ADVANCED CONTROL SYSTEMS

Developing a Solar-Powered Milk Chiller With LabVIEW and NI Single-Board RIO

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Products Used
LabVIEW
LabVIEW Real-Time
LabVIEW FPGA
LabVIEW Control Toolkit 2010
sbRIO-9601 Controller
NI 9211
NI 9216

Figure 1: *The solar photovoltaic array powers the refrigeration system located in the blue-roofed building*

The Challenge
Developing a milk refrigeration system for rural areas of India where electricity supply is unreliable.

The Solution
Using a combination of solar power and available grid power to run a refrigeration system by converting and storing thermal energy and releasing it as needed to cool the milk.

In response to the lack of a cold chain infrastructure in India to transport fresh foods, Promethean Power Systems developed a refrigeration system to meet the unique set of challenges facing the Indian dairy industry. India draws its milk supply from millions of small farmers in villages scattered across the vast countryside. The current milk collection process is inefficient. It relies on twice-a-day pick up of warm milk, which results in high transportation costs and frequent spoilage – as much as 30 percent in the hot season. If dairies can immediately cool the raw milk at the village collection centers, they can cut transportation costs in half, save milk from spoiling, and pay their farmers more. Specialized milk refrigerators already exist, but the unreliable grid electricity supply means they must be operated with diesel-powered generators, an undesirable solution that increases capital and operating cost.

Using these findings, we set out to design a milk refrigeration system that is better suited for remote, rural areas. We based our design on solar power because of our prior knowledge of solar power equipment and the wide acceptance of solar power as a viable and economical power source in sunny locations such as India. However, because a milk cooling system is a mission-critical application that must run 24 hours per day, 365 days per year, we combined solar power with the available grid power to arrive at a superior system that can operate even during extended periods of cloud coverage or grid unavailability (Figure 1).

A key component of our design is the control system that manages the power distribution from the two sources of power – solar and grid – to the loads. The loads consist of a refrigeration compressor that converts the electrical power to cooling power and stores the energy as thermal energy, basically a cold water tank. This cold water is later used to cool the milk during the morning and evening collection times. There is also a small battery system load that keeps the control system and pumps running when solar power or grid power may not be available.

We realized we needed to design an embedded control system to perform complex algorithms, yet provide a very simple operating interface for the farmers. Therefore, we decided to use the NI Single-Board RIO platform and the LabVIEW Real-Time Module as our development system.

Behind the simple operator interface is a complex system that combines NI LabVIEW software and hardware to control the milk chiller operation and collect invaluable data for further engineering analysis and design refinement. The inputs to the system are temperature, current, and flow sensors and the outputs are digital control signals, many of which are custom programmed through the built-in field-programmable gate array (FPGA) hardware on the reconfigurable I/O (RIO) platform.

The control software consists of multiple independent proportional-integral-derivative (PID) control loops running in parallel to control temperatures at key points in the system. Furthermore, the embedded software collects and stores data for further analysis. One feature of our system even publishes summary operating data using a cellphone connection – the only type of connection usually available in remote areas – coupled with a simple text messaging protocol and a dedicated Twitter account (Figure 2).

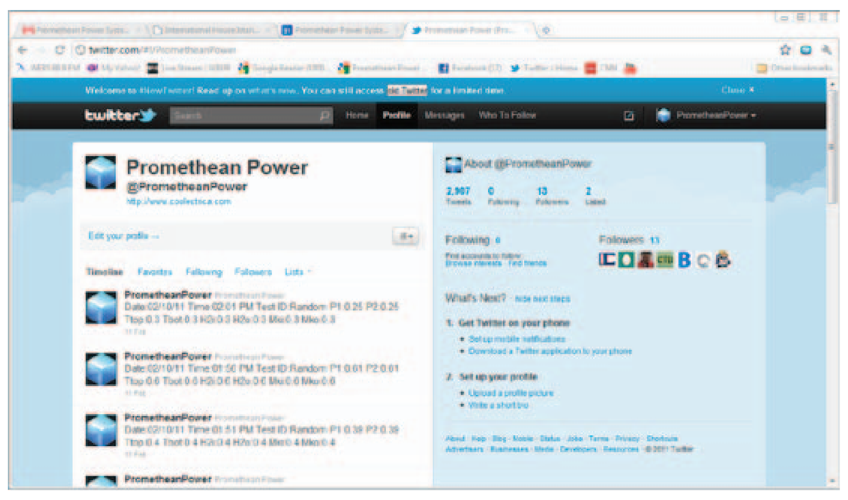

Figure 2: *The LabVIEW system sends tweets about operational data at regular intervals*

An important aspect of the system is the dynamic load balancing algorithm. This algorithm adjusts the operation of the system to work with solar power alone, grid power alone, or a hybrid of both solar and grid power (Figure 3). The dynamic load balancing is achieved by controlling the power flow to the refrigeration compressor using PWM signals that were custom programmed using the FPGA platform.

The system is made more complex by the added battery, which has the unique property of acting as both a load and a power source in the system. A control algorithm determines when the battery needs to charge or when it can supply power to run the system. The battery control is carefully designed to ensure that the batteries are always optimally charged.

Conclusion
Using the LabVIEW Real-Time Module and the NI Single-Board RIO platform, we designed and prototyped a field trial system that performs complex control algorithms and collects invaluable engineering data, yet is easy to use and diagnose if there is a problem. The system is currently running at a remote location in south India cooling milk on a daily basis. The data collected from this prototype will be used to further refine and simplify the design as we move towards mass manufacturing and commercialization.

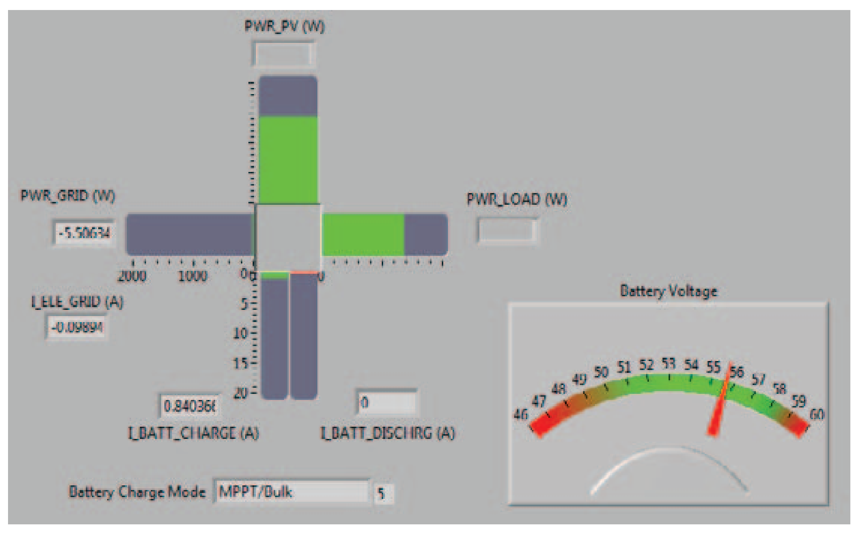

Figure 3: *Dynamic load balancing is achieved with the LabVIEW Real-Time Module and FPGA programming*