SOLAR PV

Meeting The Accuracy Demands Of Measurements On Alternative Energy Systems

BY CLIVE DAVIS

Yokogawa Europe & Africa

The demand for increased energy efficiency in solar energy production and other forms of alternative energy generation is driving the development of more accurate measuring instruments in order to provide an exact quantitative analysis of the savings that can be achieved. Devices such as solar inverters, for example, are already working at overall efficiencies of 90-96%. To increase the efficiency, even by few decimal points, is a challenging and important goal for the inverter manufacturers: hence the need for high-accuracy power analysers that can provide the necessary levels of precision to truly confirm the smallest improvements in efficiency.

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For engineers carrying out these measurements, it is important to know all the factors influencing the uncertainty of their measuring instruments. Users of power analysers often evaluate their performance with respect to voltage and current uncertainty, but what they should really be looking at is the power uncertainty. This evaluation should also consider not just the basic parameters but also other elements such as crest factor, phase angle error, temperature range, warm-up time, stability period and common-mode rejection.

Specifications of power analysers

The specifications of test instruments will often include terms such as "guaranteed" and "typical" values. Some product manufacturers use typical values in their published data, and this is something that can often mislead customers. Typical values are usually a reference value based on what a manufacturer expects from their product, but these

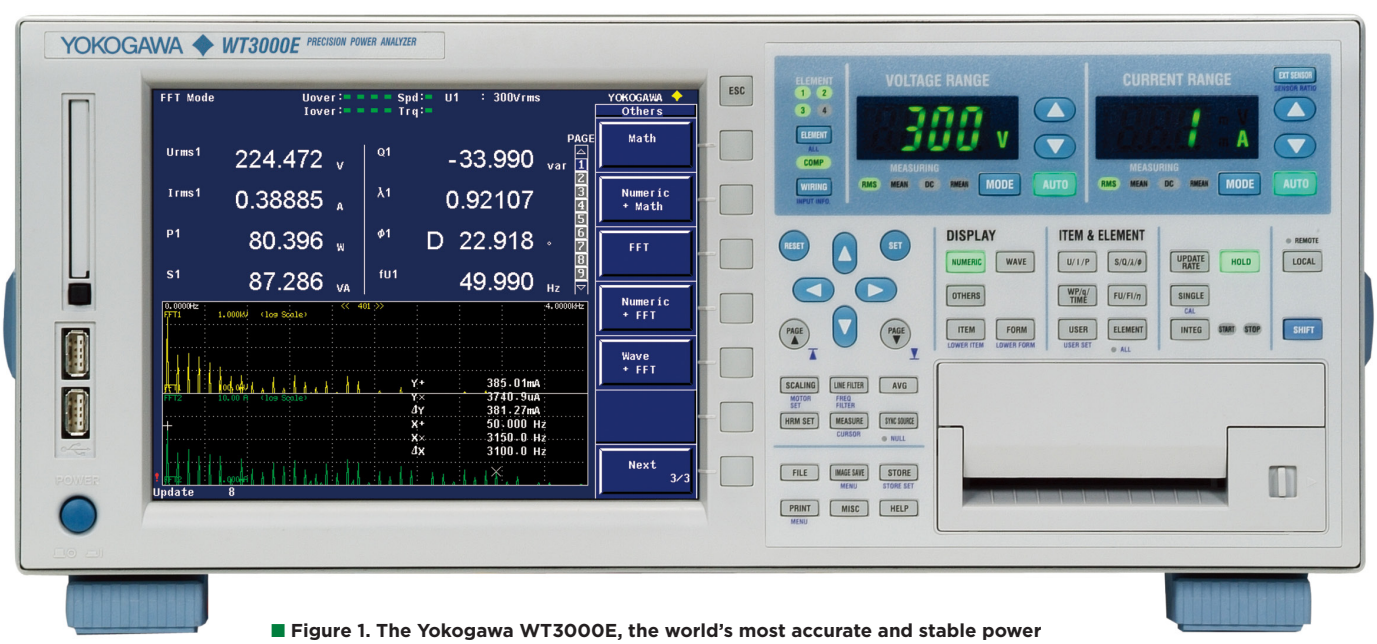

Figure 1. The Yokogawa WT3000E, the world's most accurate and stable power analyser, has a specified 45 to 65 Hz accuracy of 0.01% of reading plus 0.03% of range.

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 analysers, when calibrated, provide accuracies which are five to ten times better than the published specifications. In fact, Yokogawa is the only manufacturer of power meters that guarantees the power measurement uncertainties published in their data sheets.

Measurement range

Another factor that is often inadequately specified in manufacturers' data is measurement range. 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. For example the power accuracy of the Yokogawa WT3000E (Fig.1) – the world's most accurate power analyser - is valid from 1% to 130% of the measurement range. Without specifying the measurement range, a user 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. Again, Yokogawa is the only power analyser manufacturer to specify the measurement range for its products.

Harmonic measurements

Harmonic measurement is another area where it is important to specify the accuracy in the context of the application. Every Yokogawa power analyser has an additional oscillator dedicated to phase-locked loop (PLL) measurement which provides high-precision harmonic measurement. With the help of this dedicated oscillator and powerful digital signal processing, the frequency spectrum can be analysed up to the 500th order (depending on the instrument) harmonic simultaneously with the normal measurement. In addition, because of this dedicated circuit, it is possible for Yokogawa to specify the accuracy of the harmonic analysis – something that is not the case with many other manufacturers.

Crest factor

For evaluation purpose, 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.

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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.

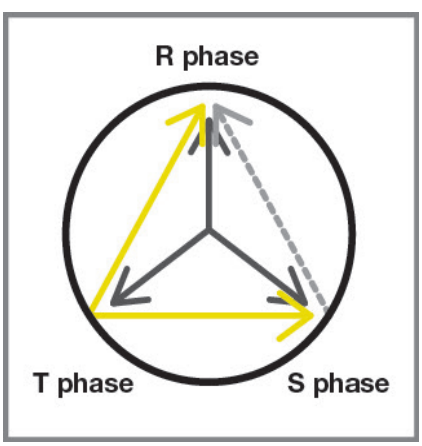

Figure 2. Delta calculation allows users to calculate individual phase voltages from the line voltage measured in a 3-phase/3-wire system.

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.

The measuring ranges of Yokogawa power meters are defined with respect to the RMS value, which means that the crest factor of the power analysers is three or six. If the range was defined using the peak value like other manufacturers, the maximum crest factor of Yokogawa power analysers would be 300. For example, in the range 100 V RMS with the crest factor set to three, peaks of ±300 V could be easily detected. By using the crest-factor formula, we get 300 V peak divided by 1 V RMS, giving the result as 300. Note that this is 1% of the range and therefore the accuracy specification is also still valid (as previously mentioned).

Peak and RMS measurement

Some power meters use RMS measurement ranges and others use peak measurement ranges. Relating the accuracy information to peak values looks impressive at first sight, but in reality it is not. For example, the accuracy value of 0.1% from the peak measurement range corresponds to 0.3% of the RMS measurement range at a crest factor of three. For active power calculation, the multiplication of voltage and current (and power factor) will enhance the effect dramatically. Yokogawa uses RMS values for both measurement range setting and tolerance calculation.

Phase error

Every power meter has a phase error associated with it which cannot be ignored in the uncertainty calculations, particularly in current measurement where using a current shunt can cause a phase shift. This phase shift must be specified by the manufacturers of power analysers. Yokogawa specifications consider all possible boundary conditions that can lead to a phase angle error or measurement error, and are included in the calculations.

Common-mode rejection ratio (CMRR)

The common-mode rejection ratio (CMRR) is the rejection by the device of unwanted input signals common to

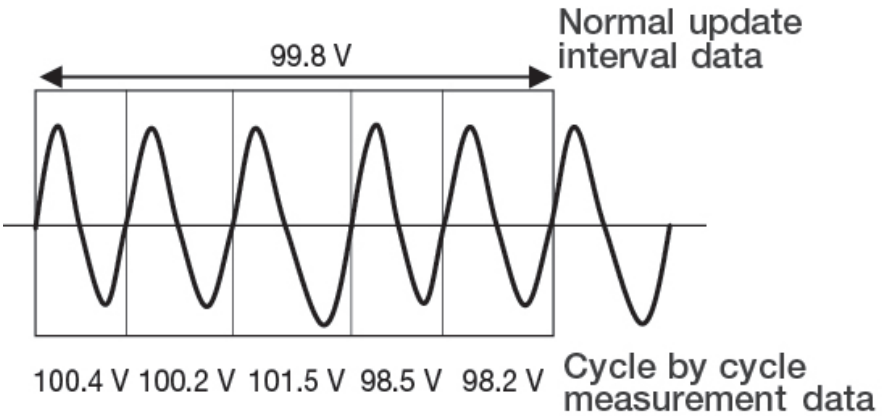

Figure 3. Cycle by cycle analysis enables users to list the measurement parameters such as voltage, current, and active power for each cycle in time series.

both input leads of the voltage input. 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 analysers have their CMRR specified and can be used while calculating the uncertainties.

Temperature effects

Another factor that affects the accuracy of a power analyser is the effect of temperature. Yokogawa uncertainty specifications are specified at 23° C ± 5° C. In some cases manufacturers indicate different temperature ranges: for example, only 23° C ± 2° C: a much lower figure which adds significant uncertainty.

Achieving optimum maximum accuracy

The specified 45 to 65 Hz accuracy for Yokogawa's most accurate instrument, the WT3000E, is 0.01% of reading plus 0.03% of range. As indicated above, these figures are based on RMS values rather than waveform peak values, confirming the superiority of the instrument. Because power ranges are the multiple of the voltage and current ranges, the actual power measurement error due to an uncertainty of 0.03% of range in a WT3000E is less than 0.01% of range for a power meter based on peak values.

The WT3000E also provides the flexibility to mix 30 A and 2 A input current elements, which enables users to test the compliance of their products with today's harmonics, flicker and standby power standards in a single instrument.

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Like other models in the WT3000 Series, the WT3000E has a variety of alphanumeric and graphic display formats, including the ability to display the input signal as waveforms for easy analysis. It also offers high-speed data updating which allows users to capture fast-changing transient signals with high precision. Further analysis can then be performed using the captured data. The WT3000E also includes as standard two features previously only available as options: delta calculation and cycle-by-cycle analysis. The delta calculation function (Fig. 2) allows users to calculate individual phase voltages from the line voltage measured in a 3-phase/3-wire system: an important feature for determining the phase voltage in applications such as motor testing where there are no neutral lines.

Cycle-by-cycle analysis (Fig. 3) enables users to list the measurement parameters such as voltage, current and active power for each cycle in a time series. Input frequencies from 0.1 Hz to 1000 Hz can be measured, and up to 3000 items of data can be saved in .CSV format. In addition, by using Yokogawa's free WTViewerEfree software, users can graphically display the data by cycle: a unique method of capturing fluctuating transient power with high precision.

IEC Standards compliance

Using the harmonic measurement mode (/G6 option), the WT3000E provides 100% compliance to harmonic measurements in conformance with the IEC61000-3-2 standard, enabling users to easily perform harmonic analysis during the evaluation of their products. With the voltage fluctuation and flicker measurement option, various values related to voltage fluctuation that are stipulated by the IEC61000-3-3 standard can be calculated from the measured data. This enables users to judge whether the voltage fluctuations in the device under test, relative to a specified minimum value, are within the IEC standard requirement.

Calibration

The guaranteed accuracy and precision of the WT3000E and other Yokogawa power measuring instruments is verified by calibration carried out at the company's European standards laboratory at its European headquarters in The Netherlands. This facility is the only industrial (i.e. non-government or national) organisation in Europe to offer traceable power calibration, to national and international standards, at frequencies up to 100 kHz: a requirement for higher harmonic measurements specified in quality standards such as ISO9000.

As a result, the WT3000E is not only the benchmark for energy efficiency measurement but can also be used as a reference for calibrating power measuring instruments in standards laboratories.

Clive Davis studied Physics and Electronics at Brunel University. After a period as a development engineer in the field of non destructive testing, he joined the world of test and measurement in 1985 and has gained nearly 30 years of practical experience in helping engineers solve their measurement challenges. He has written numerous articles on measuring techniques and applications in the fields of power and waveform measurement. Currently he is the Marketing Manager for Yokogawa Test and Measurement for Europe and Africa, based in the Netherlands.

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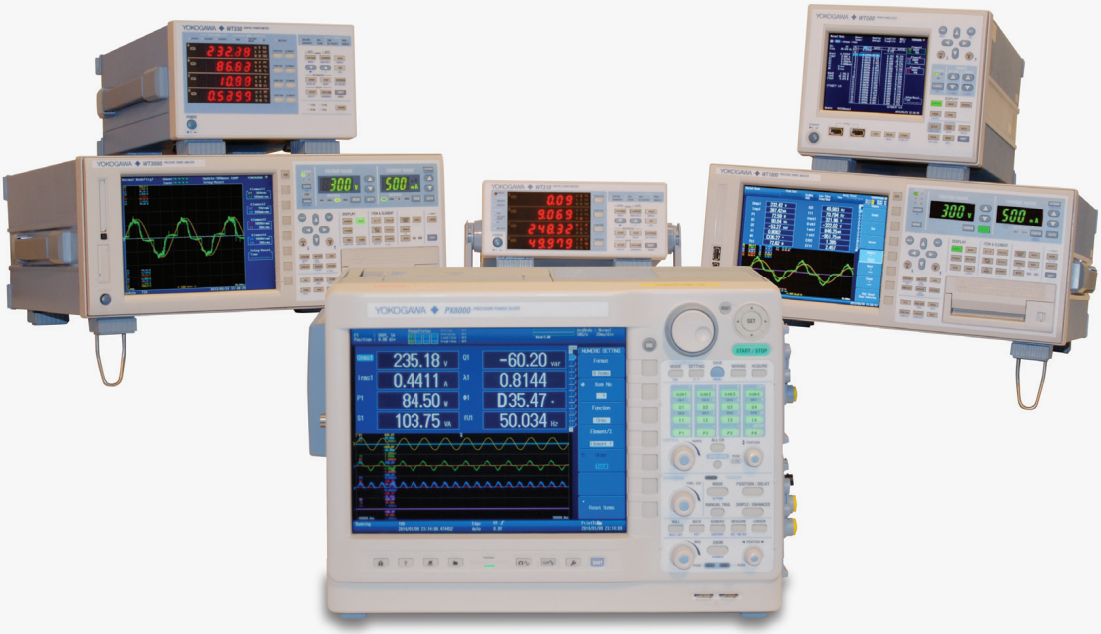
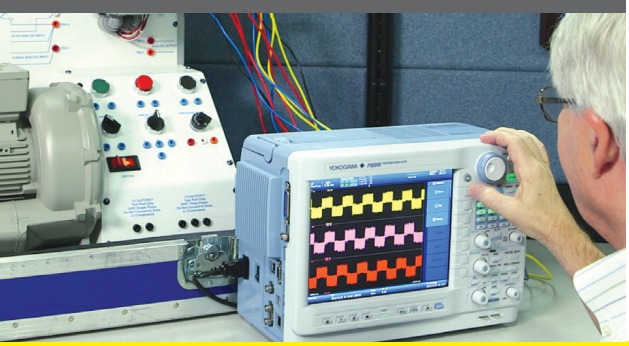


With 100 years of expertise and leadership in the precision measurement of power, Yokogawa provides a wide range of products for power analysis.

To support the development of alternative energy sources and to validate improvements in efficiency and power consumption, Yokogawa provides trustworthy measurements for both low and high frequency applications.



Accurate power measurements

3 of the things you need to know

- How accurate are your power measurements?
- The effect of internal phase shift on power measurement uncertainty
- Calibration:
  the key to meaningful power measurements

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