ELECTRICITY: Basic Theory *Part 2*

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ONCE AGAIN, The Word invites you to travel into the dark realm of subjects that are sometimes misunderstood by home inspectors. The Word hopes you will find this trip informative and maybe a little entertaining.

This month, we continue the discussion about electricity we started in the February *Reporter*. The Word finds this subject interesting because the good inspector of electrical systems knows what is deficient, but the better inspector knows why it is deficient. Inspectors who understand why something is deficient make better calls and can better explain those calls to their clients.

Electricity law and order – a review

Last time, we learned about the Laws from Mr. Ohm and Mr. Watt, as shown in Illustration 1. These laws describe how the basic characteristics of electricity in a home's electrical system (voltage, current and resistance) interact to perform work (power). Voltage is like water pressure. Current is like water flow rate. Resistance inhibits electricity's flow. Power is a measure of work performed. Change one characteristic and you change all the others. Note to the engineers: These descriptions of work and power aren't completely technically correct. They're close enough for our purposes.

Feeling low (voltage)?

A common application of these laws occurs because of the effect of current and resistance on voltage in the home's electrical system. Voltage decreases as resistance increases at a given current load. So, for example, if you add wire between the voltage source and the load, resistance increases and voltage decreases. Voltage also decreases as current increases at a given resistance. So, for example, if you turn on a high-current load device like a motor, current increases and voltage decreases.

The common label given to this phenomenon is, not surprisingly, voltage drop. An example of voltage drop is lights dimming when a compressor or other high-current load device first activates. This dimming is the result of the momentary increase in current flow that creates a voltage drop. This type of voltage drop, while annoying, is usually not considered a problem.

Circuits operating continuously at less than their intended voltage may experience problems. Motor loads and ballasts for fluorescent lights are particularly susceptible to problems caused by low voltage. They may function inefficiently or at less than designed output; they may overheat, and they may have reduced service life. Electronic equipment such as computers and printers may lock up or shut down, resulting in lost data, inconvenience and business interruption. Resistance loads such as incandescent lights and heating and cooking appliances will operate at less than designed output. Consistently low voltage also costs money. The wires themselves consume more power that is wasted as heat.

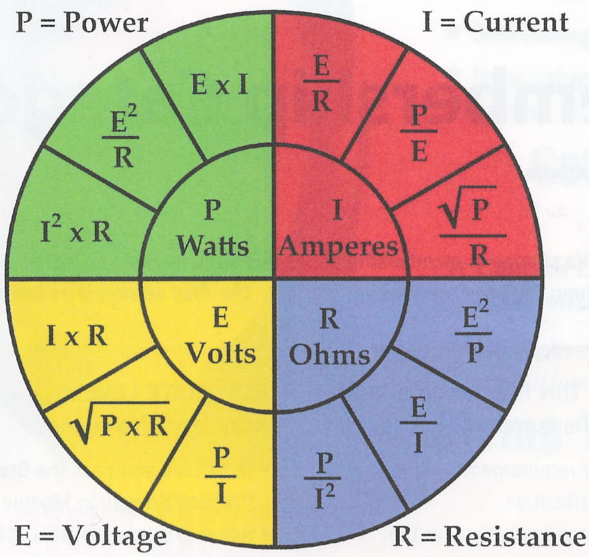
Voltage drop (at a given current load) is primarily a function of the wire diameter, material and length. Other conditions such as marginal quality splices and connections can also affect voltage drop. These factors establish the resistance between the circuit's source (the breaker or fuse) and the circuit load (the light bulb, etc.). These factors also apply to feeders between the feeder's source and a subpanel. Aluminum wire has a higher resistance than the same size copper wire. A longer wire has more resistance than a shorter wire. Increasing the wire length (or increasing the current load) creates a voltage drop that could adversely affect devices. Conversely, increasing the wire diameter decreases the voltage drop. Increasing wire diameter is a common cure for voltage drop issues.

Acceptable voltage drop?

Confusion surrounds the question of acceptable voltage drop. What's acceptable depends on who you ask and on the situation. The National Electric Code (NEC) and ANSI Standard C84.1 are sometimes cited when discussing voltage drop.

The NEC does not limit voltage drop in branch circuits. Fine print note [210-19(A) I.N.No. 4] recommends sizing branch circuit

Illustration 1



Ohm's and Watt's Laws

conductors to prevent a total voltage drop exceeding 5%, including feeder losses. Informational Notes (formerly Fine Print Notes) are for information only and are not enforceable. NEC Section 110-3(B), however, says that equipment must be installed in accordance with its listing or labeling. Most electrical equipment is designed to operate at no less than 10% below its labeled voltage rating.

Another way to address minimum acceptable branch circuit outlet voltage is by applying ANSI Standard C 84.1. This standard states that the minimum acceptable outlet (utilization) voltage over time for nominal 120-volt general lighting circuits is 110 volts and 108 volts for other circuits. Infrequent and short duration dips to 106 volts for general lighting circuits and 104 volts for other circuits are allowed under this standard.

These minimum acceptable branch circuit outlet voltages shouldn't be used without considering other factors, not the least of which is the fact that voltage from the utility (nominal voltage) isn't constant. Measuring voltage at one point in time does not provide a valid indication of voltage conditions over time. As previously discussed, manufacturers usually design devices to operate effectively at less than the nominal voltage. This is why you often see labels on devices such as motors that display an operating voltage like 115 volts for a 120-volt circuit and 230 volts for a 240-volt circuit.

Practical applications

Voltage drop usually isn't a big problem inside modern homes. Wire lengths and current loads usually are not sufficient to cause enough voltage drop to matter. Measuring voltage and measuring circuit lengths is way out of scope for a home inspection. So, how might we apply what we just learned during our inspections?

One application where we might alert our clients to a possible problem is a branch circuit serving an accessory building such as a garage. Wire ampacity limits (15 amps for #14 NM cable) are based, to a large extent, on the wire's ability to dissipate heat. Voltage drop is not considered; therefore, a circuit that may be allowed from an ampacity perspective may not work well from a voltage drop perspective.

Let's do a couple examples. Note that there are many voltage drop calculators that will produce different results depending on the inputs and on assumptions such as circuit operating temperature. Your results may vary from these results. The purpose of these examples is to give you a feel for the types of situations where voltage drop might be an issue.

The International Residential Code (IRC) allows using #14 copper wire to serve one 120-volt, 15-amp circuit in an accessory building such as a detached garage. Assume #14 copper wire, a 12-amp total load, 120 volts at the circuit's source, and a wire length of 200 feet between the service panel and the load. The voltage drop would be around 10.8% or 13 volts. Reduce the wire length to 150 feet and the voltage drop would be around 8.1% or 9.7 volts. The 200-foot circuit is a likely problem and the 150-foot circuit is a possible problem. Remember, just because the only load present in a garage is a light doesn't mean that's the way it will always be. If someone can place additional loads on a circuit, you should assume that they will.

Long branch circuit runs serving motors such as pool and well pumps are another example of where voltage drop could be a problem. Assume #12 copper wire, 7.4 amps total load, 240 volts at the circuit's source and a wire length of 200 feet from the circuit's source to the pump. The voltage drop would be around 2.1% or 5 volts. No problem here. That same pump may be connected to a 120-volt circuit where it would draw 14.8 amps. In this case, the voltage drop would be around 8.6% or 10.3 volts. This circuit could be a problem, especially if source voltage is less than 120 volts. A low-source voltage could occur for many reasons, including voltage drop between the primary panel and a subpanel such as a pool subpanel.

The bottom line

Voltage drop is a complex issue. There is no one clear standard for minimum acceptable voltage, and even if there were, determining compliance would be way out of scope. The best we can hope for is to be aware of the issue and to alert our clients when further evaluation may be prudent.

Memo to Zeus: The Word does not reside on Mt. Olympus (just at its base) and welcomes other viewpoints. Send your lightning bolts or emails to Bruce@DreamHomeConsultants.com. The thoughts contained herein are those of The Word. They are not ASHI standards or policies. ■

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