UNDERSTANDING OF SCADA APPLICATION IN PIPELINE AND DEVELOPMENT OF LOGIC SEQUENCE

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May, 2008

UNDERSTANDING OF SCADA APPLICATION IN PIPELINE AND DEVELOPMENT OF LOGIC SEQUENCE

A thesis submitted in partial fulfillment of the requirements for the Degree of
Bachelor of Technology
(Applied Petroleum Engineering & Gas Engineering)

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CERTIFICATE

This is to certify that the work contained in this thesis titled "Understanding of SCADA application in application in pipeline and development of logic sequence for case study" has been carried out by Jagdeep Bishnoi and Vibhanshu Tripathi under my supervision and has not been submitted elsewhere for a degree.

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Abstract

PLC and SCADA are used to provide automation in plants and pipelines. The need for automation arises because of better working of system, reliability, strict environment rules for pipelines and due to its cost effectiveness. The PLC stands for Programmable Logic Controller and SCADA stands for Supervisory Control and Data Acquisition. In manual control system, an operator may periodically read the process temperature and adjust the heating or cooling input up or down in such a direction as to drive the temperature to its desired value. In automatic control measurements and adjustments are made automatically on a continuous basis. This process of making products under the control of computers and programmable controllers is known as Industrial Automation. Automation is delegation of human control functions to technical equipment for increasing productivity, better quality, increasing safety in working conditions while reducing manpower and cost.

ACKNOWLEDGEMENT

This is to acknowledge with thanks the help, guidance and support that I have received for this project. First and foremost my sincerest thanks are due to Dr. B. P. Pandey (Dean, College of Engg.) for accepting the aforesaid project.

I would like to thank Mr. Kamal Bansal (Mentor) for undertaking the responsibility and pains of guiding me through my Major Project Dissertation.

I have no words to express a deep sense of gratitude to the University Of Petroleum and Energy Studies for providing me an opportunity to pursue my Project work based on the importance of subsurface maps in the petroleum industry particularly for basin analysis and for providing me sufficient help.

Finally, I would like to express thanks to all my friends and classmates who have directly or indirectly supported us during the project.

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Nomenclature

PLC	Programmable Logic Control
SCADA	Supervisory Control and Data Acquisition
CPU	Central Processing Unit
NO	Normally Open
NC	Normally Closed
LAD	Ladder Logic
I/O	Input/Output
RTU	Remote Terminal Unit
RF	Radio Frequency
SPM	Single Point Mooring
CPC	Caspian Pipeline Consortium
MMcf	Million Metric Cubic Feet
GUI	Graphic User Interface

Chapter 1
Introduction

A PLC is a solid state / computerized industrial computer that performs discrete or sequential logic in a factory environment. It was originally developed to replace mechanical relays, timers, counters. PLCs are used successfully to execute complicated control operation in plant. Its purpose is to monitor crucial process parameters and adjust process operations accordingly. A sequence of instructions is programmed by the user to the PLC memory and when the programme is executed, the controller operates a system to the correct operating specifications.

The first PLC system evolved from conventional computers in late 60s and early 70s. These first PLCs were installed primarily in automotive plants. Traditionally the auto plant had to be shut down for up to a month at model changeover time. The early PLCs were used with the other automation techniques to shorten the changeover time. The PLC programming procedures replaced the rewiring a panel full of wires, relays, timers, counters and other components. The PLCs helped reduce the changeover time to a matter of few days.

SCADA is an acronym which stands for Supervisory Control and data Acquisition. A supervisory control system has the ability and intelligence to perform controls with minimal supervision. A data acquisition system has the ability to gather data. A combination of PLC and SCADA gives the advantage of having better monitoring and control of operation. It also helps in viewing and interacting with the workings of the entire operations through graphical representation of their production process.

SCADA runs on a PC and is generally connected to various PLCs. SCADA constantly gathers data from the plant in real time, stores and processes it in the database, evaluates and generates alarms, displays information to operators, supervisors, engineers and managers who in turn can issue instructions to the various PLCs as required.

Chapter 2

PLC

Programmable Logic Controllers (PLCs), also referred to as programmable controllers, are in the computer family. They are used in commercial and industrial applications. A PLC monitors inputs, makes decisions based on its program, and controls outputs to automate a process or machine. This course is meant to supply you with basic information on the functions and configurations of PLCs.

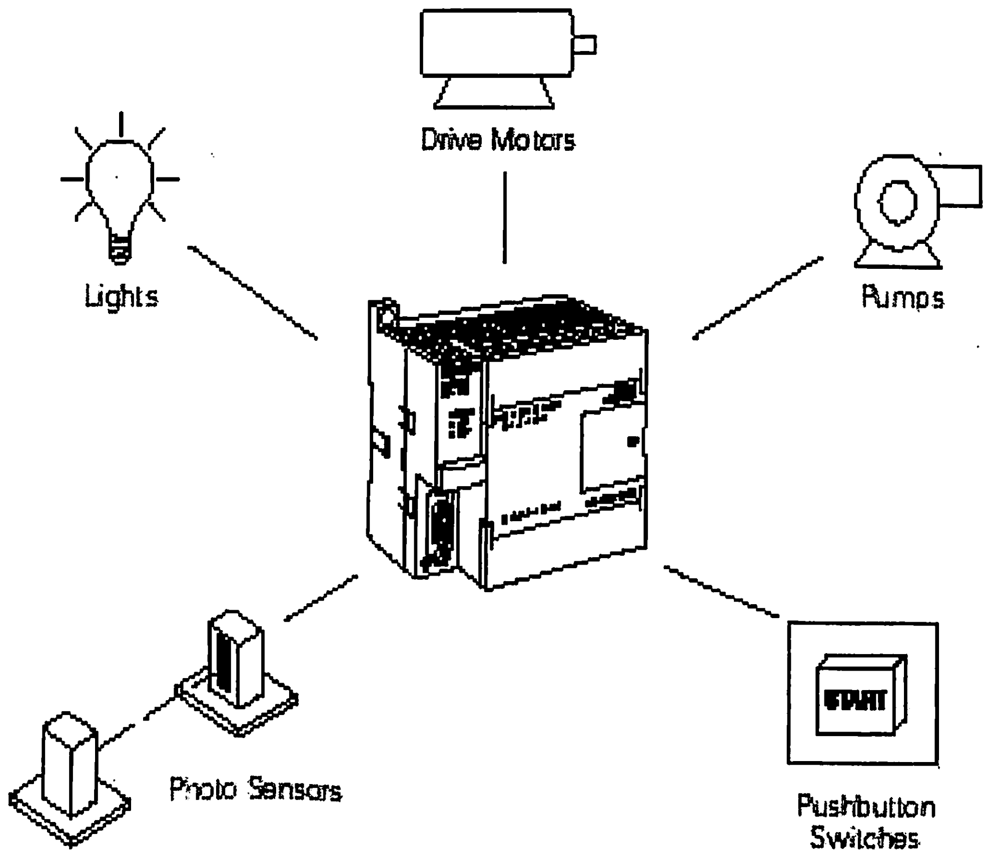


Figure 2.1: PLC System

2.1 Basic PLC Operation:

PLCs consist of input modules or points, a Central Processing Unit (CPU), and output modules or points. An input accepts a variety of digital or analog signals from various field devices (Sensors) and converts them into a logic signal that can be used by the CPU. The CPU makes decisions and executes control instructions based on program instructions in memory. Output modules convert control instructions from the CPU into a digital or analog signal that can be used to control various field devices (Actuators). A programming device is used to input the desired instructions. These instructions determine what the PLC will do for a specific input. An operator interface device allows process information to be displayed and new control parameters to be entered.

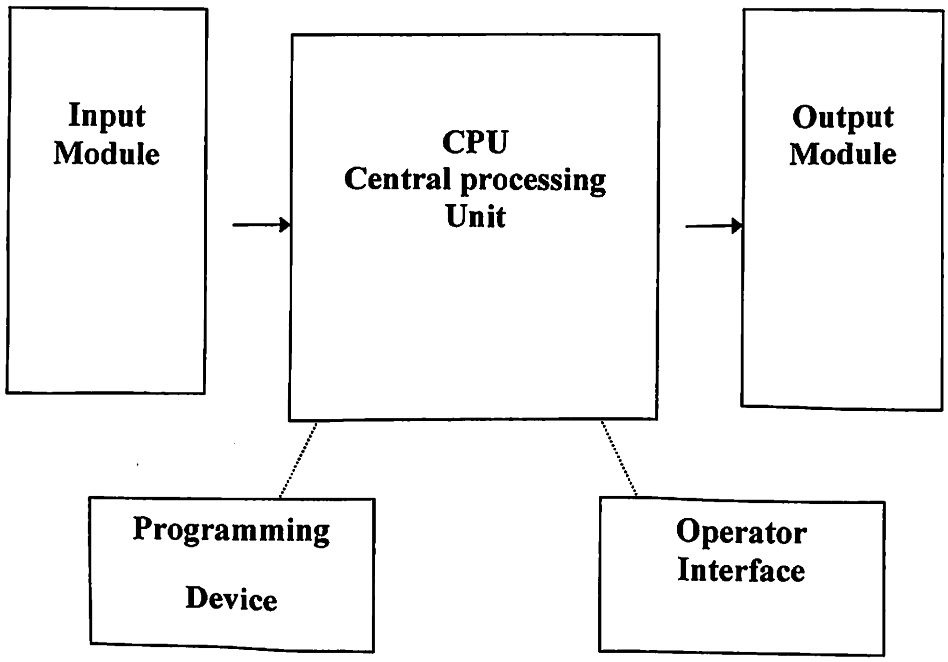


Figure 2.2: PLC Structure

Pushbuttons (sensors), in this simple example, connected to PLC inputs, can be used to start and stop a motor connected to a PLC through a motor starter (actuator).

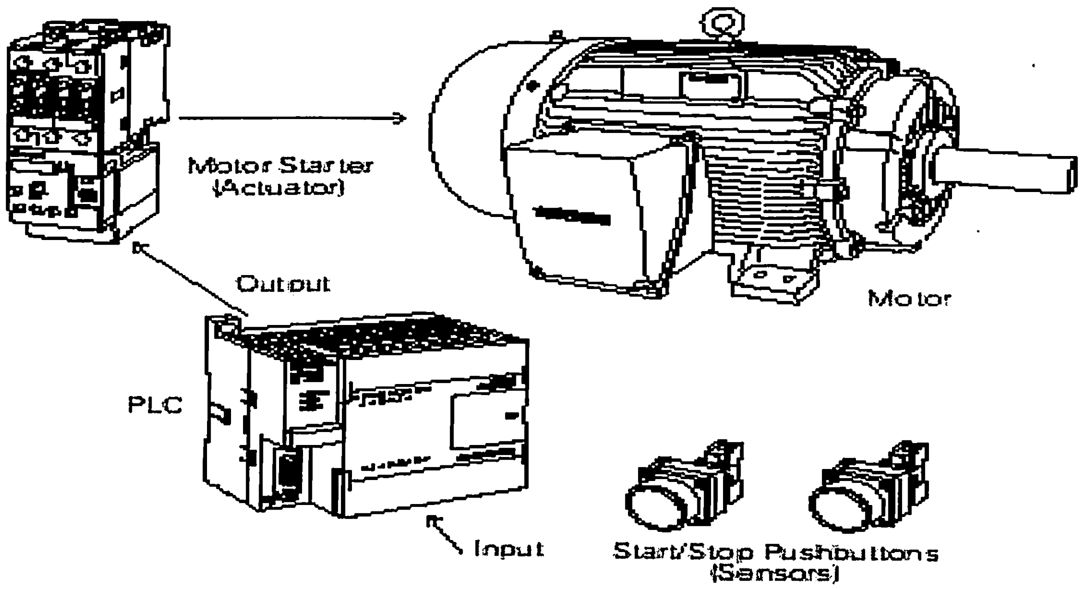


Figure 2.3: PLC Design

2.2 Advantages of PLCs:

The same, as well as more complex tasks can be done with a PLC. Wiring between devices and relay contacts is done in the PLC program. Hard-wiring, though still required to connect field devices, is less intensive. Modifying the application and correcting errors are easier to handle. It is easier to create and change a program in a PLC than it is to wire and re-wire a circuit.

Following are just a few of the advantages of PLCs:

- Smaller physical size than hard-wire solutions.
- Easier and faster to make changes.
- PLCs have integrated diagnostics and override functions.
- Diagnostics are centrally available.
- Applications can be immediately documented.
- Applications can be duplicated faster and less expensively.

2.2.1 Number Systems:

Since a PLC is a computer, it stores information in the form of On or Off conditions (1 or 0), referred to as binary digits (bits). Sometimes binary digits are used individually and sometimes they are used to represent numerical values.

Decimal System:

Various number systems are used by PLCs. All number systems have the same three characteristics: digits, base, weight. The Decimal system, which is commonly used in everyday life, has the following characteristics:

Ten digits	0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Base	10
Weights	1, 10, 100, 1000...

Binary System:

The binary system is used by programmable controllers. The binary system has the following characteristics:

Two digits	0, 1
Base	2
Weights	Powers of base 2 (1, 2, 4, 8, 16 ...)

2.3 Terminology:

The language of PLCs consists of a commonly used set of terms; many of which are unique to PLCs. In order to understand the ideas and concepts of PLCs, an understanding of these terms is necessary.

2.3.1 Sensor:

A sensor is a device that converts a physical condition into an electrical signal for use by the PLC. Sensors are connected to the input of a PLC. A pushbutton is one example of a sensor that is connected to the PLC input. An electrical signal is sent from the pushbutton to the PLC indicating the condition (open/closed) of the pushbutton contacts.

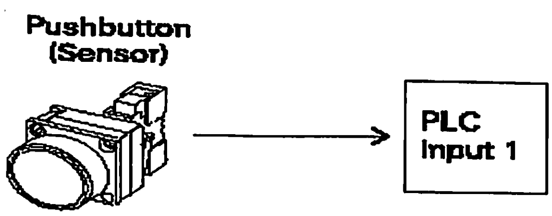


Figure2 4 Sensors

2.3.2 Actuators:

Actuators convert an electrical signal from the PLC into a physical condition. Actuators are connected to the PLC output. A motor starter is one example of an actuator that is connected to the PLC output. Depending on the output PLC signal the motor starter will either start or stop the motor.

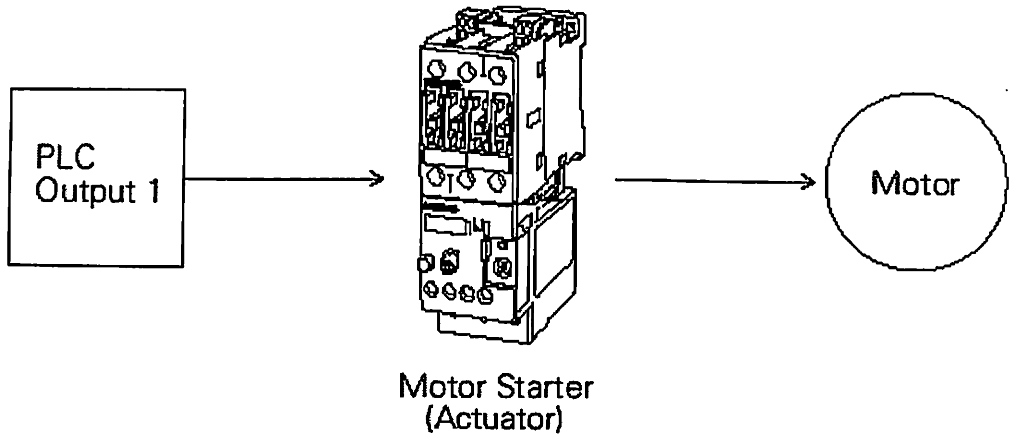


Figure 2.5 Actuators

2.3.3 Discrete Input:

A discrete input, also referred to as a digital input, is an input that is either in an **ON** or **OFF** condition. Pushbuttons, toggle switches, limit switches, proximity switches, and contact closures are examples of discrete sensors which are connected to the PLCs discrete or digital inputs. In the **ON** condition a discrete input may be referred to as logic 1 or logic high. In the **OFF** condition a discrete input may be referred to as logic 0 or a logic low.

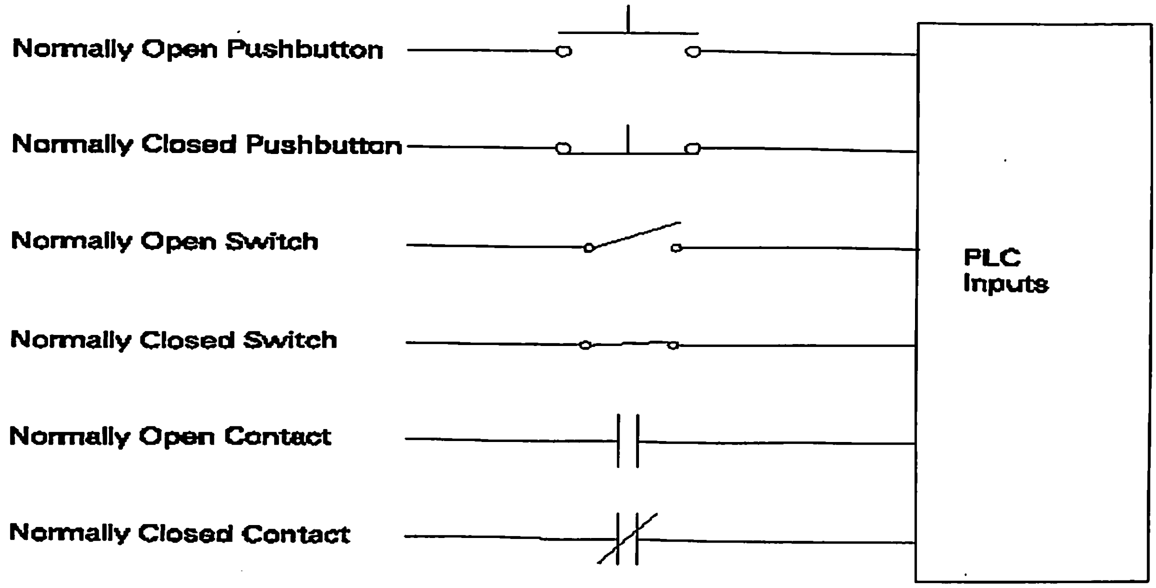


Figure 2.6 Switches

A Normally Open (NO) pushbutton is used in the following example. One side of the pushbutton is connected to the first PLC input. The other side of the pushbutton is connected to an internal 24 VDC power supply. Many PLCs require a separate power supply to power the inputs. In the open state, no voltage is present at the PLC input. This is the OFF condition. When the pushbutton is depressed, 24 VDC is applied to the PLC input. This is the ON condition.

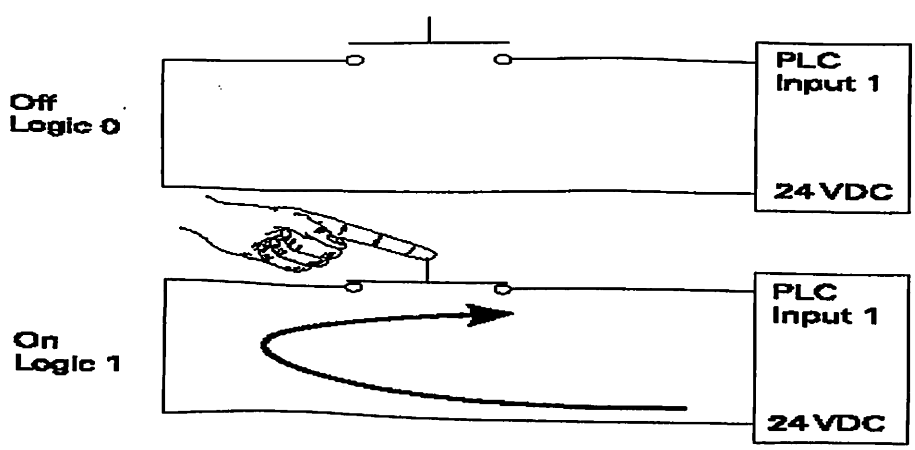


Figure 2.7 ON/OFF Switch

2.3.4 Analog Inputs:

An analog input is a continuous, variable signal. Typical analog inputs may vary from 0 to 20 milliamps, 4 to 20 milliamps, or 0 to 10 volts. In the following example, a level transmitter monitors the level of liquid in a tank. Depending on the level transmitter, the signal to the PLC can either increase or decrease as the level increases or decreases.

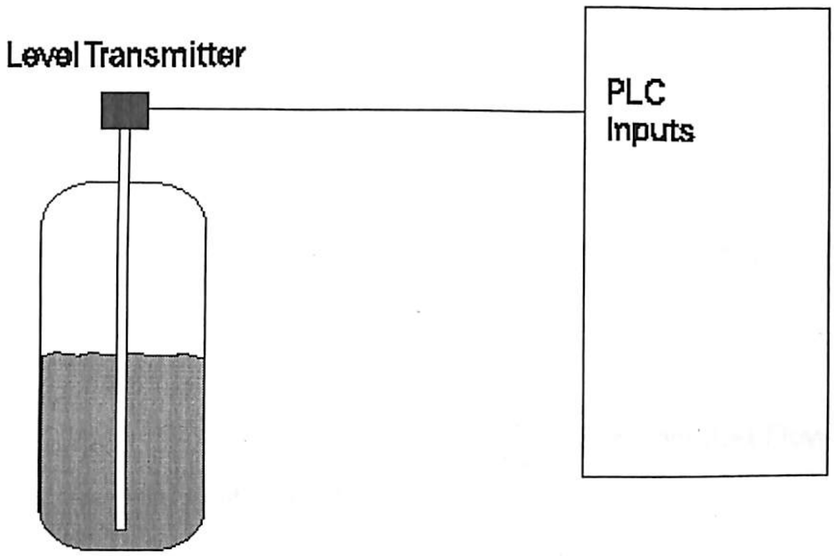


Figure 2.8 Analog input

2.3.5 Discrete Outputs:

A discrete output is an output that is either in an ON or OFF condition. Solenoids, contactor coils, and lamps are examples of actuator devices connected to discrete outputs. Discrete outputs may also be referred to as digital outputs. In the following example, a lamp can be turned on or off by the PLC output it is connected to.

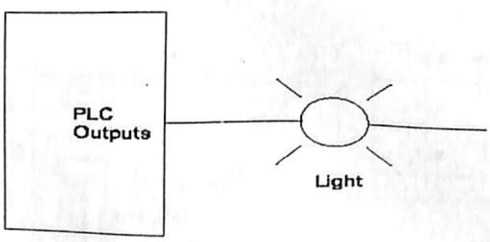


Figure 2.9 Discrete outputs

2.3.6 Analog Outputs:

An analog output is a continuous, variable signal. The output may be as simple as a 0-10 VDC level that drives an analog meter. Examples of analog meter outputs are speed, weight, and temperature. The output signal may also be used on more complex applications such as a current-to-pneumatic transducer that controls an air-operated flow-control valve.

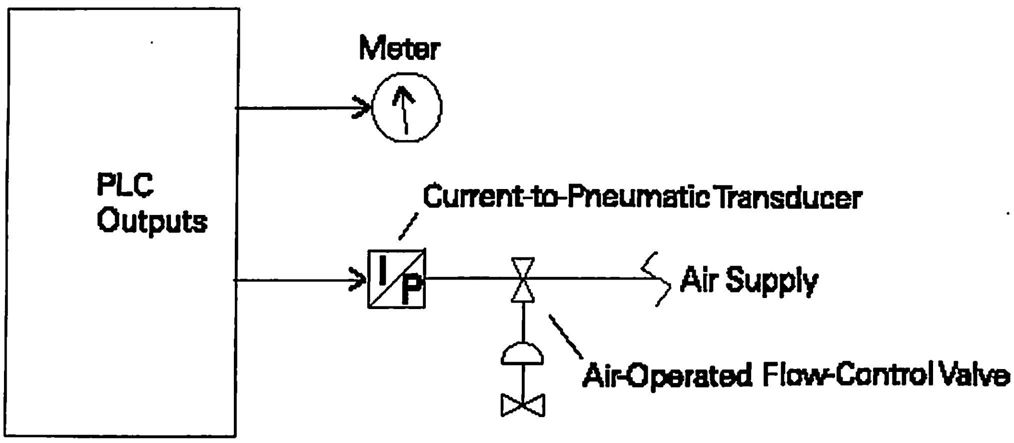


Figure 2.10 Analog output

2.3.7 CPU:

The central processor unit (CPU) is a microprocessor system that contains the system memory and is the PLC decision-making unit. The CPU monitors the inputs and makes decisions based on instructions held in the program memory. The CPU performs relay, counting, timing, data comparison, and sequential operations.

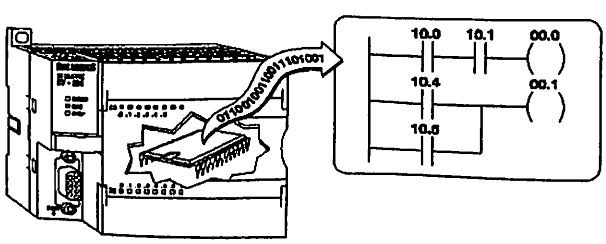


Figure 2.11 Central processing unit

2.3.8 Programming:

A program consists of one or more instructions that accomplish a task. Programming a PLC is simply constructing a set of instructions. There are several ways to look at a program such as ladder logic, statement lists, or function block diagrams.

2.4 Ladder Logic:

Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hard-wired control.

2.4.1 Ladder Logic Diagram:

The left vertical line of a ladder logic diagram represents the power or energized conductor. The output element or instruction represents the neutral or return path of the circuit. The right vertical line, which represents the return path on a hard-wired control line diagram, is omitted. Ladder logic diagrams are read from left-to-right, top-to-bottom. Rungs are sometimes referred to as networks. A network may have several control elements, but only one output coil.

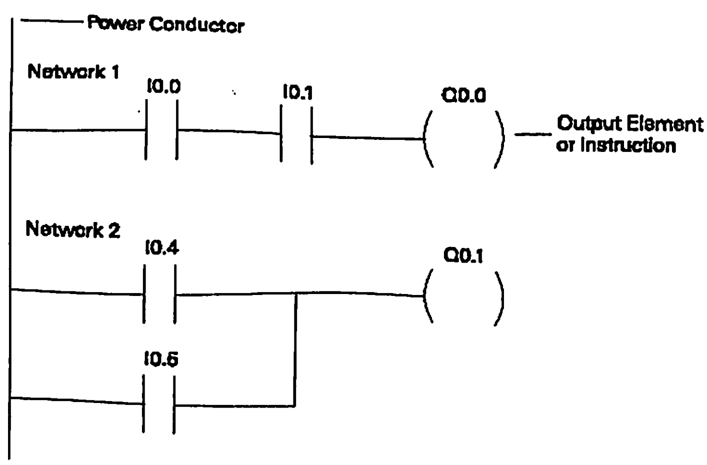


Figure 2.12 Ladder logic diagram

2.5 PLC Scan:

The PLC program is executed as part of a repetitive process referred to as a scan. A PLC scan starts with the CPU reading the status of inputs. The application program is executed using the status of the inputs. Once the program is completed, the CPU performs internal diagnostics and communication tasks. The scan cycle ends by updating the outputs, and then starts over. The cycle time depends on the size of the program, the number of I/Os, and the amount of communication required.

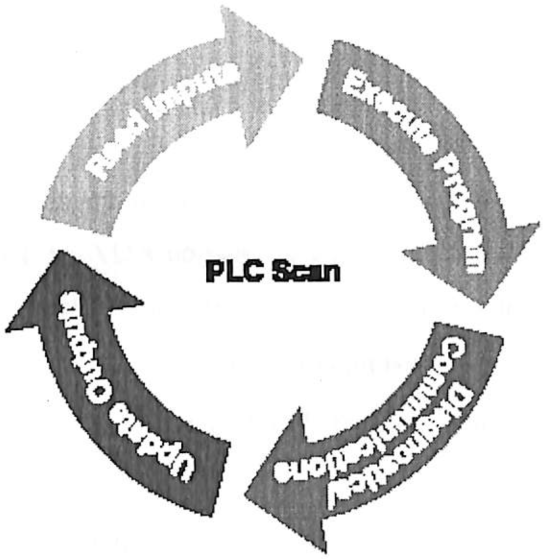


Figure 2.13 PLC Scan

So, in order to create or change a program, the following items are needed:

- PLC
- Programming Device
- Programming Software
- Connector Cable

Chapter 3
SCADA

SCADA stands for supervisory control and data acquisition. A supervisory control system has the ability and intelligence to perform controls with minimal supervision. A data acquisition system has the ability to gather data. Earlier PLC s used to be black boxes. PLCs were programmed and it would run for years. But the problem was that there was no information about what was happening inside the PLC. Now a days automation system contains PLCs and SCADA software. The use of combination of PLC and SCADA gives the advantage of better monitoring and control of the plant and also give access to the information in the way desired. SCADA enabled engineers, supervisors, managers, and operators to view and interact with the workings of entire operations through graphical representation of the production process.

SCADA runs on a PC and is generally connected to various PLCs and other peripheral devices. SCADA constantly gathers data from the plant in real-time, stores and process it in the database, evaluates and generates alarms, displays information to plant operators, supervisors and managers and can issue instructions to PLCs on the plant floor. So, SCADA systems are specialized systems used to monitor and control remote facilities. They commonly are used in the gas, oil, electric and water transmission and distribution industries where facilities are stretched over a large area. A SCADA system can be divided into following essential areas:

- Sensors and Actuators
- Remote Terminal Units (RTUs)
- Communications
- Host central computer systems
- User interface

3.1 Sensors and Actuators:

A SCADA system's ultimate purpose is to monitor and control facilities. There are various devices that provide the interface between the system and the outside world. These devices can be divided into two categories:

- Sensors convert external data into input signals that can be used by the SCADA system.
- Actuators take signals from the SCADA system and convert them into control actions.

The sensors provide means of converting a deterministic value into a signal that can be understood by the RTU. The signals can be any of the three types:

- Analog input providing a representation of a measured variable, such as temperature, flow rate and pressure.
- Status (or Digital) input provides a logical, true or false, representation of data.
- Pulse input, usually a frequency signal proportional to some measured variable.

Actuators or output devices can be driven by any of these three types of signal from the RTU:

- Analog actuators use an RTU analog output signal to control variables such as flow rate and pressure.
- Digital outputs are useful for absolute actions, such as opening a valve or launching a pig.
- Pulse outputs often are used as a hand-off signal to other RTUs or controllers.

3.2 Remote Terminal Units:

The RTU is a microprocessor based unit which is specifically designed for real-time processing of input and output data.

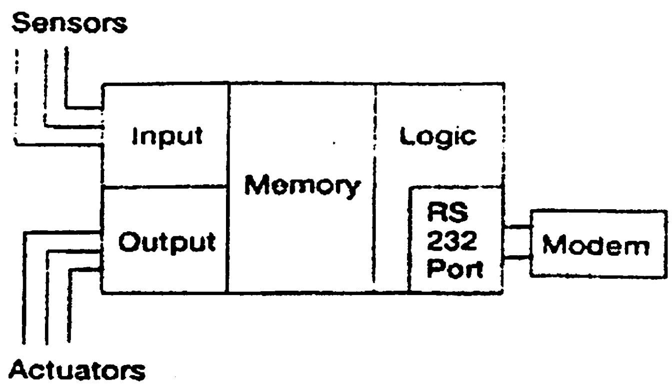


Figure 3.1 Remote terminal unit

On the RTUs input side, the sensor is connected to circuitry which, depending on the signal, converts it into a digital representation for further processing by RTU logic. Similarly, the output circuitry will convert a digital representation of data into a signal that can be understood by an associated actuator.

In the case of an analog signal processing, the sensor is connected to an analog input circuit that runs the current loop through a high precision resistor. The resistor according to Ohm's Law, creates a voltage drop proportional to the amount of current. An analog to digital converter reads the voltage across the resistor to produce a digital count.

Digital inputs are processed in a slightly different manner. The status of the digital input is determined by the input device's ability to produce a small current. Normally the contact is open and no current is flowing and the bit representing the status input is set to zero. If the contact is closed there is a current flow and the bit representing the input is set to one.

The pulse input processing circuitry has a memory variable associated with it that is incrementing by a value of one each time a pulse is sensed, usually a toggle of a status input. This memory variable is called an accumulator.

3.3 Communications:

This area of SCADA system can be looked as data transport mechanism between host computer system and the RTU.

The host can communicate with the RTU via a variety of media, including microwave, dedicated telephone leased lines, dial telephone, radio and satellite. Regardless of the communication method, SCADA systems usually use a communication format referred to as master-slave, meaning all conversations are initiated by the master host computer system. The RTU or slave only replies when it sees a message with its address. The master is one to control all conversation on a communication channel.

3.4 Host System:

The host is the heart of the SCADA system. This is not only because it is master in master/ slave relationship already mentioned but because it controls all data flow through the network.

While the host system can vary greatly, internals can be divided into three functional parts:

- Data Processor: It is system's traffic cop. It is responsible for the routine acquisition of data from RTUs on a scheduled basis, servicing user requests for database access, and activities such as control commands and downloading of parameters.
- Communication Interface: This is where the protocol driver resides. This interface formats data requests from the data processor, routes them to the appropriate communications channel for transmission to the RTU, processes the expected replies, and hands the data back to the data processor. Since the communications driver resides in this area, the system can be designed to utilize multiple drivers for multiple protocols while leaving the data processor essentially generic. This architecture makes it easy to add new protocols.

- Database: It is the repository for all collected data and contains spot data as well as historical data and calculated data. It is common today to have the RTUs store historical data on site. The RTU-generated historical data, when collected by the host, can be stored directly into the historical database.

3.5 MMI or User Interface:

It provides the operator with access to the system. The most common access is via a video display, along with a keyboard and a pointing device. Most system provides some form of graphical display capabilities with high speed resolution and bit mapped graphics.

Traditionally, MMI software ran on the same host hardware as the data processor and the database. Today the trend is to separate this functionality and to use relatively low cost workstation to handle the ever increasing resources demanded by more sophisticated graphic applications. This philosophy, known as client-server technology, separates areas of a host system into stand alone systems connected via a network.

In the client-server philosophy, when an operator calls up a particular display, the "background', or the display's static portion, is generated locally by the MMI workstation, not by the SCADA host. At the same time, the workstation generates a dynamic data request that is sent over the network to the host. The appropriate system respond with the required data elements from the database and the MMI workstation displays the dynamic data along with the static portion of the display.

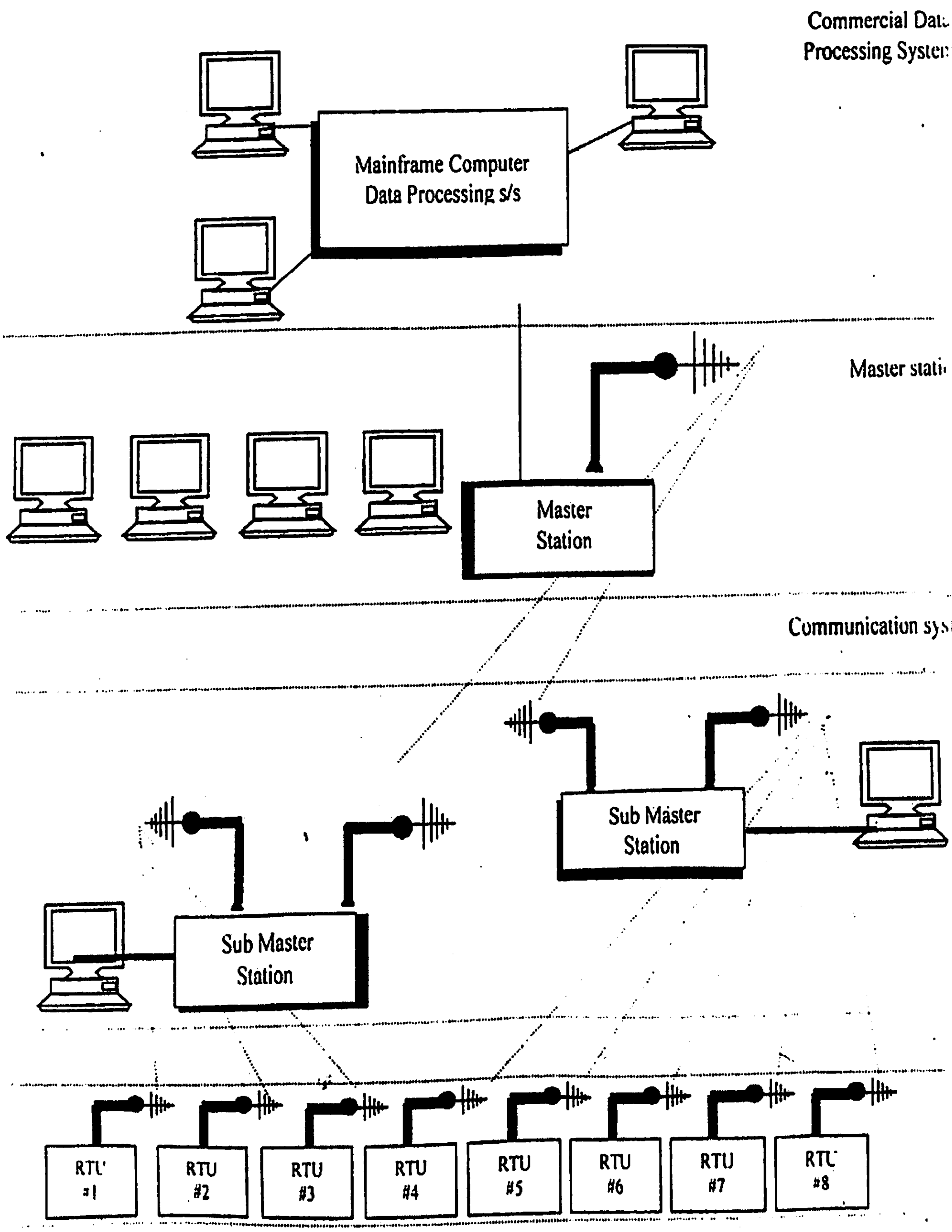


Figure: SCADA System

Figure 3.2 SCADA System

3.6 Benefits of using a SCADA system:

The initial cost of implementing a SCADA system is high and this cost has to be justified. These are few typical reasons for implementing a SCADA system:

- Improved operation of the plant or process resulting in savings due to optimization of the system. It saves money spent on labor and maintenances charges.
- Increased productivity of the personnel. After the implementation of SCADA company has to maintain a lower staff to control the pipeline operations. .
- Improved safety of the system due to better information and improved control with the help of automated alarms and cut off switches.
- Protection of plant equipment.
- Safeguarding the environment from a failure of the system.
- Improved energy saving due to optimization of the plant
- Improved and quicker receipt of data so that clients can be invoiced more quickly and accurately.
- Government regulation for safety and metering of gas (for royalties and tax etc.)

Chapter 4

TELEMETRY IN PIPELINES

4.1 Data transmission and Telemetry:

In modern measurement systems, the various components comprising the system are usually located at a distance from each other. It, therefore becomes necessary to transmit the data, or information between them through some form of communication channels.

The term data transmission and telemetry refer to the process by which information, regarding the quantity being measured, may be using a transducer and a signal conditioning equipment, is transferred to a remote location, perhaps to be processed, recorded and displayed. Telemetry is the technology which enables a user to collect data from several measurement points at inaccessible or inconvenient locations, transmit that data to a convenient location and present the several individual measurements in a usable form

4.2 Methods of Data Transmission:

The transmission of a measured variable to a remote point is an important function in instrumentation systems because of the size and complexity of modern industrial plants. The most common variables encountered in industrial plants are temperature, pressure and flow. Most measuring devices for these variables such as mercury thermometers, pressure gauges or flow rate meters would require fluid line connections of great length from the place of measurement to the place of data recording or display. This will result into excessive measurement lags. Hence, there is a need for fast transmission of data.

The methods employed for data transmission depend upon the variable and the distance over which it has to be transmitted. The following methods may be used for data transmission:

- Hydraulic transmission
- Pneumatic transmission
- Electrical and electronic transmission

The electrical and electronic methods of data transmission are extensively used in instrumentation and measurement systems.

4.3 General Telemetry System:

Telemetry may be defined as measurement at distance. The primary detector and the end device of the telemetering system have the same position and functional roles as in a generalized measuring system.

However there are three system elements in the intermediate stage which are peculiar to a telemetering system:

- Telemeter transmitter
- Telemeter channel
- Telemeter receiver

The function of telemeter transmitter is to convert the output of a primary sensing element into an electrical signal and to transmit it over a telemetering channel. This signal is in electrical format and is received by a receiver placed at a remote location. This signal is converted into a usable form by the receiver and is indicated or recorded by an end device which is graduated in terms of measurand. The end device may be a control element which may be used for the control of the input quantity (measurand), through a feedback loop to produce desired output.

4.4 Types of Telemetry System:

Two types of telemetering systems are used:

- **Land Line Telemetry:**

A land line telemetering system requires a telemeter channel which is a physical link between the telemeter transmitter and receiver. This physical link may be a cable, a specially laid out wire, existing telephone and telegraph, cables or a power line carrier. The land line telemetering is a direct transmission of information through cables and transmission lines. The direct transmissions via cables employ current, voltage, frequency, position or impulses to convey the information. Current, voltage and position type systems can be used only for short distances while for long distances telemetering pulse and frequency type of systems are used. The information may be in the form of analog or digital signals. While current, voltage, position, frequency and pulse types of signals can be used for analog telemetry, only pulse signals can be used for digital telemetry.

So, the land line telemetering system can be classified as:

Volatage Telemetering Systems

Current Telemetering Systems

Position Telemetering Systems

- **4.4.1 Radio Frequency Telemetry:**

The telemetry, earlier on, has been defined, as a technology that enables the user to collect data from several measurement points at inaccessible or inconvenient locations. This is a very true of applications which require Radio Frequency telemetry, as in such applications there is no physical link between the transmitting and receiving stations. The link, between the transmission station (where the actual measurements are being carried out and the receiving station (where the measurand is measured, recorded and information used for control purposes) can only be established through radio links.

R.F. telemetry is usually more suitable if the data is to be transmit over distances greater than 1 km. certain parts of the radio-frequency spectrum have been allocated for telemetry and microwave links about 4 MHz. radio waves at these frequencies tend to travel in straight lines, requiring repeater stations with disc like antennas on high buildings and towers (every 30 to 60 km.).

Radio links with airborne instrumentated flight vehicles often used Pulse Duration Modulation (PDM) - Frequency Modulated (FM) systems, with pulse duration varying from a minimum of about 700 micro-seconds.

Chapter 5

Case Study of Use of SCADA in Caspian Pipeline Consortium

The Caspian Pipeline Consortium (CPC) combines the cooperative efforts of the governments of the Russian Federation, The Republic of Kazakhstan, The Sultanate of Oman and a group of international oil companies including Chevron, Mobil and Lukarko. It represents one of Russia's largest ever industrial development ventures, spanning over 1600 km from the rich Tengiz oil fields in Western Kazakhstan, to those along the Caspian Sea and on to the Black Sea coast in Russia, with an eventual capacity of1.34million barrels per day. The pipeline runs from Tengiz (Kazakhstan) to Novorossyisk (Russia) with 5 pump stations and over 100 mainline block valves.

The primary mission for pipeline design and control was to provide the basis for an efficient, safe and environmentally sound operation. Environmental protection being a key concern for this project, construction would adhere to the most stringent standards of the European Union, the World Bank and other international organizations. To meet these standards, the simulation model that would eventually be used to control and operate the pipeline was also used in the design phase for engineering analysis and optimization.

The system needed to include comprehensive SCADA with fully integrated pipeline simulation, leak detection and the ability to perform predictive and look-ahead modeling of the pipeline. Applications also include Threshold Setting, Maximum Throughput Calculations Pipeline Inventory Management, Scraper Tracking, Accounting, Quality Bank, Off-line Planning and Forecasting and Operator Training and Certification. Industrial-quality reliability and redundancy was required for all critical communications, leak detection, control locations and servers.

One truly unique aspect of this project is the early delivery of the pipeline hydraulic model. CPC was able to experiment with the simulator to consider design variations continually and consistently before the final pipeline was completed. An Initial Hydraulic Model was delivered to Moscow early in 2001, and the final revision was delivered recently. CPC have found this to be a big benefit by giving their engineers and operators "hands-on" experience, and testing "what if" scenarios, with the control and monitoring of a pipeline that doesn't even exist in its final form yet. The model's method of characteristics solution technique provides extremely accurate pressure profile calculations – it is amazing to watch a simulated pressure change dissipate as it moves down the pipeline. The simulator was also invaluable as a tool for designing and testing the ladder logic for the Block Valves and Pump Stations on the pipeline. The simulator when used on-line allows leak detection and the ability to perform predictive and look-ahead modeling of the pipeline. Applications include Threshold Setting, Maximum Throughput Calculations, Pipeline Inventory Management, Scraper Tracking, Accounting, Quality Bank, Off-line Planning and Forecasting and Operator Training and Certification. Industrial-quality reliability and redundancy was required for all critical communications, leak detection, control locations and servers.

5.1 THE PIPELINE

The origin of the project dates back to 1996, when a consortium of governments and energy companies developed a plan for constructing a pipeline from the rich Tengiz oil fields in Western Kazakhstan to a new marine terminal to be located on the coast of the Black Sea near Novorossiysk in Russia. From there, oil would be loaded into tankers for shipment to foreign markets. The scope of work included repairing and refurbishing a 754 km span of crude oil pipeline originating in Tengiz and extending it north of the Caspian Sea to Komsomolsk, Russia, then constructing a new 800-kilometer pipeline from Komsomolsk to a new Marine Terminal located near Novorossiysk. The CPC's business is to export oil from the Caspian Sea area through the marine terminals on the Black Sea.

To help do this, Metso Automation was commissioned to supply the SCADA and modeling systems for the 1,600km pipeline, some new and some refurbished. It required one million tons of oil to initially fill the pipeline. During construction of the pipeline, over 160,000 joints were welded and 3,000 kilometers of cable were laid and assembled. The Operations Control Center (OCC), complete with training system, is located at the marine terminal in Novorossiysk, and the Secondary Control Center (SCC) is located at the Kropotkin Pump Station, also in Russia. The tank farm is on land, 8 km from shore, southwest of the existing port of Novorossiysk, taking into consideration the natural features of the terrain.

Figure 5.1 CPC Pipeline Map

5.2 SCADA

The full-scope pipeline management system provided by Metso Automation was used to monitor and control the entire length of the pipeline. The SCADA system links all pipeline components – Pump Stations, Marine Terminal Tank Farm and Shore Facilities, Mainline Block Valves and offshore Single Point Moorings (SPM) – and also integrates the sophisticated simulation and leak detection software. Metso Automation is providing more than one hundred mainline block valve PLC's. These PLC's work in conjunction with equipment supplied by other vendors such as power supply lines, battery power supplies, control instrumentation and high-speed fiber optics with a satellite backup all along the pipeline route. The PLC's are tested individually at the local block valve sites with SCADA software prior to a system-wide test. The SCADA system also interfaces with more than 40 other PLC's configured and installed by contractors. The testing of these PLC's is performed at the contractor location prior to equipment shipment. This was determined to be the best method of testing the SCADA control interface, including SCADA database and controller graphics, before on-site testing occurs. The SCADA system will be used to manage unattended or remote facilities; facilitate centralized control of the pipeline system; provide leak detection and dynamic modeling on-line as well as a training simulator and dynamic model off-line; provide operational interface for SCADA and Leak Detection; generate reports and records for determining shipped product, system performance and operational strategy; monitor and control the quality of crude oil received into the pipeline; minimize operating and maintenance costs and increase overall system reliability.

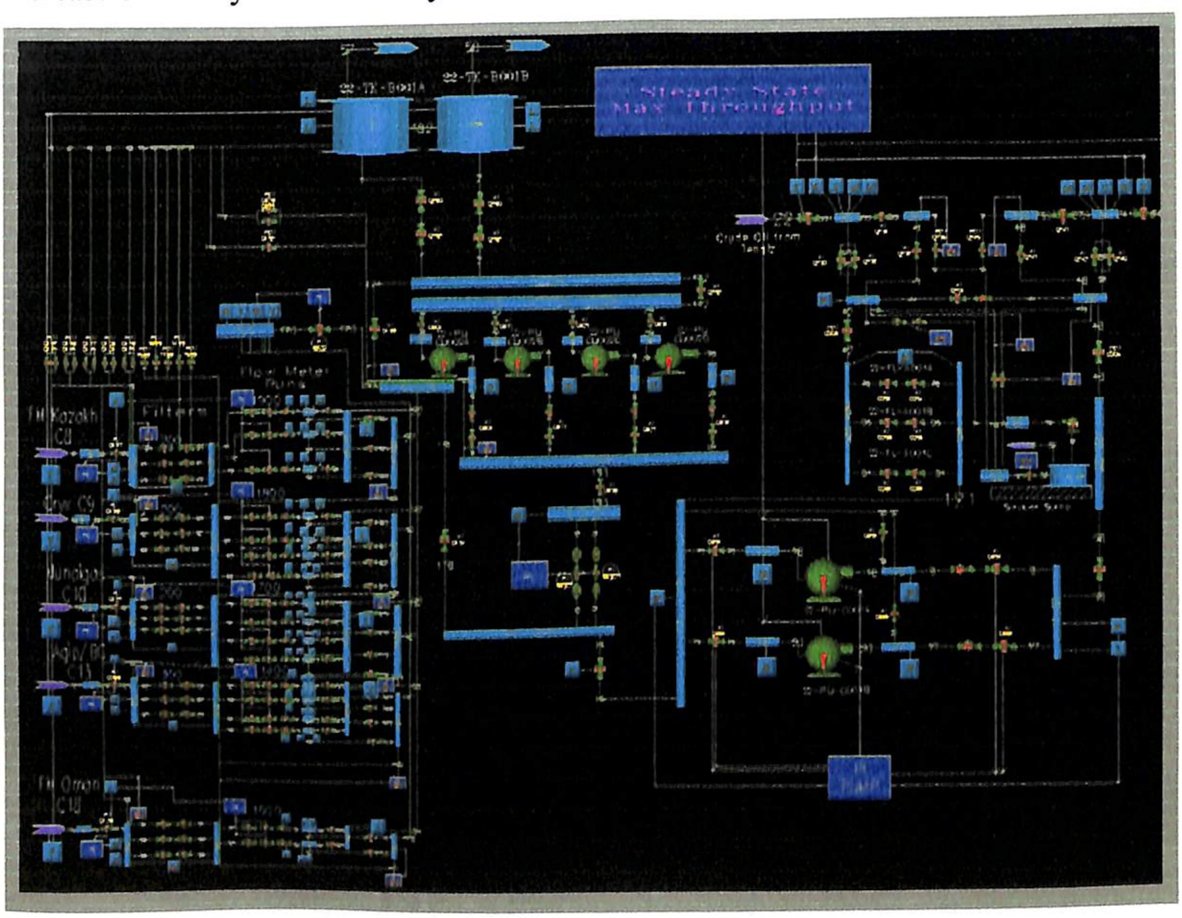


Figure 5.2 SCADA Design of the project

5.3 Benefits of using SCADA in project

All design, construction and operational solutions of the CPC Crude Oil Pipeline System will conform to the most stringent standards set by the European Union, the World Bank and other international organizations. The pipeline is built completely underground along the entire route. Horizontal directional drilling techniques, relatively new in Russia, were used for burying pipe for river crossings. Steps were taken prior to construction to identify sensitive ecosystems and determine methods for their protection. Potential cultural and archaeological sites were also identified and their treasures preserved. Now that pipeline construction and hydraulic testing have been completed, fertile soils are being restored and all lands along the pipeline route are being returned to cultivation. The simulator is very important in this area also, providing the leak detection and operational procedure analysis necessary to minimize the possibility and potential damage due to pipeline incidents. Some practical advantages of this architecture include:

- Stability over a very wide range of operating conditions
- A definite requirement for effective control center operator training using pipeline simulation technology.
- Only one set of code needs to be developed and maintained for all on-line and off-line applications
- Flexibility to utilize the numerical solution techniques best suited to address specific pipeline simulation needs
- Very fast execution speeds:
  Bringing pipeline to solution up to 4 times/ second on CPC
  Maintaining high accuracy at simulation speeds many times real-time
  Leveraging fast fiber optic telecommunication system scan times for extremely high leak detection performance
- Strong dynamic effect modeling, including DRA/waxing/Non-Newtonian flow
- Ability to completely emulate PLC/RTU logic
- Provides very accurate modeling of pipeline control element transient response

- Validates new and/or modified control system designs in an off-line environment
- Tunes PID loops in an off-line environment
- Accurate batch tracking functionality
- Flexibility to use a simple Excel interface to permit rapid facility alternative design analysis
- Models *every* pipe in the system – providing the ability to perform transient hydraulic analysis of pump and compressor station yard piping flows and pressures

The modules are connected tightly with the core real-time platform utilizing the architecture outlined in the diagram below. In this way it becomes a high-availability industrial real-time application on the same level as the core SCADA system.

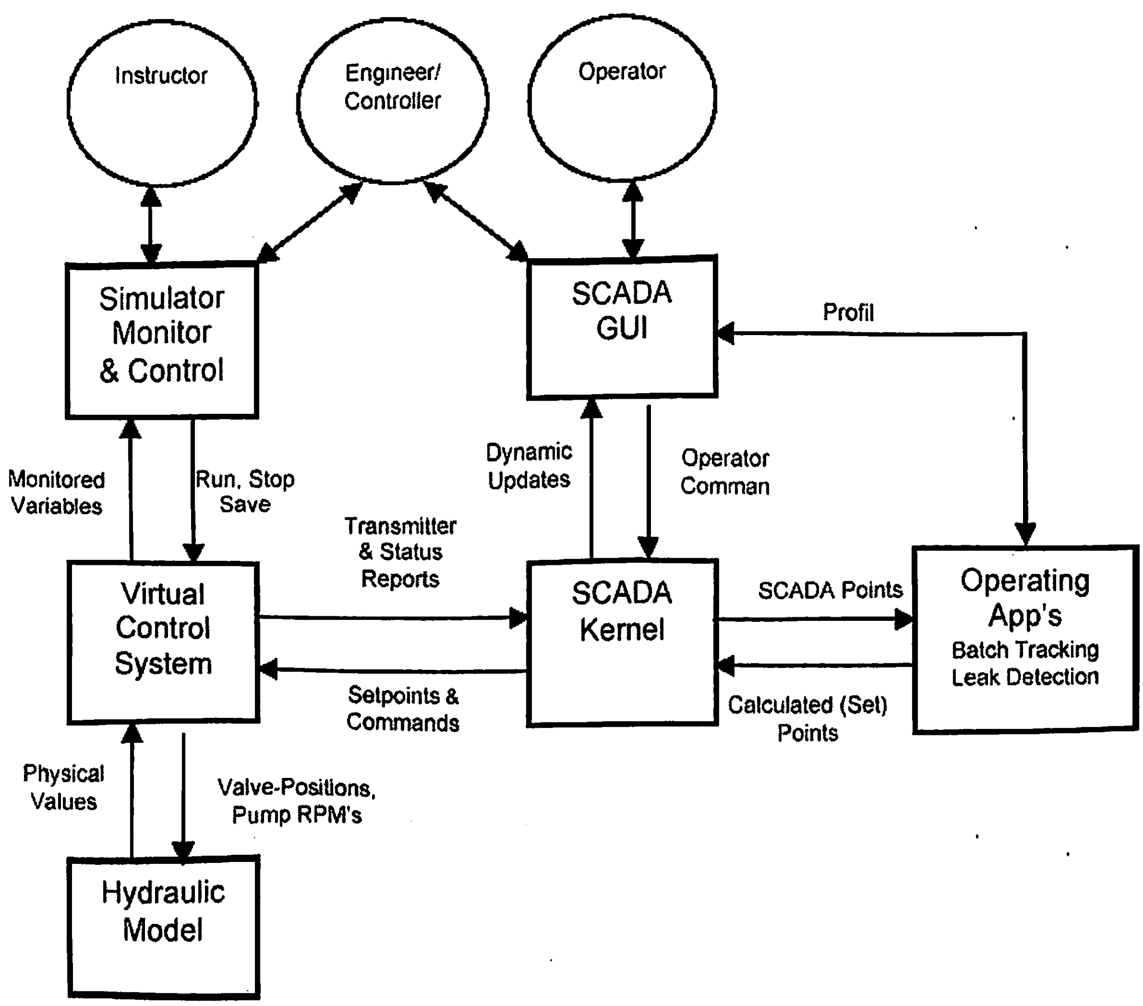


Figure 5.3 CPC SCADA System

Chapter 6

Ladder Logic for Pipeline

We are designing ladder logic for pipeline for city gas distribution. Gas is delivered to different pipelines for different purpose at different pressures. This pressure is managed through compressors and relief valves. If pressure becomes higher than prescribed level than relief valves should be opened to lower the pressure. And if pressure becomes lower than prescribed level than compressor should start working until pressure reaches required level. Also if pressure remains lower or higher than prescribed norms even after the use of compressor and valves than a cut off valve should cut off supply and alarm should set off until the problem is resolved. Although many other parameters like flow rate and gas quality also has to be measured and controlled through PLC and SCADA interface but we are designing ladder logic only for pressure. After the ladder logic has been installed in PLC, a user interface can be developed using SCADA software through which an operator, supervisor or an engineer can control and observe the whole system. The design of pipeline for which ladder logic has been made, with location of compressors, relief valves, cut off valves and alarms is shown below.

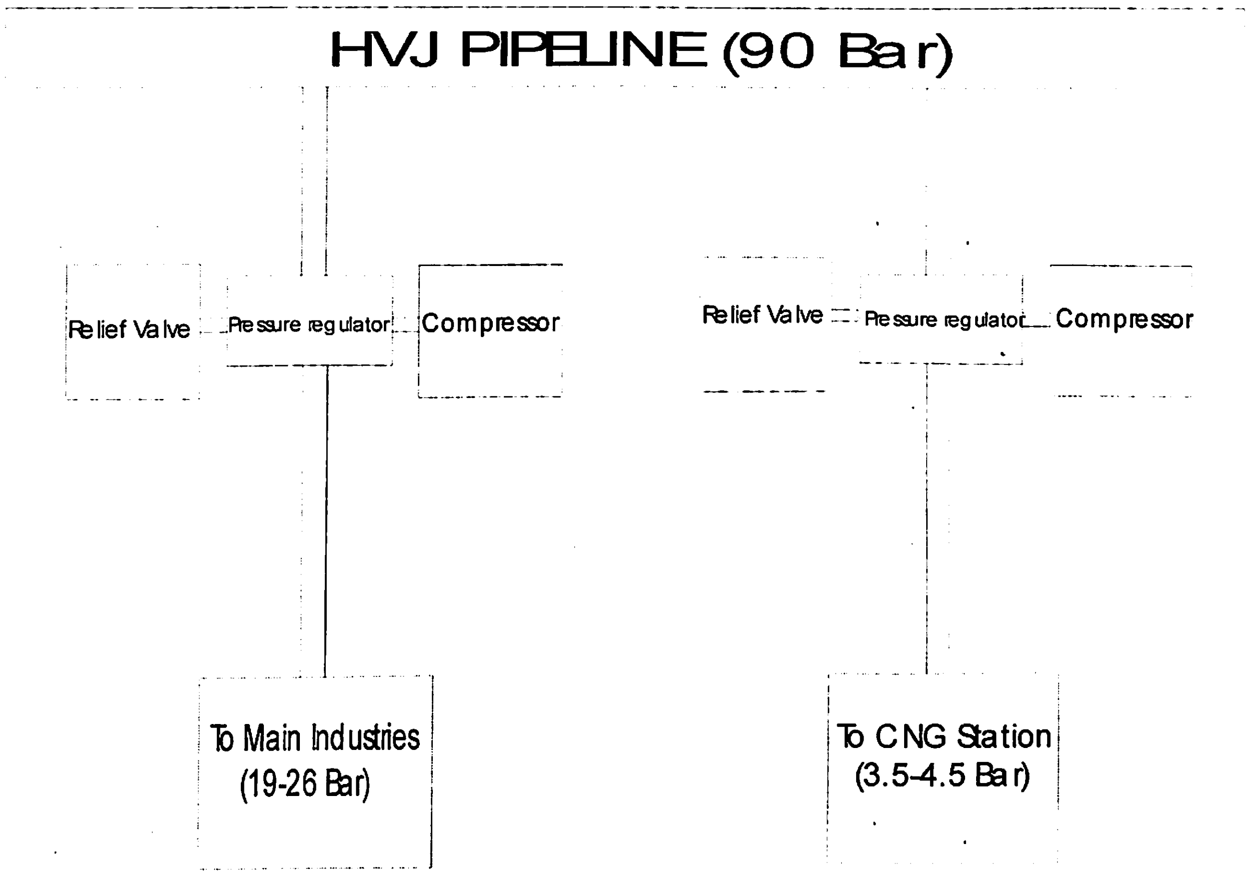


Figure 6.1

Different limits for pressure areas follows:

HVJ Pipeline 90 Bar

Major Industries: 19-26 Bar

CNG Filling Station: 4 Bar

Domestic Supply Station: 0.21 Millibar- 1Bar

These pressures will be controlled by compressor and relief valves installed in these three lines. But first of all pressure need to be measured and data must be supplied to PLC which can then take appropriate action. There are many devices which can be used to measure pressure.

6.1 Pressure sensors

Measurement of pressure requires techniques for producing the displacement and means for converting such displacement into proportional electrical signal. Because of the great variety of conditions, ranges, and materials for which pressure must be measured, there are many different types of pressure sensor designs.

6.1.1 Diaphragms

One common element used to convert pressure information into a physical displacement is the diaphragm. A diaphragm is like a spring, and therefore extends or contracts.

6.1.2 Bellow

It is a device much like the diaphragm that converts a pressure differential into a physical displacement, except that here the displacement is much more a straight line expansion. Figure shows how an LVDT can be connected to the bellows so that the pressure measurement is converted directly from displacement to voltage.

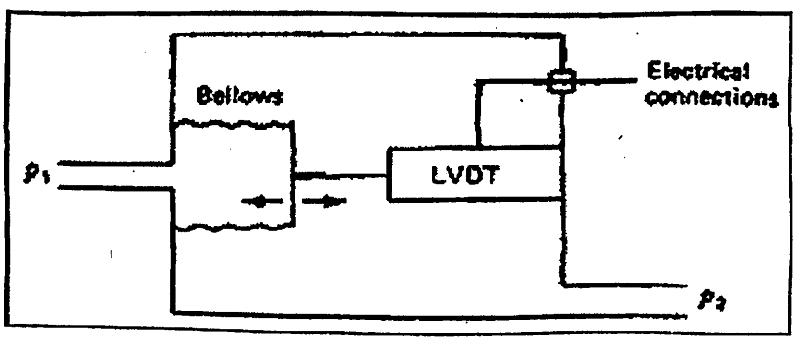


Figure 6.2 Bellow

6.1.3 Bourdon tube pressure measurement

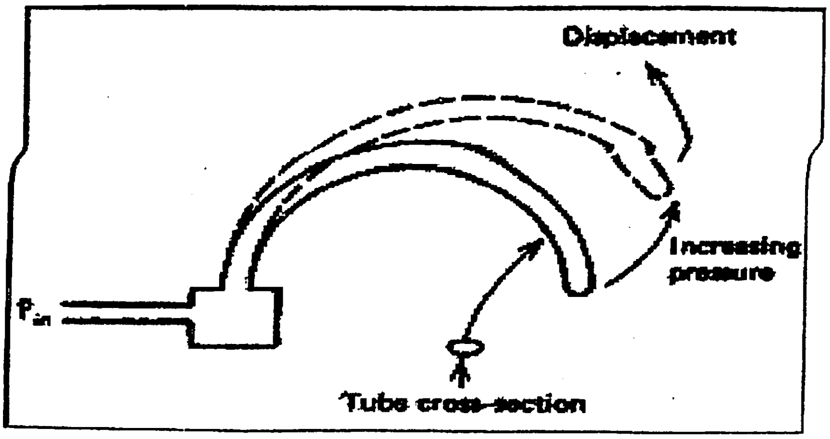


Figure 6.3 Bourdon tube pressure sensor

6.1.4 Wheatstone bridge (strain based) sensors

They are most common, offering solutions that meet varying accuracy, size, ruggedness, and cost constraints. Bridge sensors are used for high and low pressure applications, and can measures absolute, gauge, or differential pressure. All bridge sensors make use of a strain gauge and a diaphragm.

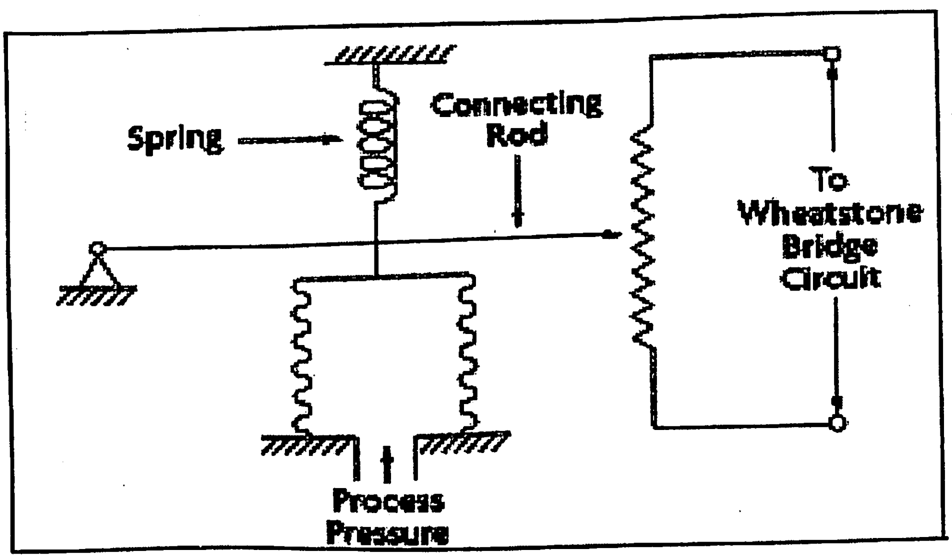


Figure 6.4 Wheatstone bridge sensors

6.1.5 Pressure transducer

They converts pressure into an analog electrical signal, which is achieved by the physical deformation of strain gages which are bonded into the diaphragm of the pressure transducer and wired into a wheatstone bridge configuration. Pressure applied to the pressure transducer produces a deflection of the diaphragm which introduces strain to the gages. The strain will produce an electrical resistance change proportional to the pressure. Pressure transducers are generally available with three types of electrical output;

1) Milli Volt
2) Volt and
3) 4-20mA

6.1.6 Milli volt output pressure transducer

These are normally the most economical. The output is normally around 30mV. The actual output is directly proportional to the input power or excitation. If the excitation fluctuates, the output changes. Because the output signal is so low, the transducer should not be located in an electrically noisy environment. The distances between the transducer and the readout instrument should also be kept relatively short.

6.1.7 Voltage output pressure transducers

It includes integral signal conditioning which provide a much higher output than a millivolt transducer. The output is normally 0-5dc or 0-10dc. Because they have a higher level output these transducers are not as susceptible to electrical noise as millivolt transducer and can therefore be used in much more industrial environments.

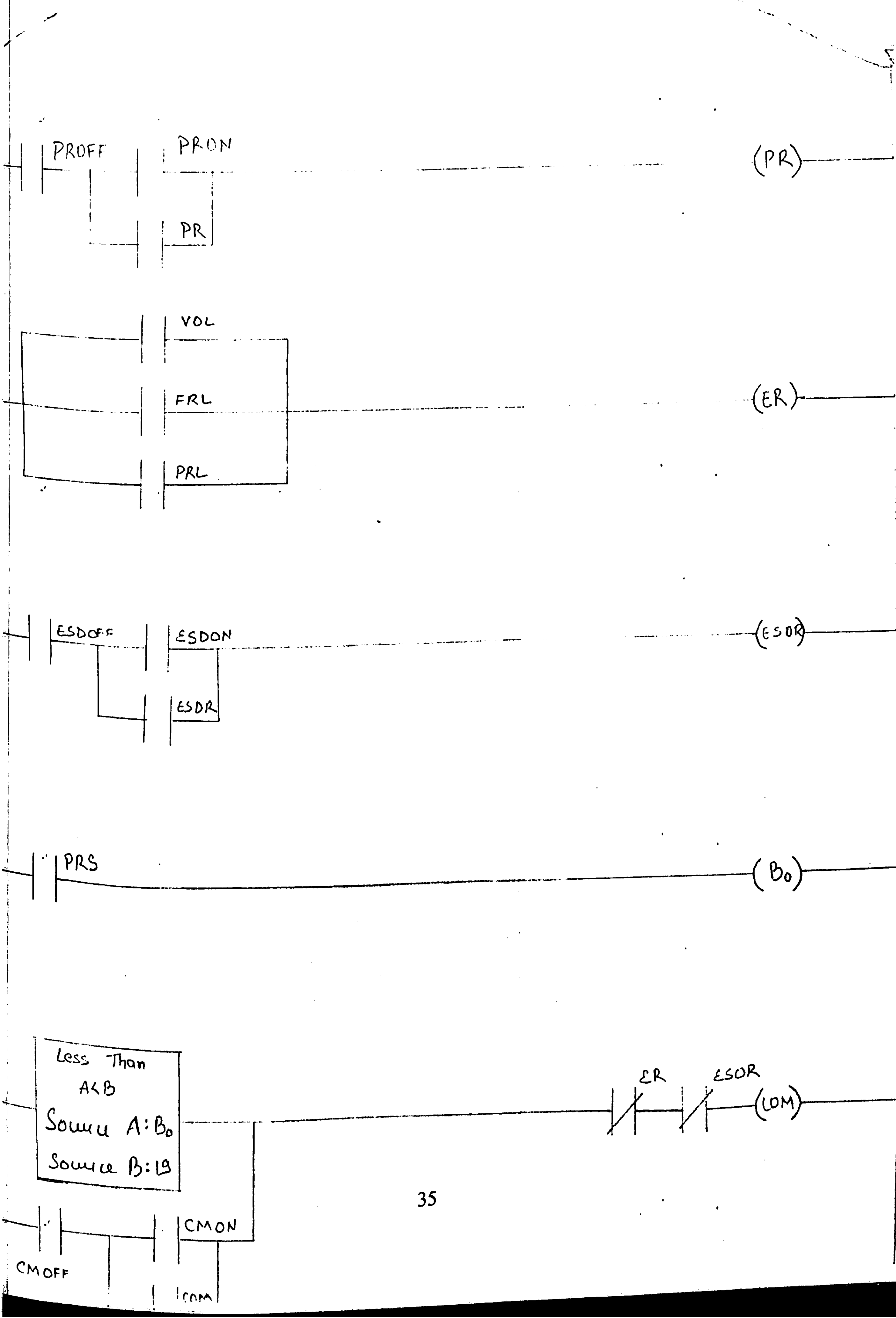
6.1.8 4-20mA output pressure transducers

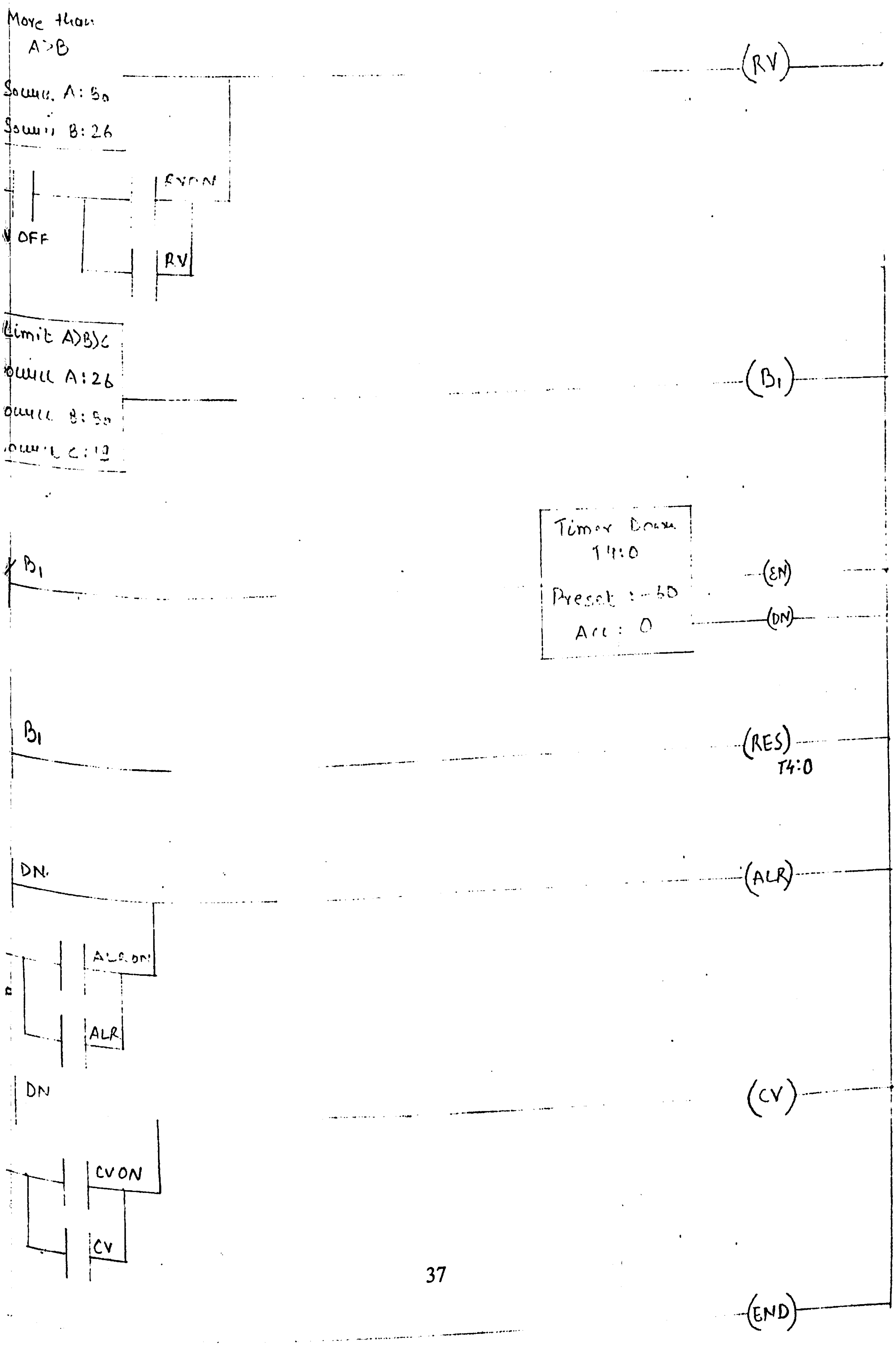
Since a 4-20mA signal is least affected by electrical noise and resistance & are best used for long distances. It is not uncommon to use these transducers in applications where the lead wire must be 1000 feet or more

6.2 Ladder Logic

These pressure measuring devices will give an analog input to RTU which will be a PLC. In the case of an analog signal processing, the sensor is connected to an analog input circuit that runs the current loop through a high precision resistor. The resistor according to Ohm's Law, creates a voltage drop proportional to the amount of current. An analog to digital converter reads the voltage across the resistor to produce a digital count. This digital value will be fed into ladder logic which will take appropriate action. The given below is a ladder logic for controlling pressure in pipeline for major industries. Gas is being taken from HVJ pipeline and pressure has to be controlled and should be between 19-26 bar. If pressure goes below 19 bar, the compressor should start working until pressure reaches a value above 19 bar. And if pressure goes above 26 bar, the relief valve should open and remain open until it goes below 26 bar. Alarm should be turned on when the pipeline pressure does not remain under prescribed level for more than 1 minute. A cut off valve will also cut supply when alarm goes off. Then appropriate action can be taken by operator. Here we have drawn Ladder logic for this process and an algorithm showing working of this program.

PLC


PROFF
PRON
PR
(PR)
VOL
FRL
PRL
(ER)
ESDOFF
ESDON
ESDR
(ESOR)
PRS
(B0)
Less Than
A<B
Source A: B0
Source B: 19
ER
ESOR
(COM)
CMOFF
CMON


More than
A>B
B: 26
(RV)
RV
OFF
(B1)
Timer
T4:0
Preset
Acc : 0
B1
(EN)
(DN)
B1
(RES)
T4:0
DN
(ALR)
ALR
DN
(CV)
CV ON
CV
(END)

6.3 Nomenclature

PROFF	Pressure Regulator Off Manual Switch
PRON	Pressure Regulator On Manual Switch
PR	Pressure Regulator Output
VOL	Working Voltage Limit Sensor
FRL	Working Flow Rate Limit Sensor
PRL	Working Pressure Limit Sensor
ER	Automatic Emergency Shut Down
ESDR	Manual Emergency Shut Down Output
ESDOFF	Manual Emergency Shut Down Off Switch
ESDON	Manual Emergency Shut Down On Switch
PRS	Input From Pressure Sensor
Bo	Binary Output no. 1
COM	Compressor Output
CMOFF	Manual Compressor Off Switch
CMON	Manual Compressor On Switch
RV	Relief Valve Output
RVOFF	Manual Relief Valve Off Switch
RVON	Manual Relief Valve On Switch
B1	Binary Output no. 2
ALR	Alarm Output
ALOFF	Manual Alarm Off Switch
ALON	Manual Alarm On Switch
CV	Cut Off Valve Output
CVOFF	Cut Off Valve Manual Off Switch
CVON	Cut Off Valve Manual On Switch

ALGORITM FOR LADDER LOGIC.

STEP 1: Is pressure Regulator switched on.

if YES, step 2.

STEP 2: Is voltage under working limits.

if YES, step 3.

STEP 3: Is flow rate under working limits.

if YES, step 4.

STEP 4: Is pressure undur working limits.

if YES, step 5.

STEP 5: Is emergency shut down switch is off

if YES, step 6.

STEP 6: Is pressure is less than 19
or
if compressor switch is On,
↳ then compressor will start.

EP 7: If pressure is more than 26.
or
if relief valve switch is On.
then, relief valve will open.

P 8: If pressure is not in between 19 to 26
then, timer will start.

P 9: If pressure is not between 19 to 26 bar for 60 seconds.
then, alarm will switch on and
cut off valve will open.

P 10: If alarm switch is On then alarm will blow.

11: If manual cut off valve, switch is On.
then cut off valve will open.

12: If pressure return to between 19-26 bar within
60 seconds.

then, timer will reset.

— END —

Chapter 7
Conclusion

SCADA system designs vary widely but there are elements common to all. For an interstate pipeline, data must be gathered from locations that are distributed widely across large geographical areas. Measurement transducers are polled frequently, often every two to five minutes and sometimes even in matter of seconds. To efficiently perform basic functions, data must be accessible by operations personnel located in the field and at a central pipeline control center.

For locations where gas is received or delivered, the level of instrumentation and telemetry is often dependent upon volume rates. At low rates, e.g. below 1 MMcf/d, gas flow is recorded locally but not telemetered by way of SCADA system. At somewhat higher rates, pressure and flow rates are recorded locally and telemetered via the SCADA system. Above a certain threshold, perhaps 5 MMcf/d, pressure, flow rates, and gas quality are continuously measured and telemetered via the SCADA system. Measurement facilities, hence SCADA data, are located at points where gas is received and delivered, at compressor stations and at other remotely actuated equipment such as valves. So the distribution of measurement points is rarely uniform across the system.

Pipeline operations are managed with a balance of automated and mechanical devices that are operated with local and remote control. For the most part, pipelines are controlled by regulation of pressure and volume through use of compression and modulating valves. Pipelines are protected from overpressure through the use of compression and modulating valves. Pipeline facilities are protected from overpressure through the use of mechanical relief valves, which are completely independent of any control systems, including the SCADA system. Compression is controlled with a combination of local and remote control. Pressure set points are sent from the pipeline control center to individual compressor stations via the SCADA system. The set points are relayed to the local station automation equipment, which select units and set their speed and loading. As discharge pressure approaches maximum allowable operating levels, local automation equipment slows and subtracts units as necessary.

With so much data available at such high frequency, the effectiveness of the SCADA system hinges on appropriate data presentation, analysis and alarming. A variety of data presentations are used to transform basic data into information. Trends, schematics and other graphics are used to convey large amounts of data, which vary over time, in a concise and informative format. Trends are especially useful in monitoring pipeline operations because the vast majority of data continuously vary with time. Trends are useful in assessing what has happened and in projecting what might happen. In an emergency situation, trends are extremely useful in corroborating incident report and providing indication of affected location.

Alarms are used indicate that operating conditions are approaching or have exceeded prescribed tolerances. Attention can then be focused on problem diagnosis and appropriate actions. However, too many minor alarms can have the reverse effect by desensitizing pipeline controllers to all alarms, important and trivial.

Basic alarm types includes high and critical high alarms, low and critical low alarms, and changes of status (on or off, open or closed). High limits can be applied to any type of data but are most often used for pressure and gas quality problems. Low limits are typically used for delivery pressures and volumes, particularly when volumes trend to zero. Status change alarms alert pipeline controllers to changes in system configuration. Changes may include an increase in compression, redirection of gas flow, or changes to gas quality.

Integration of SCADA systems with business applications has long been done. These efforts took on added importance as regulatory changes during the last decade dramatically altered the role of interstate pipeline. SCADA data have proven to be an important resource not only for managing pipeline operations but managing the business, as well. SCADA data are useful in minimizing the impact of measurement malfunctions that can lead to accounting mistakes and errant customer billing. The same measurement facility is typically used to provide SCADA data and electronic measurement data used in custody transfer calculations. Pipeline controllers can respond timely to alarms that indicate flow rates are outside the optimal range for measurement accuracy. Other measurement and communication failures are alarmed as well. Responding to these failures early on minimizes inefficiencies later in the business process.

Nominated receipts and deliveries are compared with measured quantities from the SCADA system to determine variances between actual and scheduled activity. At times these variances are planned so as to mitigate the impacts of facility work or to offset imbalances that have accrued over time. At other times, these variances aggravate existing imbalances, in which case adjustments to nominations may be required.

The data from supervisory control and data acquisition systems are indispensable to monitoring and controlling operations of interstate natural gas pipelines. Beyond these basic functions, however, the data gathered by these systems are used extensively directly and indirectly in a variety of business applications from design to invoicing.

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