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Study of a Wireless Control Unit for Automated Industrial Production Line

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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 SCADA.
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).The output of the PLC processor will trigger the engines according to a specific industrial process management program. The processed data can be transferred either by wired or wireless system. This paper will display the wireless method and will include two implementation methods.

KEYWORDS: PLC, SCADA, Actuator and Sensor.

I. INTRODUCTION

Most of our industrial and production lines are of a traditional type, which is not technically high. The challenge is how to convert these lines into high-tech lines that are manufactured using a built-in monitoring system. In our approach, we try to develop these lines by applying advanced technology to make the industrial process faster, safer and more economical. In order to make an appropriate decision to implement, we need to know the state of the various stages of work. To find out this situation, we need different types of sensors to be distributed to the industrial decision-making line.
Finally, PLC must be able to know the signals coming from the sensors and give commands to the players according to the program specifically designed to perform the specific operation.
Generally speaking, there are two ways to transfer signals from sensors to the controller and vice versa. Either wire or wireless. Each technique has advantages and disadvantages. The advantage of using wireless technique is the simplicity in adding a new production or industrial line to the system with easy to install and upgrade in addition to the low coast compared with wire technique.

II. DESIGN REQUIREMENTS

The most used things of our control system are: sensors, controller (like; PLC), and actuators. The following paragraphs will be explained in detail.

A. SENSORS

Although different industrial lines, they also need the same set of different sensors in shapes but have the same principles of work [1]. Some of these sensors are listed below:

1- Acoustic, sound, vibration.
2- Automotive, transportation.
3- Chemical.
4- Electric current, electric potential, magnetic, radio.
5- Environment, weather, moisture, humidity.

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6- Flow, fluid velocity.
7- Ionizing radiation, subatomic particles.
8- Navigation instruments.
9- Position, angle, displacement, distance, speed, acceleration.
10- Optical, light, imaging, photon.
11- Pressure, Force.
12- Density, level.
13- Thermal, heat, temperature.
14- Proximity.

B. ACTUATORS

Actuators are drivers used to drive machines and industrial lines like:

1- Motors.
2- Valves.
3- Cylinders.
4- Solenoids.
5- Position/Speed Control Drivers.
6- Heaters.
7- Lights.
8- Sirens/Horns.

C. PROGRAMMABLE LOGIC CONTROLLER

There are many types of PLCs that are found in electronic word stores that contain various software versions. PLCs can be selected according to the following specifications:

1 - compatibility with machines and control and control devices in the project.
2 - Working conditions and environment such as temperature, noise, humidity, dust ... etc.
3. PLC functions used. As some companies offer some additional features in each version such as counters, timers, etc.
4 - Number of sensors and engines and types.
5. Future expansion capability.
6. SCADA program compatible with PLC.
7- Communication ability with other types PLC or HMI.

Our system will use the ADVANTIC ADAM series to be compatible with our work.

III. ADVANTIC production ADAM series PLC

Due to the growth of computer-based technology, ADVANTEC's computer-based programmable control tools have been widely applied to a variety of industrial automation applications.

The ADAM Series (shown in Figure (1) and Figure (2)) is a set of intelligent sensor-to-computer interface modules containing built-in microprocessor. They are remotely controlled through a simple set of commands issued in ASCII format and transmitted in RS-485 protocol. They provide signal conditioning, isolation, ranging, A/D and D/A conversion, data comparison, and digital communication functions. Some modules provide digital I/O lines for controlling relays and TTL devices [2].

ADAM Series Controllers also support compact-size Ethernet port and native libraries in certain models. Features that support Ethernet include HTTP Server functionality, FTP Server, and integrated e-mail functionality. Four serial ports ADVANTEC allows ADAM series controllers to be very suitable for communications and industrial control applications.

Standard I / O design provides high flexibility for the requirements of versatile applications. ADAM series controllers also support libraries with rich Modbus functionality including libraries[2].

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Fig. (1) : Wired

Fig. (2) : Wireless ADAM

A. Software Configuration and Calibration

The ADAM analog input unit can be changed to accept multiple ranges of input voltage, thermal input, or RTD input once an order is issued from the host computer. All configuration parameters for the unit including I / O address, connection speed, HI and LO alarms, and calibration parameter settings. Remote setup can be done either using the menu-based program orconfiguring the command set in the calibration commands. Units can keep these parameters in case of power outages by storing the configuration and calibration parameters in the non-volatile EEPROM[2,3].

B. Hardware Configuration

Watchdog Timer: A watchdog timer function resets the ADAM automatically if the system fails. Thus the maintenance is simplified.

Power Requirements: Although the modules are designed to supply standard 24 VDC unregulated power, they accept any power supply unit within +10 to +30 VDC. The power supply ripple should be limited to 5 V from peak to peak, and an immediate ripple voltage between +10 and +30 VDC should be maintained.

Connectivity and Programming: ADAM can be connected and connected to all computers and terminals using RS-485 transmission standards.

The RS-485 can placed much closer to the source because it provides low-noise sensor readings. Up to 256 ADAM modules may be connected to an RS-485 multi-drop network using the ADAM RS-485 repeater which extends the maximum communication distance up to 4,000 ft. The host computer is connected to the RS-485 network with one of its COM ports through the ADAM-452x module (RS-232 to RS-422/485 converter). [4]

To boost the network's throughput, ADAM RS-485 repeater uses a logical RTS signal to manage the repeater's direction. The only two wires that are needed for the RS-485 network, DATA+ and DATA-, are inexpensive shielded twisted pair. All connections to and from the module are made in ASCII, which means that ADAM modules can be programmed in almost any high-level language [2].

Protection against the Environment: Because all configurations are controlled by software, the protection provided by the package is very important. The plastic outer cover of this packaging can be used to resist corrosive, moisture and vibration. The low power requirements of ADAMs make them operate at temperatures from 0 to 70 ° C and in humidity from 0 to 95% (non-condensing). Compactly designed withSMT technology, it can be implemented in any industrial environment.

Wireless LAN: Some ADAMs provide a wireless LAN connected to the network. Hardware design from ADAM series-based modules, but the wireless LAN interface has replaced the RJ-45 Ethernet port with IEEE802.11b to most WLAN access points without any additional hardware. Like other ADAM modules, ADAM can support Modbus / TCP and UDP protocols using HMI / SCADA software. The UDP protocol supports pre-built event playback and data stream functions for critical and real responses [1.4].

So it is the right choice for environments with wiring limitations, or expensive wiring requirements.

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C. ADAM applications

- Get data remotely.
- Monitoring process.
- Industrial Process Control.
- Energy management.
- control.
- Security systems.
- automation laboratory.
- Building automation.
- Test the product
- Direct Digital Control

IV. SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

SCADA is a computer system for gathering and analyzing real time data. It is used to monitor and control a plant or equipment in industries, like; telecommunications, water and waste control, energy, oil and gas refining, and transportation. SCADA system gathers information of faults in industrial lines such as; leak on pipelines, It transmits the information back to a central location, alerting the main station that the leak has occurred, and conducting the necessary analysis and control (determining whether the leak is critical).

SCADA systems can be relatively simple such as viewing environmental conditions

In short, the industrial process control system needs a graphical user interface (GUI) to ensure direct work between the control system and the human element (D. Bailey, 2003).

This will be achieved by using a personal computer located in the control room connected to the PLC to ensure monitoring and controlling the connected equipment. Figure (3) shows a sample of monitor screen

Other advantages of SCADA systems are:

- Reduces operational costs.
- Provides instant knowledge of system performance.
- Improves system efficiency and performance.
- Increases the life of equipment.
- Reduces expensive repairs.
- Reduces the number of hours worked (labor costs) required for troubleshooting or service.
- free staff to carry out other important tasks.
- Facilitates compliance with regulatory agencies by creating an automated report.

Fig. (3): sample of monitor screens.

V. CONTROL ROOM

There are two major aspects of designing the control room:

1- The structure suitability of the control room to withstand possible major hazards events.
2- The layout of control rooms and the arrangement of panels to ensure effective ergonomic operation of the plant in normal and emergency circumstances.

For large plants, control rooms are separate in buildings away from the treatment plant they serve. For medium or small plants, building control rooms (or control panels) can be placed near the plant. Figure (4) shows a sample of control rooms. Whatever the location, control rooms should be designed to ensure that the occupants of the control room are within acceptable limits and must be suitable for the purposes of maintaining factory control [5].

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Many events may limits the control room work, these are :
1 - vapor vapor explosions (VCEs).
2- Expanded boiling steam vapor bursts (BLEVEs).
3. Pressure bursts.
4- Exothermic reactions.
5. Emissions of toxic gases.
6. Fire, including billiard fires, jet fires, flash fires, and fireballs.

Fig. (4) sample of control rooms.

In addition to the SCADA computer, the proposed control room may contain an emulator of the industrial lines that are amplified with lights that show the status of actuators and sensors throughout the work process. This can be achieved by taking a branch of each data entry and output to attract more attention from PC Human Machine Interface (HMI).

VI. COLLECTING AND TRANSMITTING DATA

We have two options for applying PLCs on our industrial line according to theory of data collection and sending to and from control room:

Option One: Data will be collected using ADAM 6060W and ADAM 6050W which will convert it directly to a wireless signal. The data is then received in the control room using the access point, as shown in Figure (5).
The sensors will save energy from the same power source for the ADAM modules. If the power source is insufficient to cover the load requirements, additional power sources may be used but one must connect the common wire (0V) to the same point.
The digital outputs of the sensors are connected directly to the digital input (DI) ports of the ADAM module, if the power range is within the acceptable limit. The digital data output (DO) of ADAM will then be connected to the relay filesto get the actions required through their contacts.
When you use this option, you do not need to use input and / or output analog data because there is no wireless ADAM module that deals directly with analog data.

The ADAM-6050W, ADAM-6051W and ADAM-6060W support IEEE802.11b, so they can connect to most wireless LAN access points. Like other ADAM-6000 modules, the ADAM-6050W, ADAM-6051W, and ADAM-6060W also support the Modbus / TCP and UDP protocols. You can use HMI / SCADA to connect to ADAM modules through Modbus / TCP. The UDP protocol supports pre-built event playback and data stream functions for critical and real responses.

Option Two: This option is used for systems that need to use input and / or output analog data. Due to the lack of a wireless ADAM module dealing with analog data, using the next way to transfer these signals from the industrial line to the control room. Data will be collected using ADAM 5000 (or any other modules) and then converted to an Ethernet signal. And sending the signal using ADAM 4570W or ADAM 4571W as a wireless signal. This data can be received in the control room using an access point, as shown in Figure (6).
The ADAM-4570W and ADAM-4571W are cost-effective data porters between the RS-232/422/485 and 802.11b wireless LAN interfaces. It provides a fast and low-cost way to connect any RS-232/422/485 device to an 802.11b wireless LAN. Transparent and functionally effective, the ADAM-4570W and ADAM-4571W provide cost when you must continue to use current hardware and software. The ADAM-4570W and ADAM-4571W provide remote management and data access features for thousands of RS-232/422/485 devices that can not connect to the network.

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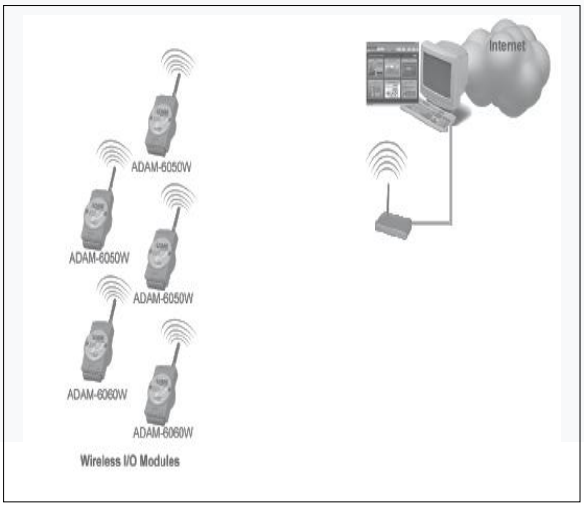

Fig. (5) Option one

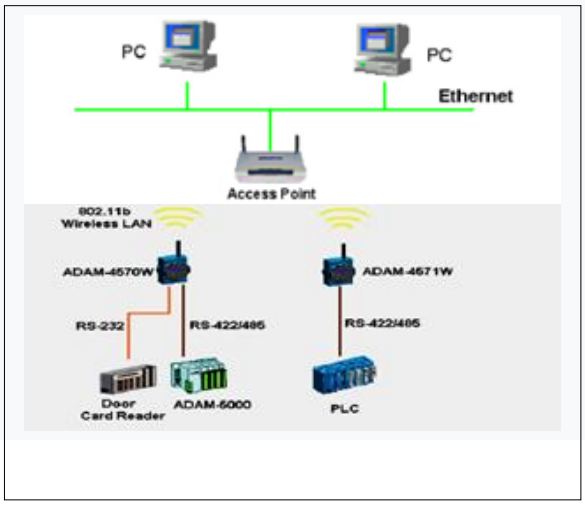

Fig. (6) Option two

VII. IEEE 802.15.4 WIRELESS PROTOCOL

A protocol is a set of rules and regulations that define how data is transmitted in telecommunications and computer networks. IEEE is an alias for the Institute of Electrical and Electronics Engineers. It is a non-profit organization dedicated to promoting technology that includes electrical and electronic devices. The 802 Group is an IEEE division involved in network operations technologies, including medium-sized networks and local networks. Group 15 specifically addresses wireless networking technologies, including the 802.15.1 workgroup everywhere, also known as Bluetooth.

ZigBee is a set of specs built around the IEEE 802.15.4 wireless protocol. The name "ZigBee" is derived from the erratic zigging patterns many bees make between flowers when collecting pollen. This is evocative of the invisible webs of connections existing in a fully wireless environment. The standard itself is regulated by a group known as the ZigBee Alliance, with over 150 members worldwide. While Bluetooth focuses on connectivity between large packet user devices, such as laptops, phones, and major peripherals, ZigBee is designed to provide highly efficient connectivity between small packet devices.

ZigBee devices are active at speeds up to 250 kbps compared with the much larger 1 Mbps Bluetooth-based 2.4GHz ISM line that is available in most parts of the world. ZigBee has been developed to meet the growing demand for wireless networks capable among many low-power devices. In the industry, ZigBee is used to automate the next generation, with small transmitters on each device on the ground, allowing communication between devices to a central computer. This new level of communication allows accurate remote monitoring and processing.

The specified maximum range of operation for ZigBee devices is 250 feet (76m), substantially further than that used by Bluetooth capable devices [6]. So we can summarize the features for ZigBee protocol as follow:

- Low duty cycle - provides long battery life
- Low latency
- Support for multiple network topologies: static, dynamic, star and mesh
- Direct Sequence Spread Spectrum (DSSS)
- Up to 65,000 nodes on a network
- 128-bit AES encryption - provides secure connections between devices
- Collision avoidance
- Link quality indication
- Clear channel assessment

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- Retries and acknowledgements
- Support for guaranteed time slots and packet freshness [6].
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VIII. CASE STUDY

The production line will be selected to run the cycling assembly to apply the automation technique to make this process faster, safer and control all the way until the final stage is completed.
As shown in Figure 7, the simulation shows the industrial line with the status lights of the switches and sensors throughout the operation process. Feeder traffic will be monitored, monitored and controlled.

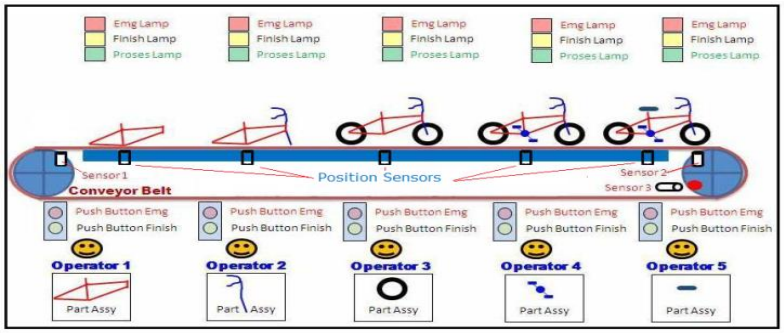

Fig. (7) simulation for the industrial line.

Now to use the PLC and place it in the system, we must study the signal input and output according to these specifications:

Input signals

1- Three digital signals for carrier movement.
2 - Five digital signals for the product sites.
3 - 10 digital signals for operator orders.

Output signals

1- Fifteen digital signals for the clarification lamps.
2- One digital signal to conveyor motor operation.

So the digital input signals are 18 and the digital output signals are 16. According to these specifications three ADAM-6060W modules will be needed for the design as shown in Figure (8).
As we explain previously, ADAM-6060W is a high-density I/O module with a built-in IEEE802.11b wireless LAN interface for seamless Ethernet connectivity. In addition to this, ADAM-6060W offers 6 relay outputs and 6 digital input channels (DI). It supports contact ratings of AC 120V, 0.5A, and DC 30V, 1A. All the digital input channels support input latch functionality for critical handling. Also, these DI channels can be used as 3 kHz counter and frequency input channels. In addition to the intelligent DI functions, the digital output channels support pulse output, [2].

ADAM-6060W Specifications

- Communication: IEEE 802.11b Wireless LAN
- Supports Protocol: Modbus/TCP, TCP/IP, UDP, HTTP, ICMP and ARP

Digital Input

- Channels: 12
- Dry Contact:
  Logic level 0: Close to Ground
  Logic level 1: Open
- Wet Contact:
  Logic level 0: 0 ~ 3 VDC Logic level 1: 10 ~ 30 VDC
- Support 3 kHz counter input (32-bit + 1-bit)
- Support 3 kHz frequency input

Relay Output

- Channels: 6

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- Contact rating (Resistive): AC: 120 V, 0.5 A DC: 30 V, 1 A
- Breakdown voltage: 500 VAC (50/60 Hz)
- Relay on time: 7 millisecond
- Relay off time: 3 millisecond

- Total switching time: 10 milliseconds
- Insulation Resistance: 1 GΩ minimum at 500 VDC
- Maximum Switching Rate: 20 operations / minute (at rated load)
- Supports pulse output (maximum 3 Hz)
- Built-in Watchdog Timer
- Isolation Protection: 2000 VDC
- Power Input: Unregulated 10 ~ 30 VDC
- Power Consumption: 2 W, 24 VDC
- Power Reversal Protection
- Operating Humidity: 5 ~ 95 % RH (non-condensing)
- Storage Humidity: 5 ~ 95 % RH (non-condensing)
- Operating Temperature: -10 ~ 60° C
- Storage Temperature: -20 ~ 80° C

Now this PLC (ADAM 6060) can be programmed using LADER program as shown in Fig.(9) connected near the industrial line and gets the input and output signals to be supervised and monitored from the control room through the SCADA program (as shown in Fig.(10).

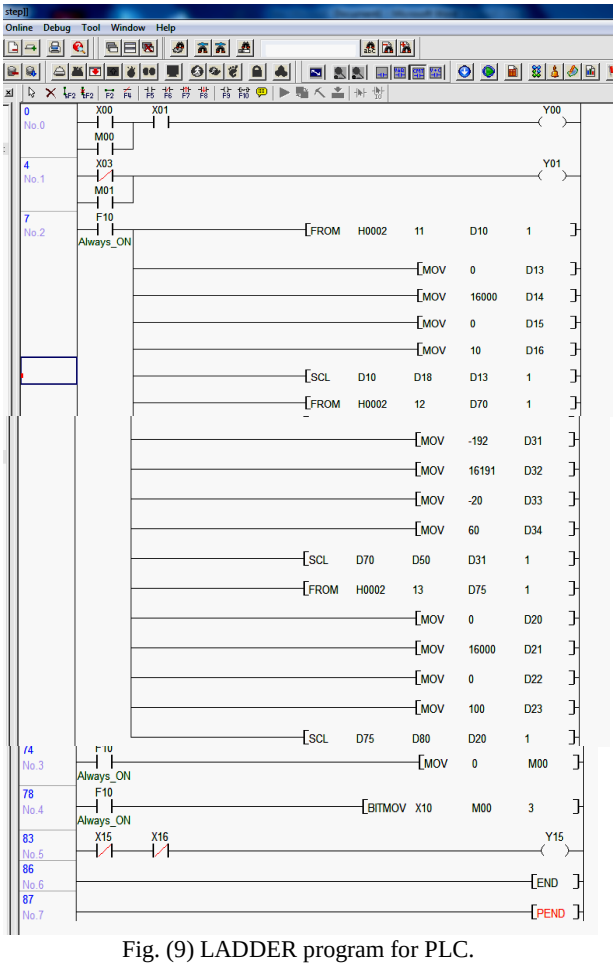

Fig. (9) LADDER program for PLC.

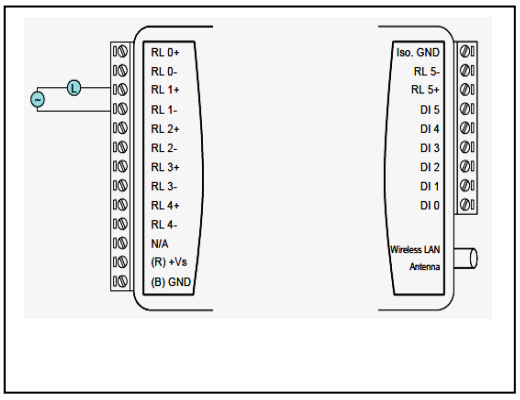

Fig. (8) ADAM-6060W wiring.

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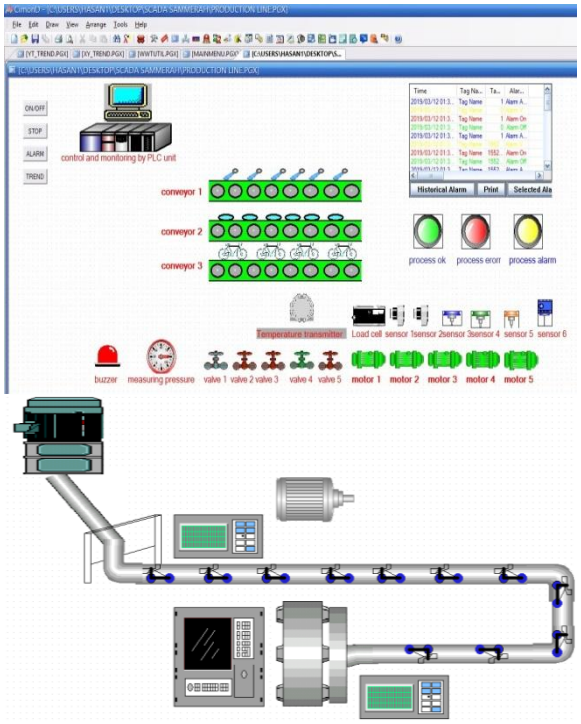

Fig.(10) SCADA design for the project.

X. CONCLUSION AND RECOMMENDATION

In this research, the steps of developing traditional industrial lines will be introduced through the application of advanced technology to make the industrial process faster, safer and more economical. Controls the system and the Internet to facilitate monitoring and control from everywhere.

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