Next Generation of Precision Power Analyzer for Drive and EV Technology

As renewable energy, electric vehicles and energy efficient technologies gain wider adoption, the need for reliability in testing efficiency, performance and safety is greatly increasing. With its high accuracy and modular architecture, the new WT5000 empowers engineers to innovate with precision, flexibility and confidence to quickly bring their products from concept to market. **Anoop Gangadharan, Yokogawa Europe, Amersfort, Netherlands**

With a guaranteed accuracy of ±0.03%, harmonic comparisons up to the 500th order and custom computations, the WT5000 delivers multichannel measurements Figure 1). Accuracy specifications are guaranteed from 1 % to 130 % of the selected voltage and current ranges. With minimum influence of low power factor (0.02 % of apparent power) the unit is also accurate at large phase shifts and frequencies.

Powerful capabilities

Seven slots for user swappable power elements and diverse options can expand or reconfigure the WT5000 as applications and their needs change. Additionally, the speed and torque from 4 separate motors are measurable. WT5000 is fully touchscreen operable, supported by hardware hotkeys and software for remote measurements. The 10.1 inch WXGA touchscreen delivers excellent noise immunity even in high noise environments such as motors and inverters.

The event trigger function allows users to set limits to capture readings that fall within or outside a specific range of power, current or other parameters. Users can also define and use up to 20 different expressions for custom calculations. Data that meets the trigger conditions can be stored, printed, or saved to a USB memory device.

The WT5000 offers up to 32 GB of internal storage memory that can be used to store and recall various custom configurations and test setups. It can also be used to log large amounts of measurement data over long periods of time, behaving just like a logger. This non-volatile memory makes it easy to store data without preparing any external media. Waveform/Numeric/Screen Copy data or Setting Information can be easily saved.

Supported communications include GP-IB, USB and Ethernet, but is also backward compatible with communication commands of previous models.

In addition to low pass frequency filters and line filters, the WT5000 features advanced filtering capabilities that provides control to analyze even tough waveforms with precision.

- Synchronization source filter: Instead of synchronizing to zero crossings, users can select any specific point of the synchronization source signal.
- Enhanced frequency filter: Allows users to simultaneously measure fundamental and switching frequencies without influencing any other parameter.
- Digital Parallel Path filters: Supported by a high frequency anti-aliasing filter, two separate line filters for normal and harmonic measurements ensures accuracy without aliasing in wide band and harmonic measurements. Users can limit the number of harmonic orders to

Figure 1: Operable by touch and/or hardware hot-keys independently, up to 7 different power phases at 10 MS/s (18 bit) can be measured on the 10.1 inch screen

Figure 2: **Swapable measurement units at the back with current probes**

eliminate attenuation in low bandwidth measurements.

The WT5000 allows to not only measure harmonics and power simultaneously but also offers side by side comparison of harmonics from two different input sources. The effects of noise and aliasing are minimized by antialiasing and line filters with Digital Parallel Path technology allowing simultaneous power analysis of wide band and narrow band components.

Precision current sensing (Figure 2) is accomplished by coaxial current shunts in the swappable 30 A input element ensuring low resistance, low inductance, low impact on phase shift and minimized heat dissipation. Heat flow pathways are optimized in the shunts and across the instrument to ensure even distribution and minimum effect on resistance.

Evaluating motors and inverters

Motor drive technology has become more complex in recent years, pure sine-wave PWM is less common, and cases where the mean voltage differs greatly from the fundamental voltage waveform, are more frequent.

Key requirements for drive analysis are:

- Multi-phase measurements from battery, inverter and motor
- Evaluation of motor characteristics such as torque, rotation speed and direction, slip and electrical angle
- Harmonic analysis of inverter signals at various rotational speeds

The WT5000 guarantees a basic power accuracy of ±0.03 %, between 1 % to 130 % of the selected voltage and current measurement ranges, at 50/60 Hz. Simultaneous measurements from the inputs and outputs of boost converter, inverter, and storage battery. In addition to computing power conversion efficiency of inverter and motor (up to 7 power inputs), the WT5000, also allows the measurement of rotational speed, torqueand output (mechanical power) from the analog/pulse inputs of rotation or torque sensor. With the ability to measure harmonics up to the 500th order even at

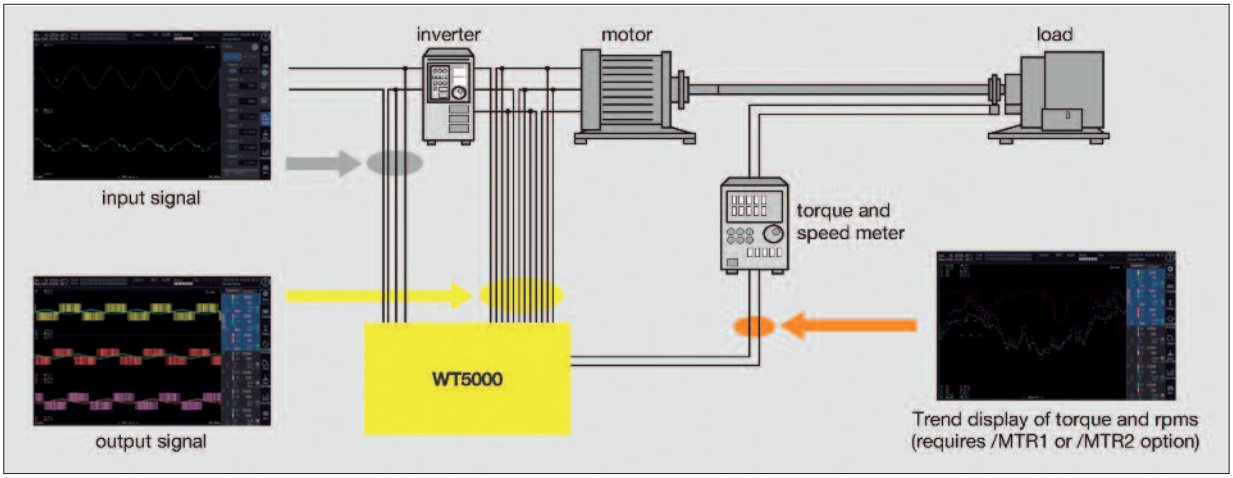


Figure 3: **With multi-channel power measurements, motor evaluation and harmonic comparison capabilities, the WT5000 helps engineers in motor and drive development**

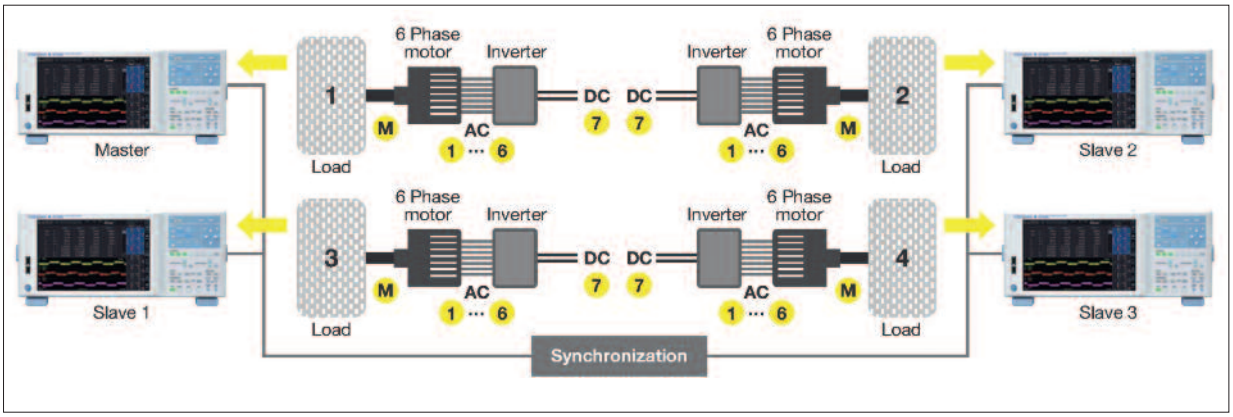


Figure 4: By synchronizing four WT5000s with one master unit and three slave units, up to 28 input elements for electrical power measurements and up to 16 motor evaluation functions can be accessed

low rotation speeds the WT5000 supports harmonic analysis without the need of an external sampling clock.

The motor evaluation function enables measurements of rotational speed and direction, synchronous speed, slip, torque, mechanical power, electrical angle and motor efficiency from an analog or pulse output of torque sensors or pulse outputs of rotation sensors. Up to 2 motors can be measured per WT5000 when the determination of the rotation direction and the electrical angle is needed.

However, a simple setting in the motor configuration menu, allows a single WT5000 to take synchronous measurements from up to 4 torque and rotation sensors enabling users to determine the overall efficiency from 4 wheel driven vehicles.

When synchronizing four WT5000s with one master unit and three slave units, users have access to 28 input elements for electrical power measurements and up to 16 motor evaluation functions (Figure 4). The WTViewerE software will support this performance.

Electric vehicle development

Up to 18 % of the total charge of an electric car is consumed by electric drive system losses. Electric and hybrid car manufacturers therefore need to accurately evaluate motor and inverter control in order to achieve higher precision and greater efficiency. Additionally, the accurate analysis of inverter waveforms without interference from switching noise is a key part of evaluating the motor drive circuit.

Key requirements in this case are:

- Multi-phase measurements from battery, inverter and motor
- Evaluation of motor characteristics such as torque, rotation speed and direction, slip and electrical angle
- Battery charging/discharging characteristics
- Harmonic analysis of inverter signals at various rotation speeds

With high accuracy, multi-channel power measurements, evaluation of up to 4 motors and harmonic comparison capabilities, the WT5000 helps automotive engineers (Figure 5). It enables simultaneous measurements of voltage, current, power, torque, rotation speed, electrical angle and mechanical power. Motor evaluation and mechatronic efficiency can be measured by rotation speed, torque, and output (mechanical power) of motors from analog/pulse inputs of rotation or torque sensors. A single WT5000 can be configured for synchronized measurements from up to 4 motors simultaneously. Battery charging & discharging characteristics can be measured by integration of instantaneous positive and negative values of energy allowing the evaluation of battery charging and discharging characteristics. And with

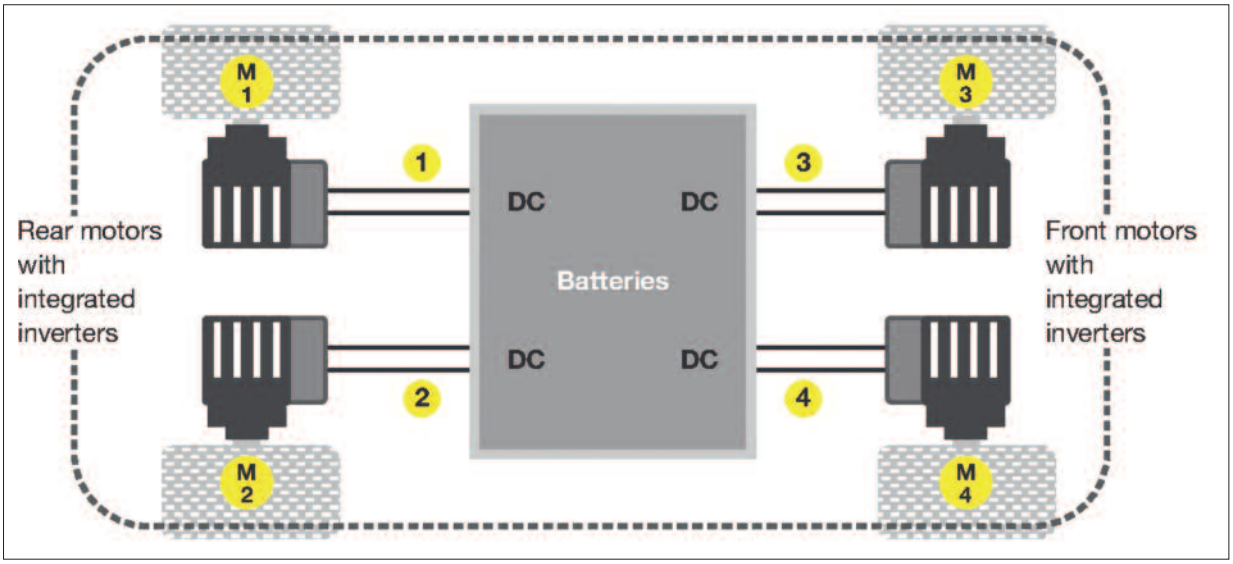
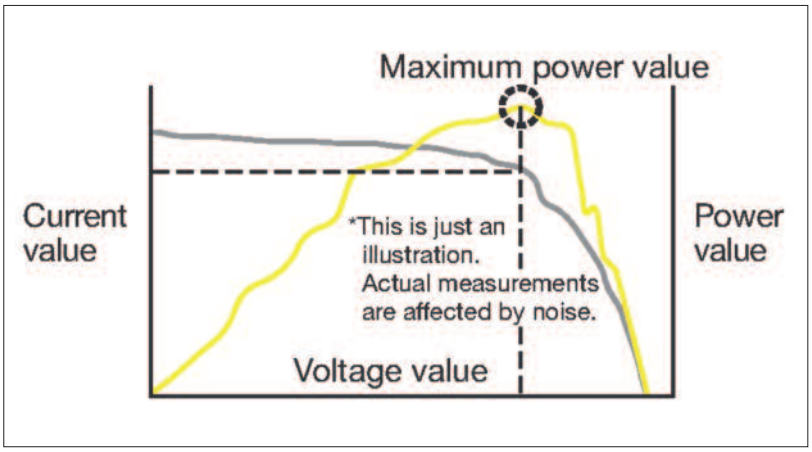


Figure 5: Modern drive systems with integrated inverters do not allow access to the AC signals. Here one of the main measurement tasks is to measure the overall drive train efficiency from DC to mechanical power. The example shows 4 DC measurements (1 to 4) with the corresponding 4 mechanical power measurements (M1 to M4)



LEFT Figure 6: **Typical voltage, current, and power measurements in MPPT control**

BELOW Figure 7: **In transformer or reactor development, the WT5000 can be used to evaluate magnetic material characteristics using Epstein frame system**

the ability to measure harmonics up to the 500th order even at low rotation speeds, the WT5000 supports harmonic analysis without the need for an external sampling clock.

Renewable energy development

Energy generated by photovoltaic cell modules and wind turbines is converted from DC to AC by a power conditioner. Minimizing losses in these conversions is key to improve the efficiency of the overall energy system.

Key requirements for this application are:

- Multi-phase measurements from boost converter, inverter and storage battery
- Evaluation of maximum power and instantaneous peak values
- Energy bought and sold in grid
- Battery charging/discharging characteristics
- Harmonic analysis of inverter signals at various generator speeds

Multi-channel power measurements evaluate power conditioner efficiency with simultaneous measurements from the inputs and outputs of boost converter, inverter, and storage battery. With measurement capabilities from up to 7 input elements the WT5000 is ideal for voltage, current, power, and frequency (for AC) before and after each converter, as well as converter efficiency and charging efficiency.

In photovoltaic power generation, an Maximum Power Point Traker (MPPT) controller varies the voltage to maximize energy harvested from the solar panel. The WT5000 is capable of measuring not only the voltage, current, and power but also the voltage, current, and power peak values plus (+) and minus (–) sides, respectively (Figure 6).

For Energy Bought/Sold and Charged/Discharged the WT5000E provides a current integration (q), apparent power integration (WS), reactive power integration (WQ), as well as effective power integration capable of integration in the power sold/bought and charge/discharge modes.

Harmonics Analysis & comparisons are accomplished by voltage fluctuations and harmonics flow into the power systems due to reverse power flow. The harmonic measurement function enables measurement of harmonic components to compute and display total harmonic distortion (THD) and harmonic distortion factor.

Magnetic characteristics testing

In transformer or reactor development, the WT5000 can be used to evaluate magnetic material characteristics using Epstein frame system.

Key requirements include:

- High precision measurements of primary coil current and secondary coil voltage is needed
- High accuracy in low power factor is needed
- The magnetic flux density B and AC magnetic field H are key parameters to calculate iron loss

Here WT5000 provides power accuracy of 0.01 % of reading + 0.02 % of range (50/60 Hz). Effect of Power Factor is 0.02 % of S (0.5 A or more) and 0.07 % of S (200 mA or less).

For customers who use a large number of power meters, WT5000 can be used as a reference standard for periodic in-house calibration of power measurement instruments, such as the WT300E series and WT500.