Enterprise Pipeline Management Solution

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In recent years, investment in production has been decreasing in the oil and gas industry due to a decline in crude oil prices. In contrast, capital investment in transportation is continuing to grow for ensuring efficient, reliable transportation of large quantities of oil and gas through pipelines to remote locations. This paper introduces the features and functions of the enterprise pipeline management solution (EPMS) based on FAST/TOOLS. FAST/TOOLS is a supervisory control and data acquisition (SCADA) software package for large-scale systems distributed across wide areas. The package collects, stores, and monitors data from remote terminal units (RTU) and distributed control systems (DCS).

INTRODUCTION

In recent years, the capital investment of major oil and gas customers is declining due to plummeting crude oil prices, while the capital investment in the pipeline industry is still expected to grow and there is an increasing demand for the pipeline management system. Enterprise Pipeline Management Solution (EPMS) is an add-on for FAST/TOOLS[1], the supervisory control and data acquisition (SCADA) software package. EPMS monitors the flow rate of gas and oil products that flow through pipelines (Figure 1), manages the planned and actual delivery of products, and efficiently operates and manages the tanks, compressors, pumps, and other facilities. This paper introduces the functions and features of EPMS.

EPMS has inherited the features of FAST/TOOLS, such as object-oriented engineering, database structure that allows for upgrading the platform to the latest one while maintaining applications that have been created, engineering operation user interface (UI), robust IT security, high compatibility with the latest technologies, such as virtualization and mobile computing, and long system life.

There are differences between gas and oil products in terms of product volume calculation and delivery methods. Therefore, two types of EPMS are available: Gas Pipeline Enterprise Management Suite (GEMS) for the gas pipeline management and Liquid Pipeline Enterprise Management Suite (LEMS) for the oil pipeline management. This paper describes first the individual functions of GEMS and LEMS and then the common functions of GEMS and LEMS.

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PIPELINE MANAGEMENT SYSTEM AND EPMS

Features of EPMS

A pipeline system is divided into management system, monitoring system, control system, and field device layers, according to ISA-95 (standards on integration of business and manufacturing systems) (Table 1). EPMS is positioned in the management system layer, which collects information from the lower-level layers, then processes it into information required to operate and manage the pipeline, such as product capacity in the pipeline and actual delivery quantity for user locations, and displays it on a human machine interface (HMI).

Table 1 Pipeline system layers

<table>
<thead>
<tr>
<th>Layer</th>
<th>System</th>
<th>ISA-95 layer level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management system layer</td>
<td>Pipeline management system, such as EPMS</td>
<td>2.5</td>
</tr>
<tr>
<td>Monitoring system layer</td>
<td>Wide area SCADA, such as FAST/TOOLS</td>
<td>2</td>
</tr>
<tr>
<td>Control system layer</td>
<td>SCADA, DCS, RTU, Flow computer, etc.</td>
<td>1</td>
</tr>
<tr>
<td>Field device layer</td>
<td>Pump, compressor, valve, etc.</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 2 shows the system configuration of EPMS. EPMS runs on the pipeline management server in the central monitoring room and manages the pipeline by collecting data from SCADA, distributed control system (DCS), remote terminal unit (RTU), flow computer, etc. distributed across a wide area.

Figure 2 Example of EPMS system configuration

EPMS functions as a Web HMI, a server that collects real-time data from various controllers and manages alarms and historical data, and an interface with business systems. Furthermore, its redundant system configuration, online configuration function, etc. provide high availability. Other EPMS features include flexible scalability that facilitates the deployment of a small system which then can be scaled up to a large system, independence from particular hardware that allows for using various operating systems such as Windows, Linux, and Unix, as well as ability to use a variety of network protocols, UIs, and software development tools.

Efficient Object-oriented Engineering

In conventional SCADA systems including FAST/TOOLS, applications to manage the pipeline (including stations and devices, etc. making up the pipeline) must be created from scratch. In contrast, EPMS uses an engineering technique to implement a ready-made template according to the project and enables building a pipeline management system in a short time without requiring a high level of skills.

Applications to manage the segments, stations, pumps, compressors, and tanks that make up the pipeline are called components which come with EPMS as templates (Figure 3).

Figure 3 Components making up the pipeline

A component is implemented as an object by assigning a property and unique tag name to it. A pipeline model is built by structuring the objects as a pipeline model in EPMS (Figure 4).

Figure 4 Pipeline model made up by objects

EPMS allows for adding each component to the Configuration tree in Engineering Module to automatically create a program for each component and structure a pipeline model. A process to aggregate the flow rate values of each station and convert them to the flow rate value of the entire pipeline and the connections in the entire system are also automatically created. Figure 5 shows an engineering example of configuring components, such as a station, inlet, outlet, meter, and tank, in the Configuration tree in Engineering Module.
EPMS provides object-oriented graphics, where symbols do not need to be updated individually, to allow for performing engineering efficiently (Figure 6). When a main symbol is changed, all sub symbols are automatically updated in the entire system. Once a symbol has been created, it can be reused any number of times in the system as needed.

### Smooth Upgrade

The management system and monitoring system layers in conventional pipeline systems are implemented with SCADA applications provided by multiple vendors. In this case, there are some problems: for example, the entire system becomes complicated; updating becomes difficult; and the system upgrade cycle becomes long, which increases the risk of security holes.

Meanwhile, EPMS is provided by Yokogawa as a single vendor, and FAST/TOOLS on which EPMS is based is compatible with the latest platform, which can reduce security holes and other risks. Furthermore, it is easy to upgrade the system, because its database structure allows for upgrading the system to the latest one while maintaining applications that have been created in the old systems when performing system upgrade engineering.

EPMS reduces the difficulty level for upgrading the management system and monitoring system layers while shortening the upgrade cycle, and using the latest platform can implement a long-life system with robust IT security and high compatibility with the latest technologies such as virtualization and mobile computing. Figure 7 shows examples of the latest platforms and latest available technologies supported by EPMS.

### GAS PIPELINE MANAGEMENT APPLICATIONS (GEMS)

The following describes GEMS functions, such as metering, gas data management, gas schedule management, gas storage management, and line pack and line balance monitoring, which are based on the FAST/TOOLS functions, such as math function and historical database.

#### Metering

The meter component of GEMS collects data from the lower-level SCADA, flow computer, RTU, flowmeter, etc. and calculates the volume and heat quantity of gas products that flow through the meter (Figure 8). It can use the flow rate, volume, and heat quantity data if available at the lower levels (Figure 8 right). The flow rate calculation process collects the count data and gas data from the lower levels and passes the heat quantity, which is calculated from the flow rate corrected based on the American Gas Association\(^3\) (AGA) standards and gas data (AGA parameter and gas composition data), to the flow rate aggregation process. The flow rate aggregation process calculates the volume from the flow rate (Figure 8 left).

If communication with the lower levels is lost, GEMS estimates the current flow rate from the actual flow rate and continues to calculate the product volume in order to continue delivery management. If FAST/TOOLS and STARDOM\(^4\) controller are at lower levels, GEMS receives the missing flow rate values from the lower levels when communication is restored and recalculates the volume values in the historical database.
Each station has multiple inlets and outlets with meters, and GEMS continues to calculate the total flow rate that is input into each station and the total flow rate that is output from each station. Each data measured by the metering function is stored in the historical database.

**Figure 8** Flow of metering process

**Gas Data Management**

This function manages the frequency of uploading and downloading gas data to and from GEMS and the flow computer, etc., which is required to calculate the flow rate, volume, and heat quantity. There are two types of gas data: AGA parameter and gas composition data. GEMS is compatible with the EFM log and CFX file formats for the gas data input and output. The compatibility with a variety of gas data input and output methods enables GEMS to be positioned at the top of a variety of devices such as the flow computer, enables a flexible system configuration, and lowers the barrier for deploying EPMS.

**Gas Schedule Management**

The daily planned delivery quantity can be defined on each station. The daily estimated delivery quantity is calculated from the actual flow rate, and if the planned delivery quantity cannot be achieved at the current flow rate, an alarm is output to notify the operator to prompt to increase the current flow rate.

Furthermore, the Gas Schedule Tracking screen displays the excessive/insufficient flow rates compared to the planned delivery quantity and allows the operator to add, edit, and delete data in the gas schedule to ensure delivery of the product to suit the circumstances. **Figure 9** shows how the existing gas schedule is edited in the popup window. The excessive/insufficient flow rates compared to the planned delivery quantity are displayed in the table in the background window.

**Figure 9** Example of gas schedule management screen

**Gas Storage Management**

This function manages the quantity to be input into or output from the gas storage, the quantity of gas stored in the tank, and the energy quantity. It calculates the gas input and output quantity per hour, day, and month.

**Line Pack and Line Balance Monitoring**

This function monitors the pack quantity of gas in each segment and changes in the quantity over a certain period of time. If the set maximum pack quantity is exceeded, an alarm is generated. It calculates the line pack from the pressure and temperature and corrects it based on AGA in real time. Furthermore, it calculates the line balance, which is the total of receipt and delivery quantities in the entire pipeline.

**OIL PIPELINE MANAGEMENT APPLICATIONS (LEMS)**

The following describes LEMS functions, such as metering, batch management, interface management, pig and DRA management, ticket management, tank management, and manifold management, which are based on FAST/TOOLS functions, such as math function and historical database.

**Metering**

The LEMS meter component collects data from the lower-level SCADA, flow computer, RTU, flow meter, etc. and calculates the volume of products that flow through each meter (**Figure 10**). It calculates two types of volume: gross observed volume (GOV) and gross standard volume (GSV). It can use the GOV and GSV data if available at the lower levels (**Figure 10** right). The flow rate calculation process collects the count data or GOV from the lower levels and passes the calculated GOV flow to the flow rate correction process. The flow rate correction process corrects the GOV flow based on the American Petroleum Institute Manual of Petroleum Measurement Standards (API MPMS) and passes the corrected GSV flow to the flow rate aggregation process. The flow rate aggregation process calculates the GSV from the GSV flow (**Figure 10** left).
As with GEMS, even if communication with the lower levels is lost, the estimated product volume and flow rate are calculated in order to ensure the continuation of delivery management. Just like GEMS, data is stored in the historical database. Furthermore, a meter prover for testing the meter can be started manually and automatically (logic can be defined freely).

**Figure 10** Flow of metering process

**Batch Management**

LEMS performs planned and actual delivery management using a batch management function. The Batch Scheduling screen allows for entering planned batch information (supplier, customer, receipt station, delivery station, delivery quantity, interface cut type, etc.). Planned batch information can be input or output in CSV format. Figure 11 shows how to view the batch status and edit, delete, merge, divide, and sort batches to ensure the delivery of products to suit the circumstances on the Batch Tracking screen.

**Figure 11** Example of batch status on the batch tracking screen

**Interface Management**

LEMS determines the position of the batch boundary surface according to the density, color, and sulfur concentration detected by field sensors and meters and calculates the volume and length of the interface (area between different batches that does not meet the product standard). The interface can be set to be delivered to the specified delivery station.

**Pig and DRA Management**

Pig (a device for cleaning and inspecting the inside of the pipe), drug reduction agent (DRA: an agent for reducing pipe friction), etc. can be started automatically after a particular batch and manually at any time.

**Ticket Management**

When a batch passes through a receipt station, intermediary station, and delivery station, a received ticket, passed ticket, and delivered ticket are generated, respectively. Tickets containing information on the passed batch and the actual data such as volume and passed time are used and stored as evidence of the actual delivery from the pipeline manager to the customer.

**Tank Management**

This function monitors the input volume per hour, the inventory volume, the inventory product density, and the time until the tank is filled up. If a tank subsystem exists, this function collects the inventory volume and other data from there and uses it. If no tank subsystem exists, LEMS can calculate the inventory volume. If the tank is cylindrical, this function uses a linear equation that calculates the volume by multiplying the value collected from RTU and other instruments by a factor. If the tank is not cylindrical, the volume is calculated by entering the volume for each tank height in the strapping table and integrating the values.

**Manifold Management**

The pipeline path is defined on each station and the manifold management process switches between paths. A station has multiple inlets, outlets, and tanks, and there are multiple paths through which a batch passes. The manifold management process switches between paths in each station according to the delivery destination information defined in Batch (Figure 12). The path switching component is activated when a batch enters the site and selects the path to activate or switches from one path to another according to the definitions and gives orders to lower-level control devices (SCADA, RTU, etc.) that perform physical control (of paths by opening/closing valves).

**Figure 12** Example of manifold management process batch switching
COMMON FUNCTIONS OF GEMS AND LEMS

The following describes GEMS and LEMS functions such as pump/compressor management and maximum allowed operating pressure monitoring, which are based on FAST/TOOLS functions such as math function and historical database.

Pump/Compressor Management
This function monitors the start/stop frequency of pumps and compressors and generates an alarm to prevent the maximum start/stop frequency per day from being exceeded. Furthermore, it monitors the power consumption quantity and calculates the operation efficiency from the current output and flow rate to monitor it in real time.

Figure 13 shows the characteristic curve of a pump, where the vertical axis indicates the compressor output and the horizontal axis indicates the current flow rate, and the black line indicates the pump efficiency. The operator can operate the pump so that the current operation efficiency (red point) falls into the high-efficiency range of the pump efficiency.

An alarm can be set to be generated if the operation efficiency becomes low. After an alarm is generated, the operator gives orders from the EPMS display to the lower-level SCADA, DCS, and RTU that control the pump and compressor.

Maximum Allowed Operating Pressure Monitoring
This function allows for monitoring the pressure in the pipeline by setting the maximum/minimum allowed pressure for each inlet/outlet of each station so that it falls into the maximum/minimum allowed pressure range.

In Figure 14, the red line indicates the maximum allowed pressure, the blue line indicates the current pressure, the orange line indicates the minimum allowed pressure, the green line indicates the compressor output, and the gray line indicates the altitude at which the pipeline is installed. For location names, the start point is a receipt station and the end point is a delivery station. Points other than the start point and end point are booster pump stations. Other numeric stations are block valve stations. In this case, the red circle indicates to the operator that the current pressure is approaching the maximum allowed pressure.

An alarm can be set to be generated if the pressure exceeds the set value. After an alarm is generated, the operator gives orders from the EPMS display to the lower-level SCADA, DCS, and RTU that control each device.

CONCLUSION

EPMS is based on FAST/TOOLS so it has the following features: a redundant system configuration; high availability achieved by the online configuration function, etc.; efficient object-oriented engineering; robust IT security by using the latest platform; and high compatibility with the latest technologies such as virtualization and mobile computing, etc. Furthermore, taking advantage of its high flexibility and connectivity, EPMS can be linked with business, simulation, leakage detection, data analysis, and other systems to add new values, such as more efficient operation of the pipeline management system, higher productivity, and better quality.

REFERENCES

(2) ISA-95 Website, https://isa-95.com/
(3) American Gas Association Website, https://www.aga.org/

* FAST/TOOLS is a registered trademark of Yokogawa Electric Corporation.
* All other company names or product names that appear in this paper are either trademarks or registered trademarks of their respective holders.