Title: Research of new technologies applied in monitoring natural gas network distribution – Roadmap of Supervision System

Abstract:

The objective of this article is to research new technologies applied in monitoring elements of the natural gas network distribution, thus providing a roadmap on Supervision Systems. The research starts with a preliminary diagnostic of the components, systems and technologies used in telemetry and gas distribution networks that identifies the state of the art science most adopted worldwide and evaluates its application in the national natural gas distribution systems. The theme is extremely important, as it serves as subsidy for the definition of the gas distribution monitoring system strategy to be used in the future by distributors in Brazil.

Keywords: roadmap, distribution, gas natural, supervision.

1. Introduction

In the process of natural gas distribution supervision the focuses must be the business, similar to what happens in the areas of sanitation, electricity and the oil industries. The automation and supervision are currently present in the various business stages, starting with the measurement of interested variables like gas flow, pressure, temperature, odorizing level; passing through the process and transmission of the data to generate useful information for operation and maintenance; finishing whit the integrated analytical insight that allows a management decision making.

The automation concept, according to ANSI / ISA S-95 focuses not only the aspects of operation that will allow some activity driving automatically, with minimal human intervention; but also aspects of quality product, stocks managing and maintenance. The latter aims to keep assets operating at high performance, providing sustainability to other activities.

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An automation and supervision system architecture begins in the field instruments and ends at the control station. The intelligence must be present at each level of the system. The main motivation for having intelligent instruments is not in the economy of cables or entry points and drivers exits, even on deployment engineering reduction costs, but in the ability to make asset management from a remote point. This enables a revolution in terms of maintenance models changing from the corrective and preventive maintenance to the condition based maintenance, where each device provides real-time indication of their work condition. We can program a maintenance knowing in detail the problem is happening, before the currency of an unscheduled shutdown and before a sharp drop in performance is noticed. These are some of the essential features to any business wishing to survive in a globalized world, where competition between companies is growing every day. This research was developed through four activities, in accordance with the goals and objectives further listed.

1.1 Objectives and targets

To carry out the research the following activities were developed:

- Activity I - Preliminary diagnostic of the components, systems and technologies used in Natural Gas Network Distribution Telemetry;
- Activity II - Selection of priority items / elements – Focus analysis
- Activity III - Detailing priority items / elements;
- Activity IV - Comparison of alternatives identified and trends analysis

The first activity sought to understand and characterize the various aspects associated with the use of natural gas network distribution control and monitoring, mostly involving the components, systems and technologies used. The activity also had intention to develop a diagnostic of the telemetry and supervision systems used by natural gas companies in Brazil.

In order to define the target for international missions to be performed, prioritization criteria were defined based on the characteristics of telemetry and supervision systems, as well as discussions about the variables that could influence the development of these systems. Six criteria was identified to be used in a preliminary selection as following: (i) territorial extension, (ii) pipeline quantity, (iii) natural gas consumption, (iv) electricity consumption, (v) features energy market and (vi) externalities. Each criteria was scored with grades 0-2. Based on the proposed methodology and the data obtained for each criteria the following countries / regions were selected for tentative investigation: Europe (Germany, France and Italy), Japan and the United States. In addition to these five countries, it was considered the inclusion of two more countries / regions: Australia and Colombia, in order to keep in consideration emerging countries. The research was performed during two missions on the following countries: Mission 1: Colombia/USA and Mission 2: Italy/Japan. The focus of investigation was defined during analyses sections in order to select priority items and elements related to automation and supervision systems in activity two.

The activity three had objective to perform real investigation using the international missions complemented by the research carried out in Brazil. The last activity were analyzed all information gathered, enabling comparisons between the various types of equipment, processes and services associated with telemetry and supervision systems.

2. Preliminary diagnostic

In this chapter is presented the study case of the telemetry and supervision system of a large natural gas company in Brazil, in order to establish a preliminary diagnostic of the current state of related operation identifying the main points to be observed in a telemetry and supervision systems. In the sequence is presented the telemetry and supervision system state of the art in order to guide the international research.

2.1. Study Case

The supervision system of the Natural Gas Company focuses on four monitoring points along the supply chain of natural gas distribution:

- Custody Transfer Station (ETC);\(^1\)
- Pressure Reducing Stations (ERP), also called Control Stations Pressure (ECP);

\(^1\) Also called odorizing Station or City Gates.
- Sets for adjustment and measurement (CRM);
- Cathode Protection (voltage rectifiers, test points and drain).

Each point has different sensors for measuring various parameters associated with gas distribution and system operational safety. Additionally, each point has also different communication systems that become more complex when the availability of information is more critical. Gathering elements of telemetry and supervisory systems for each point monitored by the Natural Gas Company, we can make a general architecture of the system, as showed in Figure 1.

![Figure 1. Overall system architecture of supervisory system of Natural Gas Company](source: prepared by the author)

It can be noted the presence of different technical solutions and outside agents of the system. It is also possible to observe the existence of different types of data transmission, not always interconnected to ensure a redundancy in the transmission of data, in order to increase system reliability. During the research visiting the installations it could be identified different structures of supervisory system, divided into four categories: (1) data acquisition, (2) data conversion, (3) data transmission and (4) infrastructure. The elements identified in each category are listed in Figure 2.

![Figure 2. Systems and equipment identified in the telemetry and supervisory systems of Natural Gas Company.](source: prepared by the author)
For each measuring point and each category showed above, it was defined the following dimensions for analysis: (i) environmental; (ii) autonomy in relation to the technology provider; (iii) reliability, (iv) cost of installation, (v) operation cost; (vi) scope; (vii) flexibility, (viii) innovation, (ix) regulatory issues, (x) cost-effectiveness, and (xi) safety. For field research, questionnaires were developed to support interviews with experts from other gas distributors companies and agents of the market telemetry and supervisory systems in Brazil and abroad.

The researched field allowed to see what the main bottlenecks and problems of existing technology and also to identify the systems and equipment used in the gas companies. These bottlenecks were important to guide part of the research, which sought to answer the following questions:

- There datalogger model, PTZ or CV's used on ERP and CRM's with integrated transmission GSM?
- There are CRM's and ERP's with built-in modem?
- The GRPS modem currently used by the natural gas company is appropriate? Are there other solutions?
- The autonomy of the solar system / battery can be improved? What are the technical solutions found in other systems to overcome this limitation?
- Regarding voltage rectifiers, they exist with GSM modem and open protocol?
- There telemetry solutions for test points and drain?

The research was performed based on questionnaire but not restricted in answering it. The research field enabled to diagnose the current state of the supervisory and telemetry system of Natural Gas Company, comparing with other systems of other natural gas distributors around world.

3. Telemetry and supervisory systems - state of art

Based on research sources identified it was developed the scenarios of the telemetry and supervisory systems. The state of the art was divided by items starting from the general view of what the system represent and where it fits into the activities of organizations to reach the detailing of components that structure the system and the processes in which these components are fitted.

3.1. Positioning

In the organizational environment of enterprises, the telemetry and supervisory systems are included within automation systems, which in turn are directly related to information systems, which together underpin the process of decision making, as well as are adapted to the goals that the board search through the business management systems. Each system has different tasks, thus the principal of each are shown in Figure 3.

![Figure 3. Attributions of the different systems](image)
As mentioned previously, automation and information systems are directly related and have different functions. While the automation system is responsible for controlling and monitoring the processes, the information system records the received data, analyzes it according to the needs of the management system and simulates different scenarios of operation based on established needs.

The operation hierarchy of this model within a company for natural gas transportation and distribution is shown in Figure 4 (left). Analyzing the telemetry systems broadly, it is necessary to identify the flow of information since the data is generated in the field process, to the control center processing. The flow of information is important for building the architecture of telemetry and supervisory system. Figure 4 (right) presents the flow of information, in order to show the interfaces between each component.

3.2. Architecture and system types

The flow of information is important for construction of architecture of telemetry and supervisory system, which should start from the process you want to monitor, to the level of processing of the data to the control center will be able to accomplish. Figure 5 shows the flow of information, in order to show the interfaces between each component.
In addition to the sensors, transmitters and actuators, it’s noted the presence of two fundamental units of telemetry and supervisory systems: (i) unity interface process (UIP) and supervision and control station (ESC). To define the architecture of system is also important to define what type of telemetry and supervision will be used. Two types of systems are identified: SCADA (Supervisory Control and Data Acquisition System) and DCS (Digital Control System).

SCADA systems have emphasis on supervision and are suitable for geographically dispersed processes that have need for coordination among themselves. Already DCS systems have an emphasis on integrated control, being more indicated for closed systems, composed by batch and continuous processes, as existing in industrial plants.

The components used by each system are similar, however SCADA systems were discussed in greater depth in the research, since the characteristics shown are directly related to operation of the natural gas transmission and distribution.

4. Technical missions

4.1. Selection of priority items and countries to be researched

In order to define the destination of international missions to be accomplished six criteria were defined for prioritization based on the characteristics of telemetry and supervisory systems and the variables that could influence the development of these systems. Table 1 presents the list of criteria used as well as related substantiation.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Substantiation</th>
</tr>
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<tbody>
<tr>
<td>Territorial extension</td>
<td>high country has greater probability in having a larger grid</td>
</tr>
<tr>
<td>Number of pipelines</td>
<td>high grid greater the complexity of operation and greater the need for a telemetry and supervisory system</td>
</tr>
<tr>
<td>Natural gas consumption</td>
<td>high consumption greater complexity and greater the need for a telemetry and supervisory system</td>
</tr>
<tr>
<td>Consumption of electricity</td>
<td>high consumption, greater complexity and greater the need for a telemetry and supervisory system</td>
</tr>
<tr>
<td>Characteristics of the energy market</td>
<td>open market is related to free competition, higher probability to have telemetry and supervisory systems for control</td>
</tr>
<tr>
<td>Externalities</td>
<td>allow that potential opportunities could be explored, without relying on the above criteria</td>
</tr>
</tbody>
</table>

Each criterion was scored with grades 0-2. Based on the proposed methodology and the data obtained for each criterion the following countries / regions were selected for investigation: Europe (Germany, France and Italy), Japan and the United States. In addition to these five countries it was also considered the inclusion of two more countries / regions: Australia and Colombia, in order to keep in consideration emerging countries.

The countries selected were the basis for the research. The international missions were conducted between the months of May and October in 2012. Three missions were performed to: Italy / Japan, Colombia and United States.

4.2 Survey research

The study was conducted using a questionnaire developed in conjunction with the Natural Gas Company team in Brazil. The development of the questions came from the measurement points and the relevance criteria selected for each one. The questionnaire was sent to the international contacts and was used to guide the process of seeking additional information from surveys conducted from Brazil.
Complementary research was conducted from a list of sources, developed on the basis of selected countries, including companies of natural gas distribution, gas associated business, telemetry and supervisory associated business, committee or commission of gas distribution control and committees or organizing commission of standards relating to telemetry and supervisory systems.

The summary of results for each country visited during the international missions is presented below.

Italy

The technical mission to Italy allowed the completion of two research questionnaires with information from the Enel Company (electric and gas distributor) and Engineering Company (software and supervisory system developer). While performing the technical mission was possible to note that the development of telemetry systems is the responsibility of the company's own distribution of natural gas. The initial idea, that maybe companies outsourced full systems development was discarded.

Two interesting points related to the administrative systems are highlighted. The first is that the Italian regulatory agency supervises and sets standards for the telemetry system, offering financial subsidies when standards are followed and maintained. It makes that the gas company can be encouraged to invest more in their system. The second interesting point is that there is different gas price depending on period of day, with intention to alleviate consumption peaks.

Japan

The mission to Japan permitted the completion of a questionnaire from Tokyo Gas information. The Tokyo Gas has approximately 10 million customers and 54,000 km of pipeline for gas transmission and distribution. At the time, the research group had an opportunity to visit to a Pressure Reduction Station (PRS) of the Company. The telemetry system was developed by Tokyo Gas in 1969. The company has specialized teams working on developing and adjusting that system, including software and hardware.

In Japan the development of telemetry and supervisory systems is made by Gas Distribution Company itself. The initial idea that companies develop their systems through a third party has been ruled. Maintenance is performed by third parties, under the responsibility of the Tokyo Gas using regular maintenance contracts with those suppliers. Generally, costs relating to technologies telemetry and supervisory system are the least of priorities. The most important point is certainly ensure the smooth functioning of the system, according to Japanese point of view.

Colombia

The technical mission to Colombia permitted the fulfillment of three surveys by three different gas distribution companies: Gas Natural, Gases del Caribe and Surtigás. Gas Natural has 1,766,932 customers and 12,518 kilometers of pipelines. Gases del Caribe and Surtigás have 670,206 and 518,845 customers respectively.

As noted in the other countries visited, telemetry and supervisory systems have an integrated management system and monitor only conventional information like: pressure, temperature and gas flow. As noted in Japan, the costs of the telemetry and supervisory system are not the main point to be considered, since the system is seen like essential to the company’s activities. Another interesting point is that there is no redundancy in the transmission system, which operates with GPRS, radio and optical fiber connection.

United States

The technical mission to the United States allowed complete a survey with information from the Southern California Gas Company. The company has 20.9 million customers in a concession area that comprises approximately 32,000 km². The company operates exclusively within its concession area.

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2 The Tokyo Gas develops RTUs, protocols and other equipment used in telemetry systems. There is also another company responsible, called Tokyo Gas Engineering Co. Ltd.
The telemetry and supervisory system attends only two measurement points: on Districts Control Stations (equivalent to city gates) and CRMs (measure stations only). Pressure reduction stations are not used. The network operates to maintain the pressure within the ranges provided and, if necessary reduction in pressure is regulated at the client. Related to the cathode protection there is no monitoring system and the equipment is inspected monthly.

Some highlights of the American system visited can be mentioned: (i) the measurement system (outflow computer) is separate from the operating system (PLC); (ii) are not performed cost-benefit analyzes of technologies, since the telemetry system is considered necessary for network operation; (iii) the software used is provided by Telvent Company, while the hardware is made by the company itself; (iv) the data transmission is performed by a phone line, and in some cases, radio is used, without redundancy; (v) the equipment installed in classified areas are explosive secure and in other areas no special requirements are necessary; (vi) a valve automatic system to be operated in distance could be found (in a thermoelectric customer).

5. Results and comparisons - preliminary analysis

The international research was based on the preliminary diagnosis and the telemetry and supervisory system state of the art, including the following main points:

- Custody Transfer Station (ETC);
- Pressure Reduction Stations (ERP), also called Pressure Control Stations (ECP);
- Sets Regulating and Metering (CRM);
- Cathode Protection (voltage rectifiers, test points and drainage) (CP).

In the Natural Gas Company, each point has its own equipment for telemetry and supervision with particular characteristics including strengths / weaknesses aspects. Internationally the same model was observed during the technical missions. Regarding the main weaknesses identified, two stand out: (1) adoption of different technical solutions, not always efficient and (2) the presence of external agents / suppliers.

These weaknesses are minimized in other gas companies through the development of proprietary technologies, or technologies developed specifically to serve the telemetry and supervisory system with centralized responsibility on the company itself. Regarding the research items developed, were selected priority themes of the Gas Distribution Company, according to the application of AHP (Analytic Hierarchy Process). The main points and related topics researched are presented in Table 2.

<table>
<thead>
<tr>
<th>Main point</th>
<th>Relevant Topic</th>
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<tbody>
<tr>
<td>1 ETC</td>
<td>Processing / Register</td>
</tr>
<tr>
<td>2 ERP</td>
<td>Acquisition</td>
</tr>
<tr>
<td>3</td>
<td>Transmission / Reception</td>
</tr>
<tr>
<td>4</td>
<td>Processing / Register</td>
</tr>
<tr>
<td>5</td>
<td>Automation</td>
</tr>
<tr>
<td>6 CRM</td>
<td>Transmission / Reception</td>
</tr>
<tr>
<td>7</td>
<td>Processing / Register</td>
</tr>
<tr>
<td>8 CP</td>
<td>Automation</td>
</tr>
<tr>
<td>9</td>
<td>Acquisition</td>
</tr>
<tr>
<td>10</td>
<td>Transmission / Reception</td>
</tr>
</tbody>
</table>

An analysis of Table 2 shows that ERPs are more significant in the Gas Distribution Company systems, since all (4) issues related to the telemetry and supervisory system were selected as important for research.
The CRMs happen with three selected topics. Observe that the topics “Transmission / Reception” and “Processing / Register” were chosen for this measurement point because the same problems in the ERPs.

For CP were selected two topics: Acquisition and transmission / reception. The relevance of these topics is different for each system that composes the CP. For the rectifier voltage transmission, reception is a relevant item, and for test points drainage is also a concern in the acquisition of data, since these points are not currently monitored by the center control.

For the ETC the most significant research has been on processing / register since the telemetry and supervision system on such points is more robust and therefore shows less instability in relation to other points.

The research analysis allowed evaluate which criteria was most relevant in terms of scores for each main point selected. The results are shown in Table 3.

<table>
<thead>
<tr>
<th>Main point</th>
<th>Criterion</th>
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<tbody>
<tr>
<td>ETC</td>
<td>Installation cost</td>
</tr>
<tr>
<td></td>
<td>Relation cost-benefit</td>
</tr>
<tr>
<td></td>
<td>Scope</td>
</tr>
<tr>
<td></td>
<td>Relation cost-benefit</td>
</tr>
<tr>
<td>ERP</td>
<td>Innovation</td>
</tr>
<tr>
<td></td>
<td>Environmental</td>
</tr>
<tr>
<td></td>
<td>Scope</td>
</tr>
<tr>
<td></td>
<td>Installation cost</td>
</tr>
<tr>
<td>CRM</td>
<td>Relation cost-benefit</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
</tr>
<tr>
<td>CP</td>
<td>Relation cost-benefit</td>
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<tr>
<td></td>
<td>Installation cost</td>
</tr>
<tr>
<td></td>
<td>Autonomy</td>
</tr>
<tr>
<td>Overall*</td>
<td>Relation cost-benefit</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
</tr>
<tr>
<td></td>
<td>Installation cost</td>
</tr>
</tbody>
</table>

* Considers the points obtained in each criterion for all measurement points added.

It is observed that the cost-benefit relation criteria have the highest score in terms of relevance. The only exception is the ETC, where the cost-benefit relation was behind the installation costs. This reveals that the cost of telemetry and supervision systems is a key point in the Gas Distribution Company. Internationally, however, it was noted that these aspects do not represent a primary factor for other distribution companies, since the systems are considered as priorities for gas distribution activities.

The true function of the telemetry and supervisory system is to provide data to the company's strategic planning and record activities in order to meet the requirements of regulatory agencies. In resume, it was observed that on the organizational environment, the telemetry and supervisory systems are inserted within automation systems and information systems, which together provide subsidies for the planning and management process business.

6. Conclusion

In general, research and international missions allowed answer the questions and issues raised in the preliminary diagnosis, as well as provided the natural gas distribution companies international overview on the use of the telemetry and supervisory systems. In resume, it was observed in the studied scenario is that telemetry and supervisory systems are central to the natural gas operation networks and, because of that, they have a tendency of sophistication, towards more robust and stable platforms.
This trend is similar to developments observed in the electrical sector, calling towards the smart grid. In the case of natural gas, smart grids are those that provide planners the information needed for better management. An example of this trend are the residential meters used by Tokyo Gas (Japan) with embedded transmitters that send consumption data from customers direct to central control. These data are used for issuing invoices, as well as the "customer management" directly by the company, involving different sectors. Another interested point is that redundancy is not an issue in data transmission systems. This is due because: (1) the transmission infrastructure is much more developed and stable than the Brazilian reality and (2) it is known exactly what information is important and how often they need to be received.

The own gas distribution company is responsible for the planning and development of the telemetry and supervisory system and consistent with planning it can found partners to implement and to provide maintenance solutions in long term. It demonstrates that the telemetry and supervisory system is integrated into the company’s business. However, it is noteworthy that a smart grid is not necessarily a more complex network but a network where the capture, transmission and use of data are done in a more integrated and optimized way. In fact, both the literature and visits demonstrate that international gas companies adopt as ideal rule: "to grow you must be simple."

References


