11.5.2: Controlling Current in Electric Circuits

Examples of devices that help protect users from electricity

Figure 17.2.1

The amount of electric current that passes through a circuit depends on the voltage pushing the current and the resistance opposing the flow of current. Circuits are designed for a specific voltage and resistance so that the current flow will be known. If the current is too large, the heat loss can damage the circuit, burn the resistors, or even burn the surrounding objects. Even with circuits designed to prevent such situations, accidents can happen, such as when wires touch each other unexpectedly. To prevent disasters, electrical circuits contain devices such as electrical fuses, circuit breakers, and surge protectors to control the amount of current in the circuit. Examples of these devices are shown above, and explained below.

Controlling Current in Electric Circuits

In the wiring of a building, the wires carrying the current in and out are different and never touch directly. The charge passing through the circuit always passes through an appliance (which acts as a resistor) or through another resistor, which limits the amount of current that can flow through a circuit. Appliances are designed to keep current at a relatively low level for safety purposes. The appropriate voltage and resistance in a circuit keeps the current in control and keeps the circuit safe. It is possible, however, for something to happen that causes the wire bringing the current in to come into contact with either the wire carrying the current out or the ground wire, thus causing what is called a **short circuit**. In a short circuit, some or all of the resistance is cut out of the circuit allowing the voltage to push a huge current through the wires.

For example, if a circuit has a potential difference of 100 volts and it is intended for the circuit to contain a 100 ohm resistance, then the wires carrying the current for this circuit will be designed for 1.0 amp. If that 100 ohm resistance is suddenly cut out of the circuit and only 0.10 ohm resistance remains, then the voltage will push 1000 amps of current through the circuit. This current overheats the wires and may damage the circuits or start a fire in the walls or the appliance. There are many possible causes of a short circuit, one possible cause could be something overheating, melting wires, and thereby fusing the circuit closed, bypassing the resistance. Another cause might be something damaging the insulation of a wire, allowing the incoming and grounds wires to touch. In any case, once the resistance is lost, the voltage pushes a huge amount of charge through the wires causing them to overheat.

There are multiple ways to prevent these situations from occurring. The three most common protective devices are fuses, circuit breakers, and surge protectors.

Fuses

An electrical **fuse** is a device that sacrifices itself to provide over-current protection in an electrical circuit.

Conducting wires have a small electrical resistance. The electrical resistance of a conducting wire is related to the type of metal used and inversely related to the cross-sectional area of the wire. The larger the diameter of a wire, the greater the cross-sectional area, and the lower the electrical resistance will be. When electrons flow through a wire, they repel each other and interfere with the passage of other electrons. If there are a very large number of electrons passing through a wire with small diameter, the electrons will experience a greater resistance than if the wire diameter were larger and the electrons had more space between them.

Close-up image of an electrical fuse

Figure 17.2.2

The image above is one type of electrical fuse. This fuse has a specially designed wire inside glass housing. The wire inside the glass is made of a particular metal and with a particular thickness to give the wire an exact resistance. This resistance will allow passage of normal current plus a marginal percentage more. If, however, the current exceeds the allowed value, the wire in the fuse will heat and melt, thus interrupting current flow through the circuit. The fuse wire is placed in the glass housing and a fuse mount to insulate the melting wire from its surroundings. Any unintended increase in current, such as short circuits, overloading, mismatched loads, or device failure will cause the fuse to burn out – protecting the other parts of the circuit from overheating and further damage.

This 'wire in glass' fuse is only one type of electrical fuse. Most fuses consist of a wire with small cross-sectional area compared to the circuit conductors, mounted between electrical terminals, and enclosed in a non-combustible housing. Regardless of the specific type of fuse, it is placed such that it carries all the current passing through the protected circuit. If the current flow gets too high, the fuse will melt. This destroys the fuse, but protects the remainder of the circuit.

Circuit Breakers

The problem with fuses is they only work once. Every time you blow a fuse, you have to replace it with a new one. Like a fuse, a **circuit breaker** opens the circuit if the current reaches unsafe levels. Unlike a fuse, however, a circuit breaker can be used over and over again. The basic circuit breaker consists of a simple **switch**, connected to an electromagnet. The diagram below shows a typical basic circuit breaker design.

Diagram of a circuit breaker

Figure 17.2.3

The red wire is the electrical circuit and is closed when the two contact points are connected. When the switch is in the on position, electricity can flow through the red circuit, through the electromagnet, and out into the rest of the circuit.

The electricity magnetizes the electromagnet. Increasing the current boosts the electromagnet's magnetic force, while decreasing the current reduces the magnetic force. When the current reaches an unsafe level, the electromagnet's magnetic field becomes strong enough to act on the soft iron bar, which is holding the left red wire in contact. When the soft iron bar is pulled down, the spring attached to the left red wire will lift the wire and break the circuit, causing the electricity to shut off. Once the circuit is broken, the electromagnet no longer emits a magnetic field, and the system can be reset by pushing the reset button. The reset button pushes the left red wire back in contact with the right red wire and also re-engages the soft iron bar that holds the contact in place.

More advanced circuit breakers use electronic components (semiconductor devices) to monitor current levels rather than simple electrical devices. These elements are a lot more precise, and they shut down the circuit more quickly, but they are also a lot more expensive. For this reason, most houses still use conventional electric circuit breakers.

When circuit breakers pop open due to excessive current, you do not have to replace the circuit breaker, you simply push a reset button. Of course, if the reason that the circuit breaker popped open is still present (like a short circuit), the circuit will simply pop open again when you reset it. When a circuit breaker pops open, you should determine the reason it opened and fix the problem before resetting the circuit breaker.

Surge Protection

A standard surge protector passes the electrical current along from the outlet to a number of electrical and electronic devices plugged into the power strip. If the voltage from the outlet **surges or spikes** (rises above the accepted level) the surge protector diverts the extra electricity into the outlet's grounding wire.

The most common type of surge protector contains a component called a **metal oxide varistor**, or **MOV**, which diverts the extra voltage. As you can see in the diagram below, an MOV forms a connection between the hot power line and the grounding line.

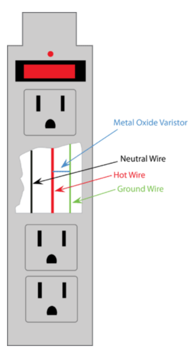

Figure 17.2.4

An MOV has three parts: a piece of metal oxide material in the middle and two semiconductors that join it to the power and grounding lines. These semiconductors have a variable resistance that is dependent on voltage. When voltage is below a certain level, the electrons in the semiconductors flow in such a way as to create a very high resistance. When the voltage exceeds that level, the electrons behave differently, creating a much lower resistance. When the voltage is low, an MOV does nothing. When voltage is too high, an MOV can conduct a lot of current to the ground line, thus eliminating the extra voltage.

As soon as the extra current is diverted into the MOV and to ground, the voltage in the hot line returns to a normal level, causing the MOV's resistance to shoot up again. In this way, the MOV only diverts the surge current, while allowing the standard current to continue powering whatever machines are connected to the surge protector. Essentially, the MOV acts as a pressure release valve, only opening when the voltage exceeds set values.

Have you ever wondered how the electricity in your house works? How can you turn the TV on without causing the lights in your living room to flicker or dim? How can the refrigerator stay on when the lights in the kitchen are off? Explore these questions and more in the Dollhouse simulation below:

Summary

- An electrical fuse is a device that sacrifices itself to provide over-current protection in an electrical circuit. If too much currentflows, the fuse wire rises to a higher temperature and melts, thus opening the circuit, but destroying the fuse.
- A circuit breaker opens a circuit as soon as the current climbs to unsafe levels, and can be used repeatedly.
- A standard surge protector passes a constant electrical current forward by diverting any extra electricity into a grounding wire.

Review

1. As a wire conductor increases in diameter, the resistance ________________.
    1. increases
    2. decreases
    3. stays the same
    4. changes color
2. The purpose of a fuse in an electrical circuit is to
    1. add another resistor
    2. increase the circuit voltage
    3. limit the maximum current in the circuit
    4. none of these
3. What is the purpose of a circuit breaker in an electrical circuit?
4. In some wire-in-glass fuses, the wire is not the same diameter all the way across the fuse. Many such fuses have one part of the wire that is considerably more narrow than the remainder of the wire. What is the purpose of this narrowing of the fuse wire?

Explore More

Use this resource to answer the questions that follow.

1. What happens to the fuse wire when the recommended current in a circuit is exceeded?
2. What is a common mistake made by homeowners when replacing burned fuses?

Additional Resources

Study Guide: Electrical Systems Study Guide

Real World Application: Circuit Breakers

Interactive: Flashlight

Videos: