PJP/2012/FKE(44C)/S01049

DESIGN AND DEVELOPMENT OF SMART MONITORING SYSTEM USING PROGRAMMABLE LOGIC CONTROLLER APPLIED FOR DOMESTIC DISTRIBUTION

MOHD SHAHRIL BIN AHMAD KHIAR
IMRAN BIN SUTAN CHAIRUL
SHARIN BIN AB GHANI
MUSA YUSUP LADA
MASTURA BINTI MOHAMMAD TAHA
GAN CHIN KIM

FACULTY OF ELECTRICAL ENGINEERING
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

NOVEMBER 2013

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PROJECT COMPLETION REPORT

FOR

SHORT TERM RESEARCH GRANT

DESIGN AND DEVELOPMENT OF SMART MONITORING SYSTEM USING PROGRAMMABLE LOGIC CONTROLLER APPLIED FOR DOMESTIC DISTRIBUTION BOARD

PRINCIPAL RESEARCHER: MOHD SHAHRIL AHMAD KHIAR (FKE)

Co-researchers:

1. Imran Bin Sutan Chairul (FKE)
2. Sharin Bin Ab Ghani (FKE)
3. Musa Yusup Lada (FKE)
4. Mastura Binti Mohammad Taha (FKM)
5. Dr. Gan Chin Kim (FKE)

Project Code No. : PJP/2012/FKE(44C)/S01049

Report Submission Date: 31 January 2014

Department of Industrial Power Engineering

FACULTY OF ELECTRICAL ENGINEERING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRACT

The rapid growth of electricity consumption increased in accordance with the country's development in order to reach its status as an industrial country. Therefore, the development of a supervisory system that can do both monitoring and controlling play a vital role to balance up the energy production as well as to evaluate the consumption needs from the consumers. Nowadays, the usage of power for individual house may increase due to the less awareness towards the power saving. By turning on the electrical appliances that may not be beneficial enough for the owner, it will increase the power usage in which will double up the cost of utility billing. Thus, the aim of this research is to monitor and control the load utilization by using Programmable Logic Controller (PLC) via Human-machine Interface (HMI). Hence, PLC is used as the centralized component in sending and receiving data to the system via HMI. This program will be run by designing a ladder programming software and user interface program while its controller will be developed using PLC. The development of this monitoring and controlling system is then simulated based on the customer usage of power consumption through several different cases. As a result, an output power obtained from HMI displays are identical with theoretical value and this research can be applied for domestic user in order to monitor and control the power usage.

ACKNOWLEDGEMENT

The PJP **(PJP/2012/FKE(44C)S01049)** research funding from Universiti Teknikal Malaysia Melaka (UTeM) is gratefully acknowledged.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 General

The growth of electric utilities in size and number of interconnecting has increased rapidly. The development of advancement in software, specifically microprocessor technology provides an excessive controller that is very useful for human daily life. There are many studies in Chapter 2 focusing on the application of control and monitoring in which is widely used at the present time. Greatest investment is made to achieve more contented conditions with optimal control of the system to obtain maximum benefits.

Furthermore, Human-Machine Interface (HMI) is a part of a machine that involves studying, planning and design of the interaction between users and other devices. There are a lot of HMI's applications such as membrane switches, rubber keypads and touch screen. In addition, HMI interface designs involve three main stages; interaction specification, interface software specification and prototyping.

Therefore, the aim of this research is to create a system that is more comfortable, more effective and able to analyze the pattern of power consume by load with the assistance of controlling and monitoring system using a Programmable Logic Controller (PLC). To make it even easier, the system should have HMI which is a touch screen program to control, monitor and display all the parameters involve.

1.2 Significance and Rational of the Research Work

Commonly, demand in loads is increasing each day. Furthermore, it is increasing rapidly in certain condition in which the generation part hard to cope with the particular occurrence

scenario that may lead to power demand exceeding the power generate in generation plants. This scenario also happens due to over-usage of power by the loads. As it is acknowledged, nowadays electrical network in domestic house is utilizing switches for on and off any particular electrical equipment. Loads, such as fans and lightings are installed in several places in the house and the switches might be installed everywhere nearer to the loads. Therefore, this research offers the usage of controlling and monitoring all the loads just in one single center. The center is meant consumer may be able to access every load in the house just in one place without putting an effort to reach for switches of the loads. Besides, this research offers consumers the power consumes per loads so that the consumer may know the actual power rating of loads utilized and increasing their awareness towards shutting downloads that are unused and consume higher power rating.

1.3 Objectives of Study

The objectives of this research are:

i. To study on the monitoring and controlling system and its applications.
ii. To design and develop a power consumption monitoring system using PLC via HMI.
iii. To design and develop a load control system using PLC via HMI.

1.4 Scope of Study

This project is focusing on a development and implementation of controlling and monitoring system for consumers for a domestic user. This is done by controlling loads and monitoring power consumption using PLC type OMRON CJ2M-CPU11 via HMI type OMRON NB-Series Programmable Terminal (PT) with real load utilization that consists of lighting and fan in a house. Initially, the equipment that involved are OMRON CJ2M-CPU11 PLC-Type, OMRON NB-Series PT and Power Analyzer. All of this equipment will

be connected via the utilization of serial communication standard (RS-232 and RS-485). Hence, OMRON NB-Series PT is the device that acts as HMI for this research. They are CX-Programmer (for PLC), CX-Protocol (for Power Analyzer) and NB-Designer (for HMI). There are number of loads involved. They are seven unit fluorescent lamps with five using magnetic ballasts and another two lamp using electronic ballasts. As additional loads, two wall fans are involved as well. The analysis will be demonstrated by comparing the power consumption between experimental results and theoretical results based on the implementation of load utilization. The implementation of all load utilization is observed based on eight cases that control and monitor by consumer.

1.5 Layout of the Report

Five chapters are presented in this research report apart from this introductory chapter. Chapter 2 provides some related information and previous research done by other researchers in the same area. It includes a review of the recent literature related to the development of controlling and monitoring system, SCADA system, HMI and power consumption.

Furthermore, Chapter 3 focused more on the details of the research. The utilization of software and hardware combination is implemented throughout the research. Besides, the eight cases for loads are manually controlled and monitored.

Chapter 4 describes the results of the most profitable method in order to reduce the energy consumption as well as bill payment. The payback period on each method will be discussed in this chapter.

Finally, Chapter 5 provides the conclusions and summary of the research effort as well as the recommendations for future research interest.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the review of the monitoring and controlling system will be presented. The first review would be on SCADA systems. Next, it would be the review on the application of SCADA systems in power substation systems, remote control and monitoring system and auto-controlled automation system. Lastly, the review on serial communication specifically RS-232 and RS-485 standard together with HMI and PLC would be presented.

2.2 Monitoring and Controlling System

Monitoring and control can be defined as the centralized to control of a system such as devices or network through the automated system or managed by control unit either with or without display information.

Nowadays, market profile is the main cause described according given to which varies among sector in industrial automation, power grid and critical infrastructure control and monitoring system [1]. Thus, with the flows to global issues in the exploration of monitoring and control system may be affected by the impacts from charging the base for drivers such as in the development of services, energy efficiency, cost of oil and gas, safety, security, and others. One of example, monitoring and control system that used nowadays is SCADA system.

2.3 Supervisory Control and Data Acquisition (SCADA) System

SCADA can be defined as a type of and industrial control system by using computer networking. The computer will be functioning as controlling and monitoring in the physical world. The main purpose of SCADA combines real-time data, monitoring and controlling equipment process in critical facilities such as oil and gas production, transmission and distribution, industrial control, electrical power distribution process monitoring, display information in a graphical user interface and others types of application that related to SCADA system [2].

A SCADA network is necessary, provided a connection between servers which in a particular inside a control center and control device which located in the fields sometimes are remote location. SCADA system essential of several equipments such as HMI, Remote Thermal Unit (RTU), Programmable Logic Controller (PLC), substation controller server, power equipment and others system [3]. Furthermore, SCADA system also plays an important role by providing utilities with valuable information at the same time in a reliable and safe manner.

2.4 Application of SCADA System

Application of the SCADA system consists of one or more devices which is RTU and PLC. A communication system is used to transfer data between field interface device and control unit of the component in the SCADA central host. Other than that, a collection of standard and custom software which is called HMI used to provide the SCADA central host and operator terminal application and support the communication system and monitor and control located field data interface devices [4].

Besides, SCADA system is applied in the power substation system, remote control and monitoring system and auto-controlled automation system. All of these applications are described in the next sub chapter under application of the SCADA system.

2.4.1 The Application of SCADA in Power Substation System

One of SCADA system power substation is shown in Figure 2.1. Today, electrical substation required manual switching or adjustment of equipment and manual collection of data for load, energy consumption and abnormal events. According to Figure 2.1, one of room control centers will control all the room, according to the connection in Ethernet, serial and others. The system use HMI (Modbus TCP) as monitoring and PLC are used as the device to control the system [5].

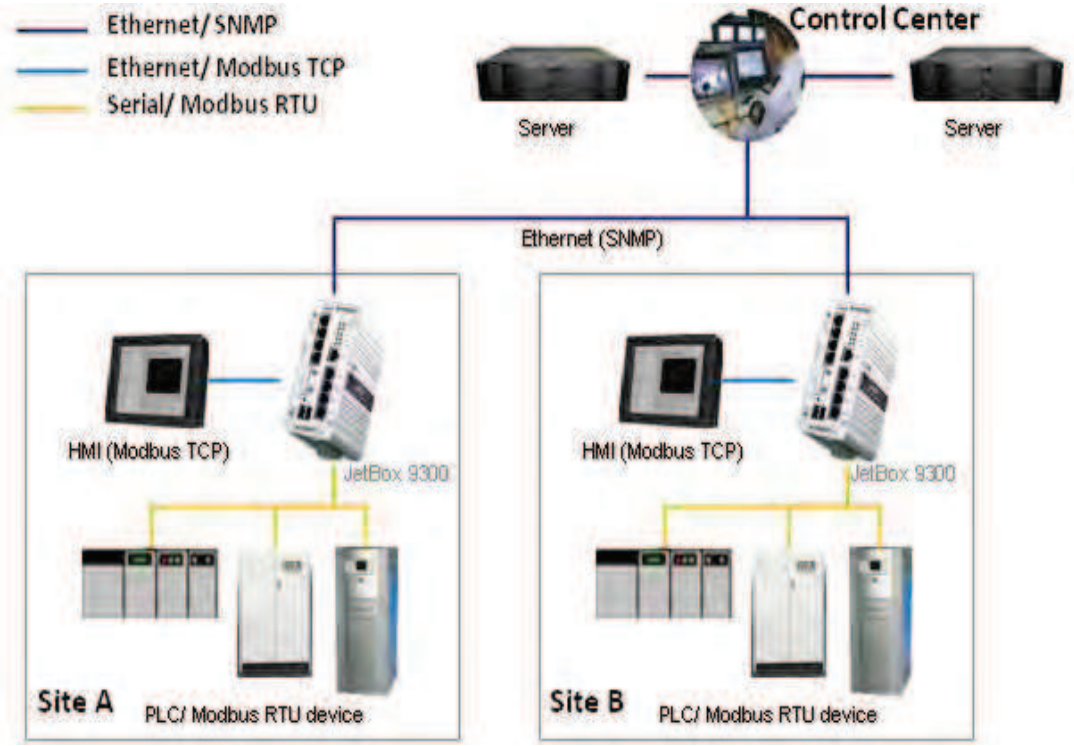


Figure 2.1: Example of SCADA system in power substation [5]

2.4.2 The Application of SCADA in Remote Control and Monitoring System

Nowadays, human daily life becomes more good cause by the exploration of current development in software and microprocessor technology. Furthermore, the internet respected as a powerful medium for future technology.

Furthermore, the internet represented as a future technology. Distributed internet access is the fundamental assumption from one side to another set of applications that come with a solution which is save time, cost and others. The use of Personal Computers (PC), subscriber station and wireless connectivity, content dispersed widely lead to the popular use of high-tech device applications. An industrial system is an example of a multi-user system that can be monitored and control by remote. The process is designed based on different equipment and methods to operate system efficiently and economically. However, new applications require further development to improve the quality of performance, standards, internet protocol (IP) addressing, accessing and security [6].

The networking allows the combination of communication which involves the management and operation of smart devices and systems [7]. All the information in controlling system and its status information, it can be sent along power line or other structure including wireless or others [8]. The implementation wiring can be formed by communication infrastructure.

2.4.3 The Application of SCADA in Auto-controlled Automation System

There are many examples in auto-controlled automation system such as in remote controller, security system and others. One of the example is based on automation system is short message system (SMS) are developed with developing technology. One of them is the outgoing message from one system to the host's cell phone and another message coming from the host of the system. Incoming message includes a group of orders which is sent to the Global System for Mobile (GSM) modem (the devices are started or stopped through the GSM network) [9].

Other than that, a constant communication over telephone lines between two points has been achieved. A home automation has been realized using telephone cables and a computer. In the system, opening and closing operations of tone multi frequency signal via cable. The system transmits video data indoor with wireless Local Area Network (LAN).

2.5 Serial Communication

In a computer communication network, a serial communication standard is elaborated to make sure communication and transmitting between computers, the communication existence must reach an acceptable agreement on communication content, mode and time which is called a communication protocol [10].

Paper [11] presents about the development of load control system either in small or big building. According to this paper, all the system use digital power meter which works as microcomputer while PLC functioning as a controller via standard serial communication RS-485. Load utilized by the system for all PLCs types are shown in Figure 2.2. Besides, RS232 and RS485, and HMI are also discussed in this chapter.

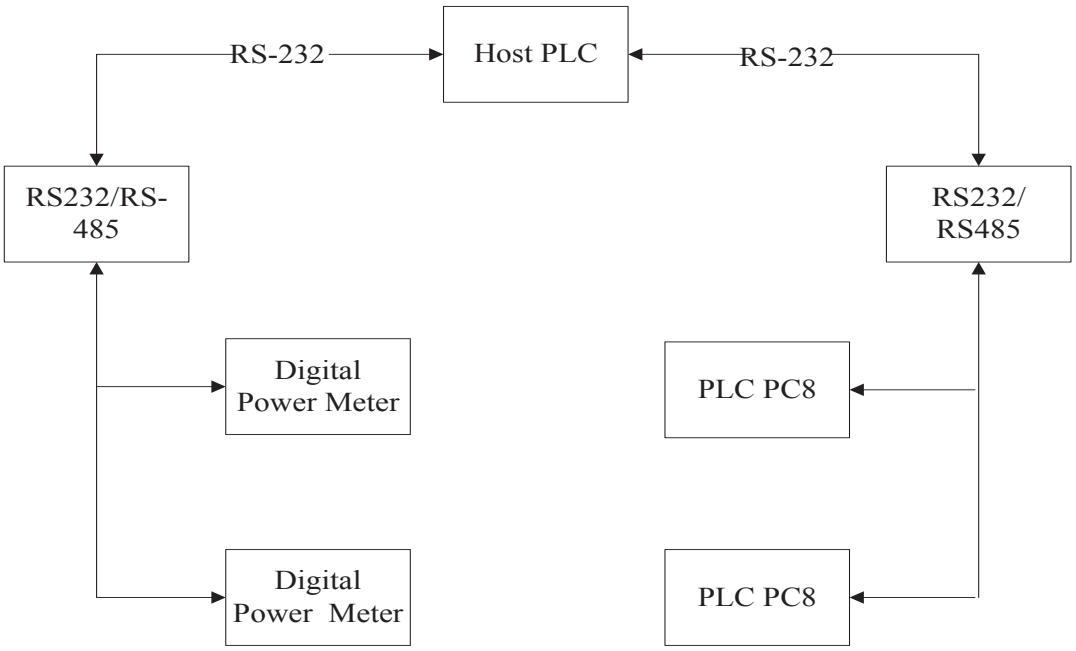


Figure 2.2: Hardware configuration system [11]

2.5.1 RS-232 and RS-485 Standard

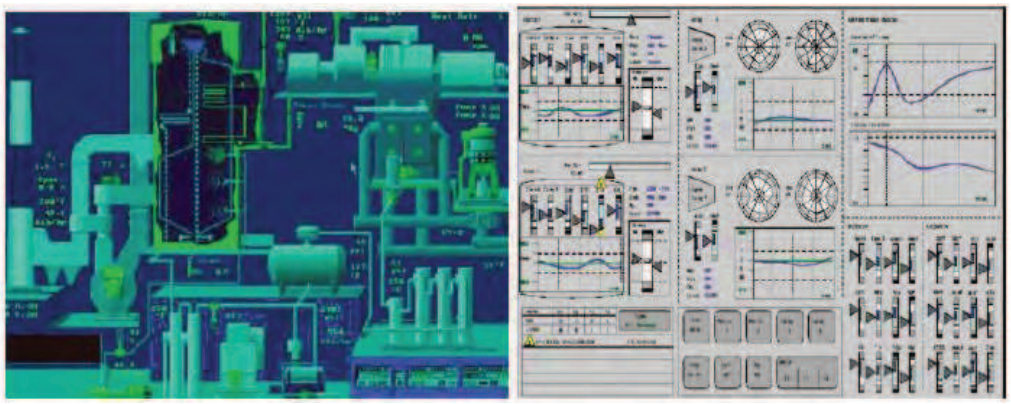
RS-232 is described as the interface between data terminal equipment and data communication equipment using serial binary data exchange. This definition defines

terminal equipment (DTE) as the computer, while data communication equipment (DCE) is the modem of the system [12]. Furthermore, RS232 is widely used for direct connections between data acquisition devices and computer system.

RS-485 is can be defined as the electrical characteristics of drivers and receivers that could be used to implement a balanced multipoint transmission line. Nowadays, RS-485 widespread accepted and used in industrial, medical and consumer application as the industry interface workhorse [12].

2.5.2 Human-Machine Interface

Nowadays, the HMI unit usually operates in the process automation industry. Thus, a positive quality of software tools is introduced and competitiveness in designed HMI displays is increasing tremendously due to the increasing application of HMIs unit. Paper [13] focused on various important aspects in designing HMI display to meet the quality criteria. These aspects regard to screen layout, color representation, graphic, picture, text and data value and others. Figure 2.3 shows an example, between a poor and good HMI graphic.



(a) (b)

Figure 2.3: Sample of HMI graphic; (a) A poor HMI graphic and (b) a good HMI graphic [14]

According to HMI design standard [15], there is a few colors are specifically should be considered for representing certain operation such as:

Red: stop, emergency or prohibition
Green : start or safe condition
Yellow : warning
Blue : mandatory operation

Then, there are two major should be taken in HMI design to monitor with multiple visual displays which are the screen must be able to hold operator attention with maximum display. Secondly, all design must allow a person with no experience to be able successfully operate with it.

2.6 Programmable Logic Controller (PLC)

PLC is a device used to automate monitoring and control of industrial facilities. It can be used as a stand-alone or in conjunction with a SCADA system or other system. PLC connects directly to field data interface to the field data interface device and incorporate programmed intelligence in the form of logical procedures that will be executed in the event of certain field condition [16].

PLC is a digital microprocessor system that processes receiving information from sensors or different input units and therefore able to manage output devices. If technical requirement change and increase, the PLC based system can be easily adapted to new conditions with little changes while updating the classical relay based system so expensive and so difficult. Furthermore, PLC needs less space and consume less energy.

There are types which PLC can operate in direct current (DC) or alternating current (AC) supply. Usually, DC type PLCs will operate with 24V DC power supply and AC types need 220V AC supply [17,18].

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In this chapter, further discussion on the method that had been used is described. Hence, it will be divided into two; software and hardware. For the software, the description of design and development project related to CX-Programmer Tool, CX-Protocol Tool and NB-Series Programmable Terminal (PTs) will be presented in this chapter. Meanwhile, for the hardware, the hardware development method together with the analysis of power consumption will be described as well.

3.2 Flow Chart of Methodology

The flow chart describes all of activities or tasks to be done for each stage of the project's planning and this is important to ensure successful completion of the project. Figure 3.1 presents the flow chart.

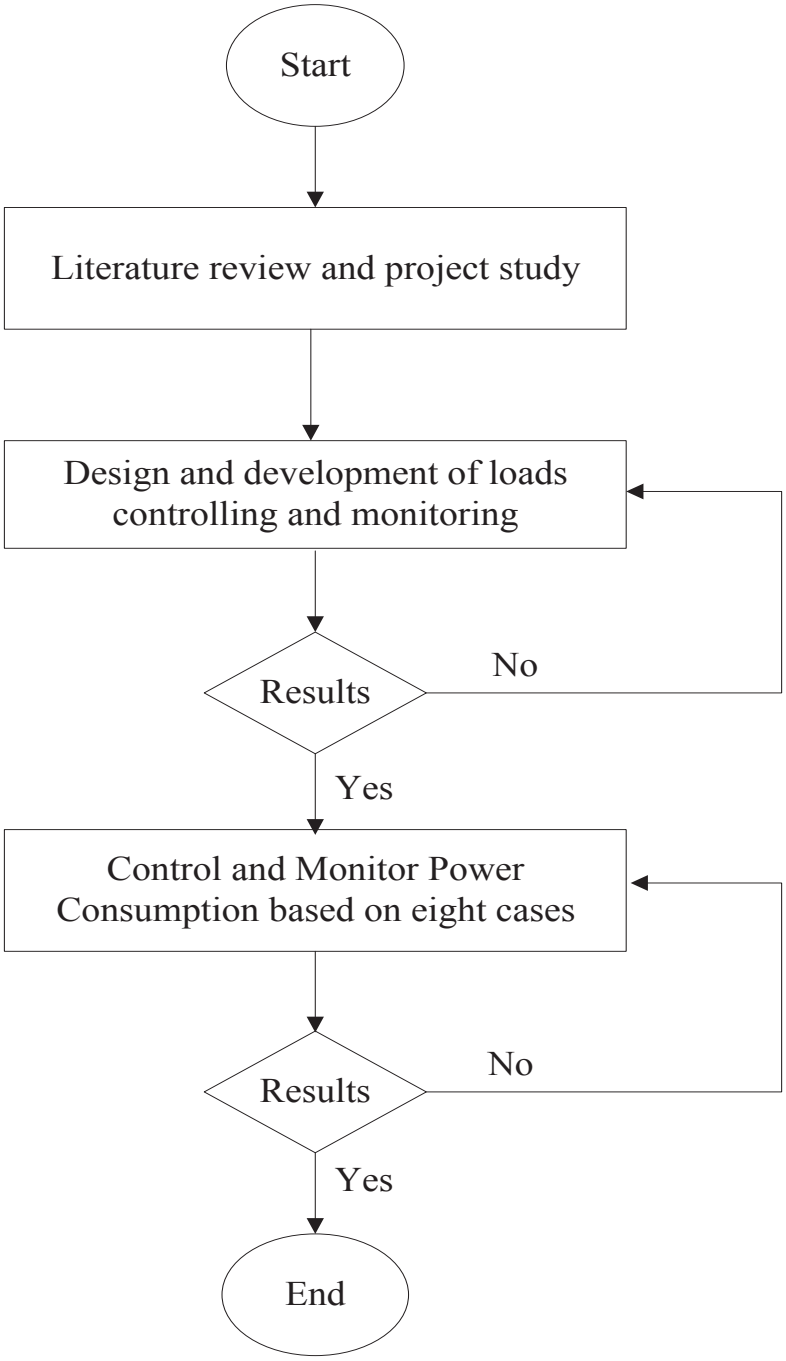


Figure 3.1: Flow chart of project methodology

(a) Literature Review and Project Study

Firstly, flow chart begins with the literature review, which focuses on control and monitoring system concept, power consumption for load management and understanding about PLC.

(b) Design and Development

In design and development, this project has been divided into two parts which is software development and hardware development. In software development, there are three tools that use in this project, which is CX-Protocol, CX-Programmer, and NB-Designer. In hardware development, real load consists of lamp and fan is used in this project. All the development is referred to design in a one house.

(c) Control and Monitoring Power Consumption

The system will control load utilization using HMI by manually and the value of power consumption will be monitored. All the control and monitoring system is based on eight cases.

(d) Observation and Analysis

The value of power consumption will be observed according to the eight cases. All the data will be illustrated in figures and tables. The comparison between theoretical results and experiment result will be analyzed.

3.3 Description of Design and Development Project

Figure 3.2 represented the main equipments for the experiment setup for this project. PLC is the main component used to send and receive data from Power Analyzer and load. Then, all data will be transferred to NB-Series PT in which it is known as touch screen display.

Firstly, it is about the connection between PLC and loads. PLC operates in AC supply. AC supply is connected to PLC in order to power up the PLC and output voltage from

PLC will be in DC voltage. This DC voltage will be used by the relay to make switching for all loads. Then, the relay will be connected to the load. The relay is functioning to protect PLC from damage. PLC is easier to get damaged if the loads are directly connected to the PLC. All loads are connected to PLC via the usage of relay and they are illustrated in Appendix A. According to Appendix A, all loads are powered up by AC supply in which the supply is connected to the relay.

Secondly, experiment setup proceeds with the connection between Power Analyzer with PLC. Function of Power Analyzer is to produce value of power for all loads. This Power Analyzer will work with PLC via standard serial communication port RS-485. Then, to read the value of power consumes by load, a current transformer is placed at the incoming supply voltage for all loads and connect with Power Analyzer. 240V is the supply for the Power Analyzer. The connection of Power Analyzer with load and PLC are shown in Appendix B.

Lastly is the connection between PLC and NB-Series PT. NB-Series PT functions to send command to PLC via its developed interface. There are buttons for loads within the interface. When the command sent to PLC, the PLC will execute the loads' actions according to command receive from NB-Series PT. All the data that PLC receives from the load and Power Analyzer will be transferred and displayed in NB-Series PT. The interface display of NB-Series PT works with PLC via standard serial communication of RS-232 and USB cable. The connection can be referred to Appendix C.

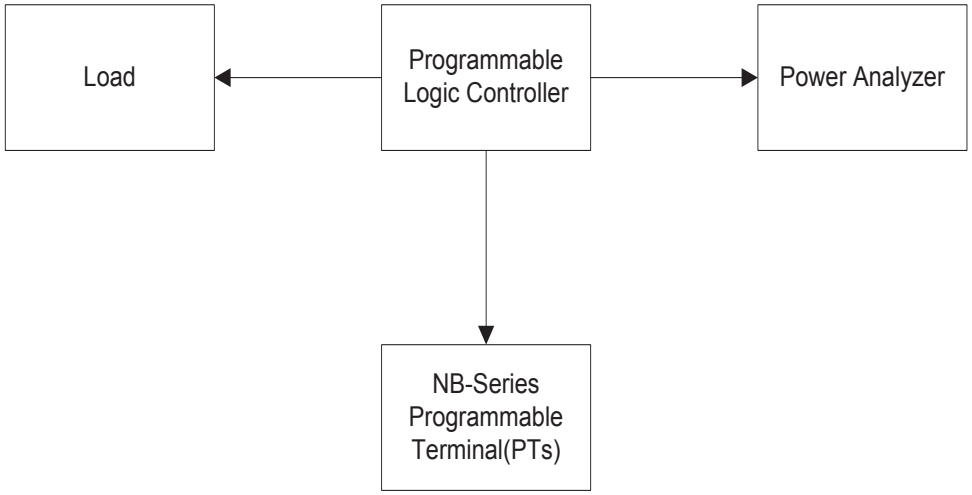


Figure 3.2: Block diagram of main equipment in this project that related to each other

3.4 Software Development

PLC that had been used in this project is CJ2M-CPU 11 by OMRON company which have its own specification by referring to Appendix D. The PLC will function as the main system that sent the command to touch screen via interface and digital power meter have been applied to fulfill requirement of this project. This chapter will discuss based on PLC software consist of CX-Programmer and CX-Protocol. Secondly, NB-Designer software is designed by referring PLC program. All this software development will be discussed in this project and the procedures are followed according to their manuals respectively.

3.4.1 CX-Programmer Tool

CX-Programmer is a PLC programming for the creation, testing, and maintenance of the program with OMRON CJ/CS PLC series. It provided facilities for the support of PLC device and addresses information and for communication with OMRON PLC and others network supportive types.

Furthermore, CX-Programmer functions in the developing ladder diagram with the assistance of several usable tools available such as PLC memory, IO table, PLC setup, Data Trace, PLC error, PLC-Clock and others.

According to Figure 3.3 (a)-(d), it is actually one whole figure that needs to be separated since is too long to be displayed. This figure is actually a ladder diagram that constructed to run the project and has been divided into four parts. Those four parts are labeled A, B, C, and D and their function are followed:

Label A: Protocol Macro has been set up in CX-Programmer to turn on and off the Protocol Macro button by using several functions in this ladder diagram programming.

Label B: Program that constructed to show the real time clock PLC on the touch screen display according to specific addresses. All the command has been setup to start and stop time functioning.

Label C: Manual setting programming that consists with start contact address, stop contact address, indicator lamp and fan address.

Label D: Automatic setting programming that consists with start contact address, stops contact address, indicator lamp and fan address. Mode 1 shown in Label D described the automatic contact will stop after mode 1 energized.

All the description, address and data types of all commands in the whole project ladder diagram is shown in Table 3.1.

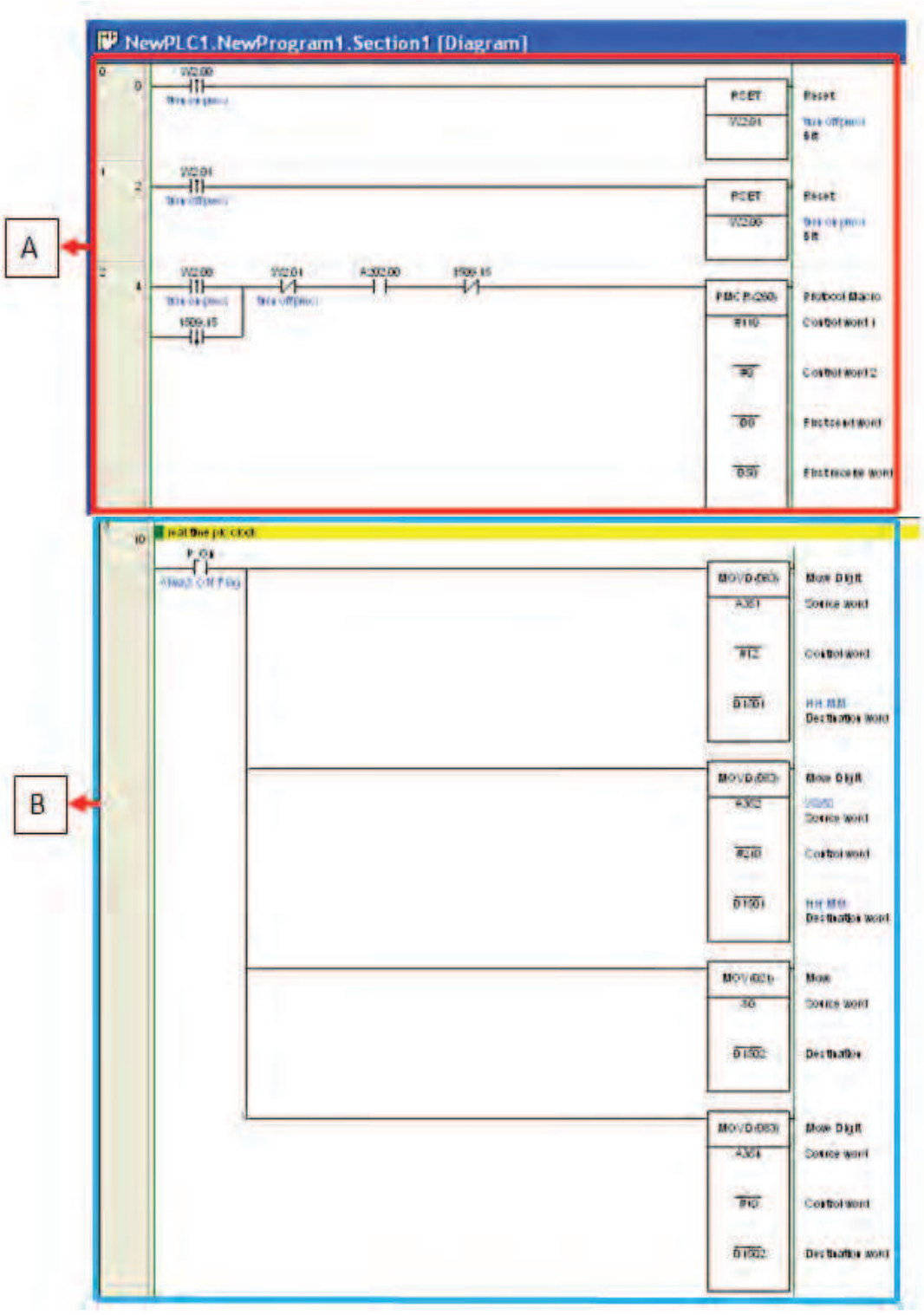


Figure 3.3(a): First part of whole ladder diagram

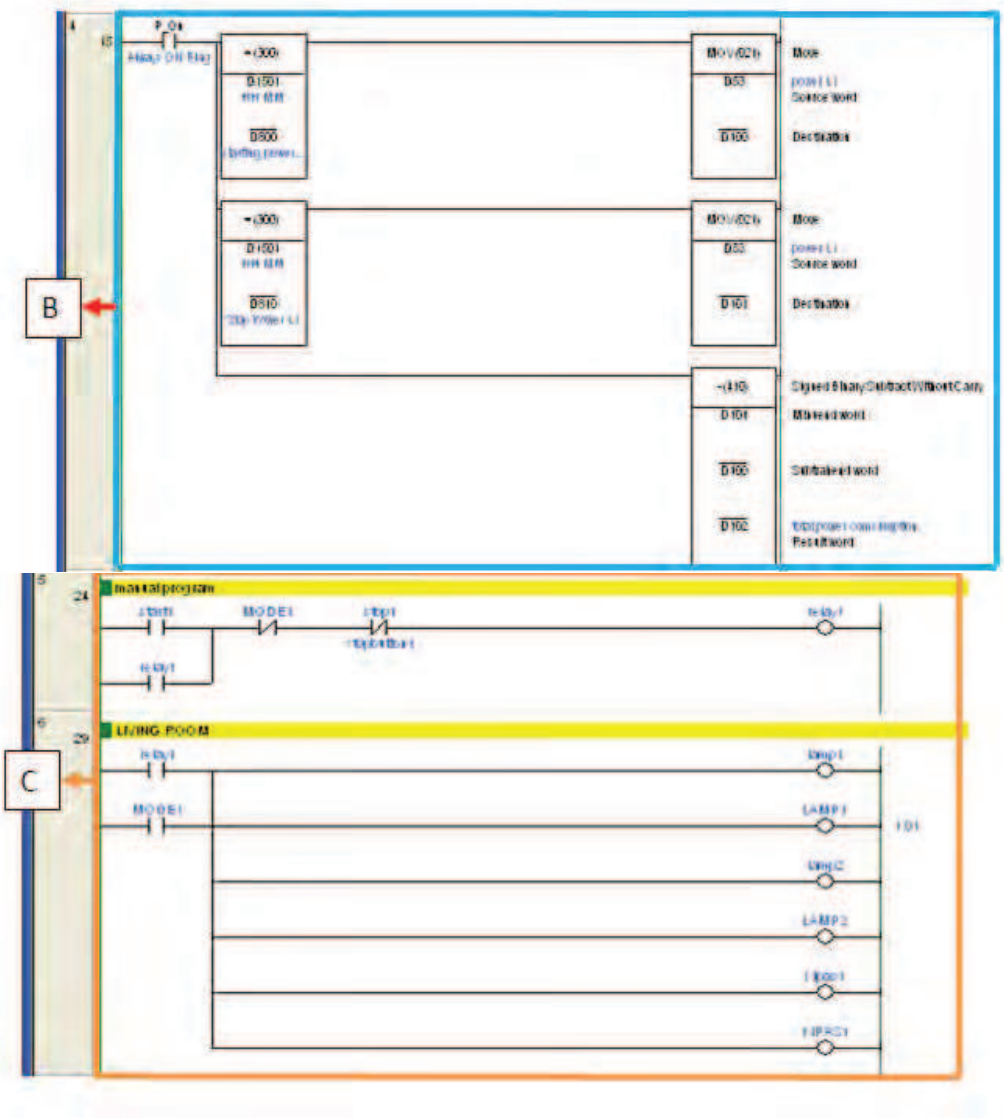


Figure 3.3(b): Second part of whole ladder diagram