

University of Southern Queensland  
Faculty of Engineering and Surveying

**Remotely Accessible 35 kVA Diesel Backup Generator**

A dissertation submitted by

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In fulfilment of the requirements of

**Courses ENG4111 and ENG4112 Research project**

towards the degree of

**Bachelor of Engineering (Electrical and Electronic)**

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## **Abstract**

Remote access controllers are widely used in many industrial engineering applications. The PLC (programmable logic controller) in conjunction with SCADA (Supervisory Control and Data Acquisition) is used to monitor and control industrial plant and equipment worldwide. Electrical plant systems can be controlled from a singular motor to many hundreds of devices. The remote control can be either hardwired or soft-wired using radio links or the internet. Modern control systems use SCADA to ensure that only authorised people have remote access to plant and equipment. PLCs provide the physical hardware interface layer for the SCADA system. They provide the necessary signal conditioning, isolation, control and communication abilities for a robust and reliable system. This dissertation describes the remote accessibility of a 35kVA Diesel Backup Generator at the University of Southern Queensland for students to access the laboratory experiment locally or remotely. A computer is used as a Mimic or HMI (Human Machine Interface) designed with SCADA Software which is linked to a PLC. The experiment is PLC controlled to enhance safety and improved convenience of performing an experiment, allowing students to align the practical and theoretical components of their courses. This project will focus entirely on the automation and remote control of the 35kVA Diesel Backup Generator at the University of Southern Queensland (USQ) Toowoomba campus.

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**ENG4111 Research Project Part 1 &  
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# Table of Contents

<b>Abstract</b> .....	<b>i</b>
<b>Limitations of Use</b> .....	<b>ii</b>
<b>Certification</b> .....	<b>iii</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>iv</b>
<b>List of Figures</b> .....	<b>x</b>
<b>Chapter 1:</b> .....	<b>1</b>
<b>INTRODUCTION</b> .....	<b>1</b>
1.1 Remote Accessibility of 35 kVA Diesel Backup Generator .....	1
1.2 Background .....	2
1.3 History of the Generator .....	3
1.4 Programmable Logic Controller (PLC).....	4
1.5 Objectives .....	5
Objectives Include:.....	5
Alternative use of the project .....	6
Advantages .....	6
<b>Dissertation Summary</b> .....	<b>7</b>
Conclusions .....	7
<b>Chapter 2:</b> .....	<b>8</b>
<b>LITERATURE REVIEW</b> .....	<b>8</b>

<b>Chapter Outline.....</b>	<b>8</b>
SCADA System.....	9
Software .....	10
SCADA Systems Architecture .....	10
SCADA Architecture .....	11
SCADA Radio Architecture.....	13
PLC.....	13
Ladder Logic .....	14
Digital Input and Digital Output .....	15
Analogue Inputs, Outputs and Internal Memory Bits .....	15
Hardware .....	16
Fuel Solenoid.....	17
Relays .....	17
Switch Contactors .....	18
Pressure Transducer .....	19
Cost Analysis.....	20
Resource Allocation .....	20
Current Situational Factors.....	20
Consequential Effects.....	21
Implementation.....	23

Conclusion.....	23
<b>Chapter 3.....</b>	<b>24</b>
<b>DESIGN METHODOLOGY .....</b>	<b>24</b>
Planning phase.....	24
Literature Review .....	24
<u>Investigate the Alternative Remote Controller.....</u>	25
Identifying System Components .....	26
<u>Hardware and Software .....</u>	26
Risk Assessment.....	28
Existing.....	28
Resource requirements .....	30
PLC and SCADA Software.....	31
<b>Conclusion.....</b>	<b>31</b>
<b>Chapter 4.....</b>	<b>33</b>
<b>SYSTEMS DEVELOPMENT AND IMPLEMENTATION .....</b>	<b>33</b>
User Machine .....	34
System logical overview .....	36
HMI and SCADA Mimic .....	36
Systems main menu.....	38
System main menu .....	38



Generator Standby Push Button (Gen Standby).....	39
Fuel Solenoid Push button: .....	39
Generator Start/ Stop Push Button .....	40
Generator Stop Push Button .....	40
Fan Push Button .....	41
Load#1, 2, 3 Push Button .....	41
Fuel Gauge and Odometer.....	41
Smoke.....	42
Detail View screen .....	43
System Screen .....	44
System screen.....	44
PLC.....	44
PLC Instruction in the memory .....	45
Features Incorporated Into Programmable Controller Logic .....	46
Systems operations .....	46
The Generator Start/ Stop.....	48
<b>Stop Subroutine .....</b>	<b>50</b>
<b>CHAPTER 5: .....</b>	<b>53</b>
<b>RESULTS DISCUSSION and CONCLUSIONS .....</b>	<b>53</b>
Types of test .....	53

Simulation test.....	54
Test per Component .....	56
System Test .....	<b>Error! Bookmark not defined.</b>
<b>Conclusion.....</b>	<b>57</b>
<b>6 APPENDICES.....</b>	<b>58</b>
<b>Appendix A: PROJECT SPECIFICATION.....</b>	<b>58</b>
<b>APPENDIX B.....</b>	<b>59</b>
<b>PLC Program Code.....</b>	<b>59</b>
<b>Appendix C .....</b>	<b>66</b>
<b>Bibliography .....</b>	<b>66</b>
Characteristics of RS485 compared to RS232, RS422 and RS423.....	66
Multi internet based point, with internet protocol.....	69
Multi –Radio Controllers Remote Systems.....	70
Typical Small Generator Distributions Systems .....	71
<b>References: .....</b>	<b>72</b>

## List of Figures

FIGURE 1.1: DIESEL BACKUP GENERATOR .....	3
FIGURE 1.2: PLC IN OPERATION .....	4
TABLE 2.1 SOME OF AUSTRALIAN UNIVERSITIES WITH REMOTE SYSTEMS .....	10
FIGURE 2: SCADA ARCHITECTURE .....	<b>ERROR! BOOKMARK NOT DEFINED.</b>
FIGURE 2.1: SCADA SYSTEM .....	11
FIGURE 2.2: SCADA WIRELESS CONNECTIVITY .....	12
FIGURE 2.3: PLC HARDWARE .....	14
FIGURE 2.4: PLC'S CODE SCREEN SHOT .....	14
FIGURE 2.3 OPTOISOLATOR .....	15
FIGURE 2.4: FREEWHEEL OR FLYBACK DIODE CIRCUIT .....	16
FIGURE 2.5: RELAY CIRCUIT .....	18
FIGURE 2.6: CONTACTOR.....	19
FIGURE 2.7:PRESSURE TRANSDUCER AND CIRCUIT DIAGRAM .....	20
FIGURE 4.1 SYSTEM OVERVIEW .....	34
FIGURE 4.2: SYSTEM HIERARCHY .....	36
FIGURE 4.3: SCADA WELCOME SCREEN.....	37
FIGURE 4.4: SCADA MAIN MENU .....	38
FIGURE 4.5: SCADA DETAILS SCREEN .....	43
FIGURE 4.6: SCADA SYSTEMS STATE .....	44
FIGURE 4.7: BLOCK DIAGRAM OF A PLC .....	46
FIGURE 4.8: MAIN SUBROUTINE .....	48
FIGURE 4.9: START SUBROUTINE.....	49
FIGURE 4.10: STOP SUBROUTINE .....	50
FIGURE 3.11 FAULT SUBROUTINE.....	52
FIGURE 5.1 .....	55

## List of Tables

TABLE 1: TEST.....	56
TABLE A.1 PLC TAGS .....	65
FIGURE 4: RS485.....	66
FIGURE 5 SCADA REMOTE LINKS.....	68
FIGURE A.6 SCADA MULTIPLE REMOTE ACCESS .....	69
FIGURE A.8 SMALL POWER DISTRIBUTIONS.....	71

## **Chapter 1:**

### **INTRODUCTION**

Remote accessibility of Backup generators fits into the category of engineering automation, it allows students to calculate running costs and plant efficiency. To achieve a preset set of conditions or to conduct an experiment, students investigate and observe the relevant data while a specific test is performed. Ideally all students would conduct such experiments locally in the laboratory, however many are unable to physically attend as they are studying via distance education. Whether students are accessing the laboratory locally or from a distance, the key learning objectives are the same.

#### **1.1 Remote Accessibility of 35 kVA Diesel Backup Generator**

In the content/context of this research project, an experimental laboratory experiment has been specially set up by a technician for students to operate a (Diesel Backup Generator remotely. It will use a computer with a designed SCADA Mimic or HMI (Human Machine Interface) linked through the SCADA System to the PLC.

## 1.2 Background

Currently there are a number of many remotely accessible laboratories in Australia, several of which are used for educational purposes. : show some of Australian's Universities, which has remotely accessible laboratories. Many remotely accessible laboratories have web-based system which allows students to perform their experiment remotely. A typical example is the remote laboratories of the University of Technology (Sydney) which uses a web server. The web server allows students to host the website to interface with the remote laboratory and communicate with the host computer. This operates at a student's residential place over the internet. It gives students some choices not to travel to the university to access the laboratory equipment. There are also soft applications that have been developed, to meet this requirement. One application developed at the University of Western Australia It is a remote laboratory which is a bit different from others. It permits students to connect to the systems to perform experiments as a group, sharing control over the actions that are taking place. This remotely accessible laboratory operates by a series of software packages that are installed and run on the client computer to control the experiment (*Tellabs Project 2007*). Australian

### 1.3 History of the Generator

The 35kVA Diesel Backup Generator is a Dunlite power generator bought by USQ in 1983. The generator is capable of delivering 38kVA on standby and 35kVA on operation. It operates on Diesel fuel and operates at 1500rpm (revolution per minute), with three phases 415volts, 50Hz. feeding to a resistive load bank. It has serviced the University for 27 years. However, the university has decided to provide remote accessible controller. It is believed that this remote controller will extend its functionality and laboratory usefulness the program controller will be dedicated for this machine's operations it will have a PLC and SCADA program, which will be used in conjunction with existing and additional hardware

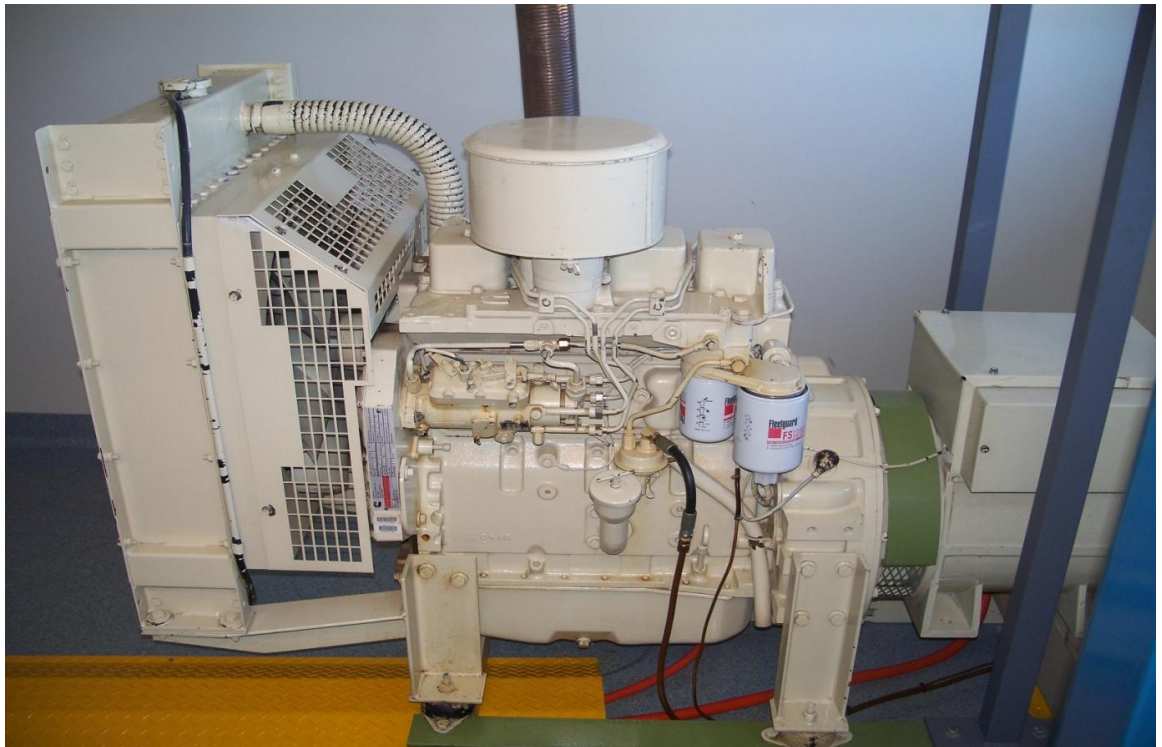


Figure 1.1: Diesel Backup Generator

## 1.4 Programmable Logic Controller (PLC)

A Programmable Logic controller is a device which is capable of being programmed to execute logical control functions. In addition to logical basic functions Boolean control elements mathematic and program sequencing instructions are included Data comparison is an extremely useful programming tool that allows input to be energised depending on whether the data in one memory location are greater than or less than the current data in respect to the instruction being executed by a program counter.. Scaling is another important application of math functions, because it allows numbers which are very large or small to be down scaled or up scaled. This is carried out by multiplying or dividing the memory location by a constant which converts different input data to much of the content of the memory location. The PLC will be a link between the hardware and software and the program will be stored in non volatile PLC memory. In addition, the SCADA HMI will visually display operation of the System.



Figure 1.2: PLC in Operation



## **Supervisory Control and Data Acquisition (SCADA)**

SCADA provides management with real-time data on production operations; implements more efficient control paradigms, improve plant and personnel safety, and reduce cost of operations. These benefits are possible by the use of standard hardware and software in SCADA systems combined with improved communication protocols and increased connectivity to outside networks such as the internet. If the system is connected to the internet system security needs to be considered vulnerability to attackers or erroneous actions give external sources.

### **1.5 Objectives**

The aim of this research project is to implement a remotely accessible laboratory experiment with a Diesel Generator experiment. This experiment is one of the electrical and electronic experiments at the University of Southern Queensland, Toowoomba Campus. The SCADA programme will operate on a PC computer system. This computer will be physically connected to a PLC. The PLC controls logical functions and provides an interface for digital and analogue signals. The operational software for PLC is calling STEP 7 Micro/WIN.

#### **Objectives Include:**

- ❖ To allows students to perform their experiment remotely in a safe and quiet environment free from noise, dirt, and bad smell of diesel fuels.
- ❖ To prevent inhalation of diesel exhaust fumes containing carbon monoxide. (CO)
- ❖ To allows students to obtain accurate measures of consumption. Students can obtain accurate measurements of fuel consumption and at various load levels may compare fuel consumption rates and determine generator efficiency.
- ❖ To teach students how to use remote access with PLC
- ❖ to reduce the risk of electrical shock as student are experimenting with 415 V equipment To allow future research and efficiency monitoring of different fuel Bio fuels

## **Alternative Use of the Project**

Besides student usage at the University of Southern Queensland, it is also possible that any member of the community can use the system concepts e.g. It could be ideal for farmers in a rural area operating their own Generators

There are many reasons to a diesel power generator remotely for several reasons, one of which is, the fact that it can be situated some kilometres away to avoid noise pollutions. It would be conceivable to have a remotely monitoring panel in an operator's living room for example.

## **Advantages**

The project can be used to meet these requirements.

- ❖ Allow a machine to be operated at operator's comfort (day or night)
- ❖ allow operation in inclement weather
- ❖ Reduce noise exposure
- ❖ Easily operated
- ❖ Safe operation
- ❖ Enhanced preventing helping Secure to children and inexperienced operators (use of operator password)
- ❖ pre run fault checking test (coolant, engine oil, fuel levels, battery power)

## **Dissertation Summary**

To allow the smooth flow of the dissertation and to meet the project objectives the document will follow the academic dissertation structural guidelines provided in the course specifications.

**Chapter 2:** covers the literature review of the components used to make this project successful, the use of SCADA system and PLC features.

**Chapter 3:** outlines the project design methodology and structural approach to implementing the project.

**Chapter 4:** describes the system development and implementations; showing how the components in the previous chapter were used in the design.

**Chapter 5:** will discuss the results provided by the project during the test.

**Chapter 6:** will summarize the project outcomes and usability. This chapter will provide the future recommendations about the benefits and possible improvements.

## **Conclusions**

This chapter has provided the overview of the subsequent chapters, an overview of each chapter and brief explanation of the components used. A brief background history of the main systems were also included.

## **Chapter 2:**

### **LITERATURE REVIEW**

Supervisory Control and Data Acquisitions (SCADA) system is the modern component used to control industrial plants or equipment. The system is widely used in the recycling plants, water treatment and manufacturing processes etc. The system provides the user with good management of real-time data in the operation of the plant being controlled. SCADA systems maximize profit, reduce production times and increase the safety standard of the equipment for the operator. This chapter will cover the basic principles of SCADA and Programmable Logic Controllers (PLC) from their basic characteristics to their controlling signals, functional features, applications and security measures.

### **Chapter Outline**

The chapter will look at the following components, in terms of functionality, limits of use and advantages.

- ❖ SCADA Systems
- ❖ PLC
- ❖ Valve Solenoid
- ❖ Relays
- ❖ Pressure transducer
- ❖ Contactors and Potential effect

## **SCADA System**

SCADA systems have many data transmission and execution techniques and these techniques allow SCADA to stand out from traditional remote control devices e.g. programmable relays and microcontrollers. Our SCADA system connected to the PLC has the capacity of accessing 32 personal computers and the ability to remotely monitor and access data through a web server, allowing data logging, alarm handling and notifications by SMS and e-mail. A number of these features are used in the implementation of this project. Research has found that, there are many companies who are currently using these systems, one of which is Ergon Energy for its smart-grid program in Queensland, Australia and Toowoomba regional council for water management plants, waste management systems and recycling plants. By reading through the SCADA system literature a clear concept of how to work with PLC and SCADA systems was learned.

Currently a number of universities across Australia are now investigating SCADA and PLC based technology for remote access of their laboratory experiments. Upgrading their systems to keep pace with rapidly growing technologies. Table2.1: shows a list of some of Australian universities which are currently using remotely accessible laboratories.

Table 2.1 Some of Australian Universities with Remote Systems

University	Software operation	System	Acknowledgement	Implementation
Curtin University of Technology	Redevelopment		Video and audio	Mat Lab and tight VNC
Deakin University	Hardware	Web browser, PLC	Video feedback	
Sydney University Technology	Software based	PLC and web browser	Video and audio	C and Unix Shell
University of Wollongong	Redevelopment	PLC Web Browser	Still images	C and Perl CGI
University of Western Australia		Software and web browser		

### Software

There was a number of software used in this project, some of the software will be use to write a program code, some will be using to graphical map the systems. Simatic WinCC Flexible 2008, this program will be use to design the graphical representation of the Diesel Generator Plant on the on the PC. Step 7 Micro Win will be used to program PLC.

### SCADA Systems Architecture

The SCADA Architecture is as shown below. It is software which runs on a personal computer; this software is used to map a graphical representation of the actual system or a plant. The personal computer (PC) will be linked to a multiple PLCs. The PLC will have a code programmed and stored in its memory. The following diagram illustrates how the SCADA Architecture when in operations.

## SCADA Architecture

SCADA systems have ability to controls multiple equipments from different locations. The controlling through SCADA can be done from one controlling station to control equipments at different sites. The equipment can either be hardwired linked or soft-wire linked as shown in Figure . According to (SIMATIC WinCC flexible 2008 website) a SCADA running on one PC would control up to 32 PLCs. The following diagrams shown how the PLCs could be connected to suit applications. (Krutz, Securing SCADA Systems, 2006 )

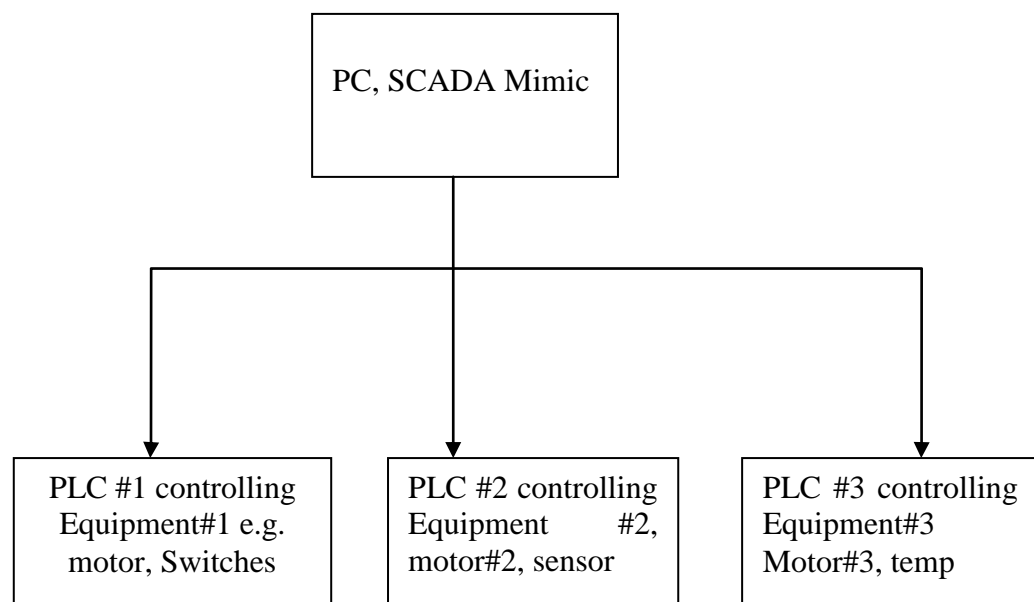


Figure 2.1: SCADA System

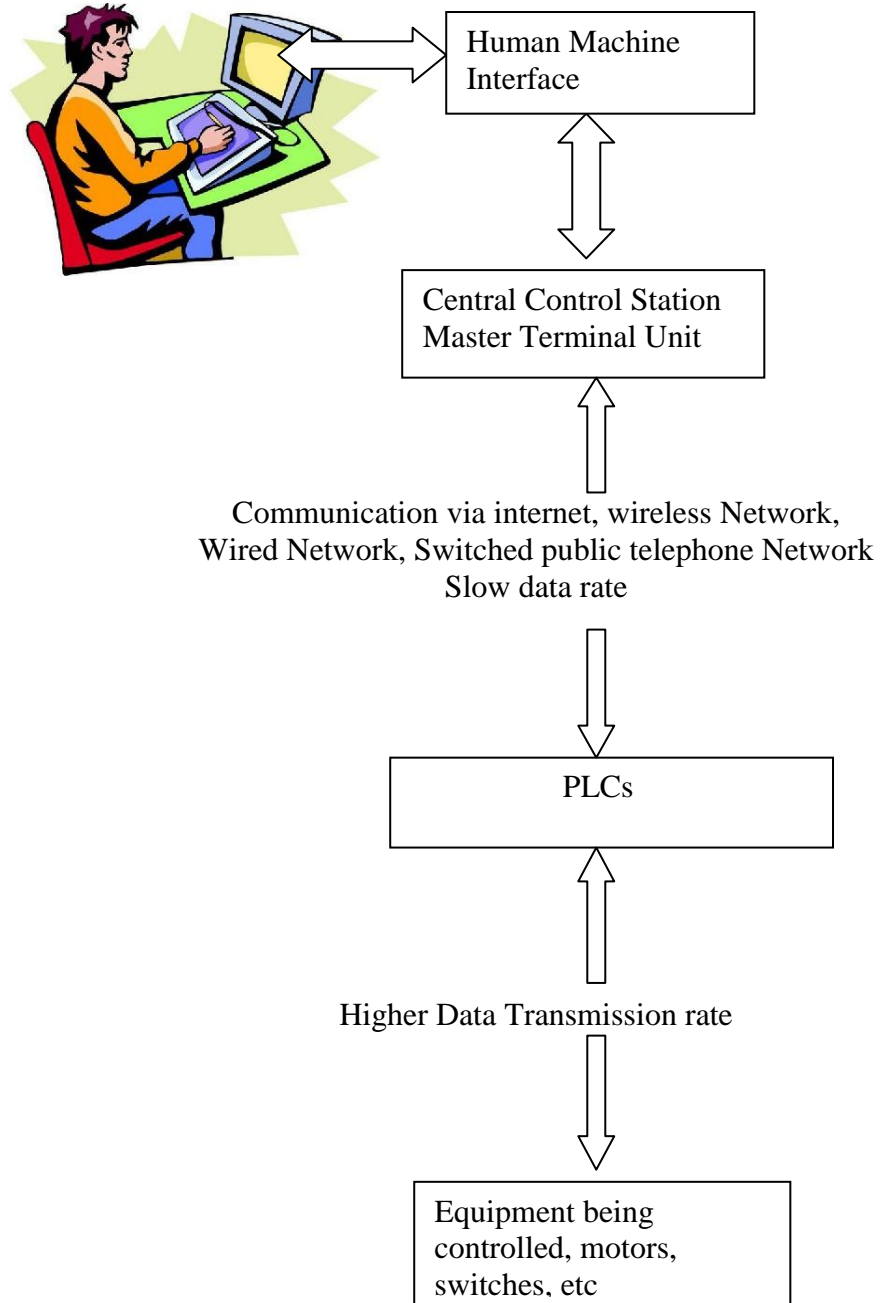


Figure 2.2: SCADA Wireless connectivity

The above diagram shows the alternative way of connecting SCADA systems to a controller.



## **SCADA Radio Architecture**

The above diagram shows how the PLC can be wirelessly or radio linked through a radio modem, this is another valuable feature of SCADA system which is very useful for a mobile controller. It could be suitable for equipment with multiples controlling base stations. The controller could be a hand held device, e.g. mobile phone, hand held remote.

## **PLC**

PLC is a physical electrically operated hardware, as shown in Figure 1.2.3. Its hardware is programmed by STEP 7-Micro/WIN V7.0. This program is used to write the codes to run the systems. It has much operations functionality. Refer to PLC Simatic s7-200 data sheets;

<http://www.automation.siemens.com/mcms/industrial-automation-systems-simatic/en/manual-overview/tech-doc-controllers/Pages/Default.aspx#SIMATICS7>,

The above web address outlines the technical data of the PLC, Simatic S7-200, and the soft program code is shown below.



Figure 2.3: PLC Hardware

## Ladder Logic

PLC programs use ladder logic to execute as instructions in parallel, executing all the logical function code effectively at once. This allows PLC be fast and accurate.

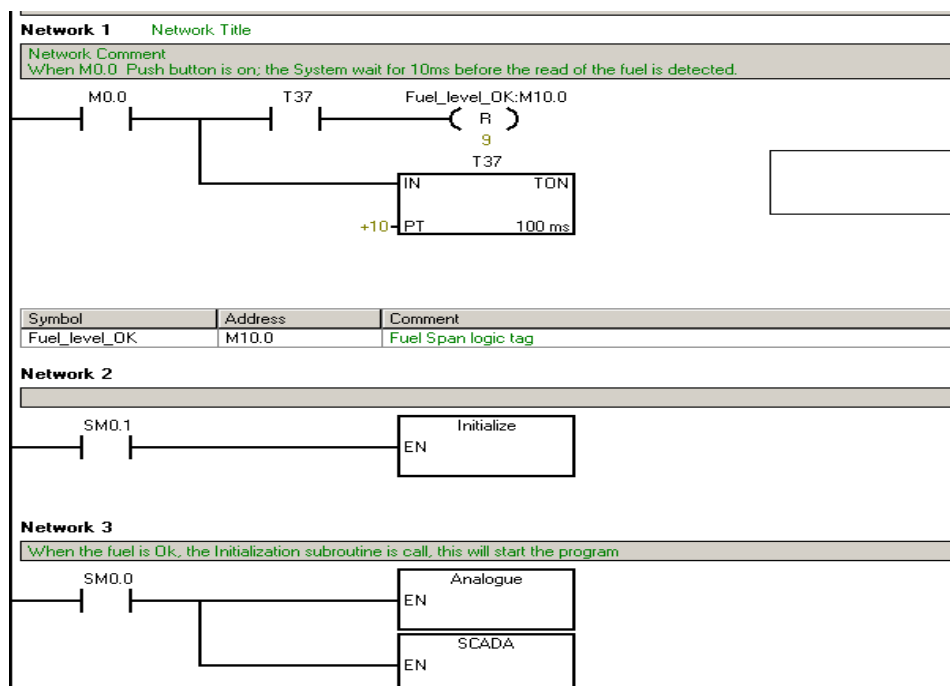


Figure 2.4: PLC's Code Screen Shot

Figure 2.4 shows how the ladder logic is effectively executed in parallel. The Boolean codes for each logical function form one network. A number of these networks can then be grouped into a subroutine. Subroutines can be called every scan or selectively from within the program.

### Digital Input and Digital Output

PLC has digital inputs and digital outputs, the digital inputs accept 24VDC digital signals and outputs 24VDC digital signal, in the S7 200 Simatic PLC the digital inputs is denoted as 'I' and the outputs as 'Q'. To select an input or output a logic I or Q they are written to Ix.x or Qx.x respectively; figure 2.3 show the Optoisolation of the PLC digital inputs..

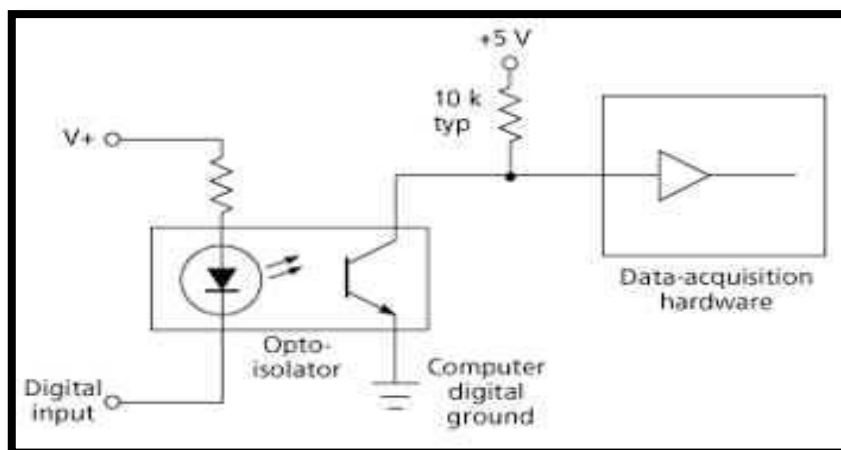


Figure 2.3 Optoisolator

### Analogue Inputs and Outputs

PLC analogue inputs and outputs are used to connect analogue signal devices, e.g. temperature and pressure sensors.

## Internal Memory Bits

Internal memory bits are used for conditions where there are no physical connections of the devices and some conditions are needed to be met. Such conditions can be when a fuel tank is empty an internal bit is set to indicate the state of fuel in a tanks.

## Hardware

During hardware design, selections and implementations, some of the circuitries were considered to be of much importance. The protection circuit of Fuel solenoid circuit was very crucial for the fact of been the only inductive load available in the system. The freewheeling diode was implemented to protect the equipment from high surf voltages.

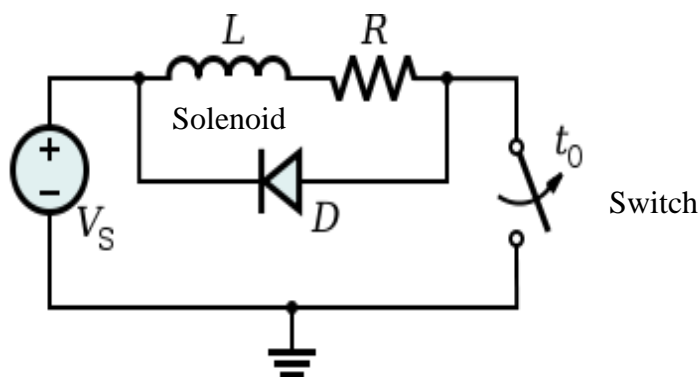


Figure 2.4: Freewheel or flyback Diode Circuit

Source: [en.wikipedia.org/wiki/Flyback\\_diode](https://en.wikipedia.org/wiki/Flyback_diode)

The voltage across the inductor is defined as

$$V(\text{coil}) = L \frac{di}{dt} \quad \text{Equation 2.1}$$

Where  $V(\text{coil}) =$  Voltage across the coil;  $di =$  change in current and  $dt =$  change in time. This protection is needed in circuits when the time difference is in an order of nanoseconds or microseconds typically.

## **Fuel Solenoid**

There are two types of solenoid valves available, normal opens and normal closes; the normal opens solenoid was selected after considering its usage and advantage to the project.

It was designed that the fuel had to be on all the time unless the operator needs to shut down the fuel flow. This allows the generator to have a constant flow of diesel fuel.

## **Relays**

Like the fuel solenoid, relays have two types - normally opens and normally closed. The state of the relay depends on the status of the relays coil. This device is a low power electromagnetic component. The device is used to switch a higher current motor contactor. In the context of this project, the normally open relay is used to switch contactors. Figure 2.5 shows the typical relays circuit connection used .Figure

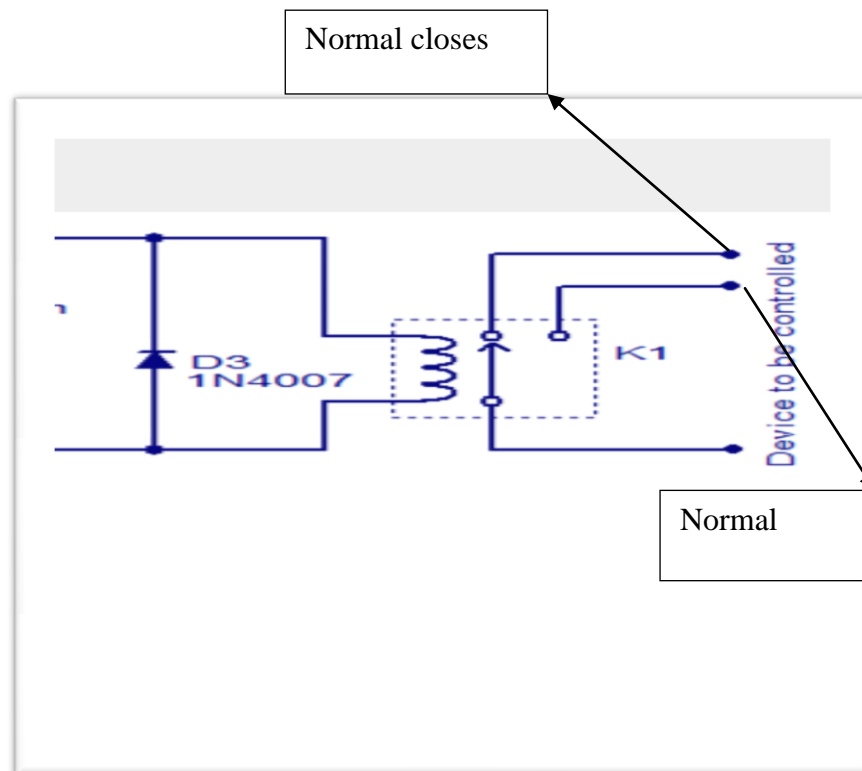


Figure 2.5: Relay circuit

Typical relays circuit. (Source: [www.circuitstoday.com](http://www.circuitstoday.com))

### Switch Contactors

Contactors are an electrical control system. This system can be remotely controlled through relay to switch a higher current device. They are suitable for starting motors to allow the higher starting current of the motor to flow without causing damage to the switch. The figure below shows the contactor.

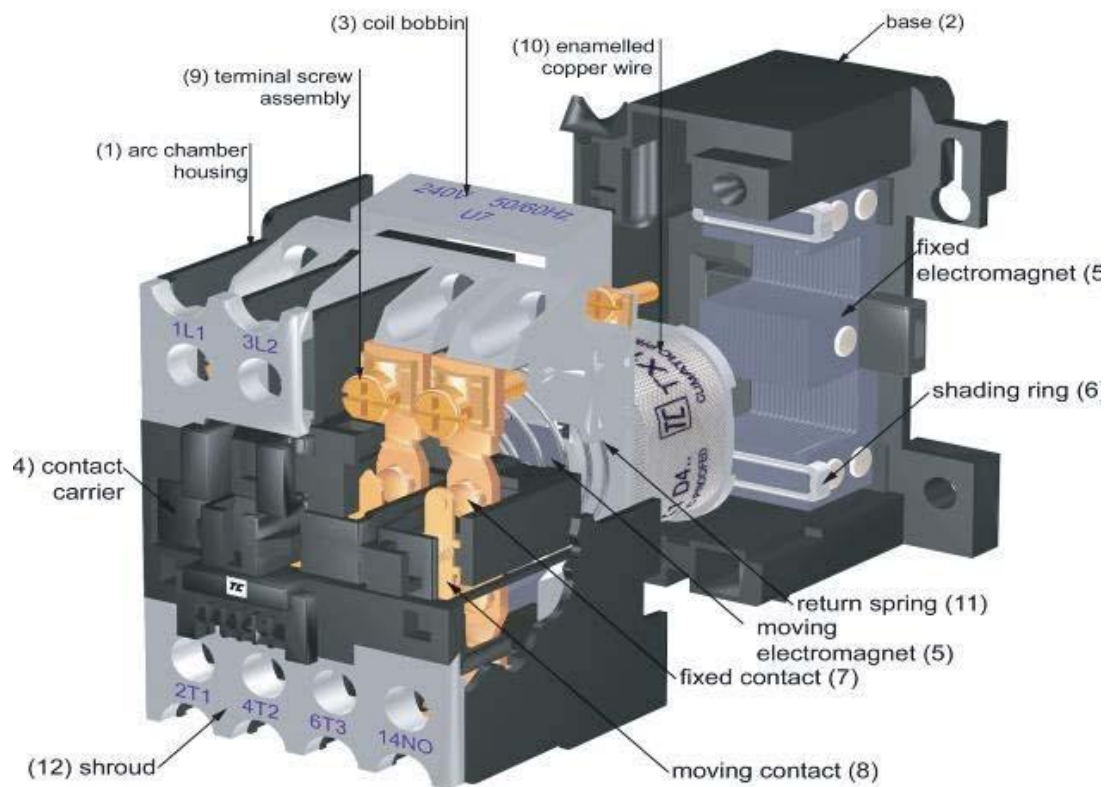
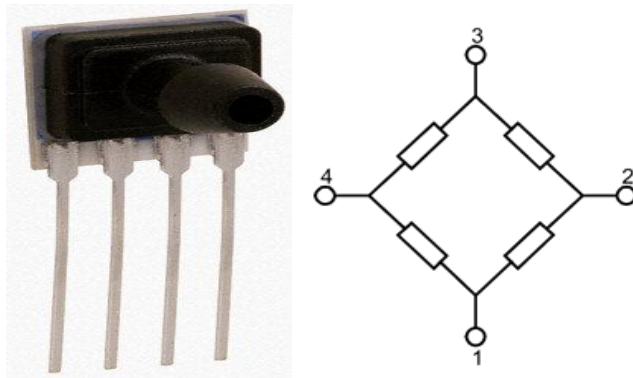


Figure 2.6: Contactor

Source ([http://www.thermalinc.com/power/pics/Contactor\\_EEC.jpg](http://www.thermalinc.com/power/pics/Contactor_EEC.jpg))

## Pressure Transducer

In this project a resistive for the transforming of data, a fixed gain amplifier was used to amplify the signal from the pressure transducer. Pressure transducer is used to measure the pressure in the fuel's tanks; this pressure is output in mV/ psi is amplified and calibrated to display in litres. This is translated to the volume of fuel in the tank.



**Figure 2.7: Pressure Transducer and Circuit diagram**

Source (rsaustrialia.com.au)

### **Cost Analysis**

Cost was a driving force during component selection. The project had a small budget allocated to it, and as such less expensive equipment was considered to be suitable for evaluating this particular project.

### **Resource Allocation**

The resources were allocated according to the importance of the equipment and the role which it played, therefore the critical equipment was given a priority.

### **Current Situational Factors**

Students at the University of Southern Queensland operate this experiment as a compulsory activity (ELE3914 Practical D, electrical and electronic Engineering practical course) and every time the experiment operates, students are exposed to noise. All students wear hearing protection (earmuffs), therefore the communication between students and the instructor is minimal. In addition, the risks could be unavoidable. Students rush take their data.

The Diesel Generator operating room is very confined and sealed to contain noise. This can make students uncomfortable to be in the room for a long time. By



introducing remote accessibility to control the equipment, students will feel comfortable when doing the experiment.

### **Consequential Effects**

While developing the remote Accessibility of Backup Generator many aspects of sustainability, safety and ethics were considered.

The set up required for the system will not undermine the development and environmental needs of future generations (*Toward sustainable Engineering practice: Engineering frameworks for sustainability 1997*) as the system will use the existing equipment and rooms where the plant is set up. It will not occupy more space as it is portable and small.

The development of this project does not influence environmental protection issues. (*Toward sustainable Engineering practice: Engineering frameworks for sustainability 1997*) as it is a combination of software and hardware of small electronic components. It is likely that less energy will be consumed through the operation of electronic components that cause environmental impact, but not enough to cause any harm to its surrounding environment. In comparison to the existing controlling system, it likely that this new system would reduce power consumption and it will emit less green house gas.

The only aspect of this project implementation that could cause environmental degradation (*Toward sustainable Engineering practice: Engineering frameworks for sustainability 1997*) is the long term side-effects of energy consumption, which is currently being researched by scientists and engineers around the world.

The participation of any concerned citizen will not be undermined (*Toward sustainable Engineering practice: Engineering frameworks for sustainability* 1997) and members of the community (USQ) will have their opinions with the implementation of this project only in the case when it is endangering human life or equipment being controlled. In addition, as such USQ deserves the right to upgrade their laboratory and equipment.

The remote Accessibility of Backup Generator will be equally accessible to all groups of people who are enrolled in the practical course (ELE3914 Electrical Practical D) as it is a University owned project so it will be managed and run by the University. The project has no limitation on the basis of use, it can be generalised to be a controller for most Electrical machine practicals.

A possible effect on employment is there will be less demand on technicians during operation. To offset that, more employment opportunities would exist in the construction, development, installation and maintaining of the system. While employment opportunities will still exist, the necessary qualifications vary significantly from the previous employment market to the new job fields. Job seekers may require further education or training but they may be rewarded by entering into a higher paying job. With more developments and analyses, many jobs could be created not just to the university but also to the community.

This project could be used for global sustainability when it is developed to be used over the internet to services external students (*Toward sustainable Engineering*

*practice: Engineering frameworks for sustainability 1997* as it gives opportunities for accessing practical exercises outside the University of Southern Queensland Toowoomba.

### **Implementation**

The components and parts were implemented by a qualified technician under the supervision of the project supervisor.

### **Conclusion**

This chapter has covered the literature review of the project and the component used in the project. It has also states the benefit of using features in a SCADA based system and PLCs, the literature review of each components was also provided.

## **Chapter 3**

### **DESIGN METHODOLOGY**

This chapter will cover the methodology part of the design project phase through to the implementation phase. It will analyze the literature reviewed in chapter two and describe step by step design logic of the project and establish the needs of the project. It will explain in depth the design requirement of the project; in the general scene, it will set the bench mark on how the system was set up and the design procedure in regard to what was needed to construct the project.

#### **Planning phase**

The basic Approach to the project specification was established and the scopes were defined to set the boundaries of the project. The project was strictly defined to meet the objectives of the project. This was a very critical point and core centre of the successful execution of the project. The foundation and building blocks of the project was laid; PLC and SCADA were considered to be used.

#### **Literature Review**

Research of literatures about a current remote accessible laboratories around Australia to understand the basic structure of how a remote system operate, however more research through relevant books for programming PLC and SCADA and interfacing circuitries was carried out.

### **Investigate the Alternative Remote Controller**

The research of alternative remote controllers was well considered not to be a better solution to the success of the project as it altered the project objectives as they were able to provide a customised solution to the implementation of the system. It was considered that only the PLC and a SCADA system with their relevant softwares were to be used. As a result it has eliminated the search for the alternative remote controller. This allowed the intensive research of the two systems - PLC and SCADA systems - from the introduction to the advanced programming function. The onboard features of SCADA and PLC were considered of importance.

Research was carried out during the implementation and code writing to acquire reasonable knowledge about the operation of the system and use of the software.

### **Identify flaws associated with currently issued method**

Through current program exploration and research of relevant literature on how the program operations will be analysed, to assess project specification against project objective to determine the project's strengths and weaknesses.

## **Identifying System Components**

The Remotely Accessible 35kVA Diesel Backup Generator project requires both hardware and software to be implemented. The project has three main parts: the Remote control; which is the internet booking based systems; the locally accessible part, which is the physical interfacing to the existing controller; and the software interfacing to bridge the gap between the internet and the existing controller. To allow a possible operation of the equipment, the equipments will be operated by a remote user; the generator started and run up to temperature, fuel flow, once up to the temperature the loads are switch on and off. While monitoring generator speed, temperature, fuel consumption etc. These components were primarily looked at in details: their functionality, affordability and useability.

## **Hardware and Software**

Through investigation of the current market for remote systems, it is more likely that there will be someone out there selling hardware and software which could be somewhat of a help. It was found that there was some equipment available at the University's electrical and electronic laboratories from the past students' projects and general equipment for students' practical exercises. These components were considered valuable resources toward the project. Considerably these components such as PLC Software and Hardware, RS485 (Industrial Ethernet cable), personal computer (PC), testing equipments; multimeters and power supply were found in the laboratories.

### **Evaluate Hardware and the Software Requirements**

There might be similar hardware and software that could perform similarly. The selection of any of the software and hardware depends on their ease of use, affordability and performances. Considerably many different approaches were deployed during the purchases of the hardware components to reduce the financial cost of the system and to reduce the installation time. But always things are not so easy in the dynamic world, as good system always come with higher prices. So getting every component according to the desired expectations was an ideal solution. The practical solution was to adjust the budget and prioritise the components. SCADA's software was considered to be the core driving component to the project, subsequently, fuel Solenoid, Pressure Transducer, Contactors, Relays and gain amplifier were purchased.

### **Research on Alternative Remote Control Methods**

By reading current journal articles and utilising current technology, a list of alternatives to each task was created. In each case, a suitable alternative was selected in regards to both project specification and scope. At this point where financial constraints and time constraints were considered, by taking a simple approach to the alternative methods, it was considered that only if the alternative is within the scope of the project specification. This minimises a broader search for alternative methods. Use of other systems apart from PLC and SCADA is considered to be outside the project domain.

## **Risk Assessment**

Safety issues were looked at the beginning of the design, to determine whether the design will be feasible to implement. This project is categorised as a high-risk system. It is a 35kVA generator. It is likely to be fatal to the user if the appropriate precautions are ignored. However, some measures were put in place to prevent possibility of electrocution or damage of the equipment. This was done by isolating the main power supply and standby/ starting batteries. Then the off line test was carried out and followed by an online risks assessment test. During the risk assessment test, the following were categorised to be of considerable risk.

- ❖ 24 volts DC starter circuit including battery (a high current) or possible explosion
- ❖ Rotating machinery (covered)
- ❖ Noise is greater than 87dBA
- ❖ Carbon monoxide exposure
- ❖ Diesel fuel exposure
- ❖ Fire hazard or combustible liquid gases
- ❖ Chemicals affect skin /eye contact

## **Existing**

Starting battery was disconnected to prevent any electrocution, to ensure that all electrical power into the controller circuit is completely isolated and secured during pre-testing operation.



This equipment is expensive therefore restricted care must be in place which involves codes to be simulated and tested thoroughly before implementing it into operation.

Diesel fuel was fully secure so that it does not leak out to cause any slip hazard during operation. This is a higher risk environment; slip hazard is very dangerous as it could cause serious injuries and any misconduct of electrical connections can produce sparks which could cause fire when it is in contact with diesel fuel.

Thorough inspection was carried out to prevent any instant and future electrocution. To overcome any errors occurring during operation, a technician and the project supervisor were involved in obtaining a technical and analytical risk assessment.

During the setup of a laboratory experiment a risk of electrical shock might occur. The likelihood is significant but the exposure will vary depending on how careful the technician might be. The consequences might vary from minor to most serious or death. The electrical power source hazard is unavoidable as it is necessary for the experiment. The risk can be drastically minimised by inspecting all equipment for a faulty source before use. Any active power source before starting any connections must be isolated. In addition, it must be ensured that all new connections are securely connected and all wires are secured. There also has to be an electrical rated fire extinguisher within easy reach of the experiment..

In case of any minor or major incident which will result in damaging equipment or humans, the above-mentioned steps should be immediately put in place.

Not following the instructions is likely to result in damage of the equipment, which could also increase danger to personnel from fumes, fire or explosion.

Once the equipment is properly connected and running, there is the small risk of a short circuit in any electrical experiment. The likelihood of this to occurring is minimal, but may be the result of student tampering. This risk will vary depending on how many different experiment and what sorts of experiment are used. As the laboratory is being accessed remotely, it is likely that, there will be any human injury in the event of a short circuit; however there is a chance of minor equipment damage occurring. To minimise this risk, experiment a circuits will need to be designed so that they have adequate protection and circuit breakers integrated

### **Resource requirements**

Remote accessibility of a 35 kVA will requires some hardware and software during the designing phase and more hardware in the implementation stage. All the financial resources were provided by the Faculty of Engineering for the purchasing of the components. It requires access to a personal computer, which will be used to write the codes and simulation of the codes.

## **PLC and SCADA Software**

The PLC and SCADA software will run on a standard PC. This PC will be connected to PLC programming Console terminal via RS485, and then the physical inputs and outputs can be connected to the PLC. The PLC will have program logic programmed STEP 7-Micro/WIN The SCADA system will use software called SIMATIC WinCC® Flexible 2008 for the HMI design on a touch panel or PC screen.

### **Fuel Solenoid:**

A Solenoid will be used as a fuel vender on/off valve, which will be electrically controlled. It will regulate the flow of diesel from a tank to a diesel generator.

### **Pressure transducer:**

This will measure the instantaneous volume of the fuel in the tanks in the form of pressure and the PLC will convert this pressure signal to litres available.

### **Relays and Contactors:**

Effectively electrically controlled switches, they are used for switching resistive load bank, Generator, fuel solenoid and fans. They will be controlled by a PLC output each.

## **Conclusion**

The main issues associated with the methodology during design of the Remotely Accessible of 35kVA Backup Generator was accomplished by the careful selections of the components. The best option was selected from the possible

alternatives. This option allows the complexities of the project to be within its objectives to achieve the desired outcomes. Risks assessments and exhaustive component selection analyse in regard to the project specifications have been well covered in details.

## **Chapter 4**

### **SYSTEMS DEVELOPMENT AND IMPLEMENTATION**

This chapter will cover the steps involved to develop and implement the project. At this stage all of the components, software, and hardware are put together to communicate and cooperate to meet the desired systems' objectives and specifications. Firstly we will look at the input and output terminals of the PLC as a building block of this project and coding structure of the PLC and SCADA systems. We will also look at the simulations and implementation procedures and the overall overview of the systems architecture and operating code sequential logics. This will be illustrated by the use of images, diagrams, tables and precise descriptions.

## System overview

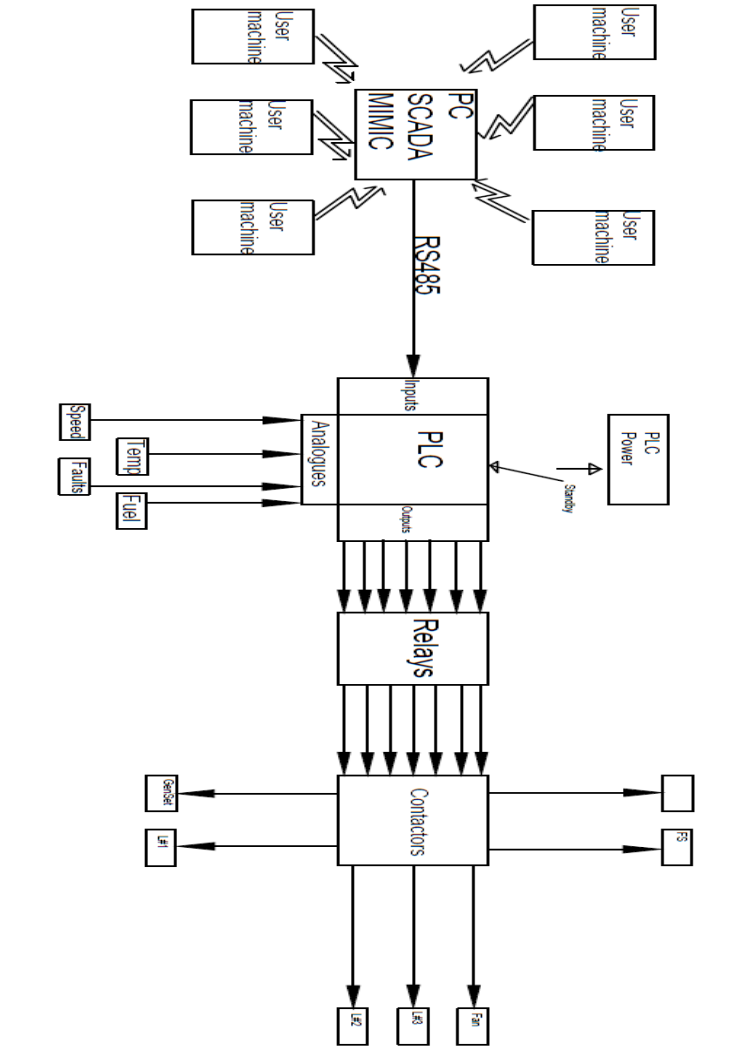


Figure 4.1 System Overview

## User Machine

Figure 4.1 gives the user the overview of the system's diagrammatic structure. The system starts operation from top to bottom, top being a user from within the University locally or from outside the University of Southern Queensland (USQ)

main ground accessing the USQ internet server remotely. These users are mainly USQ students or authorised personnel: authorised personnel are people who have been granted a right to access the equipment at the defined date and time; the user will have a timed user name and password. The user will be monitored by a course instructor to do their practical experiment. For the safety of the equipment, the instructor has to be closer to the equipment to oversee the progress of the diesel generator practical. This is done to avoid more than one user accessing the equipment at one time, or any destruction for unauthorised users to use the system. Even if the system cannot allow multiple users to access the system, human errors have to be considered as a possible hazard.

## System logical overview

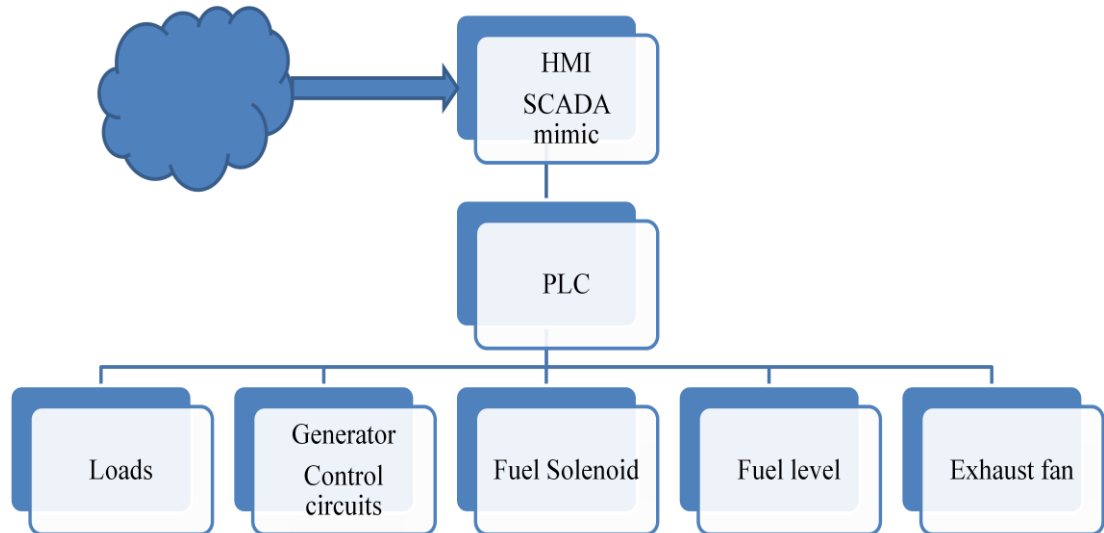


Figure 4.2: System hierarchy

### HMI and SCADA Mimic

The Human Machine Interface (HMI) and the Supervisory Control and Data Acquisition (SCADA) on the Personal Computer (PC) on campus will have the following features onboard. It will run SCADA software called SIMATIC WinCC flexible 2008. This software will have the user entered into the web page through the electrical and electronic practical course links, the welcome screen will appear. This screen will look like this screen Figure. When this screen appeared, it will ask a user to enter their user name and password. The system will check for the validity of the information and activate the main systems page.



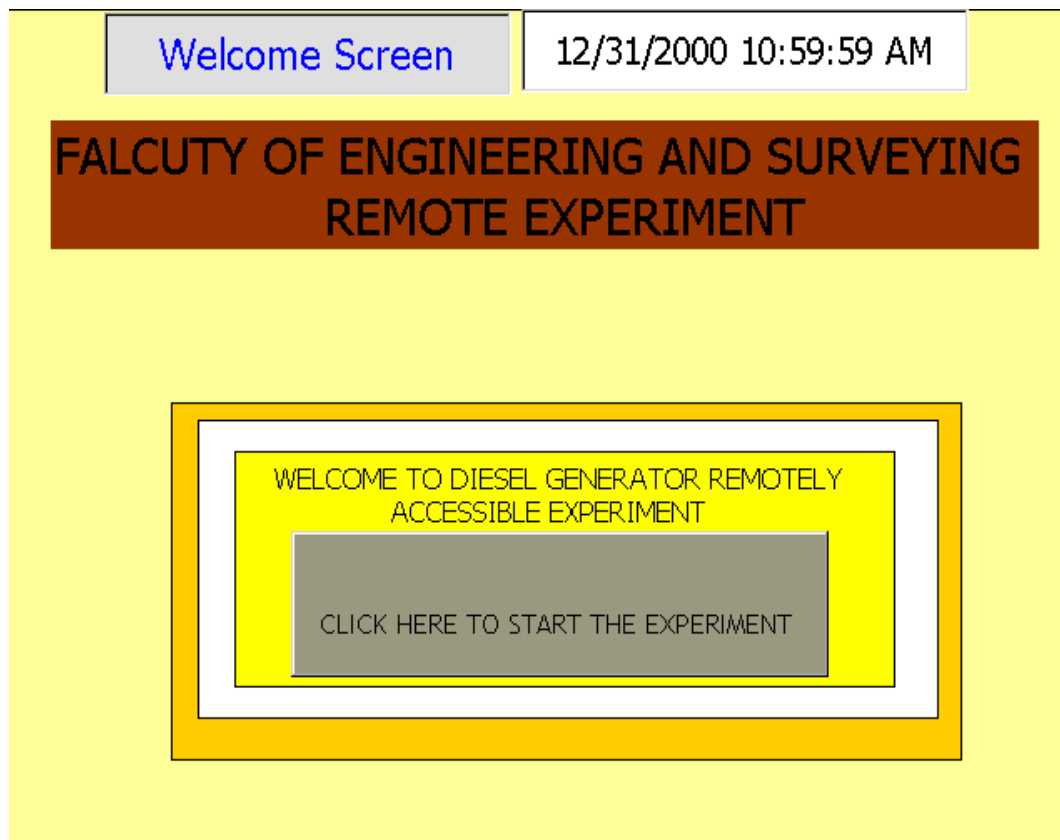


Figure 4.3: SCADA welcome Screen

This screen will activate the main menu; when the user does not have a correct logon personal identification number (an active student number or a password) the system will not activate the main menu to operate the experiment. This allows the system to be publically secure to any intruders.

## Systems main menu

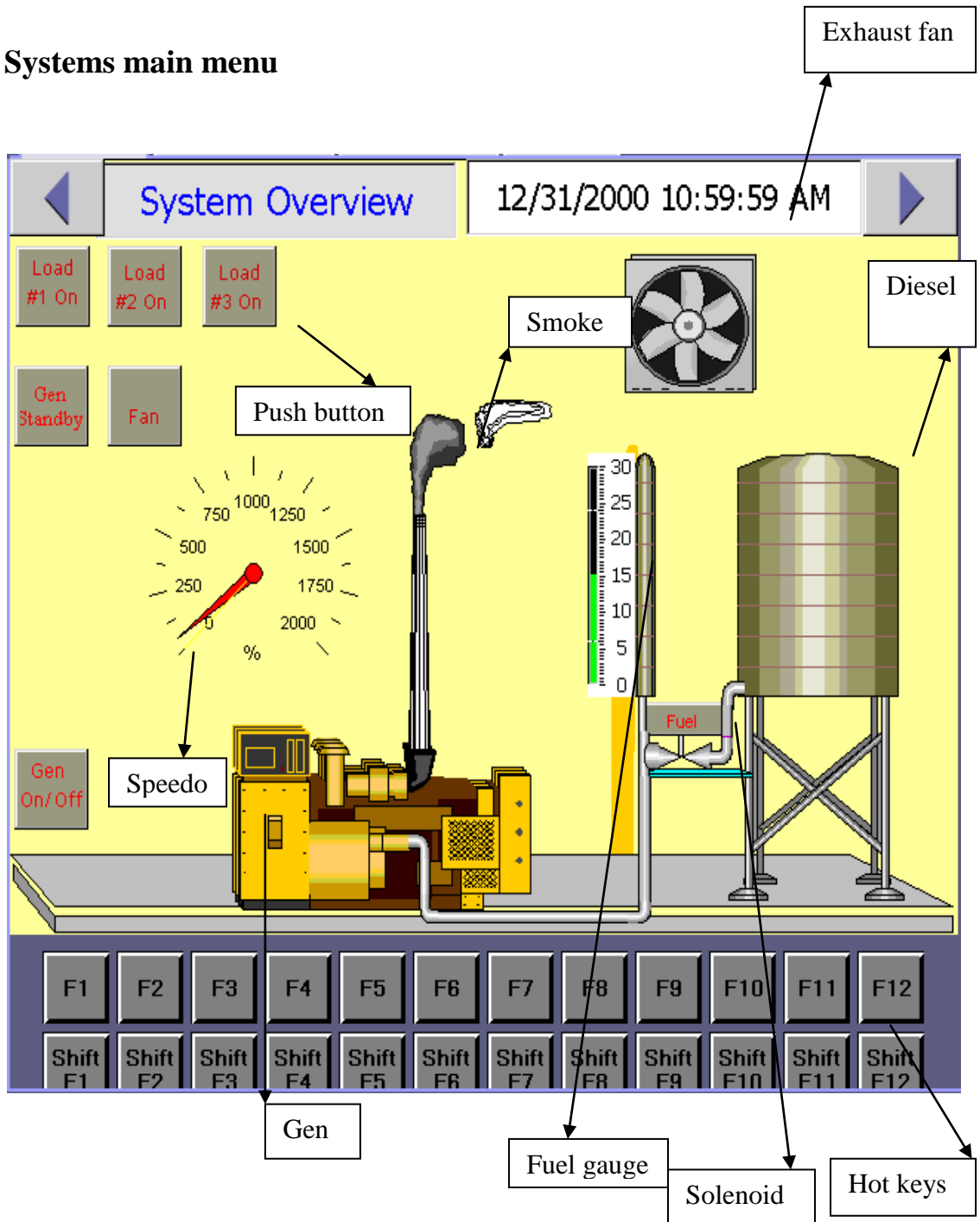


Figure 4.4: SCADA main Menu

## System main menu

Systems main menu shows the graphical representation of the actual plant, the model shown above is the actual layout of the real system. The operational

systems code is embedded into the PLC, When the system is online the Gen standby push button will automatically activate and started to flash.

### **Generator Standby Push Button (Gen Standby)**

Gen Standby Push button was employed to be a second measure in place for strengthening the safety standard of experiment. This allows the technician or supervisor to switch the remote system off, or physically isolate the website system for maintenance, manual operations or other reasons. This was done to prevent confusing situations such; as student access at the system while a technician is attempting to carry out routine maintenance on the Generator. These situations could only be avoided by physical isolation of the equipment and only if the Gen standby push button is deactivated.

### **Fuel Solenoid Push button:**

This is another critical push button for a Diesel Generator. There are so many measures in place which are designed to avoid running the Generator on low fuel or no inflow of fuel. The Fuel Valve was designed to be always on, unless there are requirements to switch it off. This allows constant flow of fuel to the generator. The fuel pressure transducer is constantly measuring the volume of fuel in the tanks to make sure that the generator does not run out of fuel. Therefore the generator always shuts down when the fuel is below a defined limit. This information is provided by the logic embedded into the PLC code. Likewise the generator does not start unless there is enough fuel to run it. This is denoted by a series connection of the pressure transducer internal memory bit in the starting sequence logic of the generator.

This leads us to explain the initialization subroutine of PLC code. This subroutine reads all the inputs and outputs of the PLC as a search for faulty triggers and

compares the set conditions of safe operations. During the operation of the initialization subroutine, the systems check for faults, out of range temperature, low fuel level, power on standby, coolant level and battery power. Any fault will set the internal memory bit and it would not allow the system to be executed unless the fault is fixed and the initialization subroutine memory bit is reset. More detail about the fuel solenoid will be covered in the following Chapter.

### **Generator Start/ Stop Push Button**

This push button has two main functionalities, one of which is to start the Generator, and the second is to stop the Generator. Under all conditions the initialization subroutine is executed. On normal start up conditions, the start system will check the state of the fuel solenoid valve, and all the conditions of initialization subroutine to satisfy the defined state of logic. These prevent the generator not to start up with little or no inlet fuel flow and to avoid a faulty start up.

### **Generator Stop Push Button**

There are two types of stopping the generator when it is running, instant stop which is an internal memory bit in the PLC memory, triggered whenever it sees a fault; faults being a high temperature, under or over speed outside the ten percentages tolerance of the synchronised speed of 1500 rpm, low fuel of less than three litres and short or open circuiting faults. These conditions activate the alarms and stop the generator operations. During the normal stopping sequence the loads switch off one at a time depending on which load is on. Once all the loads are off, the generator will go off and after two minute the exhaust fan will go off instantly.

This allows a room to be clear of fumes, and improves the standard of safety which could be caused by potential inhalation of carbon monoxide fumes.

### **Fan Push Button**

This push button is designed to be time activated or a manually operated push button. The logic behind this button is that it can automatically activate after the Generator starts and automatically shut down after two minutes from the time when the generator stops to allow any stale air to be removed. It can also be manually operated by pushing the start or stop push button.

### **Load#1, 2, 3 Push Button**

These buttons are used to turn on or off the Resistive load bank during testing. These loads are 1 kW, 9 kW and 10 kW respectively. These loads are mainly for generator tests at variable load; the first test is performed on no load, half loaded, and fully loaded. The test is carried out to determine the generator fuel efficiency. The button can also be reset when the Gen stop push button is pressed. This allows the generator to start at no load and maintain the contactors at their normal open positions. It also allows the generator to reach its synchronisation speed (1500 rpm) with no load.

### **Fuel Gauge and Odometer**

The fuel gauge shows the amount of fuel in the tanks. The pressure transducer takes in the analogue signal in the form of pressure in psi through gain amplifier to amplify the signal to allow a PLC to detect the input signal. The signal from the pressure transducer is in the range of 10 – 17 mV.

Boosting up the voltages, the PLC calibrating the signal it see from the pressure transducer and convert the signal in litres and then displaced the number on the fuel gauge.. Likewise to odometer, it reads the number of turns in the generator's rotor and displaces the instantaneous turn per minute of the Generator as revolutions per minute on the scale of zero to 2000 rpm.

### **Smoke**

Smoke is one of the visual animations beside audio and image to present the actual situation of the experiment, during simulation and testing. This feature shows how the practical experiment sounds and feels when exposed to the environment. There are many alert and interactive animations that are included in the SCADA mimic for clarity and decoration, to make the experiment more interactive to users.

## Detail View screen

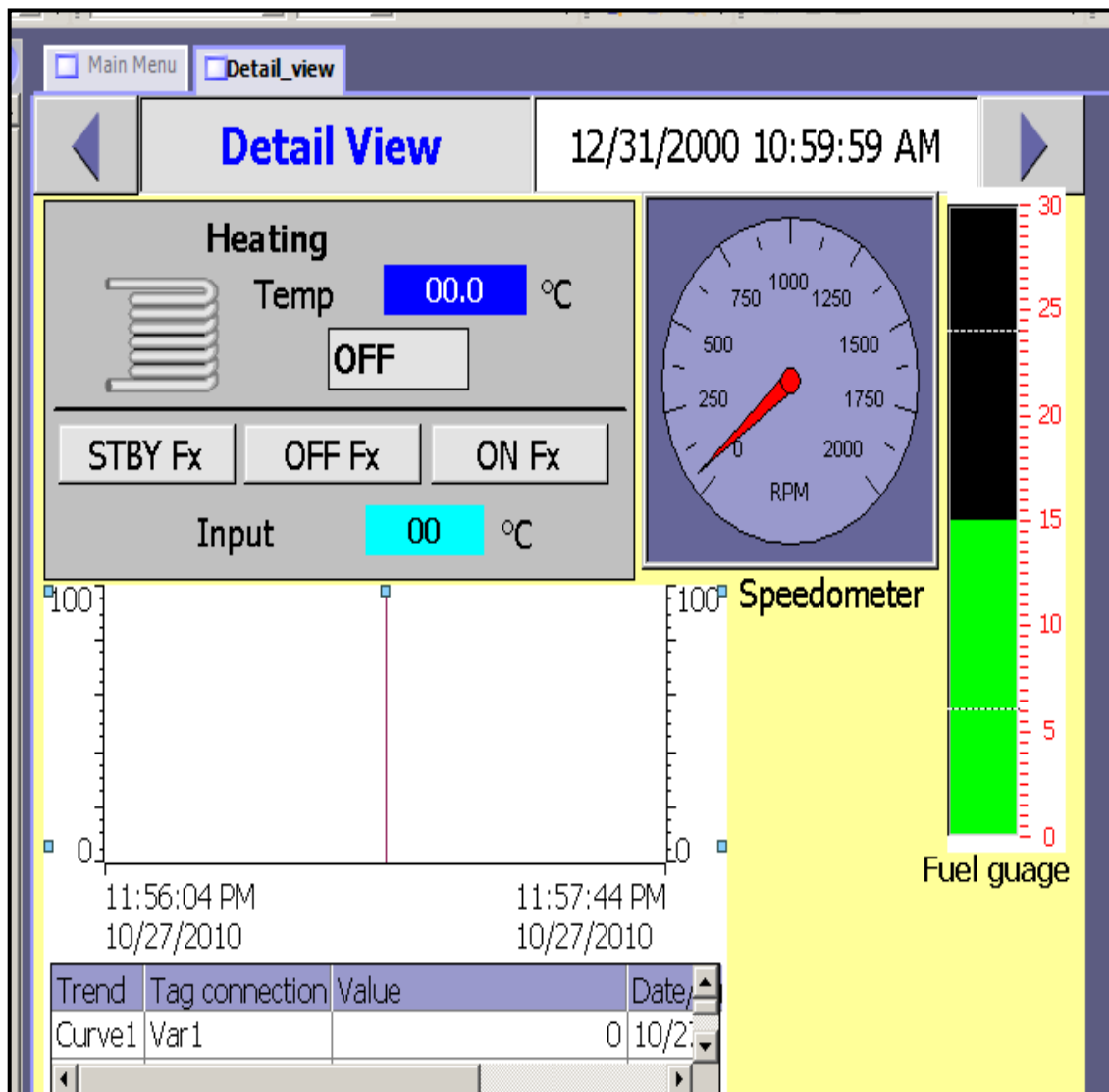


Figure 4.5: SCADA Details Screen

### Details view

This screen page is an expansion of the main menu page. For a more detailed view of the system it can be normally navigated from the main menu top arrows. It allows the user to zoom in, to keep their eyes on the amount of fuel available in the fuel tank and the speed at which the generator is running.

## System Screen

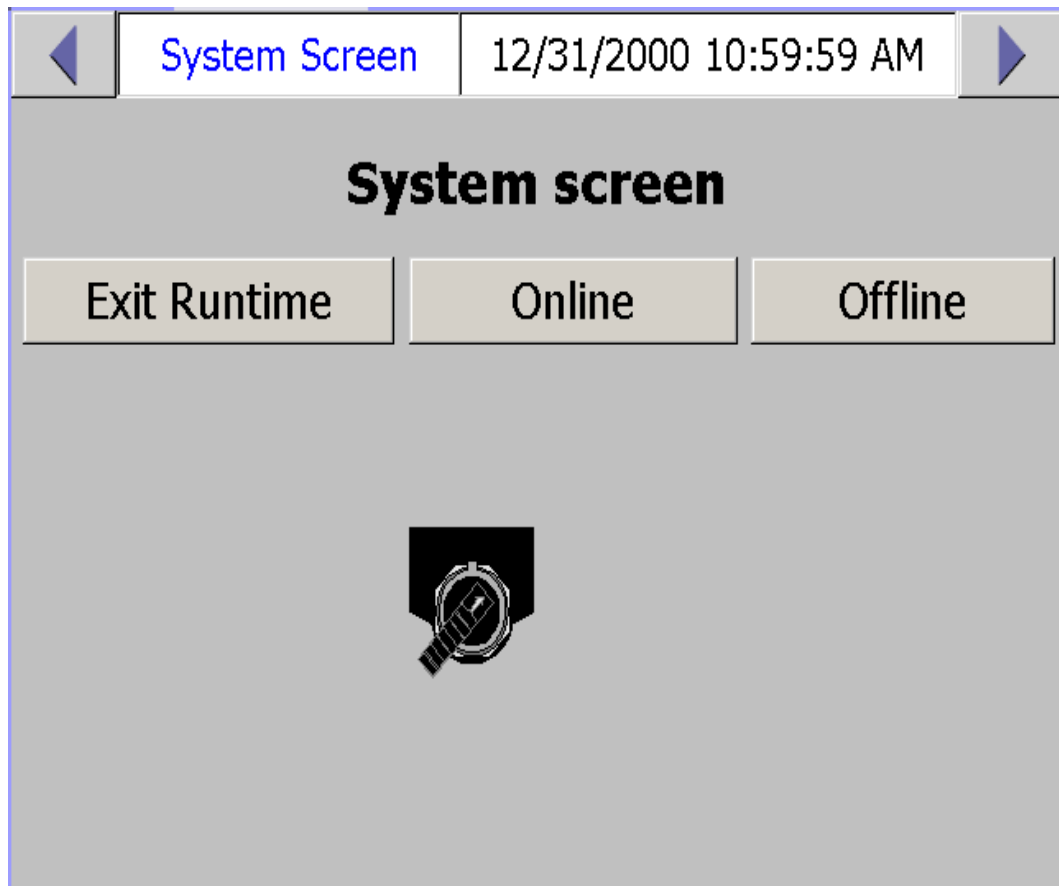


Figure 4.6: SCADA Systems State

## System screen

This screen allows the user to exit the runtime, exit from the system operations, go online, and online is the default button during the normal runtime. Offline is only used when the user wants to run some simulation or test for maintenance purposes.

## PLC

Programmable Logic Controller (PLC) is the modern tool that allows a user to control an automatic process. According to (Dunning, 1998) electrical equipment automation will help a manufacturing facility:



To gain complete control of the equipment:

- ❖ Achieve consistency in machine control
- ❖ Improve quality of the control and safety
- ❖ Improve quality of work in difficult or hazardous environments
- ❖ Increase the life of the equipment and increase the productivity of the plant
- ❖ Lower the cost of maintenance
- ❖ Allow quick change of the control systems
- ❖ Easy to control and learn.

With the above mentioned features of the PLC in mine we will look at how the smart system like PLC provides these glittering benefits for a user to control the equipment. Firstly we will explore how the overall systems function and it needs of operation. The physical and memory structure of a devices.

### **PLC Instruction in the memory**

A PLC simply follows the instructions which have already been stored in the PLC memory. These program instructions are stored in the non-volatile memory by the programmer to executed specific instructions. When the PLC is running, it uses a ladder logic executes instruction in parallel according to the input it sees from its input terminal to set a logical sequence.

## Features Incorporated Into Programmable Controller Logic

“The PLC has many features incorporated in its memory the hardware is designed to withstand the harsh factory conditions”. (John W. Webb et al, 1998, p 9)

- All PLCs are reusable. They contain a changeable program that eliminates extensive rewiring and component changes.
- The PLC offers easy troubleshooting down.
- They are easy to install and small in physical size.

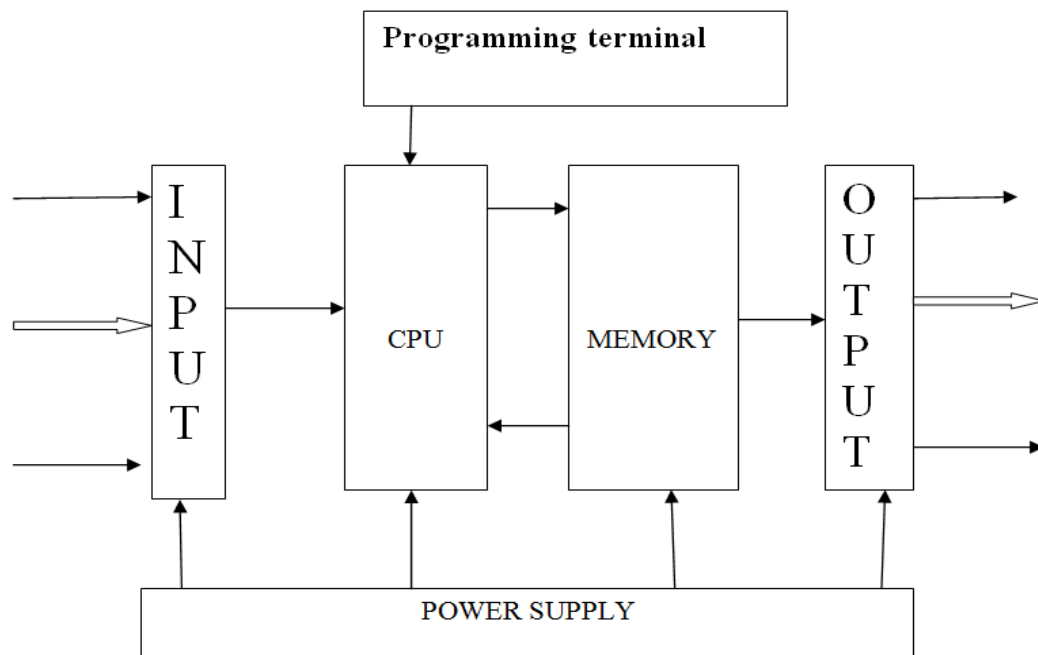


Figure 4.7: Block diagram of a PLC

## Systems operations

The system will operate logically according to requirements of the project.

This sequential logic will be executed by the PLC in this order.

- ❖ Standby
- ❖ The generator start/ stop
- ❖ Fuel solenoids
- ❖ Pressure transducer
- ❖ Exhaust fan
- ❖ Load1
- ❖ Load2
- ❖ Load3
- ❖ Faults

## The Generator Start/ Stop

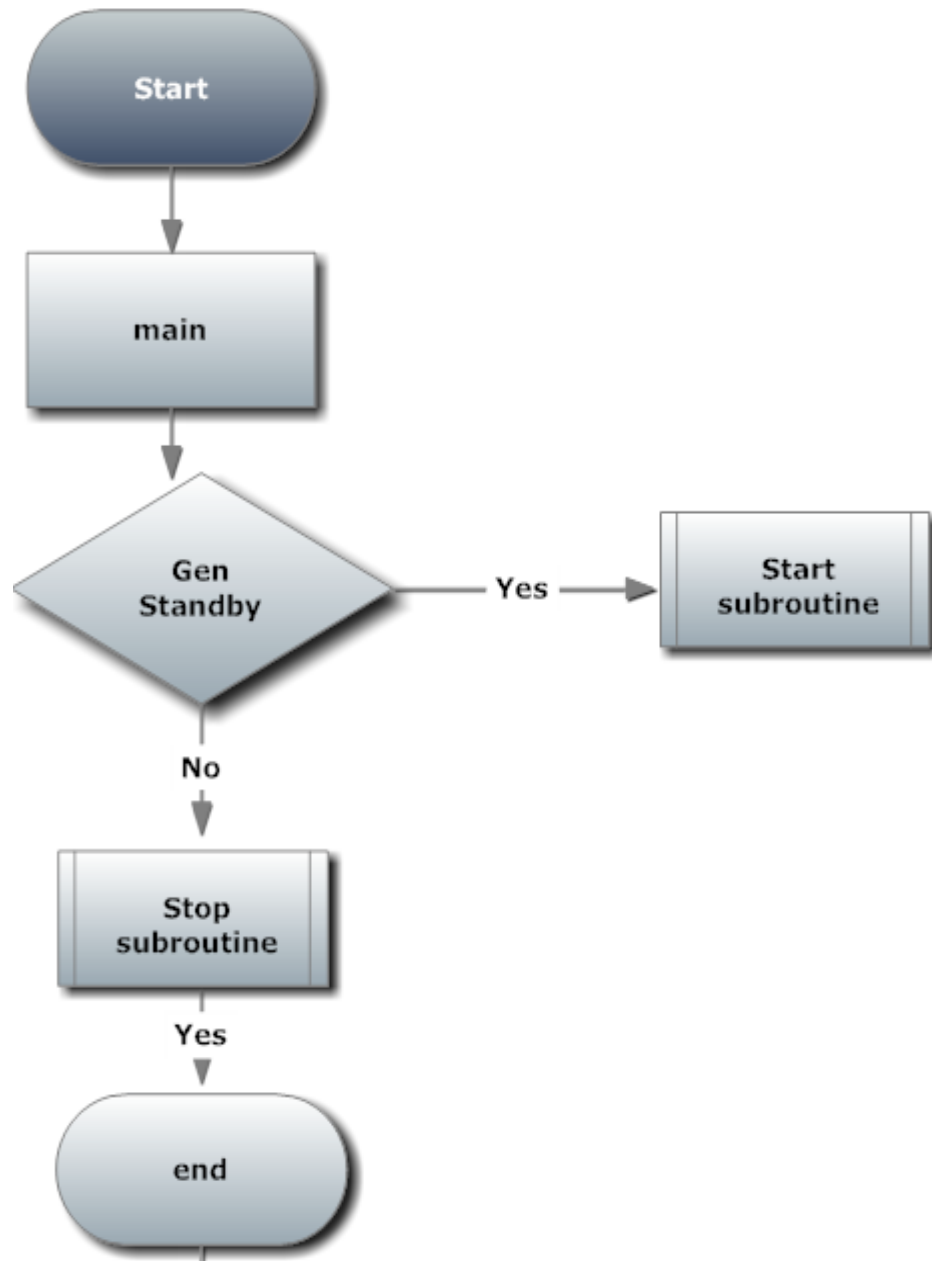


Figure 4.8: Main subroutine

The above flowchart shows how the PLC's code executes its instructions. To start the generator remotely, the programme runs the initialisation subroutine. This programme checks for the state of the standby button. If the button is not active it exits the system by calling up on the Stop subroutine or halt when the power is off.

In the case when the Standby push button is active, the program goes through the normal start up process and executes each instruction according to the input requests.

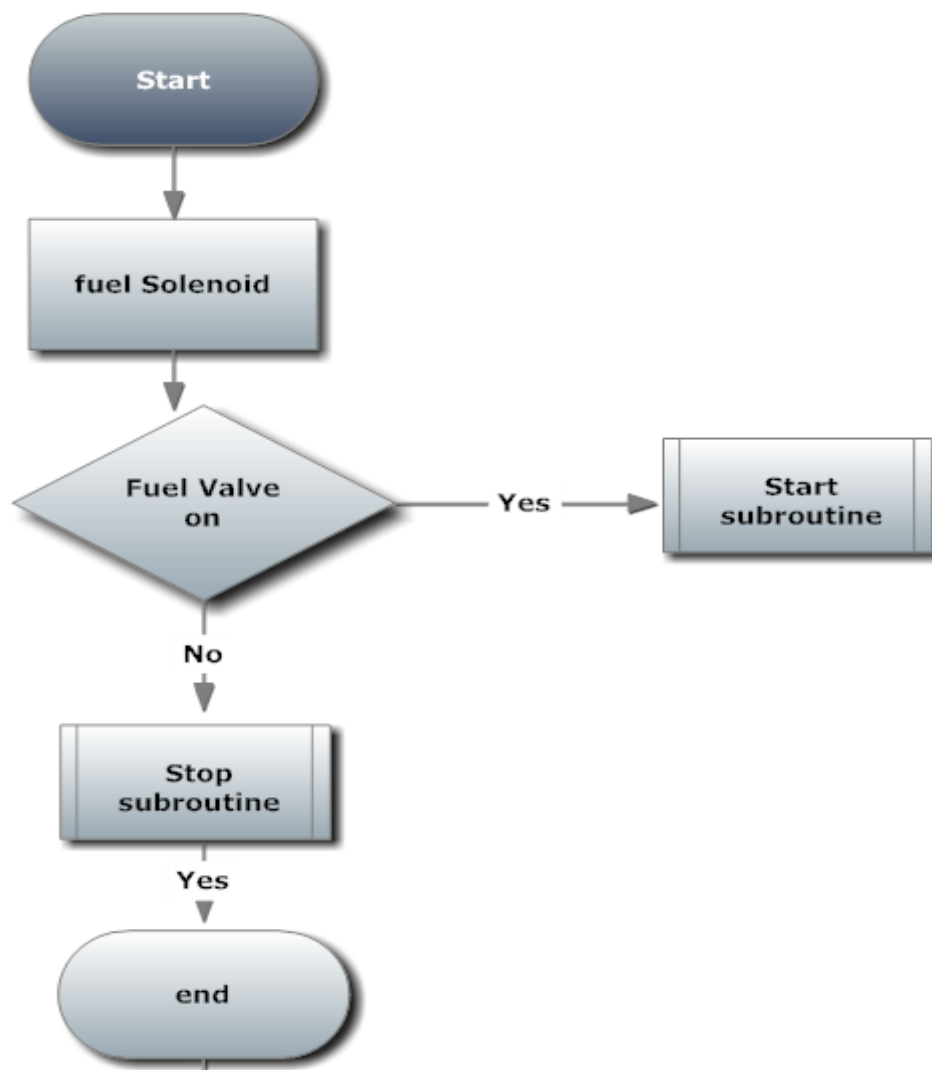


Figure 4.9: Start Subroutine

This is a fuel solenoid programme subroutine Its task is to regulate the flow of the diesel fuel from the tanks to the Generator. This subroutine is constantly running to check the state of the fuel valve. When the solenoid changes it state, the programme executes the code according to the state of operations.

## Stop Subroutine

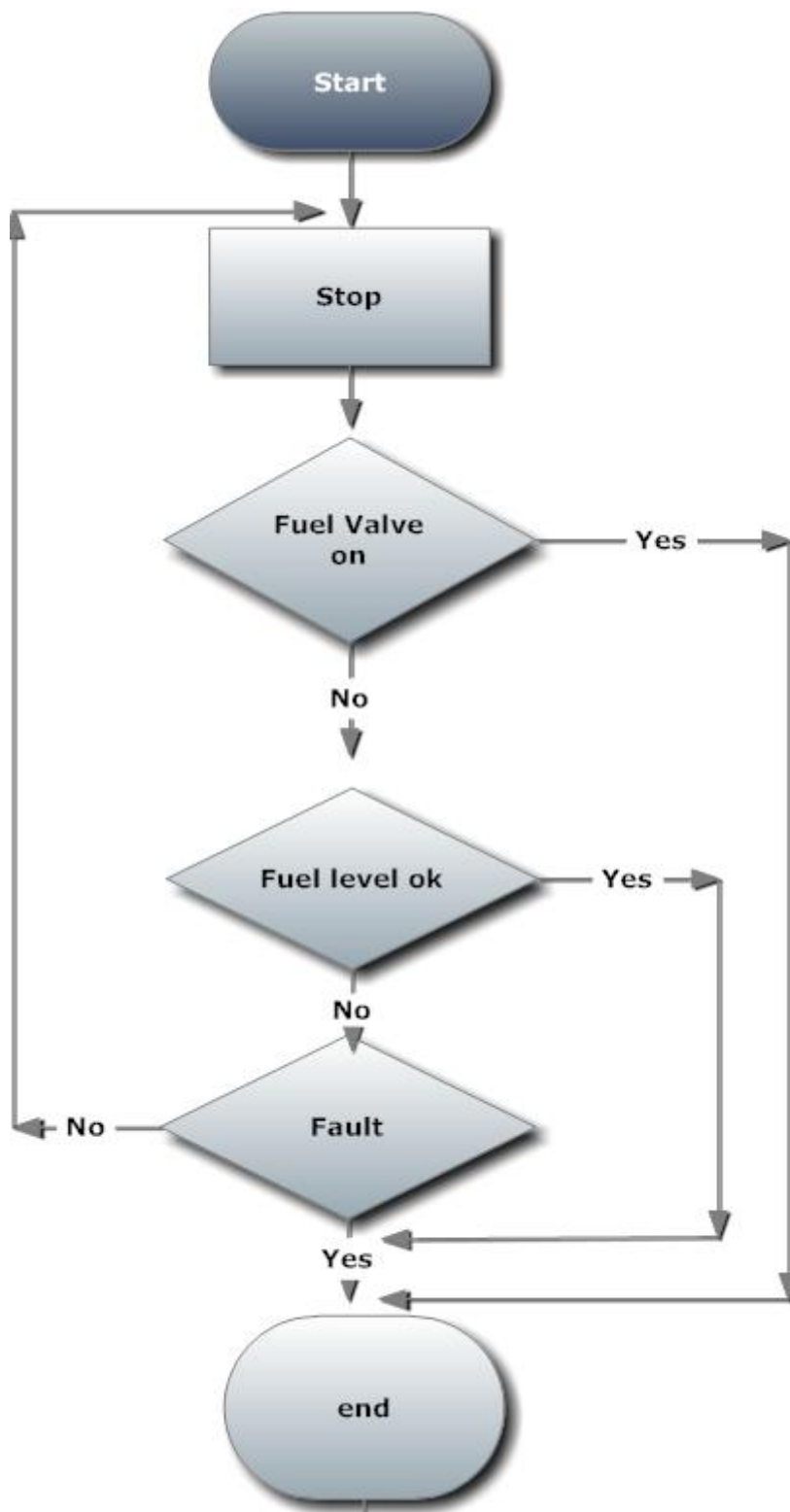


Figure 4.10: Stop subroutine

The stop subroutine is constantly updating itself, according to the internal memory bit during operation. This subroutine keeps updating itself with the volumes of fuel in the tanks, the temperature, speed, state of fuel solenoid and the emergency stop button. Any change to these components state allows the stop subroutine to activate and stop the generator from operations. This was done to ensure the safety of the operation or the equipment. The safety of the equipment is very important because there will be no human exposed to any danger, therefore the system has to have ability to detect its internal faults before they cause any damage. Most breakdowns of the diesel generator come from no fuel inlet, engine oils and low engine coolant. All of this causes a machine to overheat. Overheating of the system can be detected by a temperature sensor and executed by temperature subroutine when an unknown fault is triggered. In the case of any other conditions the associated logic will handle the faulty trigger.

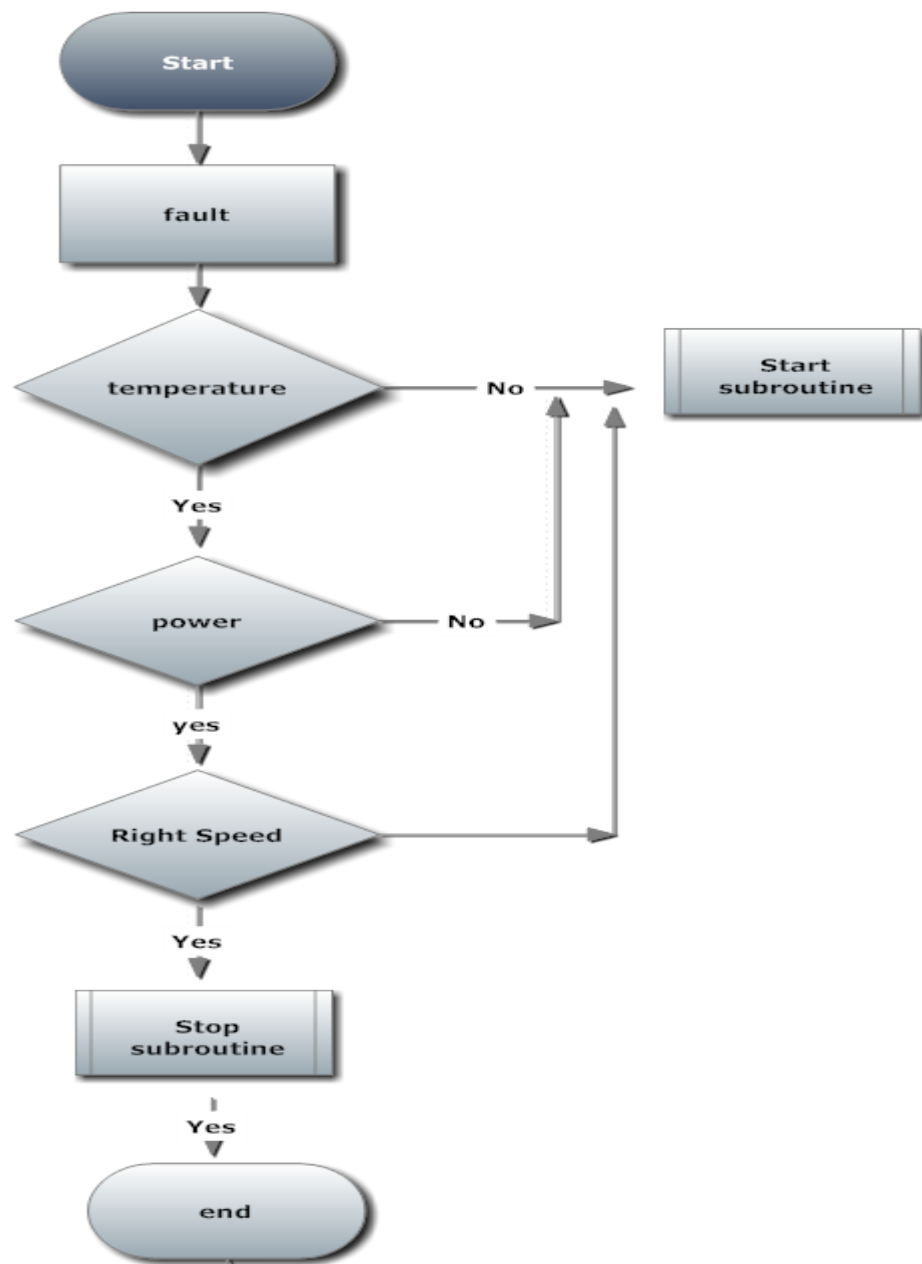


Figure 2.11 fault Subroutine

Unknown faulty triggered subroutine; this subroutine will be runs in parallel to oversee all other conditions which might occur during operations. The codes described by flowcharts are listed below in appendix B.



## **CHAPTER 5:**

### **RESULTS DISCUSSION and CONCLUSIONS**

To meet the objectives of this research project, Remotely Accessibility of a 35 kVA Backup Diesel Generator for a successful remote operation, reduce work place potential hazards; increase the servicing time of the machine and to certify the need of local and remote control of the equipment.

This chapter will outline the results obtain from the experiment from simulation and implementation of the project.

The chapter will analyses the flaws encountered and how they where eradicated as to other alternatives approaches. The approach which was taken to implement this project was considered as a successful and a better approached. The programming objectives were mate.

#### **Types of test**

There were three types of tests which were carried out; these tests were done to prevent any damage to the equipment during operation.

Simulation

Test per component

Systems Test

### **Simulation Test**

During Simulations a PLC codes was simulate to detect any flaws and errors. The simulation was very successful. This was done by using a push button to illustrate the input and observe the output conditions from the program graphical chart. These demonstrate how the system could response to the defined sequence by the programmer. When all the subroutines were deployed some adjustments were done and the system began to runs smoothly.

### **SCADA Simulation**

SCADA simulations was done by a software called SIMATIC WinCC flexible 2008, this program have ability to simulate it codes by a components or accumulative. Once the software detected a flaw in the programs, the program will display an error message and direct the programmer to make an adjustment to the codes.

### **Multiple Component Test.**

The multiple component test is carried out by simulating the whole program to ensure that is operating according to the criteria. This done by pressing the right button and observe the operation. If the animations are animating according to the design, therefore it can be concluded that the system is functioning properly.

Fuel levels, temperature and speed of the diesel generator were tested; this test gave the correct reading on the scales. The kinds of simulation results were display on the scales as show below.

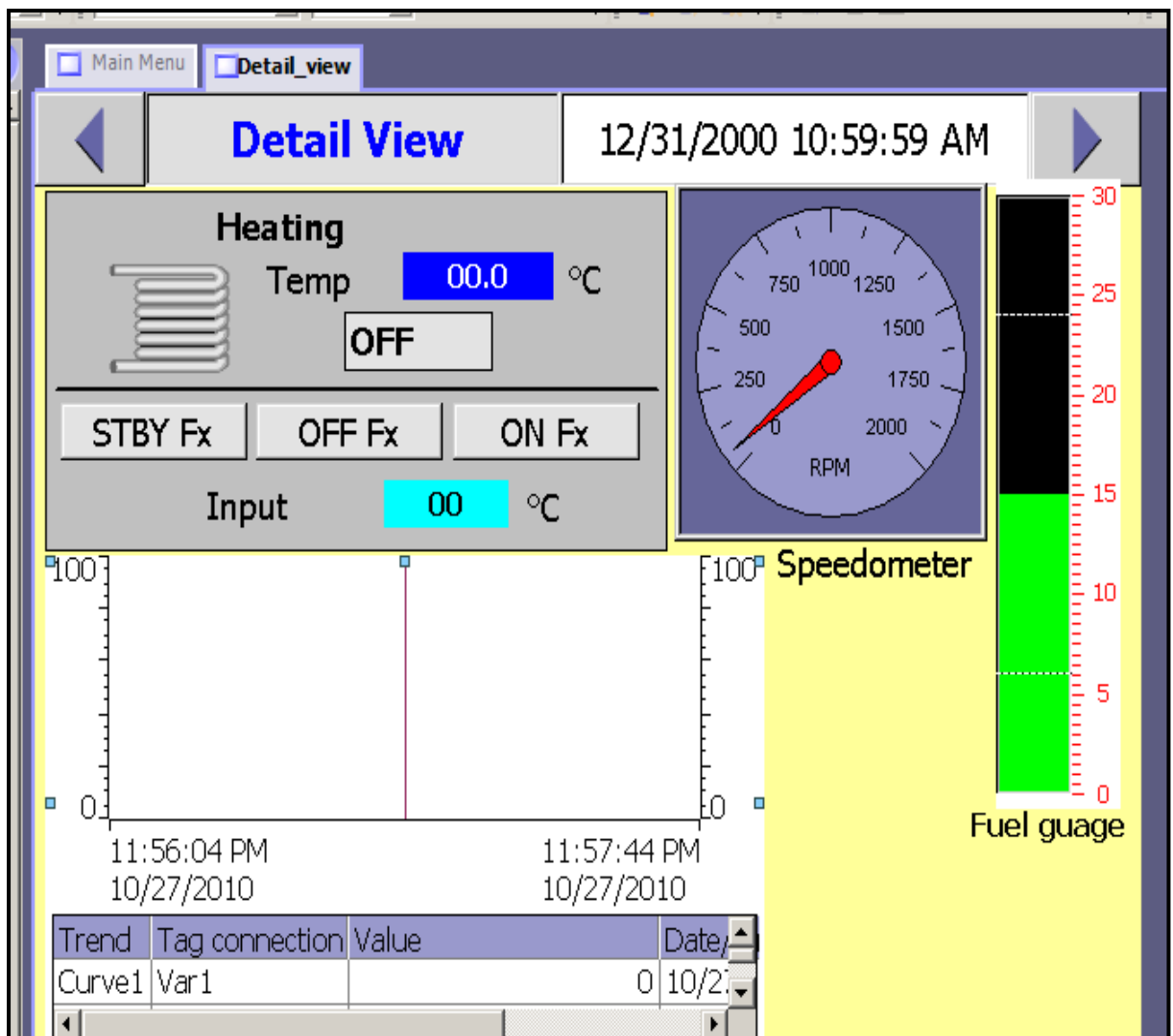


Figure 5.1 SCADA Detail view mimic

The mimic shown above show how the results were displayed for the Speedometer and Fuel gauges.

## Testing of Individual Components

Testing of individual components was done to make sure that each component was functioning according to the project specifications, each of the above mentioned elements were tested multiple times for consistency and correct functionality.

Table 2 Component test

**Table 1: Test**

Component	Test	Pass	Fail	Comment
Generator Start	Yes	Yes		Quick Start
Generator Stop	Yes	Yes		Steady Stop
Fuel Solenoid	Yes	Yes		
Pressure Transducer	Yes	L passed		Reading not precise but reasonable
Loads Contactors	Yes	Yes		Accurate
Relays	Yes	Yes		Good
PLC Code	Yes	Yes		Good
SCADA Mimic	Yes	Yes		Good
Gain Amplifier	Yes	Yes		Good
Cable RS485	Yes	Yes		Good

These tests were carried out on site for testing the systems. It was found that all components passed their individual tests. This allows the entire components to be installed.

## **Conclusion**

This chapter has outlined and explained the different approaches taken during testing to ensure the accurate performance of the systems. Three types of testing were performed; Simulation, Individual component test and the System test. These tests passed all their requirements according to the project specifications. It was concluded that, more test and on operation development were still to be carried it out to allow the program to be certified as a safe way of operating the Diesel Generator. There might have been a missed flaw in the system but at this moment in time it was considered that the project had achieved it objectives.

In summary it has proven that a Remotely Accessible 35 kVA Backup Diesel Generator technically is achievable at the University of Southern Queensland Toowoomba Campus. The main objectives and specifications were achieved with some further work required for final implementation and student trials.

## 6 APPENDICIES

### Appendix A: PROJECT SPECIFICATION

University of Southern Queensland  
Faculty of Engineering and Surveying

#### ENG4111/4112 Research Project PROJECT SPECIFICATION

FOR: **Dhieu Magot Piok**

TOPIC: Remote Access of PLC Based Laboratory

SUPERVISOR: **Mr. Leslie Bowtell**

PROJECT AIM: This project seeks to develop a PLC program to remotely access and control Diesel power Generator.

**PROGRAMME :** issue 25 March 2010

- 1) Research PLC and SCADA systems and programs to give understanding and background
- 2) Research Diesel Generator Set on AC (Alternating Current ) motors and VSD (Variable Speed Drive) motors
- 3) Research for current remote access and control in the market.
- 4) Design and implement a PLC interface to Gen Set to remotely accessible and control the Diesel Generator
- 5) Analysis and debug program considering safety of people and plant
- 6) Evaluate the benefits of the program, effectiveness and future possibilities
- 7) Submit an academic dissertation on the research and developments

#### AS TIME PERMITS

- a. Design and implement remote access and control of other electrical Laboratory experiments
- b. Wireless access and control
- c. Evaluate the cost and logistical benefits the devices and to conduct an experiments on electrical machines.

GREED \_\_\_\_\_ Student  \_\_\_\_\_  
(supervisor)

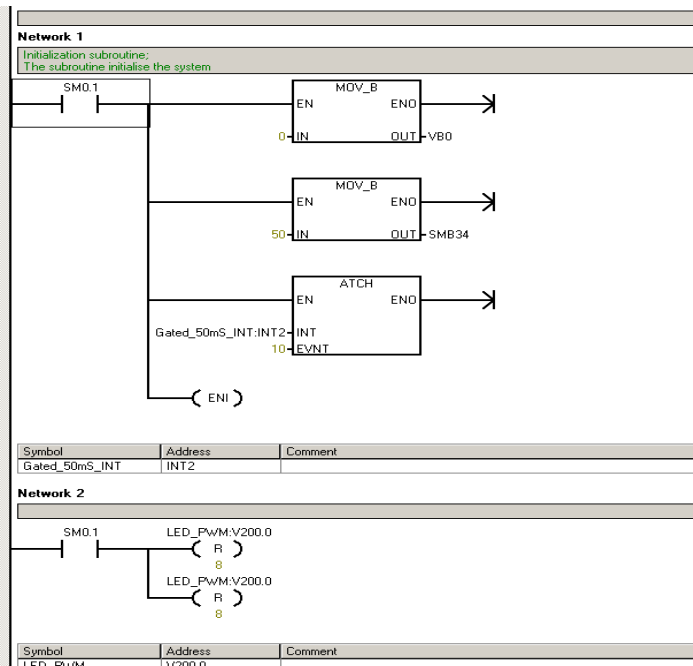
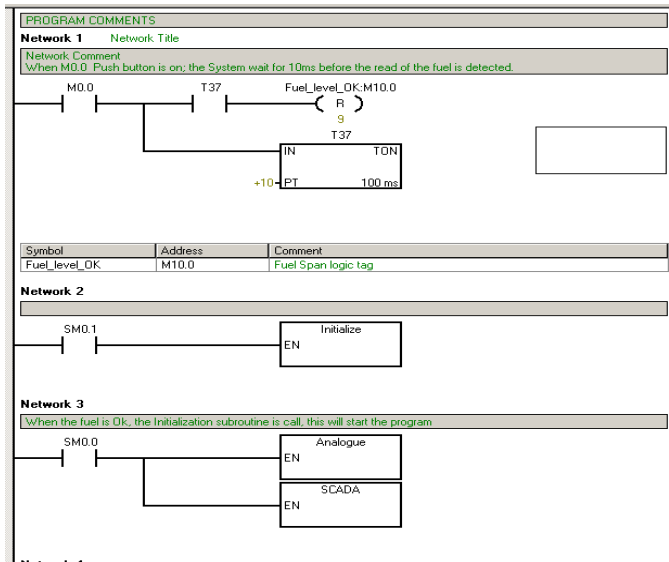
Date / / 2010

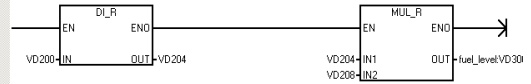
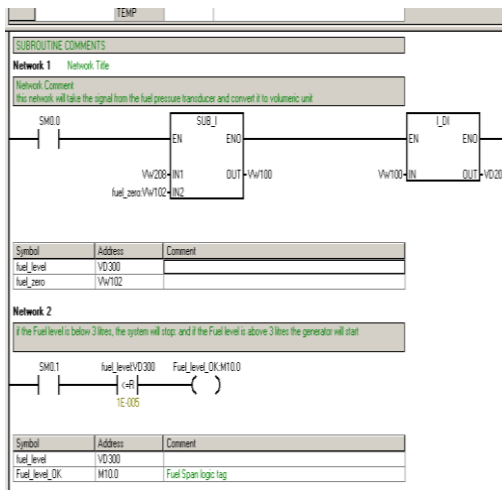
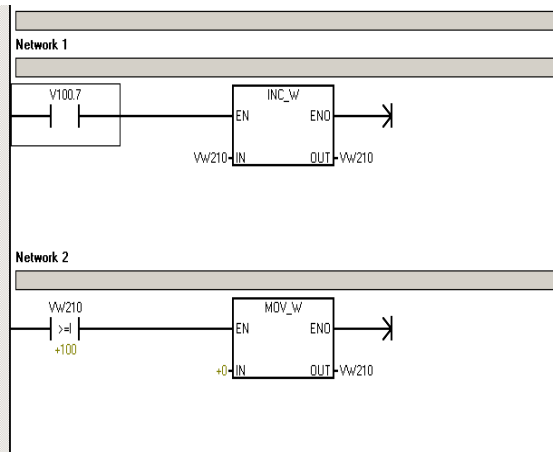
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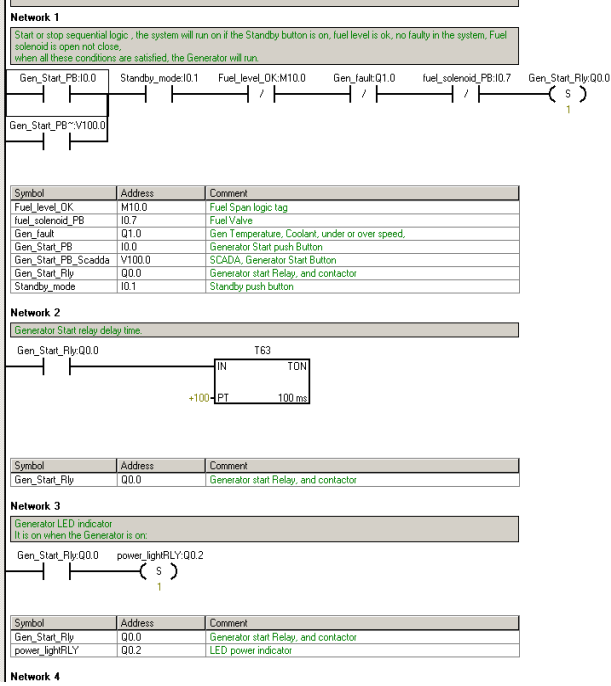
# APPENDIX B

## PLC Program Code

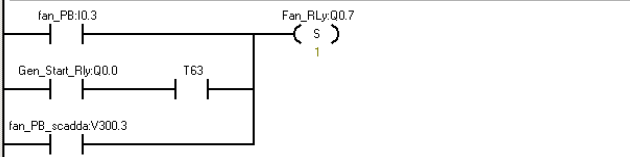








**Network 4**  
Fan Push Button, the fan can Automatically turn on after 10 second of the Generator started



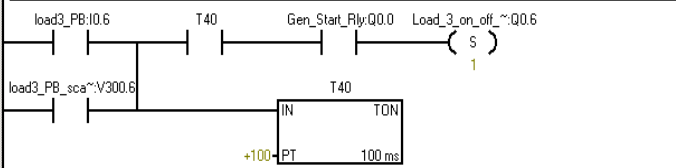
Symbol	Address	Comment
fan_PB	I0.3	Fan push Button
fan_PB_scadda	V300.3	Fan SCADA push button
Fan_RLy	Q0.7	Fan Relay
Gen_Start_Rly	Q0.0	Generator start Relay, and contactor

**Network 5**  
Stop Fan when the Generator is off or when the Stop button is pushed.



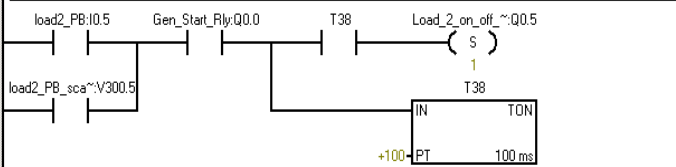
Symbol	Address	Comment
fan_PB	I0.3	Fan push Button
Fan_RLy	Q0.7	Fan Relay
Stop_PB	I0.2	Fan Stop push button
Stop_PB_scadda	V100.2	Fan Stop SCADA push button

**Network 6**  
Load 3 on Push button, load 2 only turn , If the Generator run for 10 second.



Symbol	Address	Comment
Gen_Start_Rly	Q0.0	Generator start Relay, and contactor
load3_PB	I0.6	Load3 push button
load3_PB_scadda	V300.6	Load 3 SCADA push button
Load_3_on_off_RLY	Q0.6	load 3 relay

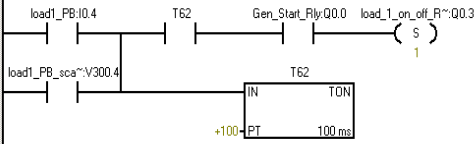
**Network 7**  
Load 2 on Push button, load 2 only turn , If the Generator run for 10 second.



Symbol	Address	Comment
Gen_Start_Rly	Q0.0	Generator start Relay, and contactor
load2_PB	I0.5	Load 2 push button
load2_PB_scadda	V300.5	Load 2 SCADA push button
Load_2_on_off_RLY	Q0.5	Load 2 Relay

**Network 8**

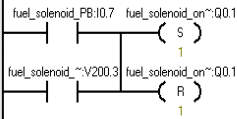
Load 1 on Push button, load 2 only turn, If the Generator run for 10 second.



Symbol	Address	Comment
Gen_Start_Rly	Q0.0	Generator start Relay, and contactor
load1_PB	I0.4	load1 Push button
load1_PB_scadda	V300.4	Load1 SCADA Push Button
load_1_on_off_RLY	Q0.3	Load1 Relay

**Network 9**

Fuel solenoid push button.



Symbol	Address	Comment
fuel_solenoid_on_off	Q0.1	Fuel Solenoid Relay
fuel_solenoid_PB	I0.7	Fuel Valve
fuel_solenoid_PB_sca...	V200.3	Fuel Solenoid SCADA push button

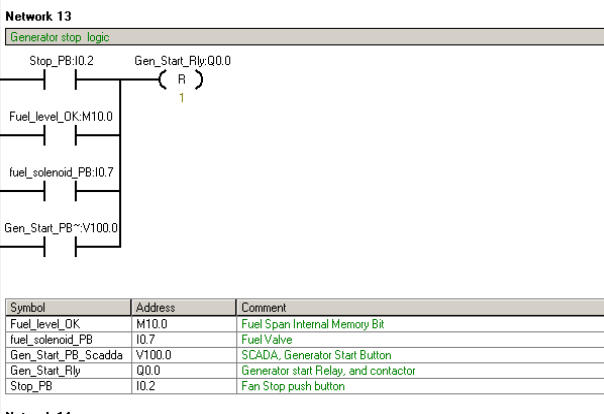
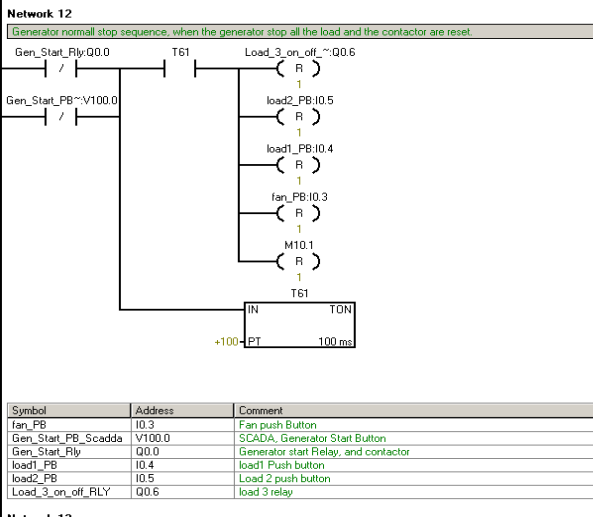
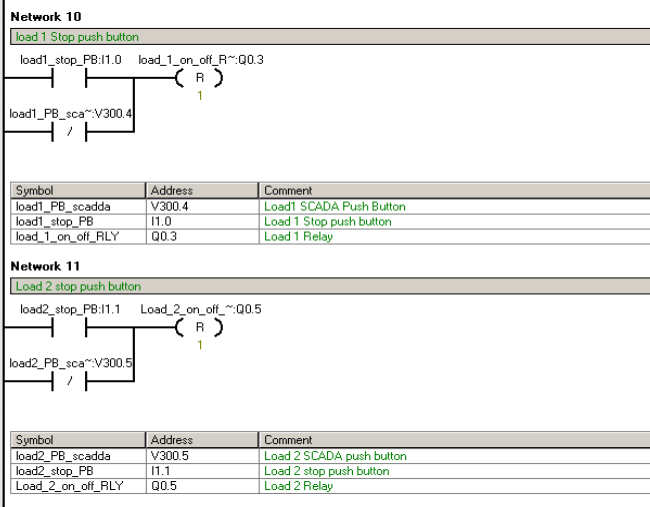
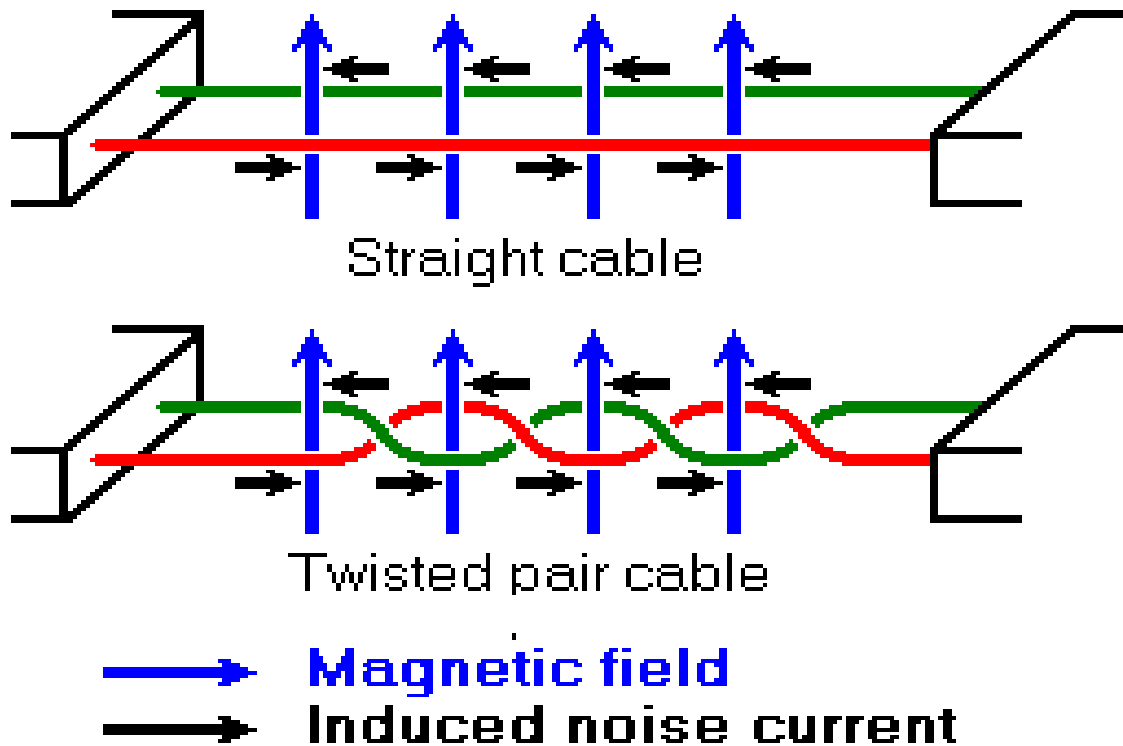


Table A.1 PLC Tags

Symbol	Address	Comment
fan_PB	I0.3	Fan push Button
fan_PB_scadda	V300.3	Fan SCADA push button
Fan_RLy	Q0.7	Fan Relay
fuel_level	VD300	Analog fuel Level
Fuel_level_OK	M10.0	Fuel Span Internal Memory Bit
fuel_solenoid_on_off	Q0.1	Fuel Solenoid Relay
fuel_solenoid_PB	I0.7	Fuel Valve
fuel_solenoid_PB_scadda	V200.3	Fuel Solenoid SCADA push button
fuel_span	VD144	
fuel_zero	VW102	
Gen_fault	Q1.0	Gen Temperature, Coolant, under or over speed,
Gen_Start_PB	I0.0	Generator Start push Button
Gen_Start_PB_Scadda	V100.0	SCADA, Generator Start Button
Gen_Start_Rly	Q0.0	Generator start Relay, and contactor
LED_PwM	V200.0	Generator Light Indicator
load1_PB	I0.4	load1 Push button
load1_PB_scadda	V300.4	Load1 SCADA Push Button
load1_stop_PB	I1.0	Load 1 Stop push button
load2_PB	I0.5	Load 2 push button
load2_PB_scadda	V300.5	Load 2 SCADA push button
load2_stop_PB	I1.1	Load 2 stop push button
load3_PB	I0.6	Load3 push button
load3_PB_scadda	V300.6	Load 3 SCADA push button
load3_stop_PB	I1.2	
load_1_on_off_RLY	Q0.3	Load 1 Relay
Load_2_on_off_RLY	Q0.5	Load 2 Relay
Load_3_on_off_RLY	Q0.6	load 3 relay
power_lightRLY	Q0.2	LED power indicator
Standby_mode	I0.1	Standby push button
Stop_PB	I0.2	Fan Stop push button
Stop_PB_scadda	V100.2	Fan Stop SCADA push button
		SCADA PB
	AIW2	

## Appendix C

### Bibliography



### *Characteristics of RS485 compared to RS232, RS422 and RS423*

source(<http://www.lammertbies.nl/comm/info/RS-485.html#intr>) 15<sup>th</sup> Oct

2010The industrial Ethernet PPI (point to point Interface) RS485 or EIA 485 cable was selected for the data transmissions

Noise in straight and twisted pair cables

Figure 3: RS485

source (<http://www.lammertbies.nl/comm/info/RS-485.html#intr>) 15<sup>th</sup> Oct 2010

Characteristics of RS232, RS422, RS423 and RS485				
	RS232	RS423	RS422	RS485
Differential	no	no	yes	yes
Max number of drivers				
Max number of receivers	1	1	1	32
	1	10	10	32
Modes of operation	half duplex full duplex	half duplex	half duplex	half duplex
Network topology	point-to-point	multidrop	multidrop	multipoint
Max distance (acc. standard)	15 m	1200 m	1200 m	1200 m
Max speed at 12 m				
Max speed at 1200 m	20 kbs (1 kbs)	100 kbs 1 kbs	10 Mbs 100 kbs	35 Mbs 100 kbs
Max slew rate	30 V/ $\mu$ s	adjustable	n/a	n/a
Receiver input resistance	3.7 k $\Omega$	$\geq 4$ k $\Omega$	$\geq 4$ k $\Omega$	$\geq 12$ k $\Omega$
Driver load impedance	3.7 k $\Omega$	$\geq 450$ $\Omega$	100 $\Omega$	54 $\Omega$
Receiver input sensitivity	$\pm 3$ V	$\pm 200$ mV	$\pm 200$ mV	$\pm 200$ mV
Receiver input range	$\pm 15$ V	$\pm 12$ V	$\pm 10$ V	$-7..12$ V
Max driver output voltage	$\pm 25$ V	$\pm 6$ V	$\pm 6$ V	$-7..12$ V
Min driver output voltage (with load)	$\pm 5$ V	$\pm 3.6$ V	$\pm 2.0$ V	$\pm 1.5$ V

## SCADA Radio Modem

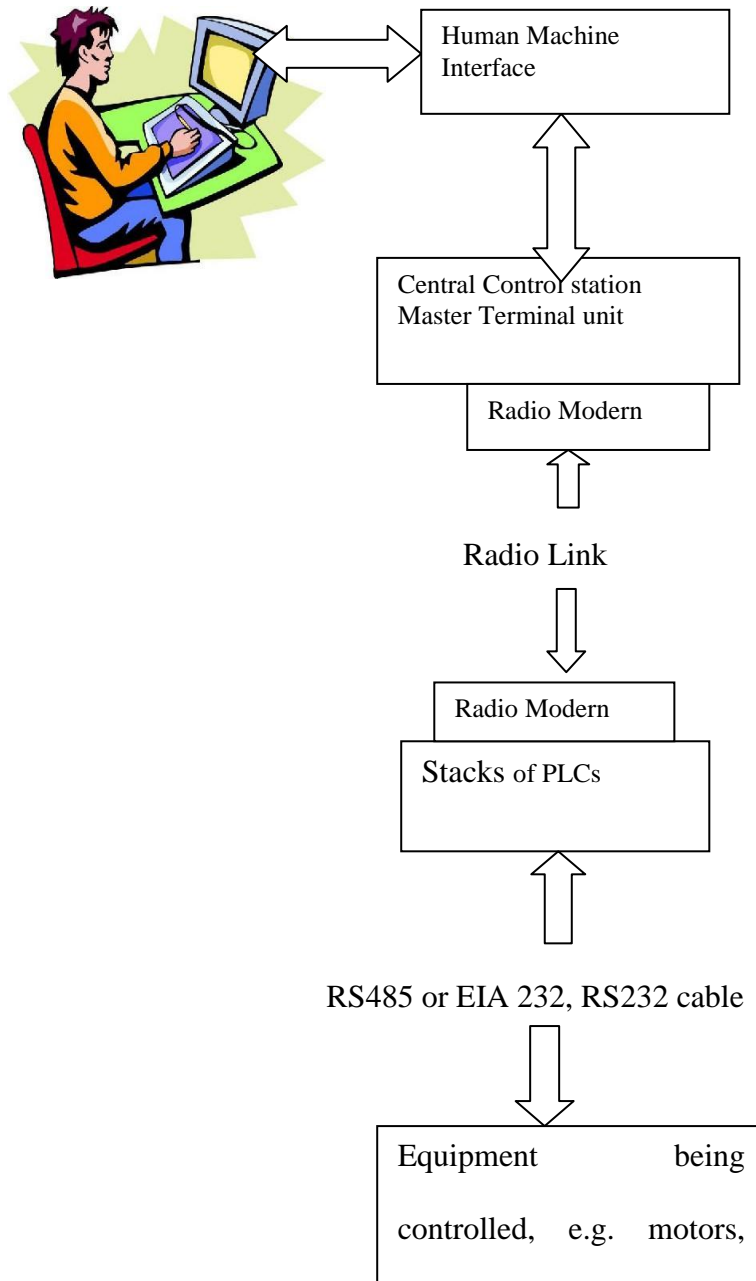


Figure 4 SCADA Remote links



## Multi internet based point, with internet protocol

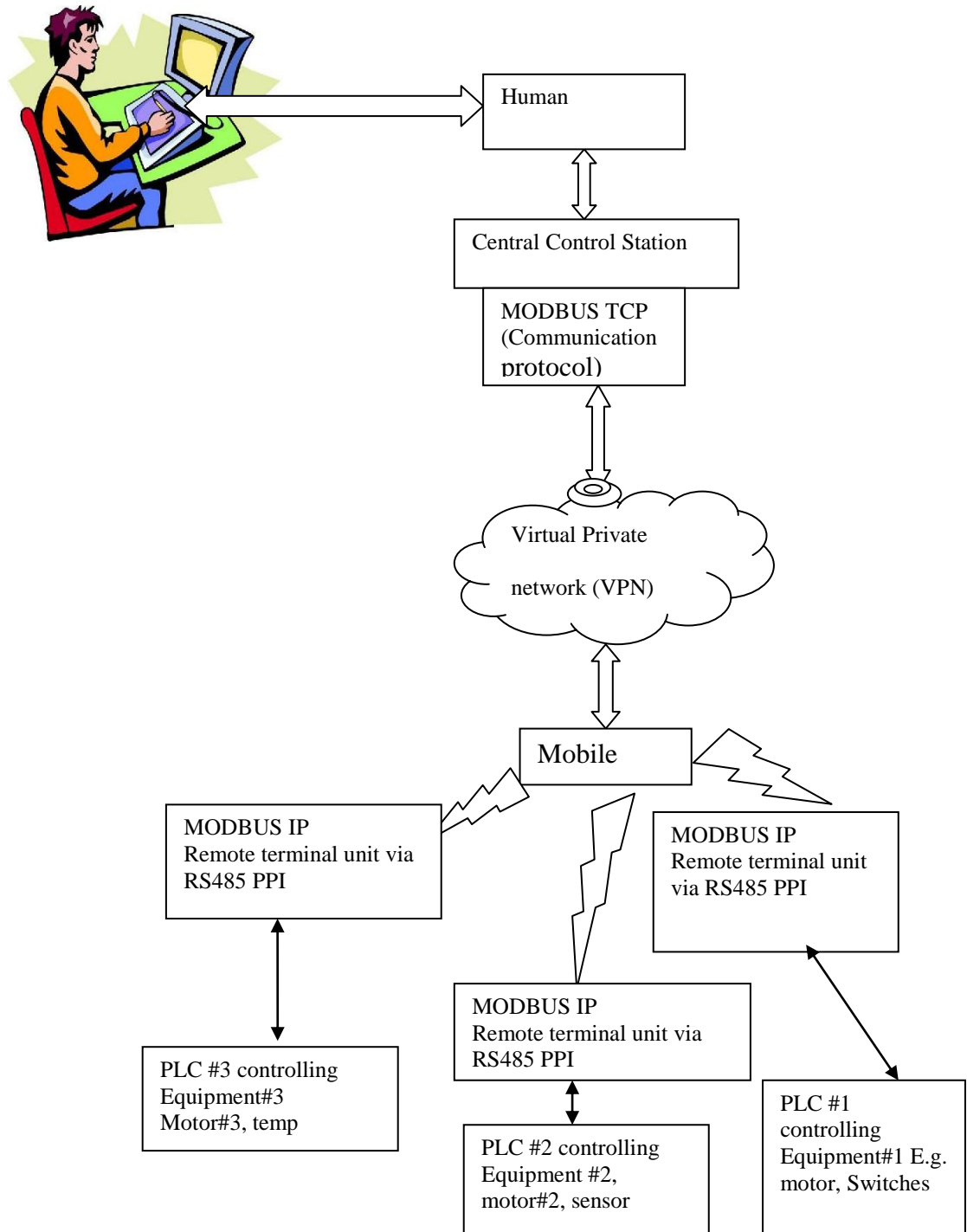
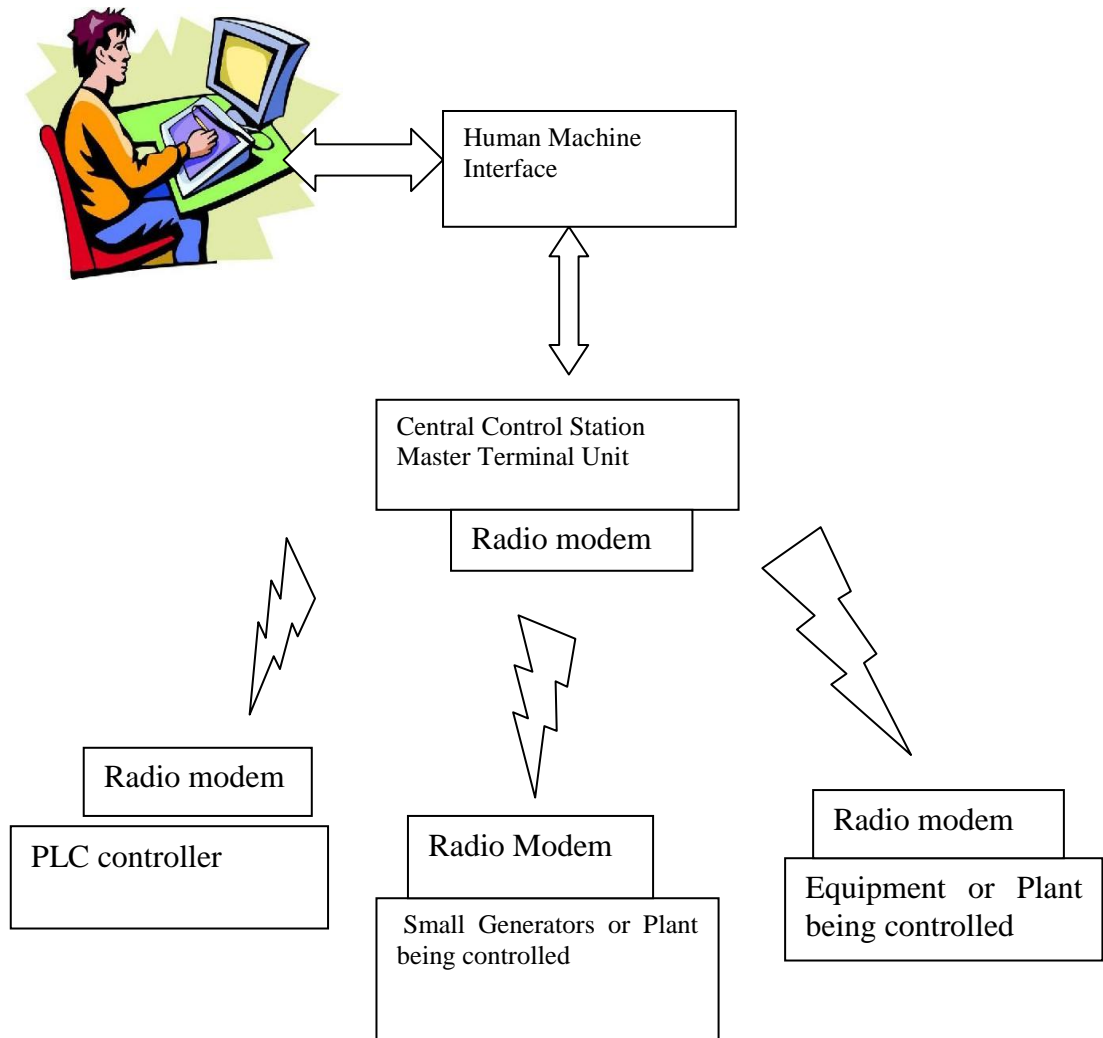


Figure A.6 SCADA Multiple Remote Access

## Multi –Radio Controllers Remote Systems

Figure A.5: Remote Access



## Typical Small Generator Distributions Systems

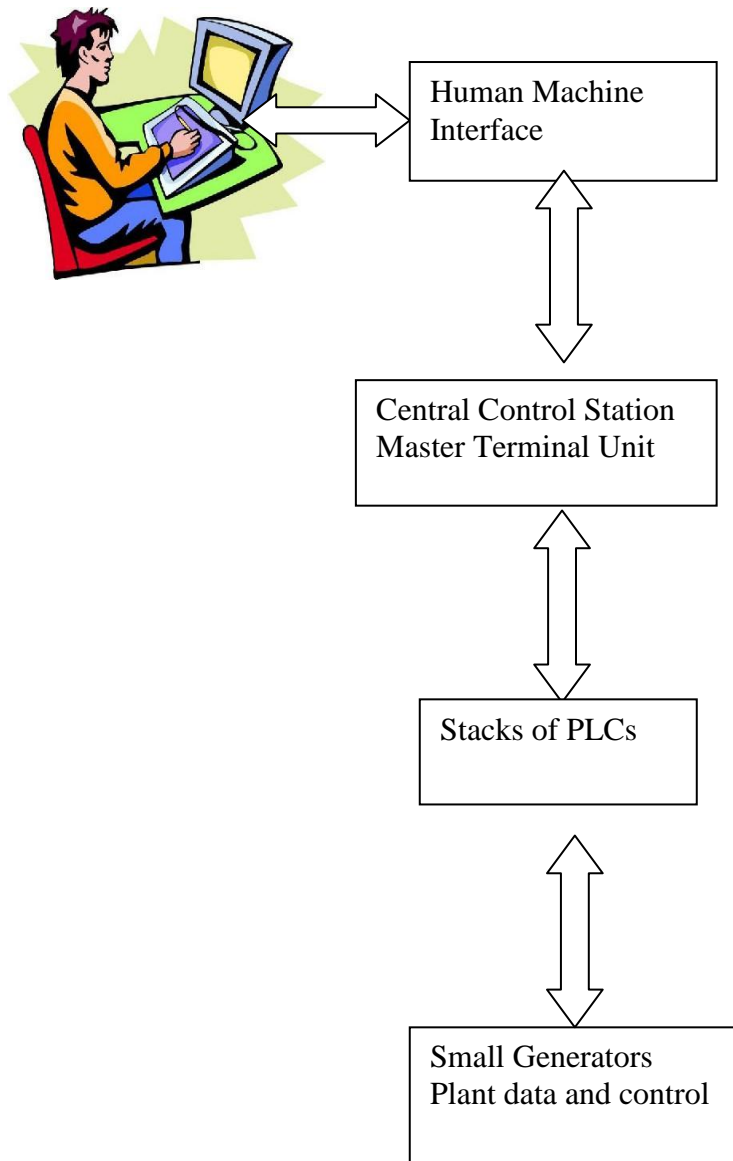


Figure A.8 Small Power Distributions

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