Measuring Current and Power

Overview

This document covers the different current transducers available and how they should be implemented for the purpose of power quality analysis or power monitoring. Magnelab acknowledges the contribution of National Instruments white paper at http://zone.ni.com/devzone/cda/tut/p/id/8198#toc0#toc0

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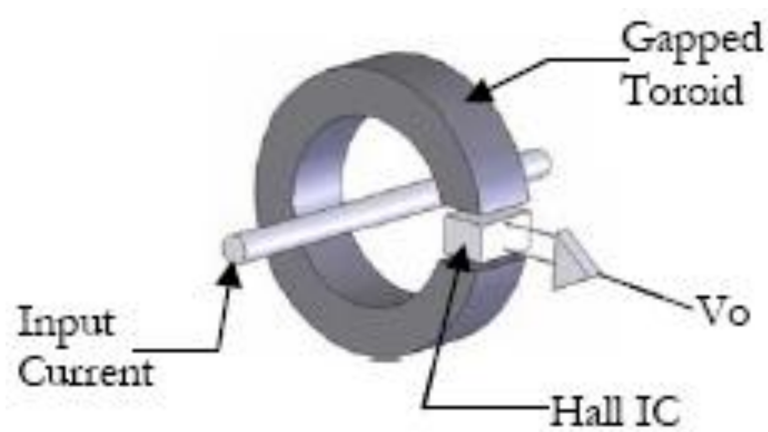
Current Transformers and Transducers

Safely measuring large currents in a laboratory or production setting presents many challenges not associated with typical signal acquisition. Measuring the voltage across small burden resistors placed in the circuit is often impractical, and can be potentially dangerous. Common instruments such as digital multimeters can typically measure currents on the order of a few amperes, but these generally have limits on the length of time that can be observed, and significant care must be taken to avoid damaging equipment or causing injury. More importantly, however, many users need to measure currents considerably larger than can be safely measured through such direct connections.

To measure high currents safely, the typical practice is to use a special purpose Current Transformer (CT) or transducer which reduces the magnitude of the current in the circuit to a more manageable level. As with other sensing technologies, there are a variety of types of these sensors suited for different applications.



Split Core vs. Solid Core

Current transformers may be split core (open) or solid core (closed). Current transformers use inductance to measure current, and as such the circuit must pass through the sensor at least once, though multiple turns can be used to multiply the current output. When installing CT's in existing circuitry, split core CT's are often seen as advantageous, as they can be opened and placed around existing wires without disrupting the circuit. Solid core CT's, on the other hand, require the circuit to be rewired in order to pass through the core. Because installation costs can easily exceed the price of the sensors themselves, split core sensors, though more expensive to purchase, may actually reduce the total cost of implementation. Solid core transformers may be preferred, however, in situations where extremely precise measurements are needed, as they are generally more accurate than similarly priced split core devices.

Magnelab Split core CTs cost more but provide for easier installation

Magnelab Solid core CTs are more accurate for a lower cost

Output and Integration with Measurement Systems

Care must be taken when integrating current sensors into a measurement system, as different sensors outputs differ significantly. Connecting the wrong sensor to your equipment, or connecting a sensor improperly can damage both the measurement equipment and the sensor, and can present a significant safety hazard to personnel. It is essential to know which type of sensor you are purchasing and how that sensor interfaces with instrumentation.

Current transformers broadly come in two different output configurations: current outputs and voltage outputs. Sensors which output voltage signals proportional to the current on the primary of the transformer are often rated in volts per primary ampere, e.g. 0.1V per amp. These sensors typically contain a precise burden resistor internally which allows the secondary current to be measured as a voltage. Sensors which output directly to a voltage can be connected to most standard test equipment, so long as the expected voltage does not exceed the ratings of the equipment. The signals produced by these sensors are low energy and may safely be connected and disconnected without damaging the sensor. Because they are low energy signals, however, they are subject to interference and signal degradation, and are not always suitable when leads must be run over extended distances between the sensor and measurement equipment.

Other current transformers output current waveforms at their secondary terminals. These sensors produce high energy signals which can produce significant safety hazards if not properly handled. The secondary terminals of these transformers are generally constructed to output a nominal 5 ampere AC (AAC) or 1 AAC signal, and cannot be directly connected to most standard equipment. A 500:5 CT, for example, would produce 5 AAC of secondary current when 500AAC passed through its primary. It is extremely important that the secondary terminals of these CT's not be in an open circuit configuration if current is passing through the primary coils, as dangerous voltages will occur across the secondary, and the sensor could sustain permanent damage. For this reason, CT secondary circuits which output currents should never be fused. In order to use these sensors with measurement equipment that does not accept current inputs, an external burden resistor is necessary. In order to preserve signal integrity, this resistor is generally placed as close to the measurement equipment as is practical. Contact the manufacturer of your test or control equipment if you are uncertain of whether it accepts voltage or current inputs.

Basic current sensors and current transformers will not perform any form of computation or analysis on a power circuit. Measurements such as RMS, power factor, power, peak-peak, phase and many others are fairly common and require more expensive sensors or can be calculated with output from a basic current sensor/transformer and software. For test systems used in design or manufacturing test, it is often preferred to have a system perform the calculations in software due to the specific and unique requirements that come with product design and validation.

See Magnelab Current Sensors and Transformers

Magnelab produces a variety of Split-Core and closed current transformers to measure current from 1 to 5,000 Amps.

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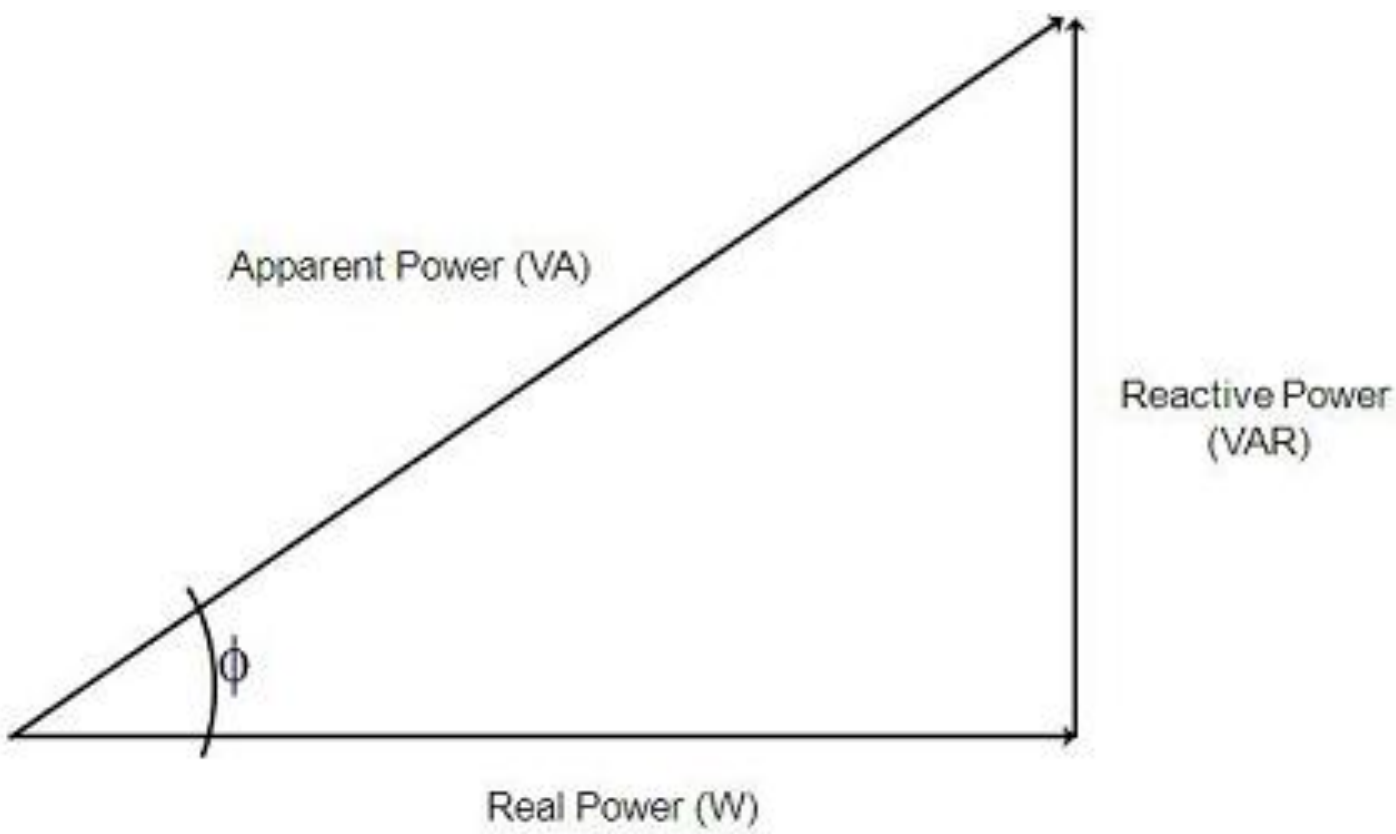
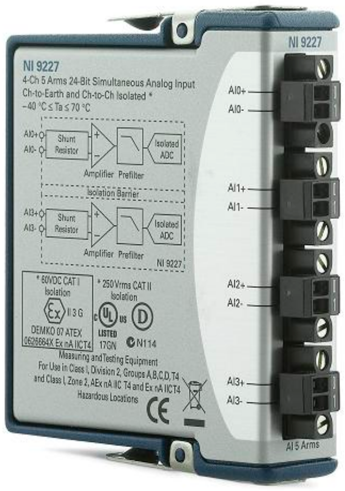
Measurements Needed

The fundamental power measurements, as seen in figure 2, are represented in what is known as the power triangle. Using the three measurements of **voltage**, **current**, and the **phase offset** between the V and I waveforms, the entire triangle can be computed.



Measuring Voltage

NI offers a wide selection of voltage measurement modules but for waveform power measurements the suggested modules will be the NI 9239 for 10V measurements, the NI 9229 for 60V measurements, and the NI 9225 for up to 300 Vrms measurements. All three of these modules are simultaneously sampled which is needed for phase measurement and have 600 Vrms CAT II channel-to-channel isolation for safety. Though it is most convenient to have a direct connection to the module for voltage measurements, for voltages above 300 Vrms a power transformer (PT) can be used to step down the voltage similar to the current transformers that have been discussed earlier in this paper.



The NI 9225 can measure up to
300 Vrms

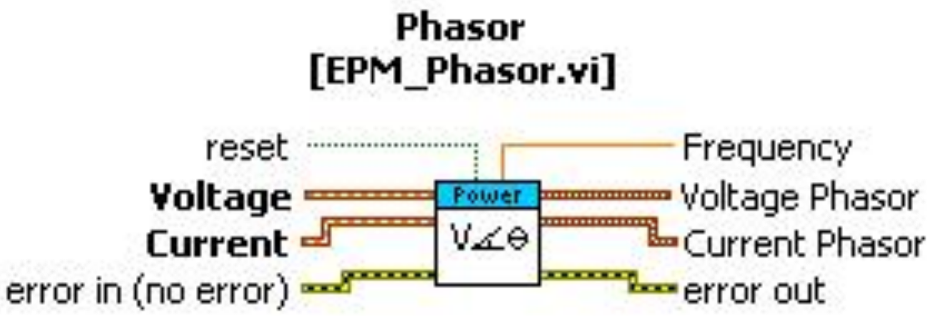
Measuring Current

Since many current sensors can output voltages proportional to the current flowing through their secondary, there are several NI products that can be used for high current measurement. For a 10V output sensor, use the NI 9239. For a current transformer that outputs 1A or 5A, use the NI 9227. These modules operate on the same architecture as the NI 9225 making them the ideal choice for synchronization. Selection of an analog input module for current measurement will depend on the particular current sensor chosen, as well as the maximum current expected on the measured circuit. While NI hardware meets all industry standards for voltage isolation and withstand, improper selection of analog input modules can result in measurement saturation or damage to the module if the sensor output voltage exceeds the module's rating. When calculating the maximum sensor voltage output, remember that many industrial machines may have startup transient currents many times their normal load rating. It is not uncommon to see transient currents which are four to ten times rated load current. Check the datasheet for the individual module you are considering to determine whether it is appropriate for your application.

The NI 9227 can measure up
to 5 A directly

Measuring Phase Offset:

To make a phase offset measurement between the two waveforms of voltage and current the channels need to be synchronized. This is accomplished by using the two modules, such as the NI 9225 for voltage and NI 9239 for current, in the same CompactDAQ or CompactRIO chassis. These backplanes will run all of the channels on the same internal clocks providing synchronous data. With this synchronous data, phase offset can be computed in software. Many software packages have built in functions for this analysis the easiest of which would be to install the Electrical Power Measurements palette for LabVIEW from the Electrical Power Measurement Tutorial and use the "EPM_Phasor.vi". For more information on phase see the Phase Modulation tutorial.



Given inputs of V and I waveforms, this function will return RMS and phase angle calculations for each component

This phasor indicator is included with the Electrical Power Measurement palette

Suggested Components for a three phase system

•1 NI CompactDAQ chassis (cDAQ-9172) OR CompactRIO Chassis (many options available)

•1 NI 9225 – 300Vrms Analog Input module for voltage measurement

•1 NI 9229 (60V_{p-p}), NI 9239 (10V_{p-p}), or NI 9227 (5A_{RMS}) Analog Input module (connected to current sensor)

•Current Sensor (see Magnelab Current Transformers or Transducers, one per phase)

This recommended system can measure a single-phase two-wire, single-phase three-wire, or three-phase three-wire system. The NI 9225, NI 9229 and NI 9239 use 24bit resolution analog-to-digital converters (ADC) to acquire data at 50kS/s/ch which is important if a calculation for transients and harmonics is needed. The modules are not only simultaneous sampling (one ADC per channel), but are automatically synchronized within the backplane which is critical when measuring the phase angle between the current and voltage on a single line.

Software Calculations for a Flexible, Expandable test or control system

Analysis functions for all of the fundamental power calculations discussed in this paper can be found in the Electrical Power Measurements resource kit available online. These common functions include:

•Voltage and Current Phasor Calculation (RMS value pared with phase angle)

•Phasor Diagram

•EPM_Power.vi

- Real Power (Watts)
- Apparent Power (VA)
- Reactive Power (VAR)
- Power Factor

A complete USB-based system using the NI 9225 and NI 9227 modules for power measurements can be found in the Electrical Power Measurement System.