Design and simulation of remote monitoring of the intelligent automatic control system in the production line

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Article Info

Article history:

Received Feb 3, 2023
Revised May 12, 2023
Accepted May 21, 2023

Keywords:

Actuator
Programmable logic controller
Sensor
Supervisory control and data acquisition
Zigbee

ABSTRACT

In this research, we will introduce implementation requirements of a remote wireless control and monitoring unit of industrial production lines automatically controlled using programmable logic controller (PLC). PLC is capable of collecting different types of data and converting them into electrical signals that can be controlled by the industrial network using supervisory control and data acquisition (SCADA) systems. SCADA will be installed in the main server inside the control unit. The PLC will be used as a decision maker of the received signals for the industrial lines that comes from a group of detectors (sensors/transducers). The output of the PLC processor will trigger the engines, according to a specific industrial process management program. The processed data could be transferred through wireless or wired method. The wireless approach will be shown in this study, along with two other ways to implement it.

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1. INTRODUCTION

Automation has taken a vital role in industrial systems. To speed up industrial operations, almost all industries perform operations remotely through supervisory control and data acquisition (SCADA) systems [1], [2]. Every industry aims to achieve a significant increase in productivity by decrease operational cost and tolerance fault [3]. SCADA system is a centralized platform that controls and monitors entire zones, or a compound of systems covering larger zones. Control decision are executed automatically using a programmable logic controller (PLC). Local controls are traditionally limited to only the supervisory intervention and/or principle overriding.

Production and industrial lines are primarily of a conventional design, which is not of a high technology standard. How to transform such lines into high technology lines, which are produced utilizing a built-in monitoring system, is challenging. Our method aims to advance such lines by implementing cutting-edge technology to make industrial process safer, quicker, and more affordable. The developers and researchers must be aware of the current status of the different stages of work for making an acceptable implementation decision. They need to disseminate various sorts of sensors/transducers throughout the industrial decision-making line in order to learn more about this issue [4], [5]. PLC should also be capable of understanding the signals arriving from sensors/transducers and issue orders to players in accordance with the software that is specifically created to carry out the required operation. There are typically two ways for transferring signals from the sensors/transducers to the controller and the other way around wired or wirelessly. Each method has benefits and drawbacks. The benefit of adopting wireless technology is the ease with which a new production or industrial line may be added to the system. It is also simple to install and upgrade, and has a lower cost than wire technology.

2. DESIGN REQUIREMENTS

To maintain appropriate operation and usefulness, control systems depend on a variety of parts and equipment drivers. This section gives a general overview of the three main components that are typically used in control systems: sensors/transducers, control units (such as programmable logic controllers PLCs), and actuators. These components will be discussed in the next paragraphs, along with thorough explanations of each one's roles and responsibilities:

a. Sensors/transducers: Although different industrial lines, they also need the same set of different sensors/transducers in shapes but have the same principles of work [6], [7]. Application fields of the sensors/transducers are: Acoustic, vibration, sound, electric current, magnetic, electric potential, radio, transportation, automotive, chemical, environment, moisture, humidity, weather, subatomic particles, ionizing radiation, navigation, angle, position, distance, speed, acceleration, displacement, flow, fluid velocity, force, pressure, density, level, thermal, temperature, heat, light, optical, photons, imaging, touch, and proximity. Basically, All the above sensors are categorized into digital and analog sensors. However, there are specific category of sensors are frequently utilized for major automation applications.
b. Actuators: In control systems that operate machinery and industrial processes, actuators are crucial drivers [8]. They include a variety of industrial parts/components; such as heaters, lights, sirens/horns, position/speed control drivers, solenoids, motors, cylinders, and valves. The movement, regulation, and signaling needed in many industrial applications are made possible by these actuators' precision control and manipulation capabilities. By transforming electrical energy into mechanical motion, producing linear or rotational force, controlling fluid flow, producing heat, and providing visual indicators, they are essential for attaining desired results. Basically, the actuators could be categorized into the following categories: The electric actuators (such as motors and solenoids), the fluid pressure (hydraulic actuators), and the air pressure (pneumatic actuators).
c. PLC: Depending on the main power supply of the PLC, PLCs are categorized into main two categories, External and built-in internal main power supply. There are many types of programable logic controllers (PLCs), which are found in electronic word stores those contain various software and hardware versions [9]. PLCs could be selected depending on the following electrical, environmental, chemical and mechanical specifications:

– Compatibility with the project's controls, machines and control devices.
– The surroundings and working conditions, like noise, temperature, dust, and humidity, among others.
– PLC functions utilized. As some companies, provide a few extra features and built-in peripherals (e.g., counters and timers) in specific version(s).
– Number of sensors/transducers, engines, and types.
– Future expansion capability.
– SCADA program compatible with PLC.
– Communication ability with other types PLC or HMI.

This paper system will be the ADVANTIC ADAM series, because it has the compatibility with other parts and components. The series covers the requirements of this paper research.

3. ADVANTIC PRODUCTION ADAM SERIES PLC

Thanks to developments in computer-based technology, ADVANTEC's computer-based programmable control tools are now widely used in a variety of industrial automation applications. The ADAM Series, shown in Figure 1(a) and (b), is one noteworthy product line that comprises of intelligent sensor-to-computer interface modules with integrated microprocessors. These modules make it possible for sensors/transducers and computers to communicate seamlessly, offering an effective and clever control option in industrial automation settings. A straightforward set of RS-485 protocol-transmitted commands in ASCII format is used to remotely control the system components. The series provide data comparison, D/A and A/D conversions, isolation, signal conditioning, digital communications, and ranging. For controlling relays and TTL devices, a few modules have digital I/O lines. In some variants, ADAM series controllers, additionally support native libraries and compact-size Ethernet ports. FTP Server, HTTP Server functionality, and integrated functionality are all features that support these Ethernet ports. Multiple serials port is available, which enable the ADAM/ ADVANTEC series controllers to make excellent choices for industrial control applications and communications facilities for these applications. For the needs of many applications, standard I/O design offers considerable flexibility. The ADAM series controllers, additionally support the manufacturer libraries with extensive Modbus functionality, such as libraries [2]. ADVANTEC firm supports this series of PLC with the essential software and hardware requirements in automation field.

(a) (b)

Figure 1. The ADAM series (a) Wireless ADA and (b) Wired ADAM

3.1. Software configuration and calibration

Once a command has been sent from the host computer, the ADAM analog input unit could be configured to take a variety of input voltage ranges, RTD input, or thermal input. Every setting for the unit's configuration, such as the I/O address, HI and LO alarms, connection speed, and calibration parameter settings. Either menu-based program or configuring command set in the commands of calibration could be used for remote setup. The calibration parameters and configuration are kept by the units by storing them in the non-volatile EEPROM chips in case of power outages. Calibration and setting process is important for the correct procedure of the automation and industrial applications. This process takes into account the hardware capability of this series. In addition to the hardware, software could be used to accomplish that process [10].

3.2. Hardware configuration

- Watchdog timer: Function of watchdog timer resets the ADAM in an automatic manner in a case when the system malfunctions. Therefore, the maintenance is simplified.
- Power requirements: The modules accept any power supply unit in the range of +10 to +30 VDC even though they have been made to give unregulated power at a standard voltage of 24 VDC. The immediate ripple voltage must be kept in the range of +10 to +30 VDC, and the power supply ripple must be kept to a maximum of 5 V from peak to peak.
- Connectivity and programming: With the use of RS485 transmission standards, ADAM could be connected to any terminals and computers. Because it offers low-noise sensor readings, RS-485 could be installed much closer to the source. With the use of ADAM RS485 repeater that increases maximal communication distance to 4,000ft, up to 256ADAM modules could be connected to RS485 multi-drop network. Through ADAM-452x module (RS-232 to RS-422/485 converter), the host computer's COM port is linked to the RS-485 network. The ADAM RS485 repeater utilizes logical RTS signal in order to control repeater's direction, which increases network throughput. DATA+ and DATA-, the only 2 wires required for RS485 network, are low-cost shielded twisted pair [4]. ADAM modules could be programmed in virtually any high-level language because all connections to and from the module are made in ASCII [2].
- Protection against the environment: The protection offered by the package is crucial since software controls every configuration. This packaging's plastic outer cover could be utilized to withstand moisture, corrosive, and vibration. ADAMs are able to function at a range of humidity and temperatures levels, from 0 to 70 °C and 0 to 95% (non-condensing), thanks to their low power consumption. Because of its small size and SMT technology, it may be used in any industrial setting.
- Wireless LAN: some ADAMs offers a wireless LAN connected to the network. The majority of WLAN access points use IEEE802.11b as its wireless LAN interface instead of RJ-45 Ethernet ports in their hardware design, which is based on the ADAM series of modules. With the use of HMI or SCADA software, ADAM could support Modbus, UDP, and TCP protocols like other ADAM modules. For critical and real responses, UDP includes built-in event playback and data stream functionalities [1], [4]. Therefore, it is the best option for settings with expensive wiring requirements or wiring limitations.

4. CONTROL METHODOLOGY

The design of automatic control systems in manufacturing lines must be optimized through the use of SCADA systems. These systems are a prerequisite for effective monitoring and management of industrial processes. In the context of automatic control system design for production lines, the current research focuses on two data gathering and transmission approaches that were used to improve the functioning of the SCADA system.

4.1. Supervisory control and data acquisition (SCADA)

A computer system that has been called SCADA is used in order to collect and analyze real-time data [11], [12]. It is utilized for monitoring and controlling an equipment or plant in sectors such as energy, transportation, water and waste management, and the telecommunications industry. The main station is notified of any defects in industrial lines, like pipeline leaks, by the SCADA system, which after that transmits information back to some central location [13]. The main station after those conducts required control and analysis (specifying whether the leak is critical). SCADA systems could be rather straightforward, like viewing environmental conditions. In order to enable direct interaction between the human element and the control system, an industrial process control system must have a GUI [14], [15]. Which will be reached through connecting a PC in control room to PLC in order to monitor and manage the connected equipment. A sample monitor screen is shown in Figure 2. Additional benefits of SCADA systems include:

- Decreases operational cost.
- Offers instant knowledge regarding system performance.
- Enhances system performance and efficiency.
- Enhances the equipment' life.
- Facilitate compliance with the regulatory agencies via creating an automated report.
- Decreases expensive repairs.
- Decreases the number of hours worked (labor costs)
- Needed for service or troubleshooting.
- Free staff for conducting other significant tasks.

4.2. Monitor room

Provide The monitor room's design focuses on two main areas:

- The control room's structural adequacy to survive any catastrophic events.
- The design of control rooms and placement of panels in order to guarantee the plant's efficient ergonomic operation in both emergency and normal situations.

Control rooms for large plants are separate and located in buildings separate from the treatment plant they serve. Building control rooms (or control panels) could be positioned close to small or medium-sized plants to better manage their plant. A sample of monitor rooms is shown in Figure 3. No matter the location, control rooms need to be suitable for maintaining factory control and must be built to guarantee that its occupants are within acceptable limits [15]. Various events might limit the control room work, these are:

- Pressure bursts.
- Expanded boiling steam vapor bursts (BLEVEs).
- Vapor explosions (VCEs).
- Fire, including billiard fires, flash fires, jet fires, and fireballs.
- Emissions of toxic gases.
- Exothermic reactions.

Along with the SCADA computer, a simulation of the industrial lines that is enhanced with lights that display the status of sensors and actuators might be included in the suggested control room. Each data entry and output would be branched as a result of this integration, better grabbing the PC Human Machine Interface's attention. By include this simulation, the work process would be visually represented, enabling operators to track the status of sensors and actuators in real-time, improving their comprehension and decision-making skills.

4.3. Collecting and transmitting data

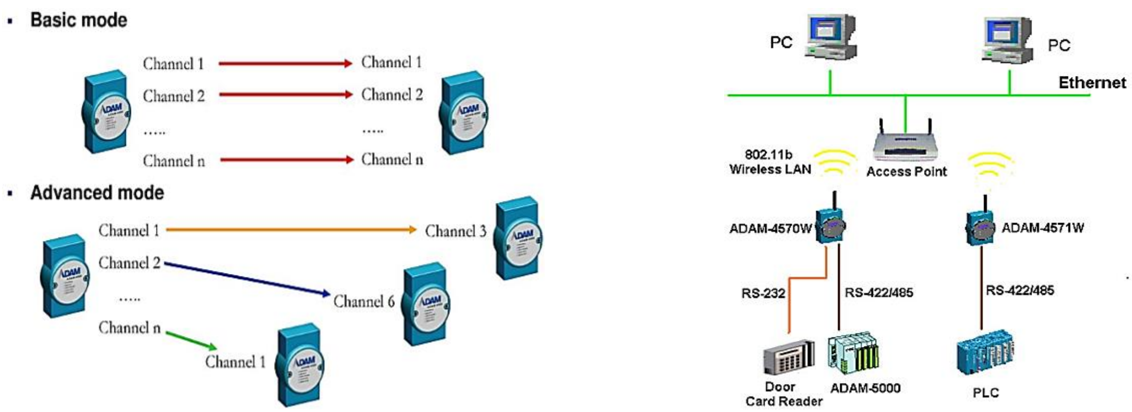
According to the idea of data collection and transmitting to and from the control room, we have two ways for implementing PLCs on our industrial line:

- The first way: Data will be collected and converted straight to a wireless signal with the use of ADAM 6050W and ADAM 6060W. The access point is after that used for receiving the data in the control room, as can be seen in Figure 4(a). Using the same power source as ADAM modules, the sensors will save energy. The common wire (0V) should be connected to the same point in the case when power source is not sufficient to supply load's requirement. Additional sources of the power could be utilized. In the case when the power range is within the allowed range, the sensors' digital outputs are directly connected to ADAM module's DI (i.e., digital input) ports. The relay files will subsequently be connected to the digital data output (DO) of ADAM in order to receive the necessary actions through their contacts. Since there is not a wireless ADAM module that deals with analog data specifically, there is no need to utilize input and/or output analog data while using this option. Since they support IEEE802.11b, ADAM-6051W, ADAM-6050-W, and ADAM-6060-W could connect to majority of wireless LAN access points. The ADAM-6051W, ADAM-6050-W, and ADAM-6060-W support Modbus/UDP and TCP protocols much like other ADAM-6000 modules. Through Modbus/TCP, HMI/SCADA could connect to ADAM modules. For real and critical responses, the UDP protocol includes pre-built event playback and data stream features.

– The second way: Systems that need the usage of analog data for output and/or input employ this option. The following method is used for transferring such signals from industrial line to control room because there is not a wireless ADAM module that can handle analog data. With the use of ADAM 5000 (or any other modules), data will be collected and after that transformed to an Ethernet signal. Additionally, the signal is transmitted wirelessly with the use of ADAM 4571W or ADAM 4570W. An access point could be used to receive this data in the control room, as can be seen in Figure 4(b). Cost-effective data porters between the RS232/422/485 and 802.11b WLAN interfaces are the ADAM-4571-W and ADAM-4570. It offers a quick and inexpensive solution for connecting any RS232/422/485 device to an 802.11-b wireless LAN. The ADAM-4571W and ADAM-4570W are cost-efficient in the case when continue using existing software and hardware since they are transparent and functionally effective. For thousands of the RS-232/422/485 devices that cannot connect to network, the ADAM-4571W and ADAM-4570W offer remote management and data access functionalities.

Figure 2. Monitor screen sample

Figure 3. Monitoring room sample



(a) (b)

Figure 4. Data collection and transmission (a) the first way and (b) the second way

4.4. IEEE 802.15.4 wireless protocol

In computer networks and telecommunications, a protocol is a group of the guidelines, which specify the way that data is transferred. Institute of Electrical and Electronics Engineers is known by abbreviation IEEE. This non-profit is focused on advancing technology, including electronic and electrical devices [16], [17]. Local networks and medium-sized networks are among the network operations technologies covered by the IEEE division known as the 802 Group. Group 15 focuses mainly on wireless networking technologies, such as Bluetooth and the 802.15.1 workgroup everywhere. A set of specifications called ZigBee has been based upon the IEEE 802.15.4 wireless protocol. In order to obtain pollen, various bees zigzag randomly between flowers, hence the name "ZigBee." This is reminiscent of the networked, imperceptible connections found in a completely wireless environment. ZigBee Alliance, which is a global organization with approximately 150 members, oversees the standard itself. ZigBee is intended to enable extremely effective communication between small packet devices, whereas Bluetooth concentrates on connectivity between large packet user devices, like phones, computers, and significant peripherals. In comparison with significantly faster 1.0 Mbps Bluetooth-based 2.4 GHz ISM line that is widely accessible, ZigBee devices can operate at speeds of up to 250 kbps. ZigBee was created to satisfy the growing demand for wireless networks that can connect numerous low-power devices. With small transmitters on each device on the ground, ZigBee is employed in the industry to automate the future generation and allow communication between the devices to some central devise. This improved connection level enables precise remote processing and monitoring. The maximum operating range for ZigBee devices is specified to be 250 feet (76 meters), which is significantly more than what Bluetooth-capable devices can use [18], [19]. Therefore, the following ZigBee protocol features could be summarized [20],

- Low duty cycle - offers long battery life
- Low latency
- Support for several network topologies: dynamic, static mesh and star
- Collision avoidance
- 128bit AES encryption - provides secure connection amongst the devices
- Up to 65,000 nodes on a network
- Clear channel evaluation
- indication link quality
- Supports for the packet freshness and guaranteed time slots.
- Retries and acknowledgements.

5. RESULTS AND DISCUSSION

The cycling assembly will be run on the production line using the automation method to speed up, make the process safer, and keep it under control up until the very end. The simulation depicts an industrial line with switch and sensor status lights throughout the operation, as seen in Figure 5. Feeder traffic will be monitored, monitored and controlled. We should now examine the signal input and output in accordance with these requirements in order to use the PLC and integrate it into the system.

a. Input signals:
- Three digital signals for the carrier movements.
- Ten digital signals for operator orders.
- Five digital signals for product sites.

b. Output signals:
- One digital signal to conveyor motor operation.
- Fifteen digital signals for clarification lamps.
- Sixteen digital output signals and 18 digital input signals.

Those specifications state that the design depicted in Figure 6 will require three ADAM6060W modules. The ADAM-6060-W can be defined as high-density I/O module with an integrated IEEE 802.11-b WLAN interface for seamless Ethernet connectivity, as we previously explained. Additionally, the ADAM-6060-W provides six relay outputs and six digital input channels (DI). It supports contacts with the contact rating values of DC 30V, 1A and AC 120V, 0.5A. For critical handling, all digital input channels support input latch functionality. Those DI channels could be utilized as frequency input channels and 3 kHz counter channels. The digital output channels support pulse output along with the intelligent DI features [21]–[23].

c. ADAM-6060W Specifications:
- Communications: IEEE802.11-b WLAN
- Supports Protocols: Modbus/TCP, UDP, TCP/IP, ICMP, HTTP, and ARP

d. Digital Inputs:
- Channels: 12
- Dry Contacts: Logic lvl0: Close to the Ground; Logic lvl1: Open
- Wet Contact: Logic lvl0: 0 ~ 3VDC Logic lvl1: 10 ~ 30VDC
- Support 3kHz counter input (32bit + 1bit)
- Support 3kHz frequency inputs

e. Relay Outputs:
- Channels: 6
- Contact rating (Resistive): AC: 120V, 0.5A DC: 30V, 1A
- Relay on time: 7ms
- Relay off time: 3ms
- Breakdown voltage: 500VAC (50/60Hz)
- Total switching time: 10ms
- Maximum Switching Rate: 20 operations/min. (at rated load)
- Insulation Resistance: 1GΩ minimal at 500VDC
- Supports pulse output (max 3Hz)
- Isolation Protection: 2000VDC
- Built-in Watchdog Timer
- Power Input: Unregulated 10 ~ 30VDC
- Power Consumption: 2W, 24VDC
- Power Reversal Protection
- Storage Humidity: 5~95% RH (non-condensing)
- Operating Humidity: 5~95% RH (non-condensing)
- Storage Temperature: -20 °C~80 °C

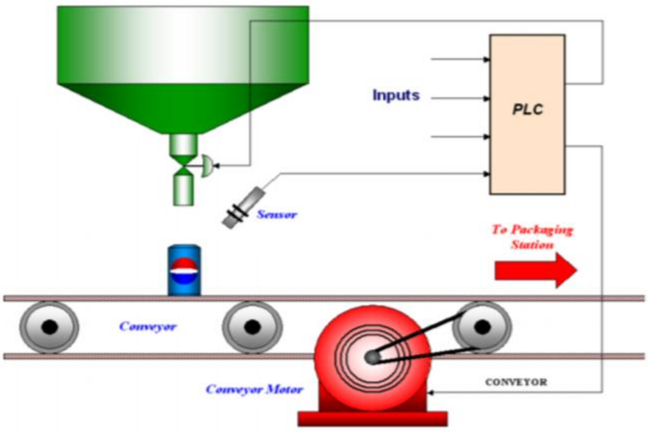


Figure 5. Simulation for the industrial line

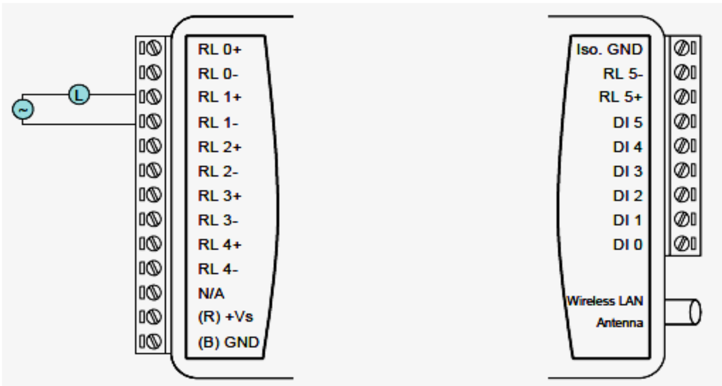


Figure 6. ADAM-6060W wiring

– Operating Temperature: -10 °C~60 °C

As shown in Figure 7, a LADDER program can now be used to program the PLC (ADAM 6060). The SCADA program is used to supervise and monitor input and output signals from the control room since it is connected close to the industrial line as shown in Figure 8 [24], [25]. Through this integration, the PLC's activities may be controlled and monitored centrally, allowing for effective management of the industrial line's operations and promoting prompt decision-making based on real-time information.

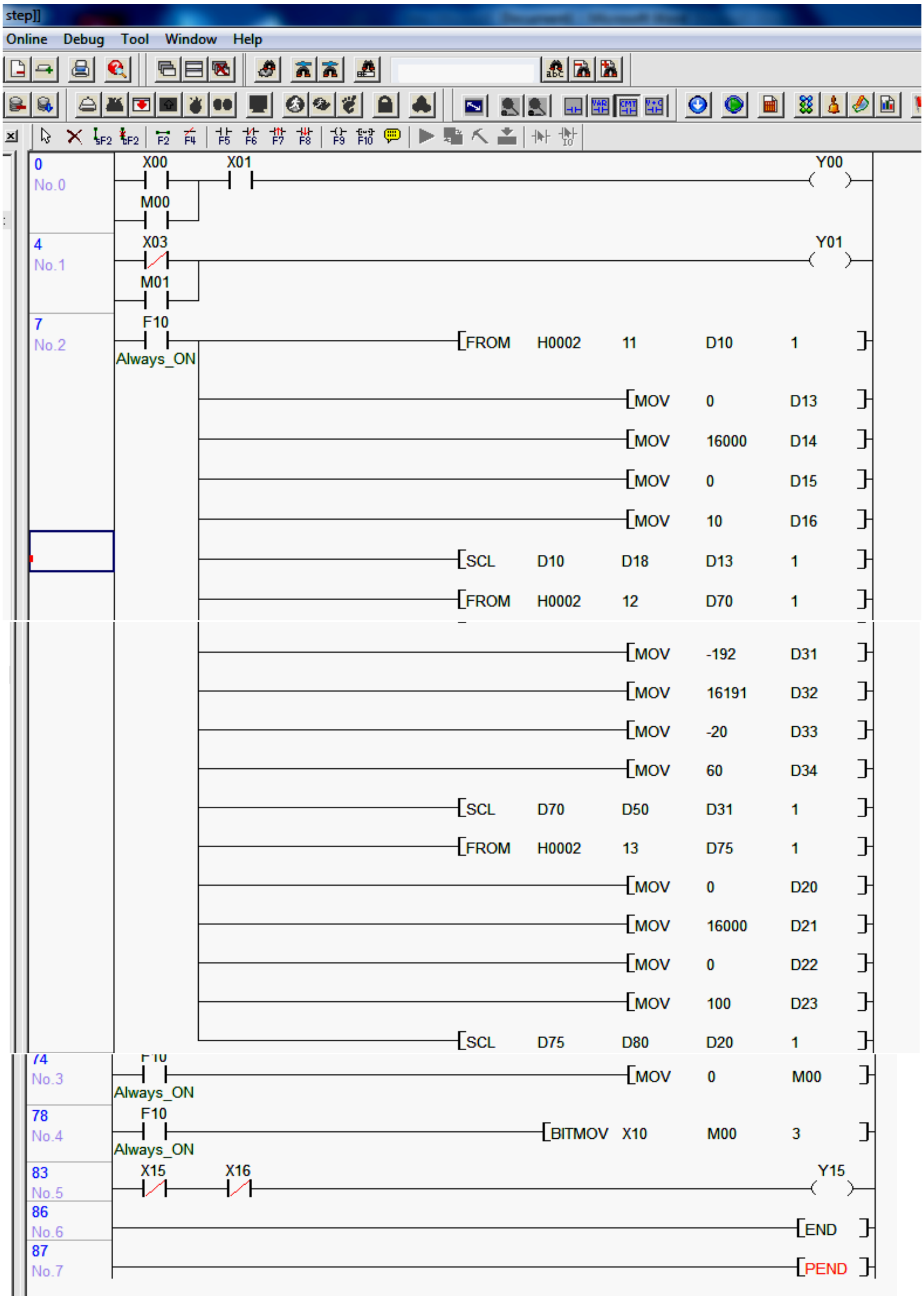


Figure 7. Ladder program for PLC

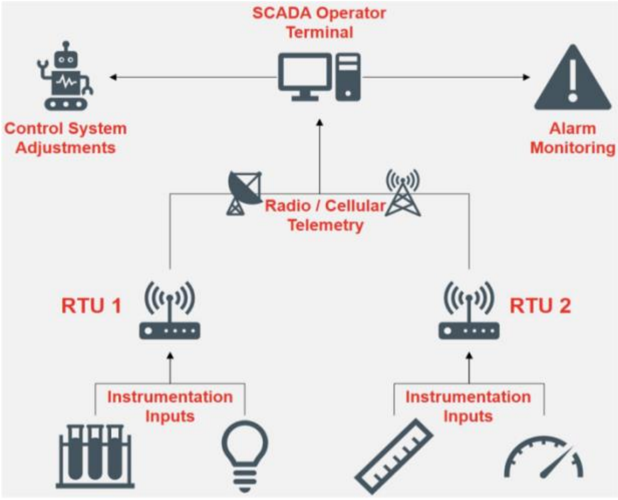


Figure 8. SCADA design typical project

6. CONCLUSION AND RECOMMENDATION

With the aid of cutting-edge technology, typical industrial processes will be improved in terms of cost-effectiveness, speed, and safety. A significant aspect of achieving these goals is the integration of control systems and Internet connectivity. Control systems can be used to monitor and control industrial operations in real time, ensuring compliance with safety regulations and enabling prompt modifications. Furthermore, having access to the Internet allows for remote monitoring and control from any location, which improves flexibility and responsiveness. The main goal of this research is to employ these technologies to improve industrial processes, leading to safer operations, quicker output, and lower prices.

ACKNOWLEDGEMENTS

The researchers thank the Electrical Engineering Department; Engineering College, Mustansiriyah University/Baghdad/Iraq "www.uomustansiriyah.edu.iq"/Iraqi MoHEandSR; for their supports.

REFERENCES

[1] Y. Cherdantseva *et al.*, "A review of cyber security risk assessment methods for SCADA systems," *Computers & Security*, vol. 56, pp. 1–27, Feb. 2016, doi: 10.1016/j.cose.2015.09.009.
[2] B. S. Rao and C. Chakravarthi, "Industrial control systems security and supervisory control and data acquisition SCADA," *International Journal for Modern Trends in Science and Technology*, vol. 03, no. 10, pp. 109–118, 2017.
[3] TechNavio, "Global lactic zcid market 2017-2021," *TechNavio*. p. 81, 2017.
[4] A. Nechibvute and C. Mudzingwa, "Wireless sensor networks for SCADA and industrial control systems," *International Journal of Engineering and Technology*, vol. 3, no. 12, pp. 1025–1035, 2013.
[5] D. Culler, D. Estrin, and M. Srivastava, "Guest Editors' introduction: overview of sensor networks," *Computer*, vol. 37, no. 8, pp. 41–49, Aug. 2004, doi: 10.1109/MC.2004.93.
[6] H. Liu, Z. Meng, and S. Cui, "A wireless sensor network prototype for environmental monitoring in greenhouses," in *2007 International Conference on Wireless Communications, Networking and Mobile Computing*, Sep. 2007, pp. 2344–2347, doi: 10.1109/WICOM.2007.584.
[7] S. Petersen, P. Doyle, S. Vatland, C. Salbu Aasland, T. M. Andersen, and D. Sjong, "Requirements, drivers and analysis of wireless sensor network solutions for the Oil & Gas industry," in *2007 IEEE Conference on Emerging Technologies & Factory Automation (EFTA 2007)*, Sep. 2007, pp. 219–226, doi: 10.1109/EFTA.2007.4416773.
[8] D. Xie, L. Chen, L. Liu, L. Chen, and H. Wang, "Actuators and sensors for application in agricultural robots: A review," *Machines*, vol. 10, no. 10, p. 913, Oct. 2022, doi: 10.3390/machines10100913.
[9] Y. Zhang *et al.*, "All your PLCs belong to Me: ICS ransomware is realistic," in *2020 IEEE 19th International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom)*, Dec. 2020, pp. 502–509, doi: 10.1109/ TrustCom50675.2020.00074.
[10] W. Han, N. Zhang, and Y. Zhang, "A two-layer wireless sensor network for remote sediment monitoring," in *2008 Providence, Rhode Island, June 29-July 2, 2008*, Mar. 2008, vol. 18, no. 3, p. 820, doi: 10.13031/2013.25011.
[11] D. Upadhyay and S. Sampalli, "SCADA (supervisory control and data acquisition) systems: Vulnerability assessment and security recommendations," *Computers & Security*, vol. 89, p. 101666, Feb. 2020, doi: 10.1016/j.cose.2019.101666.
[12] H. Kim, "Security and vulnerability of SCADA systems over IP based wireless sensor networks," *International Journal of Distributed Sensor Networks*, vol. 8, no. 11, p. 268478, Jan. 2012, doi: 10.1155/2012/268478.
[13] I. González and A. Calderón, "Development of final projects in engineering degrees around an industry 4.0-oriented flexible manufacturing system: Preliminary outcomes and some initial considerations," *Education Sciences*, vol. 8, no. 4, p. 214, Dec. 2018, doi: 10.3390/educsci8040214.

[14] Liao Zhang, "An implementation of SCADA network security testbed," *Computer Science > Cryptography and Security*, vol. 151, pp. 10–17, 2015, doi: 10.48550/arXiv.1701.05323.
[15] D. Bailey and E. Wright, "Practical SCADA for industry," *Practical SCADA for Industry*, 2003, doi: 10.1016/b978-0-7506-5805-8.x5000-4.
[16] A. F. Molisch *et al.*, "IEEE 802.15.4a channel model-final report," *IEEE 802*, vol. 15, no. 4, pp. 802.1504--0662, 2006.
[17] L.-H. Yen and W.-T. Tsai, "The room shortage problem of tree-based ZigBee/IEEE 802.15.4 wireless networks," *Computer Communications*, vol. 33, no. 4, pp. 454–462, Mar. 2010, doi: 10.1016/j.comcom.2009.10.013.
[18] N. Baker, "ZigBee and Bluetooth: strengths and weaknesses for industrial applications," *Computing and Control Engineering*, vol. 16, no. 2, pp. 20–25, Apr. 2005, doi: 10.1049/cce:20050204.
[19] V. M. Mishra and A. Kumar, "FPGA integrated IEEE 802.15.4 ZigBee wireless sensor nodes performance for industrial plant monitoring and automation," *Nuclear Engineering and Technology*, vol. 54, no. 7, pp. 2444–2452, Jul. 2022, doi: 10.1016/j.net.2022.01.011.
[20] G. A. Naidu and J. Kumar, "Wireless protocols: Wi-Fi SON, Bluetooth, ZigBee, Z-Wave, and Wi-Fi," in *Lecture Notes in Networks and Systems*, Springer Singapore, 2019, pp. 229–239.
[21] Q. Wu, Z. Xu, and Z. Han, "PLC simulation control of assembly line," *Computer Simulation in Application*, vol. 1, no. 1, pp. 13–23, 2017.
[22] Q. Bai, B. Jin, D. Wang, Y. Wang, and X. Liu, "Compact Modbus TCP/IP protocol for data acquisition systems based on limited hardware resources," *Journal of Instrumentation*, vol. 13, no. 04, pp. T04004–T04004, Apr. 2018, doi: 10.1088/1748-0221/13/04/T04004.
[23] J. Nivethan and M. Papa, "Dynamic rule generation for SCADA intrusion detection," in *2016 IEEE Symposium on Technologies for Homeland Security (HST)*, May 2016, pp. 1–5, doi: 10.1109/THS.2016.7568964.
[24] N. P. DeGuglielmo, S. M. S. Basnet, and D. E. Dow, "Introduce Ladder Logic and Programmable Logic Controller (PLC)," in *2020 Annual Conference Northeast Section (ASEE-NE)*, Oct. 2020, pp. 1–5, doi: 10.1109/ASEENE51624.2020.9292646.
[25] R. A. Taha, M. M. Mustafa, and M. K. Hamad, "Controlling system of an elevator with aid of PLC (Ladder diagram)," no. May, 2022.

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