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## **Performance Optimization Tips—Measuring the Heart Rate of Motor Systems: Electric Current**

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*Don continues his series on field measurements.*

The measurement of electric motor current is used in a variety of ways in industrial settings. Protective devices, such as fuses and thermal overload relays, work because of the heating effect of current, but current measurements usually rely on the magnetic field generated by the current passing through a conductor. Current transformers (CT)<sup>1</sup> are used to estimate this current. However, other devices, such as Hall-effect probes are also used.

Operations and maintenance personnel use current as an indicator of properly operating equipment, and use procedures or log sheets to specify "normal" current ranges. A newer use of current is to diagnose equipment health. Commercially available systems alert users to abnormal conditions, such as very lightly loaded motors (which might mean, for example, that a pump is running dry). More sophisticated techniques use information available in the motor current frequency spectrum to help evaluate the health of the motor and the device it drives.

For those of us doing energy work, current measurements often help estimate the motor load. While we're fundamentally interested in measuring input power, which requires current measurement, current alone can provide us with a means of estimating power, even when we don't have or can't use a portable power meter. For example, ITP's Pumping System Analysis Tool (PSAT)<sup>2</sup> uses average motor performance characteristics from the MotorMaster+ motor manufacturers database to estimate electric input power from current measurements<sup>3</sup>.



Figure 1. Installing a clamp-on current transducer.

Protective and operations support functions depend on permanently installed CTs. For energy measurements, we often resort to using temporary, clamp-on CTs, such as those shown in Figure 1. If a motor has permanently installed CTs (and you trust the indicator), those can be used.

### Practical Considerations for Clamp-on CTs

It should go without saying that use of accurate test equipment is of fundamental importance. But, there are several important considerations that are specific to the field use of temporary, clamp-on CTs.

1. **Make sure the jaws close properly.** This is essential to completing the magnetic circuit of the CT. If there are tight clearances where the CT is used, the jaws can bind partially open, even when hand tension is released. The indicated current may be considerably in error. Figure 2 illustrates the effect when a fixed load current of approximately 100 amps was monitored with a) the jaws of the CT fully closed and b) a gap of 0.04 inches (less than the thickness of a dime) separating the jaw faces.

To ensure the jaws are fully closed, wiggle the probe a bit, making sure it moves freely and is not bound by adjacent wires or other obstructions. At higher current levels, a magnetic "buzz" created by a slight jaw separation can be heard and felt (through gloves, of course).



Figure 2. Current indicated by current transducer with fully closed jaws (left) and 40-mil gap (right) with constant load (1 millivolt/amp scaling).

2. **When possible, measure and average all three phases.** This precaution applies to both permanent and temporary CTs. A small unbalance in the supply voltage can result in a large current unbalance among the three phases. As a rule, a 1% unbalance in voltage will result in roughly a 7% unbalance in current. Even in the presence of a balanced power supply, there may be current unbalance on the order of 5%.
3. **Use properly sized CTs.** Like most other measurement devices, CTs lose accuracy when operated at a fraction of their rated range. For example, using a 2,000-amp CT with 0.5% of full span accuracy (which is excellent) to measure a 20-amp current may result in a 50% measurement error.
4. **Average current on fluctuating loads.** Many motor loads are fluctuating in nature. The current for belt-driven equipment, for example, tends to fluctuate at belt- and sheave-pass frequencies. Some current monitoring devices grab a very short sample (a few cycles, or milliseconds) of data and display a fixed result. Other devices continuously update the data, but the fluctuations make it difficult to pin down.

A more representative measurement can be obtained on a multimeter with a min/max averaging feature. The multimeter shown in Figure 2 has this feature (note the MIN MAX button near the bottom of the picture). This feature is also helpful in averaging other system parameters that tend to fluctuate, such as pressure. If no such function is available, several samples can be statistically averaged. A computer-based data acquisition system or data logger simplifies the collection and analysis of many (and/or longer duration) samples.

5. **Make sure the current measured is really the motor current.** Power factor-correcting capacitor banks are often used with induction motors. When capacitors are used, particular care must be exercised in selecting the measurement location. The current from the line to the combination of the motor and the capacitor bank will be less than the motor current. This seemingly contradictory behavior is real, and it occurs because the current to the capacitor bank will lead the voltage by 90°, while the current to the motor will lag voltage by a variable amount, depending on load.

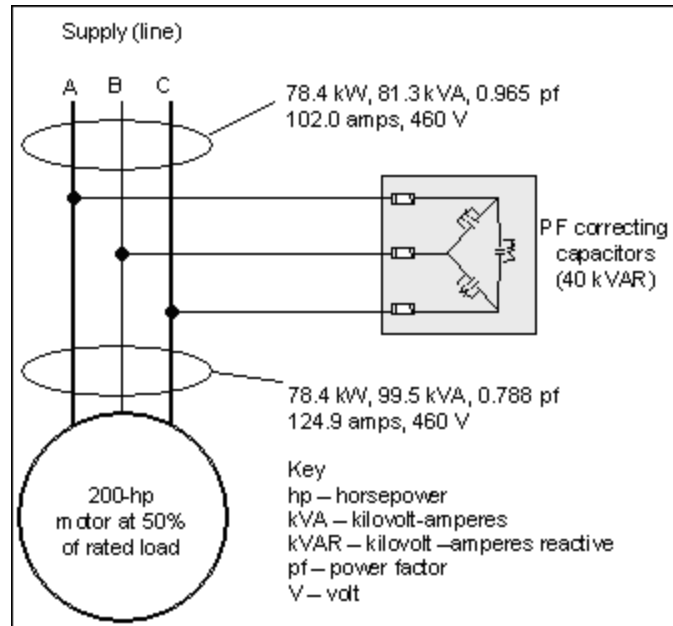


Figure 3. Motor measurements upstream and downstream of a paralleled capacitor bank.

6. If the current will be used to estimate motor load, such as when it is an input to PSAT, the current going to the motor should be measured, not the incoming current from the line. Figure 3 illustrates the error that can occur when this is not done. The current to the motor is 22% greater than the incoming line's current to the motor and paralleled capacitor bank.
7. **Take safety precautions.** This is absolutely the most important consideration<sup>4</sup>. A 50% error in the current measurement because of failure to follow previously mentioned precautions or other mistakes could result in a poor diagnosis of equipment health or a loss in company profits. But, failure to exercise proper safety precautions during testing (such as wearing insulated gloves) could result in a poor diagnosis for your health or the company's loss being you. Be careful out there!

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<sup>1</sup> CT usually refers to current transformer. However, this discussion equally pertains to Hall-effect probes; for purposes of this article, CT stands for the broader term, current transducer.

<sup>2</sup> PSAT and MotorMaster+ are available free from the [BestPractices Web site](#).

<sup>3</sup> Author's note: In my experience, the PSAT estimate of electric power (made from measured current and voltage) usually agrees with the measured power within a few percent.

<sup>4</sup> From strictly a safety perspective, I definitely prefer an instrument whose indication is NOT built into the CT. That way, I don't have to stick my nose into the electrical cabinet to get my reading.

Here are some previous articles by Don Casada on field measurements.

2000



- **Field Measurements in Pumping Systems, May/June**—Two methods of estimating flow rate in systems with no installed flow meters.
- **Field Measurements in Pumping Systems, March/April**—Understand pumping system operations by maintaining a system perspective.

#### 1999

- **Field Measurements in Pumping Systems, September/October**—Velocity is the third element of pump head.
- **Field Measurements in Pumping Systems, July/August**—Elevation is the second element of pump head.
- **Field Measurements—Practicalities and Pitfalls in a Parabolic Context, May/June**—Continues the discussion on the changing picture of system operations.
- **Understanding the Changing Needs of Your Systems, March/April**—Understanding the changing picture of system operations.

#### 1998

- **How to Cope with Potential Field Measurement Pitfalls, November/December**—Useful assessments of motor system efficiency and reliability depend on getting the right measurements in the right way.