Digital Protection of Power System
Professor Bhaveshkumar Bhalja
Department of Electrical Engineering
Indian Institute of Technology, Roorkee
Lecture 01
Introduction to Digital Relays - 1

Hello friends. So, today we will discuss the main parts or layouts of this course on Digital Protection of Power System. So, in this course, we will consider the basic concepts of digital relays.

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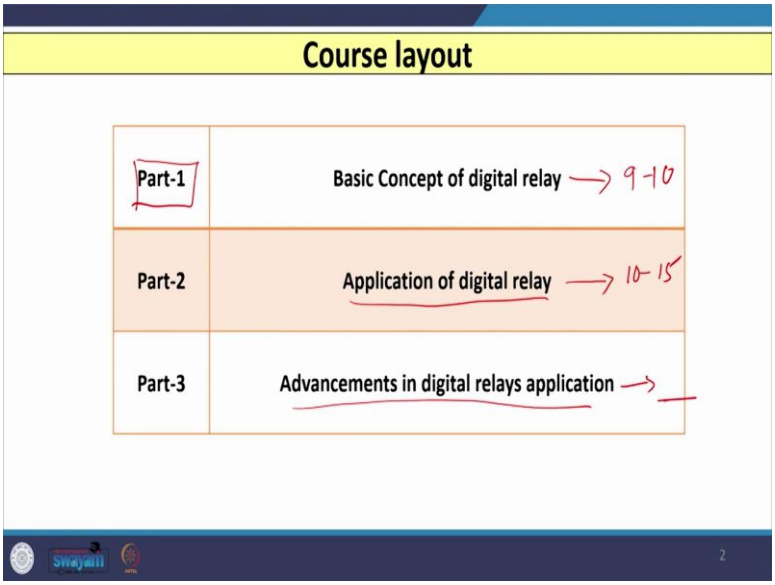

And this is the part one of this course and that will roughly cover nine to ten lectures. Then in the second part, we will cover application of digital relays and that will cover roughly around let us say almost ten to fifteen lectures. And in the third part, we will see the different application of digital relays and remaining lectures are covered in this third part.

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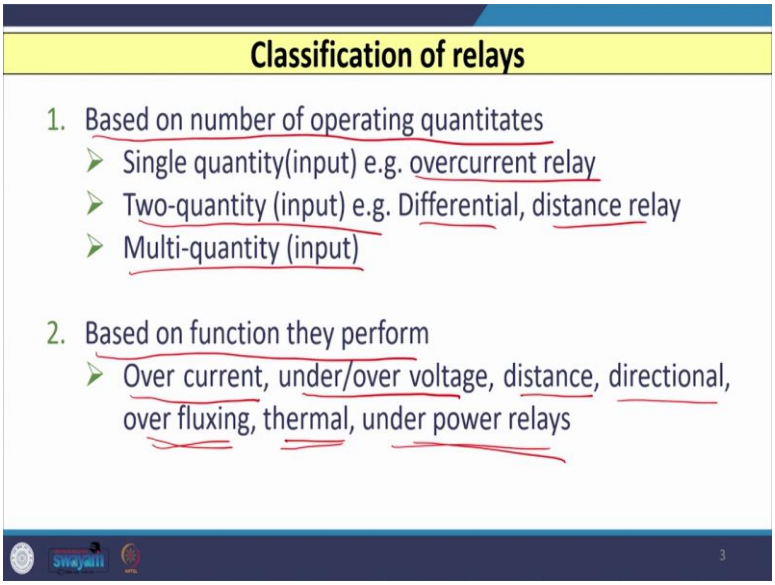

So, let us start with the classification of relays. So, we know that relay is a device which is used for sensing the fault. So, whenever fault occurs either in the overhead transmission line or whenever fault occurs or short circuit occurs in any apparatus, then the relay is a device which is going to sense the fault and after sensing the fault, it will initiate a signal to the circuit breaker further for isolation of that devices or the lines.

So, if we consider the classification of relays, then the first classification of relays that can be done based on the number of operating quantities. So, that means, if relay needs only one input for operation then that is known as single on input or single quantity relay and the best example is overcurrent relay.

The second part is the two quantity relay or two input relay and the examples are differential and distance relay. So, in two input relay, relay needs two quantities, let us say voltage and current and based on that the available voltage and current input, the relay will take appropriate decision.

The third part or category is the multi input or multi quantity relay. So, this is the first category of the classification of relays based on number of operating quantities, which we provide as an input to the relay, the second classification is carried out based on function each relay performs.

So, if we have overcurrent relay, then it works when the current exceeds a predetermined threshold value. The relay known as under voltage or over voltage relay works on the voltage

if voltage exceeds some threshold or if voltage reduces below some set value, then this relay operates.

Similarly, distance relays are also there. So, when the impedance measured by the relay is less than the set value of impedance, then distance relay operates. Similarly, we have directional relay, over fluxing relay, thermal relay and power relays. So, directional relays are used when we want to compare the direction of current in which the angle between voltage and current that is compared.

So, if current exceeds, the predetermined threshold value and the set direction is also achieved, then the directional relay operates. Similarly, we have over fluxing, thermal and low forward power relays, which are used for different applications.

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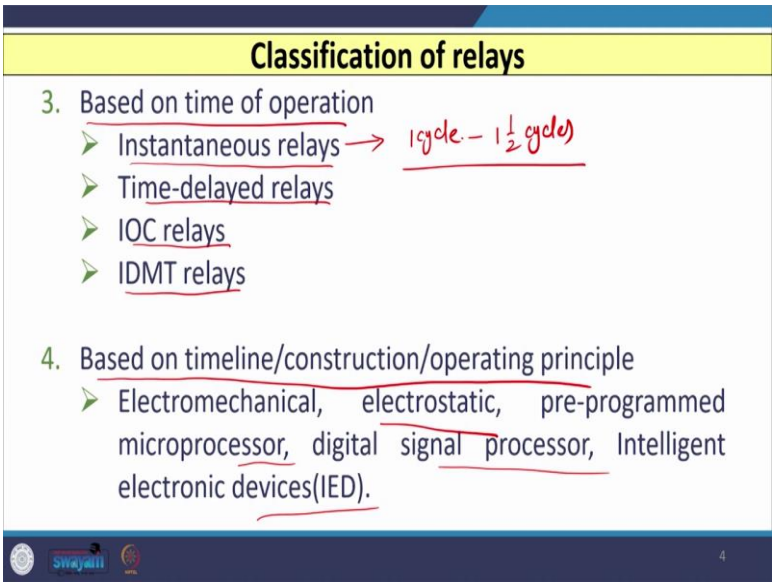

The third classification is done based on the time of operation of the relays. So, for example, instantaneous overcurrent relays are there which operates instantaneously. But we know that not a single relay is available which operates instantaneously. So, any relay which operates in one cycle, or at the most one and half cycles, that relay is known as instantaneous relays.

The second is known as time delayed relay. Let us say, we set the time say five seconds, and if current exceeds a particular value, and it remains for five seconds, then time delayed relay will operates.

The third type is inverse overcurrent relays which has inverse time characteristic. So, type of operation of relays in inversely proportional to the magnitude of current. And then we have

inverse definite minimum time IDMT relays. So, which operates with the combination of inverse time overcurrent relays for certain value of fault current and the time delayed relays if magnitude of fault current exceeds, let us say twenty times the plug setting.

The next category of classification is based on the timeline construction or operating principle. So, the first is the electromechanical relays. The electrostatic relays are also there, microprocessor based relays, digital relays and IEDs are also there. So, all these classifications starting from electromechanical to static to microprocessor to digital and IEDs, we will discuss in terms of various generation of relays. So, now let us see what are the different generation of relays.

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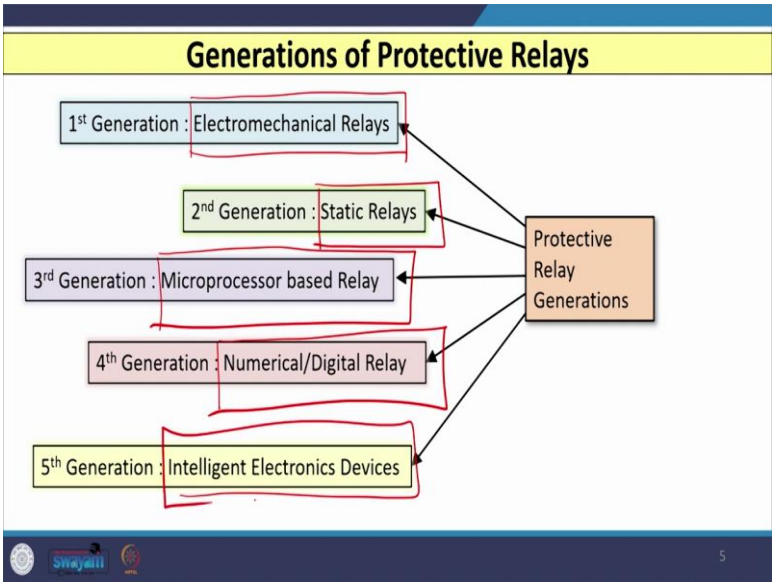

So, if we consider the first generation of relays, then the first generation of relay is nothing but the electromechanical relays. They are also known as sometimes electromagnetic relays. The second generation of relays are known as the static relays because they use the static components or semiconductor components inside the relay. That is why they are known as static relays.

The third generation of relays that is known as microprocessor based relays. Because they use microprocessor as a processing unit, the fourth generation of relays that is known as digital or numerical relays, so digital or numerical relays, they are the advanced version of microprocessor based relays and they inherits all the features of microprocessor based relays. And the latest generation of relays available nowadays, that is known as IEDs intelligent electronic devices.

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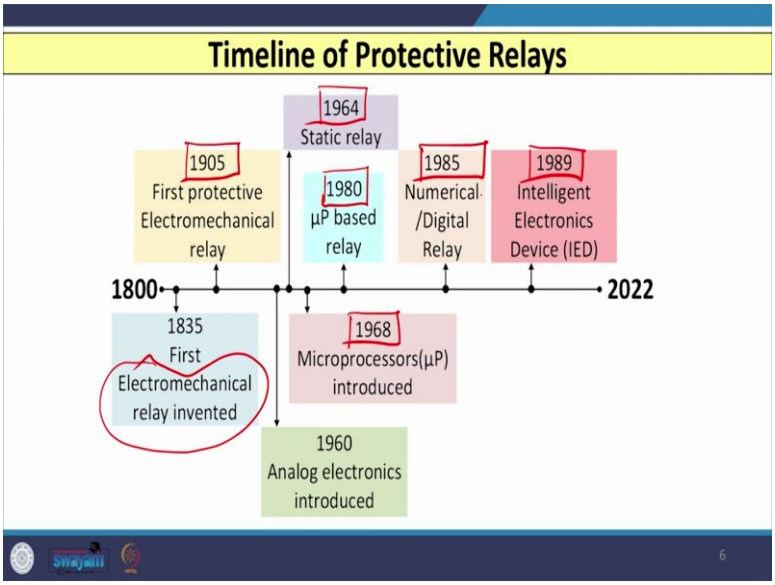

So, if I consider the timeline of this different generation of relays or file generation of relays, which we have starting from electromechanical to static to microprocessor to digital and IED. So, the first electromechanical relay invented in 1835, but the first electromechanical relay that is actually installed in the utility is in 1905.

Then the second generation of relay that is static relays came in market and this relay came in 1964. After that, we have the microprocessor-based relays, which are introduced in 1968. But the first relay commercially available for utility purpose that was in 1980s. Then in 1985, when the advancement has taken place in the microprocessor in numerical or digital relays came in market. And after that, after with the further advancement in communication technology and processors, in 1989 the intelligent electronic devices came in market.

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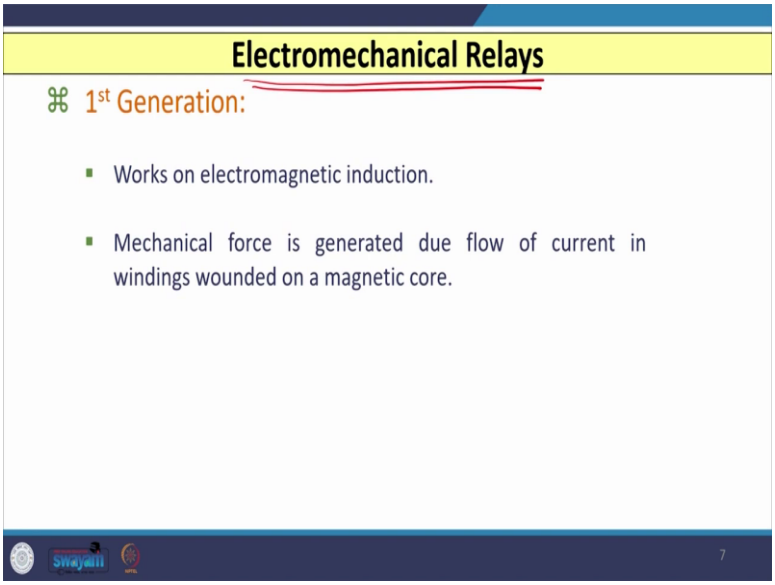

So, now let us start our discussion with the first generation of relays that is electromechanical relays. So, this relay walks on the principle of electromagnetic induction. So, whenever the current flows through the winding which is bound on the core, then some magnetic force is generated by this relay, and then the contact associated with this relay operates and finally, it gives the trip signal.

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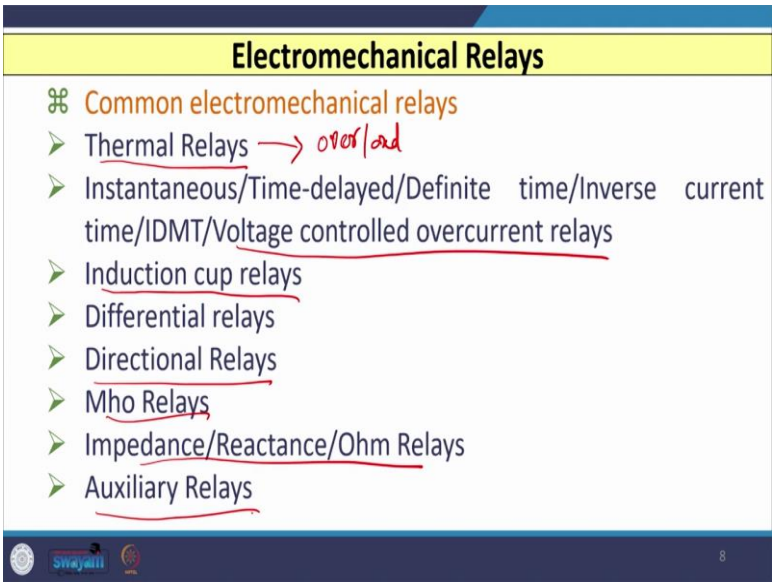

The common electromechanical relays available in market are thermal relays, which are basically used for protection against overloads. So, this is used for the protection against overloads. Then we have instantaneous definite time, minimum time, inverse time, overcurrent relay or IDMT relay or any voltage controlled overcurrent relays are there they are also available in market.

We have induction cup relays, differential relays, directional relays, mho relays, impedance, reactance, ohm or any other characteristics are there. These relays are also available. And of course, we do have some auxiliary relays which are used for taking care of the high trip coil current. These relays are also available in market. Now let us see what are the advantages of electromechanical relays.

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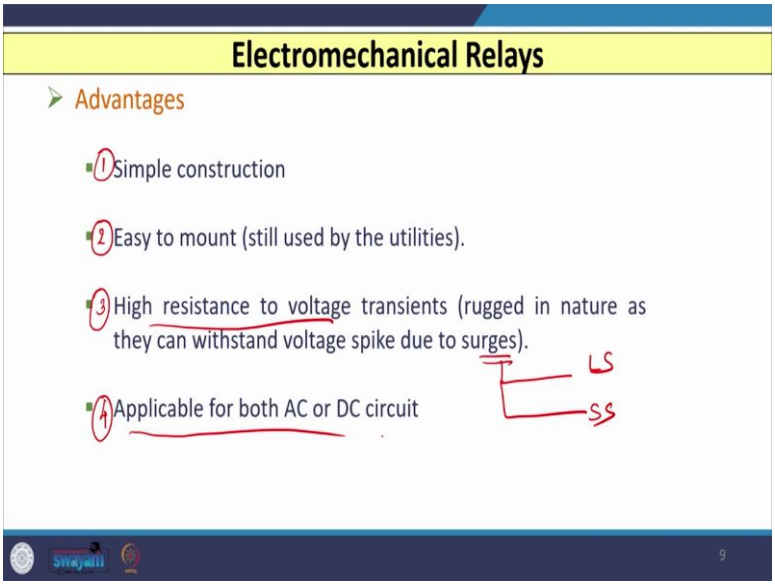

So, the first advantage of electromechanical relays that is its construction, so construct wise this relays are very simple, and we can easily understand by just seeing the construction or layout of this relay. The second advantage is we can easily installed this relays and that is why this type of relays are still used by the utilities. The third advantage is that this relay has a very high resistance against voltage transients. So, they are very rugged in nature.

So, because they can withstand the voltage spikes, which are initiated because of the surges and surges can be because of the lightning surge or it can be because of the switching surge. So, when lightning false surge that is also initiated or whenever switching surges are these are there because of opening or closing of the circuit breaker. Then such type of surges are initiated, but this relay are immune against such type of surges.

The fourth advantage of this relays that is they are applicable for both AC as well as DC circuit. However, this relay has certain limitations. So, let us see what are those limitations?

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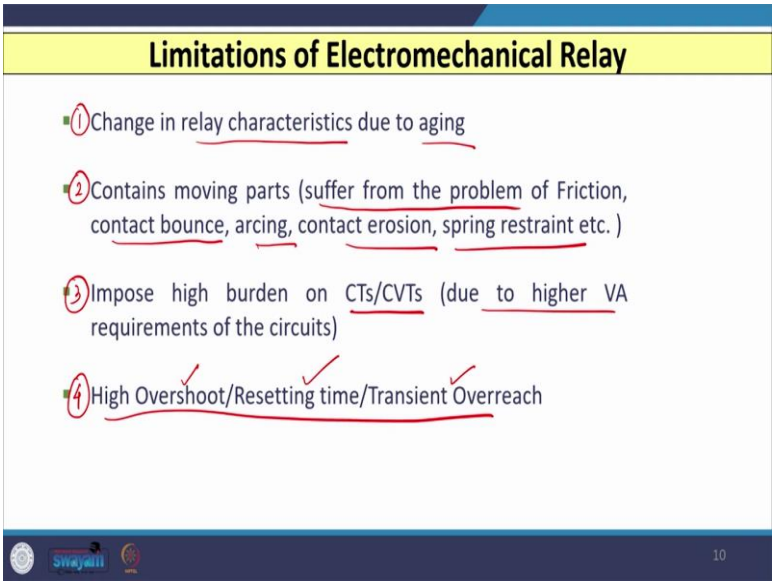

So, the first limitation of this electromechanical relay, that is the change in characteristic, we know that certain mechanical parts are used in this relay. So, the characteristic of this relay which is provided or claimed by the manufacturer, they may change because of the aging effect. So, maybe after five years, ten years, you may not get the exact relay characteristic.

The second disadvantage of electromechanical relay is that this relay contains moving parts. So, when moving parts are there inside the relay or inside the case of the relay, then this relay suffer with the problem like friction, contact pounds, arcing, contact erosion and spring restraint. So, this type of problems are faced by electromechanical relays because of the utilization of moving parts.

The third limitation of electromechanical relay that is this relay imposes very high burden on the current transformers and potential transformers. And this high burden is because of the high VA requirement by the circuitries of this electromechanical relays. So, if high burden are imposed, then the circuitry of this relay needs more power. And of course, there are certain other disadvantages also that we will discuss later on.

The fourth limitation of this relay is that it suffers against the phenomena like high overshoot, high resetting time and high transient overreach. So, overshoot is nothing but the travel performed by the disc used inside the electromechanical relay. So, if any further travel is performed, then that comes under the overshoot, resetting is also there.

So, we know that whenever relay operates completely and after fully operated state when it comes to the return position, whatever time is claimed by the relay that is known as its

resetting time. So, this time is also very high normally resetting time should be as small as possible. So, that relay will be ready for the next operation.

The transient overreach is a phenomena when relay operates beyond its zone of protection and when it operates instantaneously, then such type of phenomena is known as transient overreach phenomena and this relays are suffered with all the three phenomena's.

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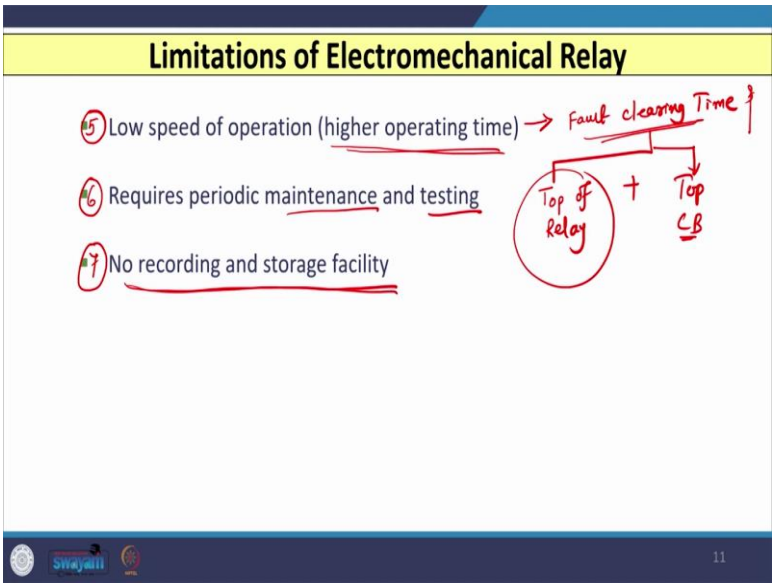

The another disadvantage of this electro mechanical relay that is the its speed of operation, so the speed of operation of this relay is very low. So, it has higher operating time and this is very important when we consider or when we talk about the fault clearing time. So, fault clearing time is nothing but the time taken by the relay.

So, we can say it is time of operation of the relay plus the time of operation of the circuit breaker. So, when you combine these two time it becomes fault clearing time. And for stability point of view fault clearing time is very important and it should be as low as possible. But when the relay operating time is higher, so time of operation of relay increases, so your fault clearing time also increases.

The next disadvantages of electromechanical relay is that this relay requires periodic maintenance and testing. So, when you installed this relay in the substation, then you have to carry out maintenance every fifteen days or once in every month and proper maintenance and testing is required. So, that when actually fault occurs, this relay must operate.

The another disadvantage of electromechanical relay is that this relay does not have any recording or storage facility. So, that means if I want to store the data of fault or let us say I want to store some important data of transients or harmonics, then such type of storage facility is not available in the electromechanical type relays compared to the latest generation of relays. Now, before we move to the next generation of relays, let us see how the electromechanical relay looks like.

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So, you can see that this is the electromechanical relays and the front panel, you can visualize this nameplate and on this nameplate you will see that there is some marking is there and this marking is nothing but the multiple of the pickup current is there against the time is there. And you can see this knobs are given where you can insert this key.

So, this is nothing but the plug settings and seven different settings are given. So, you can have you can insert this plug at minimum which is 50 percent and you can insert this plug at the maximum which is 200 percent. So, in steps of 25 percent this settings are given. This is known as plug setting or pickup setting.

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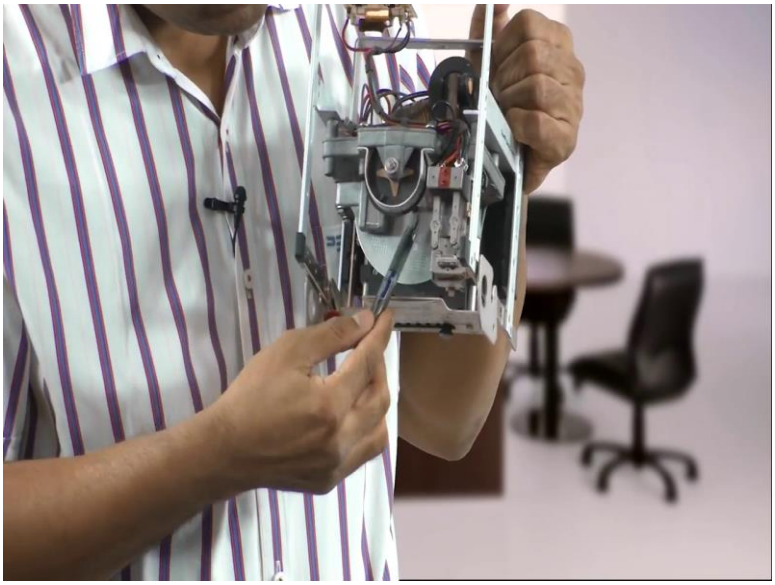

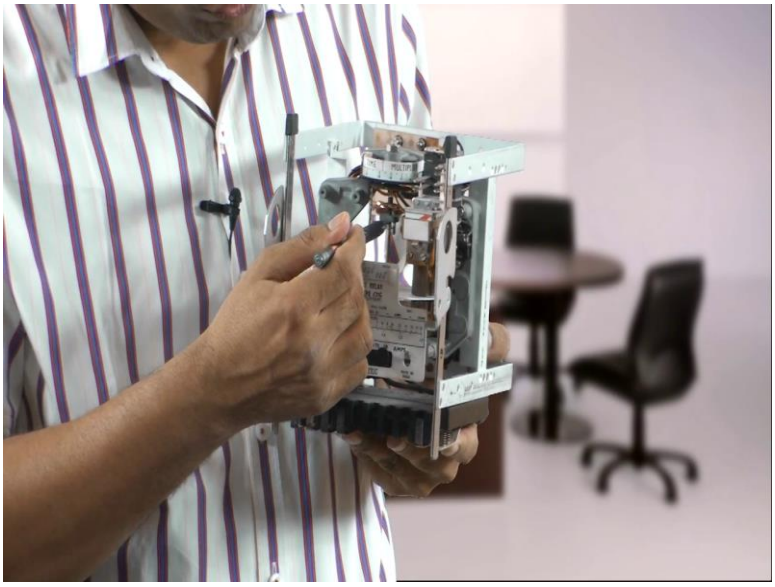

Then the another setting is also available in the relay, you can see is it the dial, where you can see the time. So, this setting is known as time dial setting. And this time dial setting, you can see below this time dial setting there is a spring is there, this is a spring. And you can see there is a disc is attached along with the shaft. So, this is the shaft if I just turn like this you can see this is the shaft and you can see about that shaft the spring is there and the contacts are also there.

So, you can look at that there are two contacts when I move this disc, one contact is available here. So, this contact is known as moving contact and when this moving contact touches the other side that is known as the fixed contact and when I move the dial of this time dial setting you can see the distance traveled by this contact that increases. So, this is how the electromechanical relay looks like.

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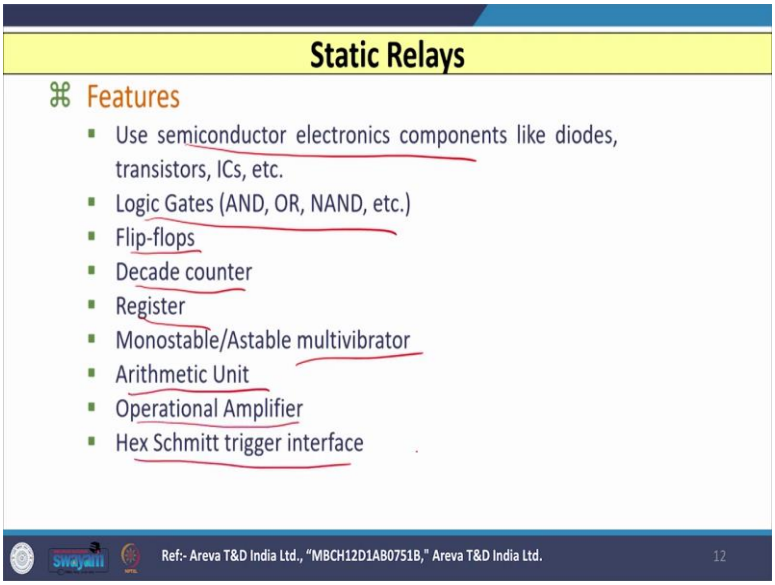

Now, with this background, let us see the second generation of relays that is known as static relays. So, the important features of static relays is this relay contains semiconductor electronic components like diodes, transistors, ICs, maybe logic gates are also there, flip flops, the counters, registers, monostable or astable multivibrator, arithmetic unit, operational amplifier and Hex Schmitt trigger interface. So, all this components are maybe used inside the static relays. And if I compare or if I see the advantages of static relays compared to the electromechanical relays.

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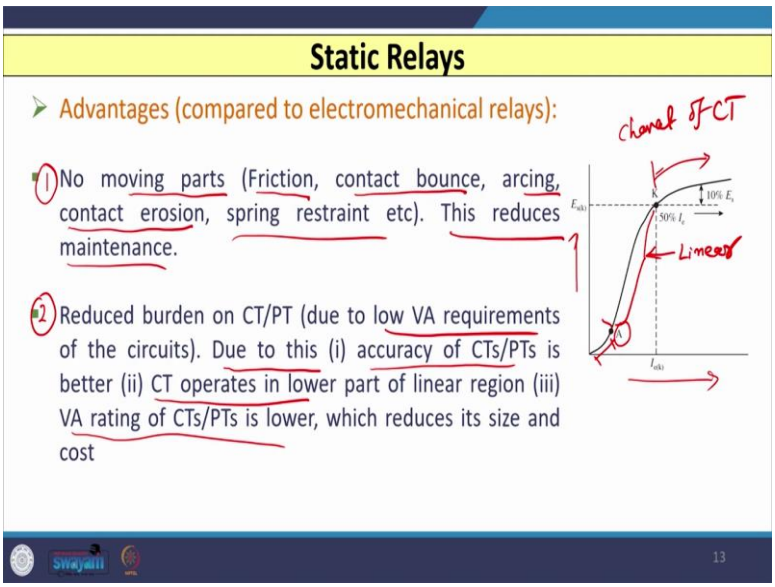

Then the first advantage of this static relays that is this relay does not contain any moving parts. So, as this relay does not contain any moving parts. So, the problem related to the

friction, contact bouncing, arcing which is going to occur between the contacts of the relay. Contact erosion that is also there with the contacts of the relay, spring restraint that is also there some force is required to overcome the spring force.

So, such type of problems are now overcome or rectified when we use static relays and because of this, this relay has reduced maintenance. The second advantage of static relays that is this relay has reduced a burden on CT/PT. So, whenever we use static relay and when we connect this relay across the CT and PT or both then this relay imposes low burden because of the lower VA requirements of the circuit inside the static relays.

So, when this burden on the CT/PT is reduced, this will give us three important advantages. The number one is the accuracy of CT and PT is better, when it has low burden. The second is the CT or current transformer operates in the lower part of the linear region. So, you can see I have shown here the characteristics of CT.

So, you can see here that on x axis you have the current and on y axis you have the voltage. And I have shown the two points that is a point A and another point K. So, this is nothing but the linear region of the CT, this is the no load region of the CT and anything beyond this point K that is the saturation region of the CT.

So, normally when we operate the CT, we want that CT should operate in the linear region of the this curve. So, that it does not move into the saturation region and whatever transformation of current that is performed by CT that can be performed faithfully.

The third important advantage because of the reduced burden that is the VA rating of the CT and PT that can be reduced, which in turn helps in the reduction in size and the cost of the CT and PT.

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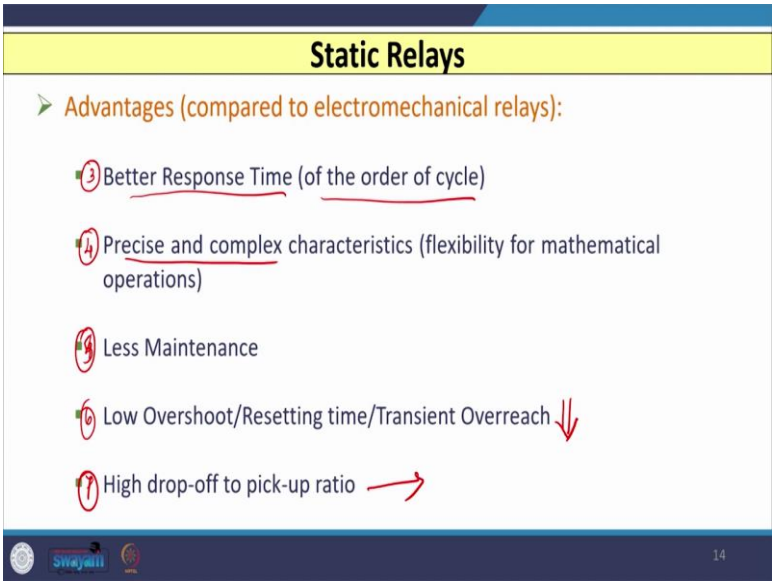

Moreover, if we consider the another advantage of the static relays compared to the electromechanical relays, then static relays has better response time and this is of the order of let us say one cycle or two cycles. So, our fault clearing time that can be reduced. The another advantage of static relays that is it has it or it gives the precise and complex characteristics.

So, we can have our own characteristic also and that is not possible in the electromechanical relays, it gives less maintenance as we have discussed earlier. The another thing is the problem of overshoot, resetting time and transient overreach, this has been reduced compared to the electromechanical relays and this relay has high drop off to pick-up ratio. So, this will be really helpful because when we say drop off to pick-up ratio, it should be as high as possible, so that relay performance improves. So, this is better in case of static relays.

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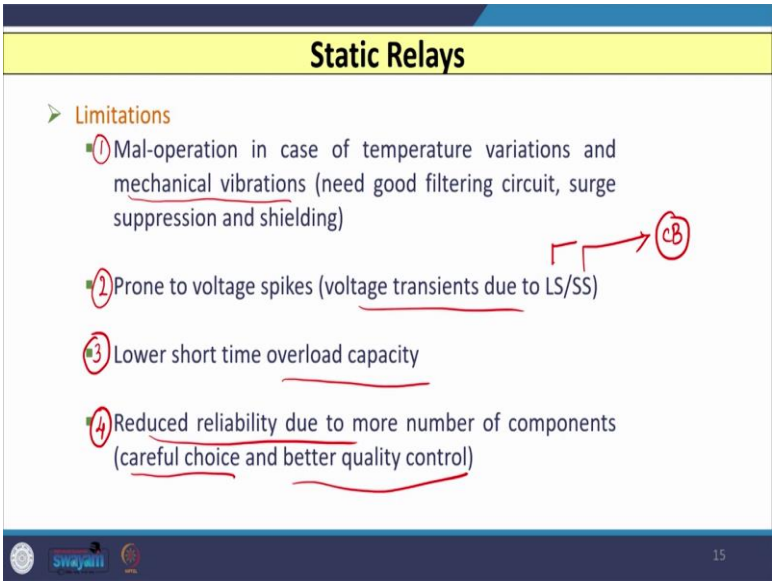

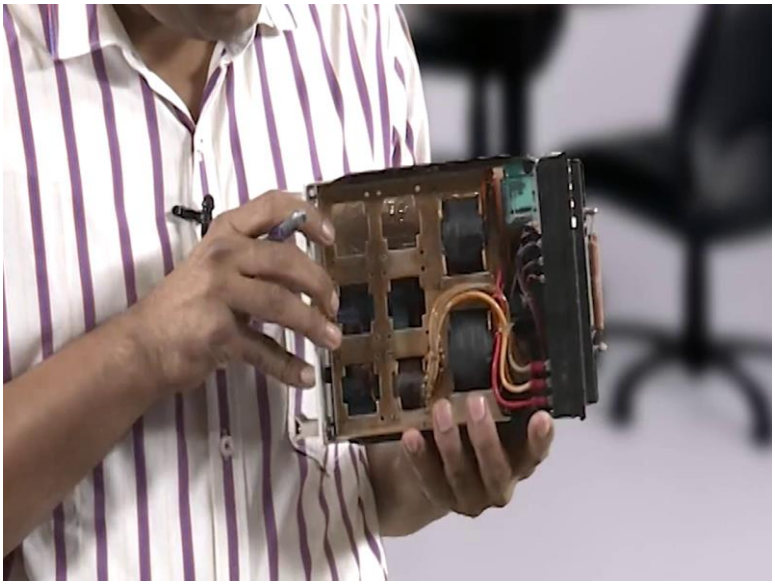

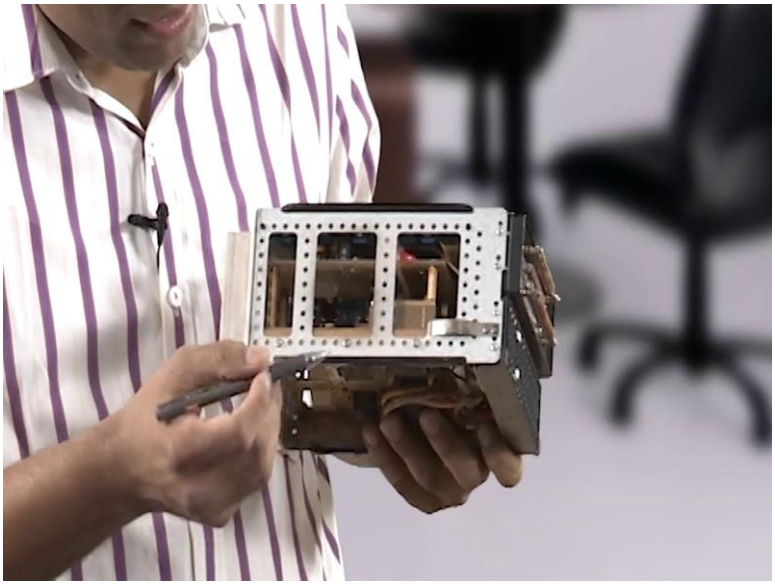

Now, let us discuss the limitation of static relays. So, before we discuss the limitation of static relays, if I just show you how this static relay looks like, then you can see this is the front side or front view of the static relay. And if I just turn this relay, then you can see that the different circuits are available. Here, you can look at these are the PCBs and different small semiconductor devices.

If I turn further, you can see here they are available here inside this relay casing. So, if I consider now the limitation of static relays, then the first limitation of static relay is that this relay mal-operates when temperature variations and mechanical vibrations are there. So, temperature variations are there, because we know that based on season temperature changes and because of that the performance of various semiconductor devices used in this static relays, that also varies.

The mechanical vibrations are there when we have let us say earthquake or when we have installed some, this type of relay in particular some special condition environment where drilling or other things are going on maybe in some industries like chemical and some other industries. So, there this is very important point.

The second disadvantage of static relay is these relays are prone to voltage spikes. So, whenever the voltage transient are there because of either Lightning Surge, we know that when Lightning Surge falls, it will create a traveling waves and because of that the transients are generated and that is going to affect the performance of these relays. The switching surges are also there because of the operation of circuit breakers.

So, we know that circuit breakers are widely used in transmission lines and transformers even with apparatus also. So, when we open or close the circuit breaker, then the surges are generated and they are going to travel with the line and those are going to affect the static relays.

The third limitation of static relay is that it has lower short time overload capacity. This is because of the utilization of semiconductor devices, which has lower overload capacity. The fourth disadvantage of static relays are there, they have reduced to reliability due to more number of components used inside this static relays.

So, obviously, when we have more number of components, reliability of each component matters and the overall reliability of the device reduces. So, if we want to avoid this that means, if we wish to improve the reliability, then the careful choice and better quality control is required when we manufacture these static relays. So, this is all about the static relays.

So, in this lecture, we have discussed the initially different generation of relays. Before that we have also discussed the classification of relays, that how the relays are classified based on time of operation or based on number of inputs given to the relay. And then we have discussed the electromechanical relays with the features and advantages and disadvantages.

And then we have discussed the advantages and limitations of static relays that is the second generation of relays. So, we will discuss the another three generation of relays in the next lecture. Thank you.