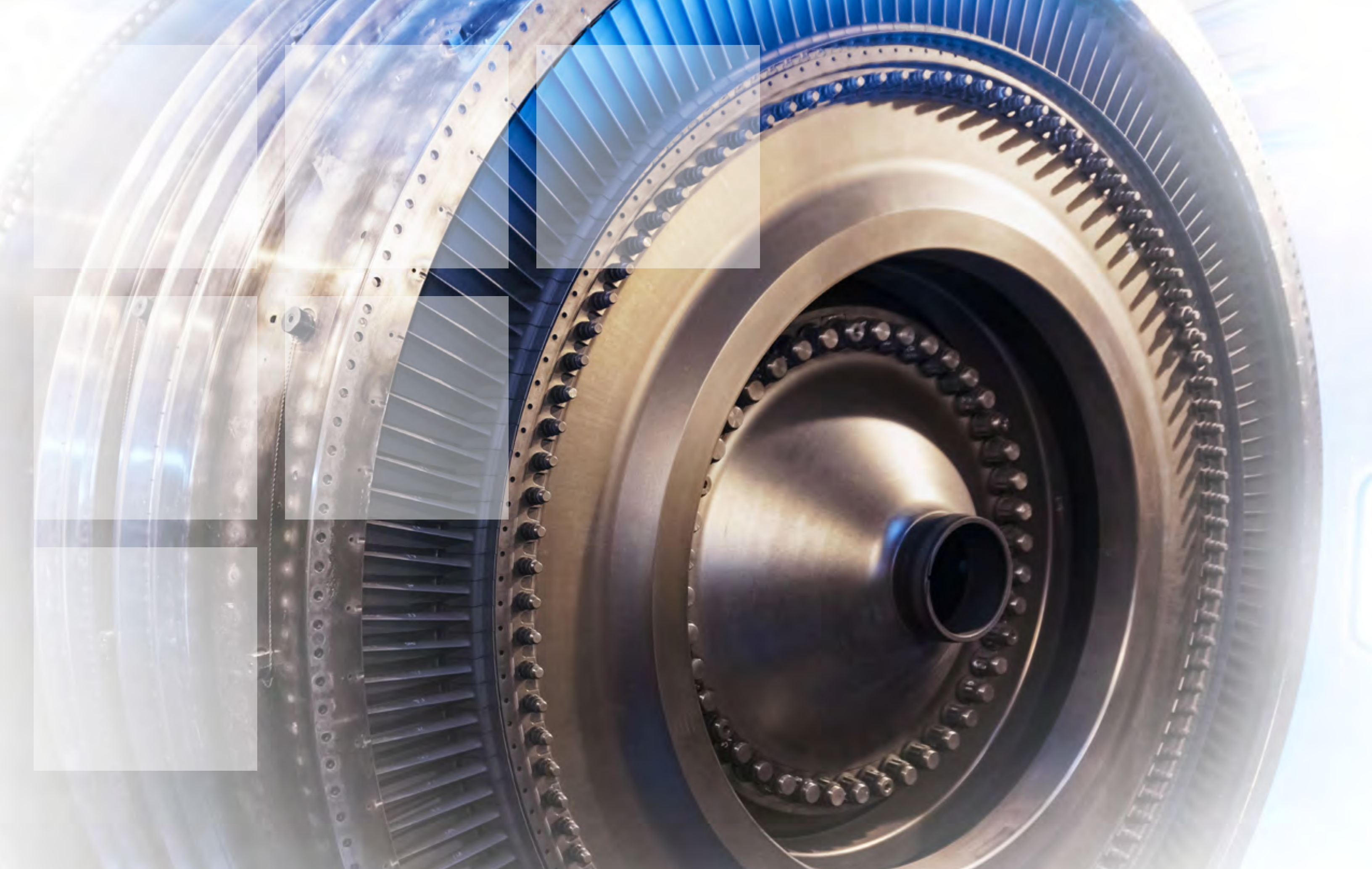
WHITE PAPER

Enhancing Gas Turbine Performance with Critical Test Instruments



Although renewable sources are roiling the power and energy industry, gas turbines provide stable, reliable generation in venues ranging from industrial facilities to oil fields. Gas turbines can help ensure grid stability and reliability when used with renewable power sources. They can also serve as large-scale backup power sources for large industrial complexes and scale down to the microturbine level to provide backup power for a single residence.

In addition, gas turbines will continue to be helpful in applications that renewable energy supplies cannot serve—at least, not without difficulty. For example, in oil fields, gas turbines can burn captured escaping wellhead gases that would otherwise be wasted and use the resulting energy to generate electricity. Gas turbines can also serve combined heat and power (CHP) applications (with gas-turbine exhaust providing heat for an industrial drying application, for example) to which renewable energy sources might not readily adapt. The U.S. Environmental Protection Agency reports that nearly two-thirds of the energy input is wasted with separate conventional power and heat generation. In contrast, the agency continues, a decentralized CHP unit that avoids distribution losses can achieve efficiencies of over 80%.

Furthermore, efforts are underway to decarbonize gas turbines or reduce the carbon they emit. Precombustion carbon-reduction methods center on using zero-carbon or carbon-neutral fuels such as hydrogen, ammonia, synthetic methane, and biofuels, while post-combustion efforts include carbon capture using liquid solvents or solid sorbents.

Consequently, given the need for reliable power as well as improvements in efficiency and strides toward carbon neutrality, gas turbines remain in demand, and the market for them continues to expand. Global Market Insights forecasts that the global gas turbine market will grow at a CAGR of 5.7% through 2032 when it will reach more than $19.9 billion.

Configurations and Operation

The gas turbines range in size from utility- and industrial-scale configurations to ones that will fit on a trailer. Applications for the latter include acting as toppers—mobile gas turbines able to move in and “top off” the power being generated when the local fixed energy sources fail to deliver sufficient power because of malfunctions or, in the case of renewable installations, insufficient sun or wind.

Gas turbines are conceptually simple. They have a shaft output that can drive a generator. But they are available in many complex configurations, including the open-cycle gas turbine and the greener, more efficient, combined-cycle power plant.

This latter configuration is a two-stage version in which an air-to-liquid heat exchanger in the exhaust path of the gas turbine boils water to power a steam turbine, which drives a second generator. This process optimizes the use of the fuel being burned. This configuration requires various temperature measurements, including gas turbine steam turbine and generator temperatures. Accurate data is critical to optimizing efficiency.

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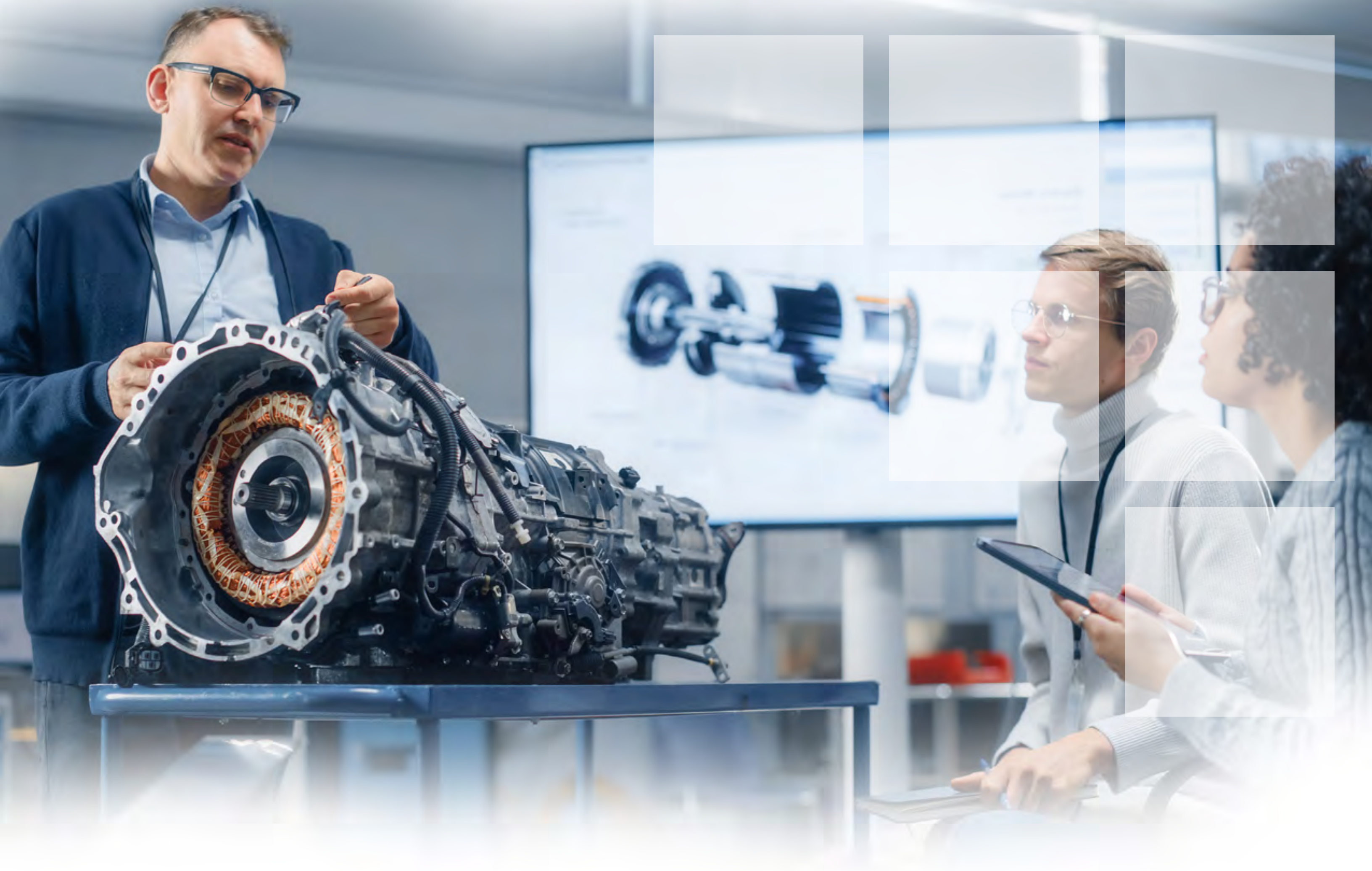

Gas-Turbine Test Requirements

Gas-turbine test efforts begin at the lengthy R&D phase, which may include extended HALT/HASS lifecycle tests. The test continues at the commissioning stage, where tests are conducted to ensure the equipment meets efficiency and other requirements. Finally, a gas turbine will require ongoing trials throughout its operating life. These tests require continuous monitoring but generally with fewer channels.

Gas-turbine tests require measurements of various parameters, with temperature measurements high on the list in importance. Maximum efficiency is a critical goal in gas turbine design, and detailed knowledge of temperatures throughout a turbine is essential to optimizing efficiency. Consequently, gas-turbine tests can require hundreds or thousands of channels of thermocouple measurements.

In addition to dedicated thermocouple instruments for temperature test, gas-turbine test also requires voltage-input data-acquisition instruments to measure values such as flow, pressure, rotation, strain, and vibration.

Test Conditions

The gas-turbine test is complex, time-consuming and expensive, with measurements of turbines under test taking place in various hard-to-reproduce scenarios. For example, the turbines that burn oilfield wellhead gas often burn fuel of poor and varying quality with many impurities. During the test, this fuel must be simulated using test gases to test the turbines over a wide range of inputs. Engineers cannot afford to lose data for this and other tests because of faulty or improperly connected test equipment, and they cannot afford downtime. In contrast, defective instruments are replaced or wiring errors corrected.

Specifications such as accuracy, resolution, channel count, acquisition speed, and price will take precedence when choosing test equipment. But beyond these headline specs, carefully consider factors that will affect the success of your test operation throughout the useful life of your equipment. Look for instruments that are easy to set up initially and that are easy to reconfigure when your equipment under test changes. Choose equipment with a reputation for reliability to avoid downtime and the time and expense of disconnecting hundreds of channels to send a unit out for repair and then reconnecting them when the unit is returned. Similarly, choose instruments that can be calibrated on-site under software control using a NIST traceable DMM or other reference. Also, select instruments that can help troubleshoot should a malfunction occur—for example, an instrument that can signal when a particular transducer has failed or become disconnected.

Test-System Architecture

In addition to choosing individual instruments, you must decide how to interconnect them. For optimal results, consider a decentralized test-system architecture that lets you locate Ethernet-compatible instruments close to the measurement location, an approach that enhances accuracy, simplifies setup and configuration, and simplifies troubleshooting. This distributed measurement capability minimizes the need for very long signal wires, which can attract interference that degrades signal quality, can be subject to miswiring or mechanical failure, and—especially for expensive thermocouple wires—can add considerable cost.

With a decentralized distributed approach, you have many small, localized test systems instead of a single larger one. With this decentralized test architecture, each test system communicates reliably to a central controller over a rugged, low-cost Ethernet cable. Choose instruments that support the IEEE 1588 Precision Time Protocol time-stamping standard, which allows clock synchronization of different data-acquisition systems over the Internet. Because this standard fully supports GPS clocks, you can maintain the accuracy of your timing from site to site — not just device to device or building to building. It lets you deploy systems globally with consistent accuracy. Timing accuracy is useful for power generation so you can ensure your power plant is ideally in phase with another power plant a few hundred or a few thousand miles away.

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High-Channel-Count Data Acquisition

AMETEK Programmable Power's VTI Instruments brand specializes in the high channel-count data-acquisition instruments required for gas-turbine tests. Every instrument VTI manufacturers conforms to the LXI standard, enabling instruments to be distributed close to the measurement points of interest along the system or combination of systems (for example, gas turbine, steam turbine, and two generators for the combined-cycle power plant), all of which might not be in the same building. In addition to LXI, the instruments support the IEEE 1588 Precision Time Protocol time-stamping standard.

The VTI products offer several ease-of-use features, including mini TC plugs, making connecting and disconnecting signal wires easy. VTI's instruments offer internal cold-junction compensation (CJC) for thermocouple applications, making it unnecessary to have a separate cold-junction box. The instruments also include an LED per channel that indicates an open transducer, facilitating troubleshooting. In addition, they incorporate an independent signal-conditioning path on each input with software-selectable filters and programmable gain for maximum flexibility and without the need for separate signal-conditioning cards.

Specific VTI products currently in use for gas-turbine tests include the modular LXI-compatible EX1200 family of scalable multifunction switch/measure units that offer functions such as a comparator, counter-timer, digital I/O, multiplexer, and programmable load. In addition, the gas-turbine industry sees widespread use of members of the EX1000 Series of 48-channel of thermocouple or general-purpose voltage measurement capability, including the EX1048A thermocouple-measurement instrument. Available in a 19-inch 1U rack-height configuration, the EX1048A includes convenient mini TC connectors, open-transducer indication, and LAN/LXI status LEDs, and it supports NIST-traceable field calibration.

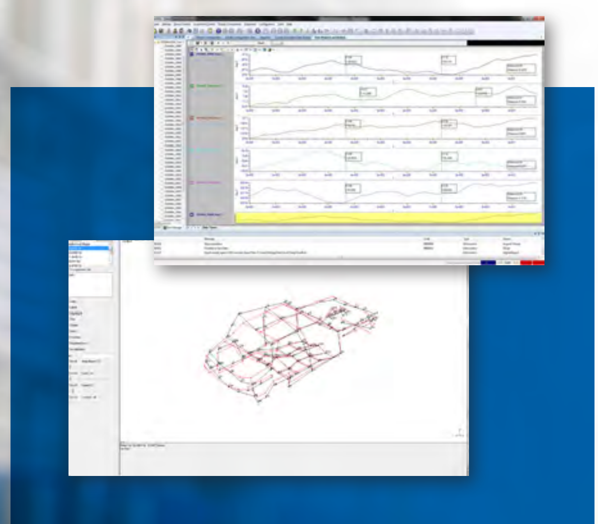
For new installations and upgrades, customers will be moving to the new EX1401 16-channel isolated thermocouple and voltage measurement instrument and the EX1403A 16-channel bridge and strain gauge measurement instrument, which feature built-in self-test capability, LXI interfaces, IEEE-1588 synchronization, power over Ethernet (PoE) capability, and a compact 1U half-rack form factor.

The EX1403A includes 24-bit delta-sigma ADC with simultaneous sampling across all 16 channels at a programmable sample rate up to 128 kS/s. It features full, half, and quarter-bridge configurations with 120-Ω, 350-Ω, and 1-kΩ bridge-completion resistances, and it generates 0.5-V to 10-V excitation voltages.

The EX1401 offers 16 channels of isolated thermocouple or general-purpose voltage inputs with independent 24-bit ADCs per channel. It features accuracies of ±0.20°C, 500-V channel-to-ground isolation, and 1,000-V channel-to-channel isolation. It can acquire data at 20 kS/s/channel to capture high-speed temperature and voltage transients. The EX1401 offers fully integrated signal conditioning and independent CJC implemented per channel.

Software Considerations

In the power and energy industry, customers building test systems tend to integrate instruments from multiple vendors and hardware they may have developed. Consequently, they tend to write custom software to tie the test system together—they do not look to their vendors for turnkey software solutions. Nevertheless, VTI Instruments makes integrating its instruments into heterogeneous test systems accessible by adhering to LXI and IVI (Interchangeable Virtual Instruments) standards and supporting multiple computing environments, including Windows and Linux. To help you get started with measurements before your custom test programs are complete, VTI Instruments offers its EXLab full-featured turnkey data-acquisition software with intuitive icon-based setup and control and spreadsheet-style channel configuration.



Conclusion

Gas turbines represent a mature, reliable technology with relatively low installed costs, and they can be expected to be part of the power and energy industry for the foreseeable future. They will continue to require extensive testing to ensure they meet performance, efficiency, and reliability targets extending from the R&D phase through ongoing monitoring when in service.

VTI Instruments specializes in high channel count and reliability in harsh environments with vibration and acoustic noise at an attractive price point for all your thermocouple and voltage measurement needs. They can meet all your gas-turbine measurement needs with easy-to-use instruments, high accuracy, and support for hundreds or thousands of channels. Leverage VTI Instruments' decades of experience in the power and energy industry to develop an accurate, rugged, reliable and flexible test system.

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