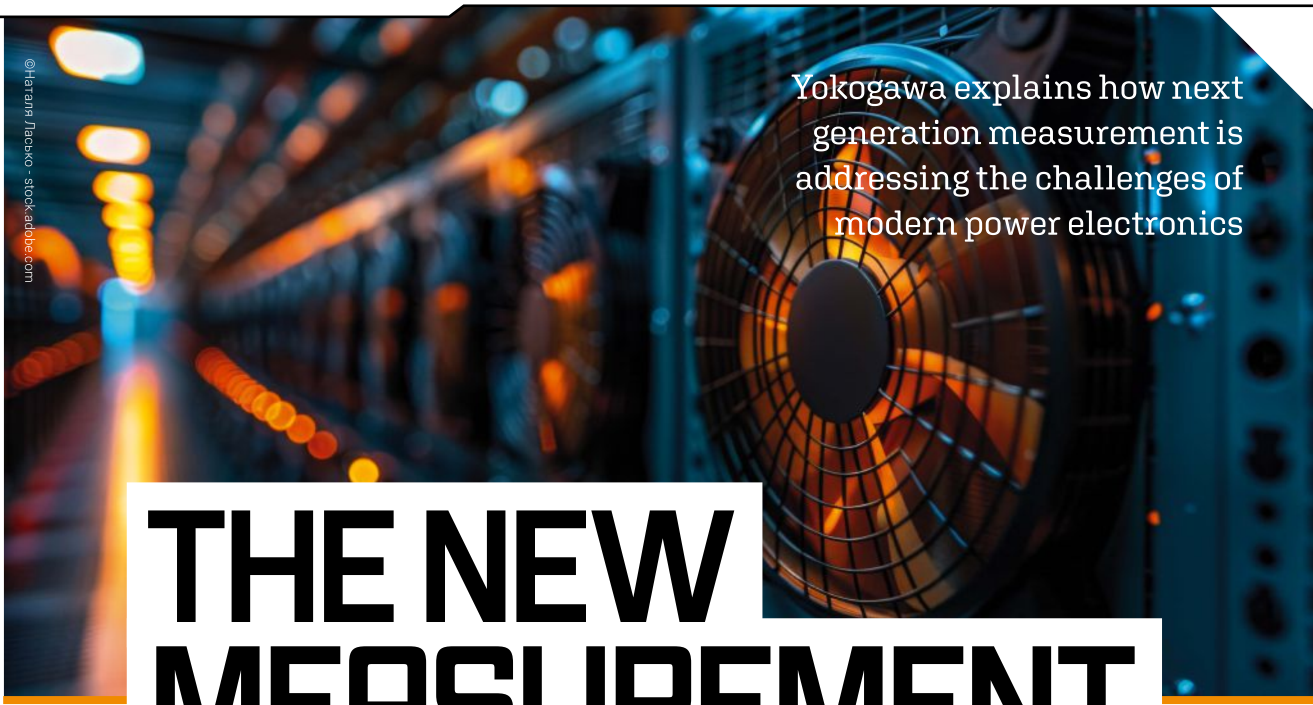


Yokogawa explains how next generation measurement is addressing the challenges of modern power electronics

THE NEW MEASUREMENT CHALLENGE

AUTHOR DETAILS

Yokogawa *is a leading test & measurement specialist*

Power electronics are becoming faster, denser, and more central to the way energy is generated, converted, stored, and consumed. From EV fast charging and renewable energy systems to AI data centres and grid-connected infrastructure, engineers are being asked to deliver higher efficiency, increased power density, and more reliable performance under increasingly dynamic conditions.

This shift is creating a new measurement challenge. It is no longer enough to measure average power or validate systems only under steady-state conditions. Engineers now need accurate, time-aligned insight into power conversion efficiency, switching behaviour, harmonics, transient response, thermal effects, and power quality.

If measurement instruments cannot capture these effects accurately, efficiency and loss calculations may not reflect real operating conditions.

As SiC and GaN devices become more widely used, this challenge becomes even more demanding. These wide-bandgap semiconductors enable faster switching and lower losses than traditional silicon devices, helping engineers improve efficiency and reduce system size. But faster switching also creates steeper voltage and current edges, higher-frequency noise, and more complex waveform behaviour. At the same time, voltages and power levels are rising with EV fast charger outputs moving from 400-600 V towards 1 kV, while data centre UPS systems are being designed to manage multi-megawatt loads.

Next-generation power systems also operate across multiple domains. In an inverter, converter, charger, or UPS system, switching events can happen in microseconds, while thermal behaviour may develop over minutes or hours. Harmonic distortion may need to be analysed across hundreds of frequency components, while power quality must be understood across several input and output nodes.

This means engineers need measurement systems with:

- Sufficient bandwidth to capture high-speed switching effects in real time
- High accuracy for efficiency and loss measurements
- Strong isolation and noise immunity that perform in high-voltage, high-current environments
- Multi-channel capability for complex AC and DC systems
- Time synchronisation across power, waveform, thermal, and control data to enable whole-system analysis

Unlike in detailed waveform analyses, the bandwidth for evaluating the power and efficiency of inverter-driven motors and power converters is based on the least-distorted waveform. High-speed switching voltages cause triangular-shaped distortion on current waveforms, which means current signal determines the bandwidth. To avoid measurement error, the bandwidth must therefore be significantly higher than the switching frequency. In some cases, five to seven times the switching frequency may be needed to keep error within 0.05%, and this rises to 25 times if the complete signal must be captured.

Other cases may require much higher bandwidth to capture the full signal shape: for example, for SiC-based systems switching at 20 kHz, a current measurement bandwidth of around 500 kHz may be needed to achieve the required accuracy.

Noise is another critical issue. High-speed switching devices can radiate electrical noise that affects readings or disrupts instruments. Measurement instruments require extra validation to perform reliably

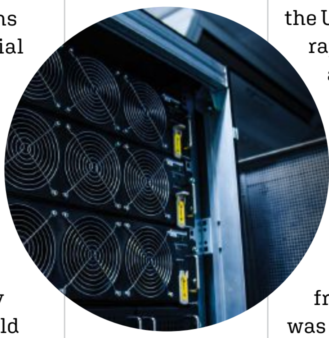
in this environment and in the case of Yokogawa Test & Measurement, the company validates instruments using high-speed switching devices to help ensure they perform in demanding real-world conditions, not only under ideal laboratory waveforms.

AI DATA CENTRE POWER SYSTEMS

AI data centre infrastructure is a key area experiencing these measurement challenges. AI workloads can create rapid and unpredictable pulses, placing new demands on power protection and energy systems.

For example, engineers at Vertiv's Bologna Power Customer Experience Centre develop and test advanced power converters and UPS systems for large data centres and industrial facilities. AI-related demands have led to the development of more sophisticated solutions, including input power smoothing. This technology, which can handle up to 2.5 MW in a single module, helps manage millisecond-level fluctuations by using UPS battery energy during peak pulses to shield upstream power sources. Without this shielding, pulses could be reflected back to the grid or back-up generators, threatening the stability of the data centre's entire energy system.

Engineers needed to ensure the technology could respond to this dynamic load behaviour to enable stable and efficient operation. This required a complex measurement setup. The UPS system included multiple inputs and outputs, including AC mains, DC battery input, and three-phase output power.



Engineers needed to monitor power flow, waveform behaviour, noise, harmonic distortion, active and reactive power, and thermal effects simultaneously during fast switching events. The test environment also required safe handling of currents up to 5,000 A.

By using an integrated measurement solution combining a precision power analyser, isolated and mixed-signal oscilloscopes with a data acquisition system, and integrated software platform (Yokogawa WT5000, DL950, GM10, and IS8000), engineers were able to analyse time-aligned electrical, thermal, and waveform data side by side. This allowed them to see how the UPS system responded during the rapid load changes, how smoothing algorithms performed, and how the stress affected efficiency and power quality. The granular insight validated that the enhanced UPS solution could shield generators from dangerous resonance.

Another important outcome from the measurement ecosystem was a more efficient engineering workflow. Having synchronised data in one environment it reduced testing complexity, shortened debugging time, and supported faster development decisions, helping accelerate time to market.

MEASUREMENT LOGIC

The same measurement logic applies across many areas of power electronics. In EV fast charging, output voltages are moving from 400-600 V towards 1 kV as battery systems are designed to accept higher charge rates. Engineers must validate efficiency, switching behaviour, harmonics, and thermal performance across a wide range of operating points while ensuring compliance with the energy management standards that govern consumption reporting.

In renewable energy systems, solar inverters, wind converters, and battery energy storage systems must interact reliably with the grid while meeting demanding efficiency and power quality requirements. Accurate measurement is essential for validating conversion efficiency, harmonic performance, and stability under variable generation and load conditions.

In grid-connected applications, converters must support increasingly complex energy flows, including storage, back-up power, distributed generation, and grid-interactive operation. This requires accurate analysis of active, reactive, and apparent power, as well as harmonics, transients, and long-term thermal behaviour.

Across all these applications, engineers face the same underlying problem: fast electrical events, slow thermal effects, multi-channel system behaviour, and strict efficiency expectations must all be understood together. As a result, they demand integrated measurement ecosystems that provide reliable, real-time measurement under demanding electrical conditions, with synchronisation for whole-system analysis.

COMPETITIVE ADVANTAGE

As SiC and GaN devices drive faster switching, EV charging infrastructure scales, renewable energy systems become more grid-interactive, and AI infrastructure places new demands on power systems, measurement capability is becoming a decisive factor in engineering success.

The companies that bring products to market fastest will be those that can validate the efficiency, reliability, and compliance of complex technology with confidence. This requires more than isolated instruments measuring average power – it requires synchronised measurement of multiple behaviours under the stress of real-world conditions.

Finally, it means that, for engineers working on next-generation power electronics, next-generation measurement is a core part of design, optimisation, and innovation.