Controlling the gas flow

ABB's SCADA and System 800xA improve LNG operations and management

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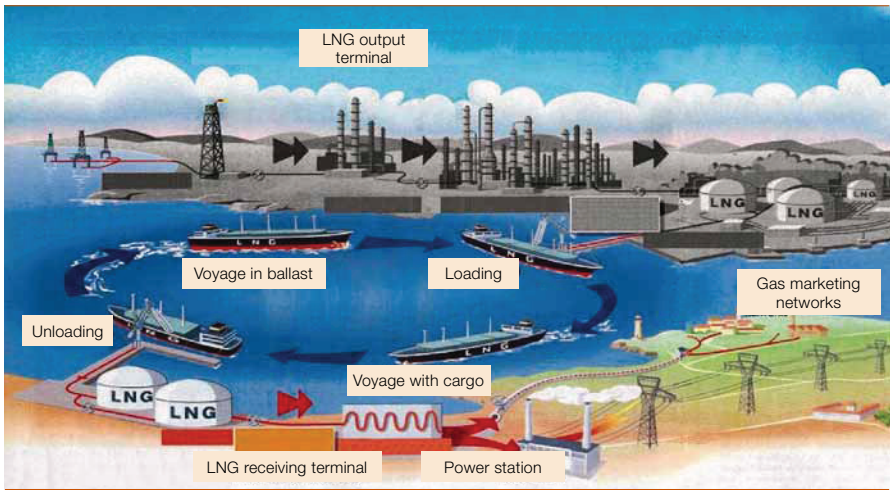
Many new liquefied natural gas (LNG) projects have been completed and are operating successfully in China, increasing LNG import trade volumes. International trade of LNG is generally based on long-term take or pay contracts where a buyer will pay even if the product is not required. This means that the import volume and storage capacity at the receiving terminal is directly influenced by downstream consumers. A transportation plan is specified in the contract, which determines the volume of LNG shipped from the upstream output terminal to the low-temperature storage tank of the receiving terminal. Through in-depth analysis of the supply and demand chain, a process control system is devised to ensure that the storage facility has the capacity to receive all scheduled shipments of LNG. This is achieved by controlling the gas transmission between the LNG receiving terminal and the trunk line. By utilizing information processing and automation control technology, errors of judgment can be avoided so that the arrival of LNG shipments at the eceiving terminal are coordinated efficiently and safely with gas transmission and combined dispatching of gas to downstream users.

The Fujian LNG project in Southeast China is the first project under the independent management, construction, operation and maintenance of a domestic enterprise in China. Since February 2009, the gas for the project has been supplied by Indonesia from its Togguh Gas Field. Its current import capacity is 2.6 million metric tons of LNG per year with a further planned expansion of 5 million metric tons per year forecast for operations beyond 2012. The project includes an LNG receiving terminal and a 360 km gas transmission line, which passes through coastal regions and cities, namely Fuzhou, Putian, Quanzhou, Xiamen and Zhangzhou in the southeast of the Fujian Province, supplying gas to five city gas companies and three gas-fired power plants.

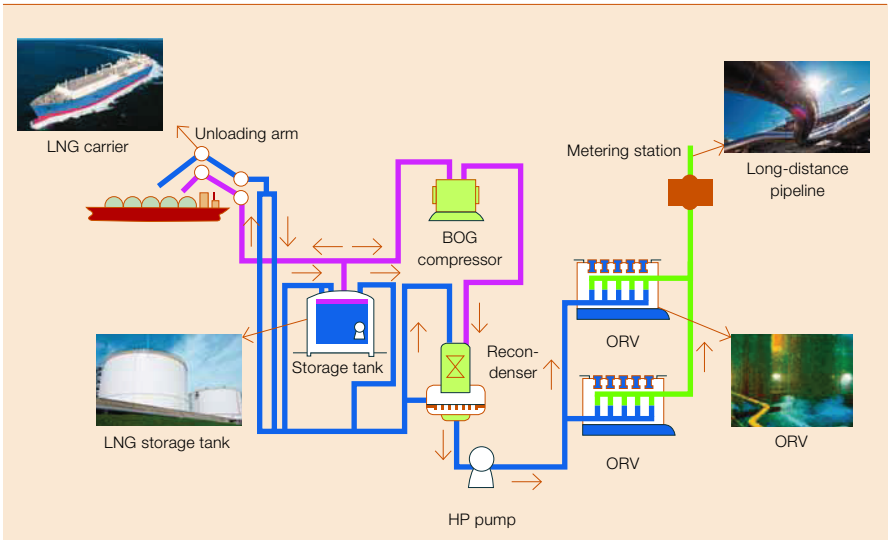
Generally, LNG is transported by special transport ships from the output terminal, at the place of origin, to the receiving terminal, where it is allowed to form a gas and is distributed through gas transmission lines to the end users. The principal ingredient of natural gas is methane (CH_4). When cooled to about –162°C, under ordinary pressure, it forms a liquid. The volume of natural gas can be reduced to about 1/600 when liquefied, making it more convenient for long distance transportation, storage and utilization. LNG has therefore become the major mode for natural gas transportation by sea.[1)]

Today, a constant supply of gas to power stations and marketing networks is maintained through integrated production, transportation and distribution. For the Fujian LNG project a process has been established that includes LNG production, storage, transportation, receiving and regasification 1.

1 LNG industry chain system



2 The processing system for an LNG receiving terminal



A constant supply of natural gas to power stations and marketing networks is maintained through integrated production, transportation and distribution.

The LNG receiving terminal

Generally, LNG receiving terminals are composed of five process subsystems; namely LNG unloading, storage, regasification (export), vapor processing and flaring (venting) 2.

LNG unloading and storage

After the LNG transport ship has berthed at the jetty, the LNG output pipeline on the ship is connected to the onshore unloading pipeline via the unloading arm on the jetty. The LNG cargo is then pumped ashore from the tank on the ship to a storage tank at the receiving terminal. During this process the gas pressure in the storage tank on the ship would gradually drop, so to maintain pressure, gas in the onshore storage tank is sent back to the ship's storage tank by way of the gas return pipeline and gas arm. During periods when no LNG is unloading, the unloading pipeline onshore is kept cold using LNG from the onshore storage tank's transfer pump outlet. This LNG is returned to the storage tank by means of an insulated pipeline.

LNG regasification and export

After pressurization through the tank's transfer pump, part of the LNG in the storage tank enters the recondenser so that a given amount of vapor is liquefied. The mixed LNG from the recondenser and the tank's low-pressure pump is pressurized using a high-pressure pump and it enters the vaporizer. Meters measure the gas volume before it passes through the gas

Footnote

1) See "Tanking along" on page 74 of *ABB Review* 1/2009.

transmission line to the end users. To guarantee the normal operation of the tank's transfer pumps and high pressure export pumps, it is necessary to set regurgitant pipelines at all pump discharges. In this way it is feasible to regulate the flow using the regurgitant pipeline to compensate for changes in LNG transport capacity, so that low temperatures in the system can be guaranteed even when output has stopped.

LNG vapor processing and venting

The vapor processing system is designed to guarantee normal LNG storage tank operation within a certain pressure range. Within the storage tank a pressure transmitter monitors pressure values to ensure the tank is neither under nor over pressure. When the pressure is above or below the set value, the vapor processing system takes appropriate action to control the gaseous pressure inside the storage tank. To prevent a vacuum in the LNG storage tank, a vacuum-gas supply system is provided in the process flow.

ABB's SCADA system adopts an open, compatible and widely accepted standard communication protocol so that information can be exchanged with most types of distributed control system controllers.

The trunk line

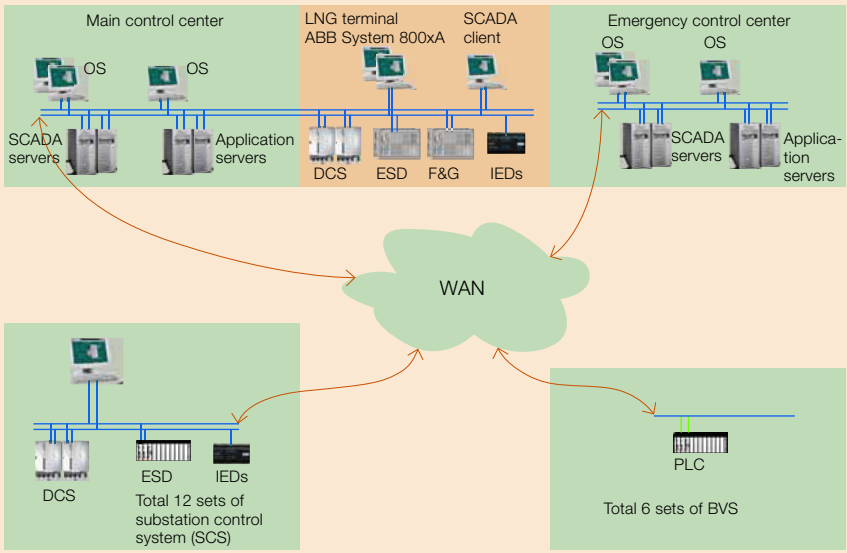
The trunk line comprises a gas pipeline with branch lines, a valve station and an offtake station. The valve station is designed to block the pipeline and provide unmanned monitoring and remote control, while the offtake station is designed to transfer natural gas downstream to end users, such as city gas stations and power plants, once it has been filtered, metered, heated and pressure regulated 3.

LNG control system

Since the Fujian LNG project involved processes, including a supervisory control and data acquisition (SCADA) system Factbox 1, an emergency shutdown (ESD) system Factbox 2, a fire and gas (F&G) monitoring system Factbox 3 and a distributed control system (DCS) Factbox 4, both local operation control and remote monitoring systems were required. Integrating these multiple systems was the most technically challenging aspect of the project.

To control the pump's direction of operation at the receiving terminal, the combined dispatch control logic was built into the DCS system at the receiving terminal. As part of the integrated design, priority was given to ensure smooth information exchange between the DCS and SCADA. At

3 The network structure drawing of Fujian LNG auto-control system



Factbox 1 Supervisory control and data acquisition (SCADA) Vantage system

The SCADA Vantage system improves the utilization efficiency of the pipeline service and the boosting station. As a result, turnover is accelerated and functions are enhanced. LNG can be transported from the place of production – in the shortest time and at minimum cost – to the place of installation. The solution provided by ABB keeps the operating cost as low as possible.

Characteristics:

- Redundant and open structure
- Object-oriented real-time database
- Integrated historic record server
- Integrated pipeline model and advanced flow chart
- Expandability from single-node equipment to multi-server system
- Intuitive configuration tools invoked in the total system and application
- Communication protocols supporting OPC and industrial standards, such as IEC 870 5 101/104 and DNP3.0
- Can be integrated simply with the automatic solution for pipeline station control

The SCADA Vantage system provides control and data acquisition for specialized industries, such as LNG storage and supply. It is versatile with open compatibility, allowing applications ranging from an installation in a single-node pattern to a multi-server system.

In addition, the processes are performed based on the principle of client/server and a redundant object-oriented system. Through a configurable authorization system, it provides a security guarantee to prevent unauthorized personnel from logging on to the system. The system communicates through the ODBC, COM, OPC and OLE standard protocols (for more details see "OPC Unified Architecture" on page 56 of this issue of *ABB Review*). In addition to these advanced characteristics, it possesses front-end communication with redundant configuration and can function using remote devices to complete automatic switchover should communications be interrupted.

present, most protocols designed for internal communication between the DCS system and the DCS controller are developed independently and are frequently incompatible. ABB's SCADA system however adopts an open, compatible and widely accepted standard communication protocol so that information can be exchanged with most types of DCS controllers. It is not easy to integrate a SCADA system with a DCS system, and it is even harder to integrate control systems when provided by different manufacturers. The Fujian LNG project adopted ABB's Extended Automation System 800xA to oversee control systems at the LNG receiving terminal and ABB's SCADA Vantage to oversee control systems on the gas-transmission line Factbox 5. This meant that the DCS, ESD system and F&G system at the receiving terminal station were fully integrated using the System 800xA platform. Its ability to use diverse communication protocols enables the System 800xA software to exchange data seamlessly with third-party equipment at the receiving terminal, while the SCADA Vantage software for the gas transmission line allows the simultaneous monitoring of both central and station control systems.

The receiving terminal control system

In terms of control areas, the automation system of the receiving terminal can be divided into a central control system and a jetty control system. The central and jetty control systems contain a DCS, an ESD system and an F&G monitoring system. The assets under central control include all devices except those on the jetty, ie, the storage tank, compressor, recondenser and open rack vaporizer (ORV), which is heated by seawater.

The DCS is a major automation system used to monitor and control the process flow at the LNG receiving terminal. In addition the system also consists of the following two independent parts: the ESD system, which is designed to shut down the receiving terminal and the F&G monitoring system, which is designed to detect fire and LNG or NG leakage. The ESD system uses ABB's safety control system with safety integrity level 3 (SIL3). When process disturbances threaten personal security, the environment or equipment, or have the potential to cause major economic losses, the ESD system initiates the corresponding interlock protection to prevent further hazards or accidents escalating. The F&G system used was ABB's fire and gas control system with SIL3. This system detects fires and the leakage of LNG and hazardous gases, initiates an alarm, activates fire extinguishing systems as required and takes measures to isolate production equipment.

Gas transmission-line control system

ABB's SCADA Vantage, used to monitor and control the gas transmission line, consists mainly of primary and backup dispatch control centers, sev-

Factbox 2 Main design functions of the ESD system

1. Through the ESD button, manual emergency shutdown can be triggered to isolate the processing equipment of various units.
2. Emergency shutdown is triggered through the automatic detection instrument of the system; for input signals, use voting to guarantee the effectiveness of alarm or shutdown signal.
3. Reset of emergency shutdown. After the interlock triggering conditions have been manually confirmed and reset, the system can recover to a normal state to guarantee the safety of production.
4. Interlock bypass. The ESD system also provides maintenance bypass and an operation override button, which are used to conduct an online test on equipment without affecting normal production, to shutdown a bypass of the signal at the time of the initial start of the process system and to conduct a bypass operation on the ESD interface when the bypass permits the switch to be on the allowable position.

Factbox 3 Main design functions of the F&G system

1. Collect and display the working states of combustible gas and fire detector
2. Detect LNG leakage and give audible and visual alarm for the detected abnormal state
3. Collect and display the working states of fire-fighting equipment and auxiliary facilities
4. Execute the logic of emergency cut-off and display emergency cut-off alarm signal
5. Link fire-fighting equipment
6. Output emergency stop signal to ESD

Factbox 4 Main design features of the DCS

1. Provide real-time monitoring of production processes, such as pressure, liquid level, temperature and flow
2. Dynamically display the production flow of the receiving station, major process parameters and the running state of equipment
3. Give alarm for abnormal operating conditions, print the alarm for the record and store important parameters
4. Allow online setting and modification of process control parameters and conduct remote operations on devices such as valves and pumps
5. Monitor the unloading, storage and gasification of LNG as well as the export and metering of natural gas
6. Maintain real-time communication with the following systems to complete the centralized management of the production information of the entire receiving station:

- LNG storage tank data acquisition system
- Boil-off gas (BOG) compressor
- Vibration monitoring system for in-tank pump and high-pressure pump
- Export pipeline SCADA control system
- Wharf berthing system
- Ship-to-shore communication system
- PMS system
- Natural gas analyzer
- Tanker loading control system
- Electrochlorine system
- Seawater system
- Trade metering system
- ESD system
- F&G system

eral station control systems for the off-take stations and a remote control valve station. Each off-take station and valve station with the control center, conducts data exchange through the main and backup communication lines, guaranteeing the reliability and security of data communication through the SCADA system. The SCADA system supports multiple communication protocols such as MODBUS TCP/IP, OPC and IEC104.[2)]

Integrated dispatching system

The SCADA system performs data acquisition and control for the offtake stations and remotely controls the valve stations of the gas transmission line. It also acquires the major process parameters of the receiving terminal in addition to data provided by the DCS, such as the level of LNG in the storage tank and the export quantity allocated for dispatch by trucks. This data is communicated by standard protocols, such as the OPC protocol or MODBUS TCP/IP. Regarding DCS as an off-take station of the SCADA system, it can realize real-time monitoring of the production operations of the receiving terminal, and through the Web server, enables users to monitor the production and operation conditions of the receiving terminal and gas transmission lines. Meanwhile, the SCADA system can collect the daily, weekly, monthly and annual gas delivery plan for downstream users and the transportation plan for the upstream LNG transport ships from Web servers. These data, together with data describing the export quantity of each offtake station, are transmitted to the DCS system. Through firewall protection, authorized users can log onto the Web server via the Internet to submit and modify the gas nomination plan. The combined dispatching function of the DCS will conduct a gas transmission and distribution forecast according to the liquid level in the storage tank, the LNG transportation plan and the gas delivery plan for downstream users. Then it will dispatch and control the export quantity

Footnote

[2)] The MODBUS Protocol is a messaging structure developed by Modicon in 1979, used to establish master-slave/client-server communication between intelligent devices. TCP/IP: Transmission Control Protocol/Internet Protocol. OPC: OLE for Process Control.

Factbox 5 Technical characteristics of ABB's control system: System 800xA

ABB's System 800xA provides a powerful control system with a simple, visually appealing human-system interface. It provides a flexible distributed engineering environment for engineering design, control strategy configuration, flow chart design, information management, resource optimization and the integration of field equipment.

Functional design of flow chart

The flow chart design of System 800xA enables the engineer to remain an engineer and not to become a computer programmer. The automatic construction of flow charts makes projects simple and practical. Since the design of flow charts is based on functions, a design can be completed without in-depth understanding of the controller and I/O. In addition, System 800xA also supports online monitoring and calibration functions.

Process visualization

Applying the elements and symbols predefined in the comprehensive library of System 800xA, the user can conveniently customize the interactive flow chart. The system also supports bitmaps, photographs and picture elements from third-parties.

Fieldbus management

Fieldbus management consists of HART (Highway Addressable Remote Transducer) communications protocols, Foundation Fieldbus and Profibus and provides the engineers with a convenient fieldbus design tool. This tool integrates network topology and field elements such as equipment parameters, a plan for application program, trial run and detailed diagnostic reporting.

Batch data management

Batch data management of System 800xA utilizes Microsoft Excel and Excel ADD-INS, allows the automatic import of external data such as signal list, label name or document. It can export system data at any time for verification and modification.

Report generation and distribution

System 800xA supports flexible and diversified report functions. The format of the report is familiar and easy to use. This not only fully meets the requirements for factory and documents, but can also act as a powerful tool for the user's decision making and planning, with improvable performances.

Perfect data conversion

The data structure and operation defined by users provide powerful algorithms and programs that can be used repeatedly. On this basis, the user can convert raw data into information, such as KPI (key performance indicators), raw material property and perfect control support. The data structure can also be used to integrate external data into the system.

Safe storage and history data access

Fault-tolerant distributed data structure guarantees reliable data storage and usability. The user has limited rights to access these data. Meanwhile, these data can be stored offline. Electronic data meets the demand of enterprise and provides a reliable basis for decision making.

Integrated management and configuration

The embedded history data processing function is designed as the configuration and management inside the system. This allows the management of single-point change and eliminates the risk of requiring additional project replication due to inconsistency of multiple databases.

Guarantees continuous batch production, stable product quality and production cycle

System 800xA batch management provides unrivaled management, batch control and program control, and observes industrial specification, security and reliability. In response to the ever-increasing product requirements, it provides fast and controllable responses and simultaneously reduces operating costs and production stoppages, thus winning a long-term competitive edge in the market.

from the receiving terminal according to the inlet pressure of the receiving terminal, the exports to the gas transmission line and the inventory of the gas transmission line 4.

In the control logic of combined dispatching, the DCS controller firstly assesses whether the export pressure is within the minimum and maximum working pressure range. If the working pressure is too high (about 90 percent of maximum working pressure), the system conducts the export decrease operation: If this pressure exceeds the maximum working pressure, the ESD system will conduct an export emergency shutdown operation. If, however, the working pressure is too low (about 110 percent of the minimum working pressure), the system conducts the export increase operation: If this pressure is lower than the minimum working pressure, the ESD system will conduct an export increase operation and signal an alarm.

The DCS controller will immediately calculate the difference between the output of the receiving terminal and the total output of the various offtake stations. It will estimate the inventory in the gas transmission line and determine whether the present export quantity plus the inventory can meet the demand over the next two hours, taking account of the previous two-hour gas delivery plan. Should the predicted demand exceed the expected export quantity, the DCS controller will conduct an export increase operation.

When the system is determining whether to conduct an export increase or an export decrease operation, it first checks whether there have been any major fluctuations in the gas consumption in the last two hours according to the gas delivery plan. If the fluctuations are within the maximum export quantity for a set of high-pressure pumps, it is merely necessary to start or stop these pumps. If the variation is higher than the maximum export quantity for this single set of high-pressure pumps, it will be necessary to start or stop two sets of high-pressure pumps or possibly three sets, depending on the size of the fluctuation. When conducting an export increase or an export decrease operation, it is also necessary to adjust the operations of other process equipment accordingly, such as low-pressure pumps and seawater pumps, to coincide with the revised export quantity. When the motor control center (MCC), which includes the controls for low pressure, high pressure and seawater pumps, fails to meet the requirement of the control logic, the DCS controller will automatically send an alarm to prompt the operator to switch to manual processing.

ABB's SCADA and System 800xA improve the working efficiency of production dispatching, avoid errors of judgment in operation, and coordinate the combined dispatch control between the LNG receiving terminal and the gas-transmission line.

With reference to the transportation plan of the LNG transport ships, the integrated dispatching system judges whether the LNG allowance can meet the planned export quantity of the gas transmission line during the forecast period until the LNG transport ship unloads. If the LNG allowance fails to meet the requirement, the system sends an alarm to remind the operator, through negotiation with the downstream users, to adjust the gas consumption plan. In addition, the system also judges whether there is adequate space in the storage tank to accommodate the discharge of LNG from the ship. Should the capacity of the storage tank be insufficient, the system sends an alarm to remind the operator that he should consult with downstream users to adjust the gas delivery plan or increase delivery of the gas through other modes (such as tanker transportation), so that adequate space can be created in the storage tank to accommodate the arrival of the scheduled LNG shipment.

The control system

The structure of the control system is shown in Factbox 5. The main control center communicates with the control system at the receiving station and the control center of the offtake station. The offtake station control center oversees several offtake stations and valve houses. The design ensures that the servers, controllers and networks are redundant so that the system's safety is guaranteed.

Optimization

Since the start of its operation, the Fujian LNG project has successfully received its first shipment of LNG. The optimized control solution can save millions of dollars on the monthly supply of LNG. Natural gas has been transported to such stations as Putian, Hui'an, Quanzhou and Honglu, and the downstream users are already using the natural gas provided by the Fujian LNG project.

By taking full advantage of automatic control and information processing technology to integrate different but associated production process control systems, the Fujian LNG project can efficiently implement the combined dispatch of LNG to end users. ABB's SCADA and System 800xA improve the working efficiency of production dispatching, avoid errors of judgment in operation, coordinate the combined dispatch control between the LNG receiving terminal and the gas transmission line, and thus improve the comprehensive capability of the enterprise in production, operation and management.

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Further reading
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