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Unified automation with digital plant architecture improves gas plant and gathering system operation

Benefits include improved quality control, safety and environmental stewardship, and reduced maintenance costs

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At the Loma la Lata gas field in Neuquén Province of western Argentina, Repsol YPF has retrofitted its main low-temperature separation (LTS) complex and much of the associated gathering system with a single control system using digital plant architecture. Featuring an Ethernet LAN that includes wireless segments for remote locations, the control system makes heavy use of intelligent field instruments connected by FOUNDATION fieldbus.

It replaces "islands of automation" consisting of a conventional distributed control system (DCS), a remote terminal unit (RTU) network and a supervisory control and data acquisition (SCADA) system. The result is state-of-the-art integration of process controls throughout the separation complex with those of associated wells, primary separators and compressors as far away as 10 kilometers. Results include valuable improvements in control quality, safety, environmental stewardship and accommodation of growth in the field and plant, coupled with substantial maintenance cost reductions.

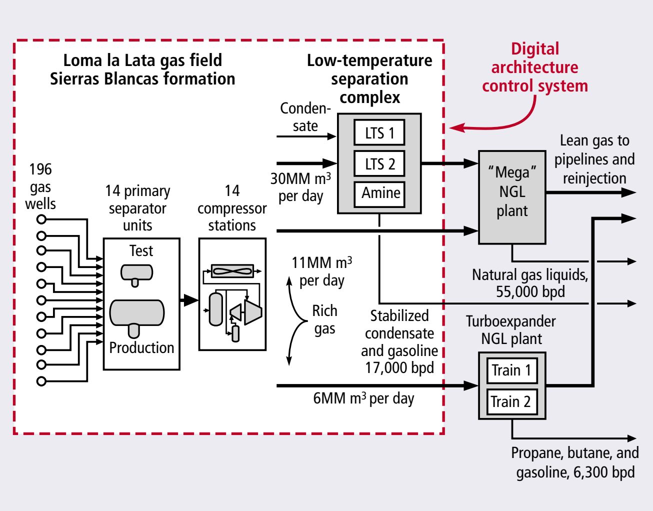

FIG. 1 Simplified flow chart of gathering system and separation facilities controlled by the digital automation system.

Production and separation facilities. The overall scope of facilities controlled by the growing digital automation system as of early 2004 is indicated in Fig. 1. One hundred ninety-six Sierras Blancas wells in the Loma la Lata field flow into 14 primary separator units, most of them associated with compressor stations.

Most of the rich gas from the field—typically 30 MMm^3 per day—goes to the low-temperature separation complex. There, liquid gasoline drops out at –17°C and 1,000 psi, and water vapor is removed by a monoethylene glycol spray. Also, CO_2 is reduced by an amine process associated with one of the separation trains. Along with condensate collected from the field, the separated liquid is stabilized by distilling out residual gases, yielding about 17,000 bpd. Expanded several times since first going into operation in 1988, this is now the largest plant of its type in Argentina. It processes nearly a fourth of all the gas produced in the country.

From the LTS complex, the stripped gas flows to a natural gas liquids separation facility (the Mega plant) that was built in 2000 by a consortium dominated by Repsol YPF. The Mega plant also receives about 11 MMm^3 per day of rich gas directly from the field. It removes the remaining liquids from the gas, yielding about 55,000 bpd of a "soup" consisting mainly of ethane, pro-

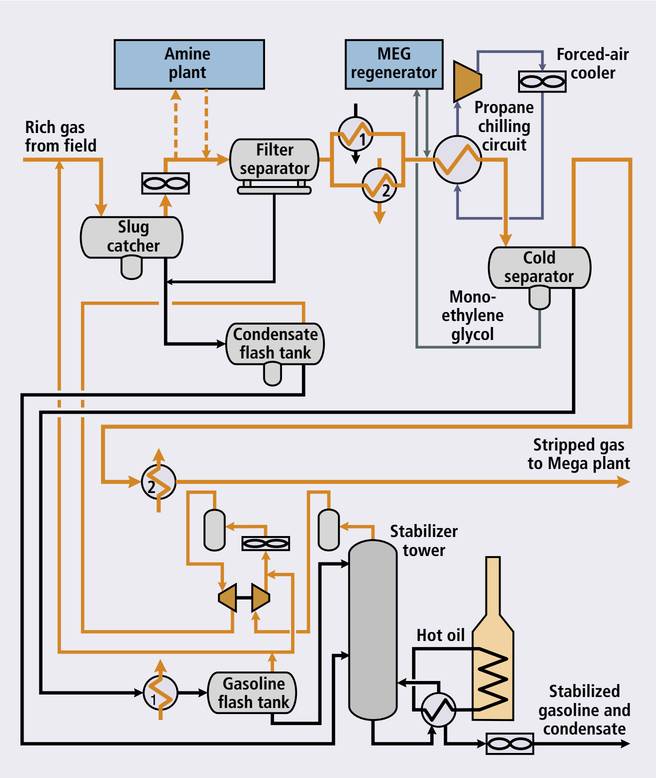

FIG. 2 Simplified diagram of a typical low-temperature separation train. The amine plant applies only to LTS 2.

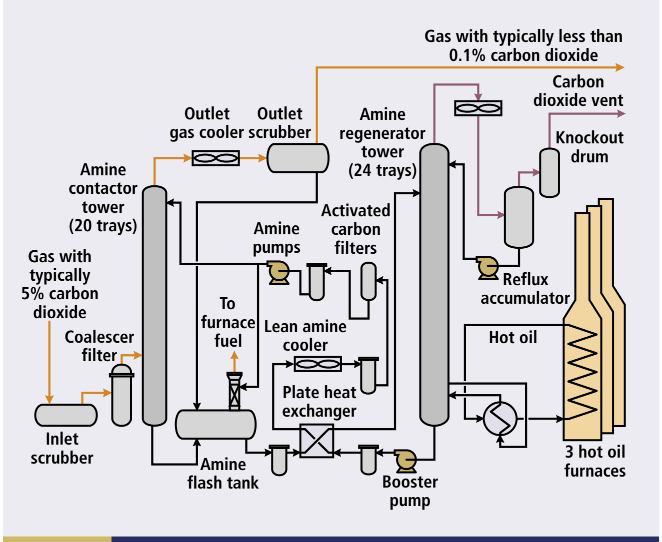

FIG. 4 Simplified diagram of amine CO_2 removal plant at LTS 2.

pane and butane, along with higher-boiling liquids from the rich gas that bypasses the LTS complex. This mixture is pipelined to a fractionation plant at Bahia Blanca on the Argentine coast.

The Mega plant was built next to another, older NGL plant (Fig. 1), that consists of two turboexpander trains. Started up in 1982, this was the first separation plant in the Loma la Lata field. It receives about 6 MMm^3 per day of rich gas directly from the field and extracts about 6,300 bbl fractionated liquids in three streams: propane, butane and gasoline.

FIG. 3 Intelligent instruments such as those communicating via FOUNDATION fieldbus in the LTS 2 plant form the field base of the digital plant architecture. (Above: differential pressure transmitter. Below: digital valve controllers on control valves.)

Control system evolution. Development of the low-temperature separation complex, along with the gas field it serves, has followed classic stages in the evolution of process automation technology. The complex began in 1988 with four separation trains having a combined capacity of 16 MMm^3 per day. The extent of processes controlled in each train is suggested by Fig. 2. This plant, now known as LTS 1, was equipped with a DCS that represented the state-of-the-art in process automation at that time.

Conventional DCS architecture appeared around 1980. It was based on proprietary controllers mounted in cabinets that were typically concentrated near the control room. The controllers were linked by a proprietary high-speed network called a data highway. Operator and engineering interface was via proprietary consoles on the data highway.

To keep up with rapid development of the Loma la Lata field, capacity of the LTS complex was augmented by 9 $MMft^3$ per day in 1995 when another separation train was built about 300 m south of LTS 1. Now known as LTS 2, this line was controlled by a network of six RTUs supervised by software in standard PCs that served as operator and engineering stations. The architectural concept of such a network resembles that of a conventional DCS, with RTUs or programmable logic controllers (PLCs) taking the place of DCS controllers. General-purpose PCs take the place of proprietary operator and engineering consoles.

The next step in development of the LTS complex came in 1999,

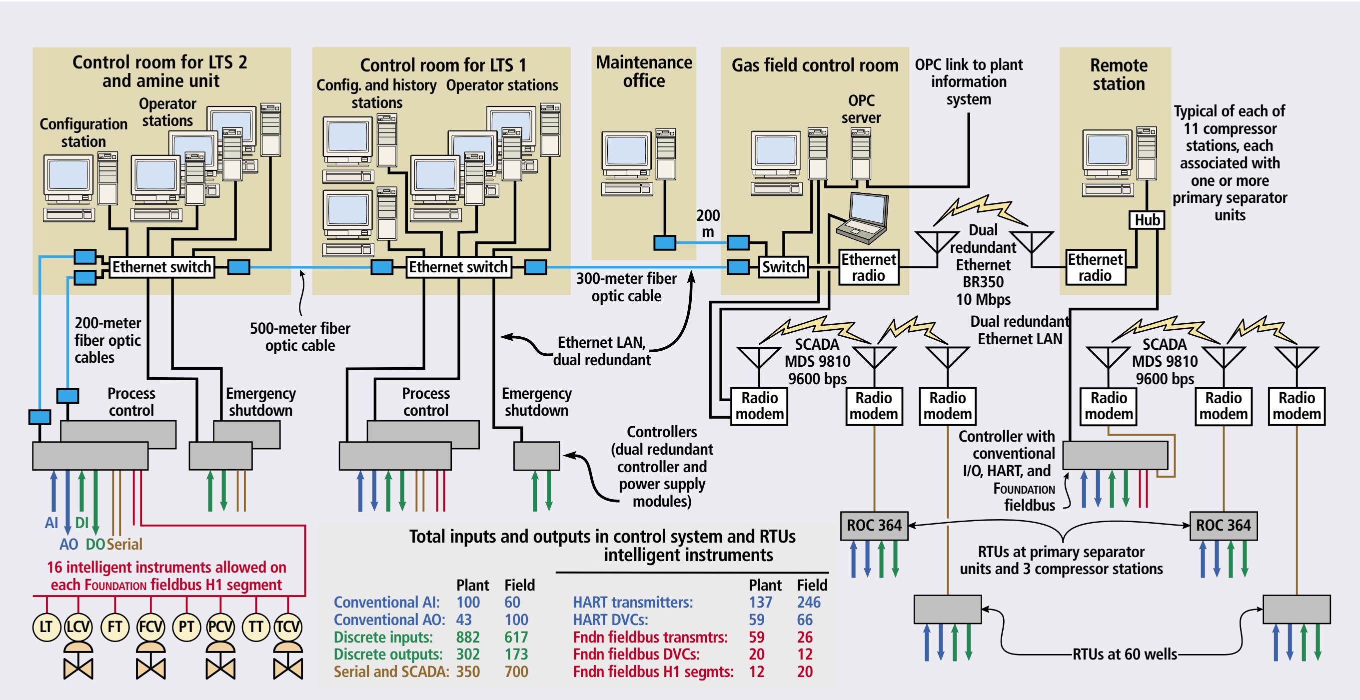

FIG. 5 Simplified digital automation system diagram.

when a fifth separation train was added to the LTS 1 plant, boosting its capacity by 5 MMm^3 per day. Concurrently, Repsol YPF was beginning to install compressor stations around the field to maintain production as downhole pressures fell due to reservoir depletion.

By this time, a new type of process automation system had appeared. The controllers, known simply as digital controllers, equal or exceed their conventional DCS counterparts in overall capabilities, but they resemble the latest RTUs and PLCs in being small, rugged and modular. Like RTU or PLC networks, the system employs open standard LANs and general-purpose computers.

However, this digital automation system was designed with the ability to implement an entirely new concept in the architecture of control systems, one that was being enabled by the recent appearance of "intelligent" or "smart" field instruments (transmitters and valve positioners or controllers). Smart instruments are based on computer circuitry and communicate with the rest of the control system as one computer to another on a network. The first such communication method was HART, which superimposes bidirectional digital pulses on a conventional 4–20 mA signal. By 1999, a more advanced method had appeared, in the form of fieldbuses. The most prominent of these arrangements, FOUNDATION fieldbus "H1," allows up to 16 smart field instruments to communicate at high speed on a multidrop basis via a single twisted pair of wires that also provides power to the instruments.

The new architectural concept is to make full use of the enormous processing and communication power that can now be packed into networks of smart field instruments. The capabilities of these instruments go far beyond immediately obvious purposes such as local execution of control algorithms. Generically, this architecture has been referred to as field-based or digital.

Selecting a digital architecture. Digital architecture was chosen not only for automating the fifth train at LTS 1 in

FIG. 6 Field instruments communicate with the digital automation system through modular controllers that can be mounted in field enclosures.

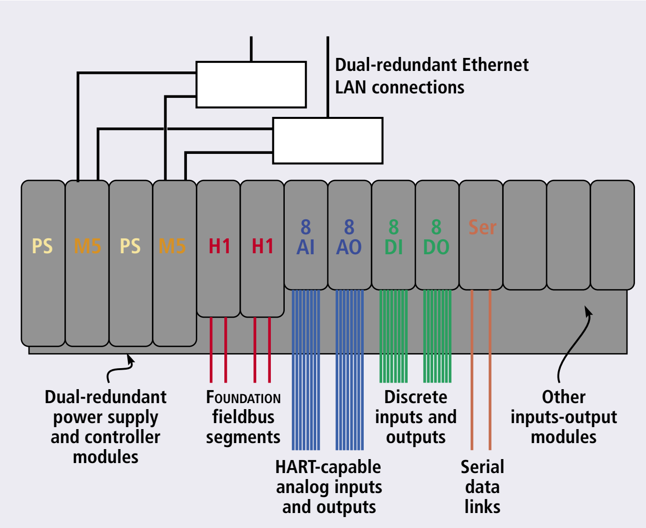

FIG. 7 A dual-redundancy option was used in this installation.

FIG. 9 Remote stations are superimposed on an aerial photograph of the Loma la Lata gas field. Area shown is 40 x 30 kilometers.

1999, but also for retrofitting the rest of the entire complex—the original four trains of LTS 1, plus LTS 2. Among other attributes, the digital system met the company's requirements for a scalable system that could readily accommodate expected enlargements of the plant complex and be extended to replace the SCADA system in the field.

Improved field automation would be especially valuable for the compressor stations that were being added. Such installations were becoming more complex, like little processing plants—including intelligent instruments such as mass flow transmitters—so that they needed more control power. A digital system was expected to facilitate future changes in existing processes and improved control strategies. It would help maximize production of gas and liquids, reduce spurious and unnecessary safety shutdowns, minimize wasteful emergency flaring and venting, eliminate fire and explosion hazards, and maintain a cleaner environment, all without increasing the payroll.

FIG. 8 The workstations are ordinary PCs running a common operating system linked by Ethernet.

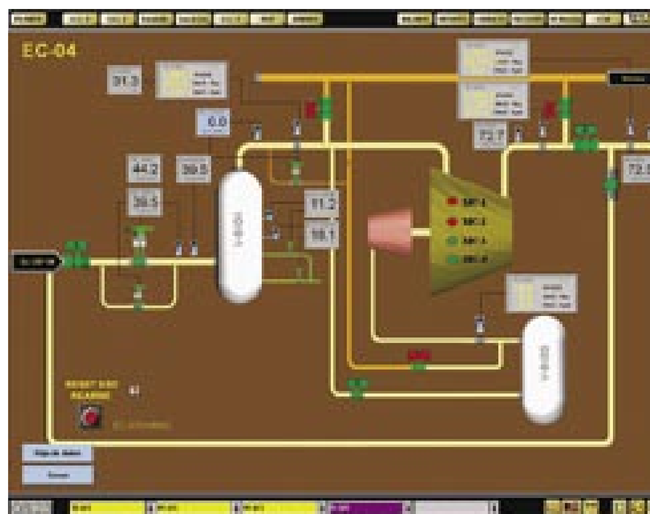

FIG. 10 Some compressor stations have up to four compressors.

Thus a single digital system was installed in 1999, embracing both LTS 1 and LTS 2. Without shutting down the old separation trains, about 1,500 signal lines from existing field instruments were migrated from the DCS and the RTU network to new digital controllers, one instrument at a time. The new fifth train being built at that time was provided with about 15 intelligent instruments using HART and 12 using FOUNDATION fieldbus on three H1 segments. As part of that changeover, another 50 valve positioners in LTS 2 and the older parts of LTS 1 were replaced with digital valve controllers (DVCs) shown in Fig. 3. Some transmitters were also replaced with intelligent varieties, such as the differential pressure transmitter seen in Fig. 3. Thus, the first steps were taken into digital architecture with its emphasis on intelligent instruments.

Finally, in August of 2000, the amine sweetening plant summarized in Fig. 4 was started up as an addition to LTS 2 and to the digital system. With a capacity of 10 MMm^3 per day, the amine plant reduces carbon dioxide concentration from about 5% to about 0.1%. This is sufficient to bring the CO_2 concentration of the blended output from the complex below 1.5% as required for pipelining. To the greatest extent possible, intelligent instruments on FOUNDATION fieldbus were used: nearly 80 transmitters and DVCs. Thus the amine plant achieved a full realization of digital architecture.

FIG. 11 Compressor station data summary display.

Toward totally digital architecture. When the first compressor stations were installed, the digital automation system was not yet available in the field. Consequently, these facilities were controlled by RTUs similar to the primary separator units and wells. Later, however, new compressor stations were provided instead with digital controllers connected to the LTS complex by wireless Ethernet links. Similarly, all but three of the earlier compressor RTUs have been replaced with digital controllers. Thus, major steps have been taken toward a comprehensive implementation of digital plant architecture, embracing not only the LTS complex, but also all of the Sierras Blancas gathering system. The result as of early 2004 is summarized in the block diagram of Fig. 5.

There are seven digital controllers in the LTS complex and another 11 at compressor stations in the field. The controllers are linked by a standard Ethernet LAN that includes secure wireless segments as long as 10 km. All portions of the LAN are dual redundant, as are the power supply and controller modules in the plant controllers. The wireless Ethernet medium is BR350, operating at 10 megabytes per second, with primary and alternate links.

The system is extended to RTUs at the three remaining compressor stations and all 14 primary separator units, and to various RTUs at 60 of the largest wells by conventional SCADA radio links from the LTS complex and some of the compressor stations. The radio signals are MDS 9810 spread spectrum at 9,600 bits per second. The eventual intent is to provide digital controllers at all compressor stations and primary separator units—both existing ones and those to be built in the future.

Figs. 6 and 7 illustrate the compact, modular nature of the digital controllers. Input-output modules are available for a wide variety of signals. Serial lines—typically using Modbus protocol—are especially useful for integrating compressor controllers, some intelligent instruments and SCADA radio modems. Digital controllers can readily be mounted in locations scattered around a plant near the instruments they serve, rather than being grouped near control rooms as in a typical conventional DCS installation.

The traditional name "controller" for these network servers may be somewhat misleading. In truly digital plant architecture, the primary function of controllers is not merely executing control algorithms as in a conventional DCS. Equally important, they serve as nodes for marshaling the resources of the intelligent instruments to which they are connected, such as those shown in Fig. 3. For instance, upon initially powering up on a FOUNDATION fieldbus segment, an intelligent instrument is configured and commissioned in just a few minutes, on a plug-and-play basis, by easy drag-and-drop methods at an engineering station. Calibration and recalibration are accomplished remotely. Malfunctions and impending failures can be automatically diagnosed and reported.

TABLE 1. Speed performance of the digital automation system

Data acquisition: data update in entire system	1 sec
Production data update	5 sec
Configuration download time to controller via wireless Ethernet	1 min
Open or close shutdown valve at any well from any workstation	2 to 3 sec
Wireless Ethernet transmission delay, main link	10 millisec
Wireless Ethernet transmission delay, alternate link	16 millisec
Emergency shutdown of all plants and wells from any workstation	20 sec

Referring again to Fig. 5, there are 27 digital automation workstations located in three control rooms and the maintenance office in the LTS complex and at 11 compressor stations. As seen in Fig. 8, these workstations are ordinary PCs running a common operating system. Some example operator displays are shown in Figs. 9–11.

Table 1 provides several impressive figures of merit pertaining to speed.

Returns on investment. After nearly five years of experience with a steadily growing digital plant architecture, a number of benefits can be discerned at Loma la Lata. The most readily quantifiable result is improved control quality compared with the most likely alternative, which would be a conventional DCS in the plant and conventional SCADA throughout the gas field.

This means running closer to maximum safe production rates for longer periods, with fewer shutdowns and slowdowns, and with quicker recovery from upsets. It is a result of better coordination of the diverse and distant facilities of the gas field; more advanced control strategies; more accurate and reliable performance of intelligent transmitters and control valves; better preventive maintenance of those instruments as well as process equipment; quicker detection and response to adverse conditions, both automatically and by human intervention from any station in the network; and more useful information for managerial decisions—all at a lower installed cost than that of an equivalent DCS and SCADA system.

Plant and field personnel learned to use the digital automation system quickly and easily. Human resource productivity has gone up considerably. Only six operators are required on duty at the complex: two for LTS 2 and the amines plant, three for LTS 1 and one for the gathering system. Likewise, fewer maintenance people are required, and maintenance costs have gone down considerably.

Unified integration of well controls allows better remote automation for reservoir management and accommodating demand. Furthermore, in an emergency such as partial or complete shutdown of the LTS plant, wells can quickly be shut in instead of venting gas to the atmosphere for extended periods.

The scalability and modularity of the digital automation system accommodate growth of the plant complex and gathering system very efficiently. Instrument technicians can easily connect new instruments that are 10 m or 10 km away, whether they communicate by HART, FOUNDATION fieldbus, 4–20 mA, Modbus or anything else. All of those field instruments can be configured into control algorithms with the same simple drag-and-drop tools. They form one seamless automation system, without having to use extraneous interfaces such as gateways.

An important aspect of the digital automation system is trouble-free compatibility with other automation systems, enterprise resource planning systems, etc. At Loma la Lata, for instance, Repsol YPF's digital automation system is integrated with a management solution for oil and gas production data. The link with the plant information system for such purposes is via object linking and embedding (OLE) for process control (OPC), with a computer in the gas field control room (Fig. 5) acting as the OPC server. OPC has become widely accepted as an efficient method of interfacing computer-based automation systems of different types. OPC is also used for communicating between the digital automation system and a meteorological instrument station near the LTS complex.

Repsol YPF especially values the digital plant architecture for support of the company's efforts in areas that transcend the company's financial performance. Such concerns include environmental stewardship, personnel safety and cordial relations with indigenous Mapuche communities residing within the Loma la Lata gas field.

The system is very helpful in gathering and analyzing information on atmospheric and water effluents. For instance, to make sure that the LTS complex does not greatly increase ambient CO_2 concentrations, the digital system receives signals from 14 CO_2 sensors located in and around the complex.

The digital automation system has been an important component in the company's certification for ISO 14000 for environmental concerns, which was achieved in 1999. Working conditions have become safer as a result of better automation. Reliable remote controls—especially those based on intelligent instruments—have not only decreased the incidence of accidental spills and emissions in the gas field, but have also greatly reduced the necessity of sending Repsol YPF personnel into environmentally and culturally sensitive zones. **HP**

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Luis Troncoso graduated from the Technological University of Córdoba in 1985 with an electronic engineering degree and completed specialization in hydrocarbon production at the University of Buenos Aires in 1987. Since that time, he has worked for Repsol YPF in the Loma la Lata gas field. Having begun in the maintenance department, Mr. Troncoso is now an instrumentation and controls project engineer in the engineering department. He has concentrated on implementing new technologies such as fieldbuses and wireless methods for automation of plants and gas fields.

Néstor César Artusi received a chemical engineering degree from the National Technological University in La Plata, Argentina, in 1979. After 10 years as a process control engineer at several Argentine companies, he joined a Fisher Controls representative firm in 1989, working in systems engineering for DCS and SCADA systems. In 1994, Mr. Artusi established Chromu S. A., a representative firm for Emerson Process Management in Neuquén Province, the main gas and oil producing area of Argentina.

René Bersier, an electronic engineer, graduated in 1989 from the National University of La Plata. Since then, he has worked for Emerson Process Management, Southern Cone, in Buenos Aires—presently with the title of PlantWeb manager. Mr. Bersier has been involved in most of the company's major SCADA and control systems projects, and is the technical advisor in new technologies such as fieldbuses and asset optimization tools.