Using CompactRIO for Control and Measurement in the Low Voltage Marine Substation at the Lysekil Wave Power Research Site

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Products Used
CompactRIO, LabVIEW

The Challenge
Developing a control and measurement system for the low-voltage marine substation at the Lysekil wave power research site.

The Solution
Using four NI CompactRIO systems, three subsea and one on the shore, and NI LabVIEW software to develop a control and measurement system at the Lysekil wave power research site.

In summer 2009, the Lysekil wave power research site consisted of three wave energy converters (WECs), one low-voltage marine substation (LVMS), and one land-based measurement station. The overview of the research site is shown in Figure 1.

Control of the LVMS
The control system consists of three CompactRIO units inside the LVMS and one CompactRIO and one PC at the land-based measurement station. The first CompactRIO system is a safety and on/off system and controls the contactors and relays in the substation. The second system controls DC-to-AC voltage conversion. The third system is a dedicated data acquisition system that logs WEC data and environmental data from sensors inside the LVMS. Figure 2 displays the first CompactRIO system, one signal conditioning module, and the modem. The fourth CompactRIO system controls the resistive power loads placed outside the measurement station and measures the voltages and currents brought to shore.

The Safety and Relay Control System
The first CompactRIO system uses only the field-programmable gate array (FPGA) to increase system stability. A real-time program consists of many processes that depend on each other, and there is always a risk that one process will block another process. Traditionally, we use three methods to overcome deadlock: deadlock prevention, deadlock avoidance, and deadlock detection.

Placement of the Data Acquisition System
We placed the measurement CompactRIO system inside the switchgear because the electronics will eventually need service and calibration. We can raise the switchgear to the ocean surface and tow it to a harbor, but the cost to lift one WEC is more expensive.

A Dedicated Data Acquisition System
The third system is a dedicated data acquisition system that measures the voltages and currents from each WEC and from sensors inside two of the WECs. The position of the translator, the magnetic flux in the generator, and the temperature on the stators are measured in WEC 2 and WEC 3. Also, WEC 2 is equipped with strain gage sensors on the metal structure and laser sensors that measure the horizontal movement of the piston. The system can measure water leakage, temperature, pressure, and humidity inside the LVMS.

The process of evaluating measured data presents a time synchronization challenge. Most data logging system clocks are accurate to within seconds. To evaluate data from a WEC, the sensors must be synchronized on a millisecond level, which is impossible to implement with the clock synchronization protocol IEEE-1588; but if the same data-logging system is used, the sensors inside the WEC are synchronized with the WEC voltage and current. Therefore, it was a good choice to transfer analog signals from the WECs and sample all signals in the same data-logging system.

Results
We successfully implemented a control and measurement system based on the CompactRIO platform. We placed the system inside the switchgear, which we placed on the ocean floor. We can control DC-to-AC conversion with an inverter design based on CompactRIO.

Inverter Control
The second CompactRIO system controls the conversion of the DC voltage to 50 Hz AC voltage. The inverter inside the LVMS consists of one CompactRIO and six insulated-gate bipolar transistors (IGBTs) with drivers, shown in Figure 5. Based on the measurements on the DC bus and the AC outputs, the inverter performs PWM of the IGBTs. We place the fast-switching algorithms in the FPGA module, which communicates with the real-time controller where the regulating calculations are made. Information about the pulse width is sent back to the FPGA. It also sends the measurements to the land-based PC that stores the data on a hard disk drive.