Section IIIA3

The Programming of Automation and Control Equipment

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Abstract

A combination of rapidly changing hardware and software for automated systems has enabled new uses for these devices that were once only utilized to automate factory floors and process control. These systems are now used in homes, farms, restaurants, and many other places for security, energy conservation, monitoring, and many other applications. These devices can be remotely programmed and monitored using various networks including the web. If maintenance is required, some systems can send alphanumeric messages regarding system status and alarm conditions to maintenance personnel around the clock. The main device in these systems is a programmable logic controller (PLC), or programmable controller. This is an industrial computer in which control devices provide incoming control signals to the unit. Incoming control signals, or inputs, interact with instructions specified in the user program, which tells the PLC how to react to the incoming signals. The user program also directs the PLC on how to control field devices like motor starters, pilot lights, and solenoids. In this paper, the various programming and operation aspects of PLC systems are discussed. Various projects that utilize these systems for controlling robots, CNC equipment, and other lab monitoring applications are explained. The main programming technique, Ladder Logic, is also discussed. Some custom commands and defined functions are also detailed.

Introduction

Since the beginning of the Industrial Revolution supervisors and efficiency experts have sought a way to increase productivity while keeping operating cost to a minimum. The advent of digital computing has given them a new source of manufacturing technologies, such as automation and robotics. Automated processes now dominate the shop floors of many industries across the world, and have proved themselves at keeping productivity high and keeping overhead operating cost at a minimum. The main device in these systems is a PLC, also known as a programmable controller.

Development

During the 1960's General Motors was using a common technology called relay logic to control some of their automation processes. A relay logic controller was a device that physically contained all of the necessary switches and circuits to control a digital process. These controllers suffered two major flaws: one, they were very large and often contained thousands of relays and cabling, and two, they were hard wired, meaning that the wiring of the controller would have to be changed if it was to be used on a different process. In the automobile industry, processes can change frequently, and the downtime required to rewire a controller was unacceptable. This meant that most controllers were often replaced entirely, since it was not economically feasible to rewire each control panel for each new car model that was produced. These devices were also so large that it made troubleshooting them very tedious, simply because there were so many relays involved.

A company known as Bedford Associates proposed something they called the Modular Digital Controller, or MODICON, to General Motors. This was a machine that contained a small number of relays and circuits; however, the relays were controlled by a microprocessor. This meant that the relays could be programmed to act differently and perform different task, without the need for manual rewiring. The MODICON could also be programmed with a minicomputer, which at the time was a DEC PDP-8. The first MODICON was unveiled on New Years' Day, 1968, and the first one was sold to General Motors a year later.

Initial sales were slow, but certain technological advancements, namely the advent of personal computing and improved microprocessor design, led to an increased use of PLC's in the automobile industry during the 1970's. As the prices of digital circuitry began to fall and the PLC technology became more available, many other companies began to enter the PLC market. Companies like Allen Bradley, Siemens, HoneyWell, and Bradford all began to produce PLCs of their own design. This began to lead to an overwhelming assortment of different hardware and software standards, so in 1980 General Motors introduced the manufacturing automation protocol (MAP). Now that the industry had a common roadmap to use for new designs, many PLCs began to include new features. PLC's could now communicate with each other across a network, being far away from each other and from the machine that was used to program them. They were also being used to send and receive varying voltages, allowing PLC's to communicate with many common analog devices.[1]

PLC Components

A typical PLC can be divided into four different parts: the central processing unit (CPU), the input/output (I/O) section, the power supply, and the programming device. The CPU in a PLC is essentially the same as the one in a personal computer. It computes the data and calculations necessary to perform the different tasks, which have been programmed by the user. The CPU also contains the memory used to store the programs and the RAM to perform calculations in real-time. This memory usually comes in the form of an electrically erasable programmable read-only memory (EEPROM). The I/O section is responsible for interacting with the processing equipment. It receives input signals from sensors, and sends output signals to motors and switches. The CPU and the I/O section are usually packaged together, and the I/O terminals cannot be changed; however, adding modules that contain extra fixed I/O units can expand some PLCs. The main advantage of this type of packaging is lower cost and reduced size.

The power supply provides the PLC with DC power to control the I/O modules and the CPU. In most PLC systems, especially the larger ones, this power supply is not used to power the field devices, such as motors. This equipment is powered by a separate AC or DC power supply. In some smaller PLC systems, the power supply can sometimes power devices that require a small voltage. The programming device, or terminal, is used to enter the desired program into the memory of the processor. This can be either a specialized hand-held device or a standard personal computer. Both of these devices have advantages and disadvantages. The hand-held devices are very portable and can be setup quickly and easily. They also do not require the need to have the software installed on them; however, a hand-held device made for a specific PLC model will usually not work on different models. The small screens on the hand-held displays can also be hard to read.

Personal Computers are the most common tool used to program PLCs. A RS 232 serial port usually connects the two devices. A variety of software for programming PLCs is available, and each is usually specific to a particular PLC model. Most of the software will run on either MS-DOS or Windows, and there are more complex versions that are available for UNIX and Linux.[2]

Initially PLCs were used for a variety of industrial manufacturing applications and consumer based functions. Robots have been widely used in manufacturing since the 1950's, and PLC's have found themselves right at home when integrated with these machines. Robots are no longer dependent on having a complex computer system to take care of monitoring and control. Since PLCs are adept at monitoring inputs from its environment, they are commonly used to change certain variables, which control how a robot is going to do its job. In one example, let's assume that an emergency stop button is attached to an input on a PLC. It then has an output attached to the control system on an industrial robot working on an assembly line. When the stop button is pushed, the PLC knows to turn on the output to the robot's control system, thereby shutting down the control system and the robot.

A modern automated assembly line is dependent on many types of sensors, including pressure sensors, temperature sensors, and proximity sensors. All of these can be attached to a PLC. If the temperature on a boiler exceeds safety limits, the temperature sensor will send a signal to the PLC input. The PLC will determine where the signal came from and what to do with the information. It will then send the necessary output to the boiler's control, to reduce the operating temperature back to normal or to make compensations. The same applies for pressure sensors; if a certain pressure is reached inside a pressure vessel, the PLC can be programmed to send signals to the vessel, which in turn will make adjustments to its operation.

PLC Programming

The programming language most commonly used for PLC's is called Relay Ladder Logic, or more commonly Ladder Logic. Ladder Logic is an object-oriented programming language that is designed to be simple to use, yet provide the user with as much flexibility and features possible. The more advanced versions currently available for Windows provide an easy graphical interface. One of the most popular software packages that utilize Ladder Logic is RS-Logix, which is produced by Rockwell Inc. for its Allen Bradley line of PLC's.

Since Ladder Logic is primarily designed to simulate the way currents and signals are passed through a digital circuit, it differs from most common programming languages. There is very little coding involved, although code can be used to specify custom features. When viewed on a personal computer screen, the interface resembles an actual ladder. There are two "legs" on each side of the screen, and there are "rungs" that run horizontal between each leg. The commands and objects are placed on these rungs. Each rung signifies a simulated electrical circuit. The order in which the commands are issued is dependent on where they are placed on the rung, and on which rung they are placed. The rung that is placed on the top of the ladder is executed first, followed by the next one below it, and so on. Rungs can also have commands placed on them in parallel, which results in a "branch" of codes and commands.

The commands used in Ladder Logic programming are meant to resemble actual electrical switches and gates. Most of these commands are the same no matter what PLC you are programming. Some of these commands are meant to examine the inputs for a signal, such as the XIC (Examine On) and the XIO (Examine OFF) commands. The commands used to turn on an output signal are the OTE (Output Energize) and the OTL (Output Latch) commands. Others can be used to send a signal for a specified amount of time, such as a TOF (Timer Off-Delay) or a TON (Timer On-Delay). There are also relay commands and timer commands, and there are some used to simply specify different rungs to execute, similar to a GOSUB command in standard computer programming.

The XIC and XIO commands are used to examine an input for a signal. If an input is on and it is attached to an XIC command, the current will be allowed to run through this rung. If it is attached to an XIO command, the current will not be allowed to run through the rung. In some versions of Ladder Logic, these two commands can be customized to allow signals from multiple inputs as well as those from other PLCs. The OTE and OTL commands are used to energize the output signals on a PLC. If placed after a XIC or XIO command, the OTE will energize a specified output and send the signal to the desired device, until the input is turned off. The OTL command will keep an output energized as soon as the input is turned on, and keep it energized even when the input is turned off. When used in conjunction with the timer commands, such as TOF and TON, an output can be specified to remain on for a certain amount of time, and to be turned on after a specified time period. The same applies for the counter commands, CTD (Count Down) and CTU (Count Up).[3] The following figure is a Ladder Logic program to control a stepper motor with a Trilogic TM1000+ PLC. It is compiled in Trilogic TBASIC.

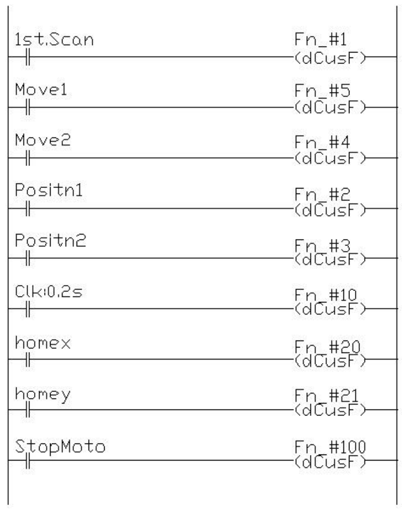

Figure 1. Ladder Logic program to control a stepper motor

PLC Advances

A turning point in PLC design was the use of personal computers for programming. In the past, the programming was often done through the use of a dedicated terminal or a handheld unit. This could be expensive, since the user often had to purchase both the PLC and its programming equipment. This was to change quickly, since most companies had access to personal computers during the 1980's. Not only did this provide users with a cheap alternative to programming, but it also gave companies a new standard to work with.

Recent innovations in Ladder Logic programming include the integration of other commonly used programming languages. Some of these languages, such as C and BASIC, have even been revised to include special functions designed specifically for PLCs. One version designed for use with the Trilogic series of PLCs, called TBASIC, allows the user to write special commands that are not normally included with standard Ladder Logic coding.

These technologies are now used in consumer and service related industries, such as farms, restaurants, and offices. They are being widely used to control security devices, energy conservation processes, home automation, and to control the integration of multiple equipment. The past few years have aroused interest in automating the home or small business. Many different devices and technologies have tried to achieve this, but one of the most prominent has been the PLC. Because of its flexibility and ease or programming, it can be used to monitor and control many common household appliances. PLCs have been used as thermostats for controlling central heating and cooling. They have been used to control automatic refrigerators, lights, and washing machines. The most common use of PLCs in the home has been for security. PLCs are widely used to monitor inputs from alarm systems and cameras. Since it is programmed across a network, a person can control almost every device in his home from one location, his personal computer.

One of the most promising innovations to PLC functionality is the ability to program and monitor the PLC over the Internet. This becomes very important if the PLC is to be used for controlling security equipment, such as alarms and cameras. This also eliminates the need for specialized networking equipment to be manually installed. The Trilogic series of PLCs, mentioned above, is one of the first of its kind that has the ability to do so. It includes software that allows the PLC to be both programmed and monitored through a web browser that has Java enabled. This device targets both industrial and consumer based applications, and has an affordable price range of about $250. The PLC is assigned its own IP address and can be accessed through both local-area and wide-area networks, and can also have a modem attached to it for dial-up access. Since it uses Java, the programming is no longer hindered by operating system incompatibilities. Any OS that has a web browser with Java capabilities and an Internet connection can be used.[4]

There are drawbacks to having a PLC connected to the Internet at all times. One of these is security. As with any computer, it is susceptible to hacking and snooping. This can be very dangerous if the PLC is to be used to control security devices in the home or business. Many PLC manufacturers have already taken this into account, and have included security protocols in the PLC server software. Passwords can be set to only give certain people access to the monitoring interface. Multiple users can also be setup to use it, as with many other computer operating systems. Different permissions can be set to different users, which can only give some users access to different functions of the PLC. The device can also be configured behind a router or firewall, adding robust network security that helps defeat denial-of-service attacks and IP spoofing.

Future Trends

What will the future hold for the PLC? It has already been widely accepted in the industrial and manufacturing fields, and will undoubtedly continue to be used for many of these applications. Many consumer applications have also been pursued, and prices for PLCs have fallen dramatically; however, programming these devices can still be cumbersome to someone that has no knowledge of computer programming or Ladder Logic. PLC manufacturers and software writers are working to resolve this issue, by making PLCs that are already pre-configured for home use and include software that will make it easy for the average person to modify its capabilities. The widespread acceptance of the Internet has also given manufacturers a new source of innovations, many of which are changing the very way that companies and people use their computers and conduct business. By introducing PLCs into the wired world, continued growth and use of these digital devices can definitely be expected.[5]

Conclusions

For the past three decades PLCs have been used successfully as a way of controlling a variety of industrial and manufacturing processes, and their use has played an active role in forging a highly technical workplace. A number of technological advances have contributed to the growth of PLC design and implementation, and new tools such as the Internet and object-oriented programming, have opened the doors for many new applications targeted towards consumers and small businesses.

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