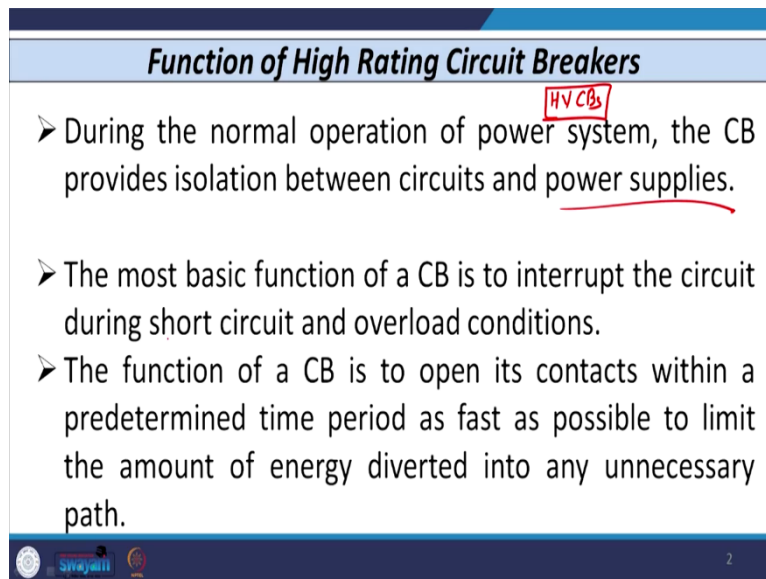


Power System Protection and Switchgear
Professor Bhaveshkumar Bhalja
Department of Electrical Engineering
Indian Institute of Technology, Roorkee
Lecture 38
Types of Circuit Breaker

Okay. So let us continue our discussion on the functions of circuit breaker and types of circuit breaker. So, let us discuss what is the function of high rating circuit breakers or high voltage circuit breakers.

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Function of High Rating Circuit Breakers

- During the normal operation of power system, the CB provides isolation between circuits and power supplies. HV CBs
- The most basic function of a CB is to interrupt the circuit during short circuit and overload conditions.
- The function of a CB is to open its contacts within a predetermined time period as fast as possible to limit the amount of energy diverted into any unnecessary path.

So, we are discussing about high voltage circuit breakers. So, whenever we consider the high voltage circuit breaker during normal operation, the circuit breaker that provides the isolation between the main circuit and our power supply or the source. The most important function of the breaker is to interrupt the short circuit current, it has to also withstand the normal current during load condition or normal condition or pre-fault condition.

The other function of circuit breaker is to open its contact within some predetermined time limit, it should be as fast as possible, but it takes certain time maybe one and a half cycle or two and a half cycle.

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Function of High Rating Circuit Breakers

- The CB has to handle different types of currents such as the resistive load current, inductive short circuit and capacitive current in unloaded lines.
- The CB has to close under faulty conditions, during which severe arc with peak instantaneous fault current appears across the contacts before they physically touch.

swayamii 3

Now, the another function is it has to handle different types of current, like resistive load current, inductive short circuit current, capacity current as we have discussed that it has to interrupt short circuit current, resistive, also it has to interrupt small inductive and capacitive current. So, the breaker is capable to handle all such type of current and it has to open without any restrike. The other function is the breaker has to close under faulty condition during which the severe arc with peak value of fault current that is going to appear across the contact before the physical touch that is going to occur.

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Low Voltage Circuit Breakers

LV CBs

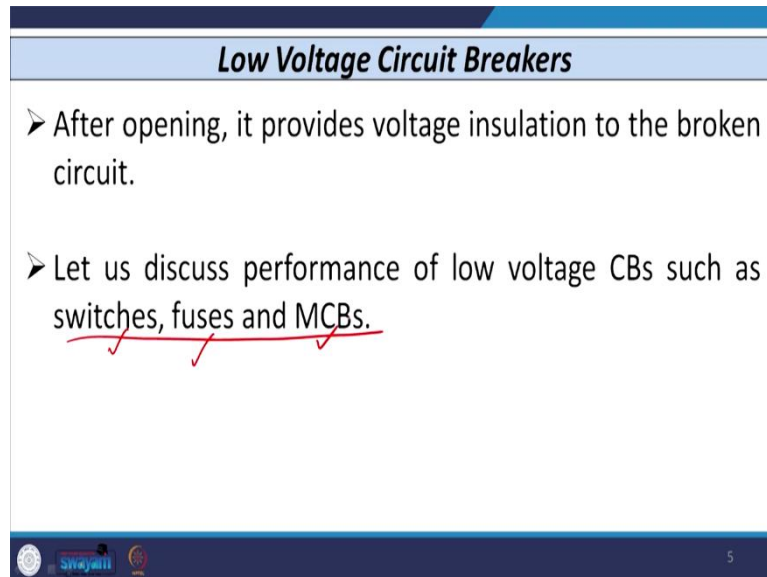
- A CB is a connecting device that closes and breaks an electric circuit up to its ultimate breaking capacity.
- Although its main function is to break the short circuit and overload currents by self-energized action, it also breaks normal currents and overload currents by voluntary action from external sources.

swayamii 4

If I consider on the other hand low voltage circuit breakers, this type of breaker is a device that simply breaks and close the circuit. This type of device does not require any arc-

quenching medium as it is required in case of high voltage circuit breakers. So, the main function that is to just break the short circuit current or maybe withstand the overload current and this is maybe during normal condition as well as in case of short circuit situation.

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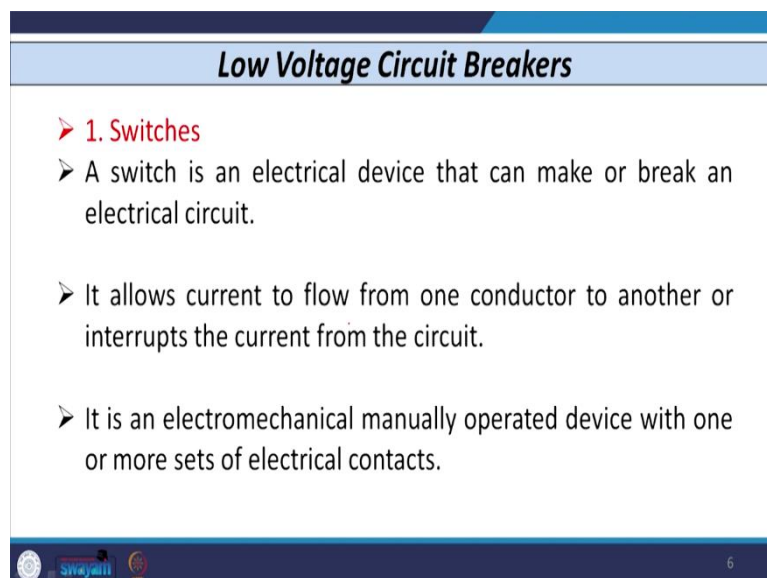
Low Voltage Circuit Breakers

- After opening, it provides voltage insulation to the broken circuit.
- Let us discuss performance of low voltage CBs such as switches, fuses and MCBs.

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Now, after opening it provides the insulation to the broken circuit. So, let us discuss some of the important low voltage circuit breakers. So this are nothing, but the switch electrical switches, different types of fuses and the MCBs.

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Low Voltage Circuit Breakers

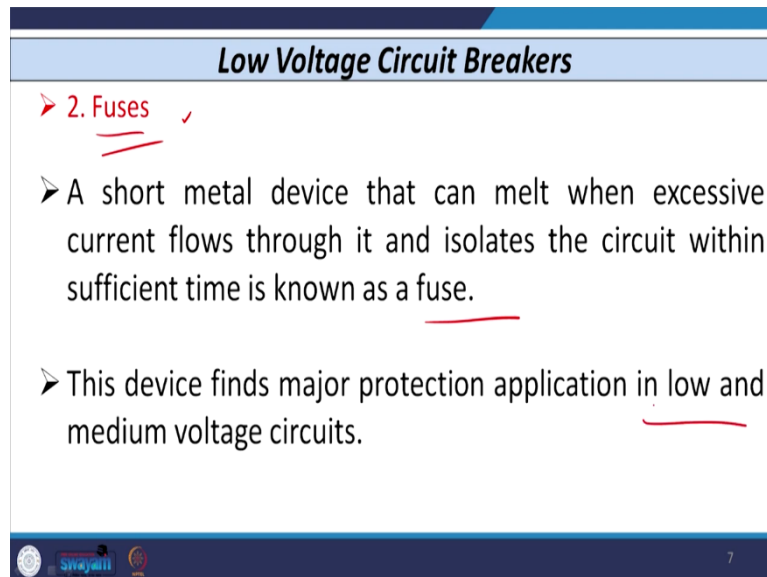
- **1. Switches**
- A switch is an electrical device that can make or break an electrical circuit.
- It allows current to flow from one conductor to another or interrupts the current from the circuit.
- It is an electromechanical manually operated device with one or more sets of electrical contacts.

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So, let us start with the switch. So the switch, again, it's a simple electrical device that can use for making and breaking the electrical circuit. It allows the current to flow from one conductor to the other and interrupts the current wherever the current exceed some value or

some threshold. So, it is nothing but the electromechanical manually operated device, with various some sets of electrical contacts maybe one contact or multiple contacts are also there.

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The slide is titled "Low Voltage Circuit Breakers" in a blue header. Below the title, there is a section titled "2. Fuses" in red text, which is underlined. There are two bullet points: the first describes a fuse as a short metal device that melts under excessive current to isolate the circuit; the second states that fuses are used for major protection in low and medium voltage circuits. The slide footer contains logos for Swayam and a small number '7'.

Low Voltage Circuit Breakers

➤ 2. Fuses ✓

➤ A short metal device that can melt when excessive current flows through it and isolates the circuit within sufficient time is known as a fuse.

➤ This device finds major protection application in low and medium voltage circuits.

The second type of low voltage circuit breaker that is nothing but the fuse. So, fuse again, it's a device that is used, so, whenever we connect the fuse in the circuit, we connect the filament. So that filament is made up of some metal, maybe copper or some other and that filament melts when the excessive current flows through it and isolate the circuit with sufficient time, and this is nothing but the main function or this is the way how the fuse works or operates. This device finds major application maybe for low voltage or medium voltage circuit.

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Low Voltage Circuit Breakers

➤ 2. Fuses

➤ It carries normal load current continuously without generating excessive temperature. $Heat \propto I^2 R t$

➤ When the magnitude of current exceeds the level that results in the melting of fuse material due to temperature effect, the circuit breaks and disconnects from the mains.

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It carries the normal load current continuously without any excessive temperature and when the magnitude of current exceed certain level, then that is going to result or that is going to melt the fuse material, that is the wire connected and because of the heating, as it works on heating principle, so it works basically on $I^2 R T$ where I is the current that flows through the filament, R is the resistance of the filament and T is the time, during which the current flows.

So, this heat generated that is proportional to this. So, wherever heat generated that exceed some value, then the filament or whatever wire we correct, that is going to melt and disconnect the circuit from the mains.

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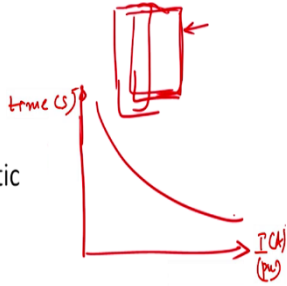
Low Voltage Circuit Breakers

➤ **2. Fuses**

➤ Fuse is a complete device that consists of a fuse casing (base) and a fuse link, where the fuse link is connected to the terminals.

➤ **Characteristics of Fuse**

- Thermal characteristics
- Very inverse melting characteristic
- Interrupting characteristics

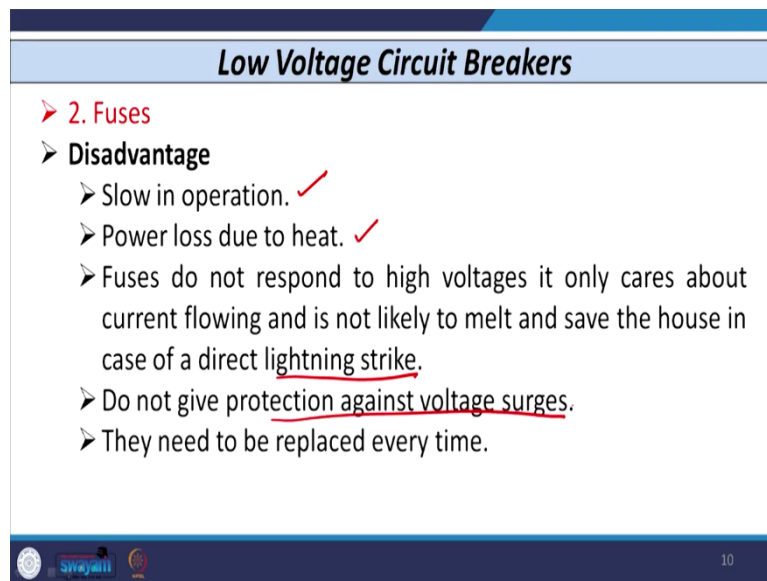


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So, fuse again it consist of two or three subcomponent, one is known as the fuse carrier, the other is known as the fuse base and one is known as the fuse link, which is nothing but the filament. So, what is there is you have one fuse base similar type on this fuse base, you have the similar type, same dimension you have the fuser carrier, so you are going to insert the fuse carrier on the fuse base. And when it is inserted you have to connect this two with the fuse link that we called as a wire or the filament.

Now, let us discuss what are the characteristics of the fuse. So, there are basically three main characteristics of the fuse, one is thermal characteristic, another is melting characteristic and the other is the interrupting characteristic. So, if I draw the characteristic of fuse that is the time versus the current, time in seconds versus the current, I , in amps or per unit, then you can see the graph of the fuse that is like this. So, as higher the value of our magnitude of current to be interrupted, the lower is the time that is taken or that is the lower is the time in which the filament melts.

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Low Voltage Circuit Breakers

- 2. Fuses
 - Disadvantage
 - Slow in operation. ✓
 - Power loss due to heat. ✓
 - Fuses do not respond to high voltages it only cares about current flowing and is not likely to melt and save the house in case of a direct lightning strike.
 - Do not give protection against voltage surges.
 - They need to be replaced every time.

swayamii 10

Now, let us see what are the disadvantages of fuse. One very important disadvantage is each and every time, you need to replace it, you need, so manual operation is required. It is slow in operation wherever the filament melts and all this operation comes, there are chances of the losses and this loss is the power loss due to heat. So, this is also there. And the another thing is that, the fuse do not respond to any high voltages, so it just simply break the circuit based on the current only. So, it is not going to provide the protection against any lightning strike, it does not provide any protection against any over voltage or any voltages, which exceeds beyond the nominal value of the voltage.

And again, it is, it does not provide protection against the voltage surges. So, this is also there. So, these all are the disadvantages.

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Low Voltage Circuit Breakers

➤ 3. Miniature Circuit Breakers (MCB) / MCCB

- Miniature circuit breaker is the latest development in CB technology for low voltage systems.
- They have replaced fuses in many fields such as domestic and industrial applications.
- In an abnormal situation, the MCB itself disconnects the circuit from the supply.

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And to overcome this now they are using another device known as Miniature Circuit Breakers also known as the MCBs. So, in this type of device, you can see on the right hand side I have shown the photograph. So, this is one of the contact of the MCB. The other actuator mechanism is also shown here and you can see some cable terminals is shown here were the terminals that is connected. This is the handle whereas, this is the solenoid through which the current flows. And again, you can see here some arc interruption device is also provided which is known as arc divider or arc extinguisher.

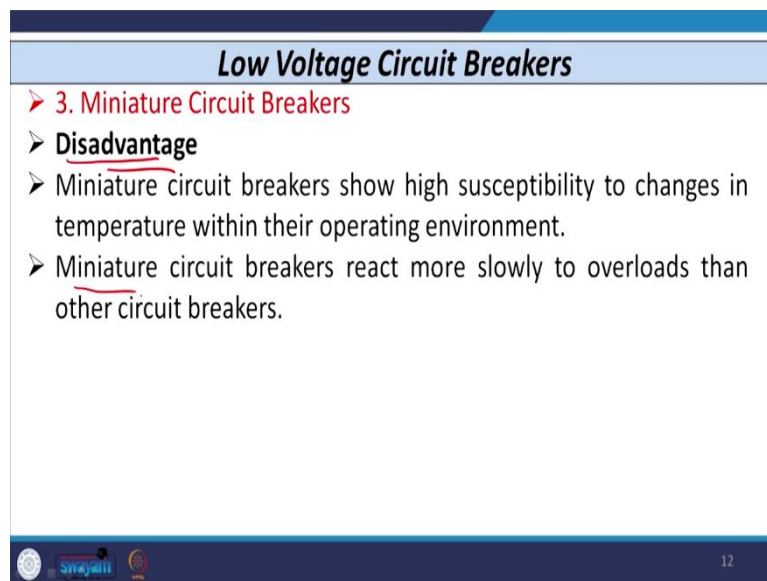
So, you can see that here this MCB works on two principles. One is when the magnitude of current that becomes very high, then immediately this solenoid comes in picture and the force produces very high, that immediate the MCB trips, so this lever which is there, that is going to be tripped and comes in the downward position, that is one thing.

If suppose the magnitude of current is not that much high, right, it is, maybe say your full load current is let us say 5 ampere and the current that flows through this that is let us say these 6.5 ampere or 7 ampere, then this current is not very high compared to this value. So, in that case what will happen, current won't flow through to this solenoid and it will flow, this current that will flow through the bimetallic strip.

So, this type of construction is similar to the construction of thermal relay. So, the current flows through bimetallic strip, so there are two strip having different coefficient of expansion, so they expand and hence the tripping that will be given after some time.

So, in this case when the magnitude of current is slightly higher than the normal full load current, then the tripping that is given after some time. When the magnitude of current is very high maybe let us say the 5 times the full load current then or maybe higher, then immediately, the immediate operation is performed by this solenoid. So, this is all about the MCB and it is widely used nowadays in the residential purpose or domestic purpose, even it is also higher version of MCB that is MCCB that molded case circuit breaker. This is also used at the 415 volt application, 3 phase application.

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Low Voltage Circuit Breakers

- 3. Miniature Circuit Breakers
- Disadvantage
- Miniature circuit breakers show high susceptibility to changes in temperature within their operating environment.
- Miniature circuit breakers react more slowly to overloads than other circuit breakers.

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Now let us see what are the disadvantages of the Miniature Circuit Breakers. The first disadvantage is the Miniature Circuit Breakers show very high susceptibility to the changes in temperature particularly with reference to the environment. So, as I told you, the bimetallic strip is also used in MCB. So, wherever the bimetallic strip comes in picture and wherever the MCB trips, you cannot immediately just lift the lever of the MCB immediately otherwise, it will again come down. So, you have to give some time, by which the bimetallic strip, that is going to become cool and comes to the normal operation or temperature, ambient temperature and then and then the operation that can be allowed.

The second disadvantage of the MCB is that all the Miniature Circuit Breakers react more slowly, particularly to the overload condition compared to some other device that is used in the field by the utility.

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Low Voltage Circuit Breakers

- 4. Earth Leakage Circuit Breakers (ELCB)/RCCB
- An earth leakage circuit breaker is a safety device used in electrical installations with high earth impedance to prevent an electric shock.
- It is used for protection against electrical leakage in circuits of single phase 230/110 V or three phase 415/440 V rated current upto 60 A.
- When somebody gets an electric shock or the residual current of the circuit exceeds the prescribed limit, the ELCB automatically cuts off the power within the prescribed time.

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So, the fourth device which is used that is known as ELCB Earth Leakage Circuit Breakers, sometimes it is also known as the RCCB, Residual Current Circuit Breaker. So, this type of device is used for the protection against the electrical shock. So, this type of protection is used mostly for the household application. So, if any person that you will have a shock then that can be protected if they use the ELCB or MCCB. It can be used for single phase as well as 3 phase applications.

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Low Voltage Circuit Breakers

- 4. Earth Leakage Circuit Breakers

(a) (b)

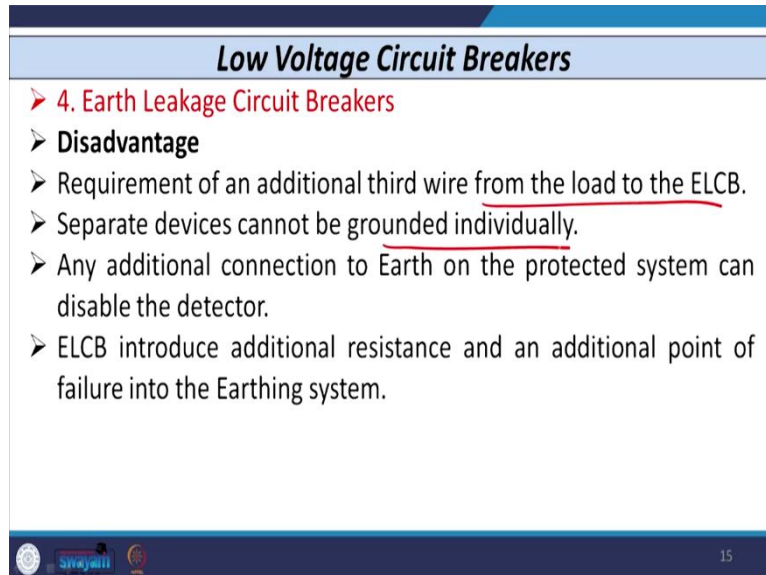
T, Reset; N, Neutral

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So, when you connect the ELCB into the circuit, then you can see that there are the neutral terminal is also there and the main terminal is also there, through which you have to connect the MCB like this. And wherever an insulation of the particular equipment that is fail or

damage, then that current that flows through the particular person, because the resistance of the human body that is around in terms of kilo. Again it depends on the condition, weather condition. And instead of flowing current through the body of the human being, the whole current that will bypass and flow through the ELCB and ELCB trips.

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Low Voltage Circuit Breakers

- **4. Earth Leakage Circuit Breakers**
- **Disadvantage**
- Requirement of an additional third wire from the load to the ELCB.
- Separate devices cannot be grounded individually.
- Any additional connection to Earth on the protected system can disable the detector.
- ELCB introduce additional resistance and an additional point of failure into the Earthing system.

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Let us see what are the disadvantages of the ELCB. So the main disadvantage of ELCB is that, it needs the third additional wire from the load because we have to connect the ELCB, so that the wire is required. The separate devices cannot be grounded individually that is the another disadvantage. And of course, some additional connection to the Earth that is on the protected system that can be disable if I use this. So, this all are the disadvantages of ELCB.

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High Voltage Circuit Breakers

- Air Break Circuit Breaker: ①
- The ACB is used for low voltage to medium voltage distribution systems.
- The process of arc interruption in ACB is achieved by natural deionization of the arc or by cooling action.
- The elongation of the arc and its cooling increases the resistance of the arc at the time of short circuit interruption, which reduces the angle between the voltage and the short circuit current.

Handwritten notes: 30V {415V}, HV CBs, 11kV or above

With this background, let us see now what are the different types of high voltage circuit breakers that is used in the field. This type of breakers all are used maybe up to 11 kV or above. Whatever low voltage circuit breaker which we have discussed earlier starting from the switch, fuse, MCB or MCCB or maybe ELCB, all are used maybe up to 230 volt single phase or 415 volt. So, they used in this only whereas, this type of high voltage circuit breaker that is used at 11 kV or higher voltage level.

So, the first type of breaker that is known as the Air Circuit Breaker, where air that is used for quenching the arc. So, this type of circuit breaker that is very old, and wherever the arc that is going to be formed or established across the contact of circuit breaker, then the resistance of the arc that is increased by certain means, maybe by cooling or maybe by lengthening of the arc. So, when you give the air with some pressure to the arc that is established across the contact of circuit breaker, then that arc that becomes lengthen, so its resistance increases and hence the chances of the quenching of the arc that is very high.

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High Voltage Circuit Breakers

- **Air Break Circuit Breaker**
- On the other hand, the energy dissipated in the arc is very high, and this prohibits the use of ACB in high voltage application above 12 kV.
- It is used only for low and medium power AC and DC systems.
- In order to increase the effective resistance of an arc in an ACB, the following methods are used.

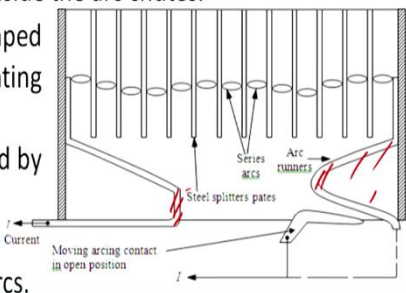
17

This type of Air Circuit Breaker that is used up to only 11 kV or 12 kV and so it is used for AC and DC circuit both.

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High Voltage Circuit Breakers

- **Air Break Circuit Breaker**
- **Arc Splitter Type** →
- In this type of ACB, a set of nickel-based or steel-based arc divider plates are arranged inside the arc chutes.
- An arc chute is a box-shaped structure made of insulating materials.
- Each pole of CB is surrounded by an individual arc chute.
- The arc plates split the arc into a number of short length arcs.



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So, now the question comes how to increase the resistance of the arc. So, there are different methods. So, one of the method that is used in our Air Circuit Breaker to just cool down or quench the arc that is the utilization of arc splitter. So, this is nothing but what they do is whenever the arc, this these are the two contacts of the breaker, one and other here and whenever they arc that is going to be formed here, you are going to split the arc in several sub-arcs. So, obviously, wherever they arc that is splitted in different small sub-arcs then the temperature of that small sub-arc that is reduced. And hence then by means of cooling, the

arc can be easily quenched. So this type of technology that is used in air circuit breaker that is the arc splitter.

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High Voltage Circuit Breakers

- Air Break Circuit Breaker
 - Magnetic Blowout Type
- This type of ACB has similar construction as the arc splitter type.
- The arc chute used in a magnetic blowout type circuit is made of ceramic materials.
- In this type of ACB, arc extinction is carried out through magnetic blast.

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The other type of technology to reduce or increase the resistance of the arc that is known as magnetic blow type. So, in this case what you do is, whenever you have two contact, one is the fixed contact and another is the moving contact of the breaker, then what you do is you blow the air from here, so that whenever the, this arc is there that is going to be lengthen like this so its resistance increases, and hence the arc can be easily quenched.

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High Voltage Circuit Breakers

- Air Break Circuit Breaker / Air Blast C.B
- Disadvantage
 - An air compressor plant has to be installed and maintained
 - In air blast circuit breaker upon arc interruption, the air blast circuit breaker produces a high level of noise when air is discharged to the open atmosphere
 - In air blast circuit breaker current chopping problem exists
 - There is a problem of re-striking voltage

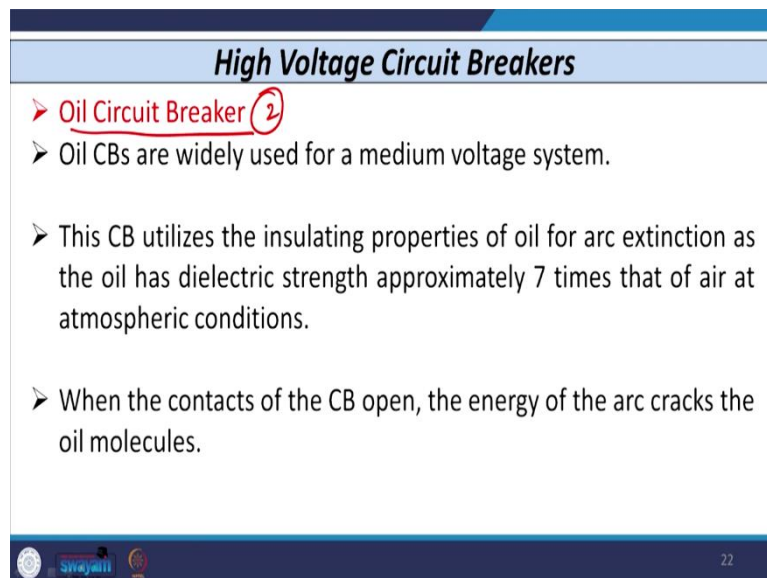
21

This is the main working principle of the air type circuit breaker. But there are certain disadvantages of Air Break Circuit Breaker, sometimes they also called is the air blast circuit

breaker. So, you can use either simple air or maybe you can use the pressurized air in this type of circuit breaker, but both type of circuit breaker has certain disadvantages.

So, the main disadvantage of this type of circuit breaker is that you need a separate air composer or separate plant is required for this type of circuit breaker. And when you use the air blast circuit breaker for quenching the arc, the air blast circuit breaker produces very high level of noise when you release the air from the breaker. So, that is also not the good practice. And the other problem is this type of breaker that is not capable to interrupt the small inductive current or maybe there are fair chances of restriking of the arc. So, this type of breaker that is not used by the utility and they become almost obsolete.

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High Voltage Circuit Breakers

➤ Oil Circuit Breaker (2)

- Oil CBs are widely used for a medium voltage system.
- This CB utilizes the insulating properties of oil for arc extinction as the oil has dielectric strength approximately 7 times that of air at atmospheric conditions.
- When the contacts of the CB open, the energy of the arc cracks the oil molecules.

swajail 22

The other type of circuit breaker that is known as the Oil Type Circuit Breaker. So, Oil Type Circuit Breaker that is used again for medium voltage applications. So, the circuit breaker utilizes the insulation property of oil because we know that the dielectric strength of oil that is almost 6 to 8 times the dielectric strength of air. So, if I use this property of the oil to quench the arc, the arc can be easily quenched.

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High Voltage Circuit Breakers

- **Oil Circuit Breaker**
- Oil CBs can be classified into the following types:
 - Bulk oil circuit breakers (BOCB): Such CBs are classified into two categories.
 - Plain break oil CB ✓
 - Arc control CBs ✓
 - Arc control CBs are further classified into two categories:
 - Self-blast oil CBs ✓
 - Forced blast oil CBs ✓
 - Minimum oil circuit breaker (MOCB)

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Now if I discuss regarding the Oil Circuit Breaker then that can be divided in two parts, one is known as bulk oil circuit breaker, the other is known as minimum oil circuit breaker. So, bulk oil circuit breakers are again classified by plain break oil circuit breaker and arc control circuit breaker, whereas, the minimum oil circuit breaker that is again divided into two parts self-blast circuit breaker and the forced blast circuit breaker.

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High Voltage Circuit Breakers

- **Oil Circuit Breaker**
- **Disadvantage**
- Due to the decomposition of the oil in the arc, the oil becomes polluted by carbon particles, which reduces its dielectric strength. Hence periodical maintenance and replacements are required
- The decomposed products of dielectric oil are inflammable and explosive. If oil circuit breaker is unable to break the fault current, the pressure in the tank may rise above safe limit and explosion may occur. This does not happen in SF₆, ABCB, and vacuum C.B.
- Oil is not a suitable medium for breakers which have to operate repeatedly.

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However, this type of circuit breaker that is also not used in actual practice because of certain disadvantages, let us see what are the disadvantages. We know that when the arc is formed across the contact of circuit breaker, in Oil Circuit Breaker utilizes the dielectric strength of oil to quench the arc. So, whenever the arc quenching is done by the oil, the oil that can be

decomposed, so that becomes polluted by certain carbon particles and dielectric strength of oil that can be reduced. So, periodical maintenance is required when you use oil type of circuit breaker and sometimes, maybe you have to clean the oil or maybe you have to completely replace the oil.

The second disadvantage is the decompose product of this oil that is inflammable. So, if oil circuit breaker that is unable to break the fault current or short circuit current, then the pressure in the tank that will increase and that explosion may occur. So, that's why this type of circuit breaker have limited applications and it is not used nowadays by the utility.

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High Voltage Circuit Breakers

- Sulphur Hexafluoride Circuit Breaker **SF6 CB**
- Most modern high voltage CBs use SF6 gas for electrical insulation and arc interruption.
- Sulphur hexafluoride is an inert insulating gas, which is increasingly popular in modern switchgears design both as an insulating medium and an arc-quenching medium.
- The properties of SF6 are superior to those of other interrupting mediums, such as its high dielectric strength and high thermal conductivity.
- As SF6 CB uses contacts surrounded by SF6 gas to quench the arc.

swayam 25

So, the third type of circuit breaker that is known as the SF6 type circuit breaker, so it is Sulphur Hexafluoride Type Circuit Breaker and it is the most widely used circuit breaker. This type of breaker that is divided in, are classified as puffer type of SF6 circuit breaker and non-puffer type of SF6 circuit breaker.

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High Voltage Circuit Breakers

- Sulphur Hexafluoride Circuit Breaker
 - Physical properties of SF6 gas
 - SF6 gas is 5 times heavier than air.
 - It does not have any colour or smell.
 - It is non-toxic, but it decomposes into SF2 and SF4, which are toxic.
 - There is no risk of fire as SF6 gas is non-inflammable.
 - The heat transfer rate of SF6 is about 2.5 times that of air at atmospheric pressure.

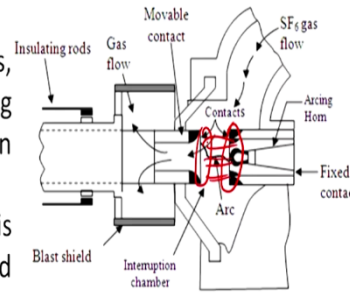
26

So, before we go into the discussion or construction of puffer and non-puffer types circuit breaker, let us see what is the property of SF6 gas. So SF6, that is five times heavier than the air, it does not have any color or smell, it is non-toxic. However, for SF6 itself is not toxic but if SF6 is converted into SF2 and SF4 due to some process then those SF2 and SF4 both are toxic in nature. No risk of the fire because it is inflammable and its dielectric strength that is also higher than the air as well as the oil, it is almost 2.5 times the oil so arc can be easily quenched if I use the SF6 circuit breaker.

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High Voltage Circuit Breakers

- Sulphur Hexafluoride Circuit Breaker
 - Non-puffer Type
 - The CB houses two contacts, namely, fixed contact and moving contact, which are enclosed in an arc interruption chamber.
 - The interruption chamber is connected to the reservoir filled with high pressure SF6 gas.
 - The fixed contact has hollow cylindrical contacts and contains a set of current-carrying contacts with an arcing horn.



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Now, let us consider the first type of SF6 that is non-puffer type SF6 circuit breaker. So in non-puffer type SF6 circuit breaker you can see here, I have shown the diagram. So there are

two contacts. The one contact is here and the other contact is here. And you can see that this contacts are again in the, enclosed in some chamber that is known as arc interruption chamber. And this chamber that is again filled with SF6 gas. So, wherever the arc is formed across the contact of this circuit breaker, the SF6 gas comes and rushed by some force and the property of SF6 gas, it is known, it is also known as electronegative gas.

So, what they do is whatever this portion of the air that is ionized and it contains number of, large number of free electrons. So, as SF6 is a electronegative gas, it will take or absorb all the electrons. So, this air which is ionized in nature now becomes deionized. So, the arc can be easily quenched when the natural current zero of the current comes.

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High Voltage Circuit Breakers

- Sulphur Hexafluoride Circuit Breaker
 - Puffer Type
 - In a non-puffer type SF6 CB, there is a closed gas circuit for arc quenching.
 - Further, it also contains two pressure systems (low and high pressure).
 - The puffer type CB is designed in its simplest form with a single pressure system.
 - In puffer designs, the blast of gas necessary for cooling of the arc is achieved through mechanical compression during opening operation of breaker.

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The other type of circuit breaker, SF6 breaker that is known as puffer type of circuit breaker, what is the difference between these two? The puffer type of circuit breaker that will take whatever is the energy of the arc is there, whenever arc is established across the contact of breaker. The energy of arc that is taken by the puffer type of circuit breaker and that energy that is used along with the dielectric strength of SF6 gas to quench the arc. So, this is the main difference between the non-puffer and the puffer type of circuit breaker.

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High Voltage Circuit Breakers

- Sulphur Hexafluoride Circuit Breaker
- Disadvantage
- In the case of leakage in the breaker tank, the SF₆ gas being heavier than air and hence SF₆ are settled in the surroundings and lead to the suffocation of the operating personnel.
- The entrance of moisture in the SF₆ breaker tank is very harmful to the breaker, and it causes several failures.
- The internal parts need cleaning during periodic maintenance under clean and dry environment.
- The special facility requires for transportation and maintenance of quality of gas.

Handwritten note: SF₂ + SF₄

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Let us see what are the disadvantages of SF₆ gas. So, we know that SF₆ gas itself, it is not a toxic gas, but whenever SF₆ is converted into the SF₂ and SF₄ due to some process, then this is toxic in nature. So, whenever such type of formation is there, then that is hazardous. The other disadvantage of the SF₆ gas is, as it is heavier than the air. So, wherever SF₆ gas comes out of the chamber, then it is going to settle through the surrounding and whatever person that is used that may feel they're suffocated.

The moisture, if any type of moisture that is, if it is available or if it goes or enters the chamber of the SF₆ gas, then that is going to form some SF₂ and SF₄. So, then that is harmful and it may lead to certain failures of the SF₆ or the whole circuit breaker.

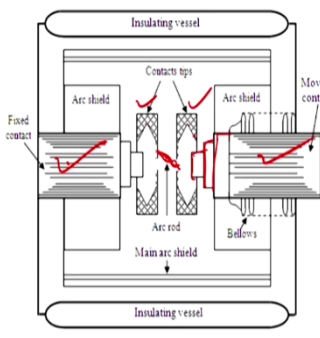
The internal parts of the SF₆ that need to be cleaned completely during dry state. So, no SF₆ gas should be present in that case. And while transportation and the maintenance, the quality, how to transport it, so you need to transport with some special care. So, this all are the disadvantage of the SF₆ type circuit breaker.

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High Voltage Circuit Breakers

➤ Vacuum Circuit Breaker ④

- The vacuum CB uses the rapid dielectric recovery and high dielectric strength of vacuum.
- A pair of contacts is hermetically sealed in a vacuum envelope.
- The actuating motion is transmitted through bellows to the movable contact.



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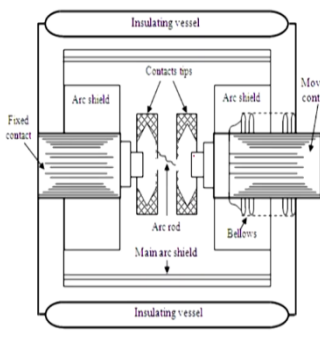
So, to avoid this nowadays, the utility, that are utilizing another type of circuit breaker, that is known as the vacuum type of circuit breaker. So, the Vacuum Circuit Breaker that uses the rapid dielectric recovery of the or the dielectric strength of the vacuum. So, here whatever contacts are there, these contacts are hermetically sealed in vacuum envelope.

So, all this are again, this contact, this two contacts are again sealed in some vacuum envelope and the actuating motion that is transmitted through the bellows to a movable contact. So, you have the, some mechanism is required between the fixed contact that is here and the moving contact that is here. So, you can see with this moving contact we have the mechanism that is connected to the contact tips. And the arc that is formed that is somewhere here.

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High Voltage Circuit Breakers

- **Vacuum Circuit Breaker**
- In a vacuum CB, the vacuum interrupters are used for breaking and making the load and fault currents.
- The properties of a vacuum interrupter depend on the material and form of the contacts.
- It is accepted that an oxygen-free copper chromium alloy is the best material for high voltage CBs



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So, in a Vacuum Circuit Breaker, the vacuum interrupters are used that is for breaking and making the load current as well as the short circuit current. The property of the vacuum interrupter that depends on what type of material you have used for developing the vacuum rod. So, normally the copper chromium alloy that is used for the development of the vacuum electrode.

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High Voltage Circuit Breakers

- **Vacuum Circuit Breaker**
- **Disadvantage**
- Loss of vacuum due to transit damage or failure makes the entire interruption useless and it cannot be repaired at site.
- It needs additional surge suppressors in parallel with each phase for interruption of low magnetizing currents in certain range
- vacuum circuit breakers are uneconomical above 36kV and SF6 breakers having equivalent properties is economical. Hence for EHV (voltages above 230kV) systems SF6 circuit breakers are employed
- It is uneconomical to manufacture vacuum interrupters in small quantities

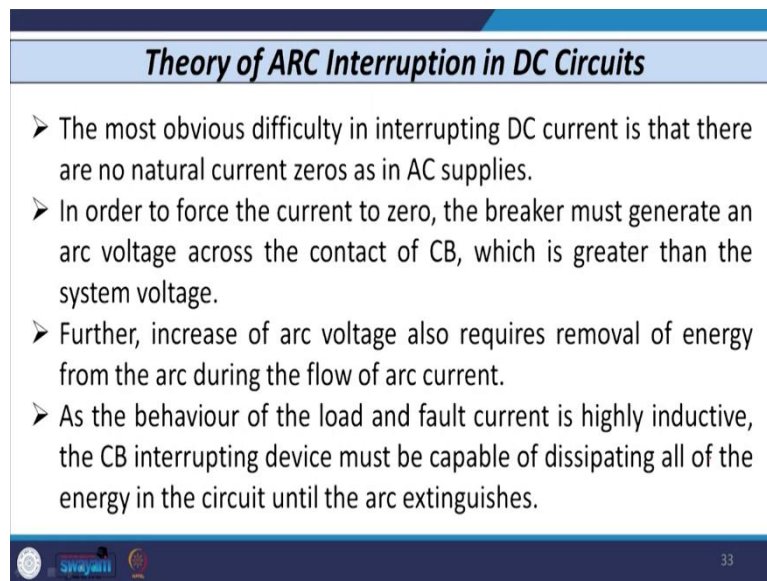
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Now, let us see what are the disadvantages of the Vacuum Circuit Breaker. So, if loss of vacuum during transit or maybe the failure maybe because of any reason, then that makes the entire interruption useless and it cannot be repaired at site, you have to again send it the same thing to the manufacturer. Vacuum type of circuit breaker needs additional surge suppressors

that is in parallel with, that is for each phase and this is required if vacuum circuit breaker is meant or utilized for interruption of small inductive current. So, if current chopping phenomena that is there, so then separate surge suppressors is required along with the vacuum electrode.

Vacuum Circuit Breakers are usually that can be used up to 33 kV, nowadays it can be also used up to 132 kV, but maybe again at 230, 220, 400 kV, again the SF6 circuit breakers, that is the only breakers that is used because vacuum circuit breakers are not economical at very high voltage applications.

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Theory of ARC Interruption in DC Circuits

- The most obvious difficulty in interrupting DC current is that there are no natural current zeros as in AC supplies.
- In order to force the current to zero, the breaker must generate an arc voltage across the contact of CB, which is greater than the system voltage.
- Further, increase of arc voltage also requires removal of energy from the arc during the flow of arc current.
- As the behaviour of the load and fault current is highly inductive, the CB interrupting device must be capable of dissipating all of the energy in the circuit until the arc extinguishes.

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Okay. So, with this background, in this class, we started our discussion with the, what are the main functions of the circuit breaker. So, we have discussed that there are basically two main functions, one is the breaker has to carry continuously the full load current or normal current, and the second is the, it is capable to interrupt the short circuit current without any damage. This is the main function of the circuit breaker.

Then we started a discussion with the, what are the different low voltage circuit breakers and high voltage circuit breakers. So, we have discussed the first low voltage circuit breakers in which we have discussed the switch, then fuse, then Miniature Circuit Breakers and then Earth Leakage Circuit Breakers. And then, we started discussion with the High Voltage Circuit Breakers and in that, we started our discussion with the Air Circuit Breaker or Air Blast Circuit Breaker. Then we have discussed the Oil Circuit Breaker and then we discussed the SF6 circuit breaker and last we have discussed the Vacuum Circuit Breaker.

So, now it is the Vacuum Circuit Breakers that is widely used up to 132 kV whereas SF6 circuit breakers are used beyond that, whereas for low voltage circuit breakers at most of the applications, MCB and ELCBs are used up to 230 volt or maybe 415, for maybe at 11 kV, utilities are still utilizing the molded case circuit breakers that is the extension of miniature circuit breaker. So I stop here. Thank you.