SCADA "Supervisory Control And Data Acquisition" implementation in "Sui Northern Gas Pipelines Limited Pakistan" (SNGPL)

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Abstract

This paper will explain SCADA "Supervisory Control And Data Acquisition", and the need for quality management information systems in today's competitive and widely spread business world. Information systems help companies extend their reach to faraway locations, reshape jobs and work flows, and perhaps profoundly change the way they conduct their business. SNGPL is the only gas transportation company in Pakistan, which is utilizing the SCADA system on such a large scale, with much effect. The SCADA system, implemented in SNGPL since 2000, has greatly changed the corporate profile and organizational procedures as well as the public image of the company. DMC phones and traditional tele-printer messages were mainly used for the communication/dissipation of information across the organization before the implementation of SCADA. No timely or abrupt response could have been given to any sabotage/rupture of pipelines, mainly due to lack of an effective and efficient information system throughout the organization. Nowadays, while monitoring mainline pressure and flow at Gas Control Center Faisalabad, the desk operator would immediately issue a command to close the nearest valve, not only to save the gas volume being purged into the atmosphere but also to ensure the safety of precious human lives and public property. Moreover, the company's image in the consumer market has improved greatly due to an uninterrupted gas supply to all major cities and towns of Punjab and NWFP. In short, SCADA has proved to be a blessing in disguise for SNGPL, keeping in view its widely spread infrastructure.

Keywords: SCADA, MIS, SNGPL, RTU, control.

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1 Introduction

SCADA stands for Supervisory Control And Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs), or other commercial hardware modules like Remote Terminal Units (RTUs). The term SCADA usually refers to a central system that monitors and controls a complete site. The bulk of the site control is actually performed automatically by a Remote Terminal Unit (RTU) or by a Programmable Logic Controller (PLC). Host control functions are almost always restricted to basic site over-ride or supervisory level capability. Data acquisition begins at the RTU or PLC level and includes meter readings and equipment statuses that are communicated to the SCADA as required. Data is then compiled and formatted in such a way that a control room operator using the SCADA can make appropriate supervisory decisions that may be required to over-ride normal RTU (PLC) controls. SCADA systems are used not only in industrial processes: e.g. steel making, power generation (conventional and nuclear) and distribution, but also for natural gas Transmission and distribution systems. SCADA systems used to run on DOS, VMS and UNIX; in recent years all SCADA vendors have moved to NT and some also to Linux.

2 Functions and future trends of the SCADA system

Suppose you have a simple electrical circuit consisting of a switch and a light. This circuit allows an operator to watch the light and know whether the switch is open or closed. The switch may indicate that a motor is running or stopped, or whether a door is open or closed, or even whether there has been a fault or the equipment is working.

The trend is for PLC and HMI/SCADA software to be more "mix-and-match". In the mid 1990s, the typical DAQ I/O manufacturer offered their own proprietary communications protocols over a suitable-distance carrier like RS-485. Towards the late 1990s, the shift towards open communications continued with I/O manufacturers offering support of open message structures like Modicon MODBUS over RS-485, and by 2000 most I/O makers offered completely open interfacing such as Modicon MODBUS over TCP/IP. The primary barriers of Ethernet TCP/IP's entrance into industrial automation (determinism, synchronization, protocol selection, environment suitability) are still a concern to a few extremely specialized applications, but for the vast majority of HMI/SCADA markets these barriers have been broken.

Recently, however, the very existence of SCADA based systems has come into question as they are increasingly seen as extremely vulnerable to cyber warfare/ cyber terrorism attacks. Given the mission critical nature of a large number of SCADA systems, such attacks could, in a worse case scenario, cause massive financial losses through loss of data or actual physical destruction, misuse or theft, even loss of life, either directly or indirectly.

3 Operation of SCADA System

3.1 System components

3.1.1 Remote Terminal Unit (RTU)

The RTU connects to physical equipment, and read status data such as the open/closed status from a switch or a valve, read measurements such as pressure, flow, voltage or current. By sending signals to equipment the RTU can control equipment, such as opening or closing a switch or a valve, or setting the speed of a pump. The RTU can read digital status data or analogue measurement data, and send out digital commands or analogue set points.

An important part of most SCADA implementations are alarms. An alarm is a digital status point that has either the value NORMAL or ALARM. Alarms can be created in such a way that when their requirements are met, they are activated. An example of an alarm is the "fuel tank empty" light in a car. The SCADA operator's attention is drawn to the part of the system requiring attention by the alarm. Emails and text messages are often sent along with an alarm activation alerting managers along with the SCADA operator.

3.1.2 Master Station

The term "Master Station" refers to the servers and software responsible for communicating with the field equipment (RTUs, PLCs, etc), and then to the HMI software running on workstations in the control room, or elsewhere. In smaller SCADA systems, the master station may be composed of a single PC. In larger SCADA systems, the master station may include multiple servers, distributed software applications, and disaster recovery sites.

The SCADA system usually presents the information to the operating personnel in the form of a mimic. This means that the operator can see a representation of the plant being controlled. The HMI package for the SCADA system typically includes a drawing program that the operators or system maintenance personnel use to change the way these points are represented in the interface. These representations can be as simple as an on-screen traffic light, which represents the state of an actual traffic light in the field, or as complex as a multi-projector display representing the position of all of the elevators in a skyscraper or all of the trains on a railway. Initially, more "open" platforms such as Linux were not as widely used due to the highly dynamic development environment and because a SCADA customer that was able to afford the field hardware and devices to be controlled could usually also purchase UNIX or OpenVMS licenses. Today, all major operating systems are used for both master station servers and HMI workstations.

3.1.3 Communication infrastructure and methods

SCADA systems have traditionally used combinations of radio and direct serial or modem connections to meet communication requirements, although Ethernet and IP over SONET is also frequently used at large sites such as railways and power stations. This has also come under threat with some customers wanting SCADA data to travel over their pre-established corporate networks or to share the network with other applications. The legacy of the early low-bandwidth protocols remains, though. SCADA protocols are designed to be very compact and many are designed to send information to the master station only when the master station polls the RTU. Typical legacy SCADA protocols include Modbus, RP-570 and Conitel. These communication protocols are all SCADA-vendor specific. Standard protocols are IEC 60870-5-101 or 104 and DNP3. These communication protocols are standardized and recognized by all major SCADA vendors. Many of these protocols now contain extensions to operate over TCP/IP, although it is good security engineering practice to avoid connecting SCADA systems to the Internet so the attack surface is reduced.

4 Communications

4.1 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.

4.2 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 (Laudon and Laudon [3]).

5 Interfacing - application interfaces/openness

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. OPC evaluated by the CERN-IT-CO group.

6 Functionality

6.1 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.

6.2 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).

7 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 cannot be sufficiently emphasized to reduce development effort and to reach a system that complies with the requirements, that is economical in development and maintenance.

8 SCADA system in SNGPL-Pakistan

SCADA (Supervisory Control and Data Acquisition) system is being operated successfully by SNGPL Pakistan (Sui Northern Gas Pipelines Limited) since 1990, for both supervisory control as well as data acquisition. The importance of the system is vital for smooth and uninterrupted transportation of natural gas right from Sui in Balochistan province up to Peshawar and Swat in North Western Frontier Province, in context with scattered network of SNGPL and increasing energy demand in the country.

8.1 SCADA facilities in SNGPL

Following is a brief description of SCADA facilities in SNGPL network: -

- Source Stations: 14
- Compression Stations: 11
- Repeater Stations: 52
- Block Valve Stations: 22
- Sales Metering Stations: 89

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- Pressure Operated Valve (POVs): 96
- Pressure Controlled Valve (PCVs): 71

Data, regarding pressure, flow, temperature, is being continuously monitored from all above mentioned field installations at Head Quarter, Faisalabad. Appropriate commands are issued; either directly by desk operator or information is communicated to field staff for the execution of activity. To Monitor and Control the following real-time Gas Parameters from various Gas Sources, Repeater Stations and Sales Metering Stations: -

- Static Pressure of Natural Gas (PSIG)
- Flow/Differential Pressure of Natural Gas (MMCF)
- Temperature of Natural Gas (°F)

Average and instant Calorific Value (CV) of natural Gas monitoring/recording at Gas Control center, Faisalabad as well as at three sectional headquarters Multan, Wah and Faisalabad; from Daniel online Gas Chromatographs (GCs) installed at Wah, Multan and Faisalabad (Btu/scf). Results of these online GCs are in-turn used to calibrate strip chart Sigma Calorimeters installed at various locations throughout the company installations. The calibration and upkeep of these strip chart CV meters is essentially required, as per OGRA's ruling, in energy based billing scenario for correct billing at distribution end in (MMBtus).

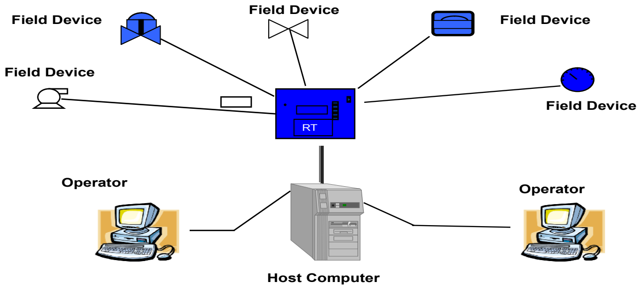

Figure 1: Systematic view of Gas Control Center.

8.2 SCADA functions in SNGPL

8.2.1 Data acquisition

Analog values and Current Status of different parameters is obtained continuously.

8.2.2 Remote control

Valves and Regulators, installed at different valve assemblies and Sales Metering Stations (SMSs), mentioned above are controlled remotely from Gas Control Center Faisalabad.

8.2.3 Historical data
Trending and Product accounting is another important function achieved from SCADA system.

8.2.4 Alarming
Equipment failure and Leak detection alarm function is achieved from SCADA, which has served as a backbone for emergency response function of SNGPL. Exception reporting is also being utilized in order to minimize emergency response time, by issuing appropriate instructions to field staff from Gas Control Center for necessary verification/remedial action.

8.2.5 Applications
Flow, Pressure and Temperature Measurement of natural gas is another important function of SCADA system, being used for optimum system monitoring. This has greatly reduced low pressure and no gas complaints.

8.3 Microwave radio repeater stations in SCADA network

There are ten numbers of microwave radio repeater stations through out the network. Which are Sui, Dhodhak, Multan, Faisalabad, Lahore I, Lahore II, Jhelum, Islamabad, Wah and Peshawar.

8.4 SCADA servers and terminals (at head quarters Faisalabad)

8.4.1 CMX (Control and Measurement eXecutive)
It collects and scales data, checks for alarm conditions; stores real-time information communicates with remote terminal units and enables the user to send out the control commands to field devices.

8.4.2 XIS (eXtended Information System)
It provides the storage space for historical data obtained from CMX, together with functions enabling the user to create historical reports and trends.

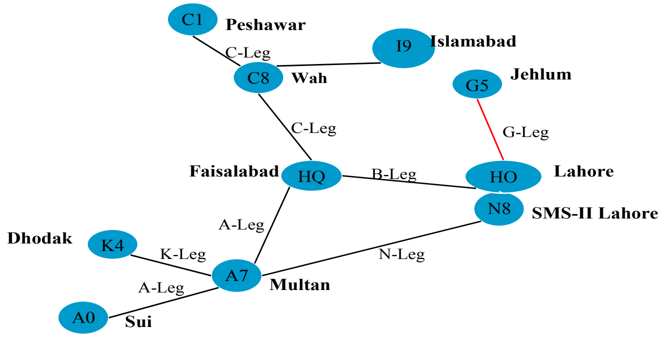

Figure 2: Microwave radio system in SNGPL network.

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8.4.3 XOS (eXtended Operator System)

It enables users to interact with the system. It includes data summaries, dynamics maps, device control pop ups and mouse controlled command interfaces.

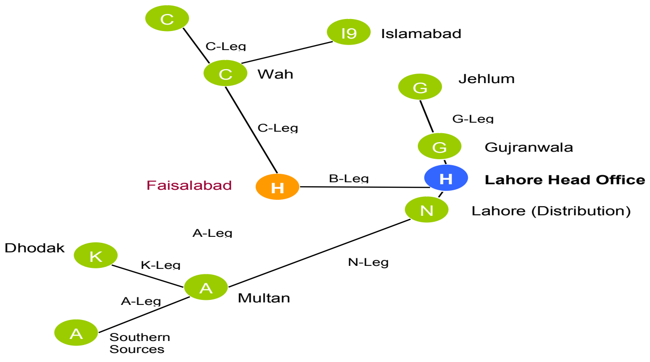

Figure 3: SCADA system in SNGPL network in Pakistan.

8.5 SCADA servers and equipment

CMX Server, XIS Server, RAID, DUAL LAN HUBS, Optical CD, Tape Drive.

8.6 Field instruments

8.6.1 Flow meter

It collects values of gas volume from the Gas Valve Assembly and sends to RTU in the form of 4-20 mA.

8.6.2 Pressure transmitter

It collects values of static pressure from the Gas Valve Assembly and sends to RTU in the form of 4-20 mA

8.6.3 Temperature transmitter

It collects values of temperature from the Gas Valve Assembly and sends to RTU in the form of 4-20 mA.

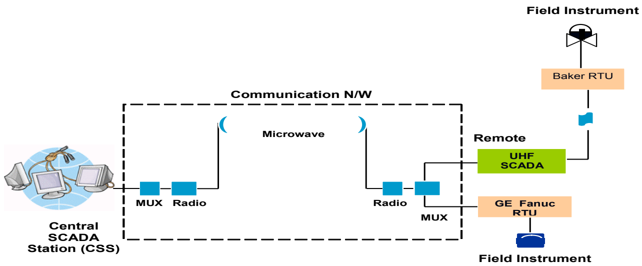

Figure 4: Schematic diagram of instruments like flow meter, valve etc.

9 Data acquisition through the SCADA system in SNGPL Pakistan

The field instruments are installed with meter run (Pipeline) at both sides of (Up-Stream and Down-Stream of the valve assembly to measure the Gas parameters like Pressure, Flow & Temperature. The current goes to the RTU/PLC installed near the valve assembly. The equivalent DATA goes to the MULTIPLEXER and MICROWAVE RADIO. At the other end DATA would be retrieved through MICROWAVE RADIO and MULTIPLEXER. This DATA channel of 9.6 Kbps is connected to the DIGITAL BRIDGE and TERMINAL SERVER. The TERMINAL SERVER converts parallel data of all stations on a single serial port and is connected with the SCADA Host Computers through LAN. SCADA Host SERVERS are installed in redundant configuration. There are four computers installed for the purpose. Two for real-time data collection called CMX (Control and Measuring executive). And two for historical data & trends called XIS (extended Information System). The Operator work stations are installed about eight numbers, on which operators monitor the data and can use for remote control and modifications. The system has Operator called XOS (extended System).

10 Supervisory control

The ACTUATORS and FLOWBOSS are installed with POVs (Pressure Operated Valves) and PCVs (Pressure Control Valves) at the various valve assemblies. They are wired up with local RTUs (Remote Terminal Units) or PLCs. In case of any emergency or any operationally required job, POVs can be controlled for Complete OPEN/CLOSE Status and PCVs for Partially Controlled Status from any Operator Workstation/Terminal (XOS) by executing commands. The command goes to the Actuator/Flowboss through the network and Control Switch would be operated.

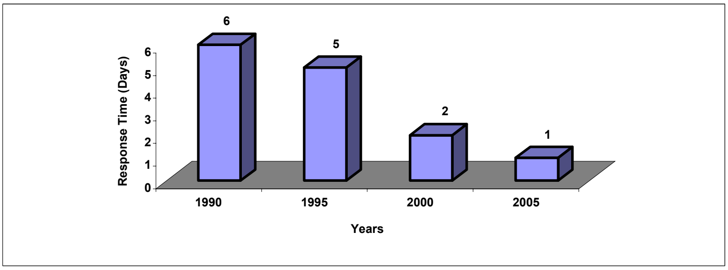

Figure 5: Emergency response time before and after SCADA system in SNGPL.

11 Discussion and results

- The increasing importance of an efficient Management Information System in today's competitive and innovative natural gas transportation sector has made SCADA an essential tool for management for real time data monitoring of flow parameters and system control.
- SCADA is of much more importance and worth for SNGPL (Sui Northern Gas Pipelines Limited), keeping in view the spread and versatility of its business needs.
- Currently, SNGPL is serving more than 2.5 Millions of valued consumers comprising of Industrial, commercial and domestic ones, with more than 6000 KM of transmission pipelines from Sui to Sawat, and 22 Nos. of gas producing sources scattered in all four provinces of Pakistan.
- In such a scattered network, there was an urgent need of efficient information system not only for efficient control of the system but also to reduce the emergency response time.
- After introduction of SCADA system in SNGPL, efficiency during emergency situations like any sabotage activity e.g. blow up of pipeline in politically vulnerable areas of Balochistan etc, tripping of relief valve at remote sales metering stations, shut down of gas supply to critical towns/cities due to malfunction or freezing of regulators during peak winter season, have increased considerably.
- City loads of all major cities of Punjab and NWFP are being continuously monitored at Gas Control Center Faisalabad in order to check any abnormality and to combat any unforeseen happening.
- These technology measures have in turn have helped to greatly reduce UFG (un-accounted for gas) as per OGRA's recommendations, caused by gas loss due to leakages or theft/pilferages in the company by continuous monitoring of load patterns of different locations.
- Real time monitoring of gas parameters through out the network have not only financially benefited the company due to volume of gas which have been saved on account of timely remedial actions but also the corporate image of SNGPL has also greatly improved.

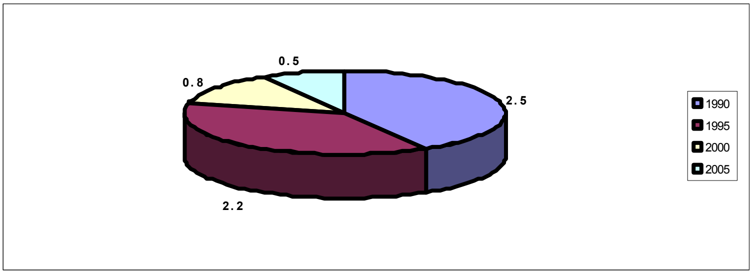

Figure 6: Cost for Emergencies before (1990 and 1995) and after (2000 and 2005) SCADA implementation in SNGPL (Millions of Rupees).

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