DESIGN AND IMPLEMENTATION OF AN AUTONOMOUS MULTISTORIED CAR PARKING SYSTEM WITH HUMAN MACHINE INTERFACE (HMI) CONTROLLED BY PROGRAMMABLE LOGIC CONTROLLER (PLC)

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ABSTRACT

With the vast growth in economy of a developing country such as Malaysia, the trend of purchasing new vehicle is seen common in the society. This indirectly causes traffic congestions especially in large towns and cities such as Kuala Lumpur and Penang Island. A typical conventional car parking facility was intended to reduce parking spaces but the parking process is somehow time consuming, where the patron has to spend time searching for empty parking lot and hence petrol consuming and environment unfriendly.

In order to alleviate the problems as mentioned, an automated multistoried car parking system has been implemented whereby it helps in minimizing parking area compared to the conventional car parking facilities. In this project a prototype of an automated car parking system based on programmable logic controller (PLC) will be developed in identifying the available parking spaces in the car parking facility, access parking and retrieval process without any help of any human personnel. This project mainly concerns about the entire operating procedure of the autonomous multistoried car parking system as well as its building architecture together with electrical and mechanical system design including software and hardware design for ideas of vehicle lifting and retrieving, which serve in reducing the period of time needed and centralize parking orientation and automation.

ABSTRAK

Dengan perkembangan pesat dalam ekonomi negara membangun seperti Malaysia, trend membeli kenderaan baru dilihat biasa dalam masyarakat. Ini secara tidak langsung menyebabkan kesesakan lalu lintas terutama di bandar-bandar besar dan bandar-bandar seperti Kuala Lumpur dan Pulau Pinang. Tempat letak kereta konvensional bertujuan untuk menjimatkan ruang tetapi prosesnya mengambil masa yang lama, di mana pengguna telah menghabiskan masa mencari tempat kosong letak kereta dan membazirkan petrol dan tidak mesra alam.

Dalam usaha untuk mengatasi masalah seperti yang dinyatakan, sebuah sistem letak kereta automatic bertingkat telah dihasilkan di mana ia membantu dalam mengurangkan tempat letak kereta berbanding dengan kemudahan tempat letak kereta konvensional. Dalam projek ini satu prototaip kereta sistem letak kereta automatik berdasarkan pengawal logik boleh atur cara (PLC) akan dibangunkan dalam mengenal pasti tempat letak kereta boleh didapati di kemudahan tempat letak kereta, dan menjalankan process meletak dan mengambil kereta secara automatik. Projek ini menceritakan mengenai prosedur operasi keseluruhan sistem letak kereta automatic bertingkat serta seni bina bangunan bersama-sama dengan reka bentuk sistem elektrik dan mekanikal termasuk perisian dan reka bentuk process meletak dan mengambil kereta, di mana dapat mengurangkan tempoh masa diperlukan dan memusatkan orientasi letak kereta dan automasi.

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LIST OF ABBREVIATIONS

DC	Direct Current
PLC	Programmable Logic Controller
HMI	Human Machine Interface
OOP	Object Oriented Programming
MAPS	Modular Autonomous Parking System
GUI	Graphical User Interface
VB	Visual Basic

CHAPTER 1

INTRODUCTION

1.1 Background Information

With the advent of advanced technology nowadays, automobiles symbolize freedom and mobility. A rapid growth of population in Malaysia leads to vehicle usage increment by leaps and bounds. The total number of registered vehicles on Malaysian roads has passed 21.25 million units. The Kuala Lumpur Federal Territory has the highest number of registrations with 4,914,992 vehicles in total, followed by Johor (2,900,984) and Selangor (2,359,126). Penang (including the mainland area of the state) is fourth with a total of 2,209,770 vehicles. *21.25 Million Vehicles on Malaysia Roads.* (2011). Retrieved February 26, 2011, from http://www.motortrader.com.my/news/21-25-million-vehicles-on-malaysian-roads.It is an existing challenge to the architects, city developers and planners in order to expand or develop the city especially in a dense and heavily populated area with mushrooming number of vehicles and the consequent insufficiency of parking spaces. There is a need for an autonomous multistoried car parking system being called in order to regulate the haphazard parking of vehicles all over the roadside which may induce traffic jam to other patrons on road. The autonomous multistoried car parking system is basically a multileveled building which serves for car placement and retrieval purpose. Instead of

accessing to different levels through ramps, the automated multistoried car parking has equipped itself with a mechanized and robotized elevator, which is able to transport cars to a certain chamber at different levels. Therefore, less construction volume is needed for the building thus cost saving. The strategies and policies in parking as well as its behaviours are to be further analyzed in prior to integrating it with other elements in transportation planning and prototyping processes. A parking system prototype with circular parking arrangement in being introduced whereby the cars are lifted by an elevator from the base, which is known as the parking platform to a vacant chamber in the building and can be retrieved using the same method of lifting at different levels. The base can be rotated at 360 degrees and the parking system is estimated to accommodate over hundreds of parking capacities.

1.2 Problem Statements

Nowadays, traffic congestions as well as problems in searching for a vacant parking lot has been increasingly difficult with the proliferation number of road users. This scenario can be best experienced by patrons in suburbs or big cities where a vacant parking lot is extremely hard to be spotted, some may even have to go round and round the parking facility but end in futile. Technically, a conventional parking facility requires the patrons to go up level by level and notice the vacant parking space manually. This situation is rather time and fuel consuming as patrons cannot leave their cars unless they get it parked, which might get their schedules delayed or postponed, especially for those who are in a hurry. Besides that, the conventional car parking facility needs a larger land construction area but accommodates fewer parking capacities compared to the building with autonomous multistoried car parking system.

1.3 Research Objectives

i. To create a prototype of an autonomous multistoried parking system with maximum parking spaces and minimum of land capacity.
ii. To reduce time in car parking and mechanize car parking process to be a more convenient process for patrons.
iii. To apply the programmable logic controller (PLC) technology in controlling the autonomous car parking system prototype.
iv. To create a user-friendly car parking system by implementing Human Machine Interface (HMI) in the control system.

1.4 Scope of Proposed Research

The scope of this project is to design and develop a prototype of an autonomous multistoried car parking system which parks and retrieves cars by an elevator. The autonomous multistoried car parking system is able to maximize parking spaces at the same time minimizes parking facility construction area. All mechanisms needed to transport a car from the parking platform to the parking chambers in the autonomous multistoried car parking system are driven and controlled by Programmable Logic Controller (PLC) and the identification between cars and its owners are done by Human Machine Interface (HMI). The programming for PLC is being done via CX-Programmer software using ladder logic method. Simulations of the entire system can be done in the same software for error detection and modifications purpose in prior of prototyping the entire system in real. Testing and analyzing the control system will be further carried out on the developed prototype.

1.5 Expected Outcomes

This project would claim to design and create a prototype of autonomous multistoried car parking system with human machine interface (HMI) based on Programmable Logic Controller (PLC). In addition, the prototype is able to lift and retrieve a car from parking platform to one of the chambers in the parking facility.

1.6 Significance of Research

There are two biggest beneficiaries from this proposed research, which are drivers and infrastructure developers. Drivers would benefit as time and fuel consumption will be greatly reduced in searching for a vacant parking space compared to the conventional car parking facilities. Drivers, especially the white collars would have themselves reaching workplace in time without having to spare any in fighting for parking lots. Infrastructure developers would be glad to reduce materials and cost in excavations for parking facilities at the same time conserves more open spaces for other purpose. Besides that, the proposed research is able to fit more cars compared to the conventional car parking facilities with lesser space in construction.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the previous studies on the autonomous multistoried car parking system based on Programmable Logic Controller (PLC) in terms of car owner identity identification, car parking control system, and implementation of Human Machine Interface (HMI) into car lifting and retrieving process.

According to W.S. Tang *et. al.* (2006), the intelligent car parking management system adopts wireless sensor in the parking facility and each of the parking chamber is equipped with a sensor node, which function to monitor and detect the occupancy of the parking chamber itself. The status of the parking facility detected by the sensor nodes will be reported to the computer periodically to a database set via the wireless sensor deployed together with its gateway. The database can be accessed for management functions such as searching for vacant parking chamber, statistics or error report as well as security management.

R. H. AI-Absi *et. al.* (2010) proposed that the automated parking system is vision-based, whereby vision-based system is being adopted for the purpose of vacant parking chamber detection and verification in the autonomous car parking facility. Such method is being utilized to detect vacant parking chambers via coordinate system for the region of interest as well as car classifier. Unlike the above ideas, where it is only focused at searching and locating vacant parking chamber, the idea of fabricating a prototype of an autonomous multistoried car parking system with PLC was thought of, whereby this system would identify the available vacancies for parking chambers using sensors, park the cars in an identified empty chamber using an elevating device and retrieves the car back from its parked chamber without the help of any human personnel.

U. Avgan (2003) preferred the use of DC motor over stepper motors when speed, weight and cost are being accounted. The direction for motor rotation can be observed by tracking the number of turns made by the motors. In this project, stepper motors were being implemented for the very reason that the error in the positioning of a stepper motor does not add up compared to DC motors. Besides that, stepper motors are better when comes into digital application, whereby the location of each and every chamber of the autonomous multistoried car parking system were computed digitally.

(J.Thmopson, 2012) stated that the autonomous multistoried car parking system needs a controller to manage and control the entire function of the whole system. There are various types of controllers available such as microprocessors, PIC microcontroller, and PLC. Programmable Logic controller is more favourable due to the fact that it is easy for users to deal with ladder logic over programming or assembly languages. According to Dana (2011), he suggested that implementation of car parking system using PLC, where PLC has been implemented as the controller for the entire parking system control.

D.R. Mueller (2012) pointed out that microcontroller is only applicable in situations where there are requirements for limited computing functions within a set of parameters that are easy to be defined. As suggested by W.James (2012), microcontroller has low capacity in output handling, which is unable to control specified automated tasks designated by industrial equipments. Softyan (2012) suggested that the output/com of PLC

can be connected to AC power equipment directly, while for microcontroller requires additional interfacing when it is connected to any of the electronic equipment.

2.2 Autonomous Multistoried Car Parking System

2.2.1 Introduction

The autonomous car parking system is an existing technology where countries such as America, Canada, Japan and most of the European countries (Shaheen *et al.*, 2005) had implemented the advanced technology in various disciplines of researches. The aforementioned problems encountered by the patrons in searching for vacant car parking spaces in conventional car parking facilities would be solved with the deployment of the technology (M.Y.I. Idris *et. al.,* 2009) in all car parking facilities in Malaysia.

The autonomous parking system is considered beneficial for car park patrons and operators as well as in environment or land conservation (Shaheen *et. al.*, 2005; R.R. Chin *et.al.*, 2007) as cost on land acquisition will be greatly reduced and world will be greener. Besides that, budget on hiring car park operators will be reduced as well due to the fully automated car parking system which involves no human personnel in operating the entire system. In terms of environment matter, the pollution level can be reduced by decreasing the process of going round and round searching for parking spaces, which is time and fuel consuming. This indirectly attributes to reduction of vehicle travelling and vehicle emission to the air (Shaheen *et. al., 2005)* will be relatively reduced as well.

Autonomous parking system is beneficial to patrons due to the fact that the parking spaces will be fully used or utilized (Kurogo *et al.*, 1995; Sakai *et al.*, 1995) with a safer (Shaheen *et al.*, 2005; Chinrungrueng *et al.*, 2007), optimized and more efficient system implemented (Sakai et al., 1995; Shaheen *et al.*, 2005). The system is being implemented in a more efficient way such that the car placement and retrieval time can be significantly

minimized by getting the car parked into the parking platform followed by the autonomous parking system will have the car parked and the patrons are welcomed to retrieve their cars at any time conveniently. Illegal parking problem is being minimized as it is eliminated with the implementation of the autonomous parking system (Kurogo *et al.,* 1995). Other than that, traffic congestion can be reduced as patrons will no longer queue at the parking entrance waiting for cars to leave so that they can get themselves vacant parking spaces.

Autonomous parking involves the implementation computer controlled mechanism, where it enables patrons to drive up to the parking platform, get their car locked, identify themselves at the parking machine and allow the machine place the car in the allocated chambers of the autonomous parking facility automatically. This type of parking facility proposes maximum space utilization due to it is computer controlled autonomously compared to conventional car parks where large spaces are required for vehicle navigation within the car park. The advantages for autonomous car park over conventional car park are that the implementation works great in terms of locations, where the infrastructure has limited space for expansion. Other than that, the autonomous car parking suggests higher efficiency in car storage because car stacking is allowed and there is no necessary for the patrons to get into the autonomous car parking facility themselves which indirectly favours higher safety measures which applies on both the patrons and their cars (Shaheen *et. al.*, 2005).

The safety of the cars in the autonomous car parking facility is being geared by safety features as it is essential to ensure that the cars are remain undamaged and in good condition with all handlings done by the computer controlled mechanisms. Researches done by Mathijssen and Pretorius (2007) had pointed out that a three-level software design consists of Logical Layer (LL), Safety Layer (SL) and Hardware Abstraction Layer (HAL) in efficient and proper storage of cars in safe manner enforcement. The car park facility has to be coordinated with rotatable shuttles, lifts, rack and pinions in order to ensure safe and successful placement and retrieval of the cars.

2.3 Programmable Logic Controller (PLC)

2.3.1 Definition and Extent of PLC

Logical control systems were designed, simulated and built exclusively around electromechanical relays before the advent of solid-state logic circuits and digital electronics. Relays have been replaced as logic-level control devices, relegated mostly to those applications demanding high current or high voltage switching which is far from obsolete in modern design (Rossiter, 2010). Systems and processes collaborated with on off control are in great demand in industries, but such control systems from either electromechanical relays or discreet logic gates are seldom built.Varieties of versions for this device is developed by engineering firms and it eventually come to known as a PLC, or Programmable Logic Controller.

The purpose of a PLC was to replace electromechanical relays directly as logic elements, substituting a stored program into a solid-state digital computer, able to emulate the interconnection of relays in order to perform varieties of logical tasks (Sekhon, 2007).Medrano (2007) suggests that a PLC has many "input" terminals, through which it interprets "high" and "low" logical states from sensors and switches. It can have many output terminals, in which it outputs "high" and "low" signals to power electronic devices lending themselves to on or off control. In order to program easily with PLCs, he proposes that ladder logic diagrams resembling can be done with PLC programming language. Thus, an industrial electrician or electrical engineer should feel comfortable when comes into programming a PLC in order to perform the identical control functions when he is accustomed to reading ladder logic schematics.

Plaza (2006) investigates that PLCs are industrial computers with their input and output signals are typically 120 volts AC, just like the electromechanical control relays they were designed to replace. There are only a portion of PLCs which have the ability to input

and output low level voltage signals are implemented in logic gate circuits. Bassily (2010) points out that for different models of PLC, the signal connection and the standard of their programming varies, but they are similar enough to allow a generic introduction to PLC programming. The connection to 120 volts AC for powering the PLC's internal circuitry is provided by two screw terminals while the connection to input devices with each terminal is provided by six screw terminals. The lower-left screw terminal is a common pole connection and it is generally connected to the neutral pole of the 120VAC power source.

According to Wagner (2011), it is essential to understand that the computer used to edit and display the PLC's program for the PLC's continued operation is unnecessary. The personal computer is allowed to be unplugged from the PLC once a program is installed into the PLC and it will continue to follow all the commands built by the program. He also suggests that PLCs are able to reveal its true ability and power whenever the engineers and programmers want to modify the behavior of a motor control system. Since the PLC is a programmable device, its behavior can be altered by alternating the commands provided by the programmers, without having to reconfigure the electrical components that are connected to it.

2.3.2 Structure of PLC for Autonomous Multistoried Car Parking System

As proposed by Vernon (2004), a PLC consists of four main units as described below:

a) The Program Memory –Stores logical control sequence instructions.

b) The Data Memory – the status of switches, interlocks, past values of data and other working data is stored here.

c) The output device – these hardware/software drivers for the industrial process actuators, such as solenoid switches, motors and valves.

d) The input devices – these are hardware/software drivers for the industrial process sensors such as switch status sensors, proximity detectors, interlock settings and so on.

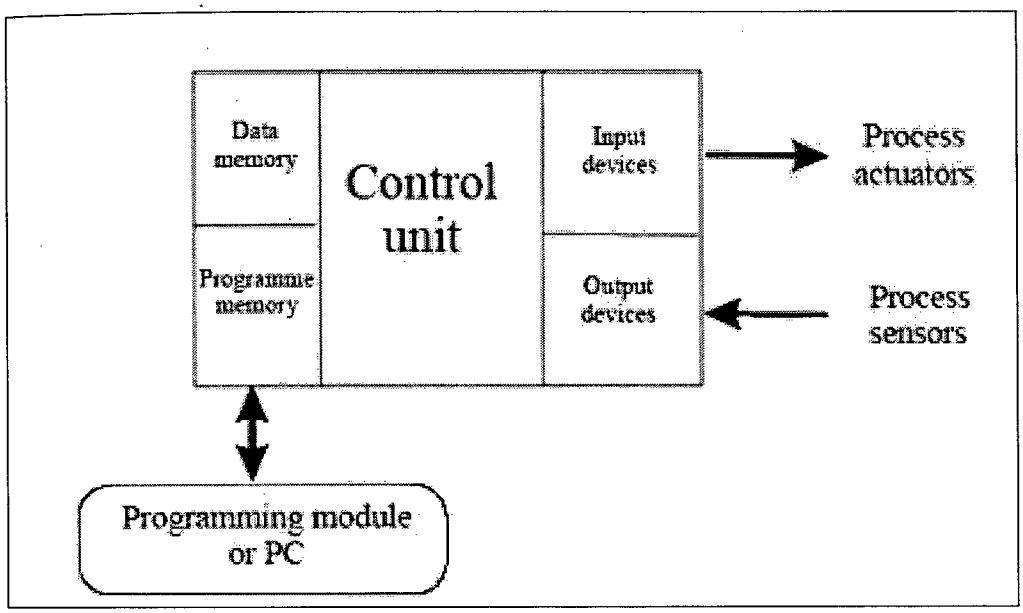

Figure 1.1: Schematic diagram of a PLC (Vernon, 2004)

The PLC also has a programming unit other than the four components mentioned as above. It is either a serial link with PC – PLC connected a specialized module, or both. The programming is being implemented to test, build and edit the logical sequence, which is also known as the ladder logic as the execution of the PLC. PLCs are generally programmed at the basic level of assembly code in the simplest form. Each of the definitions of these coding differs for different manufacturers. Other available programming which include the Sequential Function Chart, Function Block Diagrams, IEC-61131-3 standard and so on (R.Mangesh, 2011). Nevertheless, Ladder Logic or Ladder Diagram had been well known as the well-established standardized programming which is easily understood by PLC programmers (Vernon, 2004).

2.3.3 Elements of Ladder Diagram

Few of the basic components that can be found in a ladder diagram will be the coil and the contact. The contact simply means a name being assigned to a general input device where it could be either an internally set logic or external switch or as an actuator to a timer function. The coil on the other hand, is the name being assigned to any general output devices. These components are shown in Figure 1.2.

Figure 1.2: Ladder Diagram component basics – Contacts and Coil

2.4 Elevators

The mechanism of elevator design is essential due to its important role in any of the autonomous parking model nowadays. The information searching about the type and specifications of the elevator is necessary in order to ensure the best model of elevator is being implemented in the autonomous car parking system. In our real life, an autonomous car parking system is usually multistoried built for the very purpose of reducing land acquisition and infrastructure construction cost.

2.4.1 Introduction

An elevator is defined as an open or enclosed platform with the usage of lifting people or freight to upper floors within an infrastructure or a building (Horwood, 1986). It is essential to be elevators retrofitted in any residential building that are taller than two stories so that the patrons can travel to their desired floors conveniently. In the 1600s, the lifting of cargo and container storages in plants and warehouses were operated manually.

The very first modernized elevator is being designed and descended by Elisha G. Otis at the New York World's Fair in 1853 (Horwood, 1986). The Otis elevator possesses its outstanding acceptance by having it as a safety device which functions to engage and hold the elevator without failing. The first elevator was being implemented in turning cable drums, powered by steam power as the energy supply. Further in 1871, the release of first hydraulic elevator powered by water pressure acted as a ease in cargo lifting and so forth. From one piece hydraulic ram to shallower holes of a varied section of telescoping hydraulic rams are being innovated following the advancement of the technology. Due to that, hydraulic piping networks were installed with the hydraulic power supplied by the hydraulic energy companies so that hydraulic elevators can be implemented widely throughout the city. The retrofit of the first electric elevator was carried out in 1889, and followed by having electric energy being adapted as the power source in open, with the early elevators by hydraulic power (Horwood, 1896).

There are two advantages offered by the electric powered elevators, which are the universal availability of electric power, is very convenient for the electric powered elevators to be installed at any of the buildings, and electric elevators makes use of the principle of simple cable and pulley mechanisms which appears to be unlimited to height rising compared to hydraulic elevators, where the entire hydraulic system had to be fabricated in prior to installment. For decades, electric elevators made use or AC (alternating current) or DC (direct current) motors and nowadays most of the elevators make use of two types of AC motors: the most common are geared motors for elevators moving at speeds up to 500 feet

per minute (153 m per minute), while direct-drive motors are used for elevators moving at higher speeds. Some modern high-speed elevators move at up to 2,000 feet per minute (610 m per minute) (J.Simon, 1996). According to Horwood (1986), electromechanical controls were slowly replaced with the solid state electronic controls, where early stage of control systems require manual operation in regulating speed of elevators, lifting and stopping them at respective floors, as well as closing and opening the doors.

2.4.2 Elevator Design

The design of elevators consist of various factors which need to be taken into consideration, for instance, the maximum weight or load that the elevator manages to support, the maximum height for the elevator to go up to, as well as the maximum sustainability for high load usage. Most of them implement the counterweight, which aims to equalize the elevator weight with 40% of the elevator's maximum rated load (J.Simon, 1996). This reduces the weight of the motor must sustain and control the certainty of elevator getting in control all the time without malfunction or any related system errors (J.Simon, 1996).

In a drum lifting mechanism, the hoist motor, having its hoist cable running down from drive drums, which is attached to the hoist motor, to the second pulley situated at the roof of the elevator shaft, and down back to the counterweight. For the installation of traction drums, the cable will run up until the drive drum followed by the counterweight. Both the elevator and the counterweight have their very own sets of guide rails, where a second governor cable connects the governor pulley from the elevator, then run back to a tension pulley which is situated at the bottom of the shaft at the elevator, and then back to the elevator again. The governor pulley is being rotated by the cable with its speed directly proportional to the elevator speed. Just in case there is any overloading happens another

cable of the governor will grip the guide rails by using the emergency brake jaws and slows the elevator to a stop.

There are several switches situated at the outside of the elevator which are serially activated by a ramped bar on both sides of the shafts of the elevator, functions to decrease the speed or stopping the elevator at the desired floor. The ramped bar will actuate a slowdown switch, which reduces the speed of the hoist motor which is predetermined by programmers when the car reaches the floor that has a vacant parking space, and the ramped bar will actuate a limit switch when the elevator is aligned with the outer opening of the elevator door, stopping the elevator. An interlocking system is being installed so that the electric motor will be activated to open both the inner and outer door of the elevator when the elevator reaches the desired floor.

Commercial buildings such as shopping complexes or firms have several elevators synchronized with one control system. The objective of this unified control system aims to reduce the time of the call button being pushed to the arrival of the elevator by the passengers. The sophistication of the control system depends on different levels of requirement from the passengers. The simplest form will be an elevator using up and down button without having to consider the number of elevators available in the system. The system calculates the nearest distance for an elevator to reach for the call of the passenger and initiate the elevator to travel to the call. For a more sophisticated system, a set of elevators which operates side by side are monitored by the controller, where the zone of operation for all elevators are divided into sectors, with each sector consists of adjacent floors. When an elevator completes a run from any of the calls it will be available for any unanswered call from passengers. The elevator is then either being sent for another call or return to its "home" floor, waiting for the next call.

The controller will automatically compare and send the nearest elevator when a call is received from the passengers. The controller for the control system can be programmed to operate at different times with different types of responses of the day. This can be shown by the elevator operating in an office, whereby early in the morning the controller is

programmed to send all elevators to the ground floor, with the purpose of carrying passengers to their respective working floors rather than stopping by any of the sectors. The same principle applies for after lunch. A different set of programming will be applied during lunch time andoff work time, all the elevators will be available at different floors rather than staying at the ground floor, due to the face that the probabilities of passengers leaving from floors are higher than in the morning, which saves a lot of time for passengers waiting for the elevators to arrive for their calls. All modernized elevators are equipped with special override controls where a specific floor can be reached without stopping by any other floor by fire brigades during an emergency (Horwood, 1986).

2.5 Relationship between Human Machine Interface (HMI) and Programmable Logic Controller (PLC)

The descriptions provided for HMI can be wide, as suggested by Tutherow in Lipták (2002): Even though HMI refers to anonymous type of interface device, the term HMI usually directs to the computer, software, and display that acts as the operators or programmers' interface to control systems." Other relevant definition which was provided by Baumann and Lanz (1998) is that HMI plays the role of being one of the parts in electronics which responsible for information exchange between users and the devices. Charwat (1992) proposes that there are three main parts in HMI, which are the displays, inner structure, and an operating element. The inner structure consists of hardware and software, which are the electronics circuits as well as computer programs. The display exhibits and delivers information between devices and users via methods such as through switches, pushbuttons, and so forth.

According to R.Harwell (2012), the integration of HMI and PLC provides a solution of lean automation, where lean manufacturing is a useful and magnificent way of method in