
The Tool Lending Library has true RMS power-measuring devices, however, due to their relatively high cost, quantities are limited. True RMS power measuring equipment ranges from \$3,000 to \$5,000 per channel. The average per-channel cost of current-measuring equipment, however, is approximately \$800 - \$1,000.

In some installations (discussed below), you can calibrate several current loggers with one power meter. Once calibrated, the current data can be used as a proxy for power in that installation. This application note discusses when this is a viable alternative and when it will result in erroneous data. It will also describe protocols for using the equipment and interpreting collected data.

Why measure current instead of power?

1. Measuring current requires less space.

- Monitoring equipment is often best placed inside a circuit panel box for safety and security reasons. Space within panel boxes is usually very limited. Measuring power requires current transducers, voltage clips, power transducers/transformers and dataloggers. If this equipment cannot be placed inside the panel box, it will need to be placed on the floor or table nearby, presenting a hazardous situation (live voltage leads at the power transformers and an open panel box) or increasing the chance of equipment theft. When measuring current, however, voltage leads and power transducers/transformers are not necessary, eliminating at least half the bulk.
- Note: Power measurements will still need to be done for calibration purposes, however, the power-measuring equipment only needs to remain in place for one day as opposed to two weeks.

2. Measuring current is safer and more convenient.

For safety reasons, power to a piece of equipment should be turned off when making voltage connections. Since this is not always possible or convenient, it should be avoided whenever possible. Also, large motors and equipment tend to vibrate during operation, presenting the possibility of voltage clips vibrating loose. Although this may not cause harm to people or equipment, that set of data and time invested will be lost. Current measurements do not require making voltage connections. CT's are placed around the insulated part of the circuit legs either at the panel box or near the piece of equipment being monitored.

3. Current-measuring equipment is less expensive and more available.

As mentioned in the introduction, power-measuring equipment is much more expensive than current-measuring equipment. The chances of borrowing current loggers and transducers from the Tool Lending Library for two weeks are better than they are for borrowing power loggers. Power loggers are in high demand.

Type of load determines monitoring method

Three methods will be described for assessing power- true RMS power measurement, using current as a proxy for staged loads and using current as a proxy for variable loads. Each has its own method of analysis. These methods depend upon load characteristics- unpredictable, staged or variable. They also depend upon the voltage power factor and variations in total harmonic distortion (THD). Will there be multiple voltage power factors or changing THD readings for the same amp reading? If so, current as a proxy for power cannot be used.

True RMS power measurements

Load Type	THD
Plug loads (office equipment)	Non-linear
Any load with voltage fluctuations	Non-linear

Table 1: True RMS loads

proxy for power cannot be used and true RMS power **must** be measured. Since true RMS power data will be collected using a datalogger, there are no conversions.

In the cases listed in *Table 1*, the THD will vary significantly and a different power factor for the same current reading is very common, therefore, current as a

Calibration of staged loads

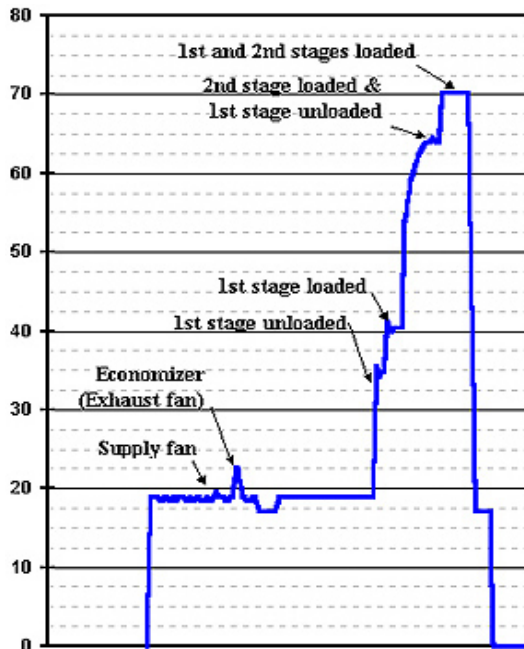


Figure 1: Graph of a rooftop AC unit's various stages.

Some types of equipment (mentioned in *Table 2*) have very distinct load stages. As the equipment being monitored goes through its various stages, "benchmarking" or "spot-checking" identifies the amount of power (kW) being used for the current being drawn (amps). From this procedure, power factor should also be recorded for each stage. Under regular operation, the amount of time it takes for the equipment to go through its full range of loads can vary from five minutes to 24 hours. Discuss this issue with the Energy Center staff or someone who is familiar with the equipment being monitored.

Some equipment such as reciprocating compressors has several stages with distinct loads. A qualified technician may be able to manually cycle the piece of equipment

through its stages as power data is being collected. This "false loading" procedure can speed up the power data collection process. Below are some examples of common equipment with staged loads.

Equipment	THD
Air-cooled chiller or packaged AC units	Linear
Switched loads (i.e. lighting or heater)	Non-linear
Cooling tower fans without VSD	Linear
Switched compact fluorescents	Non-linear
Fluorescent lighting system (non-dimming)	Non-linear

Table 2: Stage loading equipment

Calibration of variable loads

For calibrating current data to power data with a variable load, a dataset of at least 24 hours will be needed. Since the loads are constantly changing, the previously described procedure does not apply. Instead, a spreadsheet program such as Excel will be needed to run a regression analysis. The analysis will be based upon the collected true RMS power data, therefore it is important to collect enough power data to capture the expected variations during the experiment. Below are some examples of variable loads.

Equipment	THD
Constant-speed, variable load motors (fans, pumps, air compressors, etc)	Linear
Dimming fluorescent lighting	Non-linear
Fans, pumps, cooling tower or VSD's	Non-linear

Table 3: Variable load equipments

Monitoring Details

For specific instructions about the installation and use of data collection equipment, see the equipment manual or talk to the Energy Center staff. All voltage connections or any workings with equipment must have a qualified, licensed electrician or maintenance staff to handle all connections and powering of any equipment.

1. Data collection duration

The total amount of data required will also depend on the load being monitored. In most cases, two weeks' worth of data is sufficient. Collecting too little or too much data can lead to inaccurate results or needlessly large data files. When using multiple loggers, begin collecting data at the same time at the same time interval. This will facilitate data alignment and analysis.

2. Data sampling interval

The sample interval will vary by project. The collection interval should be selected on the basis of how rapidly the load varies. All major load changes should be captured. In all cases, the logger should be programmed to sample on a very tight interval, but store the average every few minutes.

Data Analysis

Once both power and current data have been collected, an establishment of a mathematical relationship between current and power needs to be done. This can be done by using regression on the coincident measurements. Most of these analysis methods can be done using Microsoft Excel's LINEST function.

Figure 2 shows the large error introduced when simply multiplying voltage by current (middle, red line). The overall error, however, can be minimized by using Excel's LINEST function. In the graph below, the green line (lowest level line) is the line generated by Microsoft Excel's LINEST function. Note that it tracks the true-RMS power line as measured by the Synergistics logger. It tracks so closely that the true-RMS line is barely visible. If the collected power data is representative of the data for the whole two week monitoring period, then the calculated power will be very close to the actual power. In this case, the error was less than 0.5%.

For detailed instructions on using regression analysis with your current and power data, see our *Regression using the Excel LINEST Function* application note.

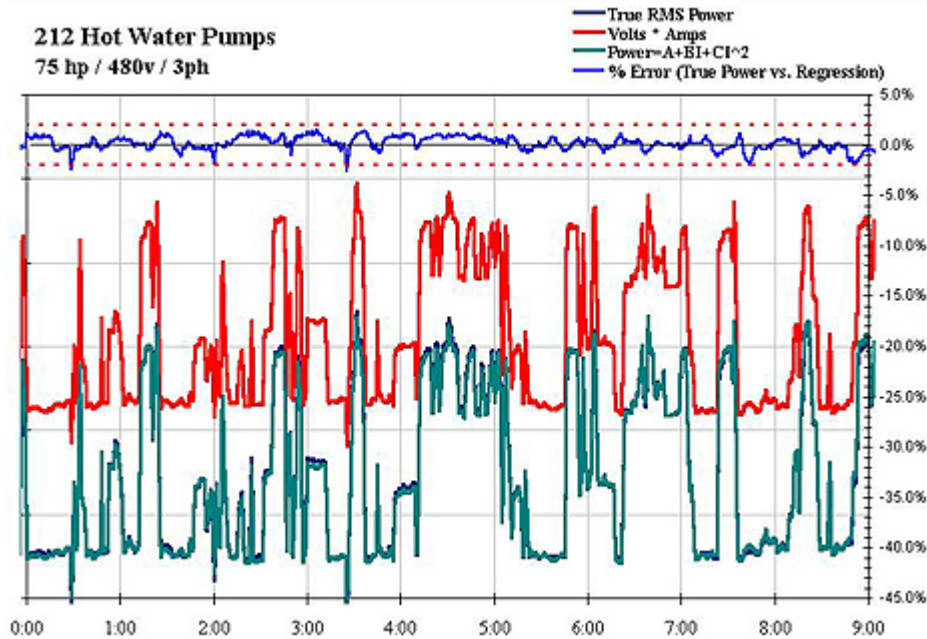


Figure 2: Graph comparing three ways of obtaining values for power.

To compare current data logged from the current logger with current data from the power logger, current readings will need to be collected from both loggers. Usually, slight variations can be noted in the current data from the different sources. Often this is due to using different current transducers from various companies with different accuracies and ranges. Using the current data from both loggers a common correction factor can be calculated and can be multiplied by both data sets to correct the discrepancy.