Choosing the Right Instrument for Power Quality and Energy Efficiency

Power Compliance, Efficiency, and Harmonics Tests

Introduction

More than 40 percent of the total energy consumed in the United States is used to operate buildings, and most of that is consumed by appliances and building-related equipment. The U.S. Department of Energy (DOE) implements minimum efficiency standards for a wide range of appliances and equipment used in residential and commercial buildings. Currently, DOE efficiency standards cover more than 60 categories of products.

With increased focus on reducing energy consumption and compliance with efficiency standards, the following provides an overview on the types of measurements needed for efficiency and power quality and the instruments that take them.

Precision Making

The Background

Power quality, power efficiency, and power compliance are terms often used interchangeably, but actually have different meanings depending on the industry being referenced.

The three variables to consider when choosing the best instrument for power compliance and power quality measurements are measurement type, measurement standard, and instrument type.

This application note defines these variables and provides guidance along a clear path to making the most accurate power quality, efficiency, or compliance measurement.

Measurement Types

The measurements in Table 1 comprise a good generalization of typical measurement types that span various applications and industries.

Measurement Type	Definition
Energy Over Time (Wh)	Power integrated over time, also called Joules
Harmonics	Sinusoidal voltages or currents having frequencies that are integer multiples of the fundamental frequency
Electromagnetic Compatibility	Measures compatibility of equipment with its electromagnetic environment and EMI interference it causes in other devices
Voltage Swell	Increase in the root mean square (rms) voltage level to 110%-180% of nominal, at the power frequency of ½ cycle to one minute
Voltage Dip/Sag	Decrease in the rms voltage level to 10% - 90% of nominal, at the power frequency for durations of ½ cycle to one minute
Voltage Interruption	Momentary or long-term power disruption
Flicker	Systematic variations of the voltage waveform envelope, or a series of random voltage changes, the magnitude of which falls between the voltage limits set by ANSI C84.1 (applies mainly to lighting or displays)
Transient Overvoltage	Power quality disturbances that involve destructive high magnitudes of current, voltage, or both
In-Rush Current	Maximum instantaneous input current drawn by an electrical device when it is first turned on
Voltage Ripple	Alternating component of the unidirectional voltage from a DC power source
Current Spectrum	The current amplitude versus frequency plot at steady state

Table 1. Measurements used to quantify power quality and efficiency.

Measurement Standard

While the number of power standards is in the hundreds, those listed in Table 2 represent the more common requirements. The standards are often specific to an industry, though some span a few, in which case the test criteria can be similar.

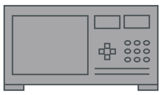
Industry/Market	Standard Compliance
Appliances	IEC62301 (Energy Star)
	EN 50564: 2011 (standby power)
Power Generation/ Grid Tied	UL1741SA
	IEC 61000-4-7
	IEC/EN 61000-3-2
	IEC/EN 61000-3-12
Industrial	IEEE519-2014
	IEC 60034-30-2
Mil/Aero	MIL-STD-704
	MIL-STD-1399
	DO-160
HVAC	DOE-STD-1153-2002 /M1
	ANSI/AHRI 210/240-2008
Lighting	IEC/EN 61000-3-3
	IEC/EN 61000-3-11
	IEC/EN 61000-4-15
	ANSI/IES LM-79-19

Table 2. Industry standards require specific measurements.

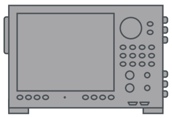
Instrument Type

There are a variety of instruments on the market that can potentially meet power efficiency and power quality measurement needs. Depending on the circumstances, one may need the waveform analysis of an oscilloscope, the high accuracy of a power analyzer, or a hybrid combination of the two with the flexibility of data acquisition added into the mix. For more details on instrument types and other considerations and functionality, recommended reading is the Yokogawa Test&Measurement white paper Choosing the Right Power Measurement Instrument.

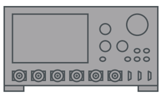
The measurements in Table 1 can be made on various power measurement instruments. Table 3 illustrates the best instrument for each measurement type.



Power Analyzer (yellow)



Power Scope (red)



Oscilloscope (blue)

Industry/Market	Standard Compliance	Energy		Harmonic Distortion Power Quality						Transient Capture			
		Consumption/Production (Wh)	Efficiency (%)	Harmonics/THD	Electromagnetic Compatibility (EMC)	Voltage Swell	Voltage Dip/Sag	Voltage Interruption	Flicker	Transient Overvoltage	In-Rush Current	Voltage Ripple	Current Spectrum
Appliances	IEC62301 (Energy Star)	✓ (yellow)	✓ (yellow)										
	EN 50564: 2011 (standby power)	✓ (yellow)	✓ (yellow)	✓ (yellow/red)									
Power Generation/ Grid Tied	UL1741SA			✓ (yellow/red)							✓ (red/blue)		
	IEC 61000-4-7			✓ (yellow/red)									
	IEC/EN 61000-3-2			✓ (yellow/red)									
	IEC/EN 61000-3-12			✓ (yellow/red)									
Industrial	IEEE519-2014			✓ (yellow/red)									
	IEC 60034-30-2	✓ (yellow)	✓ (yellow)										
Mil/Aero	MIL-STD-704			✓ (yellow/red)							✓ (red/blue)		✓ (red/blue)
	MIL-STD-1399							✓ (yellow/red)		✓ (red/blue)	✓ (red/blue)	✓ (red/blue)	
	DO-160			✓ (yellow/red)				✓ (yellow/red)		✓ (red/blue)			
HVAC	DOE-STD-1153-2002 /M1	✓ (yellow)	✓ (yellow)								✓ (red/blue)		
	ANSI/AHRI 210/240-2008	✓ (yellow)	✓ (yellow)										
Lighting	IEC/EN 61000-3-3				✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (red/blue)			
	IEC/EN 61000-3-11				✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (red/blue)			
	IEC/EN 61000-4-15				✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (yellow/red)	✓ (red/blue)			
	ANSI/IES LM-79-19	✓ (yellow)	✓ (yellow)										

Table 3. Measurement types need to be considered when choosing an ideal instrument type. There is rarely one instrument ideal for all measurements.

What makes one instrument better suited to a measurement than another? It depends on the specific measurement(s) required per the standard test specifications.

Measurements are divided into three categories: energy, power quality, and transient capture.

Energy

Energy is often expressed in units of Watt-hours (Wh) and is best measured by a power analyzer due to the streaming nature of the acquisition system to measure power over time. Oscilloscopes cannot stream continuously and are ideal for transient capture. For more information on the energy measurements of a power analyzer, please refer to the Yokogawa Test&Measurement white paper [Fundamentals of Electric Power Measurements].

Power Quality

Power quality is a measure of the deviation from the normal sine wave from which the power source was generated. Poor power quality manifests itself through various phenomena. The measure of the phenomena listed in Table 3 can help one understand potential issues with power systems and provide insight into mitigation issues. Although these measurements are transient in nature, some tests require the precision of a power analyzer. For those reasons, either a power analyzer or power scope would be recommended.

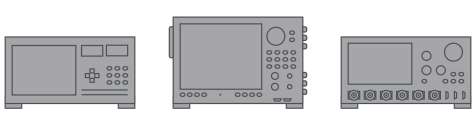
Transient Capture

Transients are short-lived and often occur only once in a sequence. Oscilloscopes are purpose-built for transient capture due to their high bandwidth, high sample rates, complex triggering, and measurement gating capabilities. The best instrument types for this measurement category are the oscilloscope and the power scope. The trade-off of accuracy of the power scope versus the bandwidth / sampling rate of the oscilloscope needs to be explored further.

Measurement Accuracy

Since every measurement device is characterized by some degree of uncertainty, accuracy is normally expressed as a range. Within the range, engineers consider power accuracy as the primary indicator of uncertainty for basic measurement parameters such as voltage, current, phase angle, and power. These parameters may be presented using terms such as “guaranteed accuracy” and “typical accuracy.” To learn more, please refer to the Yokogawa Test&Measurement white paper Accuracy Specifications: Reading it Right with Range.

There are many types of accuracy, including AC, DC, and harmonic. Table 4 helps guide the instrument selection process based on individual needs.



	Power Analyzer	Power Scope	Oscilloscope
DC Accuracy	Guaranteed	Guaranteed	Guaranteed
AC Accuracy	Guaranteed	Guaranteed	Typical
Harmonic Accuracy	Guaranteed	Guaranteed	Typical
ADC Resolution	• • •	• •	•

• • • Best • • Better • Good

Table 4. Power analyzers and power scopes are the only instruments that guarantee AC accuracy.

Guaranteed vs. Typical

What does “typical” mean in this context, in terms of Watts? The term is often misleading. A typical value is usually a reference value based on a manufacturer’s expectation from its product. In practice, it can be translated as “usually but not always,” “maybe,” “perhaps,” or “possibly.” It is deliberately vague because typical accuracies are neither guaranteed nor traceable to a national calibration standard or accredited calibration laboratory standard. When selecting a power measurement instrument, the prospective user should be sure that the published accuracies are guaranteed values rather than typical values.

AC Accuracy

In power measurement, not enough emphasis is placed on AC accuracy. Often, instruments will guarantee AC accuracy at 50-60 Hz, but more power applications measure signal content outside the 50-60 Hz range due to fundamental frequencies changing per application, and harmonic content at multiples of those frequencies. The ideal instrument will have AC accuracy specified through the entire bandwidth range.

Harmonic Accuracy

Harmonic accuracy is important for testing to standards that require specific harmonic orders. An order pertains to the specific multiple of the fundamental. An instrument that specifies harmonic accuracy provides assurances that measured values are guaranteed.

Analog-to-Digital Converter (ADC) Resolution

In measurement terms, resolution is the smallest increment that the instrument can indicate or display. The more resolution an instrument has, the more it can resolve differences or details on waveforms. It is commonly expressed as the number of bits. The number of bits is often specified by the ADC manufacturer, but noise and distortion will reduce the actual resolution of the instrument. To account for this, instrument manufacturers use effective number of bits (ENOB) or signal plus noise and distortion (SINAD) to represent the resolution of the instrument. Filters or techniques such as averaging can improve resolution as well, but come at a trade-off. A power analyzer provides the greatest resolution among measurement instruments at 18 bits, followed by the power scope at 12 bits. Oscilloscopes have a resolution between eight and 12 bits. When measurements require the best accuracy, a power analyzer is recommended.

The Solution

Power quality issues will continue to be prevalent in modern electrical systems due to the rising use of non-linear devices to control power. Due to the detrimental effects on motors, transformers, switch gear, fuses, and other devices, it is becoming more important to accurately measure and quantify harmonic orders to not only determine compliance with systems and standards, but to assist in the mitigation to reduce the harmful effects.

Oscilloscopes, power scopes, and power analyzers can perform most of the required measurements. However, selecting the appropriate instrument depends on measurement type, standard, and instrument type. Table 3 helps guide the instrument selection process through these three criteria.

Further Reading

For more information on Yokogawa Test&Measurement Power Analyzers and related software, click here.

For more information on Yokogawa Test&Measurement Power Scopes and related software, click here.

For more information on Yokogawa Test&Measurement Oscilloscopes and related software, click here.

To view additional insights, visit the Yokogawa Test&Measurement library.

Still not certain which instrument is best for a particular measurement requirement? Contact a Yokogawa Test&Measurement Precision Maker by submitting an inquiry here.