National Operational Guidance

NFCC National Fire Chiefs Council

Developed and maintained by the NFCC

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Basics

Information

Current

Electricity, when flowing along a wire (known as a conductor), is called a current; this is a measure of the number of electrons passing a particular point in a conductor.

This rate of flow is measured in units called amperes (symbol A). Pressure must be provided to cause the electrons to flow, and this pressure, which may be derived from a number of sources, is called the applied voltage or electromotive force (EMF). This is measured in volts (symbol V); the greater the applied voltage, the greater the current flowing.

An analogy can be drawn between electricity flowing in a circuit and water flowing through a pipe. In hydraulics, the pipe offers a resistance to the flow of water and this resistance to the passage of water is proportional to the diameter of the pipe.

Similarly with electricity, the conductor offers a resistance to the flow of electrons; the greater the size (diameter) of the conductor, the lower the resistance. The resistance of a conductor is measured in ohms (symbol R).

There is a direct relationship between voltage, current and resistance. This fundamental principle is known as Ohm's law, which states:

'The value of a current passing through a conductor is directly proportional to the potential difference between the ends of the conductor, and inversely proportional to the resistance of the conductor'

The equation below shows the relationship between voltage, current and resistance:

potential difference (volt, V) = current (ampere, A) × resistance (ohm, Ω)

This can be expressed mathematically by the following equation:

$V = I \times R$

Resistance

The resistance of a circuit, which is measured in ohms, depends on a number of factors, namely:

- The length of a conductor - an increase in length results in an increase in resistance

- The cross-sectional area of the conductor - the greater the cross-sectional area, the lower the resistance
- The conductivity of the material used - some materials are better conductors than others; for example, silver is a better conductor than copper
- Temperature - for most materials, the hotter the material, the greater the resistance

Conductors and insulators

Electricity is always trying to find a path to earth, that is, to escape from its conductor and reach the ground or a conducting path that is connected to the ground.

Some materials offer such a high resistance to the flow of electricity and the current cannot force its way along them; they are then said to act as insulators.

Other materials offer little resistance and are said to be good conductors; copper and aluminium are two examples of good conductors and are therefore used extensively for electric cables.

Water is also a good conductor when impure, so a firefighter with wet clothing or holding wet hose who touches a live conductor could form an electrical path to earth and receive a shock, which could be fatal.

In most instances, the use of bare wire is impossible and the conductor must be continuously insulated to prevent electrocution on contact.

Most insulated cable nowadays, however, is insulated either by an oil-impregnated paper or by PVC (polyvinyl chloride) or other plastics such as PCP (polychloroprene) or CSPE (chlorosulphonated polyethylene). These plastics are extremely durable and, while not strictly non-flammable, will only burn when a source of heat such as a naked flame is continuously applied.

A mineral powder (generally magnesium oxide) in a copper sheathing is also used as an insulating medium for cables laid in hot places, such as near furnaces or boilers or in situations where circuit integrity is vital, for example in alarm systems. These cables are known as MICS (mineral-insulated copper-sheathed) or alternatively MICC (mineral-insulated copper-clad) cables, and are also used in general situations where extra physical protection is required.

When conductors form overhead lines or switchboard connections, insulation is often neither desirable nor appropriate. In such cases, arrangements must be made to stop the cables coming into contact with their supporting structures and with each other. This is achieved by the use of insulators, which are usually made of porcelain or glass.

Short circuits

While air and most other gases are good insulators, electric current can, if the insulation becomes faulty, leak between two conductors or between one conductor and earth. The amount of current leaking depends, among other things, on the voltage, the condition of the insulating material and the distance between the conductors.

If a breakdown occurs in the insulation separating adjacent conductors or a conductor from the earth, what is known as a short circuit takes place. That is, the current, instead of following its normal path, finds a quicker return path. The electrical resistance in such cases is generally negligible, resulting in a heavy current flow; this can cause intense local heating combined with overloading of the cables. The cables may then become dangerously overheated unless the circuit is broken.

Such a breakdown in the insulation may take place in many ways. Insulating material will deteriorate with age or from other causes, and may reach a condition where its insulating properties are insufficient to prevent a short circuit. The perishing of rubber is a good example of this, and is one of the reasons PVC has superseded rubber as an insulating medium. Cables or wiring may be subjected to mechanical stress through vibration caused by external influences, while dampness is a frequent cause of the breakdown in insulating properties.

Alternatively, excessive heat through external causes, for example steam pipes or industrial processes for which the system has not been designed, will also lead to rapid deterioration. Furthermore, insulation is often destroyed by nails driven into walls and penetrating the wiring, tools striking cable runs, abrasion or rodents.

If a breakdown of insulation occurs, excessive current will probably flow through the fault, and if the fuse or circuit breaker fails to operate, overheating will result. For a fire to occur in such circumstances, it is only necessary that there should be combustible material in close proximity to an overheated wire or a hot spark. Fire can readily be started through a short circuit whether or not a cable is insulated.

Protective devices

When an electric current passes along a conductor it generates heat. If the maximum current the conductor is designed to carry is exceeded, either because of excessive load placed on the circuit or because of a short circuit, overheating will occur and the conductor may become hot enough to ignite the combustible insulation with which it is covered. To prevent this, an electric circuit is fitted with a fuse or circuit breaker to break the circuit in the event of an overload.

Fuses

In its most basic form, a fuse is a short length of wire that has a low melting point and forms part of a circuit. The size of the fuse wire is calculated for the normal expected load. If that load is greatly exceeded, the passage of the extra current causes the temperature to rise and the fuse wire to melt, breaking the circuit. Because the fuse melts at a much lower temperature than that which would result in a dangerous temperature rise in the rest of the circuit, the fuse acts as the weak link in a chain.

Circuit breakers

In the modern consumer unit, fuses may be replaced by miniature circuit breakers (MCBs), which look like an ordinary switch or a push button. They automatically interrupt the circuit if it becomes overloaded or if a fault occurs.

Once the cause of the fault or overload has been identified and connected, the MCB can be reclosed and the circuit brought back into service.

In installations of greater power, the use of fuses and MCBs is impracticable for technical reasons, and automatic circuit breakers, which operate when the current rises to a dangerous level, are installed. Such circuit breakers are designed to operate automatically if a fault occurs. They can be opened manually if necessary, for example to test the mechanism. They are often closed, manually or automatically, if they open due to a fault, to ascertain whether the overload was of a momentary nature only.

Furthermore, the circuit breaker may be closed automatically several times after a period of time to test whether the fault has cleared. This is known as auto-reclosing and it should therefore never be assumed that a circuit is dead, even when a circuit breaker has opened.

If a line has been accidentally brought down and is laying on the ground, it may not be making sufficient contact with the ground to operate the circuit breaker.

Hazards (for further information refer to National Operational Guidance: Utilities and fuel)

- Electricity (high-voltage and low-voltage)