10+1 Reasons You May Not Be Measuring Power Accurately

Table of Contents

10+1 Reasons You May Not Be Measuring Power Accurately

Energy efficiency is the most common discussion point in all forms of sustainable energy, and whenever this topic is discussed, the importance of power measurement goes to the top of the priority list. Manufacturers today offer a wide range of power measuring instruments backed up with seemingly impressive specifications, but how do potential users decide which parameters are relevant to their specific application? This article looks at some of the factors that can affect the accuracy of power measurements and shows how users can address the challenges presented by the need for accurate energy-efficiency testing.

1. Understanding Measurement Specifications

Manufacturers' specifications will often include terms such as "guaranteed" and "typical" values. In fact, Yokogawa is the only manufacturer of power meters that guarantees the power measurement uncertainties published in their data sheets. Some manufacturers use typical values in their published data, which can often mislead customers.

Typical values are usually a reference value based on what a manufacturer expects from their product, but these values are not usually 100% guaranteed. This is the reason why many manufacturers' specifications for typical values are much better than the guaranteed values – and is also why Yokogawa power analyzers, when calibrated, provide accuracies which are five to ten times better than the published specifications.

2. Accuracy vs. Uncertainty

Increasing the energy efficiency of a product - even by a few decimal points - is both an important goal and a major challenge for manufacturers. To validate small improvements in efficiency, R&D teams need to understand the total accuracy or uncertainty of their power analyzers. As a manufacturer, it is important to know all the factors influencing the uncertainty of an instrument. In many cases, for example, customers evaluate power analyzers with respect to voltage and current uncertainty, but what they should really be looking at is the power uncertainty. In addition, when considering power accuracy, the evaluation should consider not just the basic parameters but also other factors such as crest factor, phase angle error, temperature range, warm-up time, stability period and common mode rejection.

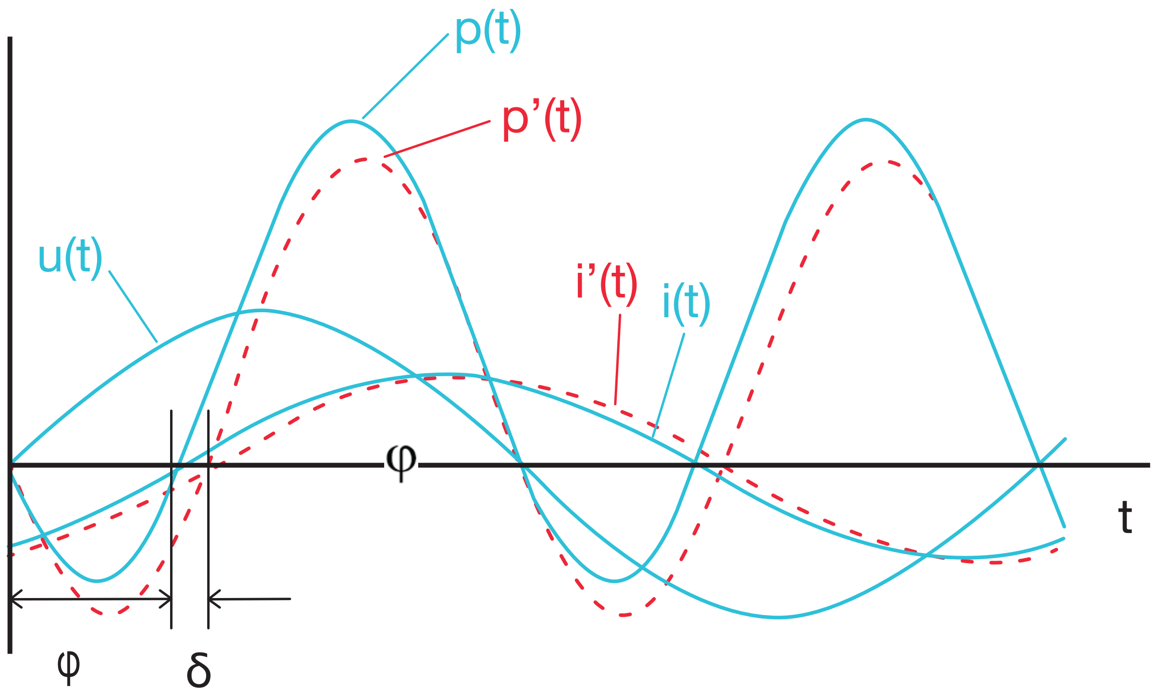
3. Measurement Range

Measurement range is often inadequately specified in manufacturer's data. This is an important point because the uncertainty of a power measurement varies depending on the measurement range, and so the accuracy value should specify the range over which it is valid. Without specifying the measurement range, users will find it difficult to know whether the accuracy values are valid only at a single point or at a few points of measurement range.

Accuracy of an instrument when its range is specified in peak values appears to look far more impressive than when using root mean square (rms). However, an accuracy value of 0.1% for example from a peak measurement range can correspond to 0.3% of an rms measurement range for a crest factor of three. So the effect on the overall measurement error of a range error of 0.1% on a peak range is much worse than a 0.1% error on an rms range. When calculating active power, the multiplication of voltage, current, the power factor, and higher crest factors will magnify this effect dramatically.

4. Phase Error

Every power meter has a phase error associated with it which cannot be ignored in the uncertainty calculations. The voltage and current inputs fed to the A/D converters are not normally in phase, resulting in a phase error which is represented in the simple active power formula for pure sine waveforms as: P = (Vrms) * (Irms) * cos (± δ) where δ is the phase error.



$$u_{(t)}=U_{pk}\sin(\omega t) \qquad i(t)=I_{pk}\sin(\omega t-\varphi) \qquad i'_{(t)}=I_{pk}\sin(\omega t-(\varphi+\delta))$$

While this has no effect on rms voltage or current or apparent power measurements, it does influence the measurement of active power and hence also the power factor. This phase shift should be specified by power analyzer manufacturers to account for all boundary conditions that can affect phase angle error and other measurement errors.

5. Common Mode Rejection Ratio

The common-mode rejection ratio (CMRR) is the rejection by the device of unwanted input signals common to both input leads of the voltage input. Here, the two input terminals are connected to each other; the reference point is the device ground. Ideally, this should have no influence on the measurement result, but in fact leakage causes an interference voltage as a function of the symmetry of the input circuit. In practical terms, the noise voltage superimposed on the signal to be measured leads to measurement errors. Therefore it is important for the customer to take into account this error in their uncertainty calculations. Common-mode noise is especially present in inverter style applications because of the presence of high voltage potentials with high-frequency components to ground. Yokogawa power analyzers have their CMRR specified and can be used while calculating the uncertainties.

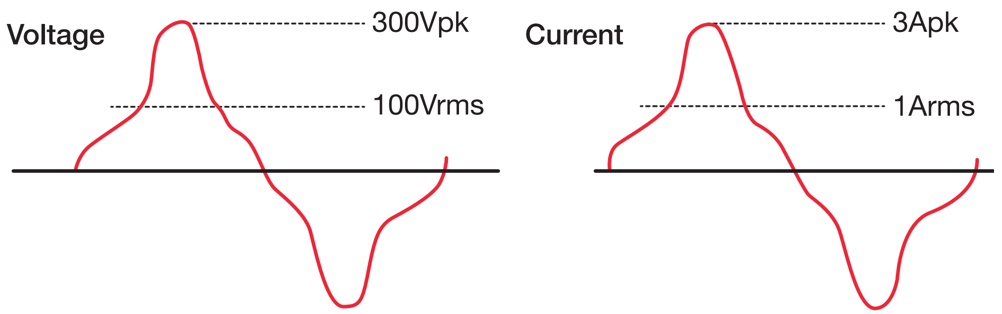
6. Crest Factor

For evaluation purposes, accuracy calculations are usually done using sine waves at a frequency of 50-60 Hz and a power factor of one, which means that all the energy supplied by the source is consumed by the load. The basic accuracy for voltage, current and power is specified as a percentage of the measured value and a percentage of the measurement range, which can be defined with respect to the peak or rms values. In order to understand the measurement range error, it is important to understand the effects of the crest factor, defined as the ratio of the peak value to the effective rms value of the waveform.

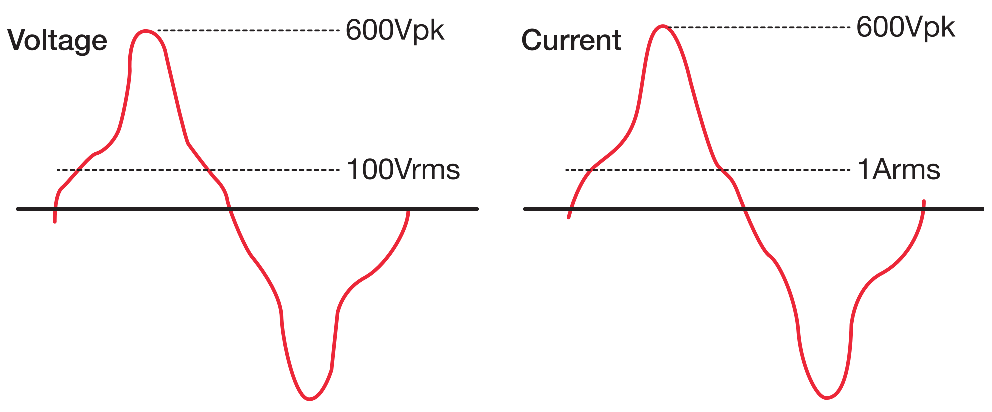
For a power meter, crest factor has significance in two ways. One is the specification of the power meter itself as it shows the capability of the instrument to measure correctly, irrespective of how much the waveform is distorted. The other is the measurement of the crest factor of the input voltage or current of an input signal, which provides an indication of the quality of the input signal.

For a measuring instrument, the crest factor expresses the extent of the dynamic range for an input signal. We define the crest factor as the value of the dynamic range based on the rated range value (rms value). For example, the crest factors of Yokogawa power meters are usually given as three or six. This means that it is possible to measure the input signal with a peak value three or six times larger than that of the rated range value. For example, using 100 V rms and 1 A rms ranges, the available input voltage and current signals are as follows:

When CF=3



When CF=6



If the input rms value is lower than the rated range value, the power meter can measure signals with a larger crest factor. The WT series can display values when the signal is more than 0.5% of the rated range value. If the input rms value is 0.5% of the rated range and input peak value is three times larger than the rated range value, the crest factor becomes 600. If an input exceeding the value shown in the specifications is measured, the peak area of the waveform is clipped to cause an error. Therefore a crest factor of three means that the maximum allowable input is three times the input rated rms value.

7. Challenges in Current Measurement

Current sensors are often used in addition with or as an extension to a power measurement instrument. This means that the error/uncertainty in the sensor will get added to the uncertainty of the input of the voltage as well as current shunt. It is therefore important to choose a sensor whose amplitude and phase uncertainty matches those of the high precision power analyzer. There are different types of current sensors in the market. For high accuracy power measurement, the zero flux sensor is most often used. Unlike Hall effect sensors that saturate over time or Rogowski coil sensors that offer lower accuracy, zero flux sensors offer greater precision. They are also able to measure both DC and AC signals, which is important as invariably AC applications also have a DC component.

8. Temperature Effects

Electronic circuits behave differently at different temperatures, so a temperature coefficient should be specified to account for the associated temperature effects. The wider an instrument's temperature range, the better. An instrument with specifications of 23°C ± 5°C for example can withstand temperature fluctuations (in heat producing measurement environments for example) better than an instrument with a 23°C ± 2°C specification. Unlike instruments that become unspecified outside a small temperature range, instruments with wider ranges don't need expensive cooling solutions.

9. Zero Crossing Detection

For accurate power measurement, it is necessary for the power analyzer to have accurate zero-crossing detection. Yokogawa power analyzers have frequency-measuring hardware for zero-crossing detection which identifies the fundamental frequencies in the pulse-width-modulated (PWM) signals. This is achieved by using a synchronization technique known as "average for the synchronous source period" (ASSP). For complex PWM signals which have many harmonics, alternative measurement methods that determine the zero crossing by means of software cannot achieve high measurement accuracy for current, voltage and active power. In order to get precise measurements of the effective power, it is essential to ensure that the current and voltage samples are synchronized, especially when low power factors and/or high frequencies are involved. The instantaneous values of power are then integrated within the defined measurement interval to get the effective electrical power which can be displayed as a waveform or numeric depending on the customer's preference.

10. High Precision Harmonics

Harmonic measurement is another area where it is important to specify the accuracy in the context of the application. When left unaccounted for, harmonics can cause capacitance losses, undesired vibrations in motors, transformer losses in no-load conditions, heating losses in conductors at higher frequencies, premature melting of fuses when electronic breakers don't respond at designed levels and many more. It is therefore important to equip an engineer with the ability to detect harmonics and assess their effects on components, systems and subsystems within an application. When measuring harmonics, it is important to ensure the harmonic measurements have a specified accuracy. Additionally, the technique to determine zero crossing and duty cycle is important since many instruments use incomplete cycle data in their harmonic calculations, resulting in spectral leakage. A technique using a phase-locked-loop (PLL) can ensure proper zero crossing is used in the harmonic's calculation. Highly accurate instruments can measure harmonics upwards of the 500th order.

+1. The Importance of Calibration

No measurement is ever "correct." There is always an unknown, finite, non-zero difference between a measured value and the corresponding "true" value. In other words, a user can never be 100% sure that an instrument is operating within its specified tolerance limits. Regular accredited calibration is a method for gaining quantifiable confidence in a measurement system by comparing the instrument's performance to a standard of known accuracy. It is also advisable to calibrate not just the measuring instrument but the extended measurement setup including sensors, cables, shunts and other devices that are part of a test bench. But it's not enough to calibrate at 50 - 60 Hz. Applications such as switch-mode power supplies, electronic lighting ballasts, soft starters in motor control systems and frequency converters in traction application, etc., consume power at higher frequencies. Most calibration facilities do not calibrate at frequencies much above 60 Hz and well short of 100 kHz, and without an ISO 17025 accredited power calibration there is no guarantee that the measurements on an ISO 9001 certificate are correct. Depending on age and quality, a measurement instrument may drift out of specification due to temperature, humidity, oxidation, loading, etc., and may need to be "adjusted" to bring it back within specifications. Instruments that need frequent or extensive adjustments are unreliable compared to instruments that only need this when a serious damage is being repaired.