LabVIEW DSC Automates Fuel Cell Catalyst Research

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Category:
R&D/Lab Automation

Products Used:
LabVIEW DSC 6.0.2
PID Toolkit for LabVIEW
PCI-6034E multifunction DAQ
PCI-485/4 serial card
SCXI-1001 chassis
SCXI-1102C, SCXI-1124, SCXI-1162HV modules
TC-2095, TBX-1303, TBX-1325, TBX-1326 terminal blocks

The Challenge: Automating complex and lengthy experiments, involving hundreds of controlled parameters, for the evaluation of chemical catalysts used in the production of hydrogen for fuel cells.

The Solution: Developing a flexible, LabVIEW DSC-based user-configurable control and data acquisition system to enable fully automated control of, and data collection from, a wide range of process control elements used in experimental catalyst reactors.

Introduction

A fuel cell is an electrochemical device that combines hydrogen and oxygen (from air) to produce electricity, heat, and water. Fuel cells operate without combustion, making them virtually pollution free. Because hydrogen is not yet easily accessible for these applications, catalyst-based fuel processing systems (FPS) are necessary to create hydrogen from fuels commonly available today, such as gasoline and natural gas. HydrogenSource, a joint venture between United Technologies Fuel Cells Corp. (UTCFC) and Shell Oil Company, develops, manufacturers, and sells fuel processors and hydrogen generation systems for the fuel cell and hydrogen fuel markets. Currently HydrogenSource is involved in research and engineering efforts to evaluate the performance of FPS catalysts and related components.

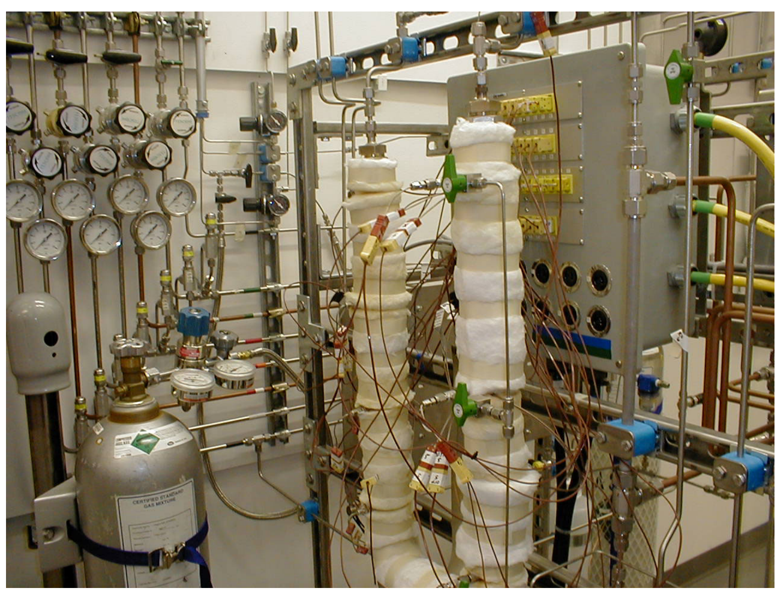

Figure 1. Experimental catalyst reactor

These studies employ experimental chemical reactors (Figure 1) that require the control and monitoring of a large numbers of process parameters (such as temperature, flow, pressure, and gas composition), for periods ranging from a few minutes to several months. Previous manual monitoring methods were extremely labor-intensive, susceptible to human error, and would not provide either the quantity or quality of data required.

HydrogenSource contracted National Instruments Select Integrator Bloomy Controls to specify, design, and implement a series of systems that would facilitate automated operation and data collection to support HydrogenSource's newly constructed FPS laboratory. This lab is a research facility where flexibility of all instrumentation and controls is of paramount importance. The tests run in each reactor vary significantly from one experiment to another, and at the time the system was designed, all of the planned experiments were not fully defined. The application was made even more challenging because certain crucial pieces of expensive analytical instrumentation needed to be shared by pairs of reactors. What was required was a system design that could accommodate a wide range of different sensors, transducers, and controls; be easily reconfigured for different experiments; and be capable of collecting large volumes of data while maintaining continuous process control.

Hardware

Figure 2 illustrates a typical component layout for controlling a pair of catalyst reactors. Each reactor has its own control PC; inside each is an E-series DAQ card interfaced to an associated SCXI chassis. A combination of temperatures, pressures, flow rates, and process alarms are acquired via SCXI. The relatively large number of various parameters, each requiring different methods of signal conditioning, combined with the need to capture signals at fast acquisition speeds for transient measurements, made SCXI the ideal platform for these systems. DIN-rail mounted connector and terminal blocks provide easy-to-wire connection points for the various types of sensors, transducers, and actuators. Through an RS-485 interface, a high-power PID temperature controller and a series of intelligent mass flow controllers are controlled via serial communications commands. A third PC acts as a shared-resource server, communicating through RS-485 with a 32-loop PID temperature controller, motion control module, NDIR spectrometer, and motorized sampling valve. Employing a combination of LabVIEW DSC network tags and VI Server links, communicating via the lab's conventional Ethernet connections, each of the individual reactor PCs acts as a client by sending commands to and receiving data from the server. Through this architecture, each reactor may be controlled independently, while simultaneously sharing common lab resources. Dedicated hardware PID temperature controllers are employed, as opposed to implementing software control, because the combination of high temperature operation and presence of flammable gases required fail-safe operation.

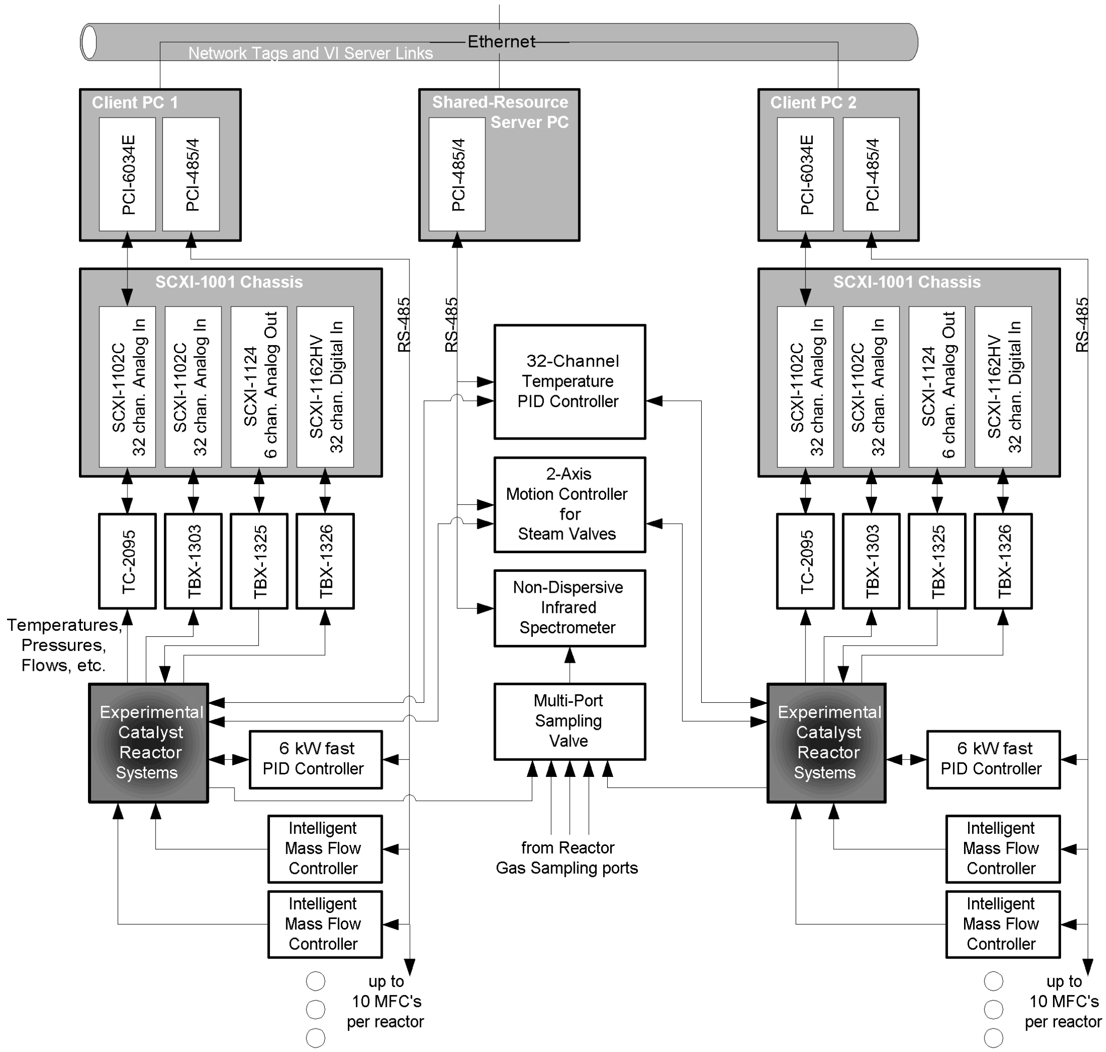

Figure 2. Dual reactor hardware configuration, illustrating client-server architecture

Software

FPS catalyst experiments typically are composed of a sequence of timed steps, with process parameters either held at constant values or linearly ramped to desired settings, while data reflecting the system's performance is collected. A sophisticated recipe-driven architecture was created to give experimenters the flexibility to define and run a wide range of test protocols. The two major software components comprising this system – the Recipe Editor and Automation Engine – were written using LabVIEW DSC.

The first component of the system is a Recipe Editor, whose Front Panel is illustrated in Figure 3. Each step in an experimental test is defined by attributes including the duration of the step in seconds, set points to each controlled process parameter, definitions of high and low alarm values, and recipe sequence controls such as holding and looping. In any step, if Hold is enabled, execution of the recipe pauses at the end of the step. User input (pressing the Continue button) resumes automatic recipe sequencing. The capability for program looping allows the user to select the desired step to which to loop back, as well as the number of loop repetitions. Additionally, simple descriptive text comments for each step may be entered for documentation. Intuitive editing commands (Insert, Delete, Go To Next Step, Go To Previous Step) enable fast and easy recipe editing. The recipe is stored in a modified Windows-style.ini format – a header section contains keys describing overall system settings (number and kind of each type of parameter, number of steps, etc.), while sections of the format [step #] each contain the detailed values for the respectively numbered recipe step.

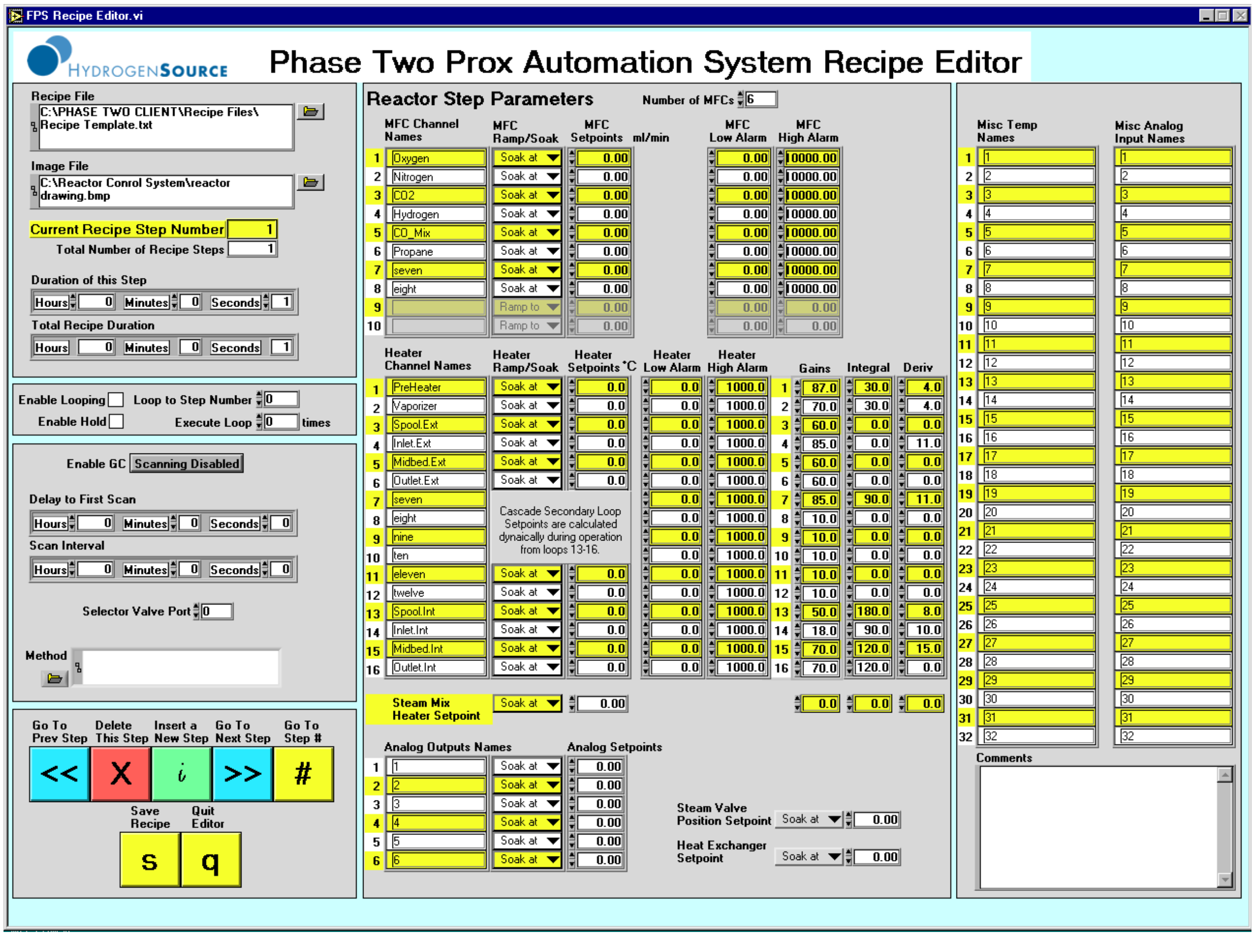

Figure 3. Automation system recipe editor

The second major software component is the Automation Engine. This VI's front panel includes all current values of the various parameters in the system, along with descriptive recipe information previously listed. Mode Control buttons enable operation of the system – start execution of the selected recipe, pause in the current recipe step, immediately advance to next step, or abort execution of the current recipe. In addition, the Automation Engine contains a Virtual Manual Controls panel, which allows manual set point overrides, on a channel-per-channel basis, for all controlled values. This function provides the option of modifying or "tweaking" individual parameter values, independent of the current recipe, in order to fine-tune or similarly interact manually with the process. Underlying the user interface, a mixture of acquisition methods is used to make best use of the available hardware resources. A custom serial server was written to control the mass flow controllers and other analytical instrumentation, while Lookout Protocol Drivers facilitate serial Modbus RTU communication with the external PID controllers. All set point and measured parameters are logged to a Citadel database through the DSC tag engine. On the other hand, the SCXI hardware is managed through programmatic DAQ commands to accommodate both slow and fast acquisition modes. During steady-state experiments, SCXI channels are written to memory tags, while in transient tests (where sampling rates in excess of 100 Hz are needed), data is written directly to a conventional spreadsheet file. Flexible extraction tools and LabVIEW DSC's native Historical Trend Viewer allow straightforward data mining and viewing of collected data. These utilities complement the automation system's capabilities for managing and examining data.

Results and Conclusions

Several versions of this system have been in operation successfully at HydrogenSource for more than a year, enabling researchers to conduct complex and lengthy experiments with a minimum of user intervention. The authors estimate that these automation systems have cumulatively saved in excess of 10,000 man-hours of work that otherwise would have been expended in manual control, monitoring, and data collection efforts. The solution developed with Bloomy Controls has helped HydrogenSource to stay in the forefront in the development of fuel processing technologies for fuel cells, leading to the next generation of clean and efficient electrical power sources.

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