Regardless of experience, the foundation of any technician's success begins with understanding electricity

By Scott McClure, CM

Stay Current With ELECTRICAL KNOW HOW

One of the main building blocks of success for an hvacr service technician or installer is mastery of electrical basics. In my experiences teaching hvac and working with and talking to other technicians in the field, the electrical side of the business is the most difficult to master.

As a seasoned veteran or a novice in the industry, a review of some basic electricity principles is useful. Defining volts, amps and ohms is a good start, following with types of voltage systems.

For instance, if you are measuring the 24 volts being applied to a contactor coil, do you know what is really happening? Reading voltage is actually taking the measurement of the pressure or electromotive force that causes electric current to flow through a circuit.

For comparison, let's look at a water hose with a pressure of 40 pounds per square inch (psi) created by a pump. The 40 psi is the available pressure to force the water down the length of hose. The 40 psi in water pressure would be like 24 volts being measured at the contactor coil.

Do you know what you are reading when you measure the amp draw of the compressor while it is running? Reading amperes is the measurement of the rate of current flow, or if converted to coulombs, the number of electrons flowing past a given point in one second. An ampere has a one-to-one relationship with coulombs.

Staying with the water hose example, measuring the gallons per hour of water flow would be comparable to measuring in amps the electron flow in a copper conductor.

If the compressor is being ohmed out to determine if the windings are good, what is the ohmmeter really telling you? The measurement of ohms tells you the resistance that a conductor has to the flow of electrons.

Using the water hose example again, a 1/2-inch hose will not flow as much water as a 1-inch hose given the same pressure. The 1/2-inch hose has more resistance than the larger hose. The same is true with an electrical conductor — the smaller the conductor, the more the resistance.

Electrical applications

Let's look at some applications involving voltage, amperage and

ohms. An air conditioner compressor has to run within manufacturer's specifications and supply the proper amount of voltage to the run and start windings of the compressor. The system data plate may state the allowable voltage span at which the equipment can safely run.

Depending on the manufacturer, the allowable voltage drop may range from 3 percent to 10 percent. For example, a technician measures 186 volts or less at the compressor terminals R (run), C (common), S (start) and C (common) while the unit is running. The voltage drop is more than 10 percent, so there will be compressor problems.

Compressors also have to run below the rated load amps (RLA) given for the specific compressor. If you are monitoring a compressor while it is running, take a current draw from the common leg to the compressor.

While reading the condenser's data plate, you will see a value of 14.7 RLA for the compressor. The clamp-on ammeter gives a reading of 16 amps. The compressor is pulling too high of amps, which suggests there is a problem in the system (see Figure 1).

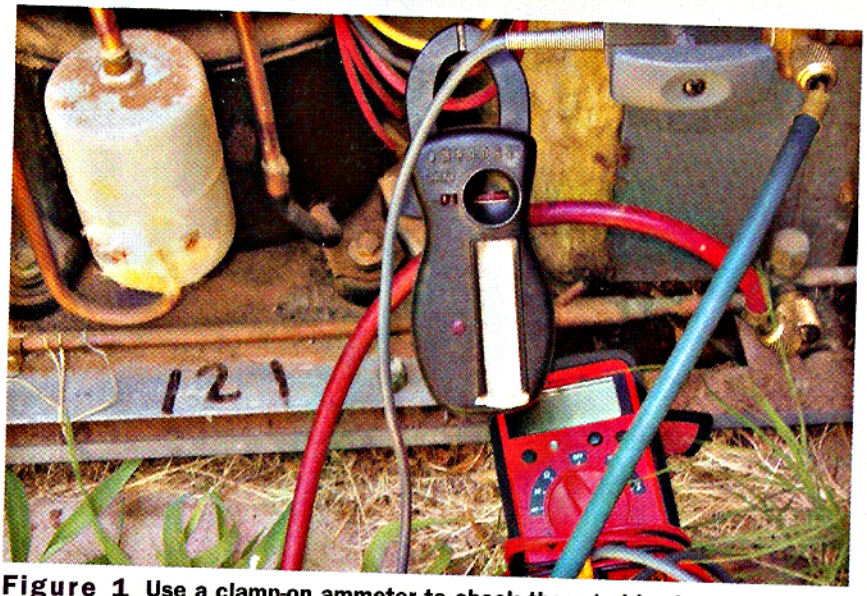

Figure 1 Use a clamp-on ammeter to check the rated load amps to the compressor.

An air conditioner compressor has to run within manufacturer's specifications and supply the proper amount of voltage to the run and start windings of the compressor

For example, let's say a technician is troubleshooting a compressor. The clamp-on ammeter's jaws are around the common leg of the compressor and show that the compressor is not pulling any amps. The voltage has been measured and determined to be correct at the common-to-run and common-to-start.

The next step would be to turn the power off to the system, always double checking with the voltmeter. Disconnect the electrical connections carefully at the run, start and common connections at the compressor and ohm out the windings. Common-to-run and common-to-start should equal run-to-start in ohms (see Figure 2).

Always exercise extreme caution during electrical checks. The potential for harm exists while systems are electrically energized. Danger also exists at the compressor terminals because there is high pressure directly behind them. Anytime the leads to the compressor terminals are removed, proceed with caution.

Voltages in the field

Now, let's take a look at the types of voltage systems you may encounter in the field. Voltage ranges for various hvac equipment will vary depending on whether the application is residential, commercial or industrial.

In residential applications the normal range generally will be 115 volts to 230 volts and usually single phase. Single phase means there are only two legs of power. Three-phase systems may be encountered in older residential equipment or in special circumstances, but are generally used in commercial and industrial businesses. Three phase means there are three legs of power available for a load.

The 115-volt and/or 230-volt primary is then stepped down by an hvac equipment transformer to the normal control voltage of 24 volts. In residential applications, 115 volts is common with gas heat furnaces and 230 volts for the outside condensing unit. If the residence has electric heat as a primary heat source or a heat pump with electric heat as

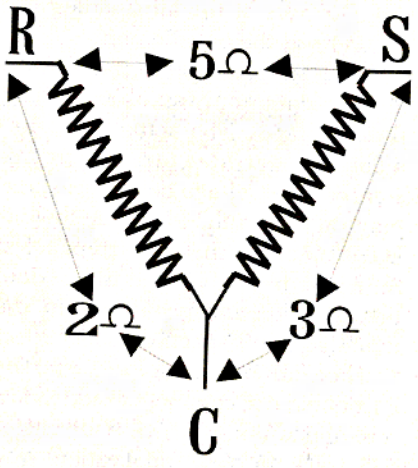

Figure 2 Common-to-run and common-to-start should equal run-to-start in ohms.

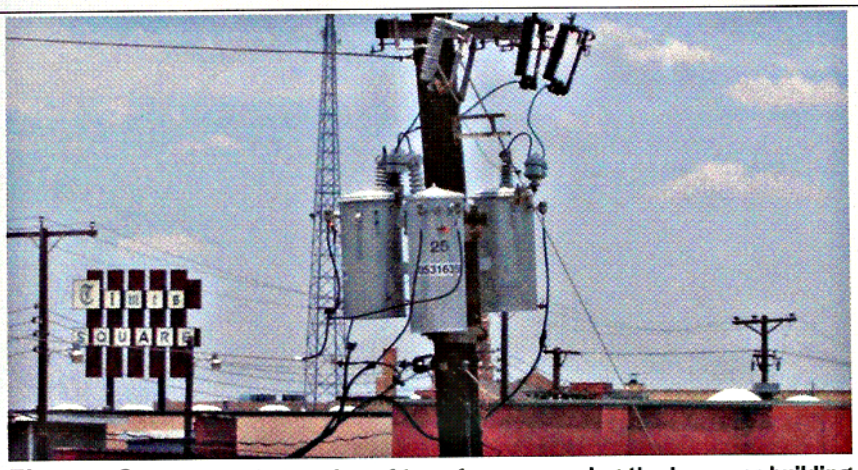

Figure 3 Knowing the number of transformers serving the house or building in which you are working can help you determine if the system is three-phase, like the one shown here with three transformers, or one phase.

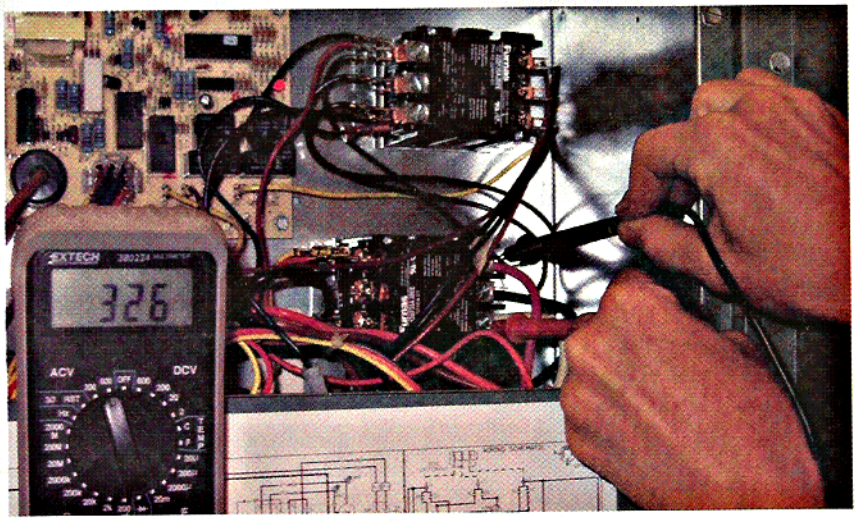

Figure 4 The tech measures the voltage at two poles of a three-pole contactor. Knowing the correct voltage is essential for precise system troubleshooting.

secondary heat source, then there are 230 volts at the air handler and 230 volts at the outside unit.

Using the numbers 115 and 230 is just the common way of expressing these voltages. The actual measurements may vary due to other circumstances. The voltage being measured may vary from the ideal due to voltage drop or voltmeter discrepancies. As noted in the voltage discussion, the variation must stay within the manufacturer's specifications.

The other voltages normally encountered in commercial and industrial applications may be 480 volts or 575 volts. In these applications you will encounter more three-phase systems. It is important to be able to identify the different voltages you may encounter for more than one reason.

Installing a piece of equipment and hooking up the wrong phase or voltage could damage the equipment beyond repair. Also, troubleshooting an hvac system without the knowledge of the voltage system may result in the wrong diagnosis.

To determine voltage, you need an accurate voltmeter and know how to use it effectively

How then will a technician know what type of voltage system he is working on? The voltage and phase that go to a home or building will be determined by the electrical power coming into the building. Three-phase power may be available in some parts of a city or town but not in others.

If the tech is at a residence and looks up at the utility pole and sees one transformer with two conductors and a ground going to the house, that means it is single phase. If there are three transformers on the utility pole and three conductors and a ground going to the house, three-phase is available (see Figure 3).

There are special circumstances where three-phase may be present with a single transformer, but it is not common. Also, there are areas where the electric cables are installed underground, so visually identifying phase availability may not be easy.

Determining voltage

To determine voltage, you need an accurate voltmeter and know how to use it effectively. For example, let's say you are troubleshooting an air-conditioning condensing unit. The unit is at a home in an older neighborhood so there is a potential for three-phase. The unit is fairly new looking, so even if three-phase is available it may not be utilized.

The technician sees a disconnect box next to the unit, so he goes ahead and turns the power off to the unit. Next, he removes the cover to access the electrical components in the unit. The first thing the tech should determine is where the high voltage wiring ties in. Generally, this is a contactor.

If a three-pole contactor is observed with three conductors, it likely is three phase. If a two-pole contactor is observed with two conductors, it likely is a single-phase system. Never assume anything, but instead confirm the voltage and phase with your voltmeter.

Set the meter to its highest AC voltage scale if it has different voltage ranges. If it is auto-ranging, then put the meter to the AC voltage scale. It is always better to set your meter to its highest voltage scale if the voltage potential is unknown. By doing,

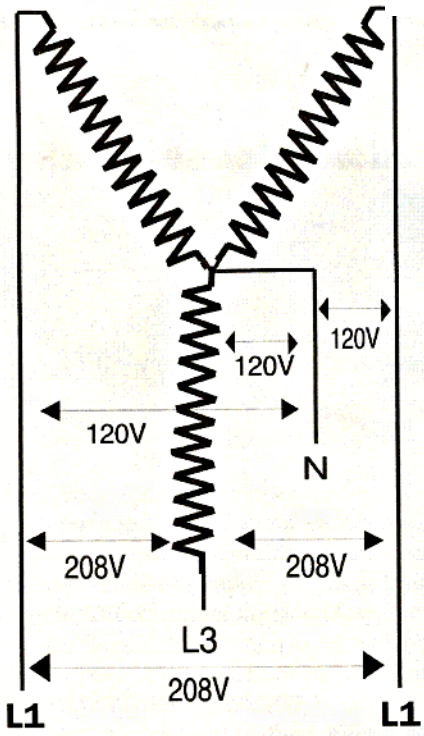

Figure 5 The diagram shows a wye transformer with 208 volts between each pole and 120 volts from each pole to neutral.

this the meter will be protected against over-voltage.

Next, turn the disconnect to the condensing unit back on. If you have a two-pole contactor, apply one meter lead to one pole and the other lead to the other pole. As long as there isn't a problem from the power source, you should now read the voltage available to the unit.

If there is a three-pole contactor with a L-1, L-2 and a L-3, take one probe to L-1 and the other probe to L-2 and note the voltage. Next, leave a probe on L-1 and move the other probe to L-3. If you're working on a three-phase system, the reading should be the same as L-1 to L-2.

In addition, a reading from L-2 to L-3 should give the same voltage reading. If not, there is a voltage imbalance and any problems depend on the extent of the imbalance. You can still assume there is nothing wrong with the system's high voltage. The voltage readings will tell you what type of transformer is serving the residence (see Figure 4).

GRAPHS BY ANN STITZER

Two transformer systems

If the meter reading is about 208 volts on the three-phase system, you are dealing with a wye transformer system. If the reading is about 230 volts on the three-phase system, you are dealing with a delta transformer system. The transformer being discussed here is the one stepping down the voltage at the high line to usable voltage to the house.

The single-phase system should give a reading of approximately 230 volts. Determining the voltage that is available to a system is important to ensure the system is within the manufacturer's specs. Determining power transformer configuration by voltages observed has an application as well (shown in Figures 5, 6 and 7).

Wye transformers normally include applications that need 120-volt circuits. With a three-phase, 208-volt wye transformer, each of the three conductors will read 120 volts to ground, thus making three legs of power with 120 volts available.

With a three-phase, 230-volt delta transformer, only two legs of power will read 120 volts to ground. The other leg will read approximately 208 volts to ground. This leg is useless in 120-volt applications. With the delta, there are only two conductors running 120-volt loads.

With a three-phase delta application it is important to know when an existing three-phase condenser may be replaced with a single-phase condenser. Only two of the three conductors will be needed, so which of the two conductors are used?

The two that individually read 120 volts to ground would be the ones to wire to the system. The conductor that reads the higher voltage to ground should be capped and taped.

Using voltmeters, ohmmeters and ammeters effectively is essential for safely and accurately troubleshooting hvac systems. The voltmeter will determine voltage or the potential available to a system. Use the amp meter to determine if a system's loads are running within manufacturers' specifications. The ohmmeter

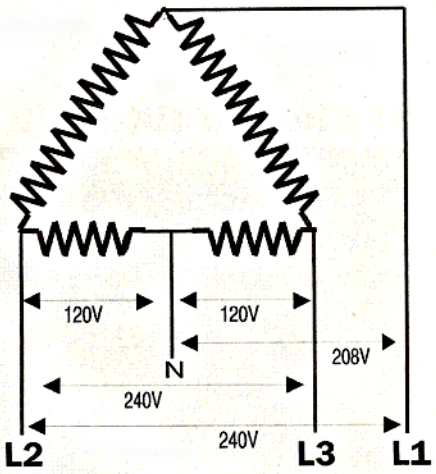

Figure 6 The diagram shows a delta transformer with 240 volts between each pole, 208 volts between L1 and neutral, and 120 volts from L2 and L3 to neutral.

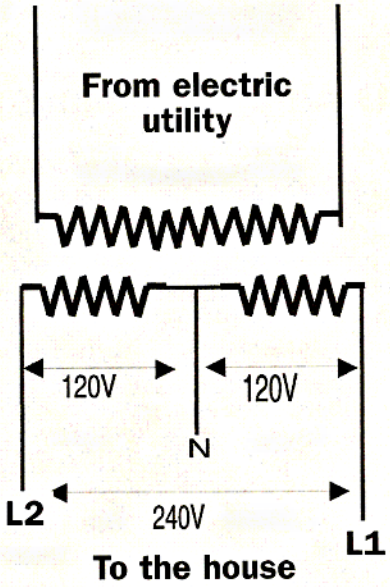

Figure 7 The diagram shows a single-phase transformer typically found in a residential application.

can tell you if a circuit is closed or open, and also if a load's windings have the proper resistance.

Also, you need to be able to determine whether a system is using single-phase or three-phase power to ensure accurate and proper hvac system troubleshooting and installation.◆

Scott McClure is a longtime hvacr contractor and instructor.