

TESTING POWER ELECTRONICS SYSTEMS: WHICH MEASURING INSTRUMENT IS BEST TO USE AND WHEN

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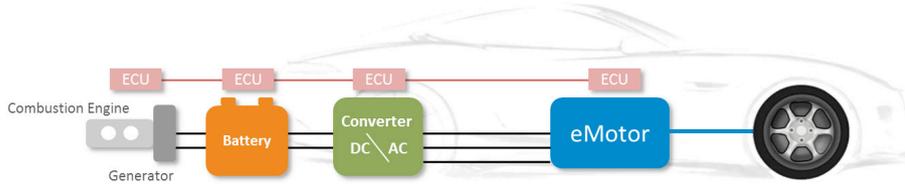


Fig.1 Hybrid vehicle power train

The performance of an electromechanical system is not just determined by the performance of its individual components. With today's increased incorporation of power electronics and switching devices in overall system design, it is often not sufficient merely to measure the power consumption and performance of these components in order to understand the overall performance and behaviour of a system. Increasingly, there is a need for accurate measurement of both the power behaviour of the applied power electronics and other inter-related electrical and physical parameters. This article describes some practical scenarios in which different types of measurement are required and describes and compares some of the measurement tools that are available.

Introduction: the product development process

In order to establish the types of measuring equipment that are required for testing power electronics systems, it is useful to look at the various stages in the development of a power electronics product, which can be summarised as:

- Architecture and design
- Verification and prototyping
- Efficiency validation.

In order to consider the testing requirements for each of these stages, it is useful to look at specific application examples, starting with the typical automotive electric drive system shown in Fig.1.

At the architecture and design stage, the important areas to consider in the test process are the fact that the system consists of a number of individual parts and that key factors in the selection of a test instrument include fast inverter switching, high-frequency dynamic behaviour, overshoot on pulses, and the need to trigger on individual waveforms.

Measurements of this type require an oscilloscope: ideally a mixed-signal instrument with multiple channels (eight is an ideal number to view input and output signals in 3-phase systems). The mixed-signal oscilloscope (MSO) shown in Fig.2, for example, is an 8-channel instrument featuring exceptionally long memory (up to 125 M points), allowing both long recordings and multiple waveforms to be acquired. It is also available with optional firmware that enables it to be used as a high-performance 3-phase power analyser, with the eight channels allowing voltages and currents to be individually measured and displayed alongside derived values. With this option, the instrument offers automated measurement of power parameters for up to four pairs of voltage and current waveforms. These values can then be statistically processed and calculated to provide peak, average and root-mean-square values, along with many other parameters such as power factor and q-factor.

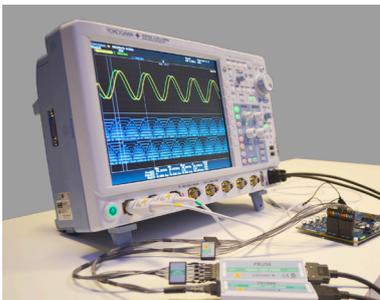


Fig.2 DLM4000, 8-channel mixed-signal oscilloscope

Moving on to efficiency validation, the key factors required in testing an electric drive are power analysis, conversion efficiency, harmonic measurement, and the battery charge/discharge process.

For tests of this type, the instrument of choice is the power analyser (Fig.3), offering high precision, high accuracy, high stability, and the ability to carry out calibrated measurements. Instruments of this type can perform up to six power input measurements, which makes it possible to perform efficiency tests between the input and output of products such as inverters. They can also accurately measure highly distorted voltage or current waveforms with high harmonic content. Harmonic analysis can be carried out up to the 500th order from a 50 or 60 Hz fundamental frequency. This facility is especially important for measurements on new power conversion and power electronics devices. A dual harmonic measurement function makes it possible to simultaneously measure the harmonic content and perform harmonic analysis on two different sources, such as the input and output of an inverter or variable-speed motor drive. The normal power parameters and harmonic data are measured simultaneously, providing for faster and more accurate power analysis.

Additional measurements

Fig.4 shows the same drive system as depicted in Fig.1, but with a number of additional parameters and measurement points that are necessary to gain a deeper insight into the overall application and the interactions that can occur between the various electrical, mechanical and physical parameters involved. These might include inputs from rotary encoders, sensor outputs that require signal processing or linearisation, and derived electrical units such as real power, energy used or RMS values. A deeper insight into an application requires the measurement and analysis of a combination of electrical, mechanical

and physical signals and, in automotive applications, signals from buses such as CAN/LIN. These results then have to be processed with various calculations being carried out to produce trend displays, which in turn are combined into a single measurement overview from which it becomes possible to find relationships and interactions between different parts of the drive system acting alongside one another.

Dynamic behaviour

For this type of measurement, providing a unique insight into the dynamic behaviour of a system, a relatively new class of portable instrument known as a ScopeCorder provides a convenient solution. As its name implies, it combines the features of an oscilloscope and a data-acquisition recorder.

As an oscilloscope, it measures waveforms and captures events, as well as analysing waveform parameters and providing the ability to calculate and trigger on power-related values in real-time. As a data acquisition recorder, it incorporates isolated input channels enabling it to handle a wide range of power measurements, and captures high-resolution details with 12 or 16 bit A/D converters. It also incorporates a large-capacity (up to two gigapoints) memory which will allow it to measure continuously for up to 200 days, while still capturing transient



Fig.3 WT1800 Power analyser

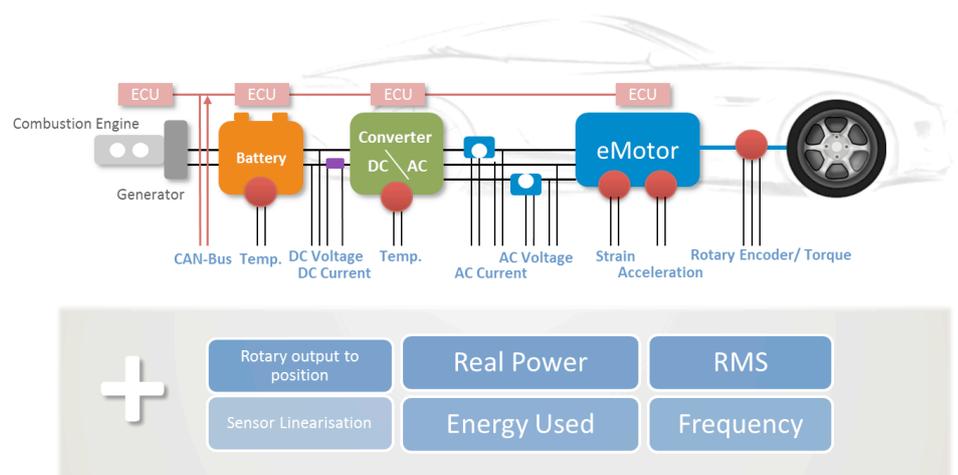


Fig.4 Drive system with additional parameters



Fig.5 DL850E ScopeCorder, WT3000 Precision power meter and sensors

events at data-capture rates of up to 100 MS/s (megasamples per second).

Using flexible modular inputs, the instrument combines measurements of electrical signals, physical (sensors) and CAN/LIN serial buses. Users can choose from 17 input modules to configure a ScopeCorder up to 128 channels, and can gain a thorough insight into any application by synchronising the measurement of different types of electrical and physical signals.

ScopeCorder applications

Today, ScopeCorders are widely used in industries such as automotive and aerospace where measurements of physical quantities need to be displayed and analysed alongside electrical signals. Their potential range of applications in power electronics measurements, however, is greatly increased by the availability of new capabilities for the real-time measurement and analysis of electrical power.

By default, the ScopeCorder is equipped with a set of basic arithmetic mathematical functions such as addition, subtraction, division, multiplication, fast Fourier transformation and other computations. In addition, several real-time options are now available, including the new /G5 power analysis option that provide real-time measurement of electrical power.

With this capability, the instrument can carry out trend calculations such as active power, power factor, integrated power and

harmonics, using a dedicated digital signal processor (DSP) that is able to calculate and display up to 125 types of electrical power-related parameters in real-time. This enables the user not only to display raw waveform signals such as voltages and currents along with calculated power parameters but also to trigger on any or all of them.. Trend waveforms of each order of harmonics, bar-graphs and vector displays can be displayed, and both RMS and power analysis modes are available.

A vehicle edition of the ScopeCorder is designed for engineers working in the automotive and railway industries. A common measurement challenge is to combine measurements of electrical signals, physical performance parameters, indicated by sensors, together with CAN- or LIN-bus data transmitted by the powertrain management system. A ScopeCorder Vehicle Edition addresses this requirement by providing a thorough insight into the dynamic behaviour of the electromechanical system. The result is a considerable saving of time saved compared to other approaches such as analysis on a PC or the use of other software. This unit is also designed for use with vehicle batteries to enable in-vehicle testing.

It is this area of vehicle testing that provides some of the more difficult challenges to the test engineer. For example, during the start-up of an electric motor, the waveform cycle time and the active power vary for each cycle. Fig.5 shows how a ScopeCorder in

conjunction with a power analyser can be used to measure the starting voltage and current.

Industrial welding

In industrial welding systems, there is a trend for transformers to be replaced by inverters, and there is a link between the quality of power supplied and the quality of the weld. Hence it is vital to measure inverter efficiency and performance, including harmonics, using a power meter as an aid to quality control. For industrial welding robots, on the other hand, additional parameters have to be taken into account, including positioning, temperature, and signals from the control system (typically CAN based). Here, the ScopeCorder can provide quality assurance by combining electrical, physical and control bus parameters and provide trending and triggering on power values.

Wind Power

Renewable energy in the form of wind power is a typical application area combining mechanical and electrical measurements. Here a power analyser would be used to measure the efficiency of energy conversion and parameters such as voltage harmonics, while a ScopeCorder would analyse dynamic behaviour using real-time power measurement on voltages and currents (including voltage gaps and other abnormal events, temperatures in bearings, vibration and strain, generator speeds, control signals, and blade pitch control. The instrument's monitoring and triggering capabilities enable simultaneous data transfer and capture, event recording, AC wave window measurements, and power quality assessment – all with the potential benefits of portability and unattended operation.

Summary

Power measurements are necessary at various stages of the product development process, including architecture and design, verification and prototyping, and efficiency validation.

For architecture and design, the multi-channel digital oscilloscope provides insight into high-frequency dynamic behaviour including the analysis of phenomena like overshoot and ringing in pulse width modulated waveforms with tests over a relatively short measurement period.

For verification and prototyping, the ScopeCorder is the tool of choice, providing a thorough insight into the dynamic behaviour of electromechanical system by linking the cause and effect of interdependent parameters. This includes the ability to calculate and trend power-related signals and trigger at the appropriate point. Flexible inputs offer a choice of voltage or current measurements, sensors for physical parameters and CAN/LIN bus signals, which measurements over periods from milliseconds up to 200 days.

Finally, for efficiency validation, the power analyser is a powerful tool dedicated to the measurement of power, including harmonic and distortion analysis, with calibrated accuracy, precision and stability.



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