Utilizing NI Tools to Develop a Vibration Monitoring Application for Gas Turbine Design and Production Test

by
Daniel Hooks, Senior Project Engineer
Patrick Kelly, Vice President of Marketing
N.D. "Buck" Smith, President
Cal-Bay Systems, Inc.
United States

Category:
Industrial Measurements and Control

Products Used:
LabVIEW 8.6.1
LabVIEW Sound and Vibration Measurement Suite 7.0
LabVIEW FPGA Module 8.6
NI-RIO 3.1
NI-DAQmx 8.8
NI PXI-1042 PXI Chassis
NI PXI-8360 MXI-Express Card
NI PXI-4472B Vibration-Optimized Dynamic Signal Acquisition Cards
NI PXI-7833R Multifunction Intelligent DAQ Cards

The Challenge:
Developing a custom vibration monitoring system to replace Bently Nevada's ADRE for use in design and production test at an industry-leading gas turbine manufacturer.

The Solution:
Utilizing National Instruments' PXI-based hardware and LabVIEW development environment to create a cutting-edge vibration acquisition and analysis system that meets the customer's specific needs while reducing hardware costs by over 50 percent.

Introduction:
During the design and production testing of large gas turbines, acquiring and analyzing vibration data is of critical importance. Vibration signatures provide insight into the health and performance of a turbine, and offer the earliest indications of potential problems. The process of acquiring and analyzing vibration data is challenging, with numerous channels of high speed data needing to be acquired, and complicated analysis routines needing to be performed. The market for vibration analysis systems consists largely of commercial products based on custom hardware platforms, with Bently Nevada's ADRE system being a long-time industry standard.

Cal-Bay Systems was approached by an industry-leading gas turbine manufacturer and asked to develop a vibration acquisition and analysis system. They wanted an alternative to Bently Nevada for use when carrying out design and production testing on their own turbines. The customer recognized the potential that commercial-off-the-shelf (COTS) hardware and PC-based software offered in terms of lowering costs and increasing performance. Cal-Bay Systems was a logical choice to develop such a system as a National Instruments Select Integrator with extensive experience using NI's vibration analysis tools.

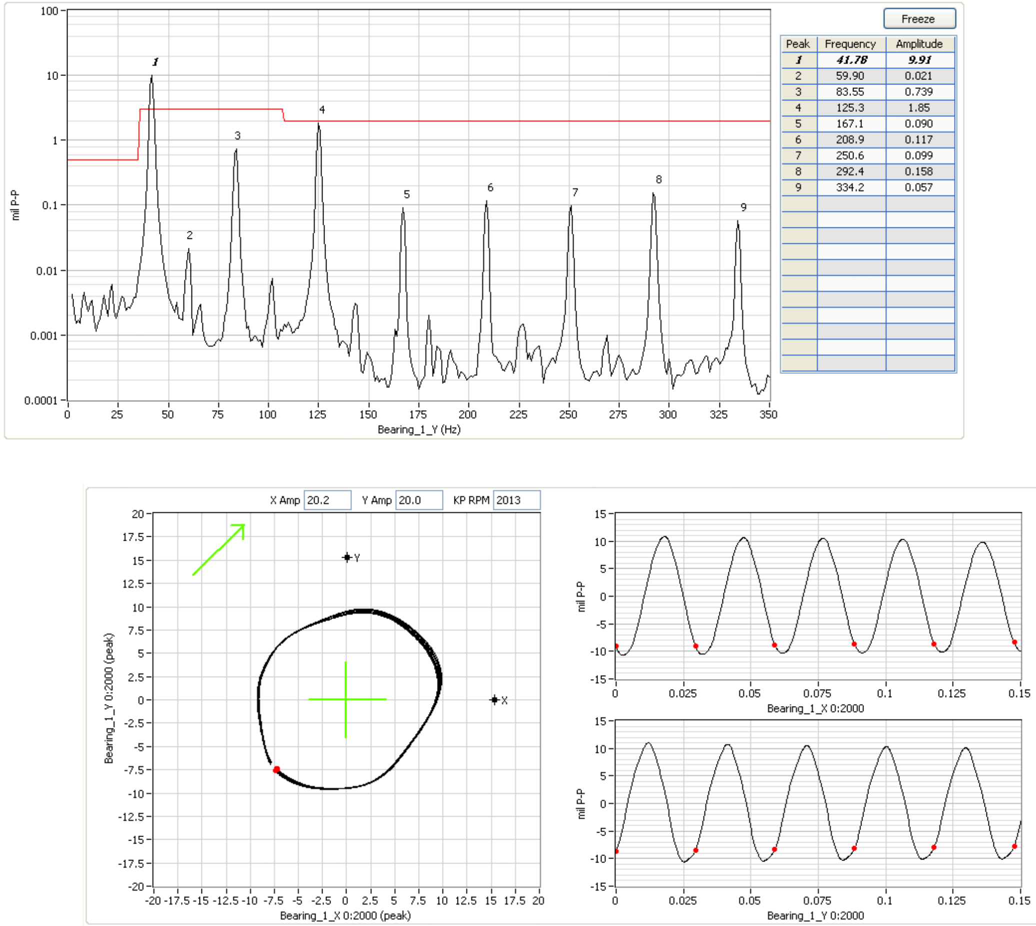

Figure 1: Common plots for vibration analysis implemented using LabVIEW.

Data Acquisition Hardware:

National Instrument's PCI eXtensions for Instrumentation (PXI) platform was chosen as the basis for our system because of its combination of high bandwidth, low latency, and support for a wide variety of hardware modules. Precise synchronization of data acquisition cards was essential for determining critical time differences between input signals, and the ruggedized industrial platform worked well for a permanently installed monitoring system. An NI PXI-8360 MXI-Express interface card allowed high rates of sustained data throughput to an attached PC, where advanced data processing and display were carried out using LabVIEW-based software.

The NI PXI-4472B vibration-optimized dynamic signal acquisition (DSA) cards were ideal for acquiring proximity probe and accelerometer data in our system. With eight channels per card, simultaneous sampling at up to 102.4 kHz, and 24-bit resolution, these cards allowed us to acquire data with the speed and precision necessary for our application. The ability to configure AC/DC coupling and IEPE excitation on a per-channel basis meant that we could mix sensor types and configurations on the same card.

In order to acquire tachometer data our acquisition system was outfitted with a NI PXI-7833R multifunction intelligent DAQ card, containing a 3 million gate reconfigurable I/O (RIO) field-programmable gate array (FPGA). Using National Instruments' FPGA hardware in conjunction with LabVIEW and the add-on FPGA Module allowed for the rapid design and implementation of a hardware-based tachometer signal acquisition and processing system. Not only was the RIO-based system capable of sampling at higher clock rates than the DSA cards – up to 200 kHz to provide unmatched phase resolution – but performing all tachometer calculations in the card's FPGA meant that the PC used for vibration analysis was not additionally taxed with software-based tachometer signal processing. The number of available vibration input channels was not reduced, and processing algorithms were flexible enough to automatically calculate trigger levels for most common tachometer sensor types. Customer requirements for highly flexible and accurate detection of tachometer pulses were met and exceeded.

Considered in relation to the price of vibration data acquisition hardware from major manufacturers, creating a system based upon National Instruments COTS hardware is extremely cost effective. Compared to the price of a Bently Nevada ADRE 408 DSPi data acquisition system, our customer was able to reduce their hardware expenditures by more than 50 percent. This allowed them to save over $750,000 when purchasing multiple analysis systems for their facilities.

Vibration Analysis Software:
Significant challenges exist in the software portion of a vibration monitoring application. The first major hurdle is the processing of raw vibration data. Advanced analysis algorithms provide users with great insight into the functioning of their rotating equipment, but require a substantial amount of processing power to implement. Additionally, the processing of raw data is only one of the functions that a vibration monitoring application needs to provide. It also needs to simultaneously receive process data from other systems on the local area network (LAN), display a variety of complicated plots in real time, log data to disk when triggering criteria is met, and publish data to the LAN for remote viewing.

Using LabVIEW to develop our application provided us with serious performance advantages when leveraging new PCs with multicore processors. Graphical programming inherently lends itself to parallel structuring, as opposed to text-based programming languages which are inherently linear in nature. LabVIEW has automated functionality to create separate execution threads for parallel calculations, and we carefully designed our code to leverage this to the greatest degree possible. Different functional blocks of the code were encapsulated into separate modules, capable of running in parallel and offering clearly defined interface calls for interacting with other portions of the application. This type of design has become even more beneficial as newer versions of LabVIEW have become better and better at harnessing the power of multicore processors. Early software prototypes were written in the LabVIEW 8.5 programming environment, and we saw as much as a 25 percent decrease in execution time of intense calculations when implementing the final versions in LabVIEW 8.6.1.

Modern vibration analysis requires complicated processing algorithms to extract meaningful information from huge amounts of data. The NI Sound and Vibration Measurement Suite for LabVIEW provides a large library of cutting-edge signal processing tools for vibration and machine condition monitoring applications. These include tools for frequency analysis, even angle resampling, order tracking, and advanced visualization tools. By leveraging the Sound and Vibration Measurement Suite we were able to provide our customer with an outstanding array of processing tools without all of the overhead of implementing and testing advanced algorithms from scratch. This lowered risk and decreased costs for all parties involved.

Implementing our vibration analysis system using LabVIEW provided significant advantages above and beyond utilizing multicore computers and advanced signal processing tools. The ease and flexibility of working in LabVIEW allowed us to develop an application that met the exact needs and criteria of our customer, rather than forcing them to compromise when using a mass market vibration analysis system. Prototyping displays and interfaces was quick and easy, and customer feedback could be incorporated with minimum difficulty. The availability of native LabVIEW tools to communicate using a variety of commonly used industrial communication protocols also made connecting our system to other process control systems within the customer’s facilities simple and straightforward.

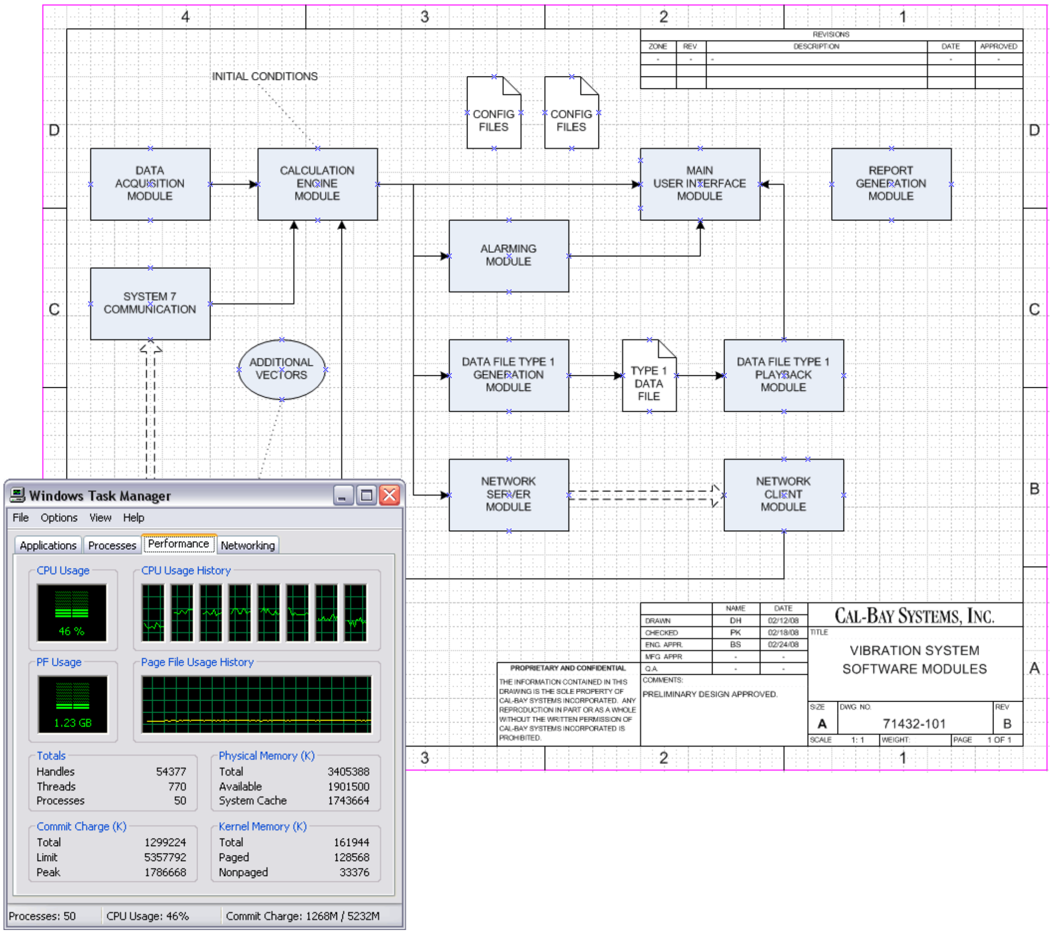

Figure 2: Designing for parallel processing leverages LabVIEW's ability to utilize multicore processors.

Conclusion:

Utilizing National Instruments tools allowed Cal-Bay Systems to efficiently develop a fully featured vibration monitoring system for our customer, a major gas turbine manufacturer. LabVIEW and the Sound and Vibration Measurement Suite gave us a way to leverage the power of today's multicore desktop computers to provide the most advanced signal processing and analysis routines available. Using PXI-based COTS hardware from National Instruments allowed for hardware cost savings of over 50 percent compared to the industry-standard Bently Nevada ADRE vibration data acquisition system. In the end our customer was able to reduce their hardware expenditures by more than three quarters of a million dollars, and received a vibration acquisition and analysis system tailored to meet their specific needs.