The automation systems that control and measure natural gas flow in transmission and distribution pipelines often involve two systems. The system that controls the gas flow in a pipeline is called a SCADA (Supervisory Control and Data Acquisition) system and an AMR (Automated Meter Reading) system measures the amount of gas flowing into, and out of, the pipeline. These automation systems which can be completely separate or combined are widely distributed throughout the service area of a pipeline and must rely heavily on long-distance communication technologies to telemeter the data necessary to coordinate and monitor pipeline activities. This is the most challenging aspect of the automation problem as the communication system is the most exposed component to service interruptions and degradation. Strategies should be implemented in the system design that will maintain continued safe operations of the pipeline during periods of communication failure.

SCADA SYSTEMS

Traditionally, SCADA systems have been distinguished from plant automation systems as they are designed to automate and monitor assets that are widely distributed geographically. SCADA systems are commonly deployed to automate remote assets that are distributed throughout cities, states, continents, or on a global basis. The control and monitoring activities necessary to maintain appropriate operation of these distributed assets are usually performed by field devices that are located at each site. The performance of the field devices and the assets they control are monitored and supervised from host computers at a central location such as a control room.

Typically, host computers provide visual performance measures to allow operational personnel to evaluate asset conditions and status. The data representing these conditions and status is received by the host computer from the field devices over a telemetry system. Data entry methods are also provided to enable adjustments to control targets and thresholds in the field devices to maintain appropriate operation of the assets. In this discussion of SCADA systems there are three major areas of focus.

- Field Devices — Field devices are equipment that is located at a remote asset to perform on-site control, data acquisition and monitoring.
- Telemetry System — The telemetry system connects the field devices and the host computer.
- Host Computer(s) — Host computers provide collection, presentation and analysis of data from the field devices. In addition, the host computers support data entry methods to enable supervisory adjustments to the control that is performed by the field devices.

AMR SYSTEMS

AMR systems gather metering data that documents the purchase and sales of natural gas. This metering data is crucial to the transmission or distribution company as it documents how much gas has passed through a point, a custody transfer point, on the pipeline and in doing so has changed ownership. The metering data is subsequently passed on to accounting departments for validation and billing purposes. AMR systems have architectures similar to SCADA with field devices that meter gas flow at distributed assets, host computers that collect the meter data, and telemetry systems that connect the field devices and host computer.

FIELD DEVICES

Field devices that were used in early SCADA systems were primary data acquisition devices with very little control capabilities. As microprocessors and memory costs became more affordable more control capabilities were incorporated into the field devices. These capabilities are modifiable through programming or configuration to address different automation applications. This autonomy decentralized control and improved the overall reliability of the system by reducing communication loads on the telemetry system and by locating control at the remote site where it cannot be interrupted by communication failure or degradation. In contrast to SCADA, field devices used in AMR systems usually only perform data acquisition and the calculations necessary for metering natural gas.

There can be two fundamentally different kinds of data in SCADA and AMR field devices. Users typically think of data that is updated in the field device on a scheduled basis as control and data acquisition functions are processed. When this data is communicated to the host computer the most current value of the data is sent. This data is often referred to as real-time or current data.

In some applications however, the field device saves data values along with the date and time at which the data value was sampled, in its local memory. This data may be retained in the memory of the field device for the
purposes such as auditing gas meter calculations. Often there is also a relationship between the values and time stamps that is significant to interpreting the events that generated the data. The block of data is referred to as a "data set". An example of a data set could be a snapshot of a spectrum of vibration data associated with a piece of rotating machinery. Another example could be the cycle of an oil field rod pump which is called a “Card”. In all of these cases the loss of a piece of data can reduce the integrity of the whole block of data. As a result, the communication of data sets such as gas metering audit data from field devices to host computers requires special consideration.

**RTUs**

The field devices that are used in SCADA systems have traditionally been called RTUs, Remote Terminal Units. Today RTUs are generally hardened, compact; computers that can be installed in environmentally exposed locations. Other industrial devices such as PLCs (Programmable Logic Controllers) which were originally developed for automotive and discrete parts manufacturing have also been used in SCADA applications where less stringent environmental requirements allow. SCADA specifications such as those below can have an impact of the selection of RTUs versus PLCs.

- Operating temperature range: -40 to 85 Degrees Centigrade
- Low power consumption: Less than 100 mV
- Class 1 Division 2 hazardous area certification

Additionally, RTUs have other internal data management differences from PLCs such as the capability to collect and communicate data sets, which supports more efficient usage of a particular telemetry method.

RTUs generally have a flexible mix of I/O to allow a RTU design to be applied to different automation applications.

- Analog Inputs: 0 to 5 VDC, or 4 to 20 ma
- Analog Outputs: 0 to 5 VDC, or 4 to 20 ma
- RTD inputs interface platinum resistance temperature measurement devices which are commonly used in EFM applications.
- Pulse inputs for which the SCADA standard is 0 to 10 kHz
- Digital Inputs and Outputs can support DC or AC signals however, AC inputs/outputs can require interfacing relays which can be problematic in meeting hazardous area classifications.

The I/O supports data acquisition to monitor the conditions and status of an asset, and also supports adjustment of control elements such as heaters, motors and valves to affect changes in the measured conditions or status. RTUs usually do not initially have the intelligence to perform these data acquisition and control tasks. A user that has knowledge about how to operate a facility or piece of equipment must first enter this knowledge into the RTU by programming or configuring the device for the targeted application. This programming can include complicated control algorithms, alarm detection and notification strategies, and communication logic. The overall performance and success of the SCADA system can be greatly affected by the quality of this programming.

Some RTUs have the capability to perform control and data acquisition algorithms and gas metering calculations simultaneously. Combining these functions into one device can significantly reduce the installation and communication costs.

**EFMs and Correctors**

EFMs and gas correctors are field devices that narrowly target gas metering. The automation logic and I/O capabilities of these devices are specifically tailored to performing gas metering calculations in compliance with standards that are sanctioned by AGA, American Gas Association. The AGA calculations compensate for the changes in density that occurs when a gas changes temperature and pressure. The result of the calculation is a mass flow rate with units of mass per time such as million pounds per hour. In addition to the AGA calculations federal and state regulatory agencies require that gas metering devices store the raw data that is used in the density calculation for 35 days. This archived data is made available to host computers through the telemetry system for the purpose of auditing the calculations performed by the metering device.

EFMs and correctors usually have environmental and power requirements similar to those establish for RTUs. They are often installed in remote locations off the grid where solar cells and batteries are the only power alternatives. The power requirement in some gas correctors is small enough to allow them to operate over extended periods on D-size batteries with no recharging system.

**Telemetry System**

Telemetry systems in SCADA provide a long-distance data connection between the field devices and the host computer. Traditional telemetry methods have included communication over leased telephone lines which are simply called “Leased-lines”, radios of all types, microwave systems and satellite. The advent of long-distance networking standards for the Internet however, has made a big impact on SCADA communications. Routers, bridges, firewalls, and access servers have extended corporate intranets further into the field. These far flung networks based on IP technologies have brought greater performance and reliability than the previous SCADA technologies. Emerging standards in the cell phone industry such as CDMA and GPRS provide wireless connections between a field devices and the Internet. Once the field device is connected to the Internet a host computer is able to communicate with the device from any location.
The key consideration in the design of a SCADA system is that communication interruptions and performance degradation will occur regardless of the technology. This is in part due to the many points of exposure to environmental and human factors in long-distance communication technologies.

**HOST COMPUTERS**

The host computer system can involve one computer or many networked computers which are connected to the field devices by the telemetry system. The purpose of the host computer depends on the mission of the system. In SCADA systems the host computer provides a means to monitor and evaluate the performance of the controls being performed at the remote assets. In addition data entry methods are provided to enable adjustments to control targets to correct for deviations from the desired operating points. Generally, this activity is performed from a central control room that is typically manned by operations personnel on a 24/7 basis.

In simpler SCADA systems the host computer may run autonomously in an unmanned facility but is designed to notify appropriate personnel through annunciation, paging, telephone call-out and email when performance measures exceed alarm tolerance. The system should also aid service personnel responding to the alarm with data to isolate and diagnose the problem.

These SCADA host systems are often based on HMI (Human Machine Interface) software products that provide tools for the development of interactive graphics representing conditions and status received from the field devices. Additionally, HMI products provide alarm indication and annunciation capabilities, data entry methods to change control targets and alarm thresholds, and data logging capabilities.

AMR host computers have requirements similar to SCADA host computers for alarming, presentation and functions. However, the primary mission of the AMR host computer is to collect the substantial amount of audit data that is retained in the EFMs and correctors. This data is received by the host computer from the field devices over the telemetry system and is subsequently passed on to gas accounting for data validation and billing purposes.

**SCADA COMMUNICATION STRATEGIES**

The measure of the amount of information that can be conveyed over a given telemetry method is call the “bandwidth”. The bandwidth of a long-distance telemetry system is a commodity that has significant value and that can be purchased and sold. One can think of a telemetry system as a data transportation system or an information pipeline through which information can be shipped. The bandwidth of this data transportation system is a measure of the greatest amount of information that can flow through that pipeline at a given time.

Generally communication loads which consume bandwidth on a given telemetry system are not constant or deterministic. There can be momentary bursts of traffic that can consume significant bandwidth for a very short period of time. There can also be extended periods of high communication traffic during working hours and periods of low volume traffic during evening and early morning hours. If at a time of high volume, an extra load occurs that causes the entire traffic level to exceed the bandwidth of the telemetry system, data delivery can be delayed or interrupted. In the worst cases data can be lost. In order to achieve reliable and economical SCADA or AMR communications it is not advisable to utilize all of the bandwidth of a given telemetry method. In addition, scheduling communication transactions to distribute loading over periods of time, to take advantage of periods of low traffic, and to leave overhead for spontaneous communication events that can result during upsets, is key to the overall performance and success of a SCADA or AMR system.

In both SCADA and AMR systems the communication transactions to convey data from field devices to the host computer can be automatically triggered on a scheduled basis. The rate at which these communication events are scheduled is one of the first considerations in the design and implementation of a SCADA or AMR system. Users often attempt to schedule communication transactions at rates that are not reasonable for a given telemetry method. For example, the rates used to communicate to field devices over PSTN (Public Switched Telephone Network) would not be the same as those used in a 100 MB TCP/IP Ethernet network. Additionally, a high rate of communication could be scheduled for one field device that would prohibit communication with any other devices in the application. The judgment as to how often it is necessary to communicate with a given field device is a critical step in the implementation of a SCADA or AMR system.

In larger SCADA systems there can be thousands of remote sites and field devices. Due to the bandwidth constraints it is generally not possible or economical to communicate with each of these field devices fast enough to perform routine control functions from the host computer. If an individual control loop has an execution interval of one second, it would be necessary for the host computer to send a control output to the appropriate field device at least once per second. As a general rule one second communication rates with even one device would use an unacceptable amount of bandwidth. In addition, long-distance communication technologies have many points of exposure to service interruptions or degradations. If communication between the host computer and the field device is interrupted or delayed the control located in the host computer would no longer be effective. A better strategy that can survive telemetry degradation and failures is to perform control, data acquisition and alarm or event monitoring functions in the field device which is located at the remote asset. In this architecture the host computer performs a “supervisory” function under which adjustments to
control targets and alarm thresholds in the field device are made on a relatively infrequent basis.

In SCADA and AMR systems communication transactions are typically scheduled to occur over a period of time or at a particular time of day in order to use available telemetry bandwidth effectively. The scheduling of communication events is controlled by the host computer. As a result, Master-Slave protocols as opposed to Peer-to-Peer protocols are used. The communication event which is initiated by the host computer is called a “Poll”. In a simple Polling scenario the host computer will send a request for data message over the telemetry system to a field device. Subsequently the field device responds with a message that contains the requested data. In more complicated protocols there maybe other steps such as acknowledgements however, the key is that the host computer initiates the communication transaction and the field device responds. This is a Poll.

There are several other types of communication events in addition to Polls and there are several types of Polls depending on how the transaction is initiated.

**Interval Polling**

In Interval Polling, the host computer initiates a communication transaction by making a request for current or real-time data from a field device periodically based on a pre-established interval. This interval is generally defined for each field device in an application. The polling rate for a particular device may be faster or slower than others depending on the criticality of the asset or application to which the field device is applied. Generally, the polling interval is a compromise between the timeliness of the data and the need to establish a baseline communication loading on a particular telemetry method. The polling interval can also be synchronized with the host computer clock to synchronize polls with periods of low traffic and to further control communication loading.

In RTU, EFM and Corrector field devices performing gas metering calculations Interval Polls can be initiated to request the EFM data that is archived in the field device. These communication transactions are initiated with a request for data from host computer however, the field device can respond with a massive block of data that must be managed as a group or a “data set”.

**Demand Polling**

In Demand Polling the communication transaction, the request for current or real-time data, is initiated from the host computer on an event such as a user input. As with Interval Polling the host computer initiates a request for data message that is sent to the field device. The main difference is that a Demand Poll is not scheduled and can happen at any time.

As with Interval Polls, Demand Polls can also initiate requests for natural gas metering data that is archived in RTU, EFM and Corrector field devices for audit purposes.

**Unsolicited Messages**

Unsolicited messages are initiated by a field device on an event or alarm circumstance and are referred to as Exception Reports or Cryouts. In these situations the field device initiates the communication transaction by sending a message without a prior request message from the host computer. As with Demand Polling an unsolicited message can be received by the host computer at any time.

Exception Reports are unsolicited messages that are generated by a field device to convey specific data regarding an event or alarm detected by the device.

Cryouts are unsolicited messages that are generated by a field device to request that the host computer Poll the device in response to an event or alarm detected in the device.

It is usually a good practice to use Interval Polling sparingly as a compromise between receiving data on a timely basis and establishing a baseline load on a telemetry system for reliable service. For the special circumstances such as alarm notification or to service personnel with critical data Demand Polling and Unsolicited Messaging can have a low impact with regard to added bandwidth consumption but can provide timely data at critical junctures.

**INTEGRATION FRUSTRATION**

The management of communication protocols and telemetry methods associated with large geographically distributed data gathering and control systems has become a complex application that is not adequately solved in leading SCADA and AMR systems. In the past, software manufacturers have focused on communication software only as a necessary add-on to their core product. These “drivers” were generally software modules called DLLs (Dynamic Link Libraries) that could not run in a standalone mode and that usually support only one protocol and telemetry method. Additionally, the drivers were written to the proprietary API (Application Programming Interface) of a particular core product insuring that they will be incompatible with other manufacturer’s products. Finally, the current business climate further emphasizes the need to integrate different protocols and telemetry systems into SCADA and AMR systems.

- Today’s corporate strategy of growth through acquisitions often necessitates the consolidation of equipment and systems communicating in various protocols over different telemetry methods, both current and legacy. Consolidation is difficult however,
in an atmosphere of reduced budgets and restricted capital expenditures which is typical following most corporate acquisitions.

- As businesses expand, contract or redirect their resources to meet changes, the automation system must also react to these changes in a timely manner. Lost opportunity, increased operating costs, and mounting profit losses, are incurred if changes must be accumulated for a window of opportunity when the automation system can be taken out of service for updates. Even safety is impacted when facilities and equipment are operated under temporary methods while awaiting integration into the mainstream automation system.

- Historically, parallel data acquisition systems have been installed and maintained to accomplish the automation missions of different business groups. For example, the gas measurement and the gas control business groups within pipeline companies and utilities often have completely separate systems. Consolidation to reduce operating and support costs has been difficult due to incompatible communication methodologies.

- Due to the unacceptable costs of replacing installed equipment and the competing standards movements the need for SCADA and AMR systems to support different protocols will continue for the foreseeable future.

CONCLUSION

Automation systems that support both SCADA and AMR have three major component areas.

- Field Devices
- Telemetry Systems
- Host Computers

The issues of communication affect each one of these areas and often have the largest impact on the success of the system.

- It is rare that a SCADA or AMR application can be found that relies on devices from a single manufacturer speaking a single protocol. While most device manufacturers provide their own software or firmware that will allow the host computer to receive data from the device, it is unusual that it would also support and communicate with a competitor’s device. Additionally, SCADA and AMR applications typically utilize different class of devices that are not intended to communicate within the same platform.

- Different telemetry systems may be necessary to provide coverage to all of the areas to which the system is applied.

- Host computer communication software should integrate the protocols and telemetry into a cohesive system.