

Review Study of a Control Room and Wireless Monitoring for the Automated Industrial Production Line

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Abstract

The requirements of a remote wireless monitoring and control room for automated industrial production lines that were run by Programmable Logic Controller (PLC).were reviewed The PLC was capable to collect different data types and convert it to network signals that were managed by controlled industrial network by using supervisory control and data acquisition (SCADA) software technique which was installed on main server or on the terminal inside the control room.

The (PLC) detects the conditions of the industrial line through a group of detectors (sensors), and depending on these conditions the PLC makes proper decisions (orders) to operate the actuators according to a certain program that was made to manage the industrial operations.

The data can be transferred from the industrial line to the control room either wire or wireless. This paper will illustrated the wireless method and provides two options to implement it.

Key words: PLC, Actuator and Sensor.

دراسة استعراضية لغرفة سيطرة ومراقبة لاسلكية لخط انتاجي صناعي آلي

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بغداد - العراق

أخلاصة

أستعرضت متطلبات غرفة مراقبة وسيطرة لاسلكية عن بعد لخطوط الانتاج الصناعية الآلية التي تدار من قبل اجهزة السيطرة المنطقية المبرمجة (PLC) القادرة على جمع أنواع مختلفة من البيانات وتحويلها إلى إشارات شبكية التي تدار بواسطة الشبكة الصناعية المتحكم بها باستخدام برنامج التحكم الإشرافي وجمع البيانات (SCADA) المثبت على الخادم الرئيسي أو محطة داخل غرفة التحكم.

ان (PLC) تتحسس حالات الخط الصناعي عبر مجموعة من المتحسسات.واعتمادا على تلك الحالات تتخذ القرارات المناسبة لتشغيل المحركات او المشغلات حسب برنامج معين معمول لادارة العملية الانتاجية.

هناك وسيلتين لنقل البيانات من الخط الانتاجي الى غرفة السيطرة، اما سلكي أو لاسلكي، في هذا البحث تقديم لطريقة النقل اللاسلكي وعرض اختيارين لتنفيذ ذلك.

كلمات مفتاحية: متحكم منطقي مبرمج ،المشغل الميكانيكي والمتحسس.

Introduction

Most of our industrial and production lines are conventional type which is not a high technological type (the high technology lines now manufactured with embedded monitoring and control systems). In this research, one tries to determine the steps to develop these lines by applying the advanced technology to make the industrial operation faster, safer and more economic. To implement that, one needs to know the status of the different stages of the working operation in order to make the suitable decision to complete the job correctly.

To know the status as mentioned above, one needs different types of sensors to be distributed all over the industrial line and to apply our decision. One needs also to use actuator which is suitable for the different parts of the line.

Between these two parts there is the programmable controllers which must be able to understand the signals coming from the sensors and give the orders to the actuators accordingly. These orders will be given according to a program designed specially to perform a specific operation.

There are two techniques to transfer the signals from the sensors to the controller and from the controller to the actuators, which can be done either wire or wireless, for each technique there are advantages and disadvantages. One can use the wireless because here one about to apply something new on existing system and it will be difficult to add new wires to the old system from the finishing side and practical side in addition to the high cost of laying new wires in conduits or trenches. On the other hand the wireless system is easy to install and upgrade.

Materials and Methods

Requirements of Design

The main things of the applied method was the detection (sensor), processing (program) and action (actuator), and that can be done through specific materials which will be clarified in details

Sensors

However the industrial lines were different, they need the same group of sensors that were with different shapes, but all share same working principles (Paula *et al.* , 2007).

The common used sensors were:

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

As-illus frateded by Paula,*et al.* ,2007

Actuators

The most common drivers and actuators that were used to drive machines and industrial lines were:

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

Now one found out that the working signals of the sensors and the actuators were either digital or analog (Paula *et al.* , 2007).

Programmable Logic Controller (PLC)

There were many brands of PLC's exist in the market and there were many software versions for each brand to control the equipment.

The PLC can be chosen according to the following:

- 1- The compatibility with the machinery, control, and monitoring devices in the project under develop.
- 2- Working conditions and environment which will allow PLC to be used, such as temperature, noise, humidity, dust....etc.
- 3- The jobs that one plan to make the PLC to perform. Since some companies provide some additional features in each version like counters or real time timers and other functions.
- 4- How many sensors will be connected to the input and their types and how many actuators will be controlled by the output and their types.
- 5- The ability of the future expansion.
- 6- The SCADA needed to be compatible with the PLC.
- 7- The ability to interconnect with other PLC or HMI.

In this system the ADVANTIC production ADAM series will be used.

Overview

The ADAM Series was a set of intelligent sensor-to-computer interface modules containing built-in microprocessor. They were 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 as mentioned by(ADAM-6000 User Manual, 2009).

Standalone Data Acquisition and Control System

As the growth of PC-based technology, ADVANTEC PC-based Programmable Controllers have been widely applied in variety of industrial automation applications. The ADAM Series Controllers are a new series of stand-alone programmable communication controllers. They do not only support high memory capacity, user-friendly configuration tool, rich serial communication interfaces, but also supported by available Ethernet port and original libraries on specific models.

Applying the ADAM Series Controller, the C language programmers would be able to handle any complex task easily.

The ADAM Series Controllers are a compact-sized Ethernet enable communication controllers under x-86 CPU architecture. They support not only Ethernet interface but also 4 serial ports, which let ADAM Series Controllers be very suitable for industrial communication and control applications.

The Ethernet-enabled features include built-in HTTP Server, FTP Server and E-mail functions. The modularized I/O design provides high flexibility for versatile application requirements. ADAM Series Controllers also support rich Modbus function libraries including Modbus /RTU (Master and Slave) and Modbus /TCP (Server and Client) function libraries as illustrated by (ADAM-6000 User Manual, 2009).

Software Configuration and Calibration

By merely issuing a command from the host computer, one can change an analog input module to accept several ranges of input voltage, thermocouple input or RTD input. All of the module's configuration parameters including I/O address, communication speed, HI and LO alarm, calibration parameters settings may be set remotely. Remote configuration can be done by using either the provided menu-based software or the command set's configuration and calibration commands.

By storing configuration and calibration parameters in a nonvolatile EEPROM, modules are able to retain these parameters in case of power failure (ADAM-6000 User Manual, 2009), (Han, *et al.* , 2008).

Watchdog Timer

A watchdog timer supervisory function will automatically reset the ADAM modules in the event of system failure. Maintenance is thus simplified.

Power Requirements

Although the modules are designed for standard industrial unregulated 24 VDC power supply, they accept any power unit that supplies power within the range of +10 to +30 VDC. The power supply ripple must be limited to 5 V peak-to-peak, and the immediate ripple voltage should be maintained between +10 and +30 VDC.

Connectivity and Programming

ADAM modules can be connected to and communicate with all computers and terminals. They use RS-485 transmission standards, and communicate with ASCII format commands. The command set for every

module type consists of approximately ten different commands.

The command set for input modules is big because it incorporates alarm functions. All communications to and from the module are performed in ASCII, which means that ADAM modules can be virtually programmed in any high-level language as mentioned by ADAM (ADAM-6000 User Manual, 2009).

Protection against the Environment

Since all the configurations are controlled by software, the protection provided by the packaging is very important. The plastic outer shell enhances resistance against corrosive materials, moistures and vibrations. ADAM modules' low power requirements help them to operate in temperatures from 0 to 70 °C, and in humidity from 0 to 95% (non-condensing). They are compactly built using automated SMT technology. Therefore, they can be implemented in any industrial environment.

Applications of ADAM

- Remote data acquisition.
- Process monitoring.
- Industrial process control.
- Energy management.
- Supervisory control.
- Security systems.
- Laboratory automation.
- Building automation.
- Product testing
- Direct digital control

RS-485 Network

The RS-485 network provides low-noise sensor readings, as modules can be placed much closer to the source. Up to 256 ADAM modules may be connected to an RS-485 multi-drop network by 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) (Communications Magazine, 2003).

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. See figure (1). As mentioned by ADAM(ADAM-6000 User Manual,2009)



Figure (1) sample for the wired communicated ADAM module.

Wireless LAN

Some of ADAM modules bring wireless LAN communication to the network. The hardware design of the modules was based on ADAM series, but a wireless LAN interface has replaced the RJ-45 Ethernet port. With support for the common IEEE802.11b so they can connect to most wireless LAN access points without any hardwiring. Like other ADAM modules, also support the Modbus/TCP and UDP protocols. One can use HMI/SCADA software to communicate with the modules through Modbus/TCP. The pre-built UDP protocol supports event trigger and data streaming

functions for critical and real time responses (Communications Magazine, 2003), (Liu, *et al.* , 2007).

So it is a right choice for environments with wiring limitations, or expensive wiring requirements. See figure (2).



Figure (2) sample for the wireless communicated ADAM module.

SCADA

Acronym of Supervisory Control And Data Acquisition (SCADA), a computer system for gathering and analyzing real time data. SCADA systems are used to monitor and control a plant or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining and transportation. A SCADA system gathers information, such as where a leak on a pipeline has occurred, transfers the information back to a central site, alerting the home station that the leak has occurred, carrying out necessary analysis and control, such as determining if the leak is critical, and displaying the information in a logical and organized fashion. SCADA systems can be relatively simple, such as one that monitors environmental conditions of a small office building, or incredibly complex, such as a system that monitors all the activity in a nuclear power plant or the activity of a municipal water system.

In short the industrial operations monitoring system needs a direct

interactive show-window using a special program to ensuring the direct action between the control system and the human element (Bailey, 2003). This will be achieved by using a personal computer located in the control room connected to the PLC and this will ensure the monitoring and control on all the equipment which are connected with it. Figure (3) shows a sample of monitor screen. As illustrated by Baily (Baily,2003)

Other benefits of SCADA Systems are:

- Reduces operational costs.
- Provides immediate knowledge of system performance.
- Improves system efficiency and performance.
- Increases equipment life.
- Reduces costly repairs.
- Reduces number of man-hours (labor costs) required for troubleshooting or service.
- Frees up personnel for other important tasks.
- Facilitates compliance with regulatory agencies through automated report generating.
- And more. . (Sandip C.Patel. and Pritimoy Sanyal, 2008).



Figure (3) sample of monitor screens.

Control Room

There are two major aspects of control room design that should be taken into account:

- 1- The suitability of the structure 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 circumstances and in an emergency.

For large plants, control rooms are likely to be situated in separate buildings away from the process plant which they serve.

For medium or small plants, control rooms might be within the plant building or control panels may be located local to the plant.

Figure (4) shows a sample of control rooms.

Whatever the location, control rooms should be designed to ensure that the risks to the occupants of the control room are within acceptable limits and that is suitable for the purposes of maintaining plant control (Wireless Communication, 2011).



Figure (4) sample of control rooms.

Events that may affect the control room are:

- 1- Vapor Cloud Explosions (VCEs).
- 2- Boiling Liquid Expanding Vapor Explosions (BLEVEs).
- 3- Pressure bursts.
- 4- Exothermic reactions.
- 5- Toxic gas releases.
- 6- Fires, including pool fires, jet fires, flash fires and fire balls.

The suggested control room may contain in addition to the PC for SCADA, a simulator of the industrial line enlarge, with lights that clarifies the status of the actuators and sensors all over the working operation in real time.

This can be achieved by taking a branch from each data input and output to bring the attention more than the PC Human Machine Interface (HMI).

Collect and Transmit Data

To apply the PLCs to our industrial line one has two options to do that, according to the theory of collecting the data and sending it to the control room.

Option One

The data will be collected using (ADAM 6060W), (ADAM 6050W), which will convert it directly to wireless signal. Then one can receive the data in the control room using an access point, as shown in figure (5).

The sensors will be supplied from the same power source which supplies the ADAM modules. In case the power source is insufficient to cover the load requirements one can use additional power sources, but one must connect the (0V) common wire to the same point.

The digital data input from the sensors are connected directly to the digital input (DI) ports, if their power ranges within the accepted limit.

The digital data output can be connected to relays coils to get the required actions through their contacts.

When this option is used in the system it doesn't need using analog data input and/or output, because there is no wireless ADAM module deals directly with analog data.

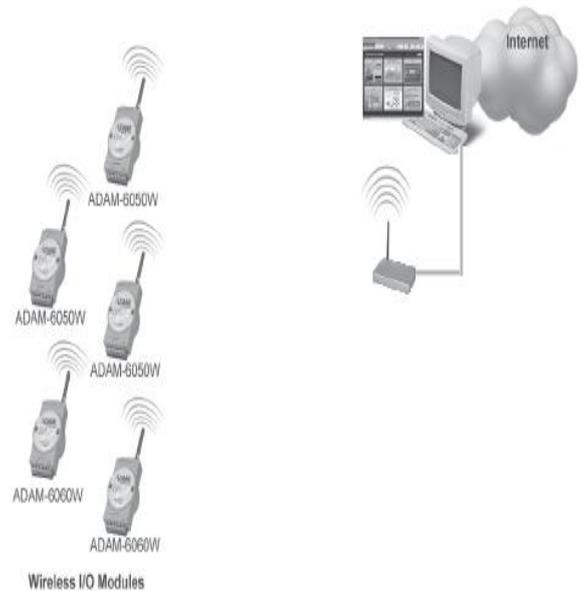


Figure (5) option one.

Feature Details

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, ADAM-6050W, ADAM-6051W and ADAM-6060W also support the Modbus/TCP and UDP protocols. One can use HMI/SCADA software to communicate with the modules through Modbus/TCP. The pre-built UDP protocol supports event trigger and data streaming functions for critical and real time responses.

Option Two

This option is used for the system that needs to use analog data input and/or output. Because of there is no wireless ADAM module deal with the analog data, one use the following way to transmit these signals from the industrial line to the control room.

The data will be collected by using ADAM 5000 or any other module, which will convert it to Ethernet signal. Then one can send it by using (ADAM 4570W) or (ADAM 4571W) as a wireless signal. These data can be received in the control room by using an access point, as shown in figure (6).

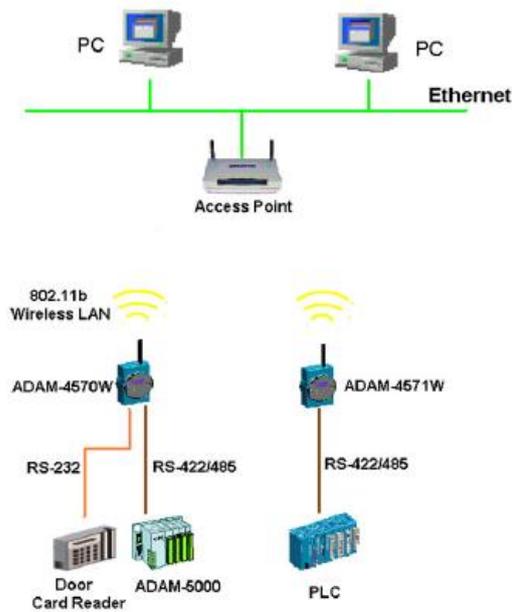


Figure (6) option two.

Feature Details

ADAM-4570W and ADAM-4571W are cost-effective data gateways between RS-232/422/485 and 802.11b Wireless LAN interfaces. They provide a quick and low-cost method to connect any RS-232/422/485 device to 802.11b wireless LAN. Functionally transparent and efficient, ADAM-4570W and ADAM-4571W saves costs when existing hardware and software must continue to be used. ADAM-4570W and ADAM-4571W bring the advantages of remote management and data accessibility to thousands of RS-232/422/485 devices that cannot connect to the network.

ADAM-4570W and ADAM-4571W integrate both your existing human machine interface software (HMI) and the RS-232/422/485 system architecture with an 802.11b Wireless LAN network. The result helps you save cabling and software development costs. Another benefit is that ADAM-4570W and ADAM-4571W make it possible to remotely download programs to a designated device via an 802.11b wireless LAN. This reduces the need for on-site maintenance and diagnosis.

Protocol

The protocol is a set of rules & regulations that determine how data is transmitted in telecommunications and computer networking. One will use ZigBee protocol.

ZigBee is the set of specs built around the IEEE 802.15.4 wireless protocol. The IEEE is the Institute of Electrical and Electronics Engineers. They are a non-profit organization dedicated to furthering technology involving electrical and electronic devices. The 802 group is the section of the IEEE involved in network operations technologies, including mid-sized networks and local networks. Group 15 deals specifically with wireless networking technologies, and includes the now ubiquitous 802.15.1 working group, which is also known as Bluetooth.

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. As a result of its simplified operations, which are one to two full orders of magnitude less complex than a comparable Bluetooth device, pricing for ZigBee devices is extremely competitive, with full nodes available for a fraction of the cost of a Bluetooth node. ZigBee devices are actively limited to a through-rate of 250Kbps, compared to Bluetooth's much larger pipeline of 1Mbps, operating on the 2.4 GHz ISM band, which is available throughout most of the world. ZigBee has been developed to meet the growing demand

for capable wireless networking between numerous low-power devices. In industry ZigBee is being used for next generation automated manufacturing, with small transmitters in every device on the floor, allowing for communication between devices to a central computer. This new level of communication permits finely-tuned remote monitoring and manipulation. In the consumer market ZigBee is being explored for everything from linking low-power household devices such as smoke alarms to a central housing control unit, to centralized lightcontrols. The specified maximum range of operation for ZigBee devices is 250 feet (76m), substantially further than that used by Bluetooth capable devices, although security concerns raised over "sniping" Bluetooth devices remotely, may prove to hold true for ZigBee devices as well as represented by Baker (Baker, 2005).

ZigBee protocol features

- 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
- Retries and acknowledgements
- Support for guaranteed time slots and packet freshness (Baker ,2005).

Results and Discussion

Case Study

Production line for bicycle assembly operation has been chosen to apply the automation technology, which will make this operation faster, safer and monitored along the way till the final completed stage.

As shown in the figure (7) one can use in the control room as a simulation for the industrial line enlarge with lights clarifies the status of the switches and sensors all over the working operation in real time.

One will monitor and control the movement of the feeding conveyor belt.

One will monitor and control each step of the working operation.

In result one will supervise the whole operation and this will make us able to upgrade the production line. As an example replaces the human in each assembling station by a manipulator, in addition to the automatic statistical reports output.

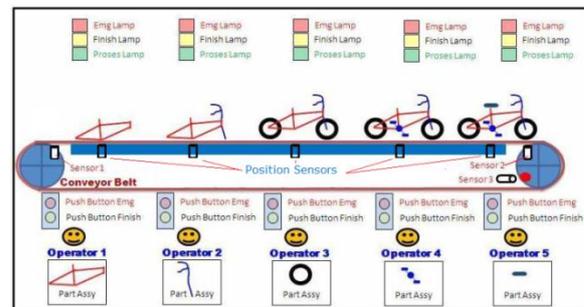


Figure (7) simulation for the industrial line.

Studying the signals (input and output) will make it easy to choose which PLC is needed.

Depending on the operation procedure, the following signals are needed:-

Input signals

- 1- Three digital signals regarding the conveyor movement.
- 2- Five digital signals regarding the product positions.
- 3- Ten digital signals regarding the operator's orders.

Output signals

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

According to that the digital input signals are 18 and the digital output signals are 16.

In the design three ADAM-6060W modules will be used, that is represented in Figure (8).

One can get benefit from these modules because of its excellent characteristics, as mentioned below.

ADAM-6060W is a high-density I/O module with a built-in IEEE802.11b wireless LAN interface for seamless Ethernet connectivity. With an Ethernet port and embedded web server, ADAM-6060W offers 6 relay outputs and 6 digital input channels. 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, (ADAM-6000 Series, 2009).

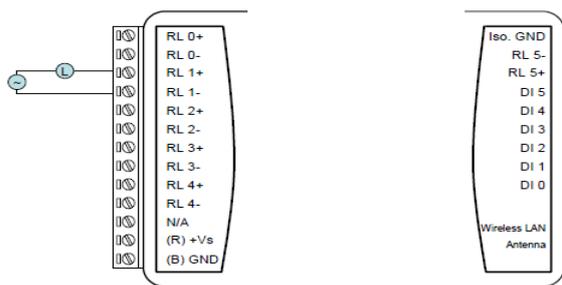


Figure (8) ADAM-6060W wiring.

ADAM-6060W Specifications as reported by (ADAM-6000 Series ,2009)

- 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
- 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)

General

- 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 these modules can be connected close to the industrial line and get the input signals and gives the output signals (for the motor through a driver or relay).

On the other side one can monitor and control these signals from the control room which is away from the industrial operation, and one can receive and transmit the signals between the PC at the control room and the modules at the industrial line wireless via access point as clarified in option one above.

Of course the PC contains a SCADA program with a presentation make it easy to monitor and control.

Conclusion and Recommendation

In this study, the steps to develop the conventional industrial lines by applying the advanced technology has been determined, to make the industrial operation faster, safer and more economic.

The recommendation is to upgrade this system to use it via internet, this will make it easy to monitor and control from everywhere.

Acronyms

- (PLC) Programmable Logic Controller
 (HMI) Human Machine Interface
 (ASCII) American Standard Code for Information Interchange
 (A/D) Analog to Digital
 (D/A) Digital to Analog
 (HTTP) Hypertext Transfer Protocol
 (FTP) File Transfer Protocol
 (Modbus) serial communications protocol
 (RTU) Remote Terminal Unit
 (TCP) Transmission Control Protocol
 (I/O) Input / Output
 (TTL) Transistor–Transistor Logic
 (RTS) Regional Transit System
 (RTD) Resistance Temperature Detector
 (HI) High
 (LO) Low
 (UDP) User Datagram Protocol
 (LAN) Local Area Network

(EEPROM) Electrically Erasable Programmable Read Only Memory

(IEEE802.11b) amendment to the IEEE 802.11 specification that extended throughput up to 11 Mbit/s using the same 2.4 GHz band. This specification under the marketing name of Wi-Fi has been implemented all over the world. The amendment has been incorporated into the published IEEE 802.11-2007 standard.

(RS-232) standard for communication between devices. Figure (9).

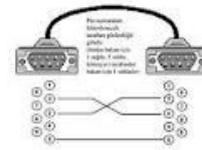


Figure (9).

(RJ-45) registered jack connector and wiring pattern used for connection of a high-speed modem to a telephone network.

(RS-485) standard defining the electrical characteristics of drivers and receivers for use in balanced digital multipoint systems. Figure (11).



Figure (11).

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