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Jet Engine Testing
using the Personal Daq

Avionics

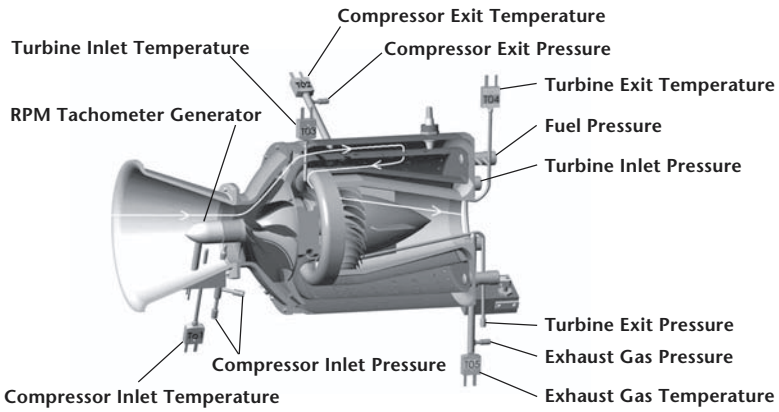
Application Note #107

Application Summary

Gas turbines are widely used in numerous industries as prime movers. The power generation industry, for example, uses them extensively to drive electrical generators. Compared to other engines, they have the advantage of being relatively simple, reliable, and lightweight and can be made in a wide range of sizes to handle generators that are rated from a just few kilowatts to several hundred megawatts. The turbine's theory of operation is straightforward and can be explained through basic thermodynamics. But, hands-on experience working with an actual engine is exceedingly valuable to students of engineering, physics, and other technologies who are the industry's future designers and researchers. Laboratory training gives them a sharper insight and better appreciation of a gas turbine's uniqueness, whether they will be designing new turbines, applying turbines in the power generation industry, or using them in other applications.

One company located in Chetek, Wisconsin, supplies a full working gas turbine, called the MiniLab™ Gas Turbine Power System, specifically intended for universities and technical institutes. Turbine Technologies, Ltd. developed the SR-30 engine and test stand based on its experience working in the aerospace industry. Over 100 universities, colleges, and research institutes are currently using the turbines for various studies.

Gas Turbine Connections to the Personal Daq



The MiniLab™ Gas Turbine Power System, specifically intended for universities and technical institutes around the world contains an embedded IOtech Personal Daq data acquisition system and is being used both as a teaching tool and as a test stand for numerous research projects. Although the SR-30 turbine engine develops a thrust of about only 18 lft, it is a real-world turbine that that students use to study basic principles and researchers use to test various fuels and servo control systems. The Personal Daq collects those data that are necessary for students to understand the SR-30's operation and for the researchers' project analyses.

Potential Solution

The college students and researchers must be able to record and analyze large files of data that include temperature, pressure, flow, and thrust. Initially, Turbine Technologies supplied only an electrical terminal strip connected to several thermocouples strategically located around the engine for customers to interface their own data collection systems. However, many customers requested full, turnkey systems, which included the data acquisition system. In response, the first generation of systems with embedded data acquisition employed dedicated software and one or more cards plugged into a computer chassis. Although this approach worked well in a number of cases, customers soon decided they needed many more channels and greater programming flexibility than could be provided by one or two boards with special software plugged into a computer. Moreover, several professors balked at the idea of having to purchase yet another computer for their lab.

IOtech's Solution

Toby Kutrieb, purchasing manager at Turbine Technologies set out to find a different solution to the problem. Says Kutrieb, "I needed at least 5 channels for thermocouples, 5 channels for pressure transducers, and one each for rpm, flow, and thrust. Also, I wanted to have a system that could interface with a customer's computer, whether it is a desktop or laptop. Lastly, the data acquisition system had to be economical, but fast and accurate." Kutrieb found all this and more in IOtech's Personal Daq™. The module can be configured with 5 to 30 double-ended inputs for type-K thermocouples that measure from 20˚ to 900 ˚C, or 10 to 60 inputs for voltage measurements. Thrust values measured with a load cell are in the range of 0 to 30 lbs. The units also contain 8 to 32 digital I/O ports and 2 to 4 frequency (or pulse) inputs for measuring speed up to 84,000 rpm and flow rates of four to six gallons per hour. The Personal Daq also connects to a computer via the USB port, the simplest of all interfaces. Furthermore, USB hubs can be used to create multiple unit systems containing up to 100 Personal Daq modules attached to a single PC. This arrangement can provide up to 8,192 analog and digital I/O lines.

"Turbine Technologies' customers are sophisticated and extremely discerning and expect to have the best system they can possibly obtain," says Kutrieb. "In order to satisfy these users, Turbine Technologies supplied the Minilab™ embedded with IOtech's hardware and software which lets them design their own Virtual Instruments and customize graphics." Personal Daqs are supplied with Personal DaqView™, IOtech's Windows®-based data logging application software

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that lets users set up their own acquisition applications and save acquired data directly to disk. The system also includes eZ-PostView™, a post-acquisition application, drivers for Visual Basic®, and C/C++® for Windows®. Users can obtain drivers for icon-based software packages LabVIEW® and DASYLab®. Many customers also download their data to Excel® spreadsheets.

Turbine Technologies' customers use the Minilab™ for many research projects, which include biodiesel fuel studies, comparing Proportional-Integral-Derivative (PID) with Fuzzy Logic Controls (FLC), Brayton cycle studies, basic principles of operation, inlet cooling studies, large scale scientific computing, and various fuel studies, to name a few. "Such a wide variety of diverse tests are made possible with the Minilab's™ OneTouch Auto Start System," says Kutrieb. "It provides an automatic start sequence with all critical engine parameters monitored during operation. In the event of a problem, the engine will automatically stop safely and alert the operator. No special training is required to operate the MiniLab™ system."

Biodiesel fuel studies employed new and used vegetable oil and the students collected data, which allowed them to appreciate the engine's flexibility to accommodate alternate fuels, and compute its efficiency and temperature, among other parameters. The PID vs. FLC studies were undertaken to provide alternative methods in improving overall engine control. In this study, soft-computing technologies were demonstrated in a real hardware-in-the-loop environment.

Brayton cycle studies required pressure sensors for measuring compressor inlet static pressure, compressor stage exit stagnation pressure, combustion chamber pressure, turbine exit stagnation pressure, and thrust nozzle exit stagnation pressure. The studies also used thermocouples to measure, compressor inlet static temperature, compressor stage exit stagnation temperature, turbine stage inlet stagnation temperature, turbine stage exit stagnation temperature, and thrust nozzle exit stagnation temperature.

Numerous universities and colleges currently use the Minilab™ for special and general studies, including Auburn University, Auburn, Ala.; the University of Wisconsin, Platteville, Wis.; India Institute of Technology, Bombay, India; Cairo University, Cairo, Egypt; and NASA's Marshall Space Flight Center, Huntsville, Ala. Additional programs concerning basic principles of turbine operation, inlet cooling studies, large scale scientific computing, and various fuel studies, can be reviewed in the respective technical papers listed at Turbine Technologies Web site, www.turbinetechnologies.com.

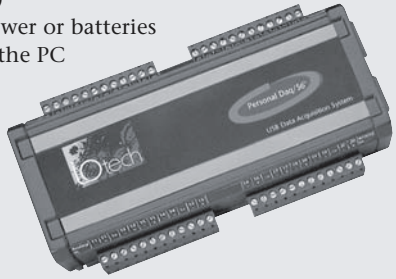
Conclusion

Turbine Technologies Ltd. supplies universities and colleges with a turn-key gas turbine engine lab, including a dedicated, embedded IOtech Personal Daq data acquisition system. The MiniLab™ provides students, professors, and scientists with real world, gas turbine operational data for education and research. It provides a test bed for numerous serious studies such as developing advanced turbine control algorithms as well as demonstrating the basic operating principles for students.

Personal Daqs

Designed for high accuracy and resolution, the 22-bit Personal Daq™ data acquisition systems directly measure multiple channels of voltage, thermocouples, pulse, frequency, and digital I/O. A single cable to the PC provides high-speed communication *and* power to the Personal Daq. The Personal Daq modules are a family of low-cost, USB-based products from IOtech. Because of the strict power limitations of the USB, the modules incorporate special power-management circuitry to ensure adherence to USB specifications.

Features



- Multifunction data acquisition modules attach to PCs via Universal Serial Bus (USB 1.0 & 2.0 compatible)
- Ultra low-power design requires no external power or batteries
- Can be located up to 5 meters (16.4 feet) from the PC
- High-resolution, 22-bit A/D converter offers reading rates from 1 to 80 Hz
- Built-in cold-junction compensation for direct thermocouple measurements
- Frequency/pulse, or duty-cycle measurements up to 1 MHz*
- Convenient removable screw-terminal signal connections
- 500V optical isolation from PC for safe and noise-free measurements
- Programmable inputs from ±31 mV to ±20V full scale
- Digital I/O lines with open collector output for direct drive applications*
- Expandable up to 80 channels of analog and digital I/O*
- Up to 100 Personal Daq modules can be attached to one PC using USB hubs, for a total capacity of 8,000 channels
- Digital calibration—no potentiometers or adjustments required

Software

- Personal DaqView™, spreadsheet-style software for *Out-of-the-Box*™ setup, acquisition, & real-time display
- eZ-PostView™, for post-acquisition data viewing
- Support for Visual Basic®, C/C++, DASYLab®, and LabVIEW®

* The Personal Daq/54 does not have frequency, digital I/O, or expansion capability