Application Note

Power and Efficiency Measurement of Motors and Inverters

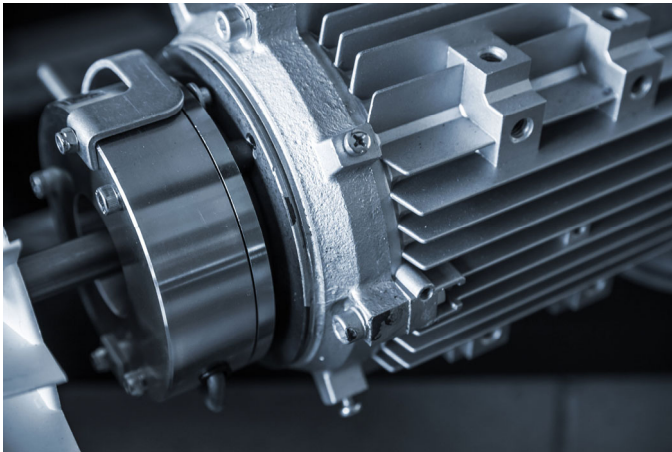Industry : Motor/Inverter, Automotive/Transportation, Power/Energy, Industrial Machine

Precision Power Analyzer WT5000, WT1800E
Precision Power Scope PX8000
AC/DC Current Sensor CT series
Current Clamp-On Probe 751552
Integrated Software Platform IS8000

Overview

High-precision power consumption and efficiency evaluations of motors and inverters used in EVs and robots are required. In an evaluation, it is important to observe the transient instantaneous power and voltage and current waveforms during acceleration and deceleration as well as during steady state.

Simultaneous measurement of motor torque, rotational speed, other sensor signals, and control data is also required for verification within a wide operating range.

Challenges

- High-precision, wide-band power and efficiency measurement
- Direct input of voltage and current
- Wide range of voltage measurement from low to high voltages
- Fast measurement of fluctuating power
- Synchronous display of power parameters and waveforms of input voltage, current, etc.
- Simultaneous measurement of motor torque and rotational speed
- IEC harmonic, voltage fluctuation/flicker test
- Synchronous measurement with an oscilloscope or data logger
- Report creation with data

Solution

Yokogawa's power meters / WT series of power analyzers, to which current and voltage can be directly input, include the WT5000 Precision Power Analyzer with high bandwidth (up to 1 MHz), high accuracy (maximum accuracy of ± 0.03%), and up to 7 inputs, and the PX8000 Precision Power Scope, which offers both "High-precision power measurement" and "Waveform measurement with improved time resolution", providing more accurate power and efficiency testing.

- Direct input supports small current to large current, low voltage to high voltage.
- High-precision DC/AC signal simultaneous measurement and power/efficiency measurement
- Large-current and high-voltage model available (up to 50 A, 1000 V)
- Testing of up to 3000 Apeak with AC/DC current sensor series
- Evaluation of 2 systems, up to 4 motors (WT5000 /MTR1, /MTR2 option)
- A wide variety of line and frequency filters, including an anti-aliasing filter, allows high-accuracy measurement of harmonic components with a motor rotational speed as the fundamental frequency along with the measurements over the entire measurement band.
- Harmonic test according to IEC/JIS, voltage fluctuation/flicker test according to IEC (WT5000)
- Synchronous measurement between the WT5000, the ScopeCorder DL950 and the Mixed Signal Oscilloscope DLM5000

■ Lineup

Inverter

Motor

Torque Sensor & Encoder

WT series or PX8000

Torque & Rotational speed
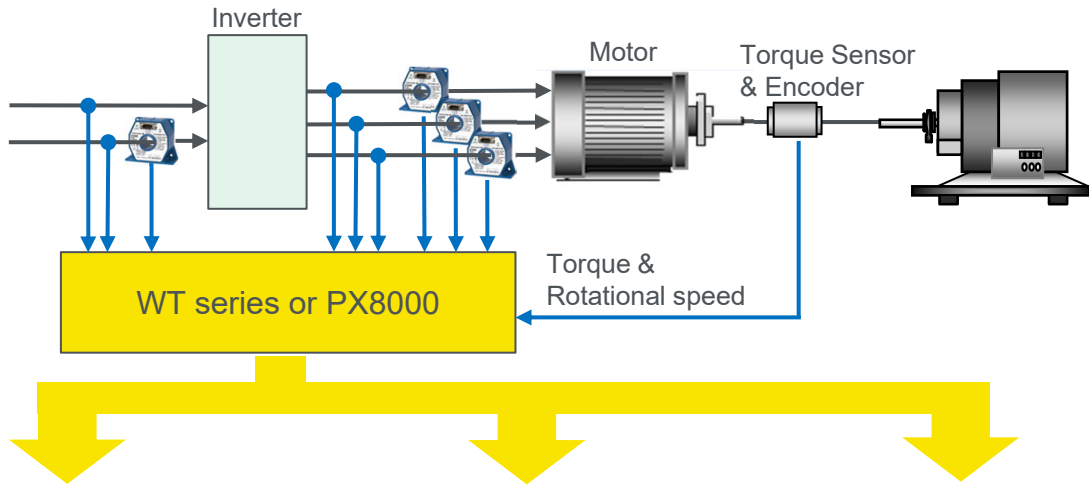
Industry's best accuracy

High-precision measurements with best-in-class basic power accuracy of ±0.03%. High-end model with up to 7 inputs, 10 MS/s 18 bit and advanced calculation functions

WT5000 Precision Power Analyzer

The average method for every few cycles with synchronous source signal and the digital filter average method can be selected, enabling more stable measurements.

Wide range/multi-channel

High-performance power analyzer that guarantees a basic power accuracy of ±0.1%. Up to 6 inputs, 2 MS/s 16bit, wide range of 1.5 V to 1000 V, 10 mA to 50 A

WT1800E Precision Power Analyzer

The high-speed data capturing function allows numerical data to be acquired every 5 ms and allows transient power measurement.

Transient wave capture

Captures waveforms at 100 MS/s sample rate & 20 MHz bandwidth, then calculates transient events and power parameters.

PX8000 Precision Power Scope

Trend function calculates numerical values for each cycle. Voltage/current waveforms and calculated instantaneous power waveforms can be displayed.

■ Current Measurement

Current Clamp-On Probe 751552

For high-precision measurements
Wide dynamic range:
  0.001 Arms to 1000 Arms (AC),
  Max. 1400 Apeak (AC)
Wide measurement frequency range:
  30 Hz to 5 kHz (± 2%)
Highly-precise basic accuracy:
  ± 0.3% of reading
Phase error: 0.7 deg (50/60 Hz)
Current output model: 1 mA/A

AC/DC Current Sensor CT2000A/ CT1000A/ CT1000/ CT200/ CT60

The AC/DC current sensors can measure large DC and AC currents.
The current output mode makes it possible to connect the AC/DC current sensors to the direct current input terminals of the WT Series & PX8000 for measurements. The WT5000 (760903), WT1800E and PX8000 also have an integrated sensor power supply.

Current Sensor Unit 751522/751524

The built-in AC/DC current sensor CT1000 enables high-current measurement with high reproducibility.
Large current measurement:
  0 to 1000 A (DC) / 1000 Apeak (AC)
Wide measurement frequency range:
  DC to 100 kHz (-3 dB)
High-precision fundamental accuracy:
  ±(0.05% of reading + 40 μA)

751522
for single-phase measurements

751524
for three-phase measurements

■ Application example

Evaluation of up to 4 motors (WT5000)

In EV development, it is necessary to evaluate multiple motors at the same time. Simultaneous evaluation of 4 motors is required especially in the development of four-wheel drive vehicles.

With the /MTR1 and /MTR2 options, a single WT5000 provides simultaneous evaluation of 4 motors. These options can also be used to measure rotational speed, direction and electrical angles from the input of A, B and Z phase signals of two motors.
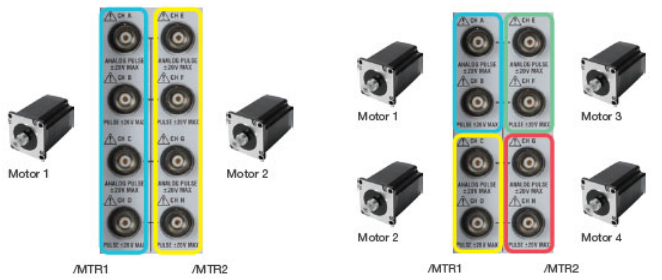
Measurements from two motors to determine torque, rotation speed, direction, and electrical angles

Measurements from four torque and rotation sensors to determine overall efficiency of four motors.

Waveform data streaming at up to 2 MS/s, synchronous measurement of highly precise power values and waveforms (WT5000)

Synchronized with normal power parameter measurements, the voltage/current waveforms and torque/rotational speed data of the same measurement period , on which the power calculations are based, can be continuously streamed to a PC at up to 2 MS/s without any gaps (/DS option).

By analyzing both numerical values and waveforms at the same time, it is possible to analyze in more detail how changes in noise on the waveform or changes in the control state affect the power values and each parameter through the changes in the waveform.

In an efficiency map creation where a combination of rotational speed and torque is tested, not only the efficiency data, but also the waveform data synchronized with power value calculation results can be saved. Additionally, you can always back up the original data of voltage/current waveforms, which may be required in evaluation reports.


Waveform data streaming (up to 2 MS/s)

Basic characteristics test of voltage, current, torque and rotational speed
Testing of I-V, S-T, and I-T characteristics

The X-Y display and mathematical functions of the PX8000 Precision Power Scope can be used to convert the rotational speed and torque data to time-series data for each cycle to evaluate the I-V characteristics (current-voltage phase characteristics), S-T characteristics (rotational speed-torque), I-T characteristics (current-torque), and other motor characteristics.
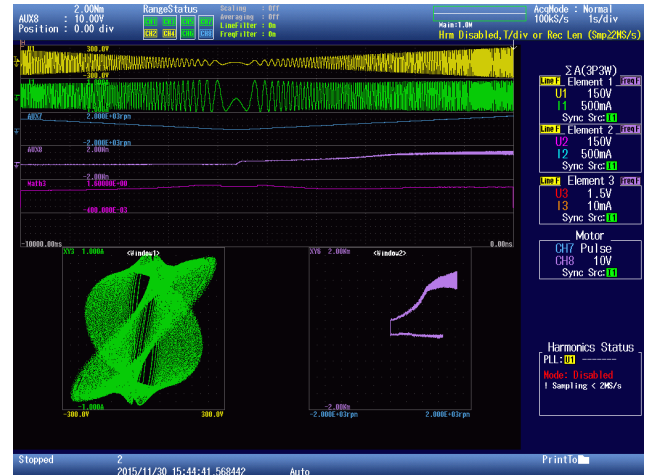
Example of waveforms and evaluation of V-I and S-T characteristics
The voltage and current waveforms directly measured can be X-Y displayed in real-time.

Transient power measurement of motors and inverters

The PX8000 Precision Power Scope has 100 MS/s, 20 MHz bandwidth, and 12-bit resolution to accurately capture high-speed inverter waveforms and perform instantaneous transient power calculations.

In addition, torque and rotational speed can be input together with voltage/current electrical signals, enabling evaluation of inverter efficiency, motor efficiency and overall efficiency of an inverter-driven motor.

Power calculation between Start/End cursors

IEC/JIS standard test

With the Precision Power Analyzer WT5000 (with /G7 option) and IS8011/IS8012 Harmonic/Flicker Analysis Software, you can complete tasks from IEC/JIS Harmonic/Flicker standard compliance assessment up to test report output without any specialized knowledge.
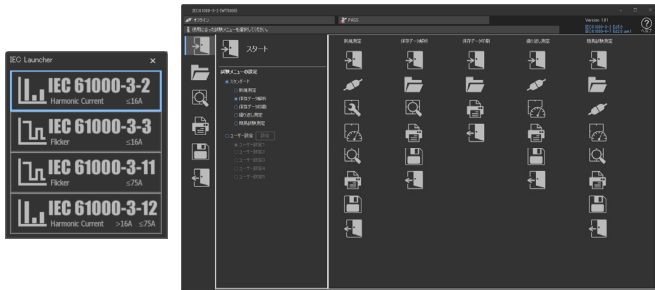
Test menu / Measurement menu of IS8011/IS8022

Harmonics standard test

You can import the harmonic data measured by the WT5000 with /G7 option to a PC and perform harmonics tests according to IEC/JIS standards by using the IS8011/IS8012 Harmonic/Flicker Analysis Software. With the CT200 current sensor, you can test large equipment over 16 A/phase (IEC61000-3-12).

Voltage fluctuation and flicker standard test

The WT5000 with the /G7 option can measure voltage fluctuation and can conduct a flicker test, according to IEC61000-3-3 standard. This option shows a trend of parameters such as dc, dmax and Pinst (instantaneous flicker sensation). To capture test results, this option generates a comprehensive test report.

■ Synchronous Measurement with ScopeCorder DL950

The combination of Precision Power Analyzer WT5000, ScopeCorder DL950, and Integrated Software Platform IS8000 enables simultaneous recording and display of highly reliable power measurements calibrated to national standards and high speed, high precision voltage/current and motor torque waveforms. Motors and inverters can be evaluated accurately and efficiently.
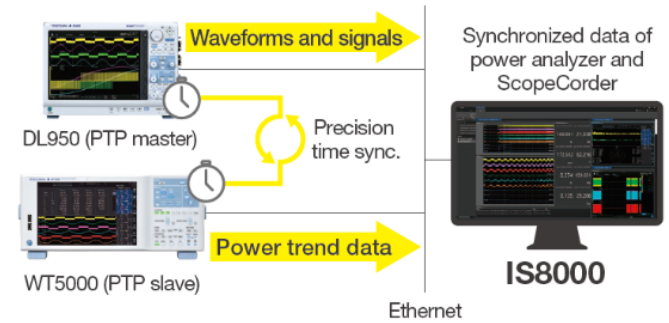
■ Power calculation function of Oscilloscope and ScopeCorder

You can use the power calculation function of the Oscilloscope or ScopeCorder, if you only need rough power measurements, rather than the high-precision power measurements using a power analyzer.

DLM5000 /G03 Power supply analysis option

It can measure power parameters automatically for up to four pairs of voltage and current waveforms, such as active power, apparent power, reactive power and power factor.

DL950 /G05 Power math function option

The DL950 calculates the conversion efficiency from the input and output power of an inverter and analyzes the effects of harmonics caused by external disturbances while capturing mechanical variations in motor speed and torque.

Also, the DL950 can trigger on the trend waveforms of power parameters.