PLC & SCADA BASED SUBSTATION AUTOMATION

Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Engineering

in

Electrical

By

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(UNIVERSITY OF MUMBAI)

Academic Year 2014-2015

Affectionately Dedicated
To My Beloved

Ammi jaan

&

Abbu Jaan

Who Always Sacrifice Their Happiness
To Make Me Happy

CERTIFICATE

This is to certify that a project report entitled ***"PLC & SCADA Based Substation Automation"*** is bonafide project work done by

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APPROVAL OF PROJECT

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DECLARATION

We declare that the project report on **"PLC & SCDA Based Substation Automation"** written submission represents our ideas in our own words and where others' ideas or words have been included, We have adequately cited and referenced the original sources.

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Acknowledgement

*It is indeed a matter of great pleasure and proud privilege to be able to present this project on **“PLC & SCADA based Substation Automation".***

*The completion of the project work is a millstone in student life and its execution is inevitable in the hands of guide. I am highly indebted the project guide **Prof.Iftekar Patel,** AIKTC-School of Engineering & Technology, NewPanvel ,for his invaluable guidance and appreciation for giving form and substance to this report. It is due to his enduring efforts; patience and enthusiasm, which has given a sense of direction and purposefulness to this project and ultimately made it a success.*

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ABSTRACT

Electrical power systems are a technical wonder. Electricity and its accessibility are the greatest engineering achievements of the 20^{th} century. A modern society cannot exist without electricity.

Generating stations, transmission lines and distribution systems are the main components of power system. Smaller power systems (called regional grids) are interconnected to form a larger network called national grid, in which power is exchanged between different areas depending upon surplus and deficiency. This requires a knowledge of load flows, which is impossible without meticulous planning and monitoring .Also, the system needs to operate in such a way that the losses and in turn the cost of production are minimum.

The major factors that influence the operation of a power system are the changes in load and stability. As is easily understood from the different load curves and load duration curve, the connected load, load varies widely throughout the day. These changes have an impact on the stability of power system. As a severe change in a short span can even lead to loss of synchronism. Stability is also affected by the occurrence of faults, Faults need to be intercepted at an easily stage and corrective measures like isolating the faulty line must be taken.

As the power consumption increases globally, unprecedented challenges are being faced, which require modern, sophisticated methods to counter them. This calls for the use of automation in the power system. The Supervisory Control and Data Acquisition (SCADA) and Programmable Logic Controllers (PLC) are an answer to this.

SCADA refers to a system that enables on electricity utility to remotely monitor, co-ordinate, control and operate transmission and distribution components, equipment and real-time mode from a remote location with acquisition at date for analysis and planning from one control location.

PLC on the other hand is like the brain of the system with the joint operation of the SCADA and the PLC, it is possible to control and operate the power system remotely. Task like
Opening of circuit breakers, changing transformer taps and managing the load demand can be carried out efficiently.

This type of an automatic network can manage load, maintain quality, detect theft of electricity and tempering of meters. It gives the operator an overall view of the entire network. Also, flow of power can be closely scrutinized and Pilferage points can be located. Human errors leading to tripping can be eliminated. This directly increases the reliability and lowers the operating cost.

In short our project is an integration of network monitoring functions with geographical mapping, fault location, load management and intelligent metering.

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Abbreviations

AC	Alternating Current
AMIS	**Automated Metering and Information System**
ARM	Advanced RISC Machines
CPU	Central Processing Unit
CB	Circuit Breaker
DC	Direct Current
EEPROM	Electrically Erasable Programmable Read Only Memory
EMS	**Energy Management System**
FPGA	Field-Programmable Gate Arrays
GTG	Gas Turbine Generator
GUI	Graphical User Interfaces
GSM	Global System for Mobile Communications
GPRS	General Packet Radio Service
HMI	Human-Machine Interface
HTML	Hyper Text Markup Language
IED	*Intelligent Electronic Device*
IEC	*International Electrotechnical Commission*
ISO	Isolator
IAP	**Intelligent Alarm Processors**
ISC	Industrial Control System
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
LED	Light Emitting Diode
LTC	Load Tap Changer
MMI	Man-Machine Interfaces
PLC	Programmable Logic Controllers
PDF	Portable Document Format
PC	*Personal Computer*
PCB	Printed Circuit Board
RTU	Remote Terminal Units
RLL	Relay Ladder Logic
RAM	*Random Access Memory*

ROM	Read Only Memory
SCADA	Supervisory Control And Data Acquisition
SMPS	Switched-Mode Power Supply
TTL	*Transistor–Transistor logic*
VSAT	*Very Small Aperture Terminal*
WAN	*Wide Area Network*

Chapter 1

Introduction

1.1. Introduction

Much attention has been given to the use of PLCs (Programmable Logic Controllers) in substation and distribution automation applications in recent years. Innovative engineers and technicians have been actively seeking new applications for PLCs in substations and SCADA (Supervisory Control And Data Acquisition) systems. The manufacturers of PLCs have responded by developing new products that meet the unique requirements of substation automation and SCADA applications. PLCs are very cost competitive with traditional RTUs and have many benefits in substation automation applications. PLCs have an important place in substation automation and their use in substation applications will grow.

As the use of PLCs in substation automation applications increases, and the demand for substation and distribution automation increases, utility engineers are seeking ways to implement applications. With deregulation, utilities are decreasing engineering staff levels.

Utility engineers are required to field more projects with fewer available resources. The services of outside control system integrators, engineering firms or consultants are often called upon to meet the needs of the utilities. Selection of an outside firm is an important task of the utility engineer and the selection of the particular outside firm can determine the success or failure of a project.[9]

1.2. History of PLC use in substations

The Hydramatic Division of General Motors Corporation specified the design criteria for the first programmable controller in 1968. The first PLCs only offered control relay functionality and were programmed in RLL (Relay Ladder Logic). PLCs offered the automobile industry quick change for year to year model changes.

In addition, PLCs were modular and easily understood by plant floor personnel.

The first programmable controllers were known as PCs; the acronym PLC for programmable logic controller, was actually a trade name used by Allen-Bradley. With the introduction of personal computers known as PCs the term PLC became the common term to avoid confusion.

By 1971 PLCs were coming into wide spread use in industries outside the automotive industry. Still providing control relay replacement only, they were found in industries such as food and beverage, pharmaceutical, metals, manufacturing and pulp and paper.

The introduction of microprocessors changed the PLC industry. PLCs have been reduced in size from the size of an apple crate to smaller than a loaf of bread. Some PLCs are smaller than a deck of cards. Processing power increased and PLCs are now capable of the most complex program algorithms. Originally PLCs were programmed only in RLL; they can now be programmed in several styles and types of programming languages such as SFC

(sequential function chart), state language, control block languages and statement languages such as Basic. With the growth in technology, PLCs are now capable of advanced data manipulation, communications and process control.

PLCs were first used by the utility industry in generating stations. This is undoubtedly because of the similarity of generating station applications to industrial applications in which PLCs were already being applied.

Private industry has been applying PLCs in substations for many years. Exxon has applied PLCs in refinery substations for load shedding and load restoration (called re-acceleration because of the connected motor loads) since the early 1980s. PLCs have been used in emergency power systems in commercial buildings and hospitals for many years for switching, load shedding and restoration and emergency generator control.[9]

1.3. Benefits of using PLCs in substation automation

Reliability, a large installed base, extensive support resources and low costs are some of the benefits of using PLCs as a basis for substation automation and SCADA systems.

PLCs are extremely reliable. They have been developed for application in harsh industrial environments. They are designed to operate correctly over wide temperature ranges and in very high electromagnetic noise and high vibration environments. They can operate in dusty or humid environments as well. The number of PLCs (in the millions) which have been applied in various environments has allowed the designers of PLCs to perfect the resistance to the negative effects of harsh environments.

The large installed base of PLCs offers the advantages of reduced costs, readily available

and low cost spare parts and trained personnel to work on PLCs. The large installed base also allows the manufactures more opportunity to improve design and offer new products for more varied applications.

PLCs have extensive support throughout the US and most of the world. PLC manufactures have extensive of field offices, distributors and authorized control system integrators. Most technical schools and colleges offer courses in PLC application, programming and maintenance.

In many, if not all, applications PLCs offer lower cost solutions than traditional RTUs for SCADA systems. They offer lower cost solutions than traditional electromechanical control relay systems for automated substation applications. With the lower cost solutions PLC

based systems offer in substation and distribution automation applications along with the other benefits, it is no surprise that there is so much interest in the application of PLCs in substation. [9]

How new technologies can improve monitoring and control?

Substations are a critical component for maintaining electrical supply and load control in low voltage, medium voltage and high voltage electrical distribution networks. In order to ensure the proper functioning of substations and related equipment such as line-mounted switches and capacitors, most utilities use SCADA (supervisory control and data acquisition) systems to automate monitoring and control.

Fig.1.1 Improve monitoring

New sites typically implement a SCADA system to monitor and control substations and related equipment. However, older facilities can also benefit by adding a SCADA system or by upgrading an existing SCADA system to take advantage of newer technologies.

Not only will a new or upgraded SCADA system provide better monitoring and control, it can also extend the life of substations and related equipment by providing current data for troubleshooting small problems before they escalate. Furthermore, the ample historical data provided by SCADA systems can improve preventive maintenance scheduling and cut associated[9]

Why are SCADA Systems Important?

Electrical distribution systems involve many remote applications and sites, and monitoring and controlling these sites has often been difficult. To solve this problem, utilities began installing remote terminal/telemetry units (RTUs) at substations. Early RTUs were initially custom-made units, but later versions relied on standard hardware such as programmable logic controllers (PLCs) or industrial PCs. Intelligent electronic devices (IEDs) are a more recent technology development, and these devices are now installed at most substations to some extent. These IEDs generally communicate with the substation RTU.

Power distribution to various electrical loads at substations is controlled by switchgear feeders. Sensors mounted on the switchgear collect various data on current, voltage, power and switchgear status. This data is transferred to the RTU, which is in turn polled by a SCADA system.

The SCADA system consists of a master control station with one or more PC-based human machine interfaces (HMIs). The SCADA system may also contain other secondary control stations with HMIs, and large substations may also have local HMIs.

Operators view information on the HMIs to monitor and control substation operations and related equipment. Modern SCADA systems are extremely adept at handling the large amounts of data necessary to monitor the electrical state of all power lines, cables and equipment.[9]

1.4. Block Diagram

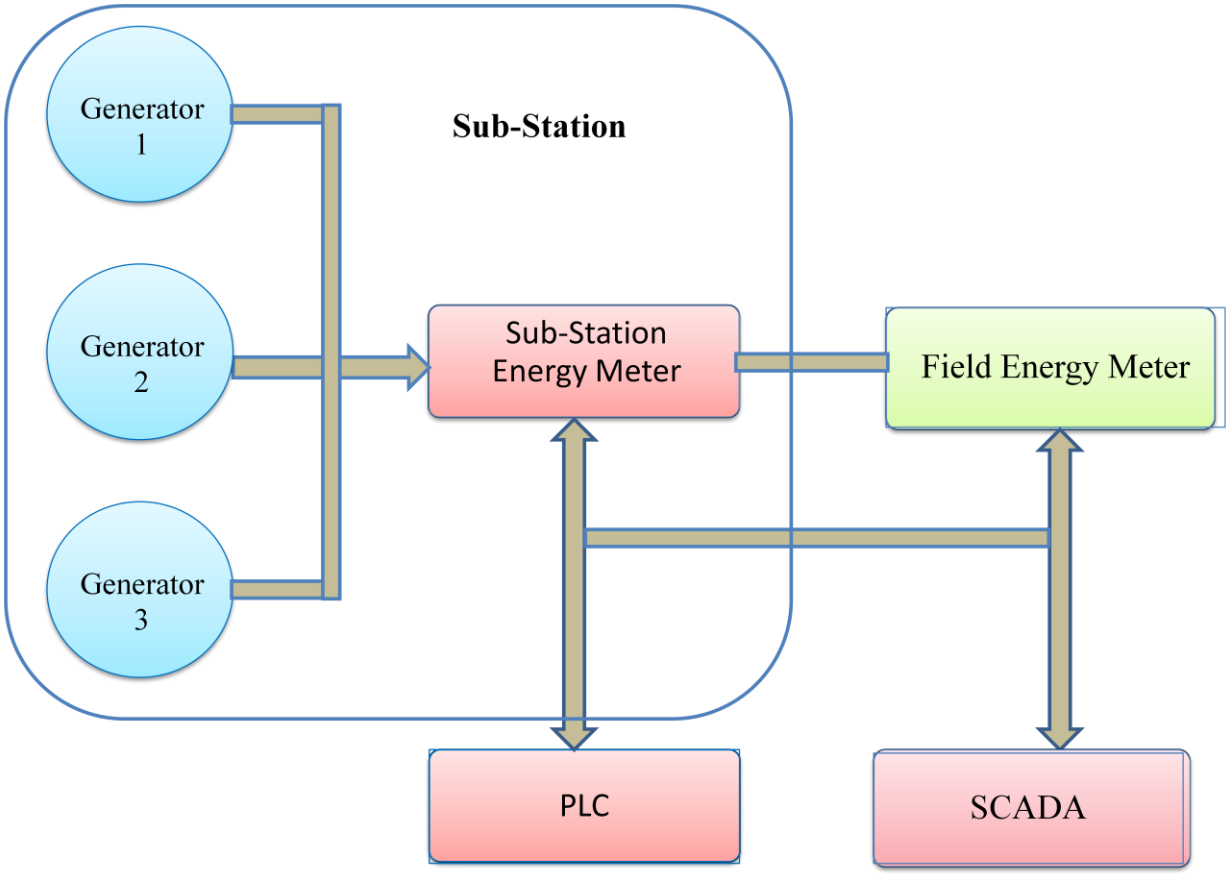


Fig.1.2 Block diagram of project

The energy of switching devices (relays/contactors)to opertate Generatords in the substation are measured using an energy meter. Energy received in the field is measured by another energy meter. The measured energy of the substation and field are communicated to PLC and monitored by SCADA. Based on the difference in energy PLC actuates the switching devices in the substation.

The purpose of the project is automate a substation. The aim is to detect energy losses during transmission of electricity between substation and field. This loss of energy may be due to theft or any other reason resulting in energy loss.

Chapter 2
Review of Literature

There have been so many researches done in its theoretical & application field which are briefly discussed in this chapter.

In [1] V.K. Mehta ,Rohit Mehta, PRINCIPLES OF POWER SYSTEM, presented in his book regarding requirements of distribution system and its objectives.

In [2] Jigiiesh C. Sailor, Himanshu Naik, Prof. S.U.Ku1karni, presented Substation Automation Integration and proposed several initial optimization indexes to make the system more practical. They proved that substation automation is very effective and optimization method can achieve both high performance and increased efficiency.

In [3] LOURENCO TEODORO, SCADA for Substations, InduSoft , presented brif idea of SCADA based substation automation.Finally the paper ends presenting some real-world applications of the technique, carried out by the author.

In [4] John McDonald, Substation Automation Basics, presented the basics of substation automation, SCADA techniques and issue related with it.

In [5] GE Substation Automation System Solutions, this journal represents the features and hardware.

In [6] MAHESH KUMAR YADAV, A PROJECT REPORT ON SUBSTATION AUTOMATION, Project report submitted to BSES New Delhi, Which gives the information about need of automation in this area and requirements of this system and its benefits and efficiency of this system.

In [7] Nicholas Honeth, Substation Automation Systems, Royal Institute of Technology. Presented SCADA refers to a system that enables on electricity utility to remotely monitor, co-ordinate, control and operate transmission and distribution components, equipment and real-time mode from a remote location with acquisition at date for analysis and planning from one control location.

In [8] ABB Substation Automation Systems, ABB brochure, this brochure describes the system installation and designing of system.

In [9] Tom Wilson, PLC BASED SUBSTATION AUTOMATION AND SCADA SYSTEMS And Selecting a Control System Integrator, In the first part of the paper summarized the main concepts of the PLC & SCADA used for substation automation with examples and case study.

In [13] GETCO Annual Technical T & D Report 2009-210 by Gujarat gov, Represents the detail report of Total substation in Gujarat State and age wise list of substation and how much % of substations are manually operated and how much % of substations are automated

From the reading of the above literatures it was found that it is good to find the global optimum solution to a problem associated.

Chapter 3

Programmable Logic Controller

3.1. PLC

Fig. 3.1 Programmable Logic Controller

A **programmable logic controller**, **PLC**, or **programmable controller** is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many machines, in many industries. PLCs are designed for multiple arrangements of digital and analog inputs and outputs, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. A PLC is an example of a "hard" real-time system since output results must be produced in response to input conditions within a limited time, otherwise unintended operation will result.

3.2. Features

- ✓ Compact PLC
- ✓ Configurable LED display
- ✓ Window based software
- ✓ program for configuration
- ✓ **Siez:** 48mm*96mm [18]

Control panel with PLC (grey elements in the center). The unit consists of separate elements, from left to right; power supply, controller, relay units for in- and output

The main difference from other computers is that PLCs are armored for severe conditions (such as dust, moisture, heat, cold), and have the facility for extensive input/output (I/O) arrangements. These connect the PLC to sensors and actuators. PLCs read limit switches, analog process variables (such as temperature and pressure), and the positions of complex positioning systems. Some use machine vision.[4] On the actuator side, PLCs operate electric motors, pneumatic or hydraulic cylinders, magnetic relays, solenoids, or analog outputs. The input/output arrangements may be built into a simple PLC, or the PLC may have external I/O modules attached to a computer network that plugs into the PLC.

Scan time

A PLC program is generally executed repeatedly as long as the controlled system is running. The status of physical input points is copied to an area of memory accessible to the processor, sometimes called the "I/O Image Table". The program is then run from its first instruction rung down to the last rung. It takes some time for the processor of the PLC to evaluate all the rungs and update the I/O image table with the status of outputs.[5] This scan time may be a few milliseconds for a small program or on a fast processor, but older PLCs running very large programs could take much longer (say, up to 100 ms) to execute the program. If the scan time were too long, the response of the PLC to process conditions would be too slow to be useful.

As PLCs became more advanced, methods were developed to change the sequence of ladder execution, and subroutines were implemented.[6] This simplified programming could be used to save scan time for high-speed processes; for example, parts of the program used only for setting up the machine could be segregated from those parts required to operate at higher speed.

Special-purpose I/O modules may be used where the scan time of the PLC is too long to allow predictable performance. Precision timing modules, or counter modules for use with shaft encoders, are used where the scan time would be too long to reliably count pulses or detect the sense of rotation of an encoder. The relatively slow PLC can still interpret the counted values to control a machine, but the accumulation of pulses is done by a dedicated module that is unaffected by the speed of the program execution.

System scale

A small PLC will have a fixed number of connections built in for inputs and outputs. Typically, expansions are available if the base model has insufficient I/O.

Modular PLCs have a chassis (also called a rack) into which are placed modules with different functions. The processor and selection of I/O modules are customized for the particular application. Several racks can be administered by a single processor, and may have thousands of inputs and outputs. A special high speed serial I/O link is used so that racks can be distributed away from the processor, reducing the wiring costs for large plants.

User interface

PLCs may need to interact with people for the purpose of configuration, alarm reporting, or everyday control. A human-machine interface (HMI) is employed for this purpose. HMIs are also referred to as man-machine interfaces (MMIs) and graphical user interfaces (GUIs). A simple system may use buttons and lights to interact with the user. Text displays are available as well as graphical touch screens. More complex systems use programming and monitoring software installed on a computer, with the PLC connected via a communication interface.

Communications

PLCs have built-in communications ports, usually 9-pin RS-232, but optionally EIA-485 or Ethernet. Modbus, BACnet, or DF1 is usually included as one of the communications protocols. Other options include various fieldbuses such as DeviceNet or Profibus. Other communications protocols that may be used are listed in the List of automation protocols.

Most modern PLCs can communicate over a network to some other system, such as a computer running a SCADA (Supervisory Control And Data Acquisition) system or web browser.

PLCs used in larger I/O systems may have peer-to-peer (P2P) communication between processors. This allows separate parts of a complex process to have individual control while allowing the subsystems to co-ordinate over the communication link. These communication links are also often used for HMI devices such as keypads or PC-type workstations.

Formerly, some manufacturers offered dedicated communication modules as an add-on function where the processor had no network connection built-in.

Programming

PLC programs are typically written in a special application on a personal computer, then downloaded by a direct-connection cable or over a network to the PLC. The program is stored in the PLC either in battery-backed-up RAM or some other non-volatile flash memory. Often, a single PLC can be programmed to replace thousands of relays. [19]

3.3. Block Diagram Of PLC

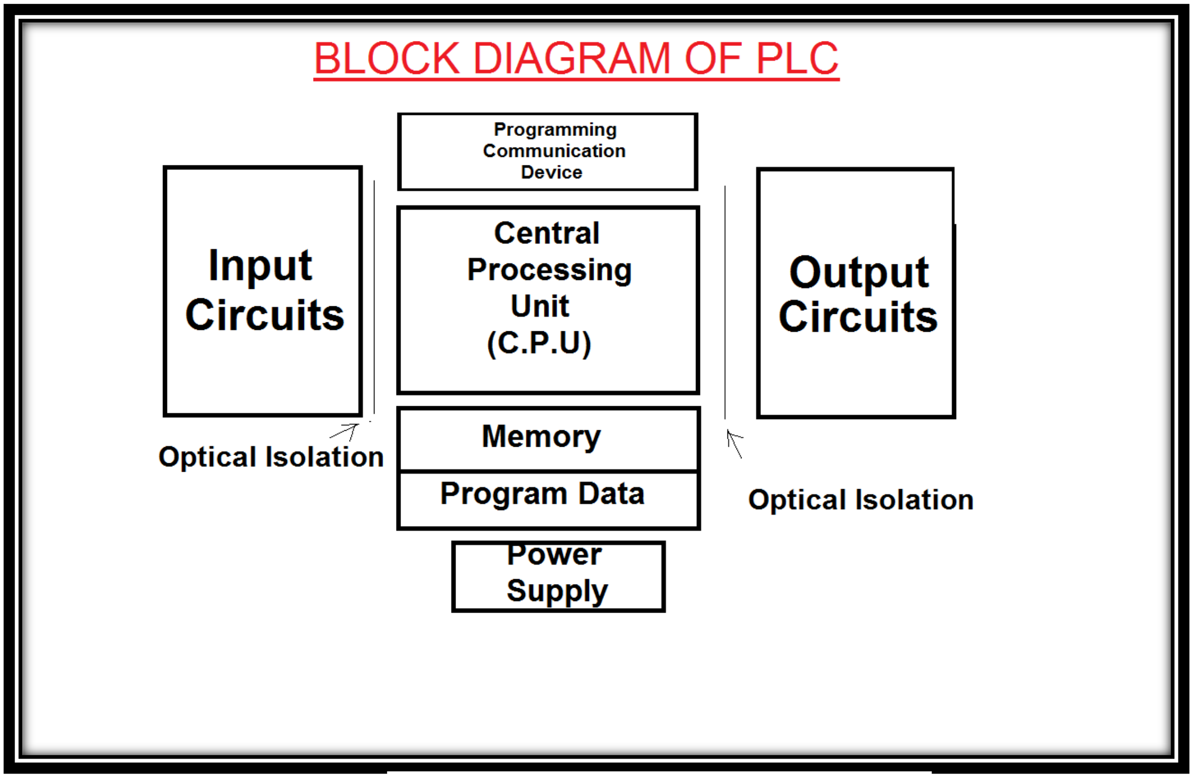


Fig.3.2 Block Diagram of PLC

A Programmable Controller is a specialized computer. Since it is a computer, it has all the basic component parts that any other computer has; a Central Processing Unit, Memory, Input Interfacing and Output Interfacing. A typical programmable controller block diagram is shown below,

The Central Processing Unit (CPU)

is the control portion of the PLC.

1. It interprets the program commands retrieved from memory and acts on those commands.
2. In present day PLC's this unit is a microprocessor based system.
3. The CPU is housed in the processor module of modularized systems.

Memory

in the system is generally of two types; ROM and RAM.

1. The ROM memory contains the program information that allows the CPU to interpret and act on the Ladder Logic program stored in the RAM memory.
2. RAM memory is generally kept alive with an on-board battery so that ladder programming is not lost when the system power is removed.
3. This battery can be a standard dry cell or rechargeable nickel-cadmium type.
4. Newer PLC units are now available with Electrically Erasable Programmable Read Only Memory (EEPROM) which does not require a battery.
5. Memory is also housed in the processor module in modular systems.

Input units

Discrete and analog signals

Discrete signals behave as binary switches, yielding simply an On or Off signal (1 or 0, True or False, respectively). Push buttons, limit switches, and photoelectric sensors are examples of devices providing a discrete signal. Discrete signals are sent using either voltage or current, where a specific range is designated as On and another as Off. For example, a PLC might use 24 V DC I/O, with values above 22 V DC representing On, values below 2VDC representing Off, and intermediate values undefined. Initially, PLCs had only discrete I/O.

Analog signals are like volume controls, with a range of values between zero and full-scale. These are typically interpreted as integer values (counts) by the PLC, with various ranges of accuracy depending on the device and the number of bits available to store the data. As PLCs typically use 16-bit signed binary processors, the integer values are limited between -32,768 and +32,767. Pressure, temperature, flow, and weight are often represented by analog signals. Analog signals can use voltage or current with a magnitude proportional to the value of the process signal. For example, an analog 0 to 10 V or 4-20 mA input would be converted into an integer value of 0 to 32767.Current inputs are less sensitive to electrical noise (i.e. from welders or electric motor starts) than voltage inputs.

Output units

Operate much the same as the input units with the exception that the unit is either sinking (supplying a ground) or sourcing (providing a voltage) discrete voltages or sourcing analog voltage or current.

1. These output signals are presented as directed by the CPU. The output circuit of discrete units can be transistors for TTL and higher DC voltage or Triacs for AC voltage outputs.
2. For higher current applications and situations where a physical contact closure is required, mechanical relay contacts are available.
3. These higher currents, however, are generally limited to about 2-3 amperes.
4. The analog output units have internal circuitry which performs the digital to analog conversion and generates the variable voltage or current output.

Extending PLC

- Every PLC controller has a limited number of input/output lines.
- If needed this number can be increased through certain additional modules by system extension through extension lines.
- Each module can contain extension both of input and output lines.
- Also, extension modules can have inputs and outputs of a different nature from those on the PLC controller (ex. in case relay outputs are on a controller, transistor outputs can be on an extension module).

3.4. Terminal Connections and Features of PLC

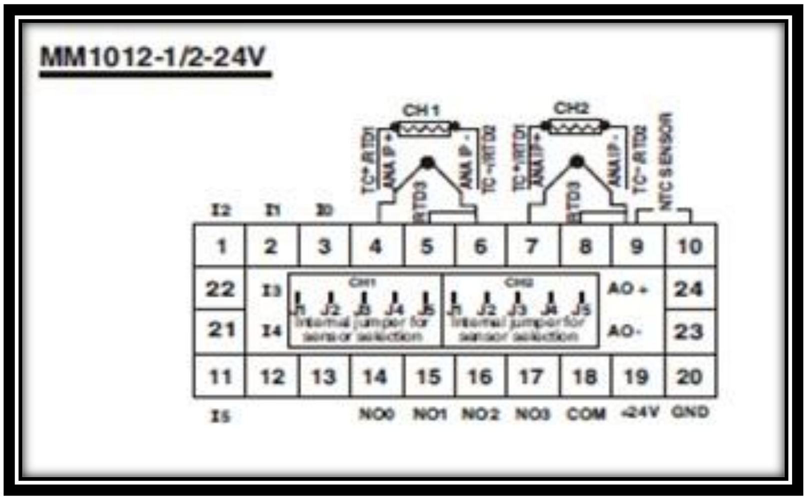


Fig. 3.3 Terminal Connections of PLC

Functional Features

Timer Operational Modes	On Delay, Off Delay, Pulse, Special [Up/Down] Timer
Timer Resolution	1 ms (Accurate only for 1 msec Timer block)
Timer Display Format	Sec, Min, Hr, Day, Min.Sec, Hr.Min, Day.Hr.
Counter	Up Counter, Down Counter, Up/Down Counter, Special Up Down Counter
Other Blocks	PID Control with Autotune, Analog input, Rampsoak, FTC, Analog Output, Hysterisis, Scaling.
Memory Retention	10 years (4k memory)
RTC	No

Supply Voltage

Supply Voltage [As per product selection]	180 - 270V AC, 50Hz 18 - 30V DC

Environmental Specifications

Temperature	Operating : 0 to 50 °C Storage : -20 to 60 °C
Humidity (non-condensing)	95% RH
Weight	258gms

Output Specifications

Digital Output - Relay	
Contact Rating	NO type : 3A resistive @ 230V AC [For MM101X-24V] 5A resistive @ 230V AC
Isolation	2.5kV
Analog Output	
Output Type	**Current** - 0-20mA **Voltage** - 0-10V
Resolution	14.5 bits
Conversion time	20 msec
Linearity error	0.1%

Functional Specifications:

Programming Method	Windows based software for ladder programming and HMI configuration.
Memory	Data memory: 16 kbytes Code memory: 223 kbytes
Max. no. of Objects	5000 (As per memory)
Minimum Scan Time	200 μsec
Typical Scan Time	1 ms

Communication:

Communication Ports	RS485 port [slave]
Communication Protocol	MODBUS RTU

Dimensions (in mm)

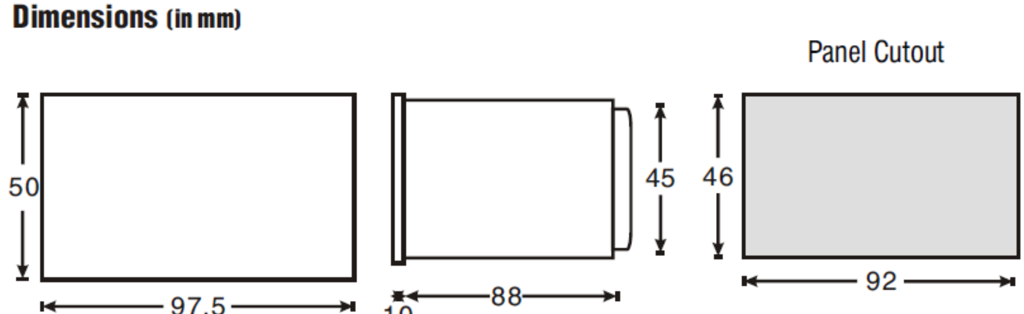


Fig.3.4 PLC panel Cutout

Chapter 4

Supervisory Control And Data Acquisition

4.1. System Architecture

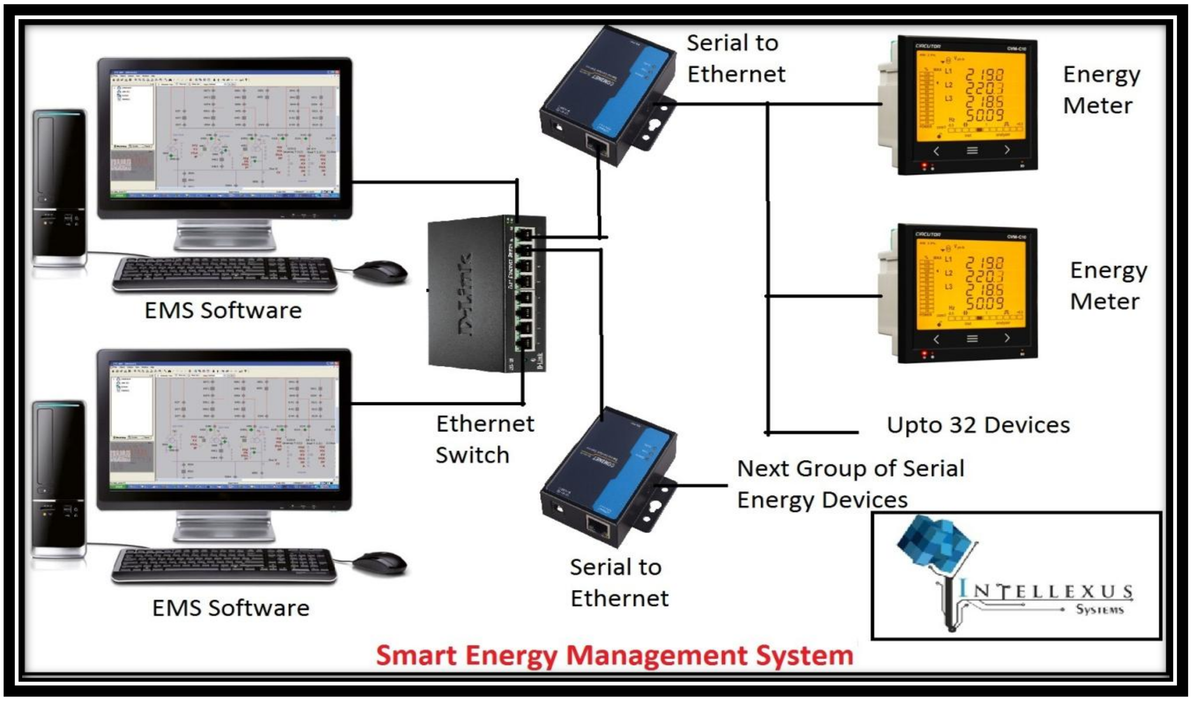


Fig. 4.1 System architecture

As **Energy Management System (EMS)** handles these by balancing the demands of the transmission system, generating units, and consumption.

Monitoring and controlling of substations are essential task for supplying healthy power to the consumers in this automated era. Depending on the voltage levels and end users, there are transmission or distribution substations those supply electrical power to various loads. Remote monitoring and control make these substations to be operated through wireless communication technologies like GSM, GPRS, Ethernet, etc.

4.2. SCADA

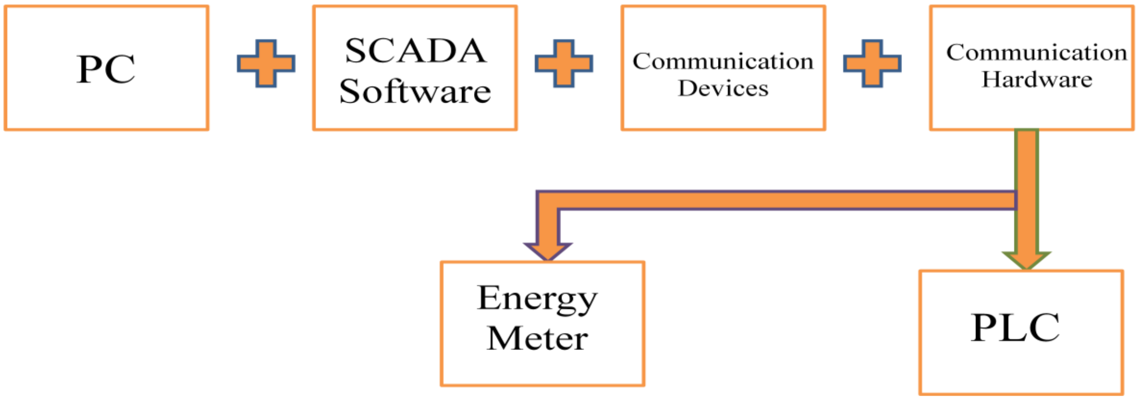


Fig. 4.2 SCADA

SCADA (**supervisory control and data acquisition**) is a system operating with coded signals over communication channels so as to provide control of remote equipment (using typically one communication channel per remote station). The control system may be combined with a data acquisition system by adding the use of coded signals over communication channels to acquire information about the status of the remote equipment for display or for recording functions. It is a type of industrial control system (ICS). Industrial control systems are computer-based systems that monitor and control industrial processes that exist in the physical world. SCADA systems historically distinguish themselves from other ICS systems by being large-scale processes that can include multiple sites, and large distances. These processes include industrial, infrastructure, and facility-based processes, as described below:

- Industrial processes include those of manufacturing, production, power generation, fabrication, and refining, and may run in continuous, batch, repetitive, or discrete modes.

Common system components

A SCADA system usually consists of the following subsystems:

- Remote terminal units (RTUs) connect to sensors in the process and convert sensor signals to digital data. They have telemetry hardware capable of sending digital data to the supervisory system, as well as receiving digital commands from the supervisory system. RTUs often have embedded control capabilities such as ladder logic in order to accomplish boolean logic operations.

- Programmable logic controller (PLCs) connect to sensors in the process and convert sensor signals to digital data. PLCs have more sophisticated embedded control capabilities (typically one or more IEC 61131-3 programming languages) than RTUs. PLCs do not have telemetry hardware, although this functionality is typically installed alongside them. PLCs are sometimes used in place of RTUs as field devices because they are more economical, versatile, flexible, and configurable.
- A telemetry system is typically used to connect PLCs and RTUs with control centers, data warehouses, and the enterprise. Examples of wired telemetry media used in SCADA systems include leased telephone lines and WAN circuits. Examples of wireless telemetry media used in SCADA systems include satellite (VSAT), licensed and unlicensed radio, cellular and microwave.
- A data acquisition server is a software service which uses industrial protocols to connect software services, via telemetry, with field devices such as RTUs and PLCs. It allows clients to access data from these field devices using standard protocols.
- A human–machine interface or HMI is the apparatus or device which presents processed data to a human operator, and through this, the human operator monitors and interacts with the process. The HMI is a client that requests data from a data acquisition server.
- A Historian is a software service which accumulates time-stamped data, boolean events, and boolean alarms in a database which can be queried or used to populate graphic trends in the HMI. The historian is a client that requests data from a data acquisition server.
- A supervisory (computer) system, gathering (acquiring) data on the process and sending commands (control) to the SCADA system.

4.3. System Description

4.3.1. User Friendly Software

Software Screens are very user friendly.

All Screens will be customized as per plants requirement.

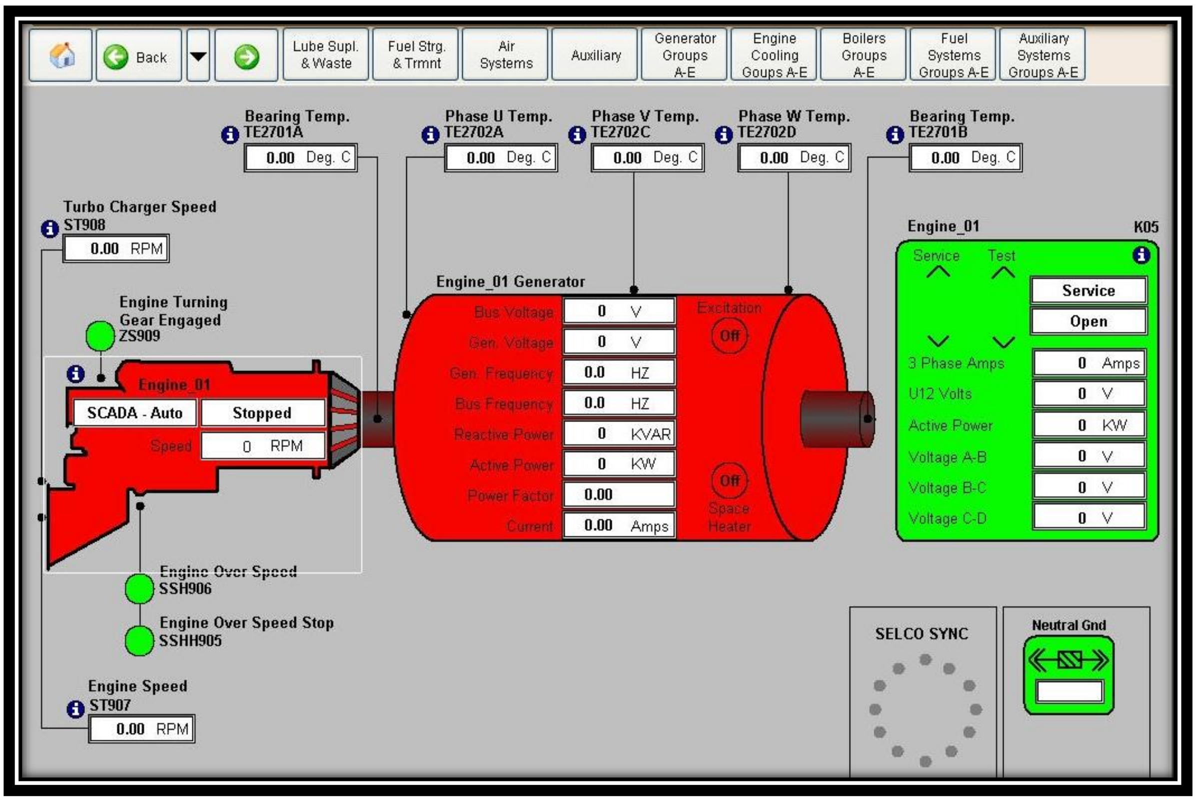


Fig. 4.3 SCADA software screen user friendly

4.3.2. Data Acquisition of full range of parameters

All Parameters which are being measured will be stored in Configured Database.

Parameters may be Line voltage, Line current, Line Frequency, power factor, KW, V-THD,I-THD,KVA,KWH etc.

ID_SAGE_ORG	kconv1	kconv2	NPORG	NPDST
PA10IB--2RDRE----Fail	1	0	27772	27772
PA10IB--2ZCPP----InFl	1	0	27773	27773
PA10IB--0ZCPP----CmFl	1	0	27774	27774
PA10IB--0ZCPP----InFl	1	0	27775	27775
PA10TR1--PDIF----Fail	1	0	27776	27776
PA10TR1-2ZCPP----CmFl	1	0	27777	27777
PA10TR1-2ZCPP----InFl	1	0	27778	27778
PA10TR1-0ZCPP----CmFl	1	0	27779	27779
PA10TR1-0ZCPP----InFl	1	0	27780	27780
PA10TR3--PDIF----CmFl	1	0	27781	27781
PA10TR3--PDIF----Fail	1	0	27782	27782
PA10TR3-2ZCPP----CmFl	1	0	27783	27783
PA10TR3-2ZCPP----InFl	1	0	27784	27784
PA10UTRX-ZTCO----Locl	1	0	27785	27785
PA10UTRX-ZTCO----Remt	1	0	27786	27786
PA10UTRX-ZUTR----CmFl	1	0	27787	27787
PA10UTRX-ZUTR----Fail	1	0	27788	27788
PA10UTRX-ZUTR--02Fail	1	0	27789	27789
PA10UTRX-ZUTR--02Rsrv	1	0	27790	27790
PA10UTRX-ZUTR--01Fail	1	0	27791	27791
PA10UTRX-ZUTR--01Rsrv	1	0	27792	27792

Fig. 4.4 SCADA software screen data acquisition

4.3.3. Real Time Trends

All Parameters which are being measured can be monitored in real time trends.

Trends can be standard as well as customized.

Data can be exported to various formats.

User can select parameters to be displayed in live trend for monitoring.

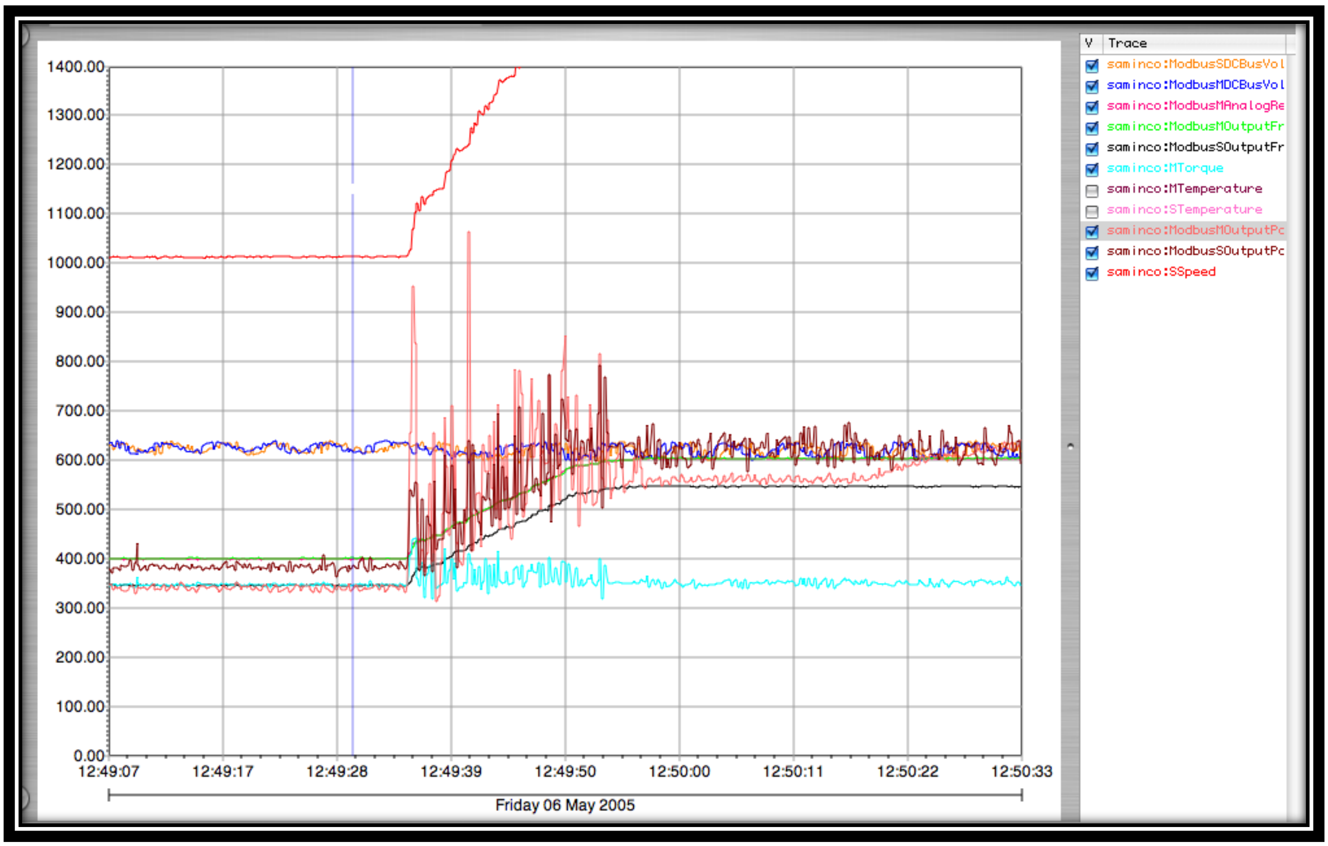


Fig. 4.5 SCADA software screen real time trends

4.3.4. Historical Trends

Historical Data for all parameters can be monitored in Historical trends.

Data can be exported to various formats.

User can select parameters to be displayed in live trend for monitoring.

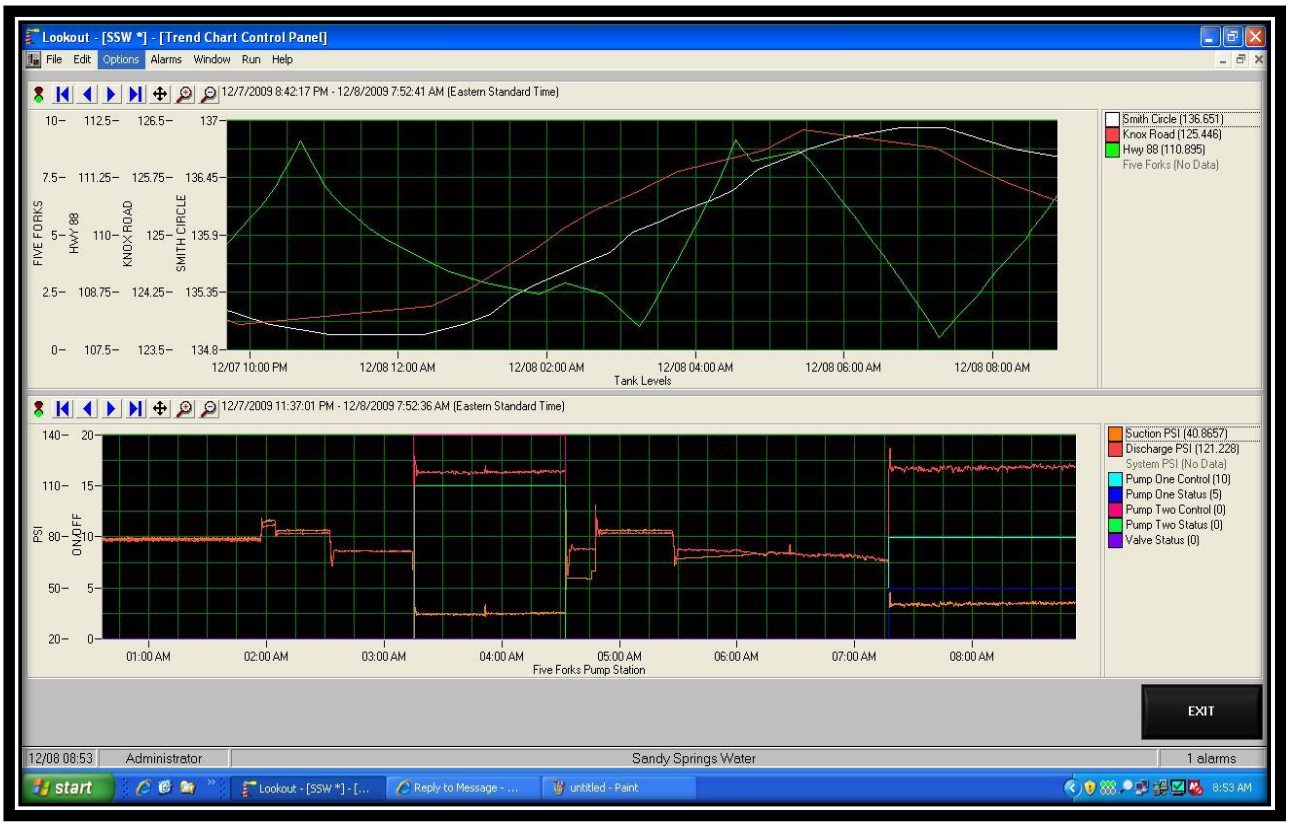


Fig. 4.6 SCADA software screen Historical Trends

4.3.5. Alarms

If any parameter exceeds normal range of value then alarm will be generated.

User can select low and high set point of alarms and customize alarm.

Fig. 4.7 Buzzer   Alarm

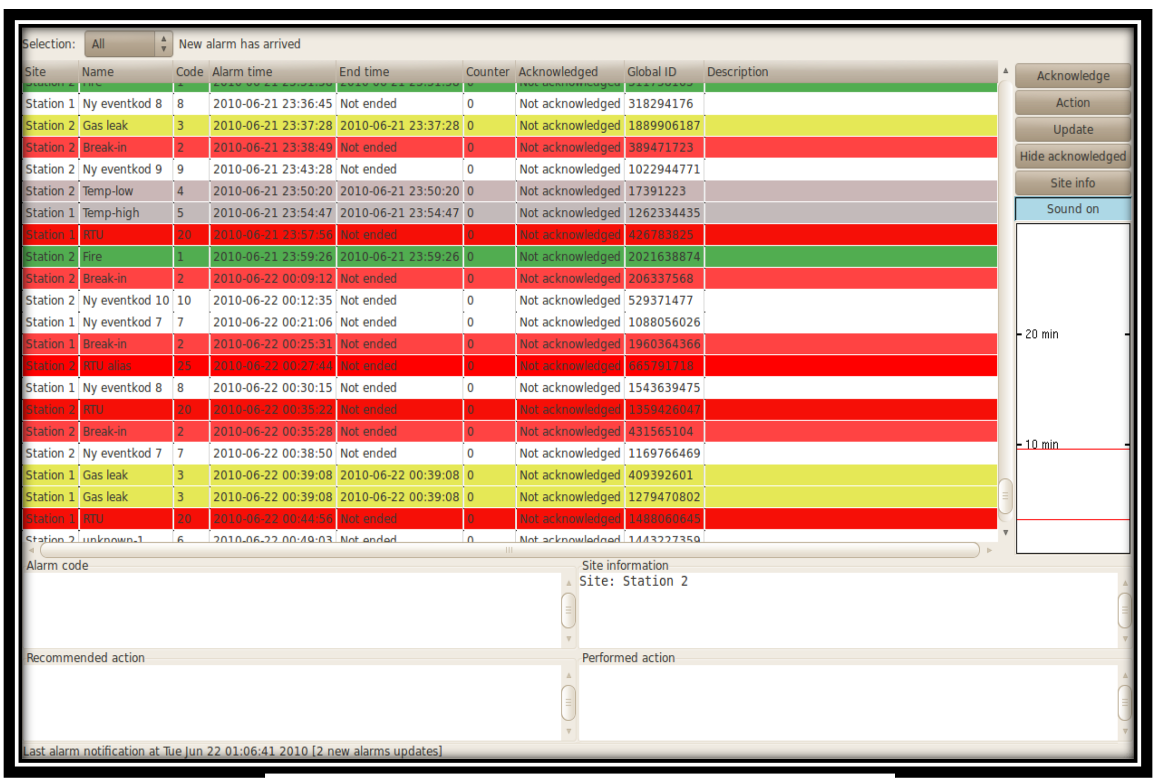


Fig. 4.8 SCADA software screen Alarm

4.3.6. Security

There will be multiple levels of security for different types of operations.

Complete data is fully secured by High level of encryption technology.

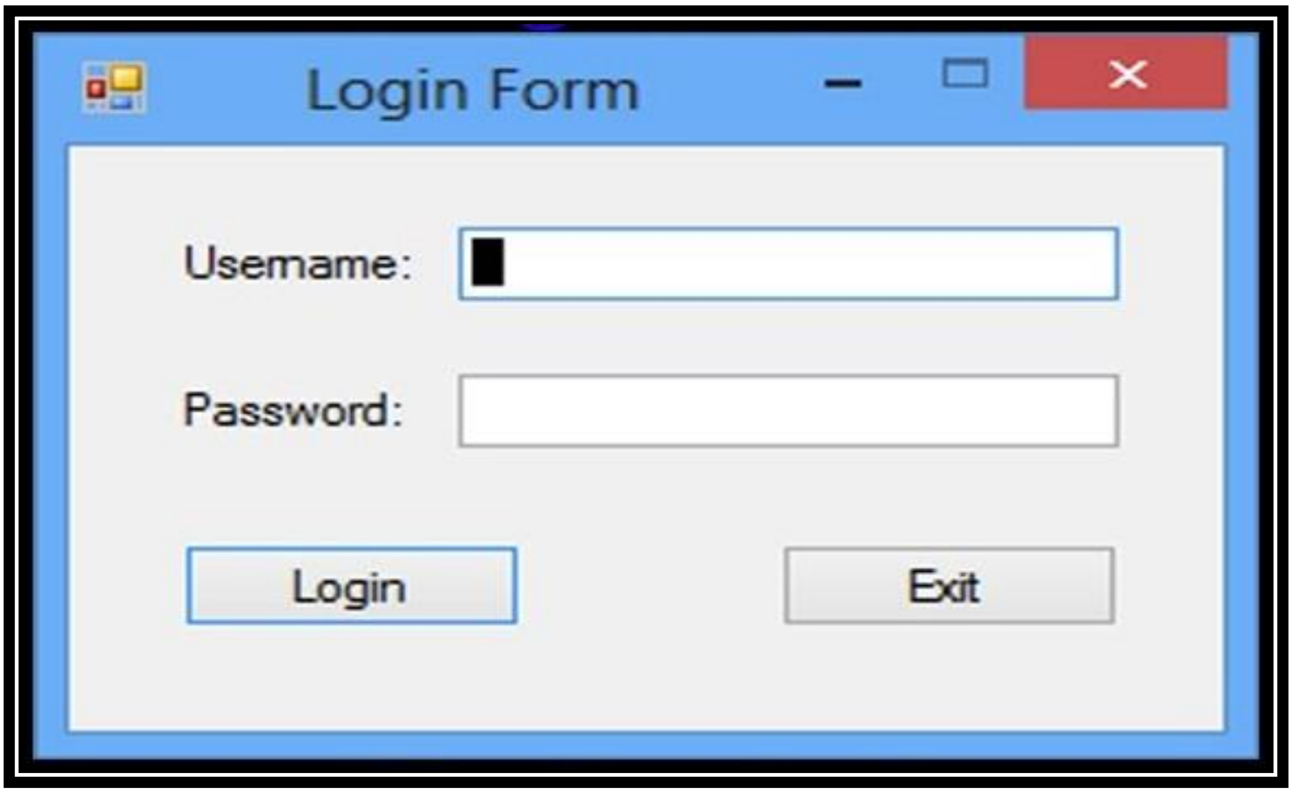


Fig. 4.9 SCADA software screen security

4.3.7. Detailed Reporting

Reports can be generated for selected parameters or for group of parameters.

Reports can be used for observation of Losses considerations.

All Reports can also be exported to various formats including Excel, Word, PDF, HTML etc.

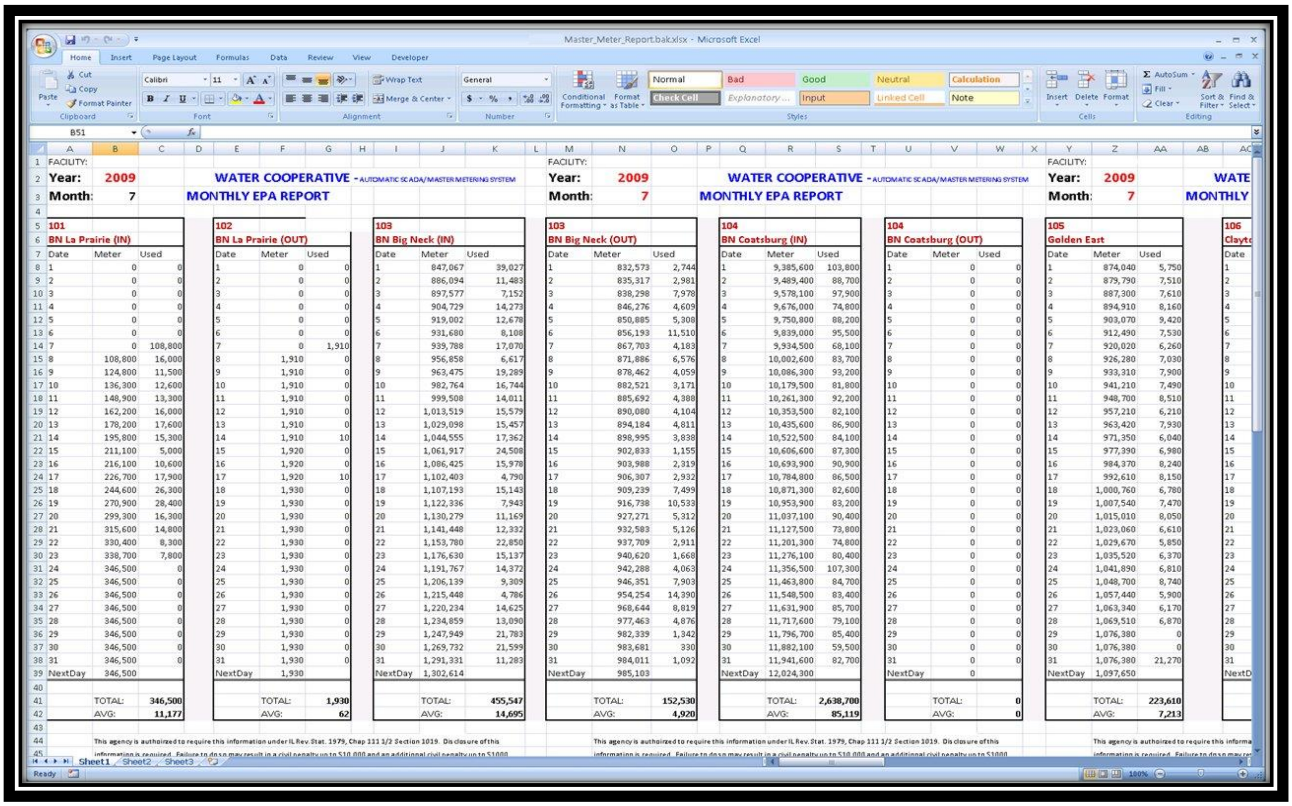


Fig. 4.10 SCADA software screen detailed reporting

Chapter 5

Substation Automation

5.1 Substation Devices [14]

Circuit breakers are high-speed switches that are designed to open automatically in the case of an overload or short circuit event. Unlike most low voltage breakers, medium and high-voltage breakers in substations typically rely on external devices (i.e., protective relays) to sense these conditions. They also can be used for routine switching, or reconfiguration, of power lines, transformers, and loads in and out of service. Opening a breaker causes a large energy arc within the breaker. Because of the high temperature (>20,000°C) of the arc that must be extinguished when opening a circuit at medium and high voltages, breakers must be maintained or replaced after several hundred operations.	 Gas Circuit Breaker (www.abb.com)
Power transformers change power from one voltage level to another voltage level. Transformers can range in size from 1 to 5 MVA in smaller distribution substations to several hundred MVA in larger transmission substations. Transformers are often the most expensive components in a substation and have the longest replacement lead times. A large power transformer can cost well over $1M and take a year to order. Power transformers, especially at the distribution level, often contain LTCs. LTCs adjust the secondary voltage of the transformer by mechanically changing the transformer's turns ratio in small steps. LTCs usually can regulate the voltage by ± 10%, in steps of 1% or less.	 Power Transformer (www.abb.com)

Phase-shifting transformers are used to regulate power flow between two substations. They are usually installed on tie lines between utilities and are used to control the import or export of power between utilities.	 Phase Shifting Transformer (www.abb.com)
Capacitor banks are used to support voltage, maximize power transfer between substations, and inject reactive power to the system without relying on rotating machinery (i.e., generators or synchronous condensers). In transmission applications capacitor banks are most often installed in series with the line, whereas in distribution applications they are often installed in a shunt configuration. Shunt applications usually require that the capacitor bank be switched in and out so that they are on only when required (i.e., when the load is great enough to cause the voltage to sag).	 Series Capacitor Bank (www.nokiancapacitors.fi/)
Disconnect switches are slower speed switches that are used to isolate equipment like breakers or transformers for maintenance. In most cases, a disconnect switch is installed on either side of a breaker; a bypass disconnect switch may bypass the breaker when it is not in service. Disconnect switches usually cannot be opened under load, so their associated breaker must be opened first.	 Disconnect Switch (http://www.southernstatesllc.com)
Instrument transformers provide signals that can be measured by protective relays, meters, fault recorders, etc. Potential transformers take the transmission or distribution voltage and transform it to low voltage, usually 120 V. Current transformers reduce the line current by a standard ratio such that the secondary current is on the order of a few amps; the most common secondary ranges are 0 to 5 A or 0 to 1 A.	 Potential Transformer (www.abb.com)

Table 5.1 Substation devices

5.2 Applications of PLCs in Substation Automation and SCADA

There are many applications for PLCs in substation automation, distribution automation and SCADA systems. As utility engineers become more familiar with the capability of PLCs and PLC manufactures develop new substation specific products, the number and type of potential applications continues to increase.

- RTU (Remote Terminal Unit) emulation and replacement
- Alarm reduction and intelligent messaging
- Utilize existing SCADA protocols
- Ethernet, TCP/IP
- Multiple protocols, DNP 3.0, Modbus, Modbus Plus, AB DF1, ControlNet
- Analog and Discrete I/O
- Data Concentration from IEDs
- Metering and station information management
- Parameter monitoring, logging and trending
- Integration of IEDs
- Protection and control
- Circuit breaker lockout
- Protective relay interface/interaction
- Dynamic protective relay setting for dynamic station topology
- Automatic switching
- Emergency Load Shedding
- Re-routing services for station maintenance
- Automatic transfer schemes
- Load sectionalizing
- Custom, automatic reclosing schemes
- Automatic service restoration
- Circuit breaker control and interlocking
- Feeder automation and fault recovery
- Voltage regulation management
- LTC (Load Tap Changer) Control
- Voltage regulator control
- Capacitor control
- Transformer management

- Parameter monitoring and alarming
- Real-time modeling
- Interface to existing transformer monitors
- Automation System diagnostics
- Power apparatus health monitoring
- PLC and communications self monitoring
- Report and Alarm on IED self diagnostics
- Maintenance and Safety
- Kirk-key interlock management
- Maintenance “Lock-out/Tag-out” management
- Automatic circuit isolation control
- Station HMIs – Graphical User Interface (GUI)
- Interactive real-time single line displays
- Interactive real-time breaker and switch control display
- On-line operations and maintenance logs
- Sequence of events recording
- IED detail displays
- Parameter trending displays
- Oscillography
- Remote Control
- Demand Control
- Synch check and generator synchronization. [9]

Intelligent Alarm Processors (IAPs)reduce the critical time needed to analyze faults in the grid and take corrective action, as well as the risk of incorrect analysis.

The Automated Metering and Information System (AMIS) records the power consumption of each individual consumer over time, and in turn, consumers are given detailed information about their power consumption.

Substations consist of various equipment like transformers, circuit breakers, relays, APFC panels, etc., and these equipment ought to be operated in such a way that the loads must be delivered safely with specified parameters. These parameters include voltage, current, frequency, power factor, temperature, and so on.

Today's practice in monitoring circuit breaker operation and status in real time is reduced to the use of Remote Terminal Units (RTUs) of Supervisory Control and Data Acquisition (SCADA) system to assess CB status. Based on detected voltage levels on circuit breaker contacts, these units are providing information on final statuses of the circuit breakers such as "**OPEN**" or "**CLOSE**".

Moreover, a SCADA system can significantly increase the speed of power restoration following an outage. SCADA-enabled switches and line reclosers can help operators isolate the outage and open adjacent automatic switches to reroute power quickly to unaffected sections

Load shading: It provides both the automatic and manual control tripping of load during the emergency. During power plant operation, various conditions exist. Load-shedding logic is designed to cover all possible emergency conditions. The actual loads and rated generation outputs are determined by online monitoring of the gas turbine generator (GTG) circuit breaker (CB) status, output power, and ambient air temperature. Emergency-case recognition is activated through trigger signals. An emergency case applies if trigger signals are received.

"The voltage regulator systems were failing earlier than the transformers or circuit breakers. The PLC induction voltage regulator control provides us with life extension of the existing equipment

Chapter 6

Implementation of Project

6.1. Circuit Diagram of Project

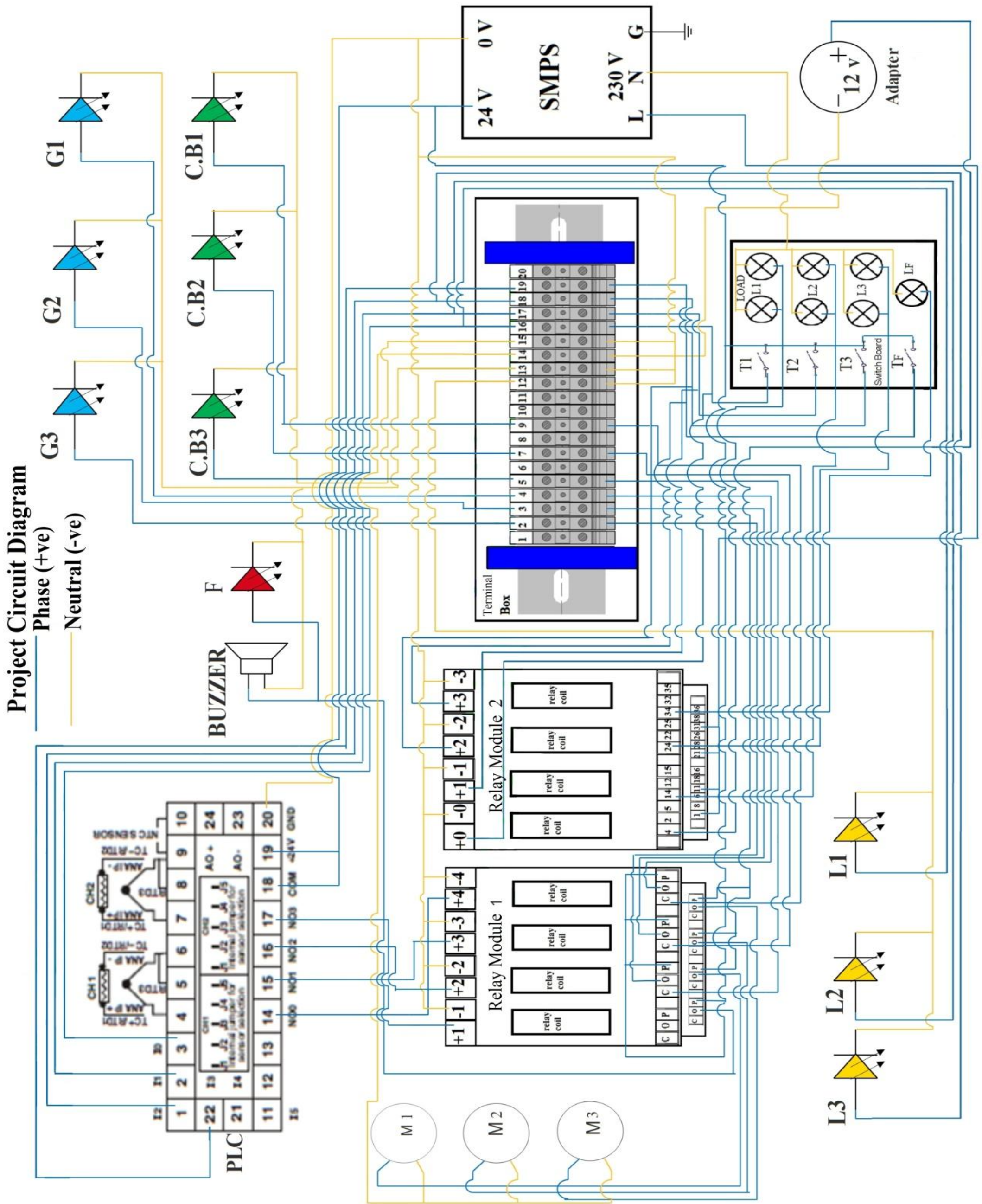


Fig. 6.1 Circuit diagram of project

6.2. Project Circuit Layout Single Line Diagram

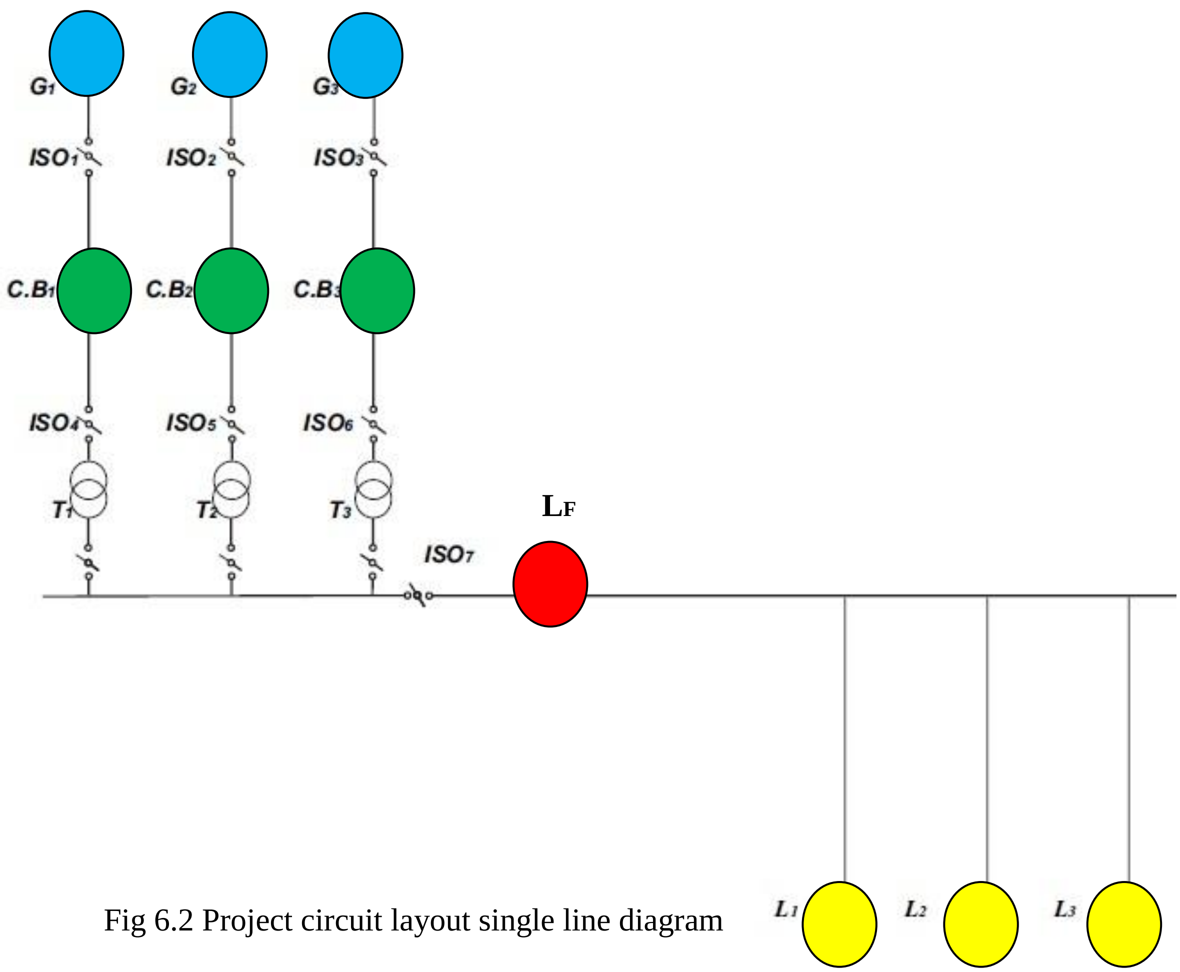


Fig 6.2 Project circuit layout single line diagram

Fig. 6.3 Motors

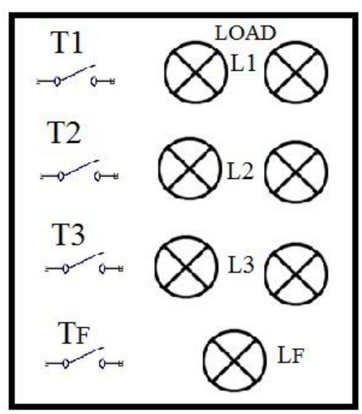
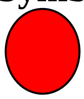
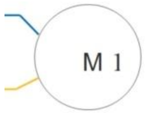


Fig. 6.4 Switch board

Symbols of components use in single line diagram

 -LED's

-Toggle Switch (**T**)



-Motor (**M**)

Fig. 6.5 Symbols of compenet use in single line diagram

Layout notation used

G - generator

ISO -isolator

CB -circuit breaker

T -toggle switch

L -load

M-motor

Inputs & Outputs use in PLC

Inputs – Toggle switches 4

T1,T2,T3,TF

Outputs –LED's 10

L1,L2,L3

G1,G2,G3

CB1,CB2,CB3

LF

-Motors 3

M1,M2,M3

6.3. Circuit Working

Step1: Switch ON supply , circuit runs at default condition. Initially All ISO are connected and M1,G1,CB1 will simultaneously ON.

Step2: Switch ON T1 then L1 will ON.

Step4: Switch ON T2 then L2,G2,CB2,M2 will simultaneously ON.

Step5: Switch ON T3 then L3,G3,CB3,M3 will simultaneously ON.

<u>**Step6:** Switch ON TF then LF,Buzzer will ON and all CB are turned OFF</u>

<u>**Note:**</u> In the case of if T1 & T2 or T1 & T3 or T2 & T3 are ON then From G1 or G2 or G3 there will be Two either G1 & G2 or G1 & G3 or G2 & G3 will Operate at the same time respectively

6.4. Component List

Sr. No.	Component	Rating/Size	No. of Units	Price (Rupees)
01	PLC	12V	1	6000
02	Relay Module	230V	2	1600
03	SMPS	24V	1	1000
04	Adapter	12V	1	150
05	DC Motor	12V	3	390
06	Indicator LED	24V	10	400
07	Zero Bulb	230V	7	80
08	Lamp Holder	-	7	70
09	Toggle Switch	5A	4	60
10	Switch Board	25*30 cm^2	1	90
11	Panel Board	2*2.5 ft^2	1	350
12	DIN Rail	1 ft	1	200
13	Terminal Block	-	As required	50
14	L Clamp for DC Motor	-	3	30
15	Nut & Bolt	-	As required	20
16	Buzzer	24V	1	15
17	Layout Sticker	-	1	250
18	Wooden Stand	-	2	150
19	Connecting Wire	10 A /0.5 mm^2	As required	150
20	Other Accessories	-	As required	200
21	Guidance Charge	-	-	6000
Total Price (Rupees)				17255/-

Table. 6.1 Component list

6.5. Data Sheet

6.5.1. Relay Module

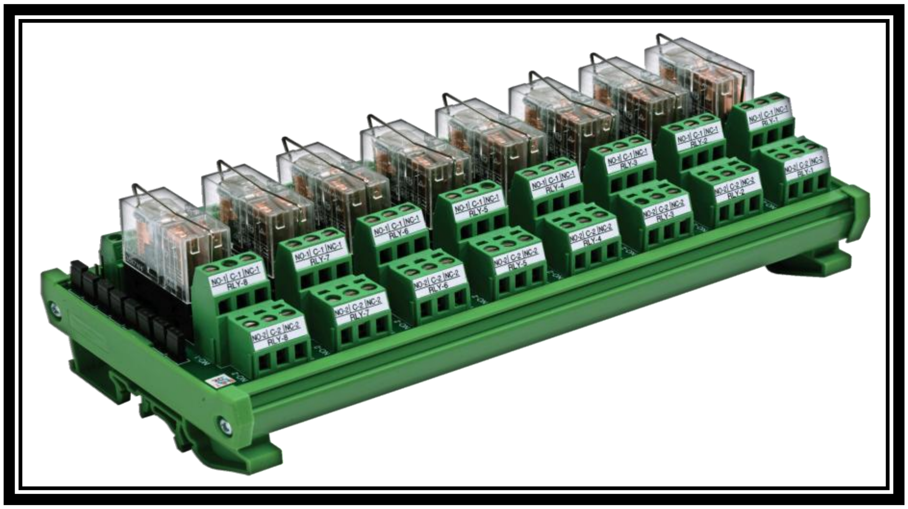


Fig. 6.6 Relay module

A **relay** is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

Basic design and operation

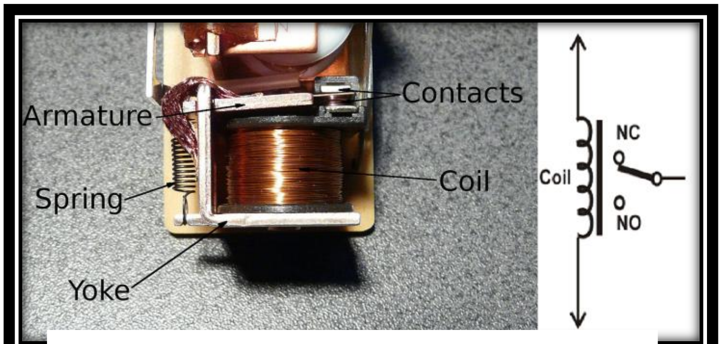


Fig. 6.7 Basic design and symbol of relay

A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more sets of contacts (there are two in the relay pictured). The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. It is held in place by a spring so that

when the relay is de-energized there is an air gap in the magnetic circuit. In this condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open. Other relays may have more or fewer sets of contacts depending on their function. The relay in the picture also has a wire connecting the armature to the yoke. This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the printed circuit board (PCB) via the yoke, which is soldered to the PCB.

When an electric current is passed through the coil it generates a magnetic field that activates the armature, and the consequent movement of the movable contact(s) either makes or breaks (depending upon construction) a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually this force is provided by a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low-voltage application this reduces noise; in a high voltage or current application it reduces arcing.

Relay Coil Terminal Detail [18]

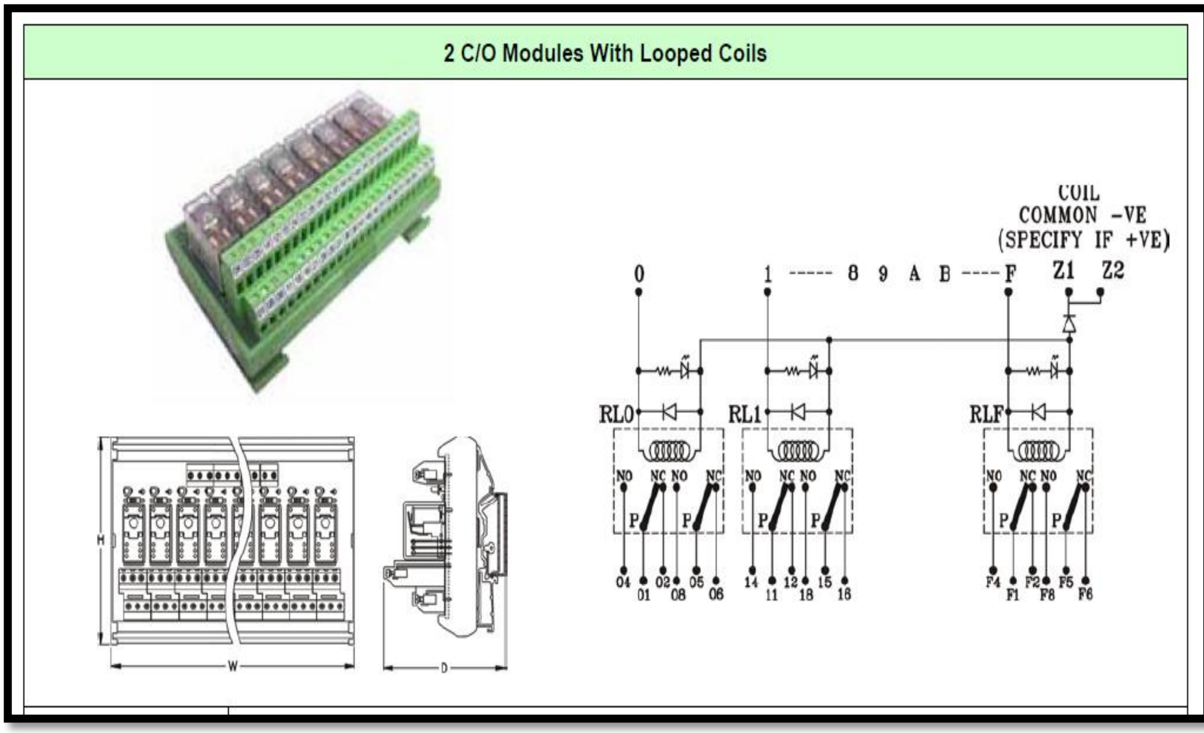


Fig. 6.8 Relay coil terminal detail

6.5.2. SMPS

Fig. 6.9 SMPS

A **switched-mode power supply** (**switching-mode power supply**, **SMPS**, or **switcher**) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a source, like mains power, to a load, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor

Features

- ✓ Single Phase Input
- ✓ Built In Transient protector & EMI filter
- ✓ Protection against short circuit, overload & overvoltage
- ✓ Low ripple & noise
- ✓ Cooling by free air convection
- ✓ Power OK indication, terminations, output set control & rating details on front
- ✓ 100% full load burn in tested
- ✓ Low cost
- ✓ High reliability
- ✓ Compact [17]

Explanation

A linear regulator provides the desired output voltage by dissipating excess power in ohmic losses (e.g., in a resistor or in the collector–emitter region of a pass transistor in its active mode). A linear regulator regulates either output voltage or current by dissipating the excess electric power in the form of heat, and hence its maximum power efficiency is voltage-out/voltage-in since the volt difference is wasted.

In contrast, a switched-mode power supply regulates either output voltage or current by switching ideal storage elements, like inductors and capacitors, into and out of different electrical configurations. Ideal switching elements (e.g., transistors operated outside of their active mode) have no resistance when "closed" and carry no current when "open", and so the converters can theoretically operate with 100% efficiency (i.e., all input power is delivered to the load; no power is wasted as dissipated heat).

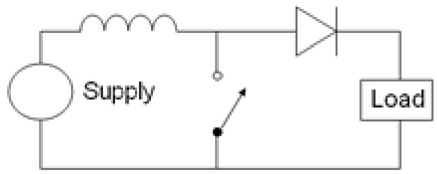


Fig. 6.10 Schematic diagram of a booster converter

The basic schematic of a boost converter.

For example, if a DC source, an inductor, a switch, and the corresponding electrical ground are placed in series and the switch is driven by a square wave, the peak-to-peak voltage of the waveform measured across the switch can exceed the input voltage from the DC source. This is because the inductor responds to changes in current by inducing its own voltage to counter the change in current, and this voltage adds to the source voltage while the switch is open. If a diode-and-capacitor combination is placed in parallel to the switch, the peak voltage can be stored in the capacitor, and the capacitor can be used as a DC source with an output voltage greater than the DC voltage driving the circuit. This boost converter acts like a step-up transformer for DC signals. A buck–boost converter works in a similar manner, but yields an output voltage which is opposite in polarity to the input voltage. Other buck circuits exist to boost the average output current with a reduction of voltage.

In a SMPS, the output current flow depends on the input power signal, the storage elements and circuit topologies used, and also on the pattern used (e.g., pulse-width modulation with an adjustable duty cycle) to drive the switching elements. The spectral density of these switching waveforms has energy concentrated at relatively high frequencies. As such, switching transients and ripple introduced onto the output waveforms can be filtered with a small LC filter.

Advantages and disadvantages

The main advantage of the switching power supply is greater efficiency because the switching transistor dissipates little power when acting as a switch. Other advantages include smaller size and lighter weight from the elimination of heavy line-frequency transformers, and lower heat generation due to higher efficiency. Disadvantages include greater complexity, the generation of high-amplitude, high-frequency energy

6.5.3. Adaptor

Fig. 6.11 Adapter

An **adapter** or **adaptor** is a device that converts attributes of one electrical device or system to those of an otherwise incompatible device or system. Some modify power or signal attributes, while others merely adapt the physical form of one electrical connector to another.

An electric power adapter may enable connection of a power plug used in one region to a AC power socket used in another, by offering connections for the disparate contact arrangements, while not changing the voltage. An AC adapter, also called a "recharger", is a small power supply that changes household electric current from distribution voltage (in the range 100 to 240 volts AC) to low voltage DC suitable for consumer electronics.

6.5.4. DC Motor

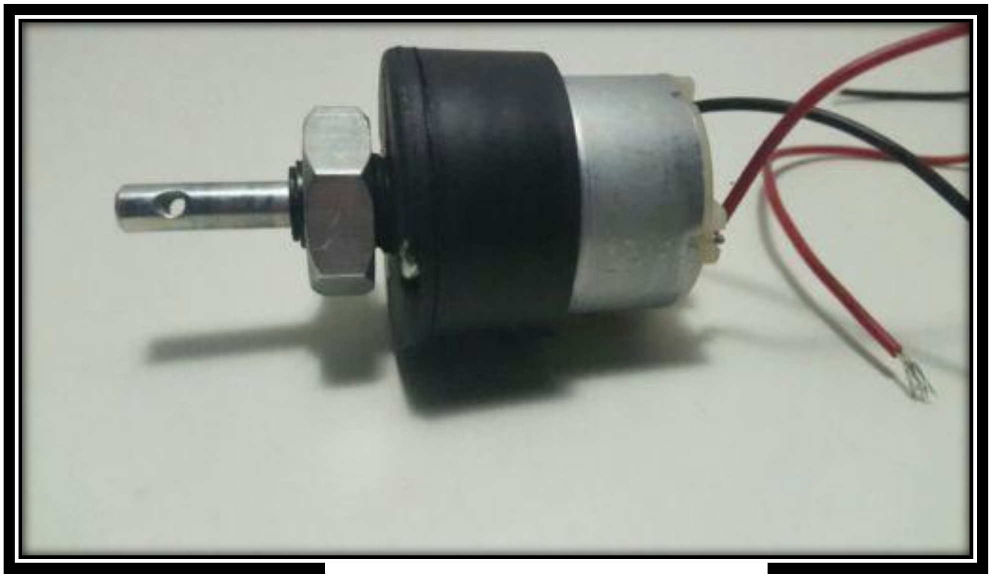


Fig. 6.12 DC motor

Motor principles

All motors require two magnetic fields, one produced by the stationary part of the motor (the stator, or field), and one by the rotating part (the rotor, or armature). These are produced either by a winding of coils carrying a current, or by permanent magnets. If the field is a coil of wire, this may be connected in a variety of ways, which produces different motor characteristics. The basic law of a motor, the reason why they rotate, is governed by Fleming's left hand rule (see figure below). This tells you the direction of the force on a wire that is carrying current when it is in a magnetic field.

Features

- ✓ 500RPM 12V DC motors with Gearbox
- ✓ 6mm shaft diameter with internal hole
- ✓ 125gm weight
- ✓ Same size motor available in various rpm
- ✓ 1kgcm torque
- ✓ No-load current = 60 mA(Max), Load current = 300 mA(M

6.5.5. Panel LED Lighting

Fig. 6.13 Panel LED lighting

Light Emitting Diodes are great for projects because they provide visual entertainment. LEDs use a special material which emits light when current flows through it. Unlike light bulbs, LEDs never burn out unless their current limit is passed. A current of 0.02 Amps (20 mA) to 0.04 Amps (40 mA) is a good range for LEDs. They have a positive leg and a negative leg just like regular diodes. To find the positive side of an LED, look for a line in the metal inside the LED. It may be difficult to see the line. This line is closest to the positive side of the LED. Another way of finding the positive side is to find a flat spot on the edge of the LED. This flat spot is on the negative side.

When current is flowing through an LED the voltage on the positive leg is about 1.4 volts higher than the voltage on the negative side. Remember that there is no resistance to limit the current so a resistor must be used in series with the LED to avoid destroying it. It has high brightness panel led indicators light in various colors like red, green, yellow, blue, white. Various volt range in led indicators lights. Long life working. Different Volt is available 24v, 110v, 220v,

Features

- ✓ Power: 24V
- ✓ Colour: Green,Yellow,Red,Blue
- ✓ Multi segment
- ✓ Long life: 30,000 hours
- ✓ 24V & 110V AC/DC
- ✓ 230V AC
- ✓ Complete with locking nut
- ✓ Current rating: 20mA

Fig. 6.14 LED lights

6.5.6. Toggle Switch

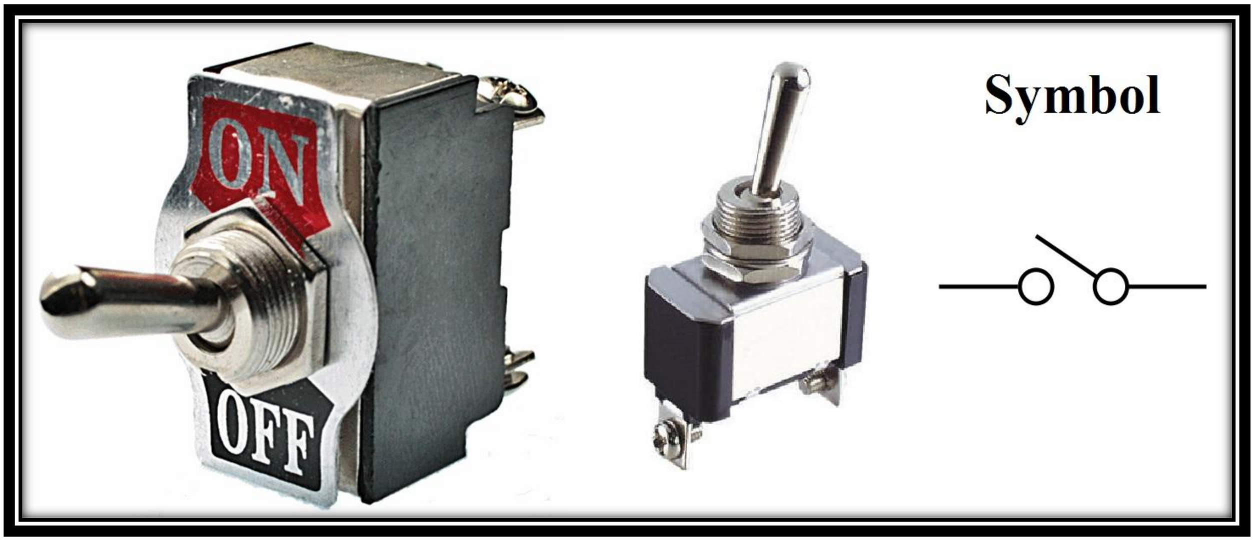


Fig. 6.15 Toggle switch and its symbol

A toggle switch is a class of electrical switches that are manually actuated by a mechanical lever, handle, or rocking mechanism.Toggle switches are available in many different styles and sizes, and are used in numerous applications. Many are designed to provide the simultaneous actuation of multiple sets of electrical contacts, or the control of large amounts of electric current or mains voltages.

The word "toggle" is a reference to a kind of mechanism or joint consisting of two arms, which are almost in line with each other, connected with an elbow-like pivot. However, the phrase "toggle switch" is applied to a switch with a short handle and a positive snap-action, whether it actually contains a toggle mechanism or not. Similarly, a switch where a definitive click is heard, is called a "positive on-off switch".Multiple toggle switches may be mechanically interlocked to prevent forbidden combinations.

Switches are devices that create a short circuit or an open circuit depending on the position of the switch. For a light switch, ON means short circuit (current flows through the switch, lights light up and people dance.) When the switch is OFF, that means there is an open circuit (no current flows, lights go out and people settle down. This effect on people is used by some teachers to gain control of loud classes.) When the switch is ON it looks and acts like a wire. When the switch is OFF there is no connection.

Chapter 7
Software Used

7.1. Programming of PLC

Ladder logic

Ladder logic was originally a written method to document the design and construction of relay racks as used in manufacturing and process control. Each device in the relay rack would be represented by a symbol on the ladder diagram with connections between those devices shown. In addition, other items external to the relay rack such as pumps, heaters, and so forth would also be shown on the ladder diagram. See relay logic.Ladder logic has evolved into a programming language that represents a program by a graphical diagram based on the circuit diagrams of relay logic hardware. Ladder logic is used to develop software for programmable logic controllers (PLCs) used in industrial control applications. The name is based on the observation that programs in this language resemble ladders, with two vertical rails and a series of horizontal rungs between them. While ladder diagrams were once the only available notation for recording programmable controller programs, today other forms are standardized in IEC 61131-3

Overview

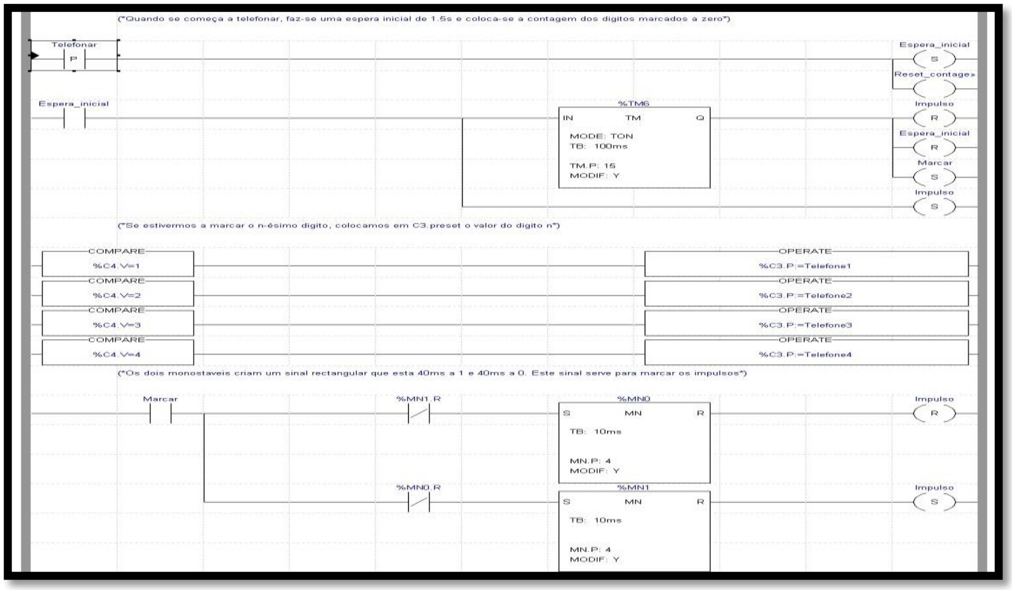


Fig. 7.1 Part of ladder diagram

Part of a ladder diagram, including contacts and coils, compares, timers and monostable multivibrators

Ladder logic is widely used to program PLCs, where sequential control of a process or manufacturing operation is required. Ladder logic is useful for simple but critical control systems or for reworking old hardwired relay circuits. As programmable logic controllers became more sophisticated it has also been used in very complex automation systems. Often the ladder logic program is used in conjunction with an HMI program operating on a computer workstation.

The motivation for representing sequential control logic in a ladder diagram was to allow factory engineers and technicians to develop software without additional training to learn a language such as FORTRAN or other general purpose computer language. Development, and maintenance, was simplified because of the resemblance to familiar relay hardware systems. Implementations of ladder logic have characteristics, such as sequential execution and support for control flow features, that make the analogy to hardware somewhat inaccurate. This argument has become less relevant given that most ladder logic programmers have a software background in more conventional programming languages.

Manufacturers of programmable logic controllers generally also provide associated ladder logic programming systems. Typically the ladder logic languages from two manufacturers will not be completely compatible; ladder logic is better thought of as a set of closely related programming languages rather than one language. (The IEC 61131-3 standard has helped to reduce unnecessary differences, but translating programs between systems still requires significant work.) Even different models of programmable controllers within the same family may have different ladder notation such that programs cannot be seamlessly interchanged between models.

Ladder logic can be thought of as a rule-based language rather than a procedural language. A "rung" in the ladder represents a rule. When implemented with relays and other electromechanical devices, the various rules "execute" simultaneously and immediately. When implemented in a programmable logic controller, the rules are typically executed sequentially by software, in a continuous loop (scan). By executing the loop fast enough, typically many times per second, the effect of simultaneous and immediate execution is achieved, if considering

intervals greater than the "scan time" required to execute all the rungs of the program. Proper use of programmable controllers requires understanding the limitations of the execution order of rungs. [19]

7.2. Project PLC programming

Software Name: SELPRO

Fig. 7.2 SELPRO software

Selec's SELPRO is integrated with an HMI calibration facility, and a ladder editor that complies with international IEC61131-3 standards. This programming system features an exhaustive function and function block library, an auto-declared variable that represents physical I/O of the selected structure, and an auto-read and auto-save facility. It also sports an extensive hardware compatibility, modified protocol support (MM3010, MM3030-2) and an on-line and off-line simulation capability. [18]

Software Features

- ✓ User friendly ladder editor on lines of IEC61131-3
- ✓ Built-in HMI configuration facility
- ✓ On-line and Off-line simulation possible
- ✓ Exhaustive function and function block library
- ✓ Auto read and Auto save facility
- ✓ Auto declared variable to represent physical IO of selected configuration
- ✓ Project upload from target
- ✓ Editable passwords for download, upload and project
- ✓ Facility to set debounce time for physical inputs
- ✓ Hardware compatibility - Facility to download applications into the previous versions of bootloader by selecting respective hardware version.
- ✓ Customized protocol support (MM3010, MM3030-2) [18]

7.3. Project Ladder Diagram

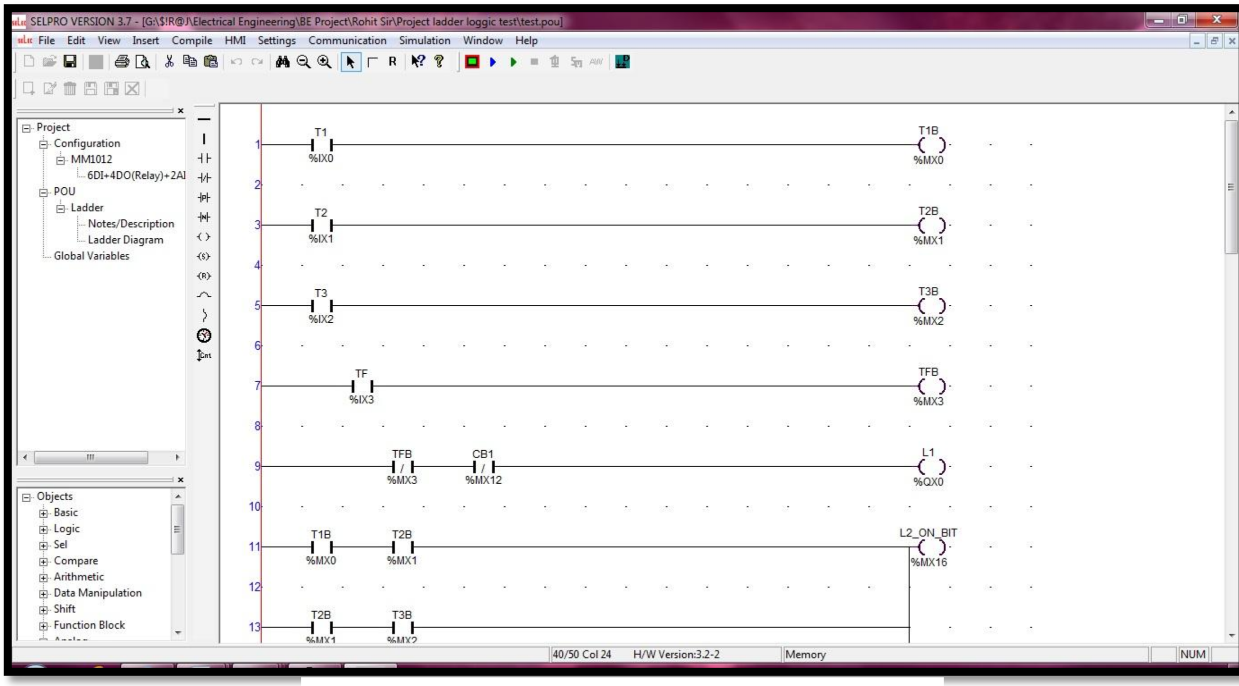


Fig. 7.3 Project Ladder diagram screenshot 1

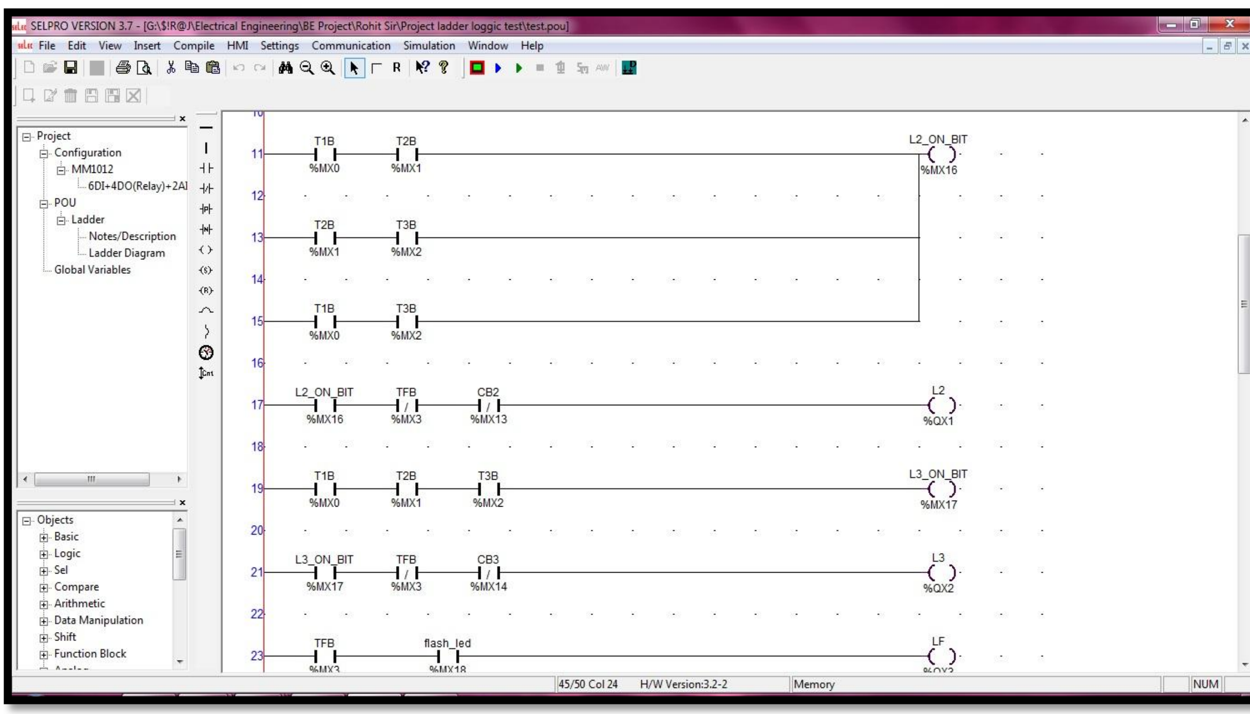


Fig. 7.4 Project Ladder diagram screenshot 2

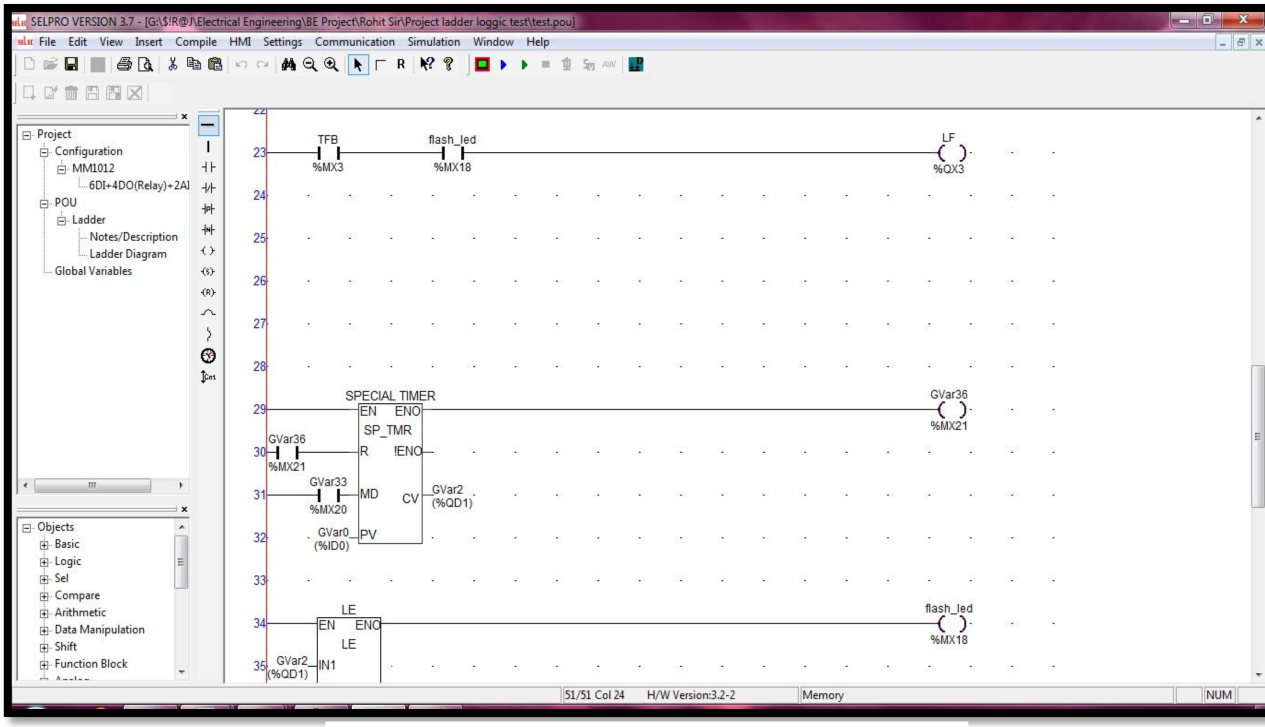


Fig. 7.5 Project Ladder diagram screenshot 3

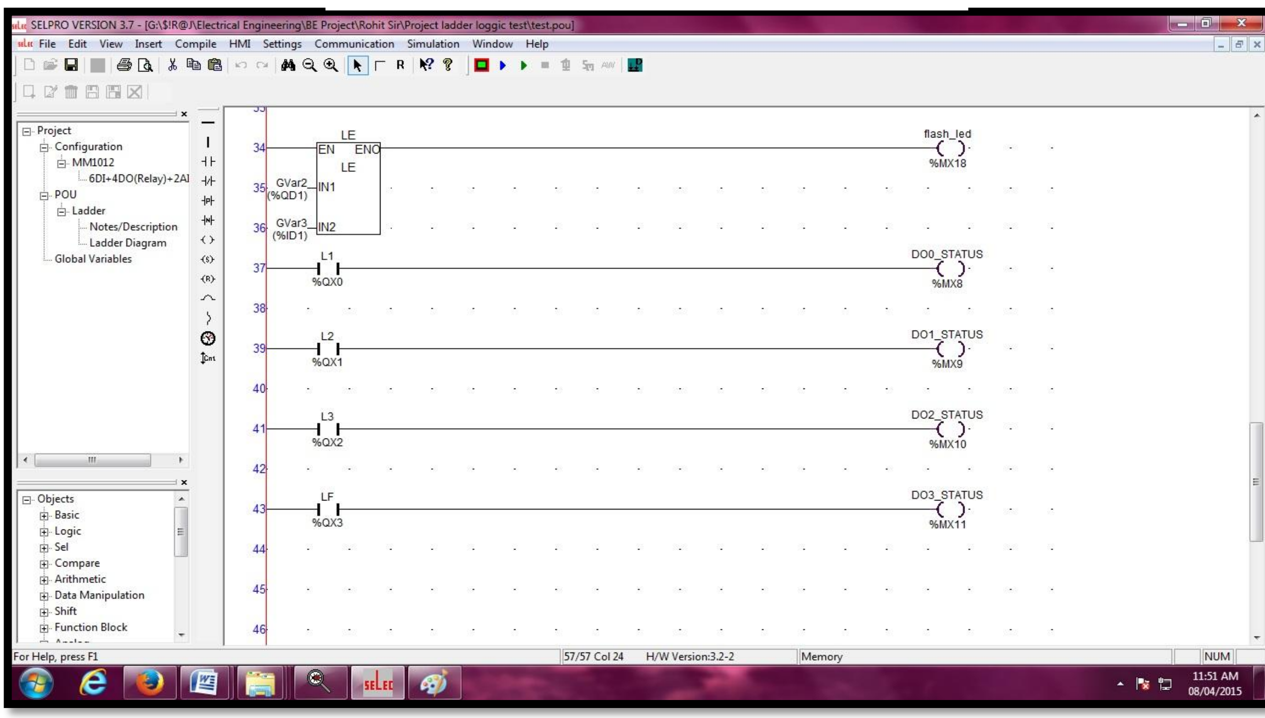


Fig. 7.6 Project Ladder diagram screenshot 4

7.4. Project SCADA Software

Name of Software: LabVIEW

What Is LabVIEW?

1. What Makes Up LabVIEW?
2. Benefits of LabVIEW
3. LabVIEW – More Than Just Software
4. Productivity and Empowerment with LabVIEW

NI LabVIEW software is used for a wide variety of applications and industries, which can make it challenging to answer the question: “What is LabVIEW?” I have heard many conflicting opinions and debates over the years, so I thought it would be appropriate to take this opportunity to discuss what LabVIEW is.

LabVIEW is a highly productive development environment for creating custom applications that interact with real-world data or signals in fields such as science and engineering.

The net result of using a tool such as LabVIEW is that higher quality projects can be completed in less time with fewer people involved.

So productivity is the key benefit, but that is a broad and general statement. To understand what this really means, consider the reasons that have attracted engineers and scientists to the product since 1986. At the end of the day, engineers and scientists have a job to do – they have to get something done, they have to show the results of what they did, and they need tools that help them do that. Across different industries, the tools and components they need to succeed vary widely, and it can be a daunting challenge to find and use all these disparate items together. LabVIEW is unique because it makes this wide variety of tools available in a single environment, ensuring that compatibility is as simple as drawing wires between functions.

What Makes Up LabVIEW?

LabVIEW itself is a software development environment that contains numerous components, several of which are required for any type of test, measurement, or control application.

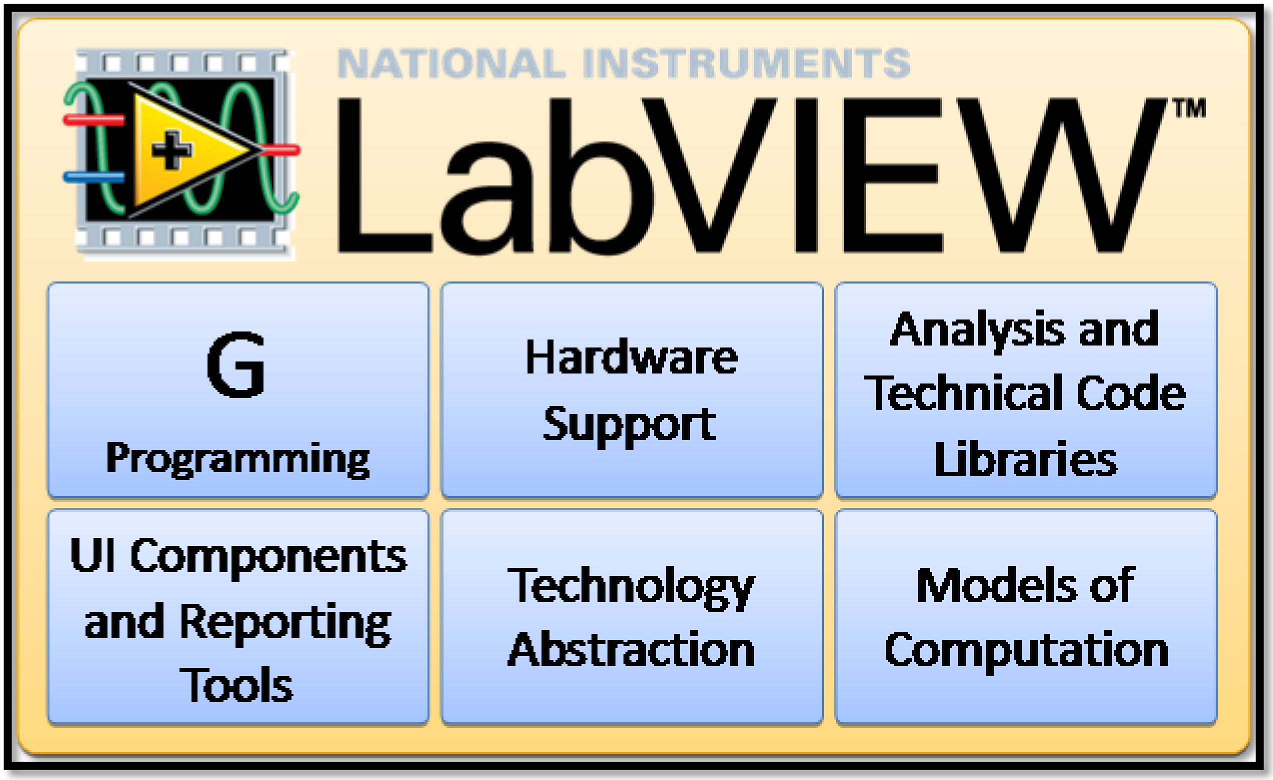


Fig. 7.7 LabVIEW contains several valuable components.

To quote one of our software developers, “We write low-level code so you don’t have to.” Our global team of developers continually works on the six areas called out in Figure 1 to free you, the LabVIEW user, up to focus on the bigger problems and tasks you are trying to solve.

G Programming Language

- Intuitive, flowchart-like dataflow programming model
- Shorter learning curve than traditional text-based programming
- Naturally represents data-driven applications with timing and parallelism

The G programming language is central to LabVIEW; so much so that it is often called "LabVIEW programming." Using it, you can quickly tie together data acquisition, analysis, and logical operations and understand how data is being modified. From a technical standpoint, G is a graphical dataflow language in which nodes (operations or functions) operate on data as soon as it becomes available, rather than in the sequential line-by-line manner that most programming languages employ. You lay out the "flow" of data through the application graphically with wires connecting the output of one node to the input of another.

The practical benefit of the graphical approach is that it puts more focus on data and the operations being performed on that data, and abstracts much of the administrative complexity of computer programming such as memory allocation and language syntax. New programmers typically report shorter learning curves with G than with other programming languages because they can relate G code to flow charts and other familiar visual representations of processes. Seasoned programmers can also take advantage of the productivity gains by working at a higher level of abstraction while still employing advanced programming practices such as object-oriented design, encapsulation, and code profiling.

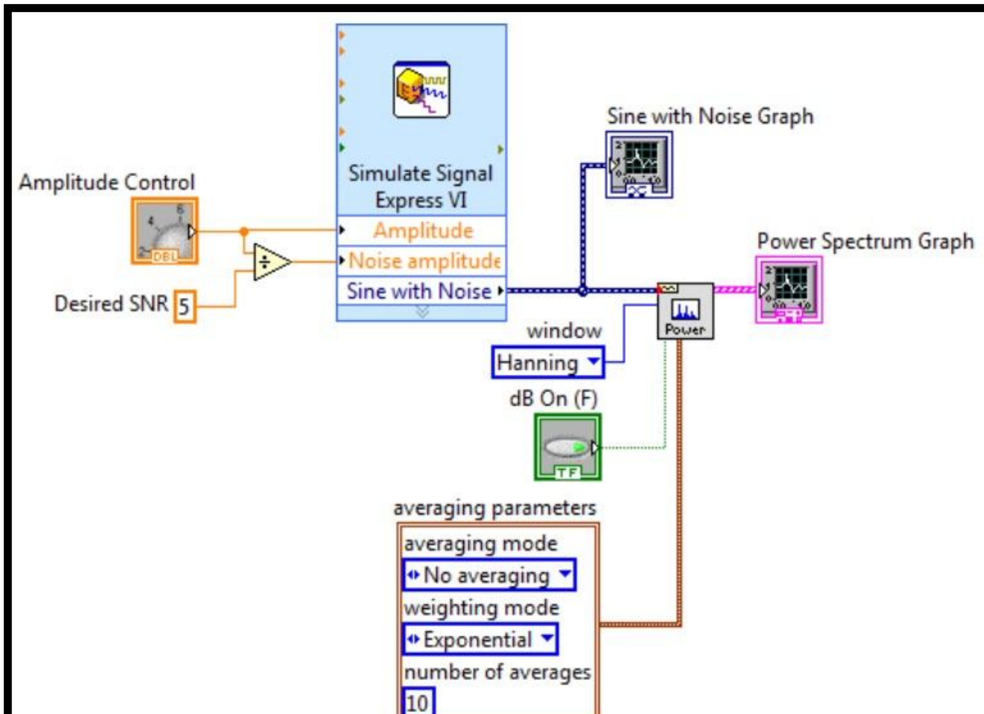


Fig 7.8 Block diagram of self-documenting G code

LabVIEW contains a powerful optimizing compiler that examines your block diagram and directly generates efficient machine code, avoiding the performance penalty associated with interpreted or cross-compiled languages. The compiler can also identify segments of code with no data dependencies (that is, no wires connecting them) and automatically split your application into multiple threads that can run in parallel on multicore processors, yielding significantly faster analysis and more responsive control compared to a single-threaded, sequential application.

With the debugging tools in LabVIEW, you can slow down execution and see the data flow through your diagram, or you can use common tools such as breakpoints and data probes to step through your program node-by-node. The combination of working with higher-level building blocks and improved visibility into your application's execution results in far less time spent tracking down bugs in your code.

Hardware Support

- Support for thousands of hardware devices, including:
  - Scientific instruments
  - Data acquisition devices
  - Sensors
  - Cameras
  - Motors and actuators
- Familiar programming model for all hardware devices
- Portable code that supports several deployment targets

Typically, integrating different hardware devices can be a major pain point when automating any test, measurement, or control system. Worse yet, not integrating the different hardware pieces leads to the hugely inefficient and error-prone process of manually taking individual measurements and then trying to correlate, process, and tabulate data by hand.

Fig 7.9 . LabVIEW connects to almost any hardware device.

LabVIEW makes the process of integrating hardware much easier by using a consistent programming approach no matter what hardware you are using. The same initialize-configure-

read/write-close pattern is repeated for a wide variety of hardware devices, data is always returned in a format compatible with the analysis and reporting functions, and you are not forced to dig into instrument programming manuals to find low-level message and register-based communication protocols unless you specifically need to.

LabVIEW has freely available drivers for thousands of NI and third-party hardware. In the rare case that a LabVIEW driver does not already exist, you have tools to create your own, reuse a DLL or other driver not related to LabVIEW, or use low-level communication mechanisms to operate hardware without a driver. Chances are if the hardware can be connected to a PC, LabVIEW can talk to it.

The cross-platform nature of LabVIEW also allows you to deploy your code to many different computing platforms. In addition to the popular desktop OSs (Windows, Mac, and Linux), LabVIEW can target embedded real-time controllers, ARM microprocessors, and field-programmable gate arrays (FPGAs), so you can quickly prototype and deploy to the most appropriate hardware platform without having to learn new toolchains.

Analysis and Technical Code Libraries

- Libraries of signal processing, analysis, and control algorithms
- Libraries of communication, file I/O, and connectivity
- Library functions that consume data in the same format as the hardware drivers return it

LabVIEW tailors the G programming language to engineering and scientific use by incorporating hundreds of specialized functions and algorithms that are not typically included with general-purpose programming languages.

In addition to the standard programming language constructs, LabVIEW contains functions for:

- String, array, and waveform manipulation
- Signal processing, including filters, windowing, spectral analysis, and transforms
- Mathematical analysis, including curve fitting, statistics, differential equations, linear algebra, and interpolation
- Communication, including high-level communication protocols, HTTP, SMTP, FTP, TCP, UDP, Serial, and Bluetooth
- Report generation, file I/O, and database connectivity
- Add-on packages supplement the core functionality for more specialized disciplines, such as:

  - Control design and simulation
  - Sound and vibration analysis
  - Machine vision and image processing
  - RF and communication

With the comprehensive analysis capabilities of LabVIEW, you can perform all the signal processing you need without wasting any time moving data between incompatible tools or resorting to writing your own analysis routines. All of the included functions in LabVIEW work seamlessly with the data you acquire from your hardware so you do not need to worry about converting and passing data. When you do have specific file format or communication protocol needs, LabVIEW can help you get the data into the right format.

UI Components and Reporting Tools

- Interactive controls such as graphs, gauges, and tables to view your acquired data
- Tools to save data to file or databases, or automatically generate reports

Every LabVIEW block diagram also has an associated front panel, which is the user interface of your application. On the front panel you can place generic controls and indicators such as strings, numbers, and buttons or technical controls and indicators such as graphs, charts, tables, thermometers, dials, and scales. All LabVIEW controls and indicators are designed for engineering use, meaning you can enter SI units such as 4M instead of 4,000,000, change the scale of a graph by clicking on it and typing a new end point, export data to tools such as NI DIAdem and Microsoft Excel by right-clicking on it, and so on.

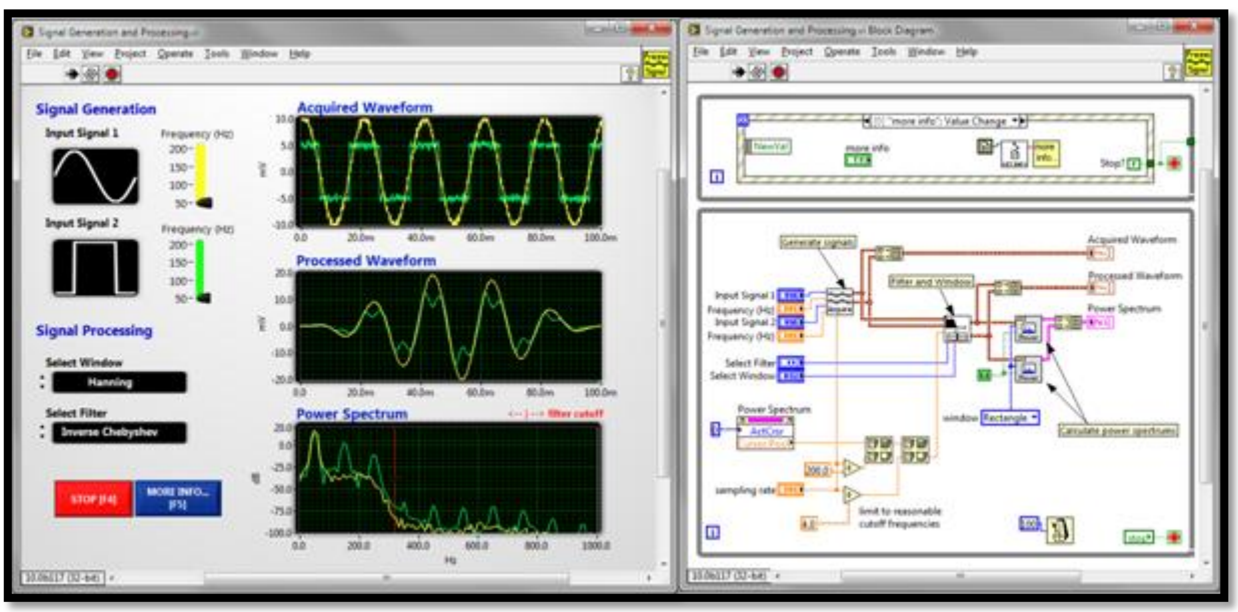


Fig. 7.10 LabVIEW block diagram has an associated front panel, such as this signal generation example with custom UI.

Controls and indicators are customizable. You can add them either from a palette of controls on the front panel or by right-clicking on a data wire on the block diagram and selecting “Create Control” or “Create Indicator.”

In addition to displaying data as your application is running, LabVIEW also contains several options for generating reports from your test or acquired data. You can send simple reports directly to a printer or HTML file, programmatically generate Microsoft Office documents, or integrate with NI DIAdem for more advanced reporting. Remote front panels and Web service support allow you to publish data over the Internet with the built-in Web server.

Technology Abstraction

- Harness emerging technologies such as FPGAs, multicore CPUs, and virtualization without painful relearning and additional development effort
- Use common protocols and platforms without getting bogged down by details

Technology advances at a rapid pace and the pressure to keep current and take advantage of state-of-the-art performance is rarely matched with enough time and training to learn and implement emerging technologies. LabVIEW addresses this problem by quickly adopting advances in personal and embedded computing in such a way that you get the new capabilities without having to learn significant new paradigms. Examples of this approach include how LabVIEW is able to automatically generate multithreaded code for execution on multicore processors or program FPGAs to gain the speed and reliability of custom hardware chips without the LabVIEW user needing to learn the underlying details of multithreading or the hardware description languages typically required to use FPGAs.

The same applies to new OSs, networking protocols, and more. LabVIEW moves with the industry and our engineers work diligently to ensure that applications created with LabVIEW are able to easily move with it. If you do not use LabVIEW, the responsibility of moving to a new or updated OS or other computer standard is on you.

Models of Computation

- Simulation syntax, textual math, statecharts, component-level IP (CLIP) nodes, DLL calls, and other models are available for whenever G is not the most natural representation of the solution.
- Incorporate and reuse existing code and IP to minimize development effort

When LabVIEW was first released, G was the only way to define the functionality you needed. Much has changed since then. With LabVIEW, you can now pick the most efficient approach to solve the problem at hand. Examine the following considerations:

- Graphical data flow is the default model of computation for LabVIEW.
- Statecharts provide a higher level of abstraction for state-based applications.
- Simulation diagrams are a familiar way of modeling and analyzing dynamic systems.
- Formula Node puts simple mathematical formulas in line with your G code.

- LabVIEW MathScript is math-oriented, textual programming for LabVIEW that you can

use to call .m files without the need for extra software.

- DLL calls, ActiveX/.NET communication, and the inline C node let you reuse existing ANSI C/C++ code and code from other programming languages.
- CLIP and IP integration nodes import FPGA intellectual property so you can use VHDL.

These flexible models of computation allow you to pick the right tool for the particular problem you are trying to solve. In any given application you will likely want to use more than one approach, and LabVIEW is the perfect tool to quickly tie everything together.

Benefits of LabVIEW

As Complex As You Need It to Be

One of the reasons LabVIEW makes you successful is its ability to scale to meet the needs of a given application. Picking the right software is all too often a balancing act between ease of use and learning curve on one side and power and flexibility on the other. Simple, fixed-function applications are generally easy to use and can be configured off the shelf, but they rarely meet all of the requirements for real world usage. Full-fledged programming, on the other hand, is powerful and flexible but comes at the cost of increased training and development time.

LabVIEW addresses this problem by providing several ways to accomplish similar tasks, so you can make the trade-off between simplicity and customization yourself on a task-by-task basis.

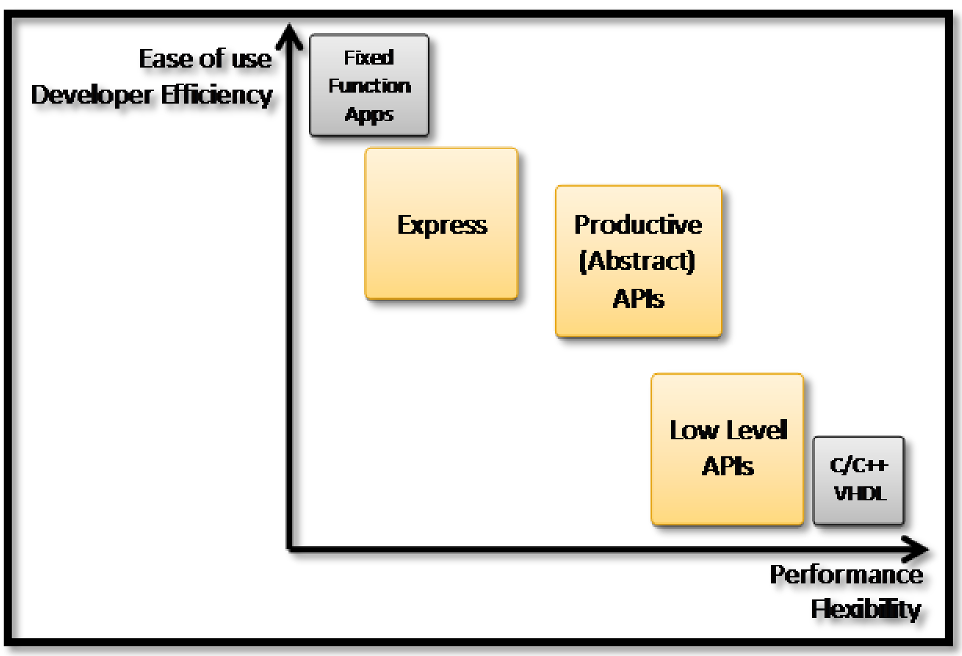


Fig. 7.11 LabVIEW gives you the freedom to choose between ease of use and low-level flexibility.

Express VIs

- Quick and easy, but limited
- Similar to other fixed-function/configurable, non programming tools

Express VIs are normally the quickest and easiest way to perform a task in LabVIEW. You choose the settings you want for a given operation, such as acquiring from an NI data acquisition (DAQ) device or saving data to a file, from a configuration window with several options and settings. When you click the OK button, LabVIEW configures the underlying code for you and just relies on you defining the flow of data between Express blocks (or Express VIs, as they are called in LabVIEW).

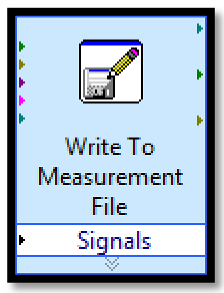


Fig. 7.12 Express VIs provide common functionality with configuration dialog simplicity.

The downside to this simplicity is that you are restricted to the options that are in the configuration dialog. If you have custom requirements, then configuration dialogs are generally not flexible enough to meet your needs. Therefore, this approach is most useful for quick prototypes and simple tasks.

Productive (Abstract) APIs

- High degree of customization
- Require application expertise, but abstract many programming complexities

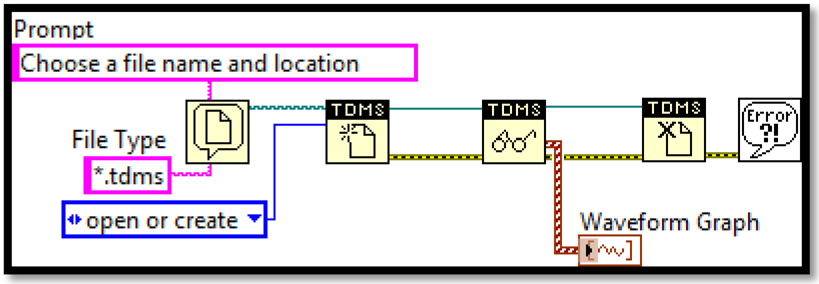


Fig. 7.13 The TDMS file API exposes only the functionality and not the complexity.

The most common way to program in LabVIEW is using high-level functions that strike a balance between abstracting the unnecessary administrative tasks such as memory management and format conversion, but keep the flexibility of being able to customize almost every aspect of whatever task you need to accomplish.

Most of these APIs implement a specific technology, such as working with the TDMS file format (shown in Figure 7), talking to an instrument (the NI-VISA API), or manipulating and processing waveform data (any of the Wfm functions). Each API gives you full control of the actual process involved but does not require you to deal with all of the intricacies of implementing the minutia of the protocol. These APIs save you time by eliminating the steps that you do not need to define – whether it be calculating the number of bytes to read and byte order for file I/O when all you care about is reading in the previous day's measurements or implementing all of the intermediate math operations when you need only the fundamental frequency of a waveform.

Low-Level APIs

- Powerful, but require both application and programming expertise and development time
- Similar to C or other multipurpose programming languages/tools

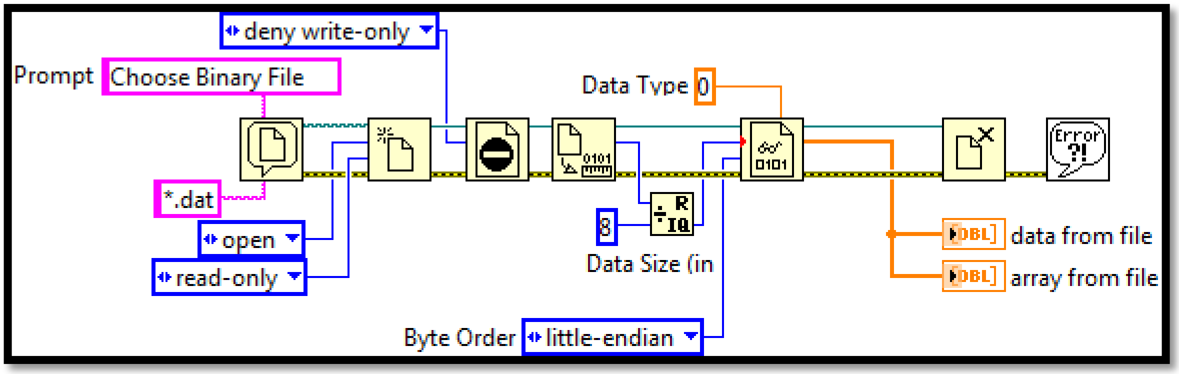


Fig. 7.14 Low-level access gives you complete freedom to implement custom solutions.

When you need to be able to completely define every detail of your task, LabVIEW offers the same low level access as you would get in traditional programming languages. LabVIEW can support any file type or any communication protocol because in the worst-case scenario you can implement them yourself, forming whichever headers or packets you need and sending raw binary data. For example, if your company uses a proprietary file format for which LabVIEW does not have a built-in function, you can use the low-level file I/O VIs to describe exactly how your data should be written to file – right down to the individual bits on the disk if you need to.

LabVIEW – More Than Just Software

We have discussed what the LabVIEW product is, but in reality, LabVIEW is more than just what we develop and you install on your computer. LabVIEW has a thriving ecosystem of products, services, and people around it that continue to drive adoption and ensure success.

Fig. 7.15 An ecosystem of products, services, and people make LabVIEW more than just a product.

NI Support and Services

National Instruments stands behind LabVIEW with comprehensive support, training, and certification options. You can contact our applications engineers via phone and e-mail to help you get up and running, troubleshoot issues, and ensure that you are successful with LabVIEW.

Training courses range from the basics of LabVIEW to advanced architectures and managing software engineering processes to ensure that you are best placed to take advantage of the benefits that LabVIEW offers.

Certification allows individuals to provide proof of their capabilities and for organizations to recognize and distinguish expertise among employees and make potential outsourcing decisions.

Beyond NI

In addition to NI support and services, there is a substantial community of users and professionals with expertise and products that extend the reach of LabVIEW. The NI Discussion Forums and LAVA are large, active message boards for LabVIEW discussion where developers of varying experience ask questions and help each other out. Another way to interact with other LabVIEW users is through user groups in both physical and virtual meetings where users share presentations, advice, and best practices.

The LabVIEW Tools Network houses code reuse libraries, architectures, and toolkits from NI and third parties to further enhance the capabilities of LabVIEW for specific applications.

When you need extra assistance solving a problem, the National Instruments Alliance Partner program is a worldwide network of more than 600 consultants, system integrators, developers, channel partners, and industry experts who partner with NI to provide complete, high-quality virtual instrumentation solutions to customers.

Productivity and Empowerment with LabVIEW

As you can see, there is a lot to LabVIEW. Some people need every component. Others only use some parts. However, everyone who uses LabVIEW is aware of the productivity and empowerment that comes from abstracting unnecessary complexity and being able to focus on the challenge at hand, not the challenges typically associated with creating custom software.

7.5. Project SCADA Software Program Logic

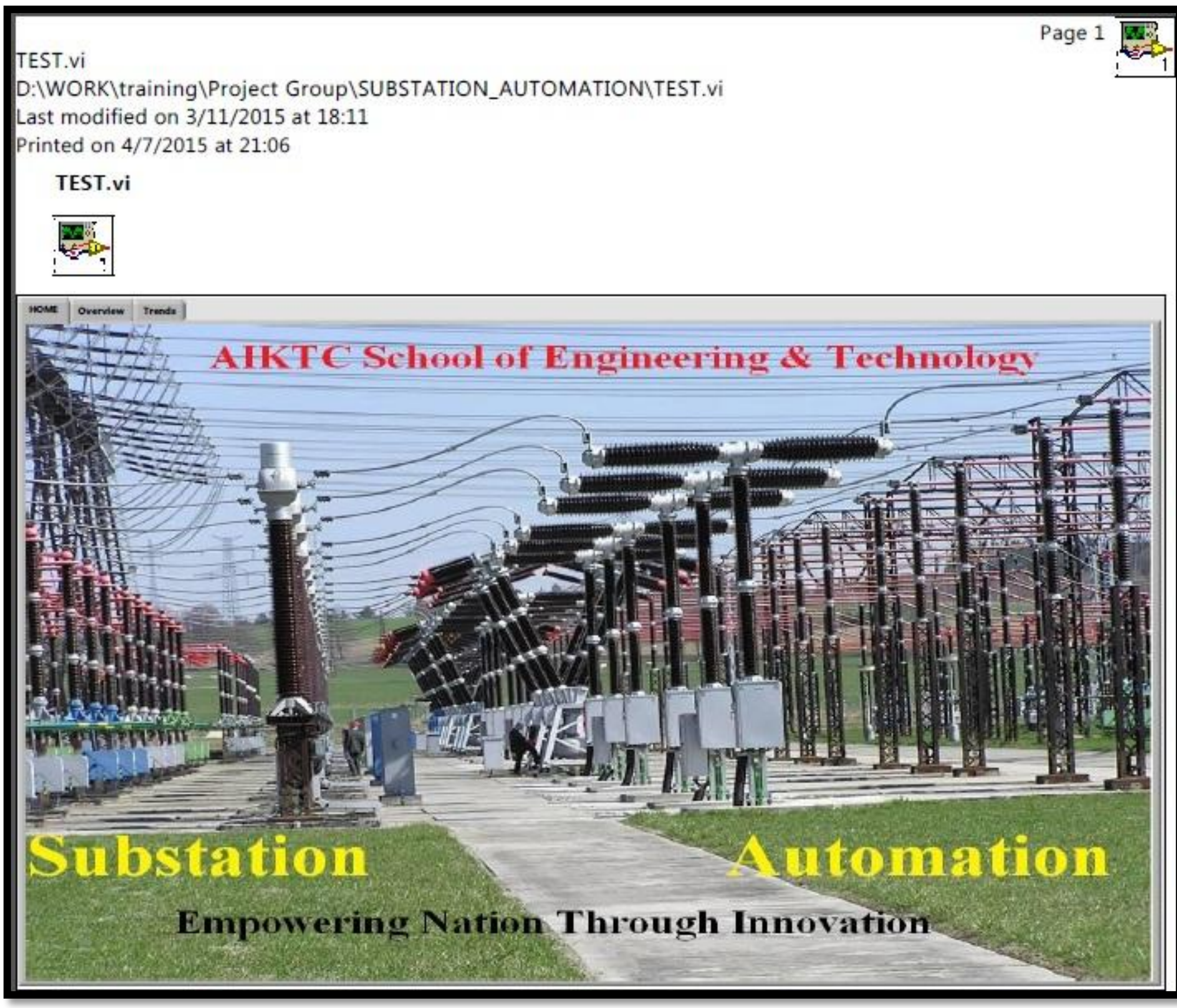


Fig. 7.16 Project SCADA software program logic screenshot1

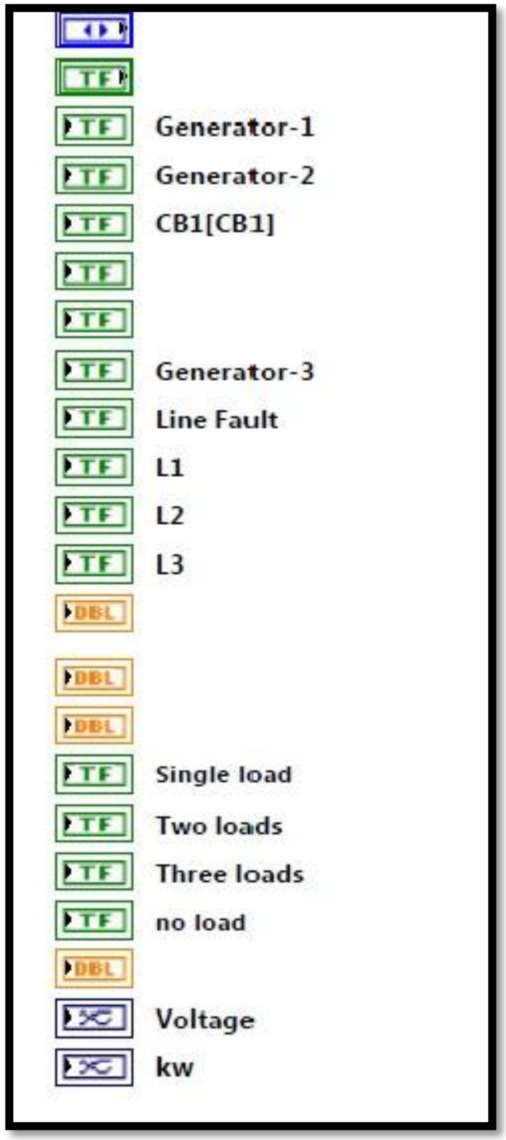


Fig. 7.17 Project SCADA software program logic screenshot2

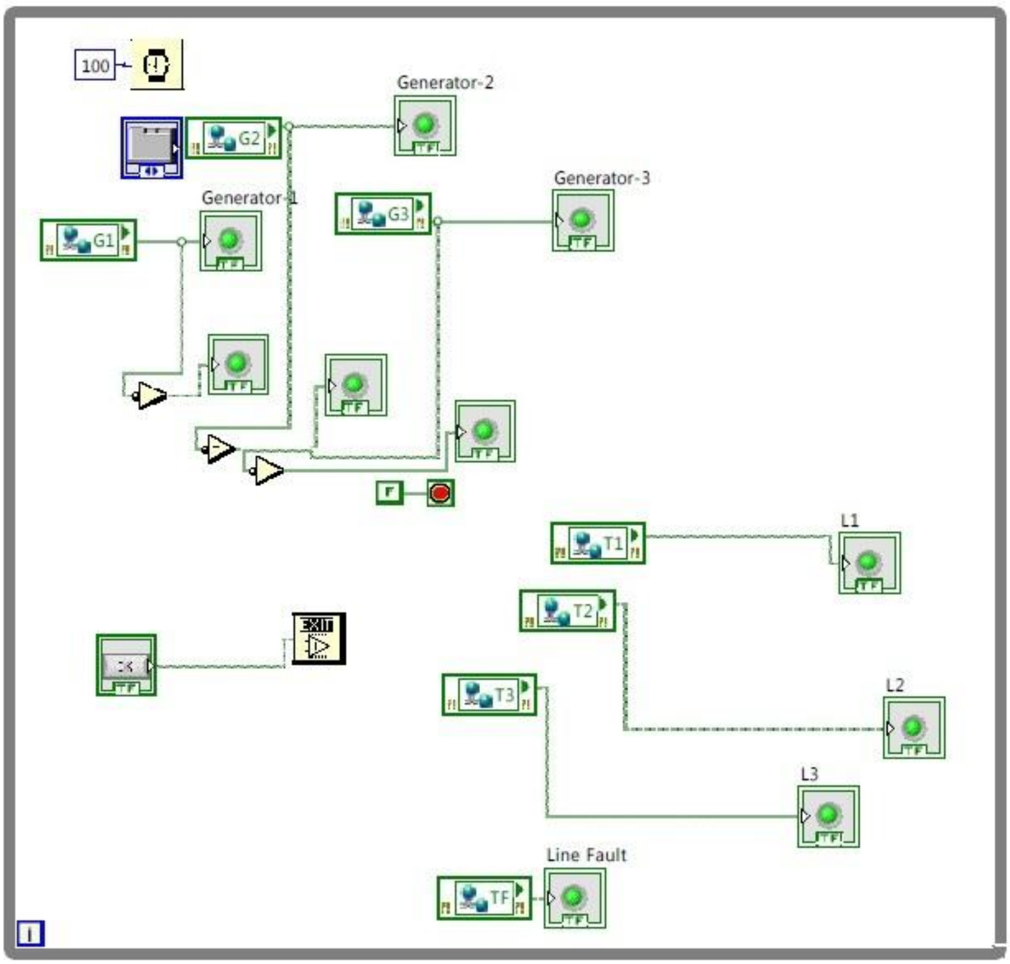


Fig. 7.18 Project SCADA software program logic screenshot3

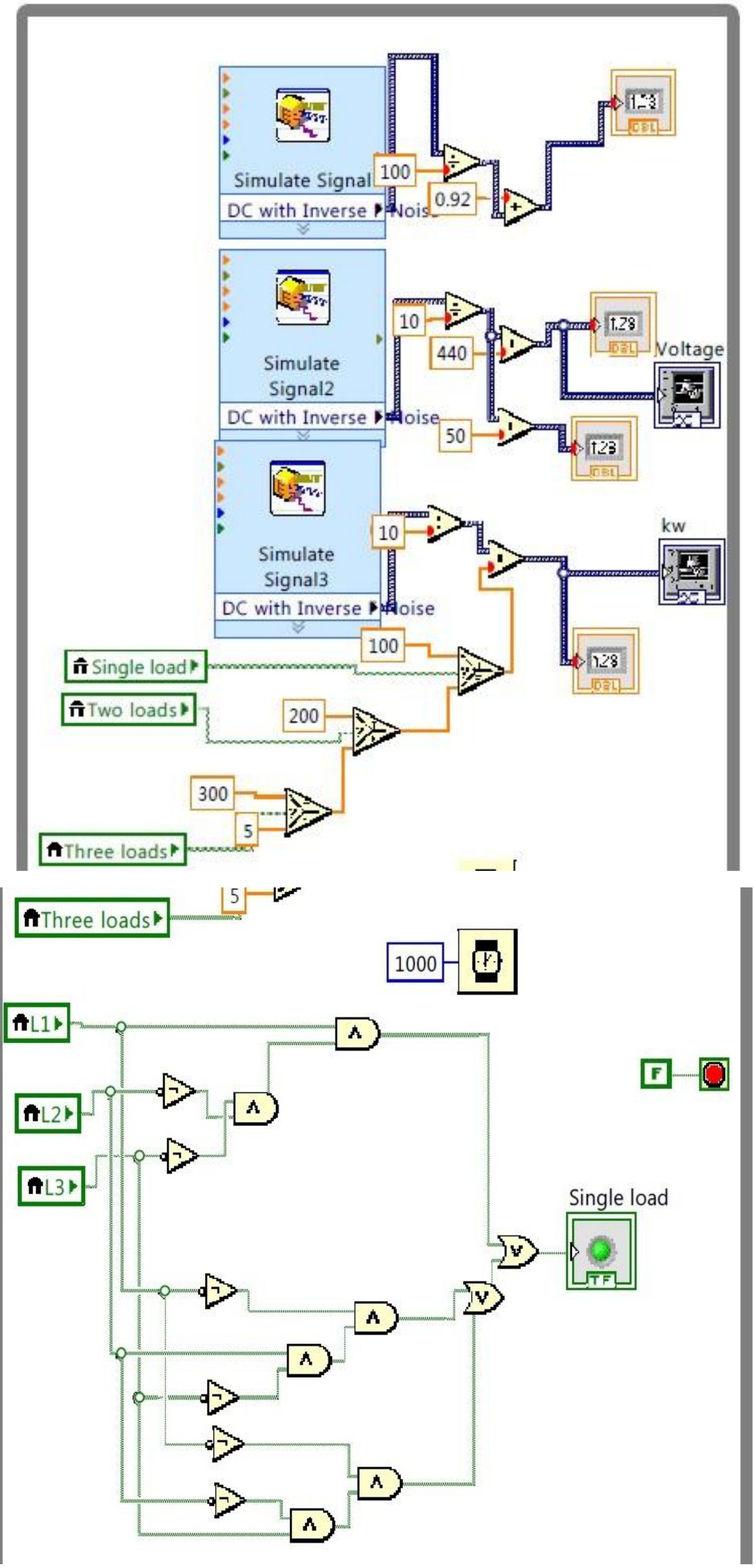


Fig. 7.19 Project SCADA software program logic screenshot4

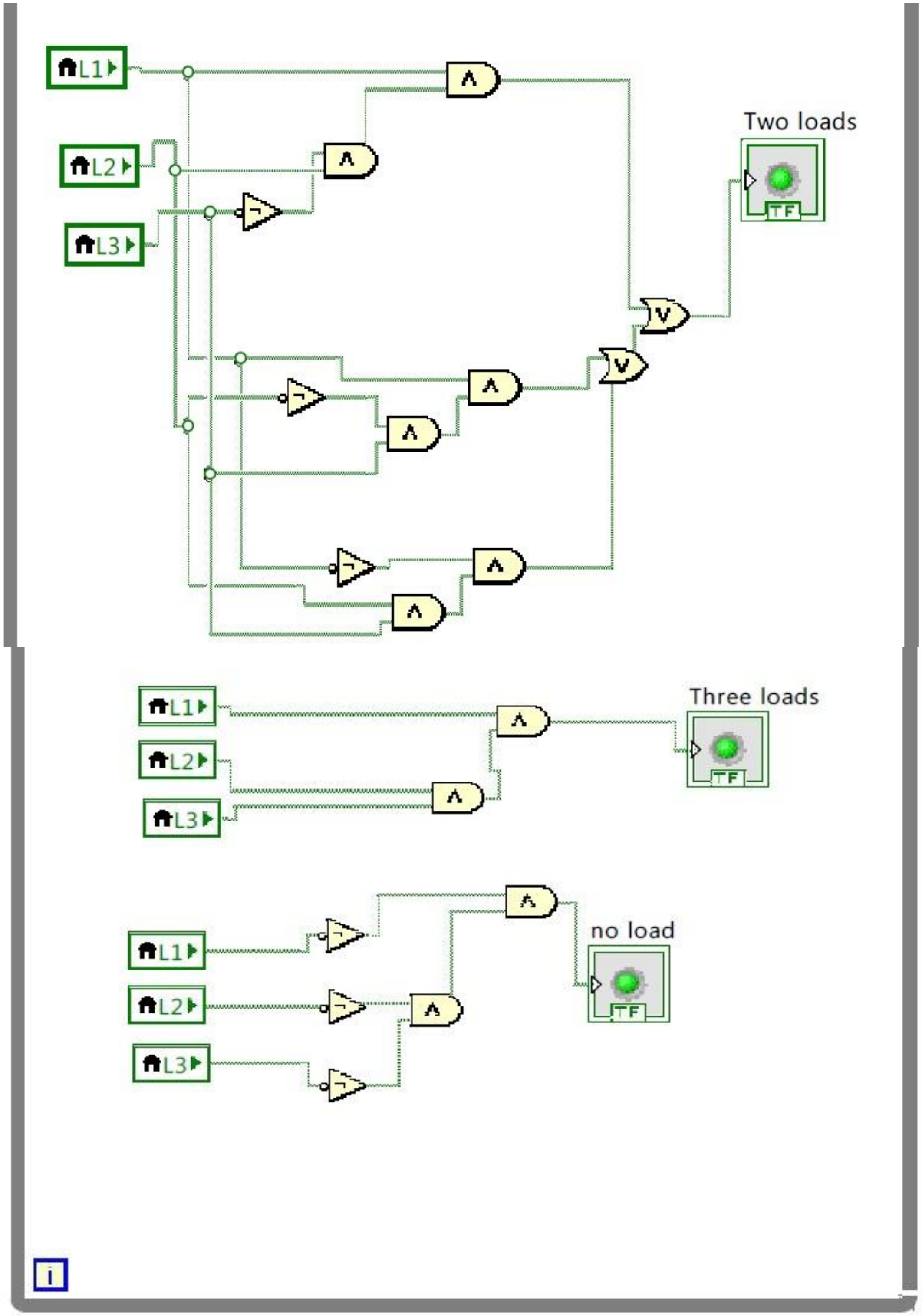


Fig. 7.20 Project SCADA software program logic screenshot5

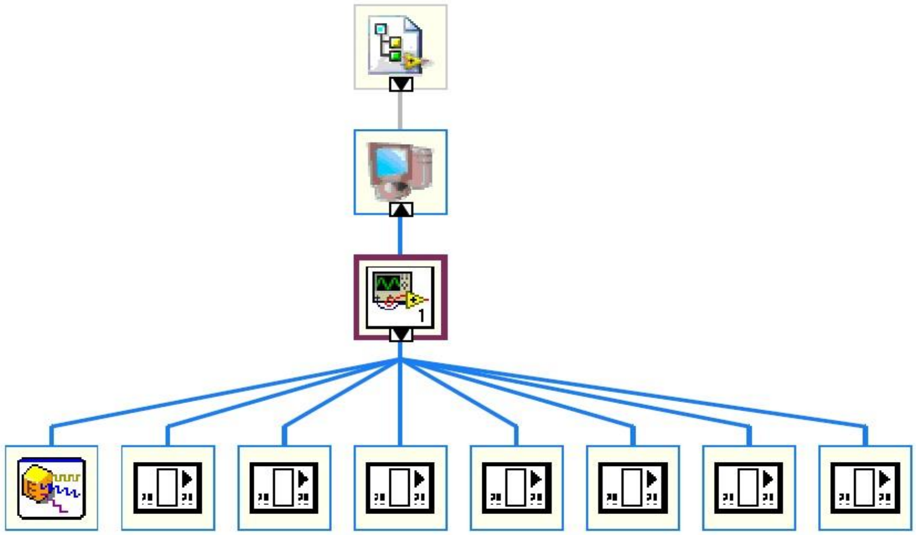


Fig. 7.21 Project SCADA software program logic screenshot6

7.6. Project SCADA Screen View

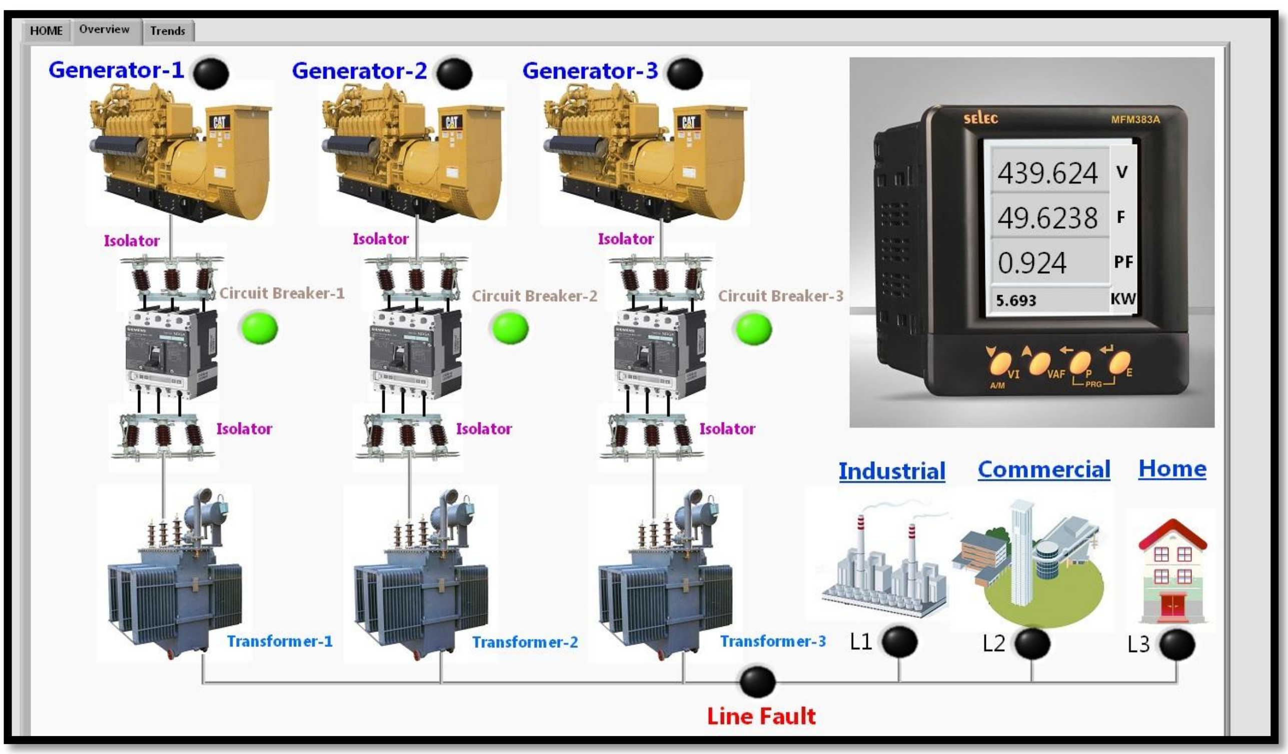


Fig. 7.22 Project SCADA screen view

Chapter 8

Results and Discussions

A considerable amount of effort is necessary to maintain an electric power supply within the requirements of various types of consumers without failure of system.

Proper voltage. One important requirement of a distribution system is that voltage variations at consumer's terminals should be as low as possible. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage causes lamps to burn out permanently and may cause failure of other appliances. Therefore, a good distribution system should ensure that the voltage variations at consumers terminals are within permissible limits. The statutory limit of voltage variations is ± 6% of the rated value at the consumer's terminals. Thus, if the declared voltage is 230 V, then the highest voltage of the consumer should not exceed 244 V while the lowest voltage of the consumer should not be less than 216 V. [1]

Availability of power on demand. Power must be available to the consumers in any amount that they may require from time to time. For example, motors may be started or shut down, lights may be turned on or off, without advance warning to the electric supply company. As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules.[1]

Reliability. Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately, electric power, like everything else that is man-made, can never be absolutely reliable. However, the reliability can be improved to a considerable extent by (*a*) interconnected system (*b*) reliable automatic control system (*c*) providing additional reserve facilities.[1]

The use of PLCs (Programmable Logic Controllers) in substation and distribution automation applications has grown in recent years. The economics of PLC based solutions mean that substation automation and SCADA solutions can be applied even more widely. This will help the utilities respond to the challenges presented by deregulation. As the use of PLCs in substations increases, the criteria for selection of control system integrators, engineering firms and consultants will become an extremely important factor in the success of PLC substation automation and SCADA projects. One of the most important criteria is that the control system integrator, the engineering firm or the consultant has sound business practices in place. They should also have a project management methodology in place to assure the success of these projects [9]

This type of an automatic network can manage load, maintain quality, detect theft of electricity and tempering of meters. It gives the operator an overall view of the entire network. Also, flow of power can be closely scrutinized and Pilferage points can be located. Human errors leading to tripping can be eliminated. This directly increases the reliability and lowers the operating cost.

In short our project is an integration of network monitoring functions with geographical mapping, fault location, load management and intelligent metering

Chapter 9

Conclusions

9. Conculsions

Voltage Class			
400 Kv	220 Kv	132 Kv	66 Kv
9	64	48	727

Table. 9.1 Number of substation with
Voltage level at Gujarat

	AGEWISE SUB-STATIONS									
Name of circle	0 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40	above 41	Total
NAVSARI	13	12	11	9	7	3	6	4	5	**70**
BHARUCH	6	7	11	7	5	5	2	1	1	**45**
JAMBUVA	8	10	15	17	12	5	14	8	2	**91**
NADIAD	22	12	27	14	9	9	6	7	2	**108**
MEHASANA	23	9	23	15	12	13	7	3	0	**105**
PALANPUR	36	18	30	20	4	7	5	1	0	**121**
GONDAL	22	16	19	10	4	5	3	2	4	**85**
JUNAGADH	7	18	17	8	6	4	8	2	1	**71**
AMRELI	17	21	22	11	2	6	3	4	0	**86**
ANJAR	15	13	11	6	2	7	3	0	0	**57**
ASOJ	3	2	1	3	0	0	0	0	0	**9**
Total:	**172**	**138**	**187**	**120**	**63**	**64**	**57**	**32**	**15**	**848**

Table. 9.2 Age wise substation of Gujarat region

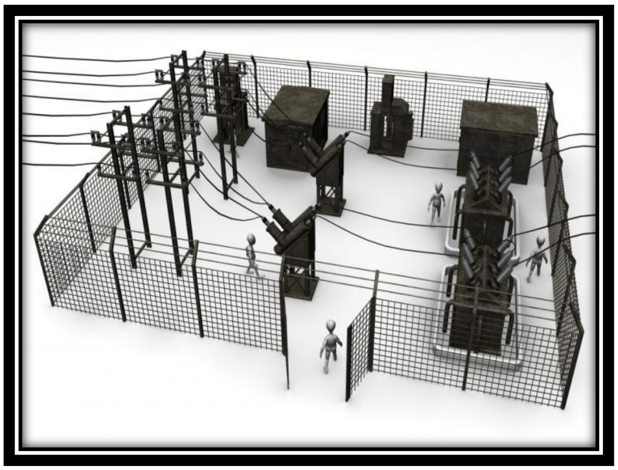
One analysis say that in only Gujrat rgion more than 60% substation is manually operated or just metering is automated. Hardly 5% to 7% Substation is High Standard Automated. Now GETCO try to move towards to total automation through SIS (System Improvement Scheme).[13]

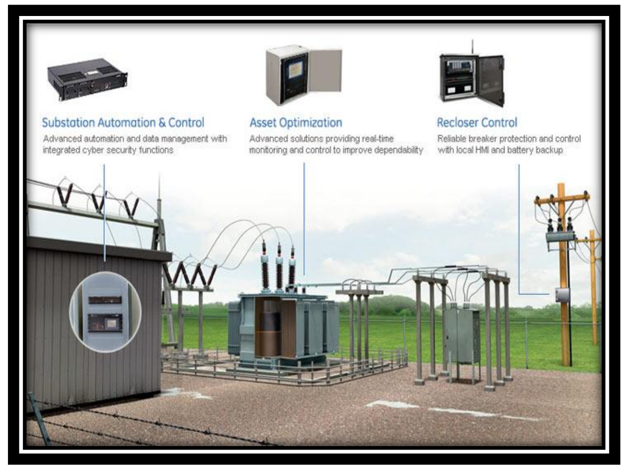
With the help of Substation Automation we can improve reliability, Power Quality & power handling and distribution capacity/management. The implementation of automation is very costly & complex procedure with increasing use of power electronics & electronics equipment, for implementation in practical existing field. After investing more equity for automation we can achieve a lot from the system.[13]

Total 60% to 65% of existing substation's age is more than 25 years. According to its age government has started renovating and improving towards system automation. This improvement should be IEC 61850 instead of distinctive Substation Automation.

At present in INDIA knowledge of IEC 61850 & implementation technology is only with private sectors. This standard is worldwide accepted. So, government should try to train engineers to get enhanced output.[13]

Let's go Invent tomorrow instead of worrying about what happened yesterday….!




Substation Automation & Control
Advanced automation and data management with integrated cyber security functions
Asset Optimization
Advanced solutions providing real-time monitoring and control to improve dependability
Recloser Control
Reliable breaker protection and control with local HMI and battery backup


Thank You!

Chapter 10

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Fig.10.1 Project Model of "PLC & SCADA Based Substation Automation"