# KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

**DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING**


**FINAL PROJECT REPORT**

# PLC BASED POWER SUPPLY MANAGEMENT & LOAD PROFILE MONITORING


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**Sept 2018**

# CERTIFICATION

## FINAL YEAR PROJECT
## ON

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|---|---|---|

ACKNOWLEDGEMENT

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This project has helped us broadened our knowledge in the field of PLC automation and it gives us detail idea on how the existing system can be modified and automated by implementing PLC-based HMI.

We forward our vote of thankfulness to all persons who directly or indirectly gave a realistic view on this project.

# ABSTRACT

Power Supply Management is the process of balancing the supply of electricity in the electrical network with the aid of power switching and power sharing mechanism. It is a flexible control and monitoring system with automated control unlike traditional system which demands the physical presence of a user. Lack of proper power supply management in the network leads to frequent brownouts or even blackouts in the utility. Backup generators are costly to run; with the aid of power supply management, utility can rapidly switch in between the normal and backup power supply which prevents excessive use of backup power. It also reduces the economic burden to the utility.

This system implements PLC for the power switching purpose and allows the operator to monitor the load profile of particular load. It also allows to view each feeder supply voltage, current drawn by the load and power delivered to the load. The system also provides flexibility to automatically on/off the generator supply in case of power cut on both feeders. The main benefit of the system is that the user can monitor and control the processes in computerized interface. The system implements HMI; which facilitates operator to monitor the voltage, current, power and energy of each supply and control the system directly through the screen of HMI.

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# LIST OF ABBREBIATIONS

| | |
|---|---|
| PLC | Programmable Logic Controller |
| HMI | Human Machine Interface |
| KVA | Kilo Volt Ampere |
| NEA | Nepal Electricity Authority |
| NO | Normally Open |
| NC | Normally Closed |

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# CHAPTER 1

# 1. INTRODUCTION

## 1.1 Background

The project emphasizes on automatic switching of power supply and monitoring of load profile of Kathmandu University; taking several readings of current and voltage of different loads. When power is supplied from the national grid; the university operates on power from two different feeders (one of 500KV and another of 200KV). During the power cut, the required power is fed from the generator house. In present scenario, under normal working conditions; the load in Kathmandu University is fed from either of the feeders where the supply is available. However, when there is a power cut in either of the feeder, an operator must go the site and switch the load to the feeder where supply is available. Incase both the feeders are down; the operator must manually cut off the load from normal supply and switch the load to the generator. And; whenever the supply is available in either of the feeders; the operator must cut off the generator supply and switch back to either of the supplies. Thus, it is a tiresome and a time-consuming task. In this particular regard, the rapid and reliable power transfer to the load from one source to another during certain faults is made successful by implementing PLC for multi-source switching. Further, taking the load profile of university into consideration; the power supply management is carried out implementing PLC to control the relays thus to operate the contactors as per the requirement. Hence the choice of the most appropriate feeder to supply the required power is made and the generator operation is automated during the outage of supply from both the feeders. [1]

## 1.2 Objectives

The main objective of this project is to automate the multi-source switching and monitor the load profile of Kathmandu University. Further, objectives can be pointed out as:

- To design PLC based control system for automatic switching between multiple sources whenever fault occurs for continuous and reliable supply of power to the load.
- To implement HMI so that the operator can easily monitor the load profile and control the system through HMI screen.
- To provide automated control along with an option of user input to control the operation.
- To design PLC based load profile monitoring system.
- To design the automatic switching of generator.

## 1.3 Scope

The following scopes are set out to meet the objectives of the project:

- It provides flexibility to operate on automatic user-friendly environment.
- It makes the operation fast and reliable.
- It automates the system and increases the system efficiency.

## 1.4 Methodology

Any project in order to be carried out in a systematic way; it should follow some predefined steps so that the progress can be traced and errors can be rectified. The methodology undertaken for developing this system is:

- **Study of the existing system and coding in PLC**: For understanding the different conditions on which supply sources are switched among them and what work is done when there is complete outage in the system, the study of existing system has to be done. Also, the overall working of the existing system is to be understood. Thus, under the guidance of operators, the working of existing system was understood. Further for designing an automated system using PLC, it is necessary to understand what kind of PLC is being used and its software requirements. Also, the instruction list must be studied using concerned PLC's manual. Thus, the existing system was surveyed and its working was understood along with that coding on PLC was learned.

- **Development of sensors:** The input to be fed to the PLC must be decided beforehand. PLC has prescribed values for sensed quantities thus the sensed values must be converted to the prescribed values beforehand using proper sensing circuit arrangement. Voltage and current sensors comprising of voltage and current transformers along with rectifier unit are implemented to sense the voltage and current values and feed them to the PLC.

- **Design and study of program for model system and its implementation**: After the logic is developed after repeated algorithm and flowchart development, a Grafcet was designed for the developed logic. Further, it is implemented in ladder logic diagram and tests are carried out in the system.

- **Implementing different functions and modules for working of the system**: After the design of program logic, its implementation is done. For this, use of different functions must be done. The system designed till now includes function of jump, set and other simple functions. Further functions like timer, interrupts are implemented and test to be carried out.

- **Design of timer logic:** Precise timing is used to switch between the sources after set time. This is used to avoid continuous turning on and off of the generator whenever there is an outage in system. It also avoids frequent switching between the available sources. It increases the reliability of the system and turns on and off the generator after set time.

- **Testing the prototype of switching of supplies**: The prototype of switching of supplies was tested after completing the switching program in PLC by implementing required hardware components.

- **Design and implementation of the automatic switching of generator:** After completing the switching of power supplies during normal operating conditions, PLC ladder was implemented for generator switching taking into consideration the scenario of outage. Further, implementing the necessary hardware components the switching of generator was realized in hardware.

- **Voltage and current calibration of sensors**: After completing the power supply switching, voltage and current sensors were calibrated accordingly as a part of power supply management.

- **Derivation of slope of voltage and current calibrated values and implementing it to the PLC ladder logic:** Slope of the data obtained from the calibration of voltage and current sensors was calculated and implemented it to the ladder logic so that it can be realized in hardware accordingly.

- **Calculation of power consumed by load using supply voltage and current drawn by the load:** After sensing the voltage and current, power consumed by the load from respective source was calculated using PLC program and was displayed in the HMI interface.

- **Design of HMI program and interface with PLC:** For user easiness, the HMI program was designed using the software "Touchwin Edit Tool" and was interfaced with the PLC. The interrupt was also given to the PLC. HMI devices provide the user an access to control the system from the screen. The switching mechanism of this system can be easily controlled by the aid of HMI while the HMI screen also displays the voltage, current, power and energy from each supply.

- **Testing the prototype of entire system:** Finally, after rigorous tests and improvements, the whole system was realized, tested and controlled from the HMI device.

## 1.5 System Overview

### 1.5.1 Block Diagram and its Description

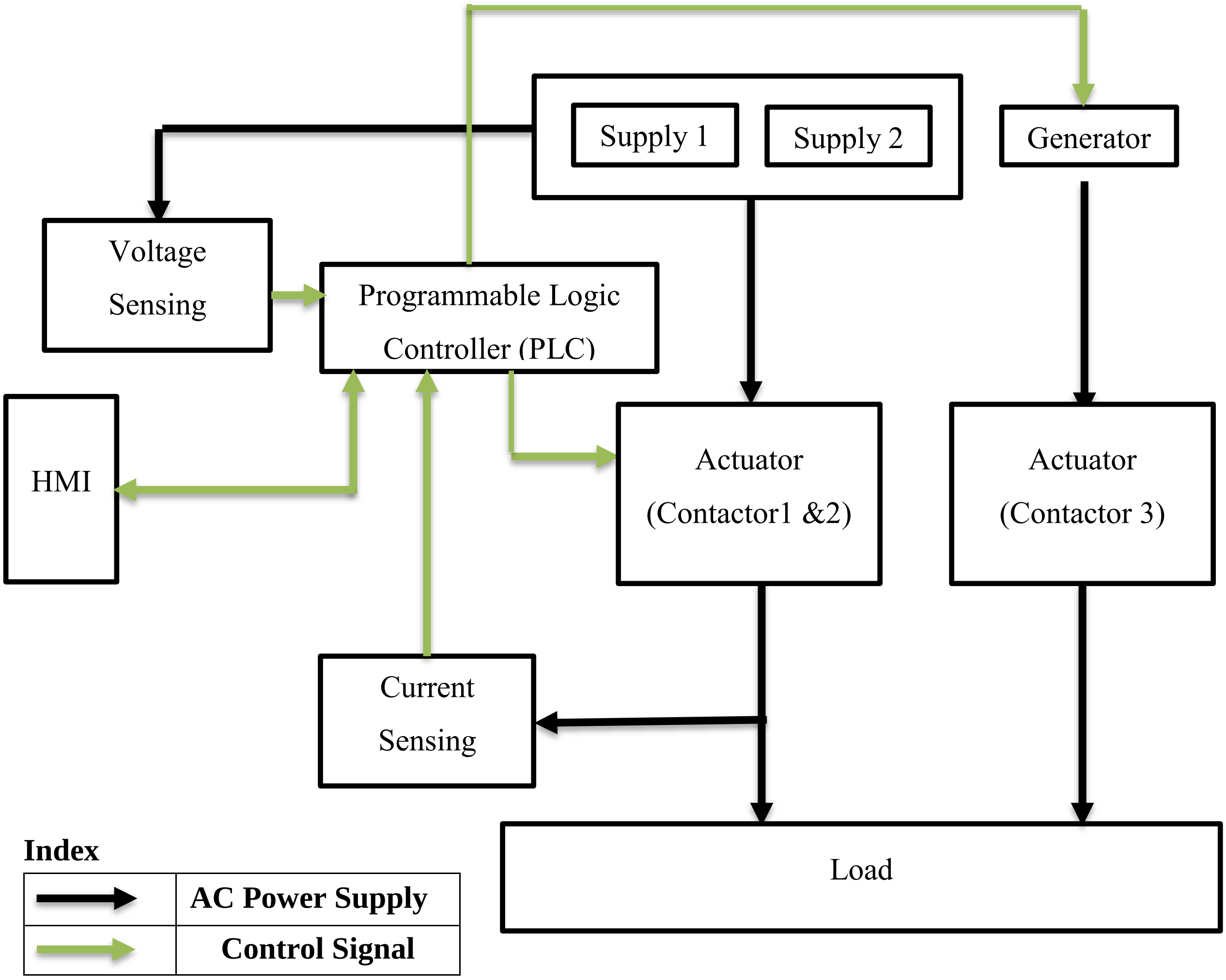



Figure 1.1 Block Diagram

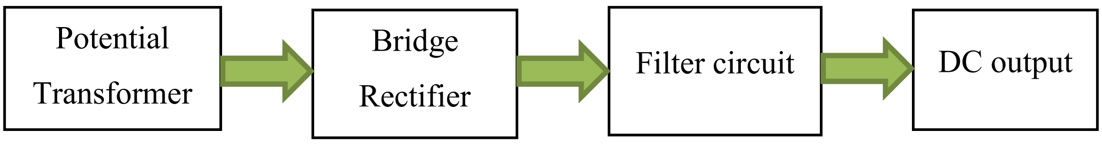



Figure 1.2 Block Diagram of Voltage Sensor

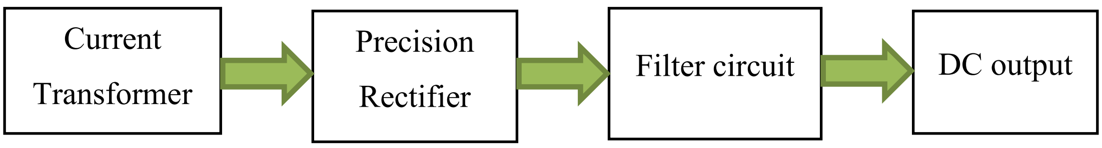



Figure 1.3 Block Diagram of Current Sensor

The project uses arrangement of three different sources of supply which are channelized to load so as to have uninterrupted operation of the load. As it is no practicable to get all the supply working at the same time, we need to switch between the sources according to the imposed conditions. Thus, voltage sensors and current sensors are used to sense the voltage and current in the system. The voltage sensor comprises of transformer and rectifier unit. This unit feeds the readable DC voltage value to the PLC. PLC is the main block of the system. It sends control signal to the contactors according to the sensed voltage value. If the sensed voltage level is in the range of 0-5V, the control signal is low and if the sensed voltage is in the range of 12-24V, the control signal is high and the contactor which behaves as switch is closed. Thus, the selected source supplies power to the load. The PLC continuously monitors the supply and selected supply feeds the power to the load. The load draws current from the source which is sensed by the current sensor. The sensed current value is further fed to the PLC which is stored in memory so that total power drawn by the load from individual sources can be calculated from the stored voltage and current values. Consequently, load profile monitoring of system can also be done.

# CHAPTER 2

# 2. LITERATURE REVIEW

## 2.1 Hardware Review

### 2.1.1 Programmable Logic Controller (PLC)

A Programmable Logic Controller (PLC) industrial computer system that continuously monitors the state of the input device and makes decisions based upon a sequence of program to control the state of output devices. It is developed to handle sequential logic. PLC is mainly used is industries to monitor and control building system and production process. It is a modular system so we can mix and match various input and output devices according to our need.

From figure 2, the PLC system can be described as follows:

1. CPU: Central Processing Unit generally consist of three parts:
    a) Microprocessor: It is responsible for data manipulation and carrying out mathematical and logical operation required for the system.
    b) Memory: it is stored data and program involved in program execution. Generally, the basic programming of PLC is done in ROM and user program and data are stored in EEPROM (Electrically Erasable Programmable Read Only Memory)
    c) Power Supply: DC power is required to operate CPU and modules.
2. Programmer/ Monitor: PC is used for writing the program and displaying it on the monitor.
3. I/O Module: It is an interface that is to be controlled for desired processing E.g. Digital I/O, Analog I/O, Encoder interface, PWM output etc.
4. Special Module: It is used for a special purpose like PID controller Module, Interrupts handling module.
5. Racks and Chassis: It is used to enclose CPU and different modules.


Figure 2.1 XC3-19AR-E Module

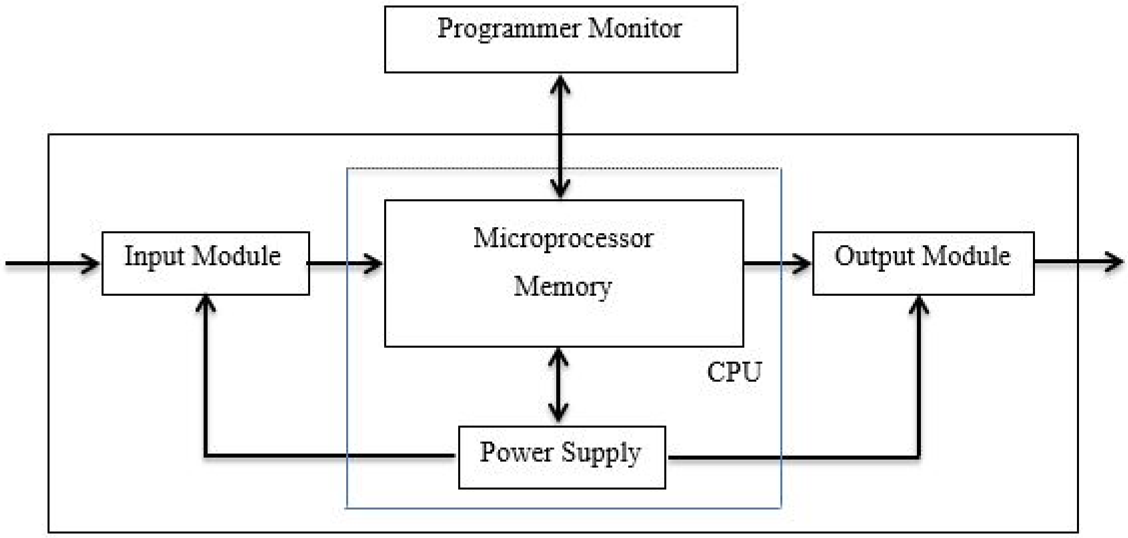



Figure 2.2 PLC System [2]

Analog special module XC3-19AR-E has been used in this project. It has integrated control logic with analog input/output in a single body. It has high performance price ratio and saves more space. The features for this module are as follows:

1. Digital input: 9 points [X0-X11]
2. Digital output:10 points (relay)
3. Analog input: 8 points (0-10V)
4. Analog output: 2 points (0-10V, 4-20mA)
5. Input voltage: 100-240v AC
6. Rated frequency: 50/60 HZ
7. Power consumption: 12W
8. Power for sensor: 24V DC, max 400mA
9. Operating temperature: 0-50 degree

XC series PLC has two types of programming form i.e. instruction list and ladder diagram. These two types can switch to each other. It contains abundant instructions like data transfer and compare, high-speed counter, interruption (external interrupt, time interrupt), PID etc. it has compact size and convenient to install. It realizes precise time.

**Relay logic:**

Relay logic is used for the sequential control of the program. Relay logic diagram represents the physical connection of devices. The relay circuit forms an electrical schematic diagram for the control of input and output device.

**Ladder Diagram:**

The ladder diagram is the graphical programming language used in PLC. It resembles ladder with two vertical rails (power supply) and rungs (horizontal lines). It is based on relay logic.

Basic Components of Ladder Diagram

| | | | |
|---|---|---|---|
| Normally Open (NO) Contact | X2 | Coil/Output | Y OUT |
| Normally Closed (NC) Contact | X2 | | |

**Timer:**

It is used to estimate an event for desire length of time. In this project the feeder and the generator are turn on according to the time set. Timer used in the ladder diagram is as shown in figure below.

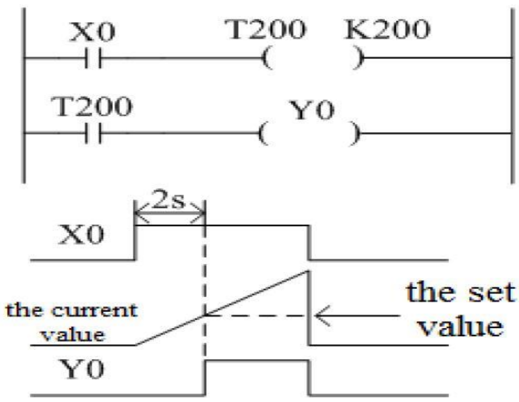



Figure 2.3 Timer Logic

The timer will be ON when the current value is equal to or greater than preset value i.e. 20 sec. when XO is turn ON, timer T200 will start and when the timer reaches the preset value of 20sec then timer status T200 turns ON. When T200 is ON, the output will be high.

**2.1.2 Contactor**

For all intend purposes, a contactor behaves identical as a relay. The term ‘relay’ is used in electronics industry and is usually applied to switch devices in low voltage circuit. When a relay is used to switch a large amount of electrical power through its contacts, it is termed as contactor. Contactor typically has a number of contacts and those are ‘normally open’ so that power supply to load is shut off when the coil is de-energized. When the power is applied and the coil gets energized, and the contact are closed. There are three contactors used in this project. Two contactors for two different supply and another for the generator switching. [3]


Figure 2.4 Contactor

### 2.1.3 Human Machine Interface

HMI is an interface that links the system with an operator through a well-defined program can be written in PLC. The operator can give input command to PLC through HMI. Usually a PLC is fed with input from sensors and sensed information is transferred to Boolean algebra which PLC can decipher and make decision. The use of HMI makes the system user friendly. It gives the operator a realistic view of the system. The operator does not need to go the site to solve the problem; instead he can easily monitor the data and control the malfunctioning from his monitor through an HMI. It displays the digital data and user can control the system from the HMI screen. In this project, TouchWin (Model: TH765-N) touch panel has been used as an HMI device. [4]


Figure 2.5 Human Machine Interface (HMI)

### 2.1.4 Current Transformer and Voltage Transformer

Current transformers are generally used to measure currents of high magnitude. These transformers step down the current to be measured, so that it can be measured with a normal range ammeter. A Current transformer has only one or very few numbers of primary turns. The primary winding may be just a conductor or a bus bar placed in a hollow core. The secondary winding has large number turns accurately wound for a specific turn's ratio. Thus, the current transformer steps up (increases) the voltage while stepping down (lowering) the current. Potential transformers are also known as voltage transformers and they are basically step-down transformers with extremely accurate turns ratio. Potential transformers step down the voltage of high magnitude to a lower voltage which can be measured with standard measuring instrument. These transformers have large number of primary turns and smaller number of secondary turns. [5]

Figure 2.7 Potential Transformer

Figure 2.6 Current Transformer

### 2.1.5 Precision Rectifier

The precision rectifier, also known as a super diode, is a configuration obtained with one or more operational amplifiers in order to have a circuit behave like an ideal diode and rectifier. They can amplify the AC signal and then rectify it. During the positive half of the AC cycle the output of the op-amp forward biases diode and current flows only through that diode. During the negative half of the input swing, however, diode is forward biased, so current will flow through it and through resistor. Therefore, DC will only show up across resistor during the negative part of the incoming AC cycle. Because we're rectifying the voltage in the feedback loop of the op-amp and not at its input, the circuit will be able to handle very small AC signals. The inherent high gain of the op-amp allows us to rectify signals that are substantially below the voltage needed to forward-bias the diode. Thus, during current sensing process precision rectifier provide better accuracy and behaves as a measuring device rather than a power converter. The sensed DC equivalent value of AC quantity is fed to the PLC as input. [6]

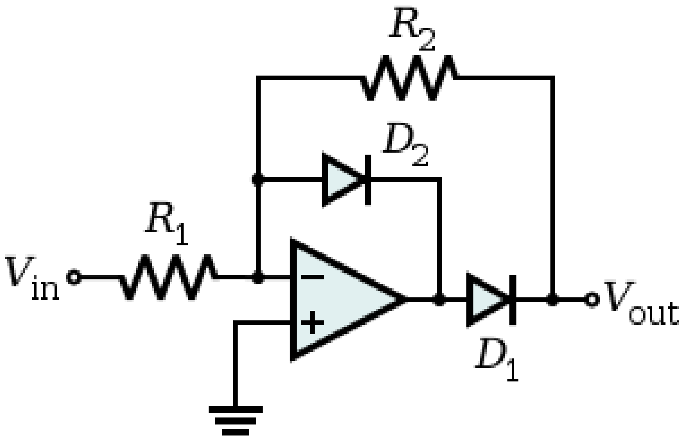



Figure 2.8 Precision Rectifier

**2.1.6 Full-Bridge Rectifier**

A Full wave rectifier is a circuit arrangement which makes use of both half cycles of input alternating current (AC) and converts them to direct current (DC). It comprises of four diodes which are connected in bridge arrangement as shown in the figure. Full wave bridge rectifier uses four individual rectifying diodes connected in a closed loop bridge configuration to produce the desired output wave. The four diodes labeled D1 to D4 are arranged in series pairs with only two diodes conducting current during each half cycle duration. When the positive half cycle of the supply goes, D1, D2 diodes conduct in a series while diodes D3 and D4 are reverse biased and the current flows through the load. During the negative half cycle, D3 and D4 diodes conduct in a series and diodes D1 and D2 switch off as they are now reverse biased configuration. [7]

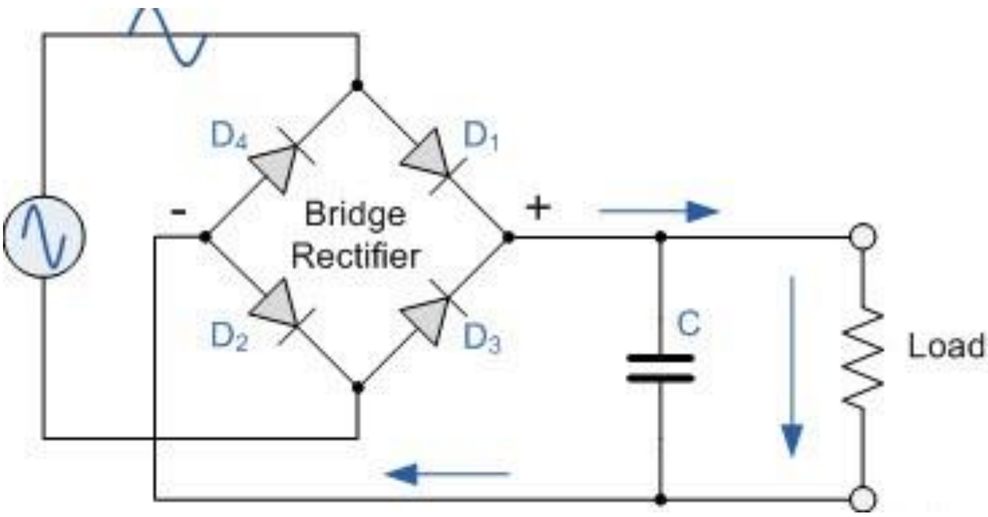



Figure 2.9 Full-Bridge Rectifier

## 2.2 Software Review

PLC ladder logic was designed in the software XCPPro V3.3. Features of software:

- Support two kinds of programming languages: instructions list and ladder diagram and these two languages can convert each other.
- Program encrypted to prevent unlawful copying and modification i.e. password facilities.
- Facilities of adding comments to the program if the program becomes too large.
- Can perform arithmetic operation and logical control.
- Support the connection to GPRS net.

For displaying the output and monitor the system we have to use TouchWin Touch Panel (Model: TH765-N and version V2.c.6). It has the advantages of user-friendly interface, provides a perfect humanized solution for industrial system and makes it easy to control the system. The main features of this software are:

- Adjust the function to touch screen.
- Support multinational language: Japanese, English, and Korean
- Can define the font as we like, support, support underline, italic, bold, shadow.
- User define data collection and saving function.
- Data logging.

The instruction set used during program development are:
STL: This command is used to start the branch for program execution.
STLE: This command is used to end the branch after program execution.
OUT: This command activates the output pin in PLC.
SET: This command is used to set the path for jump instruction.
LD and LDI: This command is used to load the input variable.
TMR: This command is used to delay the operation for a certain time.
MOV: This command is used to move the data between different register.
MUL: It is used to multiply the two data stored in register.
DIV: Used to divide the values sored in register.
EMUL & EDIV: Used to divide and multiply the float value.
FLT: It is used for the floating variable.

# CHAPTER 3
# 3. DETAILS OF PROJECT ACTIVITES

## 3.1 Project Activities

During the project, different algorithms were developed to switch between the sources as per the situations that might be confronted. After subsequent analysis and iterations, a suitable algorithm was chosen and its flowchart was developed. A concrete logic was thus built which was implemented in Grafcet diagram for execution of logic in ladder logic diagram that is understandable by the PLC.

### 3.1.1 Development of Algorithm and Flowchart

Algorithm to switch between supplies:

Step 1: Start

Step 2: Define two input variables X1 X2 to receive sensors input.

Step 3: Check if the input variables are high or low.

a) Is X1 high and X2 low?
   If yes, jump to S1.
   If no, jump to step 3.

b) Is X2 high and X1 low?
   If yes, jump to S2.
   If no, jump to step 3.

c) Is X1 high and X2 high?
   If yes, check for priority and jump to S3.
   If no, jump to step 3.

d) Is X1 low and X2 low?
   If yes, jump to S4.
   If no, jump to step 3.

Step 4: Execute S1, S2, S3 and S4 as per the conditions and respective switches are closed.

Step 5: Repeat the process from Step 3 to Step 4.

Step 6: End

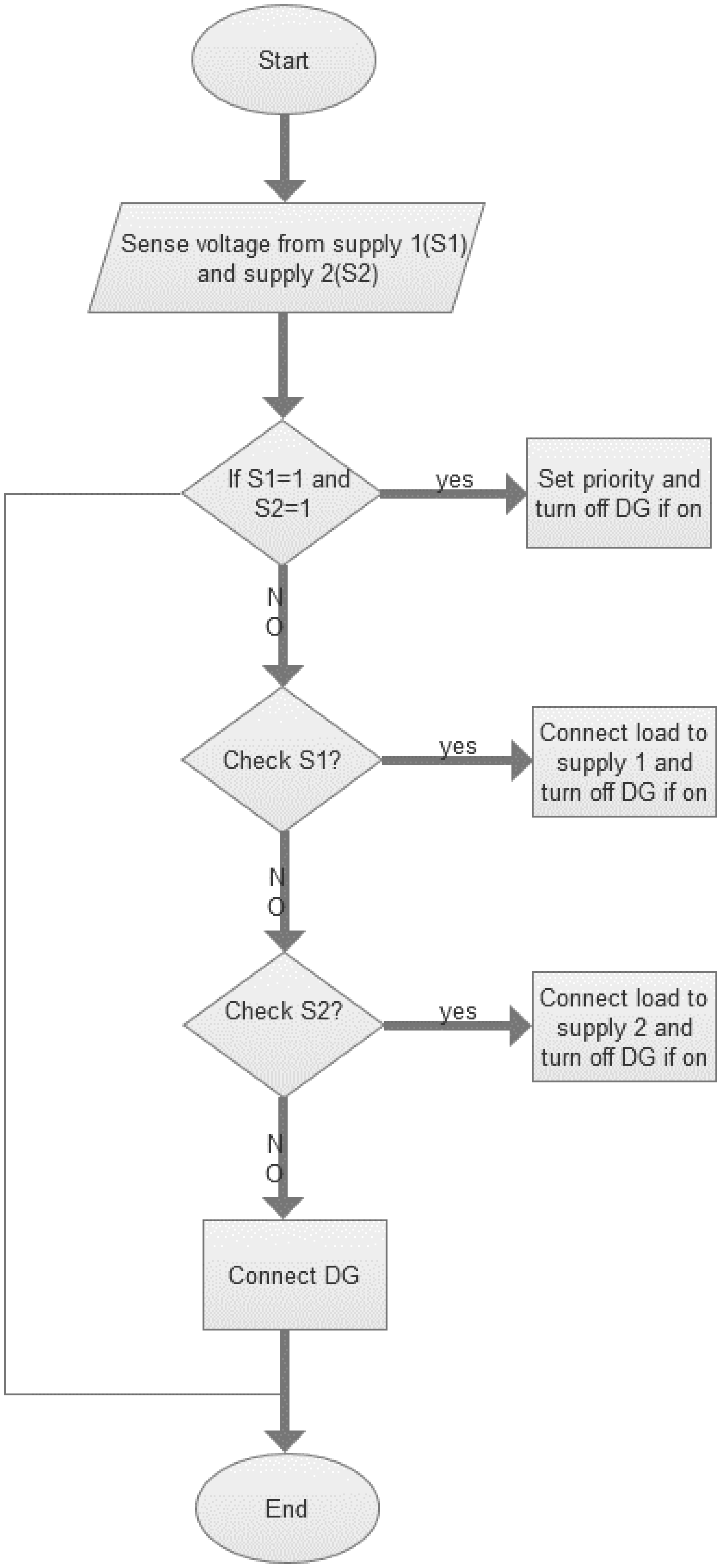



Figure 3.1 Flow Chart

### 3.1.2 Design of voltage and current Rectifier

**a) Voltage Sensing Circuit**

In order to feed the sensor's input to the PLC module; voltage transformer of 12-0-12 and current transformer of 150-5 were implemented. And as the PLC worked on DC value, the obtained AC quantities were converted into equivalent DC values using rectifiers.

We first step down the 220V AC to workable range of 24V AC using a voltage transformer of 12-0-12 rating. Since the PLC takes DC voltage, the AC voltage was rectified to DC voltage using Diode Bridge; however, the DC output still contained ripples which were removed to workable extend using filter circuit of capacitor and resistor combination. The value of capacitor was calculated according to the formula.

$V_{ripple\ (p\text{-}p)} = \frac{I_{DC}}{Cf} = \frac{V_{DC}}{CfR_L}$

$C = \frac{V_{DC}}{V_{ripple(p-p)}R_L f}$

Thus, the capacitor value is calculated as

$C = \frac{24}{24*\sqrt{2}*42*50}$

C = 330 µF

Design of voltage rectifier in multisim is as shown in figure 6

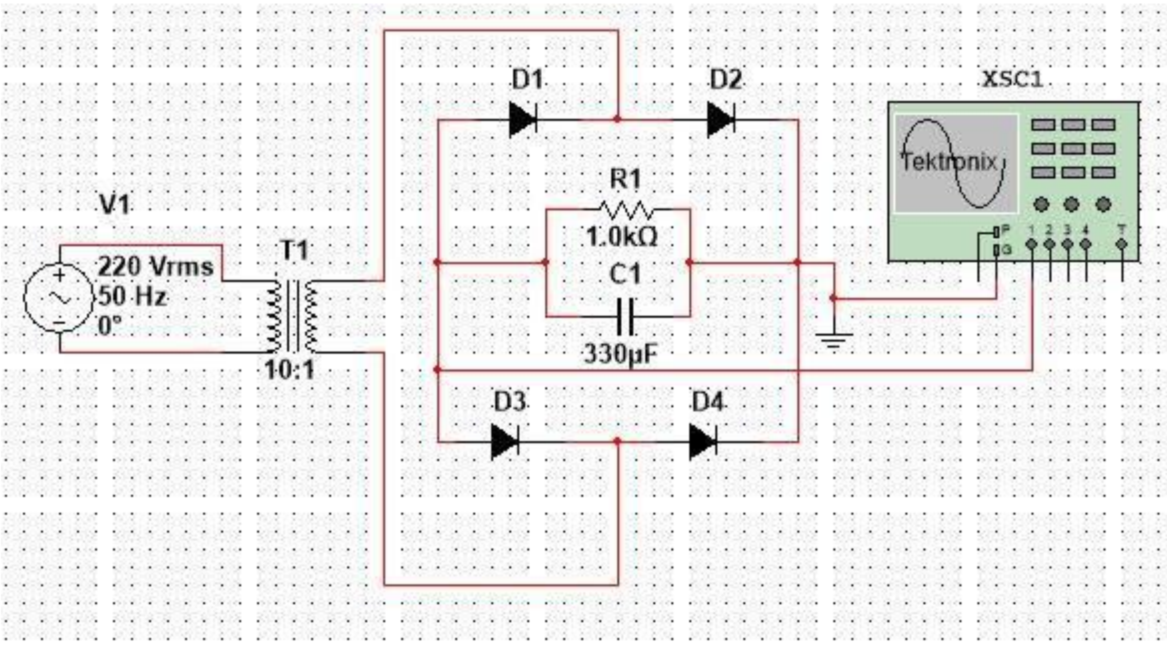



Figure 3.2 Voltage rectifier in multisim

**b) DC input with External Circuit**

The sensed DC voltage is feed into the PLC input port. The relay switch is used in the voltage sensing circuit to give the input to the PLC input ports. One terminal of relay is connected to the common of the PLC and another terminal is connected to the input port of PLC. The circuit diagram of the switching circuit as shown below:

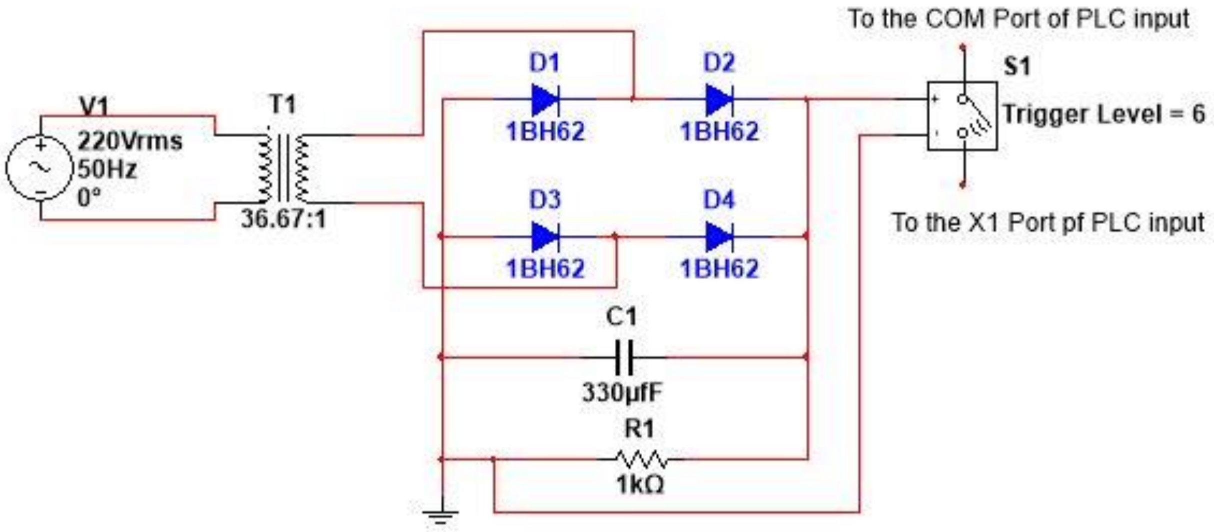



Figure 3.3 Relay Switch for input

**c) Current Sensing Circuit**

The range for primary side peak current = 0 – 150A

Primary Peak current: RMS current * √2 = 150 * √2 = 212.13 A

Peak current is divided by number of turns to give peak current in the secondary side.

Number of turns = 30

Secondary Peak Current $= \frac{\text{PrimaryCurrent Peak}}{\text{Number of turns}}$

$= \frac{212.13}{30}$

= 7.071 A

To maximize measurement resolution the voltage across the burden resistor at peak current should be to one half of the PLC analog reference voltage. Since PLC analog reference voltage = 10V

We have 5V available.

Ideal burden resistance = $\frac{V_{ref}}{2*\text{Secondary Peak current}}$

$= \frac{5}{14.142}$

= 0.353 ohm

Design of the current rectifier in Multisim as shown below.

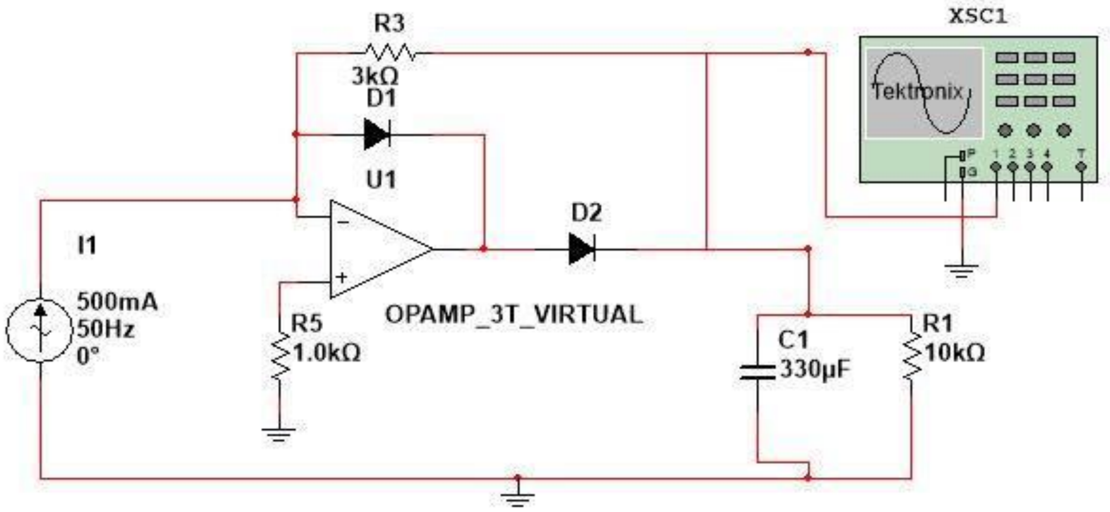



Figure 3.4 Multisim Simulation of the Current Rectifier

### 3.1.3 Development of Grafcet

The Grafcet of the system model is as shown in the figure. This system has three parallel sources channelized to load. In case if either of the supply source is available, the available supply source is selected to transfer power to the load. However, if both the sources are not available then, time is checked to confirm that it is not a false power failure. Once it is confirmed that it is a permanent power failure from utility at both the feeders, generator supplies power to the load. Timer is yet to be implemented in the system. Once the power is restored, another time delay is set to ensure either of utility feeder can supply the load. Then as the source feeds the power to the load, the current drawn by the load is sensed using current sensor. Voltage fed by the source is also sensed by the voltage sensor. Both current and voltage are fed to the PLC for calculating the power drawn by the load.

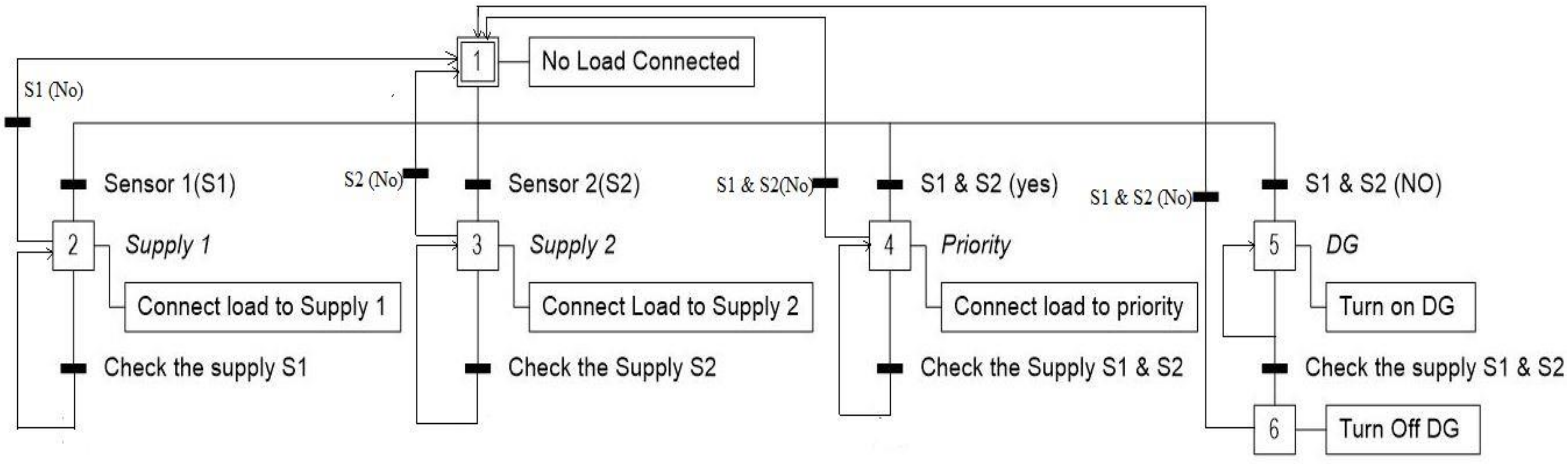



Figure 3.5 Grafcet Diagram Designed System

### 3.1.4 Development of Ladder Logic for switching

The Grafcet diagram gives the layout of the ladder logic. Using Grafcet diagram the ladder logic of switching system was developed in the software model. The ladder diagram is attached later at the appendix. Ladder logic when implemented to the PLC, the rules are executed simultaneously in a continuous loop. The conditions evolved in real environment leads to development of certain scenario which triggers certain rungs of the ladder logic. This executes the desired operations in the real environment and the required output is obtained. Ladder logic for switching of supply as shown in the appendix.

The input and output pin defined in PLC port as shown un table.

Table 3.1 Input and Output Pin of PLC

| Supply | Input Pin | Output Pin |
|---|---|---|
| Supply 1 | X0 | Y0 |
| Supply 2 | X1 | Y6 |
| Generator Supply | X2 | Y2 |

### 3.1.5 Hardware Implementation of Switching System

After completing the ladder logic of switching system, the hardware implementation of switching system was done. The hardware part includes the contactors, relays, CT, PT etc. each sensor outputs were connected to input of the PLC module and the contactors were connected to the output of the PLC module. The output pin of the contactor was connected to the load.

### 3.1.6 Voltage Calibration

Calibration refers to the process of verifying the performance or adjusting any instrument that measure or tests electrical parameters. Sensor calibration plays an important role in instrument development and accuracy. Thus, the voltage and current calibration of the sensor output was done. The voltage calibration was done by the following procedure:

PLC Analog Input bits = 12 bits binary data

So For 10V;

$2^{12}$ bits = 10 V

4096 bits = 10 V

1 bit = (10/4096) V

**Analog Input:**

Analog Input channel (0~10V): 8 channels

Table 3.2 PLC Register specification

| Channel | Register |
|---|---|
| 0CH | ID0 |
| 1CH | ID1 |
| 2CH | ID2 |
| 3CH | ID3 |
| 4CH | ID4 |
| 5CH | ID5 |
| 6CH | ID6 |
| 7CH | ID7 |

Table 3.3  PLC Analog Pin

| Channel | PLC Pin |
|---|---|
| 0CH | VI0 |
| 1CH | VI1 |
| 2CH | VI2 |
| 3CH | VI3 |
| 4CH | VI4 |
| 5CH | VI5 |
| 6CH | VI6 |
| 7CH | VI7 |

**Sensor circuit:**

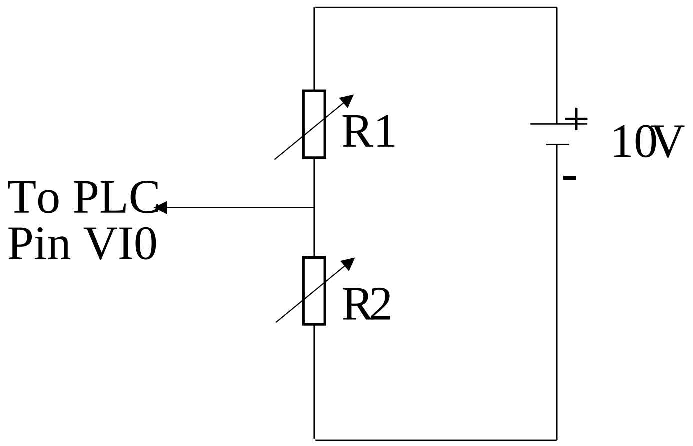
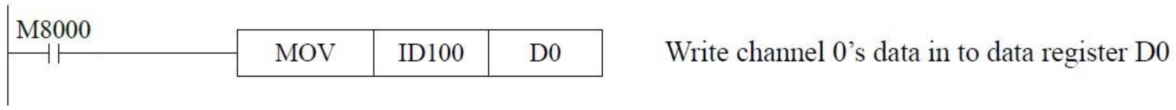



Figure 3.6 Circuit Diagram for Analog Input

**PLC Code:**




Register **D0** will store the voltage across resistor **R2** in the range of (0 to 4095). To get the measured voltage calibrate the value stored in register **D0**.

### 3.1.6 Current calibration

As similar to the voltage calibration, the current was calibrated for the different values of input current and obtained the respective voltages.

### 3.1.7 Provision of Generator Switching

According to the developed logic in Grafcet diagram, whenever there is an outage of the normal supply in both the feeders, backup generator must be started. The backup generator remains standby until there is an outage in both the feeders and is brought to operation as an when needed. This provision is made available through logic implementation in the ladder diagram. For the design consideration of generator switching, a contactor is switched on incase the generator feeds the power to the load.

### 3.1.8 Display of Voltage, Current and Power Calculation

With the aid of current transformers and voltage transformers, sensing of voltage and current was done and accordingly the calibration of those values was done. These values were fed to the PLC and were displayed as voltage and current. Further, these values were stored in respective registers and using instructions as EMUL the power delivered to the load was calculated from respective sources. Thus, the operator can analyze the scenario by reading the power values displayed in the HMI interface. Ladder logic for the calculation of power and energy and design of HMI program as shown in the appendix.

### 3.1.9 HMI System Design

HMI interface that links user or an operator with the predefined program in PLC by continuously monitoring the input and output condition. The operator can give input commands to PLC through HMI.

HMI program was designed in the "TouchWin Edit Tool" software for this project. Switching of power supplies can also be controlled by the HMI. On/Off button are used to control the supplies for the manual operation of the system. The indicators/lamps are used to indicate the output high/low. The lamp button was used for the manual operation of switching. The green color of the lamp indicates the Normally Open (NO) signal and red color of the lamp indicate the Normally Close (NC) signal.


Figure 3.7 Button at NO condition


Figure 3.8 Button at NC condition

While designing the HMI system the address specified in each button must be specified in the ladder logic as an interrupt. The address specifies as:

In figure below address M0 specified for the supply 1 input and Y0 for its output. Thus, same address M0 and Y0 must be used in the ladder logic.

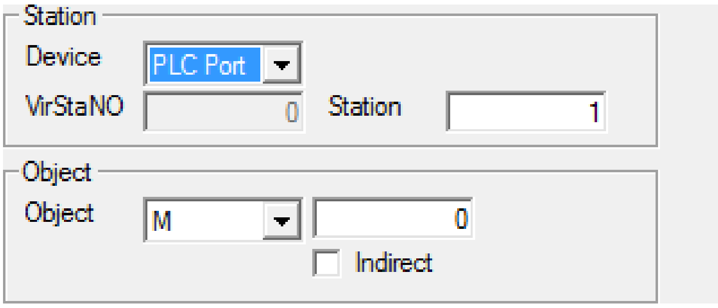



Figure 3.9 Input Address

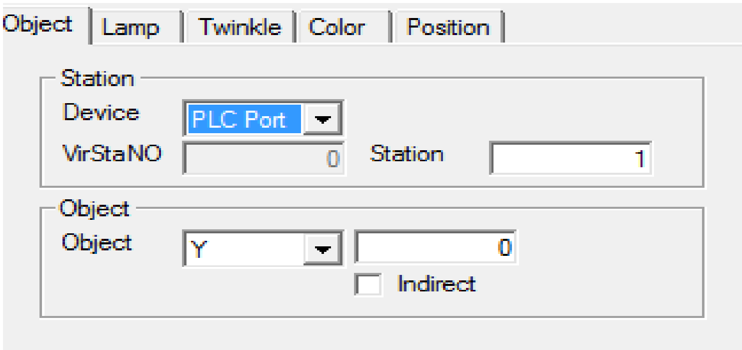



Figure 3.10 Output Address

In this project, we have designed the supply switching window and load profile monitoring window using the HMI device. Supply switching window controls the supplies outputs and load profile monitoring window gives the voltage, current, power and energy value consumed by the load.

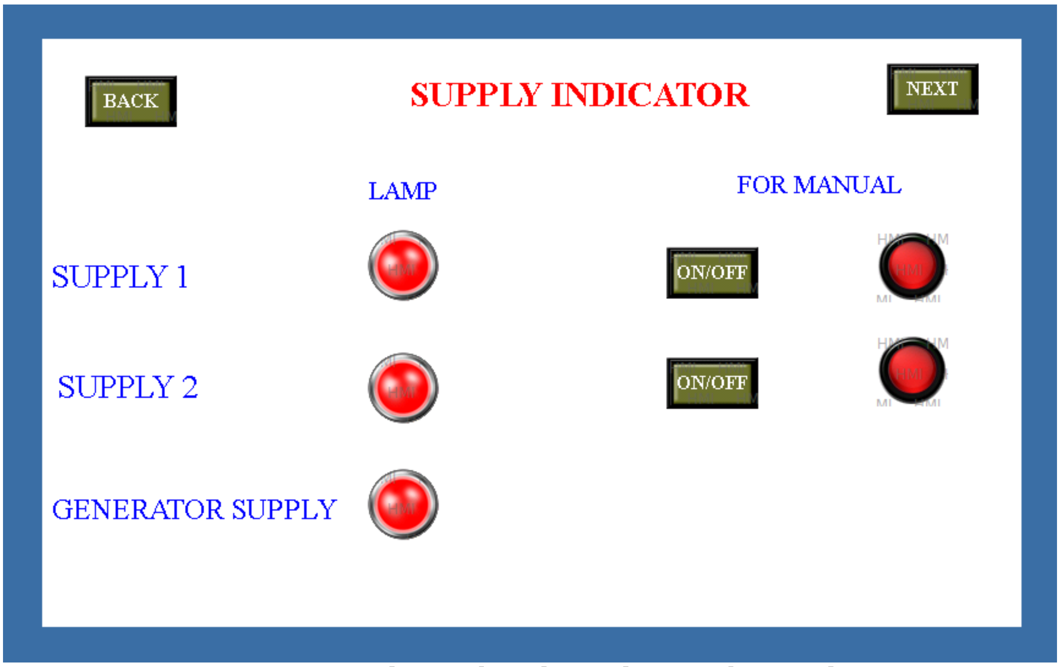



Figure 3.11 Manual Switch and Supply Switching Indicator

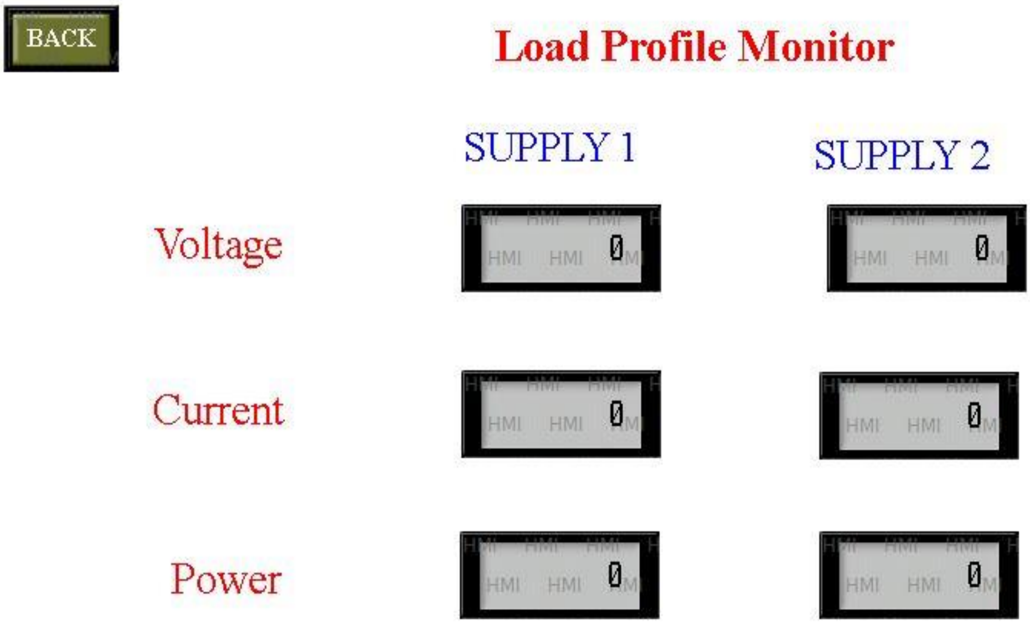



Figure 3.12 Load Profile Monitor

# CHAPTER 4
# 4. RESULT AND DISCUSSION

## 4.1 Simulation Results

### 4.1.1 Voltage rectifier and Current Sensing Circuit Output

As per the circuit designed for the voltage sensing purpose in multisim, the simulation was carried out. And the output waveform of the voltage rectifier is as shown.

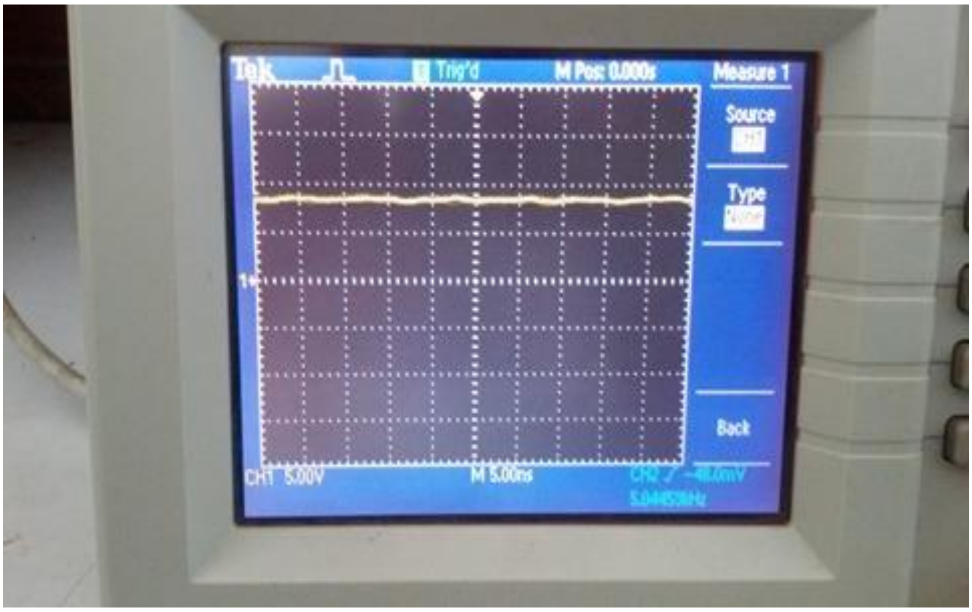



Figure 4.1 Output waveform of the voltage rectifier

Similarly, from the design of the current sensing circuit the simulation result of the output waveform of the current rectifier as shown.

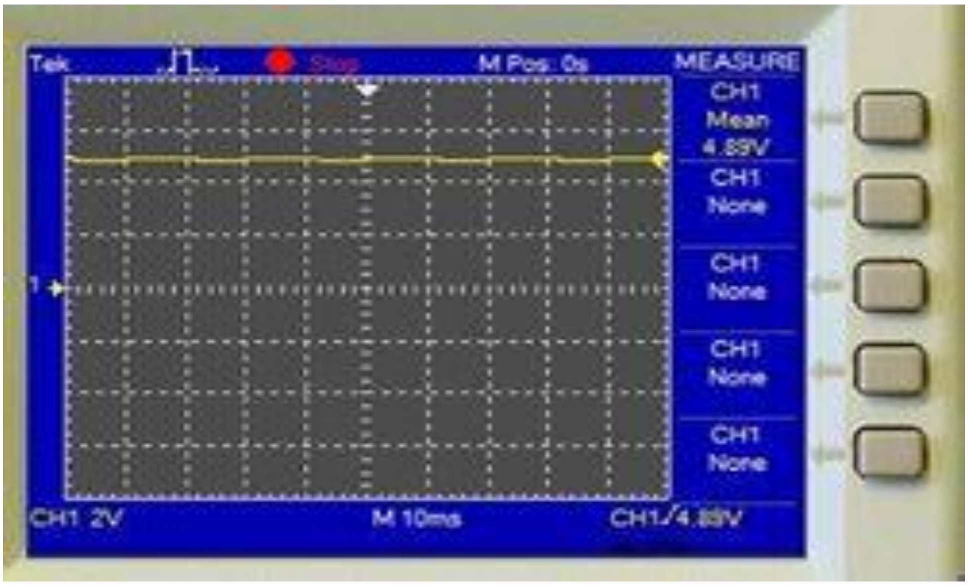



Figure 4.2 Output Waveform of the Current Rectifier

### 4.1.2 Voltage Calibrated Data:

The calibrated data are obtained as follows. For the first sensor the calibrated data and the respected slope of the graph is as shown below:

Table 4.1 Data for Voltage Calibration for supply 1

| DC | AC |
|---|---|
| 7.74 | 220 |
| 7.39 | 211.5 |
| 6.93 | 200.7 |
| 6.57 | 191.3 |
| 6.11 | 180.7 |
| 5.64 | 170 |
| 5.35 | 161.6 |
| 4.84 | 149.5 |
| 4.4 | 138.9 |
| 3.95 | 127.6 |
| 3.51 | 116.8 |
| 3.14 | 108 |
| 2.73 | 97.5 |
| 2.38 | 89.1 |
| 1.6 | 69.6 |
| 1.25 | 60.6 |

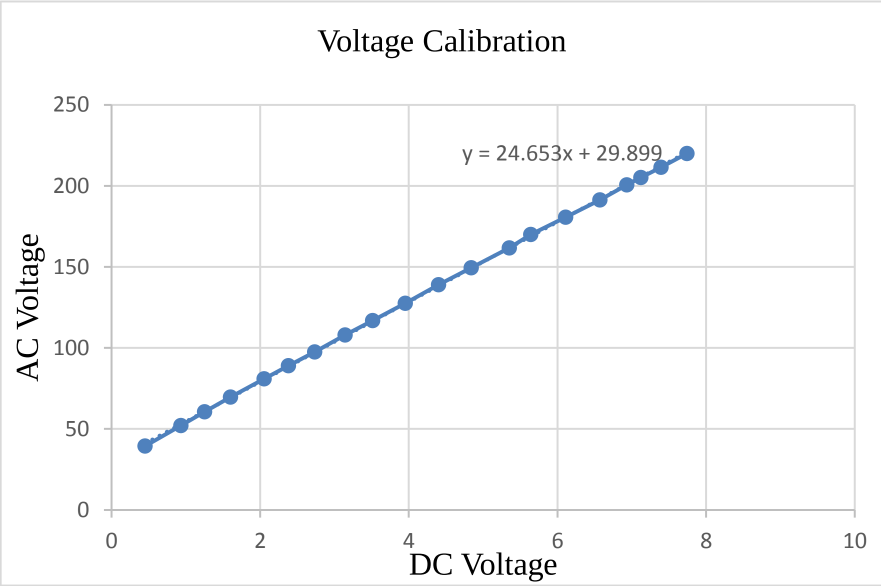



Figure 4.3 Graph for Voltage Calibration of supply 1

Similarly, for supply 2 the voltage sensor calibrated data and the respected slope of the graph obtained as shown below:

Table 4.2 Data for Voltage Calibration for Supply 2

| DC | AC |
|---|---|
| 8 | 220.8 |
| 7.78 | 215 |
| 7.54 | 209.5 |
| 7.36 | 205.6 |
| 7.11 | 199.7 |
| 6.96 | 195.6 |
| 6.73 | 190.6 |
| 6.48 | 184.4 |
| 6.34 | 180.3 |
| 5.88 | 170 |
| 5.4 | 158.7 |

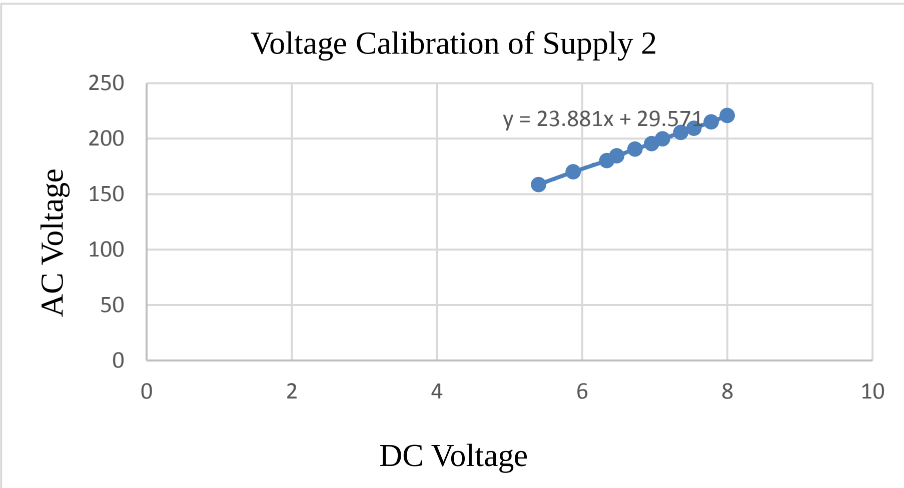



Figure 4.4 Graph for Voltage Calibration of Supply 2

According to the slope obtained from the calibration of sensors, the PLC ladder logic was implemented and it displays the approximate value of voltages for each supply.

### 4.1.3 Current calibrated Data:

The calibrated data for each supply with slope of the graphs as shown below:

Table 4.3 Data for Current Calibration of Supply 1

| voltage | current |
|---|---|
| 7.6 | 6.74 |
| 7.36 | 6.35 |
| 6.85 | 5.58 |
| 6.6 | 5.19 |
| 6.28 | 4.76 |
| 5.88 | 4.25 |
| 5.65 | 3.98 |
| 5.13 | 3.45 |
| 4.88 | 3.25 |
| 4.61 | 3.05 |
| 4.35 | 2.87 |
| 4.03 | 2.61 |
| 3.68 | 2.38 |
| 3.29 | 2.18 |

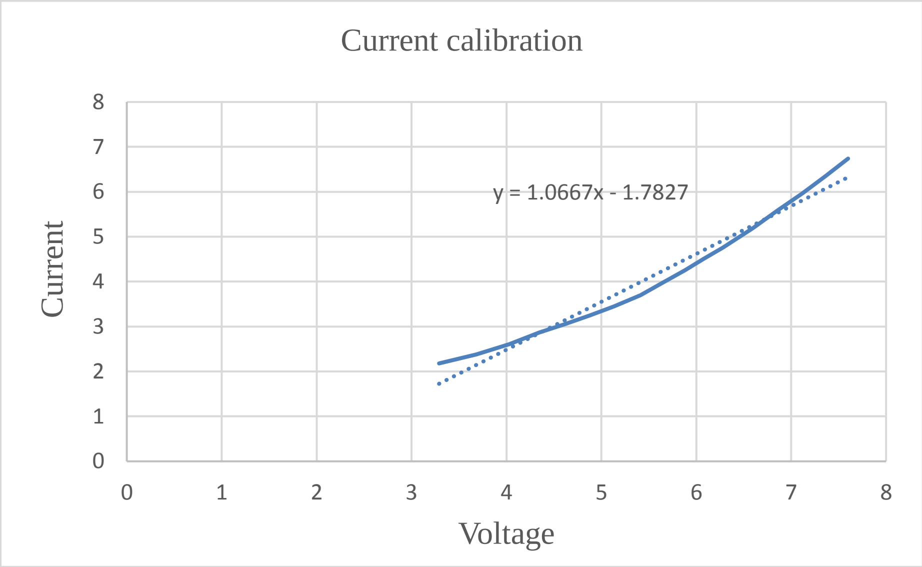



Figure 4.5 Graph for Current Calibration of Supply 1

Table 4.4 Data for Current Calibration of Supply 2

| voltage | current |
|---|---|
| 5.05 | 6.29 |
| 4.78 | 5.75 |
| 4.46 | 5.21 |
| 4.2 | 4.77 |
| 3.92 | 4.29 |
| 3.66 | 3.87 |
| 3.43 | 3.46 |
| 3.19 | 3.07 |
| 2.99 | 2.79 |
| 2.87 | 2.64 |
| 2.75 | 2.48 |
| 2.48 | 2.08 |

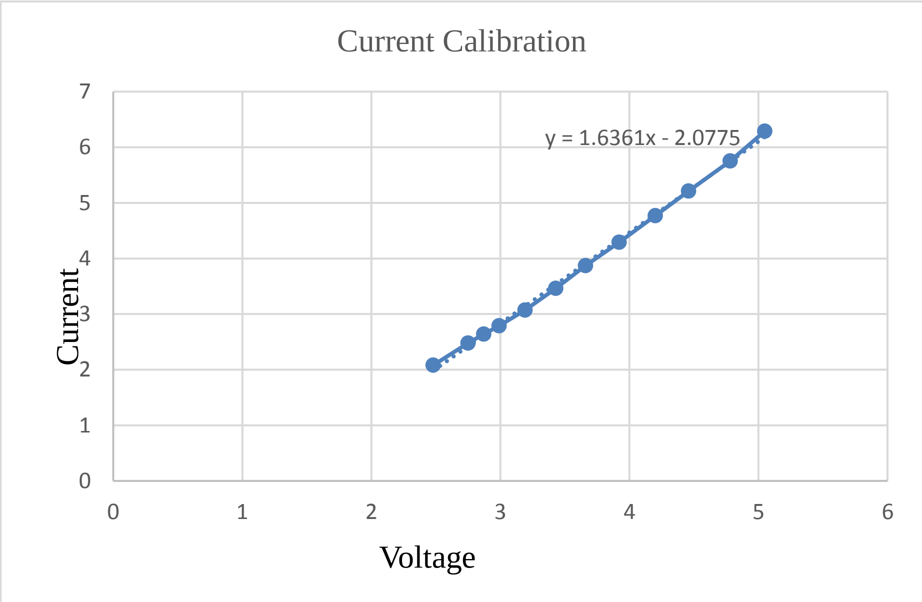



Figure 4.6 Graph for Calibrated data of Supply 2

According to the equation obtained from the calibration data, PLC ladder logic was implemented and it displays the current drawn by each supply.

## 4.2 Gantt Chart

| Month / Tasks | Nov | Dec | Jan | Feb | March | April | May | June | July | Aug | Sept |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Literature Review | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| Proposal Presentation | ■ | | | | | | | | | | |
| Study on coding | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| Study of voltage and current sensor | ■ | ■ | ■ | ■ | | | | | | | |
| Implementation of sensors | | | ■ | ■ | ■ | ■ | | | | | |
| Ladder logic implementation and testing | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Calibration of Voltage and Current sensor | | | | | | ■ | ■ | ■ | ■ | | |
| Study and implementation of HMI | | | | | | | | ■ | ■ | ■ | ■ |
| Assembling | | | | | | | | | | ■ | ■ |
| Final presentation | | | | | | | | | | | ■ |

# CHAPTER 5
# 5. CONCLUSION AND FUTURE SCOPE

This report discusses the detail development of algorithm for supply switching, methodology involved for control operation of supplies, Grafcet and ladder logic development including the entire hardware modeling of the system. This system consists of three different sources; two of which are normal supply from the NEA feeders and the remaining one is a backup generator. Thus, the system can automatically switch between the supplies as when required. Further, the operator can get a realistic view of the system through HMI interface and can also monitor the system parameters using it. However, the system can be made much efficient and the incurred limitations can be overcome.

The future scope of this project is:

i. Developing of much robust system for household and industrial application.
ii. Features of data accumulation can be added and such data can be made available in cloud network for inspection and future use.

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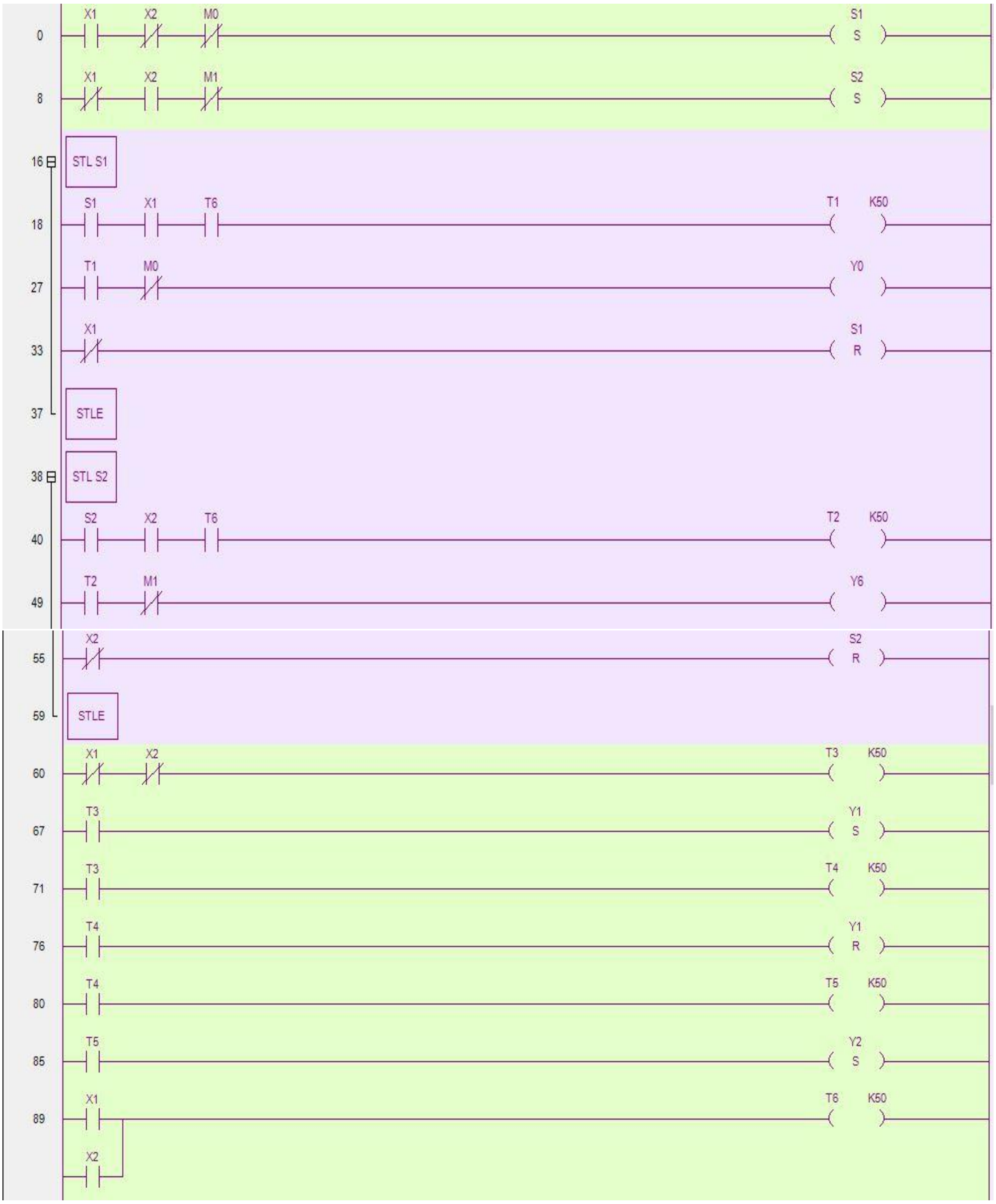
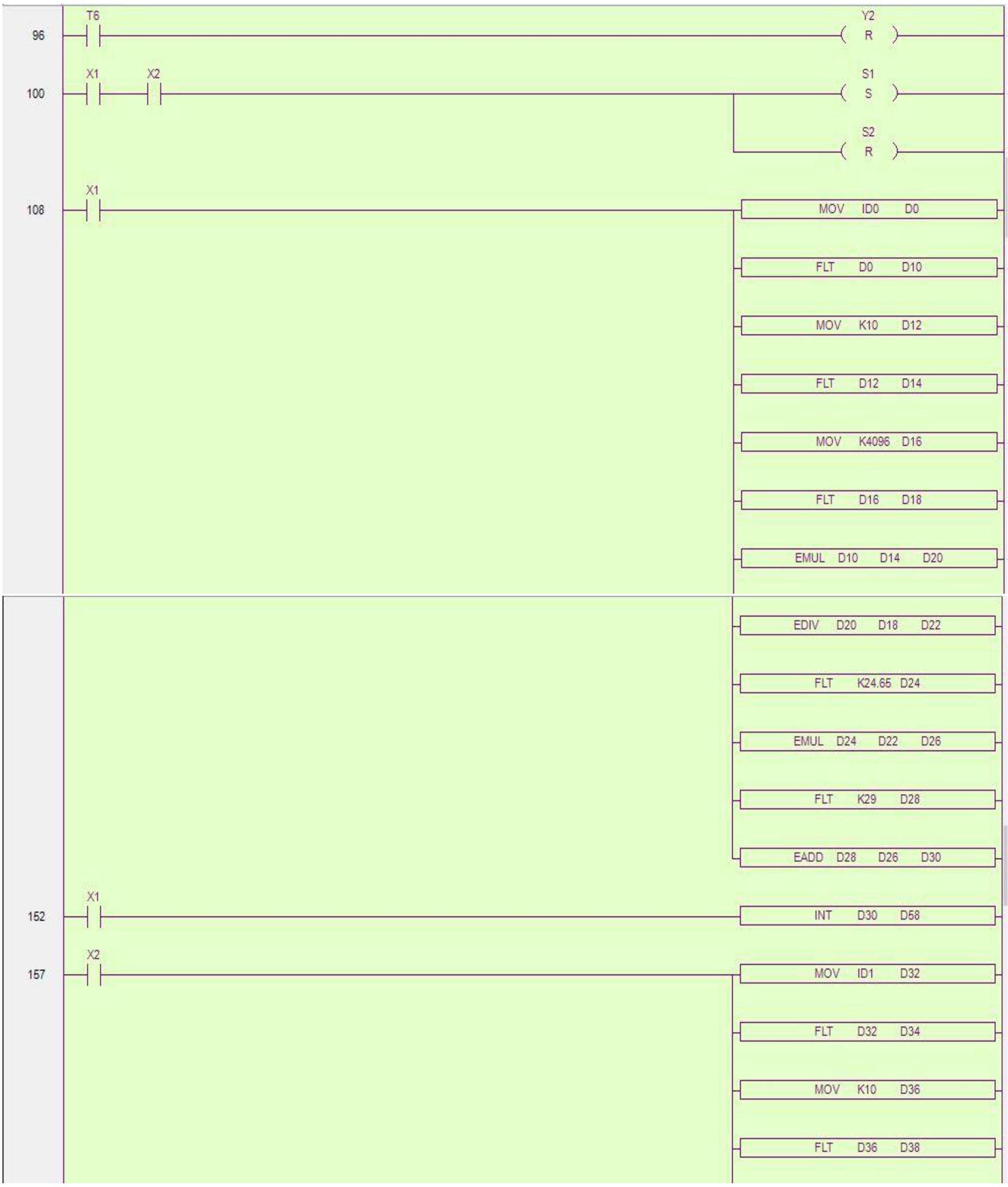
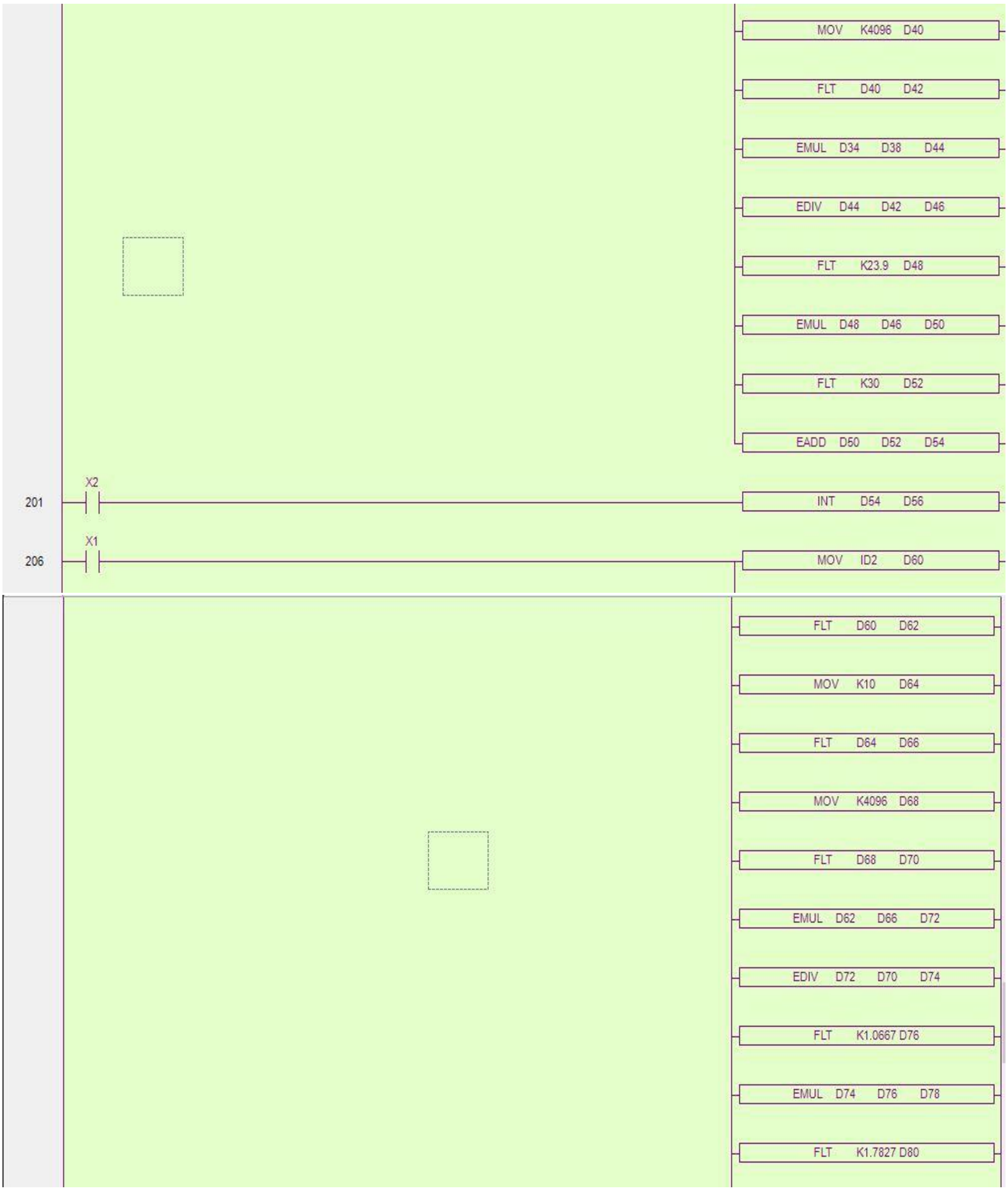
# 7. APPENDIX

## APPENDIX I (LADDER LOGIC)




96
T6
Y2
R
100
X1
X2
S1
S
S2
R
108
X1
MOV ID0 D0
FLT D0 D10
MOV K10 D12
FLT D12 D14
MOV K4096 D16
FLT D16 D18
EMUL D10 D14 D20
EDIV D20 D18 D22
FLT K24.65 D24
EMUL D24 D22 D26
FLT K29 D28
EADD D28 D26 D30
152
X1
INT D30 D58
157
X2
MOV ID1 D32
FLT D32 D34
MOV K10 D36
FLT D36 D38


MOV K4096 D40
FLT D40 D42
EMUL D34 D38 D44
EDIV D44 D42 D46
FLT K23.9 D48
EMUL D48 D46 D50
FLT K30 D52
EADD D50 D52 D54
X2
201
INT D54 D56
X1
206
MOV ID2 D60
FLT D60 D62
MOV K10 D64
FLT D64 D66
MOV K4096 D68
FLT D68 D70
EMUL D62 D66 D72
EDIV D72 D70 D74
FLT K1.0667 D76
EMUL D74 D76 D78
FLT K1.7827 D80

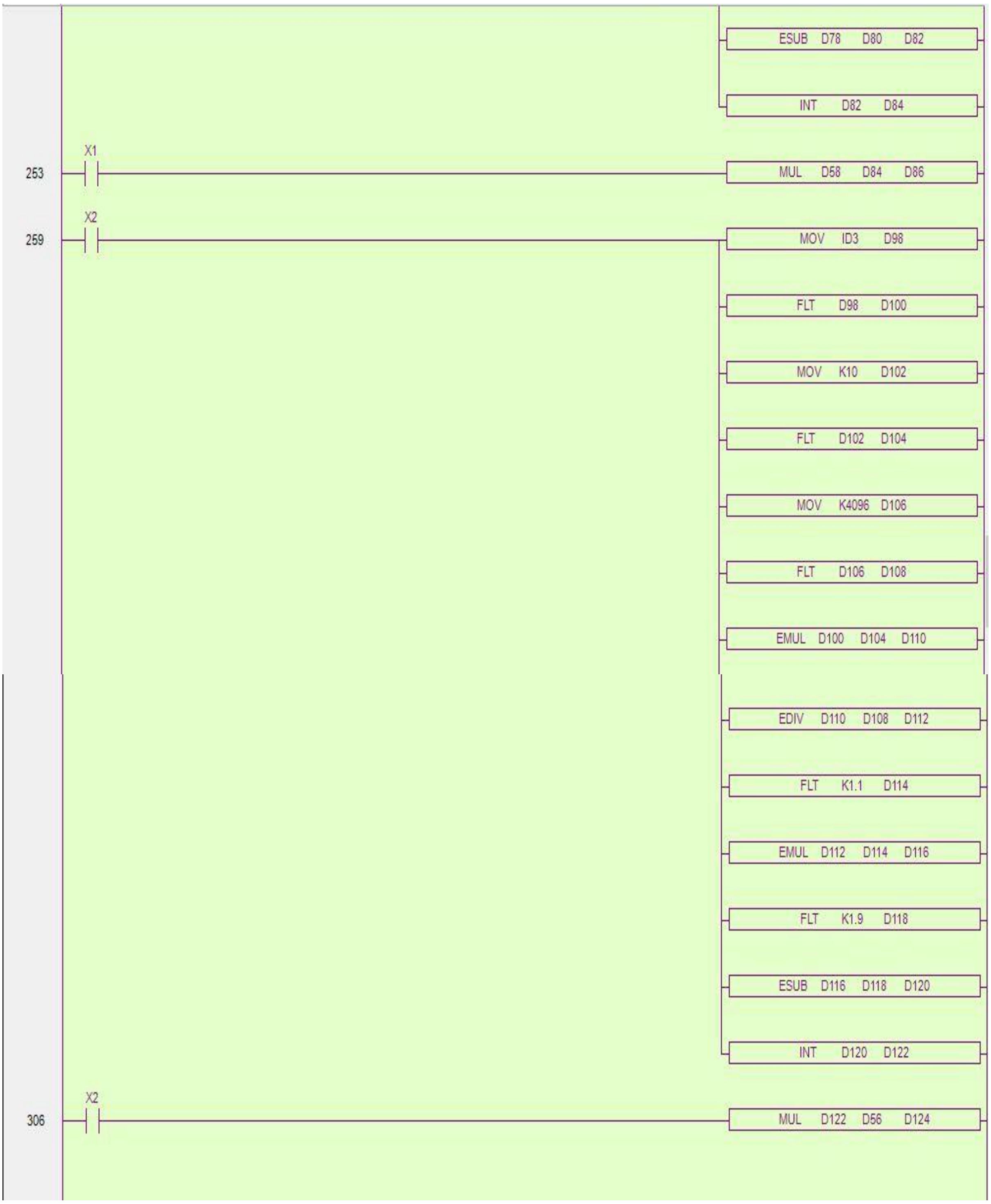



Figure 7.1 Ladder Logic Diagram

## APPENDIX II (HMI)

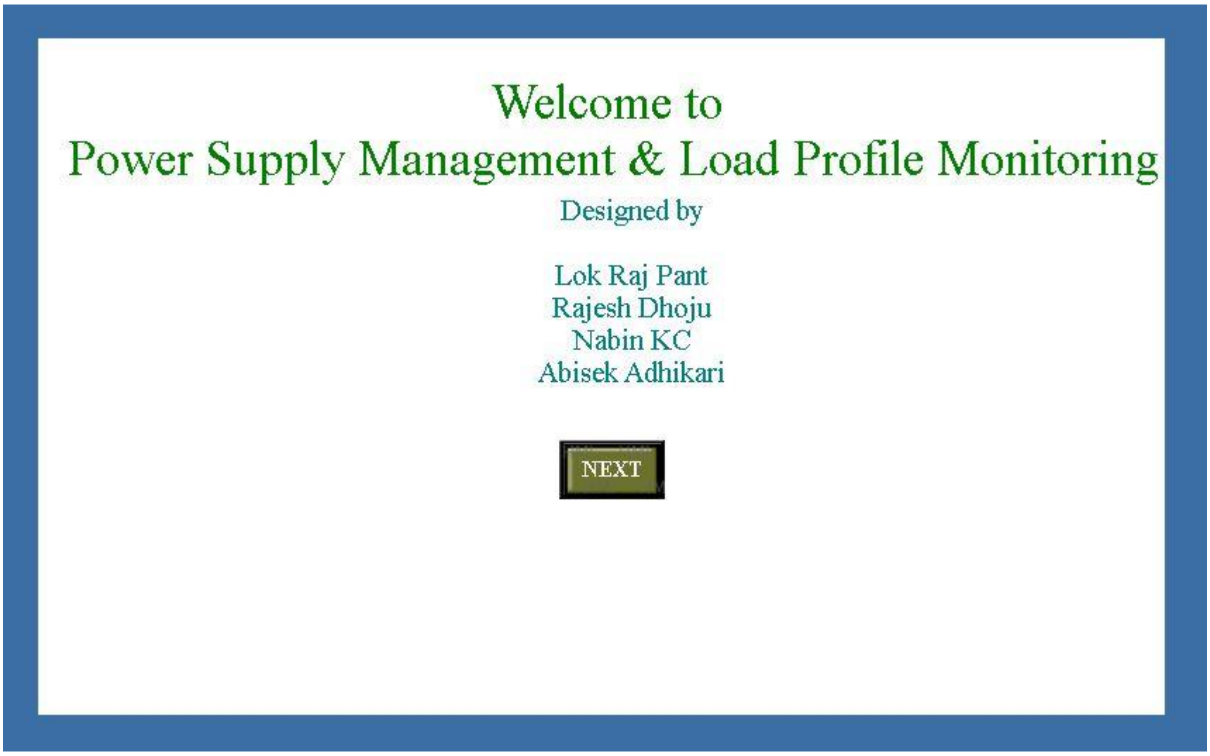



Figure 7.2 Home page of HMI panel

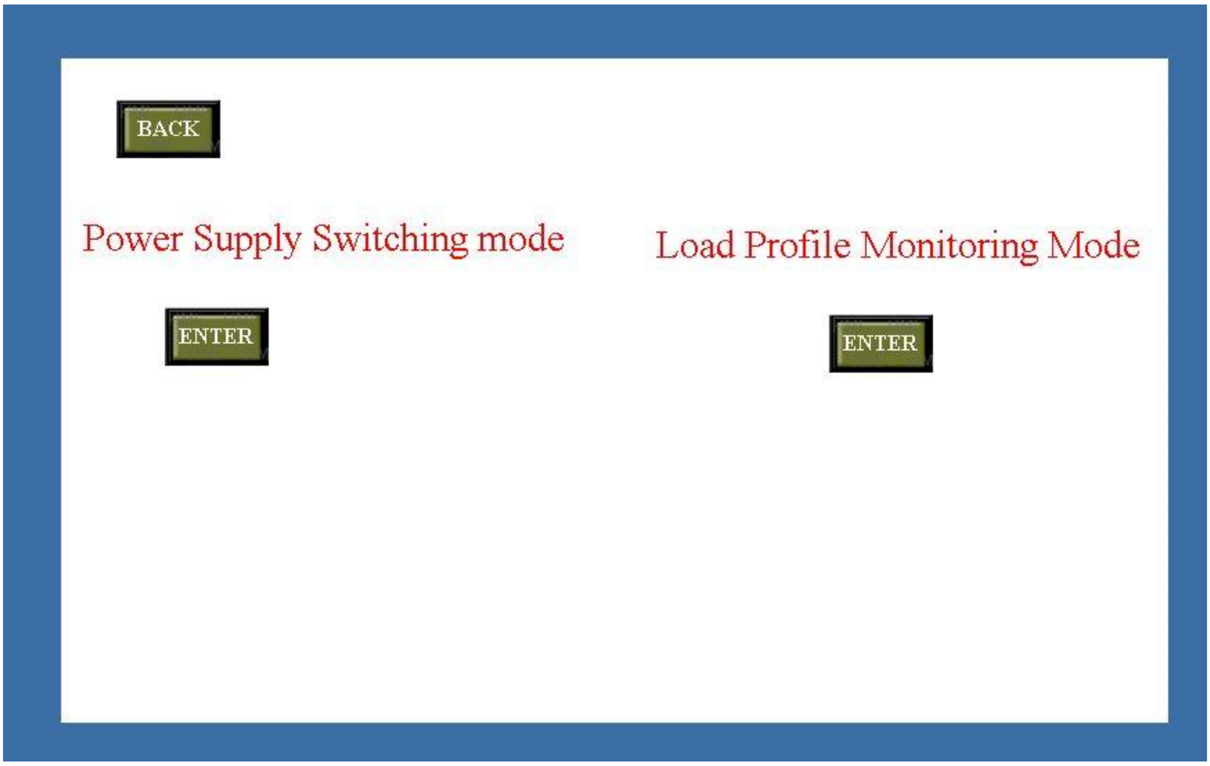



Figure 7.3 Mode Selection Panel

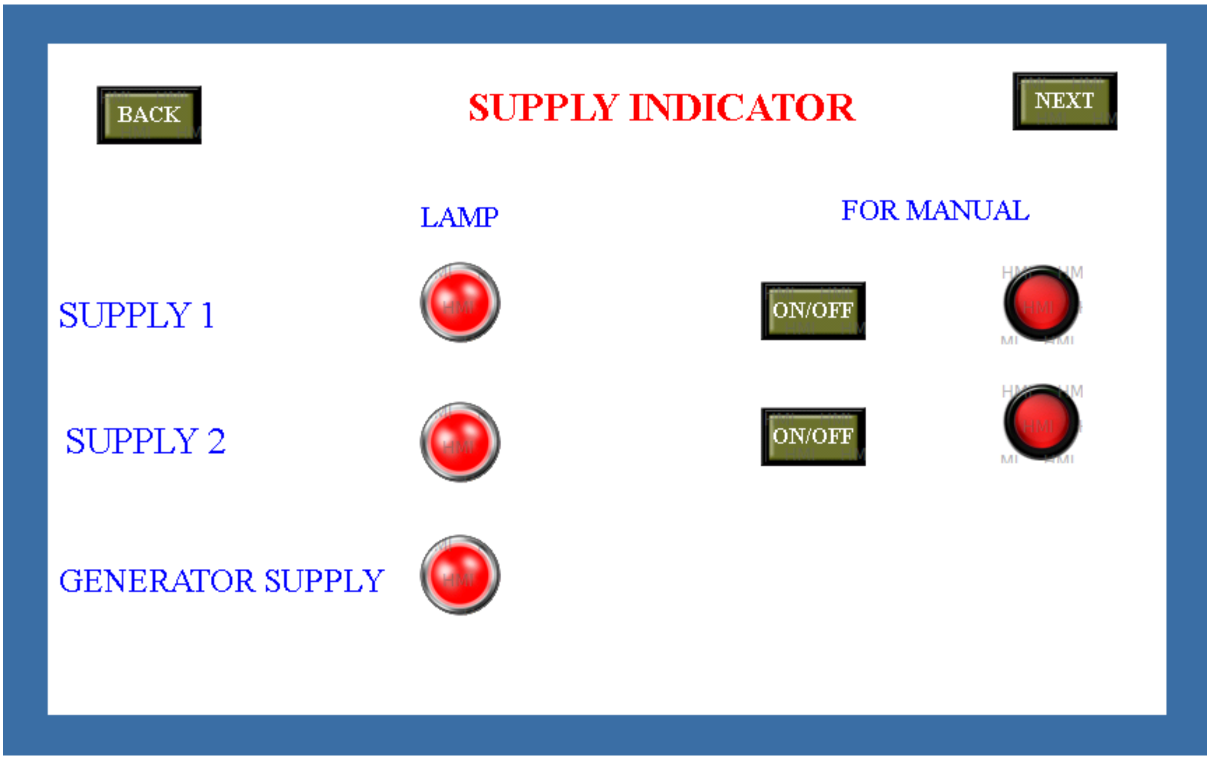



Figure 7.5 Supply Indicator and Manual Switch Panel

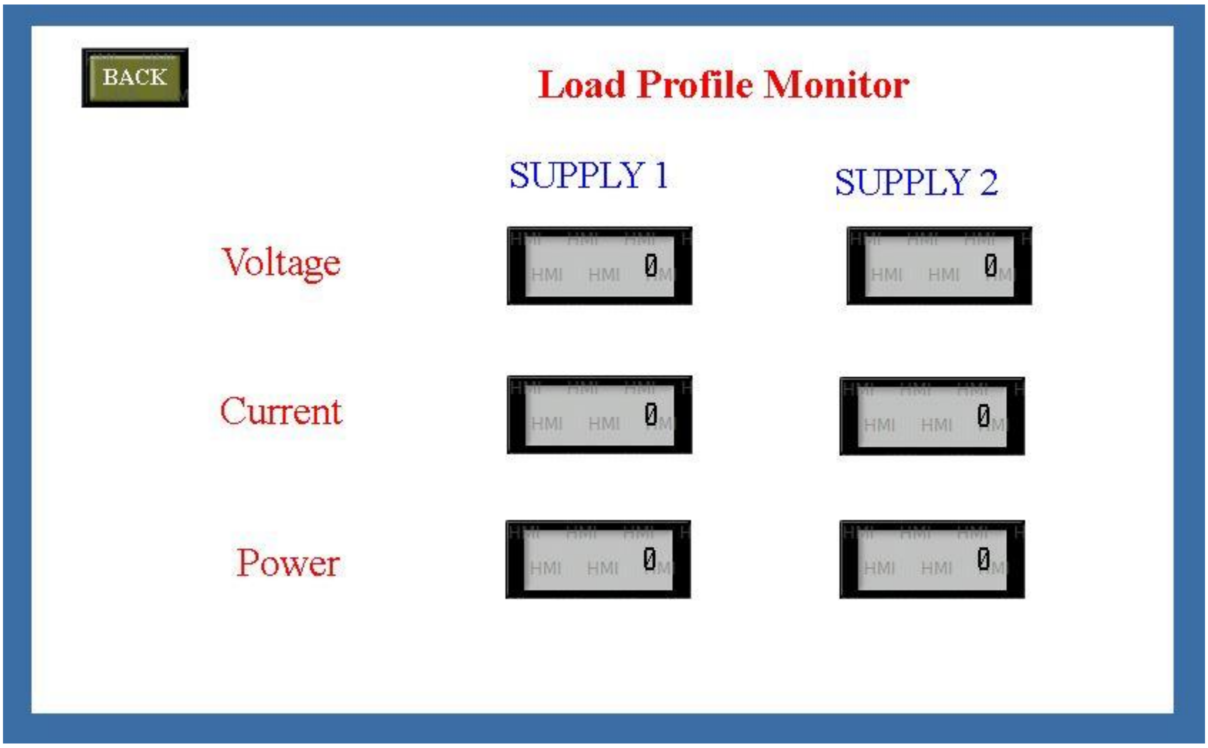



Figure 7.4 Load Profile Monitor Panel

# APPENDIX III (HARDWARE DESIGN)

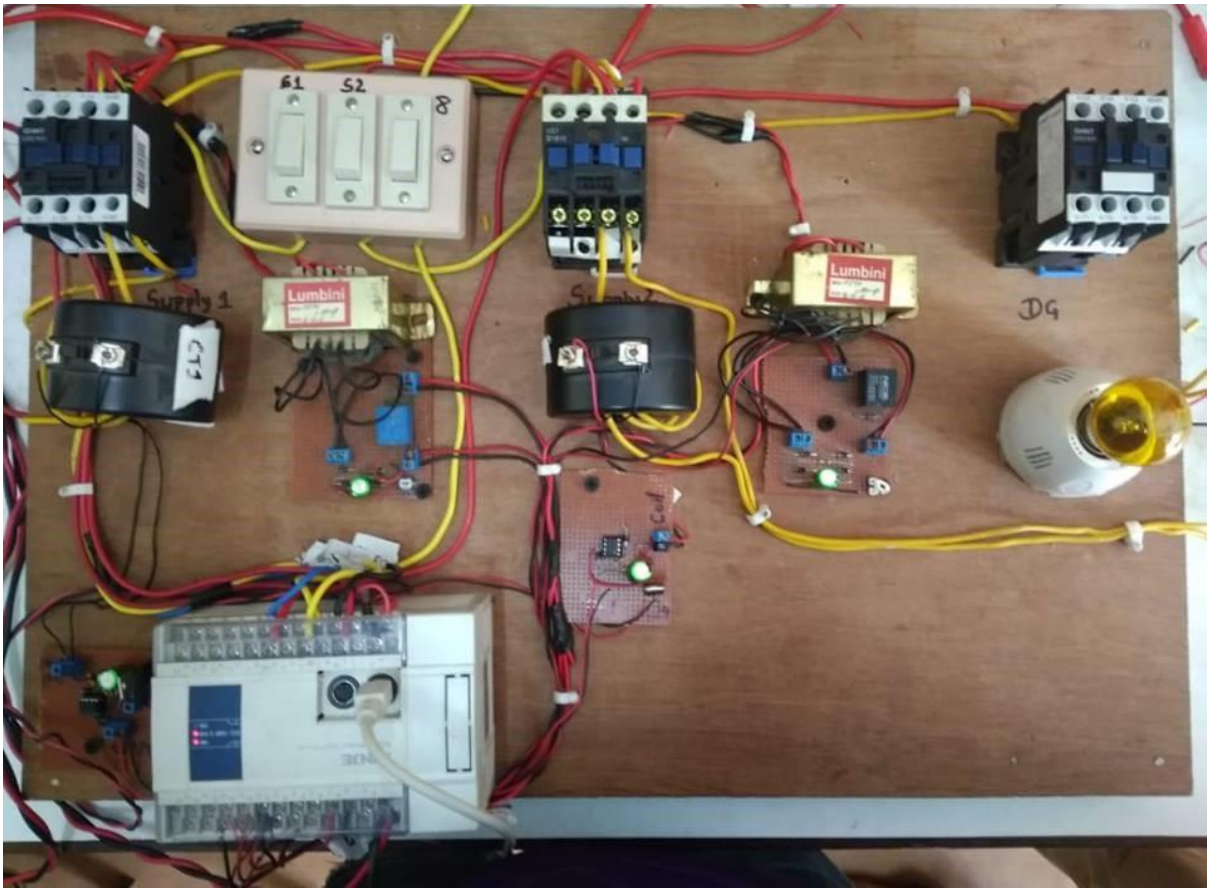



Figure 7.6 Hardware Design