Basic Electrical Engineering for HVAC Engineers

An Online Continuing Education Course for Engineers

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Basic Electrical Engineering for HVAC Engineers

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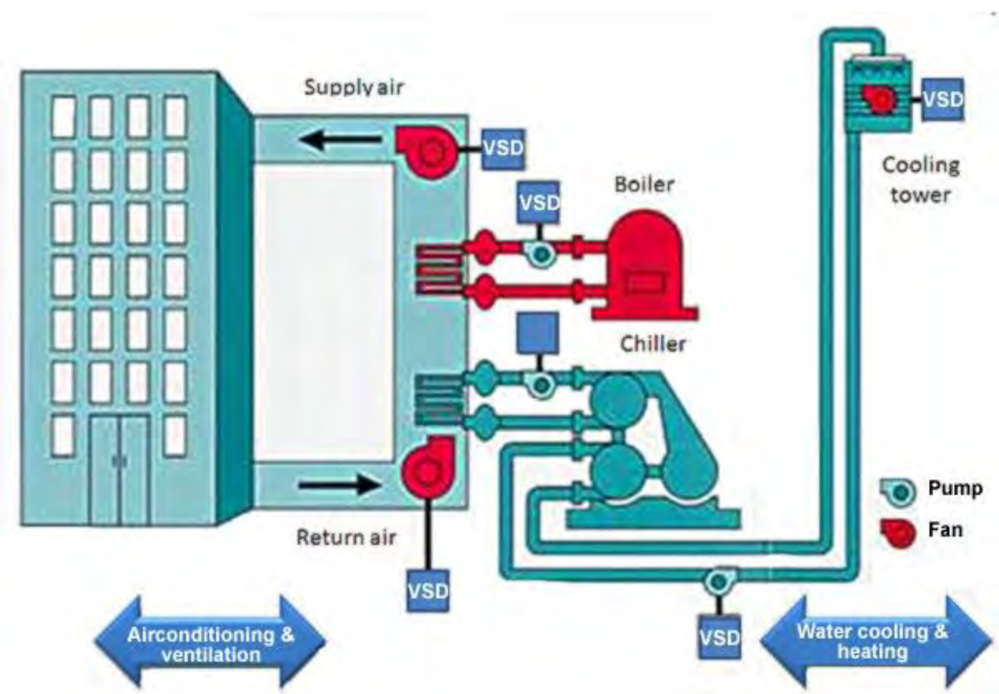
An HVAC system is a simple system of heating and cooling exchangers using water or a refrigerant (direct expansion system) as the medium. Pumps move the heated or cooled water to the exchangers. Fans then move the warmed or cooled air created at the exchangers to the occupied building interiors.

There are two stages to heating and cooling:

1. Water stage: water is the most efficient and inexpensive medium that we can use to cool directly (through a chiller) or heat (through a boiler)
2. Air stage: air is the medium for heat exchange in the building, as it can be cooled or heated through coils.

The following figure illustrates a typical HVAC system showing water and air heat exchangers:



Big energy users in HVAC

1. Fans: for air circulation and ventilation.
2. Cooling: for the production of chilled water for large buildings or for the use of direct expansion cooling systems such as packaged air-conditioners for small buildings; accomplished via chillers.
3. Heating: most frequently, the energy use of boilers is utilized for the production of hot water for heating, but also often utilized for zonal reheat.
4. Pumps: for the circulation of heating hot water, chilled water and condenser water.
5. Cooling towers: for heat rejection. The primary energy use is the cooling tower fan and pumps.

Power distribution systems and equipment used to drive HVAC machinery, motors and other auxiliaries can be complex to the non-electrical engineer. This course will address some basic electrical concepts that will be useful to HVAC engineers and other mechanical engineers in their day-to-day work. The course is divided in 4 sections:

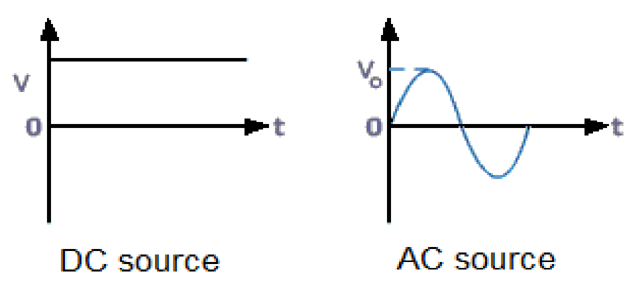
Part -1: Basic Electrical Concepts and Fundamentals
Part -2: Electrical Distribution Systems and Components
Part -3: Motors and Variable Speed Drives
Part -4: Electrical Energy Efficiency in HVAC Systems

PART -1: BASIC ELECTRICAL FUNDAMENTALS

In each plant, the mechanical movement of different equipment is caused by an electric prime mover (motor). Electrical power is derived from either utilities or internal generators, and is distributed through transformers to deliver usable voltage levels.

Electricity is found in two common forms:

1. AC (alternating current)
2. DC (direct current)



The selection of energy source for equipment depends on its application because each has its own merits and demerits. However, for HVAC systems or for typical building services, we are concerned with AC voltage.

Industrial AC voltage levels are roughly defined as LV (low voltage) and HV (high voltage), with a frequency of 50–60 Hz. An electrical circuit has the following three basic components, irrespective of its electrical energy form:

1. Voltage (V) is defined as the electrical potential difference that causes electrons to flow.
2. Current (I) is defined as the flow of electrons and is measured in amperes.
3. Resistance (R) is defined as the opposition to the flow of electrons and is measured in ohms.

All three are bound together with Ohm’s law, which gives the following relation between the three components:

$V = I \times R$

In a more technical expression, you can state it as:

With Constant Resistance

- Lower voltage gives small current
- Higher voltage gives large current

With Constant Voltage

- Lower resistance passes large current
- Higher resistance passes small current

Example: A conductor has a resistance of 1.5 ohms and the current flowing on the wire is 5 amperes. The voltage drop along the wire will be the current times the resistance of the conductor, or 7.5 volts.

Example: A resistance type heating element from an electric water heater operating at 240 volts has a current flow of 14.6 amperes. The resistance of the heating element will be the voltage divided by the current, or 16.4 ohms.

CIRCUITS

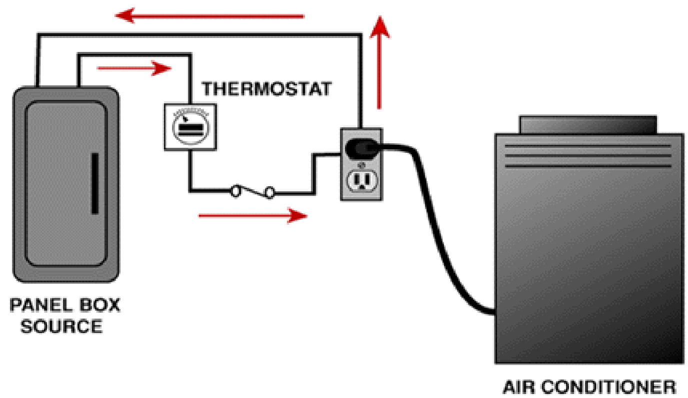
In order to flow, electricity must have a continuous, closed path from start to finish, like a circle. The word “circuit” refers to the entire course an electric current travels, from the source of power, through an electrical device, and back to the source. Every circuit is comprised of three major components:

1. A conductive "path," such as wire, or printed etches on a circuit board;
2. A "source" of electrical power, such as a battery or household wall outlet, and,
3. A "load" that needs electrical power to operate, such as a lamp.

The current flows to the devices (called loads) through a “hot” wire and returns via a “neutral” wire (so-called because under normal conditions it’s maintained at zero volts), or what is referred to as ground potential.

There are also two optional components that can be included in an electrical circuit. These are control devices and protective devices. Control and protective devices, however, are not required for a circuit to function. They are optional. For example, a circuit that switches on an air conditioner when the temperature is too high would contain the following components:

- a source of electrical energy; in this case, such as a simple household current
- a protective device that senses current flow on the circuit, such as the circuit breaker in the panel box
- a control device that redirects the current, such as the switch in the thermostat
- a load such as an air conditioner that cools the space down until the circuit opens and shuts the air conditioner off.



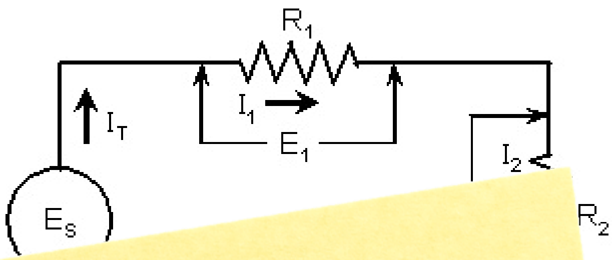
Types of Circuits

There are several types of circuits. Their names describe the way the circuit is wired or its main function. Elementary types of circuits include:

- Series
- Parallel
- Open
- Short
- Power
- Control

Series Circuit:

A series circuit is defined as a circuit in which the elements in a series carry the same current, while voltage drops across each may be different. It has only one path for current to flow through the circuit. A typical series circuit follows:



The following are the

- Current: In a se ... verywhere in the circuit.
  $I_T = I_1 = I_2 = I_3$
- Voltage: The tot ... ges across each of the resistors in the c
  $V_T = V_1 + V_2 +$ V
- Resistance: The ... individual resistors in the circuit.
  $R_T = R_1 + R_2 +$ R

Parallel Circuit:

A parallel circuit is defined as a circuit in which the elements in parallel have the same voltage, but the currents may be different. It has multiple paths for the current to follow as shown in the following figure: