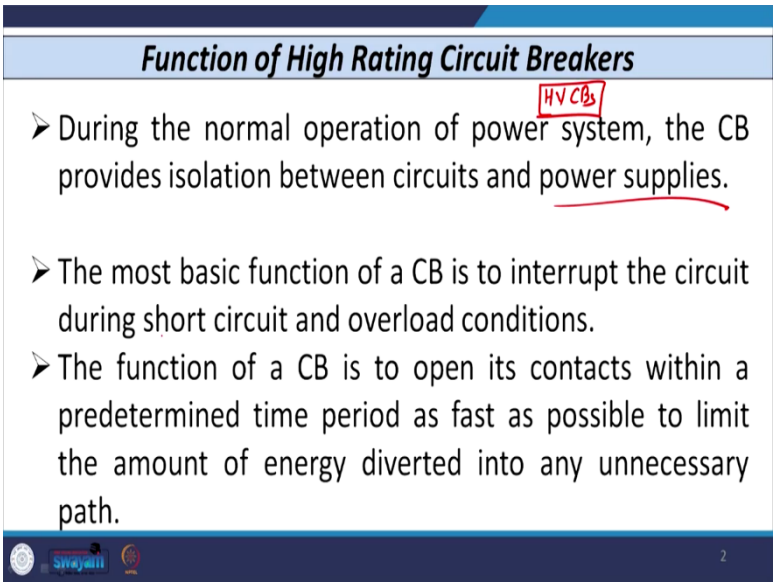
Power System Protection and Switchgear
Professor Bhaveshkumar Bhalja
Department of Electrical Engineering
Indian Institute of Technology, Roorkee
Lecture 38
Types of Circuit Breaker

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.

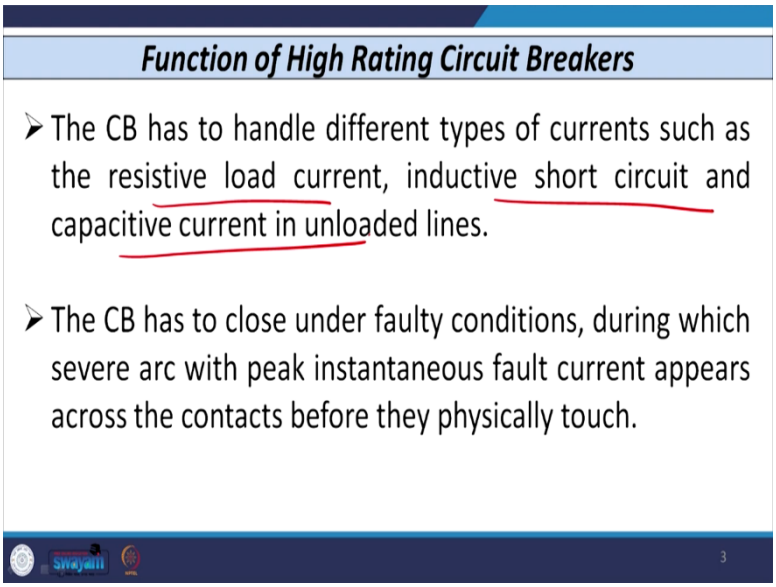
(Refer Slide Time: 0:42)



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 mostimportant 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.

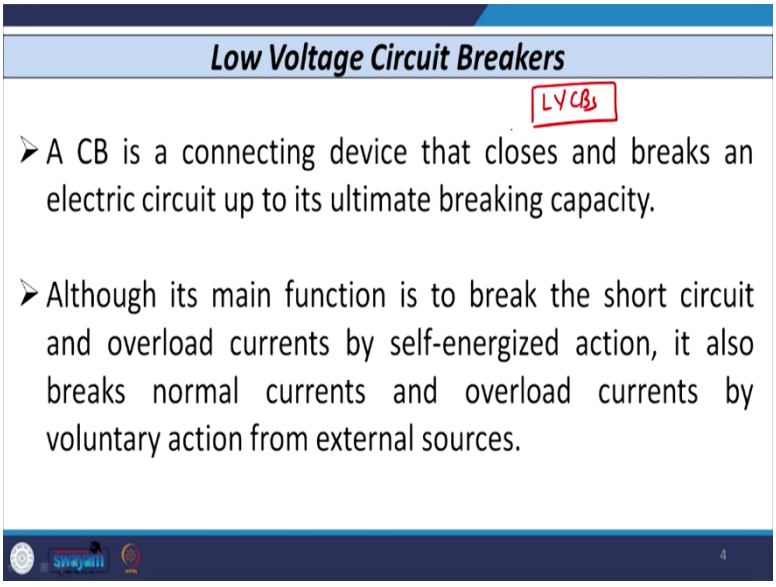
The other function of circuit breaker is to open its contact within some predetermined time limit, it should be as fast as possible, but it takes certain time maybe one and a half cycle or two and a half cycle.

(Refer Slide Time: 1:27)



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.

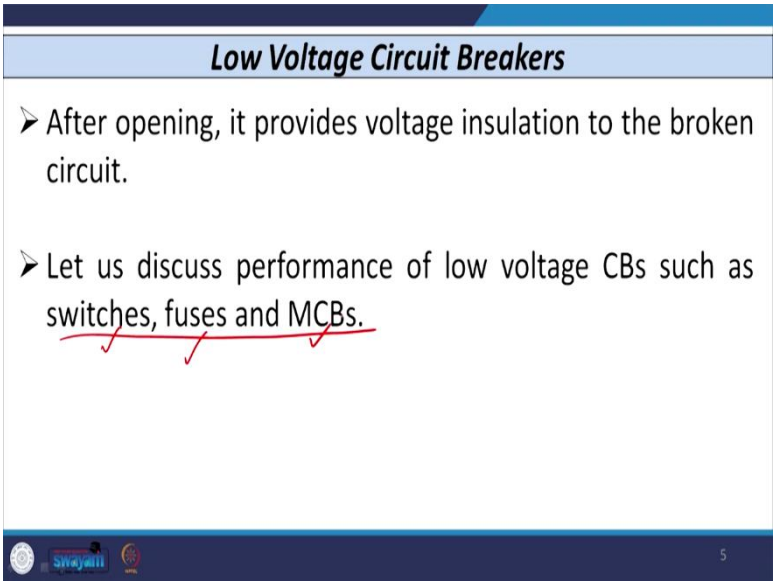
(Refer Slide Time: 02:09)



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-

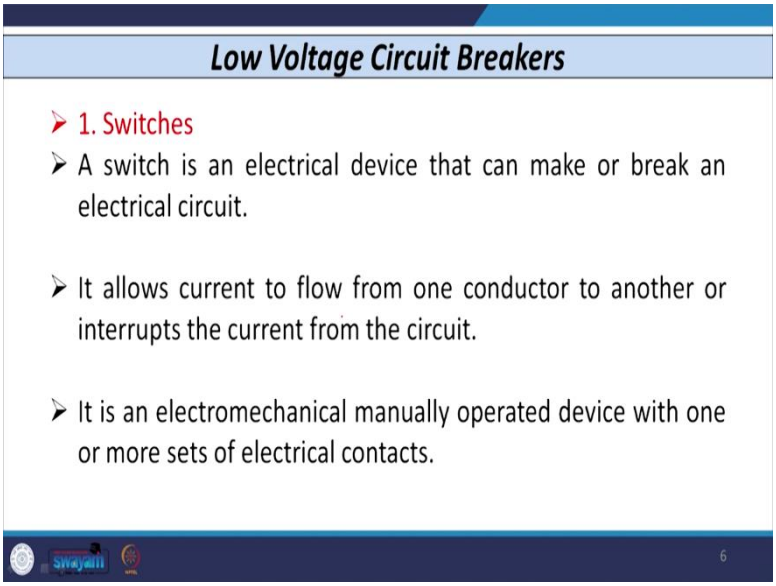
quenching medium as it is required in case of high voltage circuit breakers. So, the main function that is to just break the short circuit current or maybe withstand the overload current and this is maybe during normal condition as well as in case of short circuit situation.

(Refer Slide Time: 2:39)



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.

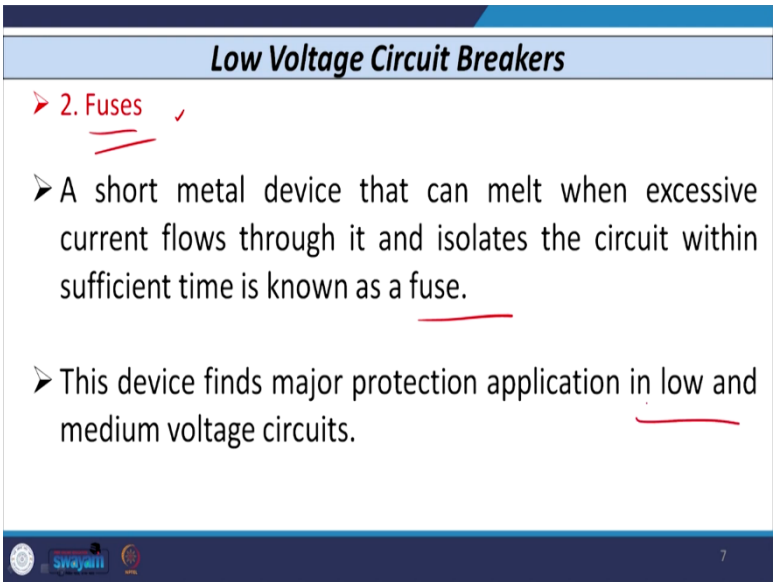
(Refer Slide Time: 2:59)



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

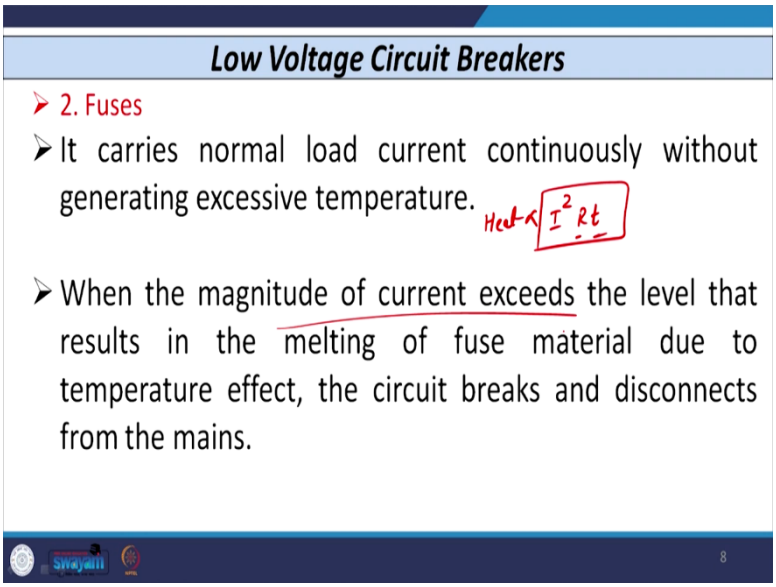
some threshold. So, it is nothing but the electromechanical manually operated device, with various some sets of electrical contacts maybe one contact or multiple contacts are also there.

(Refer Slide Time: 3:31)



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.

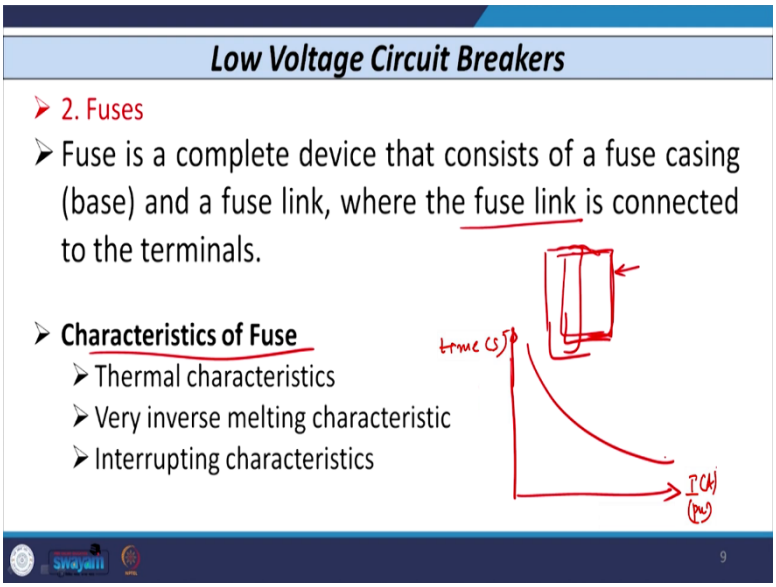
(Refer Slide Time: 4:08)



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 square RT 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.

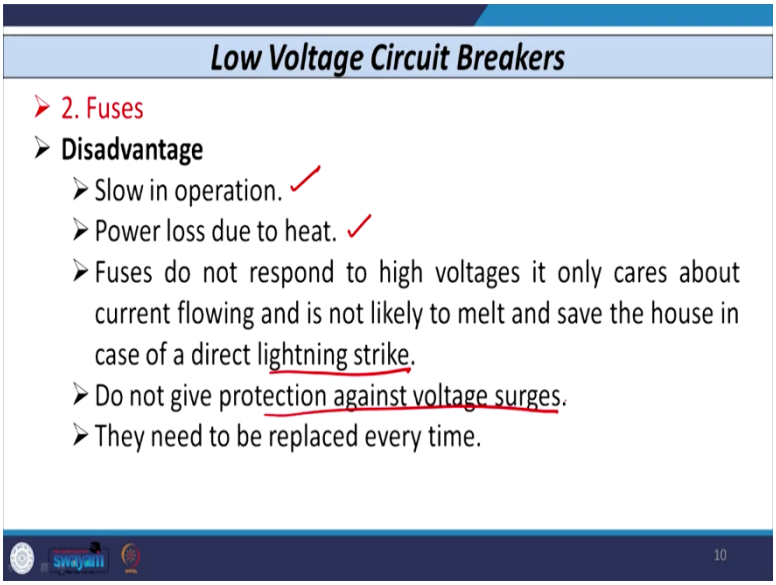
(Refer Slide Time: 4:55)



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.

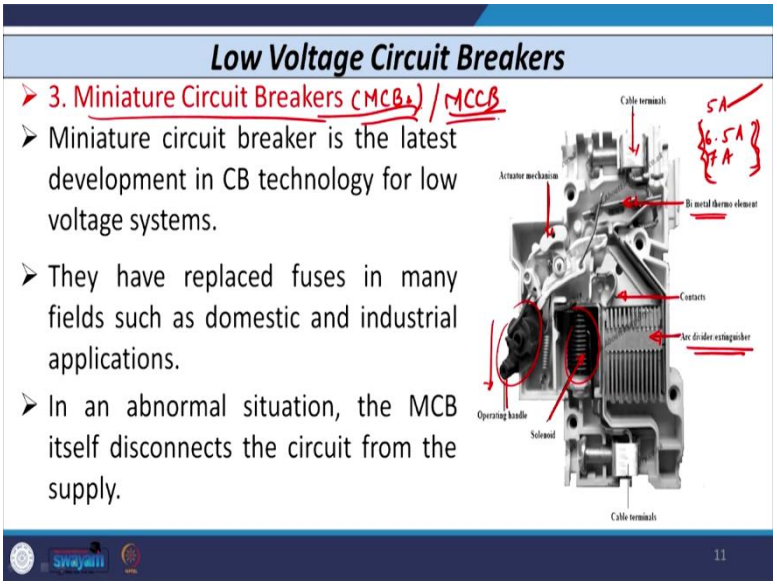
(Refer Slide Time: 6:13)



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.

(Refer Slide Time: 7:05)



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.

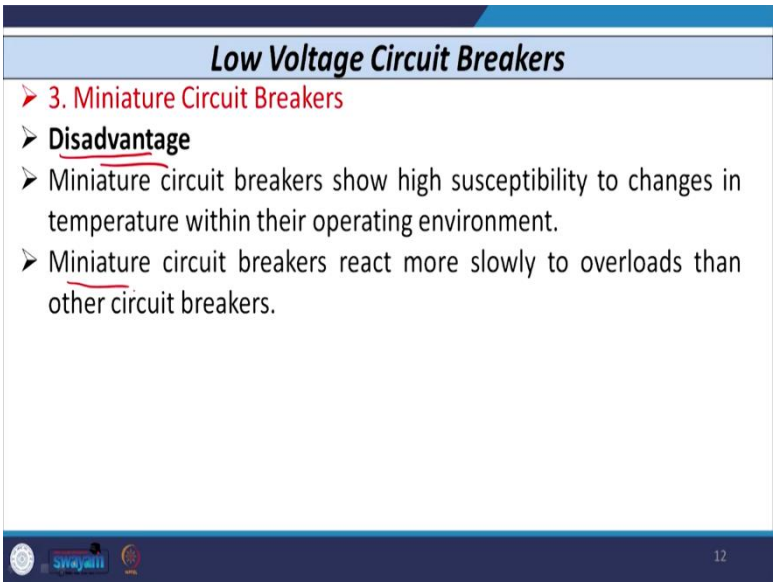
So, you can see that here this MCB works on two principles. One is when the magnitude of current that becomes very high, then immediately this solenoid comes in picture and the force produces very high, that immediate the MCB trips, so this lever which is there, that is going to be tripped and comes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

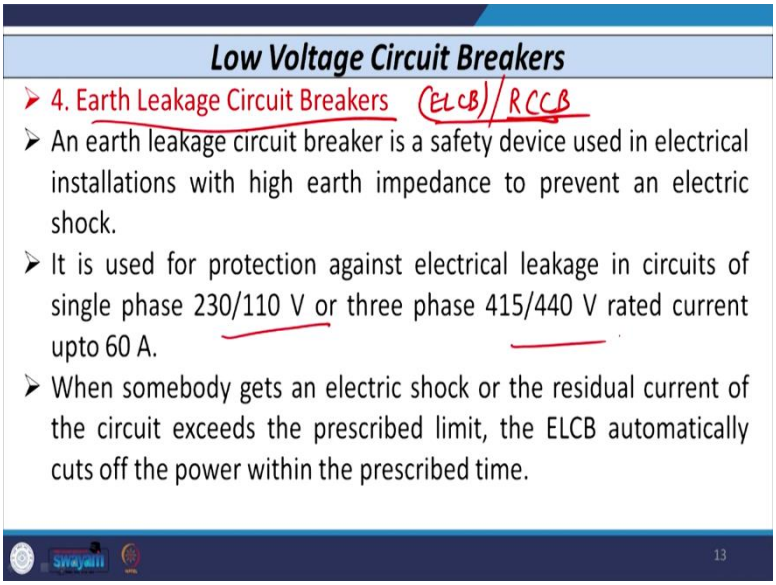
(Refer Slide Time: 9:44)



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.

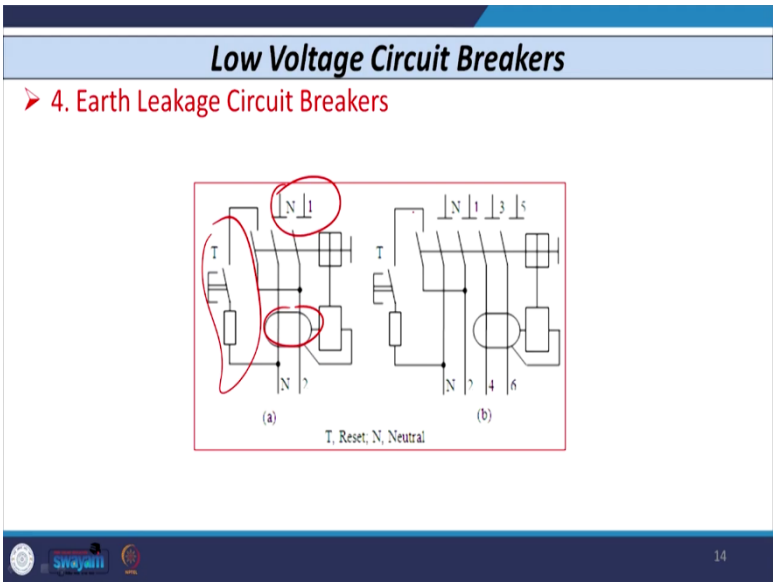
The second disadvantage of the MCB is that all the Miniature Circuit Breakers react more slowly, particularly to the overload condition compared to some other device that is used in the field by the utility.

(Refer Slide Time: 10:47)



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.

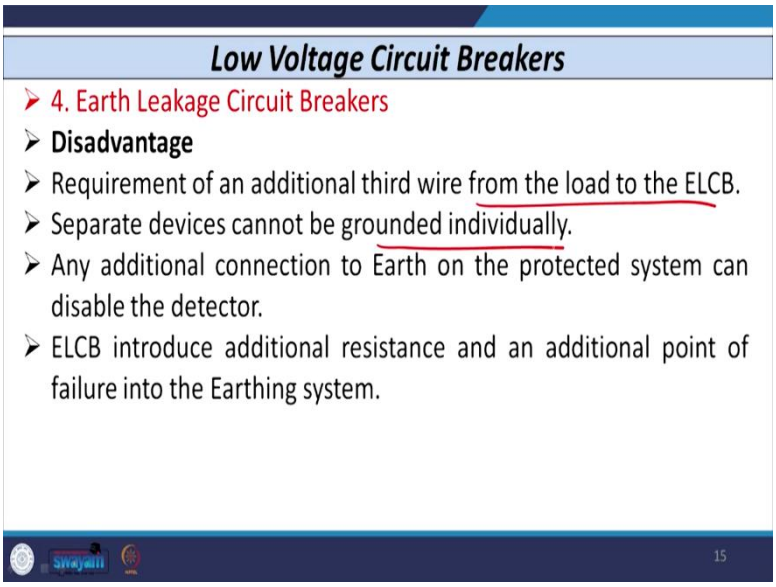
(Refer Slide Time: 11:20)



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

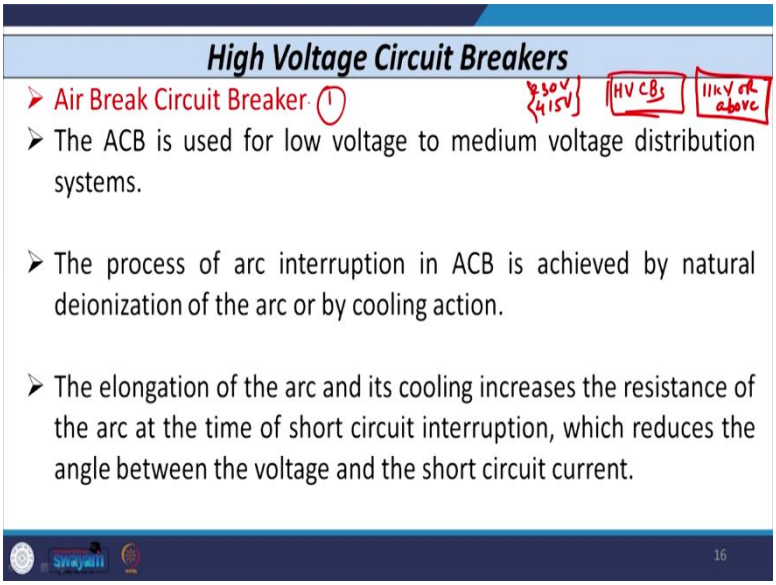
damage, then that current that flows through the particular person, because the resistance of the human body that is around in terms of kilo. Again it depends on the condition, weather condition. And instead of flowing current through the body of the human being, the whole current that will bypass and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

(Refer Slide Time: 12:01)



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.

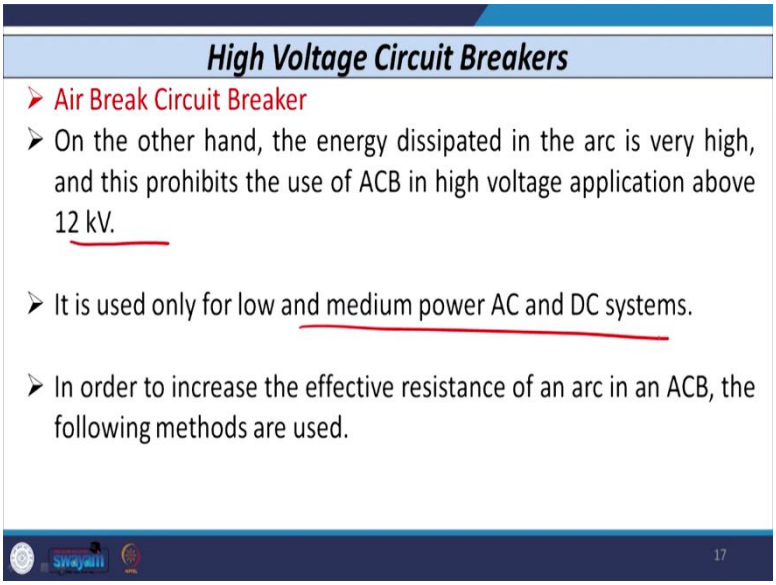
(Refer Slide Time: 12:34)



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.

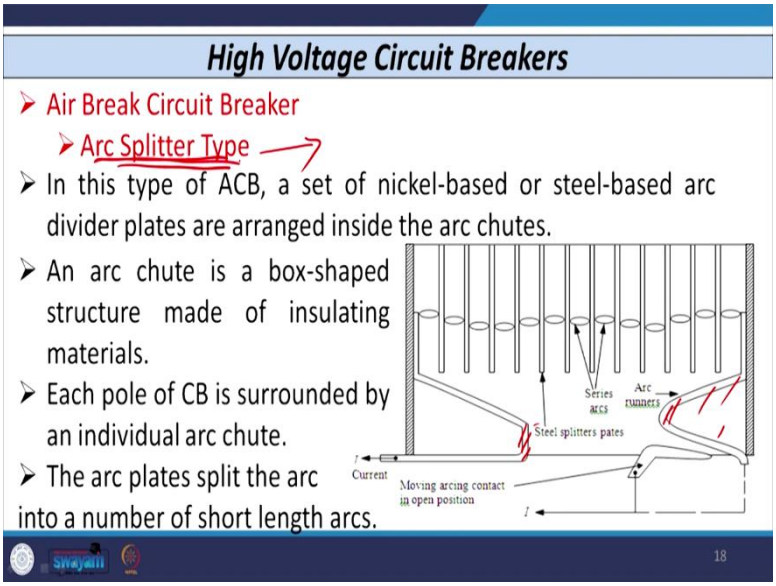
So, the first type of breaker that is known as the Air Circuit Breaker, where air that is used for quenching the arc. So, this type of circuit breaker that is very old, and wherever the arc that is going to be formed or established across the contact of circuit breaker, then the resistance of the arc 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.

(Refer Slide Time: 13:55)



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.

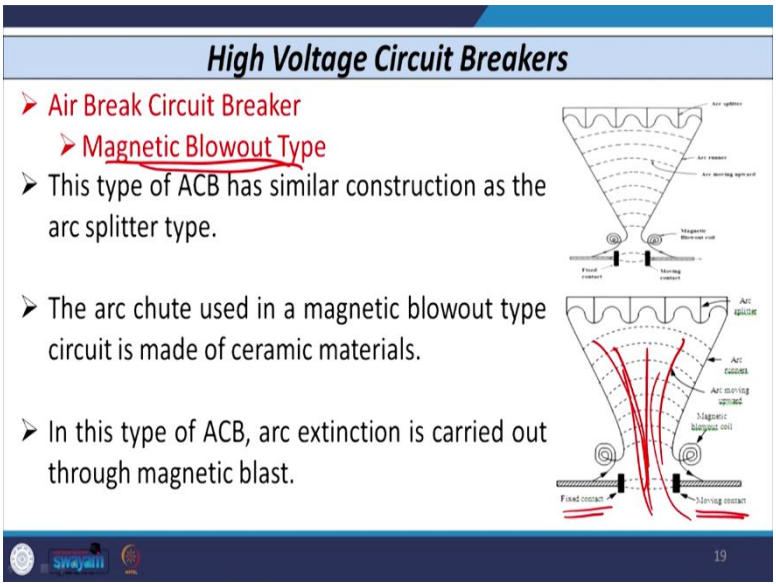
(Refer Slide Time: 14:07)



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

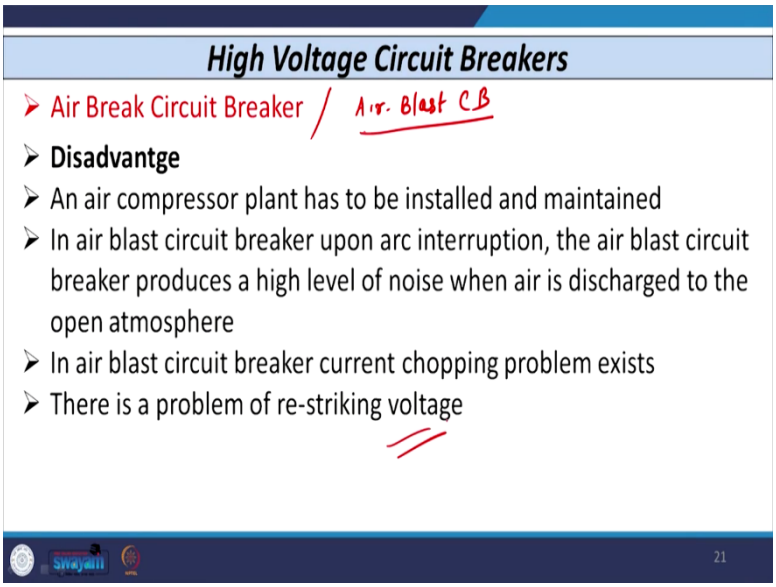
arc can be easily quenched. So this type of technology that is used in air circuit breaker that is the arc splitter.

(Refer Slide Time: 14:56)



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.

(Refer Slide Time: 15:32)

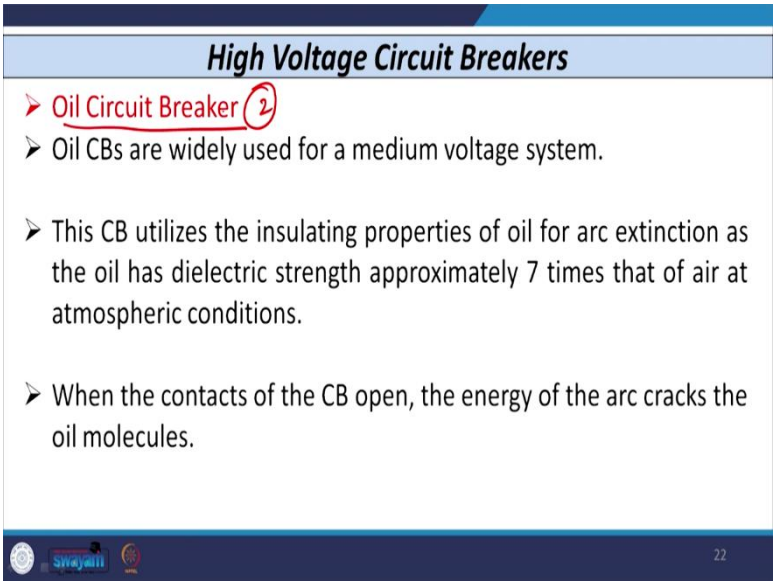


This is the main working principle of the air type circuit breaker. But there are certain disadvantages of Air Break Circuit Breaker, sometimes they also called is the air blast circuit

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.

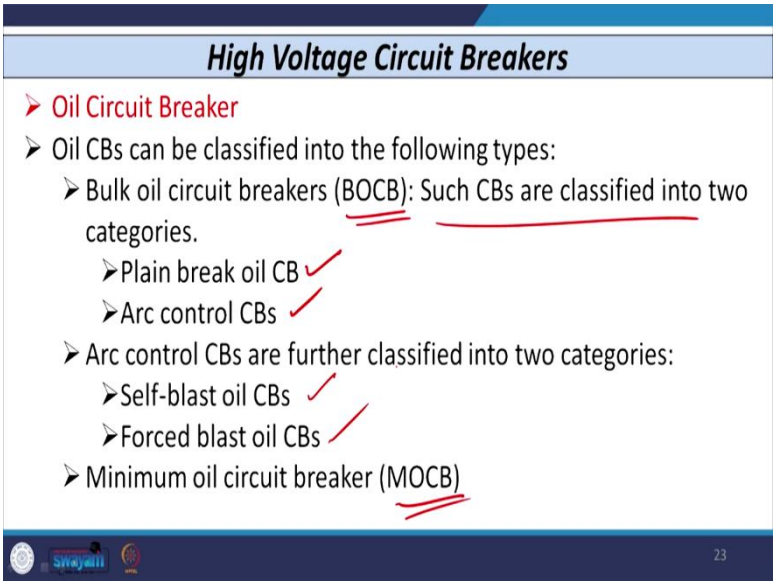
So, the main disadvantage of this type of circuit breaker is that you need a separate air composer or separate plant is required for this type of circuit breaker. And when you use the air blast circuit breaker for quenching the arc, the air blast circuit breaker produces very high level of noise when 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.

(Refer Slide Time: 16:34)



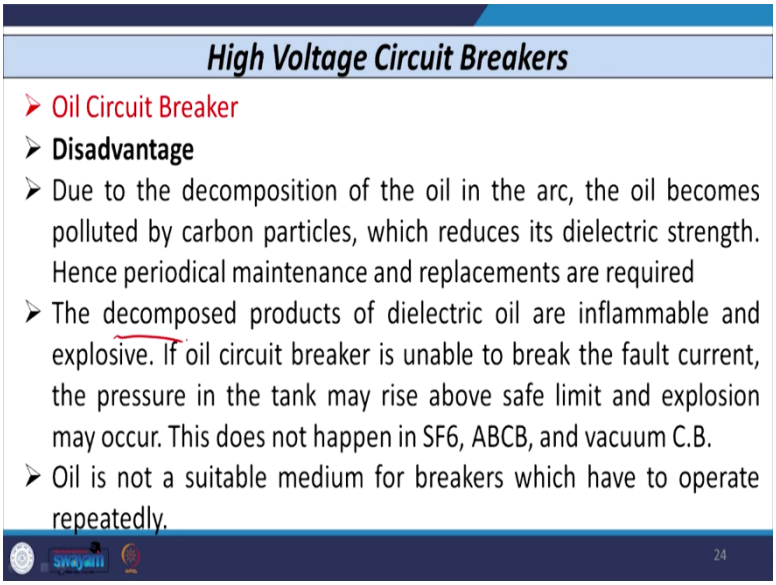
The other type of circuit breaker that is known as the Oil Type Circuit Breaker. So, Oil Type Circuit Breaker that is used again for medium voltage applications. So, the circuit breaker utilizes the insulation property of oil because we know that the dielectric strength of oil that is almost 6 to 8 times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

(Refer Slide Time: 16:59)



Now if I discus 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 plainbreak 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.

(Refer Slide Time: 17:33)

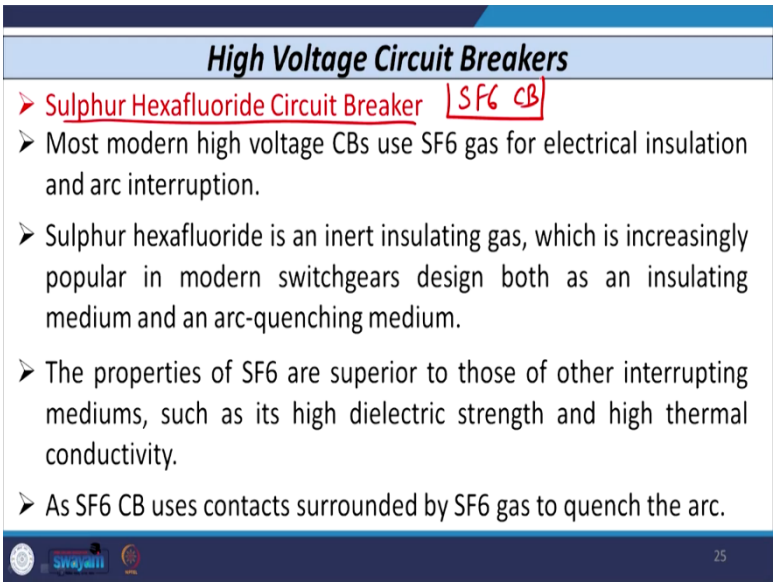


However, this type of circuit breaker that is also not used in actual practice because of certain disadvantages, let us see what are the disadvantages. We know that when the arc is formed across the contact of circuit breaker, in Oil Circuit Breaker utilizes the dielectric strength of oil to quench the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

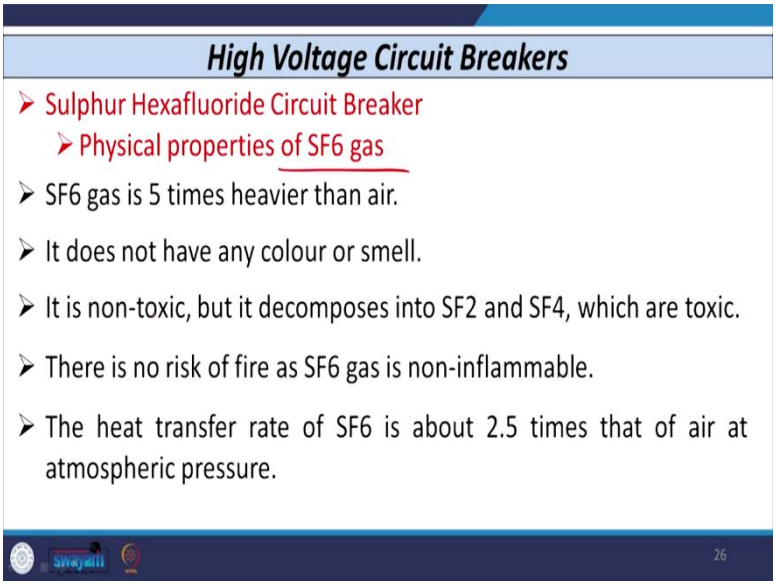
The second disadvantage is the decompose product of this oil that is inflammable. So, if oil circuit breaker that is unable to break the fault current or short circuit current, then the pressure in the tank that will increase and that explosion may occur. So, that's why this type of circuit breaker have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

(Refer Slide Time: 18:34)



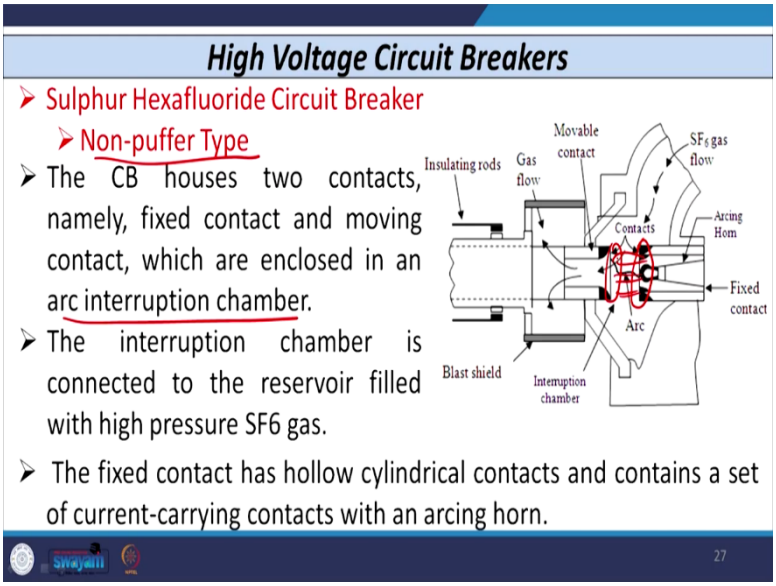
So, the third type of circuit breaker that is known as the SF6 type circuit breaker, so it is Sulphur Hexafluoride Type Circuit Breaker and it is the most widely used circuit breaker. This type of breaker that is divided in, are classified as puffer type of SF6 circuit breaker and non-puffer type of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

(Refer Slide Time: 18:56)



So, before we go into the discussion orconstruction 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.

(Refer Slide Time: 19:41)

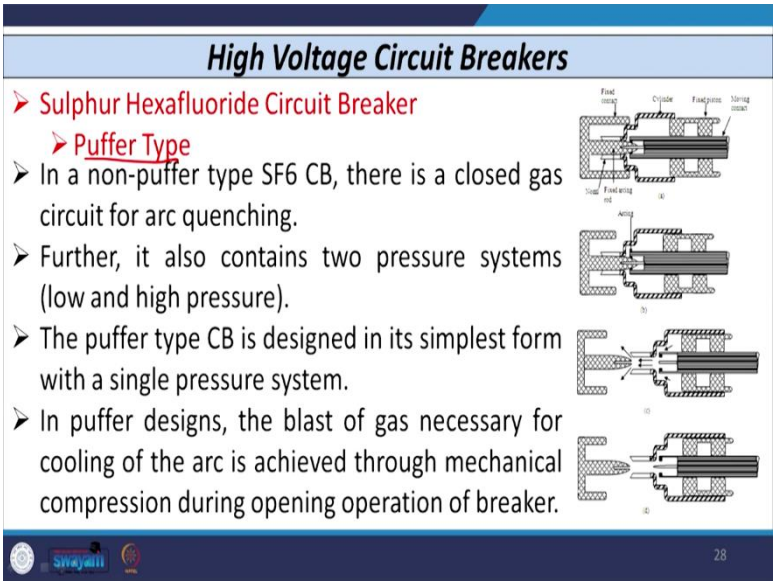


Now, let us consider the first type of SF6 that is non-puffer type SF6 circuit breaker. So in non-puffer type SF6 circuit breaker you can see here, I have shown the diagram. So there are

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.

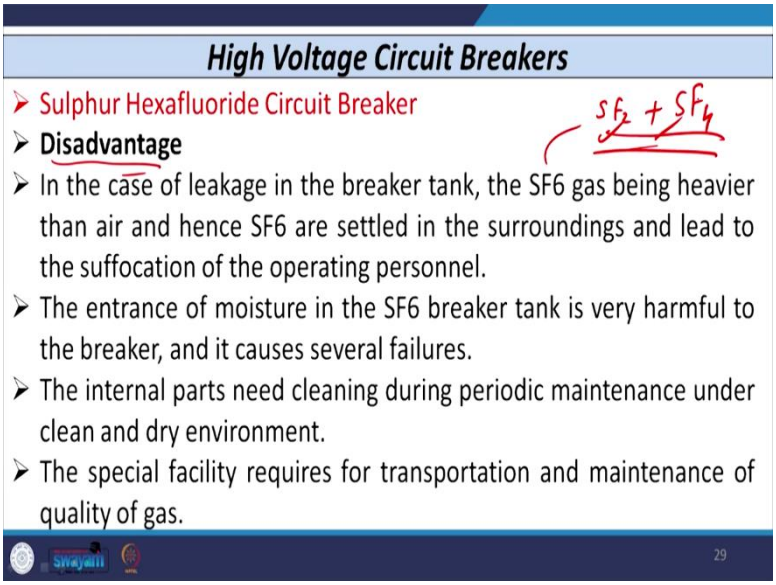
So, what they do is whatever this portion of the air that is ionized and it contains number of, large number of free electrons. So, as SF6 is a electronegative gas, it will take or absorb all the electrons. So, this air which is ionized in nature now becomes deionized. So, the arc can be easily quenched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

(Refer Slide Time: 20:57)



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.

(Refer Slide Time: 21:33)

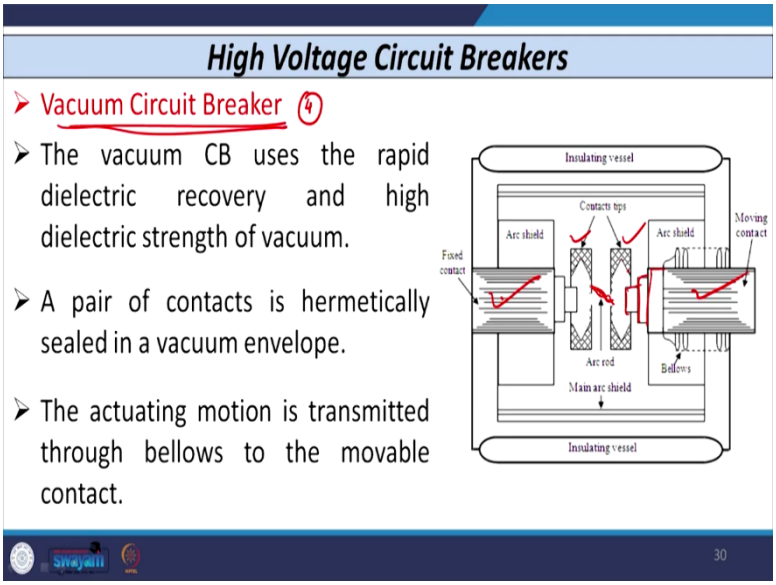


Let us see what are the disadvantages of SF6 gas. So, we know that SF6 gas itself, it is not a toxic gas, but whenever SF6 is converted into the SF2 and SF4 due to some process, then this is toxic in nature. So, whenever such type of formation is there, then that is hazardous. The other disadvantage 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.

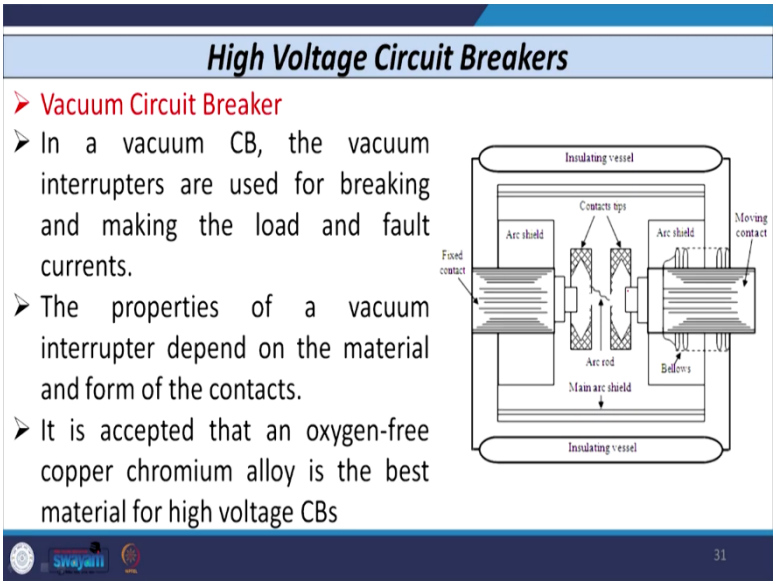
(Refer Slide Time: 22:56)



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.

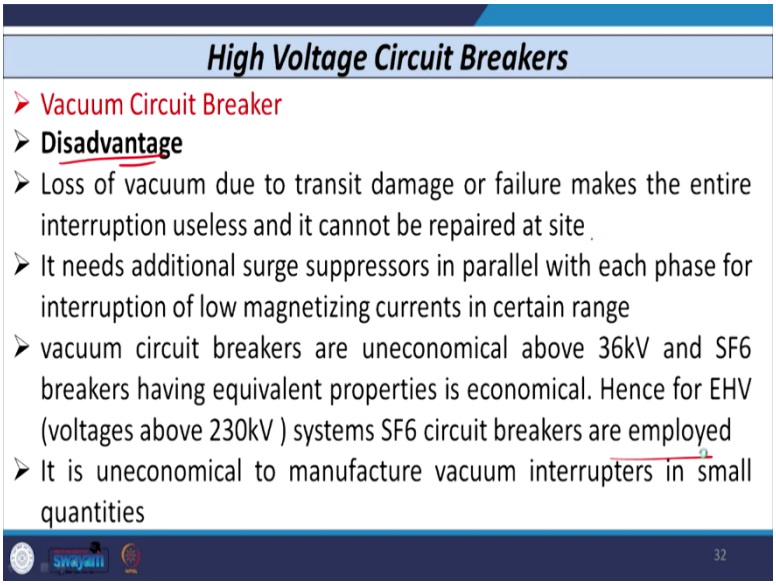
So, all this are again, this contact, this two contacts are again sealed in some vacuum envelope and the actuating motion that is transmitted through the bellows to a movable contact. So, you have the, some mechanism is required between the fixed contact that is here and the moving contact that is here. 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.

(Refer Slide Time: 23:56)



So, in a Vacuum Circuit Breaker, the vacuum interrupters are usedthat 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.

(Refer Slide Time: 24:22)

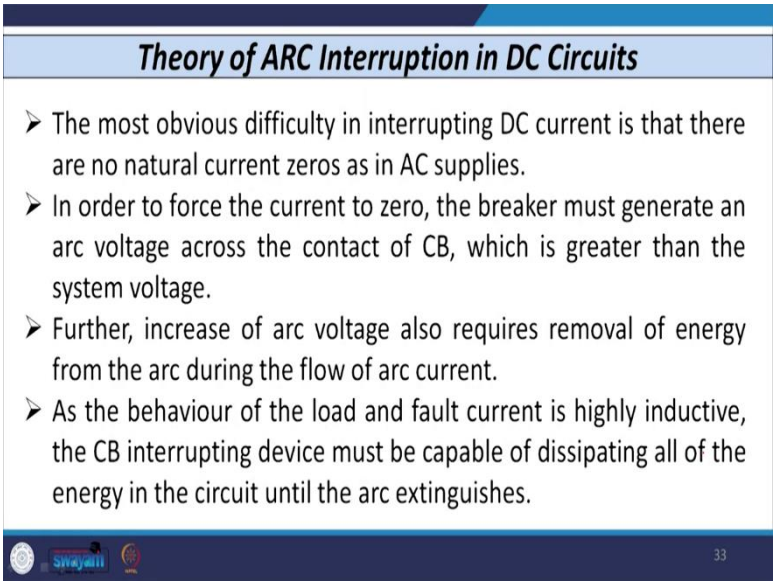


Now, let us see what are the disadvantages of the Vacuum Circuit Breaker. So, if loss of vacuum during transit or maybe the failure maybe because of any reason, then that makes the entire interruption useless and it cannot be repaired at site, you have to again send it the same thing to the manufacturer.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

(Refer Slide Time: 25:29)



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.