding the setting of different relays. So how we coordinate the phase relays, phase overcurrent relay that is that can be decided.

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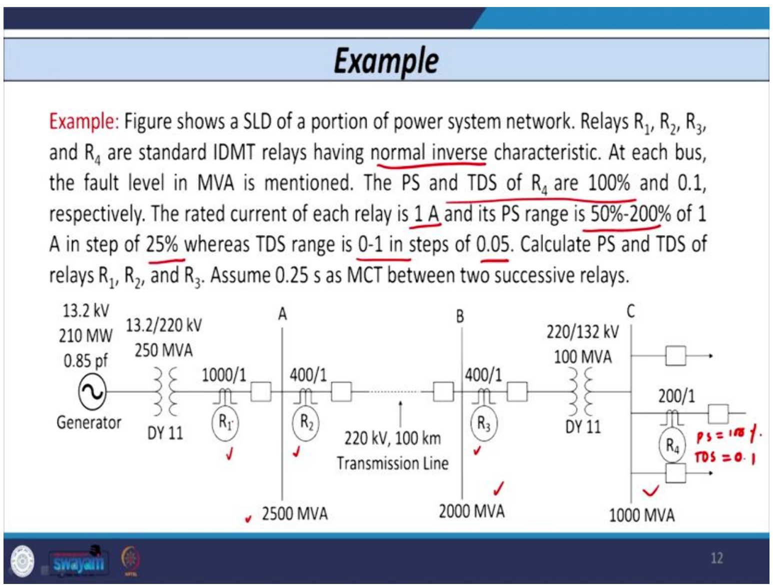

So in this example, the single line diagram of the network is given that is shown here. You can see that there are four relays connected: R1, R2, R3, R4. And, all this R1 to R4 all relays are IDMT overcurrent relays having normal inverse characteristic. Further, at each bus, bus A, bus B and bus C, the fault level in MVA that is mentioned. So you can calculate the magnitude of fault current at each bus utilizing this because the voltage level is also given. The rated current of all these relays are 1 ampere. So this relay rated current is same as city secondary current as I told you. So, relay related current of all relays R1 to R4 are 1 ampere.

And its plug setting range is from 50 to 200 percent of rated current in steps of 25 percent. Whereas the time dial setting range is 0 to 1 second in steps of 0.05 second. And the plug setting and time dial setting of relay R4 is given. So we can say that the plug setting of relay R4 that is 100 percent.

So plug setting of relay R4 is 100 percent of 1 ampere that is relay rated current. And it TDS value that is also given that is 0.1. So plug setting and time dial setting of relay R4 is given and you need to calculate the plug setting and time dial setting of all other three relays that is R3, R2 and R1. So let us solve this example considering that the R1, R2, R3, R4 are phase relays and let us solve this example.

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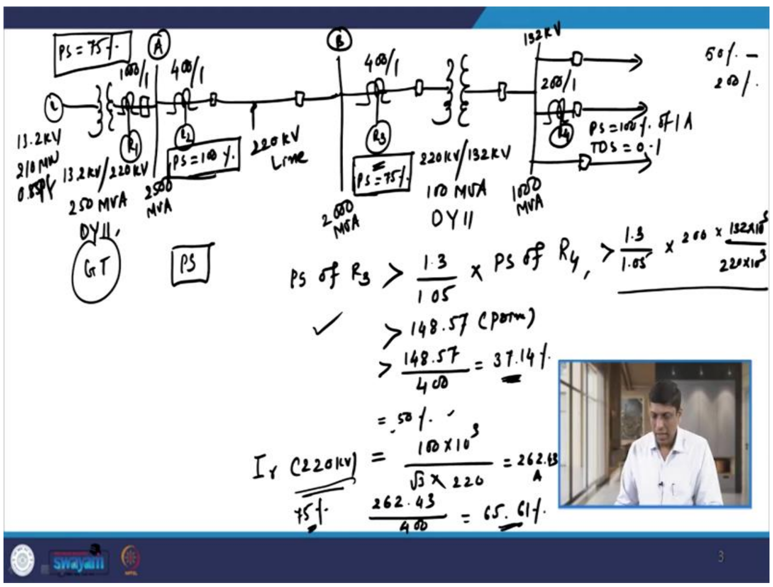

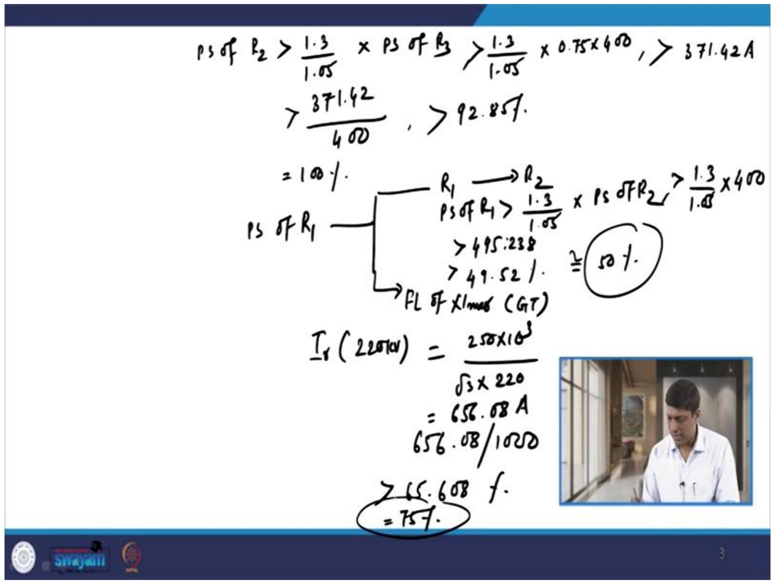

So to solve this, let us consider the same figure. So we have a generator connected with the generator transformer. And then we have a bus that is bus A and then we have a relay connected somewhere here. So that relay is R1, right? And the magnitude of fault level at bus A is 2500 MVA. Then we have a another feeder connected here with bus B, the relay connector here that is say R2, the fault MVA level at this bus that is 2000 MVA.

And then we have the another feeder connected here, that is the connected to the transformer here and then we have a another bus. So, one relay is connected here, that is let us say the R3 and its CT ratio is 400 by 1. The CT ratio of R2 is also 400 oblic 1 ampere and the CT ratio of R1 that is also 1000 by 1 ampere.

With this background, again at this bus, this is a 132 kV bus and the fault level that is given is 1000 MVA here and we have a different feeder from this bus. So, the different feeders are available and let us assume that on one feeder we have a relay R4 whose plug setting is 100 percent and TDS that is given as 0.1. The CT ratio of R4 four that is given us 200 by 1 ampere and the rating of this transformer that is given as 220 kV by this bus is 132; so it is 132 kV and the MVA rating is 100 MVA and it winding connection is DY 11.

Same way we have the transformer here, other on the left hand side of relay R1 and its value is 13.2 kV by obviously the line is 220, this line is 220 kV line, so the transformer ratio is 220 kV and its MVA rating is 250 MVA with the connection DY 11. And this transformer is known as, as it is connected to generator, it is known as generator transformer. The generator rating is also given that is 13.2 kV, its MVA is megawatt value is 210 megawatt at 0.85 power factor.

So with this background, let us solve the example. We need to find out the plug setting and time dial setting of R1, R2, R3 relays. So let us start the solution with plug setting. So let us decide the plug setting of relay R3. So as I told you, the relay R3 plug setting is decided based on the plug setting of relay R4. So as I told you earlier, plug setting of relay R3 that is greater than 1.3 divided by 1.05 into plug setting of relay R40. So if I consider this, then the plug greater than 1.3 1.05 into plug setting of relay R4.

So, plug setting of relay R4 that is given as 100 percent of 1 ampere that is a relay rated current. If I consider it based on the primary value, then it is 100 percent of 200 ampere. So it is 200 ampere. So that comes 200 here. And you can also visualize that there is a transformer between relay R3 and R4. So we need to multiply the ratio also from 132 kV to the 220 kV. So that also comes here. So if you solve this, then that comes out to be roughly around 148.57. This is on primary side of relay R3.

If I convert it on secondary side, so I have to divide it by its city ratio that is 400 ampere. So the value available that comes out to be 0.3714. So if I write in percentage, 37.14 percentage. So obviously, based on this we can decide the setting that is 50 percent because the setting ranges of all the 4 relays that is from 50 percent to 200 percent of 1 ampere in steps of 25 percent. So a higher value beyond 37.14 percent that is available that is 50 percent. So we can decide the setting of relay R3 that is 50 percent.

So if I decide plug setting of R3 that is 50 percent by this rule, then we have to also crosscheck that the relay R3 should not operate in case of when the transformer draws a full load current on to 20 kV side. So, if I just find out the rated current of the transformer on 220 kV side, then that is given by 100 MVA divided by root 3 into 220 kV. So, if you solve this, then that comes out to be the value that is roughly around the 262 MVA. So, 262.43 ampere; that is the current.

If I convert this on secondary side of relay R3, then I have to divide this 262.43 by CT ratio of R3 that is 400. So, this comes out to be roughly around the value that is 65.61 percentage. So, the setting of relay, plug setting of relay R3 should be greater than this. So next range available greater than this, that is 75 percent.

See in earlier case, if I utilize this rule the setting comes out to be 50 percent but when I use check the rated current of the transformer then the setting comes out to being 75 percent. So I have to select higher value that is 75 percent. So, plug setting of relay R3 that is 75 percent of its rated current, 1 ampere or 75 percent of primary that is 400 ampere.

So now let us decide the plug setting of relay R2 because next related from this source from relay R3 that is the relay R2. If I want to decide the plug setting of relay R3 then you have to; what you have to do is? Let us write down the plug setting of relay R2 that is greater than 1.3, 1.05 into plug setting of relay R3. So that is 1.3 1.05 into plug setting of relay R3.

So plug setting of relay R3 we have selected as 75 percent of 1 ampere or 75 percent of 400 ampere. So here that is the 75 percent of 400 ampere. So if I just solve this, then the value available that is greater than; if I just saw this value, then the value comes out to be roughly around the value is say 371.42 ampere; so 371.42 ampere.

So, if I again reproduce this on secondary side of R2, then you can see that the city ratio of R2 is 400 by 1. So, if I convert this value, 371.42 divided by 400, then the value available on secondary side in percentage that is 92.85 percent, right? So obviously, we can select the next setting range available higher than this that is 100 percent. So plug setting of R2 that can be selected as the 100 percent.

So now, let us decide the plug setting of R1. So plug setting of R1 that can be decided based on again two rules, you coordinate relay R1 with relay R2. So if I just do it, the coordination then plug setting of R1 that is greater than 1.3 upon 1.05 into plug setting of R2. So that should be greater than 1.3 1.05 into plug setting of relay R2. So plug setting have relay r2 is 100 percent of 400 ampere. So, that is 400.

So if I solve this, then the value comes out to be 495.238 ampere. If I convert it on the secondary side of relay R1, then you can see the CT ratio of R1 that is 1000 by 1. So if I divided it, the value comes out to be 49.52 percentage. So we can say that we can select next higher rate that is 50 percent.

But at the same time, we need to also look at the relay R1 is connected on 220 kV side of this generator transformer. So let us see if what is the full load current of the generator transformer.

So, if I just calculate the full load current of transformer that is GT, then the rated current of the transformer on 220 kV side that is given by the rating is 250 MVA.

So, we can say that is 250 into 10 raise to 3 divided by root 3 into 220 kV. So the value comes out to being 656.08 ampere. If I convert on secondary side, I have to divided it by 1000 because that is the CT ratio of R1; so 656.08 divided by 1000. So the value comes out to be in percentage that is 65.608 percentage. So whatever setting we select, the next available setting rate that is the 75 percent.

So in earlier case we obtained 50 percent, in this case we obtained 75 percent, so we will consider the setting of plug setting of relay that is higher value that is 75 percent. So, plug setting of relay R1, we have decided that is the 75 percent. So, we have now decided the plug setting of R1. We have calculated the plug setting of the R3. We have also calculated the plug setting of R2. So the first task we have completed. Now in the next class, we will decide on how to determine the time dial setting of relay R3, then R2 and then R1.

So, in this class we started our discussion with what are the different rules to decide the plug setting and time dial setting of phase relays and ground relays. And then we started one example that how the coordination of phase overcurrent relays that is to be carried out. So coordination means we need to decide the plug setting and time dial setting of relays. So we have considered one example and we have determined the plug setting of three relays, R1, R2, R3. In the next class, we will decide the time dial setting of three relays that is R3, R2 and R1. Thank you.