بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Development of PLC Program and Monitoring System For Robotic Arm

تطوير برنامج متحكمة منطقية قابلة للبرمجة ونظام مراقبة زراع آلي

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Electrical Engineering

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September 2017

الآيـــة

قال تعالى:

بسم الله الرحمن الرحيم

{أَفَحَسِبْتُمْ أَنَّمَا خَلَقْنَاكُمْ عَبَثاً وَأَنَّكُمْ إِلَيْنَا لَا تُرْجَعُونَ}

صدق الله العظيم

(المؤمنون : 115)

Dedication

TO MY DEAR MOTHER

Acknowledgement

All praise is due to Allah, the lord of all that exists and may peace and blessing be upon our prophet Mohammed and upon his family and his companions in their entirety.

My thankful at the beginning and at the end will be to Allah thank you lord for being with me at all my life for giving me faith and hope throw my darkest time, lighting and open up the road for me thank you Allah very much.

I would like to thank my supervisor Dr Ahmed Abdalla Emam for directing me, advice me and provide by necessary information. Thank you Dr. Ahmed very much for all your efforts and for be patient with me.

I also would like to thank the engineer mister ASaad for his rich help and advices thank you very much mister Asaad.

Finally I would like to thank the engineer and mister Naggi for show me the road thank very much mister Naggi.

THANK YOU ALL VERY MUCH MAY ALLAH BLESSES YOU

Abstract

Picking and placing an object or products in specific place or boxes play an important part in industry process, it consumed a lot of time also need patience and accuracy and cannot handle any mistakes. Pick and place robot is a robot that can be programmed to pick product or any object and place it somewhere. these robots are popular among many automation applications and material handling system, they are especially practical in applications where repetitive and difficult tasks need to be performed with accurate time and specific place.

Programmable Logic Controller Sematic 300 has been programmed to control a Cartesian robot which is used to pick objects from one production line and places them in boxes at another line. The program has been run and tested through simulation at sematic 300 software.

WinCC Flexible Human Machine Interface has been used to design a graphical user interface for monitoring the overall operation and for error detection. The simulation showed that the designed program and GUI meets the design objectives.

المستخلص

عملية تعبئة منتج في مكان محدد او صناديق تلعبا دورا مهما في العملية الصناعية ، تحتاج دقه عالية وكثير من الوقت.

Pick and place روبوت هو احد الروبتيك الصناعية التي تقوم بتعبئة او تحريك اي منتج من مكان الي مكان اخر حسب برمجتها. هذا النوع من الروبتيك هو الاكثر عمليا في التطبيقات الصناعية التي تكون فيها العمليات صعبة ومتكررة وتتطلب كثير من التركيز والوقت .

متحكمة الPLC استخدمت للتحكم في روبوت Pick and place ثلاثي الابعاد ليقوم بتحريك منتج من خط انتاج وتعبئته في صناديق توجد في خط انتاج اخر . لقد جرب البرنامج وفحص خلال برنامج300 Programmable Logic Controller Sematic. ايضا لمراقبة حركة النظام والقدرة علي تحديد اي خطا قد يحدث في النظام استخدم برنامج محاكاة النظام Human Machine Interface WinCC Flexible .

لقد رؤي من خلال برنامج المحاكاة والبرنامج المصمم ان البرنامج حقق اهداف البحث.

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General Introduction

1.1 Overview

A robot is an intelligent, device that can move by itself whose motion can be modeled, planned, sensed and controlled, and also its motion and behavior can be influenced by programming. A robot is a general purpose programmable manipulator. In today's world robots are all around us, they come in a variety of different shapes and sizes, designed to do an extraordinary range of tasks. Robots are widely used in industry, manufacturing, assembly packing, medical , military operations , earth and space exploration, laboratory research and mass production of consumer[1].

There are many reasons that its important to use robots in human life for example robots can help access new resources, for instance under the seas, or under lakes or conduct mining in dangerous environments, Robots can help recycling resources through their ability to sense the type of plastic using spectroscopic methods, which humans are not capable of, robots can help reduce waste during industrial production, agricultural production and elsewhere in the food chain. Robots are ideal candidates for many harsh and dangerous working environments that are unsuitable for human personnel. Robots have a level of consistency and repeatability in performing the work cycle, which cannot be attained by humans. Robots can be reprogrammed and equipped as necessary to perform different work tasks one after another. Robots use computers which allow them to be networked with other computers and machines, thus enabling computer integrated manufacturing.

An industrial robot is an automatically controlled reprogrammable multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications. Industrial robots are used as transporting devices like material handling of work pieces between machines, or in some kind of additive- (e.g. assembly, welding, gluing, painting etc.) or subtractive- manufacturing process (e.g. milling, cutting, grinding, de-burring, polishing etc.).[1]

Pick and place is one of the most famous applications which have been used widely. This pick and place operation is done everywhere and every time because a lot of human movement involves picking and placing objects . Pick and place robot can be defined as a simple robot, often with only two or three degree of freedom and little or no trajectory control, which is main function is to transfer items from one place to another. Their operation is very common in pharmaceutical industry, electronic industry, food industry and consumer goods industry.

1.2 Problem Statement

Picking and placing operation for a product from one production line into another with very repetitive and accurate motion or picking and placing any objects according to specific size and shape is tedious work for human and it require a very high conscious, a lot of manpower and long time consuming which increase the operating cost and the probability of mistake which reduce production efficiency and may lead to huge losses for the manufacturing companies.

1.3Objective

Designing a program which control the motion of pick and place robot that can perform easier and faster picking and placing operation for multiple shapes and sizes of metals, This can improve the picking and placing operation in manufacturing field so as to increase the productivity. Also design a program that keep monitoring the robot motions and the entire system.

1.4 Methodology

Using programmable logic controller (PLC) to program and control the motion of three dimensional robots and connecting the program with human machine interface (HMI) to simulate all the system operation.

1.5 Thesis layout

This thesis consists of five chapters. Chapter one give general introduction including overview, problem statement, objective and methodology. Chapter two discussed automation and programmable logic controller briefly. Chapter three contains sensors, type of sensors, actuator and type of actuators. Chapter four include PLC description and HMI simulation. Finally chapter five contains conclusion and recommendation.

Chapter Two

Automation and Programmable logic Controllers

Chapter Two

Automation and Programmable Logic Controllers

2.1 Automation

The word automation is derived from Greek words auto (self) and matos (moving). Automation therefore is the mechanism for systems that move by itself. However, apart from this original sense of the word, automated systems also achieve significantly superior performance than what is possible with manual systems, in terms of power, precision and speed of operation. Automation is a set of technologies that results in operation of machines and systems without significant human intervention and achieves performance superior to manual operation [2].

Automation or automatic control is the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching on telephone networks, steering and stabilization of ships, aircraft and other applications with minimal or reduced human intervention. Some processes have been completely automated. It have been achieved by various means including mechanical, hydraulic, pneumatic, electrical, electronic devices and computers, usually in combination. Complicated systems, such as modern factories, airplanes and ships typically use all these techniques combined. The biggest benefit of automation is that it saves labor; however, it is also used to save energy and materials and to improve quality, accuracy and precision.

2.1.1 Types of automation

The main type of automation are:

(a)**Discrete control (on/off)**

One of the simplest types of control is on-off control. An example is the thermostats used on household appliances. Electromechanical thermostats used in HVAC may only have provision for on/off control of heating or cooling systems. Electronic controllers may add multiple stages of heating and variable fan speed control. Sequence control, in which a programmed sequence of discrete operations is performed, often based on system logic that involves system states. An elevator control system is an example of sequence control.

(b) Continuous control

The advanced type of automation that revolutionized manufacturing, aircraft, communications and other industries, is feedback control, which is usually continuous and involves taking measurements using a sensor and making calculated adjustments to keep the measured variable within a set range. Moreover, it can be understood as the relation of two variables, one for the "x" axis and a second for the "y" axis. If the value of "y" increases, then the value on the "x" axis will also increase, and vice versa[2].

(c)Loop control

All the elements constituting the measurement and control of a single variable are called a control loop. Control that uses a measured signal, feeds the signal back and compares it to a set point, calculates and sends a return signal to make a correction, is called closed loop control. If the controller does not incorporate feedback to make a correction then it is open loop, it's normally accomplished with a controller. The theoretical basis of open and closed loop automation is control theory.

An early development of sequential control was relay logic, by which electrical relays engage electrical contacts which either start or interrupt power to a device. Relays were first used in telegraph networks before being developed for controlling other devices, such as when starting and stopping industrial-sized electric motors or opening and closing solenoid valves. Using relays for control purposes allowed event-driven control, where actions could be triggered out of sequence, in response to external events. These were more flexible in their response than the rigid single-sequence cam timers. More complicated examples involved maintaining safe sequences for devices such as swing bridge controls, where a lock bolt needed to be disengaged before the bridge could be moved, and the lock bolt could not be released until the safety gates had already been closed. The total number of relays, cam timers and drum sequencers can number into the hundreds or even thousands in some factories. Early programming techniques and languages were needed to make such systems manageable, one of the first being ladder logic, where diagrams of the interconnected relays resembled the rungs of a ladder. Special computers called programmable logic controllers were later designed to replace these collections of hardware with a single, more easily re-programmed unit[2].

In a typical hard wired motor start and stop circuit (called a control circuit) a motor is started by pushing a Start or Run button that activates a pair of electrical relays. The "lock-in" relay locks in contacts that keep the control circuit energized when the push button is released. The start button is a normally open contact and the stop button is normally closed contact. Another relay energizes a switch that powers the device that throws the motor starter switch (three sets of contacts for three phase industrial power) in the main power circuit. Large motors use high voltage and experience high in-rush current, making speed important in making and breaking contact. This can be dangerous for personnel and property with manual switches. The lock in contacts in the start circuit and the main power contacts for the motor are held engaged by their respective electromagnets until a stop or off button is pressed, which de-energizes the lock in relay, commonly interlocks are added to a control circuit. Suppose that the motor in the example is powering machinery that has a critical need for lubrication. In this case an interlock could be added to insure that the oil pump is running before the motor starts. Timers, limit switches and electric eyes are other common elements in control circuits. Solenoid valves are widely used on compressed air or hydraulic fluid for powering actuators on mechanical components. While motors are used to supply continuous rotary motion, actuators are typically a better choice for intermittently creating a limited range of movement for a mechanical component, such as moving various mechanical arms, opening or closing valves, raising heavy press rolls, applying pressure to presses [1]

(d) Computer control

Computers can perform both sequential control and feedback control, and typically a single computer will do both in an industrial application. Programmable logic controllers are a type of special purpose microprocessor that replaced many hardware components such as timers and drum sequencers used in relay logic type systems. General purpose process control computers have increasingly replaced stand alone controllers, with a single computer able to perform the operations of hundreds of controllers. Process control computers can process data from a network of PLCs, instruments and controllers in order to implement typical (such as PID) control of many individual variables or, in some cases, to implement complex control algorithms using multiple inputs and mathematical manipulations. They can also analyze data and create real time graphical displays for operators and run reports for operators, engineers and management.

Information technology, together with industrial machinery and processes, can assist in the design, implementation, and monitoring of control systems. One example of an industrial control system is a programmable logic controller. PLCs are specialized hardened computers which are frequently used to synchronize the flow of inputs from (physical) sensors and events with the flow of outputs to actuators and events.

Human-machine interfaces or Computer Human Interfaces (CHI), formerly known as man-machine interfaces, are usually employed to communicate with PLCs and other computers. Service personnel who monitor and control through HMIs can be called by different names. In industrial process and manufacturing environments, they are called operators or something similar. In boiler houses and central utilities departments they are called stationary engineers.

2.1.2 Industrial automation system

In a general sense the term industries defined as Systematic economic activity that could be related to manufacture/service/ trade [2]. Sematic by Siemens is one of the world's leading industrial automation systems. It includes a range of industrial automation products designed to accommodate a large variety of tasks. Flexible and cost-effective, the sematic system is ideally suited to manage the ever-growing demands the manufacturing and process industry requires of today’s machines and systems.

2.2 Programmable Logic Controllers Definition

Programmable logic controllers, also called programmable controllers, are solid-state members of the computer family, using integrates circuits instead of electromechanical devices to implement control functions. They are capable of storing instructions, such as sequencing, timing, counting, arithmetic, data manipulation, and communication, to control industrial machines and processes. Figure 2.1 illustrates a conceptual diagram of a PLC application [3].

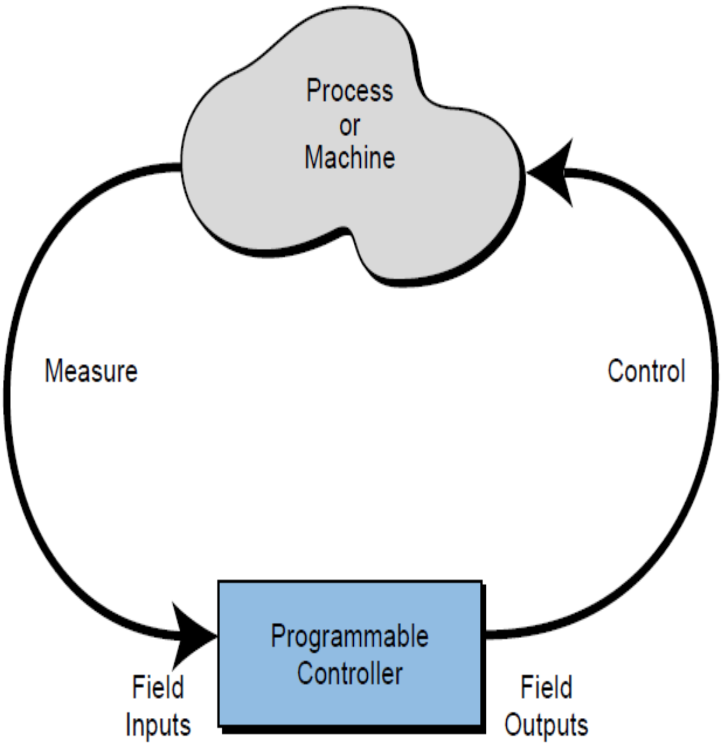

Figure 2.1: PLC conceptual application diagram

Programmable controllers have many definitions. However, PLCs can be thought of in simple terms as industrial computers with specially designed architecture in both their central units (the PLC itself) and their interfacing circuitry to field devices (input/output connections to the real world).Also PLC is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, control of amusement rides, or control of lighting fixtures. Every aspect of industry from power generation to automobile painting to food packaging uses programmable controllers to expand and enhance production

2.2.1 A historical background

The hydromantic Division of the General Motors Corporation specified the design criteria for the first programmable controller in 1968. Their primary goal was to eliminate the high costs associated with inflexible, relay controlled systems. The specifications required a solid-state system with computer flexibility able to first survive in an industrial environment, second be easily programmed and maintained by plant engineers and technicians, and third be reusable. Such a control system would reduce machine downtime and provide expandability for the future. Some of the initial specifications included the following:

- The new control system had to be price competitive with the use of relay systems.
- The system had to be capable of sustaining an industrial environment.
- The input and output interfaces had to be easily replaceable.
- The controller had to be designed in modular form, so that subassemblies could be removed easily for replacement or repair.
- The control system needed the capability to pass data collection to a central system.
- The system had to be reusable.
- The method used to program the controller had to be simple, so that it

could be easily understood by plant personnel.

The product implementation to satisfy hydramatic’s specifications was underway in 1968; and by 1969, the programmable controller had its first product offspring's. These early controllers met the original specifications and opened the door to the development of a new control technology. The first PLCs offered relay functionality, thus replacing the original hardwired relay logic, which used electrically operated devices to mechanically switch electrical circuits They met the requirements of modularity, expandability, programmability, and ease of use in an industrial environment. These controllers were easily installed, used less space, and were reusable. The controller programming, although a little tedious, had a recognizable plant standard: the ladder diagram format.

The first programmable controllers were more or less just relay replacers. Their primary function was to perform the sequential operations that were previously implemented with relays. These operations included ON/OFF control of machines and processes that required repetitive operations, such as transfer lines and grinding and boring machines. However, these programmable controllers were a vast improvement over relays. They were easily installed, used considerably less space and energy, had diagnostic indicators that aided troubleshooting, and unlike relays, were reusable if a project was scrapped [3].

2.2.2 Today's programmable controllers

Many technological advances in the programmable controller industry continue today. These advances not only affect programmable controller design, but also the philosophical approach to control system architecture. Changes include both hardware (physical components) and software (control program) upgrades. The following list describes some recent PLC hardware enhancements:

- Faster scan times are being achieved using new, advanced microprocessor and electronic technology

- Small low-cost PLCs which can replace four to ten relays, now have more power than their predecessor, the simple relay replacer.
- High-density Input/output (I/O) systems provide space-efficient interfaces at low cost.
- Special interfaces have allowed certain devices to be connected directly to the controller. Typical interfaces include thermocouples, strain gauges, and fast-response inputs.
- Peripheral equipment has improved operator interface techniques, and system documentation is now a standard part of the system.

Programmable controllers are now mature control systems offering many more capabilities than were ever anticipated. They are capable of communicating with other control systems, providing production reports, scheduling production, and diagnosing their own failures and those of the machine or process. These enhancements have made programmable controllers important contributors in meeting today's demands for higher quality and productivity. Despite the fact that programmable controllers have become much more sophisticated, they still retain the simplicity and ease of operation that was intended in their original design [3].

2.2.3 PLC versus other type of controls

In this section the PLC compared with different controls techniques as follows:

(a) PLC versus relay control

For years, the question many engineers, plant managers, and original equipment manufacturers (OEMs) asked was, "Should I be using a programmable controller?" At one time, much of a systems engineer's time was spent trying to determine the cost-effectiveness of a PLC over relay control. Even today, many control system designers still think that they are faced with this decision. One thing, however, is certain—today's demand for high quality and productivity can hardly be fulfilled economically without electronic control equipment. With rapid technology developments and increasing competition, the cost of programmable controls has been driven down to the point where a PLC-versus-relay cost study is no longer necessary or valid. Programmable controller applications can now be evaluated on their own merits. When deciding whether to use a PLC-based system or a hardwired relay system, the designer must ask several questions. Some of these questions are:

Is there a need for flexibility in control logic changes?

Is there a need for high reliability?

Are space requirements important?

Are increased capability and output required?

Are there data collection requirements?

Will there be frequent control logic changes?

Will there be a need for rapid modification?

Must similar control logic be used on different machines?

Is there a need for future growth?

What are the overall costs?

The merits of PLC systems make them especially suitable for applications in which the requirements listed above are particularly important for the economic viability of the machine or process operation. If system requirements call for flexibility or future growth, a programmable controller brings returns that outweigh any initial cost advantage of a relay control system. Even in a case where no flexibility or future expansion is required, a large system can benefit tremendously from the troubleshooting and maintenance aids provided by a PLC. The extremely short cycle (scan)time of a PLC allows the productivity of machines that were previously under electromechanical control to increase considerably. Also, although relay control may cost less initially, this advantage is lost if production downtime due to failures is high.

(b) PLC versus computer control

The architecture of a PLC's Central Process Unit is basically the same as that of a general-purpose computer; however, some important characteristics set them apart. First, unlike computers, PLCs are specifically designed to survive the harsh conditions of the industrial environment. A well-designed PLC can be placed in an area with substantial amounts of electrical noise, electromagnetic interference, mechanical vibration, and no condensing humidity. A second distinction of PLCs is that their hardware and software are designed for easy use by plant electricians and technicians. The hardware interfaces for connecting field devices are actually part of the PLC itself and are easily connected. The modular and self-diagnosing interface circuits are able to pinpoint malfunctions and, moreover, are easily removed and replaced. Also, the software programming uses conventional relay ladder symbols, or other easily learned languages, which are familiar to plant personnel. Whereas computers are complex computing machines capable of executing several programs or tasks simultaneously and in any order, the standard PLC executes a single program in an orderly, sequential fashion from first to last instruction. Bear in mind, however, that PLCs as a system continue to become more intelligent. Complex PLC systems now provide multiprocessor and multitasking capabilities, where one PLC may control several programs in a single CPU enclosure with several processors[].

2.2.4 Major components of a common PLC

Figure 2.2 show the basic components of PLC.

(a) Power supply

Provides the voltage needed to run the primary PLC components

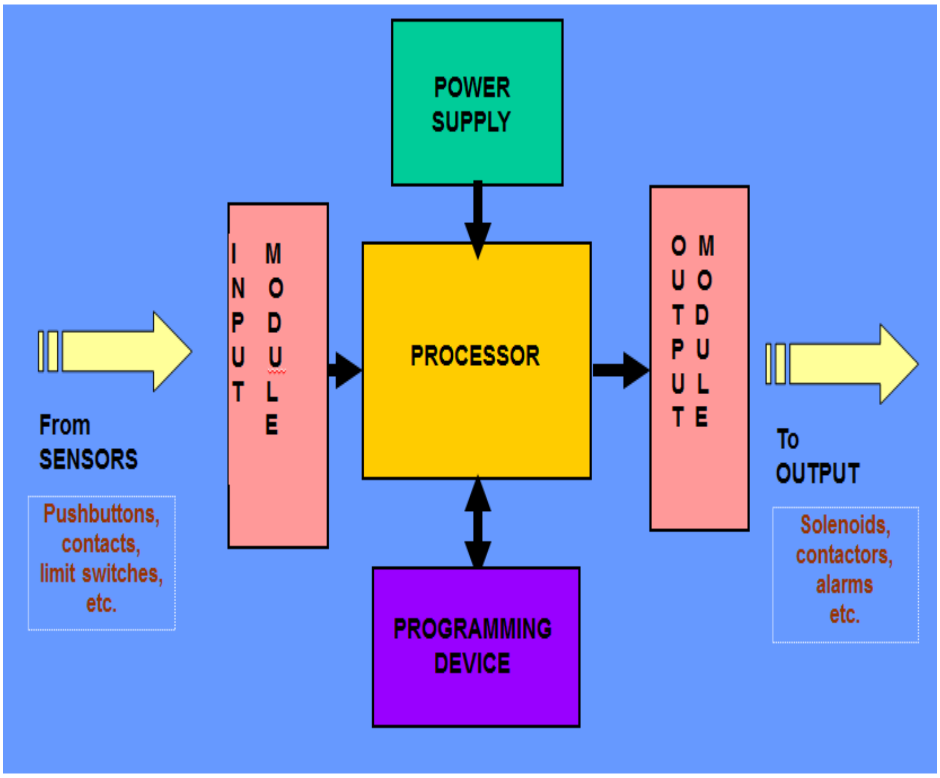

Figure 2.2: PLC basic components

(b) I/O Modules

Provides signal conversion and isolation between the internal logic-level signals inside the PLC and the field's high level signal.

(c) Processor

Provides intelligence to command and govern the activities of the entire PLC systems. Programing device used to enter the desired program that will determine the sequence of operation and control of process equipment or driven machine.

2.2.5 Principle of operation

A programmable controller, as illustrated in Figure 2.3 consists of two basic section the central processing unit and the input/output interface system.

The (CPU) governs all PLC activities. The operation of a programmable controller is relatively simple. The I/O system is physically connected to the field devices that are encountered in the machine or that are used in the control of a process. These field devices may be discrete or analog input/output devices, such as limit switches, pressure transducers, push buttons, motor starters, solenoids, etc. The I/O interfaces provide the connection between the CPU and the information providers (inputs) and controllable devices (outputs).

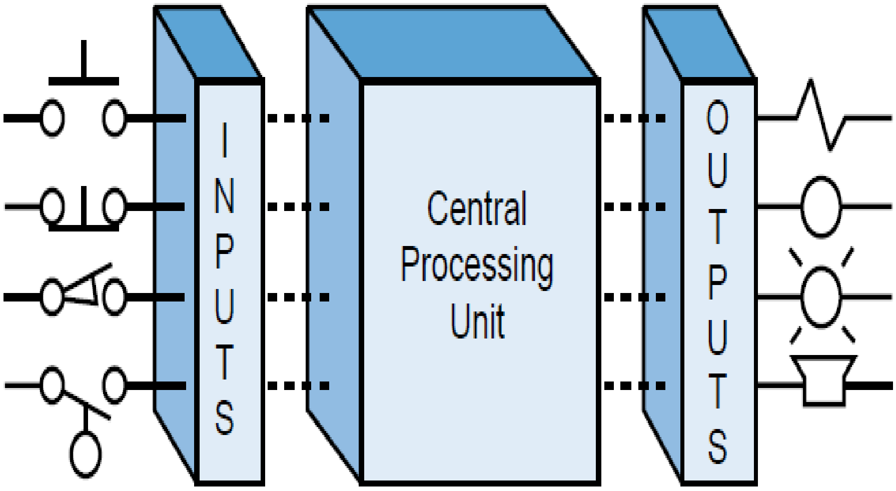

Figure 2.3: Programmable controller block diagram.

During its operation, the CPU completes three processes: one it reads, or accepts, the input data from the field devices via the input interfaces, two it executes, or performs, the control program stored in the memory system, and three it writes, or updates, the output devices via the output interfaces. This process of sequentially reading the inputs, executing the program in memory, and updating the outputs is known as scanning**.** Figure 2.4 illustrates graphic representation of a scan.

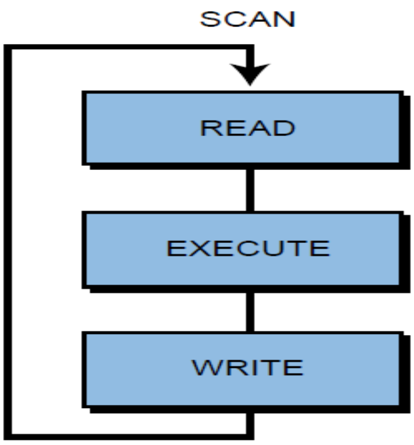

Figure 2.4: Illustration of a scan

The input/output system forms the interface by which field devices are connected to the controller (see Figure 2.5). The main purpose of the interfaces to condition the various signals received from or sent to external field devices. Incoming signals from sensors (e.g., push buttons, limit switches, analog sensors, selector switches, and thumbwheel switches) are wired to terminals on the input interfaces. Devices that will be controlled, like motor starters, solenoid valves, pilot lights, and position valves, are connected to the terminals of the output interfaces [3].

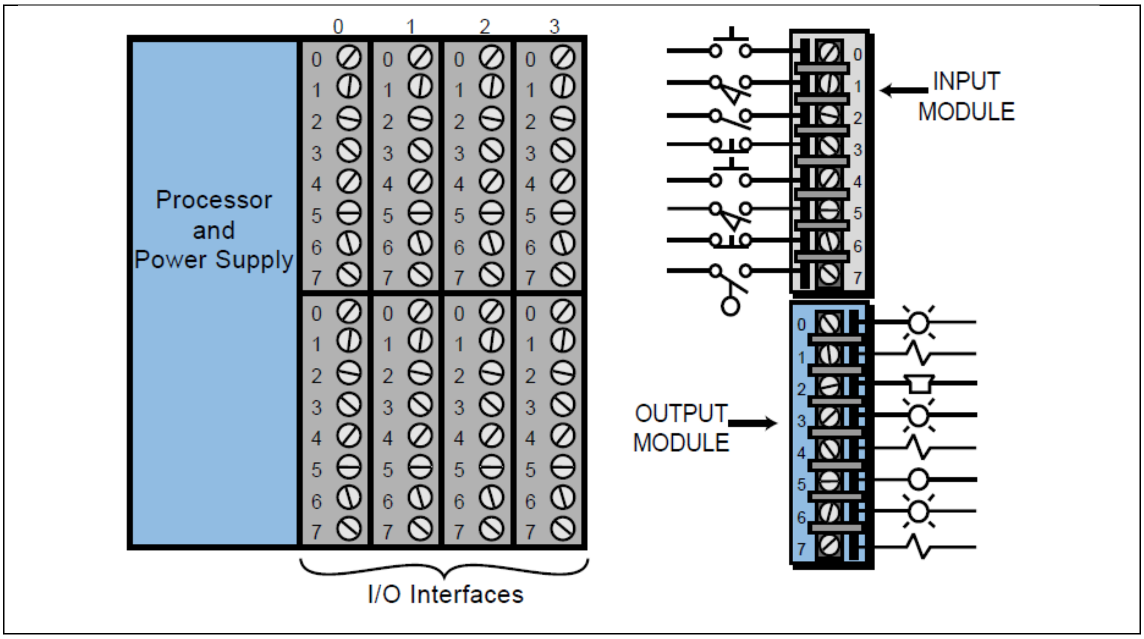

Figure 2.5: Input/output interface.

2.2.6 Typical area of PLC applications

Since its inception, the PLC has been successfully applied in virtually every segment of industry, including steel mills, paper plants, food-processing plants, chemical plants, and power plants. PLCs perform a great variety of control tasks, from repetitive ON/OFF control of simple machines to sophisticated manufacturing and process control. Figure2.6 show a few of the major applications that use programmable controllers.

2.2.7 PLC size

The size of PLC can be classified as follow:

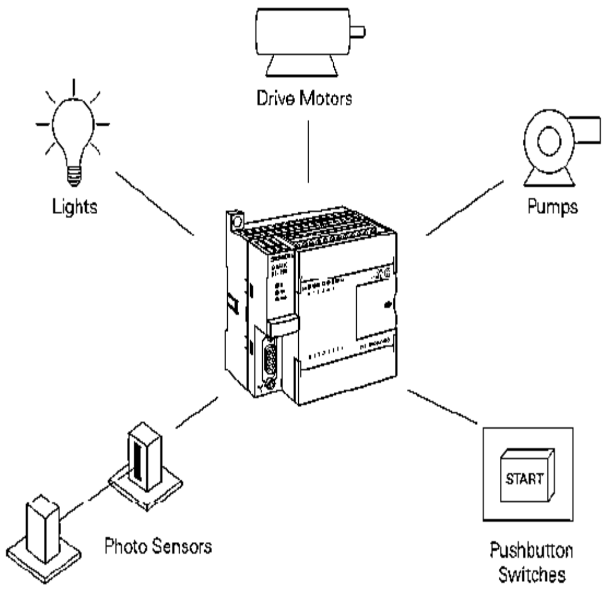

Figure 2.6: Some areas of applications in PLC

(a)SMALL it covers units with up to 128 I/O's and memories up to 2 Kbytes. these PLC's are capable of providing simple to advance levels or machine controls.

(b)MEDIUM have up to 2048 I/O's and memories up to 32 Kbytes.

(c) LARGE the most sophisticated units of the PLC family. They have up to 8192 I/O's and memories up to 750 Kbytes. can control individual production processes or entire plant.

2.2.8 PLC programming languages

The term PLC programming language refers to the method by which the user communicates information to the PLC.The four most common language structures are:

(a) Ladder Diagram.

(b) Function Block Diagram.

(c) Statement List .

(d) Sequential Function Charts (SFCs).

Figure 2.7 shows some type of PLC programming languages.

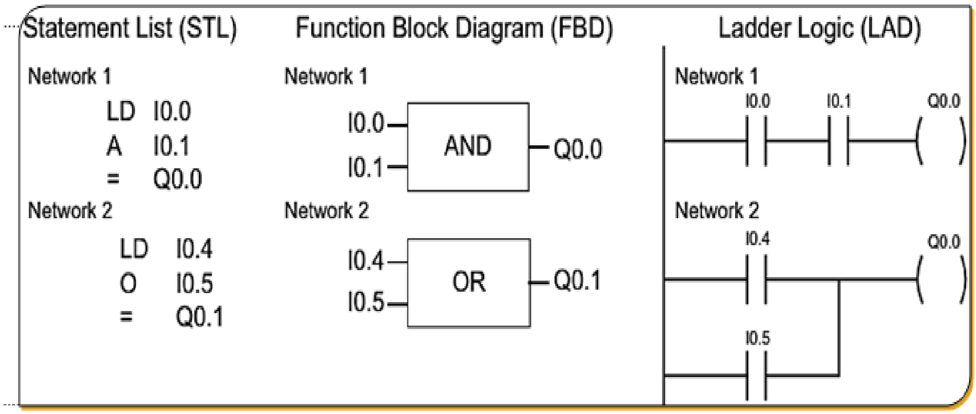

Figure 2.7: PLC programming Languages.

SFCs or Graphic (Graphic Functional de Command Étape Transition) is a symbolic, graphic language, which originated in France, that represents the control program as steps or stages in the machine or process.

Chapter Three

Sensors and Actuators

Chapter Three

Sensors and Actuators

3.1 Sensors

A sensor is often defined as a device that receives and responds to a signal or stimulus, it detect changes in the environment such as energy, heat, light, magnet, supersonic, etc. and convert them to electric signals. They convert a physical condition into an electrical signal for use by a controller, such as a PLC. Sensors are also devices used to provide information on the presence or absence of an object [4].Figure 3.1 represents sensor job.

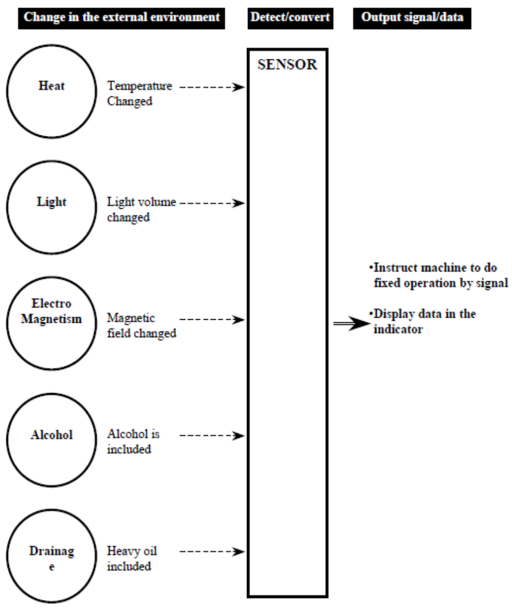

Figure 3.1: Sensors job

3.1.1 Control sensors

A sensor as a control component is to capture correctly and speedy data of an environment where a machine is installed and data of products that are being processed, and then convert those data to controllable electric signals or information that human can easily confirm.

3.1.2 Role of sensor in automation

The role of sensors can be appears as shown in figure 3.2 that is show the flow of control between the sensors and personal computer pc , the control act depends basically on singles from the sensors. Figure 3.3 also represents the control steps.

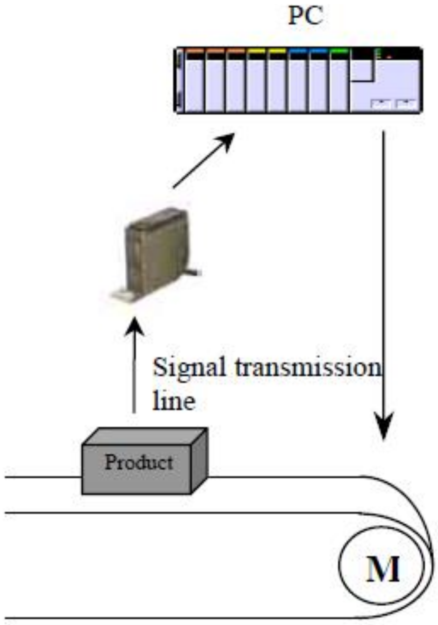

Figure 3.2: Flow of control between sensors and pc

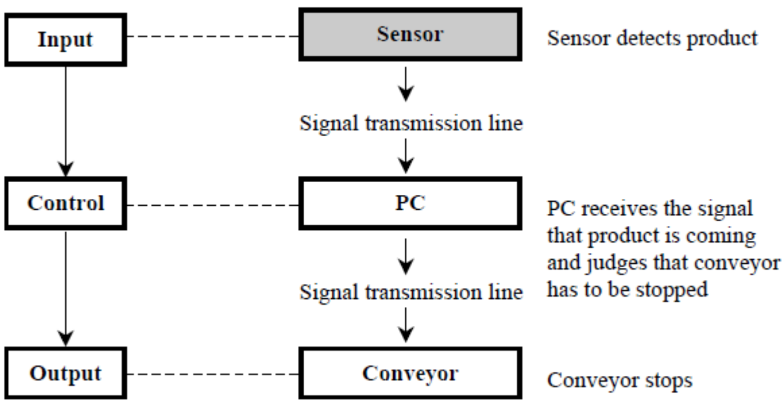

Figure 3.3: Control steps

3.1.3 Sensor output

(a) ON/OFF Output is ON or OFF when input value exceeds the value set (it may be called High/Low, 1/0).

(b) Digital sensor input which changes itself continuously the output is digital value such as BCD/BIN.

(c) Analog sensor input which changes itself continuously the output is consecutive value of voltage/electric current [4].

3.1.4 Type of sensors

Sensors can be classified into different types. These products are packaged in various configurations to meet virtually any requirement found in commercial and industrial applications. The famous types of the sensors are:

(a) Limit switches

The standard limit switch figure 3.4 is a mechanical device that uses physical contact to detect the presence of an object (target).When the target comes in contact with the actuator; the actuator is rotated from its normal position to the operating position. This mechanical operation activates contacts within the switch body. A typical limit switch consists of a switch body and an operating head. The switch body includes electrical contacts to energize and deenergize a circuit. The operating head incorporates some type of lever arm or plunger, referred to as an actuator.

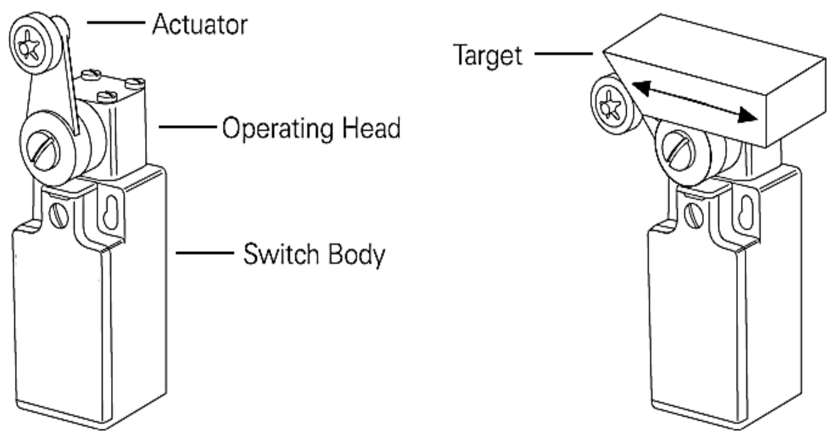

Figure 3.4: Limit switch sensors

A number of terms must be understood to understand how a mechanical limit switch operates. Figure3.5 shows these terms.

- The free position is the position of the actuator when no external force is applied.
- Pretravel is the distance or angle traveled in moving the actuator from the free position to the operating position.
- The operating position is where contacts in the limit switch change from their normal state (NO or NC) to their operate state.
- Over travel is the distance the actuator can travel safely beyond the operating point.
- Differential travel is the distance traveled between the operating position and the release position.
- The release position is where the contacts change from their operated state to their normal state.
- Release travel is the distance traveled from the release position to the free position.

When the target comes in contact with the actuator, it rotates the actuator from the free position, through the pretravel area, to the operating position. At this point the electrical contacts in the switch body change state. A spring returns the actuator lever and electrical contacts to their free position when the actuator is no longer in. contact with the target.

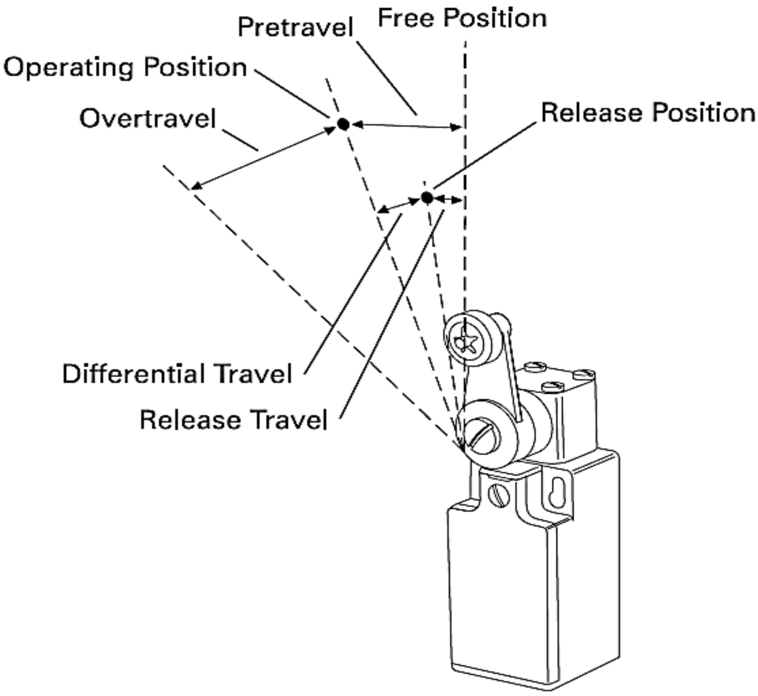

Figure 3.5: Limit switch sensors parts

(b) Photoelectric sensors

A photoelectric sensor is another type of position sensing

Device, these sensors react on changes in the received quantity of light. Some photoelectric sensors can even detect a specific color. Photoelectric sensors, similar to the ones shown below, use a modulated light beam that is either broken or reflected by the target. Figure 3.6 show photoelectric sensors.

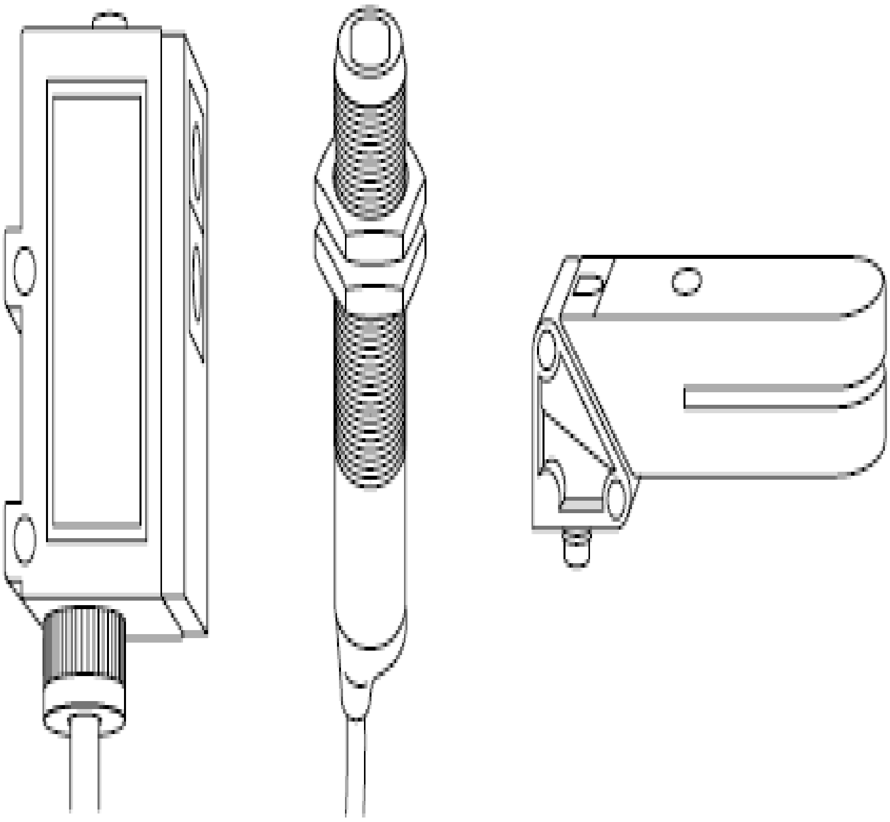

Figure 3.6: Photo electric sensors

The control consists of an emitter (light source), a receiver to detect the emitted light, and associated electronics that evaluate and amplify the detected signal causing the photo electric's output switch to change state. Figure 3.7 shows the simple application of a photoelectric sensor placed in the entrance of a store to alert the presence of a customer. This

of course, is only one possible application[5].

(c)Inductive sensors

Inductive proximity sensors use an electromagnetic field to detect the presence of metal objects. They are available in a variety of sizes and configurations to meet varying applications. Figure 3.8 shows inductive sensors.

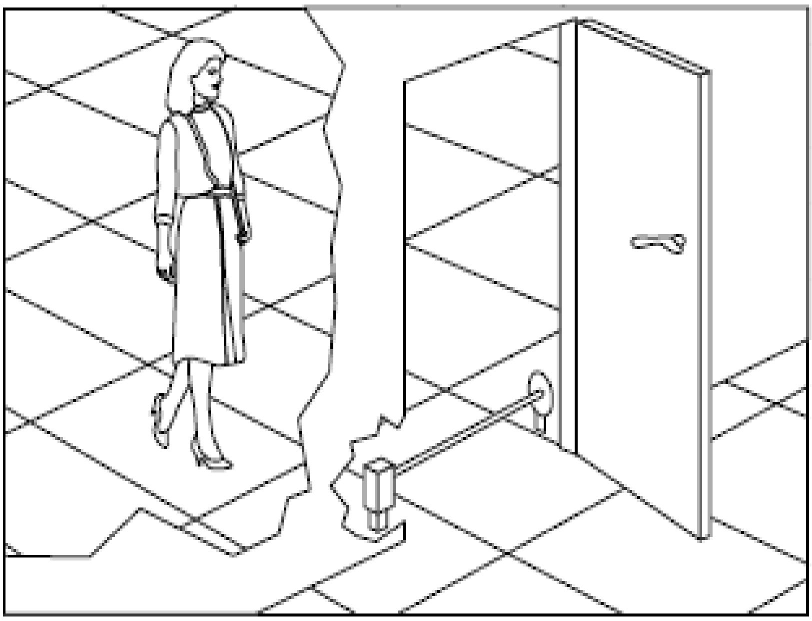

Figure 3.7: Example of photo electric in door automatic open application

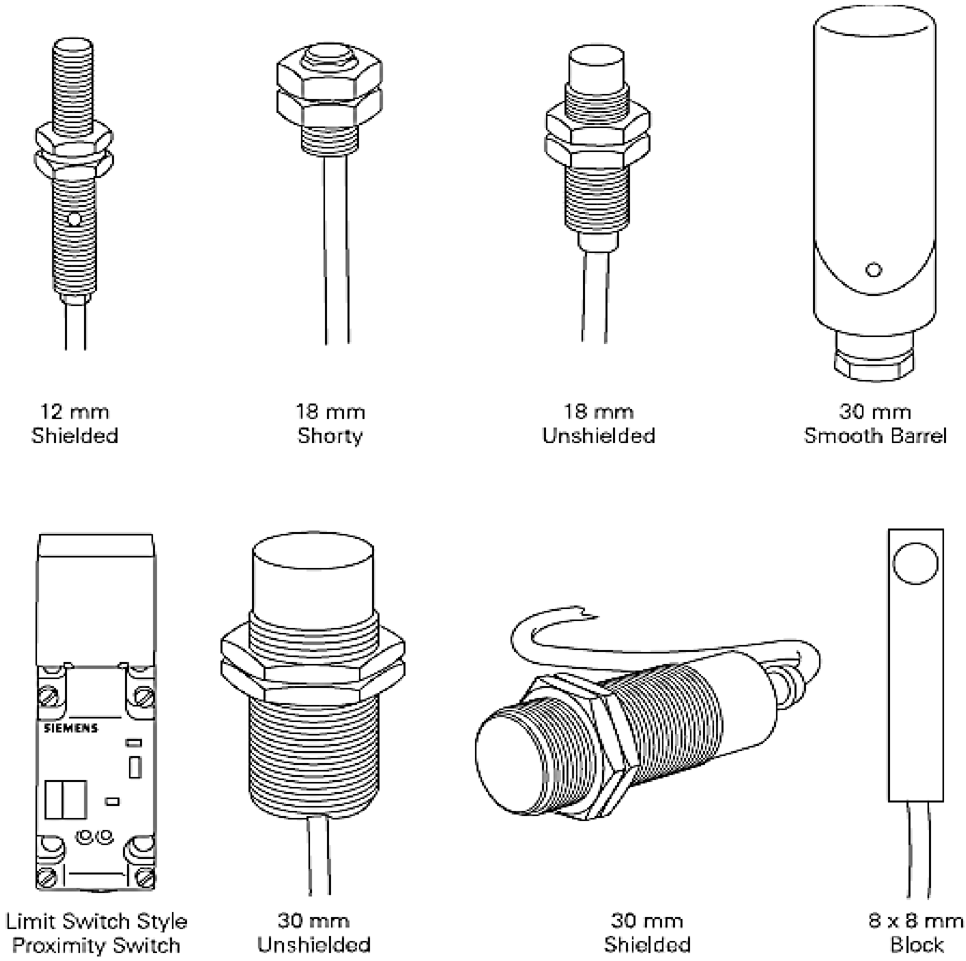

Figure 3.8: Inductive sensors

The sensor incorporates an electromagnetic coil that used metal to detect the presence of a conductive metal object. The sensor will ignore the presence of an object if it is not metal. Figure 3.9 shows the inductive sensor with metal object.

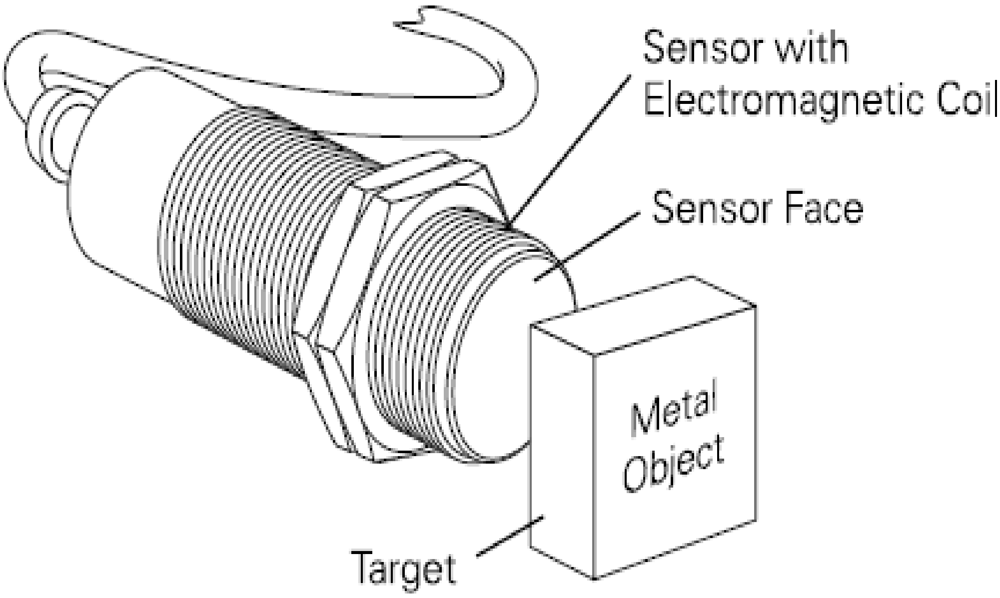

Figure 3.9: Inductive sensors with metal object

Inductive proximity sensors are operated using an Eddy Current Killed Oscillator (ECKO) principle. This type of sensor consists of four elements: coil, oscillator, trigger circuit, and an output. The oscillator is an inductive capacitive tuned circuit that creates a radio frequency. The electromagnetic field produced by the oscillator is emitted from the coil away from the face of the sensor. The circuit has just enough feedback from the field to keep the oscillator going. Figure 2.10 illustrated the electromagnetic field in inductive sensor.

When a metal target enters the field, eddy currents circulate within the target. This causes a load on the sensor, decreasing the amplitude of the electromagnetic field. As the target approaches the sensor the eddy currents increase, increasing the load on the oscillator and further decreasing the amplitude of the field. The trigger circuit monitors the oscillator's amplitude and at a predetermined level switches the output state of the sensor from its normal condition (on or off). As the target moves away from the sensor, the oscillator's amplitude increases at a predetermined level the trigger[5].

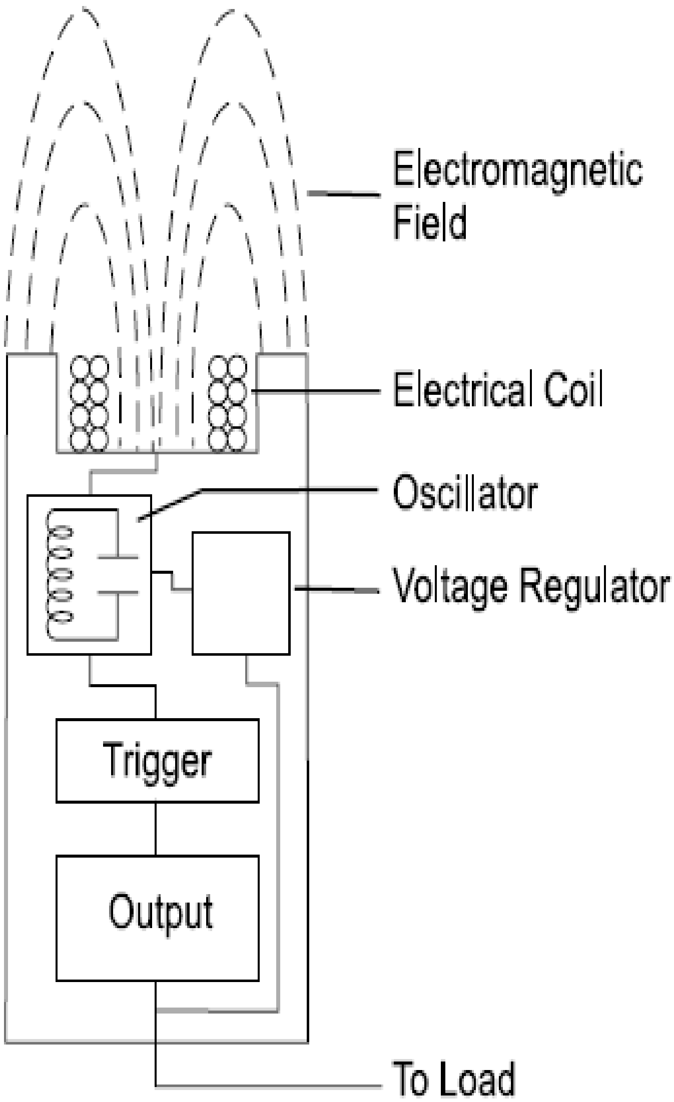

Figure 3.10: Electromagnetic filed in inductive sensors

(c) Capacitive sensors

Capacitive proximity sensors figure 3.11 are similar to inductive proximity sensors. The main difference between the two types is that capacitive proximity sensors produce an electrostatic field instead of an electromagnetic field. Capacitive proximity switches will sense metal as well as nonmetallic materials such as paper, glass, liquids, and cloth.

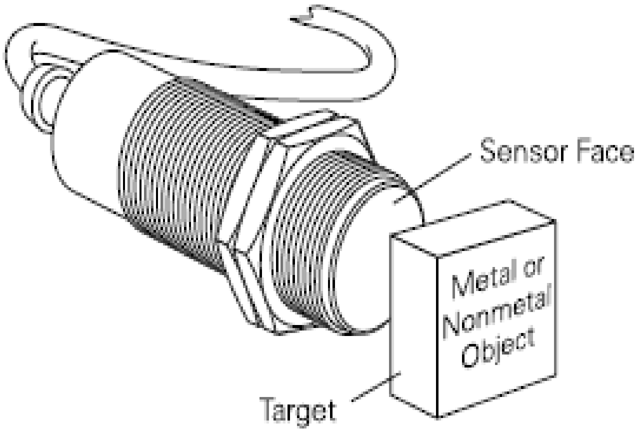

Figure 3.11: Capacitive sensors

The sensing surface of a capacitive sensor is formed by two concentrically shaped metal electrodes of an unwound capacitor. When an object nears the sensing surface it enters the electrostatic field of the electrodes and changes the capacitance in an oscillator circuit. As a result, the oscillator begins oscillating. The trigger circuit reads the oscillator's amplitude and when it reaches a specific level the output state of the sensor changes. As the target moves away from the sensor the oscillator's amplitude decreases, switching the sensor output back to its original state.

(e)**Ultrasonic sensors**

Ultrasonic proximity sensors figure 3.12 use sound waves to detect the presence of objects. They use a transducer to send and receive high frequency sound signals. When a target enters the beam the sound is reflected back to the switch, causing it to energize or DE energize the output circuit.

A piezoelectric ceramic disk is mounted in the sensor surface. It can transmit and receive high-frequency pulses. A high frequency voltage is applied to the disk, causing it to vibrate at the same frequency. The vibrating disk produces high-frequency sound waves. When transmitted pulses strike a sound-reflecting object, echoes are produced. The duration of the reflected pulse is evaluated at the transducer. When the target enters the preset operating range, the output of the switch changes state. When the target leaves the preset operating range, the output returns to its original state. Figure 3.13 shows the transmitted sound and echo wave in ultrasonic sensors.

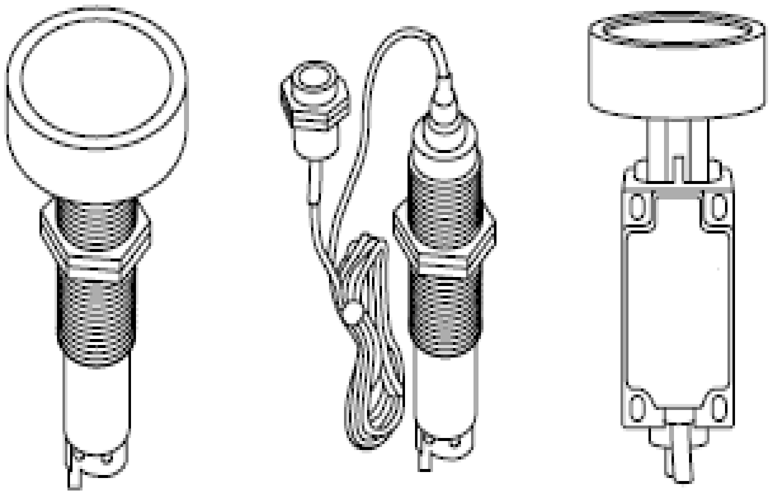

Figure 3.12: Ultrasonic sensors

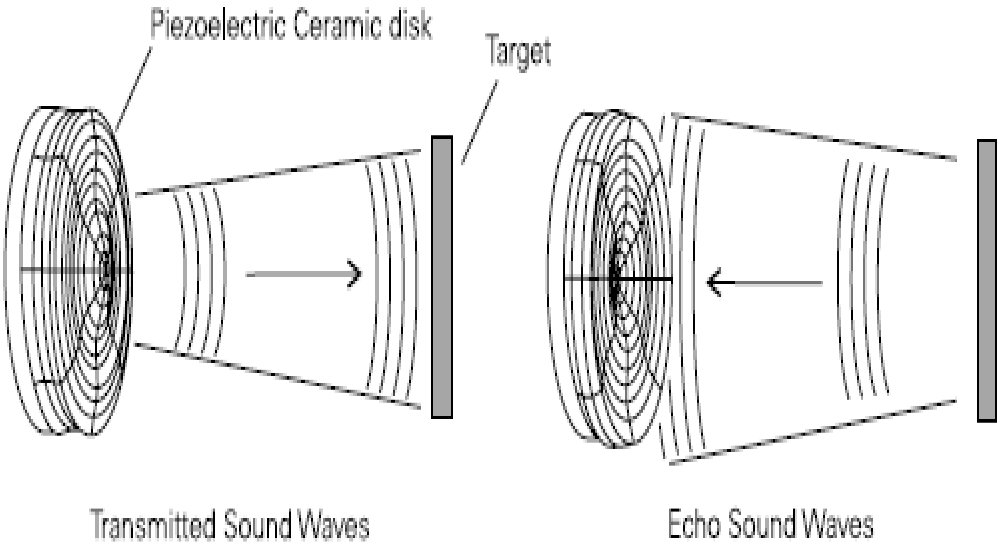

Figure 3.13: Transmitted sound and echo waves in ultrasonic sensors

The emitted pulse is actually a set of 30 pulses at amplitude of 200 Kvolts. The echo can be in microvolt [5].

3.1.4 Comparison between the types of sensors

Table 3.1 shows the comparison between four sensors.

Table 3.1: basic differences between sensors

Sensor	Objects Detected	Technology
Inductive	Metal	Electromagnetic Field
Capacitive	Any	Electrostatic Field
Ultrasonic	Any	Sound Waves
Photoelectric	Any	Light

3.1.6 Sensor applications

There is any number of applications where sensors can be utilized, and as it seen throughout pervious there are a number of sensors to choose from. Choosing the right sensor can be confusing and takes careful thought and planning. Often, more than one sensor will do the job. As the application becomes more complex the more difficult it is to choose the right sensor for a given application. Figure 3.14 and figure 3.15 show some applications of ultrasonic and Photo electric sensors respectively [5].

3.2 Actuators

Actuation is the process of conversion of energy to mechanical form. A device that accomplishes this conversion is called actuator. An actuator is a component of machines that is responsible for moving or controlling a mechanism or system. it requires a control signal and source of energy. The control signal is relatively low energy and may be electric voltage or current, pneumatic or hydraulic pressure, or even human power, When the control signal is received, the actuator responds by converting the energy into mechanical motion. The control codes aims at deriving the actuator when an event has occurred [6].

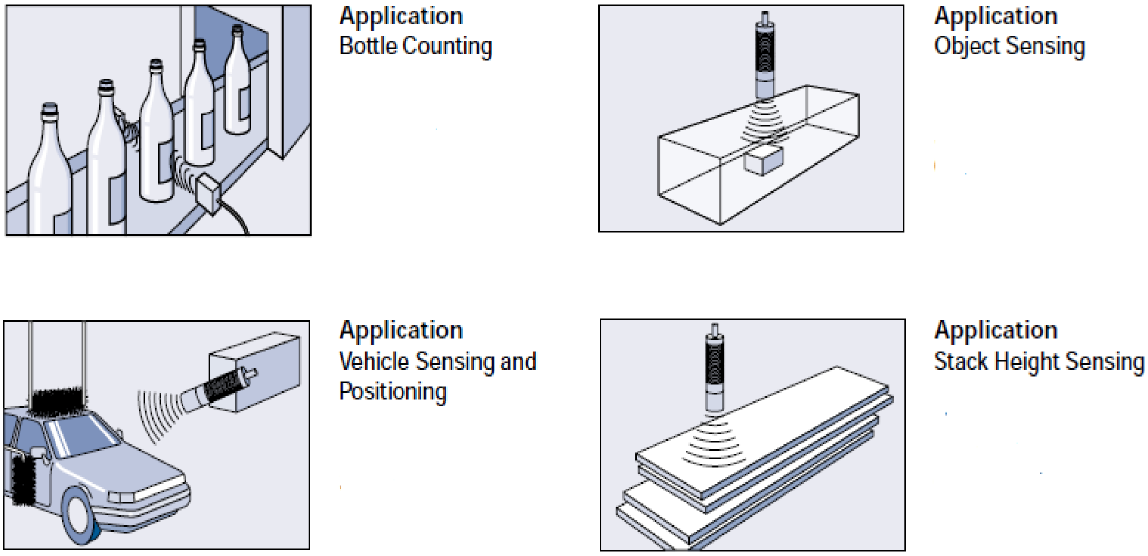

Figure 3.14: Some application of ultrasonic sensors

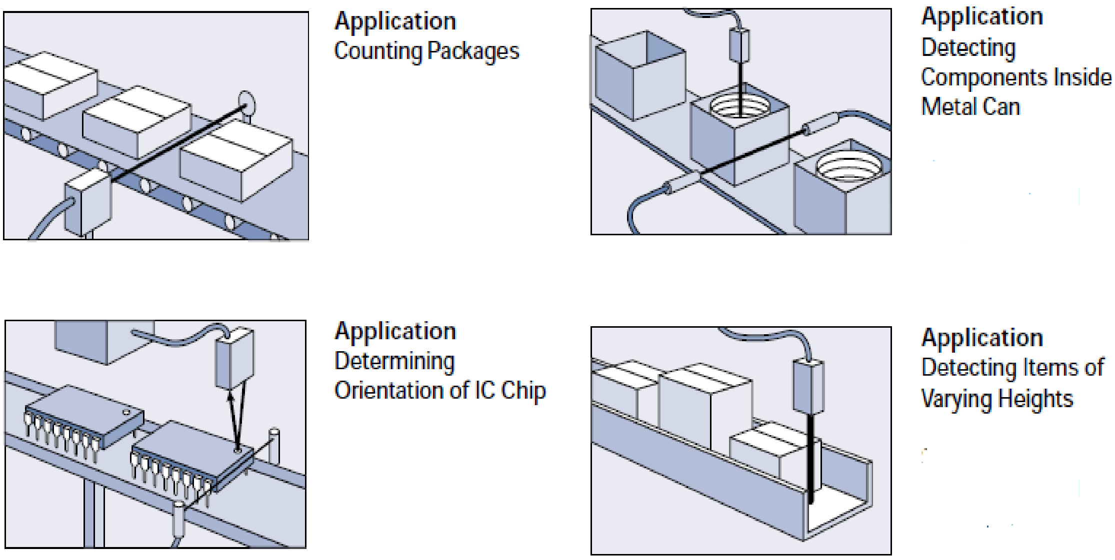

Figure 3.15: Some application for photoelectric sensors

An actuator is capable of doing physical work. The actuator is a controllable mechanical device for performing manufacturing operations An actuator uses electrical, hydraulic or pneumatic energy from an external source, converts and transmits it into mechanical movement energy (physical work) of a manufacturing device due which the form and nature of the product material and manufacturing device may alter [7].figure 3.16 illustrated flow of signals between sensors, microprocessor, actuators and plant.

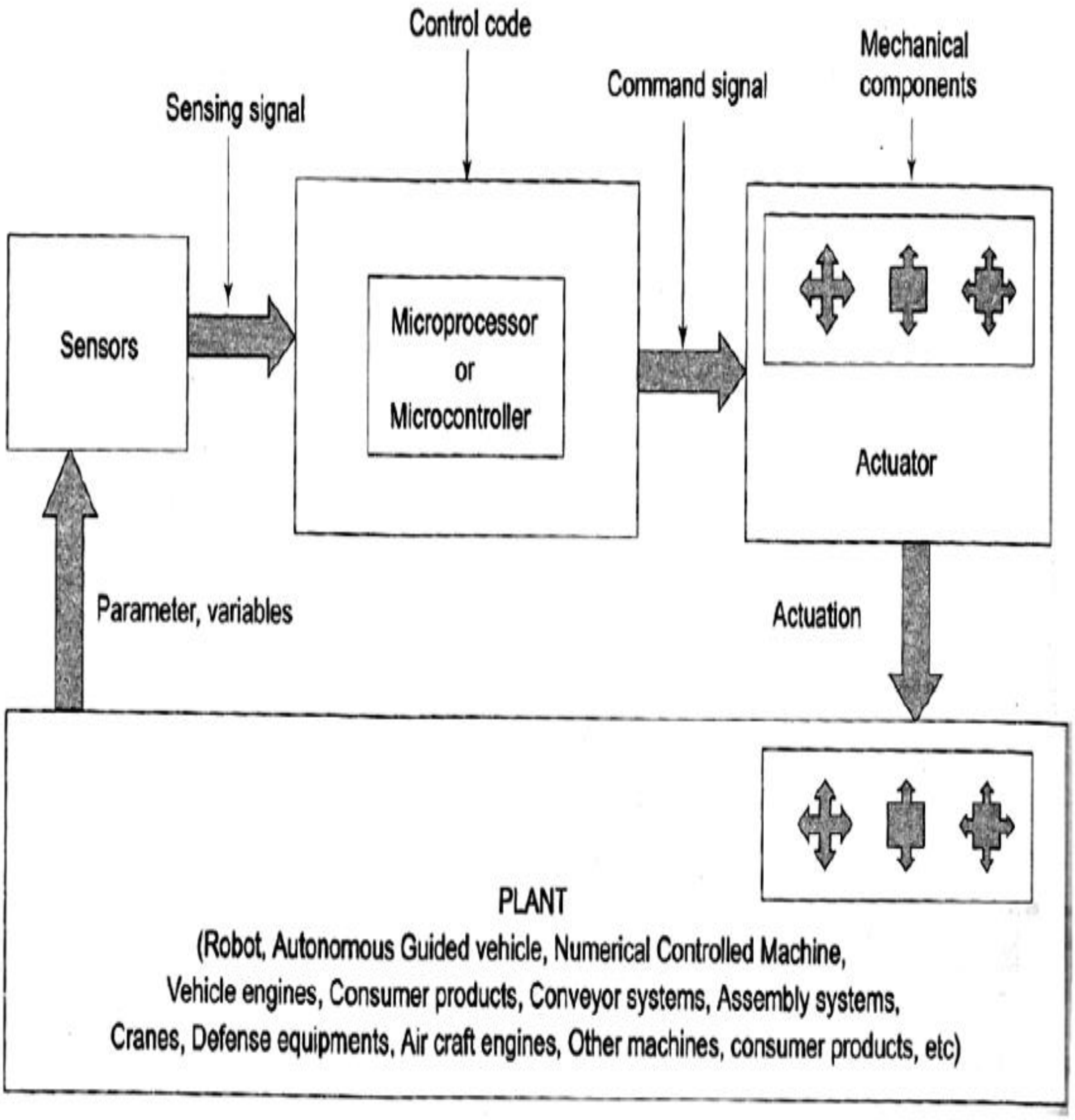

Figure 3.16: Flow of signals between sensors, microprocessor, actuators and plant.

3.2.1 Type of actuators

Actuators are classified by the type of energy transmitted from an energy source as shown in Figure 3.17 . Actuators are also classified by the form of mechanical movement (shape of geometrical movement) that is applied from the output of the actuator towards the input of driven equipment [7].

(a) Rotary actuators
(b) Linear actuators
(c) Trajectional actuators with trajectory generators

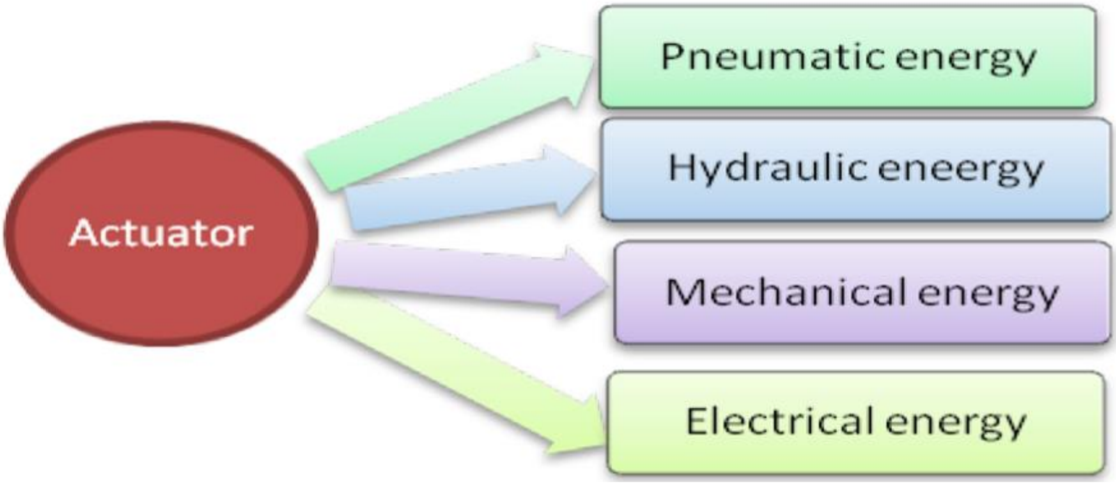

Figure 3.17: Classification of actuators

Also actuators can be classified depending on the load involved. The term load is associated with many factors including force, torque, speed of operation, accuracy, precision and power consumption One broad classification of actuators separates them into two types: incremental-drive actuators and continuous-drive actuators. Stepper motors, which are driven in fixed angular steps, represent the class of incremental-drive actuators. They can be considered as digital actuators, which are pulse driven devices. Each pulse received at the driver of a digital actuator causes the actuator to move by a predetermined fixed increment of displacement. Most actuators used in control applications are continuous-drive devices. Examples are Direct Current (DC) servo motors, induction motors, hydraulic and pneumatic motors, and piston–cylinder drives (rams). Micro actuators are actuators that are able to generate very small (micro scale) actuating forces or torques and motions. Typically, they are manufactured using micromachining similar to what is used in semiconductor devices. The main type of actuators based on energy transmitted from energy source are:

(a) Electric actuators

Electricity actuated system are very wildly used in control system because they are easy to interface with control system. Also electricity is easily available unlike fluid power which require pumps and compressors. Electricity actuators are easily routed to actuator; cables are simpler than pipe work, it is easy to control by electronic unit also the faults easier to diagnose[8]. There are three types of electric motor used in control applications:

- **AC motors**

AC motor as shown in figure3.18 mainly used for producing large power outputs at affixed speed ,such motors are controlled by switching them on and off. Increasingly, speed control is being used with ac motors on applications such as pumps where it is found to be more economical to control the flow rate by changing speed rather than by opening or closing a pipe line valve .Speed control is achieved electronically by varying the frequency or by chopping the power supply. These motor are usually geared down in order to produce greater torque and increase control range they also have the rotation converted to linear by lead screw mechanism .

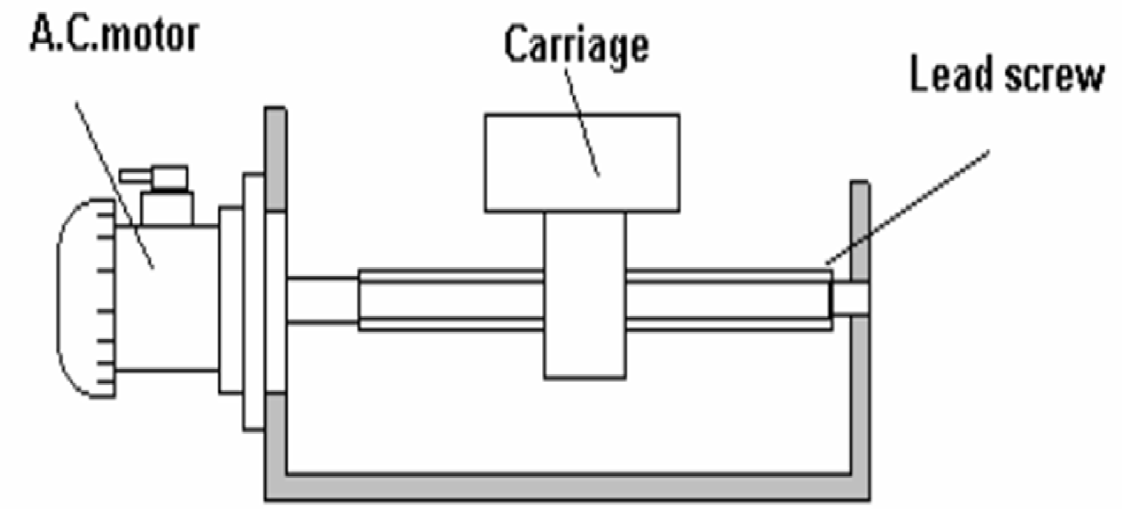

Figure 3.18: AC motor actuators

- **DC motors**

  Direct current motors figure 3.19 are more widely used in control applications and they are usually referred to as servo motors, the development of more powerful magnets is improving the power weight ratio but they are still not as good as hydraulic motors in this respect. Servo motor are usually have a transducer connected to them in order to measure the speed or angle of rotation.

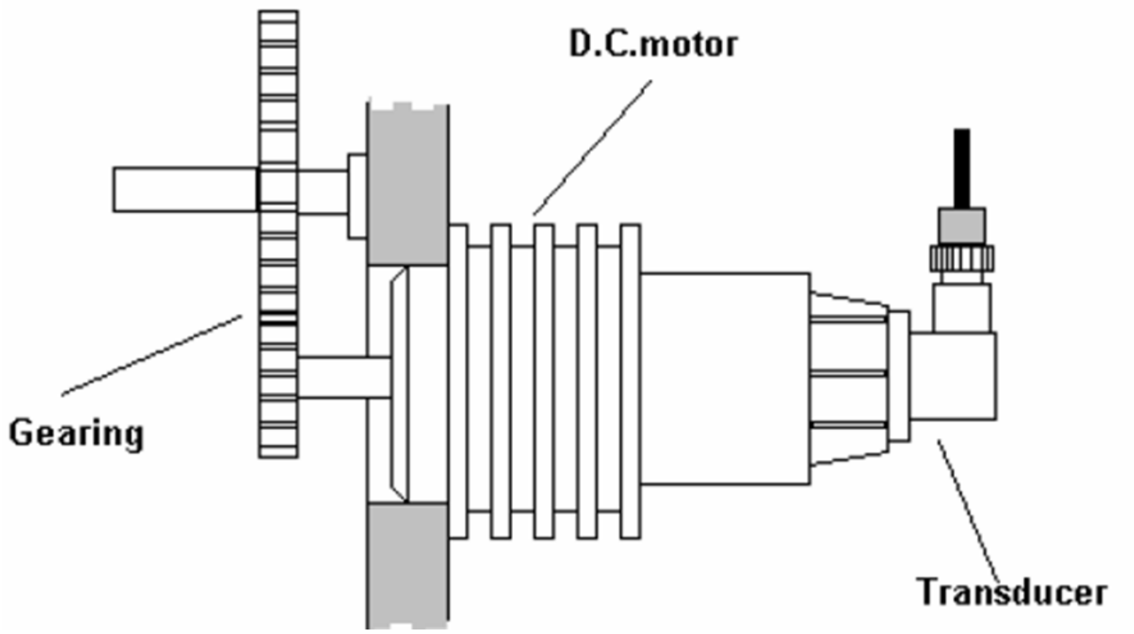

Figure 3.19: Dc motor actuators

- **Stepper motor**

  Basically a stepper motor as shown in figure 3.20 rotates a precise angle according to the number of pulses of electricity sent to it, because there is confidence that the shaft rotates to the position requested, no transducer is needed to measure and check the position and so they are common on open loop systems.

Figure 3.20 : Stepper motor actuators

There are three type of stepper motor in common used, Permanent magnet type, the variable reluctance type and hybrid type.

- **Linear electric actuators**

  In recent years, arrange of linear electric actuators have been developed to perform functions similar to hydraulic and pneumatic cylinders ,these are based on motor driven lead screw , the motor maybe dc or ac, the speed of the motor is reduce with a compact gear box before driving the lead screw [8].figure 3.21 shows the linear electric actuators.

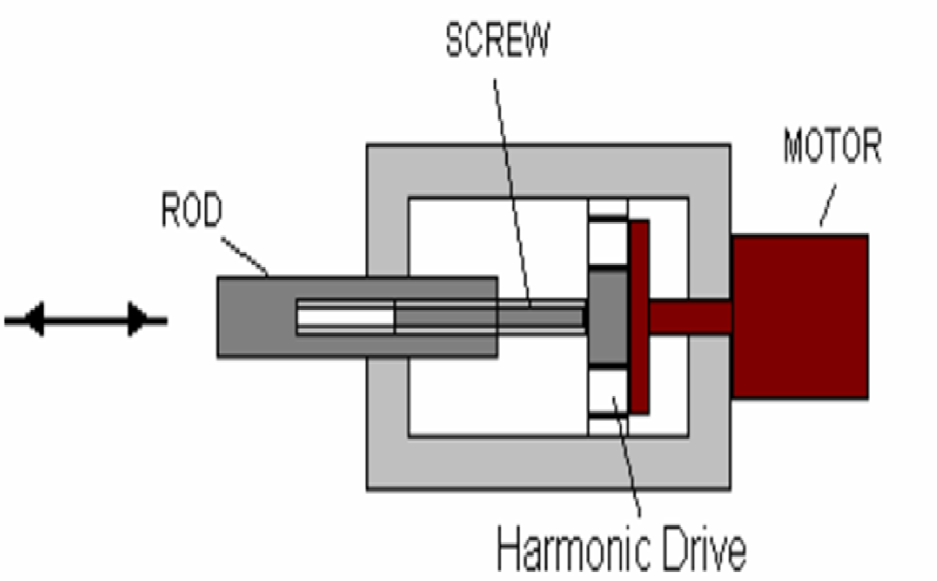

Figure 3.21: Linear electric actuators

(b) Hydraulic actuators

Hydraulic actuators are used in industrial process control, employ hydraulic pressure to drive an output member. These are used where high speed and large forces are required. The fluid used in hydraulic actuator is highly incompressible so that pressure applied can be transmitted instantaneously to the member attached to it. A hydraulic actuator consists of cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation. Because liquids are nearly impossible to compress, a hydraulic actuator can exert a large force. The drawback of this approach is its limited acceleration [9].

Hydraulic systems are used to control and transmit power. A pump driven by a prime mover such as an electric motor creates a flow of fluid (Figure 3.22), in which the pressure, direction and rate of flow are controlled by valves. An actuator is used to convert the energy of fluid back into the mechanical power. The amount of output power developed depends upon the flow rate, the pressure drop across the actuator and its overall efficiency. Thus, hydraulic actuators are devices used to convert pressure energy of the fluid into mechanical energy.

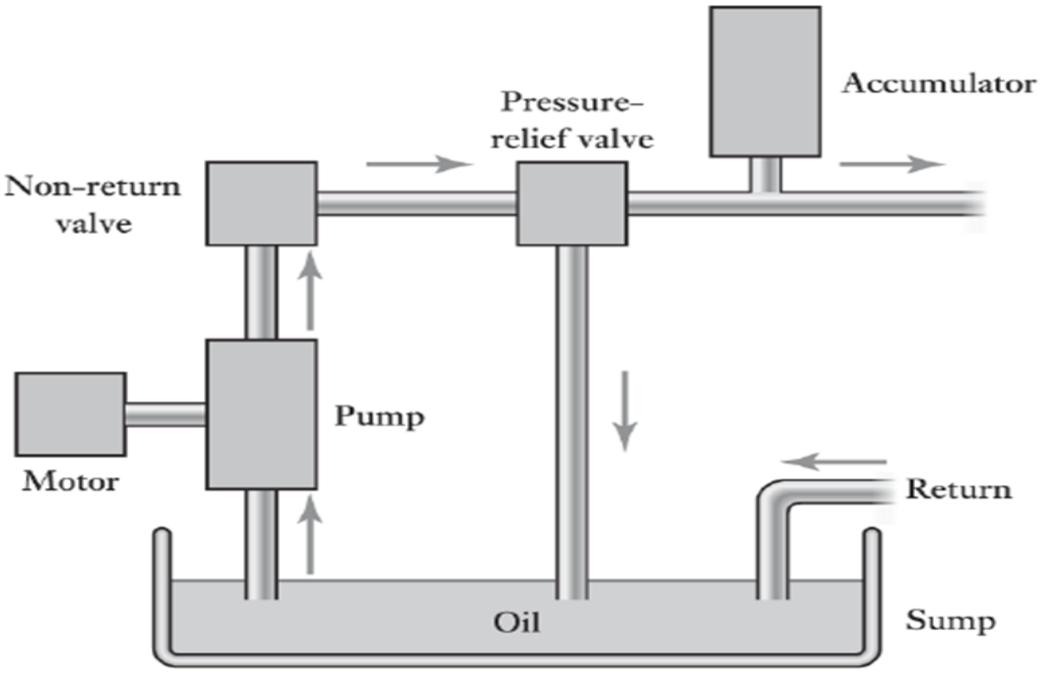

Figure 3.22: Flow of the oil in hydraulic actuators

•The pump pumps oil from a sump through a non-return valve and an accumulator to the system, from which it return to the sump.

• The pressure relief valve is to release the pressure if it rises above a safe level,

• The accumulator is to smooth out any short term fluctuations in the output oil pressure.

Depending on the type of actuation, hydraulic actuators are classified as follows:

- Linear actuator: For linear actuation (hydraulic cylinders).
- Rotary actuator: For rotary actuation (hydraulic motor).
- Semi-rotary actuator: For limited angle of actuation (semi-rotary actuator).

Hydraulic linear actuators, as their name implies, provide motion in a straight line. The total movement is a finite amount determined by the construction of the unit. They are usually referred to as cylinders, rams and jacks. All these items are synonymous in general use, although ram is sometimes intended to mean a single-acting cylinder and jack often refers to a cylinder used for lifting. The function of hydraulic cylinder is to convert hydraulic power into linear mechanical force or motion. Hydraulic cylinders extend and retract a piston rod to provide a push or pull force to drive the external load along a straight-line path.

Continuous angular movement is achieved by rotary actuators, more generally known as a hydraulic motor. Semi-rotary actuators are capable of limited angular movements that can be several complete. The hydraulic cylinder consists of a hollow cylindrical tube along which a piston can slide. The term single acting is used when the fluid pressure is applied to just one side of the piston. The piston can move in only one direction, a spring being frequently used to give the piston a return stroke. The term double acting is used when pressure is applied on each side of the piston; any difference in pressure between the two side of the piston moves the piston to one side or the other. Figure 3.23 shows the single acting hydraulic cylinders[10].

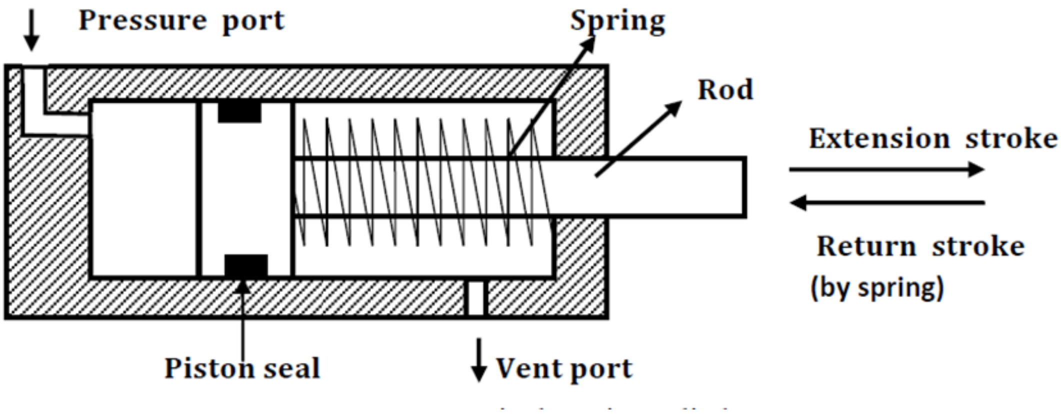

Figure 3.23: Single acting hydraulic cylinders.

(c)**Pneumatic actuators**

A pneumatic actuator converts energy formed by vacuum or compressed air at high pressure (Figure 3.24) into either linear or rotary motion. Pneumatic energy is desirable for main engine controls because it can quickly respond in starting and stopping as the power source does not need to be stored in reserve for operation. Pneumatic actuators enable considerable forces to be produced from relatively small pressure changes. These forces are often used with valves to move diaphragms to affect the flow of liquid through the valve. In pneumatic Power system an electric motor drives an air compressor , The air inlet to the compressor is likely to be filtered and via a silencer to reduce the noise level .A pressure relief valve provides protection against the pressure in the system rising above a safe level, Since the compressor increase the temperature of the air, there likely to be a cooling system and to remove contamination and water from the air, a filter with water trap is used, An air receiver increases the volume of air in the system and smoothes out any short-term pressure fluctuations[10].

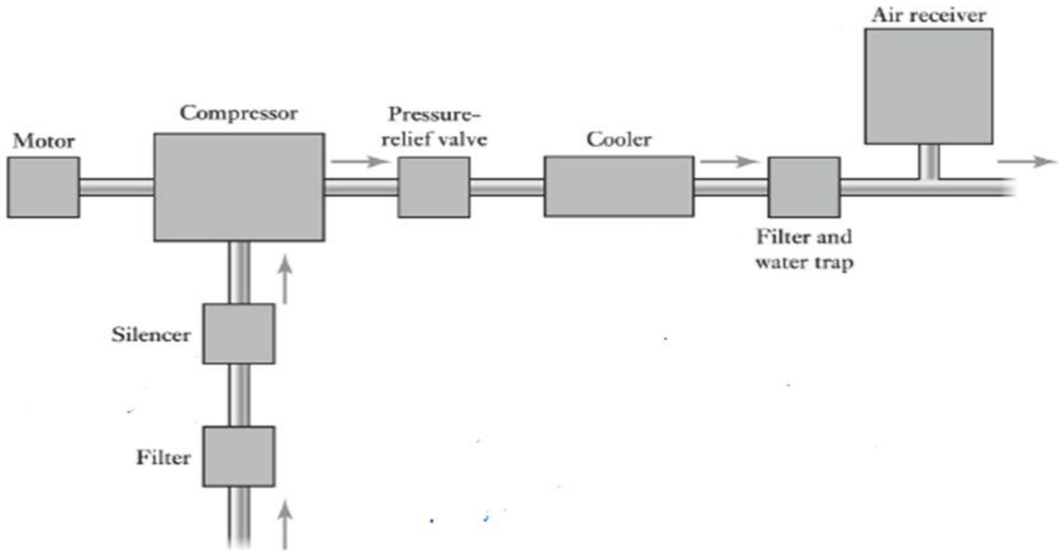

Figure 3.24: Flow of air in Pneumatic actuators

(d)Mechanical

A mechanical actuator functions to execute movement by converting one kind of motion, such as rotary motion, into another kind, such as linear motion. An example is a rack and pinion. The operation of mechanical actuators is based on combinations of structural components, such as gears and rails, or pulleys and chains

3.2.2 Selection of actuator mechanisms

The task of choosing the right kind of actuator mechanisms is complicated and highly responsible because actuators influence the whole automated manufacturing system dynamically. The actuator type determines the power supply (e.g. direct or alternating current) and the transmission mechanism for the system. Sometimes it is possible to achieve the desired movement by integrating the actuator directly to the system and the use of transmission mechanism can be avoided. For example, linear movement can be achieved without the use of rotary motor by using the linear motor instead. When choosing an actuator, a designer has to think about the following parameters:

• Continuous power output – maximal force / torque that an actuator can continuously output without overheating

• Range of motion – the range of linear or circular movement

• Resolution – the smallest step of the developed force / torque

• Accuracy – the uninflected ratio between input and output

• Peak force / torque – the highest force / torque achievable for an actuator

• Heat dissipation – the maximum heat dissipation power in steady running conditions

• Speed characteristics – characteristic of the force / torque and speed

• Idle speed – speed in a state where no load is applied

• Frequency response – frequency range where the output still responds to the input properly

• Power supply – energy supply type (electric current, compressed air etc)

Additionally, another determining task is the selection of the transmission mechanism. For example if gear transmission is chosen, the accuracy could be compromised due to the development of a slack. The same applies to belt drives if the belt should begin to slip[10].

Chapter Four

PLC System Description and HMI Simulation

Chapter Four

PLC Description and HMI Simulation

4.1 PLC System Operation Description

The pick and place system considered in this work is composed of a conveyer belt for the object to be picked, a three axis manipulator and a conveyer belt for the boxes. Boxes are transported by a conveyor belt (A) that positions the boxes in the placing area. The conveyor belt (B) transports randomly supplied parts .Figure 4.1 show the two conveyers and three axis manipulator.

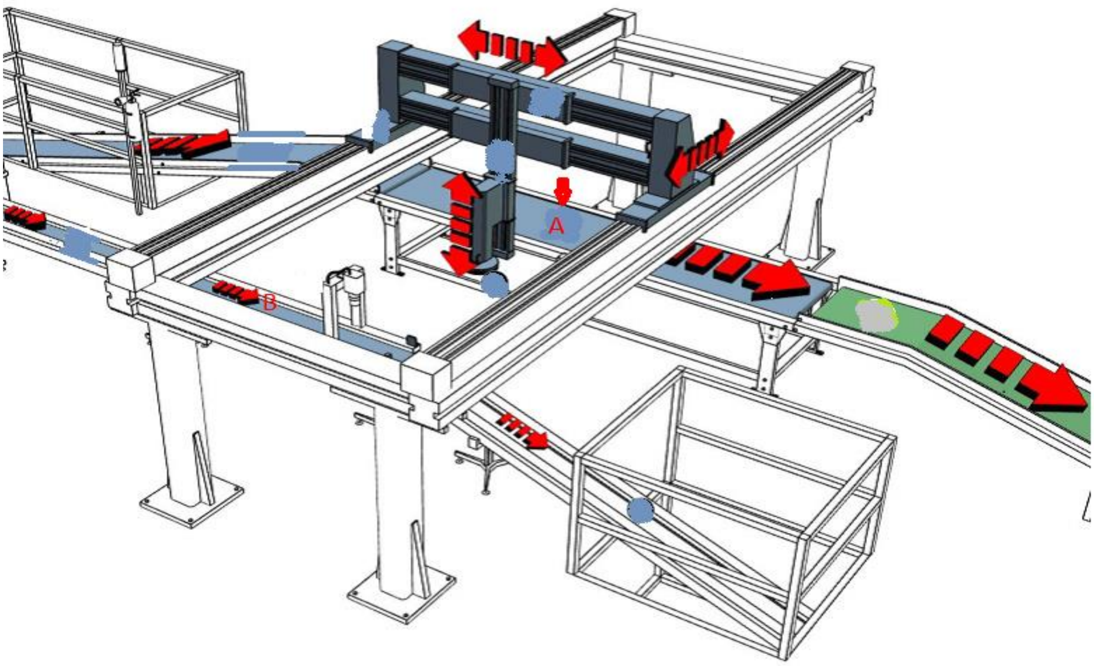

Figure 4.1: Three axis manipulator and the two conveyers belt

First there is system ready bush bottom which places the boxes and the object at specific area, also places the manipulator at up position, after we make sure that everything in it place then the first condition is done system is ready .after that we will start the system by start bush bottom, the three axis manipulator go to down position and picks a parts using a magnetic gripper ,moving to box conveyor and place it in the previously positioned box. Then coming back to pick the second object doing the same thing until it place the last object (nine object), then the system will star over and so on .Figure 4.2 represent system round. Table 4.1 show the input/output description of PLC used in this project and their symbols.

Table 4.1: PLC symbols

Name	Symbol
System ready	I0.0
System start	I13.0
Start position sensor	I0.5
Product sensor	Q0.4
Box sensor	Q0.5
Manipulator up sensor	I0.4
Manipulator down sensor	I0.3
End postion1 sensor	I0.6
End postion2 sensor	I0.7
End postion3 sensor	I1.0
Position 1 sensor	I1.1
Position 2 sensor	I1.2
Position 3 sensor	I1.3
Gripper coil	Q1.0
Manipulator up	Q0.5
Manipulator down	Q0.6
Manipulator forward	Q1.6
Manipulator backward	Q1.5
Manipulator left	Q1.1

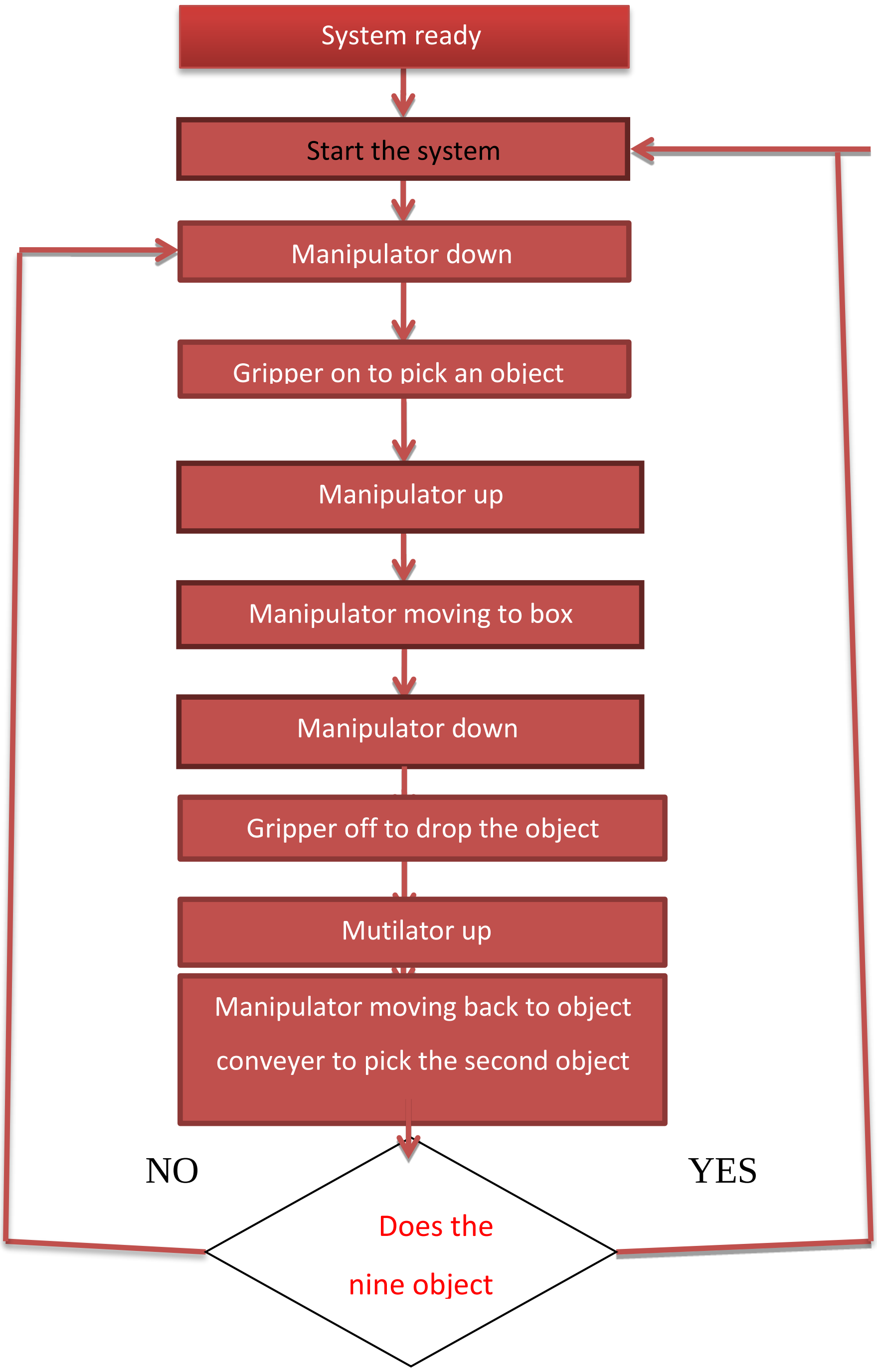

Figure 4.2: System round

4.2 Human Machine Interface

Human Machine Interfaces broadly refer to any graphical device that allows a user to interact with a machine's real-time control system and visualize the process, it have been prevalent in manufacturing applications for decades. Modern HMIs typically include a touch screen interface, a display with multiple pages, electronic storage for data logging, and a method of displaying alarms. Recently, HMIs have been introduced in automotive applications as a means of transmitting large amounts of disparate information to the driver.

The HMI system represents the interface between man (operator) and process (machine/plant). There is an interface between the operator and HMI witch is Sematic WinCC flexible software in this thesis (at the HMI device) and an interface between WinCC flexible and the PLC. The process is visualized on the HMI device, the screen on the HMI device is dynamically updated, This is based on process transitions. Critical process states automatically trigger an alarm, for example, when the set point value is exceeded.

HMI offers a totally integrated, single-source system for manifold operator control and monitoring tasks. With sematic HMI, user always masters the process and always keep machinery and units running.

The HMI output alarms and process value reports. This allows you to print out production data at the end of a shift and analyses the system performance and maybe make some improvement on the system [11].

An HMI consists of a touch screen interface and an HMI computer, which communicates with the machine's controller or Programmable Automation Controller (PAC) . The HMI computer and the PAC both operate on an embedded platform, such as Windows CE. The HMI is essentially the portal which allows the user to interact with the PAC. The HMI and the PAC can interface through a number of means. including proprietary methods such as National Instruments' "shared variables" or through open standards such as controller-area networks (CAN-buses) [11].

4.2.1 Wincc HMI flexible tools

The software contains a series of editors and tools for different configuration tasks. user can configure, for example, in level technology using 32 screen levels. For the configuration of displays, various convenient functions are available, such as zoom in/out, rotate and align. In WinCC flexible user can set up working environment according to your needs [12]

(a) Project window

For displaying the project structure (project tree) and for managing the project figure 4.3 represents the project window, From this window the type of screen and the type of PLC controller can be chosen.

(b) Toolbox window

This window allow selection of objects which user can add screens, e.g. image objects or operator control elements. In addition, the toolbox also provides libraries containing object templates and collections of faceplates. It contains various objects and access to the object library.

(c) Work area window

Project objects are edited in the work area. All WinCC flexible elements are arranged on the borders of the work area. With the exception of the work area, user can organize, configure, for example, move or hide any of the elements to suit individual requirements.(in which the displays can be created (lay out and animation))[12].

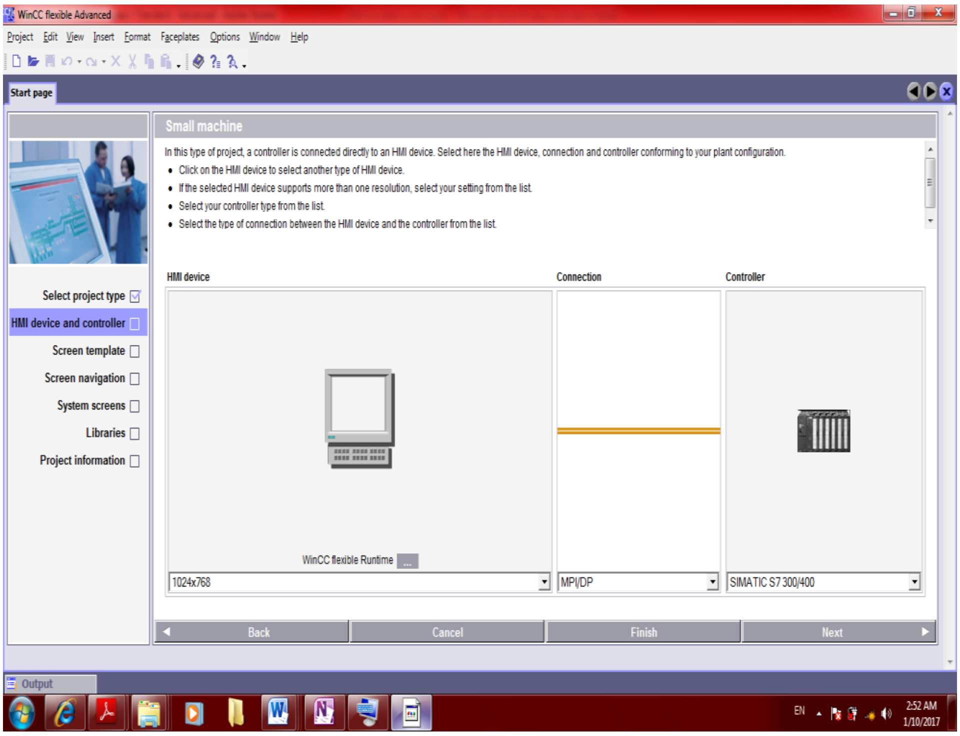

Figure 4.3: WinCC project window

(d) **Properties window**

It is used to edit object properties, e.g. the color of screen objects. The property view is only available in specific editors, also for the parameterization of the objects in the work area.

(e) Project window

All component parts and editors available in a project appear in a tree structure in
the project view. Folders are provided as sub-elements of each editor in which user can save objects in a structured way. In addition, direct access to the configured objects is available for screens, recipes, scripts, protocols and user dictionaries. In the project windows user have access to the device settings of the HMI device, the language settings and the version management [12].

(f) The output window

Displays system alarms generated, for example, in a project test run. Figure 4.4 show the toolbox ,work area ,properties ,and project windows .

4.2.2 HMI project description

In this thesis three screens are used in HMI program. First one is the start screen to start HMI simulation. It contain the project name and HMI start bottom that lead you to the second screen. Figure 4.5 shows the start screen.

The second screen is the monitoring and control screen. It shows the conditions of the system. It contain system ready indicator to make sure that everything is in its specific place (product, box, robotic arm). Below system ready there is system stared indicator to show the system is started and its running now, users have conveyers belt indicators to show the condition of the conveyer if it is running ,stopped , overloaded or in emergency mode. The screen also contain alarm to indicate in mistake or delay in robotic arm motion. Also there is a counter to show, how many boxes filled and a box condition to shows how many product filled, there is a control panel to control the system and the conveyer belt (stop , emergency), In the screen there is also bottom that lead to the third screen, Figure 4.6 represents the monitoring screen .

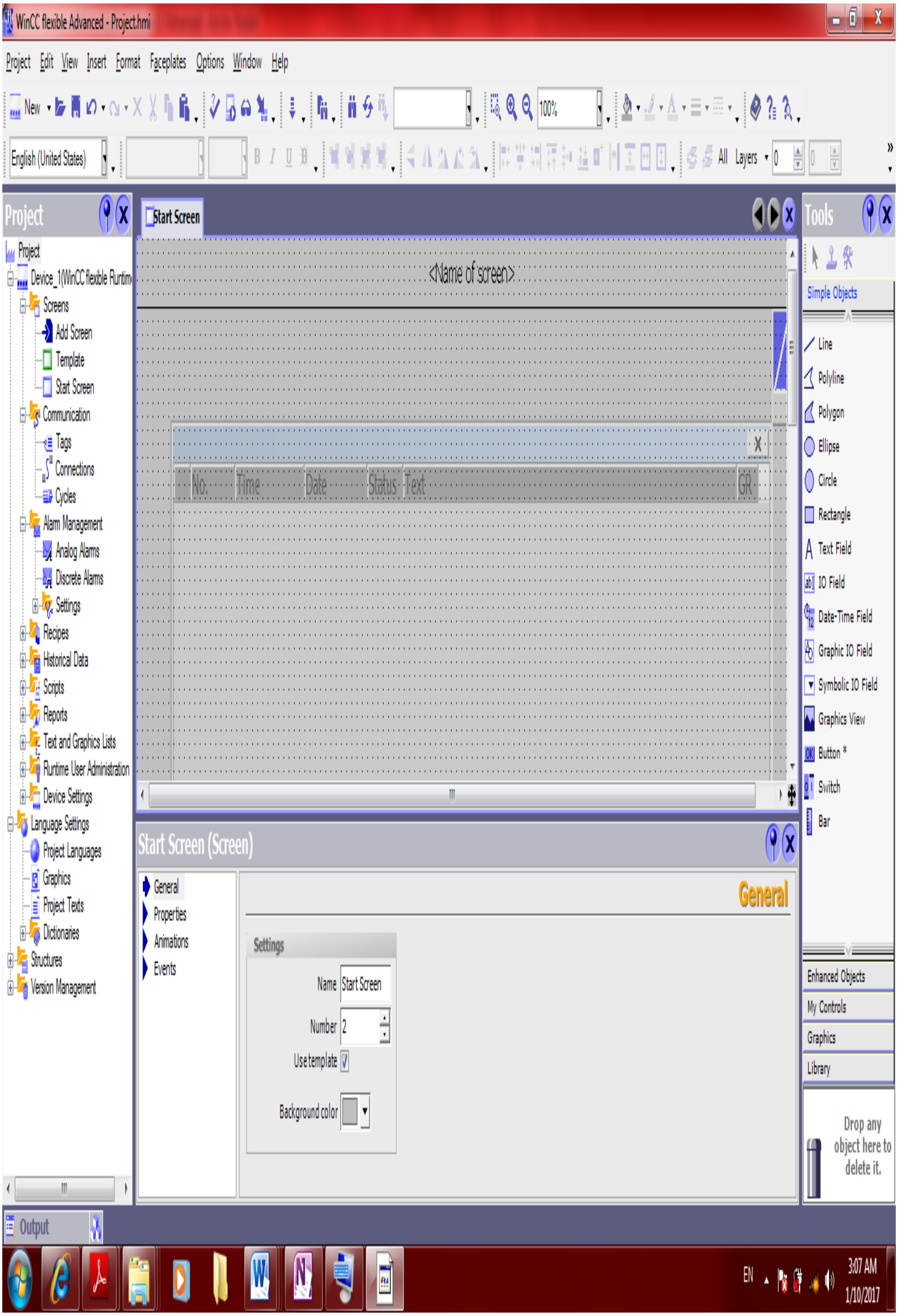

Figure 4.4: HMI tools

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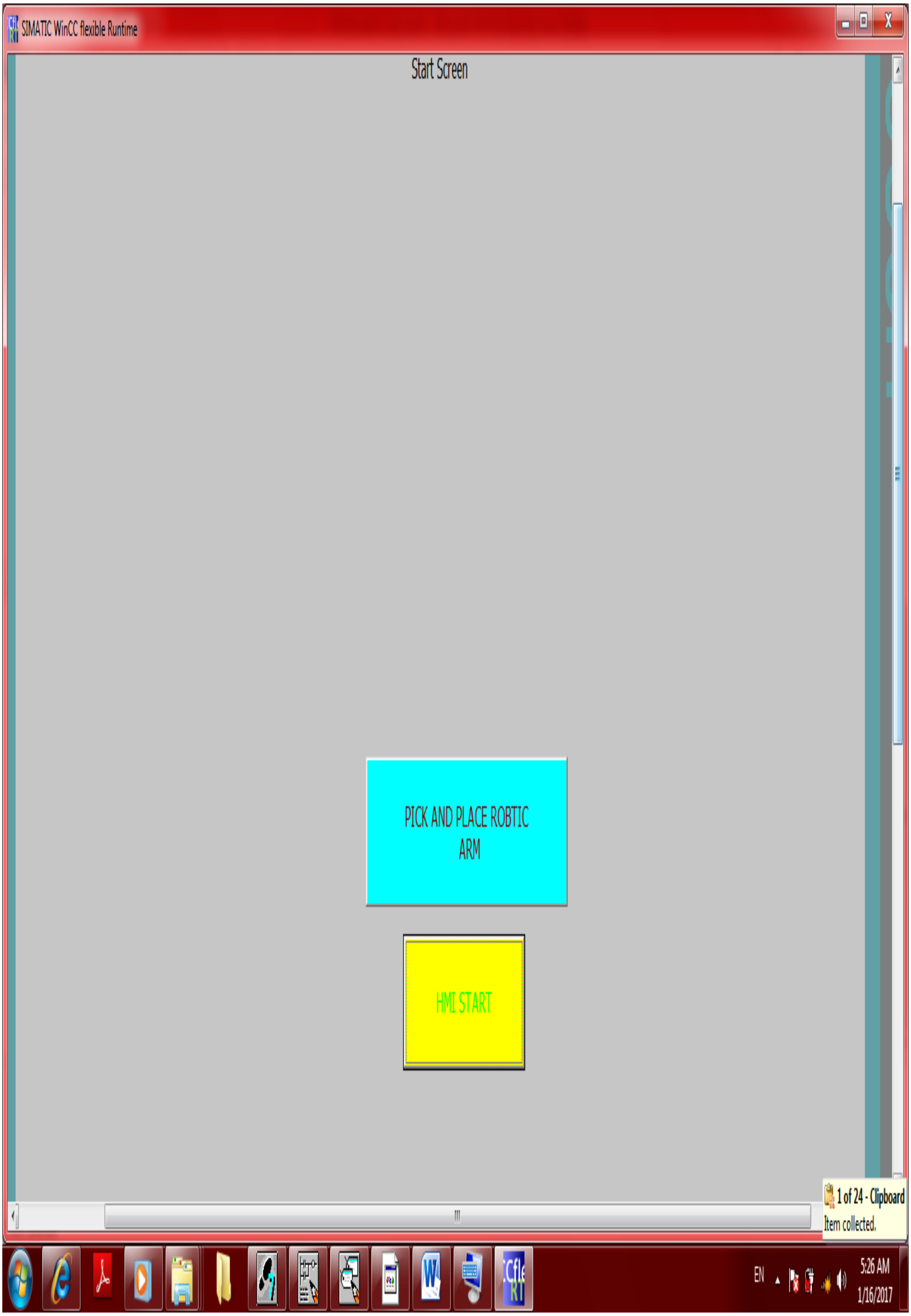
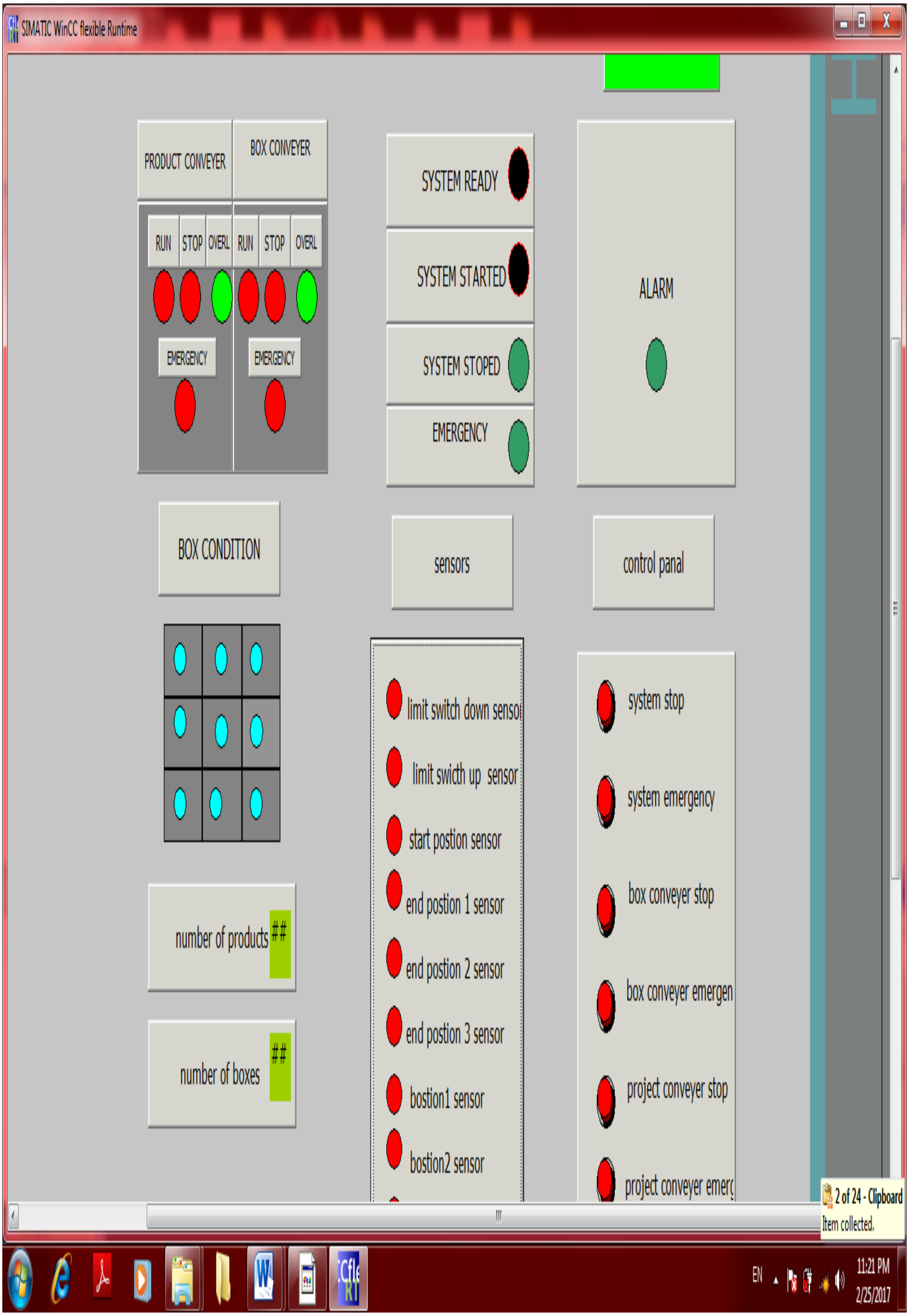


Fig4.5: Start screen



Figur4.6: Monitoring screen

The third screen represent the product movement screen. Figure 4.7show the third screen .

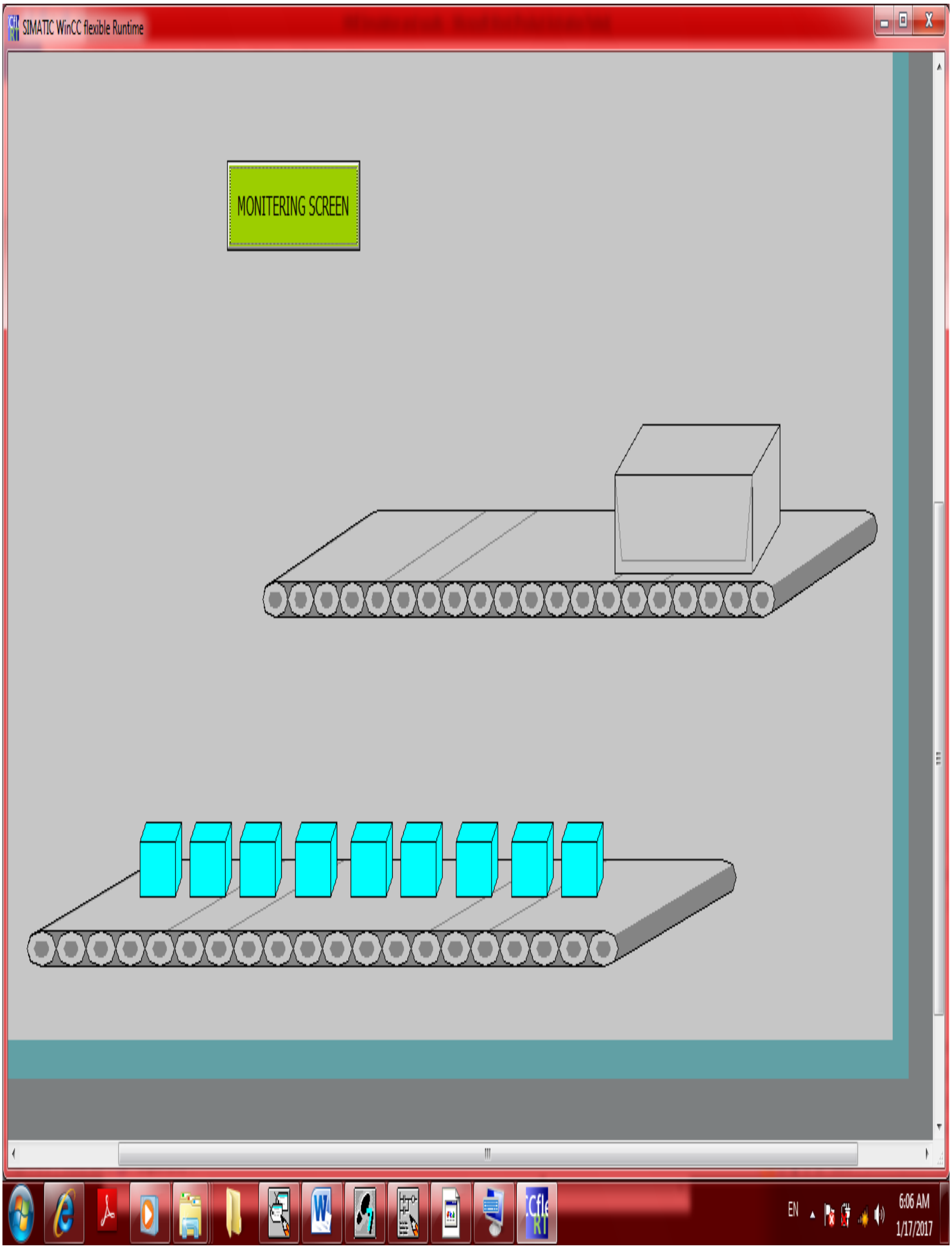


Figure 4.7:Product movement screen

4.2.3 Some HMI screens example when the system is working

Figure 4.8 shows the monitoring screen when the first object is about to be picked, its seen that the system ready and start system lamps is green witch mean the system is ready to work and its started, Also the limit switch down sensor is green that's mean it is working to pick The object.

Figure 4.8: Monitoring screen with system ready, system start and limit switch down sensor is on

Figure 4.9 shows the product movement screen when the first object has been placed in its position.

Figure 4.10 shows the monitoring screen after the first object has been placed , it can be noticed at the counter counted one , also from box condition that the first position was filled .

Figure 4.11 shows the product movement screens when the second object has been placed in its position.

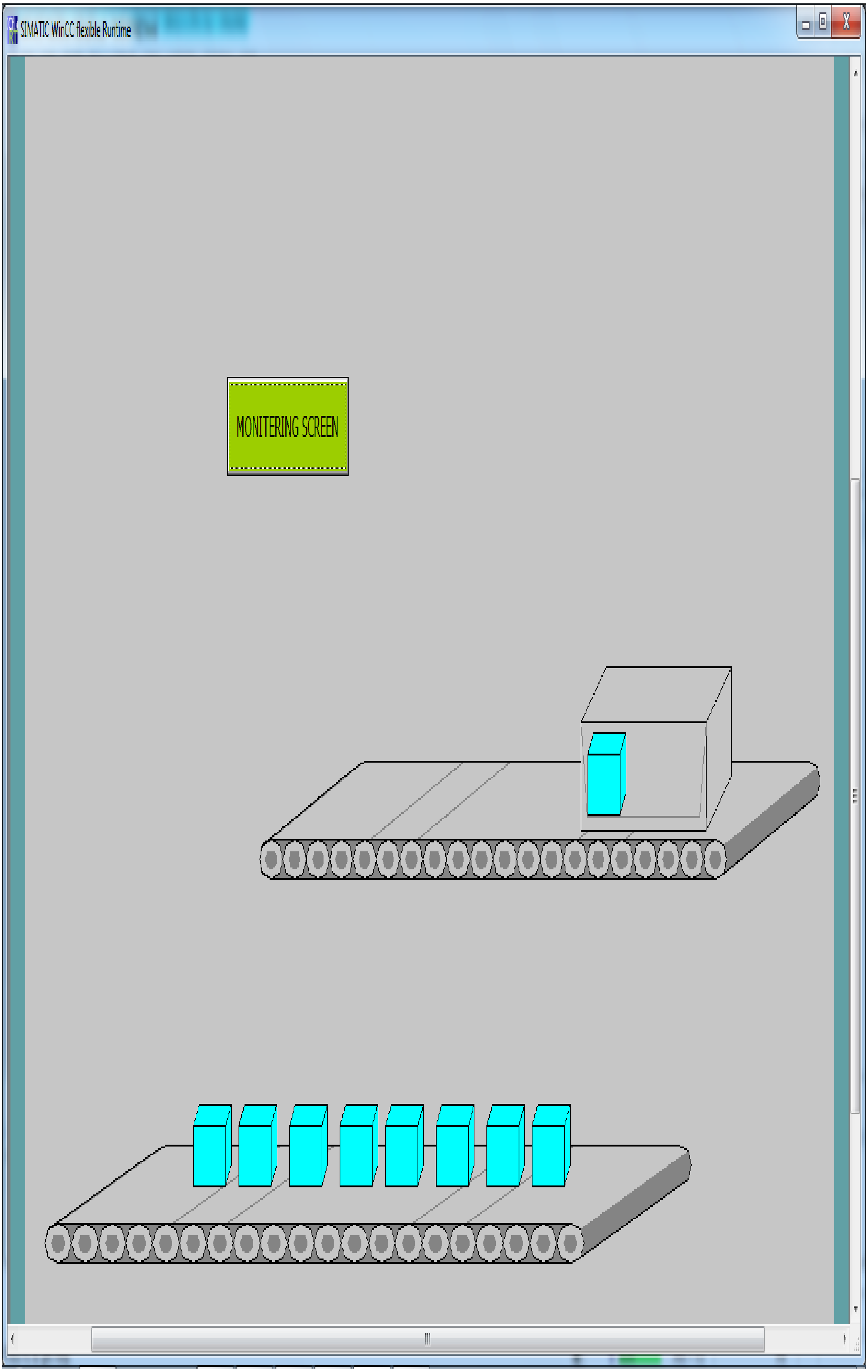


Figure 4.9: Product movement screen when the first object has been placed

Figure 4.10: Monitoring screen after the first object has been placed

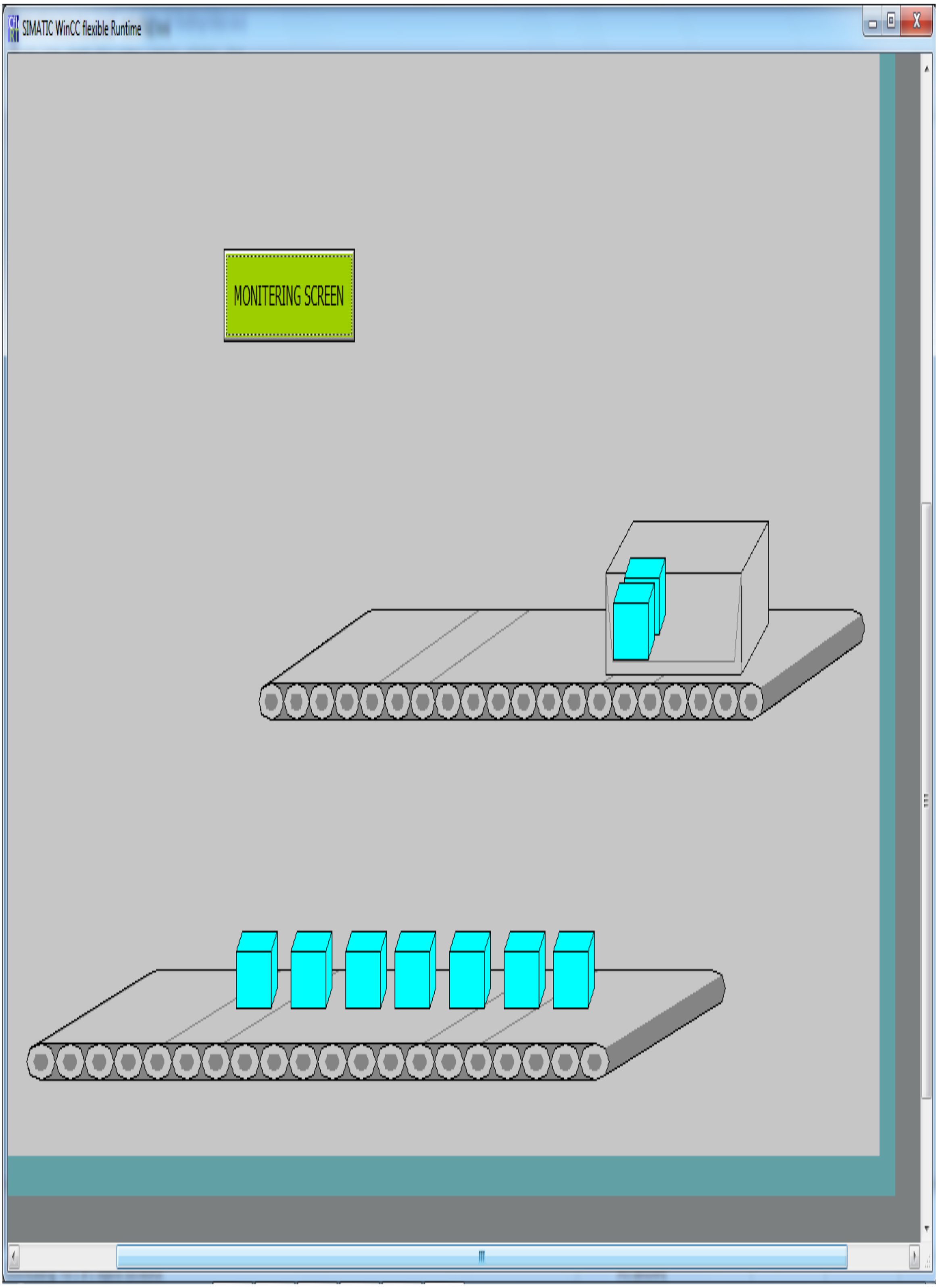


Figure 4.11: Product movement screens when the second object has been placed

Figure 4.12 shows the monitoring screen after the second object has been placed , the counter counted two and at the box condition the second position also has been filled.

Figure 4.12: Monitoring screen after the second object has been placed

Chapter Five

Conclusion & Recommendations

Chapter Five

Conclusion and Recommendation

5.1 Conclusion

It appear that in this thesis using pick and place robotic arm in industry process is more efficient and give better performance than using human power, save a lot of time, reduce the mistakes and of course reduce the running cost for the factory by saving the money that could be spent it in human hands. Also using WinCC HMI flexible for control and monitoring the system make it easier and quick to detect any error in system operation and make a quick response to it.

5.2 Recommendations

For more expansion in this thesis in the future we recommend the following:

i. Use smart sensors that can detect the defected items so as to be automatically rejected.

ii. Try to program a lot of alarm cases that could be happen to fix and avoid quickly the error that are happening or could happen

iii. Try to make more enhancements in human machine interface monitoring software.

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