Digital Protection of Power System
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Lecture 22
Coordination of Overcurrent Relays for Distribution Network - II

Hello friends. So, in the previous lecture, we have discussed regarding the coordination of an overcurrent relay, particularly when we consider the distribution network.

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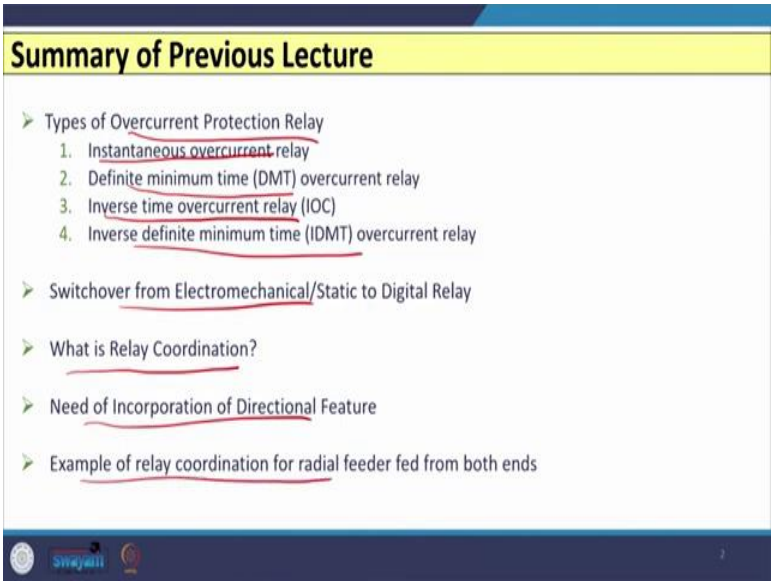

And in that network we have discussed that we can use overcurrent relay having different characteristic, such as, we can use instantaneous overcurrent relay, we can also go for definite minimum time delay relay, we can also use inverse time overcurrent relay or we can go for inverse definite minimum time overcurrent relay. After that we have discussed regarding the switchover from electromechanical or static to digital relay.

We have discussed that, what are the reasons? Why most of the researcher have switched over from electromechanical or static to the digital relays? And the main reason is the settings that is plug settings and time dial setting ranges those are fixed in electromechanical and static relays within specific range. Whereas, in case of digital relay, this are not fixed, it is user defined. Then we have discussed regarding the relay coordination, what is relay coordination? Why it is required?

So, in that we have discussed that relay coordination is important particularly for an interconnected power system network, where the number of relays are more. And then in that case, we have to see that in order to achieve selectivity criteria and discrimination criteria of the power system protection, we have to go for relay coordination. So, relay coordination is basically nothing but the coordination among several relays available in a particular network.

So, that for a specific fault in that particular zone, only those relays operate, rest of the relays will provide backup protection. Then we have discussed regarding the need of incorporation of directional feature. So, we have discussed in this that whenever we have radial feeder, fed from both the ends or when multi source networks are available, that in that case we have to go for directional relays.

So, we have discussed that whenever a particular location or a point where fault current reverses those relays must be directional in nature, whereas, the other relays are bi-directional or directional in nature. So, this thing we have discussed in case of radial feeder fed from one end and this is also applicable to parallel feeder, cascaded parallel feeder, ring network and so on.

Then, at last we have discussed regarding the example of how the relay coordination is carried out in a radial distribution network, particularly when it is fed from one end. And we have discussed that we can carry out the relay coordination by considering two cases. In case one, we have to consider the source only from one end and the other end we consider the load end. And in the second case, the other end we have considered as a source end. And the previous we have to consider as a load end. And then we combine and we can calculate the plug setting and time dial setting of the relays.

Now, in this lecture, we will concentrate on digital relays used for the protection of radial distribution network or maybe when radiality of the distribution network is not there, that means wherever multiple sources are available in a distribution network, then also how digital overcurrent relay works and what are the various features of digital overcurrent relay. So, let us first start with the, what are the features available in digital overcurrent relay.

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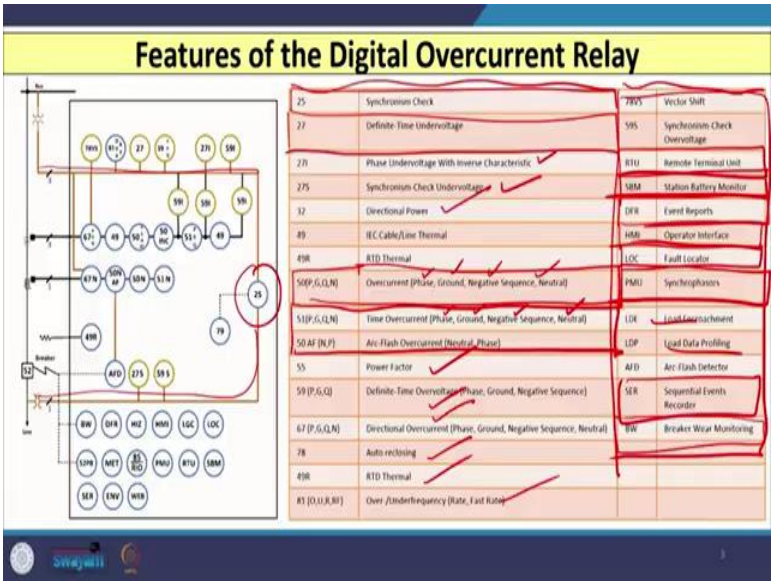

So, here you can see on the screen, (as sown in above slide) the features of digital relays are listed in the table. Whereas, in the first two columns you can see, these are the features which are compulsory features provided by most of the manufacturers. Whereas, these are the features, those are optional in nature. This can be provided by few manufacturers or maybe one or other features are not available in some different manufacturer.

So, if we go and compare with the digital relay which we have discussed for power transformer and some other equipment, then we can see that, the features like 51 and 50, which are related to the overcurrent, maybe 50 we when we go for it is instantaneous in nature. And when we go for 51, then it is time overcurrent. And this can be given for phase, for ground, for negative sequence and for neutral (as sown in above slide).

So, 51 is for time overcurrent and then 50 is for the instantaneous feature. That means, when we want instantaneous operation of overcurrent relay, whether it is working in phase, ground, negative sequence and neutral this features are also available in digital overcurrent relay. Along with this the features like the synchronism check, 25 so, you can see here, (as sown in above slide) these are connected from the two sides of the transformers.

So, synchronism check feature is also available in digital overcurrent relay. Along with that, the features related to the definite time under voltage function that is also available. Then we have

directional power feature, we have phase under voltage with inverse characteristics. So, voltage versus time characteristic is also available.

Then we have synchrocheck under voltage is also available, along with that power factor, definite time over voltage, directional overcurrent, auto reclosing, RTD thermal and over frequency and under frequency features are also available in digital overcurrent relay. Along with this you can see (as sown in above slide) that as I told you these are the several other features available in digital overcurrent relay.

This consists of if any circuit breaker is there and we want to carry out breaker we are monitoring, so, in that case that feature is also available in digital overcurrent relay. This relay has also features like the HMI that is human machine interface. So, if operator wants to carry out some interfacing, that is also possible. Fault locator is also available. So, this relay can also tell you the location of fault.

Along with that this feature is related to sequence of event recorders and the digital fault recorders, DFR these are also available in digital overcurrent relay. This relay has also act as a remote terminal unit. So, RTU feature is also available. And it is also capable to carry out monitoring of station battery, available in the substation. So, this feature is also available in digital overcurrent relay.

Along with that, this digital overcurrent relay will also work as a PMU phasor measurement unit, so this is also available and with this, the load encroachment and low data profiling this features are also available in digital overcurrent relay. So, we can say that along with all these optional features which are compatible with reference to either IEC 61850 or maybe IEEEC 37.118 standard, which are for PMU's these are also available with these relays along with this some communication capabilities are also there for this relay.

So it is the communication facilities like let us say it is supported with TCP IP protocol or maybe Modbus Communication or maybe some other type of communication, SNTP and so on. So, these type of features are also available in this digital relay. Now, with this background, we are going to discuss coordination of all the relays, when we talk about coordination of relays in a distribution network, then these relays can be all digital overcurrent relays.

These relays can be combination of let us say digital overcurrent relays and electromechanical or static relays or it can be all electromechanical or all static relays. So, such types of combinations are possible.

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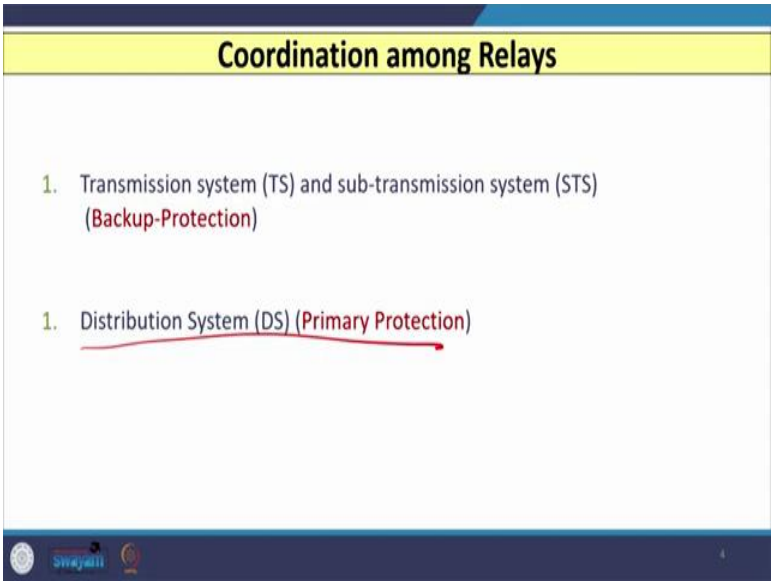

In that case, when we consider all this type of combination of overcurrent relay, then the overcurrent relay protection is carried out for distribution network. So, it will act as a primary protection. And when we use the overcurrent relays for transmission and sub-transmission network, then these relays will act as a backup.

Because for transmission and sub-transmission network distance relays are used as the primary protection. So, this is the main difference between the application of overcurrent relay for transmission and sub-transmission system and on the other end for distribution network.

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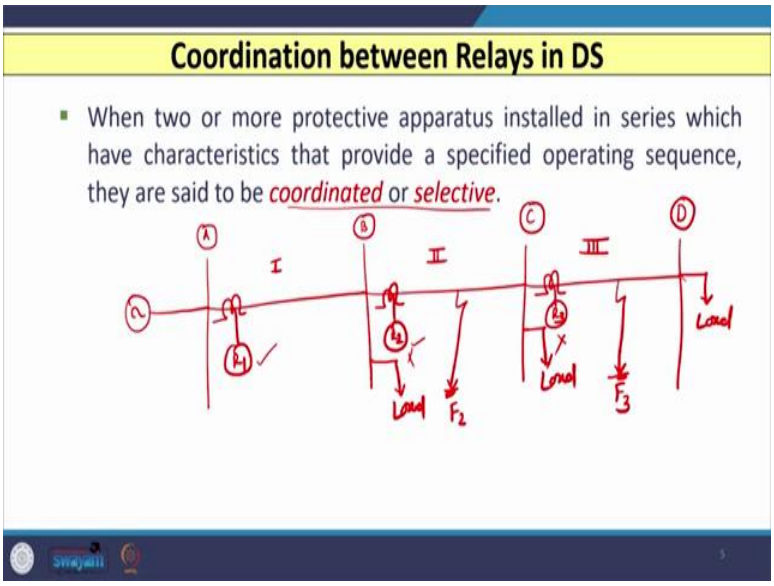

Now, let us see how the coordination is carried out, with the help of overcurrent relays or directional overcurrent relays or combination of these relays in distribution network. So, whenever we have two or more relays available in a particular radial network or maybe some other network also, ring mains network and if these relays are installed or connected in series, then these relays are going to operate in a particular specified sequence.

And then these relays are coordinated with each other or their operation of these relays or protective device are selective in nature. So, to understand this, let us consider one example, let us say we have a bus A, then we have one distribution feeder, which is connected between bus A and bus B. And we do have another feeder which is connected between B and C. And then we do have let us say another feeder which is connected between C and D.

So, this is my section 1, section 2 and section 3, 3 sections are available of distribution feeder. And source is may be on one side and loads are connected at different buses. Now, in this case, suppose we have a relay located in section 1, let us say R_1, in section 2, let us say it is R_2 and in section 3, let us say it is R_3. So, 3 relays are there, these relays are overcurrent relays, may be digital overcurrent relay or it can be electromechanical any type.

Now, what is the meaning of this coordinated or selective? So, whenever fault occurs in section 3, let us say at F_3 then relay R_3 has to operate first, because this fault at F_3 in its first zone or particular specified zone of relay R_3. So, R_3 will act as a primary relay for this fault. If R_3 fails, because of

some reason, maybe relay is not going to pick up or maybe circuit breaker is not operate or maybe some other reason, then R_2 relay will provide backup.

So, R_2 will act as a backup relay for fault in section 3. Similarly, if we have a fault in section 2, let us say at F_2 then relay R_2 will act as a primary relay. No other relays will operate in this case, when a fault at R_2 occurs in section 2. R_2 will act as a primary relay. If R_2 fails, because of some reason, then R_1 will provide backup and so on.

So, this is the meaning of the how the coordination of this three relays or maybe multiple relays available in a particular radial network or some other networks, then how the coordination of these relays are carried out. So that is nothing but the relay coordination among different relays.

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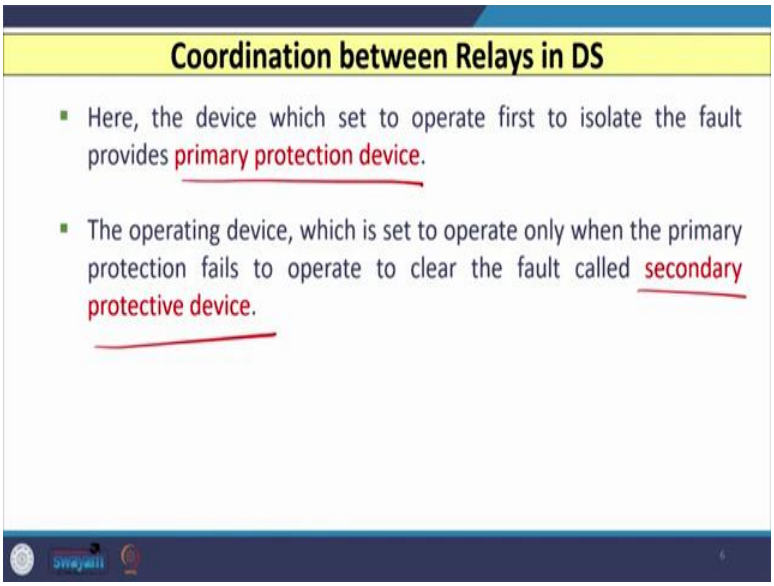

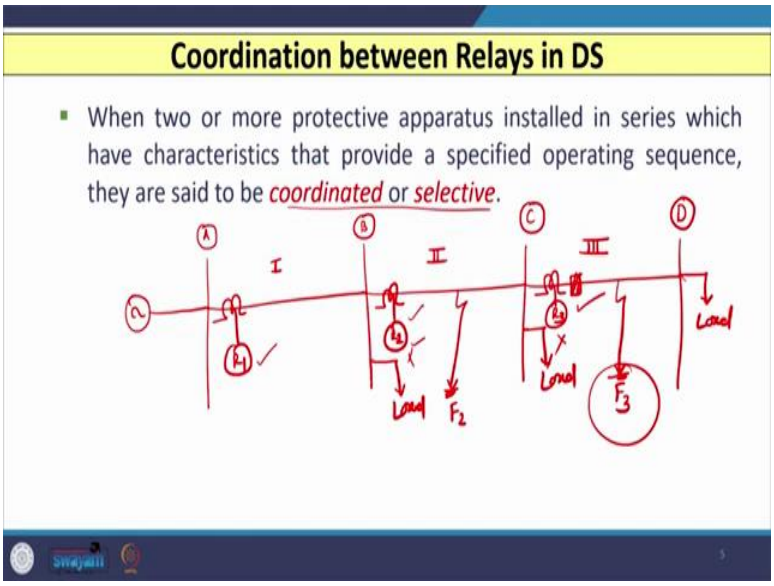

As I told you, one relay will act as a primary protective device and the other relays for the same fault will also act as a secondary protective device. In actual interconnected network, when we consider more number of relays let us say 20 relays or 30 relays are available, then it may be possible that for one particular primary relay, maybe there are more than one backup relays are available.

Let us say for example if I consider the previous example, we know that if fault occurs at F_3, then R_3 will act as a primary relay. It will act as a primary relay and it detects the fault and it gives signal to the breaker and whatever breaker is connected here, this breaker gets disconnected. If R_3 fails, then R_2 will provide backup. But this is possible when we have a radial network or radial structure distribution network.

If we have ring network, then for this R_3 relay act as a primary relay, it may possible that R_2 will act as a backup relay and some other relays are also there, which will provide backup, that is the meaning of that.

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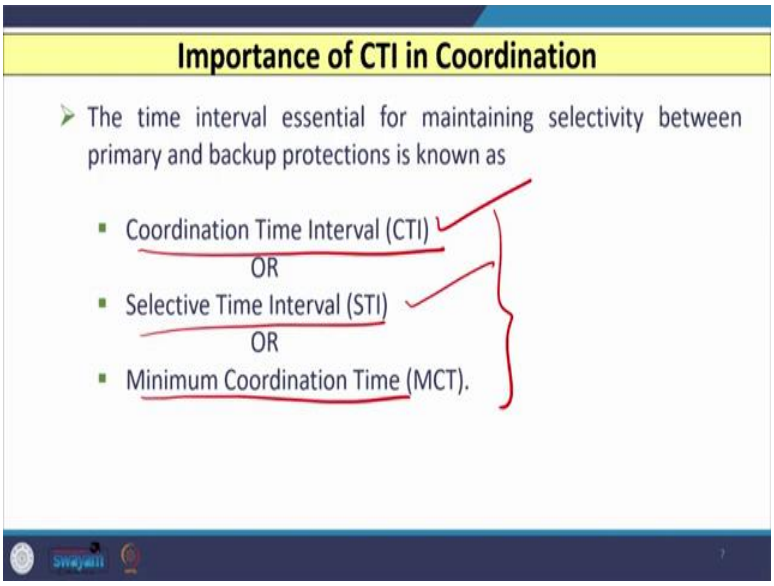

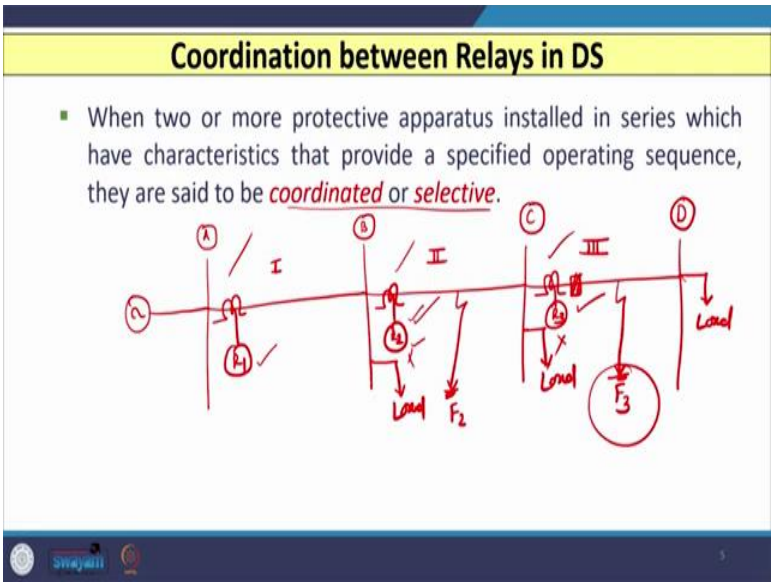

Now, when we consider that this relay will act as a primary relay, let us say R_3 will act as the primary relay for a fault at F_3 and R_2 will provide backup for a fault at F_3 if relay R_3 fails to operate, then how to decide the time of operation of relay R_3 R_2 and R_1? There must be some discrimination between the time of operation of relay R_3, time of operation of relay R_2 and similarly time of operation of relay R_1.

So, that is decided by the factor known as coordination time interval sometimes it is known as CTI. It is also known as selective time interval STI or it is also known as minimum coordination time MCT. So, whatever we consider all are more or less same. So, this factor is very important when we are dealing with the coordination of relays in radial distribution network.

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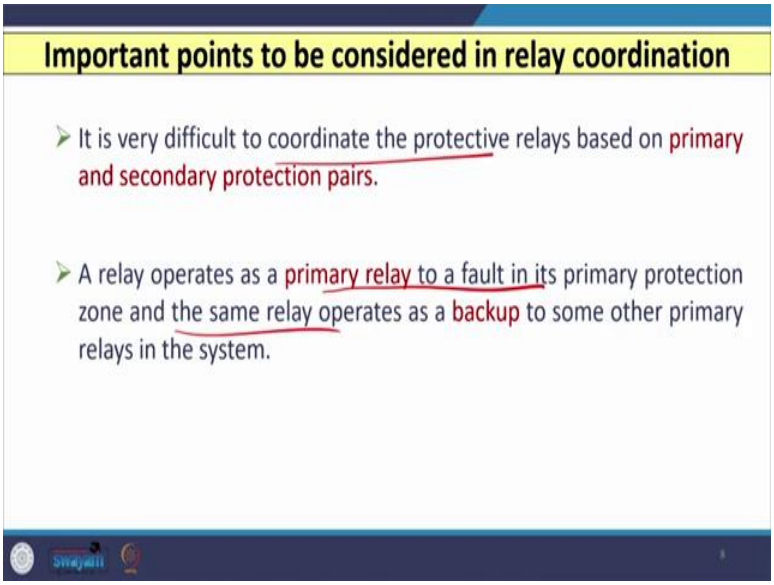

Now, let us see what are the important points that is to be considered when we carry out the relay coordination for a distribution network. So, we know that the very important point is our electrical network is an interconnected network and multiple sources are available, number of branches or distribution feeders are also available, and a number of relays are also available and they are also more.

So, it is very difficult to coordinate the protective relays based on primary and secondary protection pairs. So, it is very difficult to find out which relay will provide backup and which relay will act as a primary relay, when we are talking about an interconnected distribution network. A relay which operates as a primary relay for a particular fault in its primary protection zone and the same relay can also act as a backup.

So, whenever we consider a particular relay, let us say relay x, then that relay will act as a primary relay for a fault in that zone of relay. And the same relay will also act as a backup relay for a fault somewhere else or nearby adjourning sensor. So, it is really difficult to decide whether this relay will operate as a primary relay or as a backup relay.

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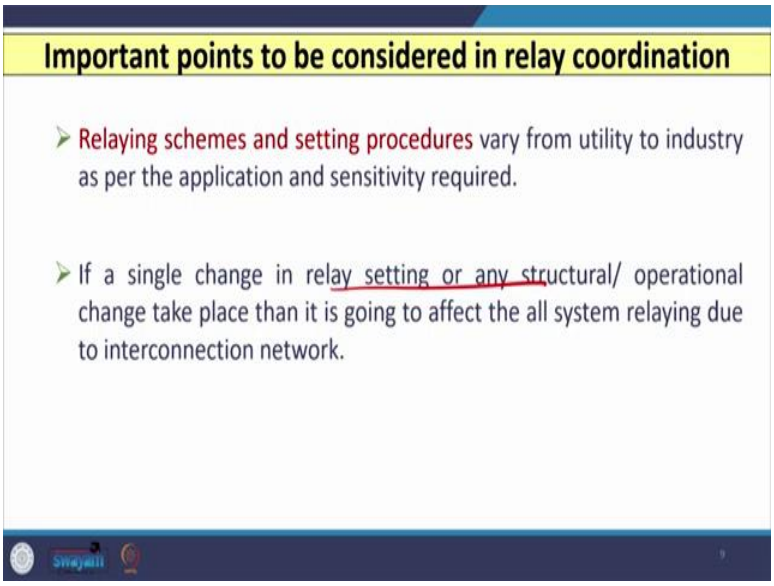

So, relaying schemes and setting procedures are also different. If I have particular one utility or if we consider one industry, then the setting procedures are different, even it changes with the manufacturer who is providing the relay. So, setting procedures and relaying schemes are also entirely different. That is why it is very difficult to carry out the relay coordination among the relays available in distribution network.

So, if we carry out a single change in relay setting, or if we simply change the structure of the distribution network, then that is going to impact a huge on the settings of the relays available in an interconnected distribution network.

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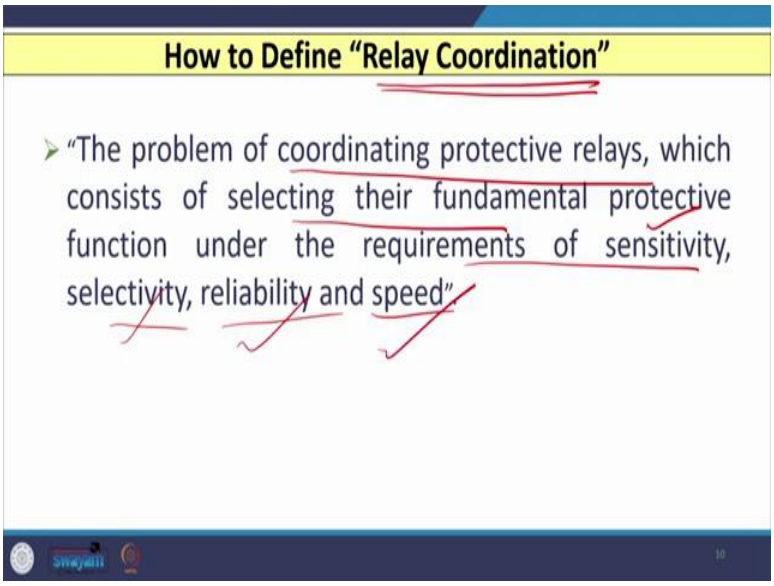

So, let us see how we can define the term relay coordination. So, relay coordination in a general way, it is defined as it is a problem of coordinating protective relays, which consists of selecting their fundamental protective function under the requirements of sensitivity, selectivity, reliability and speed.

So, that means we are going to carry out a sequential operation of the relay in a particular network, in such a way that the criteria of protection system such as sensitivity, selectivity, reliability, speed, and discrimination, all are achieved simultaneously by all the relays. And there should not be any mal operation or nuisance trip of any relay. Now, let us see how we can apply this relay coordination on what type of network.

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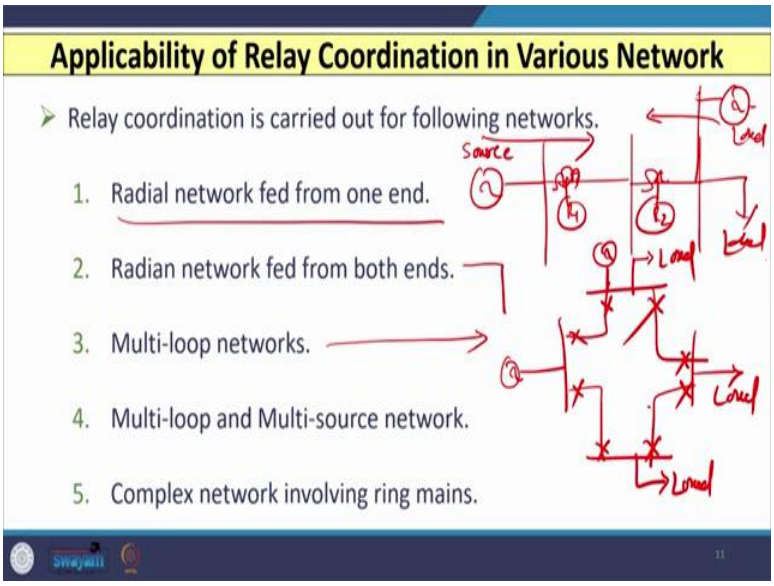

So, if we wish to carry out the relay coordination, then it can be carried out on several networks such as radial network fed from one end. So, it is as simple as you have the source at one end and then you have the relays and you have the load at the other end. The relays are located somewhere here, let us say R_1 R_2 and so on and loads are connected on right hand side. Whereas source that is available on the left hand side.

So, this is radial feeder or radial network fed from one end. We do have radial network fed from both ends. So, we do have a source available here also. So, now you can see (as sown in above slide) this will provide also current and this will also feed the power. So, radial feeder fed from both ends, we do have multi loop networks. Multi loop and multi-source networks that is also possible. So, we do have a network let us say like this, where you have the source and you have several lines connected and you have the load available at other buses, like this.

So, this is nothing but your multi loop multi source network, maybe you can connect a source here also and you have the relays available all these points, these are the relays location of relays. So, on each feeder two relays are there, four feeders are there (as shownin above slide). So, 8 relays are there and some more complex network like ring network that is also there. So, there also we need to carry out the coordination of relays.

Now, let us see what are the parameters we need to determine when we carry out the relay coordination in any of the available or given network, say radial network or ring network. So,

whenever we carry out relay coordination of overcurrent relays, then we have to find out the following settings.

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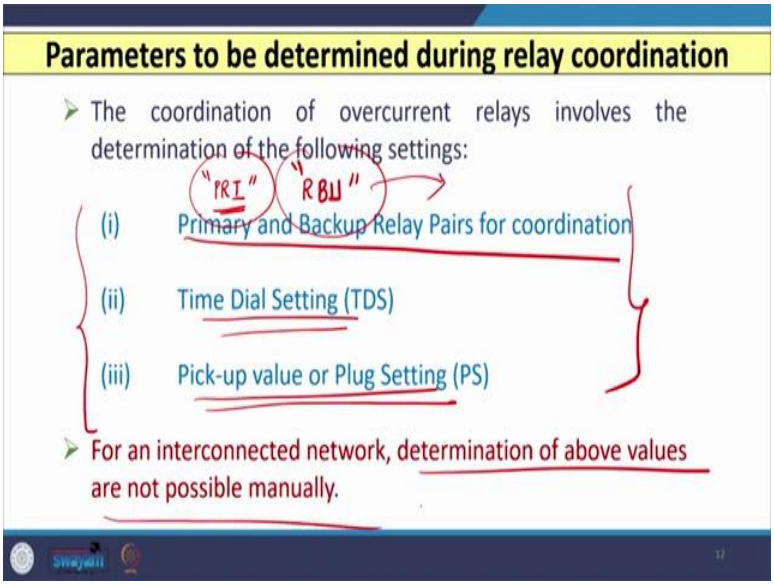

The first thing we need to determine is the primary and backup relay pairs. So, normally primary relays are known as PRI in a short form. So, PRI is nothing but your primary relay. And backup relay is nothing but it is also denoted as RBU, it is nothing but remote backup. The relay which provides backup, so relay backup like that, so RBU. So, primary relays denoted by PRI, and the backup relays are denoted by RBU.

There can be more number of RBUs are there because it may possible that for a particular one primary relay, there has to be more than one backup relays. The second thing we need to determine that is the time dial setting of the relay. And the third thing we need to determine that is the pickup value or plug setting of the relay. So, these three things we need to determine when we carry out the coordination of overcurrent relays for radial or maybe ring mains network for distribution network.

So, for an interconnected network determination of these three settings are not possible manually. Because the whole network that is very interconnected network, number of feeders are very large, number of relays are also very large let us say 30 relays are available, 40 relays are available. And calculation of time dial setting, plug setting or pickup setting and determination of primary and backup relay pairs, that is not possible manually for large network.

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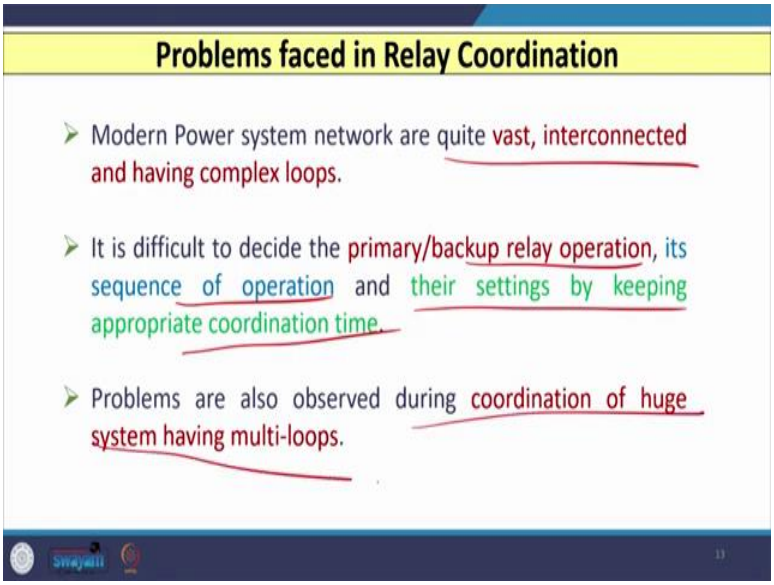

So, in that case, we have to go for some other strategy. The other issues are we know that modern power systems are very complex. And hence it is difficult to carry out the or calculate the primary backup relay pairs. The sequence of operation that means which relay will act as a primary relay, which will act as a backup relay. What are the settings of this relay, so that the coordination time between each relay that is maintained. And, this philosophy will vary particularly when we consider a ring network or multi loop multi source network.

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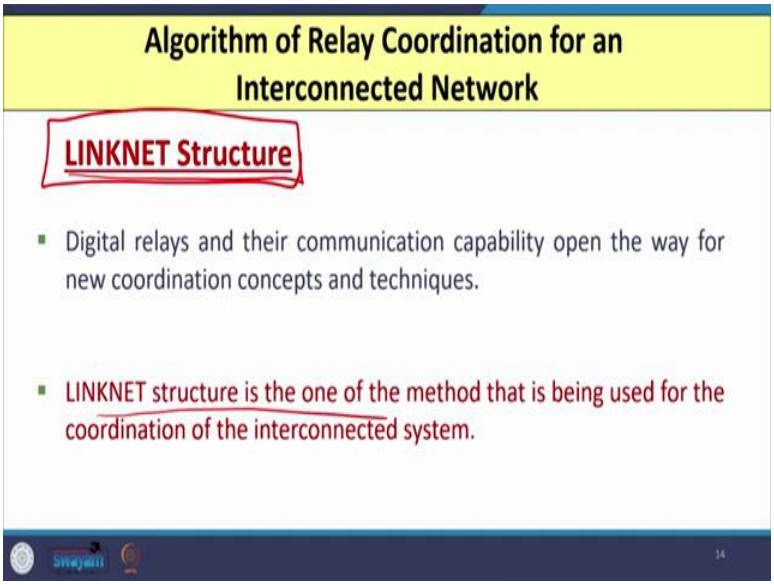

So, for that, we need to go for some specific strategy and that strategy is known as LINKNET structure. That strategy is known as LINKNET structure. So, digital relays and their communication capability, all the features of digital relays, they have opened one of the way for coordination of these relays, particularly when we have a complex network for distribution network.

So, as I told you LINKNET structure can be used as one of the way using which we can calculate the settings that is time dial settings and plug settings, along with that, we can also find out primary and backup relay pairs for any interconnected large network which consists of large number of relays and large number of distribution feeders. So, LINKNET structure is nothing but the method or procedure using which the coordination of an interconnected electrical power system network whatever relays are available, that is carried out.

So, when we consider the LINKNET structure, then the first task of any relay coordination process is to store the network information optimally in computer memory. So, whenever we talk about LINKNET structure, because LINKNET structure is the procedure or method, which is used for calculation of or to carry out the coordination of overcurrent relays for an interconnected network and no manual intervention is required.

It is based on some algorithm and the heart of the algorithm is we have to store the structure of the of the whatever algorithm available may be ring network, radial network in optimal in a computer

memory that is the heart of this LINKNET structure. So, in this lecture initially we started our discussion with the features of the digital relays. And we have seen that most of the features are available in the digital relays along with the features related to the fault recording or sequence or event recording or maybe remote terminal unit or it may act as a PMU. So, all these features are available in digital relay.

And then we have discussed that what is the primary relay and what is the secondary or backup relays are there. So, the relay which operates for a particular fault or for a fault in its own zone, those relays are known as primary relays. Whereas, whenever primary relay fails, the other relays are there, which are known as backup relays.

And we have seen that it is very difficult to carry out coordination of an interconnected electrical network manually because our whole network or system is very complex, setting procedures are entirely different and it may changes from network to network. And the utility to utility also it changes.

So, it is very difficult to carry out coordination of overcurrent relays manually and hence, we have to use some algorithm and that algorithm is known as LINKNET structure. So, remaining thing regarding LINKNET structure that we will be discussed in the upcoming lectures. Thank you.