Ensuring the Safety and Performance of Small-Scale Wind-Turbines With NI CompactRIO

"We used the CompactRIO platform and LabVIEW to build an application that analyzes the performance of small-scale wind turbines as defined by the international regulations and required by the manufacturers to meet the market requirements for efficiency, capacity, structural integrity, safe operation, and performance."

- Acioidan Betancort Montesdeoca, Aresse Engineering S.L.

The Challenge:
Creating a stand-alone, unified platform to acquire and analyze data that certifies small-scale wind turbine efficiency, operation, and structural integrity.

The Solution:
Using NI CompactRIO hardware to build a system that combines multiple distributed sensors to gather data in four main groups: reference condition, operational, loading, and electrical parameters.

Author(s):
Acioidan Betancort Montesdeoca - Aresse Engineering S.L.
Gorka Gauza González - Aresse Engineering S.L.
Mariano Aristu Aguerri - Aresse Engineering S.L.

Small-scale wind turbine installations are growing with the demand for affordable clean energy for isolated consumption as well as the environmental concern of users who try to sustainably use energy resources. These small-scale wind turbines need efficiency, operation, and structural integrity evaluations to verify that they are safe and appropriate for the users and their communities.

In cooperation with Kliux Energies, we developed a stand-alone, unified platform to acquire and analyze the data required by international standards (IEC 61400/2, IEC 61400/11 and IEC 61400/12) to certify the operation of small-scale wind turbines and give the manufacturer a required database to optimize their design.

Hardware Setup
Based on the standard requirements and the data required to validate the analytical design, we chose the CompactRIO platform for our system. We combined multiple sensors distributed on the turbine and its adjacent devices to capture the data provided by the Kliux GEO4K vertical axis small-scale wind turbine. The data is classified into four main groups: reference condition data, operational data, loading data, and electrical parameters. All the data, up to 34 channels, is acquired, analyzed, stored, and classified based on the reference condition by the CompactRIO installed in a cabinet at the small-scale wind turbine (SSWT) ground. A router connected to the Internet via 3G permits access to instantaneously check the installation status and download the stored data.

The system is defined according to the following four subsystems:

Reference Condition Data: We compare the production data to the environmental conditions to calculate the energy the turbine can use. The NI cRIO-9014 embedded controller receives wind speed data from a GILL WindMaster sonic anemometer and temperature, pressure, and humidity data from a Vaisala sensor through RS485.

Operational Data: We analyze the gearbox and gearbox high-frequency accelerations, acoustic noise, and internal gearbox temperature to perform predictive machine condition monitoring. We do this with a single NI 9234 C Series DAQ module that conditions and inputs data from a PCB tri-axial accelerometer and a G.R.A.S. microphone. An NI 9219 C Series module acquires temperature from a PT-100.

Loading Data: To verify the aerodynamic loads of the wind turbine meet the analytical design, we measure the rotor torque and revolutions, the loads at the tower base, the accelerations at the rotor, and the lateral accelerations at different heights of the tower. We can do all this with a single NI 9205 C Series module that reads data from different sensors distributed along the rotor and the tower. An NI 9219 module conditions three strain gages that detect axial load and bending moments on the tower.

Electrical Parameters: To determine the performance of the turbine, we calculate the electrical energy production using an NI 9205 module to digitize three-phase voltage and current data from Phoenix Contact and CR Magnetics sensors at both the generator and the inverter.

Software Setup
We implemented an acquisition and analysis system on the CompactRIO. To monitor and set up the system, we built an application using NI LabVIEW system design software. This application remotely communicates with the CompactRIO through a 3G router interface. We can use this to monitor real-time variables in the system as well as to set up hardware for different calibration coefficients, ranges, units, wind speed parameters, offsets, and many other functions including web browsing, datalogging backup, and queue handling.

CompactRIO performs statistical online analysis of all the processes. This statistical data is logged into a Technical Data Management Streaming (TDMS) file. We log data for long time periods (months) so we save the data to CompactRIO on-board nonvolatile flash memory. We also provide software tools that help our customer to monitor all statistical parameters online, access the CompactRIO flash memory to download the data, upgrade the software, plot the data, and set different acquisition and logging parameters.

We also need to perform offline analysis with the data we remotely obtain from the CompactRIO so we can evaluate the behavior and performance of the wind turbine. First, we need to check the wind speed, direction, and turbulence to calculate the Weibull parameters that characterize the wind resources at the deployment location. Then, we calculate mechanical parameters to further upgrade the system. This includes optimizing rotor RPM and wind speed or mechanical power ratio, and gearbox and generator efficiency. Finally, we try to optimize the electrical parameters through offline analysis. We analyze the relation between the voltage produced at the generator and wind speed to obtain the optimum load at the inverter. All this postprocessing fulfills the requirements defined in the following country-dependent standards:

- IEC-61400/12: Efficiency Analysis
  - Power curve
  - Annual energy production
IEC-61400/1: Noise Emissions

- Acoustic power
- Tone identification

IEC-61400/2: Testing Part

- Test to verify design data: nominal torque and power, rotation speed, and efficiency
- Part 13.3. Mechanical load testing, bending moments and torque induced by wind speed
- Part 13.4. Duration testing, reliable operation analysis and dynamic operation (This includes mode shape identification based on the recorded accelerations and correlation with the forced vibrations caused by a more relevant harmonic of rotation as plotted on the Campbell diagram in Figure 4 that was obtained from the torque transducer.)

Conclusion

We used the CompactRIO platform and LabVIEW to build an application that analyzes the performance of small-scale wind turbines as defined by the international regulations and required by the manufacturers to meet the market requirements for efficiency, capacity, structural integrity, safe operation, and performance. This modular, flexible system permits ad hoc definition as required by the wide variety of small-scale wind turbine machines.

Author Information:
Acoidan Betancort Montesdeoca
Aresse Engineering S.L.
Polígono Industrial Berriainz, Calle C, Nave 103
Berriozar – Navarra - Spain
Spain
general@aresse.com
Figure 1: Measurement Points Diagram

Reference Condition
- Tower Data
  - 3D Wind Speed
  - Ambient Temperature
  - Atmospheric Pressure
  - Humidity

Loads
- Strain Bridges
- Rotor Torque
- Rotor RPM
- 2D Accelerations

Operation Data
- Temperature
- Noise
- Vibration

Electrical Parameters
- Generator V and I
- IDC, VDC
- Programmable Automation Controller

NI CompactRIO System
- NI cRIO-9014 Real-Time Controller
- NI cRIO-9103 Reconfigurable Embedded Chassis
- NI 9219 Bridge Amplifier
- NI 9205 Analog Input Module
- NI 9234 Dynamic Signal Acquisition Module

NI LabVIEW Real-Time Module
- Data Storage
- Pretreatment

USB Data Storage
- TDMS Files
- Text Files

Web Data Publication
- Remote Visualization

Figure 2: Data Acquisition System Diagram
Figure 3: Power Versus Rotor Speed Results
Legal
This case study (this "case study") was developed by a National Instruments ("NI") customer. THIS CASE STUDY IS PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND AND SUBJECT TO CERTAIN RESTRICTIONS AS MORE SPECIFICALLY SET FORTH IN NI.COM'S TERMS OF USE (http://ni.com/legal/termsofuse/unitedstates/us).