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Case Study

Vertiv: Precise Power Analysis for UPS Systems in AI Data Centres – Page 11

Test&Measurement Magazine

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Editorial

Flexibility: The Key to a Modern, Future-Ready Workplace – Page 3

Background

Speed and Rotation Direction Detection in Electric Motors
Reliable Measurement with the SmartDAC+ GM10 Data Logger – Page 4

New Products

For Measurement Applications That Demand More
New WT1500 Precision Power Analyzer – Page 7

Open. Position. Measure.
Split-Core Current Transformers with Zero-Flux Technology – Page 12

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Yokogawa Europe B.V.
Euroweg 2
3825 HD Amersfoort, The Netherlands
Phone +31 (0)88 464 1000
PrecisionMaking.EU@yokogawa.com
tmi.yokogawa.com/eu

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Precision Making

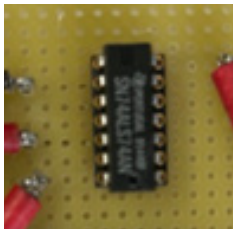


Speed and Rotation Direction Detection in Electric Motors

Reliable Measurement with the SmartDAC+ GM10 Data Logger

In many industrial applications, simply measuring the speed of a motor or drive is no longer sufficient. In addition, information about whether the shaft is rotating clockwise or counterclockwise is often required. This functionality can be reliably implemented using a simple external logic circuit based on a D-type flip-flop, such as a 74HC74, in combination with the Yokogawa SMARTDAC+ GM10, its universal input module configured with the Digital Input input type, and an incremental encoder.

Required Hardware



74HC74 D-FlipFlop



SmartDAC+ GM10



GX90XA



GX90XP



Incremental Encoder
(example: Baumer)

Image: 123RF – naumoid, Baumer Holding AG (Incremental Encoder)

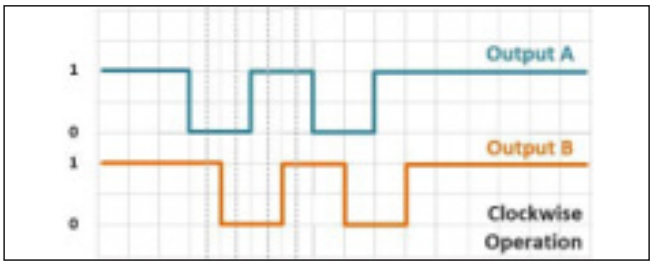
5 **Principle of Rotation Direction Detection**

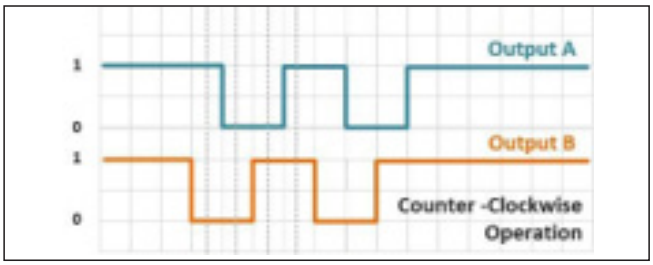
The incremental encoders used provide two square-wave signals, A and B, with an electrical phase shift of 90°. This so-called quadrature information contains not only speed information but also the direction of rotation.

The following applies:

- If signal A leads signal B, the shaft is rotating clockwise.
- If signal B leads signal A, the shaft is rotating counterclockwise.

The 74HC74 is used here as a digital D-type flip-flop. Signal A serves as the clock signal (CLOCK 1), while signal B is connected to the data input (DATA 1). With each rising edge of signal A, the flip-flop captures and stores the current state of signal B.

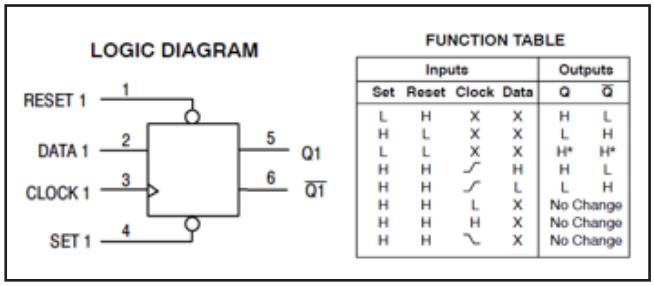




This creates stable rotation direction signals at the Q and Q (inverted Q) outputs:

Q Output State: HIGH	**Rotation Direction** Clockwise Rotation
Q (Inverted Q) Output State: HIGH	**Rotation Direction** Counterclockwise Rotation

Excerpt from the 74HC74 Datasheet



The Q signals can be connected directly to two digital inputs of the GM10 universal input module.

Configuration of Universal Inputs 0002 and 0003 as Digital Inputs on the GX90XA Module of the GM10.

K	Typ	Bereich	Bereich un Spanne	Bereich ob Spanne
0001	Skip	2V	-2.0000	2.0000
0002	DigIN	Pegel	0	1
0003	DigIN	Pegel	0	1

Speed Measurement

At the same time, one of the incremental encoder signals, for example channel A, is connected to the pulse input of the GM10 GX90XP pulse module.

The module counts the incoming square-wave pulses and uses them to determine the rotational speed or frequency. This provides the following information simultaneously within the system:

- Pulse frequency for speed measurement
- Digital direction signal for clockwise and counterclockwise rotation

Configuration of Pulse Input 0201 on the GX90XP Module of the GM10.

K	Typ	Bereich	Rauschfilter	Bereich un Spanne	Bereich ob Spanne
0201	Pulse	Pegel	☐	0	10000

A special situation arises when the motor comes to a standstill. Without additional logic, the output of the flip-flop would retain its last state. As a result, the system would continue to indicate either clockwise or counterclockwise rotation, even though the shaft is no longer moving.

To prevent this, the mathematical functions of the GM10 are used to monitor the measured pulse frequency:

- Frequency > 0 → Rotation detected
- Frequency = 0 → Standstill

In addition, the rotation direction signal is combined with the "speed detected" status using a logical AND function. This ensures that a direction is indicated only when rotational speed is actually present.

Configuration of the Math Channels in the GM10

A001	☑	0002AND0201
A002	☑	0003AND0201

0002 = Digital Input Channel 2 on the GX90XA module
0003 = Digital Input Channel 3 on the GX90XA module
0201 = Pulse Input Channel 1 on the GX90XP module

Result

Speed	Q	Inverted Q	Right	Left
>0	1	0	1	0
>0	0	1	0	1
0	1	0	0	0
0	0	1	0	0

Advantages of the Solution

The described solution offers several advantages:

- Simple and cost-effective hardware requiring no programming
- Robust digital signal processing
- Reliable forward/reverse rotation detection
- Clear standstill detection
- Direct integration into the GM10 system
- No complex external signal processing hardware required

This solution is particularly suitable for functionally extending existing SmartDAC+ Data Logger applications without the need for additional, complex signal processing hardware.

Conclusion

By combining the SmartDAC+ Data Logger with the mathematics option, a simple 74HC74 D-type flip-flop, and the two input modules, a reliable direction-of-rotation detection solution for incremental encoders can be implemented.
In addition, the logical signal processing enables clear standstill detection, ensuring that neither forward nor reverse rotation is indicated when no rotational movement is present.

PROMO



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Verify.
Document.

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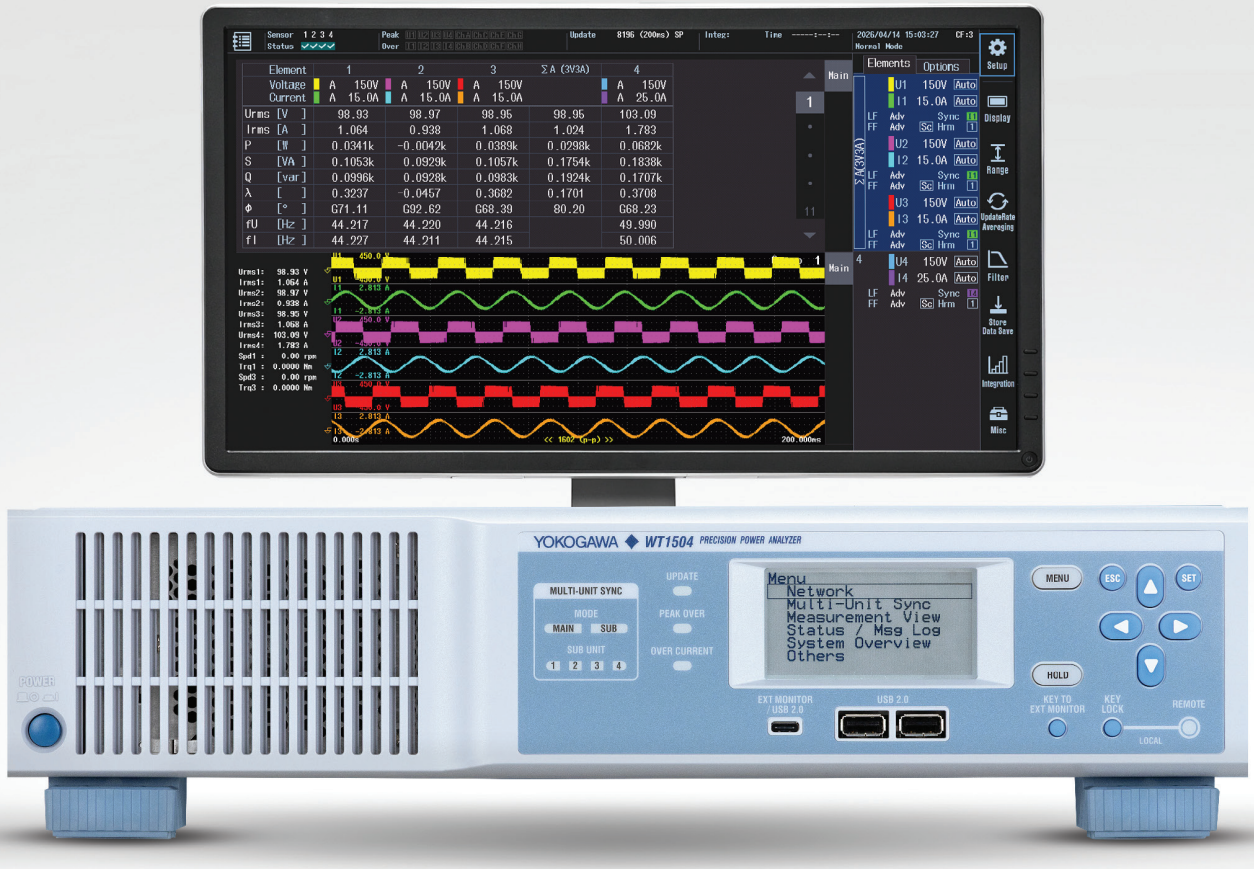


The most flexible.
For measurement tasks that demand more.

The new WT1500 Precision Power Analyzer

Whether in e-mobility, renewable energy, power electronics, or components for data centers and AI infrastructures, the WT1500 Precision Power Analyzer combines highly accurate power measurement with flexible expandability and integrated motor analysis capabilities.

The WT1500 combines direct voltage measurements of up to **2000 V DC and 1500 V AC** with integrated acquisition of encoder and resolver signals in a compact, scalable platform, while delivering the high level of measurement accuracy for which Yokogawa is known.
Each WT1500 supports up to four power measurement channels. For applications requiring additional channels, up to five instruments can be connected to form a single measurement system with a total of up to **20 power measurement channels.**
This scalability makes the new Precision Power Analyzer ideally suited for demanding development, validation, and production testing applications.

Two Power Elements for Different Measurement Requirements
E-mobility, renewable energy systems, advanced power electronics, and components for data centers and AI infrastructures are placing ever greater demands on power measurement. Drive systems, energy storage solutions, and power converters increasingly operate at kilovolt-level voltages. At the same time, fast-switching power semiconductors generate complex, high-frequency waveforms that must be accurately captured to determine power, losses, and efficiency with confidence.



High Voltage Element with voltage inputs for direct measurements up to 2000 V DC and 1500 V AC, plus a sensor input with integrated power supply for current sensors.

Depending on the measurement requirements, the WT1500 can be configured with two different power elements:

- **High Voltage Element (HV)**
- **Wide Bandwidth Element (WB)**

The High Voltage Element (HV) enables direct voltage measurements up to **2000 V DC and 1500 V AC,** allowing many measurement setups to be implemented without the need for external voltage dividers. Eliminating external dividers reduces measurement uncertainty within the measurement chain while also lowering installation and wiring effort. In addition, direct voltage measurement minimizes the need for supplementary peripheral equipment. These capabilities make the HV Element particularly well suited for testing power conditioning systems **(PCS) and energy storage systems (ESS).**

The **Wide Bandwidth Element (WB)** supports direct voltage measurements up to **1000 V RMS** and enables active power measurements up to **1 MHz.** It is therefore ideally suited for analyzing high-frequency signals generated by fast-switching power electronics in modern xEV drive systems and inverter applications.
Both power elements can be freely combined within a single WT1500, enabling the instrument configuration to be tailored to specific measurement requirements. This flexibility is particularly valuable in applications that require both high-voltage inputs and wide-bandwidth power measurements within the same test setup.

Proven High Measurement Accuracy
Separate 16-bit effective resolution (ENOB) A/D converters capture current and voltage signals at 2.5 MS/s each. With a guaranteed power measurement accuracy of ±0.038% for DC and 50/60 Hz measurements, the WT1500 delivers the highest DC power measurement accuracy in the Yokogawa WT Series.
This level of accuracy enables engineers to reliably identify and evaluate even small power losses and efficiency differences, providing a high degree of confidence in performance assessments and design validation.

Direct Connection and Power Supply for Current Sensors
For current measurement, each power element is equipped with a dedicated sensor input that enables the direct connection of high-precision zero-flux current transducers for primary currents up to 2000 A, as well as current probes with a ±5 V output.
Integrated power supplies within the WT1500 provide ±15 V for zero-flux current transducers and ±12 V for current probes, eliminating the need for external transducer interfaces or sensor power supplies.
This simplifies current measurement, as only the selected current sensor and a connection cable are required. By removing the need for external power supplies, the WT1500 also helps free up valuable space in test cabinets and measurement systems, resulting in a cleaner and more efficient test setup.

Resolver and Encoder Measurements
A key enhancement of the WT1500 is its ability to directly process not only encoder signals but also resolver signals for motor evaluation and the acquisition of mechanical parameters. The two motor input functions can be equipped with either encoder or resolver inputs, depending on the application, and mixed configurations are also supported.

When configured with two encoder inputs, the WT1500 provides up to four mechanical power measurements in addition to four electrical power measurements. These calculations are based on the acquired torque and speed signals, enabling applications such as determining the overall efficiency of electric all-wheel-drive systems with a single WT1500. With two resolver inputs, up to two mechanical power measurements can be performed.

Direct resolver signal processing also enables precise real-time angle and position measurements without the need for additional signal conditioning. Because electrical and mechanical quantities are acquired and processed synchronously within the WT1500, there is no need to align separately recorded data sets on a PC after the measurement. This simplifies the test setup, improves the correlation between electrical and mechanical data, and increases the value of motor and efficiency analyses.
In addition, the WT1500 supports i**d/iq analysis based on the Clarke-Park transformation**. By evaluating the rotor-oriented d-axis and q-axis current components, engineers can perform more advanced motor control analyses, providing a robust basis for the evaluation and optimization of electric drive systems.

From Standalone Instrument to a 20-Channel Measurement System

A single WT1500 combines up to four power measurement channels and, depending on the configuration of the two motor functions, up to four mechanical power measurements within a compact 2U, 19-inch chassis. This enables space-saving integration into existing test benches and automated test systems.

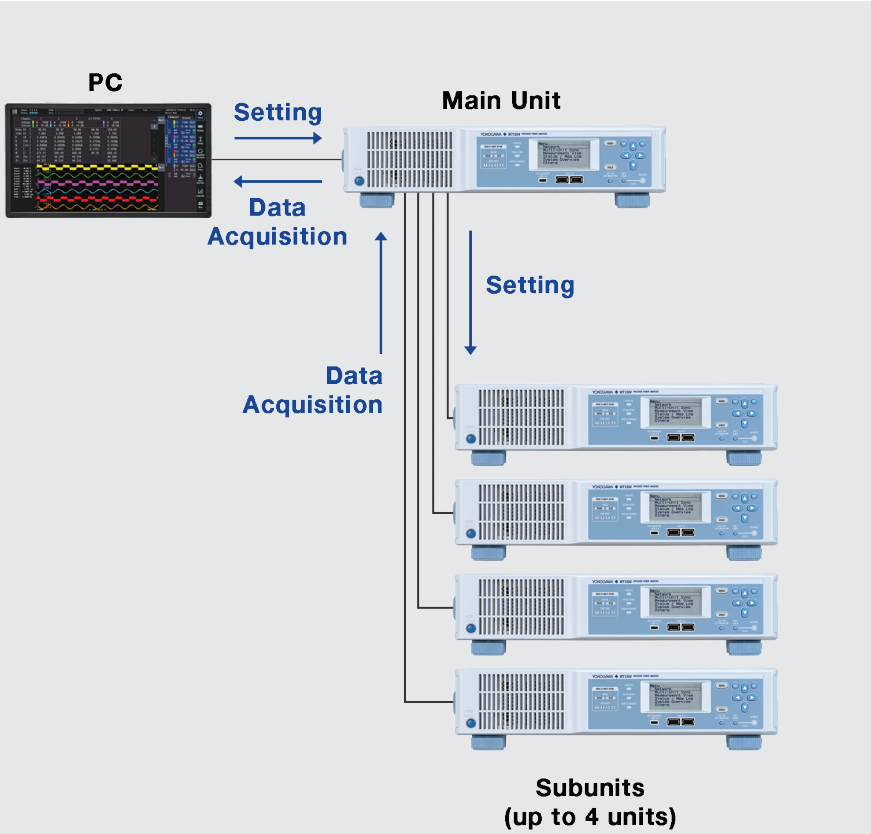
For applications requiring a higher channel count, up to five WT1500 Precision Power Analyzers can be synchronized via fiber-optic links to form a single measurement system. This configuration provides up to **20 electrical power channels and up to 20 mechanical power channels**, offering exceptional scalability for complex testing environments.

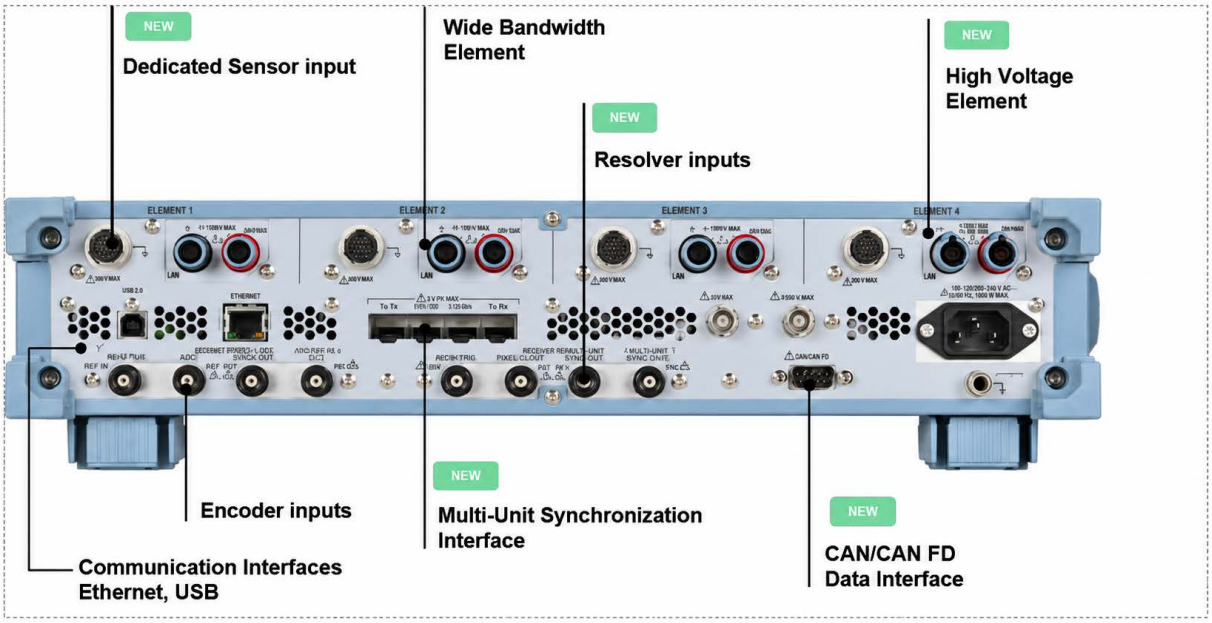
One instrument operates as the Main Unit, controlling the configuration of all connected Sub Units and centrally consolidating their measurement data. As a result, measurement results from all synchronized instruments are available through the Main Unit and can be accessed, analyzed, and processed from a single interface.

With **fiber-optic connections of up to 300 m,** Sub Units can be positioned close to the respective devices under test, providing maximum flexibility in test system design. Measurement data is transmitted optically, ensuring robust communication that is inherently immune to electromagnetic interference.
This long-distance optical communication capability is particularly advantageous for large-scale solar installations, where multiple measurement points across solar modules, power conditioning systems (PCS), and grid connection equipment must be captured and synchronized with high timing accuracy.

Designed for Automated Test Systems

For integration into automated test environments, the WT1500 provides Ethernet, USB, and CAN/CAN-FD interfaces. Over Ethernet, it supports the VXI-11, TCP/IP, Modbus, and UDP communication protocols, enabling measurement results to be transferred directly to automated test software for further processing and analysis.
The WT1500 also supports the Precision Time Protocol (PTP) in accordance with IEEE 1588, allowing electrical and mechanical measurement data to be synchronized with data acquired by external PTP-enabled instruments. This capability enables seamless integration with systems such as DAQ platforms used for temperature, vibration, and waveform acquisition.
By providing precise time alignment across multiple measurement sources, the WT1500 simplifies correlation of electrical, mechanical, and environmental parameters, helping engineers gain a more comprehensive understanding of system performance during development, validation, and production testing.





WT1500 at a Glance

- Power measurement accuracy of ±0.038% for DC and 50/60 Hz measurements
- Direct voltage measurements up to 2000 V DC and 1500 V AC
- 2.5 MS/s sampling rate with separate A/D converters and 16-bit effective resolution (ENOB)
- Flexible combination of High Voltage (HV) and Wide Bandwidth (WB) Elements within a single instrument configuration
- Active power measurements up to 1 MHz with the Wide Bandwidth Element (WB)
- Encoder and resolver support, including integrated id/iq analysis
- Up to four electrical power measurement channels and two flexibly configurable motor functions per instrument
- Scalable to up to 20 power measurement channels
- Compact 2U, 19-inch chassis for efficient integration into test benches and automated test systems

This enables different measured variables to be acquired on a common time base and subsequently analyzed within automated test system software.
A compact front-panel interface, an integrated web server, and the option to connect an external touch monitor via the front-panel USB-C interface provide flexible configuration and operation of the power analyzer. As a result, the WT1500 can be deployed both in automated test systems and as a standalone instrument, adapting easily to a wide range of testing and measurement requirements.

Your Benefits with the WT1500
The WT1500 combines Yokogawa's renowned measurement accuracy with direct voltage measurements in the kilovolt range, real-time evaluation of encoder and resolver signals, and a flexibly scalable number of power measurement channels. This enables complex testing tasks to be implemented with less additional peripheral equipment and with fully synchronized acquisition of electrical and mechanical measurement parameters.

The WT1500 is therefore particularly well suited for development, validation, and production testing in e-mobility, renewable energy applications, battery and energy storage systems, modern power electronics, and components for AI data centers and their infrastructure.

Typical Applications of the WT1500
The WT1500 is particularly suited for power and efficiency measurements as well as harmonic analysis in:

- Hybrid and electric vehicles
- Electric drive systems
- Electric motors and variable frequency drives
- Power converters and energy storage systems
- Power supplies and UPS systems for data centers and AI infrastructures
- Drives for refrigeration, pumping, and ventilation systems
- Railway propulsion systems
- Wind turbines
- Photovoltaic inverters
- Aircraft power supply systems
- Household and office appliances

Secure the new WT1500 Precision Power Analyzer.

All information and contact form available at

https://pages.yokogawa.com/PowerAnalyzerWT1500



Case Study: Vertiv

Precise Power Analysis for UPS Systems in AI Data Centers

As the use of artificial intelligence continues to grow, the demands placed on data center power infrastructure are changing. While conventional applications often exhibit relatively stable power consumption, AI workloads can shift from low to high load levels within milliseconds. These pulsed load profiles place stringent requirements on the dynamic performance, efficiency, and reliability of uninterruptible power supply (UPS) systems. At the Vertiv Power Customer Experience Center in Bologna, high-power UPS systems for data center and industrial applications are developed and tested. These include the Vertiv™ Trinergy™ and Vertiv™ PowerUPS 9000 systems, which provide power ratings ranging from 500 kW to 2.5 MW per module.

Managing Dynamic AI Loads

A particular challenge arises when diesel generators take over power supply during a grid outage. If rapid load fluctuations are passed through by the UPS to the upstream power source, they can place additional stress on the generators and compromise the stability of the overall system.

To address this challenge, Vertiv developed the Input Power Smoothing function. In this approach, the battery system acts as a short-term energy buffer, absorbing the effects of rapid load changes at the UPS output and thereby reducing fluctuations in input power seen by the upstream supply. To validate this functionality, the development team needed to simultaneously measure multiple UPS inputs and outputs. The evaluated Vertiv™ Trinergy™ topology included two three-phase AC inputs, one DC battery input, and one three-phase output.

In addition to long-term data collection for thermal evaluation, measurements with high time resolution were required to analyze transient signal behavior, waveform distortion, high-frequency noise components, and total harmonic distortion during load transitions. At the same time, active, reactive, and apparent power values had to be recorded.

Integrated Measurement Technology from Yokogawa

For this demanding measurement application, Vertiv implemented an integrated solution from Yokogawa Test & Measurement. The WT5000 Precision Power Analyzer provided highly accurate analysis of the relevant AC and DC power paths. The DL950 ScopeCorder captured fast voltage and current waveforms during dynamic load transitions, while the GM10 Data Acquisition System recorded thermal measurement data.
The IS8000 software platform consolidated the different measurement data streams into a common analysis environment. The WT5000 and DL950 were synchronized using the IEEE 1588 Precision Time Protocol (PTP), enabling precise correlation between power measurements and fast-changing signal waveforms.

Precise Data for Validation

The integrated measurement solution enabled the development team to investigate UPS behavior in detail during rapid load changes. The measurements demonstrated how the Input Power Smoothing function uses the battery system as a short-term energy buffer, reducing power fluctuations seen by the upstream power supply.
Based on these results, Vertiv was able to validate the performance of the developed control strategy. At the same time, thermal data, electrical power measurements, and fast signal waveforms could be analyzed within a single software environment. This reduced test complexity and simplified both analysis and troubleshooting for the development team.
“Reliability is one of the most important factors for our customers. Therefore, the accuracy of these measurements is critical to us. Today, we rely on Yokogawa to provide this level of accuracy and reliability.” Francesco Centritti, Head of the Test Engineering Team at Vertiv.

For the full case study:
https://yokogawa.magazines.nu/case-study/vertiv

Bild: VERTIV 2026



Open. Position. Measure.

Split-Core Current Transducers with Zero-Flux Technology.

The new CT500SA and CT200SA split-core current transducers bridge the gap between highly accurate zero-flux current transducers and conventional current clamps that are easy to install.

E-mobility, power electronics, renewable energy systems, and AI data centers are placing ever higher demands on current measurement technology. With the new CT500SA and CT200SA split-core current transducers, Yokogawa offers a solution for precise current measurements on existing conductors, even in applications with limited installation space.

Electrical systems are becoming increasingly powerful and compact. At the same time, the demands placed on development, validation, and testing measurements continue to grow. In many cases, currents must be measured without modifying existing wiring or carrying out extensive changes to the test setup. The new CT500SA and CT200SA AC/DC split-core current transducers have been specifically developed for these conditions, enabling precise current measurements even where installation space is limited.

Accuracy or Ease of Installation?

Many users face a familiar dilemma: Closed-loop zero-flux current transducers offer very high measurement accuracy, but require the conductor to be routed through the sensor opening. Retrofitting such a transducer to an existing installation may even require disconnecting and reconnecting wiring. This is often labor-intensive and difficult, particularly where installation space is limited. Conventional current clamps, on the other hand, can be installed quickly and easily, but often do not provide the accuracy required for demanding development and validation tasks.

With the new CT500SA and CT200SA current transducers, Yokogawa significantly reduces this trade-off. They bridge the gap between the exceptional accuracy of conventional zero-flux current transducers and the ease of installation of traditional current clamps. As a result, users benefit from precise measurements even in applications where compromises between accuracy and installation effort were previously unavoidable.

With the CT1000S and the new CT500SA and CT200SA models, Yokogawa now offers the right split-core solution for a wide range of current measurement applications.

From compact measurement points with limited installation space to applications involving currents up to 1000 A, there is a suitable split-core solution for a variety of requirements.

A Zero-Flux Current Transducer Compatible with Any Measuring Instrument

Modern development and validation projects often require both power and waveform analysis. Power analyzers are used for the precise determination of efficiency, power, and losses, while oscilloscopes and transient recorders provide detailed insight into signal waveforms, switching events, and dynamic processes.

Thanks to their voltage output, the split-core zero-flux current transducers can be connected directly via a BNC interface to power analyzers, oscilloscopes, and transient recorders from Yokogawa or other manufacturers. Additional shunts are not required.

This allows identical current signals to be acquired and analyzed using different measuring instruments. Additional measurements, separate sets of current transducers, or time-consuming modifications to the test setup are no longer necessary. At the same time, relationships between power measurement data and signal waveforms can be analyzed more easily, and measurement results from different systems can be compared directly.

For power supply, an external power adapter is available. Alternatively, the current transducers can be powered directly via the integrated supply connections available on many Yokogawa measuring instruments.

Compact Design

In addition to measurement accuracy, the physical size of the measurement equipment is becoming increasingly important. Whether for electric drives, power electronics, photovoltaic systems, or power supplies in AI data centers, installation space for measuring instruments and sensors is often limited. With compact dimensions of just 110 mm × 62 mm × 25 mm, the current transducers can be easily integrated into existing measurement setups.

An integrated opening mechanism enables convenient one-handed installation directly onto the conductor. In addition, an M4 threaded mounting hole and a cable-tie mounting option support secure and repeatable positioning of the transducer. This directly contributes to the high repeatability of measurement results.



Yokogawa's split-core current transducer portfolio with zero-flux technology: the CT1000S for current measurements up to 1000 A, along with the new CT500SA and CT200SA models for particularly compact and precise current measurements.

For use in development and testing environments, the current transducers provide additional functionality. The integrated DEMAG function allows the magnetic core to be demagnetized when required.

The **ZERO ADJUSTMENT** function also enables convenient zero-point adjustment. This helps reduce the effects of residual magnetization and offset deviations, supporting the high repeatability of measurement results.

High Accuracy and Wide Bandwidth
The CT500SA and CT200SA models achieve a guaranteed accuracy of:

±(0.09% of reading + 0.01% of range)
at 50/60 Hz and an ambient temperature of 23 ± 5°C.

This level of performance delivers exceptionally high accuracy for split-core current transducers. Users benefit from a significantly more accurate alternative to conventional current clamps and can perform measurement tasks with higher accuracy requirements without sacrificing the advantages of easy installation.

For different current ranges, two variants are available:

- CT200SA for current measurements up to 200 A
- CT500SA for current measurements up to 500 A

Both models are suitable for the precise analysis of current waveforms at the output of inverters, power electronic systems, and other dynamic applications.

The bandwidth is 1 MHz (-3 dB) for the CT200SA and 500 kHz (-3 dB) for the CT500SA. Both models provide a phase accuracy of ±0.1° over a frequency range from 0.1 Hz to 1 kHz.

Versatile Applications
The new split-core current transducers have been developed for a wide range of modern measurement applications.



In addition to sensor`s compact measuring head, the split-core current transformers feature a separate control unit with demagnetization (DEMAG) and zero adjustment (ZERO ADJUSTMENT) functions.

Typical applications include:
- Electric vehicles and electrified powertrains (EV/xEV)
- Inverters and power electronics
- Photovoltaic systems and energy systems
- Heating, ventilation, and air conditioning (HVAC)
- Power supplies and power converters
- Components for AI data centers and their infrastructure

Applications involving high currents, existing wiring that is already installed, and limited installation space particularly benefit from the combination of high measurement accuracy, easy installation, and versatile use.

Benefits: Precision and flexibility combined in a new way
The new CT500SA and CT200SA split-core current transformers combine the high measurement accuracy of conventional zero-flux current transformers with the ease of use of traditional clamp meters.

They are particularly advantageous in applications where existing cables cannot be disconnected, installation space is limited, and high measurement accuracy is essential. This gives you a more precise alternative to conventional clamp meters without sacrificing their flexibility.

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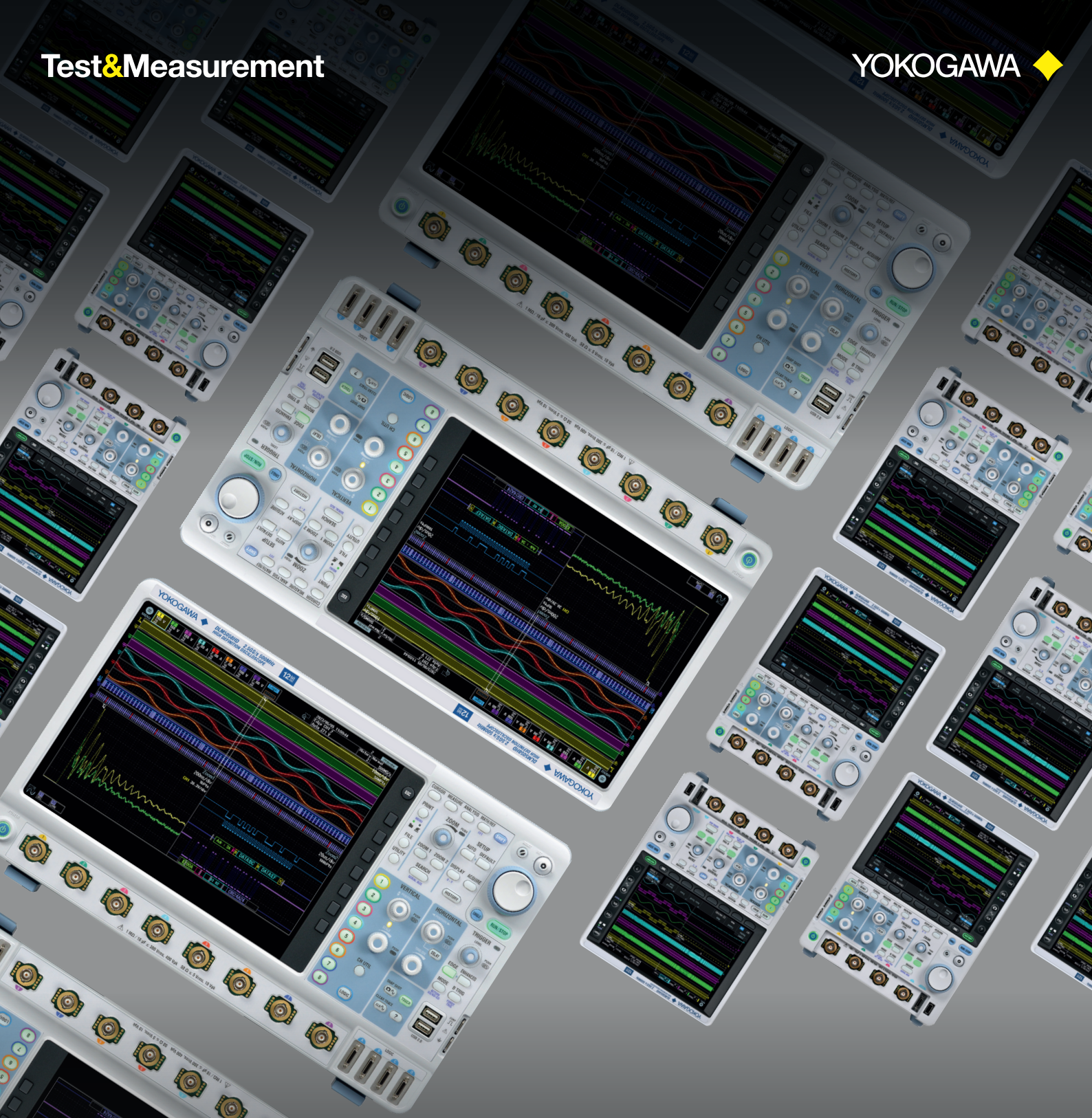

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Webinar

Measurement Technology Insights – Concise and Practical, German language

Universal Viewer Software – More Than Just Displaying Waveforms Thursday, 4 March 2027 // Christian Thoma

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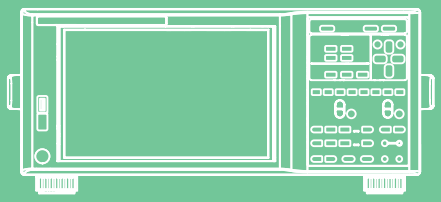


Power-Workshops

Understanding and Applying Power Measurement in Practice, German language

Power Workshop WT5000
1–3 December 2026, Herrsching am Ammersee

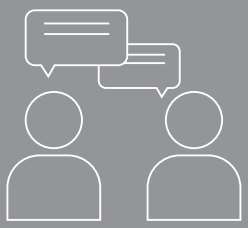
Power Workshop WT5000
9–11 March 2027, Herrsching am Ammersee

Power Workshop WT1800E/R
27–29 April 2027, Herrsching am Ammersee

Power Workshop WT5000
8–10 June 2027, Herrsching am Ammersee

Power Workshop WT1800E/R
26–28 October 2027, Herrsching am Ammersee

Power Workshop WT5000
7–9 December 2027, Herrsching am Ammersee



Meet the Precision Makers

Experience Measurement Technology. Exchange Knowledge. Find Solutions.

Coiltech Deutschland
International Exhibition for Electromechanics
17–18 March 2027, Augsburg // Hall 5, Booth G-26

PCIM Expo
Leading Trade Fair for Power Electronics
11–13 May 2027, Nuremberg // Hall 9, Booth 400

ECOC
European Conference on Optical Communication
11–13 October 2027, Milano// Booth F17

Laser World of Photonics
World's Leading Trade Fair and Congress for Photonics
22–25 June 2027, Munich

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