



Allen-Bradley

White Paper

Converting Relays to Programmable Controllers



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Introduction

For years now, engineers have been considering programmable controller versus relay-based control for their applications. While many applications can be controlled using either technology, programmable controllers often prove to be the best selection for a number of reasons. This article will briefly discuss when to convert your control system from relays to programmable controllers, and then explain, step-by-step, how to choose and install the programmable controller.

In general, PLCs become economically viable in applications that require more than two or three relays. Programmable controllers use considerably less space, are designed to work in demanding industrial environments and provide flexibility for rapid control logic modification or future application expansion. Programmable controllers also offer advanced diagnostic capabilities that simplify troubleshooting, maintenance and data processing tasks. Furthermore, increasing competition and technological innovations have driven down the cost of programmable controllers to the point where relay users can hardly afford NOT to convert. In fact, a micro programmable controller on the market today can replace a relay system with up to 32 inputs and outputs with the advantages of a “programmable” solution for an initial investment of less than \$300.

However, many relay users choose not to implement programmable controller-based controls because they are comfortable with their existing relay-based control system. Other relay users may be satisfied with the performance of relays because their plant production requirements are stable and are not severely affected by downtime in their plant. These users choose not to change what they believe is an already good system. Many other factors influence the decision to choose relays over a programmable controller, including the belief that relays are less expensive. Where the initial cost of relays may in some cases be less, the limitations of electromechanical control far outweigh this benefit in most applications.

Relay users that have a machine or process operating with some or all of the following characteristics would be candidates for programmable controller-based control: repetitive operations, time-driven operations, event-driven operations, high speed control, and requirements for data acquisition/manipulation. A few application examples with these characteristics include conveyors, packaging operations and vending machines.

Choosing the Right Programmable Controller

After a user justifies the conversion from relays to programmable controllers, the next step is to **Define the Control Application**. Defining the control application to get the number of field devices is the first of four procedures in choosing the programmable controller specification. This procedure involves identifying and describing each of the functions within the process. For example, in a bottling facility, one of the functions could involve detecting the position of an empty bottle. After describing each of the functions, the field devices needed in the system must be determined. This can be accomplished by listing the functions and assigning a specific type of device (or devices) to each one. In the bottling facility, for example, photoelectric sensors can be assigned to detect the bottle's position, and drives can be assigned to advance the conveyor, etc. These field devices also should be grouped by whether they sense an event has occurred or is occurring (inputs) or whether they are to be controlled (outputs). Then proceed to count the number of field devices (whether they be inputs or outputs) the control system requires. (Note that although control systems require up and down counters -- as well as timers and other higher level functions -- they should not be considered I/O devices.)

The second procedure is determining the **Speed of the Operation**. A programmable controller is faster than relay-based systems in all but the simplest control systems. However, throughput times vary from programmable controller to programmable controller. For this reason, it is important to consider the following:

- How fast does the process occur or machine operate?
- Are there "time critical" operations?
- In what time frame must the fastest action occur?
- Is speed or position being measured?
- Does the programmable controller need to count pulses from an encoder or flow-meter and respond quickly?

Answering these questions will help determine what will be required of the programmable controller. For high-speed applications, the user can install I/Os with fast or adjustable response times or a programmable controller with an adjustable input filter, high-speed counter or triac output circuits.

The **Electrical Requirements** of a system are determined by the type of power available (i.e., 24V dc, 120 or 240V ac) and how the machine or process will be used. The programmable controller should be rated for the same voltage as the relays it replaces. The only reason a voltage would change is if the user decides to convert from an AC to a DC-based system for additional safety. If, for instance, people physically contact the

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machine, field input devices could be powered by 24V dc to prevent shock.

Considering the plant **Environment** is the fourth procedure in specifying the programmable controller. Will the programmable controller be subjected to temperature extremes? Water? Humidity? Salt? Shock? Dust? Vibration? While some environmental concerns such as humidity can be addressed by choosing an enclosure with specific features, most environmental concerns are addressed during the installation stage. For instance, in a high-temperature environment, you may need to put heat sinks on the outside of the panel or some kind of cooling system. In any application, be cautious of locating the programmable controller in an enclosure with other heat-generating sources -- 60 degrees Celsius is typically the maximum temperature for most programmable controllers.

Programmable controllers are segmented into four major areas: Micro (up to 32 I/O), Small (32 to 128 I/O) Medium (128 I/O up to 512) and Large (512 I/O and higher). Since some of the options, such as analog inputs and outputs and networking capabilities, are only available on select programmable controllers, a modular approach is also an option. While fixed programmable controllers have a predetermined combination of discrete inputs and outputs, the modular approach allows the user to match the I/O requirements of the application for the ideal solution. Many fixed programmable controller systems can accept different I/O voltages and are typically the less expensive approach. Fixed controllers can also be much faster.

Once the programmable controller has been chosen, a ladder logic program can be developed. Because programmable controllers are programmed in relay ladder logic and have similar symbols, it is relatively simple to convert electrical diagrams to the programmable controller program. This process involves defining the rules of operation for each control point, converting these rules to ladder logic, and identifying and labeling outputs (addressing).

When defining the rules, refer back to the list of field devices developed. Start with the output instructions and work backward to define the condition that produces the desired action. It is important to remember that emergency-stop switches should not be programmed in the programmable controller. Only a hardwired master control relay provides a reliable means for emergency shutdown. These emergency devices should therefore be documented as such. When writing, the text needs to use language that helps convert the operating characteristics to ladder logic. For instance, the AND logic function connects condition instructions in series on a ladder diagram rung, while the OR logic function connects inputs in parallel.

Addressing all elements of a ladder diagram involves identifying and

labeling inputs and outputs with a letter/numerical designation. Use an “I” to indicate inputs and an “O” for outputs. (Designating Ø for zero will prevent confusion between O for output and the number zero). For instance, the first input device is addressed I/Ø, the second is I/1 and so forth. Outputs are addressed in the same fashion; O/Ø, O/1, O/2. The program is then downloaded into the programmable controller and ready to be tested.

Installing the Programmable Controller

Before installing the programmable controller, it is necessary to analyze the control cabinet currently housing the relays. Are all the field devices wired to terminal blocks? Or, are all the field devices brought into individual relays scattered throughout the panel? In essence, the engineer will have to mock-up a layout of the cabinet’s contents because the programmable controller typically takes up less space. This is important because if you pull relays out and install a small programmable controller in the middle of the panel, you will find that some of the wires may not reach. If this is the case, you may need to wire in terminal blocks to land the wires coming from the field and then wire from the terminal blocks to the programmable controller. This process is obviously easier when the relays are wired to terminal blocks because you do not have to disturb the field side of the terminal strip wiring -- all you have to do is modify the control side that connects to the programmable controller. At this point the field wires should be labeled with the device names, I/O address or some other identifying code to help document the installation and simplify troubleshooting. Color coding similar characteristics such as AC vs. DC devices further simplifies this process.

Depending on the skill level of the plant personnel, the installation can be done internally or by a hired systems integrator. Typically, the tools that are needed include drill equipment for mounting DIN rails and terminal blocks, a screwdriver to land the terminals, and wire labels to document the physical wires in the cabinet. The programmable controller, in most cases, is installed horizontally on a vertical surface using either a DIN rail or directly to a surface using mounting screws. Beyond this, most additional recommendations similarly affect both relay and programmable controller-based control systems and are clearly outlined in the programmable controller installation manual. This includes the consideration of hazards such as dust, falling dirt, condensation and high voltage.

Input power to the controller and I/O should be shut off before the user loosens the terminal screws on the programmable controller. Locate the wire corresponding to each input and output device and route it through the duct to the programmable controller terminal. Starting with the wire that connects to the first terminal, cut the wire at a length that extends 1/4 inch past the edge of the terminal screw. Strip the insulation from the wire

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approximately 3/8 of an inch. Insert the uninsulated end of the wire under the pressure plate of the terminal and tighten the screw. Repeat this procedure until all inputs and outputs are wired.

Consider the following when wiring the programmable controller:

- Allow at least 2 inches (50 mm) between I/O wiring ducts or terminal strips and the programmable controller.
- Do not run signal or communication wiring and power wiring in the same conduit. Wires with different signal characteristics should be routed by separate paths.
- Follow grounding instructions carefully. Use good grounding practices as dictated by the manufacturer's recommendations, customer specifications, and the national electric code. Also use the right size of ground wire and ground the proper lug on the power supply or on the processor itself.
- Inductive loads such as motor starters and solenoids may require a form of surge suppression to protect the programmable controller output contacts. Locate the suppression device (i.e., a varistor for an AC load, a diode for DC) as close as possible to the load device.

When starting up the programmable controller, you may want to remove the fuses to all the output devices until you debug your program. You may force devices ON or OFF through the programmable controller to simulate field device activity. Contrary to turning on a relay-based system and attempting to troubleshoot it, advanced features such as single scan and trace will help in debugging a programmable controller-based system.

In terms of maintenance, there are a number of differences between a relay- and programmable controller-based control system. If a machine stops running, it could be a broken wire, a malfunctioning limit switch or a blown fuse. Unlike relays, programmable controllers have diagnostic capabilities and can communicate alarm conditions to the user through an operator interface terminal, message display or lights -- and if the lights indicate that the programmable controller has not faulted, the operator will immediately know to look elsewhere. Programmable controllers also allow for superior preventative maintenance. For instance, you can write in your program that a motor needs to be lubricated after one million cycles. You can program a light to say "Lubricate motor."

Technological advancements have encouraged many engineers to replace their relay-based systems with programmable controller-based systems. Programmable controllers provide the flexibility needed to meet the demands of a rapidly changing plant environment. Furthermore, they are equipped with troubleshooting, maintenance and other "programmable" features that allow for easy use and installation.

Glossary of Terms

Relay: An electromechanical device that responds to a small current or voltage change by activating switches or other devices in an electric current.

Input device: A digital or analog device, such as a limit switch, push button switch, pressure sensor, or temperature sensor, that sense a condition has occurred.

Output device: Any machine/process load device, such as a solenoid or motor starter, controlled by a programmable controller output circuit.

Ladder diagram program: A programmable controller program written in a format similar to a relay ladder diagram.

Programmable controller: A solid-state industrial control system that has a user-programmable memory for storage of instructions to implement specific functions such as I/O control, logic, timing, counting, report generation, communication, arithmetic, and data file manipulation. A controller consists of a central processor, input/output interface and memory.

Program scan time: The amount of time it takes for a programmable controller to complete its cycle of operation. Scan time is primarily influenced by the size of the ladder program, each instruction's status during the scan and the speed of the processor.

Throughput: The time required to sense an input and energize a corresponding output.

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Americas Headquarters, 1201 South Second Street, Milwaukee, WI 53204, USA, Tel: (1) 414 382-2000, Fax: (1) 414 382-4444
European Headquarters SA/NV, avenue Herrmann Debroux, 46, 1160 Brussels, Belgium, Tel: (32) 2 663 06 00, Fax: (32) 2 663 06 40
Asia Pacific Headquarters, 27/F Citicorp Centre, 18 Whitfield Road, Causeway Bay, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

