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Improving Natural Gas Liquefaction Plant Performance with Process Analyzers

Case Study • December 2007

Liquefaction of natural gas to LNG

Natural Gas (NG) is a vital component of the world's supply of energy. It is one of the cleanest, safest, and most useful of all energy sources. NG is colorless and odorless in its pure form. While it is formed primarily of methane, it can also include ethane, propane, butane, pentane and certain impurities.

Liquified Natural Gas (LNG) is natural gas in its liquid form. It is an odorless, non-toxic and non-corrosive liquid. Natural gas is converted to LNG by cooling it to about -180 °C, at which point it becomes a liquid. This process reduces its volume by a factor of more than 600. This allows natural gas to be transported economically by sea. At its destination, LNG is stored as a liquid until it is warmed to convert it back to gas, blended to comply with local composition and BTU requirements and then sent through pipelines for distribution to consumers and industries.
The first LNG liquefaction unit came into operation in 1964 at Arzew, Algeria.

Typical natural gas includes additional components like sulphur, CO_2, water and heavier hydrocarbons which have to be removed from the natural gas before cooling. If not, some of them would become solid during refrigeration and interrupt the cooling process. Consequently, a LNG liquefaction unit produces also other chemicals like solid sulphur, NGL (Natural Gas Liquids) and LPG (Liquified Petroleum Gas).

To day LNG accounts for about 4% of natural gas consumption worldwide, and is produced in dozens of large-scale liquefaction plants.

oil & gas INDUSTRY

LNG is natural gas in its liquid state with high energy density, which makes it useful for storage and transportation over long distances from the gas fields to the consumers. LNG is recovered from natural gas in large-scale liquefaction plants. Process automation is a key issue in LNG plants to ensure cost efficient plant operation and high product quality. Process analyzer deliver important data therefore.

Siemens Sensors & Communication, a leader in process analytical instrumentation, has proven over decades its capability to plan, engineer, manufacture, implement and service analyzer systems for NG liquefaction plants. This *Case Study* provides an overview of the processes and describes how Siemens with its analyzer and application know-how meets best the process requirements.

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LNG supply chain from gas fields to consumers

The LNG supply chain from gas fields to consumers comprises a number of process and logistic (storage and transportation) steps as shown in fig.1.

NG pre-treatment

The liquefaction process requires all impurities and components that solidify at liquefaction temperatures to be removed from the wellstream prior to liquefaction. When the raw gas reaches the process plant it consists of three phases: natural gas, condensate and water. They are separated and split into three streams in a unit called slug catcher.

The condensate is heated to remove any residual gas. Pure condensate is stabilized by removing lighter hydrocarbons (NGL, Natural Gas Liquids) such as methane, ethane, propane and butane. Condensate is used as an additive in motor fuel production at refineries and as a feed material at petrochemical plants.

The liquid removed from the bottom of the slug catcher is treated to remove solid particles, salts and most of the water. The water is filtered through a biological treatment system before being discharged.

The Natural Gas is further treated by

- passing through an absorption column to remove carbon dioxide using the amine method. This is necessary to prevent the CO_2 freezing during liquefaction and cause damages along the process,
- drying it in dewatering columns to prevent the water turning to ice later in the process,
- removing very small quantities of mercury that could damage metal equipment in other parts of the process by passing through a separate unit (not shown in fig. 1).

Some of the natural gas is diverted from the flow to generate electricity in gas turbines. Exhaust heat from these units is used to warm up the heating medium in the plant.

NGL removal

The product specification for liquefied natural gas (LNG) defines the minimum content of propane, butane and other heavier hydrocarbons the gas is allowed to contain, and its calorific value. To meet these requirements, the heavier components (natural gas liquids, NGL) must be removed through a fractionation process by passing the gas through a fractionation column. Methane and ethane are taken off from the top of the column and continue into the gas liquefaction process. NGL products such as propane, butanes and other heavier hydrocarbons are removed from the bottom of the column and sent on to the plant for liquefied petroleum gases (LPG).

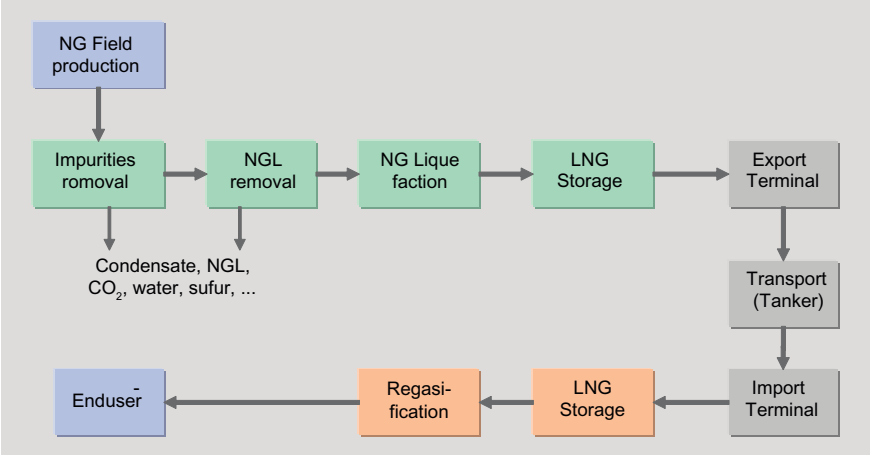

Fig. 1: LNG value chain, simplified

Liquefaction

The gas continues to the liquefaction part of the plant ("cold box") for cooling to liquefied natural gas (LNG). This facility consists fundamentally of several heat exchangers. The gas passes through them for pre-cooling to about -50 °C, beginning of liquefaction at about -80 °C and sub-cooling at about -160 °C and finally emerges as a liquid. The gas flows through thin tubes which are constantly bathed in coolant – pure fluids or mixes of nitrogen, methane, ethane and propane. The coolant takes up heat from the gas and evaporates, while the gas is cooled and condenses to liquid.
When it enters the cooling process, the gas may contain too much nitrogen in relation to the specification. This surplus is extracted initially in a nitrogen removal column. The top product of that process is nitrogen and some LNG, which go to a separate two-column removal process. Separated nitrogen is finally released to the air and any LNG returns to the process flow. LNG taken out at the bottom of the nitrogen removal column has a temperature of about -163 °C. It is piped from the cold box to storage tanks.

Transport and Regasification

The liquefaction process reduces the volume of natural gas by a factor of 600 allowing it to be shipped by sea. LNG is typically transported by specialized tanker with insulated walls, and is kept in liquid form by autorefrigeration, a process in which the LNG is kept at its boiling point. Upon arrival at its destination, LNG is generally transferred to specially designed and secured storage tanks and then warmed to its gaseous state in evaporators with different design – a process called regasification. Finally it is transported via pipelines to the enduser.

Real processes or plants may deviate from the above description depending on varying technologies and product demands.

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Liquefaction technologies

A refrigerant or a mixture of refrigerants is used in most technologies to cool and liquefy the process gas. The natural gas, beeing a mixture of compounds, liquefies over a wide temperature range. Energy efficient operating conditions can be obtained by minimizing the temperature difference between the cooling process gas and the refrigerant streams. This can be realized by using a mixture of refrigerant to match best the cooling curve of the process gas. Thus, the composition of the refrigerant represents an important process parameter.

The cooling process can be performed along different process routes, e. g. :

- **Classic cascade cycle**
  Following carbon dioxide and water removal, the natural gas is cooled down in three cooling cycles, where propane, ethane and methane are used as coolants. The propane from the first cycle is also used to cool ethane from the second cycle, and the ethane from the second cycle to cool the methane in the third cycle. This method is quite energy efficient.
- **Cascade cycle with mixed coolant**
  This is a modification of the classic cascade cycle, which uses only one compressor and one coolant made of a mixture of hydrocarbons. Natural gas is first pre-cooled with propane
- and then further cooled with a hydrocarbon mixture.
  This method is slightly more energy intensive than the classic cascade cycle but requires less installations effort and is therefore used more frequently.
- **Decompression cycle**
  This version operates similar to installations that produce liquid oxygen and nitrogen using the low-temperature air fractioning method. In this process, a part of the gas is decompressed in a turbo-expander, and then cooled down to a very low temperature. The cooled gas is then used to liquefy the next portion of the gas passing through the installation.

Natural Gas Liquefaction Technologies (selection)	
Air Products and Chemical Inc., APCI PPMR process	This propane precooled mixed refrigerant process (PPMR) uses pure propane for pre-cooling, while the liquefaction and subcooling cycle uses a mixed refrigerant made up of nitrogen, methane, ethane and propane.
Philips optimized cascade process	In this optimized cascade liquefaction (OCLP) process refrigeration and liquefaction is achieved by using three pure component refrigerants (propane, ethylene and methane) in series.
Statoil / Linde	This mixed fluid cascade process (MFCP) uses three mixed (from methane, ethane, propane and nitrogen) refrigerants for precooling, liquefaction and subcooling.
Shell	This dual Mixed Refrigerant (DMR) process uses two separate mixed refrigerant cooling cycles. One is for pre-cooling gas to about - 50°C (PMR cycle), and the other is for final cooling and liquefaction (MR cycle).

Fig. 3: LNG technologies (selection)

Proprietary processes

- The refrigeration and liquefaction section is the key element of a LNG plant. Many proprietary process technologies are available and more under development. All of them are based on the general methods described above but designed in detail by the respective companies, see fig. 3.

Fig. 2: LNG liquefaction plant

Fig. 4 LNG terminal

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Process Analytics in the LNG supply chain

Manifold analysis demands

The development of new liquefaction technologies, the construction of larger plants and the increasing demand in energy efficiency and product quality has also increased the demand in efficient process analytical techniques.

Manifold measuring points with different analysis tasks are located along the process route from the gas field through the NG production and NG shipping to the NG distribution and consuming section (fig. 5 and 6). Measuring tasks include process control, products quality control and heating value measurement (BTU).

Need of Gas Chromatography

Process gas chromatographs are the prevailing type of process analyzers in LNG plants to collect the required information from the process for plant performance optimization and for fast, accurate and reliable determination of the calorific value for fiscal energy measurement. Gas chromatographs are completed by continuous gas analyzers to measure e. g. CO_2.

Optimal solutions by Siemens

With the line of three different process gas chromatographs (MAXUM II, MicroSAM and SITRANS CV) Siemens Process Analytics is able to offer optimal solutions to any analysis task along the route from one hand. Highest flexibility and analysis performance of MAXUM II, the miniature size and micromechanical technology of MicroSAM and the special design of SITRANS CV (calorific value) for calorific measurements are key elements of this outstanding products line of gas chromatographs.
Read more about on the next pages.

Analysis systems

Siemens Process Analytics also supplies turnkey analysis systems for LNG plants as well as for tanker and pipe line control, from planning and engineering to start-up, commissioning and training services. Read more on page 8.

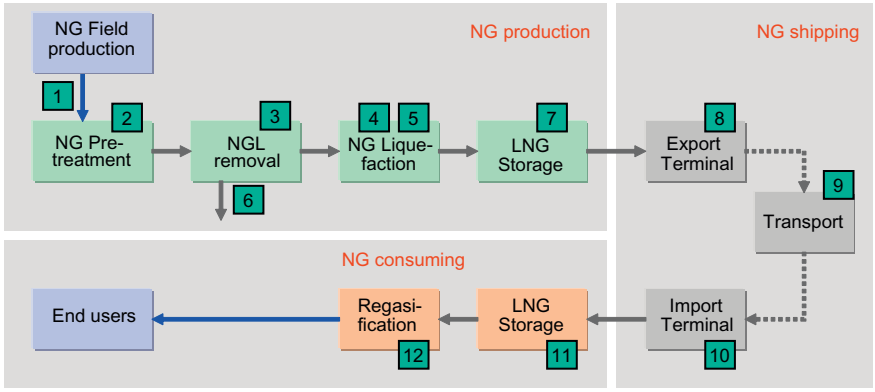

Fig. 5: LNG supply chain with analysis measuring points

Sampling point Sampling stream		Measuring Components	Suitable Siemens Analyzers
1	From gas field	CO_2, H_2S	MAXUM II, ULTRAMAT
2	NG pretreatment	C_1 -C_5 +	MicroSAM / MAXUM II
3	NGL removal	N_2, C_1 - C_4	MicroSAM / MAXUM II
4	Liquefaction, gaseous	C_1 - C_4, C_5 +	MicroSAM / MAXUM II
5	Liquefaction, liquid	C_2 - C_5, C_6H_6	MAXUM II
6	From separation	N_2, C_1 - C_4	MicroSAM / MAXUM II
7	LNG storage	C_1 - C_5, C_6 +, N_2, CO_2	SITRANS CV
8	Export terminal	C_1 - C_5, C_6 +, N_2, CO_2	SITRANS CV
9	LNG tanker	N_2, CO_2, C_1	SITRANS CV
10	Import terminal	C_1 - C_5, C_6 +, N_2, CO_2	SITRANS CV
11	LNG storage	C_1 - C_5, C_6 +, N_2, CO_2	SITRANS CV
12	LNG regasification	C_1 - C_5, C_6 +, N_2, CO_2	SITRANS CV
	Various	H_2O	Third party analyzer

Fig. 6: Typical tasks for process analytics (ref.: Fig. 5)

Fig. 7: SITRANS CV installation in a metering station

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SITRANS CV, the new Calorific Value Chromatograph

SITRANS CV Basics

Design and application

SITRANS CV (fig. 9) is the consequent advancement of an existing, micromechanical technology based process chromatograph to a high performance calorific value (CV/BTU) analyser. It has been specially developed for fast, exact and reliable determination of calorific values of Natural Gas. Because of its rugged and compact design SITRANS CV is suitable for extreme areas of use, e.g. off-shore exploration, or direct mounting on a pipeline. Weighing only 15 kg, the compact analyzer can be installed at any position in the plant (fig. 8). SITRANS CV has been assigned the required certificates for such applications, such as explosion protection EEx d and splashwater protection according to IP65 or NEMA 4X.

Fiscal energy measurement

SITRANS CV provides all information to the natural gas quality and its physical properties such as calorific value and density, which are required for manifold applications in the natural gas industry, especially for fiscal energy measurement. From the measured concentration of gas components, SITRANS CV calculates the superior and inferior calorific values, standard density and Wobbe index according to ISO 6976. The analyzer saves the mean values of all components and the calorimetric values for a period of up to 100 days.

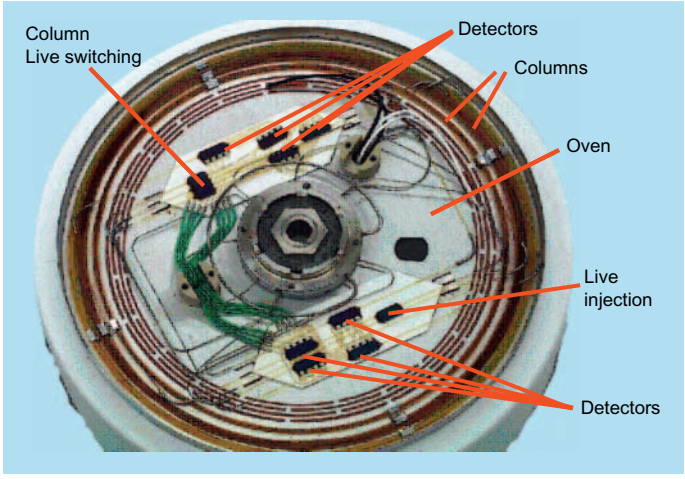

Fig. 9: SITRANS CV design

SITRANS CV Highlights

- Fast analysis through innovative micro electromechanical systems (MEMS) technology. For example, when analyzing natural gas, C_1 to C_6+ with N_2, CO_2 and O_2 measurements are possible in less than three minutes.
- Precision through valveless live injection. The system is independent of variations in sample pressure, and guarantees reliable injection of the natural gas sample. In this manner, the SITRANS CV achieves a repeatability of RSD (Relative standard deviation) of 0.007% for the superior and inferior calorific values
- High separation performance through narrow-bore capillary columns which can therefore be optimally combined with MEMS technology and live injection in the SITRANS CV in order to achieve as high a separating performance as possible
- Low detection limits through powerful detectors
- High linearity over the measuring range saves expensive calibration gases. Multi-level calibration is unnecessary with the SITRANS CV because of the high linearity of the calibration function throughout the measuring range. Reliable measurements can be achieved using a single-point calibration, giving the possibility to abandon expensive calibration gases.
- Easy and safe operation using CV Control. Operation of SITRANS CV using software CV Control is simple, clear and fast. The software has been specially developed for measurements requiring verification, and requires, for example, the input of a password in order to access fiscal metering mode.
- Automatic optimization of methods increases availability.
  SITRANS CV optimizes the column switching commands and retention windows depending on the current retention times

Fig. 8: Typical SITRANS CV installations, mounted in shelter (left) and field mounted (right)

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Siemens Process Analytics at a glance
Products

Siemens Process Analytics

Siemens Process Analytics is a leading provider of process analyzers and process analysis systems. We offer our global customers the best solutions for their applications based on innovative analysis technologies, customized system engineering, sound knowledge of customer applications and professional support. And with Totally Integrated Automation (TIA). Siemens Process Analytics is your qualified partner for efficient solutions that integrate process analysers into automations systems in the process industry.

From demanding analysis tasks in the chemical, oil & gas and petrochemical industry to combustion control in power plants to emission monitoring at waste incineration plants, the highly accurate and reliable Siemens gas chromatographs and continuous analysers will always do the job.

Siemens process Analytics offers a wide and innovative portfolio designed to meet all user requirements for comprehensive products and solutions.

Our Products

The product line of Siemens Process Analytics comprises extractive and in-situ continuous gas analyzers (fig. 10 to 13), process gas chromatographs (fig. 14 to 17), sampling systems and auxiliary equipment. Analyzers and chromatographs are available in different versions for rack or field mounting, explosion protection, corrosion resistant etc.

A flexible networking concept allows interfacing to DCS and maintenance stations via 4 to 20 mA, PROFIBUS, Modbus, OPC or industrial ethernet.

Extractive Continuous Gas Analyzers (CGA)	
ULTRAMAT 23	The ULTRAMAT 23 is a cost-effective multicomponent analyser for the measurement of up to 3 infrared sensitive gases (NDIR principle) plus oxygen (electrochemical cell). The ULTRAMAT 23 is suitable for a wide range of standard applications. Calibration using ambient air eliminates the need of expensive calibration gases.
CALOMAT 6/62	The CALOMAT 6 uses the thermal conductivity detection (TCD) method to measure the concentration of certain process gases, preferably hydrogen.The CALOMAT 62 applies the TCD method as well and is specially designed for use in application with corrosive gases such as chlorine.
OXYMAT 6/61/64	The OXYMAT 6 uses the paramagnetic measuring method and can be used in applications for process control, emission monitoring and quality assurance. Due to its ultrafast response, the OXYMAT 6 is perfect for monitoring safety-relevant plants. The corrosion-proof design allows analysis in the presence of highly corrosive gases. The OXYMAT 61 is a low-cost oxygen analyser for standard applications. The OXYMAT 64 is a gas analyzer based on ZrO_2 technology to measure smallest oxygen concentrations in pure gas applications.
ULTRAMAT 6	The ULTRAMAT 6 uses the NDIR measuring principle and can be used in all applications from emission monitoring to process control even in the presence of highly corrosive gases. ULTRAMAT 6 is able to measure up to 4 infrared sensitive components in a single unit.
ULTRAMAT 6 / OXYMAT 6	Both analyzer benches can be combined in one housing to form a multicomponent device for measuring up to two IR components and oxygen.
FIDAMAT 6	The FIDAMAT 6 measures the total hydrocarbon content in air or even in high-boiling gas mixtures. It covers nearly all requirements, from trace hydrocarbon detection in pure gases to measurement of high hydrocarbon concentrations, even in the presence of corrosive gases.
In-situ Continuous Gas Analyzer (CGA)	
LDS 6	LDS 6 is a high-performance in-situ process gas analyser. The measurement (through the sensor) occurs directly in the process stream, no extractive sample line is required. The central unit is separated from the sensor by using fiber optics. Measurements are carried out in real-time. This enables a pro-active control of dynamic processes and allows fast, cost-saving corrections.

Fig. 11: Product scope „Siemens Continuous Gas Analyzers“

Fig. 10: Series 6 gas analyzer (rack design)

Fig. 12: Series 6 gas analyzer (field design)

Fig. 13: LDS 6 in-situ laser gas analyzer

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Siemens Process Analytics at a glance
Products (continued) and Solutions

Fig. 14: MAXUM edition II Process GC

Fig. 15: MicroSAM Process GC

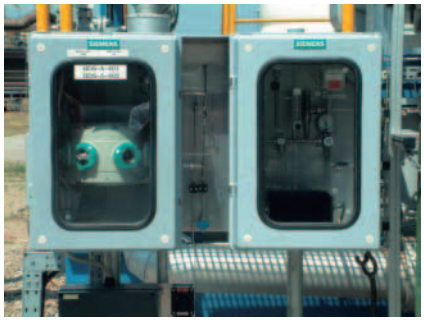

Fig. 16: SITRANS CV Natural Gas Analyzer

Process Gas Chromatographs (Process GC)	
MAXUM edition II	MAXUM edition II is very well suited to be used in rough industrial environments and performs a wide range of duties in the chemical and petrochemical industries and refineries. MAXUM II features e. g. a flexible, energy saving single or dual oven concept, valveless sampling and column switching, and parallel chromatography using multiple single trains as well as a wide range of detectors such as TCD, FID, FPD, PDHID, PDECD and PDPID.
MicroSAM	MicroSAM is a very compact explosion-proof micro process chromatograph. Using silicon-based micromechanical components it combines miniaturization with increased performance at the same time. MicroSAM is easy to use and its rugged and small design allows mounting right at the sampling point. MicroSAM features drastically reduced cycle times, provides valveless sample injection and column switching and saves installation, maintenance, and service costs.
SITRANS CV	SITRANS CV is a micro process gas chromatograph especially designed for reliable, exact and fast analysis of natural gas. The rugged and compact design makes SITRANS CV suitable for extreme areas of use, e.g. offshore exploration or direct mounting on a pipeline. The special software "CV Control" meets the requirements of the natural gas market, e.g. custody transfer.

Fig. 17: Product scope „Siemens Process Gas Chromatographs“

Our solutions

Analytical solutions are always driven by the customer´s requirements. We offer an integrated design covering all steps from sampling point and sample preparation up to complete analyser cabinets or for installation in analyser shelters (fig. 18). This includes also signal processing and communications to the control room and process control system.

We rely on many years of world-wide experience in process automation and engineering and a collection of specialized knowledge in key industries and industrial sectors. We provide Siemens quality from a single source with a function warranty for the entire system.

Read more in "Our Services“.

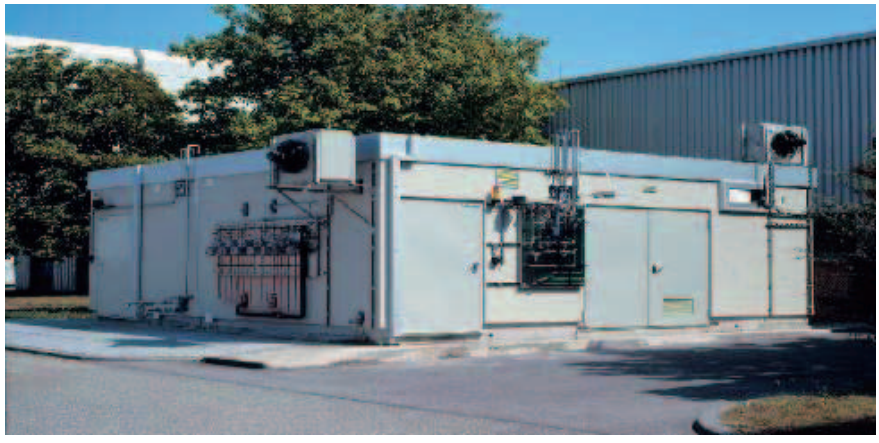

Fig. 18: Analyzer house (shelter)

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Siemens Process Analytics at a glance
Solutions (continued) and Services

Our solutions ...

Analyzer networking for data communication

Engineering and manufacturing of process analytical solutions increasingly comprises "networking". It is getting a standard requirement in the process industry to connect analyzers and analyzer systems to a communication network to provide for continuous and direct data transfer from and to the analysers.
The two objectives are (fig. 20):

- To integrate the analyzer and analyzer systems seamless into the PCS / DCS system of the plant and
- To allow direct access to the analyzers or systems from a maintenance station to ensure correct and reliable operation including preventive or predictive maintenance (fig.19).

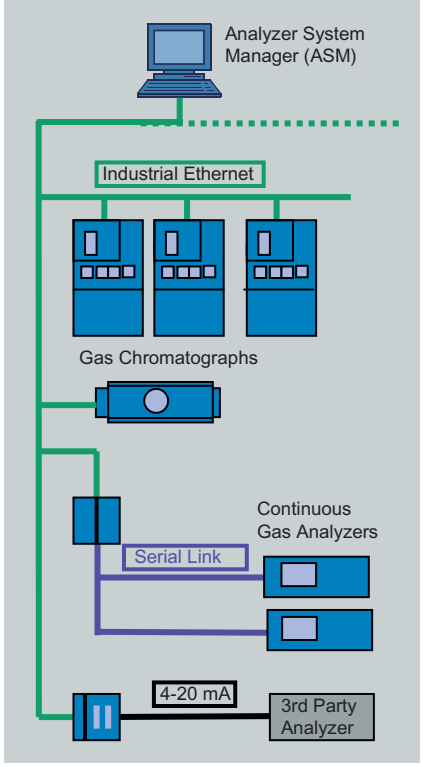

Fig. 19: Communication technologies

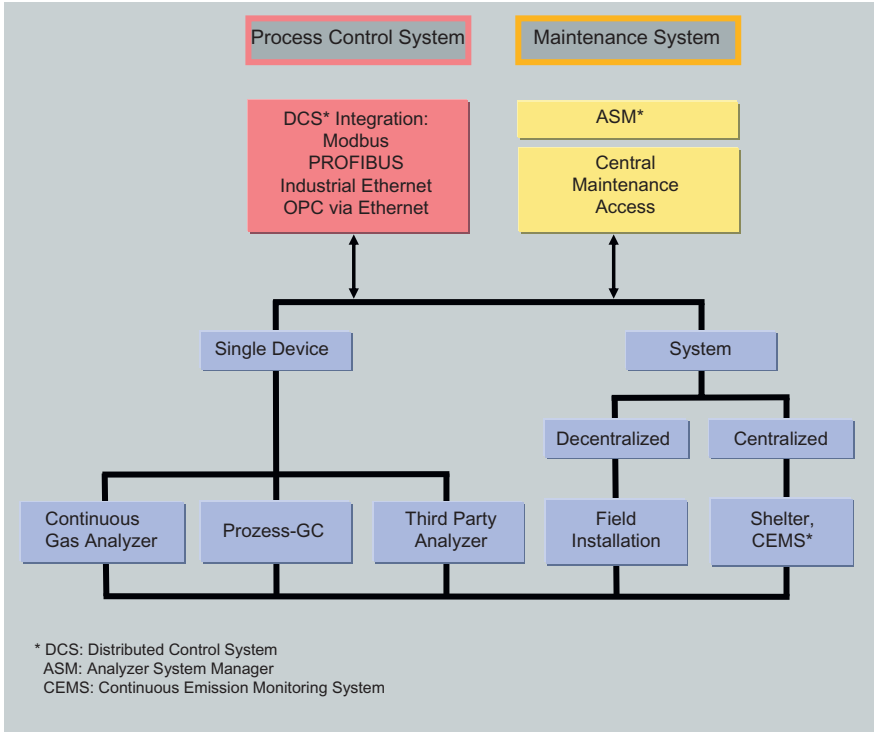

Fig. 20: Networking for DCS integration and maintenance support

Siemens Process Analytics provides networking solutions to meet the demands of both objectives.

Our Services

Siemens Process Analytics is your competent and reliable partner world wide for Service, Support and Consulting.

Our rescources for that are

- Expertise
  As a manufacturer of a broad variety of analyzers, we are very much experienced in engineering and manufacturing of analytical systems and analyzer houses.
  We are familiar with communication networks, well trained in service and maintenance and familiar with many industrial pro cesses and industries.
  Thus, Siemens Process Analytics owns a unique blend of overall analytical expertise and experience.
- Global presence
  With our strategically located centers of competence in Germany, USA, Singapore, Dubai and Shanghai, we are globally present and acquainted with all respective local and regional requirements, codes and standards.
  All centers are networked together.

Fig. 21: Portfolio of services

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Siemens Process Analytics at a glance
Services, continued

Our Services ...

Service portfolio

Our wide portfolio of services is segmented into Consulting, Support and Service (fig. 21 to 22). It comprises really all measures, actions and advises that may be required by our clients throughout the entire lifecycle of their plant. It ranges from site survey to installation check, from instruction of plant personnel to spare part stock management and from FEED for Process Analytics (see below) to internet-based service Hotline.

Our service and support portfolio (including third-party equipment) comprises for example:

- Installation check
- Functionality tests
- Site acceptance test
- Instruction of plant personnel on site
- Preventive maintenance
- On site repair
- Remote fault clearance
- Spare part stock evaluation
- Spare part management
- Professional training center
- Process optimisation
- Internet-based hotline
- FEED for Process Analytics
- Technical consullting

FEED for Process Analytics

Front End Engineering and Design (FEED) is part of the planning and engineering phase of a plant construction or modification project and is done after conceptual business planning and prior to detail design. During the FEED phase, best opportunities exist for costs and time savings for the project, as during this phase most of the entire costs are defined and changes have least impact to the project. Siemens Process Analytics holds a unique blend of expertise in analytical technologies, applications and in providing complete analytical solutions to many industries.

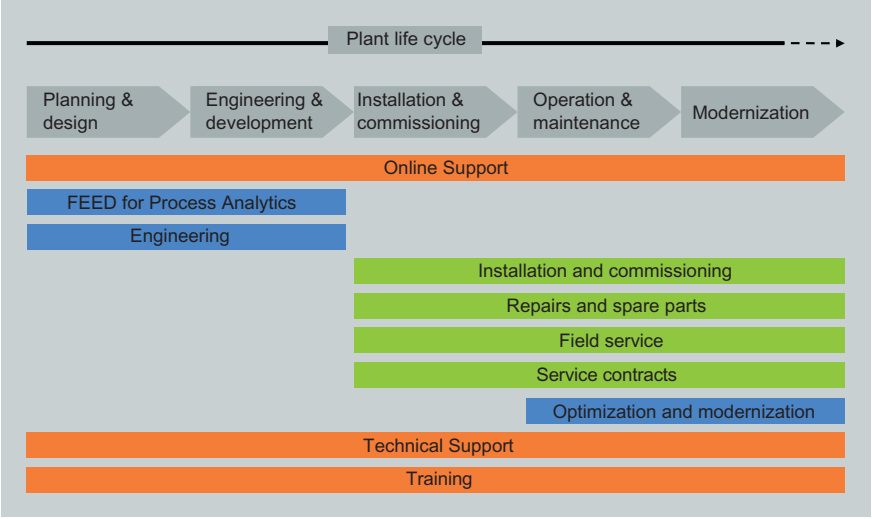

Fig. 22: Portfolio of services provided by Siemens Process Analytics

Based on its expertise in analytical technology, application and engineering , Siemens Process Analytics offer a wide scope of FEED services focused on analysing principles, sampling technologies, application solutions as well as communication system and given standards (all related to analytics) to support our clients in maximizing performance and efficiency of their projects.

Whether you are plant operators or belong to an EPC Contractor you will benefit in various ways from FEED for Process Analytics by Siemens:

- Analytics and industry know how available, right from the beginning of the project
- Superior analyzer system performance with high availability
- Established studies, that lead to realistic investment decisions
- Fast and clear design of the analyzer system specifications, drawings and documentation
- Little project management and coordination effort, due to one responsible contact person and less time involvement
- Additional expertise on demand, without having the costs, the effort and the risks of building up the capacities
- Lowest possible Total Costs of Ownership (TCO) along the lifecycle regarding investment costs, consumptions, utilities supply and maintenance.

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Case Study

Siemens Process Analytics - Answers for industry

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