Taking Back Control ...using Programmable Logic Controllers (PLCs)

by Linda Hafar, P.E., CEM and Daniel A. Leon, P.E.

Are you tired of being "over promised and under delivered?" Are you fed up with controls companies gouging you for their proprietary products? Is your current relationship with your controls service provider a bit strained? If you answered yes to any of these questions you may benefit from this article. If you are completely happy with your controls service company, then turn the page—this article isn't for you!

At California State University, Sacramento (Sacramento State) we have taken the plunge moving to programmable logic controller (PLC) technology for HVAC control, lighting control, domestic booster pump monitoring, electrical substation monitoring, and sewer flow monitoring to name a few applications. In fact, we are open to using PLCs on nearly anything that can be monitored or automated.

Why Even Consider PLC Technology?

Our engineering services department embarked on a journey to automate the campus more completely in the late 1980s. We installed a Barber-Colman Net8000 system with a QNX operating system in the Host or graphical user interface (GUI) computer. Global Control Modules (GCMs) and Local Control Modules (LCMs) ran sequences of operation that met occupant comfort needs and maximized energy conservation including extensive time clock control. As time went on, as all things do, the system grew old and became outdated. It is now referred to as a "legacy" system.

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The term "legacy" means if you want to purchase replacement parts, they are probably only available from brokers specializing in used parts or by scavenging from "donor" buildings as they are converted to more current technology. Furthermore, the company where you bought the system may no longer have technicians who are familiar with it.

In some cases, a building was newly constructed with a legacy system. That is, the controls company was transitioning to new and improved technology just after your project was bid. The old system was specified and was installed. Never mind that it was already on its way to becoming obsolete.

We still have the Net8000 system in most campus buildings. We have made efforts to bring in competing systems. As you can probably guess, each system must be monitored and controlled through its own proprietary GUI. There are now several computers or "islands of control" at the operator's workstation.

We thought we found the ultimate solution with a flat LON system architecture. At first it appeared the LON product would provide great interoperability along with a more competitive bidding environment. We thought we could easily integrate a variety of LON systems. However, we found three major shortcomings for our application:

1) Contractors on various projects were not willing to extend the existing system due to integration and compatibility issues.
2) The flat LON network proved to be inadequate to handle the volume of communication necessary to control the entire building HVAC system.
3) The open LON protocol has very limited data access. Therefore, proprietary protocols are used to access expanded data values and setpoints. For example, optimal start-stop time clocks are a vendor specific function. They are difficult to integrate into the flat LON architecture.

Moving Toward Programmable Logic Controller (PLC) Technology

All of the above factors have driven the decision at Sacramento State to use PLC technology for controlling HVAC systems. The use of PLCs is adaptable to more unified facility and utility controls integration. The technology has been in use for industrial processing applications for many years. There are challenges in implementing PLCs for HVAC and facility control. However, they are by no means insurmountable. In fact, you may find implementation is much easier than you thought. We have identified the following challenges and their solutions:

Challenge #1: What are the compatibility issues between the legacy systems and the PLC systems?

We could not get rid of our legacy hardware all at once. We needed a GUI that would be compatible with both the legacy and PLC systems and one that could efficiently monitor and control both the legacy and new PLC systems. We determined the best solution for our application was a GUI software that has a large library of drivers and is compatible with a number of third-party protocol drivers.

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Challenge #2: What about higher costs and are PLCs effective in HVAC applications?

a. Costs for PLCs. If considered without understanding how to effectively utilize them, PLCs appear to cost 20 to 50 percent more than the typical HVAC-specific field controllers. One reason for this extra cost is controlling variable air volume (VAV) systems. The cost of using a PLC for every VAV terminal unit is prohibitive. This expense is due to the distributed nature of VAV input/output (I/O). On the other hand, there are alternatives that neutralize higher installation costs for PLCs and actually make them more practical than proprietary systems. By running wiring strategically, it is possible to operate an entire floor of VAV terminal units with one PLC. Sometimes a floor may require up to three PLCs, depending on the configuration of the floor plan. Major systems such as air handlers need a dedicated PLC. In this application the cost of a PLC is competitive with proprietary HVAC controllers. Programming tool costs are comparable. Software for the GUI and other computers (where required) are also comparable. Ultimately, due to their reliability, availability, flexibility, and longevity, PLC systems can cost less than proprietary systems over the life of a building.

b. *PLCs are robust in their ability to control.* They were originally designed for industrial applications such as manufacturing facilities, water and wastewater treatment plants, power generation, and distribution systems. PLCs possess qualities and attributes that make them effective for HVAC applications. These qualities and attributes include a high degree of reliability, the ability to process large amounts of data, and a high degree of executing speed and precision.

c. *PLCs have extensive breadth of control available.* They have a large amount of user memory, are capable of processing thousands of register values such as setpoints and digital status points, and can execute thousands of instructions. Air handlers, pumps, and zone dampers are easily interfaced with PLCs. VAV controls require slightly more I/O points. Because PLCs are not inherently designed to receive a 4-20 mA signal, the use of a thermister requires more programming than is typically encountered.

d. *PLCs have an extended life expectancy and higher reliability.* They can operate at least two to three times longer than HVAC-specific controllers. Most manufacturers of name brand PLCs will support their system hardware for 20 years.

e. *PLCs are highly expandable.* A single PLC controller can be connected to hundreds of I/O points. The amount of user memory is the only limiting factor.

f. *Some PLCs have proprietary communication protocol versus others that have open protocol.* Some brands of PLCs use proprietary communication protocols. We evaluated a number of the industry manufacturers and ultimately chose a brand that uses a common and "open" communication protocol.

Challenge #3: What resources are needed for this conversion?

a. *Appropriate staffing including controls specialists with strong computer savvy, an analyst-programmer, and an open-minded management team, are all essential.* Our controls specialists, analyst-programmer, and others have worked together to design and implement conversions for existing buildings. We have programmed and installed PLCs to control various HVAC equipment including air handlers, zone temperature, airflow controls, and pumps. We have also participated in the design phases of several new projects and are incorporating PLC-based controls in those buildings as well. Having dedicated staff for controls work enables the campus to benefit a number of ways: 1) technical expertise is available at all times; 2) we avoid price gouging for contracted labor; 3) we avoid expensive service agreements; and 4) a high level of attention is given when developing and reviewing engineering specifications. This activity reduces contractor's addition of large contingency amounts to their bids.

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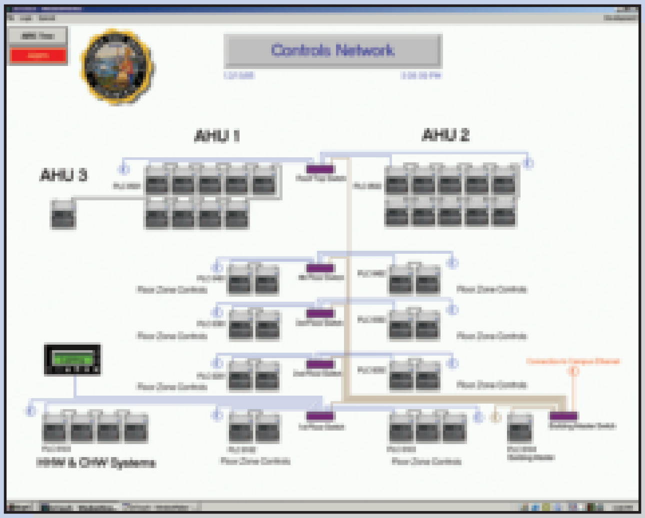
b. *Interface devices that allow communication from existing field devices to PLCs.* It is a straightforward process to connect PLCs to field equipment such as air handlers, valves, dampers, and variable frequency drives (VFDs).
In most cases, the existing field wiring is reused and connected to a PLC control panel. Interfacing to standard HVAC thermisters presented a challenge because PLCs are not inherently designed to accept a thermister signal. We have, however, successfully implemented a method of installing a resister, thus converting the 4-20 mA signal to an analog voltage signal. This installation, along with a programming module, allows the PLC to measure and control from that signal. Literally hundreds of thermisters are used throughout the campus. Finding this solution saves thousands of dollars by allowing standard technology HVAC thermisters for use with PLCs.

c. *A solid communications network including Ethernet and a dedicated virtual Local Area Network (LAN) established to reduce virus infections.* We have several types of proprietary control networks within buildings. Unfortunately, most of these networks can only be used for one type of protocol and cannot be connected to devices using different protocols. Given our past experiences with proprietary networks, we realized the importance to selecting an "open" control network, that is, one that is compatible with the most types of control hardware. We chose to use Ethernet as the control network for our application. Most of the campus Ethernet is interconnected with fiber optic cable. The campus Ethernet network has been highly reliable and has backup power sources. For our control network, we are using a sub-network, or virtual LAN, to isolate the control network from the main campus network. For further protection from virus infection, we have installed and commissioned a firewall router between the control network and the main campus network.

d. *Definition of the communication protocol.* There are a number of different PLC communication protocols, some are proprietary while others are published and "open." We evaluated several and chose Modbus communicating over TCP/IP for our campus control network backbone. Modbus is a common communication protocol that transmits over the Ethernet TCP/IP network. It is used by several different manufacturers of PLCs. In selecting an open communication protocol, we again attempted to select one that is compatible with the most types of control hardware. It is used for peer-to-peer and master-slave communication between PLCs. It is also used between PLCs and I/O server computers.

e. *A library of sequences of operation for HVAC system equipment such as air handlers, VAV terminal units or zone*



Typical air handler graphic with several real time points.

Typical network configuration for building.

Typical floor plan with real time temperatures. Lower right corner provides real time information about the two air handlers serving the floor.

control, heating and cooling control loops. The development of this library can be supplemented by programming the PLC with known HVAC function blocks that are already in use. We are currently developing, testing, and commissioning custom PLC function blocks that replicate the commonly used function blocks. Some examples include AHU timeclocks, AHU optimal start-stop, overrides for digital and analog signals, thermister conversion, reset schedules, damper control, and zone control.

f. *System maintenance.* In-house staff maintain the existing PLC systems. By using "open architecture" systems, we are not reliant upon a single proprietary controls company for maintenance and spare parts. Additionally, PLC control systems can be installed, serviced, and maintained by several local controls companies.

g. *Technical support.* There are several choices for PLC technical support, including service agreements with manufacturers of PLCs, local vendors, and local controls companies. Growing competent internal expertise is our ultimate goal. Thus, even further reducing dependency on outside service providers.

Challenge #4 When to implement the change?

While it is most desirable to convert to PLC technology all at once, this is not usually feasible for most campuses. The beginning of conversion can occur with the next new building scheduled for design and construction. The graphical user interface (GUI) software should be selected for the best interoperability with the old and new systems. With each new building the PLC-based system can be expanded.

As for existing buildings, when remodeling projects are funded, they can be converted incrementally. Additionally, as the legacy system continues to fail, in-house staff or controls contractors can install and program PLCs instead of continuing to reinstall the legacy system. In some cases the buildings have simple control strategies. In these buildings the main controller can be replaced relatively easily with a PLC.

Blazing the Trail

There is a terrific business opportunity if PLC manufacturers were to build a small VAV controller. There is potential to use this same controller with a common protocol such as Modbus TCP/IP for other small industrial type applications. The manufacturers could sell thousands of these small-application, low-cost controllers for chemical feed control, feedback and monitoring, lighting control, security, and access. All of these components could become more integrated and provide facility and utility monitoring through one central computer.

Sacramento State has been complimented for our forward thinking. We have also been criticized for such a crazy notion as using programmable logic controllers in an HVAC application. This technology may not be suitable for every campus. But for those of us who want to get closer to truer interoperability, it is the right choice!