

Why true-rms matters for HVAC technicians

Non-linear loads need a true-rms test tool for accurate readings

Application Note

For today's HVAC technician, troubleshooting electrical problems is becoming more difficult without the use of true rms test tools. This is due in part to the proliferation of new solid state adjustable speed motor drives and heating controls containing power semiconductors or rectifiers. These loads are referred to as "non linear." Non linear loads draw current in short pulses rather than the smooth sine wave drawn by a linear load such as an induction motor. The current wave shape can have a drastic effect on a test tool reading.

There are two types of electrical test tools commonly available: "Average responding-rms indicating" and "true-rms." The average responding units give correct readings for linear loads such as induction motors, resistive heaters, and incandescent lights.

But when loads are non-linear, average responding meters may read anywhere from 5 % to as much as 40 % low when measuring line side currents.



Checking current on a compressor controller with a true-rms Fluke 902 HVAC Clamp Meter.

True-rms implications for HVAC

Consider all the problems found in complex HVAC and refrigeration systems. There's a full range of electrical and mechanical issues, of course, but also control system problems, air supply balance, compressor performance and the delicate balance of coolant temperature and pressure,

superheat, subcooling and air flow that is fundamental to air conditioning and refrigeration performance.

Now consider how many of those involve non-linear loads. Essentially, any control or system containing semiconductors in the power supply would be considered a non linear load.

Normally when troubleshooting an HVAC equipment failure

or nuisance trips due to an electrical problem, your first instinct would be to check the panel for tripped circuit breakers or overloading.

However, if a non-linear load is on that circuit, you'll need a true-rms test tool to accurately measure the true load current to determine where the problem is—is the circuit faulty, is it overloaded, or is the problem with the load itself?



One current—two readings. Which do you trust? The branch circuit above feeds a non-linear load with distorted current. The true-rms clamp on the right reads correctly but the average responding clamp reads low by 32 percent.

HVAC electrical measurements affected by rms

Here's a birds-eye view of the HVAC electrical measurements that require a true-rms test tool.

- Measuring supply side current and voltage as well as load side current and voltage
- Measuring current and voltage phase balance on 3 phase systems
- Troubleshooting compressor electrical motor faults

Troubleshooting compressor motor faults

Compressor failures are often caused by electrical faults. The best tool for this measurement sequence is a true-rms clamp meter like the Fluke 902 or a true rms digital multimeter with a current clamp accessory.

1. Allow the compressor to cool down prior to the electrical test. This allows the device to reset to its normal position. Then, remove the electrical terminal cover.
2. Check line voltage at the load center with the compressor off. Low line voltage causes the motor to draw more current than normal and may result in overheating and premature failure. Line voltage that is too high will cause excessive inrush current at motor start, again leading to premature failure.

3. Check line voltage at the motor terminals with the compressor running. The true-rms voltage should be within 10 % of the motor rating.
4. Check running current. The readings should not exceed manufacturers' full load rated amps during heavy load periods. Low amps are normal during low load conditions. Excessive current may be due to shorted or grounded windings, a bad capacitor, a faulty relay, or bearing fatigue.

Troubleshooting compressor motor failures caused by refrigeration system problems

Compressor electrical problems are often caused by mechanical system failure or installation and service errors. Compressor bearings can fail or lock up due to improper lubrication or insufficient oil return to the compressor (largely due to poor piping). To diagnose this problem, measure the compressor current with a true-rms test tool. The current readings should not exceed manufacturers full load ratings. Worn bearings will cause higher than normal current readings.

Checking for voltage imbalance in a three-phase compressor motor

Voltage imbalance in three-phase motors causes high currents in the motor windings.

These higher currents generate additional heat that degrades and destroys winding insulation. A 10 °C rise in motor temperature can reduce motor life by half.

Voltage unbalance is usually caused by adding single phase loads on the same circuit used by the compressor, although sometimes component failure is the culprit. Voltage unbalance for three phase motors shouldn't exceed one percent, otherwise the motor load capacity should be derated. To calculate voltage unbalance, use this formula:

$$\% \text{ Voltage Unbalance} = 100 \times \frac{\text{(maximum deviation from average)}}{\text{Average voltage}}$$

For example, given true-rms voltages of 449, 470, and 462, the average voltage is 460. The maximum deviation from the average is 11 volts. The percent unbalance is $100 \times 11 / 460 = 2.39 \%$. That result indicates a voltage unbalance problem. The closer the motor is matched to the load, the less reserve power it has and the more important it becomes to periodically check motor supply voltages.

Checking for current unbalance in a three-phase compressor motor

For accurate results, measure current with a true-rms clamp meter or true rms DMM with a clamp attachment. The goal behind measuring current on a three-phase compressor motor is to ensure that the full load rating on the motor nameplate isn't exceeded and to verify that all three phases are balanced.

Unbalanced current can be caused by voltage imbalance between the phases, a shorted motor winding, or a high resistance connection. To calculate current unbalance, use the same formula as above but substitute current in amps. Maximum current unbalance for three-phase motors is typically 8 % to 10 %. A 1 % voltage unbalance will cause an 8 % current unbalance.

What is true-rms?

“RMS” stands for root-mean-square. It comes from a mathematical formula that calculates the “effective” value (or heating value) of any ac wave shape. In electrical terms, the ac rms value is equivalent to the dc heating value of a particular waveform—voltage or current. For example,

if a resistive heating element in an electric furnace is rated at 15 kW of heat at 240 V ac rms, then we would get the same amount of heat if we applied 240 V of dc instead of ac.

From a measurement perspective, the rms value is equal to .707 of the peak value of the sine waveform.

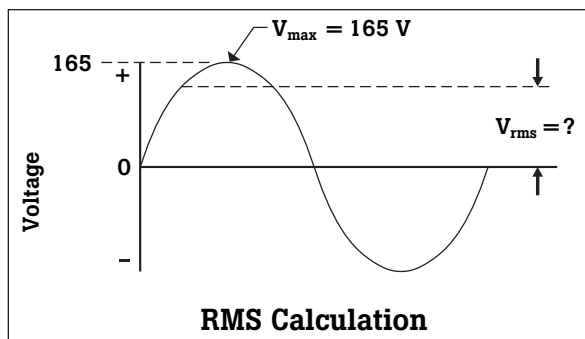
$$V_{rms} = V_{peak} \times .707$$

For example, say an ac voltage source has a positive peak value of 165 V.*

$$V_{rms} = V_{peak} \times .707$$

$$V_{rms} = 165 \times .707$$

$$V_{rms} = 116.655 \text{ V}$$



RMS voltage conversions for sine waves

To convert	To	Multiply by
Rms	Average	.9
Rms	Peak	1.414
Average	Rms	1.111
Average	Peak	1.567
Peak	Rms	.707
Peak	Average	.637
Peak	Peak-to-Peak	2

*Example and supporting data courtesy of American Technical Publishers Inc.

Electrical components such as fuses, bus bars, conductors, and thermal elements of circuit breakers are rated in rms current because their main limitation has to do with heat dissipation. If we want to check an electrical circuit for overloading, we need to measure the rms current and compare the measured value to the rated value for the component in question.

True-rms multimeters and other test tools respond accurately to ac voltage values regardless of whether the waveform is linear. If a test tool is labeled and specified to respond

to the true-rms value, it means that the tool’s internal circuit calculates the heating value according to the rms formula. This method will give the correct heating value regardless of the current wave shape.

Average responding-rms indicating tools don’t have true rms circuitry. Instead, they use a short cut method to find the rms value. These meters capture the rectified average of an ac waveform and multiply the number by 1.1 to calculate the rms value. In other words, the value they display is not a true value, but rather is a calculated

value based on an assumption about the wave shape. The average responding method works for pure sine waves but can lead to large reading errors up to 40 percent, when a waveform is distorted by nonlinear loads such as adjustable speed drives or computers. The table below gives some examples of the way the two different types of meters respond to different wave shapes.

In today’s high tech HVAC environment the best choice is to choose and use only true rms test tools for the best results.

A comparison of average responding and true-rms units

Multimeter type	Response to sine wave	Response to square wave	Response to single phase diode rectifier	Response to 3 Δ phase diode rectifier
Average responding	Correct	10 % high	40 % low	5 % to 30 % low
True-rms	Correct	Correct	Correct	Correct

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