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WHITE PAPER

Real-Time Monitoring and Optimisation of Data Centres

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1. Introduction

Modern data centres face growing pressure to maximise uptime, improve energy efficiency, and manage the increasing complexity introduced by AI workloads and high-density computing. However, operators often lack the high-resolution, real-time visibility needed to detect fast transient events, optimise cooling systems, and prevent failures – both during the design and installation phases and throughout day-to-day operations.

Conventional DCIM (Data Centre Infrastructure Management) systems provide valuable operational visibility; however, even the fastest solutions typically update only every half second, limiting their ability to capture fast transient events and dynamic infrastructure behaviour.

Beyond core monitoring, data centres must address a range of operational challenges, from ensuring reliable power delivery and effective thermal management to enabling predictive maintenance and validating supplier performance. Customers consistently prioritise uptime, efficiency, and early fault detection – objectives that depend on a deeper understanding of infrastructure performance. Meeting these demands requires a measurement approach that combines high-speed data acquisition across electrical, thermal, and mechanical domains with real-time analytics and integration into existing monitoring systems.

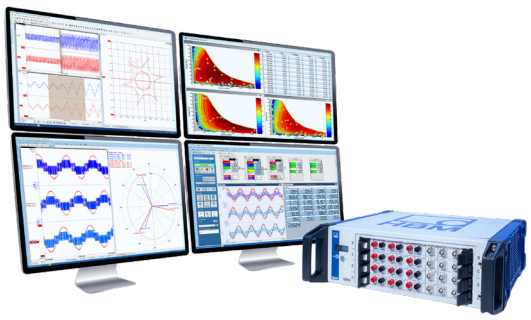
HBK supports this approach through high-fidelity measurement technologies, real-time analytics, and integration capabilities that complement existing monitoring environments. Together, these solutions provide deeper operational insight into electrical, thermal, and mechanical infrastructure performance, helping operators detect issues earlier and transition from reactive maintenance to predictive operations.

HBK measurement solutions enable high-resolution monitoring across critical data centre infrastructure.

2. Electrical Power Monitoring

Data centres have substantial and dynamic power demands, supplied by the grid or renewable energy sources with battery systems. Maintaining operational stability requires continuous insight into power quality, load behaviour, transient disturbances, battery health, runtime prediction, and thermal performance. However, conventional monitoring systems often lack the temporal resolution needed to capture fast transient events, creating a critical blind spot in power quality analysis.

Capturing these events requires high-speed, synchronous data acquisition capable of resolving fast dynamic behaviour. This supports applications such as switchgear validation, battery testing, and power quality assessment, while enabling earlier fault detection and improved asset reliability. Platforms such as HBK's Genesis HighSpeed DAQ (Gen DAQ) system provide these capabilities and can be deployed with conventional or fibre-optic cabling to address electromagnetic compatibility and safety challenges.



Genesis HighSpeed DAQ captures and analyses fast electrical transients in real time.

Reliable power delivery is fundamental to data centre uptime. While conventional monitoring systems can reveal high-level trends, many disturbances occur too quickly to be detected. Without deeper visibility, minor electrical issues can escalate into outages, equipment damage, or accelerated asset degradation.

A key differentiator is real-time power analytics, where data is processed at the edge in real-time and transmitted via the GenDAQ API to deliver pre-analysed, high-resolution insights into energy consumption and power disturbances. This enables real-time energy attribution and rapid anomaly detection beyond the capabilities of conventional DCIM systems, improving reliability in dynamic power environments.

3. Temperature Monitoring

Thermal performance is a top priority for data centre operators, as overheating can lead to equipment failures, reduced reliability, and increased operating costs.

Increasing AI workloads are driving higher rack densities and greater thermal loads. As a result, operators need more detailed insight into temperature behaviour to optimise cooling performance while maintaining reliability and uptime.

To maintain uptime and safely increase rack density, operators need precise, real-time visibility into temperature behaviour across their infrastructure. High-speed, accurate temperature measurements make it possible to quickly identify hot spots and respond before they impact operations. In practice, many temperature monitoring systems lack the spatial and temporal resolution needed to detect rapid changes or localised hot spots, limiting the ability to confidently increase rack density or optimise cooling strategies.

Addressing these challenges requires a combination of distributed temperature sensing and high-speed localised measurements that provide flexible and scalable thermal monitoring. Solutions such as HBK's QuantumX and digiBOX platforms support large-scale, distributed temperature measurement across multiple locations, and integrate easily into existing monitoring systems. For applications requiring faster response times, digiBOX combined with TT3 sensors captures rapid temperature changes and processes data locally to provide immediate insights.

QuantumX and digiBOX enable scalable, high-speed temperature monitoring across multiple locations.

Together, these technologies enable real-time thermal mapping, early hot-spot detection, and automated alarming during system design, installation, and normal operations. This allows operators to proactively protect critical equipment, optimise cooling performance, and run their data centres more efficiently by enabling early detection of thermal issues, reducing the risk of localised overheating, and supporting more effective use of cooling infrastructure.

4. Cooling System Efficiency and Mechanical Performance

Cooling systems are one of the largest energy consumers in a data centre and a critical factor in both reliability and operating costs. As operators push for higher rack densities and improved power usage effectiveness (PUE), alongside the growing adoption of liquid cooling technologies for AI-driven and high-performance workloads, understanding how cooling systems behave under dynamic conditions becomes essential. To maintain uptime and optimise energy efficiency, operators need visibility into how cooling infrastructure performs under changing thermal and operational conditions.

However, performance issues such as flow inefficiencies, vibration and component degradation are often not visible through conventional monitoring approaches.

A combined measurement approach – covering electrical power, temperature, flow rate, pressure, and vibration – provides a more complete understanding of cooling system behaviour. These measurements can be implemented using data acquisition systems alongside sound and vibration tools, including accelerometers and software platforms such as Fusion-LN and BK Connect®. Analysis techniques such as Operating Deflection Shape (ODS) and Frequency Response Function (FRF) can be used to validate system behaviour during design and installation, while also supporting condition monitoring during operation.

Beyond efficiency, predictive maintenance is a key priority for reducing unplanned downtime. The same measurement infrastructure can support vibration monitoring, anomaly detection, and threshold-based alerting through asset monitoring systems such as HBK Monitor360. This enables early detection of degradation, improves cooling efficiency, and extends the lifetime of critical components.

Integrated measurement provides real-time insight into cooling performance and equipment condition.

5. Conclusion

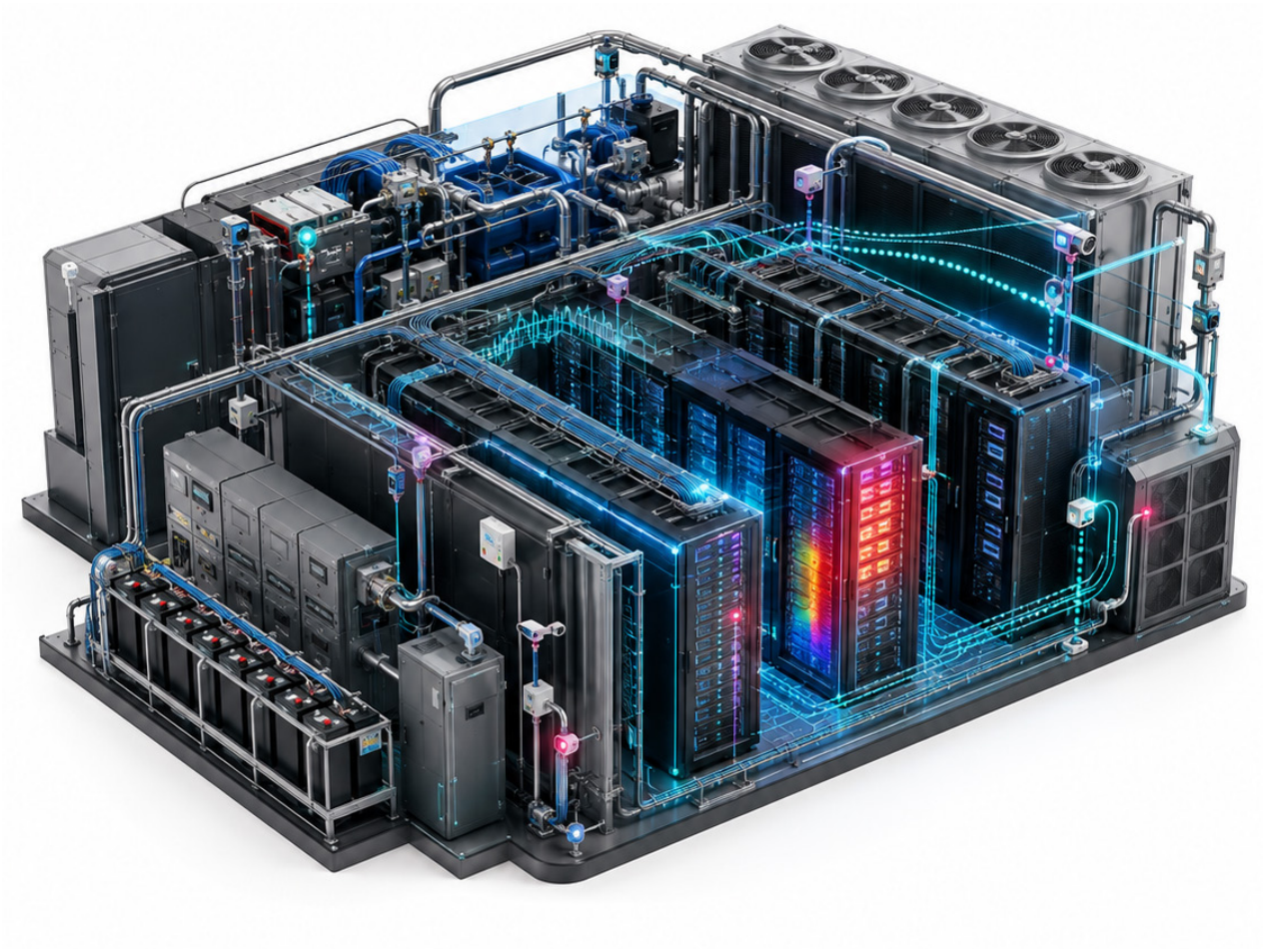
As data centres continue to increase in complexity and density, driven by AI and high-performance computing workloads, traditional monitoring approaches are no longer sufficient to ensure reliable and efficient operation. High-resolution, real-time insight into electrical, thermal, and mechanical behaviour is becoming essential – not only during operations, but also throughout system design and validation.

By combining multi-domain data acquisition with real-time analytics and system-level integration, operators gain the insight needed to detect issues earlier, optimise infrastructure performance, and make more informed operational decisions.

HBK solutions support this approach by providing detailed visibility across critical infrastructure, helping data centre operators improve reliability, increase efficiency, and reduce operational risk.

Together, high-fidelity measurement, advanced analytics, and continuous monitoring provide a foundation for more resilient, efficient, and data-driven operations. As facilities continue to grow in scale and complexity, these capabilities will play an increasingly significant role in helping operators maximise uptime while optimising performance and energy usage.

For organisations looking to complement operational monitoring with design-stage optimisation, HBK also offers reliability engineering and RAM digital twin solutions that help evaluate availability, outage risk, and infrastructure resilience before systems are deployed.



Multi-domain monitoring unifies electrical, thermal, and mechanical insights across the data centre.

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