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ENHANCING EFFICIENCY AND PRODUCTIVITY USING AUTOMATION-PROGRAMMABLE LOGIC CONTROLLERS (PLC)

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Abstract

As the world of manufacturing evolves, it has become increasingly important to optimize processes to meet modern market demands. One solution that has increased in popularity is PLC automation. PLC automation uses industrial computers to automate repetitive tasks on a production line. This technology can be used for various purposes, including quality control and data processing.

Programmable Logic Controller (PLC) automation has become an essential component of modern manufacturing, with many companies using it to enhance their productivity and efficiency. From reducing labor costs to improving product quality, PLC automation has many benefits that have helped it become an integral part of the manufacturing process. PLC automation enables organizations to improve their production processes, leading to increased efficiency, which can lead to reduced downtime and improved productivity, leading to increased profitability. Automation can also reduce labor costs and remove the need for manual work, which may be expensive and time-consuming. This can lead to significant cost savings over time. PLC automation also improves the quality of products by reducing the risk of errors and inconsistency, which can lead to increased customer satisfaction. Automation can also be customized to meet the specific needs of the organization. This can enable organizations to quickly adapt to changing market conditions and customer requirements, and automation can improve employee safety by reducing the risk of accidents and injuries. This can lead to a safer work environment and reduce the organization's liability. PLC automation allows organizations to collect and analyze data related to their production processes. This can provide many benefits to help organizations improve production efficiency, reduce costs, and increase profitability. By taking advantage of automation technology, organizations can remain competitive in today's fast-paced business environment and our country, Iraq, in particular.

Introduction

Research Problem

The lack of development in Iraqi industries to achieve improvement and raise efficiency in manufacturing and production in private and government sector factories has led to the introduction of knowledge and applying programmable logic controllers (PLC) in our country, Iraq. PLCs are control systems that monitor and control low-level devices such as switches, relays, timers and motors. Relay logic systems perform logical operations, known as relay logic, by energizing and de-energizing magnetic coils in electrical circuits.

Relays enable the connection of circuits that use different currents and voltages, so historically, they were ideal for controlling and coordinating various industrial automation devices. The disadvantage of a relay logic system is that, like a keyboard, it is hard-wired and is challenging to maintain due to multiple wiring. The development of microcontrollers solved this problem by enabling relay logic operations to be coded programmatically and stored on a computer.

Aim of the Research

Unlike traditional logic control systems, PLCs are more accessible to build, install, maintain and modify.PLC components do not require complex wiring because software implements the control logic. Modifications and updates can be easily implemented by downloading the new ladder logic software. Adjustments can be made remotely rather than manually, as with relay logic systems. Ladder logic notation allows the rapid development of complex logical expressions.

PLC programming is relatively simple, and because the PLC system design is modular, it can be installed in different physical settings and is easily scalable with many input and output devices. PLCs are specialized devices designed to withstand harsh environmental conditions such as cold, extreme heat, and dusty and humid factory conditions. The PLC is included with a real-time operating system that has certain housekeeping functions but does not require supplementary utilities used by computers such as antivirus software or registry cleaners. Microprocessor-based PLC execution times are faster than logic control systems, which contain multiple mechanical parts.

Programmable logic controllers (PLC) are;“ Industrial computers‹ with different inputs and outputs‹ used to control and monitor industrial equipment based on custom programming”.

PLCs come in different sizes and form factors; some are small enough to fit in one's pocket, while others are large enough to require heavy-duty rack installation. Some PLCs are modular, with only basic I/O (inputs and outputs) .Still, they can be customized with additional backplanes and function modules (such as analogue I/O, communications modules, or display modules) to suit different types of industrial devices”. (Farouk, 2013, p: 12)

PLCs are widely used in various industries because they are fast, easy to operate, and considered easy to program. There are five standard PLC programming languages. The most commonly used language is Ladder Logic. Still, it is also possible to use function block diagrams, function sequence diagrams, structured text, or instruction lists to achieve the same functionality.

SCADA and HMI systems enable users to view data from the manufacturing floor and provide user interfaces for control and monitoring. A PLC is a key hardware component of these systems. PLCs are physical interfaces between factory or manufacturing floor devices and a SCADA or HMI system. PLC can communicate, monitor and control complex automated processes such as conveyors, temperature control, robotic cells and many other industrial machines.

The need for data from remote locations has increased as the Industrial Internet of Things (IoT) becomes more popular. This translates into a need for more PLCs and computing devices at the network's edge. Cellular networks are frequently used for communications with terminal devices that require data transmission over long distances. However, due to the high frequency of survey response communications, cellular networks can incur an incredibly high cost when used in this manner. To address this issue, solutions like MQTT and the Sparkplug B specification use the publish-subscribe protocol to simplify communications from the edge of the network. While modern PLCs use modern communication protocols, older PLCs still at the network's edge require additional hardware to provide the same functionality.

Edge gateways, such as Ignition Edge IIoT with an MQTT broker, pull data from the legacy PLC using poll response and then transfer the data using a publish-subscribe protocol.

The Industrial Internet of Things (IoT) architecture allows industrial organizations to build IIoT solutions on top of platforms, optimizing bandwidth usage and making data from the PLC at the edge of the network widely available throughout the enterprise.

The industry continues to see new products entering the market ranging from devices such as programmable automatic controllers (PACs), which combine PLC and high-level PC functions, through to embedded industrial devices.

Even with these new products, PLCs remain popular because of their simplicity, affordability, and usefulness. Software like Ignition will enable organizations to maximize their utility for many years.

1. Definition of PLC

PLC is short for "programmable logic controller" A PLC is a computer-programmable device used to manage electromechanical processes, usually in the industrial field. PLC is sometimes referred to as an industrial computer, a term that describes the primary function of a PLC as a specialized industrial computing machine" (Atallah, 2020, p: 25).

The PLC monitors the state of an input device, such as signals from a light switch, and makes decisions about the next state of the output device, for example, turning a light on or off. PLCs also transfer information from factory machines or off-site locations to central applications, often running on personal computers. PLCs are commonly used to monitor and report on devices, to diagnose faults in devices such as industrial machines and tools, and to influence device events. Figure (1) shows a model of programmable logic controllers (PLC) from Siemens.

Fig. 1. A model of PLC modules from Siemens

2. PLC components and working method

A typical PLC is connected to a power supply and consists of a central processing unit (CPU), rack mount, read-only memory (ROM), random access memory (RAM), input/output (I/O) modules, and a typical PLC controller, power supply, And programming device. The PLC has a modular design; I/O modules and other specialized modules are inserted into the PLC rack. PLC modules are sometimes called cards. A PLC rack can be compared to a car chassis to which other components are connected. “The connected components in a PLC rack are grouped into three sections: the central processing unit (CPU)، multiple I/O modules، and the power supply. Power Supply; the power supply converts alternating current (AC) into direct current (DC). DC is used by the CPU and I/O components” (Ismail, 2016, p: 18).

Central Processing Unit As with a computer, the CPU is the brain of the PLC. The CPU has two operating modes: programming mode and operating mode. In programming mode, the CPU downloads the logic through user-generated programming instructions to the computer.

In run mode, the CPU executes the logic. The CPU controls all PLC operations according to programming instructions stored in memory. The control bus system transmits information to and from the central processing unit.

Input/Output Modules: The PLC receives or senses data from input devices such as proximity and photoelectric sensors, switchboards, level meters, timers, meters, console lights, electric motors, and temperature and pressure switches. Sensor data refers to the nature of PLC input data, which comes from electronic signals. Digital input cards handle discrete signals, for example, on/off signals.

Analog input cards convert voltage into numbers that the CPU can understand. PLC outputs include valves, actuators, drives, motors, solenoids, alarms, control relays, printers, and pumps.

Digital output cards turn devices on and off, for example, a light .Analog output cards such as power machines convert digital numbers into electrical voltage. A PLC can make logical decisions and perform actions based on the input data it receives, for example, processing the input data and sending the processed data to an output device. A programming device processes the input data. For example, a temperature switch may monitor the temperature in a refrigeration plant and intermittently send this information via a PLC to a printer in a factory operation center (Nasr, 2012, p: 32).

The programming device is usually a computer, controller, or special hand-held device. I/O modules route input signals to the PLC's central processing unit (CPU) where output signals are generated. The format of the output data is determined by an application program executed on the programming device. Memory and Storage ROM stores operating system data and drivers. Random Access Memory (RAM) stores the status and details of input and output data, application programs, and data. Communication I/O modules transfer information between the PLC and communication networks. To communicate with external devices, the PLC uses the recommended standard (RS-232), which is a serial communication standard. RS-232 uses binary code to read and write data in American Standard Code for Information Interchange (ASCII) format. At the control level, the PLC communicates with field components at the physical level using a variety of communication protocols depending on the component. PLCs also use communication protocols to communicate over networks and wireless devices.

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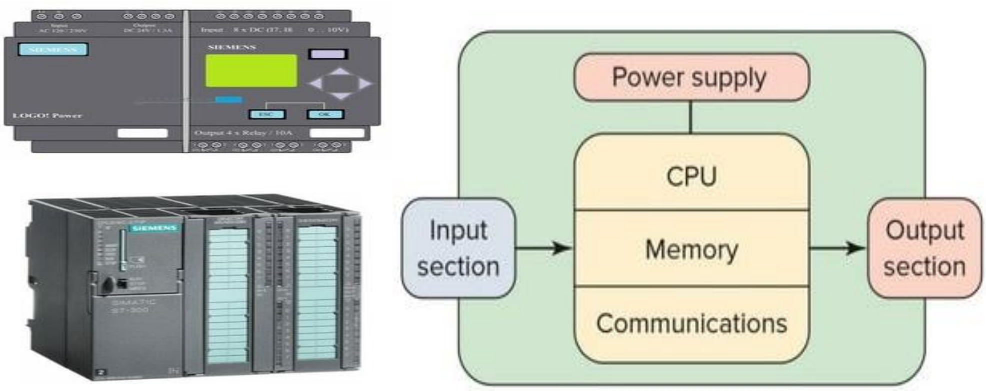
Modbus RTU is a serial communication protocol often used in industrial communications networks to transmit data over long distances. However, serial communication protocols lack the performance and speed of Ethernet protocols. Ethernet protocols used by PLC Ethernet include TCP/IP, Modbus TCP/IP, and Profinet, which are used to connect to factory networks and the Internet. Proprietary protocols may be customized for special devices. Universal Serial Bus (USB) protocols communicate with drivers and printers. For wireless devices, the Bluetooth protocol can be used.

The PLC performs four basic operational functions; first, it scans any connected input devices to see their operational status. Second, it executes a program that determines what should happen with the entered data. Third, it creates the executed output data. Fourth, it uses the operational housekeeping function to perform internal diagnostics. A PLC uses a set of ports and communication protocols to communicate with control applications such as supervisory control and data acquisition (SCADA) systems. Operators in industrial plants and line managers interact with the PLC in real time using a human machine interface (HMI). The HMI is the operator's dashboard, the interface between the person and the PLC.

An HMI allows the operator to coordinate, manage and control industrial processes and devices. PLCs are used for a wide range of automated machine operations, for example controlling elevators or turning light switches on and off in smart buildings. PLCs are used for surveillance or security cameras, automatic alarms, traffic signals, and industrial processes such as cutting glass and paper. The PLC monitors run-time data, for example machine run time, operating temperature and usage statistics. It also starts and stops processes and issues notifications if the device malfunctions.

PLCs are used in product assembly, packaging, motion control, batch control, machine diagnostics and testing, and robotics operations. Ladder logic is most commonly used to program a PLC but other languages are also used, for example function block diagram, structured text, sequential function diagram, and instruction list. Ladder logic uses graphical diagrams based on relay circuit devices to express and define the logical structure of operations in PLC software applications. The ladder logic symbol resembles an electrical diagram. Figure (2) shows the components of the PLC, (Al-Taher, 2010, p: 47).



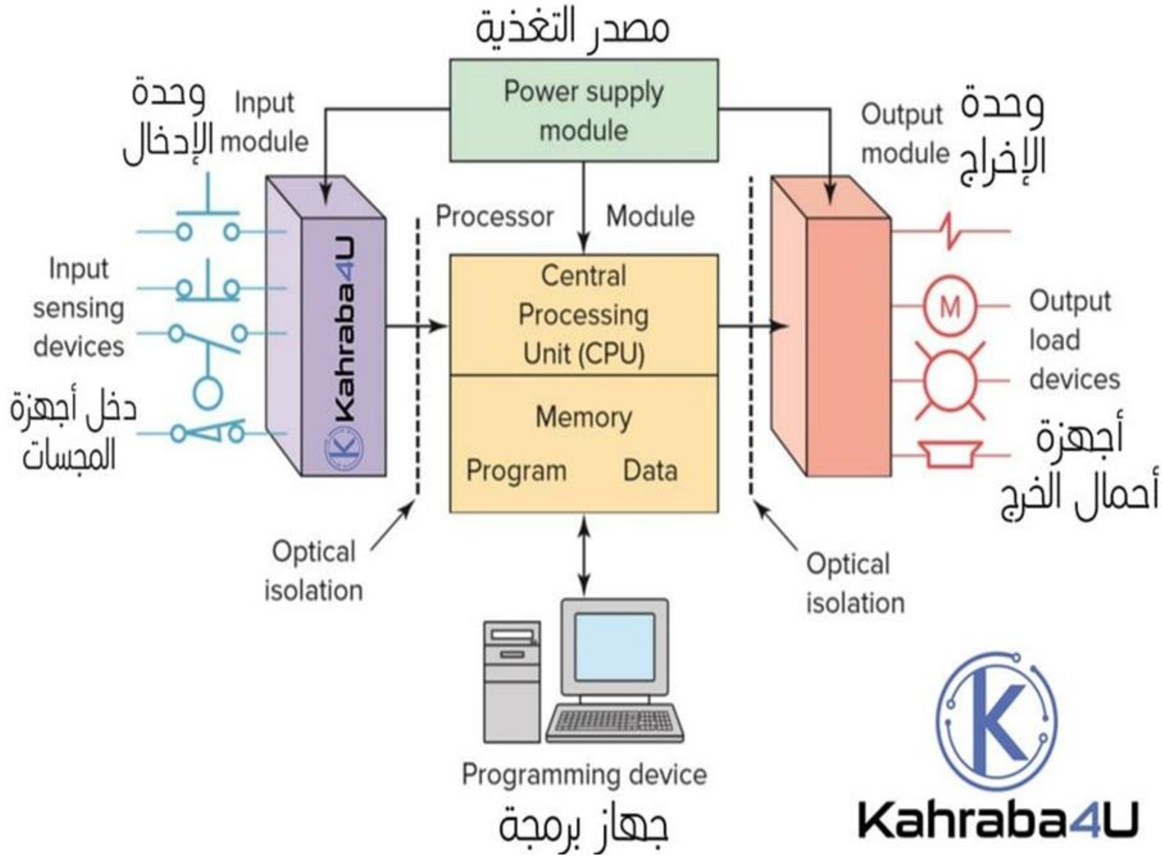


Fig. 2. Components of programmable logic controllers (PLC)

3. PLC automation

PLC automation is becoming increasingly popular in industry because it provides an effective solution to improve efficiency and productivity. Many benefits come with PLC automation, from reducing labor costs to improving production processes. One of the most important advantages of PLC automation is that it enables organizations to streamline operations and improve their bottom line.

There are many benefits associated with PLC automation, and below we will provide an in-depth look at some of the most important ones:

3.1. Increased efficiency:

One of the most important benefits of PLC automation is its ability to improve efficiency. By automating tasks that would otherwise be performed manually, PLC automation can help reduce the time it takes to complete a process, for example, a company that uses PLC automation to sort and package products will be able to do so much faster than a company that does it manually. This increased efficiency can lead to cost savings and improved productivity.

3.2. Improve quality control:

Another benefit of PLC automation is its ability to improve quality control. PLC programming can monitor the production process and identify any potential problems before they become major problems; for example, PLC programming can monitor a machine's temperature and make adjustments to ensure it stays within a certain range. This can help prevent defects and improve overall product quality.

3.3. Data collection and analysis:

PLC automation can also be used to collect and analyze data. A PLC can be programmed to collect data about various aspects of the production process, such as machine performance and product quality. This data can then be analyzed to identify areas for improvement. For example, a company can use data collected by a PLC to identify the most common causes of defects and take steps to address them.

3.4. Increased safety:

PLC automation can also help improve workplace safety. By automating dangerous or repetitive tasks, companies can reduce the risk of accidents and injuries. For example, a company that uses PLC automation to handle hazardous materials can do so without putting workers at risk.
PLC automation has become an integral part of the manufacturing process for many companies. With benefits such as increased efficiency, improved quality control, data collection and analysis, increased safety, It is no wonder that many companies are turning to this technology to enhance their productivity and remain competitive in the modern market, (Bouhliqa, 2011, p:37).

4. PLC programming languages

PLC programming languages are an essential part of the automation process in various industries. These languages are used to create programs that control the behavior of machines and processes. PLC programming languages vary in complexity and are designed to suit different applications. Understanding the options available is crucial to ensuring you choose the right programming language for a particular application.
Several types of PLC programming languages exist, such as ladder logic, function block diagrams, structured text, and Sequential Function Charts. Each of these programming languages has its unique features and benefits" (Kamal, 2020, p:29).
Choosing the right PLC programming language is crucial to ensuring efficient and productive automation processes. Each programming language has its unique features and benefits, making it suitable for different applications. By understanding the options available, manufacturers can choose the right programming language for their specific needs and maximize productivity.

5. PLC system maintenance

PLC automation has become increasingly popular in many industries due to its ability to enhance efficiency and productivity, however, like any other device; PLCs require maintenance and troubleshooting to ensure they function optimally.
Maintenance involves regularly checking the PLC system to identify potential problems and fix them before they escalate into major problems, troubleshooting, on the other hand, involves identifying and fixing problems that have already occurred. PLC maintenance and troubleshooting are critical components to ensuring the smooth operation of a PLC system, they

help prevent downtime, reduce repair costs, and extend the life of the PLC system, (Bolton, 2015, p: 63).

6. Applications for PLC automation

PLC automation has been widely used in various industries to increase efficiency, productivity and safety, it is now an important part of many manufacturing processes, making it possible to automate repetitive tasks and reduce the need for manual labor. PLC is used in many applications such as assembly lines, automated welding, food and beverage production, chemical plants, and many more. Using PLC automation has been proven to reduce downtime, increase production rates, and improve product quality.

Many industries have implemented PLC automation systems and have seen significant benefits, including faster production times, increased accuracy, and cost savings.

Here are some real-life applications of PLC automation that demonstrate its effectiveness and versatility: https://chintglobal.com/blog/programmable-logic-controller-plc/.

6.1. Automated assembly lines:

PLC automation is widely used in the automotive industry for automated assembly lines, it helps reduce cycle times, increase production rates and improve product quality. PLC-controlled machines can perform precise tasks with less human intervention, reducing the risk of errors and increasing efficiency.

6.2. Food and beverage industry:

In the food and beverage industry, PLC automation is used to maintain consistent product quality, reduce labor costs, and improve safety.

The PLC controls the processing and packaging equipment, ensuring that products are produced with the correct ingredients, of the right size and weight, and are packaged correctly.

6.3. Chemical factories:

In chemical plants, PLC automation is used to control many of the processes involved in the production of chemicals. PLC is used to control mixing of raw materials, heating and cooling of reactors, and packaging of finished products. This ensures that the process is consistent and that the product is of high quality.

6.4. Automated welding:

PLC automation is used in the welding industry to control robotic welding machines. The machines can be programmed to perform precise welding operations, reducing the need for human intervention and increasing productivity. This makes it possible to produce high quality welds in less time, which is essential to achieving production goals.

6.5. Water treatment plants:

PLC automation is used in water treatment plants to control the treatment process and ensure that the water meets the required quality standards. PLCs control the pumps, valves, and other

equipment used in the treatment process, and can be programmed to adjust the treatment process based on water quality, (Tubbs, 2018, p: 78).
PLC automation has many real-world applications that are essential for enhancing efficiency and productivity, it has revolutionized the way many industries operate, making it possible to automate repetitive tasks, reduce downtime, and increase production rates. The above applications demonstrate the effectiveness and versatility of PLC automation and how it can be used to improve product quality, reduce costs, and increase safety.

7. The future of PLC automation

Automation Automation is the key to efficiency and productivity in industries, as technology advances, the future of automation is becoming increasingly exciting. PLC has been the backbone of automation in industry for decades, and its future looks promising. Automation has moved from simply automating tasks to creating more intelligent systems that can adapt to changing conditions. The future of PLC automation is a journey into the world of artificial intelligence, cloud computing and the Internet of Things (IoT), as in the following points:

7.1. Artificial Intelligence and Machine Learning:

Artificial Intelligence and Machine Learning are rapidly changing the way PLC automation works. Artificial intelligence and machine learning algorithms can be used to predict machine failures, optimize production processes, and improve product quality. Using artificial intelligence and machine learning, a PLC can learn from historical data and make better decisions in real time. This will improve the overall efficiency and productivity of the industry.

7.2. Cloud computing:

Cloud computing is changing the way public limited companies operate. It allows data to be shared and analyzed in real time, making it easier to monitor and control devices remotely. Using cloud computing, data can be stored and analyzed in real time, allowing better decisions to be made, and this will improve productivity and efficiency

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7.3. Internet of Things (IoT):

The Internet of Things is changing the way we interact with machines. Using the Internet of Things, devices can be connected to each other, allowing data to be shared and analyzed. This will improve decision-making and productivity. For example, using the Internet of Things, machines can be monitored and controlled remotely, reducing downtime and increasing productivity.

7.4. Cyber security:

As PLC automation becomes more connected, cyber security becomes more important. It is necessary to take cyber security measures to protect against cyber attacks. This includes firewalls, encryption, and intrusion detection systems. Cyber security is essential to protect data and ensure the smooth operation of the industry, (Bouhliqa, 2009, p: 41).

The future of PLC automation looks promising. With the advent of artificial intelligence, cloud computing and the Internet of Things, public limited companies are becoming more powerful and sophisticated. This will improve decision-making, productivity and efficiency. However, cyber security measures must be taken to protect against cyber-attacks.

8. Conclusion

Programmable logic controller (PLC) language has helped develop the control system, and it has become the most useful language. Programmable Logic Controllers have become the language that most companies and factories use. They supply and support engineers with what they need and they keep operators protected from hazardous machines. The potential of programmable logic controllers in controlling systems is almost limitless. Programmable logic controls have fed and supported control systems in many ways. Most process computers utilized in factories with humans have more advantages than disadvantages as a secure system when dealing with complex process. Programmable logic controllers have proven to be an effective and helpful tool in many industries in the past. With their many advantages, they will continue to be useful in the future as well.

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