Sudan University of Sciences and Technology

College of Engineering

School of Electrical and Nuclear Engineering

Distribution Automation System (Case Study)

نظام التحكم الآلي في التوزيع (دراسة حالة)

A Project Submitted Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) Electrical Engineering

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الآيه

قال تعالى :

﴿فَتَعالَى اللَّهُ المَلِكُ الحَقُّ وَلا تَعجَل بِالقُرآنِ مِن قَبلِ أَن يُقضى إِلَيكَ وَحيُهُ وَقُل رَبِّ زِدني عِلمًا﴾

صدق الله العظيم

[طه: 114]

DEDICATION

Anyone who ignites a flame of hope for science…

For those who see us a good seed in the path of science…

Everyone has given his efforts for science…

To our honorable families and our parents…

To the dear patch…

Take our thanks.

ACKNOWLEDGEMENT

Our peace and grace from Allah be upon him.

To the utmost knowledge lighthouse, to our greatest and prophet Mohammed Ibn Abdalla.

We offer the most beautiful words of thanks and gratitude from the heart, with love and friendliness And respect and appreciation to all staff of the department and to our teacher: Gaffar Babiker. And the engineers on the khartoum automation center.

ABSTRACT

The importance of research is to study the distribution automation system, to learn about its problems and to explore the most important ways to develop it, as distribution control plays a key role in the stability of electricity and its safe access to consumers.

The research is within the scope of case studies, a study of the distribution n control system, based on field visits to gather information for the Khartoum Automated Control Center and the Omdurman Automated Control Research Center, as well as a collection of references and scientific papers, especially the research center papers.

The Sudan Automated Control System (ASPC) is generally a sophisticated system that is frequently updated, especially distribution control, and needs to be more carefully maintained and qualified staff to deal with it, preferably a local control system with Sudanese hands to avoid programming, development and software problems.

المستخلص

تكمن أهمية البحث في ضرورة دراسة نظام التحكم الآلي في مجال التوزيع ومعرفة مشاكله وبحث أهم طرق تطويره ، حيث أن التحكم في التوزيع يلعب دوراً أساسياً في استقرار الكهرباء ووصولها بأمان إلى المستهلك .

يعتبر البحث ضمن نطاق دراسات الحالة، حيث يمثل دراسة لنظام التحكم في التوزيع ، واعتمد فيه على الزيارات الميدانية لجمع المعلومات لكل من مركز التحكم الآلي بالخرطوم ومركز أبحاث التحكم الآلي بأم درمان ، إضافة للجمع من المراجع والأوراق العلمية خاصة أوراق مركز الأبحاث .

نظام التحكم الآلي في السودان بشكل عام نظام متطور ويتم تحديثه بشكل متكرر خاصة نظام التحكم في التوزيع ، ويجب العناية به بشكل أكبر وتوفير الكوادر المؤهلة للتعامل معه ، كما يفضل أن يتم تصميم نظام تحكم آلي محلي بأيدي سودانية لتفادي مشاكل البرمجة والتطوير والبرمجيات .

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CHAPTER ONE

INTRODUCTION

1.1 Overview

The word Automation means doing the particular task automatically in a sequence with faster Operation rate. This requires the use of microprocessor together with communication network, and some relevant software programming. Now days due to advancement in the communication technology, Distribution Automation System (DAS) is not just a remote control and operation of substation and feeder equipment but it results into a highly reliable, self-healing power system that responds rapidly to real-time events with appropriate actions.

1.2 Project Statement

Power Distribution system need to be automated because the system can suffer from many types of delays of operation that can accrued in the network and causes damages or risk to the human being.

1.3 Project Objectives

The distribution automatic system should have to be studied to know how it works and knowing the main components technic of it, then knowing the main problems in the distribution system to solve these problems using the supervisory control and data acquisition.

1.4 Project Methodology

A collection of the basic information on the distribution automation system and the SCADA. Was studied to solve the distribution automation cases and method of operation were identify. A series of visits cover the practical Areas in the distribution system.

1.5 Project Layout

The Project contents five chapters and references, where chapter one deals with an introduction consist of an overview and the research problem, methodology, objectives and structure.

The second chapter talks about the components of distribution automation system, chapter three talk about scada system, chapter four talk about the application of this system, and at last chapter talk about conclusion and recommendations.

CHAPTER TWO

THE CONCEPT OF DISTRIBUTION OF DISTRIBUTION AUTOMATION SYESTEM

2.1 Introduction

Distribution automation is a set of technologies that enable an electric utility to remotely monitor, coordinate and operate distribution components in a real-time mode from remote locations. Distribution Automation (DA) or Distribution Management System (DMS) outstation devices are multi featured installations with an extended range of control, operations, planning, switching, and system performance issues for the utility personnel. Each device provides specific SCADA functionality, supports system control operations, includes fault detection, collects planning data, and records power quality information. These devices usually are found in the electrical power substation and at specific locations along the transmission line. The multi featured capability of the DA device increases its ability to be used in the electric power system. The functionality and operations capabilities supplement each other with respect to the control and operation of the electrical micro grid and grid.

Power-system automation is the act of automatically controlling the power system via instrumentation and control devices. Substation automation refers to using data from intelligent electronic devices (IED), control and automation capabilities within the substation, and control commands from remote users to control power-system devices.

Since full substation automation relies on substation integration, the terms are often used interchangeably. Power-system automation includes processes associated with generation and delivery of power. Monitoring and control of power delivery systems in the substation and on the pole reduce the occurrence of outages and shorten the duration of outages that do occur. The IEDs, communications protocols, and communications methods, work together as a system to perform power-system automation. The term “power system” describes the collection of devices that make up the physical systems that generate, transmit, and distribute power. The term “instrumentation and control (I&C) system” refers to the collection of devices that monitor, control, and protect the power system. Many power-system automation are monitored by SCADA.

Electricity distribution is the final stage in the delivery of electricity to end users. A distribution system’s network carries electricity from the transmission system and delivers it to consumers. Typically, substations and pole-mounted transformers, low-voltage (less than 1 kV) distribution wiring and sometimes meters. The power system network, which generally concerns (or which is in close proximity of) the common man, is the distribution network of 11 KV lines or feeders downstream of the 33 KV substation. Each 11 KV feeder, which emanates from the 33 KV substation branches further into several subsidiary 11 KV feeders to carry power close to the load points, where it is further step down to either 230V or 415 V. The electrical power distribution is shown in the flowing Figure(2.1)

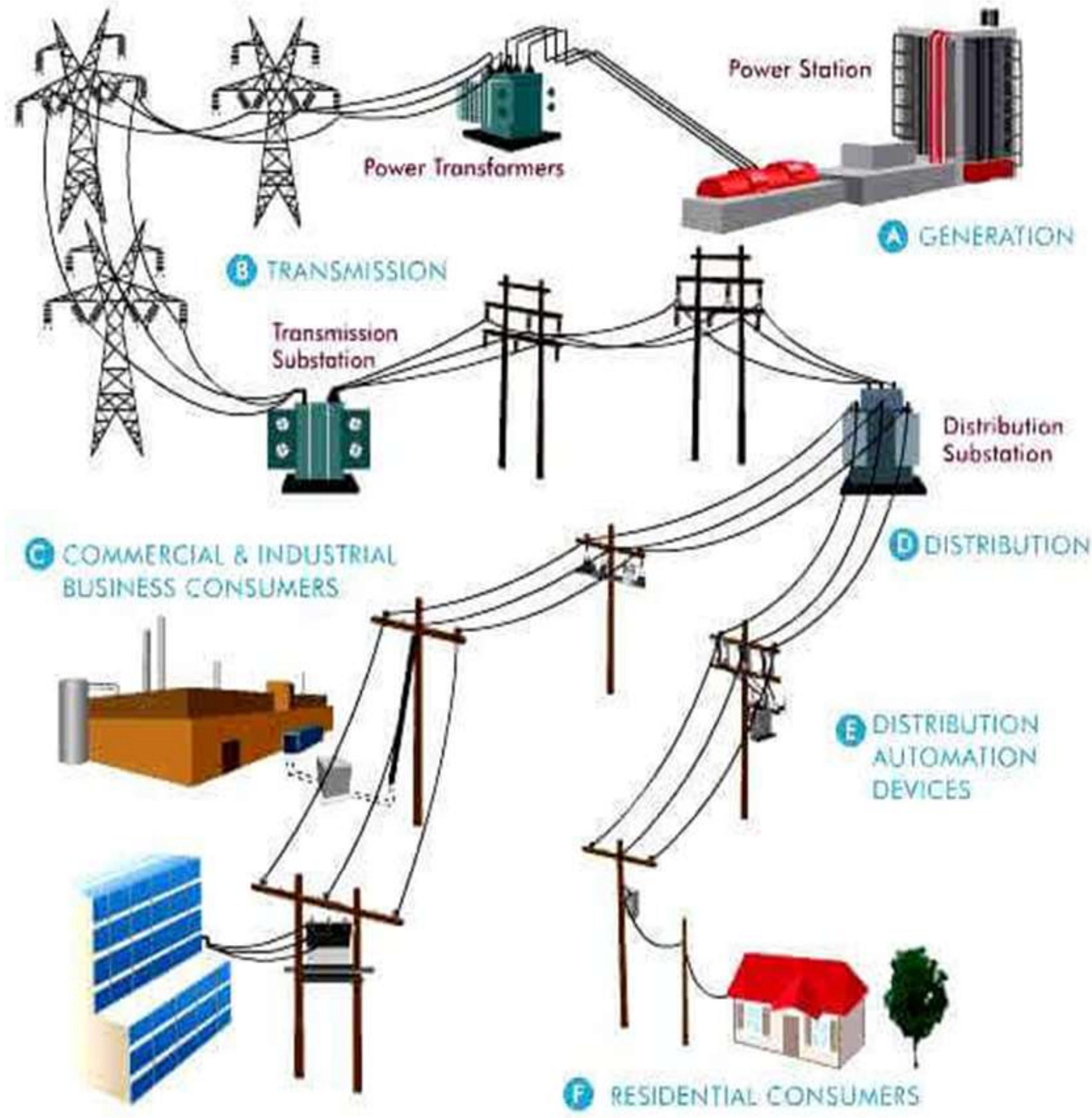


Figure 2.1: Electrical power distribution automation system

2.2 Supervisory and Data Acquisition System

A SCADA system refer to a system consisting of a number of Remote Terminal Units (or RTUs) collecting field data connected back to a master station via a communications system. The master station displays the acquired data and also allows the operator to perform remote control tasks. The accurate and timely data (normally real-time) allows for optimization of the operation of the plant and process. A further benefit is more efficient, reliable and most importantly, safer operations. This all results in a lower cost of operation compared to earlier non-automated systems. A successful SCADA installation depends on utilizing proven and reliable technology, with adequate and comprehensive training of all personnel in operation of the system.

Today hardware reliability is less of a problem, but the increasing software complexity is producing new challenges. It should be noted in passing that many operators judge a SCADA system not only by the smooth performance of the RTUs, communication links and the master station (all falling under the umbrella of SCADA system) but also the field devices (both transducers and control devices). The field devices however fall outside the scope of SCADA in this manual and will not be discussed further.

The RTU provides an interface to the field analog and digital signals situated at each remote site. The communications system provides the pathway for communications between the master station and the remote sites. This communication system can be radio, telephone line, microwave and possibly even satellite. Specific protocols and error detection philosophies are used for efficient and optimum transfer of data. The master station (and sub-masters) gather data from the various RTUs and generally provide an operator interface for display of information and control of the remote sites. In large telemetry systems, sub-master sites gather information from remote sites and act as a relay back to the control master station.

2.3 Distribution SCADA

Distribution SCADA involves collecting and analyzing information to take decisions, implementing the appropriate decisions and then verifying whether the desired results are achieved. Data acquisition in an electric utility SCADA system concentrates on the power system performance quantities like bus line volts, transformer currents, real and reactive power flow, C.B.

Status (circuit breaker status), isolator status and secondary quantities such as transformer temperature, Insulating gas pressure, tank oil levels, flow levels etc. Often transformer tap positions, usual positions or other multiple position quantities are also transmitted in analog format. The usual reason for installing supervisory control is to provide the system with sufficient information and control to operate the power system or some part of it in a safe, secure and economic manner. The utility system with SCADA and distribution automation shown in Figure 2.2

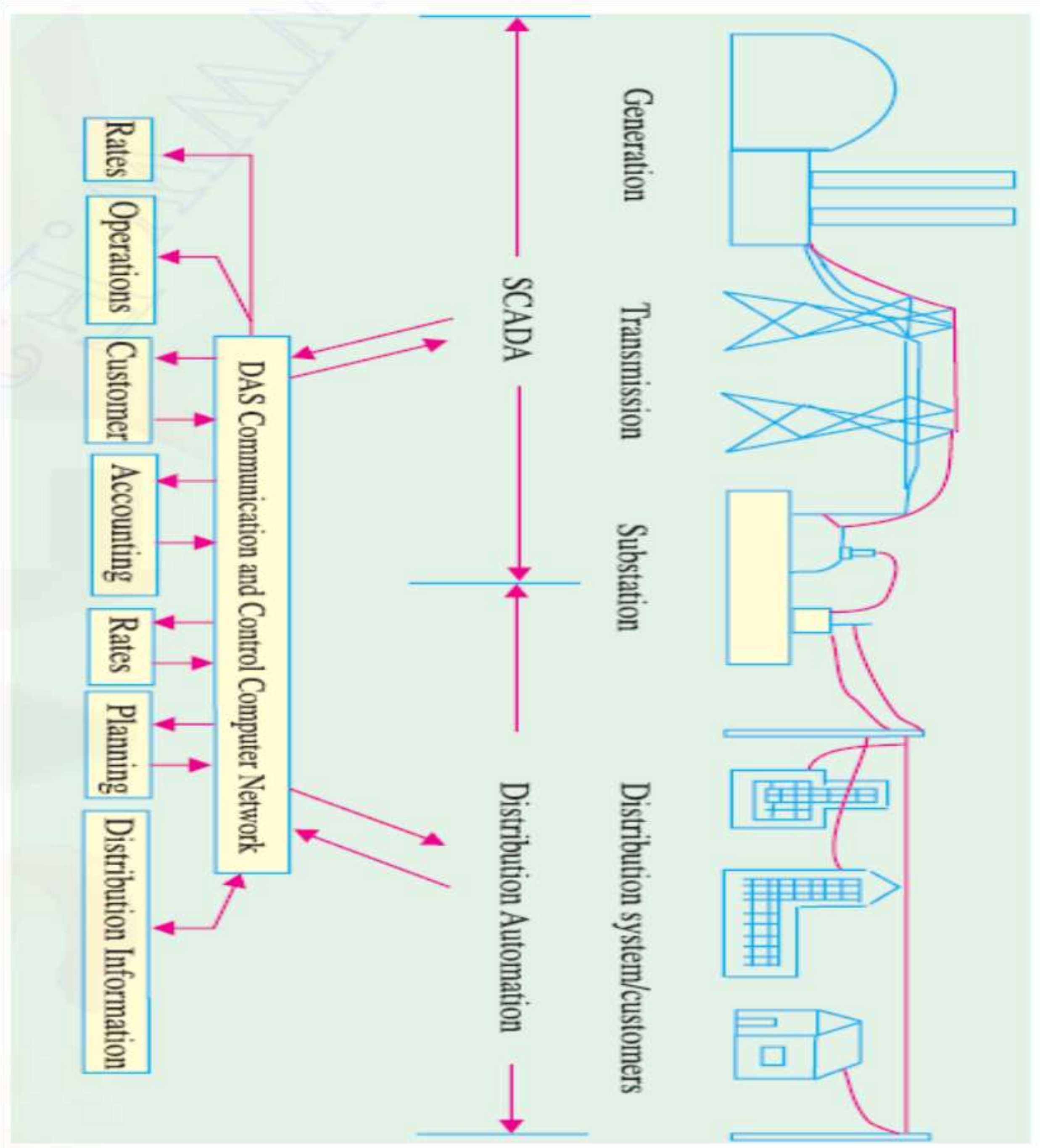


Figure 2.2: Utility system with SCADA and distribution automation system

In DA system, the various quantities (e.g., voltage, current, switch status, temperature and oil level, etc..) are recorded in the field at the distribution transformers and feeders, using a data acquisition device called Remote Terminal Unit. These quantities are transmitted on-line to the base station through a communication media. The acquired data is processed at the base station for display at multiple computers through a Graphic User Interface (GUI). In the event of a system quantity crossing a pre-defined threshold, an alarm is generated for operator intervention. Any control action, for opening or closing of the switch or circuit breaker, is initiated by the operator and transmitted from the 33 KV base station through the communication channel to the remote terminal unit associated with the corresponding switch or CB. The desired switching takes place and the action is acknowledged back to the operator.

Distributed Control System (DCS), is another variant of SCADA where data acquisition and control functions are performed by a number of distributed microprocessor-based units situated near to the devices being controlled or the instrument from which data is being gathered. DCS systems have evolved into systems providing very sophisticated analog (e.g. loop) control capability. A closely integrated set of operator interfaces (or man machine interfaces) is provided to allow for easy system configurations and operator control. The data highway is normally capable of fairly high speeds.

Another variant of SCADA components widely used is the Programmable Logic Controller (PLC). PLCs have replaced hardwired relays with a combination of ladder– logic software and solid state electronic input and output modules. They are often used in the implementation of a SCADA RTU as they offer a standard hardware solution, which is very economically priced.

2.4 Load Management in DMS

This involves controlling system loads by remote control of individual customer loads. Control includes suppressing or biasing automatic control of cyclic loads, as well as load switching. Load Management can also be effected by inducing customers to suppress loads during utility selected daily periods by means of time-of-day rate incentives. Distribution Automation provides the control and monitoring ability required for both the load management scenarios -viz - direct control of customer's loads and the monitoring necessary to verify that programmed levels are achieved. Execution of load management provides several possible benefits to the utility and its customer's. Maximum utilization of the existing distribution system can lead to deferrals of capital expenditure. And the functions of distributed management system shown in Figure 2.3

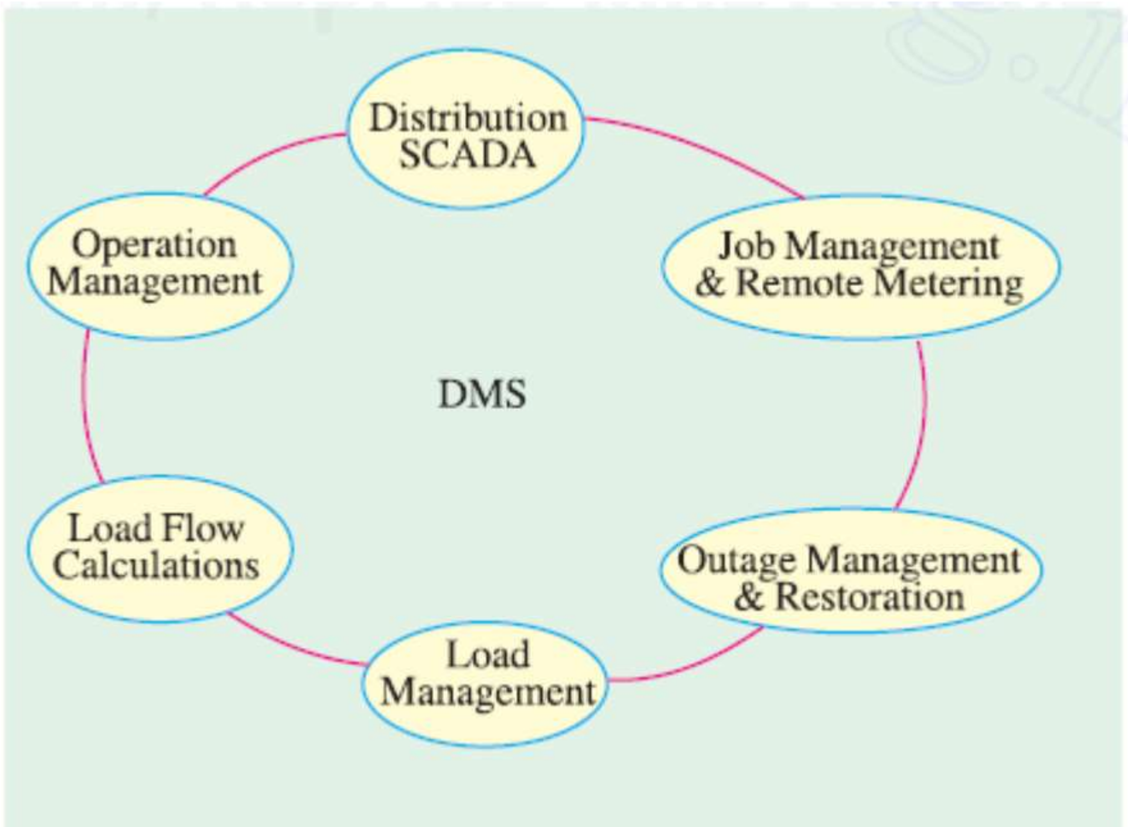


Figure 2.3: Functions of distributed management system

2.5 Distribution Automation System Components

Distribution automation can be broadly classified as:

- Substation automation.

- Feeder automation.

- Consumer side automation.

2.5.1 Substation automation

Substation automation is the cutting edge technology in electrical engineering. It means having an intelligent, interactive power distribution network including:

- Increased performance and reliability of electrical protection.

-Advanced disturbance and event recording capabilities, aiding in detailed electrical fault analysis.

- Display of real time substation information in a control center.

- Remote switching and advanced supervisory control.

- Increased integrity and safety of the electrical power network including advanced interlocking functions.

- Advanced automation functions like intelligent load-shedding

- Requirements:

The general requirements for selecting an automation system while designing a new substation are:

- The system should be adaptable to any vendor's hardware.

- It should incorporate distributed architecture to minimize wiring.

- It should be flexible and easily set up by the user.

- The substation unit should include a computer to store data and pre-process information.

- Functioning:

Bus voltages and frequencies, line loading, transformer loading, power factor, real and reactive power flow, temperature, etc. are the basic variables related with substation control and instrumentation. The various supervision, control and protection functions are performed in the substation control room. The relays, protection and control panels are installed in the controlled room. These panels along with PC aids in automatic operation of various circuit breakers, tap changers, auto recloses, sectionalizing switches and other devices during faults and abnormal conditions. Thus, primary control in substation is of two categories

- Normal routine operation by operator's command with the aid of analog and digital control system.

- Automatic operation by action of protective relay, control systems and PC.

2.5.2 Feeder automation

Automating the fault diagnosis and supply restoration process significantly reduces the duration of service interruptions. The key objective behind automating the service restoration process is to restore supply to maximum loads in out-of-service zones. This is achieved by reconfiguring the network such that the constraints of the system are not violated. Providing timely restoration of supply to outage areas of the feeder enhances the value of service to customers and retains the revenue for the power industry.

The system data consisting of the status signals and electrical analog quantities are obtained using a suitable Data Acquisition System and processed by the control computer for typical functions of fault detection, isolation and network reconfiguration for supply restoration. The equipment's normally required in Feeder Automation are discussed below:

- Distribution equipment:

This includes transformers, breakers, load break switches and motor operators, power recloses, voltage regulators, capacitor banks etc.

- Interface equipment:

Interface equipment is required for the purpose of data acquisition and control. Potential transformers, current transformer, watt, var meter and voltage transducers, relays are some examples.

- Automation equipment:

Automation Equipment includes a DAS, communication equipment, substation Remote Terminal Units (RTU) and distribution feeder RTU, current-to-voltage converters, etc..

2.5.3 Consumer side automation

Consumer side automation is very important for a distribution company as almost 80% of all the losses are taking place on distribution side alone. It is needed to evaluate the performance of a specific area in the distribution system and judge the overall losses.

2.6 Advantages of Distribution Automation

More and more electric utilities are looking to distribution automation as an answer to the three major economic challenges facing the industry: the rising cost of adding generating capacity, increased saturation of existing distribution networks and greater sensitivity to customer service. Therefore, utilities that employ distribution automation expect both cost and service benefits. These benefits accumulate in areas that are related to investments, interruptions and customer service, as well as in areas related to operational cost savings, as given below:

- Reduced line losses:

The distribution substation is the electrical hub for the distribution network. A close coordination between the substation equipment, distribution feeders and associated equipment is necessary to increase system reliability. Volt/VAR control is addressed through expert algorithms which monitors and controls substation voltage devices in coordination with down-line voltage devices to reduce line loss and increase line throughout.

- Power quality:

Mitigation equipment is essential to maintain power quality over distribution feeders. The substation RTU in conjunction with power monitoring equipment on the feeders monitors, detects, and corrects power-related problems before they occur, providing a greater level of customer satisfaction.

- Deferred capital expenses:

A preventive maintenance algorithm may be integrated into the system. The resulting ability to schedule maintenance, reduces labor costs, optimizes equipment use and extends equipment life.

- Energy cost reduction:

Real-time monitoring of power usage throughout the distribution feeder provides data allowing the end user to track his energy consumption patterns, allocate usage and assign accountability to first line supervisors and daily operating personnel to reduce overall costs.

- Optimal energy use:

Real-time control, as part of a fully-integrated, automated power management system, provides the ability to perform calculations to reduce demand charges. It also offers a load-shedding/ preservation algorithm to optimize utility and multiple power sources, integrating cost of power into the algorithm.

- Economic benefits:

Investment related benefits of distribution automation came from a more effective use of the system. Utilities are able to operate closer to the edge to the physical limits of their systems. Distribution automation makes this possible by providing increased availability of better data for planning, engineering and maintenance. Investment related benefits can be achieved by deferring addition of generation capacity, releasing transmission capacity and deferring the addition, replacement of distribution substation equipment. Features such as voltage/VAR control, data monitoring and logging in.

- Compatibility:

Distribution automation spans many functional and product areas including computer systems, application software, RTUs, communication systems and metering products. No single vendor provides all the pieces. Therefore, in order to be able to supply a utility with a complete and integrated system, it is important for the supplier to have alliances and agreements with other vendors.

An effective distribution automation system combines complementary function and capabilities and require an architecture that is flexible or “open” so that it can accommodate products from different vendors. In addition, a distribution automation system often requires interfaces with existing system in order to allow migration and integration.

CHAPTER THREE

SUPERVISORY CONTROL AND DATA ACQUISITION

3.1. Introduction

A SCADA is a technology that enables a user to collect data from one or more distant facilities and to send limited control instructions to those facilities. SCADA makes it unnecessary for an operator to be assigned to stay at or frequently visit remote locations when those remote facilities are operating normally. SCADA includes the operator interface and the manipulation of application-related data-but it is not limited to that. Some manufacturers are building software packages that they call SCADA, and while these are often well suited to act as parts of a SCADA system, because they lack communications links and others necessary equipment they are not complete SCADA systems.

3.2 SCADA Contents

The main SCADA contents are master station and the RTU's**.** And the contents of SCADA system in the main diagram shown in Figure 3.1

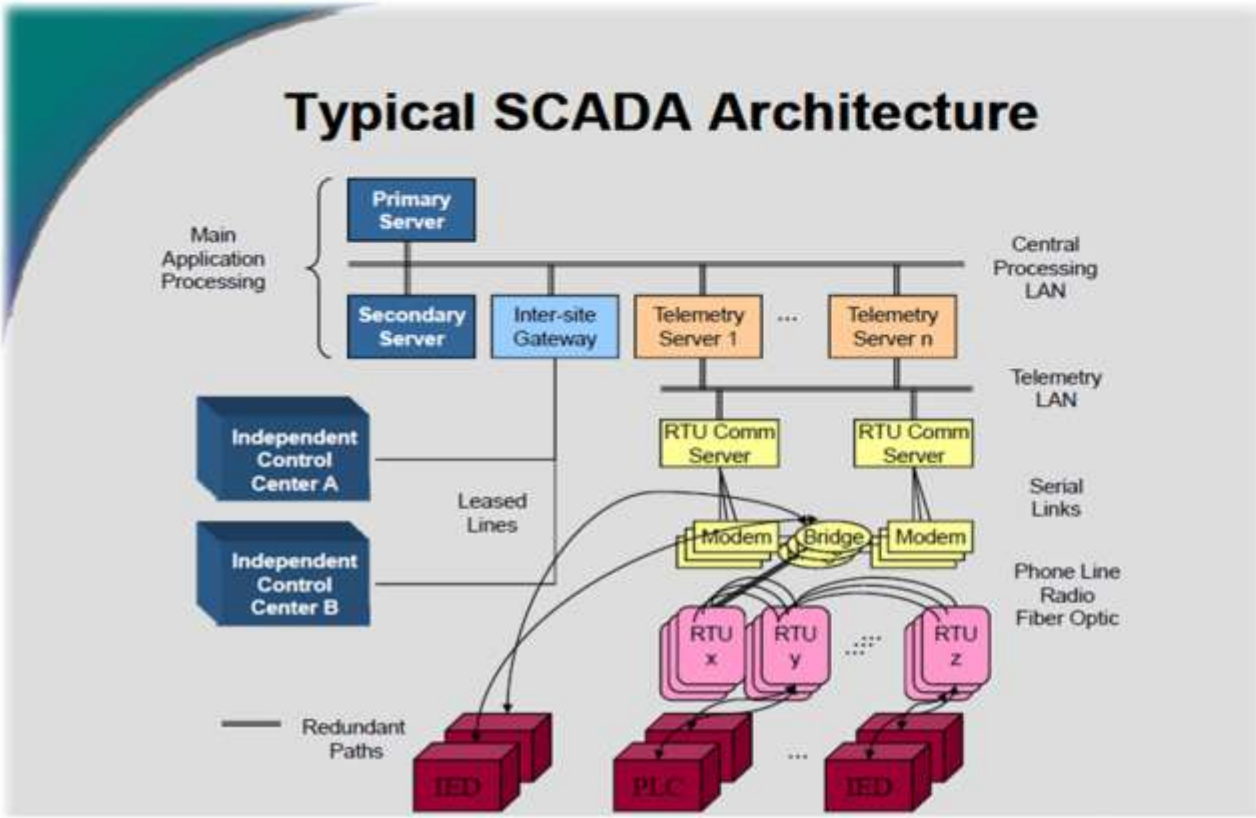


Figure 3.1: Typical SCADA architecture

3.2.1 Master station

The master station is a central site can be pictured as having one or more operator stations connected to a communication system, and we can say: A communication system consisting of modem and radio receiver/transmitter. And we can see clearly the diagram of the master station structure in diagram shown in Figure 3.2

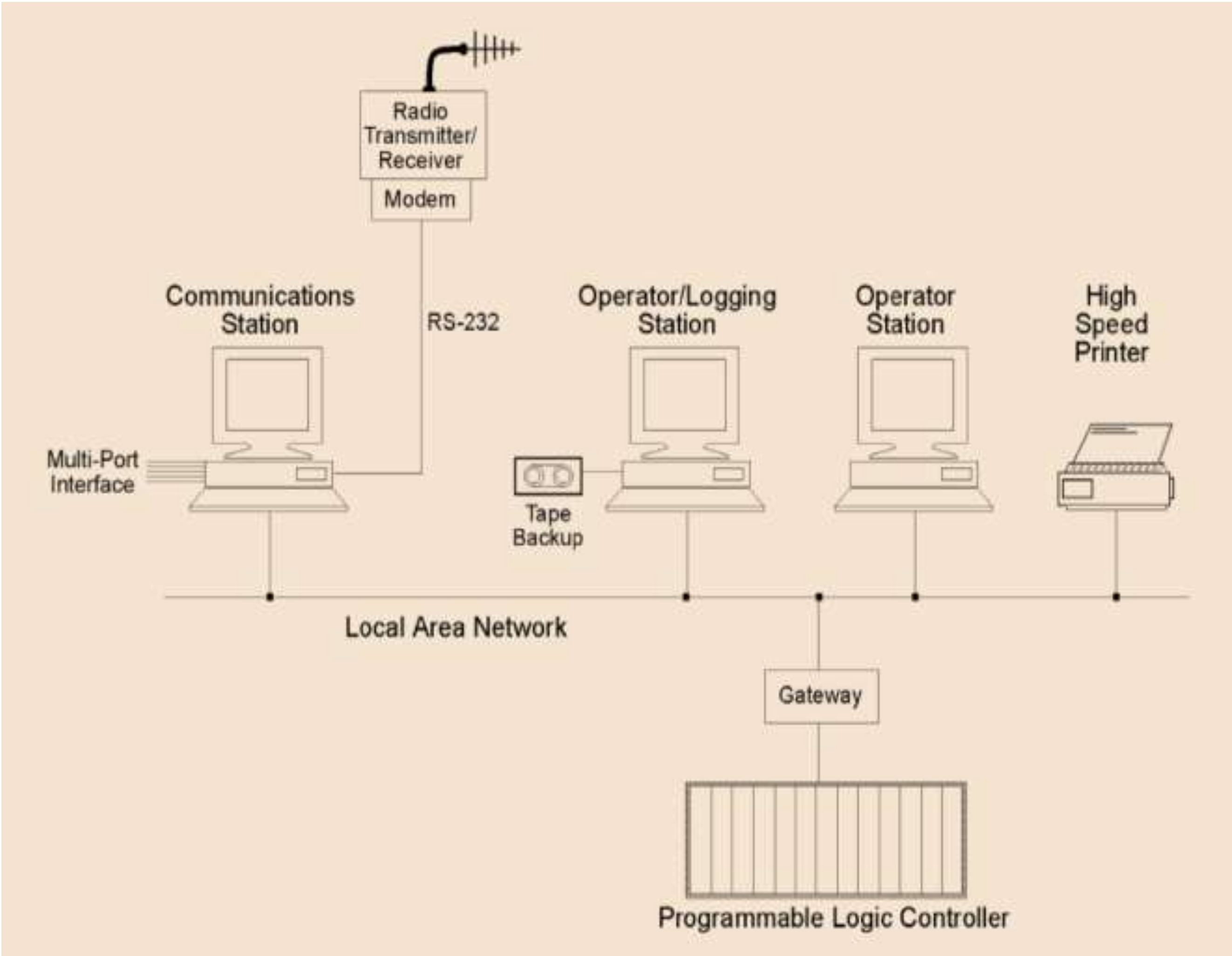


Figure 3.2: Master Station structure

- Master Station Designing Approaches:

There are two main types of master station design:

- **Centralized**: And in this type a single computer or mainframe performs all plant monitoring and all plant data is stored on one database that resides on this computer, and it is and old type of master station, and it is shown in Figure 3.3

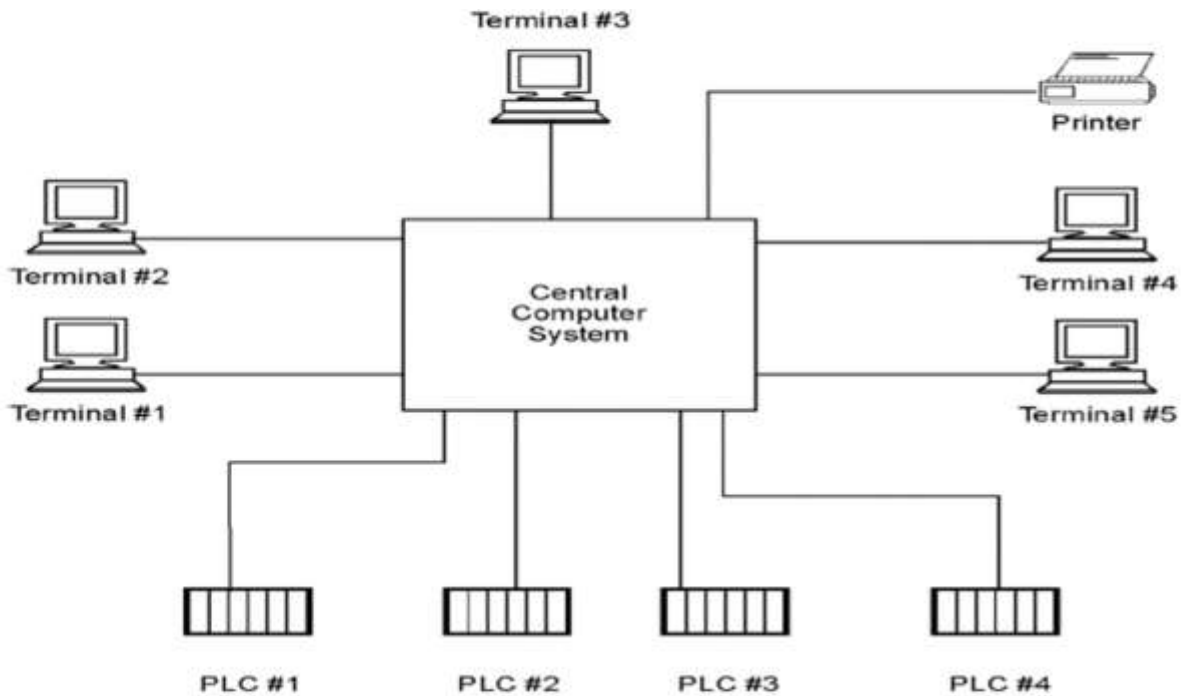


Figure 3.3: Centralized master station

- Distributed: Where the SCADA system is shared across several small computers. In the second type we will get low efficiencies as a result of duplicating data processing and databases across all computers in the system. For this An effective solution is to examine the type of data required for each task and then to structure the system appropriately; and this approach called “A client server approach” and the client server is a device that provides a service to other nodes on the network. And this type shown in Figure 3.4

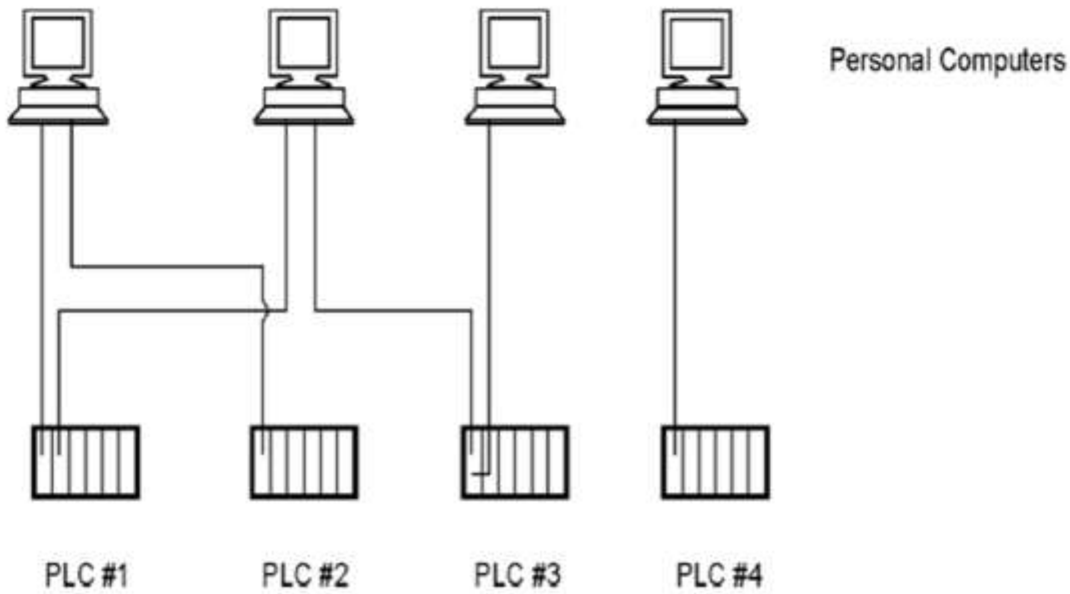


Figure 3.4: Distributed Master station

- Master Station functions:

The master station as a communication system has many functions as:

Establishment of communications:

Configure each RTU.

Initialize each RTU with input/output parameters.

Download control and data acquisition programs to the RTU.

Operation of the communications link:

If a master slave arrangement, poll each RTU for data and write:

RTU.

Log alarms and events to hard disk.

Link inputs and outputs at different RTUs automatically.

Diagnostics:

Provide accurate diagnostic information on failure of RTU and possible problems.

Predict potential problems such as data overloads.

- Master station software:

And it is three components to the master station software:

-The operating system software: for example: Dos, Windows, UNIX .

-The system SCADA software: and it consists of four main modules: Data acquisition, Control, Archiving storage, HMI.

-The SCADA application software.

- Master station networks:

The Central site structure can be based on a distributed architecture and a high-speed data highway using one of the LAN standards such as:

Token Bus, Token Ring, Ethernet.

i- Token Bus Network:

The Token bus network is becoming increasingly popular in industrial systems due to its philosophy that all nodes will receive access to a bus with a guaranteed maximum time. As in Figure 3.5

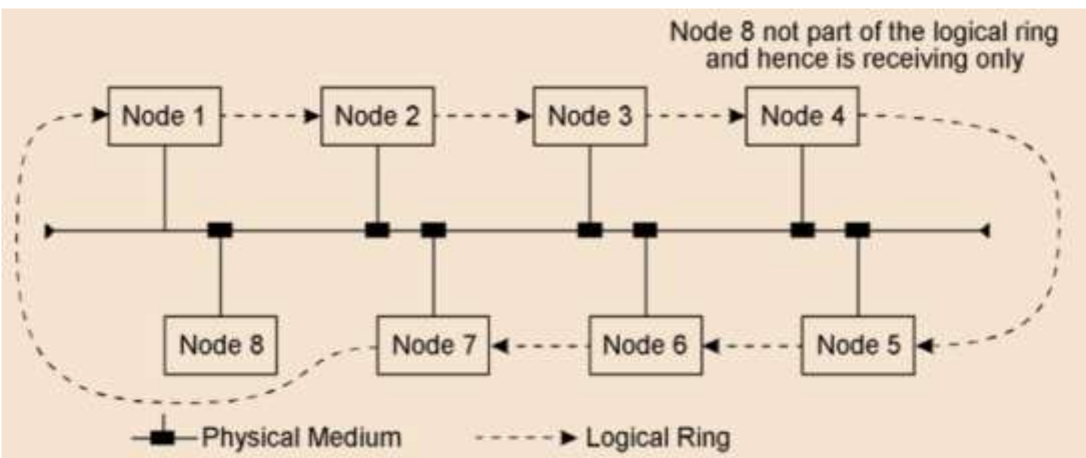


Figure 3.5: Token bus network

ii- Token Ring Network:

It uses a token message to pass control from one node to another. When a node receives the token, it has control of the ring network for a short maximum period of time. As in Figure 3.6

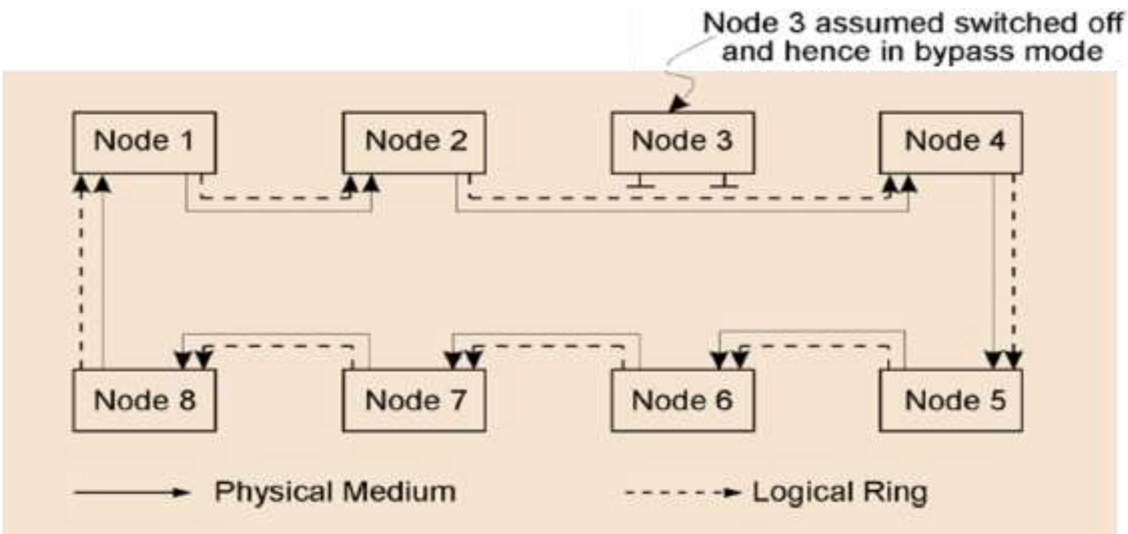


Figure 3.6: Token ring network

iii- Ethernet LANs:

This is generally implemented as a 10 Mbps baseband network. Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is the Media Access Control (MAC) method used by Ethernet. As in Figure 3.7

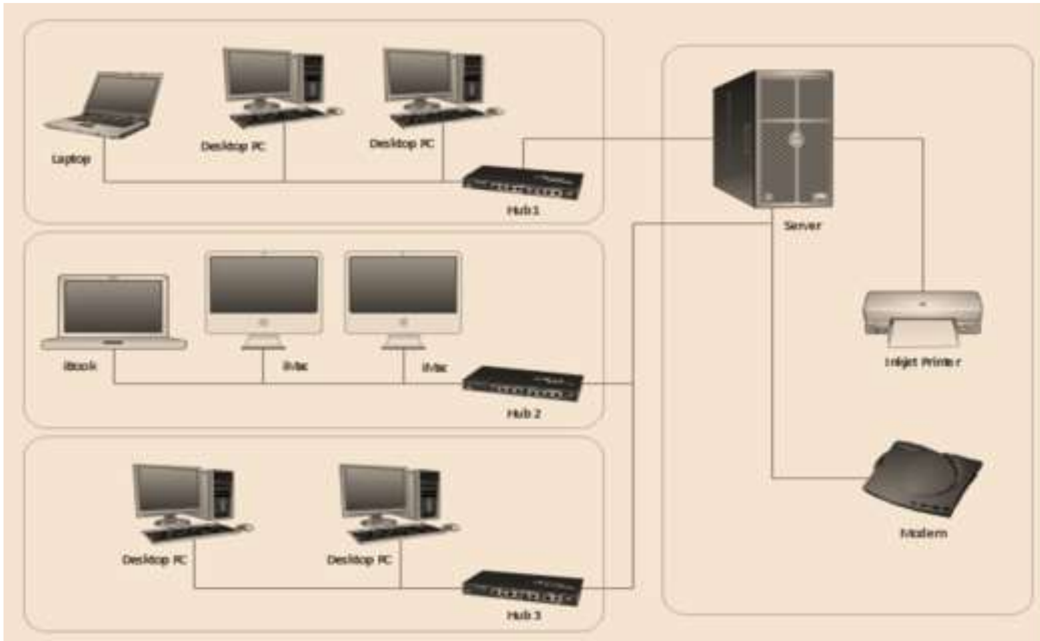


Figure 3.7: Ethernet LANs

3.2.2 Remote triminal unit

An RTU is a standalone data acquisition and control unit, generally microprocessor based, which monitors and controls equipment at some remote location from the central station. The RTU gather information from the filed about analog value, alarm and status points and metered amounts. It keeps this information available in memory until the MTU asks for it. It then codes and transmits the information to the MTU. Figure 3.8 shows the RTU block diagram.

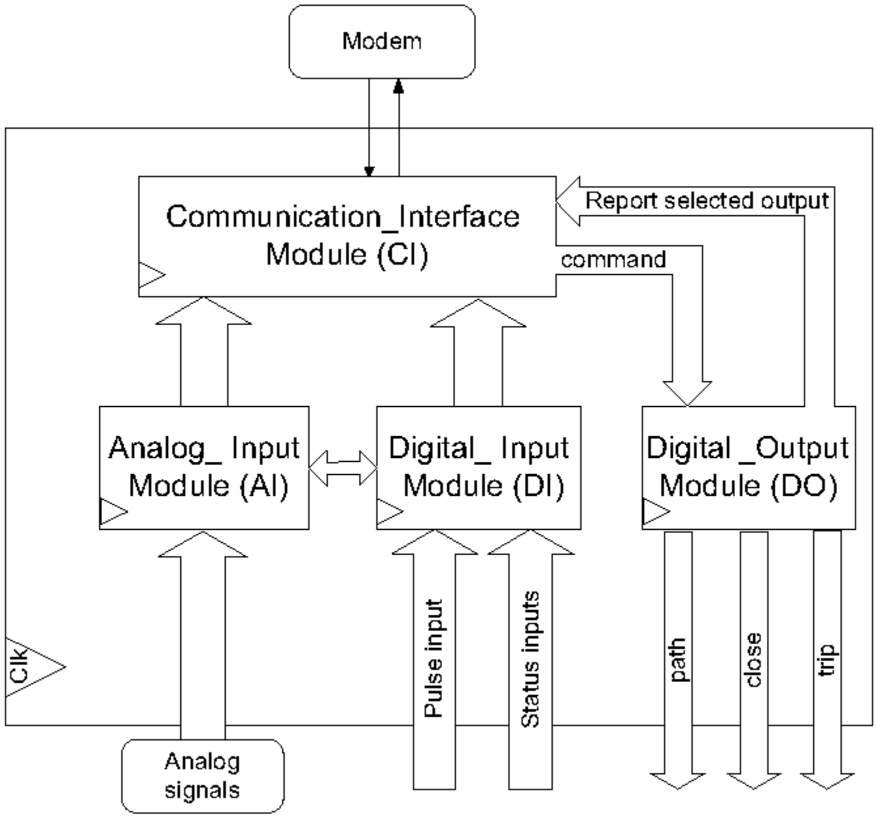


Figure 3.8: RTU

- RTU types:

i. Small sized RTUs generally have less than 10 to 20 Analog and Digital signals.

ii. Medium sized RTUs have 100 Digital and 30 to 40 Analog inputs.

iii. RTUs having a capacity greater than this can be classified as large.

- RTU hardware modules include:

- RTU Rack:

The RTU RACK is used to carry the slots of Power Supply Units (PSU) slots that can be used for I/O boards, Communication Units (CMU) or a mixture of both.

- **Power supply:**

The RTU should be able to operate from 110/240 V AC ± 10% 50 Hz or 12/24/48 V DC ± 10%.

Batteries requirements here are for 20-hour standby operation and a recharging time of 12 hours for a fully discharged battery at 25°C.

- **Control process unit:**

RTU CPU is microprocessor based (16 or 32 bit) e.g. 68302 or 80386.

Total memory capacity of 256 k Byte (expandable to 4 Mbytes) broken into three types:

i- EPROM Erasable Programmable Read Only Memory, 256 k Byte .
ii- RAM: Random Access Memory 640 k Byte.
iii- EEPROM: Electrically Erasable Memory or (flash memory) 128 k Byte.

- **Digital inputs:**

Digital input are used to indicate items such as status and alarm signals.

- **Digital outputs:**

-Typical digital output modules**:**
-8 digital outputs or more depend on manufactures.
-240 V AC/24 V DC (0.5 amp to 2.0 amp) outputs.
-Associated LED indicator for each output to indicate current status
-Optical isolation or dry relay contact for each output.

- **Analog inputs**

There are five main components making up an analog input module. They are:

i- The input Multiplexer.

ii- The input signal Amplifier.

iii- The Sample and Hold circuit.

iv- The A/D converter.

iv- The Bus interface and board Timing system.

- Analog output:

Output channels which are isolated and can be configured to different output current ranges. The output format, unipolar or bipolar resp. Live-Zero (4...20 mA), can be configured by software parameters.

- Communication interfaces:

Communication Interfaces used for following purpose:

i- RTUs Master Station Connection:

RTUs collect data (data Acquisition) from field devices and send these data to Master Station (using communication Protocols) through communication Network connected to communication interface in RTUs.

ii- RTUs IEDs Connections: RTUs collect data from field devices using two types for data collections first type using RTU I\O modules. Second type through Network between IEDs and RTUs (Using protocols) through communication interface in RTUs.

And all the RTU hardware structure shown on the following diagrams (Figure 3.9 and Figure 3.10)

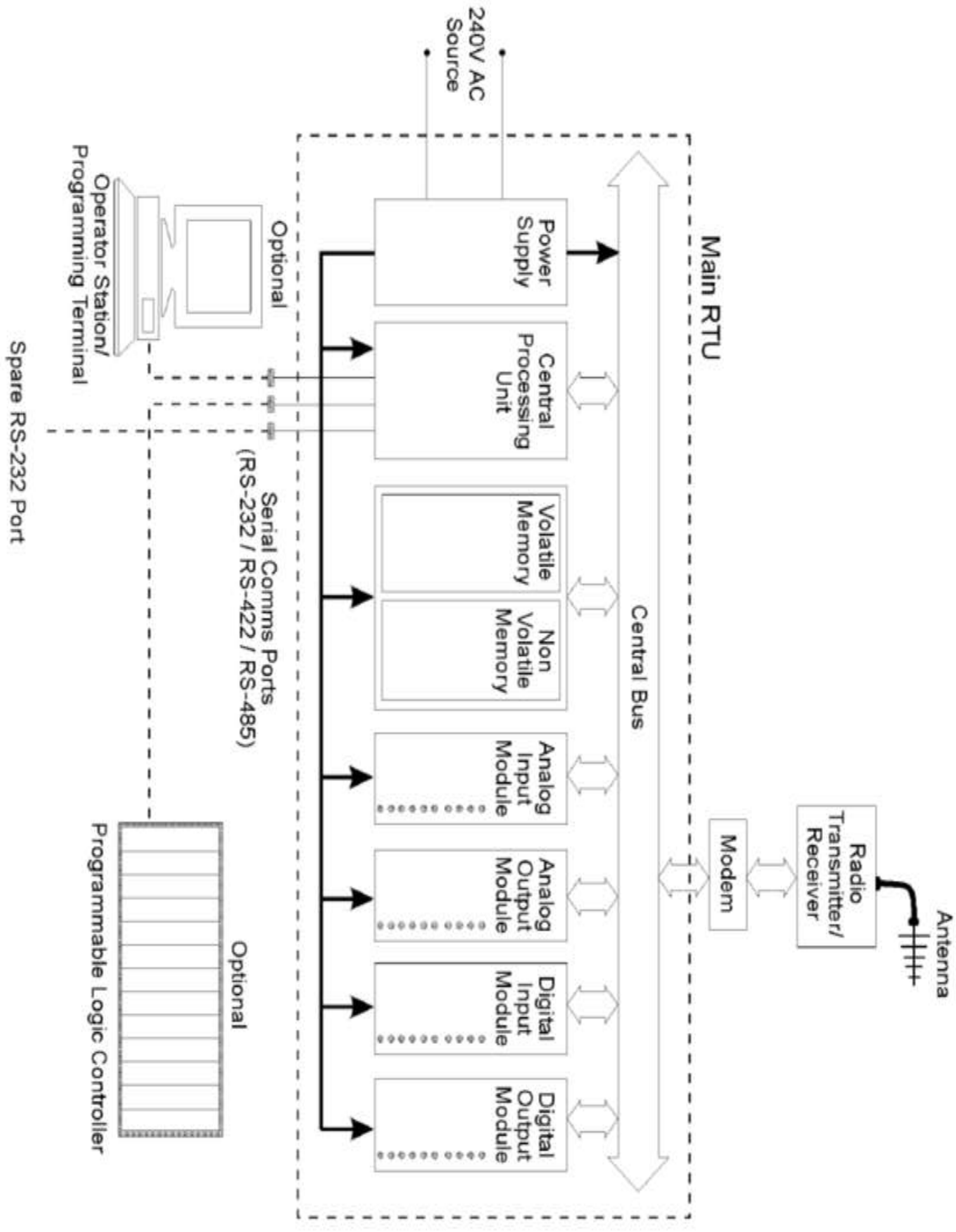


Figure 3.9: RTU hardware structure

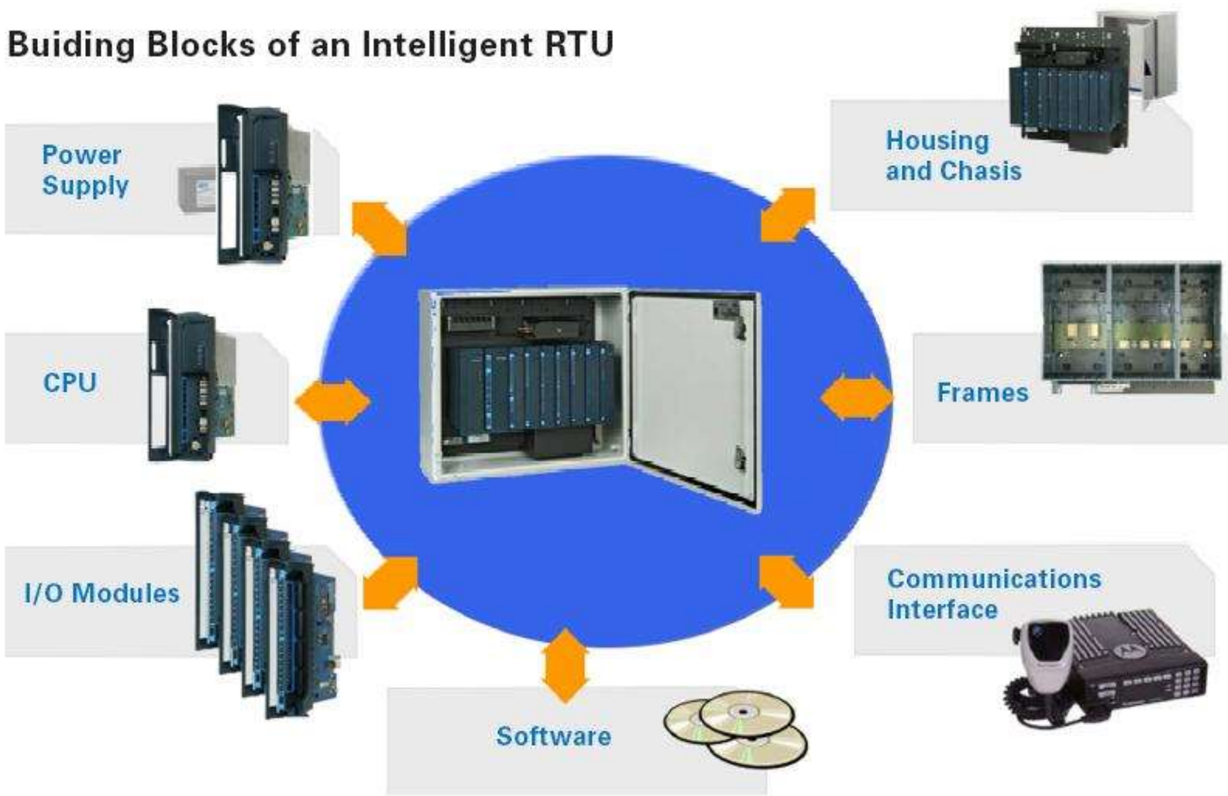


Figure 3.10: Building blocks of an intelligent RTU

3.3 SCADA Communication Protocols

SCADA Communication Protocols: is a set of standard rules that define how devices talk to each other. This include data representation, signaling, authentication and error detection required to send information over communication channel. Many of these protocols, however, are generally based on the Internet Protocol Suite (TCP/IP).

SCADA communication system should use appropriate standard non-proprietary protocol that is available to any and that has ability for transmission of data from point A to point B using serial and IP communications.

3.3.1 Objectives of SCADA protocols

- Provide Standardized rule for data transfer (interoperability among vendors)

- Ensure Reliable data transfer (CRC or checksum).

- Provide useful features (Timestamps or Freeze operations).

- Provide data quality indicators.

- Provide features to detect or prevent unauthorized user or monitoring of data

- SCADA communication TERMs:

-System Integration: is the process of liking together different computing systems and software applications physically or functionally.

- Device Integration: is the idea that Data or Information on any given electronic device can be read or manipulated by another device using standard format.

- Interoperability: is the capability of advice or a system to interact and function with other devices or systems, without any access or implementation restrictions .

- Information Objects: Types of data that can be exchanged between Control center and outstation.

- Report By Exception (RBE): only transmit change data (not all data like Modbus) each data has its time stamps, can be polled or unsolicited.

- Communication philosophies between RTUs and master station:

There are two main communication philosophies possible these are:

i-Polled (or master slave)

The slaves do not initiate the transaction but rely on the master.

- It is essentially a half-duplex approach where the slave only responds on a request from the master.

ii-Unsolicited responses:

This is a mode of operating where the outstation spontaneously transmits a response without having received a specific request for the data.

This mode is useful when the system has many outstations and the master requires notifications as soon as possible after a change occurs. Rather than waiting for a master station polling cycle to get around to it, the out station simply transmits the change.

iii-Communication between control centers:

IEC 60870-6 (ICCP)

3.3.2 MODBUS master/slaves protocol principle:

The MODBUS serial line protocol is a master-slaves protocol.

Only one master (at the same time) is connected to the bus, and one or several (247maximum number) slaves nodes also connected to the same serial bus.

The master node initiates only one MODBUS transaction at the same time.

The master node issues a MODBUS request to the slave nodes in two modes:

i-In **UNICAST** mode, the master addresses an individual slave.

ii- In **BROADCAST** mode, the master can send a request to all slaves.

3.3.3 DNP3 protocol

DNP3 or Distributed Network Protocol Version 3.3 is a telecommunications standard that defines communications between master stations, remote telemetry units (RTUs) and other intelligent electronic devices (IEDs). DNP3 is one of the open protocols for SCADA communications The benefit of an open standard is that it provides for interoperability between equipment from different manufacturers .

3.3.4 IEC 61850 protocol

IEC61850, the international standard for communications within substations was established between 2003 to 2005 and has become very popular and its application has increased very rapidly in recent years.

A major break-through has been achieved with the application of the IEC 61850 standard. This is the realization of “Interoperability” which is one of the key objectives of this standard.

Substation Automation Systems (SASs) are widely used for the purpose of control, protection, monitoring, communication etc. in substations to improve the reliability of the power system.

- **Basic functions of SAS:**

  i- Monitoring Functions :

Monitoring of switchgear status, Tap position, Status of protection and control equipment’s', etc
Monitoring of electrical quantities, eg. Current, voltage, frequency, power and reactive power etc .

ii- Control Functions :

- Control of switchgear and transformer Tap.

- Synchronism check and interlocking.

- Voltage regulating control and voltage –reactive power control.

- Recording Functions:

- Recording the Monitoring data and manapulation Fault record of facilities and device disturbance record.

- Protection Functions:

Protection for Transmission line, Transformer, Bus bar, Generator. Feeder, shunt reactor, shunt capacitor etc..

And all these Architecture as shown in Figure 3.11

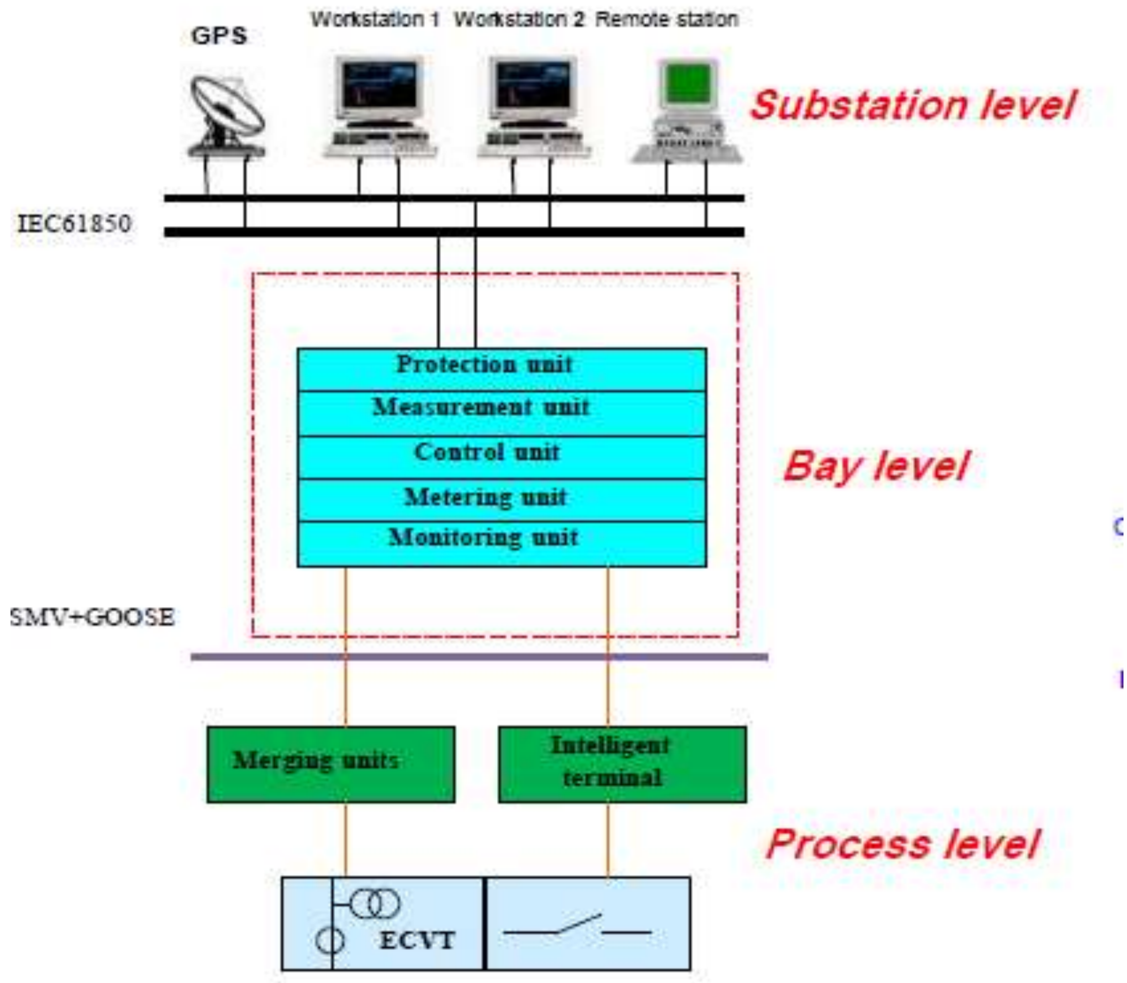


Figure 3.11: SAS architecture

-Substation elements:

i. Bay

- for each incoming / out coming line ("feeder") bay.

- transformer bay.

- generator bay.

- connection between bus bars.

ii. Bus bar (interconnects all elements)

iii. Equipment: is divided into.

iv. Primary equipment:

- breaker.

- transformer.

And all these contents shown in Figure 3.12

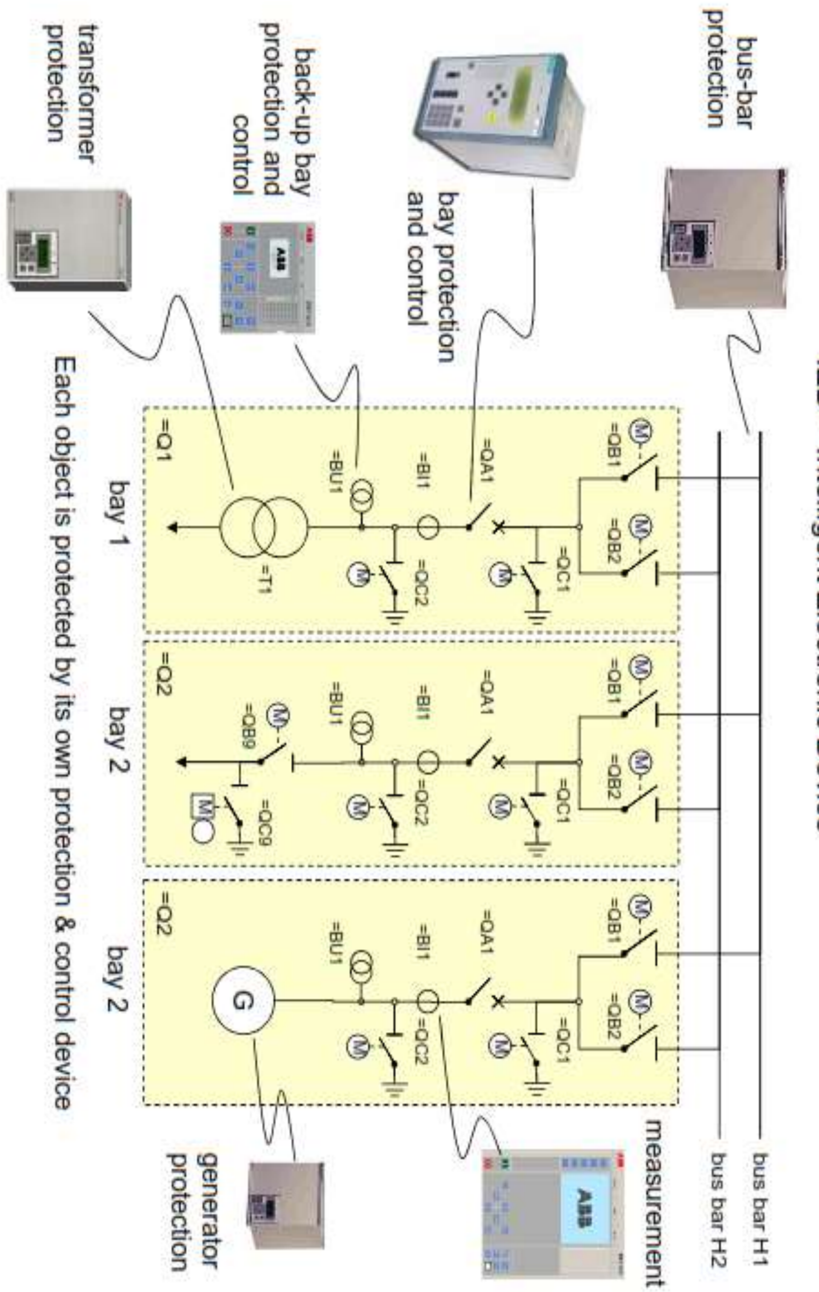


Figure 3.12: Substation elements

- Generic Object Oriented Substation Event (GOOSE):

It is a mechanism for the fast transmission of substation events, A single GOOSE message sent by an IED can be received and used by several receivers.

Such as commands, alarms, indications, as messages. One device (sender) publishes information, only the subscriber devices are receiving it. The reaction of each receiver depends on its configuration and functionality.

One device (sender) publishes information, only the subscriber devices are receiving it. The reaction of each receiver depends on its configuration and functionality.

3.4 Benefits of SCADA for power systems

-Improved quality of service.

-Improved reliability.

-Reduced operating costs.

-Maintenance /Expansion of customer base.

-Ability to defer capacity addition projects.

-High value service providers.

-Improved information for engineering decision.

-value added services.

-Flexible billing option.

-Improved customer information access.

-Reduced system implementation costs.

-Reduced manpower requirements.

3.5 SCADA operation

In the SCADA system, the data collection process is performed first in the process of scanning the RTU information obtained from the devices attached to them. The time to execute this task is called the internal scan time. Servers scan RTUs to collect data from these RTUs. To control, the server sends the required signal to the RTUs, thereby allowing the RTUs to send control signals directly to the executing devices.

Data transmitted in the SCADA system can be continuous (analog), digital or pulse. Data transmission in SCADA system is shown only in digital form called data field. This digital data is formed from logic signals (on / off), analog / current signals, high-speed pulse signals. The basic interface for operating at the terminal is a GUI (Graphical User Interface) screen that is used to display the entire monitoring system or devices in the system. At one point, the data is displayed as a static image, when the data changes, the image also changes. In case the system data changes continuously over time, the SCADA system often displays the process of changing this data on the graphical interface (GUI) screen in the form of graphs. A great advantage of SCADA system is the ability to handle errors very successfully when the system occurs. In general, when there is a problem the SCADA system can choose one of the following ways:

Using data stored in RTUs: In SCADA systems, there are RTUs with large memory capacity, when the system operates stably the data will be backed up in the RTU’s memory. Therefore, when the system fails, the RTUs will use this data temporarily until the system becomes normal again. Use of system redundant hardware: most SCADA systems are designed with additional spare parts, such as two-way communication system, dual RTUs or two servers … thus, These spare parts will be put to use when the SCADA system crashes or works offline (possibly for maintenance, repair, testing, etc..). Operator interface or human-machine interface (HMI) for SCADA systems provide the functions of status indication, alarm reporting, operator intervention in control action, and data storage and programming.

3.6 Some general applications of SCADA

SCADA is widely used in different areas from chemical, gas, water, communications and power systems. The list of applications of SCADA can be listed as follows.

i- Electric power system, operation and control:

SCADA systems are used in electric power generation plants, transmission area and distribution system

ii- Manufacturing Industries or plants:

A SCADA helps in management of different inventory items or raw materials, controlling of automated systems in synchronous manner.

iii- Telecom and IT based systems:

Management of different RF based systems, communication mediums and large communication systems including data logging through antennas can be easily done through the SCADA.

iv- Water and sewage treatment plants and supply management:

SCADA based systems are used by the state or municipal corporation to monitor, control and regulate water capacities in reservoir.

v- Traffic controls:

SCADA helps in regulation of traffic signals , controls the traffic flow in railway systems on road systems and air traffic controls.

vi- Mass transit and Railway Traction:

Transit authorities use SCADA to regulate electricity to subways, trams and trolley buses; to automate traffic signals for rail systems; to track and locate trains and buses; and to control railroad crossing gates.

CHAPTER FOUR

APPLICATION OF DISTRIPUATION AUTOMATION SYSTEM

4.1 introduction

The electric network of Khartoum city consists of 9 transmission stations, which are (Khartoum east, green square, kilo-Ashara, Soba, Alsouq Almahaly, Al-Shughrah, Farouk, Al-Ghaba, Jabal Awleya). Transmission stations feed (54) distribution stations in Khartoum City, and in the station of 10 MVA, 15 MVA and 20MVA there are 2 different capacities of transformers. And the number of participants in the administration is 383,185 consumers.

4.2 The automation system development

According to Sudanese Electricity Distribution Company Ltd the Automation Research Center (ARC) the distribution Automation system run throw several step, and it is Fitic which was Microsoft program then automation system which use the SCADA. Which the contents of the ring main unit, pneumatic switches and at last the Fault Based indicator (FBI), as in following:

- **Ring Main Unit (RMU):** is a compact, sealed for life metal-enclosed switchgear widely used in Urban Power Distribution Network. A Ring Main Unit includes a combination of one or more Load Break Switch (LBS) cum Earth Switch as incomer and outgoing feeder and Vacuum Circuit Breaker with associated Dis connector and Earth Switch for load feeders. And it shown in Figure 4.1

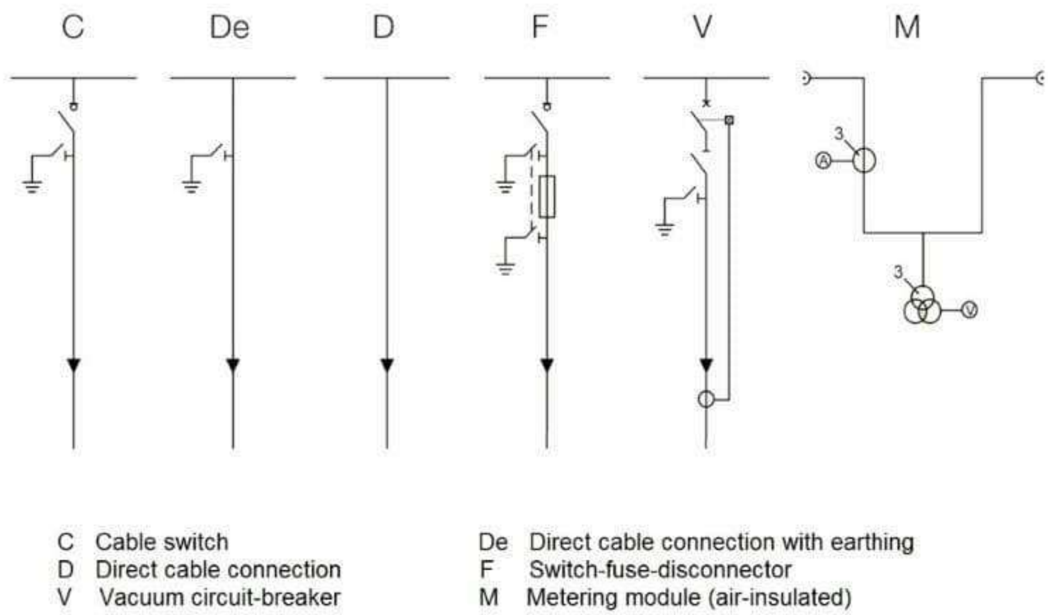


Figure 4.1: (RMU)

- **Pneumatic switches:** it is a device that activates or deactivates an electrical signal in a system based on the level of air pressure detected by the component, and for Autorocloser and smaliser, and the contents shown in Figure 4.2

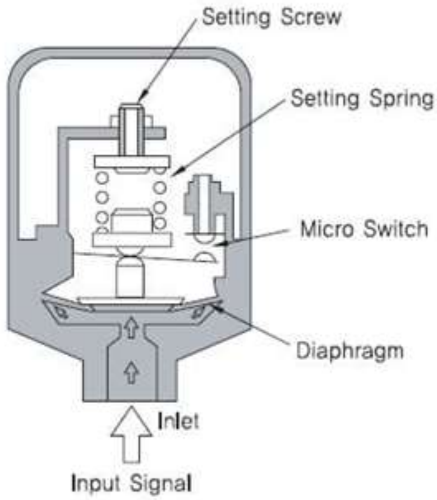


Figure 4.2: pneumatic switches

- **Fault Based indicator(FI):** Fault indicator (FI) is used in impedance-based methods for improving fault section estimation in power distribution feeders. The location and number of FIs effects on the reliability indices and can extra charge the distribution companies and consumers. And the system of it shown in Figure 4.3

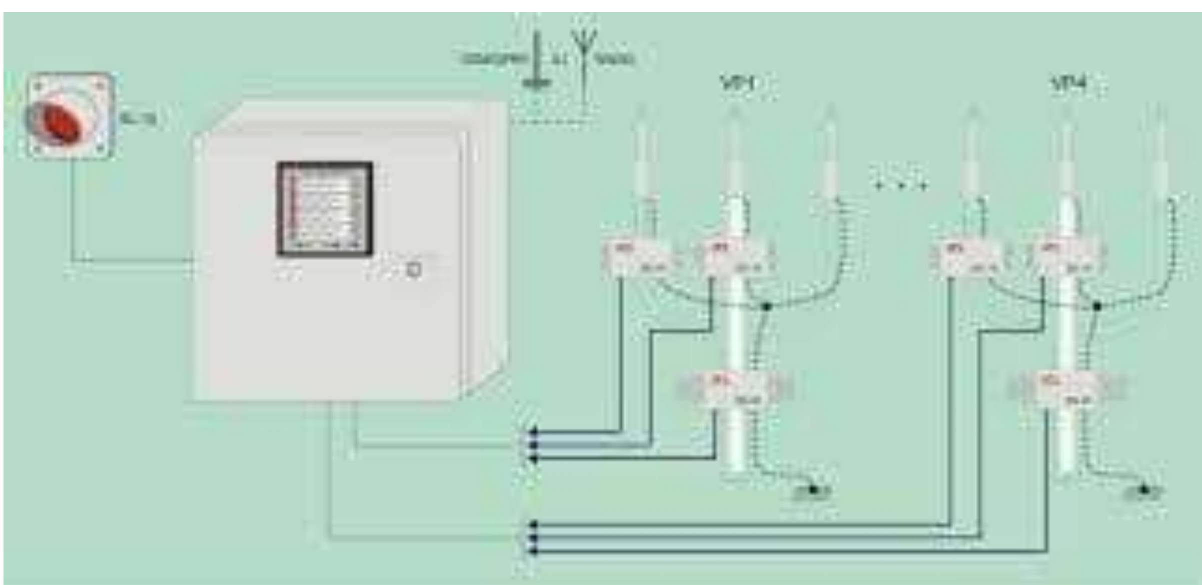


Figure 4.3: Fault based indicator

4.3 Main functions of the system

- Automation system become more benefit and easy to control and it do control shifts operate over (24) hours and done.

- The speed at which faults are detected and handled and the service returned to customers (faults that are not transverse (maintenance required).
- Monitor the loads in the lines and switches.
- Save time and effort for engineers.
- Help him plan future load management.
- Maintain the company's financial return by reducing the loss caused by the failures.
- Increase network stability by reducing fault time.
- Make alternative feeds in stations and lines via keys in coordination with the network RMUS and LBS engineers.

4.4 Main problems of the system

i- The design of the software is from out of Sudan, that mean for the update we need a team from the company that have the software.

ii- Some of the Chinese substation are difficult to control because of the differences of the companies.

4.5 The contents and general operation of the overall distribution system of khartoum

One of the biggest control station of the distribution system in sudan is the khartoum control center, and in the following this is the overall distribution system line diagram of khartoum shown in Figure 4.4

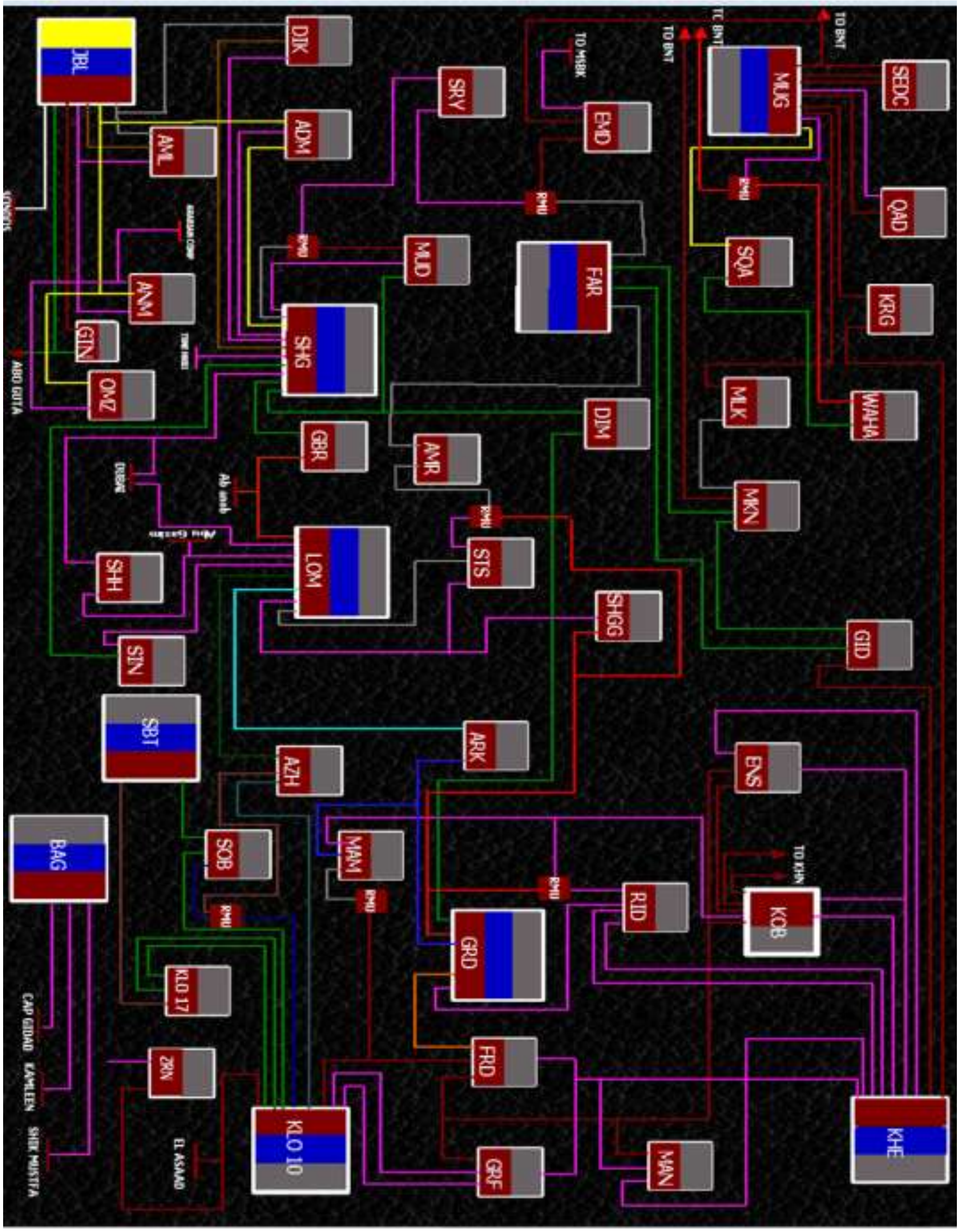


Figure 4.4: The overall distribution system line diagram of khartoum

i- **Contents**:

- **transmission substation**: A transmission substation connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. A transmission station may have transformers to convert between two transmission voltages, voltage control/power factor correction devices such as capacitors, reactors or static VAR compensators and equipment such as phase shifting transformers to control power flow between two adjacent power systems. As shown in Figure 4.5

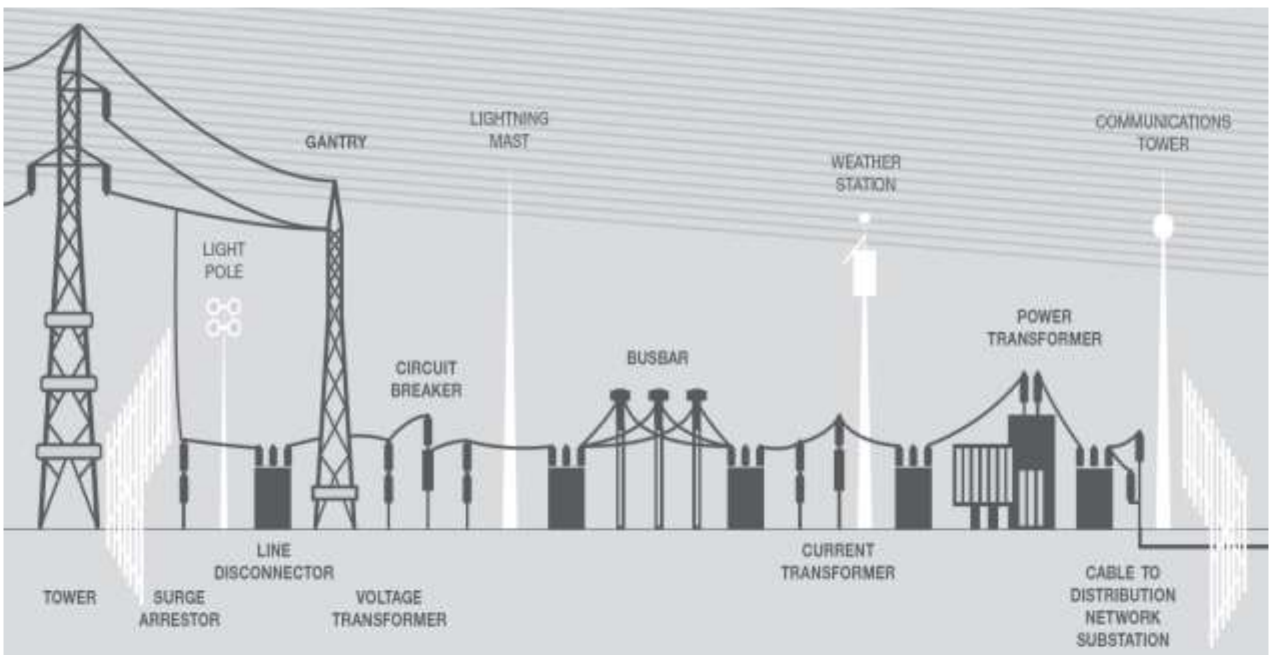


Figure 4.5: Transmission substation

- Distribution substation: A distribution substation transfers power from the transmission system to the distribution system of an area.[2] It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution station reduces voltage to a level suitable for local distribution. As shown in Figure 4.6

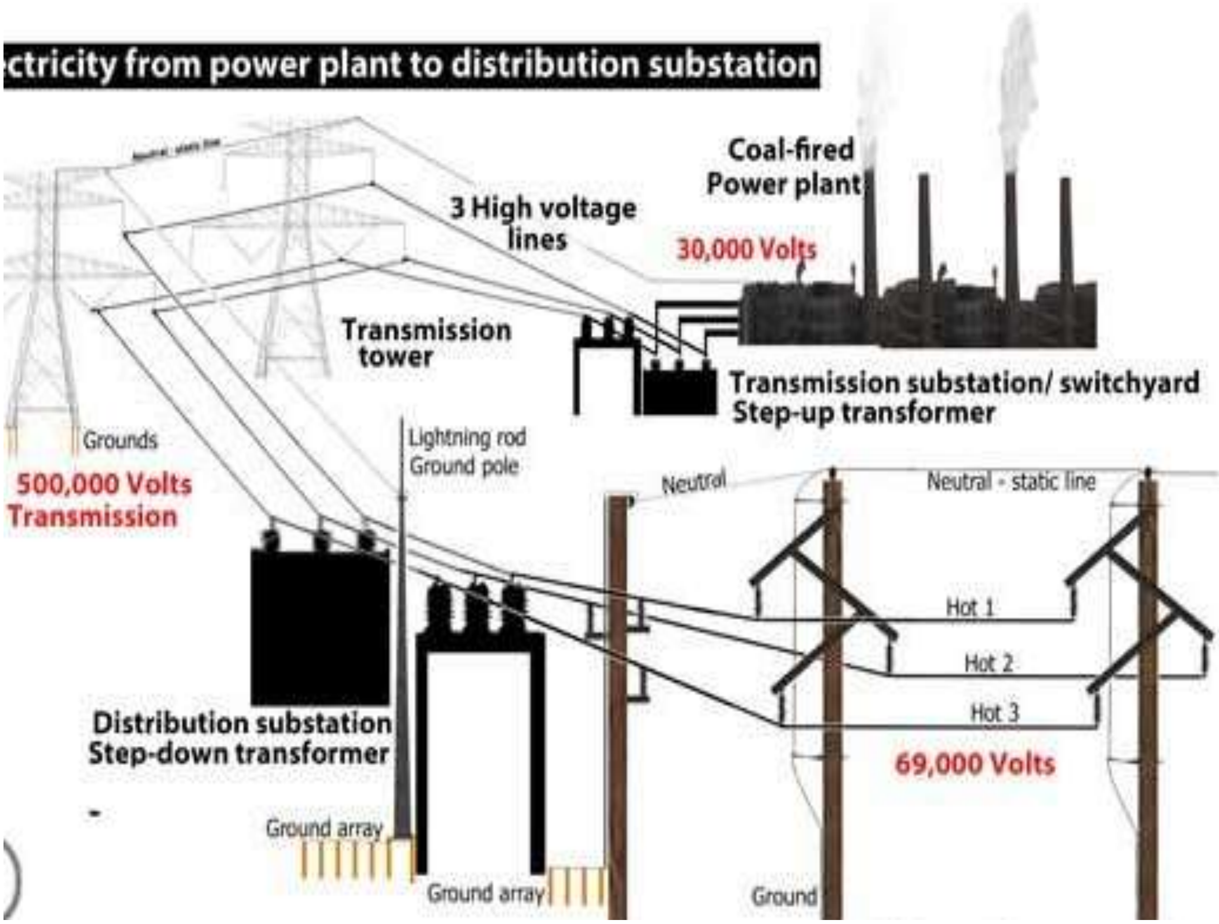


Figure 4.6: Distribution substation

- **Ring Main Unit:** and it is one of the main development in the system.
- **transmission lines:** (110/33/11)KV as in Figure 4.7

Figure 4.7: Transmission lines

ii. The general Technical operation of the system:

Sudanese Automation system use the SCADA to link all the network together, then controlling it from the control centers in All over Sudan, by the contents that mention in the previous paragraph.

4.6 Study of khartoum control center

i. Operation of single line diagram of the SCADA system:

The specific operation of scada in the Automation center shown in Figure 4.8

The representation of a power system using the simple symbol for each component. The single line diagram of a power system is the network which shows the main connections and arrangement of the system components along with their data (such as output rating, voltage, resistance and reactance, etc.). Substation provides the energy supply for the local area in which the line is located. The main function of the substation is to collect the energy transmitted at high voltage from the generating station and then reduce the voltage to an appropriate value for local distribution and gives facilities for switching. The substation has an additional function like they provide points where safety devices may be installed to disconnect equipment or circuit in the event of the fault. The synchronous condenser is placed at the end of the transmission line for improving the power factor and for measuring the operation at the various part of the power system. Street lighting, as well as the switching control for street lighting, can be installed in a substation. The single line diagram of an 11 KV substation is shown in the figure below. The single line diagram makes the system easy and it provides the facilitates reading of the electrical supply and connection. Single line diagram provide information's (voltage, current, frequency, status of lines, CT, etc.) to the supervisory so he can take discussions according this information's such as give instruction to distribution substation to shedding load or full load. The supervisory also receive order from top centers of control to do some mission like programmable cutting of power .

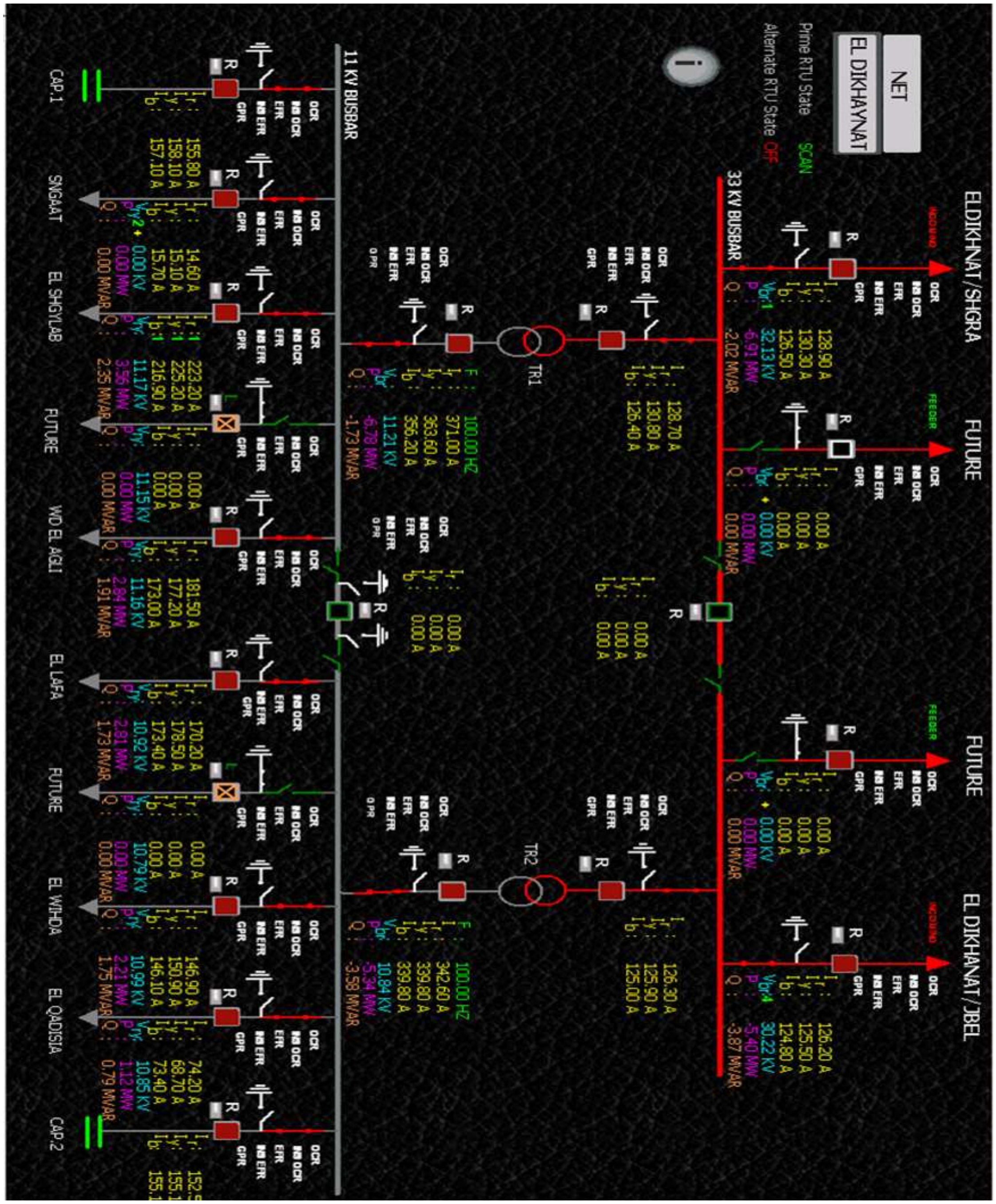


Figure 4.8: The specific operation of scada in the automation center

ii. Main Components of 11kV Substation:

-Isolator:

The isolator connects or disconnects the incoming circuit when the supply is already interrupted. It is also used for breaking the charging current of the transmission line. The isolator is placed on the supply side of the circuit breaker so that the circuit breaker isolated from the live parts of the maintenance.

- Lightning Arrester:

The lightning arrester is a protective device which protects the system from lightning effects. It has two terminals one is high voltage and the other is the ground voltage. The high voltage terminal is connected to the transmission line and the ground terminal passes the high voltage surges to earth.

- CT Metering:

The metering CT measure and records the current when their secondary terminal is connected to the metering equipment panel.

- Step-down Transformer:

The step-down transformer converts the high voltage current into the low voltage current.

- Capacitor Bank:

The capacitor bank consists series or parallel connection of the capacitor. The main function of the capacitor bank is to improve the power factor of the line. It draws the leading current to the line by reducing the reactive component of the circuit.

- Circuit Breaker:

The circuit breaker interrupts the abnormal or faults current to flow through the line. It is the type of electrical switch which open or closes the contacts when the fault occurs in the system.

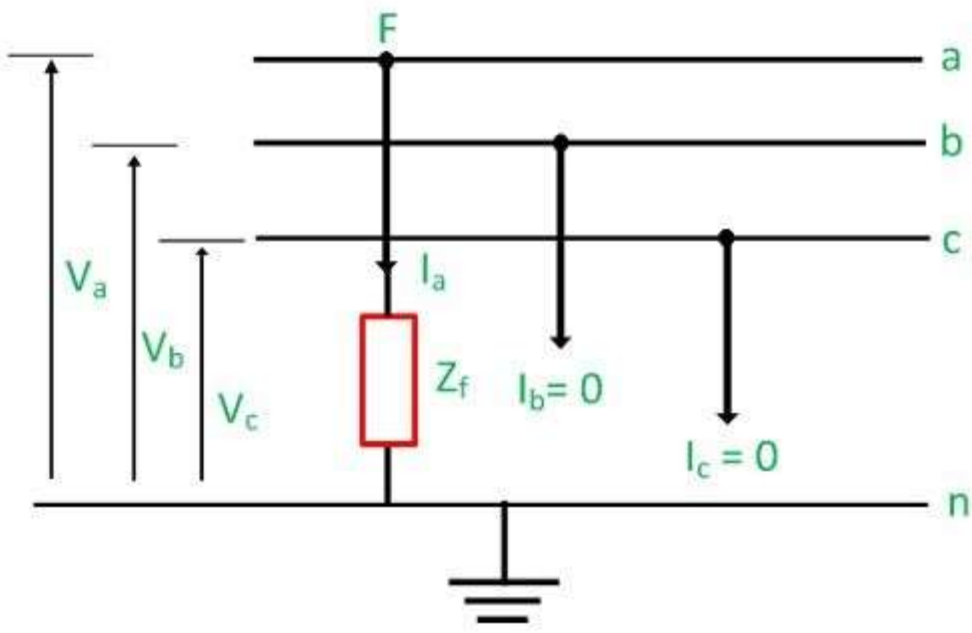
The outgoing feeder supplies the input power to the consumer end.

4.7 The common types of fault that occurs on transmission line are

- Single Line-to-Ground Fault:

Generally, a single line-to-ground fault on a transmission line occur when one conductor drops to the ground or comes in contact with the neutral conductor. Such types of failures may occur in power system due to many reasons like high-speed wind, falling off a tree, lightning, etc..

The Circuit diagram of single line-to-ground fault is shown in figure below. Suppose the phase a is connected to ground at the fault point F . I_a, I_b and I_c are the current and V_a, V_b and V_c are the voltage across the three phase line a, b and c respectively. The fault impedance of the line is Z_f.



Single line-to-ground fault

Since only phase a is connected to ground at the fault, phase b and c are open circuited and carries no current; i.e fault current is I_a and $I_b = 0$, $I_c = 0$. The voltage at the fault point F is $V_a = Z_f I_a$.

This relation can be found by matrix method as follows:-

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \frac{I_a}{3} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \qquad I_{a0} = I_{a1} = I_{a2} = \frac{1}{3} I_a$$

In the case of the sequence current is given by equation,

$$3I_{a0} = 3I_{a1} = 3I_{a2} = \frac{V_f}{Z_f + \frac{1}{3}(Z_{a0} + Z_{a1} + Z_{a2})}$$

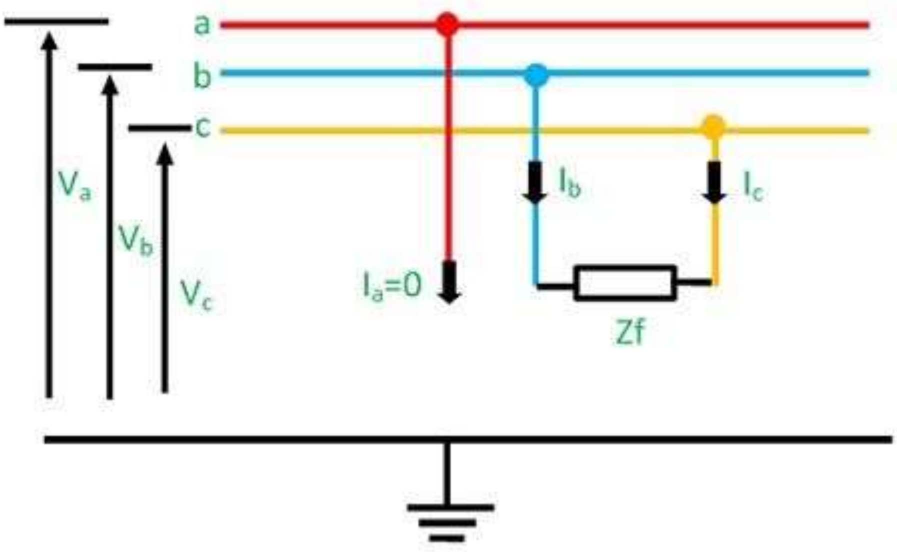
$$I_{ao} = I_{a1} = I_{a2} = \frac{V_f}{3 \times [Z_f + \frac{1}{3}(Z_{a0} + Z_{a1} + Z_{a2})]}$$

$$I_{ao} = I_{a1} = I_{a2} = \frac{V_f}{[3Z_f + (Z_{a0} + Z_{a1} + Z_{a2})]}$$

- **Line-to-Line Fault:**

A line to line fault or unsymmetrical fault occurs when two conductors are short circuited. In the figure shown below shows a three phase system with a line-to-line fault phase's b and c. The fault impedance is assumed to be Z_f. The LL fault is placed between lines b and c so that the fault be symmetrical with respect to the reference phase which is un-faulted.

The symmetrical components of a fault current in phase 'a' at the fault point can be divided into three component. The zero sequence component of current at phase a



The fault current is given by the equation

$$I_f = \frac{(\alpha^2 - \alpha)V_f}{Z_{a1} + Z_{a2} + Z_{a3}}$$

CHAPTR FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research identifies the advantages of automation application at distribution level. Distribution automation enhances the efficiency and productivity of a utility, and also provides quality and reliable supply to the consumers. Commercially available products for distribution automation application are also discussed. Later part of the report discusses the challenges faced by current distribution automation system and need for advanced distribution automation. Sometimes instrumentation engineers confuse about the difference between SCADA and HMI systems and PLC:

HMI: any screen let the user react with any machine's system.

Supervisory Control and Data Acquisition (SCADA) and Human Machine Interface (HMI) are closely related, and often referred to in the same context since they are both parts of a larger industrial control system, but they each offer different functionality and opportunities. While HMIs are focused on visually conveying information to help the user supervise an industrial process, SCADA systems have a greater capacity for data collection and control system operation. DCS is focused on process control with analog signals, used as the main control system in process industries like refining, petrochemicals, and chemicals etc. PLC is focused on discrete automation with discrete on-off signals, used on factory assembly lines and bottling lines etc. PLC and DCS are both constantly evolving.

5.2 Recommendation

In the future, the advances in distribution operations technology must add a new set of challenges:

- Customer demand for better power quality and less outages

- Utility business pressures to minimize capital and operational expenses

- Market opportunities that are beginning to reach into the distribution arena, such as “demand response” and “real-time pricing”.

- Regulatory pressures for system reliability and performance.

- Increased interconnection of Distributed Energy Resources (DER) to the distribution system, either at substations or within customer premises. All these DER systems will interact among themselves and with all other controllable devices and systems connected to the same distribution area.

- Advanced integrated and coordinated protection using intelligent electronic devices (IEDs): It includes the functions like intelligent fault location and isolation, auto restoration systems, contingency analysis, relay protection integration and coordination, restoration of normal connectivity, etc. This requires remotely controlled switching devices and reliable and fast communication systems. This results into improvement of the service reliability.

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