A
Master Thesis Report
On

PLC And SCADA Implementation in CNG Station

By

M.SANTHOSH
M.Tech (Gas Engineering)
Reg. No: R030205010

University of Petroleum & Energy Studies

Harnessing Energy Through Knowledge

A master thesis report submitted in partial fulfillment of the requirements for *MASTER OF TECHNOLOGY IN GAS ENGINEERING* of University of Petroleum &Energy Studies, INDIA

College of Engineering
University of Petroleum &Energy Studies,
Dehradun, INDIA.

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M.SANTHOSH

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Under The Guidance of

Mr. Kamal Bansal

Associate Professor

COE, U.P.E.S.

Mr. T.Chandrasekhar

Lecturer

COE, U.P.E.S.

At

Sofcon India Pvt. Ltd.

Noida

UNIVERSITY OF PETROLEUM &ENERGY STUDIES

Dehradun, INDIA.

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E-mail : training@sofcononline. com
www.sofcononline.com

To whomsoever it may concern

This is to certify that Mr. M.Santhosh of U.P.E.S, Dehradoon has successfully completed a project under my guidance on following topic:

PLC and SCADA Implementation in CNG Station

Using **RSLogix 500** Software (for **Allen Bradley PLC's**) and **SCADA** Software (Wonderware Intouch).

Sofcon India wishes him all the very best in his future career.

(Raj Singh)
Sr. Manager Training

DELHI
E-107, Vishwakarma Colony
Mehrauli Badarpur Road,
New Delhi - 110 044
Tel : 011 - 45696584
e-mail : support@sofcononline.com

JAIPUR
135, Shanti Nagar,
Kings Road.
Nirman Nagar, Jaipur
Tel : 09828100500
e-mail : jaipur@sofcononline.com

CERTIFICATE

This is to certify that the project work entitled **"PLC and SCADA implementation in CNG station"** submitted by M. Santhosh in partial fulfillment of the requirements for the award of the degree of Master Of Technology (Gas Engineering), at college of engineering, University of Petroleum and Energy Studies, is a record of the work carried by under the guidance of "Mr. Kamal Bansal and Mr. T.Chandrasekhar, Distinguished Professors, COE, UPES" and Mr. Raj Singh, Sr. Manager (Training), **Sofcon India Pvt. Ltd.**, Noida.

11/5/07

Mr. Kamal Bansal
Associate Professor
UPES
Dehradun

15/05/07

Dr. B. P. Pandey
Dean, COE
UPES
Dehradun

T.Chandrasekhar 11/5/07

Mr. T.Chandrasekhar
Lecturer
COE, U.P.E.S.

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M.Santhosh

Abstract

Compressed Natural Gas (CNG) Mother stations are connected to the pipeline and have high compression capacity. These stations supply CNG to both vehicles and daughter stations (through mobile cascades). The Mother station requires heavy investment towards compressor, dispensers, cascades, pipelines, tubing etc. In CNG station compressor and dispenser plays an important role than other equipments. CNG being flammable, safety predominates the compressor operations in CNG station.

With the advent of Supervisory Control and Data Acquisition Systems (SCADA) the problem of real time monitoring and control became easy to handle the unsafe operating conditions in CNG Stations. The following are some other advantages achieved with proper implementation of SCADA in CNG stations

- Improved operation of the plant or process resulting in savings due to optimization of the system
- Improved safety of the system due to better information and improved control
- Protection of the plant equipment
- Safeguarding the environment from a failure of the system
- Improved energy savings due to optimization of the plant

This project provides an answer to main operating parameters of CNG Compressor Station and also a program using **RS Logix 500 software (Allen-Bradley PLC'S)** and **SCADA software (Wonderware Intouch)** has been developed which helps it to work in optimum way without any difficulties.

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LIST OF ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
API	American Petroleum Institute
CNG	Compressed Natural Gas
CPU	Central Processor Unit
DCS	Distributed Control System
DDE	Dynamic Data Exchange
DLL	Dynamic Link Library
FSM	Finite State Machine
I/O	Input/Output
LAN	Local Area Network
LCV	Light Commercial Vehicle
MDPE	Medium Density Poly Ethylene
MMI	Man Machine Interface
ODBC	Open Data Base Connectivity
OLE	Object Linking and Embedding
PLC	Programmable logic controller
RCV	Remote Control Valve
RTDB	Real Time Data Base
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SCMH	Standard Cubic Meter Hour
TCP/IP	Transfer Control Protocol/Internet Protocol

1.0 INTRODUCTION

1.1 About CNG station

Compressed Natural Gas (CNG) Mother stations are connected to the pipeline and have high compression capacity. These stations supply CNG to both vehicles and daughter stations (through mobile cascades). The Mother station requires heavy investment towards compressor, dispensers, cascades, pipelines, tubing etc. In CNG station compressor and dispenser plays an important role than other equipments. CNG being flammable, safety predominates the compressor operations in CNG station.

The main safety parameters in CNG Station are:

- Suction Pressure for each stage in 3 stage Reciprocating Compressor.
- Discharge Temperature at each stage in 3 stage Reciprocating Compressor.
- Fire Detection.

Here 1200 SCMH capacity compressors are used to compress the natural gas from a pressure of 19-26 kg/cm^2 (g) to 255 kg/cm^2 (g). All categories of vehicles are refueled i.e., bus, car/LMV and auto. Apart from above, LCV mounted mobile cascades for feeding CNG to other daughter booster station will also be refueled from this station. Mother station (bus terminal) shall have only bus filling facility.

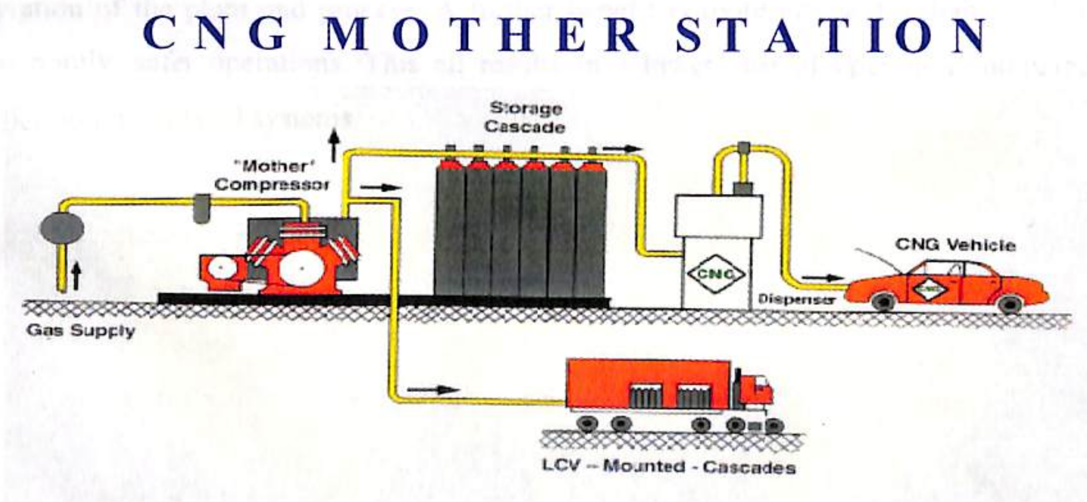


FIG 1. CNG MOTHER STATION

1.2 SCADA SYSTEM:

SCADA is an acronym that 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.

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 out over a large area.

SCADA System shall be provided to ensure effective and reliable control, management and supervision of the pipeline from a centralized location using remote terminal units (RTUs) located along the pipeline at suitable locations.

A SCADA (or supervisory control and data acquisition) system means a system consisting of a number of remote terminal units (or RTUs) collecting field data connected back to a master station via a communications system. The master station displays the acquired data and also allows the operator to perform remote control tasks.

The accurate and timely data (normally real-time) allows for optimization of the operation of the plant and process. A further benefit is more efficient, reliable and most importantly, safer operations. This all results in a lower cost of operation compared to earlier non-automated systems.

2.0 FLOW PROCESS OF GAS ON CNG STATION

Flow process of gas on CNG station starts from Main Line Followed by Metering Skid, Metering Skid, Compressor, Priority Panel, Stationery Cascade, LCV Cascade, Dispenser, Coalescent Filter, Actuator, Flow Meter and Pressure Gauge

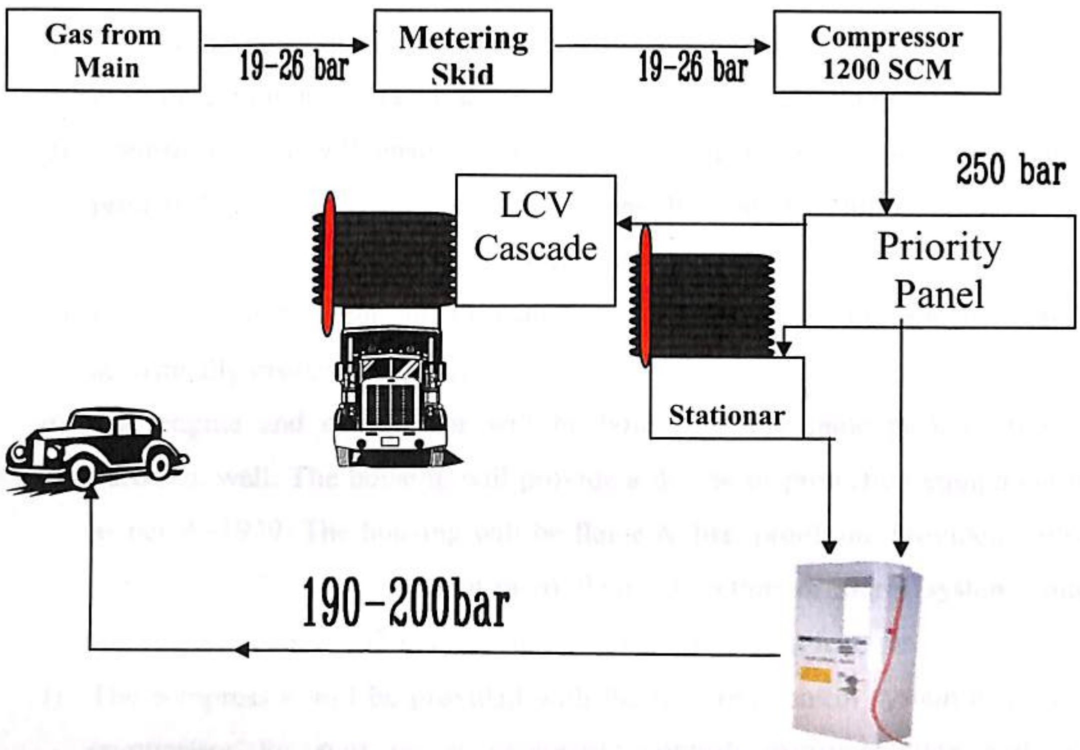


Fig 2.1 FLOW PROCESS OF GAS ON CNG STATION

2.1 GAS FROM MAIN LINE:

Natural Gas from main line comes at 19-26-bar pressure to CNG Station.

2.2 COMPRESSOR:

The purpose of compressor is to compress the Natural Gas from 19-26 bar of pressure to 250 bars in three stages of compression.

Reciprocating type compressors, each of capacity *1200* SM3/hr at suction pressure 12-29(+) Kg/cm2 and discharge pressure 255 Kg/cm2 shall be installed at mother station. Approximate gas consumption of gas engine will be 55 SM3/hr. The compressor will start automatically in case cascade pressure falls less than 210 Kg/cm2 and will unload at pressure 255 Kg/cm2.

Main Specification Features

a) 3 stage reciprocating type compressor with console type air cooling and safety relief valve at each stage, after cooler at final discharge along with all services. Lines, tubing, valves, instrument and auxiliaries.

b) Gas engine with air and coolant water based cooling system; gas flow meter with electronic volume corrector, tantalizer and associated equipment.

c) Control system will ensure unattended safe operation in automatic mode. The priority fill system: will ensure maximum flow rate by filling of vehicle, storage cascade and mobile cascade in assigned order.

d) Entire compressor equipment shall be mounted on one skid and packaged in an acoustically insulated housing.

e) The engine and compressor will be housed in the same package unit with a partition. wall. The housing will provide a degree of protection equipment to IP44 as per AS1939. The housing will be flame & fire. proof and provided with forced ventilation, flame arrestor, infrared flame detection & alarm system, automatic shutoff, automatic CO_2 flooding and other fire retardant features.

f) The compressor will be provided with the required control system using PLC; air compressor for start up & pneumatic control; instrumentation and controls; emergency. shut down device and electric supply system. Metering Skid shall be provided.

g) The entire compressor system shall be earthed.

2.3 PRIORITY PANEL:

The purpose of Priority Panel is to provide the compressed Natural Gas to the Dispenser/ LCV Cascade on the basis of which is on higher priority.

Priority Panels

The priority panel directs the gas flow from the compressor to the High bank, Medium bank or Low bank of the storage cascade, depending on demand. If the storage pressure is low, the discharge gas is sent directly to the vehicle to provide faster fuelling. A priority panel is necessary for fast-fill CNG systems.

2.4 STATIONERY CASCADE:

The purpose of Stationery Cascade is to store the compressed Natural Gas when ever cascade is on higher priority thus dispenser is in off position. The Cascade, freestanding type with High-pressure seamless gas cylinders for CNG gas Service suitable for a filling pressure of 250 kg/cm2 at 15°C. Imported High Pressure Cylinders are assembled inside a sturdy frame in three independent banks, Low Bank, Medium bank and High Bank. The cylinders are mounted in the frame such that there is no lateral or rotational movement of the cylinder during transportation. The cylinders assembled keeping a minimum gap of 30mm between them. The frame have a lifting eye to facilitate lifting with the crane as well as forklift with full weight of cylinder filled with gas, and have suitable tie down clamps at the base. The cascade painted with a special paint to withstand environmental corrosion.

2.5 LCV:

The purpose of LCV cascade is to store the buffer of Natural Gas and is used on mother stations, thus station which is not online station

2.6 DISPENSER:

The purpose of dispenser is to dispense the CNG to vehicles and recording the volume of gas dispensed.

CNG dispensers are available in the following models

- ✓ Single Hose CNG dispenser
- ✓ Double Hose Dispenser
- ✓ Four Hose Dispenser

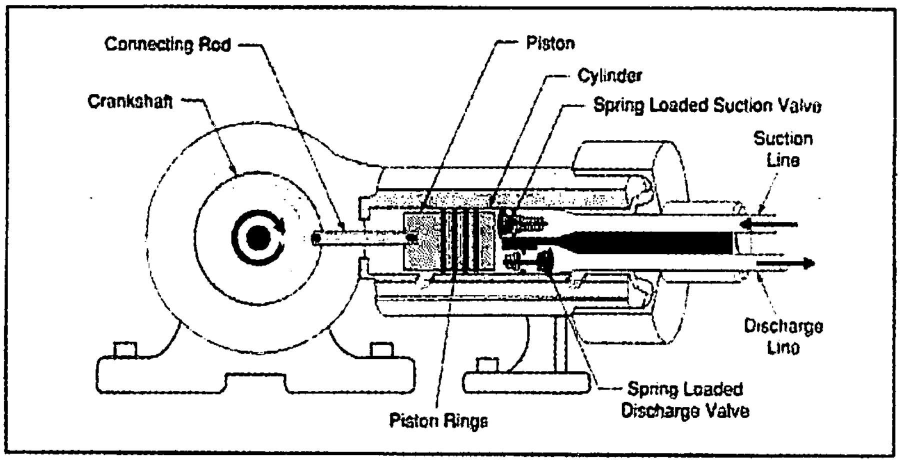
Fig2.2 Dispenser

Four Hose CNG Dispenser

The four hose dispenser could be used for filling Busses/Trucks and the other side is for filling cars. Depending which type of nozzle switch is pressed the according valve will be switched to the write hose. At the same time a bus and car could be filled or 2 busses.

3.0 RECIPROCATING COMPRESSORS

In industry, reciprocating compressors are the most widely used type for both air and refrigerant compression. They work on the principles of a bicycle pump and are characterized by a flow output that remains nearly constant over a range of discharge pressures. Also, the compressor capacity is directly proportional to the speed. The output, however, is a pulsating one.



Reciprocating Compressor

Fig 3.1 A cross-sectional view of a reciprocating compressor

A compressor is considered to be single stage when the entire compression is accomplished with a single cylinder or a group of cylinders in parallel. Many applications involve conditions beyond the practical capability of a single compression stage. Too great a compression ratio (absolute discharge pressure/absolute intake pressure) may cause excessive discharge temperature or other design problems. Two stage machines are used for high pressures and are characterized by lower discharge temperature (140 to 160oC) compared to single-stage machines (205 to 240oC).

For practical purposes most plant gas reciprocating gas compressors over 100 horsepower are built as multi-stage units in which two or more steps of compression are grouped in series. The gas is normally cooled between the stages to reduce the temperature and volume entering the following stage. Reciprocating gas compressors are available either as air-cooled or water-cooled in lubricated and non- lubricated configurations, may be packaged, and provide a wide range of pressure and capacity selections.

3.1 General Selection Criteria of Compressors

Type of Compressor	Capacity (m^3/h)		Pressure (bar)	
	From	To	From	To
Roots blower compressor single stage	100	30000	0.1	1
Reciprocating				
- Single / Two stage	100	12000	0.8	12
- Multi stage	100	12000	12.0	700
Screw				
- Single stage	100	2400	0.8	13
- Two stage	100	2200	0.8	24
Centrifugal	600	300000	0.1	450

Fig 3.2 Selection Criteria of Compressors

3.2 Reciprocating compressor Operation

Reciprocating compressors consists of a ringed piston that moves inside a cylinder. They may be of 2 types; single acting and double acting in which two single acting pistons operate in parallel inside one cylinder, thereby compressing on both sides. Besides the piston and cylinder and a suction valve discharge valve is also provided. The suction valves open when the pressure in the cylinder falls below the intake pressure. The discharge valve opens when the pressure in the cylinder equal or exceeds the discharge pressure. First the cylinder is full of gas that is to be compressed and is at the beginning of compression cycle. Then the compression stroke completes and discharge valve opens. During the delivery stroke the gas is delivered at constant pressure. Next the expansion stroke occurs with both valves remaining closed. The small amount of gas trapped is expanded leading to a reduction in pressure inside the cylinder. This causes inlet valves to open and the intake cycle begins. Reciprocating compressors are the older type with more moving parts and hence a lower mechanical efficiency and higher maintenance power. They have a volumetric rate up to 30,000 cfm and discharge pressure up to 10,000 psig.

4.0 Fundamental principles of modern SCADA systems

In modern manufacturing and industrial processes, mining industries, public and private utilities, leisure and security industries telemetry is often needed to connect equipment and systems separated by large distances. This can range from a few meters to thousands of kilometers. Telemetry is used to send commands, programs and receives monitoring information from these remote locations.

SCADA refers to the combination of telemetry and data acquisition. SCADA encompasses the collecting of the information, transferring it back to the central site, carrying out any necessary analysis and control and then displaying that information on a number of operator screens or displays. The required control actions are then conveyed back to the process.

In the early days of data acquisition, relay logic was used to control production and plant systems. With the advent of the CPU and other electronic devices, manufacturers incorporated digital electronics into relay logic equipment. The PLC or programmable logic controller is still one of the most widely used control systems in industry. As need to monitor and control more devices in the plant grew, the PLCs were distributed and the systems became more intelligent and smaller in size.

4.1 SCADA system

A SCADA (or supervisory control and data acquisition) system means a system consisting of a number of remote terminal units (or RTUs) collecting field data connected back to a master station via a communications system. The master station displays the acquired data and also allows the operator to perform remote control tasks.

The accurate and timely data (normally real-time) allows for optimization of the operation of the plant and process. A further benefit is more efficient, reliable and most importantly, safer operations. This all results in a lower cost of operation compared to earlier non-automated systems.

There is a fair degree of confusion between the definition of SCADA systems and process control system. SCADA has the connotation of remote or distant operation. The inevitable question is how far 'remote' is – typically this means over a distance such that the distance between the controlling location and the controlled location is such that direct-wire control is impractical (i.e. a communication link is a critical component of the system).

A successful SCADA installation depends on utilizing proven and reliable technology, with adequate and comprehensive training of all personnel in the operation of the system.

There is a history of unsuccessful SCADA systems – contributing factors to these systems includes inadequate integration of the various components of the system, unnecessary complexity in the system, unreliable hardware and unproven software. Today hardware reliability is less of a problem, but the increasing software complexity is producing new challenges. It should be noted in passing that many operators judge a SCADA system not only by the smooth performance of the RTUs, communication links and the master station (all falling under the umbrella of SCADA system) but also the field devices (both transducers and control devices). The field devices however fall outside the scope of SCADA in this manual and will not be discussed further. A diagram of a typical SCADA system is given opposite.

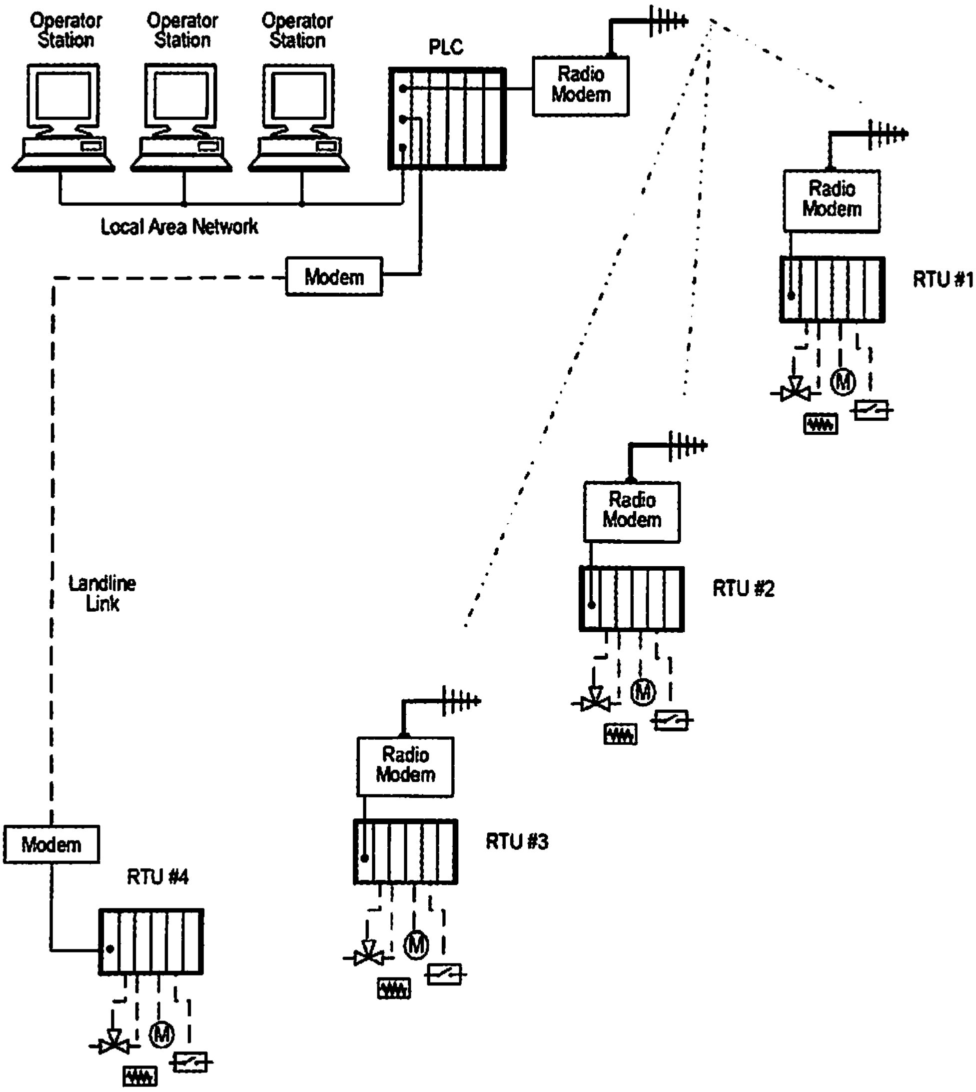


Fig 4.1 Typical SCADA System

On a more complex SCADA system there are essentially five levels or hierarchies:

- Field level instrumentation and control devices
- Marshalling terminals and RTUs
- Communications system
- The master station(s)
- The commercial data processing department computer system

The RTU provides an interface to the field analog and digital signals situated at each remote site.

The communications system provides the pathway for communications between the master station and the remote sites. This communication system can be radio, telephone line, microwave and possibly even satellite. Specific protocols and error detection philosophies are used for efficient and optimum transfer of data.

The master station (and submasters) gather data from the various RTUs and generally provide an operator interface for display of information and control of the remote sites. In large telemetry systems, submaster sites gather information from remote sites and act as a relay back to the control master station.

SCADA technology has existed since the early sixties and there are now two other competing approaches possible – distributed control system (DCS) and programmable logic controller (PLC). In addition there has been a growing trend to use smart instruments as a key component in all these systems. Of course, in the real world, the designer will mix and match the four approaches to produce an effective system matching his/her application.

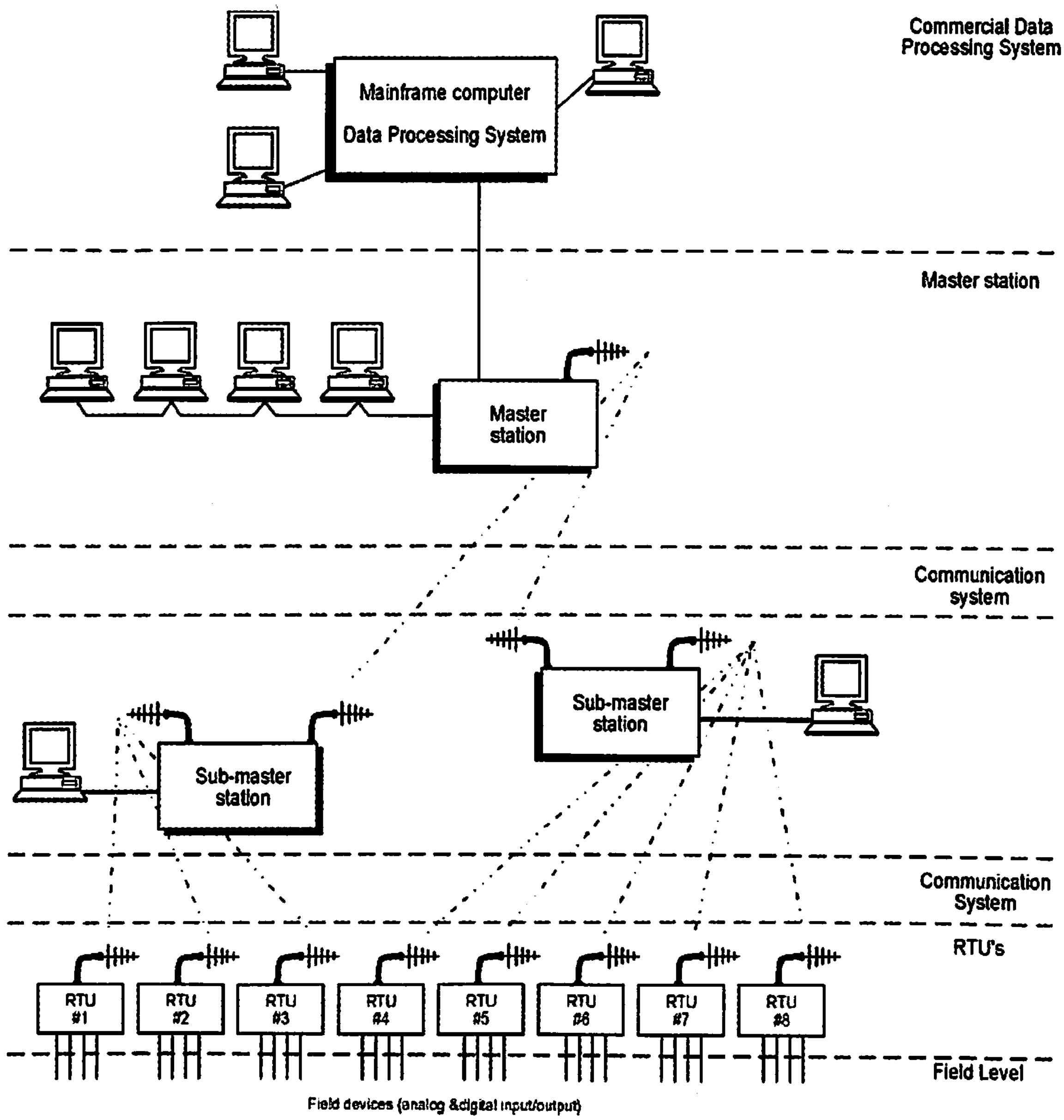


Fig 4.2 SCADA Commercial Data Processing System

4.2 ARCHITECTURE

➢ **Hardware Architecture**

One distinguishes two basic layers in a SCADA system: the "client layer" which caters for the man machine interaction and the "data server layer" which handles most of the process data control activities. The data servers communicate with devices in the field through process controllers. Process controllers, e.g. PLCs, are connected to the data servers either directly or via networks or field buses that are proprietary (e.g. Siemens 1), or non-proprietary (e.g. Profibus). Data servers are connected to each other and to client stations via an Ethernet LAN. The data servers and client stations are NT platforms but for many products the client stations may also be W95 machines. Fig.1. shows typical hardware architecture.

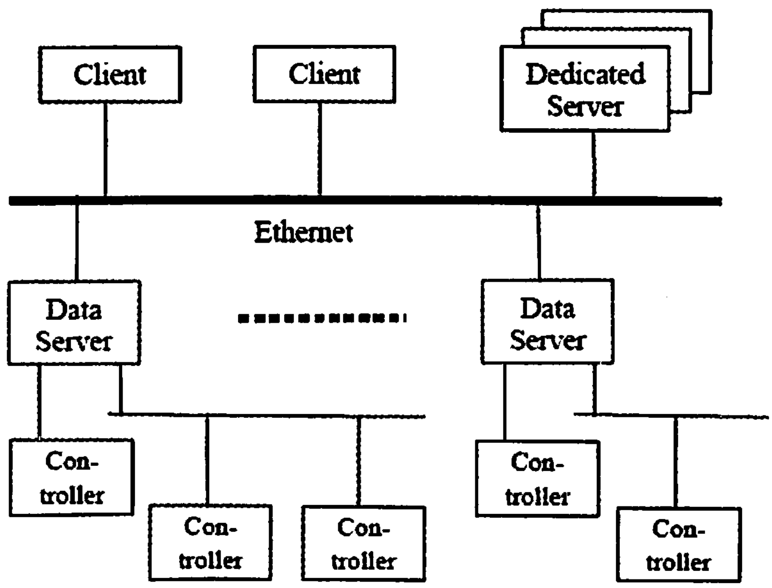


Fig 4.3 Typical Hardware Architecture

➢ **Software Architecture**

The products are multi-tasking and are based upon a real-time database (RTDB) located in one or more servers. Servers are responsible for data acquisition and handling (e.g. polling controllers, alarm checking, calculations, logging and archiving) on a set of parameters, typically those they are connected to. However, it is possible to have dedicated servers for particular tasks, e.g. data logger a SCADA architecture that is generic for the products that were evaluated.

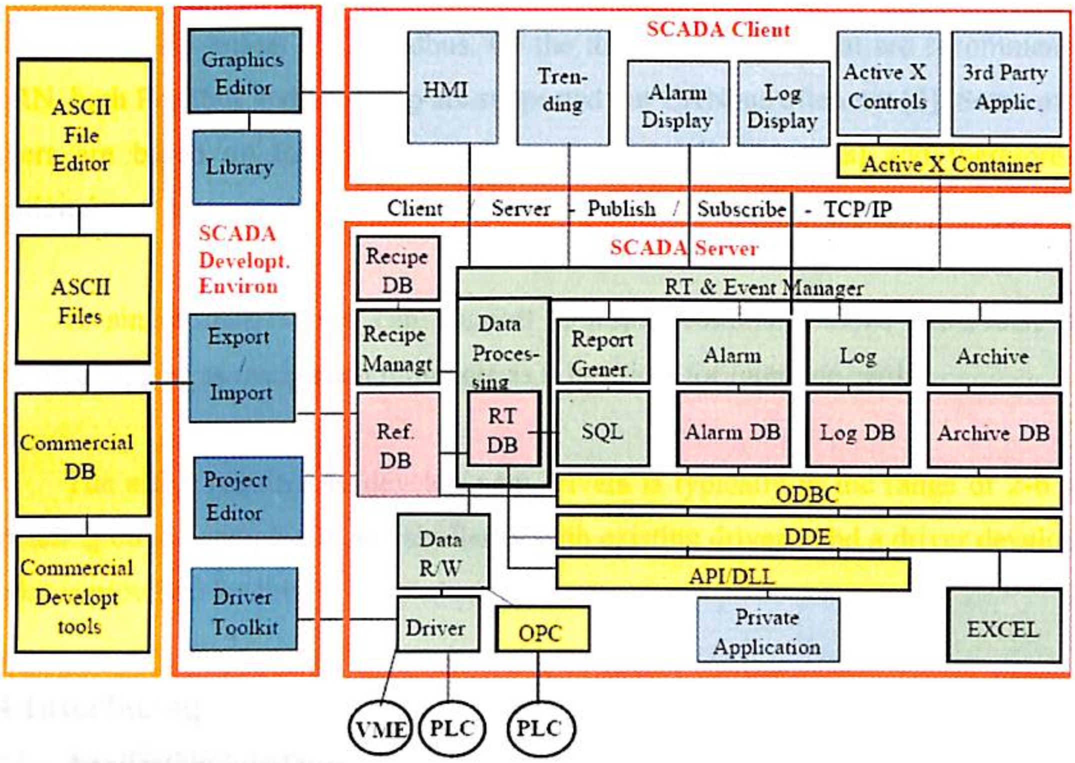


Fig 4.4 Generic Software Architecture

4.3 Communications

Internal Communication Server-client and server-server communication is in general on a publish-subscribe and event-driven basis and uses a TCP/IP protocol, i.e., a client application subscribes to a parameter which is 'owned' by a particular server application and only changes to that parameter are then communicated to the client application.

Access to Devices

The data servers poll the controllers at a user defined polling rate. The polling rate may be different for different parameters. The controllers pass the requested parameters to the data servers. Time stamping of the process parameters is typically performed in the controllers and this time-stamp is taken over by the data server. If the controller and communication protocol used support unsolicited data transfer then the products will support this too.

The products provide communication drivers for most of the common PLCs and widely used field-buses, e.g., Modbus. Of the three field buses that are recommended at CERN, both Profibus and Worldfip are supported but CANbus often not [3]. Some of the drivers are based on third party products (e.g., Applicom cards) and therefore have additional cost associated with them. VME on the other hand is generally not supported.

A single data server can support multiple communications protocols: it can generally support as many such protocols as it has slots for interface cards.

The effort required to develop new drivers is typically in the range of 2-6 weeks depending on the complexity and similarity with existing drivers, and a driver development toolkit is provided for this.

4.4 Interfacing

Application Interfaces

The provision of OPC client functionality for SCADA to access devices in an open and standard manner is developing. There still seems to be a lack of devices/controllers, which provide OPC server software, but this improves rapidly as most of the producers of controllers are actively involved in the development of this standard. The products also provide

- An Open Data Base Connectivity (ODBC) interface to the data in the archive/logs, but not to the configuration database
- An ASCII import/export facility for configuration data
- A library of APIs supporting C, C++, and Visual Basic (VB) to access data in the RTDB, logs and archive. The API often does not provide access to the product's internal features such as alarm handling, reporting, trending, etc.

The PC products provide support for the Microsoft standards such as Dynamic Data Exchange (DDE) which allows e.g. to visualise data dynamically in an EXCEL spreadsheet, Dynamic Link Library (DLL) and Object Linking and Embedding (OLE).

Database

The configuration data are stored in a database that is logically centralised but physically distributed and that is generally of a proprietary format.

For performance reasons, the RTDB resides in the memory of the servers and is also of proprietary format.

The archive and logging format is usually also proprietary for performance reasons, but some products do support logging to a Relational Data Base Management System (RDBMS) at a slower rate either directly or via an ODBC interface.

Scalability

Scalability is understood as the possibility to extend the SCADA based control system by adding more process variables, more specialised servers (e.g. for alarm handling) or more clients. The products achieve scalability by having multiple data servers connected to multiple controllers. Each data server has its own configuration database and RTDB and is responsible for the handling of a sub-set of the process variables (acquisition, alarm handling, archiving).

Redundancy

The products often have built in software redundancy at a server level, which is normally transparent to the user. Many of the products also provide more complete redundancy solutions if required.

4.5 Functionality

Access Control

Users are allocated to groups, which have defined read/write access privileges to the process parameters in the system and often also to specific product functionality.

MMI

The products support multiple screens, which can contain combinations of synoptic diagrams and text.

They also support the concept of a "generic" graphical object with links to process variables. These objects can be “dragged and dropped” from a library and included into a synoptic diagram.

Most of the SCADA products that were evaluated decompose the process in “atomic” parameters (e.g. a power supply current, its maximum value, its on/off status, etc.) to which a Tag-name is associated. The Tag-names used to link graphical objects' to devices can be edited as required. The products include a library of standard graphical symbols, many of which would however not be applicable to the type of applications encountered in the experimental physics community.

Standard windows editing facilities are provided: zooming, re-sizing, scrolling... On-line configuration and customisation of the MMI is possible for users with the appropriate privileges. Links can be created between display pages to navigate from one view to another.

Trending

The products all provide trending facilities and one can summarise the common capabilities as follows:

- The parameters to be trended in a specific chart can be predefined or defined on-line
- A chart may contain more than 8 trended parameters or pens and an unlimited number of charts can be displayed (restricted only by the readability)

- Real-time and historical trending are possible, although generally not in the same chart
- Historical trending is possible for any archived parameter
- Zooming and scrolling functions are provided
- Parameter values at the cursor position can be displayed

The trending feature is either provided as a separate module or as a graphical object (ActiveX), which can then be embedded into a synoptic display. XY and other statistical analysis plots are generally not provided.

Alarm Handling

Alarm handling is based on limit and status checking and performed in the data servers. More complicated expressions (using arithmetic or logical expressions) can be developed by creating derived parameters on which status or limit checking is then performed. The alarms are logically handled centrally, i.e., the information only exists in one place and all users see the same status (e.g., the acknowledgement), and multiple alarm priority levels (in general many more than 3 such levels) are supported.

It is generally possible to group alarms and to handle these as an entity (typically filtering on group or acknowledgement of all alarms in a group). Furthermore, it is possible to suppress alarms either individually or as a complete group. The filtering of alarms seen on the alarm page or when viewing the alarm log is also possible at least on priority, time and group. However, relationships between alarms cannot generally be defined in a straightforward manner. Emails can be generated or predefined actions automatically executed in response to alarm conditions.

Logging/Archiving

The terms logging and archiving are often used to describe the same facility. However, logging can be thought of as medium-term storage of data on disk, whereas archiving is long-term storage of data either on disk or on another permanent storage medium. Logging is typically performed on a cyclic basis, i.e., once a certain file size, time period or number of points is reached the data is overwritten. Logging of data can be performed at a set frequency, or only initiated if the value changes or when a specific predefined event occurs. Logged data can be transferred to an archive once the log is full. The logged data is time-stamped and can be filtered when viewed by a user. The logging of user actions is in general performed together with either a user ID or station ID. There is often also a VCR facility to play back archived data.

Report Generation

One can produce reports using SQL type queries to the archive, RTDB or logs. Although it is sometimes possible to embed EXCEL charts in the report, a "cut and paste" capability is in general not provided. Facilities exist to be able to automatically generate, print and archive reports.

Automation

The majority of the products allow actions to be automatically triggered by events. A scripting language provided by the SCADA products allows these actions to be defined. In general, one can load a particular display, send an Email, run a user defined application or script and write to the RTDB.

The concept of recipes is supported, whereby a particular system configuration can be saved to a file and then re-loaded at a later date.

Sequencing is also supported whereby, as the name indicates, it is possible to execute a more complex sequence of actions on one or more devices. Sequences may also react to external events.

Some of the products do support an expert system but none has the concept of a Finite State Machine (FSM).

4.6 Application development

Configuration

The development of the applications is typically done in two stages. First the process parameters and associated information (e.g. relating to alarm conditions) are defined through some sort of parameter definition template and then the graphics, including trending and alarm displays are developed, and linked where appropriate to the process parameters. The products also provide an ASCII Export/Import facility for the configuration data (parameter definitions), which enables large numbers of parameters to be configured in a more efficient manner using an external editor such as Excel and then importing the data into the configuration database.

However, many of the PC tools now have a Windows Explorer type development studio. The developer then works with a number of folders, which each contains a different aspect of the configuration, including the graphics.

The facilities provided by the products for configuring very large numbers of parameters are not very strong. However, this has not really been an issue so far for most of the products to-date, as large applications are typically about 50K I/O points and database population from within an ASCII editor such as Excel is still a workable option.

On-line modifications to the configuration database and the graphics is generally possible with the appropriate level of privileges.

Development Tools

The following development tools are provided as standard:

- A graphics editor, with standard drawing facilities including freehand, lines, squares circles, etc. It is possible to import pictures in many formats as well as using predefined symbols including e.g. trending charts, etc. A library of generic symbols is provided that can be linked dynamically to variables and animated as they change. It is also possible to create links between views so as to ease navigation at runtime.

- A data base configuration tool (usually through parameter templates). It is in general possible to export data in ASCII files so as to be edited through an ASCII editor or Excel.
- A scripting language
- An Application Program Interface (API) supporting C, C++, VB
- A Driver Development Toolkit to develop drivers for hardware that is not supported by the SCADA product.

Object Handling

The products in general have the concept of graphical object classes, which support inheritance. In addition, some of the products have the concept of an object within the configuration database. In general the products do not handle objects, but rather handle individual parameters, e.g., alarms are defined for parameters, logging is performed on parameters, and control actions are performed on parameters. The support of objects is therefore fairly superficial.

4.7 Evolution

SCADA vendors release one major version and one to two additional minor versions once per year. These products evolve thus very rapidly so as to take advantage of new market opportunities, to meet new requirements of their customers and to take advantage of new technologies. As was already mentioned, most of the SCADA products that were evaluated decompose the process in "atomic" parameters to which a Tag-name is associated. This is impractical in the case of very large processes when very large sets of Tags need to be configured. As the industrial applications are increasing in size, new SCADA versions are now being designed to handle devices and even entire systems as full entities (classes) that encapsulate all their specific attributes and functionality. In addition, they will also support multi-team development. As far as new technologies are concerned, the SCADA products are now adopting:

- Web technology, ActiveX, Java, etc.

- OPC as a means for communicating internally between the client and server modules. It should thus be possible to connect OPC compliant third party modules to that SCADA product.

4.8 Engineering

Whilst one should rightly anticipate significant development and maintenance savings by adopting a SCADA product for the implementation of a control system, it does not mean a "no effort" operation. The need for proper engineering can not be sufficiently emphasised to reduce development effort and to reach a system that complies with the requirements, that is economical in development and maintenance and that is reliable and robust. Examples of engineering activities specific to the use of a SCADA system are the definition of:

- A library of objects (PLC, device, subsystem) complete with standard object behaviour (script, sequences, ...), graphical interface and associated scripts for animation,
- Templates for different types of "panels", e.g. alarms,
- Instructions on how to control e.g. a device ...,
- A mechanism to prevent conflicting controls (if not provided with the SCADA)
- Alarm levels, behaviour to be adopted in case of specific alarms, ...

4.9 POTENTIAL BENEFITS OF SCADA

The benefits one can expect from adopting a SCADA system for the control of experimental physics facilities can be summarised as follows:

- A rich functionality and extensive development facilities. The amount of effort invested in SCADA product amounts to 50 to 100 p-years
- The amount of specific development that needs to be performed by the end-user is limited, especially with suitable engineering.
- Reliability and robustness. These systems are used for mission critical industrial processes where reliability and performance are paramount. In addition, specific development is performed within a well-established framework that enhances reliability and robustness.

- Technical support and maintenance by the vendor.

For large collaborations, as for the CERN LHC experiments, using a SCADA system for their controls ensures a common framework not only for the development of the specific applications but also for operating the detectors. Operators experience the same "Look and feel" whatever part of the experiment they control. However, this aspect also depends to a significant extent on proper engineering.

4.10 Considerations and benefits of SCADA system

Typical considerations when putting a SCADA system together are:

- Overall control requirements
- Sequence logic
- Analog loop control
- Ratio and number of analog to digital points
- Speed of control and data acquisition
- Master/operator control stations
- Type of displays required
- Historical archiving requirements
- System consideration
- Reliability/availability
- Speed of communications/update time/system scan rates
- System redundancy
- Expansion capability
- Application software and modeling

Obviously, a SCADA system's initial cost has to be justified. A few typical reasons for implementing a SCADA system are:

- Improved operation of the plant or process resulting in savings due to optimization of the system

- Increased productivity of the personnel
- Improved safety of the system due to better information and improved control
- Protection of the plant equipment
- Safeguarding the environment from a failure of the system
- Improved energy savings due to optimization of the plant
- Improved and quicker receipt of data so that clients can be invoiced more quickly and accurately
- Government regulations for safety and metering of gas (for royalties & tax etc)

5.0 Programmable logic controller (PLC)

Since the late 1970s, PLCs have replaced hardwired relays with a combination of ladder logic software and solid state electronic input and output modules. They are often used in the implementation of a SCADA RTU as they offer a standard hardware solution, which is very economically priced.

5.1 PLCs used as RTUs

A PLC or programmable logic controller is a computer based solid state device that controls industrial equipment and processes. It was initially designed to perform the logic functions executed by relays, drum switches and mechanical timer/counters. Analog control is now a standard part of the PLC operation as well.

The advantage of a PLC over the RTU offerings from various manufacturers is that it can be used in a general-purpose role and can easily be set up for a variety of different functions.

The actual construction of a PLC can vary widely and does not necessarily differ much from generalizing on the discussion of the standard RTU.

PLCs are popular for the following reasons:

- **Economic solution**

  PLCs are a more economic solution than a hardwired relay solution manufactured RTU

- **Versatility and flexibility**

  PLCs can easily have their logic or hardware modified to cope with modified requirements for control

- **Ease of design and installation**

  PLCs have made the design and installation of SCADA systems easier because of the emphasis on software

- **More reliable**

  When correctly installed, PLCs are a far more reliable solution than a traditional hardwired relay solution or short run manufactured RTUs.
- **Sophisticated control**

  PLCs allow for far more sophisticated control (mainly due to the software capability) than RTUs.
- **Physically compact**

  PLCs take up far less space than alternative solutions.
- **Easier troubleshooting and diagnostics**

  Software and clear cut reporting of problems allows easy and swift diagnosis of hardware/firmware/software problems on the system as well as identifying problems with the process and automation system.

5.2 PLC software

The ladder-logic approach to programming is popular because of its perceived similarity to standard electrical circuits. Two vertical lines supplying the power are drawn at each of the sides of the diagram with the lines of logic drawn in horizontal lines.

The example below shows the 'real world' circuit with PLC acting as the control device and the internal ladder-logic within the PLC.

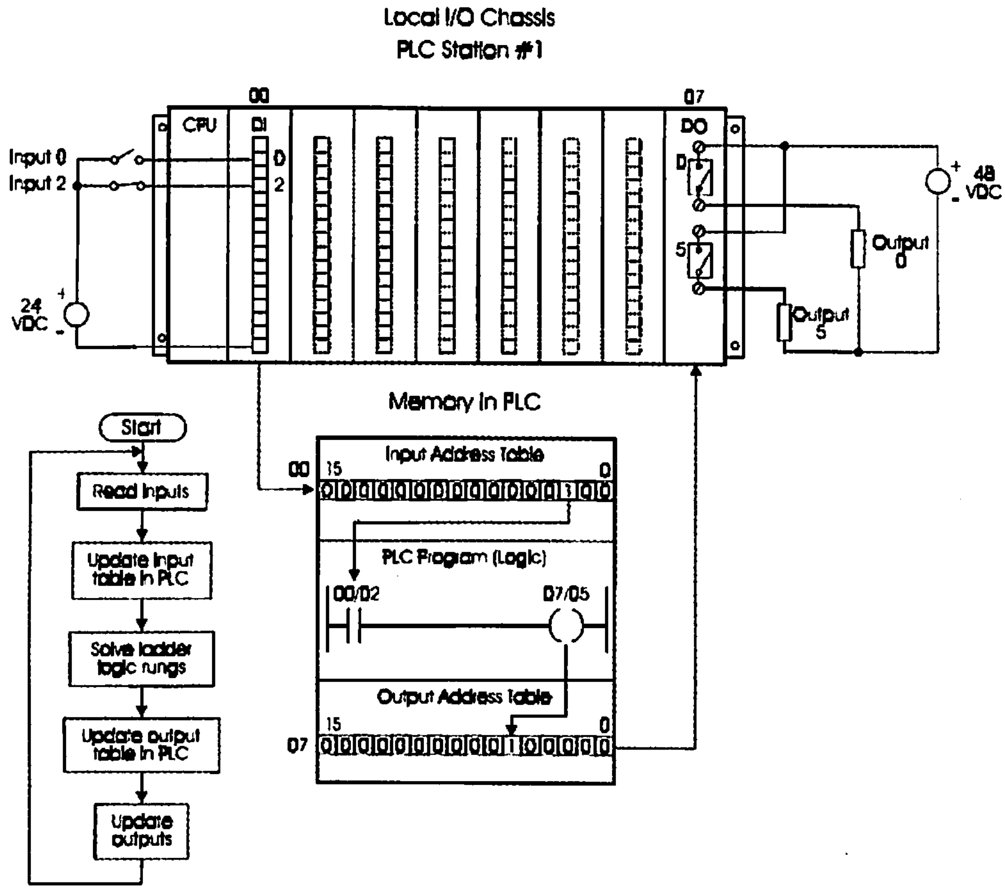


Fig 5.1 The concept of PLC ladder-logic

5.3 Basic rules of ladder-logic

The basic rules of ladder-logic can be stated to be:

- The vertical lines indicate the power supply for the control system (12 V DC to 240 V AC). The 'power flow' is visualized to move from left to right.
- Read the ladder diagram from left to right and top to bottom (as in the normal Western convention of reading a book).
- Electrical devices are normally indicated in their normal de-energized condition. This can sometimes be confusing and special care needs to be taken to ensure consistency.
- The contacts associated with coils, timers, counters and other instructions have the same numbering convention as their control device.

- Devices that indicate a start operation for a particular item are normally wired in parallel (so that any of them can start or switch the particular item on). See below Figure for an example of this.

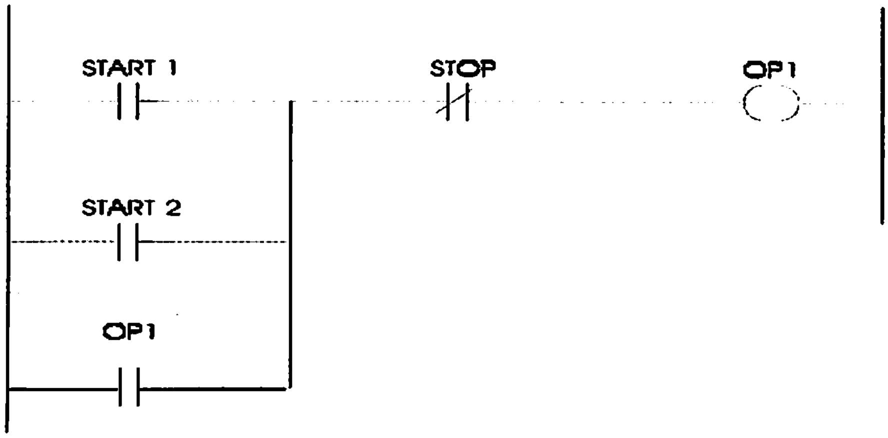


Fig 5.2 Ladder-logic start operation (& logic diagram)

- Devices that indicate a stop operation for a particular item are normally wired in series (so that any of them can stop or switch the particular items off). See below Figure for an example of this.

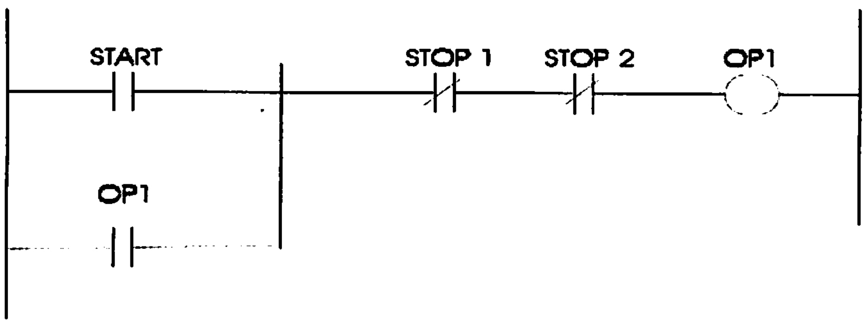


Fig 5.3 Ladder-logic stop operation (& logic diagram)

- Latching operations are used, where a momentary start input signal latches the start signal into the on condition, so that when the start input goes into the OFF condition, the start signal remains energized ON. The latching operation is also referred to as holding or maintaining a sealing contact. See the previous two diagrams for examples of latching.

- Interactive logic: Ladder-logic rungs that appear later in the program often interact with the earlier ladder-logic rungs. This useful feed back mechanism can be used to provide feed back on successful completion of a sequence of operations (or protect the overall system due to failure of some aspect).

5.4 The different ladder-logic instructions

Ladder-logic instruction can be typically broken up into the following different categories:

- Standard relay logic type
- Timer and counters
- Arithmetic
- Logical
- Move
- Comparison
- File manipulation
- Sequencer instructions
- Specialized analog (PID)
- Communication instructions
- Diagnostic
- Miscellaneous (sub routines etc)

5.5 System response time

These should be carefully specified for the following events. Typical speeds that are considered acceptable are:

- Display of analog or digital value (acquired from RTU) on the master station operator display (1 to 2 seconds maximum)
- Control request from operator to RTU (1 second critical; 3 seconds noncritical)

- Acknowledge of alarm on operator screen (1 second)
- Display of entire new display on operator screen (1 second)
- Retrieval of historical trend and display on operator screen (2 seconds)
- Sequence of events logging (at RTU) of critical events (1 millisecond)
- It is important that the response is consistent over all activities of the SCADA system.

Hence the above figures are irrelevant unless the typical loading of the system is also specified under which the above response rates will be maintained. In addition no loss of data must occur during these peak times.

A typical example of specification of loading on a system would be:

- 90% of all digital points change status every 2 seconds (or go from healthy into alarm condition).
- 80% of all analog values undergoing a transition from 0 to 100% every 2 seconds. The distributed approach to the design of the SCADA system (where the central site/master station does not carry the entire load of the system) ensures that these figures can be easily achieved.

6.0 Communication architectures

There are three main physical communication architectures possible. The approaches can be combined in one communication system. However, it is useful to consider each one in isolation for the purposes of this discussion. The ancillary philosophies of achieving communications will be considered next.

6.1 Point-to-point (two stations)

This is the simplest configuration where data is exchanged between two stations. One station can be setup as the master and one as the slave. It is possible for both stations to communicate in full duplex mode (transmitting and receiving on two separate frequencies) or simplex with only one frequency.

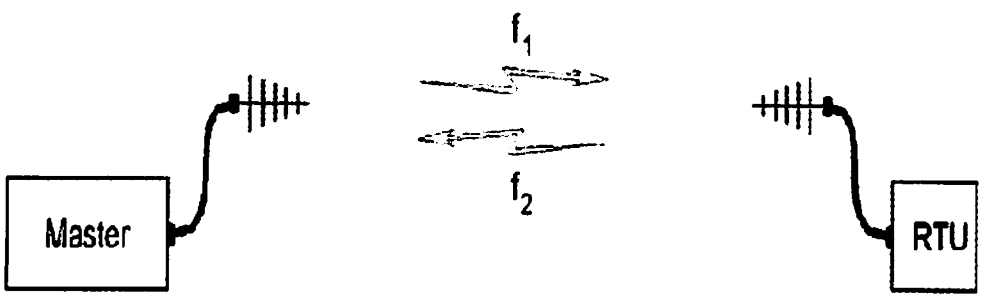


Fig 6.1 Point-to-point (two station)

6.2 Multipoint (or multiple stations)

In this configuration, there is generally one master and multiple slaves. Generally data points are efficiently passed between the master and each of the slaves. If two slaves need to transfer data between each other they would do so through the master who would act as arbitrator or moderator.

Alternatively, it is possible for all the stations to act in a peer-to-peer communications manner with each other. This is a more complex arrangement requiring sophisticated protocols to handle collisions between two different stations wanting to transmit at the same time.

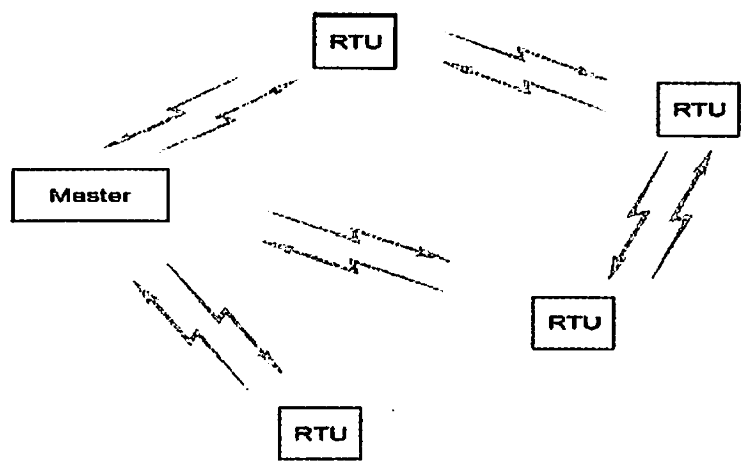


Fig 6.2 Multiple stations

6.3 Relay Stations

There are two possibilities here:

- **Store and forward relay operation**

  This can be a component of the other approaches discussed above where one station retransmits messages onto another station out of the range of the master station. This is often called a store and forward relay station. There is no simultaneous transmission of the message by the store and forward station. It retransmits the message at the same frequency as it received it after the message has been received from the master station. This approach is slower than a talk through repeater as each message has to be sent twice. The advantages are considerable savings in mast heights and costs.

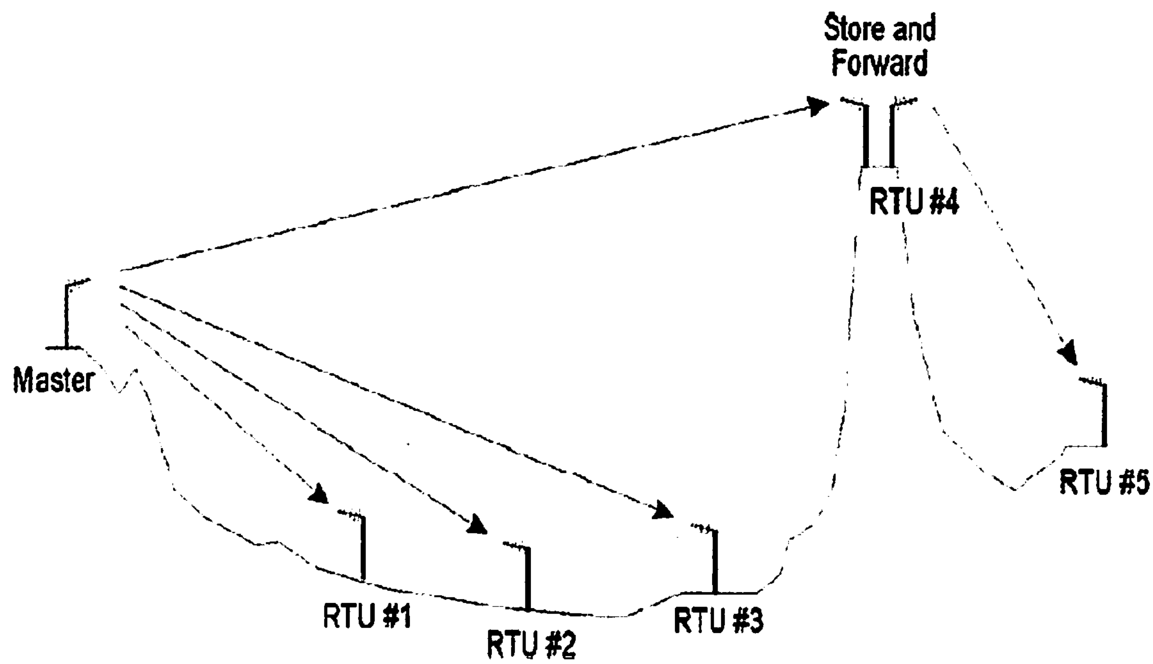


Fig 6.3 Store and forward station

- **Talk through repeaters**

  This is the generally preferred way of increasing the radio system's range. This retransmits a radio signal received simultaneously on another frequency. It is normally situated on a geographically high point. The repeater receives on one frequency and retransmits on another frequency simultaneously. This means that all the stations it is repeating the signal to must receive and transmit on the opposite frequencies. It is important that all stations communicate through the talk through repeater. It must be a common link for all stations and thus have a radio mast high enough to access all RTU sites. It is a strategic link in the communication system; failure would wreak havoc with the entire system. The antenna must receive on one frequency and transmit on a different frequency. This means that the system must be specifically designed for this application with special filters attached to the antennas. There is still a slight time delay in transmission of data with a repeater. The protocol must be designed with this in mind with sufficient lead time for the repeater's receiver and transmitter to commence operation.

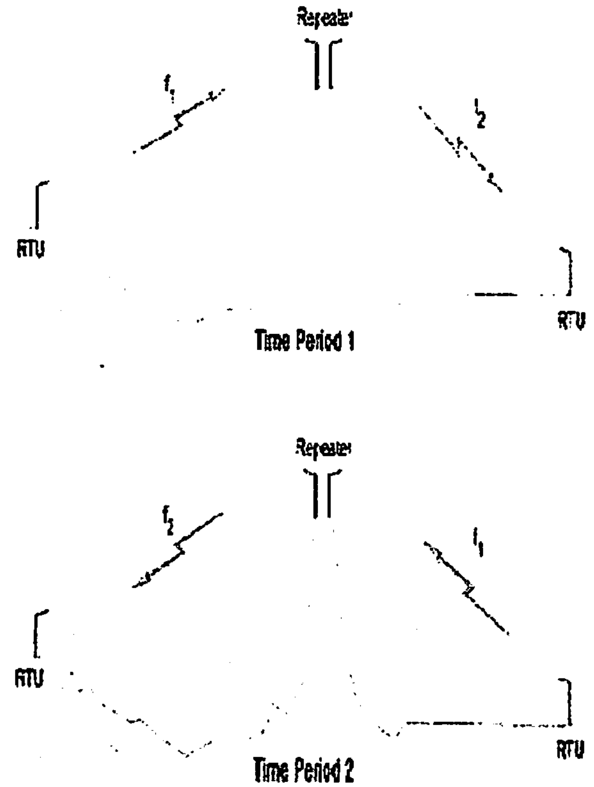


Fig 6.4 Talk through repeaters

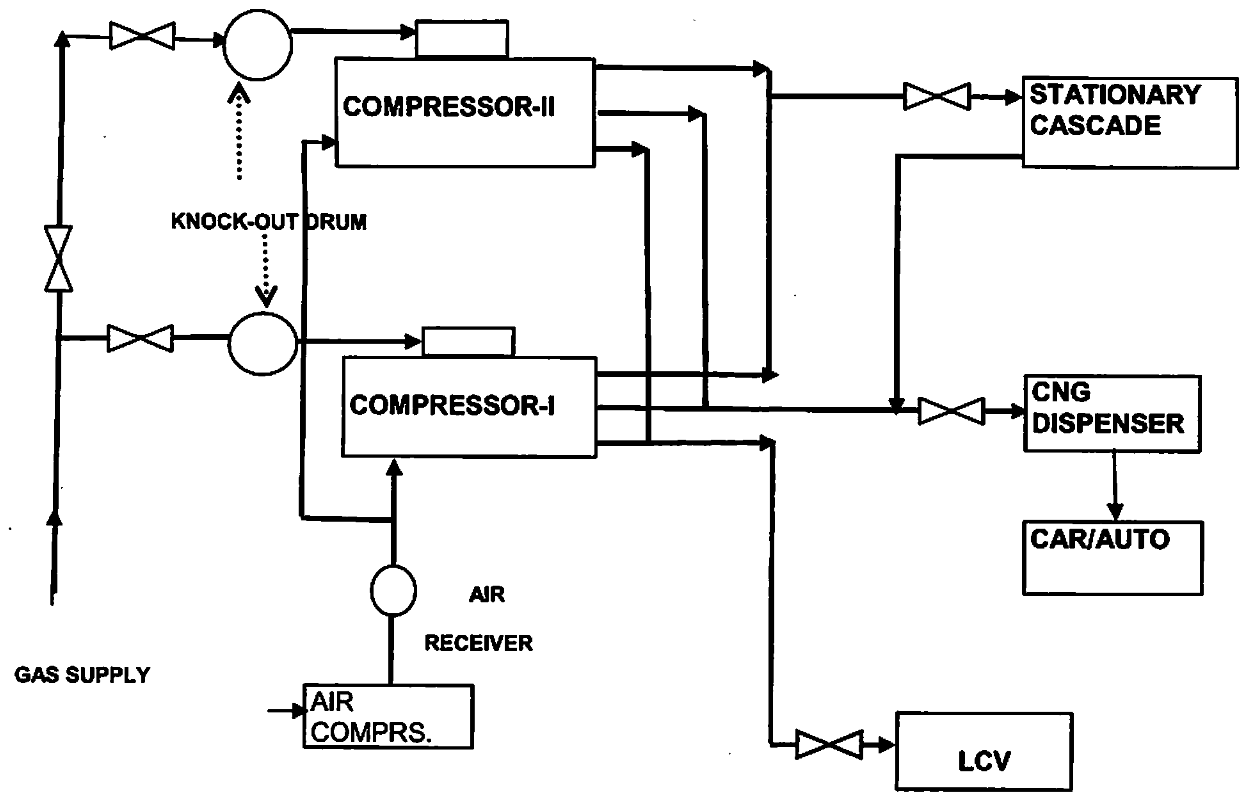


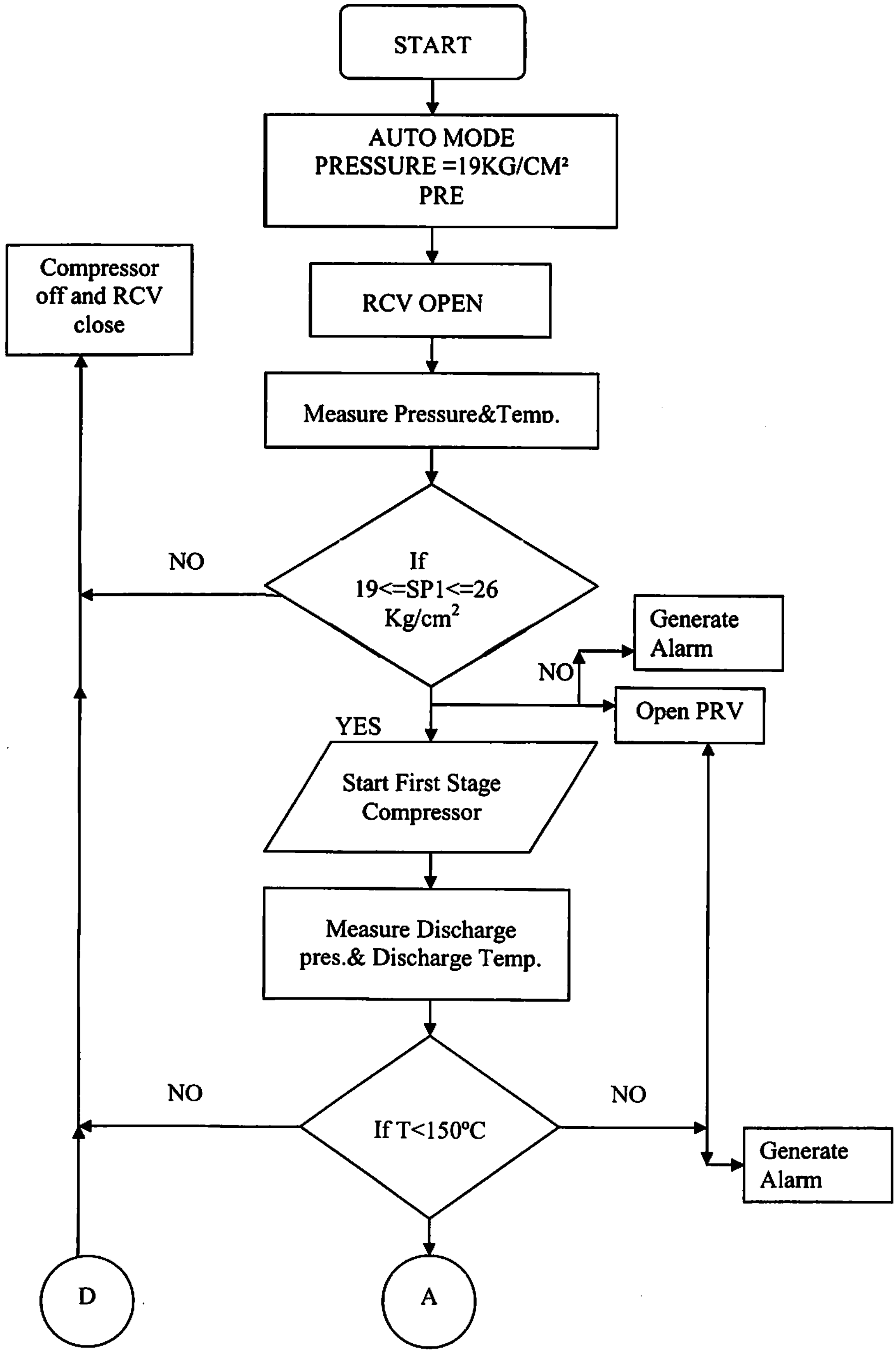
Fig7.1 CNG MOTHER STATION

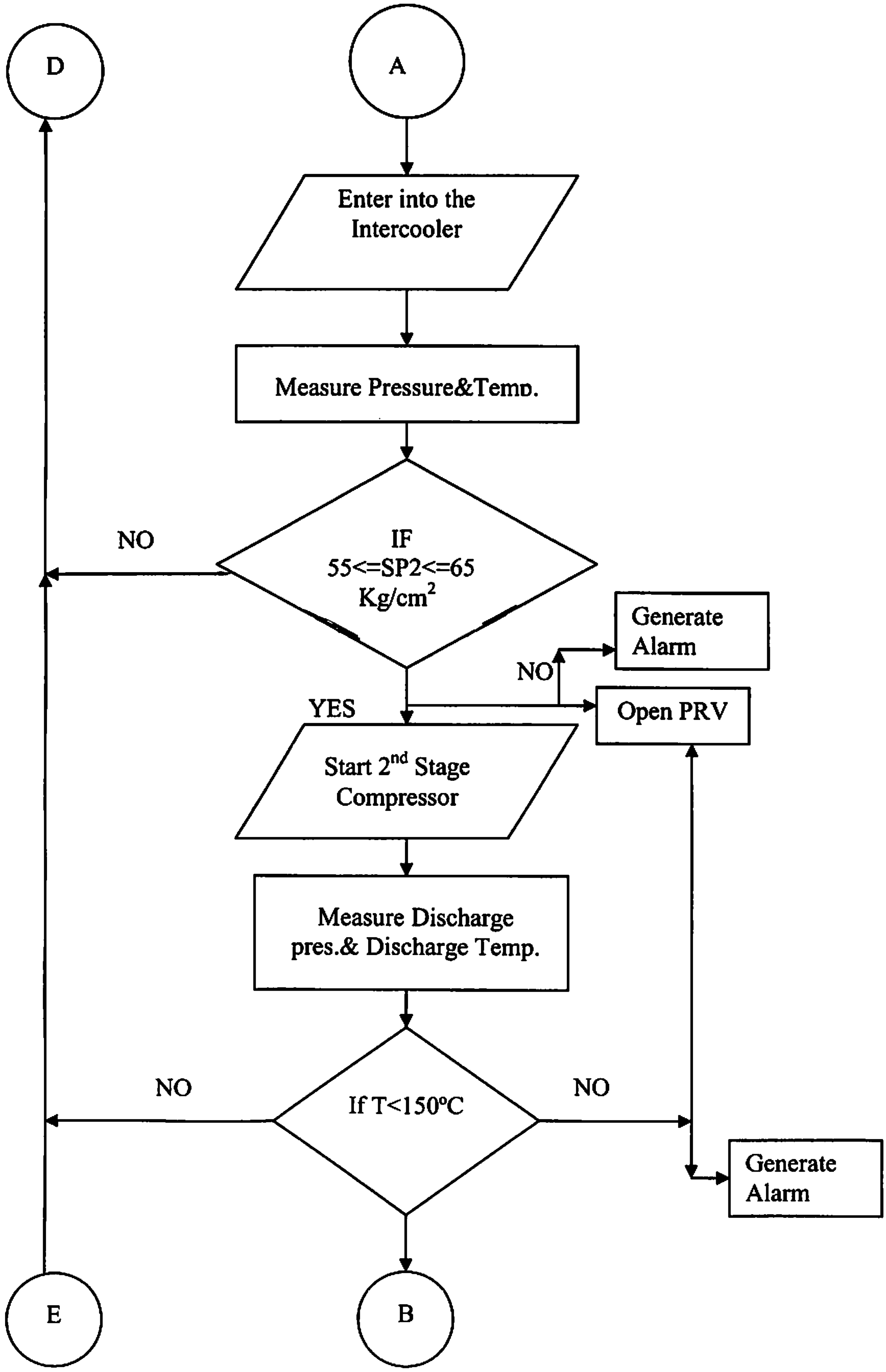
7.1 Algorithm for the Safety of a Gas Compressor in CNG Station

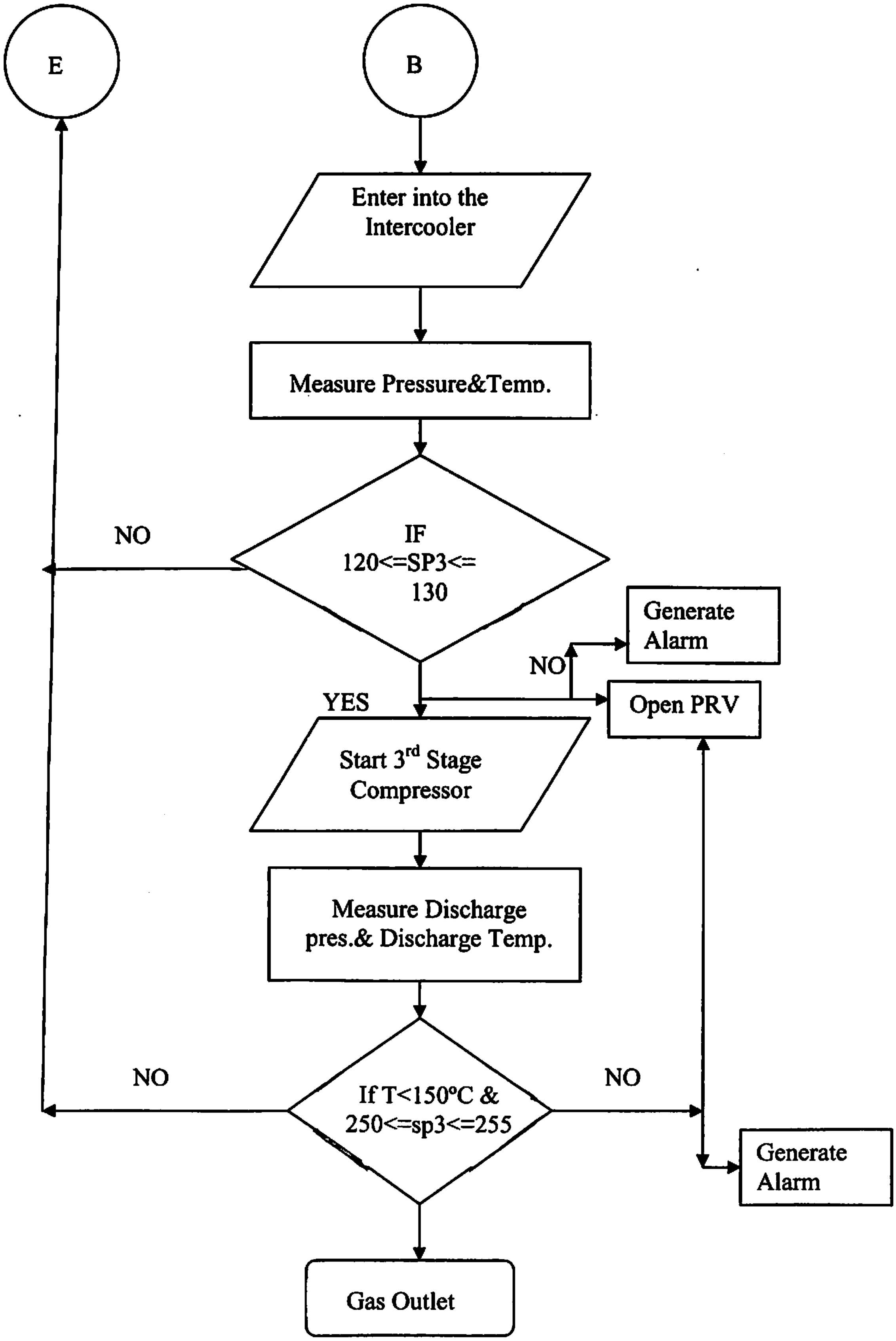
1. Start the system in Auto mode.
2. Open Ball valve at the Gas suction from client conditioning Skid.
3. Control Gas supply through pressure RCV valve.
4. Measure the Pressure and Temperature at suction of the First Stage compressor.
5. If Pressure is in between the 19 and 26Kg/sq.cm, then only gas enters into the first stage compressor, otherwise the compressor will be trip and generate the alarm, the RCV is closed and relief valve 1 is open.
6. Measure the gas pressure, temperature at discharge side of the First stage compressor.
7. If discharge temperature is less then 150 °C then only gas enter into the Inter cooler, otherwise the compressor will be trip and generate the alarm, the RCV is closed and relief valve 1 is open.
8. Measure the gas pressure and temperature at the suction side of the Second Stage Compressor.
9. If the Pressure is in between the 55 and 65Kg/sq.cm, then only gas enters into the second stage compressor otherwise the compressor will be trip and generate the alarm, the RCV is closed and relief valve 2 is open.
10. Measure the gas pressure, temperature at discharge side of the Second stage compressor.
11. If discharge temperature is less then 150 °C then only gas enter into the Inter cooler, otherwise the compressor will be trip and generate the alarm, the RCV is closed and relief valve 2 is open.
12. Measure the gas pressure and temperature at suction side of the Third Stage Compressor.
13. If the Pressure is in between the 120 and 130Kg/sq.cm, then only gas enters into the third stage compressor otherwise the compressor will be trip and generate the alarm, the RCV is closed and relief valve 3 is open.

14. Measure the gas pressure, temperature at discharge side of the third stage compressor.
15. If discharge pressure is not in between 250 and 255kg/sq.cm at the Third stage compressor, then the compressor will be trip and generate the alarm, the RCV is closed and relief valve 3 is open.
16. If discharge temperature is less then 150 °C then only gas enter into the Inter cooler, otherwise the compressor will be trip and generate the alarm, the RCV is closed and relief valve 3 is open.

7.2 Flow sheet for the Safety of a Gas Compressor in CNG Station


START
AUTO MODE
PRESSURE =19KG/CM²
PRE
RCV OPEN
Measure Pressure&Temp.
Compressor
off and RCV
close
NO
If
19<=SP1<=26
Kg/cm²
NO
Generate
Alarm
Open PRV
YES
Start First Stage
Compressor
Measure Discharge
pres.& Discharge Temp.
NO
If T<150°C
NO
Generate
Alarm
D
A


D
A
Enter into the Intercooler
Measure Pressure&Temp.
NO
IF 55<=SP2<=65 Kg/cm2
Generate Alarm
NO
YES
Open PRV
Start 2nd Stage Compressor
Measure Discharge pres.& Discharge Temp.
NO
If T<150ºC
NO
Generate Alarm
E
B


E
B
Enter into the Intercooler
Measure Pressure&Temp.
NO
IF 120<=SP3<= 130
Generate Alarm
NO
YES
Open PRV
Start 3rd Stage Compressor
Measure Discharge pres.& Discharge Temp.
NO
NO
If T<150°C & 250<=sp3<=255
Generate Alarm
Gas Outlet

7.4 SCADA Control Panel

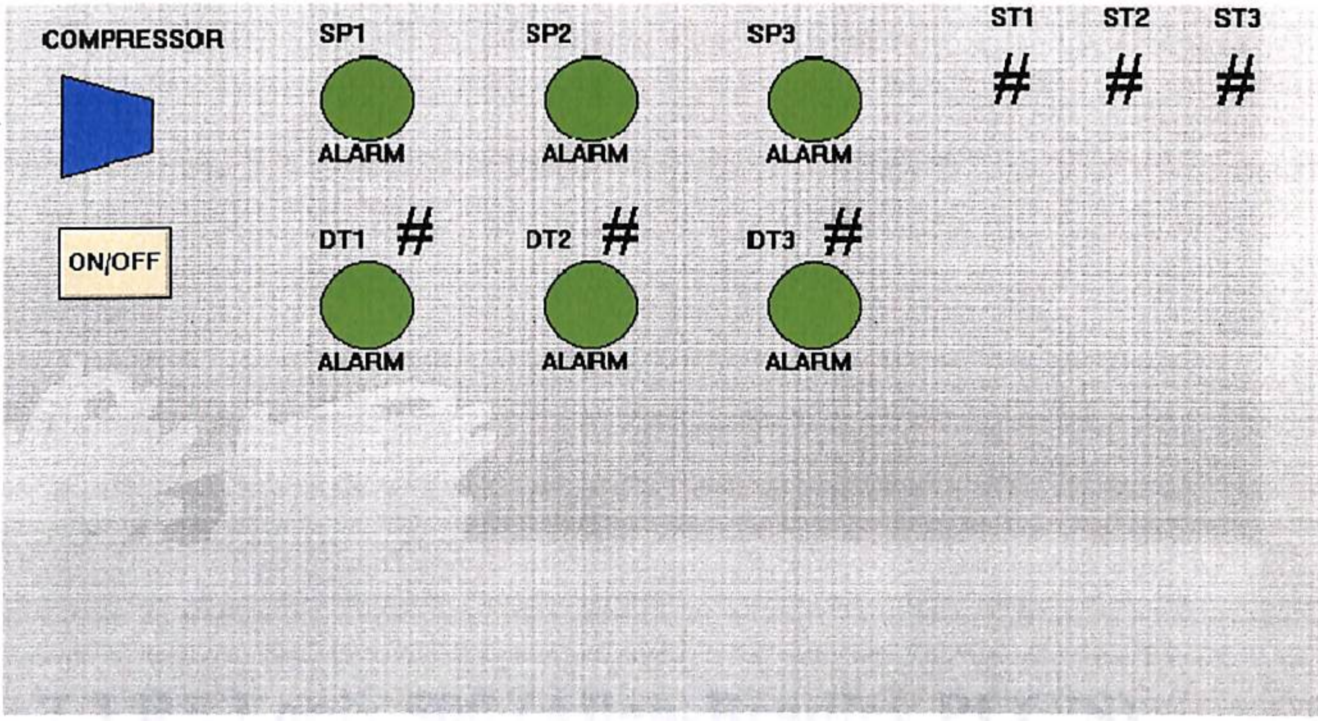


Fig. 7..2 SCADA control panel

7.3 RS Logix 500 (Allen-Bradley PLC'S) PROGRAM

Processor Type: 1747-L531   5/03 CPU - 8K Mem. OS302

Processor Name: UNTITLED

Total Memory Used: 188 Instruction Words Used - 60 Data Table Words Used

Total Memory Left: 3908 Instruction Words Left

Program Files: 4

Data Files: 9

Program ID: bf09

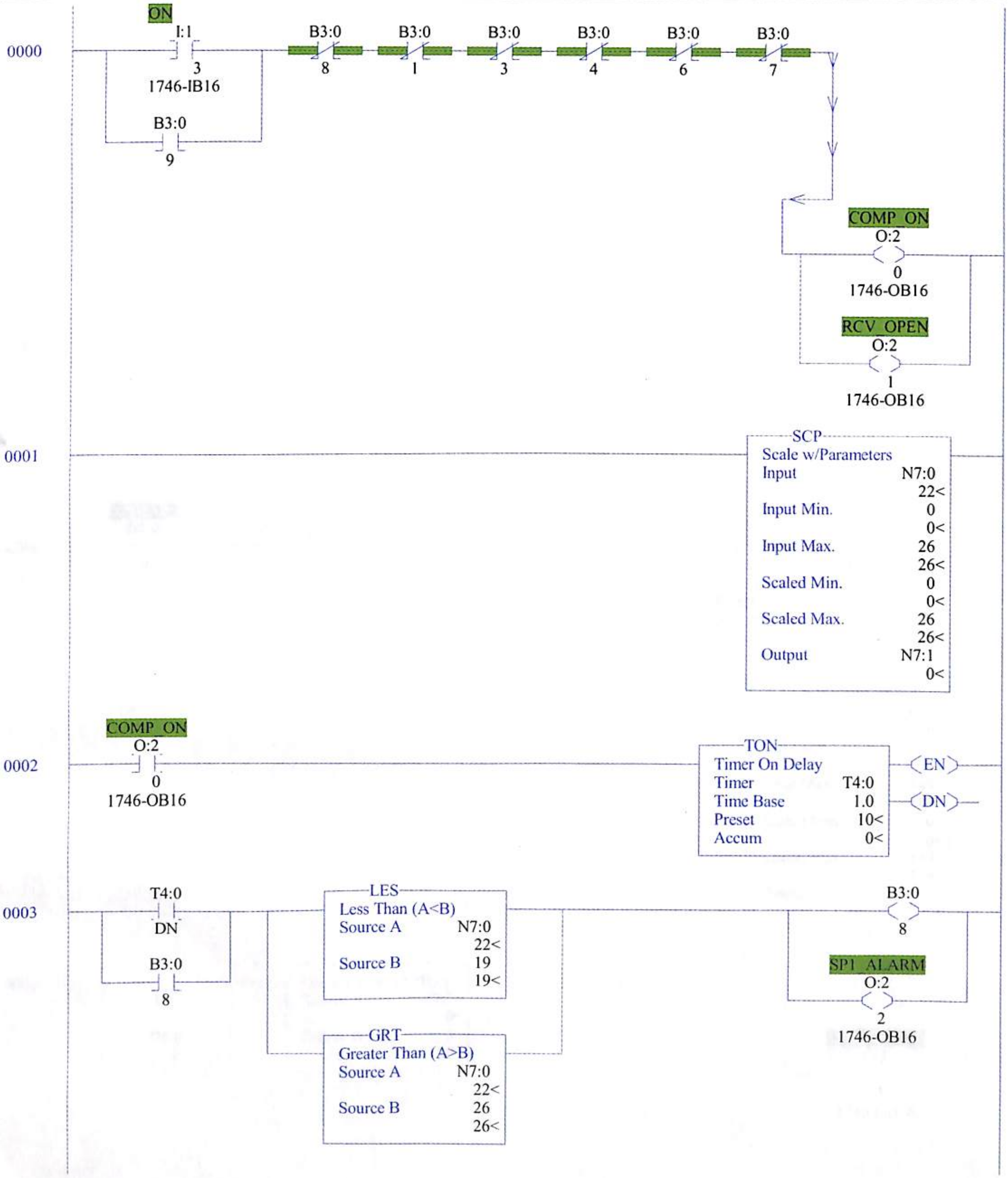
SAN 3STAGE COMPRESSOR

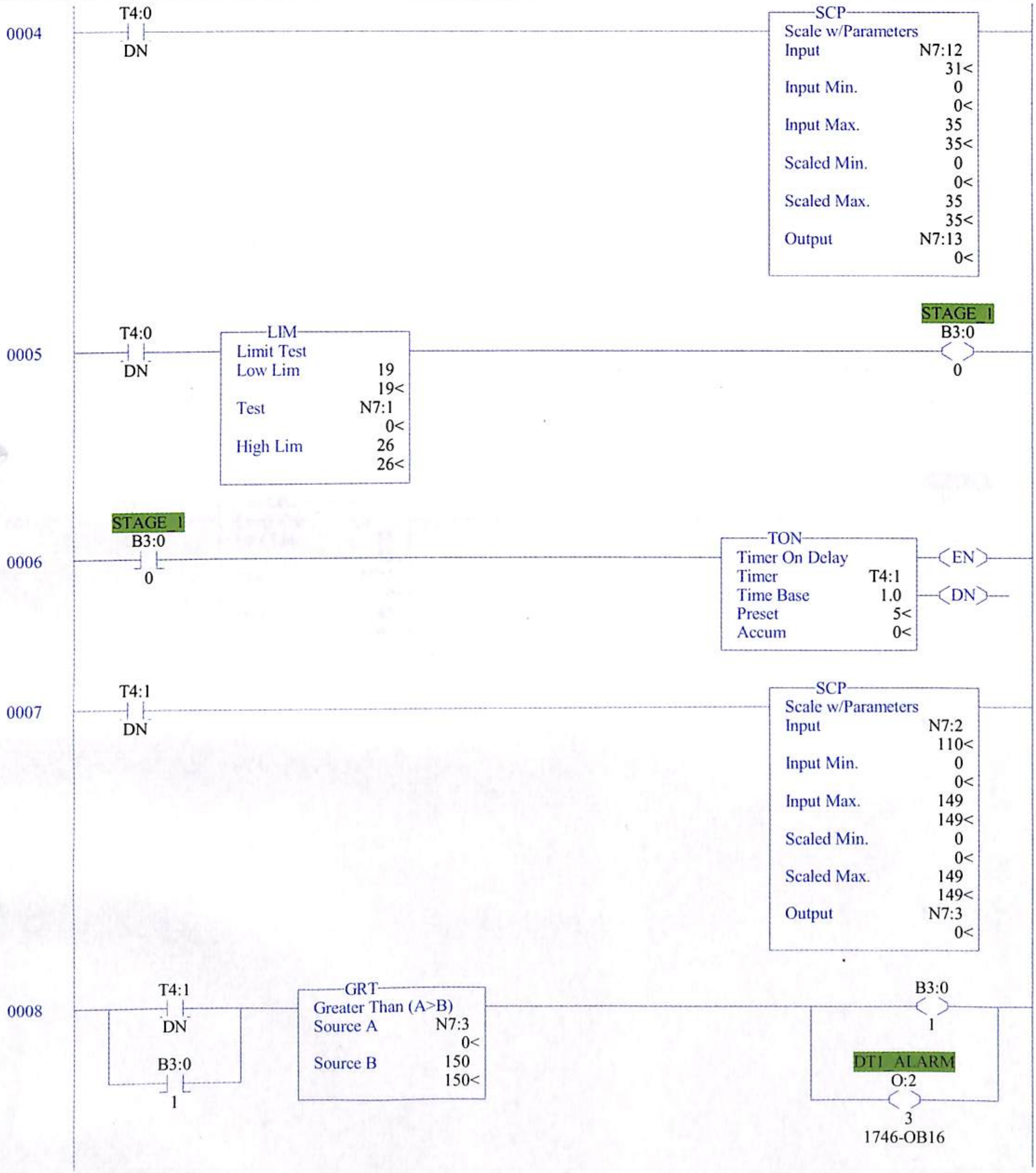
Program File List

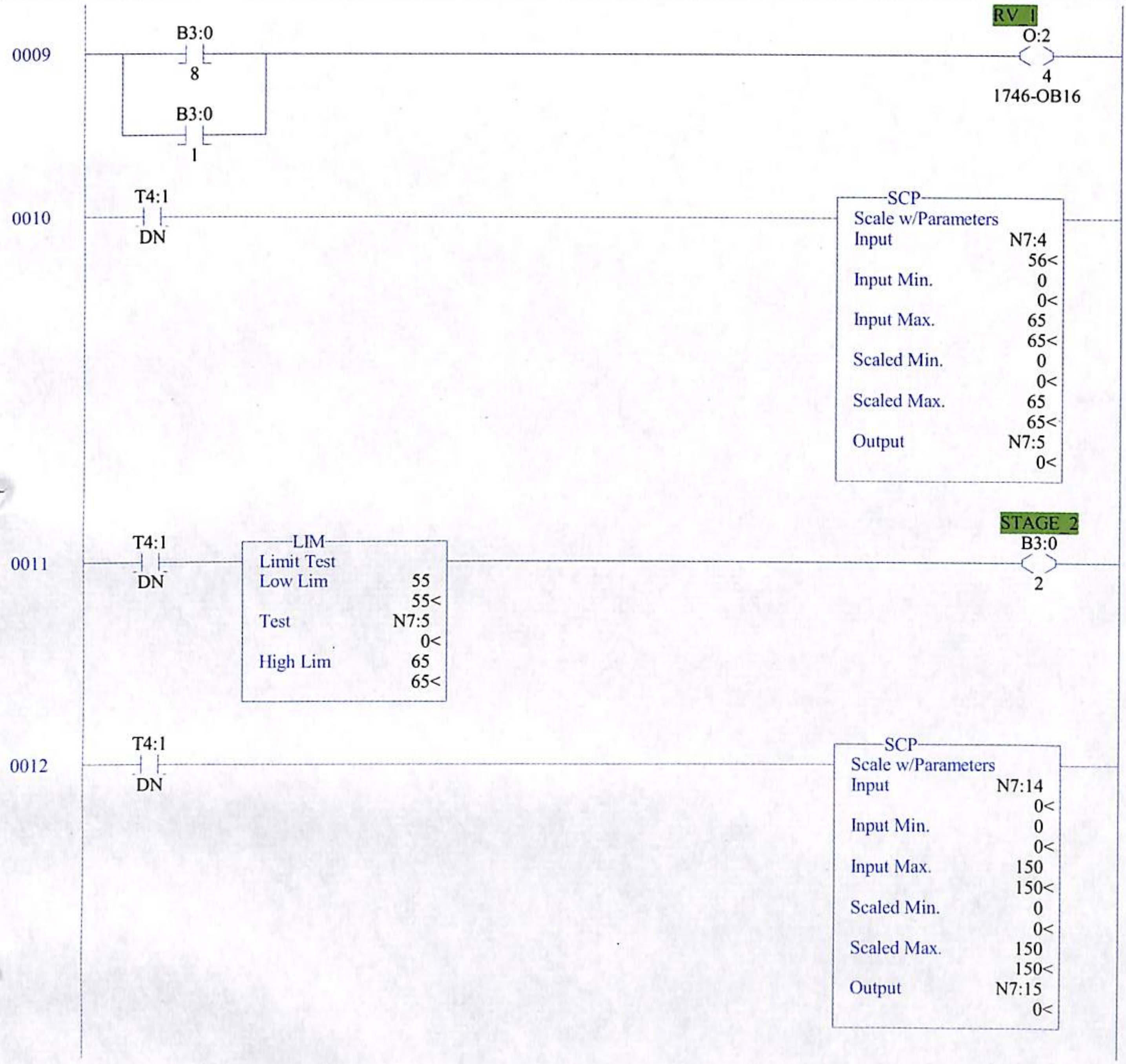
Name	Number	Type	Rungs	Debug	Bytes
[SYSTEM]	0	SYS	0	No	0
	1	SYS	0	No	0
	2	LADDER	27	No	1137
DISP	3	LADDER	1	No	3

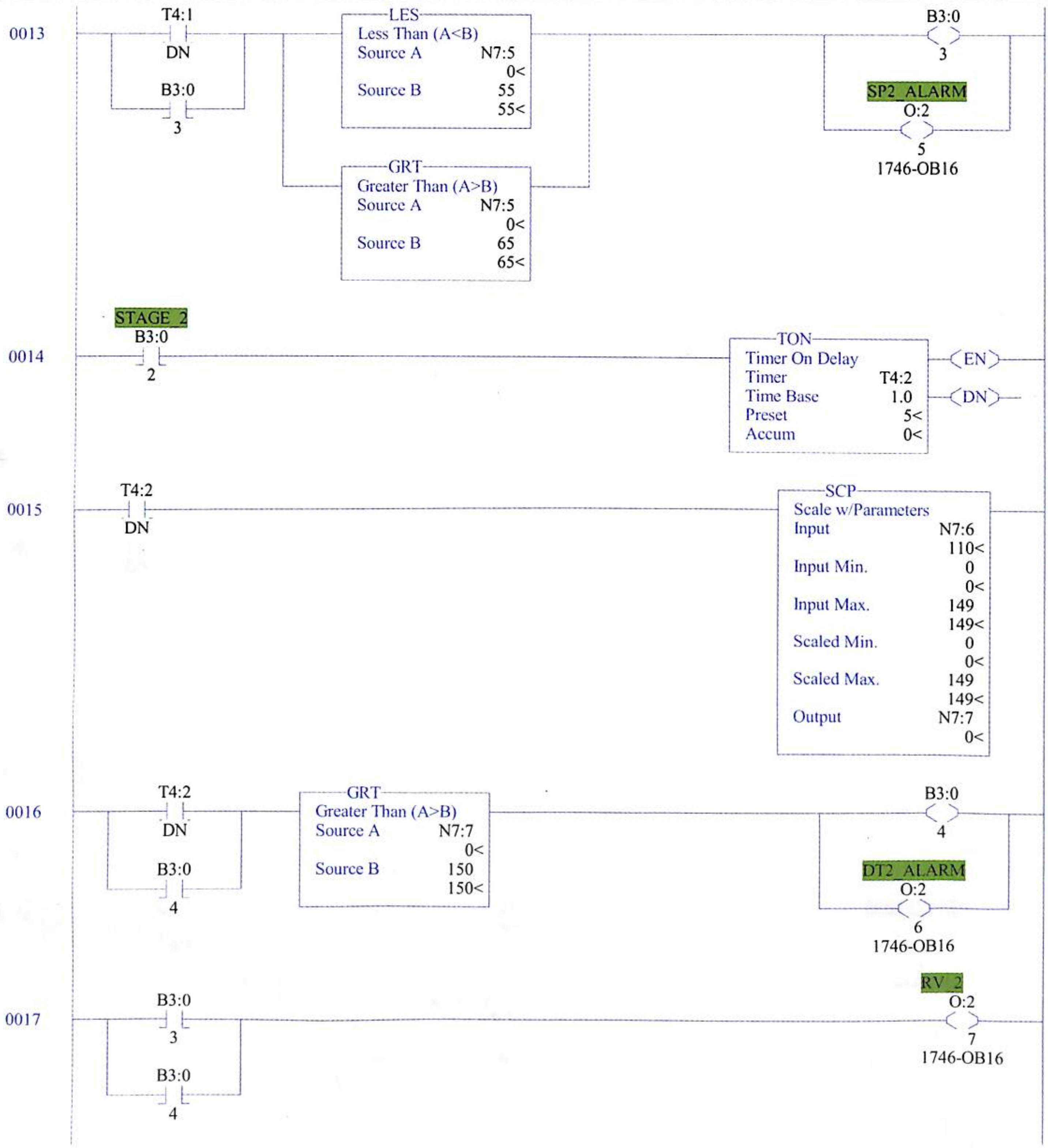
SAN 3STAGE COMPRESSOR

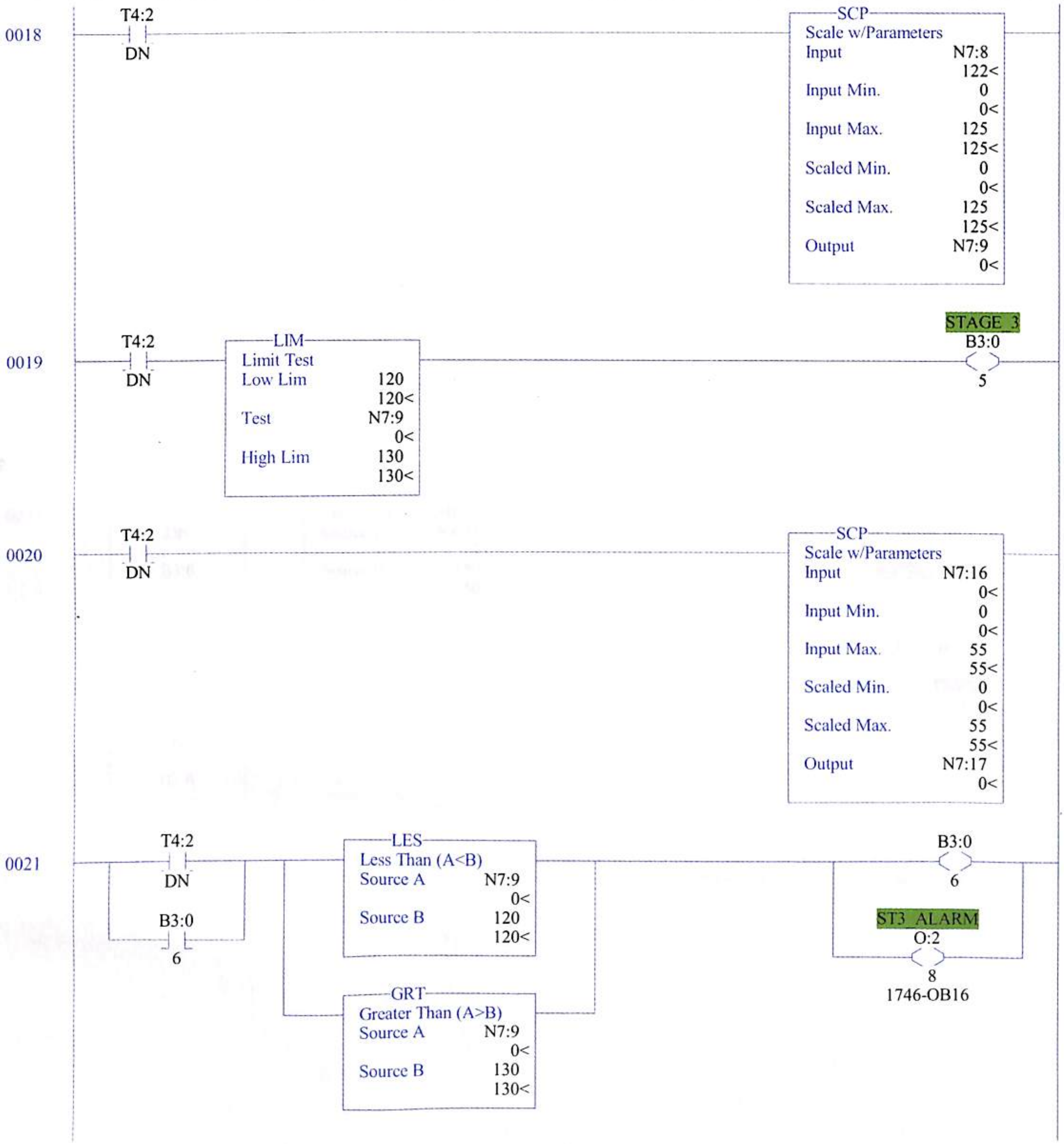
LAD 2 - --- Total Rungs in File = 27

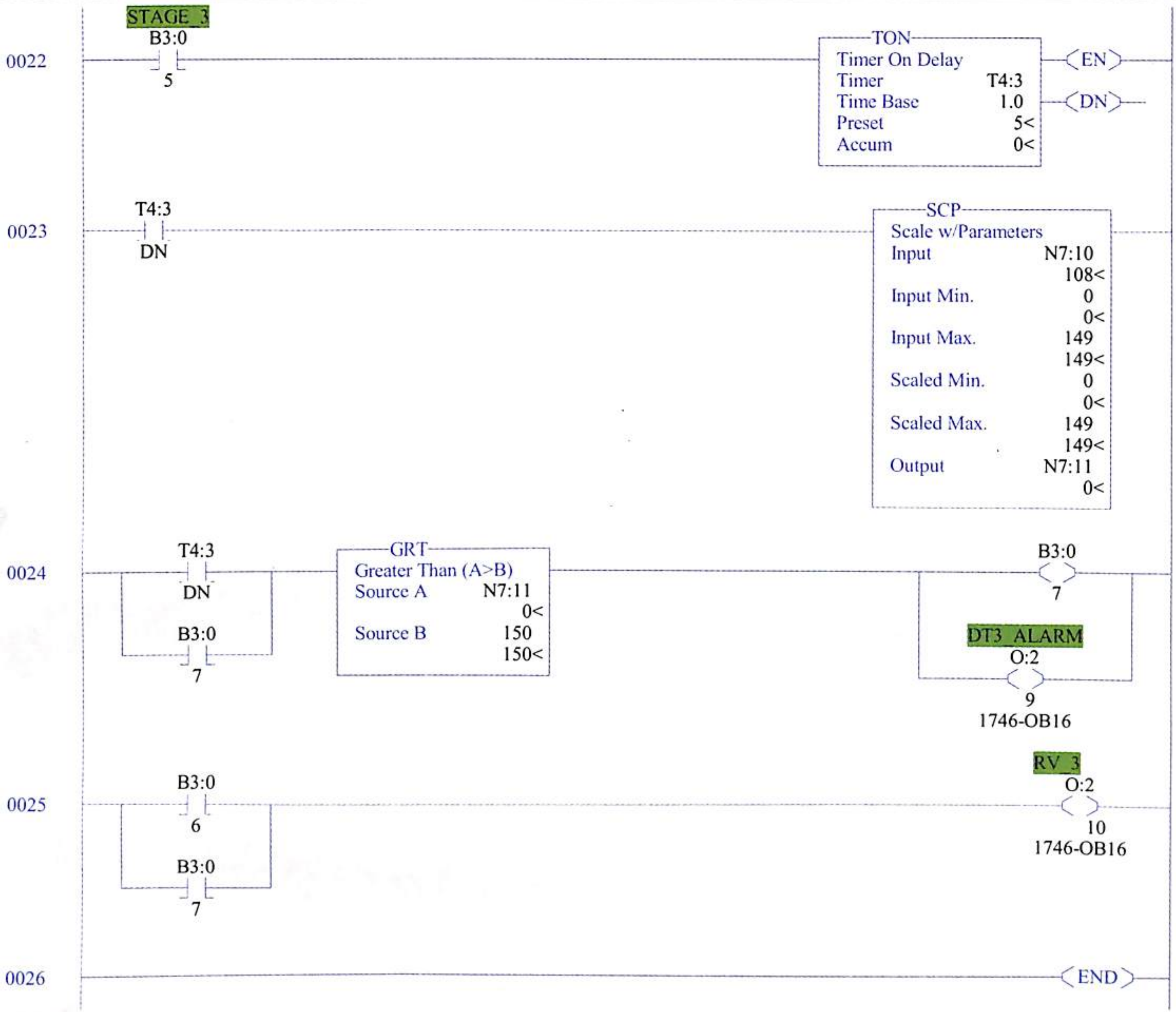



0004
T4:0
DN
SCP
Scale w/Parameters
Input N7:12
31<
Input Min. 0
0<
Input Max. 35
35<
Scaled Min. 0
0<
Scaled Max. 35
35<
Output N7:13
0<
0005
T4:0
DN
LIM
Limit Test
Low Lim 19
19<
Test N7:1
0<
High Lim 26
26<
STAGE_1
B3:0
0
0006
STAGE_1
B3:0
0
TON
Timer On Delay
Timer T4:1
Time Base 1.0
Preset 5<
Accum 0<
EN
DN
0007
T4:1
DN
SCP
Scale w/Parameters
Input N7:2
110<
Input Min. 0
0<
Input Max. 149
149<
Scaled Min. 0
0<
Scaled Max. 149
149<
Output N7:3
0<
0008
T4:1
DN
B3:0
1
GRT
Greater Than (A>B)
Source A N7:3
0<
Source B 150
150<
B3:0
1
DT1_ALARM
O:2
3
1746-OB16


0009
B3:0
8
B3:0
1
RV_1
O:2
4
1746-OB16
0010
T4:1
DN
SCP
Scale w/Parameters
Input N7:4
56<
Input Min. 0
0<
Input Max. 65
65<
Scaled Min. 0
0<
Scaled Max. 65
65<
Output N7:5
0<
0011
T4:1
DN
LIM
Limit Test
Low Lim 55
55<
Test N7:5
0<
High Lim 65
65<
STAGE_2
B3:0
2
0012
T4:1
DN
SCP
Scale w/Parameters
Input N7:14
0<
Input Min. 0
0<
Input Max. 150
150<
Scaled Min. 0
0<
Scaled Max. 150
150<
Output N7:15
0<


0013
T4:1
DN
B3:0
3
LES
Less Than (A<B)
Source A N7:5
0<
Source B 55
55<
GRT
Greater Than (A>B)
Source A N7:5
0<
Source B 65
65<
B3:0
3
SP2_ALARM
O:2
5
1746-OB16
0014
STAGE_2
B3:0
2
TON
Timer On Delay
Timer T4:2
Time Base 1.0
Preset 5<
Accum 0<
EN
DN
0015
T4:2
DN
SCP
Scale w/Parameters
Input N7:6
110<
Input Min. 0
0<
Input Max. 149
149<
Scaled Min. 0
0<
Scaled Max. 149
149<
Output N7:7
0<
0016
T4:2
DN
B3:0
4
GRT
Greater Than (A>B)
Source A N7:7
0<
Source B 150
150<
B3:0
4
DT2_ALARM
O:2
6
1746-OB16
0017
B3:0
3
B3:0
4
RV_2
O:2
7
1746-OB16


0018
T4:2
DN
SCP
Scale w/Parameters
Input N7:8
122<
Input Min. 0
0<
Input Max. 125
125<
Scaled Min. 0
0<
Scaled Max. 125
125<
Output N7:9
0<
0019
T4:2
DN
LIM
Limit Test
Low Lim 120
120<
Test N7:9
0<
High Lim 130
130<
STAGE 3
B3:0
5
0020
T4:2
DN
SCP
Scale w/Parameters
Input N7:16
0<
Input Min. 0
0<
Input Max. 55
55<
Scaled Min. 0
0<
Scaled Max. 55
55<
Output N7:17
0<
0021
T4:2
DN
B3:0
6
LES
Less Than (A<B)
Source A N7:9
0<
Source B 120
120<
GRT
Greater Than (A>B)
Source A N7:9
0<
Source B 130
130<
B3:0
6
ST3_ALARM
O:2
8
1746-OB16


0022
STAGE_3
B3:0
5
TON
Timer On Delay
Timer T4:3
Time Base 1.0
Preset 5<
Accum 0<
EN
DN
0023
T4:3
DN
SCP
Scale w/Parameters
Input N7:10
108<
Input Min. 0
0<
Input Max. 149
149<
Scaled Min. 0
0<
Scaled Max. 149
149<
Output N7:11
0<
0024
T4:3
DN
B3:0
7
GRT
Greater Than (A>B)
Source A N7:11
0<
Source B 150
150<
B3:0
7
DT3_ALARM
O:2
9
1746-OB16
0025
B3:0
6
B3:0
7
RV_3
O:2
10
1746-OB16
0026
END

LAD 3 - DISP --- Total Rungs in File = 1

0000 -- (END)

DISPENSOR

Program File List

Name	Number	Type	Rungs	Debug	Bytes
[SYSTEM]	0	SYS	0	No	0
	1	SYS	0	No	0
	2	LADDER	5	No	123

Processor Information

Processor Type: 1747-L531 5/03 CPU - 8K Mem. OS302

Processor Name: UNTITLED

Total Memory Used: 23 Instruction Words Used - 62 Data Table Words Used

Total Memory Left: 4073 Instruction Words Left

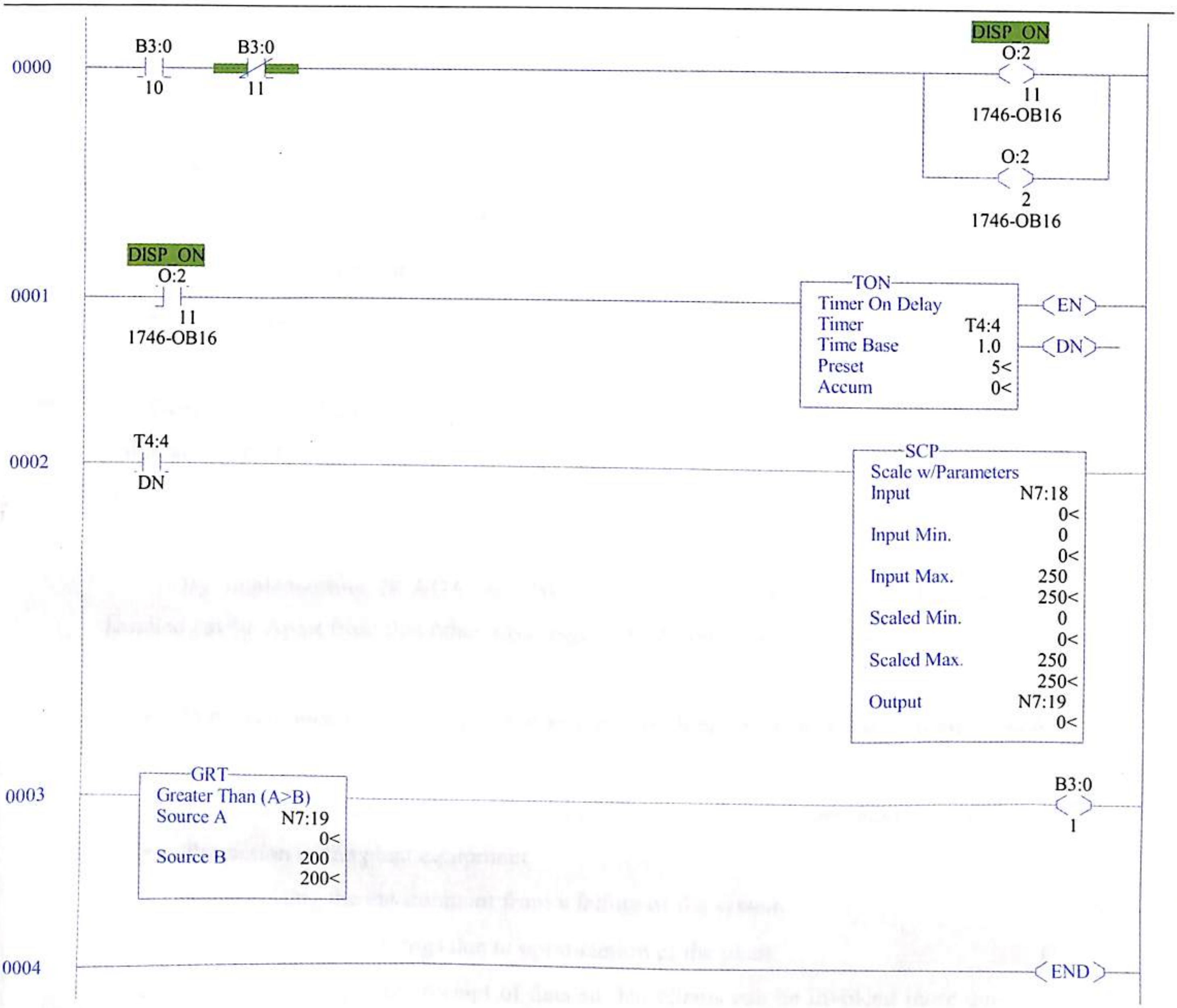
Program Files: 3

Data Files: 9

Program ID: 6125

DISPENSOR

LAD 2 - --- Total Rungs in File = 5



CONCLUSION

In CNG Mother Station safety takes major role. The main safety parameters in CNG Station are:

- Suction Pressure for each stage in 3 stage Reciprocating Compressor.
- Discharge Temperature at each stage in 3 stage Reciprocating Compressor.
- Fire Detection.

There is a limitation for suction pressure, discharge pressure and fire detection. If any value goes out of limit the compressor is going to be effected and that may cause accidents in CNG station.

By implementing SCADA in CNG station unsafe operating conditions can be handled easily. Apart from that other advantages which can be achieved are:

- Improved operation of the plant or process resulting in savings due to optimization of the system
- Improved safety of the system due to better information and improved control
- Protection of the plant equipment
- Safeguarding the environment from a failure of the system
- Improved energy savings due to optimization of the plant
- Improved and quicker receipt of data so that clients can be invoiced more quickly and accurately

The PLC and SCADA program that has been developed by using **RS Logix 500 software (Allen-Bradley PLC'S)** and **SCADA software (Wonderware Intouch)** and successfully executed in **Sofcon India Pvt. Ltd** ensures safe operation of above mentioned parameters and is ready for direct implementation in the industry.

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