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CASE STUDY

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Title:
PAC's, PID's, and P&ID's - Controlling a Biodiesel Refinery with LabVIEW

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Industry:
Industrial Control, Alternative Energy

Products:
LabVIEW, PXI, EtherCAT, FPGA, Real-Time

The Challenge:
Develop a complete controls system for a demonstration scale bio-refinery that includes distributed I/O, failsafe controls systems, a rich display for operators, and a reconfigurable logic system.

The Solution:
Signal.X Technologies has developed a NI-based control system on an unprecedented scale using PXI and the RIO architecture. Two PXI controllers interface to 10 EtherCAT chassis, subsystem PLC's, and networked sensors for a total of more than 3,000 points of I/O. The logic that controls the refinery is completely configurable via a ladder logic emulator that allows engineers to modify the behavior of the system without modifying source code.

Overview:
This project is a demonstration plant for bringing the proprietary refining process of converting biomass (woodchips, rice hulls, and more) to diesel fuel on a commercial scale. The refinery is designed to take in up to 25 tons per day of biomass, and generate a direct commercial replacement for diesel fuel from petroleum sources. Key factors in the choice of controls system included re-configurability, clear user and operator interfaces, and the ability to trend and log data during a run of the refinery at a given recipe setting with a given feedstock.

Working closely with plant controls engineers, Signal.X designed a comprehensive graphical interface that mimics the layout of the refinery and gives operators immediate visual awareness of process status. A number

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of user configurable auxiliary screens offer a drill-down to representations of the plant's many sub-systems. To organize functionality over the large amount of distributed I/O, Signal.X introduced our proprietary PAX™ technology. This user-configurable automation core allows engineers to define any number of high level command functions, safety and fault behaviors, and automation sequences.

Distributed I/O and Controls:

The 3000+ points of I/O are scattered throughout the refinery, as much as 500 ft or more apart, rendering the wiring of signals back to a single enclosure very costly and time consuming. Utilizing distributed NI-9144 EtherCAT chassis' throughout the refinery, the wiring task was greatly diminished with short signal runs to each chassis in the field; the only wire back to the main control room and the PXI chassis being Ethernet.

Another attribute of the NI-9144 was instrumental for the success of the project – the integrated Field Programmable Gate Array (FPGA). Due to the nature of the application, system uptime and reliability were the two most critical factors when considering the architecture. To satisfy these requirements, it was decided to leverage the on-board FPGA for all critical control parameters. The FPGA code was developed such that each chassis is capable of up to 16 independent and configurable PID control loops, controlling and maintaining items such as chiller temperatures, valve flow rates, and fluid levels. This design ensured full control of the safeties and processes' even if other primary system components such as Ethernet cabling, the PXI chassis, or the PC failed.

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Figure 1: EtherCAT chassis' are distributed throughout the refinery, simplifying wiring effort and maximizing signal quality.

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Real-Time Functionality:

The two NI PXI Express controllers chosen for the refinery controls fulfill the superior processing power, data storage, and memory requirements, as well as act as the EtherCAT master for the distributed I/O. The core of the control system application, written and deployed in LabVIEW RT, is responsible for the following primary functions:

- Acquire/Log/Control signals from all I/O threads
    - EtherCAT
    - ModbusTCP from networked sensors
    - PLC via EthernetIP
    - UDP streams
- Evaluate user-defined logic
- Execute output control based upon logic evaluation
- Publish data for User Interface

To accomplish these tasks, our internal technology called Signal.X PAX™ was used to speed development and minimize commissioning time. Signal.X PAX technology is a logic based execution system that leverages multi-threaded embedded software development in LabVIEW. By utilizing a defined data space from each thread of the application, PAX creates a logic engine that makes decisions based on the state of the system, and sets outputs and sends commands to each thread.

PAX incorporates concepts that are familiar to ladder logic programmers in that a simple table editor is used to define sequential logic rungs. However, the full computation capabilities of the PC are also available to define more advanced data management, display and waveform acquisition and processing behaviors. Fundamentally, PAX is configured to evaluate decisions based on inputs and command actions when a rung evaluates to TRUE. It can be structured to support various modes and evaluate actions in sequence or in parallel, accommodating continuous limit checks and sequence control in manual or automatic mode, or as a global check.

This provides the customer with a sophisticated and flexible tool to serve their testing needs while allowing an engineer with limited or no LabVIEW knowledge to configure the test system to future needs. However, the modularity of the architecture allows experienced developers to modify the threads (loops) of their custom application that provide data to the PAX logic engine.

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The ability to log all data relevant to the entire refining process at the real-time level was a key benefit of the LabVIEW architecture. Controls and chemical engineers have critical recipe quality and efficiency data at their fingertips in the form of datafiles logged by each PXI controller. The rate of acquisition can be modified on the fly based on refinery conditions or state, and the data is logged in the NI standard TDMS format.

User Interface:
The LabVIEW Datalogging and Supervisory Control Module (DSC) was used to create a user interface that closely represents the overall refinery layout. The many customizable and industry-specific images and LabVIEW controls made it possible to create an intuitive and familiar environment for any user to quickly determine refinery status, navigate to trouble areas, as well change process variables/recipes seamlessly.

Native multiple-monitor support in LabVIEW and Windows made it possible to create independent displays for every monitor connected to the PC; more displays could be added by simply using video cards with more monitor outputs. A total of (6) high definition displays in a pyramid configuration were used. Each 42” widescreen was used to display and control refinery status in the control room simultaneously. The primary screen represented the overall refinery layout. From this screen, users can click on one of the subsection areas to automatically load its detailed information on one of the sub-screen monitors. Since so much information can be visible at one time, visual cues such as drastic color changes and blinking controls/indicators for alarm conditions were critical; this also included choosing color schemes that were appropriate for color-blind users.

The Bottom Line: This application realizes the vision of the National Instruments hardware platform for distributed I/O to the fullest extent. It is a powerful example of what can be accomplished with graphical system design. By partnering with Signal.X and National Instruments, the refinery realized a safe, reliable, and configurable system with reduced hardware cost, quick development time and significant flexibility for long-term maintenance and scalability.

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