Sudan University of Science and Technology

College of Engineering

School of Electrical And Nuclear Engineering Becholor of Technology

SCADA Supervisory Control and Data Acquisition (case study)

نظام التحكم الإشرافي وجمع البيانات(بالعاصمة القومية)

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

Prepared By:

1. Amin OsheikEdrisAbakr
2. Asma Mohamed MahgoubMohammed
3. Rayan Salah Mohammed Salih Mansour
4. HamzaElfadil Ibrahim Abualkailk

SUPERVISED BY:

A.GafarBabiker Othman

November,2020

الاية

قال تعالي :

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

{اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ {1} خَلَقَ الْإِنسَانَ مِنْ عَلَقٍ
{2} اقْرَأْ وَرَبُّكَ الْأَكْرَمُ {3} الَّذِي عَلَّمَ بِالْقَلَمِ {4} عَلَّمَ
الْإِنسَانَ مَا لَمْ يَعْلَمْ {5}}

صدق الله العظيم

سورة العلق الآيات (1-5)

DEDICATION

To Dear Fathers

A man, who is like no other, a man who gave me life, nurtured me, taught me, fought for me, help us, but most importantly loved us unconditionally. Thank you for being the reason of success.

To Mothers

Who has always been there when I needed her most, thank you for your encouragement, love, well wishes and your words of wisdom.

To Dear Teacher **Dr. GafarBabiker**

Thank you for guiding and inspiring, we will forever be grateful to you.

For Brothers, Sisters, and Friends

To Whom My Heart Belongs.

ACKNOWLEDGEMENT

First of all, we want to thank Allah, who give me everything and without him nothing can be done.

*We would like to express our deep appreciation and sincere gratitude to supervisor***Dr. GafarBabiker***for his assistance, guidance and endless help throughout the steps of this thesis.*

We great thanks extend to colleagues in The Sudan University of Science of Technology for their valuable suggestions and information during this research.

Last but not least, a lot of thanks are due to our families for their motivation and contribution.

Abstract

The main objectives of this research are to understanding that supervisory control and data position component that use control the power system.

Operate the SCADA system

مستخلص

الأهداف الرئيسية لهذا البحث هي:

فهم عناصر التحكم الاشرافي للحصول على البيانات التي□ستخدم في التحكم في نظام القدرة.

□شغيل نظام الاسكادا.

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CHAPTER ONE

INTRODUCTION

1.1 Overview:

Supervisorycontrolanddataacquisition (SCADA) is a control systemarchitecture comprising computers, networked data communications and graphical userinterfaces(GUI) for high-levelprocess supervisory management, while also comprising other peripheral devices like programmable logic controllers(PLC) and discrete proportional-integral-derivative (PID) controllers tointerface with process plant or machinery. Theuse of SCADA has been considered also for management and operations of project- driven-process in construction.

The operator interfaces which enable monitoring and the issuing of process commands, like controller set point changes, are handled through the SCADA computer system. The subordinated operations,e.g.thereal-timecontrollogic or controller calculations, are performed by networked modules connected to the field sensors andactuators.

The SCADA concept was developed to be a universal means of remote-access to a variety of local control modules, which could be from different manufacturers and allowing access through standard automation protocols. In practice, large SCADA systems have grown to become very similar to distributed controlsystems in function, while using multiple meansofinterfacingwiththeplant.They can control large-scale processes that can include multiple sites, and work over large distances as well as small distance. It is one of themost commonly-used types of industrialcontrol systems, in spite of concernsabout SCADA systems being vulnerable tocyber warfare/cyber terrorismattacks.

The key attribute of a SCADA system is its ability to perform a supervisory operation over a variety of other proprietary devices.

The accompanying diagram is a general model which shows functional manufacturing levels using computerised control.

Referring to the diagram,

Level 0 contains the field devices such as flow and temperature sensors, and final control elements, such as controlvalves.

- Level 1 contains the industrialised input/output(I/O)modules,andtheir associated distributed electronic processors.
- Level 2 contains the supervisory computers,whichcollateinformation from processor nodes on thesystem, and provide the operator control screens.
- Level3istheproductioncontrollevel, which does not directly control the process, but is concerned with monitoring production andtargets.
- Level 4 is the productionscheduling level.

Level 1 contains the programmable logiccontrollers (PLCs) or remote terminalunits (RTUs).

Level 2 contains the SCADA to readings and equipment status reports that arecommunicated to level 2 SCADA as required. Data is then compiled and formatted in such a way that a control room operator using the HMI (HumanMachine Interface) can makesupervisory decisions to adjust or override normal RTU (PLC) controls. Data may also be fed toahistorian,oftenbuiltonacommodity database management system, to allow trending and other analyticalauditing.

1.2 Problem Statement:

The power system operation is more complex system that needs to be controlled for reliability and faith ability of the system without this control the system can accrue many faults that damage equipment’s and system components and made risk for man power

1.3Objectives:

-Monitoring: Continuous monitoring of the parameters of voltage, current, etc...

- Measurement: Measurement of variables for processing.

- Data Acquisition: Frequent acquisition of data from RTUs and Data Loggers / Phasor data Concentrators (PDC)..

- Data Communication: Transmission and receiving of large amounts of data from field to controcentre,s

-. Control: Online real time control for closed loop and open loop processes.

- Automation:: Automatic tasks of switching of transmission lines, CBs, etc.

1.4 -Reseach Methodology:

The Omdurman research center of destruction system control all of Omdurman substation therefore background knowledge has been obtain from this center to cover operation of the SCADA system

1.5Research Structure:

This research contains an abstract and five chapters:

- Chapter onerepresents, aninterdiction,consents of overview,researchproblem,research objectives, research methodology,research,and research Structure

- Chapter two Remote Terminal Unit (RTUs) introduction, RTU hardware, digital input for RTU, digital output for RTU, analog input module of RTU, communication interfaces for RTU

- Chapter Three Master terminal unit (MTUs) introduction, the master station structure, remote devices connection methods, master station faction, sub-master station, master station software, master station network, system reliability and availability, redundant master station configuration

- Chapter Four operation system introduction, components of data communication, dada communication, signals, SCADA protocols

-ChapterFIVE Conclusion, Recommendations, References

CHAPTER TWO

REMOTE TERMINAL UNIT (RTUs)

2.1 Introduction:

- 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.
- Its primary task is to control and acquire data from process equipment at the remote location and to transfer this data back to a central station.

The RTU Types are:

- Small sized RTUs generally have less than 10 to 20 Analog and Digital signals.
- Medium sized RTUs have 100 Digital and 30 to 40 Analog inputs.
- RTUs, having a capacity greater than this can be classified as large.

The Facilities of RTU are:

- Having its Configuration and Control Programs dynamically downloaded from some Central station.
- Also Configured locally by some RTU programming Unit.
- RTU also act as a Relay station (sometimes referred to as a store and forward station) to another RTU, which may not be accessible from the central station.

The RTU Environmental Enclosures:

- Circulating air fans and filters:
  - This should be installed at the Base of the RTU enclosure to avoid heat buildup.
  - Hot spot areas on the electronic circuitry should be avoided by uniform air circulation.

Hazardous Areas:

- Operating Temperatures of RTUs are variable.
- Humidity ranges are 10–95%, high humidity (circuit boards - contact corrosion or short-circuiting), low humidity air (5%) can generate static electricity on the circuit boards due to stray capacitance.

The Electro Magnetic Interference (EMI) and Radio Frequency Interference (RFI):

- They are anticipated in the vicinity of the RTU, special screening and earthing should be used.

2.2 RTU Hardware:

RTU hardware modules include:

- RTU Rack.
- Power supply.
- Control processor and associated memory.
- Digital inputs.
- Digital outputs.
- Analog inputs.
- Analog outputs.
- Communication interface(s).

RTU hardwar

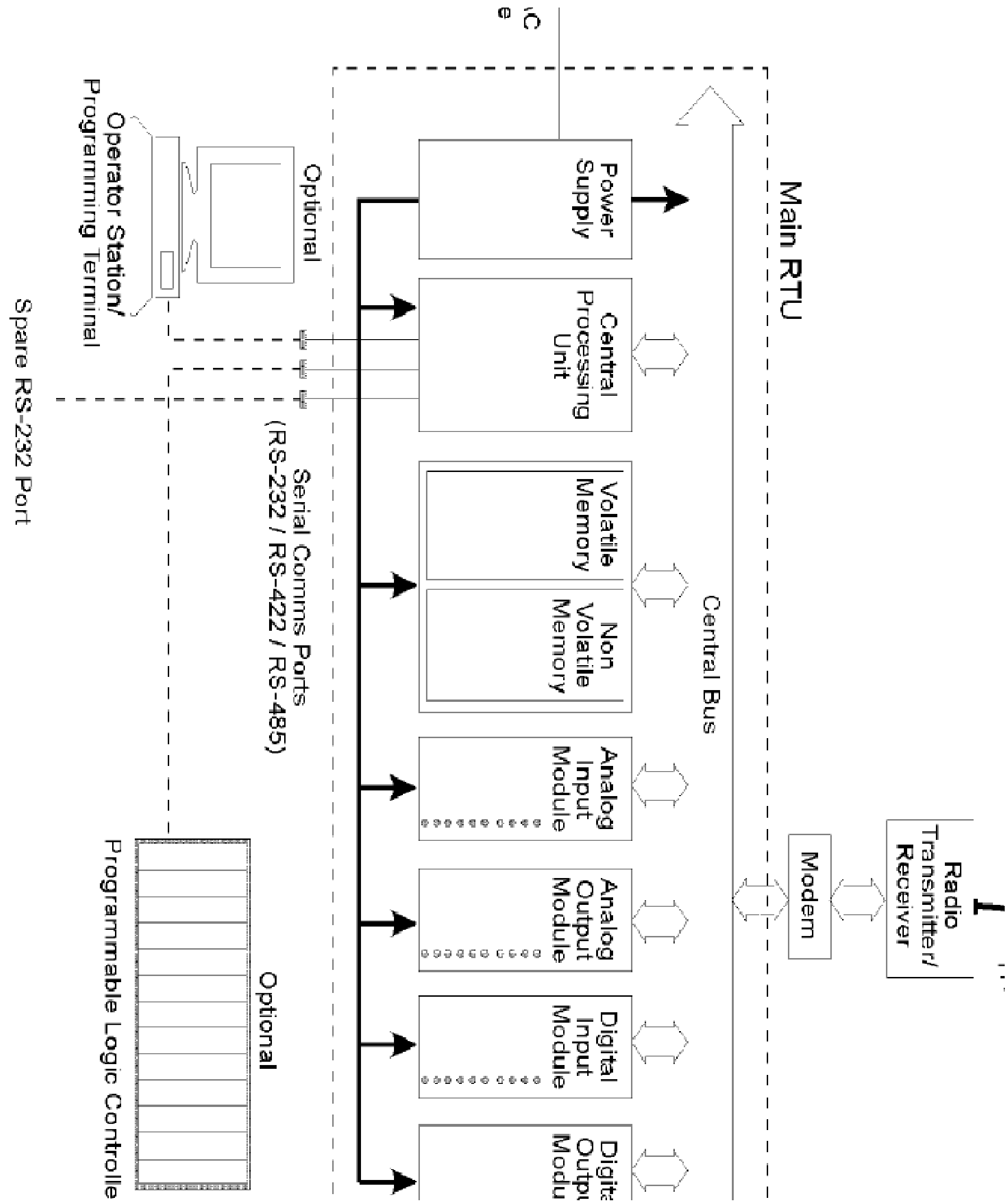

Fig. (2. 1) TRU Hardware Structure Diagram

RTU hardware structure: shown Fig. (2.2).

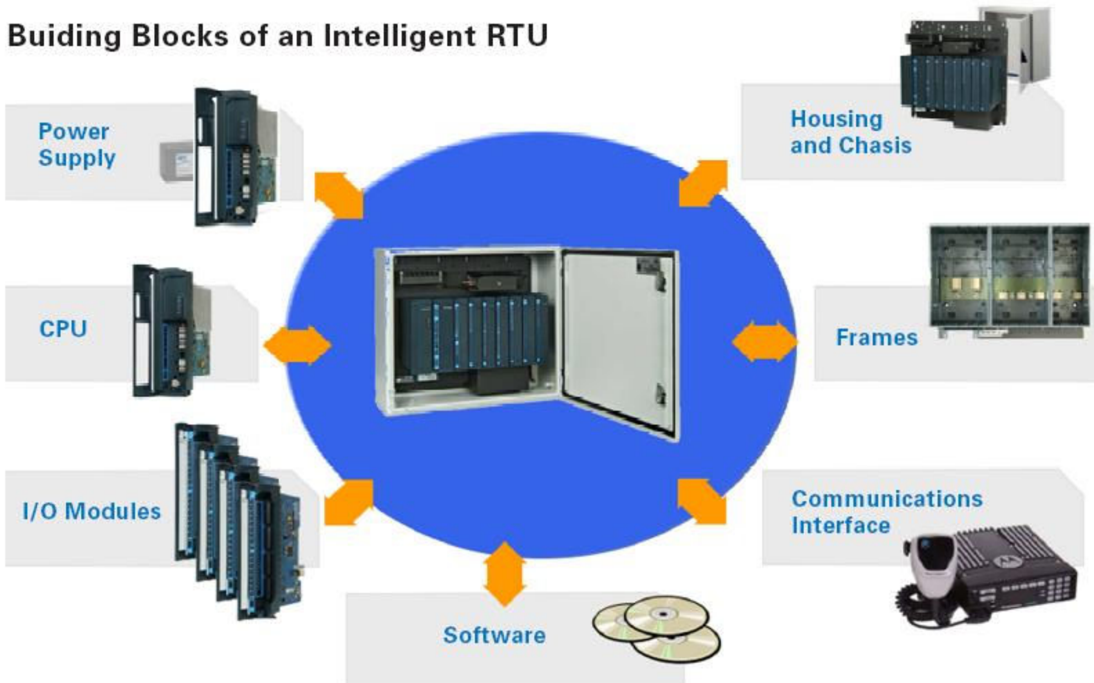

Fig. (2. 2) RTU Hardware Structure

Power supply module RTU:

- 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.
- RTU RACK Interfaced to other Racks via the serial peripheral bus.
- 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.
- Other important monitoring parameters, which should be transmitted back to the central site/master station, are**:**

Analog battery reading.

Alarm for battery voltage outside normal range.

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

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

  i. EPROM Erasable Programmable Read Only Memory, 256 kByte , is a type of memory chip that Retains its data when its power supply is switched off. In other words, it is non-volatile.
  ii. RAM: Random Access Memory 640 Kbyte. device allows data items to be read and written in roughly the same amount of time regardless of the order in which data items are accessed.
  iii. EEPROM: Electrically Erasable Memory or (flash memory) 128 kByte. used in electronic devices to store small amounts of data that must be saved when power is removed, e.g., calibration tables or device configuration.

- A mathematical processor is a useful addition for any complex mathematical calculations. This is come times referred to as a coprocessor.

- Diagnostic LEDs- provided on the control unit ease Troubleshooting and Diagnosis of problems (such as CPU failure / failure of I/O module etc).

Diagram for RTU CPU: shown Fig. (2.3).

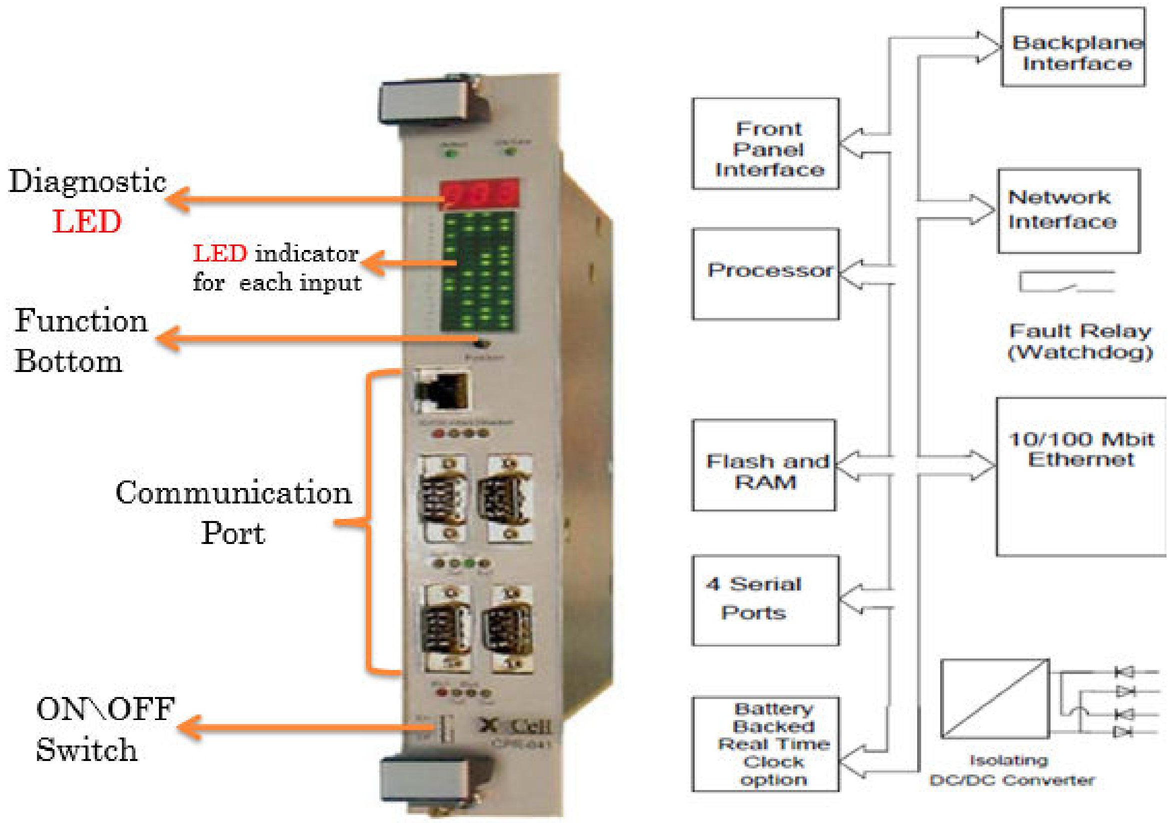

Fig. (2. 3) Diagram For RTU CPU

2.3 Digital input for RTU:-

- Digital input are used to indicate items such as status and alarm signals.
- . Status signals from a Switchgear could comprise two limit switches with Contact closed indicating Switchgear - open status and the other contact closed indicating Switchgear – closed status.
- When both open and closed status contacts are closed, this could indicate the Switchgear is in transit. (example Alarm DBI).

Diagram for RTU Digital input: shown Fig. (2.4).

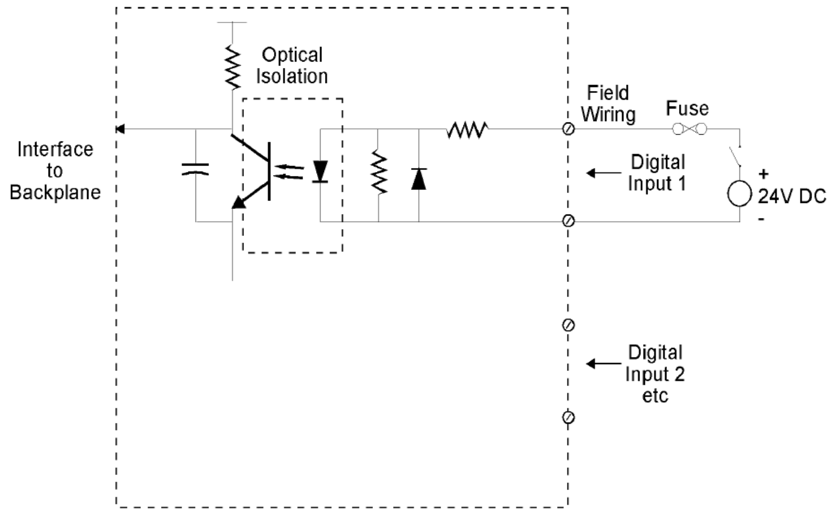

Fig. (2. 4) Diagram for RTU Digital Input

- The Two main Approaches of setting the input module up as a sink or source module.

- **Sink:** The contacts are powered externally and pull up the input terminal voltage when closed. shownFig. (2.5).

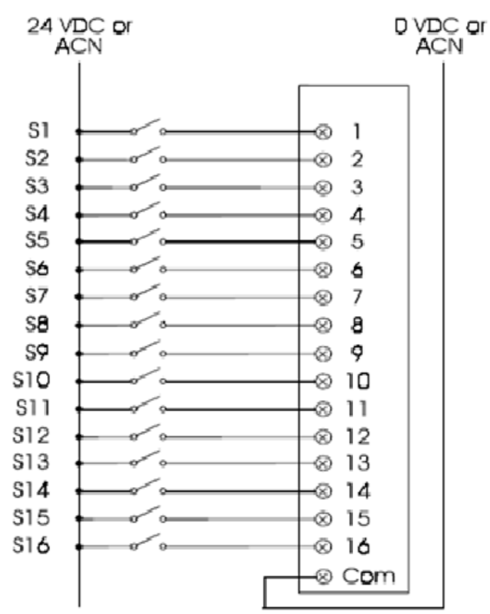

Fig. (2. 5) Frist approaches Input Module

- Source (Dry contact): (power is provided from the RTU power supply) The contacts are connected to ground and pull down the input terminal voltage when closed. shown Fig. (2.6).

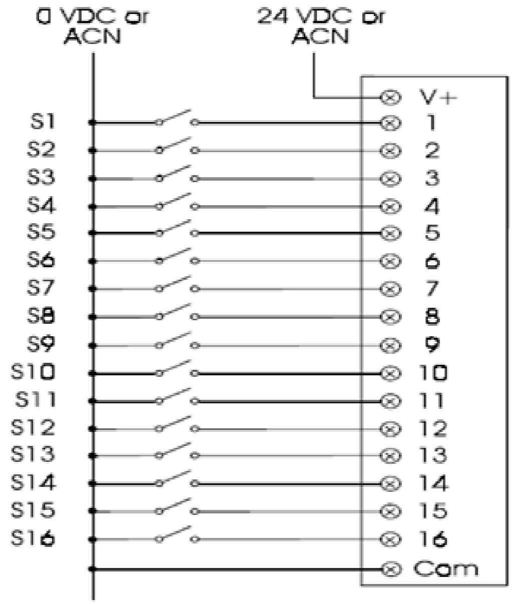

Fig. (2. 6) Second Approaches Input Module

Examples for RTU Digital input: shown Fig. (2.7).

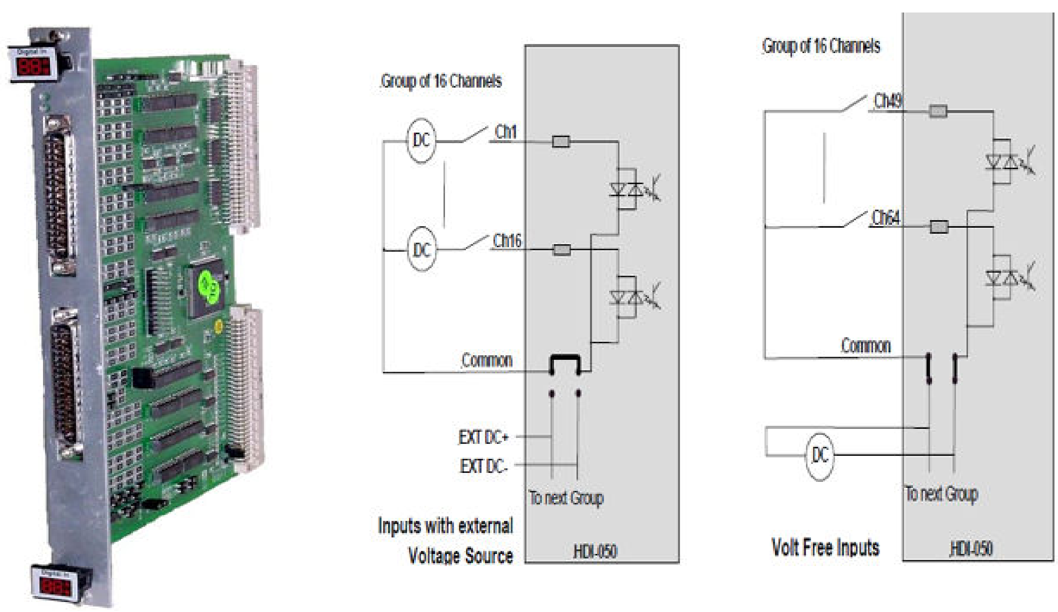

Fig. (2. 7) Example for RTU Digital Input

Examples for RTU Digital input: shown Fig. (2.8).

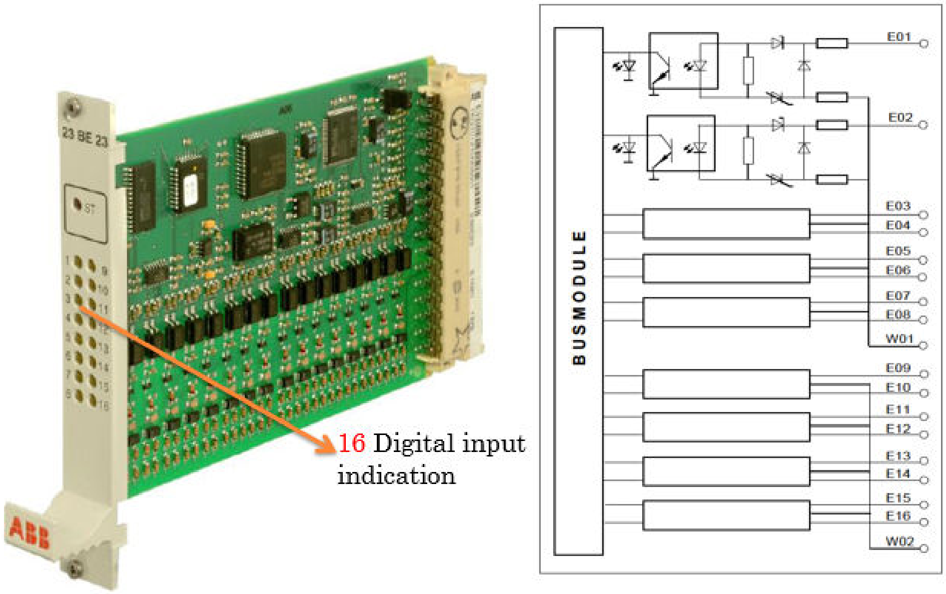

Fig. (2. 8) Example for RTU Digital Input

Counter or Accumulator digital inputs

- There are many applications where a Pulse-input module is required.
- This can be a contact Closure signal or if the pulse frequency is high enough, solid state relay signals.

Two approaches are possible:

i. The Accumulator Contents can be Transferred to RAM memory at Regular intervals where the old and current value difference can be stored in a register.

ii. The second approach is where a detailed and accurate Accounting needs to be made of liquids flowing into and out of a specific area(freeze accumulator Command).

Diagram for accumulator RTU Digital input: shown Fig. (2.9).

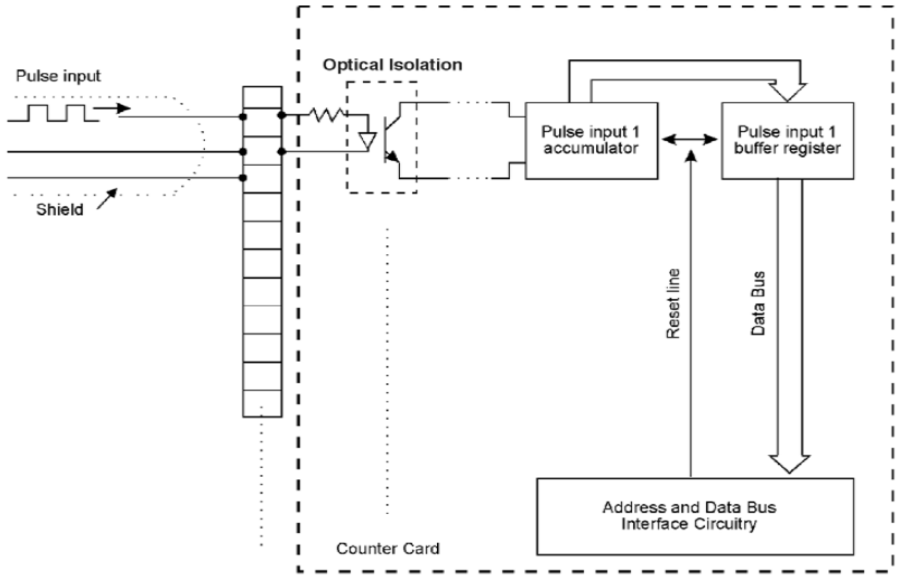

Fig. (2. 9) Diagram for accumulator RTU Digital input

2.4 Digital output for RTU:

A digital output module drives an output voltage at each of the appropriate output Channels.

Diagram for RTU Digital Output: shown Fig. (2.10).

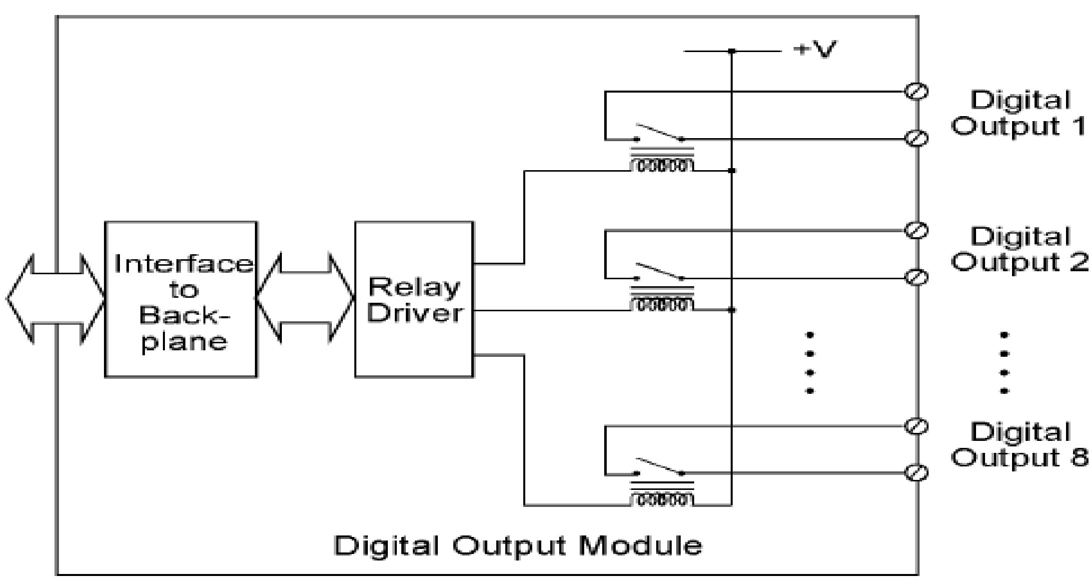

Fig. (2. 10) Diagram for RTU Digital Output

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.

Ensure that the Current Rating is not Exceeded for these devices.

A Maximum Current Rating for the module of typically 60% of the number of outputs multiplied by the maximum current per output.

Also the difference in sinking and sourcing of an I/O module. If a module sinks a specified current, it means that it draws this current from an external source. If a module sources a specific current it drives this current as an output.

When connecting to inductive loads it is a good suggestion to put a flywheel diode across the relay for DC systems.

This minimizes the back EMF effect for DC voltages with the consequent voltage spikes when the devices are switched off. shownFig. (2.11).

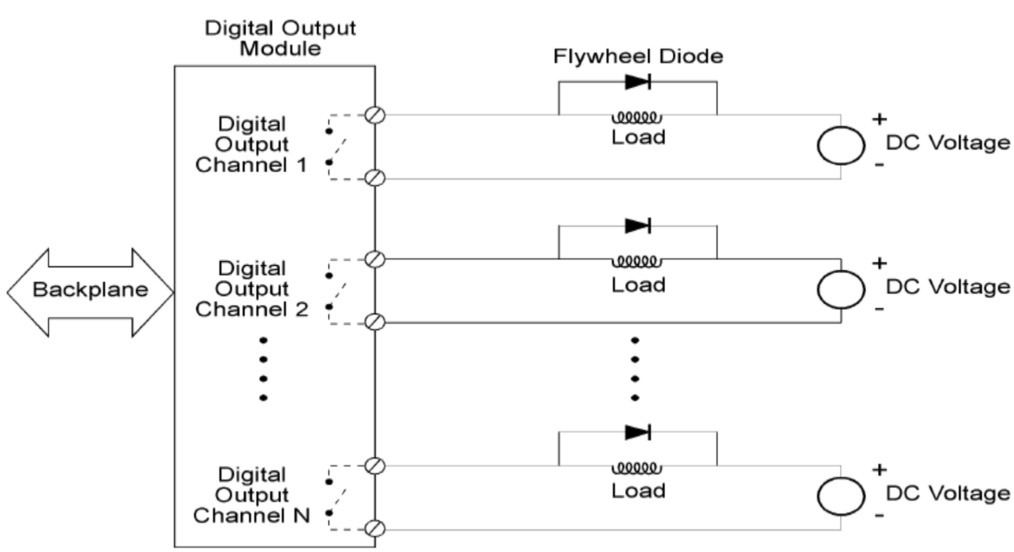

Fig. (2. 11) Digital for RTU Digital Output

When connecting to inductive loads it is a good suggestion to put a Capacitor/Resistor combination for AC systems. shownFig. (2.12).

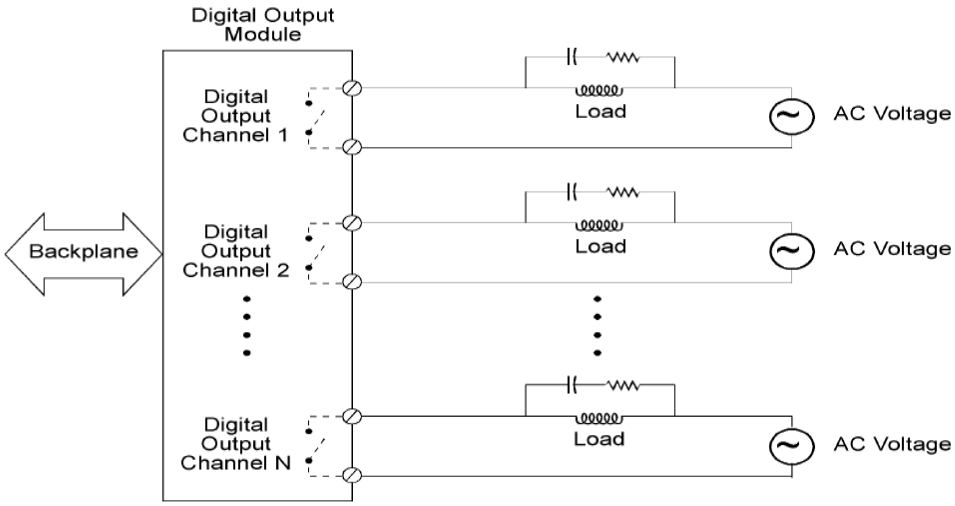

Fig. (2. 12) Digital for RTU Digital Output

Example for RTU Digital Output: shown Fig. (2.13).

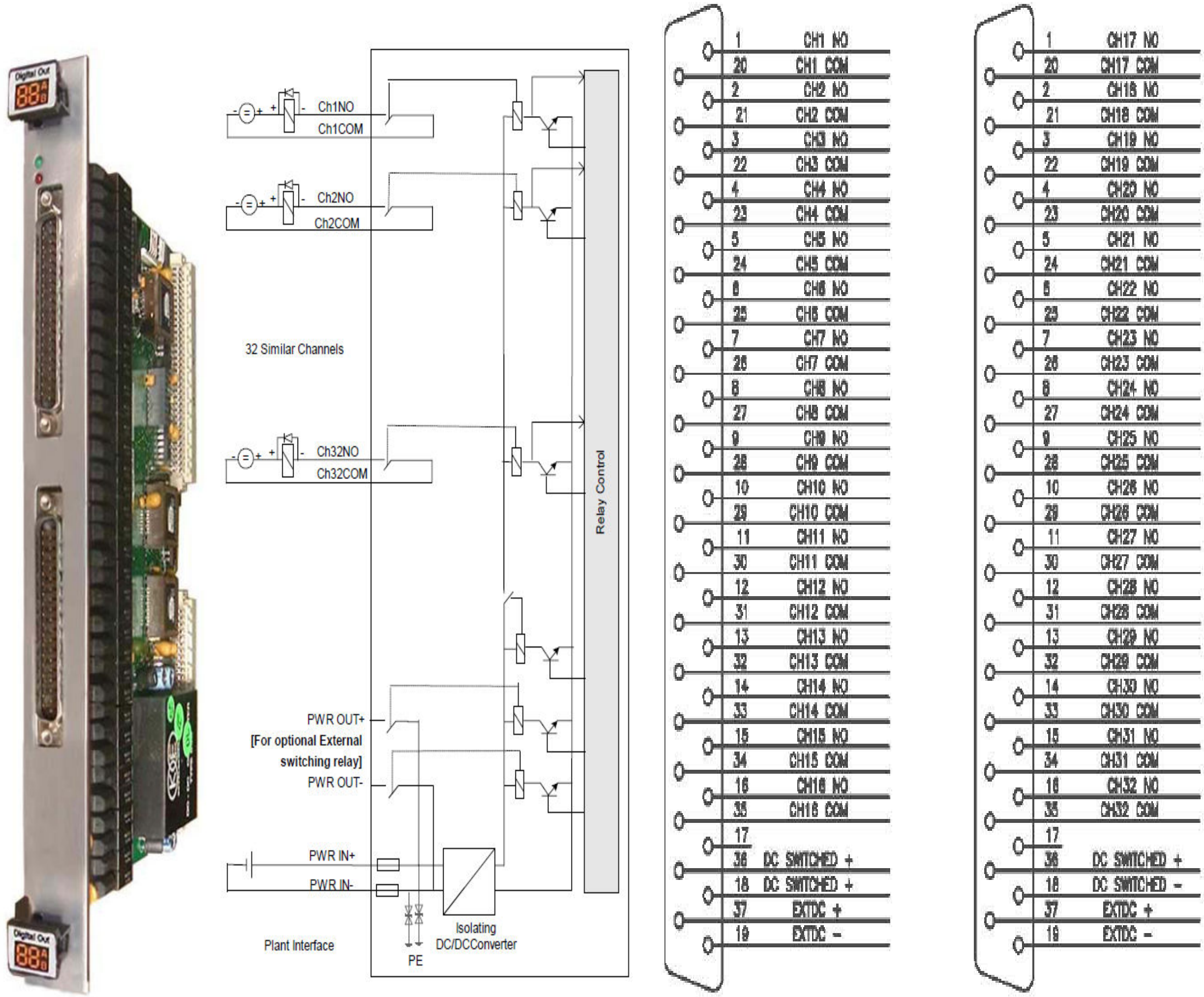

Fig. (2. 13) Example for RTU Digital Output

Diagram for RTU Digital Output: shown Fig. (2.14).

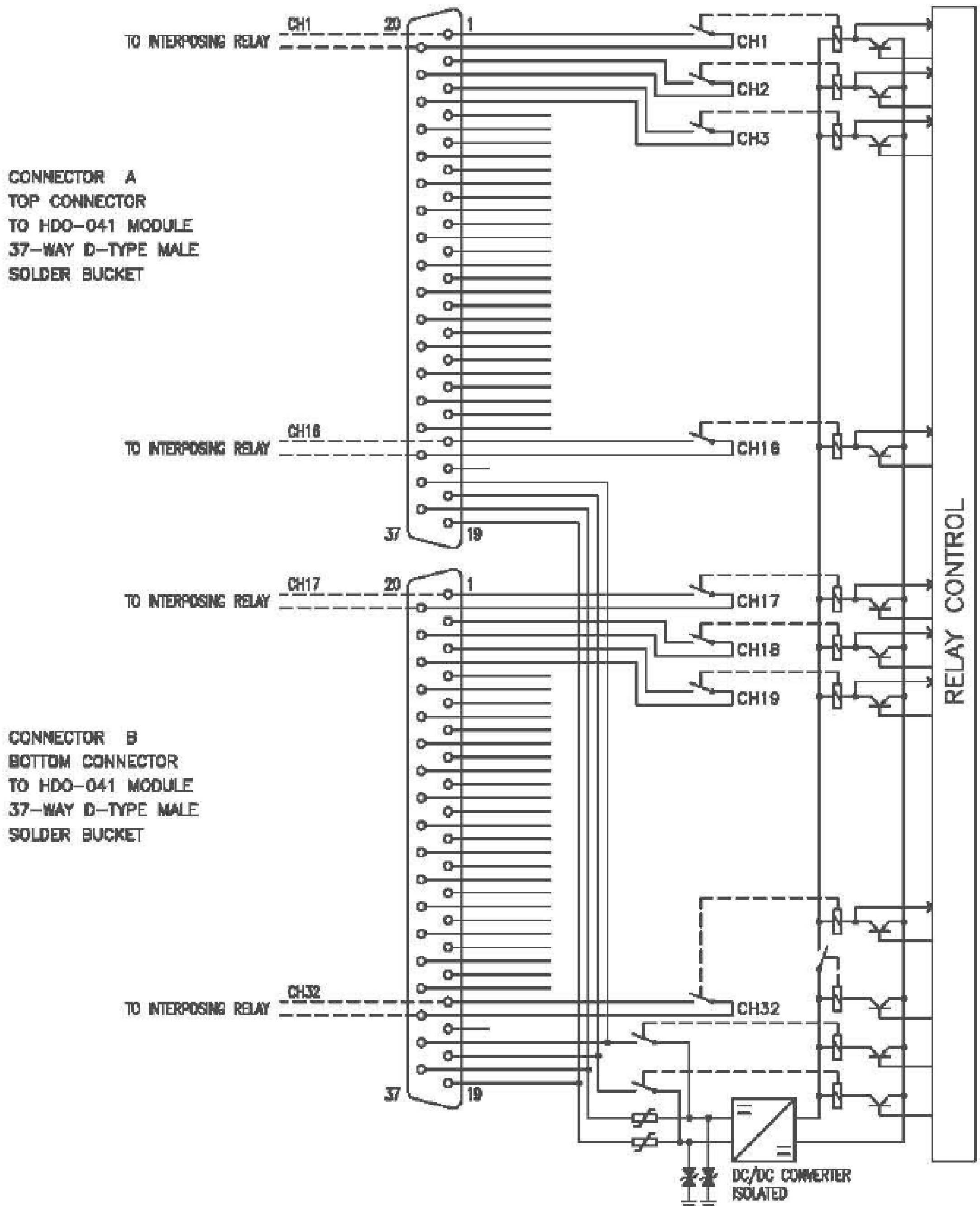

Fig. (2. 14) Diagram for RTU Digital Output

Example for RTU Digital Output: shown Fig. (2.15).

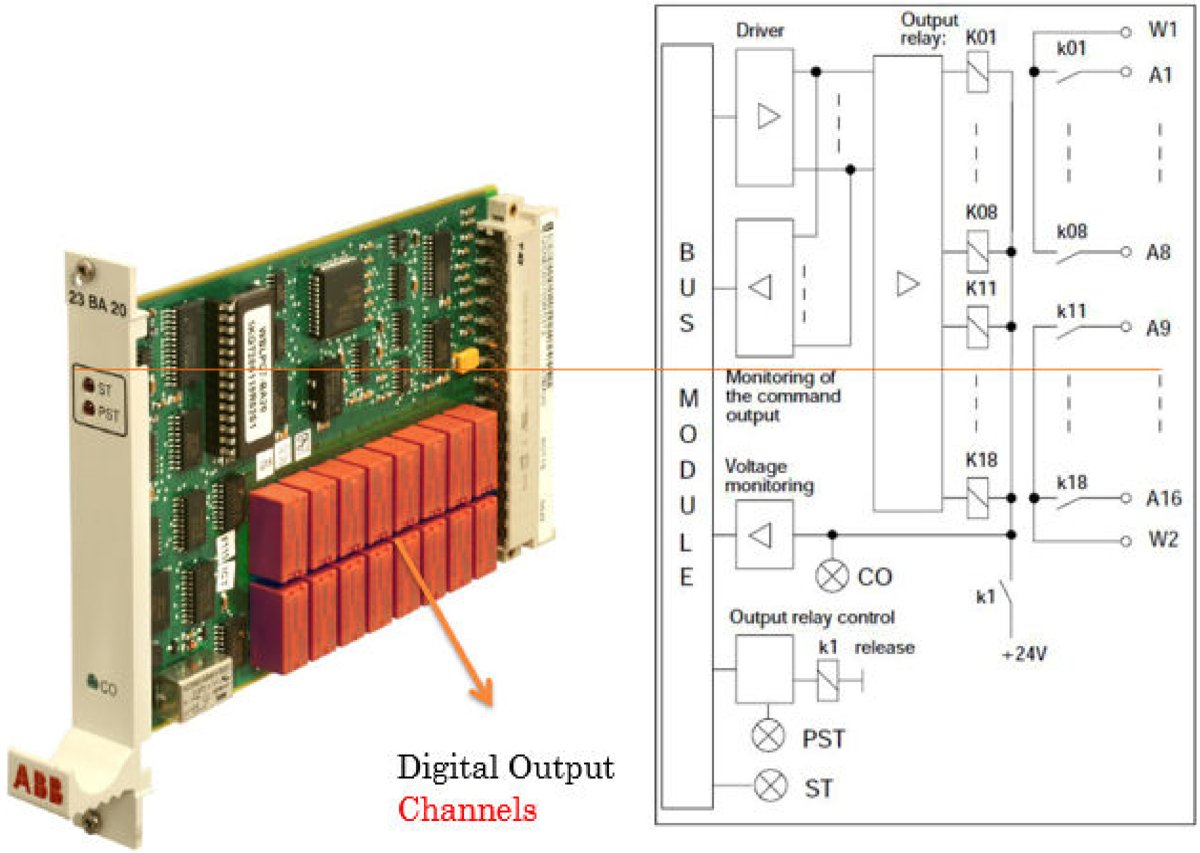

Fig. (2. 15) Example for RTU Digital Output

2.5 Analog input module for RTU:

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

- The input Multiplexer.
- The input signal Amplifier.
- The Sample and Hold circuit.
- The A/D converter.
- The Bus interface and board Timing system.

Multiplexers:

- A Multiplexer is a device that Samples several (usually 16) analog inputs in turn and switches each to the output in sequence.
- The output generally goes to an A/D converter, eliminating the need for a converter on each input channel.

Amplifier:

- Where low-level voltages need to be digitized, they must be amplified to match the input range of the board's A/D converter.
- If a low-level signal is fed directly into a board without amplification, a loss of precision will be the result.
- PGA make it possible to select from software, different gains for different channels.

Sample-and-hold circuit

- Most A/D Converters require a fixed time during which the input signal remains constant (the aperture time) in order to perform an A/D conversion.
- If the input were to change during this time, the A/D would return an inaccurate reading.
- S&H Circuitsamples the output signal from the multiplexer or gain amplifier very quickly and holds it constant for the A/Ds aperture time.
- The standard design approach is to place a simple sample-and-hold chip between multiplexer and A/D converter.

A/D converters:

- The A/D converter is the heart of the module. Its function is to measure an input analog voltage and to output a digital code corresponding to the input voltage.
- **There are two main types of A/D converters used:**

i. **Integrating (or dual slope) A/Ds :**These are used for very low frequency applications. (a few hundred hertz maximum)

ii. **Successive approximation A/Ds :**Successive approximation A/Ds allow much higher sampling rates (up to a few hundred kHz with 12 bits is possible) while still being reasonable in cost. shownFig. (2.16).

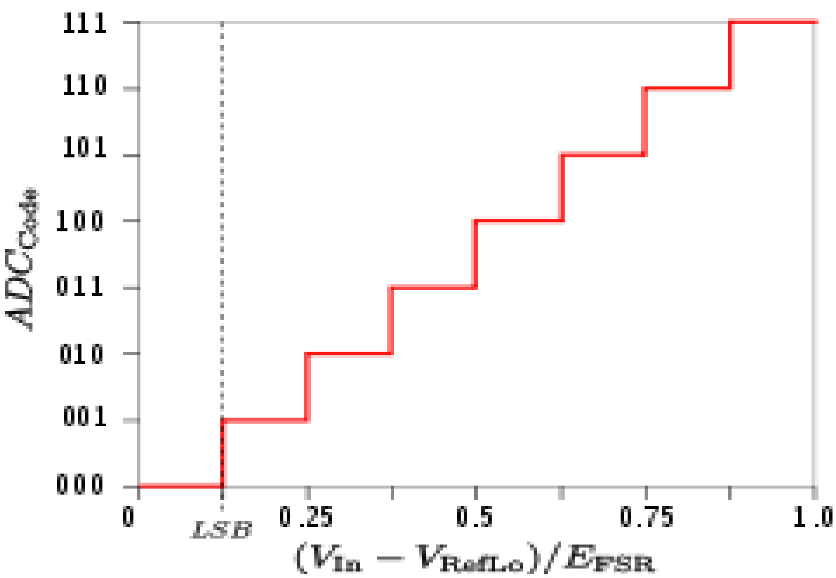

Fig. (2. 16) AC to DC Convert Diagram

The bus interface and board timing system:

The bus interface provides the mechanism for transferring the data from the board and into the host PCs memory, and for sending any configuration information (for example , gain/channel information) or other commands to the board. The interface can be 8-, 16-or 32-bit.

Diagram for RTU Analog input module :- shown Fig. (2.17).

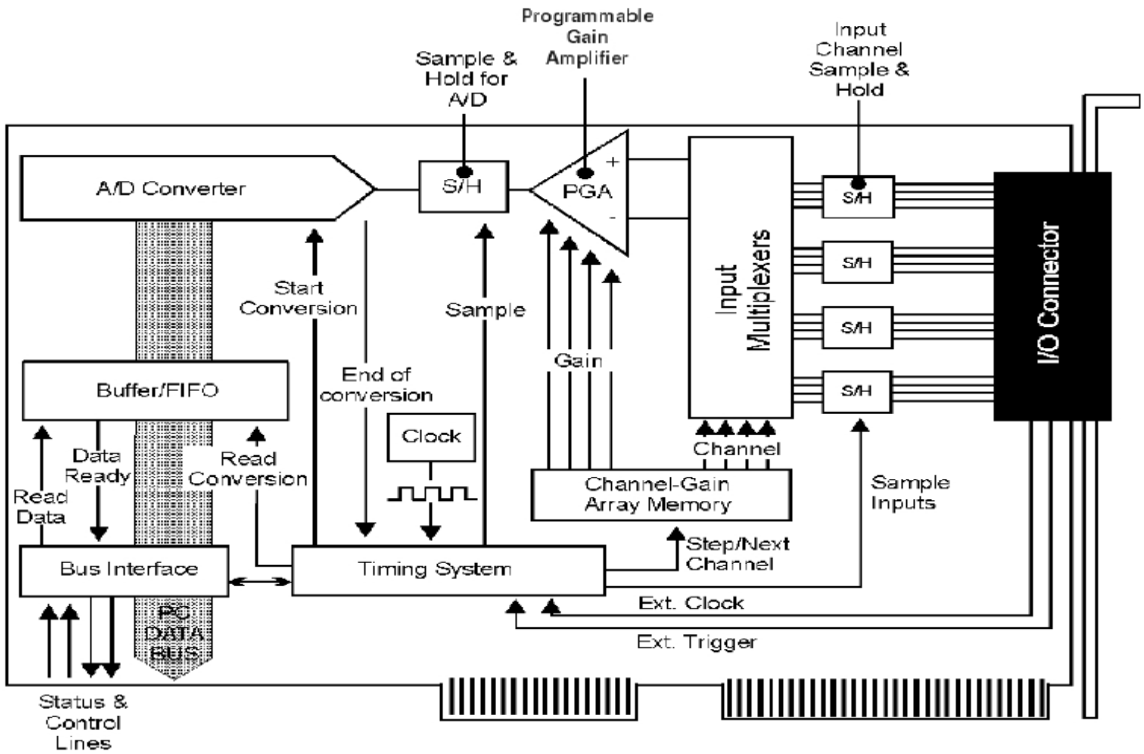

Fig. (2. 17) Diagram for RTU Analog input module

Analog input method:

i. **Single-ended inputs Boards:** that accept single-ended inputs have a single input wire for each signal, the source's HI side. All the LO sides of the sources are commoned and connected to the analog ground AGND pin.shownFig. (2.18).

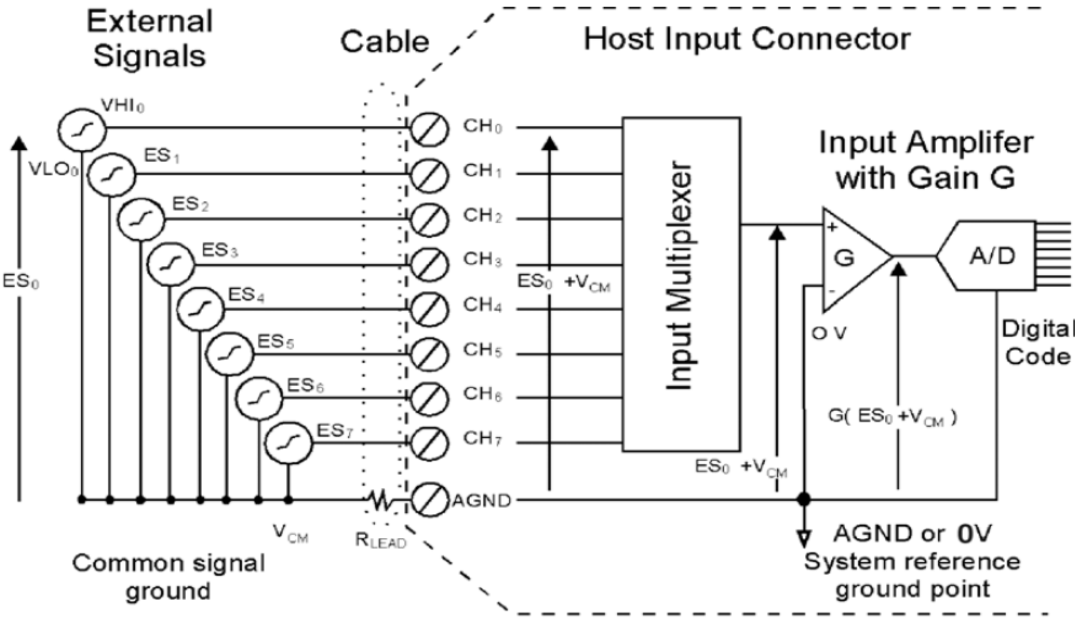

Fig. (2. 18) Connect to the Analog input method

Analog input method:

Differential inputs Boards: This method must also beused where the signal sources have different ground points and cannot be connected together. True differential inputs provide the maximum noise immunity. shownFig. (2.19).

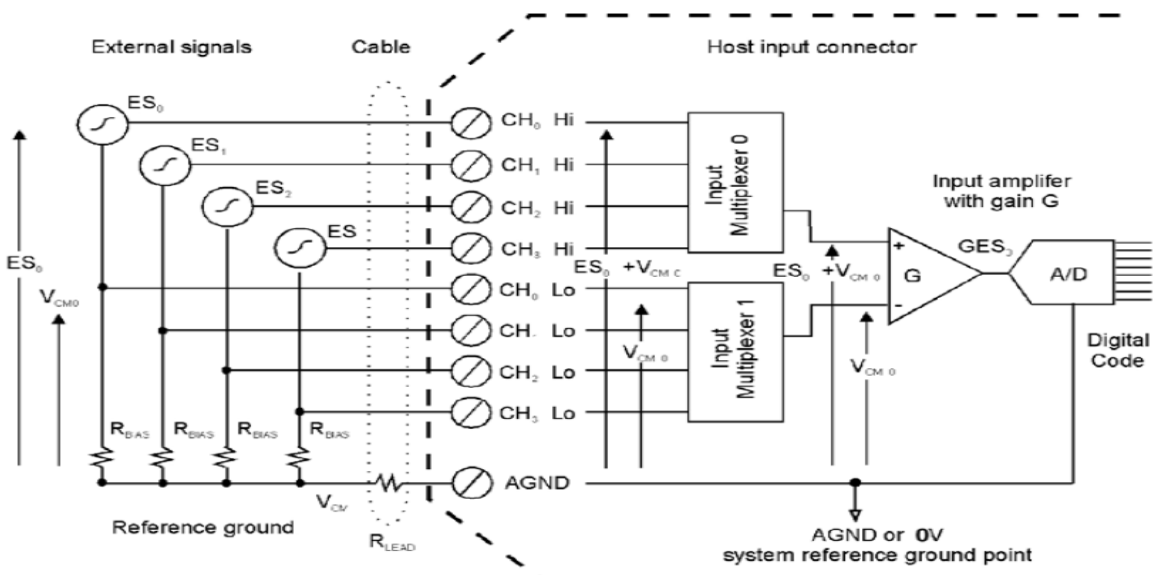

Fig. (2. 19) System References Ground Point

Analog input modules Specifications:

i. These have various numbers of inputs 8 or 16 analog inputs or more depend on manufactures.

ii. Resolution of 8 or 12 bits.

iii. Range of 4–20 mA (other possibilities are 0–20 mA/±10 volts/0–10 volts).

iv. Input resistance typically 240 kΩ to 1 MΩ.

v. Conversion rates typically 10 microseconds to 30 milliseconds.

vi. Inputs are generally single ended (but also differential modes provided).

Diagramfor RTU Analog input module : shownFig. (2.20).

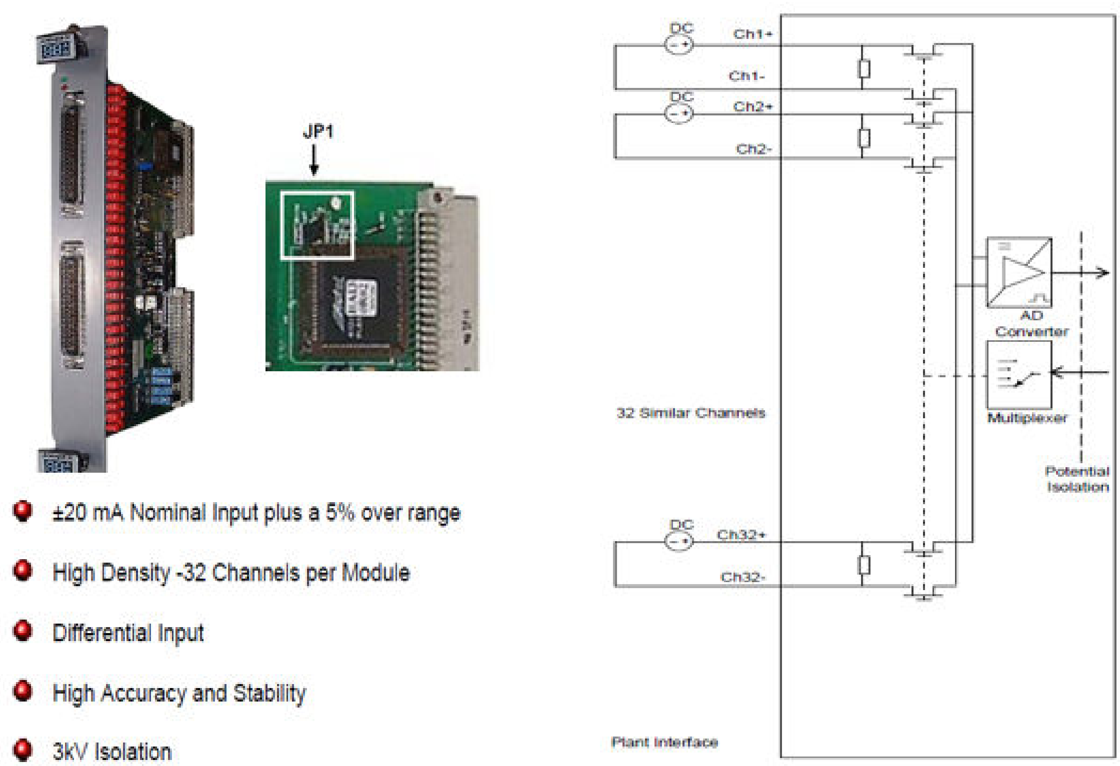

Fig. (2. 20) Diagram for RTU Analog input module

Diagram for RTU Analog input module :- shown Fig. (2.21).

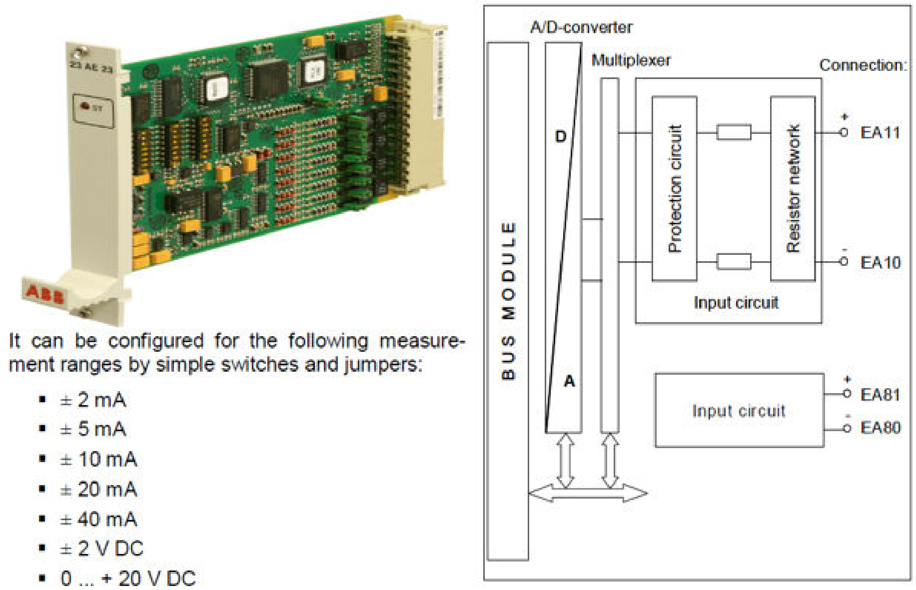

Fig. (2. 21) Diagram for RTU Analog input module

- Analog output module designs generally prefer to provide voltage outputs rather than current output (unless power is provided externally.
- 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.
- The Analogue output module has the following features:

i. These have various numbers of inputs 8 or 16 analog outputs or more depend on manufactures.

ii. Resolution of 8 or 12 bits.

iii. Conversion rates typically 10 microseconds to 30 milliseconds.

iv. Outputs ranging from 4–20 mA/± 10 volts/0 to 10 volts.

Diagram for RTU Analog Output module :- shown Fig. (2.22).

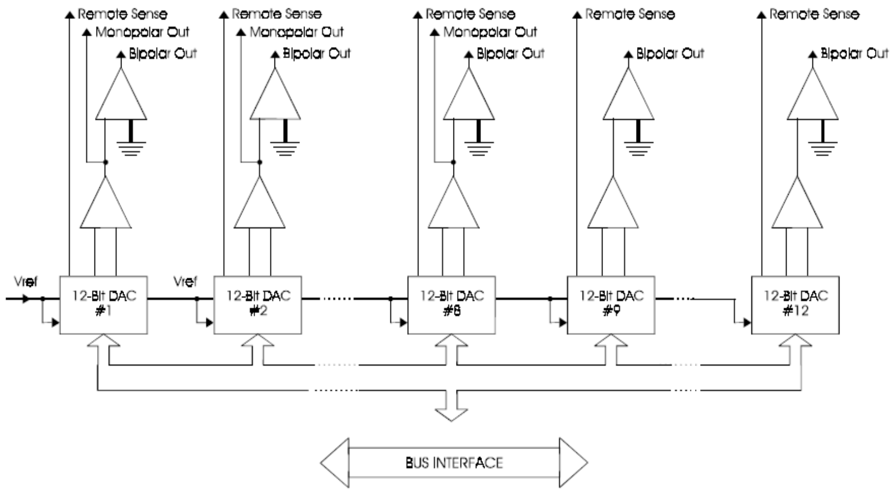

Fig. (2. 22) Diagram for RTU Analog Output module

Example for RTU Analog Output module :- shown Fig. (2.23).

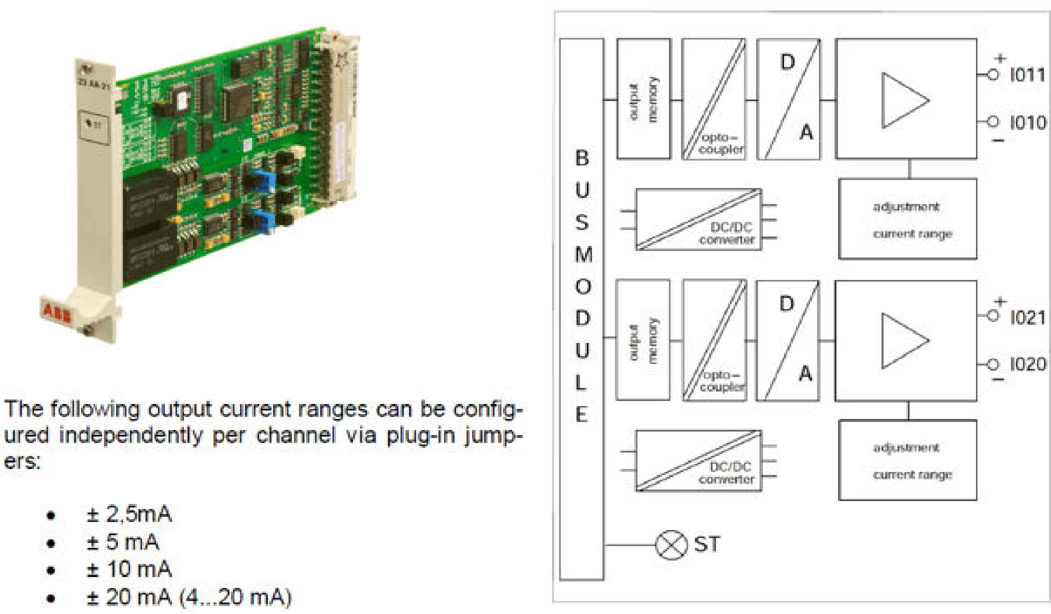

Fig. (2. 23) Example for RTU Analog Output module

2.6 Communication Interfaces for RTU

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 tow types for data collections first type using RTU I\O modules as Previous slides. Second Type through Network between IEDs and RTUs (using communication Protocols) through communication interface in RTUs.

Communication ports:

The modern RTU should be flexible enough to handle multiple communication media such as:

- RS-232/RS-442/RS-485
- Dialup telephone lines/dedicated landlines.
- The Ethernet interface

Example for RTU Communication interfaces module: shown Fig. (2.24).

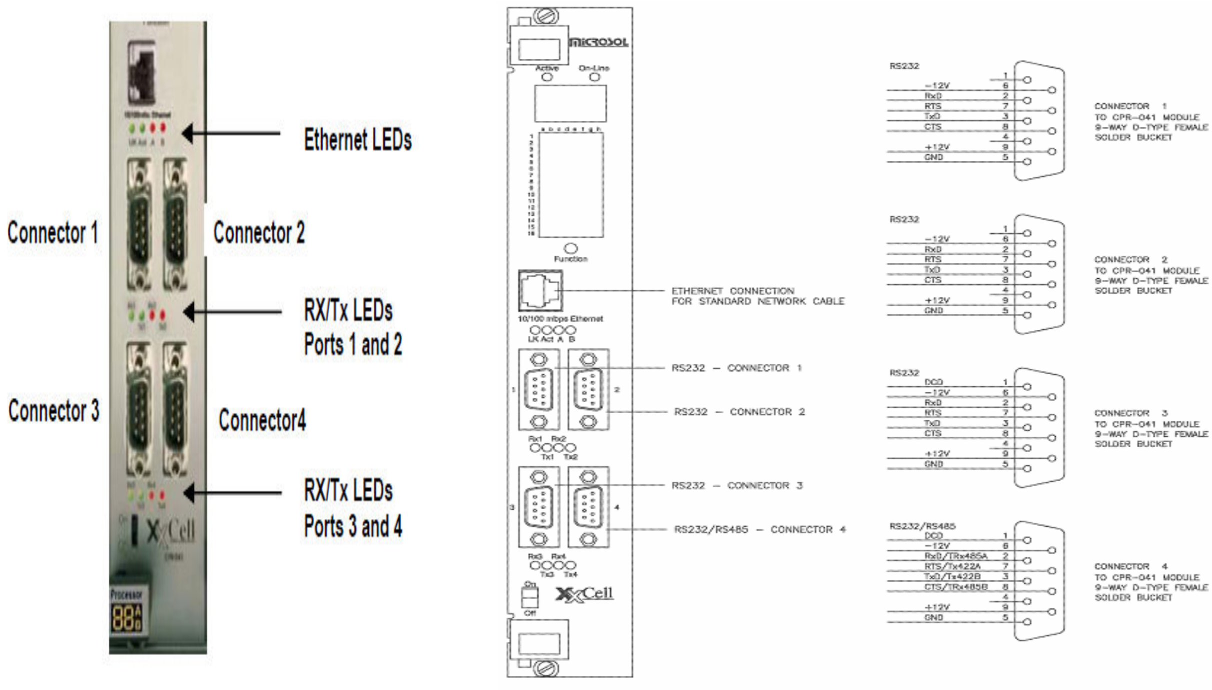

Fig. (2. 24) Example for RTU Communication interfaces module

Example for RTU Communication interfaces module: shown Fig. (2.25).

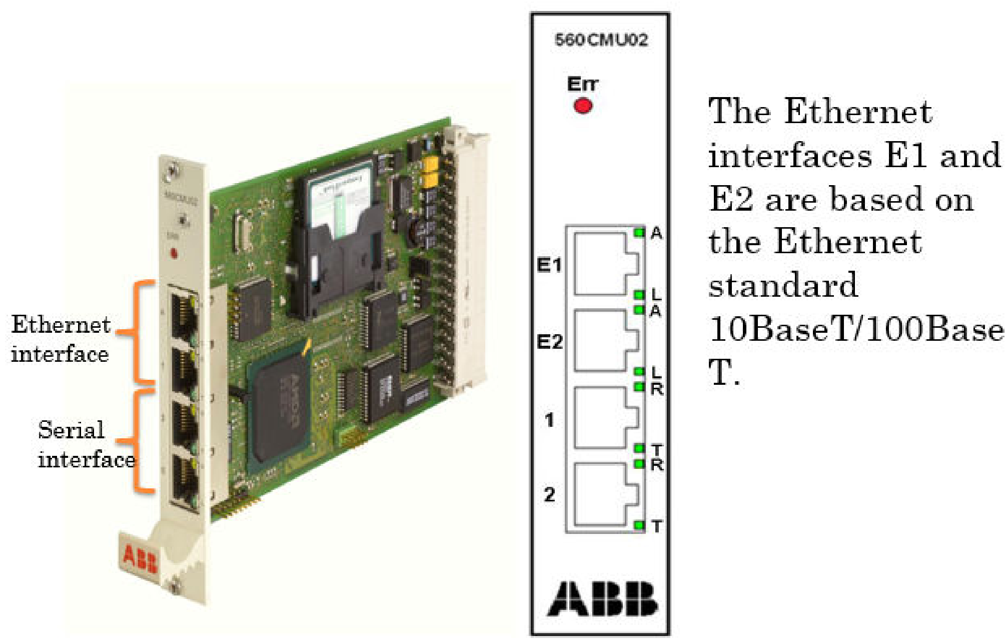

Fig. (2. 25) Example for RTU Communication interfaces module\

Example for RTU Communication interfaces module:

The serial communication interfaces CP1, CP2, CPA and CPB are designed for RS232C and RS485 standard.

The interfaces ‘E1’ and ‘E2’ are based for the Ethernet standard 10BaseT/100BaseT.

The connectors of the serial and Ethernet communication interfaces are provided as RJ45 jacks. shownFig. (2.26).

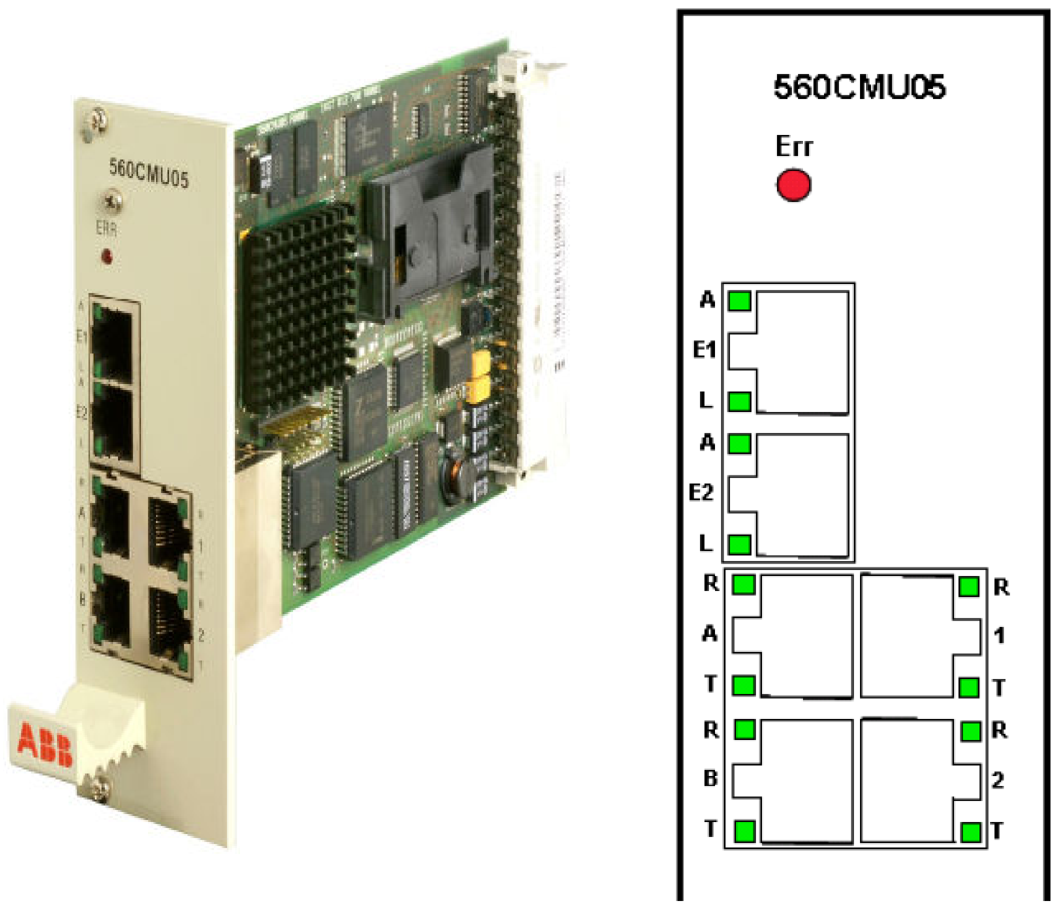

Fig. (2. 26) Example for RTU Communication interfaces module

CHAPTER THREE

MASTER TERMINAL UNIT (MTUs)

3.1 Introduction:

ITisthecentralsite (masterstation)canbepicturedas havingoneormoreoperatorstations(tied togetherwitha localareanetwork)connectedto a communication system.

Master StationCommunication System consisting of modemandradioreceiver/transmitter. Itispossiblefora landlinesystemtobeusedin placeoftheradiosystem,in this case themodem willinterfacedirectlyto the landline.

Normallytherearenoinput/outputmodules connected directlytothemasterstationsalthoughthere maybeanRTUlocatedin closeproximitytothemaster controlroom.

3.2 The Master Station structure:

The main diagram of the master Station Structure is shown in Fig.(3-1).

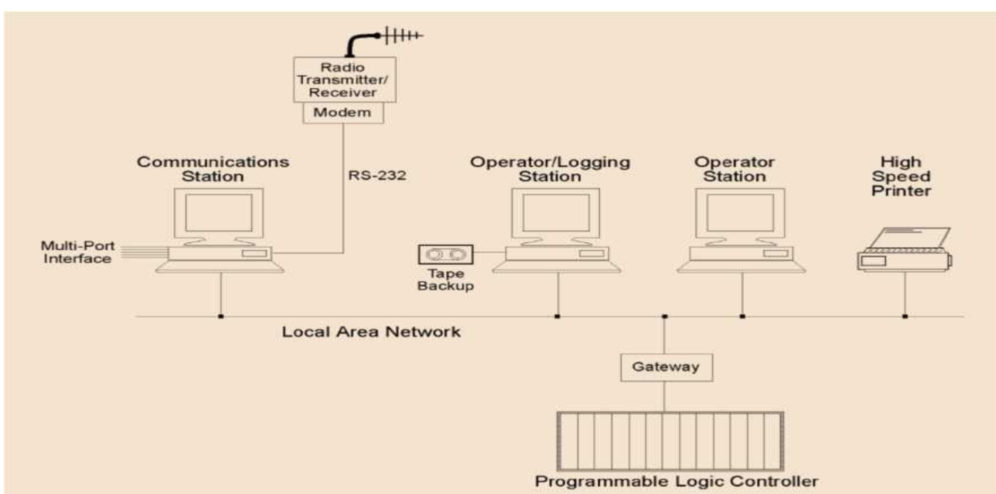

Fig. (3. 1) Master Station structure

Therehavebeentwomainapproachestofollowin designingtheSCADAsysteminthepast.Theyare: centralizedand distributed.

-Centralized:

where a singlecomputerormainframeperformsall plant monitoringandallplantdataisstoredononedatabase thatresideson thiscomputer.

Diagram of designingthe SCADAsystem inthe past is shown in fig (3-2)

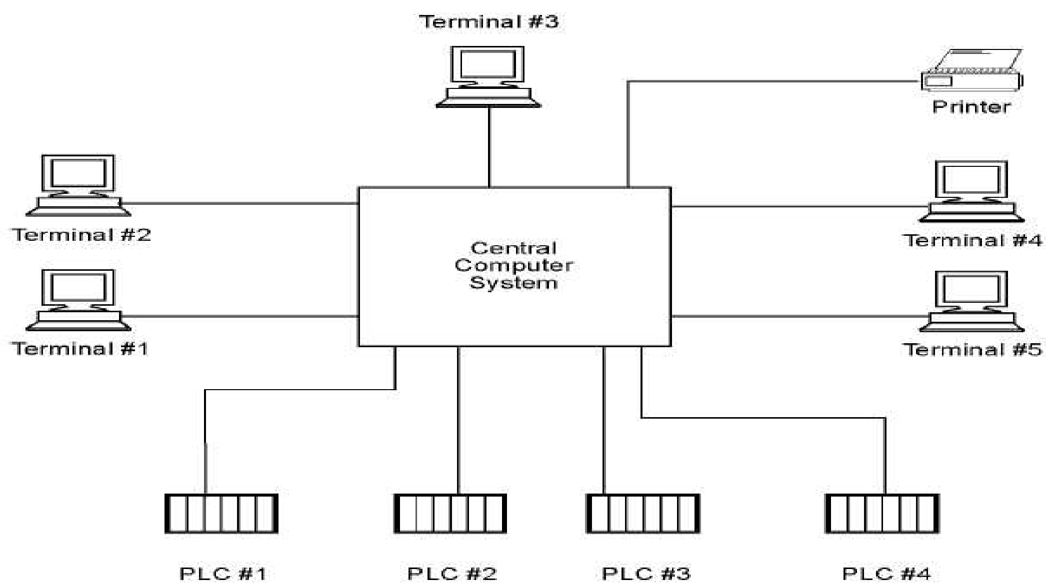

Fig. (3. 2) SCADA system in the past

-Distributed:

Wherethe SCADAsystem isshared acrossseveral small computers(usuallyPCs) is shown in fig (3-3)

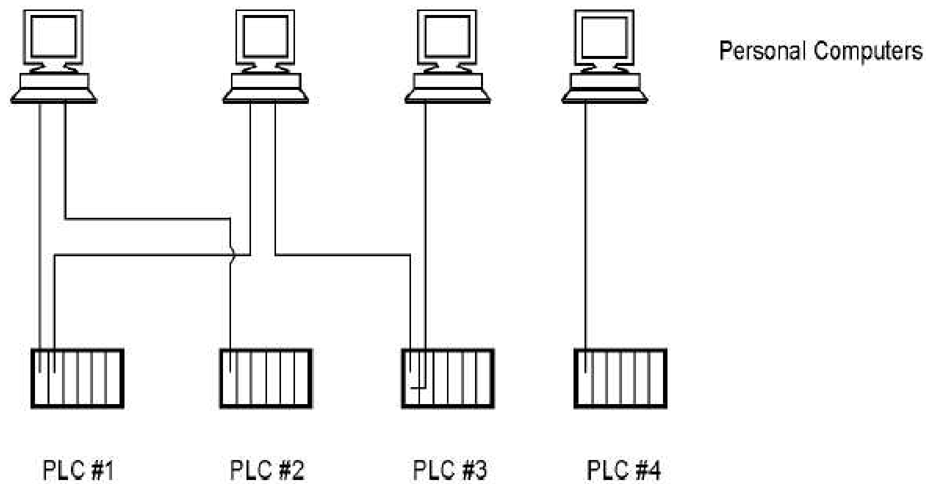

Fig. (3. 3) SCADA system is shared across several small computers (usually PCs)

Dataprocessinganddatabaseshavetobeduplicated acrossall computersinthesystem,resultinginlow efficiencies.

Thereisnosystematicapproachtoacquiring datafrom theplantdevices–if twooperatorsrequirethesamedata, the RTUisinterrogatedtwiceAneffectivesolutionistoexaminethetypeofdata requiredforeachtaskandthentostructurethesystem appropriately.A clientserver approach

- **ClientServer:**

Aservernodeisadevicethatprovidesaservicetoother nodes(clients requesta service) on the network.

Thewordclientandserverrefertotheprogram executing on aparticular node.

The Diagramofclientandserver is shown in fig (3-4):

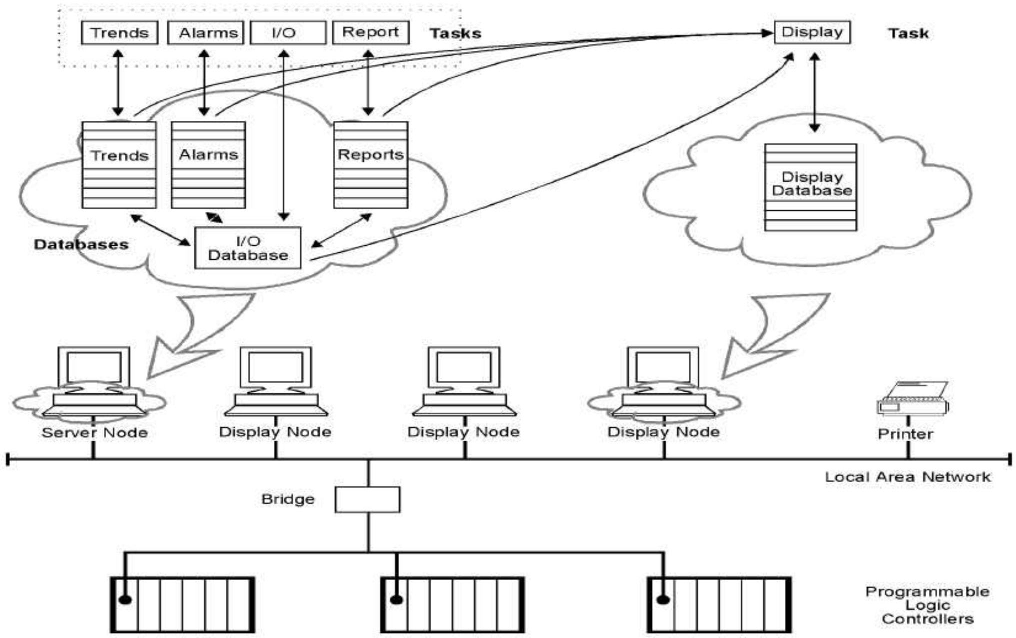

Fig. (3. 4) client and server diagram

Alargesystemwithcouldhavearchitectureas shown in fig (3-5)below.

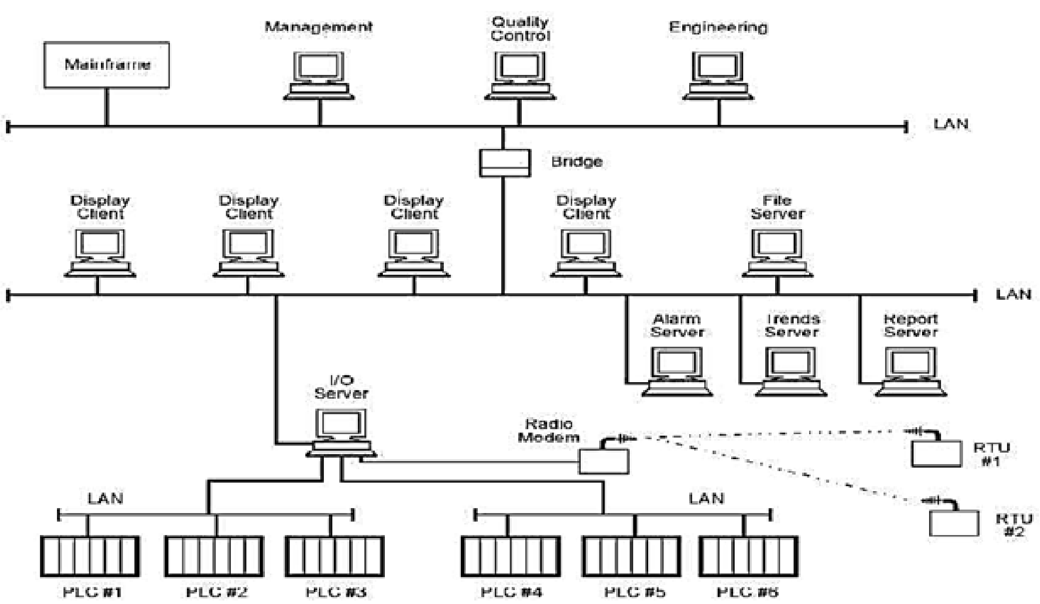

Fig. (3. 5) the large system with could have architecture

3.3 RemoteDevices Connection Methods:

Controlremote devices through the operator stationThereare variouscombinationsof systemspossible,as indicatedin the diagram below:

- Alternative1 is shown in fig(3-6)

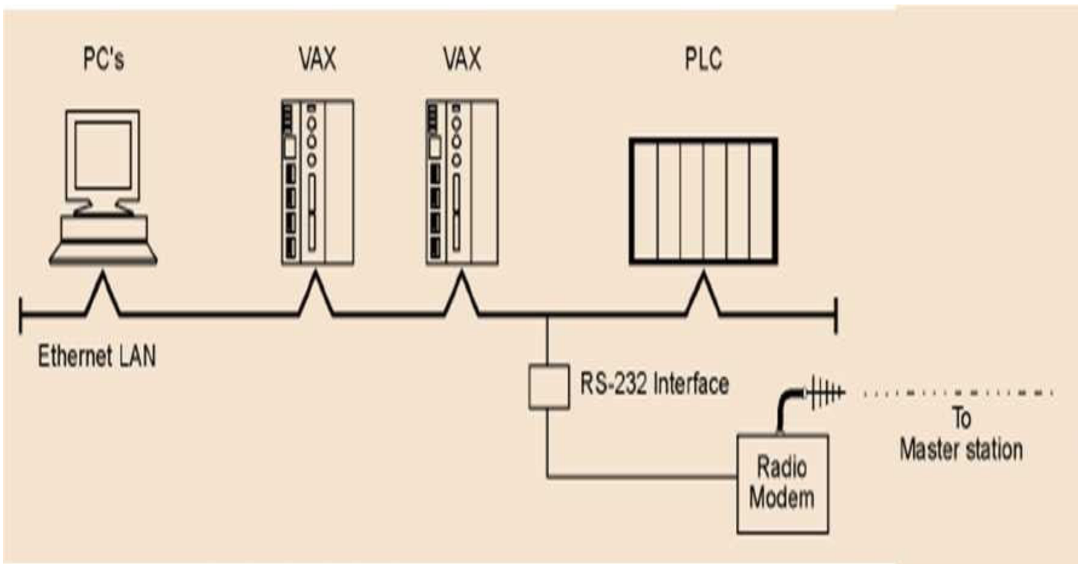

Fig. (3. 6) Alternative 1

- Alternative2 is shown in fig(3-7)

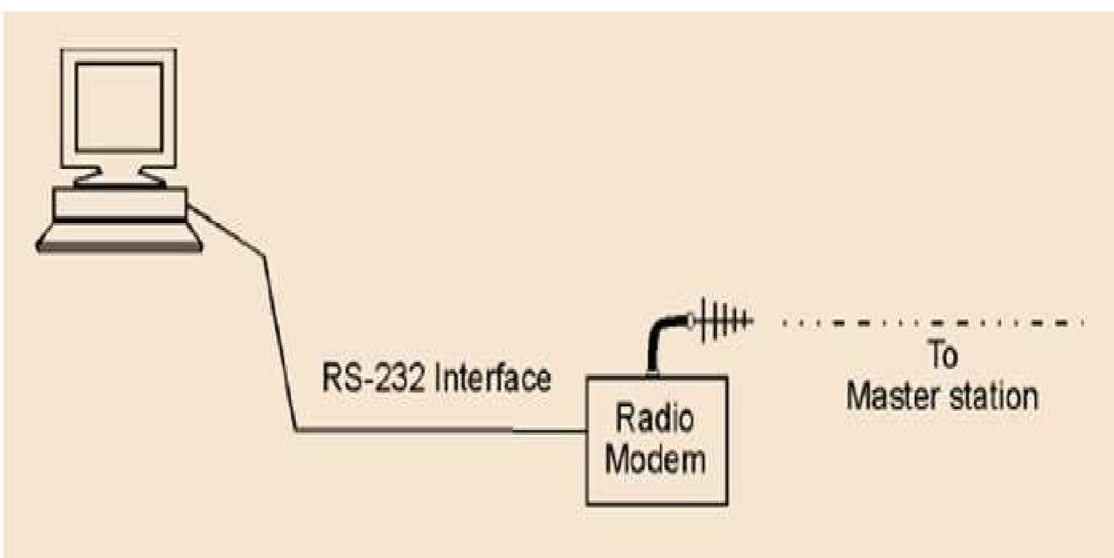

Fig. (3. 7) Alternative 2

- Alternative3 is shown in fig(3-8)

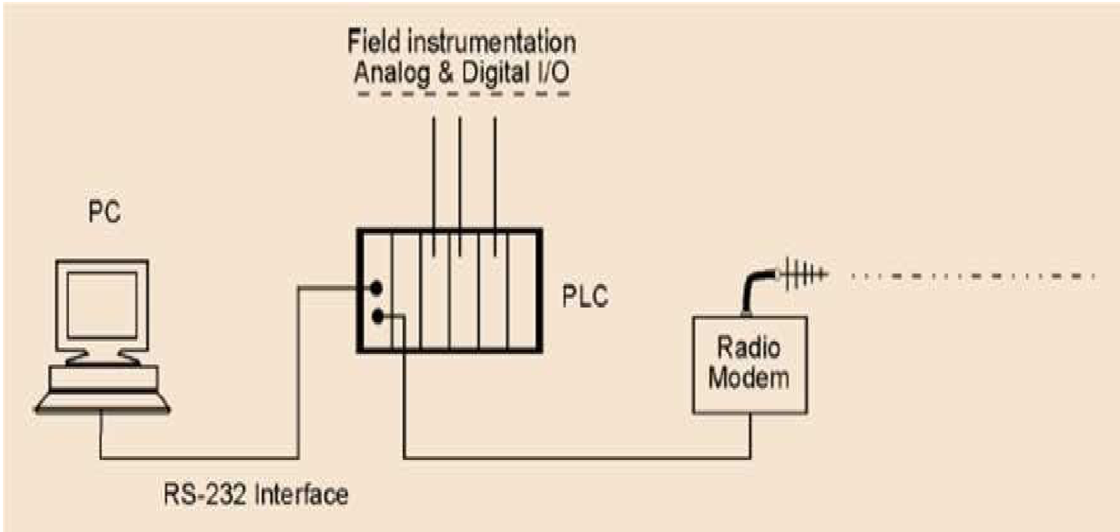

Fig. (3. 8) Alternative

3.4MasterStationfunctions

- Establishmentofcommunications:

Configure each RTU.

Initializeeach RTU withinput/outputparameters.

Downloadcontroland data acquisitionprogramsto the RTU.

- Operationofthecommunicationslink:

Ifamasterslavearrangement,polleachRTUfor dataand writeto RTU.

Log alarms and events to harddisk(and operator displayifnecessary).

Link inputsand outputsat differentRTUsautomatically.

- Diagnostics:

Provideaccurate diagnosticinformationon failureofRTU and possibleproblems.

Predictpotentialproblemssuch as data overloads.

3.5Sub-MasterStation

Itmayalsobenecessarytosetupasub-masterstation.

This isto controlsites withinaspecificregion which is shown in fig(3-9).

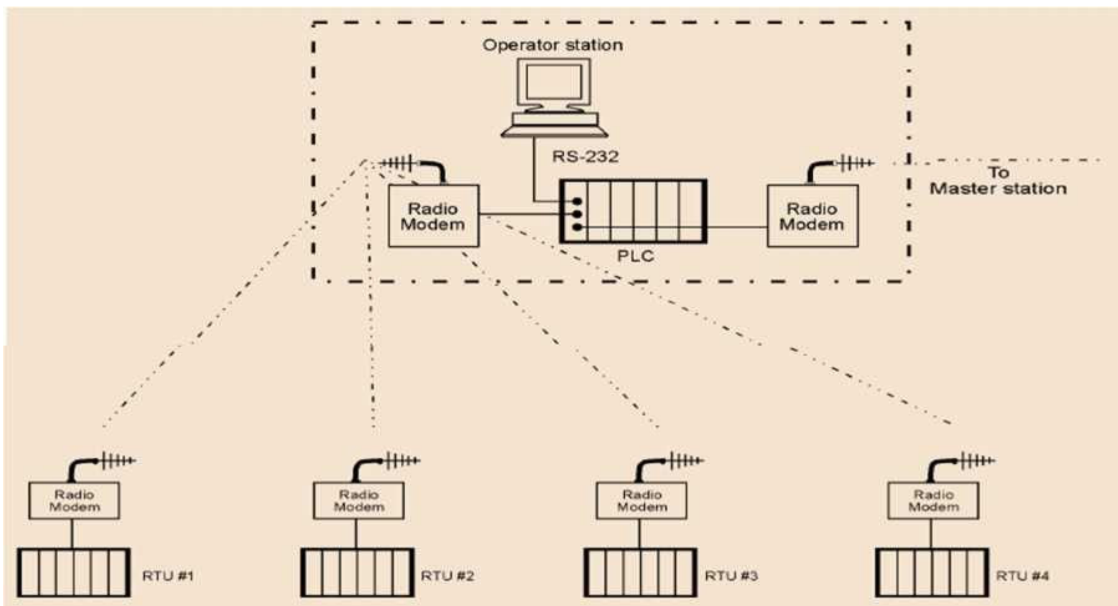

Fig. (3. 9) sub-master station

Thesub-master stationhasthefollowingfunctions:

Acquire data fromRTUswithinthe region

Log and displaythisdata on a localoperatorstation.

Pass databackto the master station.

Pass on controlrequestsfromthe master station to the RTUsinits region.

3.6 MasterStationSoftware

There are three componentsto the master station software:

- TheOperating Systemsoftware:

(Goodexamples of operatingsystem areDOS,Windows, WindowsNTand the various UNIXsystems).

- The systemSCADAsoftware(suitably configured):

Itconsistsof four main modules:

Dataacquisition

Control

Archivingor databasestorage

The human machineinterface(HMI)

- TheSCADAapplicationsoftware.

3.7MasterStationNetworks

TheCentralsitestructurecanbebasedona distributedarchitectureand ahigh-speed datahighway usingoneoftheLAN standardssuchas:

- Token Bus.
- Token Ring.
- Ethernet.

Themostcommonapproach istousetheEthernetor tokenbusarrangement,wherethereis noonemaster operator station.

Theapproachthatappearsto begainingacceptancein themarketplaceisthetokenbusapproach wherea tokenisusedtotransfercontrolfrom onestationto another.

- TokenBus Network:

TheTokenbusnetworkisbecomingincreasingly popularinindustrial systemsduetoitsphilosophythatall nodeswill receiveaccessto abuswith aguaranteed maximumtime.

Pass control from nodeto node is shown in fig (3-10).

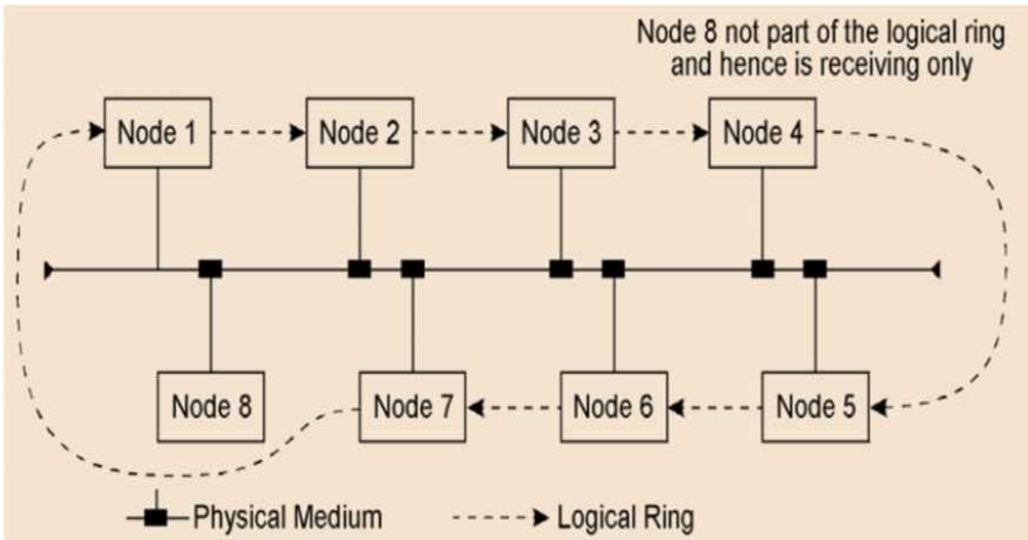

Fig. (3. 10) Pass control from node to node

- TokenRing Network:

Token ringwas developedby IBMin the early eighties.

Itusesatokenmessagetopasscontrolfromonenode toanother. Whena nodereceivesthetoken,ithas control of the ringnetwork for ashort maximum periodof time. It is shown fig(3-11)

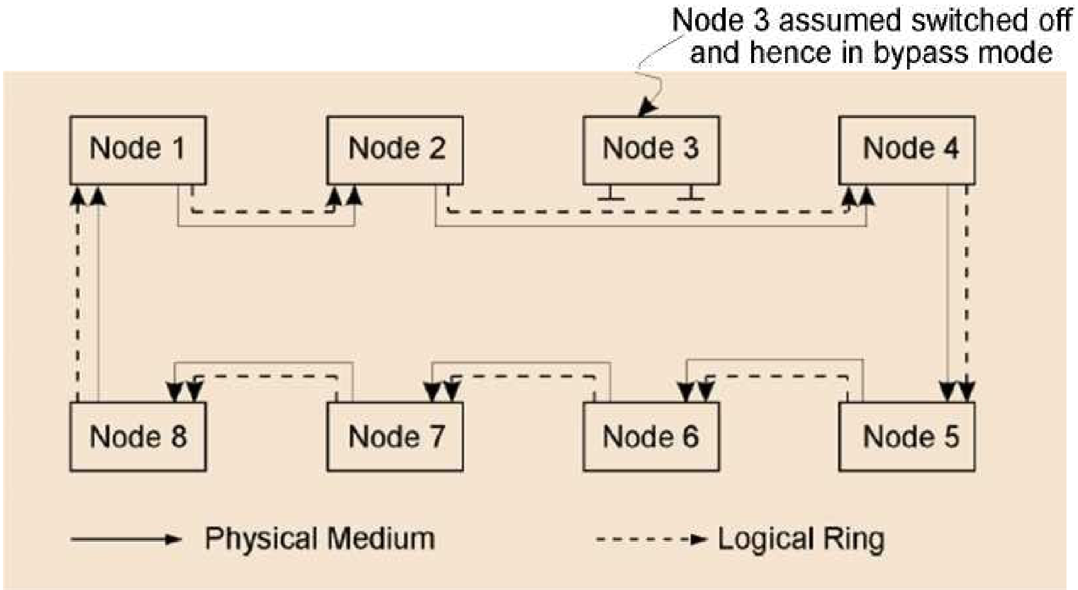

Fig. (3. 11) pass control from one node to another

-EthernetLANs:

This is generally implementedasa 10 Mbpsbaseband network. CarrierSenseMultipleAccesswithCollision Detection(CSMA/CD)isthe MediaAccessControl (MAC)method usedby Ethernet.

Thephilosophyof Ethernetoriginatedfromradio transmissionexperimentswith multiple stations endeavoringtocommunicatewitheach otheratrandom times.

- EthernetLANsdiagram is shown in fig(3-12):

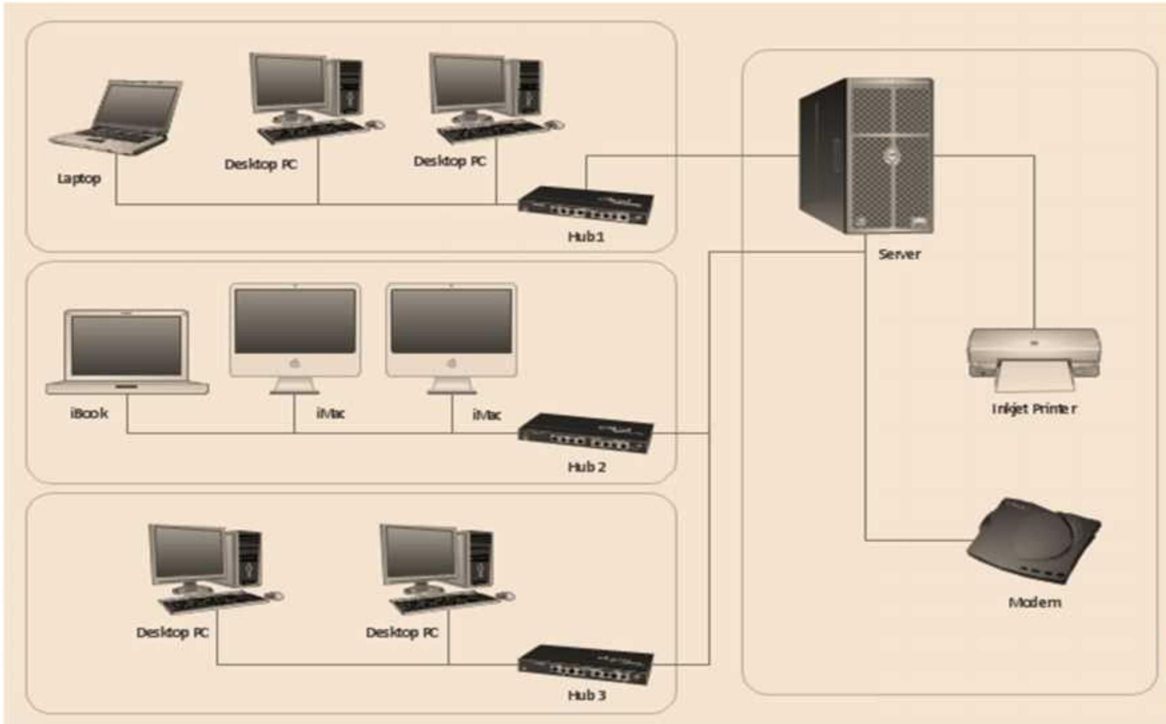

Fig. (3. 12) Ethernet LANs diagram

3.8 SystemReliabilityandavailability

TheindividualcomponentoftheSCADAsystem contributedtotheoverallReliabilityofthe system. Asthe MasterStationisa StrategicpartoftheentireSCADA system,it isimportantthatthesystemreliabilityand availability are carefullyconsidered.

LossofasingleRTU,althoughunpleasant,shouldstill allow the system tocontinueto functionas before.

- Master stationcomponents that arecriticalare:

- Control ProcessingUnit(CPU).
- Main memoryand bufferreprinters.
- Dishdrive and associatedcontrollercard.
- Communications interfaceand channel.

3.9 Redundant Master Station Configuration

There are variousRedundant Configurationspossible.

Two approachespossibleare:

- ColdStandbyConfiguration:

Itisthesimplestapproachis tohaveacoldstandby Changeover wherea switch isgeneratedtochangeover from primaryto secondary.

DiagramofCold standby SCADAsystem is shown in fig (3-13)

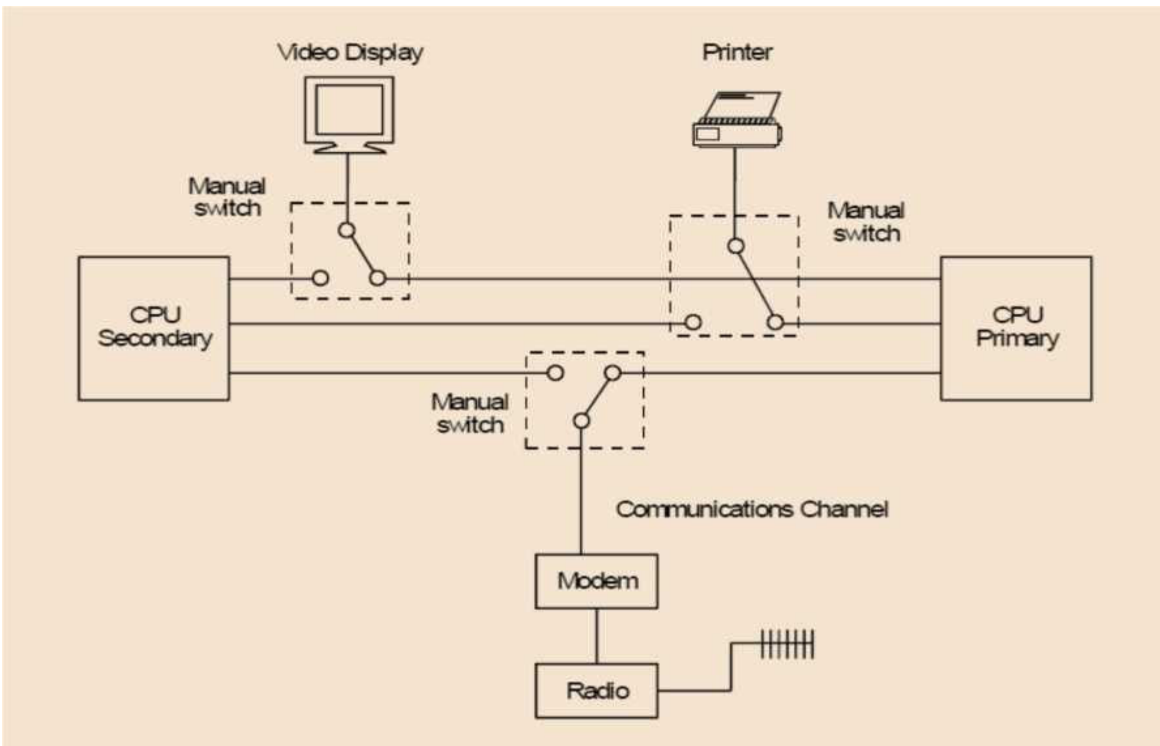

Fig. (3. 13)) Cold standby SCADA system

- HotStandbyConfiguration:

HereaWatchDog Timer(WDT)isactivatedifthe primaryCPUdoesnotupdateorresetit withina given time period.

OncetheWDTisactivated,achangeoveriseffected from the primaryto thesecondaryCPUsystem.

Dueto theuse ofcontinuoushigh-speedmemory updatingofthesecondaryCPU'smemory,thesecondary orbackupCPUcontainsallthelateststatusdata(until the WDT activatedthe changeover).

DiagramofHotstandby SCADA system is shown in fig (3-14)

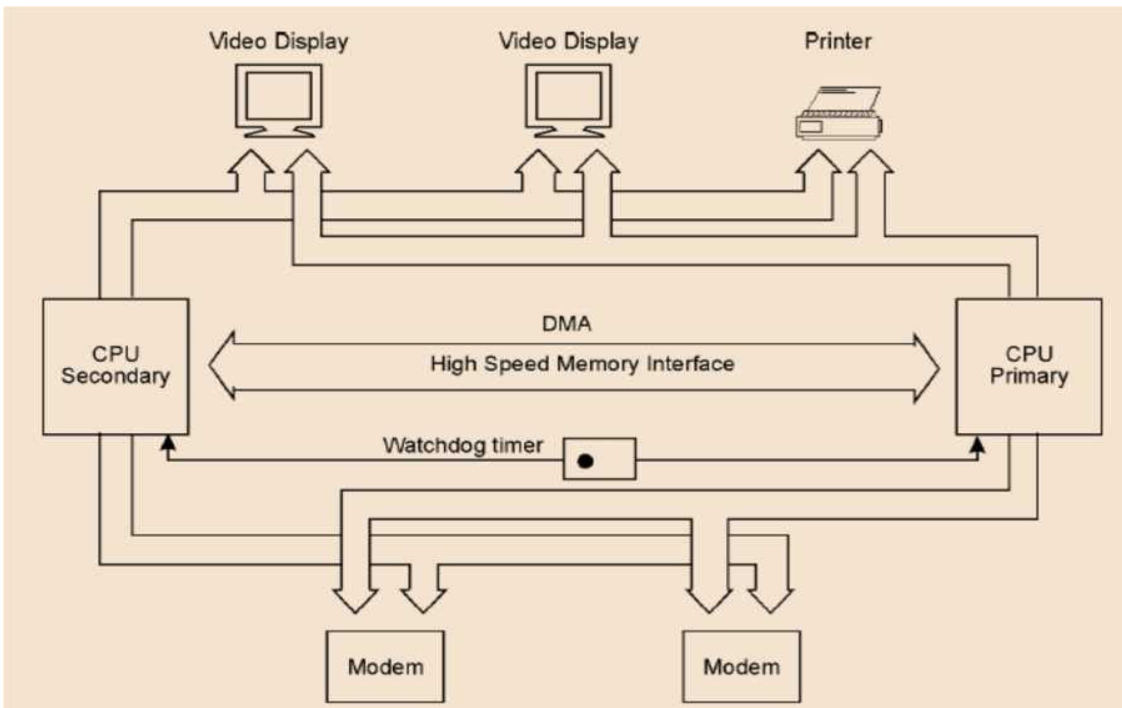

Fig. (3. 14) Hot standby SCADA system

CHAPTER FOUR

OPERATION SYSTEM

4.1 Introduction:

The operation system is composed fromTelecommunicationand protocol were. Data communicationsaretheexchange of data betweentwo devicesviasomeformoftransmissionmediumsuchasawire cable.

ThewordDatareferstoinformationpresentedinwhateverform isagreedupon by thepartiescreatingand usingthedata.

The effectiveness of a data communications system depends on four fundamental characteristics:

- Delivery.
- Accuracy.
- Timeliness
- Jitter.

4.2 Components of data communication

The Data Communication, shown Fig. (4.1)

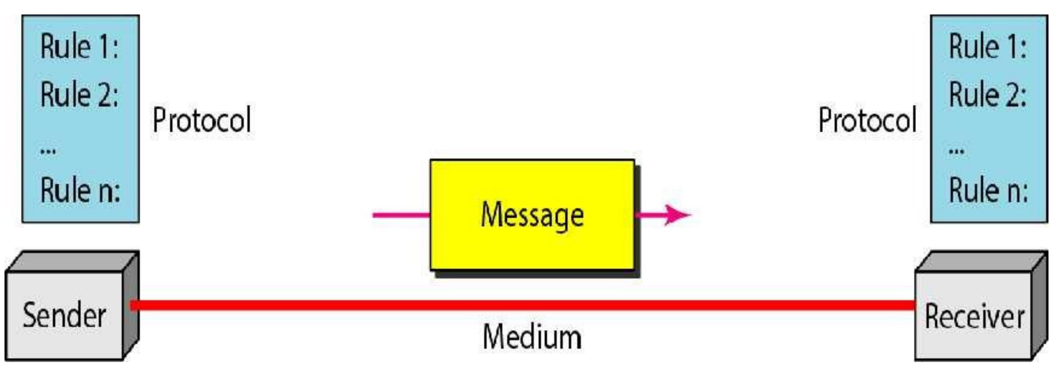

Fig. (4. 1) The Data Communication

- **Message:**The messageis the information(data) to be communicated popularformsofinformationincludetext, numbers, pictures,audio, and video.
- **Sender:** Thesenderisthe devicethat sendsthedata message.Itcanbea computer,workstation,telephone handset, video camera, and so on.
- **Receiver**: Thereceiveristhedevicethatreceivesthe message. It can beacomputer, workstation, telephone handset, television,and so on.
- -**Transmissionmedium**: Thetransmissionmedium isthe physicalpathbywhicha messagetravelsfrom senderto receiver.Someexamplesoftransmissionmedia include twisted-pair wire, coaxialcable, fiber-optic cable, and radiowaves.
- **Protocol:**Aprotocolisa setofrulesthatgoverndata communications.It representsanagreementbetweenthe communicatingdevices.Withoutaprotocol,two devices may beconnectedbut not communicating..
- **DataFlow**:
  Communication between two devices can be simplex, half-duplex,or full-duplex.
- **Simplexmode**, thecommunicationisunidirectional, onlyoneofthetwodevicesonalinkcantransmit;the other can onlyreceive. Direction of Data, shown Fig. (4.2).

Fig. (4. 2) Direction of Data

- **Half-duplex**mode,eachstationcanbothtransmitand receive,butnot atthe sametime. Direction of Data 2, shown Fig. (4.3).

Fig. (4. 3) Direction of Data 2

-DataFlow

- **Full-duplex**mode(alsocalledduplex),bothstations cantransmitand receivesimultaneously.In full-duplex mode, signalsgoinginonedirectionshare thecapacityof the link. Direction of Data Time, shown Fig. (4.4).

Fig. (4. 4) Direction of Data Time

Process describing transfer of information, data, instructionsbetweenone ormore systemsthrough CHANNEL(somemedia).

ACHANNELisapathbetweentwocommunication deviceswhichConsistsofoneormore transmission media.

Signalspassingthroughthecommunicationchannel can be:

- **Digital:**individualelectrical pulses(bits).
- **Analogsignals**:continuouselectricalwaves.

4.3 -DataCommunicationSignals:

Signals: When data is sent over physical medium itneedstobe first convertedinto electromagnetic signals.

Datacan be representedin:

-DigitalSignals:

Digitalsignalsarediscreteinnatureandrepresents sequenceofvoltagepulses. Digitalsignalsareused within the circuitryof acomputer system.

-AnalogSignals:

Analog signals arei n continuous waveformin natureand representedbycontinuouselectromagnetic waves.

AnalogandDigitalSignals is shown in fig (4.5)

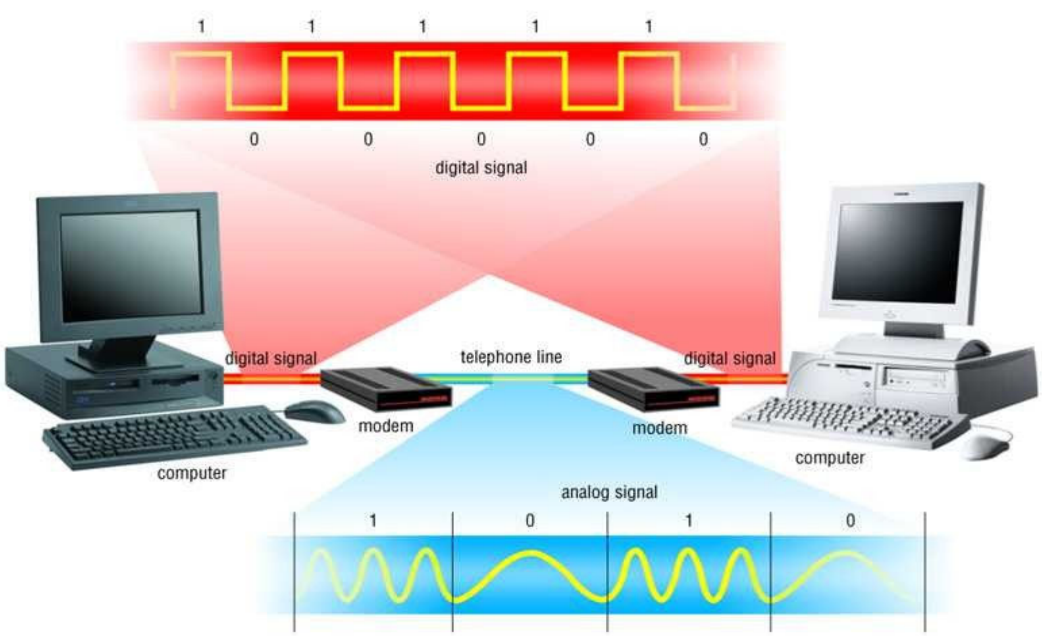

Fig. (4. 5) Analog and Digital Signals

Transmission Methods in Current Communications Networks is shown in fig (4.6).

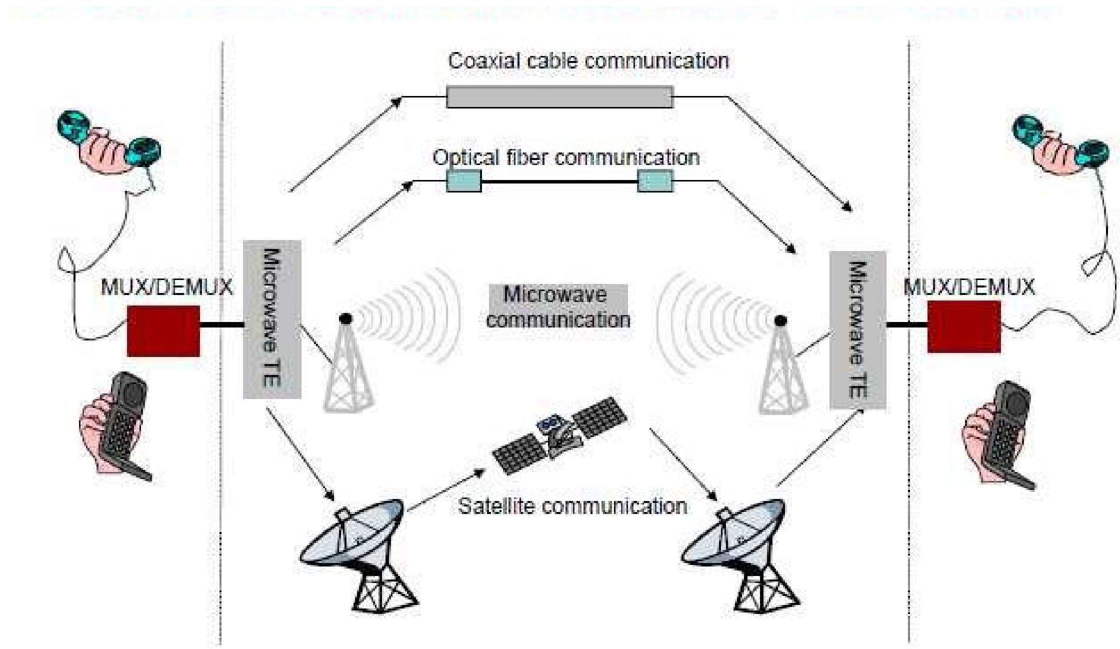

Fig. (4. 6) Transmission Methods in Current Communications Networks

4.4 SCADAProtocols

SCADACommunicationProtocols: i s asetofstandard rules thatdefinehow devices talk toeach other. This includes data representation, signaling, authentication anderrordetectionrequiredtosend informationover communication channel.

Manyoftheseprotocols, however,aregenerallybasedon the Internet Protocol Suite(TCP/IP)

SCADA communication system should used appropriate standard non-proprietary protocol that is availabletoanyandthathasaabilityfortransmissionof data from point A to point B using serial and IP communications.

- ObjectivesofSCADA protocols:

Provide Standardized rule for data transfer (interoperabilityamong vendors).

Ensure Reliable datatransfer (CRCorchecksum).

Provide useful features (Timestamps or Freeze operations).

Providedataqualityindicators.

Providefeaturestodetectorpreventunauthorizeduser or monitoringof data

Minimizeprotocoloverhead(optimizeuseofavailable bandwidth).

The main block diagram of SCADA Protocols is shown fig (4.7)

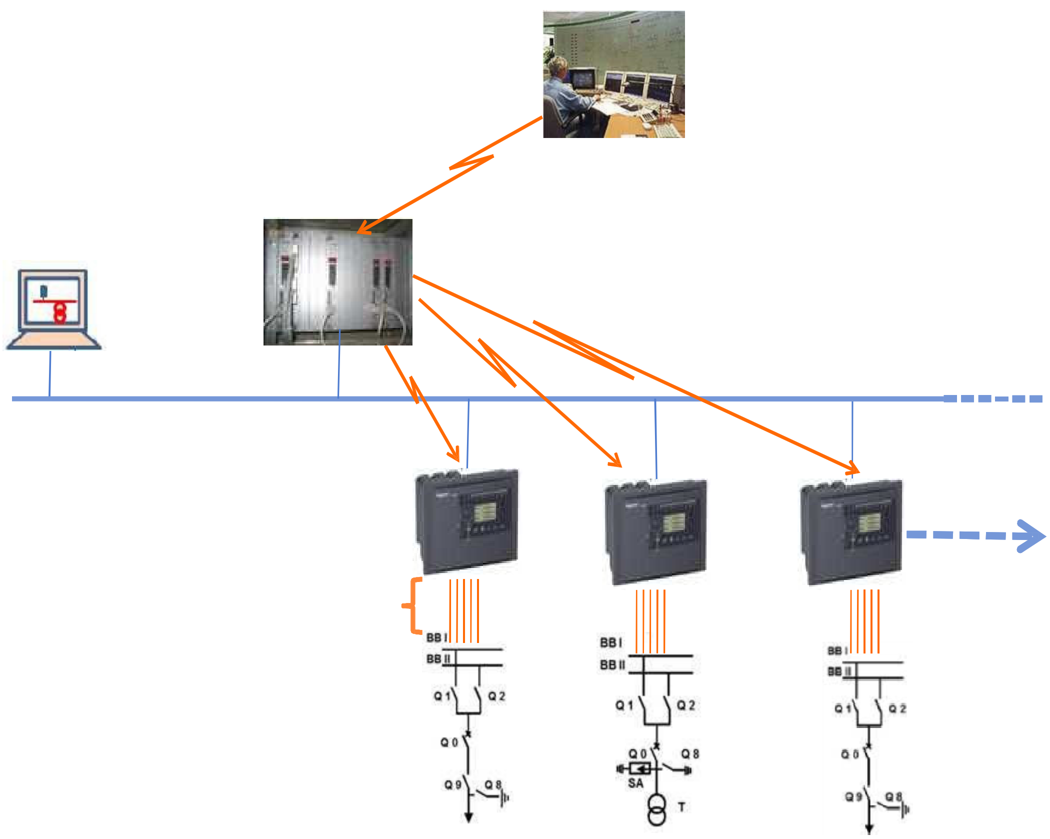

Fig. (4. 7) The Main Block Diagram of SCADA protocol

The Diagram of Polling techniques for master station and RTUs, shown fig (4-8)

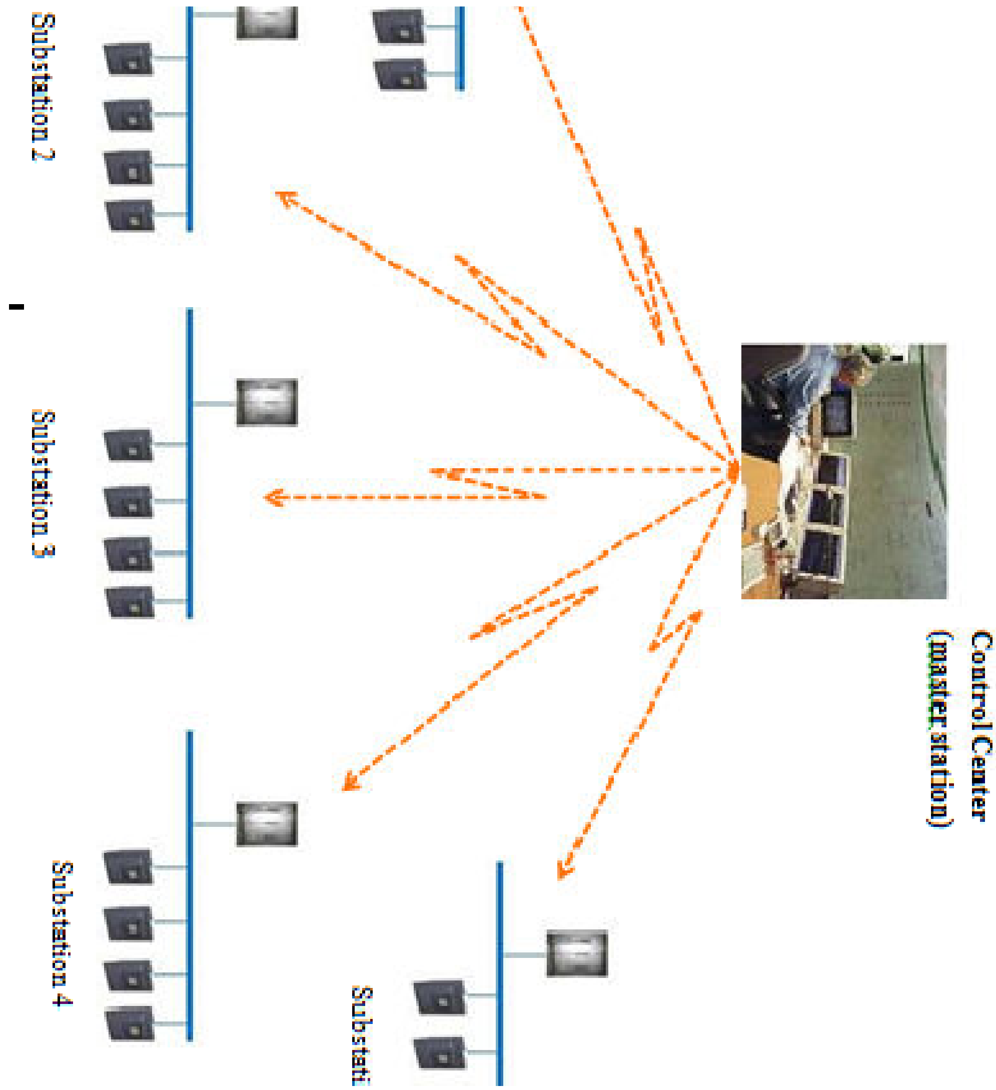

Fig. (4. 8) The Diagram of Polling techniques for master station and RTUs

The Diagram of Polling techniques for master station and RTUs , shown Fig. (4.9).

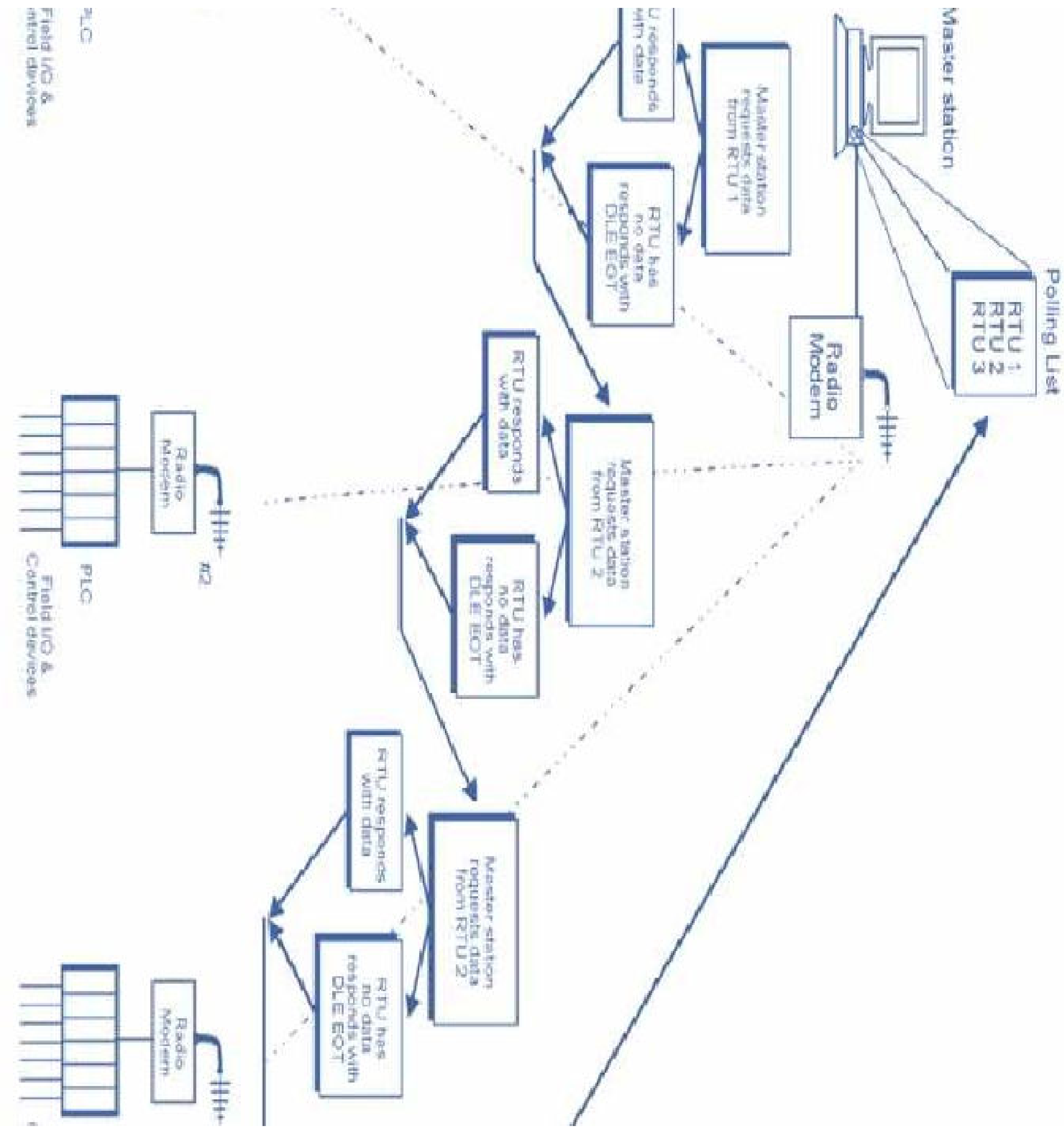

Fig. (4. 9) The Diagram of Polling techniques for master station and RTUs

Unsolicited Responses techniques for master station and RTU,Shown in fig(4.10).

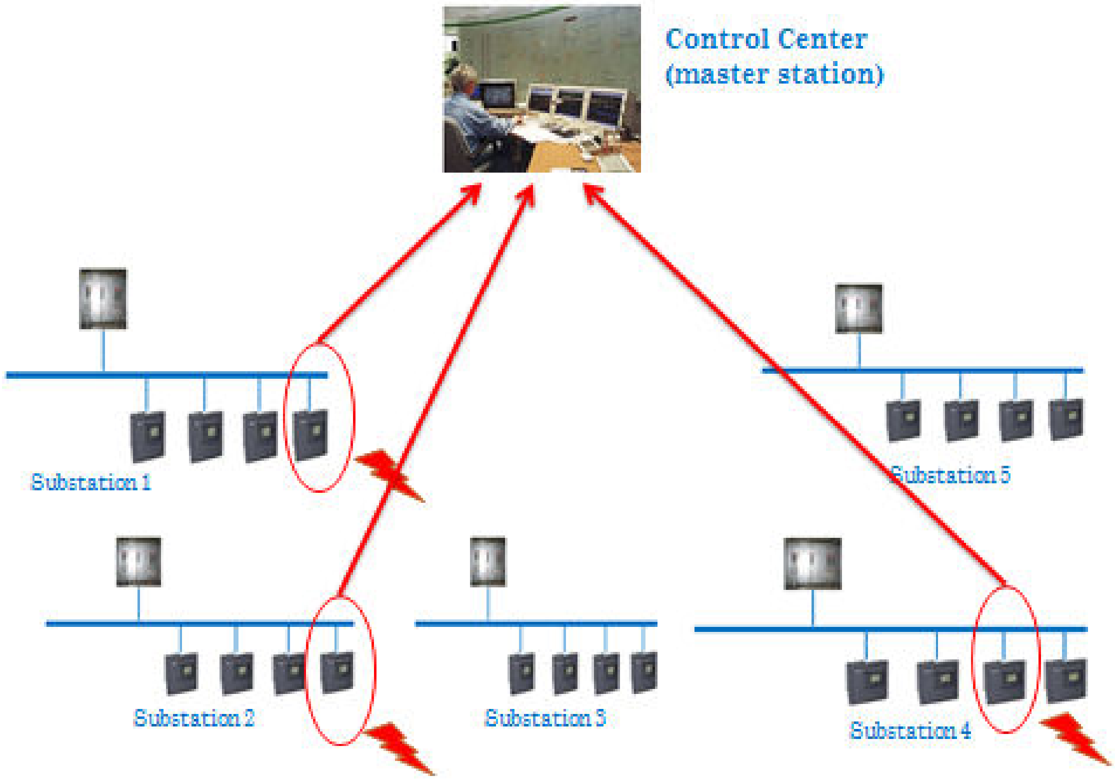

Fig. (4. 10) Unsolicited Responses techniques for master station and RTU,

4.5 SendingCommand:

a. ResettheRelay:

- Selecttheresetbutton.
- Press F9
- Choosethe reset option
- Confirmthecommand

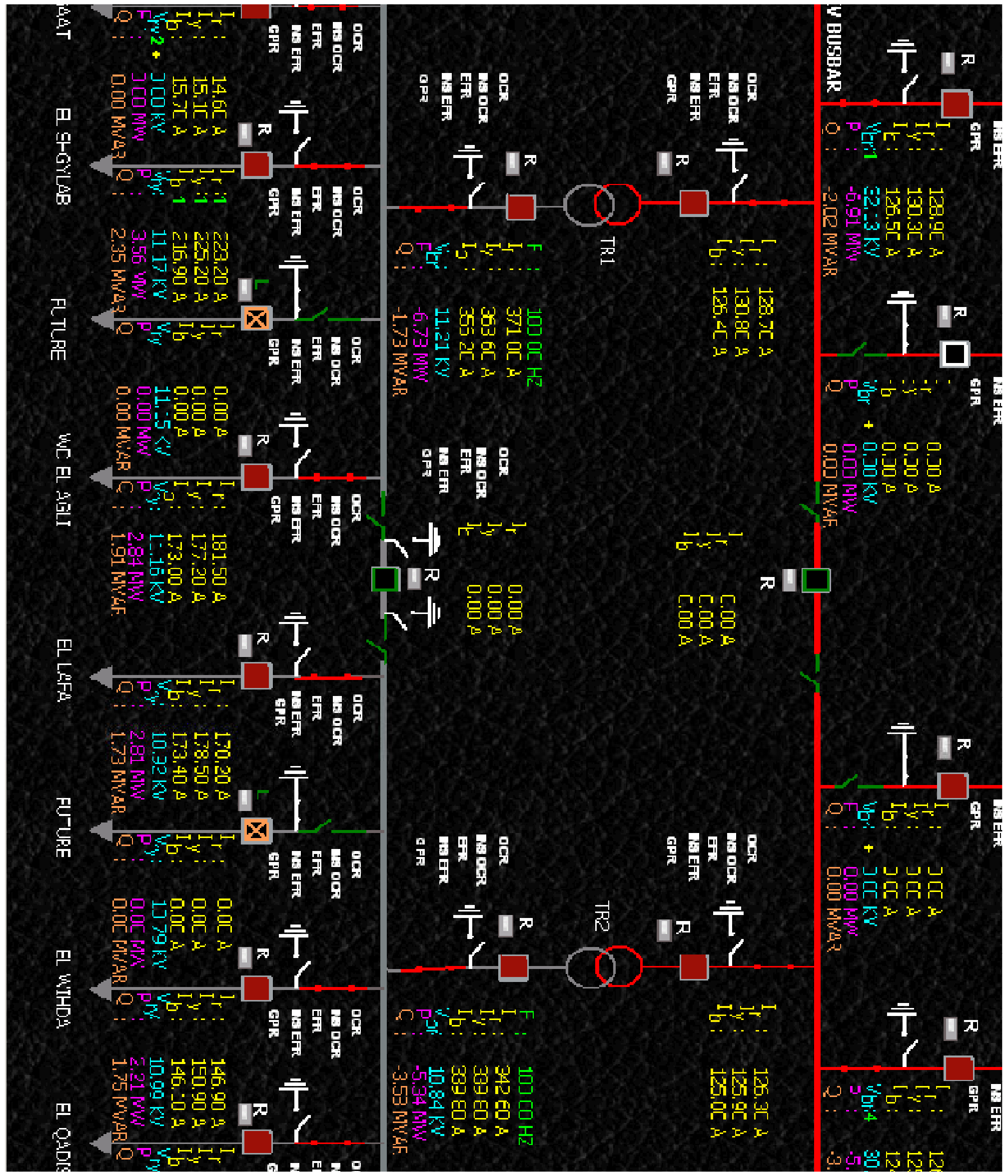

Fig. (4. 11) Operation System

4.6 Monitoring:

a. Monitoring analogvalues.

b. Monitoring status.

c. See the protection alarms&trips.

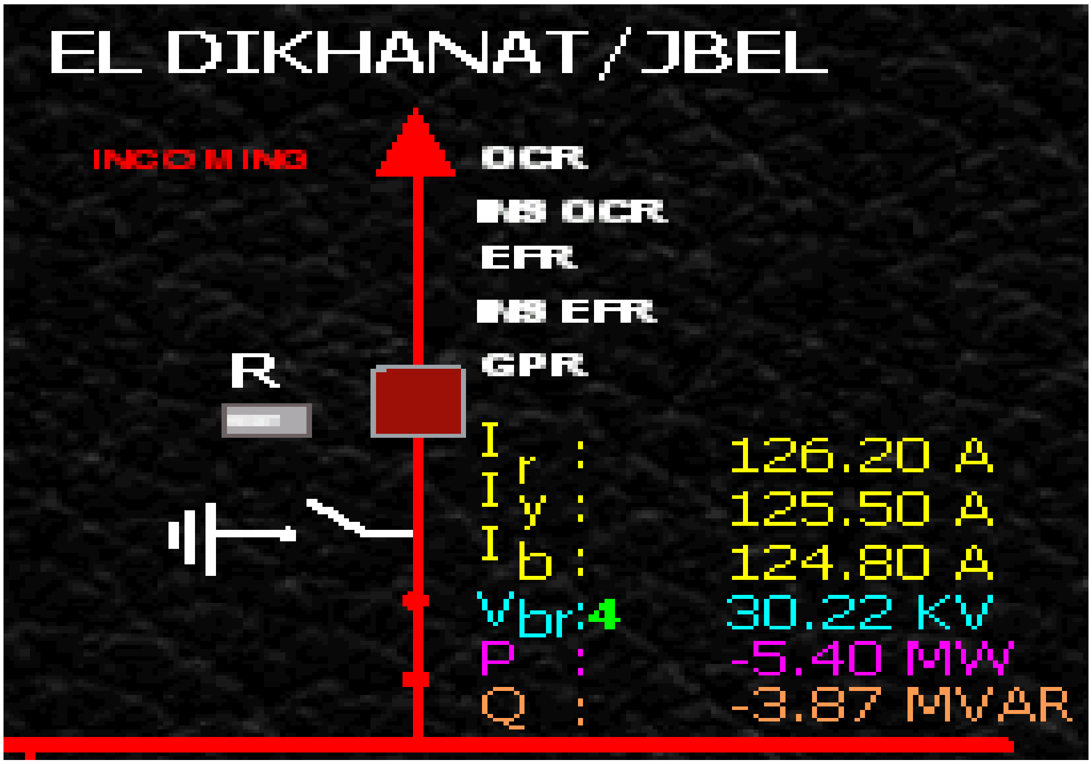

Fig. (4. 12)Single Line Diagram

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion:

The SCADA is a supervisory system used in large and complex systems. National Company for the Distribution of Sudanese Electricity has the strongest control system in neighboring countries despite the generation problems.

SCADA the important benefits of an EMS can be addresses as the following functions:

Continuous monitoring of process.

Real timecontrol.

Automation and Protection.

Remote control and operatio

5.2 Recommendations:

The supervisory control and data acquisition can be applied in may industrial area such as the load dispatch center, complex control system, industries pipe line petroleum system.

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5. https://www.allaboutcircuits.com/technical-articles/an-introduction-to-scada-systems/. 4.11.2020, 10:00 PM.