

SCADA AND TELEMETRY IN GAS TRANSMISSION SYSTEMS

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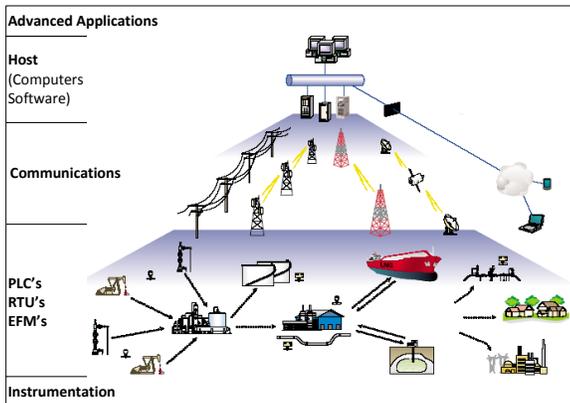
Introduction

SCADA systems provide a combination of field devices, communications infrastructure and software integrated into a system that provides for safe, reliable, and effective operation of remote facilities. Producers, gatherers, midstream operators and pipelines use SCADA systems for operations. In addition, SCADA gathers data used by advanced applications such as measurement accounting. SCADA is key for highly profitable operation.

This paper provides an overview of the building blocks of the SCADA system. The SCADA host and advanced applications are discussed in detail. The paper concludes with a discussion of SCADA trends.

SCADA System for Natural Gas Operations

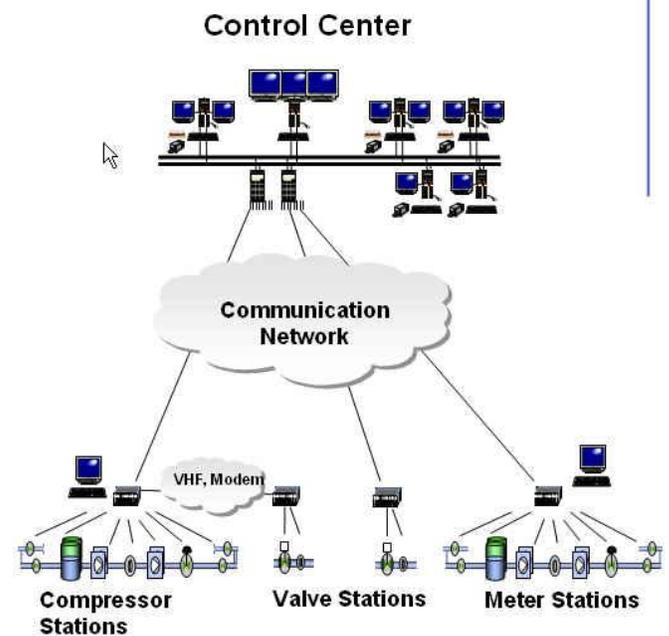
The following drawing shows the five logical levels that make up the SCADA system.



The physical connection to the pipeline is through the end devices or instrumentation. This instrumentation is connected to Programmable Logic Controllers (PLCs), Remote Terminal Units (RTUs) and/or flow computers, depending on the type of remote station. Data then flows from remote devices through the communications network to the SCADA host (also referred to as the SCADA Master or Master Station). Examples of applications at the top of the pyramid would be advanced control and optimization applications used by the gas controllers as well as business applications such as back office measurement and marketing used by other departments within the pipeline company's organization.

SCADA Topology

The previous diagram is a functional component view. Another way to depict the SCADA system is a diagram of the SCADA system equipment and the physical connectivity, referred to as a topology diagram.



Field Devices

The term "Field Device" refers to the automation device installed at the remote facility to provide data collection, automation and communications to the SCADA host.

PLC (Programmable Logic Controller)

PLCs are programmed to perform critical process control. A PLC typically requires AC power and some level of environmental control and programming. PLCs are generally used at larger facilities.

RTU (Remote Terminal Unit)

RTU are smaller, low power, lower cost devices primarily used to convert electrical signals from instrumentation to data, and to make that data available to the SCADA Host.

EFM (Electronic Flow Computer)

EFM are special, for purpose RTUs build to perform measurement in compliance with the various API and AGA standards. In addition, EFM create an auditable record of measurement and make this auditable record available to the measurement back office.

Station Automation

The term “Station” refers to the remote facilities. In Natural Gas pipeline you typically find compressor stations, valve stations and meter stations. Larger facilities such as gas storage, gas processing and fractionators in midstream can also be considered station. Basically stations are remote facilities whose operation impacts the operation of the pipeline.

Compressor Stations

Each compressor typically has its own “Unit PLC”, typically supplied by the compressor manufacturer. The Unit PLCs are interfaced to a “Station PLC” which aggregates all of the unit data critical unit data as well as station specific data such as pressures, valve positions, liquid levels, power information, fire and gas detection, and analyzers to name a few items. The SCADA host communicates with the Station PLC.

Most compressor stations have a local Human Machine Interface (HMI) so a local operator can view station information. Note that although there is often a meter station at or near the compressor station, the meter station is usually handled separately (see next section).

It is not uncommon for a large compressor station to have dozens of PLCs and multiple HMIs. These stations may also serve as communications hubs to pick up data from nearby valve and meter stations. In total, millions of dollars of automation and communications equipment might be installed at a major compressor station.

Meter Stations

Meter stations can range from small, single run stations to large multiple run, bi-directional stations. Common primary measurement elements are orifice meters, turbines and ultrasonic meters. The EFM is used to perform measurement complaint to AGA and API standards. Logic and controls for tube switching, pressure regulation, heaters, valves, and odorant control may be provided by the EFM or by an additional PLC or RTU.

Some meter stations have local HMIs although it is more common for the operator to interface remote device via a laptop.

Valve Stations

This is the simplest station on the pipeline. A small RTU is installed to monitor pressure (oftentimes both upstream and downstream of the valve) and to support remote operation of the block valve by activating remote control commands to open and close and by indicating current valve position.

Field Communications

Historically, SCADA was supported by narrow band, serial communications technologies using satellite and/or data radios. While much of this equipment still exists in the field, wireless communications in particular is undergoing radical and accelerating change, particular with regards to cellular and newer IP radios.

Network Communications

Whose life hasn't been changed by the communication revolution? High speed digital communication is available almost everywhere. For SCADA, moving data from the field to the host has become almost a “no-brainer”. Most major gas transmission companies have extended their corporate WANs out to at least their major compressor stations. Smaller stations, or more out-of-the-way sites, are easily picked up by inexpensive spread spectrum radios and mesh networks which utilize the IP communications protocol, for example. Even satellite costs, both hardware and time, have decreased drastically.

SCADA Data Flow

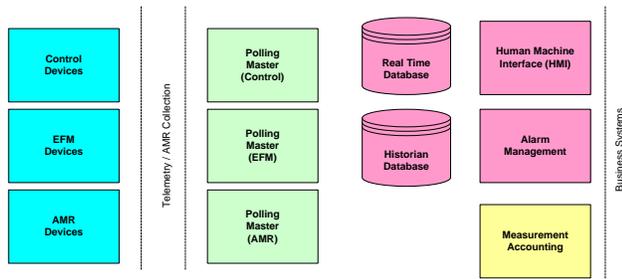
Where a SCADA Topology Diagram is used to describe the various hardware components and the physical (ethernet or serial wires) connections in a SCADA System, a SCADA Data Flow is used to describe software connections and the logical connections (protocols).

The primary purpose is the real-time operation of the pipeline. To meet this requirement, the following major functions are performed.

- Communicate with the field devices
- Process and store the data in the real-time database
- Historize real-time data and store in a historian.
- Visualize data to the controllers
- Alarm data that exceed defined operating limits

A secondary purpose is sourcing data to other applications and departments for safe and profitable operation of the pipeline.

The diagram below provides a simple SCADA Data Flow Diagram.



Polling Master

The SCADA host must be capable of interfacing to the various communications circuits employed to communicate with Field devices. This hardware interface is the easy part. More difficult is the software interface between the host and the field devices, said another way, arbitrating the numerous asynchronous (Serial) connections from the synchronous (IP) processes. It is not uncommon for a major gas transmission company to have 10, 15 or more different types of PLCs, RTUs and flow computers installed on the pipeline, each communicating using a different serial protocol.

There have been attempts to establish gas industry protocol standards such as Enron Modbus, but for the most part, it is still a requirement that the SCADA host have a library of protocol drivers to handle the wide variety of devices. The software must be able to support backup communications paths to key stations.

Real-Time Database

The core of a SCADA system is the real-time database. This is where all the data from the field is processed and stored. For a large system, it must be capable of handling hundreds of thousands of data points, quickly and robustly. The real-time database is memory-resident, meaning all of the data is stored in the memory (RAM) of the server, not on the disk. Alarm processing, control sequences and other functions are all performed by the real-time database.

The real-time database serves data to the human machine interface (HMI) typically installed on operator workstations and other users, as well as to other real-time applications such as leak detection.

The real-time database often runs on two servers in redundant fashion to provide 99.999% availability.

HMI

The HMI or client software is the graphical display environment used by the gas controllers to view and control the pipeline. Example displays would be situation overviews, area overviews, overview maps, station displays, control pop-ups, etc.

Advanced Applications

Line Pack

Advanced applications are those software components that provide specialized functionality. Line pack and draft calculations are examples. This applications are used to calculate the natural gas inventory in the pipeline. It would not be unusual for a major pipeline can have well over 1 Bcf of storage available to meet deliveries. The line pack application requires that the user input the pipeline segment data (length and diameter). The application acquires real-time pressure measurements (and temperature and gas composition, if available) from the SCADA system. The calculated information on line pack is returned to the SCADA system for display to the gas controllers.

Gas Scheduling

Another common application is Gas Schedule Tracking. This application takes the gas plan from the nominations system and compares it to the real-time flow values to help the controller meet the receipt or delivery requirements.

Real-time Transient Models

Many gas transmission companies have built numerical hydraulic models for both offline and online uses. One of the primary online uses is leak detection. The actual pressure and flow readings from the SCADA system are compared with the modeled pressure and flow readings. Discrepancies could indicate a leak. Other model-based applications include the following:

- Look-ahead simulation
- Survivability analysis
- What-if analysis
- SCADA data validation
- Flow studies for smart pigging

Models are also used to build training simulators. With a training simulator, an offline copy of the SCADA system is connected to a model that simulates the pipeline. An

instructor, through his training console, introduces an upset in the model which propagates through to the SCADA system. The trainee operates the SCADA console as if he was operating the pipeline.

Measurement Systems

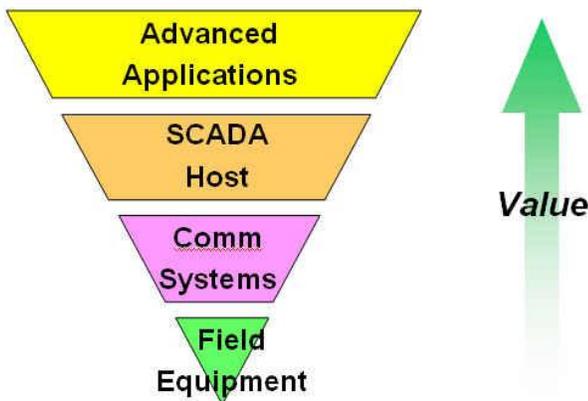
Measurement systems are used by pipeline companies to manage the custody transfer data from the metering stations. This is often referred to as the “cash register” aspect of operating a pipeline. The flow computers and/or RTUs at the metering stations provide both real-time flows and volumes for operational purposes and API 21.1 records for custody transfer. The host measurement system is almost always separate from the SCADA system. However, the communications front end of most modern SCADA systems can poll for both real-time operational data and API 21.1 custody transfer data.

Other High-Value-Add Applications

Gas production and pipeline companies are finding that their SCADA systems are a virtual goldmine of information which can be used to optimize the return from their assets. Some examples of applications which have been developed include:

- Expert systems and neural networks for load forecasting
- Long-term and short-term capacity planning
- Variable cost estimators
- Station optimizers and system optimizers
- Production optimization

Many of these applications provide a huge payback in relational to the costs to implement them. For that reason, some people in our industry invert the SCADA pyramid as shown below.



Most of the cost in a SCADA system is in the lower layers. These costs are necessary to safely operate. The advanced applications aren't entirely necessary to operate

the pipeline. Yet spending a relatively small amount of money (in comparison to the large amount spent of field devices, for example) on an capacity planning application, for example, could dramatically increase the profitability of a pipeline.

SCADA, Then and Now

SCADA systems used to be complete solutions from a single vendor. The vendor packaged his RTUs with his communications equipment with his SCADA software into a monolithic SCADA system. The only items that the customer was free to choose were the instruments. Fewer choices meant less competition, higher prices, and more reliance

In the 80's and 90's, systems became less monolithic with more choices for RTUs, PLCs and flow computers. The SCADA vendor still bundled the SCADA system with the applications.

Today, companies have many choices at every level. This has brought many benefits:

- Prices have fallen, in some cases, dramatically
- More vendors = more investment = better products
- More functionality = more bottom-line benefit to

However, resources are required to put it all together. Many pipeline companies hire consultants and contractors that are specialists in system integration.