Power System Protection and Switchgear
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Lecture - 03
Fundamentals of Protective Relaying - 3

Okay, so today, we will discuss regarding the basic tripping mechanism of the relay. Now, we know that relay is always connected either on the secondary of CT or secondary of PT. We may use either CT or PT or both. So, the main function of relay is to just detect or sense the inception of fault, whereas the rest of the tripping task that is isolation of defaulted part or circuit or section, that is done by auxiliary relay or circuit breaker.

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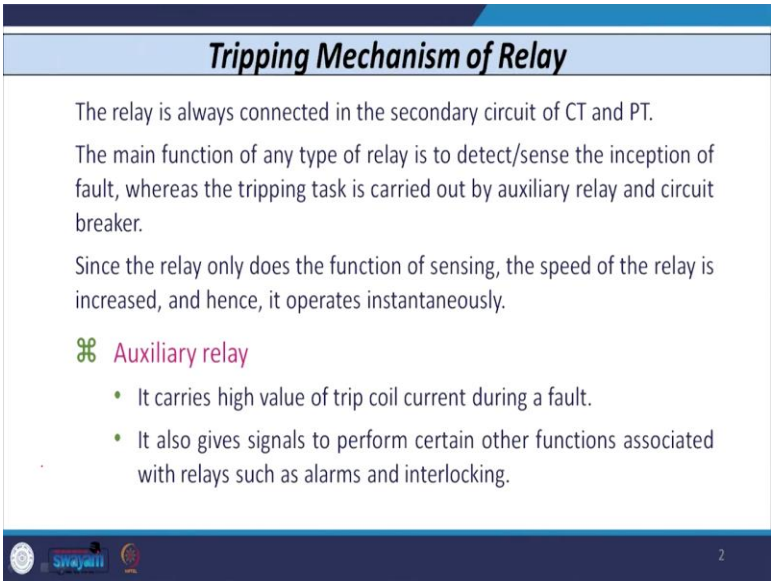

Now, since the relay does the function of just sensing or detection of fault, so it's speed increases and some relay may operate instantaneously or depending upon the magnitude of flowing current. So, what is the function of auxiliary relay? So, the main, auxiliary relay has two main task.

First, it carries high trip coil current during the fault. So, relay will just only sense the fault, whereas the remaining task that is carrying of high trip coil current that is carried out or done by auxiliary relay and it also gives signals to perform several other functions like alarms, interlocking, say, we may require mechanical interlocking or we may require

electrical interlocking, then those task, that is performed by the auxiliary relay as it has multiple contacts.

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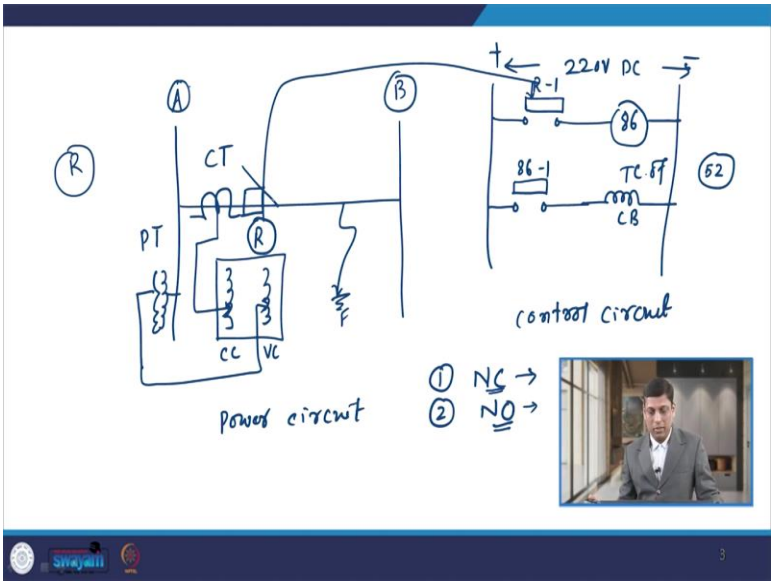

So to understand this, let us consider a simple, say we have a bus A and there is a line connected between bus B. So on this, let us assume that there is a CT placed at bus A and there is a PT also placed at this bus. So, this is the current transformer and this is the potential transformer. Now as, if I consider the relay, then the relay usually indicated or denoted by circle and then R. So, that means if I have the relay, then this indicates the coil of the relay.

So, relay has basically two coils, one is known as the current coil, this is known as current coil of the relay and this is known as the potential or voltage coil of the relay. So, the signal to the current coil of the relay that is given through secondary of CT, whereas signal to voltage coil of the relay that is given to secondary of the PT.

So, whenever any abnormal condition or fault occurs on this line, then depending upon the magnitude of current, the whether, it depends on whether the relay is a single input relay or multiple or two input relay; relay operates and it gives signal to the circuit breaker or further auxiliary relay. So, this circuit is known as the power circuit.

Now, the other circuit which relay has that is the control circuit. So, in control circuit all the contacts of the relay that is connected. So, if I just draw the control circuit, let us say this is the, it requires 220 volt DC supply, sometimes it may have, it may get 110 volt DC supply. Nowadays, the multiple means you can also give the AC supply also. So this relay, if I consider the relay connected in power circuit that is R, then this relay has certain or several contacts.

So, basically there are two types of contacts available in the relay. One contact that is known as normally closed contact and the other contact that is known as normally open contact. So, normally closed contact or normally open contact are those contacts which are, so, normally closed contact that will remain in close condition when the coil of relay is de-energized, whereas normally open contact that remaining open condition when coil of relay is de-energized.

So, if I consider that this relay R has, let us say, normally open contact, then its contact that is available here, this is normally open contact, let us give the name that is R1. So, whenever the, any fault occurs on this line, the relay, coil of the relay is energized and it give signal to its contact. So, this relay will give signal to its contact, let us say, R1. So, as this contact is normally open, whenever the relay coil is energized, this contact closes and it gives further signal to the auxiliary relay.

So, auxiliary relay is indicated by the standard number, let us say, 86. So whenever the any fault occurs, the relay coil is energized and it gives signal to the, its contact, say, R1, which is normally open and due to closure of this contacts, coil of auxiliary relay, 86, that is energized. This 86 auxiliary relay has several contacts. So if I consider that this 86 auxiliary relay has normally open contact, let us say, it is 86 - 1. So, because of energization of the coil of auxiliary relay 86, its contact 86 - 1 closes which gives signal to the trip coil of circuit breaker. So, normally circuit breaker is indicated by the number that 52.

So whenever any fault occurs in the system or circuit, then the coil of relay is energized and it gives signal to its contact, so its contact closes. If normally open contact is there then it becomes, it closes, if normally closed contact is there then it becomes open.

So, accordingly the further coil of auxiliary relay 86 is energized and due to closure of its contact, the trip coil of circuit breaker that is energized which further gives signal to the circuit breaker. So, circuit breaker is somewhere here and this circuit breaker becomes open. So, the faulted section that is isolated or disconnected from the network. So, this is all about the working of, this is all about the working of the tripping mechanism of the relay.

So, if I consider the main thing whenever you, whenever you trace or whenever you go to substation and whenever you trace any control circuit or power circuit for the relay, any type of relay, then one thing you have to keep in mind that in control circuit all the relay coils, that is shown in de-energized condition and all the circuit breakers are shown in open condition.

Now, with this background, let us see that how the relays are classified. So, protective relays used in this, in the application, those are classified based on what function they perform, what are the actuating quantities or what components that are used in the relay.

So, the first type of classification that is known as, this classification according to the quantities given to the relay. So, for example, there are several types of relay available say, overcurrent relay. So, it takes the, it works on the, on the function of overcurrent. If current exceeds some pre-determined threshold or a pre-defined value, then relay operates. The other example is over voltage relay. So, if voltage exceeds nominal value or rated value, then relay operates. Under voltage relay, so if voltage reduces or goes below some standard or some value, then under voltage relay operates.

Similarly, there are other types of relay like, under frequency relay, over frequency relay, which works when frequency exceeds certain value or when frequency goes below a certain limit. The other type of relay that is over fluxing relay, which is normally used in case of transformer and then power relay. So power relay is for, best example is low forward power relay, which is for particularly used when we want to detect the reversal of power in the power system network. So, reverse power protection that is the best example of this power type of relay.

The second type of classification, that is according to the construction. So there are based only construction, relays are also classified as attracted armature type relay. So attracted armature type relay best example is instantaneous over current relay that is the attracted armature type relay. The other example is induction disc relay or induction cup relay. So the examples of these relays are directional relay or distance relay, whereas the next another type of relay that is balanced beam type relay and the best example of such type of relay that is differential relay.

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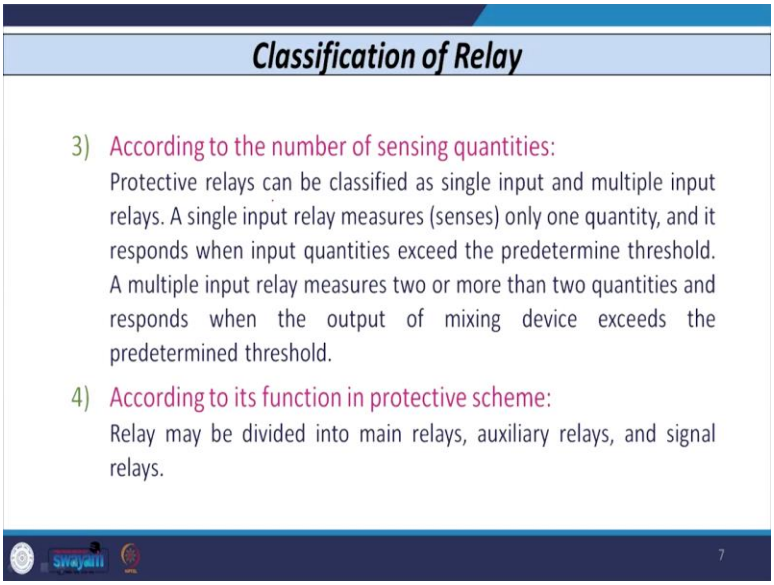

The third type of classification that is according to the number of sensing quantities available or given input to the relay. So, we know that protective relays can be, can give or can, that can accept several input quantities. So, if it have only single input, then single input type relay. If it has multiple inputs, then multiple input type relays are available. So, single input relay measures only single quantity and when that quantity exceeds certain pre-defined value, then relay operates, whereas in case of multiple input relay, it measures two or more quantities and when mixture of these quantities exceeds certain threshold value, then relay operates.

The fourth type of classification that is based on according to the function that is performed by the protective device or protection scheme. So, such type of relays are, example is main relay, auxiliary relay, signal type of, if I have been want to give specific

type of signal to the circuit, say actuating type of relay. So those relays are known as the, such type of different relays.

The fifth type of classification, that is according to the components and device used in the protective circuit. So, these type of examples are electromagnetic or electromechanical type of relay, which uses mechanical devices; static relays, which uses semiconductor devices; microprocessor based relay, which uses some several or sophisticated type of algorithms; the digital and numerical relays, which uses very fast processor with communication facilities. So those relays are again classified based on what type of components that is used in the protective relay.

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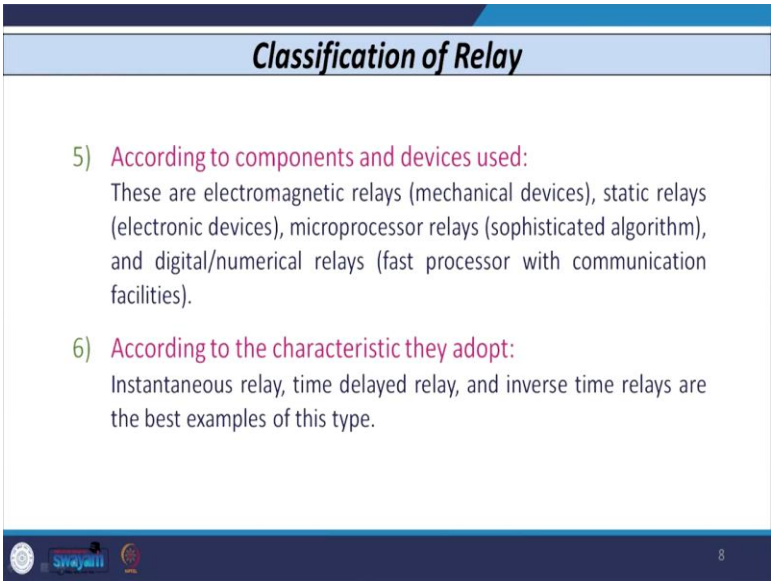

The sixth type of classification is according to the characteristic that is utilized by the protective device. So, if relay operates instantaneously say, within for example, 20 or 30 or 40 millisecond, then those type of relays are known as instantaneous over current relay or instantaneous over voltage based relay. The other type is time delay relay. So if the current exceeds some value, then relay operates after some specific time period and that is known as time delay relay. The other examples of this type of relay that is known as inverse time overcurrent relays, so IDMT, inverse definite minimum time relays are the example of inverse time overcurrent relays.

So, let us start with some historical development, what type of relays were used earlier and what type of relay that are used nowadays by the utilities. So, the first relay that came in market in 1901 that is the electromechanical type relays. These relays are very rugged, they are very reliable and still used by utilities because its cost is very less. The main operating principle of this relay is whenever the current flows through the winding, which is wound on a magnetic core, then the force is produced, which in turn energize the coil of the relay and further tripping that is given to the context of the relay.

There are certain advantages of electromechanical type relay. The first advantage is this type of relays are reliable and still used by the utilities. The second advantage is it provides proper isolation between input circuit and output quantities. And the third advantage is they are very rugged in nature, they are very sturdy, so they can withstand voltage spikes. So such type of voltage spikes and mechanical vibrations are there when we have the earthquake or when we have the substantial switching surges or lightning surges are there, then they can, they are capable to withstand such type of phenomena.

However, this electromechanical relays has certain disadvantages also. The first disadvantage is, this type of relay consist several moving parts, so they are suffered from the friction. Second disadvantage is, they produce very low torque for certain or several types of faults. So, best example is, if triple line to ground fault occurs or triple line fault occurs, then this type of relay produce low torque and they sometimes it may possible that they may not operate.

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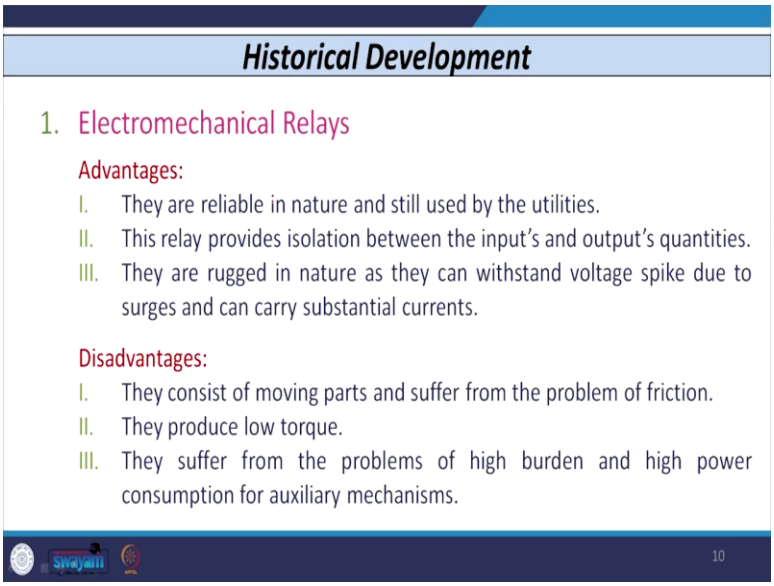

The third disadvantage of electromechanical type relays are, they suffer from the problem of very high burden and so, that means, the whatever, burden means, burden means if any load, whatever load is connected across the relay or CT secondary, that is known as burden and this burden is usually specified in terms of either ohm or VA. So, if I consider the electromechanical type relay, then their circuitries require or consume a very high power, roughly of the order of maybe 60 watt to 80 watt. So, such type of relays are nowadays not used by the utilities.

The second type of relay that is known as static relays. This type of relays came in market in around 1950s. This relay has several advantages compared to previous electromechanical type relays. They have low burden. Using this relay, we can have precise and complex characteristic and its size is also very small compared to the previous generation of electromechanical type relays. However, their cost is a little bit higher compared to the electromechanical type of relays and sometimes, and the biggest disadvantage of static type of relay is that they use semiconductor components or devices.

So, these components' performance are affected by temperature variations and mechanical vibrations. Moreover, such type of relays are also required DC power supply,

so you have to provide separate DC power supply if working of such type of relay is required or used in the substation.

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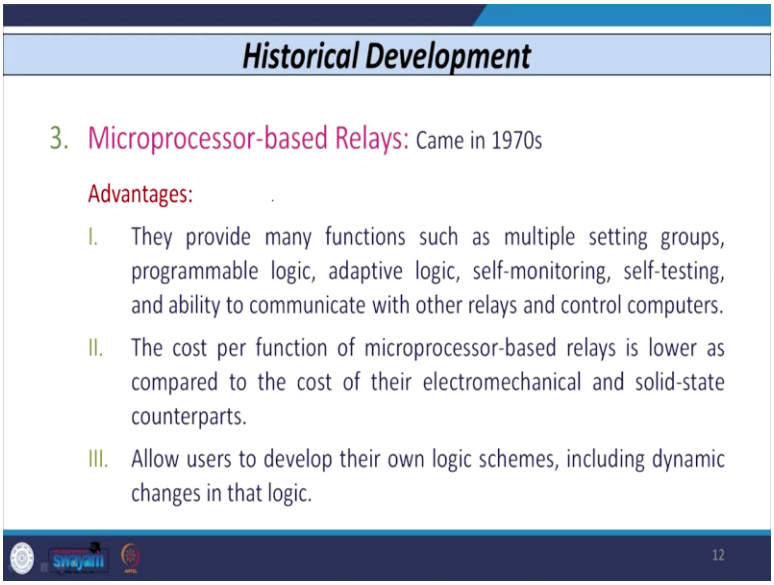

The third generation of relays that is known as microprocessor based relays, this type of relays came in market in 1970s and they have certain advantages. The first advantage is they provide many functions, multiple setting groups.

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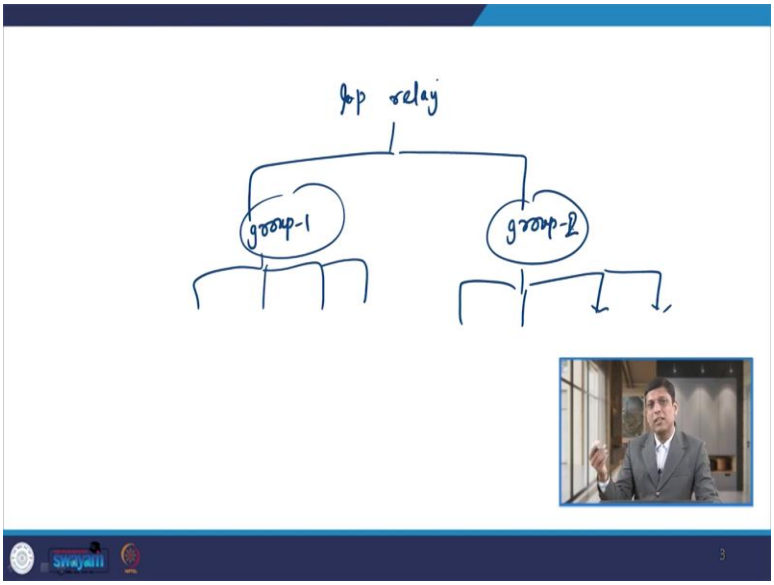

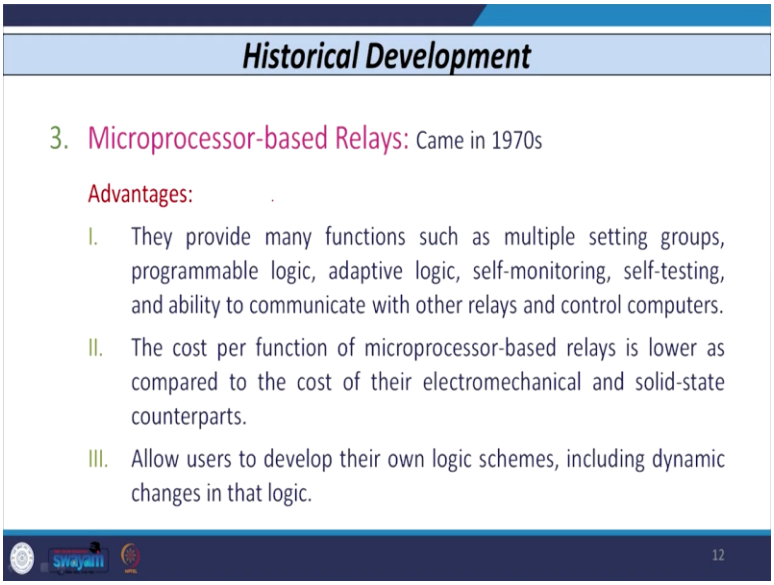

So setting groups means suppose, if microprocessor based relay is available, then they provide usually two type of setting groups that is known as group 1 and group 2. So, in group 1 type of setting, you have several functions and in group 2 type of settings, you have several functions. So whenever you installed such type of relay in the substation, usually first group is used by the utilities, second group, second group that is meant for the backup. So, that is the first thing.

This type of relay has programmable logic. So that means, you can develop your own logic, even that logic can be adaptive in nature also. So whatever type of function you want to develop or you wish to develop, you can develop, whatever type of characteristic you want to develop, you can develop using such type of logic.

The other that the advantage of microprocessor based relay that is they have the feature known as self monitoring and self testing. So now, we know that whenever we install any relay in the substation, then these relays are going to operate only and only when fault occurs. So for, and we do not know at what instant fault occurs, sometimes fault may occur maybe multiple times in a month or sometimes it may not happen in a year also.

So periodically, we need to carry out testing of such type of relay. So, in earlier generation of relays that is electromechanical and static type of relays, we have to test the relay separately every say, 15 days or once in a month by using some external circuits, whereas such microprocessor type of relay, they do not require separate external circuit for self monitoring and self testing because they have such type of feature, so they are capable to test all the functions by themselves. So, that is the main advantage of this type of relay.

The another advantage is, this relay is capable to communicate with other relay and other computers also. So if you want to send some logic or some command to other relay which is situated very far from the substation, then also such type of relay that is used. The second advantage of microprocessor based relay that is cost per function that is lower compared to earlier type of relays. So what is the meaning of cost per function?

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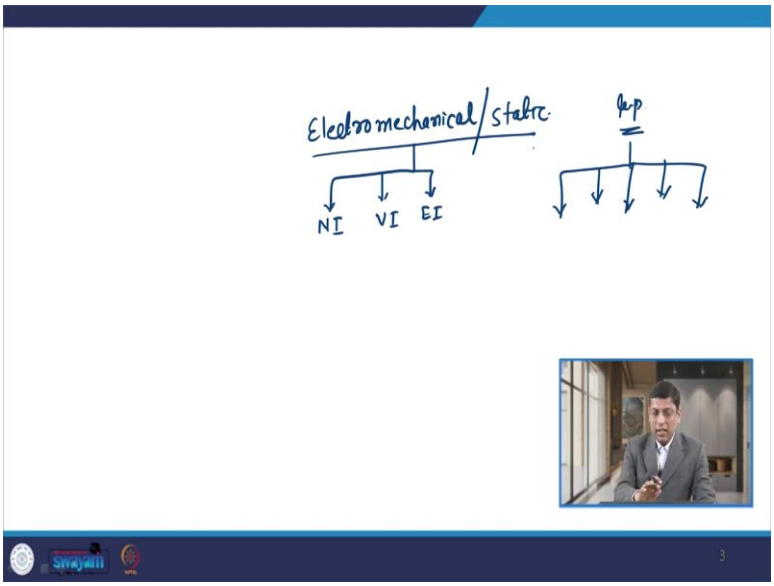

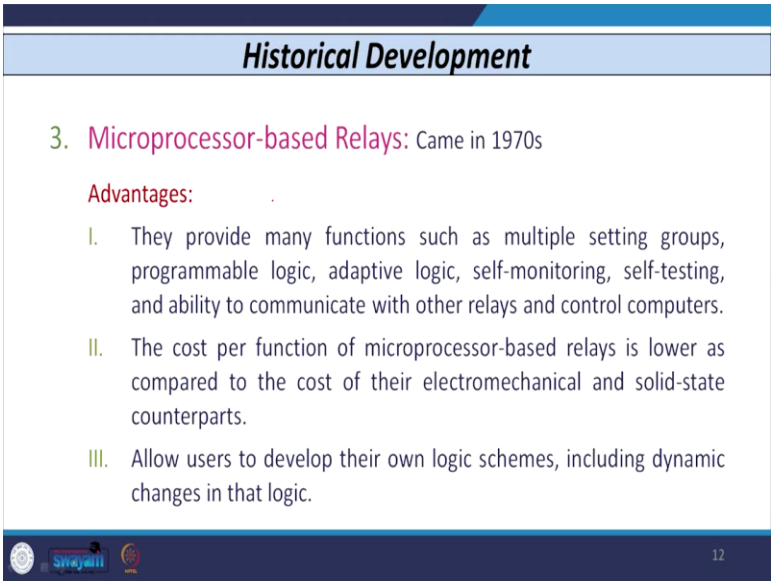

So if I use suppose, electromechanical relay, let us say, we use electromechanical or let us say we use a static type of relay at one side. So, if I want to have some specific type of characteristic, let us say, normal inverse, then I have one relay. If I want another type of characteristic say, very inverse, then I have to buy another relay. If I want to extremely inverse type characteristic, then again, I have to purchase a new relay.

Whereas if I use microprocessor based relay, then all such type of characteristic that is available in this relay. So, there is no need to purchase for other relay. So, the cost per

function per characteristic that is lower compared to electromechanical and static type of relays. So, that is the main advantage of this relay.

The third advantage of microprocessor based relays, that is they you can develop your own logic, even you can develop, carry out some dynamic changes in that logic that means, at the time of working if you wish to carry out some change, then that type of changes are also allowable in this type of relay.

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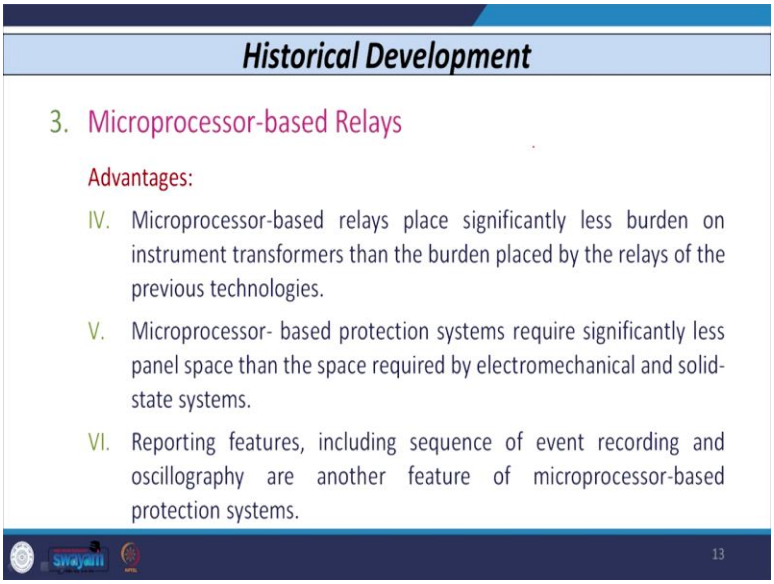

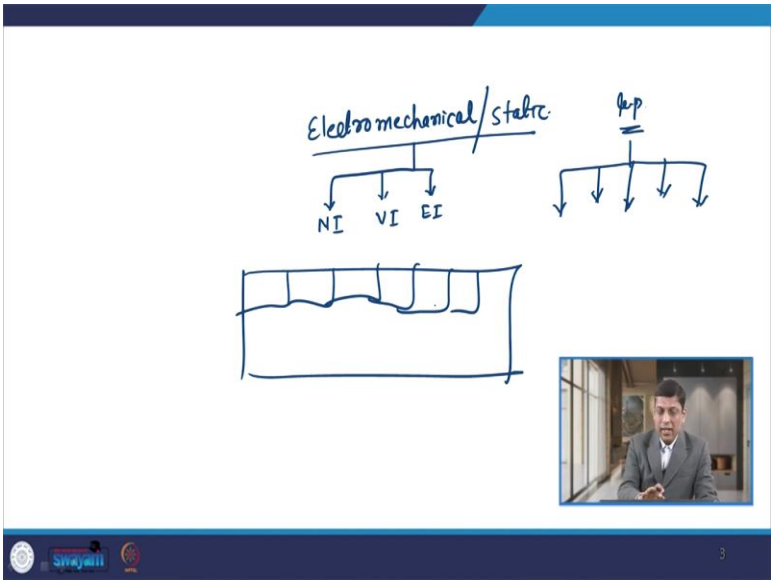

The next advantage of microprocessor based relay is they place less burden compared to the other type of, previous generation of relays that is electromechanical and static relays. So if burden of electromechanical or static relays are, let us say, 30 VA or 20 VA, then the burden placed by microprocessor based relays that is very less, maybe say, 5 VA or 1 VA, like that.

The next advantage of microprocessor based relay, that is the, this type of relay require less space, less panel space compared to electromechanical and solid state relays. So that means, if I use the substation, there in substation if I have limited space, then I can accommodate multiple type of or more type of, more number of microprocessor based relays compared to electromechanical and static relays. The next advantage of microprocessor based relays, that they have the reporting features.

So whatever, if any event or any abnormal condition takes place, then this type of event that is captured by this relay, and you can play back such type of event, you can visualize, maybe graphically or maybe you can access the data also in some form, let us say text form or some content from with the help of this relay. However, this relay, relays has certain or several disadvantages also. So, let us see what are the shortcomings of this relay.

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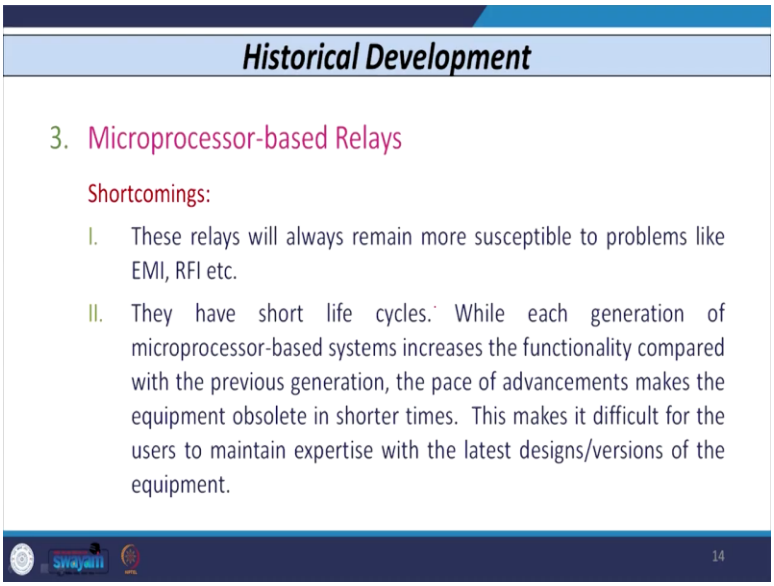

The first disadvantage of microprocessor based relays that is, they are susceptible against several phenomena like electromagnetic interference or radio frequency interference. So, if such type of interference is there and if you install this type of relay, then they may, there are fair chances of mal-operation of such type of relays.

The second disadvantage is that this relays has very short life cycles. Such thing we can compare with the say, for example, operating system that we are utilizing in computers. So, we know that operating system changes frequently. So every six month, we have another operating system. So, even we familiarize with one type of operating system, after six months the another type of or another version of operating system that is available.

So, same thing also happens with the each and every generation or version of microprocessor based relay. So, it is very difficult to take the track or for previous versions of each and every version of microprocessor based relays, so what we have to do is, we have to keep a continuous track. When next version of microprocessor based relay that is available, then we have to see that what new function, that is available in next version of microprocessor based relay.

The third disadvantage of microprocessor based relay is that they have large number of settings. So, if I want to carry out, means if I want to understand what are the type of test, if I want to manage those settings or if I want to carry out some functionality test on this, then I, it is very difficult to understand all such type of settings. Of course, practically whatever manufacturers or whatever other manufacturers are there, they are using some special testing techniques.

So, at the time of testing of suppose, if I am carry out or if I am conducting functionality test or if I want to manage settings then what they do is they simply enable or disable several features of microprocessor based relay and then they perform the functionality test of such type of relays. So, but in a short, this type of relays, if I want to manage the settings, then it is very difficult.

So later on, fourth type of generation of relays, those are known as digital relays or numerical relays, they came in market in 1975 and they have very special functions like compared to previous generation of relays, they have mathematical functions. So, you can have different mathematical functions and they also provide long term storage for pre-fault data as well as post-fault data.

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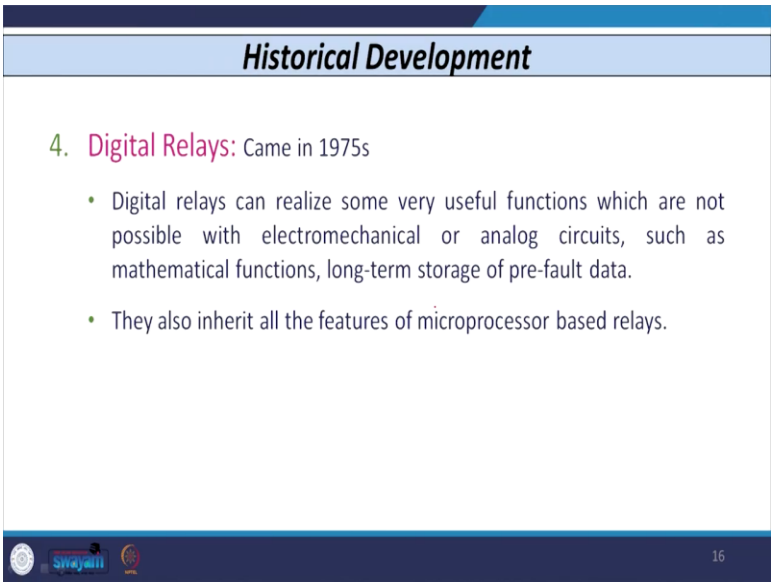

Also, they inherit all the features of microprocessor based relay. So, whatever features are there in the earlier version of relays, all those features are available in digital or numerical relays. The next generation of relays that is known as adaptive relays.

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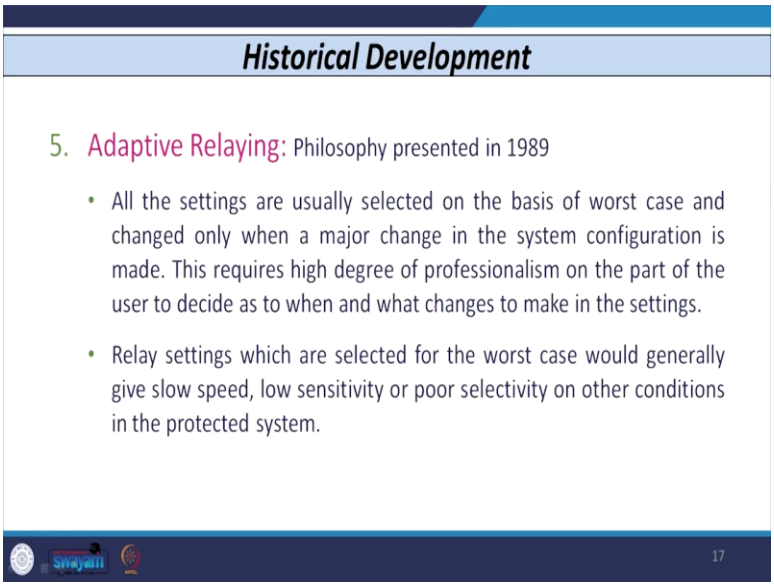

The philosophy is presented in 1989. Now, we know that why there is a need of adaptive relaying. So we know that all the settings that is carried out or performed on the relays available in substation, those settings change only when there is a huge change in the system configuration or external, whole external system.

Such type of settings or configuration require high degree of professionalism as far as the user or engineer is concerned. So, relay settings which are carried and usually, they carry out the relay setting for worst cases, considering the worst case. So, whatever setting you have done for worst case, those settings are lower for other type of cases. So, for other type of cases, which are not worst case, you will have slow speed, low sensitivity and poor selectivity.

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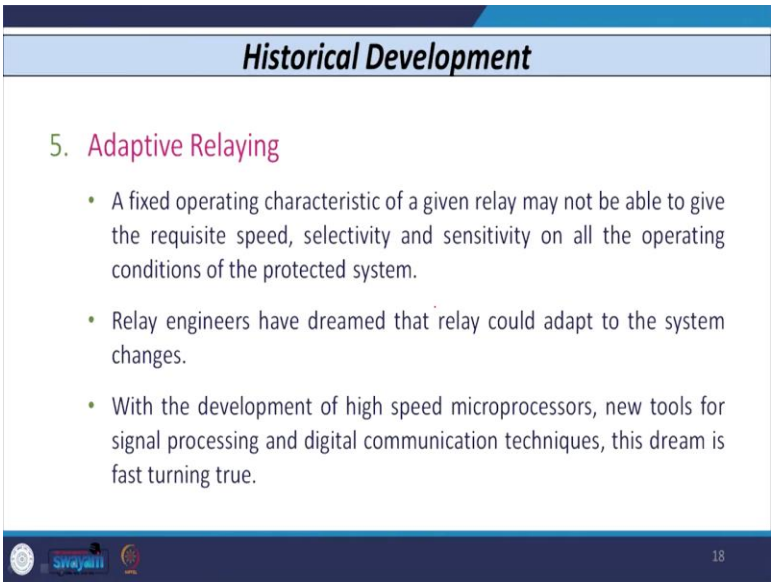

Moreover, a fixed operating characteristic that is used by earlier version of relays, however, using adaptive relaying you can have the different variable type of relay characteristic. So, that is possible with the help of such type of philosophy. So, if we use now, if I want to utilize such type of philosophy, if I wish to have variable type of relay characteristic, then I have to use a very high speed processor, it has communication facility. So, if I want to adopt such type of feature, then I have to use digital or numerical relays with communication facility.

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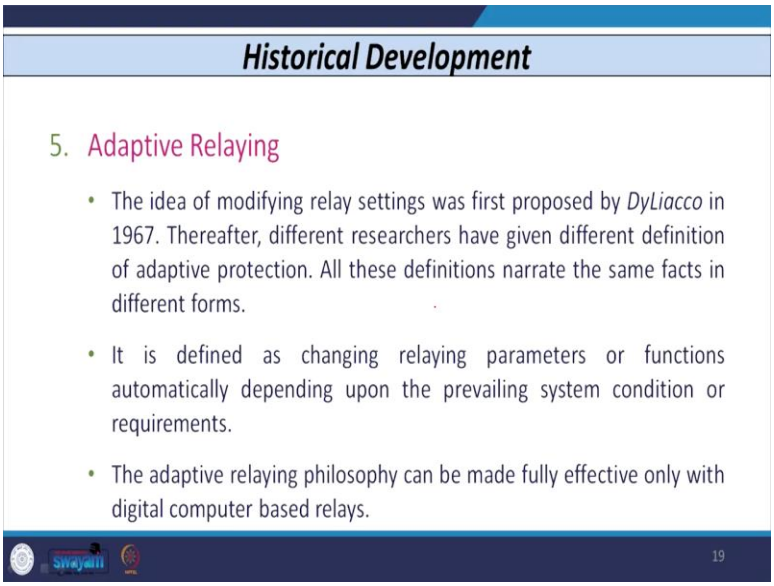

So the idea of adaptive relaying that is initially presented in 1967, by one researcher known as DyLiacco and later on in 1989, G.D. Rockefeller and the AG Phadke. This, their groups, they have presented the philosophy and they have given different definition of adaptive relaying. However, most of the definitions if you study, then they narrate the same meaning. So, what is that, what is the meaning of this? The adaptive relaying philosophy is defined as the changeing relaying parameters or functions automatically depending upon the prevailing power system conditions.

So, that means relay settings, their functions and parameters are changed as and when there is a change in the external system disturbances or parameters. So, this is the main philosophy of adaptive relaying. However, adaptive relays are not available or manufactured by any manufacturers, they are not available in market. So whatever relays are available in market that is digital or numerical relays and that is used by utilities.

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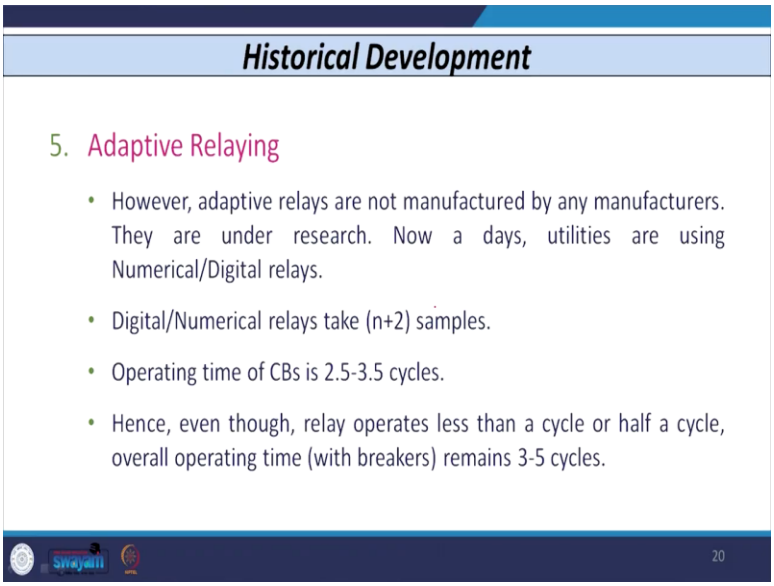

The main operating time of digital or numerical relays is that they use almost a cycle, 1 cycle time with some few samples. So, operating time, on the other hand, operating times of circuit breaker that is 2 and half cycle to 3 and a half cycle. So, even though if I manufacture the relay, which operates less than a cycle, let us say, half a cycle, then also the overall operating time of or overall fault clearing time, that is, that includes both relay time as well as breaker time that is of the order of 3 to 5 cycles. The next generation of relay available that is known as Intelligent Electronic Devices.

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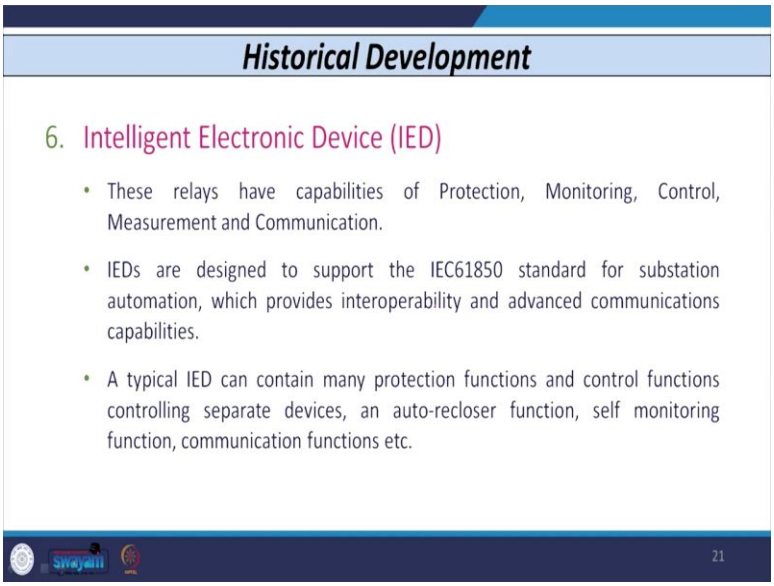

So, this type of relay has the capability of protection. So, it incorporate all the protection functions. It has monitoring features, so it is capable to monitor several parameters throughout the power system network. It is also capable to provide control feature, it is also capable to measure several parameters and it has also a communication facility. So, one relay can communicate with other relay. So all protection monitoring control measurement and communication features are available in single device that is known as intelligent electronic device. So, now relay that is known as IED. Now, IEDs are designed to support several protocols or standards. Now, why this standards are required?

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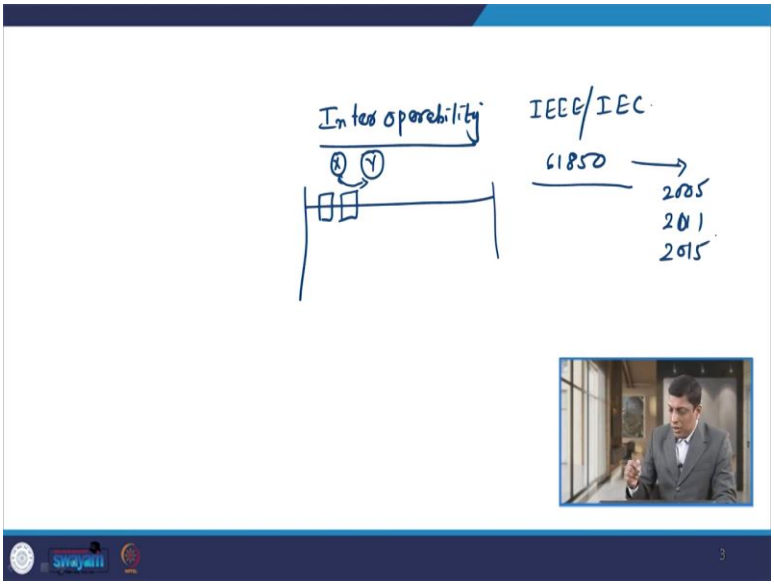

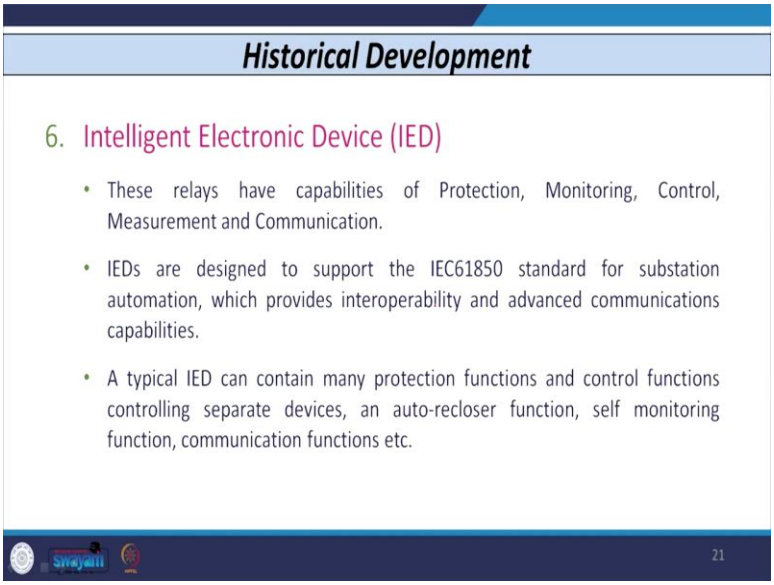

So, there is a one term known as interoperability, interoperability. So, what do you mean by interoperability? Now suppose, in substation, I am the in charge of substation and I purchased through some tender, one relay that is manufactured by one X Company. Now, there are many companies who is manufacturing such type of relay like HCL, a U.S. based company; ABB, then GE, maybe some other, Schneider and some other companies are also there.

So let us say, I purchased one specific type of manufacturer's relay and I install it. Say after two years, I purchased another relay and installed in the substation that is of manufacturer Y. So now, the question comes how one relay can communicate or X relay can communicate with Y relay. Because they are from different manufacturers and each and every manufacturer has its own logic they do not give, because they have, that is against the piracy or plagiarism. So, that means if I want to provide interoperability between these two or different manufacturer's relay, then I have to design certain protocols or logic.

So, this IEEE and IEC, combinely they have designed a protocol known as substation automation protocol that is 61850. Of course, there are some other protocols also, these protocols are designed earlier in 2005 and later on, it has been amended in 2011 and then 2015 also. So nowadays, if any manufacturer is manufacturing any IED, then this IED is compatible with several protocols given by IEC or IEEE entity.

So, all the IEDs manufactured by all manufacturers, they are compatible with IEC 61850 protocol. The special function that is performed by IED that is they have, that is for example, they have the feature like auto reclosing function, self monitoring, communication facility. So, all such type of advanced functions that is performed by IED.

So, in this lecture we have discussed the, initially we have discussed the basic tripping mechanism of the relay. So we have discussed that how relay operates, so only sensing and detection tasks that is performed by relay, whereas the, all the tripping tasks that is performed by auxiliary relay and circuit breakers. So, that we have discussed.

We have also discussed how the, whenever we consider any relay in the substation, then it is classified by either, power circuit and control circuit. So, how power circuit works and how control circuit works that we have discussed. And then, afterwards we have discussed the different classification of relay. So how relays are classified based on which type function they use, based on what type of quantity they use, based on what type of characteristic they use.

So, we have classified the relays in different ways and thereafter, we have we have discussed different generation of relays starting from electromechanical relay, then static relay, then microprocessor based relay, then we have discussed the digital or numerical relays and then we have discussed adaptive relays.

And finally, we have discussed the recent or latest generation of relays that is intelligent electronic devices. We have also discussed the merits and demerits of each and every relay. So in the next, in the next class, we will discuss the each and every relay one by one, thoroughly. Thank you.