High Performance Power Analyzers Improve the Efficiency of Testing Alternative Energy Technologies

White Paper

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Introduction

As government policies in areas such as the promotion of solar power and electric vehicles (EVs) and smart grid initiatives are formalized, power meter performance and functionality can be expected to evolve in response. This paper introduces some recent power meter trends and measurement needs surrounding the use of high-precision power analyzers to support the development of high-efficiency control systems, with a focus on power measurement in EV motors and inverters as example applications.

Market demand and operator wishes for power measurement instruments are growing in the face of new opportunities worldwide for reducing CO_2 emissions in order to protect the environment and prevent global warming. Looking at the alternative energy field, demand for solar power, wind power, biomass, nuclear power, and fuel cells is increasing. Designers are improving products such as climate control systems, inverter motors used in power lines at manufacturing plants, air conditioners, refrigerators, and washing machines to save energy and boost efficiency. Demand for EVs and batteries is robust. Similarly, boosting the efficiency of three-phase motors and inverters has been identified as an urgent priority.

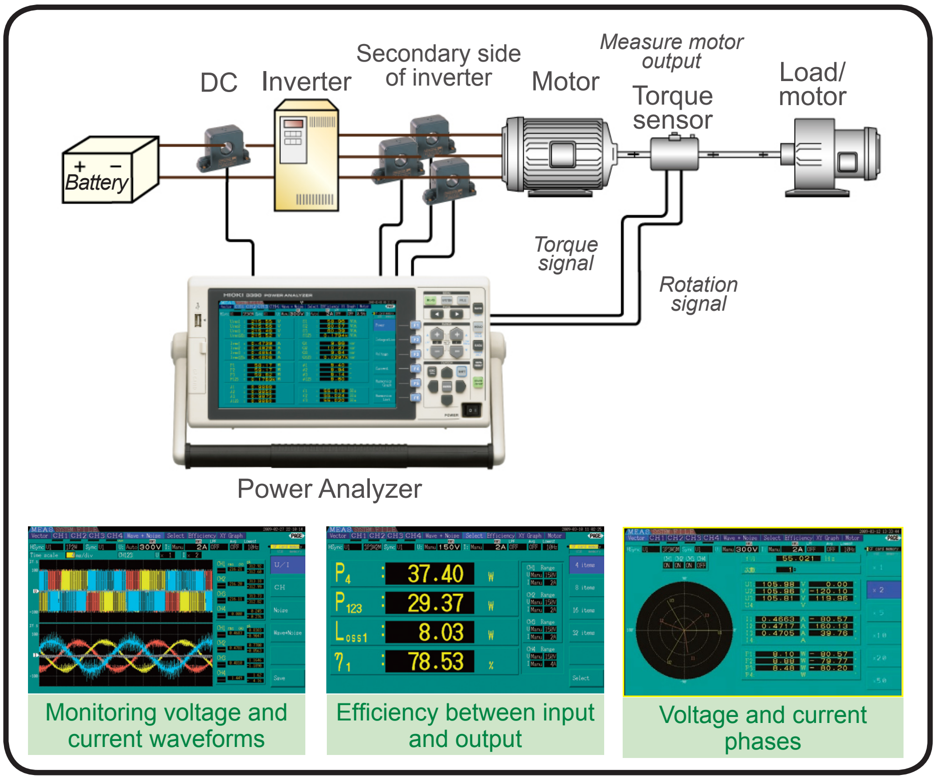

Figure 1: Typical inverter measurement example

Diversification of power measurement, expansion of measurement possibilities

Intensifying efforts to develop alternative energy systems and modify equipment to boost energy savings are creating new requirements for power meters to satisfy. Figure 1 illustrates a typical example of inverter motor measurement, and the following are examples of recent trends and primary measurement needs:

(1) Demand for the ability to measure power at a high level of precision in a contactless manner (simultaneously measuring the primary and secondary sides of an inverter)
(2) Demand for the ability to measure parameters such as harmonic distortion and inverter noise with a single power meter
(3) Increasing number of applications involving DC/AC conversion (PWM inverters)
(4) Increasing performance of vector control inverters
(5) Increasing efficiency of inverters, motors, and power conditioners
(6) Expansion of measurement applications from conventional R&D to include installation sites

Recently, manufacturers have been working steadily to develop a variety of high-precision power analyzers in response to these needs. For example, current sensors capable of measuring currents with magnitudes ranging from minute to large (500 A) satisfy (1) above, while power meters with waveform analysis, power measurement, harmonic analysis, and FFT analysis functionality satisfy (2). In face of demand for the ability to simultaneously measure multiple parameters, currently available instruments can now instantaneously display motor and inverter evaluation data.

Similarly, today's instruments now offer broadband measurement capability extending from DC to inverter bands (0.5 Hz to 150 kHz) in response to (3), and manufacturers have offered the ability to measure motor electric angle and power parameters simultaneously in response to (4). Instruments with an increasingly high level of precision for power conversion efficiency measurement, for example with 1% or greater precision and repeatability improvements, address (5). Finally, manufacturers have been able to respond to situation (6) by meeting a variety of needs ranging from high-precision sampling to simple measurement using compact, portable instruments featuring rugged enclosures.

Evaluation and analysis of recent electrical vehicle (EV) motors

To measure the efficiency of motors and inverters, technicians must first simultaneously measure power on the primary and secondary sides of the inverter at a high level of precision and then calculate the efficiency. In this type of application, it is important that the power meter being used support measurement of high voltages and large currents, and that it offers enhanced isolation functionality and wide-band frequency characteristics. In voltage measurements, there is increasingly strong demand for instruments with 1000V AC inputs, and in current measurements, it is desirable that current sensors support measurement of currents ranging in magnitude from very small to large (500 A). Conventional power meters that have been considered in the past to offer high-precision performance have delivered the necessary functionality by means of shunt input-type designs, but it is becoming difficult to simultaneously satisfy the needs described above with such architecture.

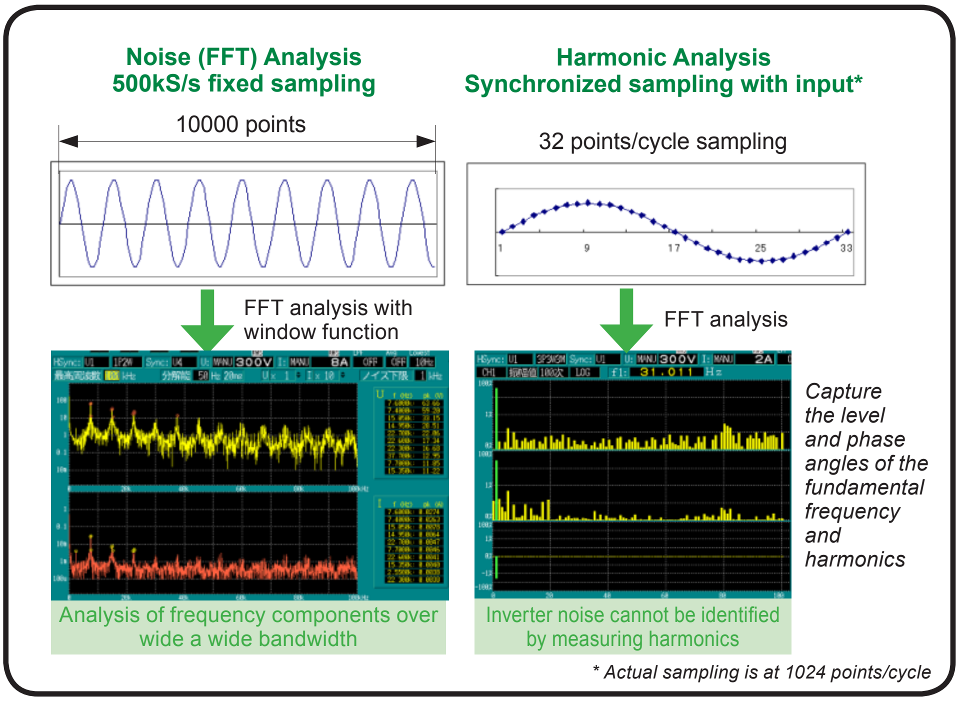

Figure 2: FFT and harmonic analyses

Used in combination with high-precision current sensors, power meters can be used to realize high-precision power measurement.

When analyzing motor performance, it is essential to measure the fundamental wave voltage and current as well as higher-order phases by means of accurate harmonic analysis. If the power analyzer being used supports the use of an incremental encoder, the sync signal from the motor can be detected easily and measurement can be performed at a high level of accuracy. Then the electric angle can be measured by synchronizing the instrument to the A- and Z-phases and performing a harmonic analysis of the motor's input voltage and current.

Today's power analyzers can perform harmonic analysis, starting with the motor's 0.5 Hz sync frequency. By synchronizing the instrument with the fundamental frequency from 0.5 Hz to 5 kHz and conducting harmonic analysis of up to the 100th order at the same time as power measurement, it is possible to perform harmonic analysis of motors, even low-rpm units.

Advanced power analyzers can also display a motor's electric angle as a vector and plot the motor's dynamic characteristics in the form of a graph, as well as measure temperature data, which is essential in motor evaluation, at the same time. In this way, a single instrument can measure inverter efficiency, loss, and motor power.

Evaluation and analysis of inverter-equipped devices

One area in which engineers must exercise care when performing power measurement of inverter-equipped devices involves wiring mistakes when connecting three-phase motors to their instruments. Personnel can make accurate measurements and reduce the incidence of measurement mistakes if they take time to review circuit schematics to check the status of wiring and inputs. Thanks to the ability to gather and ultimately manage data on a computer, measurement of inverter efficiency and loss parameters has become simple enough that even inexperienced users can accomplish these tasks easily and at a high level of precision.

The following parameters are important when measuring inverter motors:

- **RMS value:** RMS value of fundamental wave + carrier frequency
- **MN value:** RMS value closest to the fundamental wave component (mean value)
- **FND value:** Fundamental wave true RMS value
- **THD value:** Indicator of the extent of

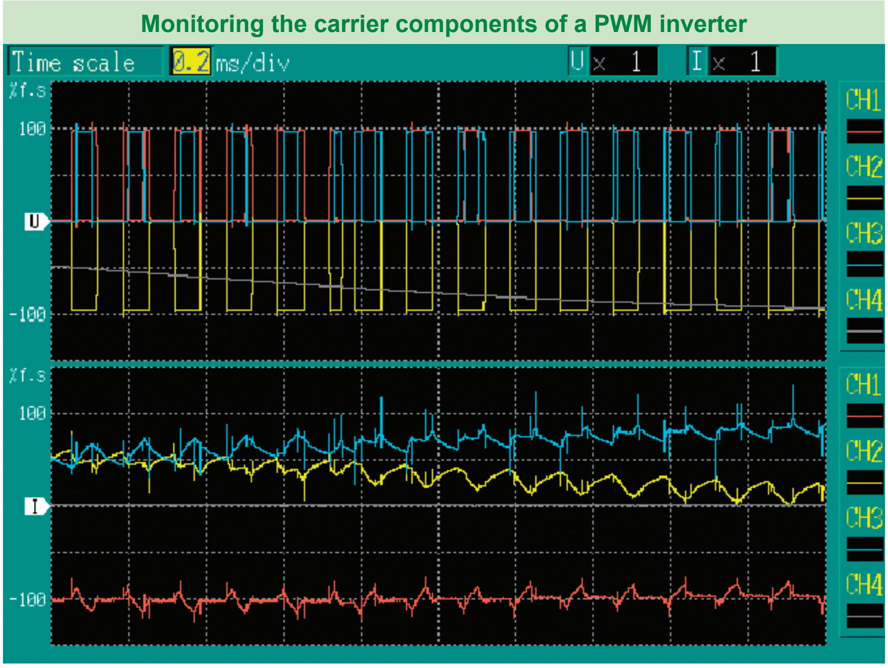

Figure 3: Waveforms sampled at a high speed of 500kS/s

measurement waveform distortion

- **UNB value:** Indicator of state of balance between phases
- **±PK value:** Maximum value of positive and negative waveforms during measurement
- **DC value:** Indicator of DC component that is harmful to the motor
- **AC value:** RMS value obtained by removing the DC component from the RMS value
- **F value:** Frequency for each phase, etc.

Other essential capabilities for power measurement include functionality for plotting dynamic characteristics as a graph for easy recognition; measuring harmonics, which is essential in inverter evaluation; and performing FFT evaluation of noise (at up to 100 kHz), which is a concern with inverters (see Figure 2). Some power analyzers today can display voltage and current waveforms using high-speed sampling at rates such as 500k samples per second (see Figure 3).

To date, the measurement process for meeting these needs has been troublesome due to the need for researchers and technicians to use digital oscilloscopes, differential probes, and clamp-type current probes. Recent power analyzers developed specifically to address these shortcomings give operators the ability to observe waveforms with a single instrument.

About HIOKI

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