OPERATING INFORMATION SYSTEM FOR LNG FACILITIES

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1. INTRODUCTION

Natural gas is a naturally occurring mixture of hydrocarbon and non-hydrocarbon gases found under the earth's surface. The principal constituent of natural gas is Methane, so natural gas has been widely used as a clean energy resource. Natural gas is usually liquefied for the convenience of the transport and storage, because the volume of LNG is about 1/600 that of the gas in its vapor state. Liquefied Natural Gas (LNG) is a colorless, transparent liquid stored at a very low temperature (-162ºC) at atmospheric pressure.

Natural gas consumption has been rapidly increasing not only in Korea but also in the world due to the abundance of its reserves. Raw natural gas drawn from the gas reserves is liquefied by cooling, and then the LNG ships transport LNG worldwide. The imported LNG is stored in the LNG storage tanks, and then it is vaporized and distributed to a service area through gas trunklines. Here, the LNG receiving terminal receives LNG from the LNG ships and stores it in the storage tanks, and vaporizes it and sends out the natural gas to the trunklines as the needs of demand.

Korea Gas Corporation (KOGAS) is the main LNG provider in Korea. KOGAS has three LNG receiving terminals and the supply chain networks for LNG importation and the natural gas supply. The receiving terminal facilities are located in Incheon, Pyongtaek and Tongyong. Table 1 shows the site areas and their major facilities of the terminals. KOGAS has 1,981 km trunkline and 6 district offices for remote control and monitoring.

Table 1 LNG Terminal Facilities in KOGAS

	Area	Major Facilities
Pyongtaek	About 601,000 m^2	10 Tanks of 100,000kl, Send out capacity: 2,020 ton/hr
Incheon	About 992,000 m^2	10 Tanks of 100,000kl, 2 Tanks of 140,000kl, 2 Tanks of 200,000kl Send out capacity: 3,060 ton/hr
Tongyong	About 1,322,000 m^2	3 Tanks of 140,000kl Send out capacity: 990 ton/hr

Operating Information System (OIS) was developed in Incheon LNG receiving terminal. The objectives of the developed OIS are to improve the operability and the safe operation in the terminal, and to make the infrastructure of information integrated manufacturing system.

The operating information has to be regularly managed for the analyses, improvements and managements of a plant, so the system is indispensable for the operability and the safety of the terminal.

2. INCHEON LNG RECEIVING TERMINAL

Incheon LNG receiving terminal has 14 LNG storage tanks with the send-out capacity of 3,060 ton/hr. Incheon LNG receiving terminal is divided into two parallel plants, 1st and 2nd plant. Each plant has its facilities from a jetty for LNG unloading to a metering station for natural gas send-out, therefore it has the ability of independent operation except the facilities of the common utilities.

Fig.1 depicts the Process Flow Diagram (PFD) of Incheon LNG receiving terminal. As shown in the PFD, the terminal receives LNG from LNG ship and stores it in the LNG storage tanks. For the send-out LNG, the high-pressure LNG pumps raise the pressure of LNG up to 70 bars. Then LNG is vaporized when passing through the open rack vaporizers (ORVs) and/or submerged vaporizers (SMVs), and it becomes natural gas. The ORV uses seawater to vaporize LNG. It is enough to use seawater for vaporizing LNG, because the temperature of LNG is very low of -162°C, whereas the SMV uses fuel gas.

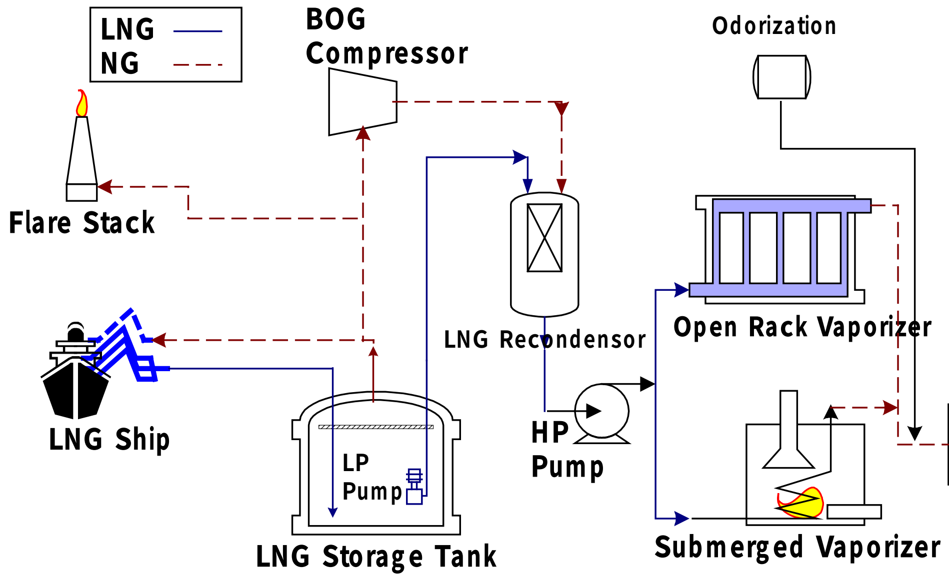

Fig. 1 PFD of LNG receiving terminal.

Each process in the PFD consists of a number of units connected in parallel. The detail specifications and capacities are listed in table 2.

Table 2 Main facilities in Incheon LNG receiving terminal

Facilities		Unit	Capacity (Total Capacity)
Unloading Arm	LNG	6	3,700m^3/hr/unit (22,200m^3/hr)
	BOG	2	11,000m^3/hr
	B.C.	2	500m^3/hr
LNG Storage Tank (1,680,000 kℓ)		10	100,000 kℓ /unit (1,000,000 kℓ)
		2	140,000 kℓ /unit (280,000 kℓ)
		2	200,000 kℓ /unit (400,000 kℓ)
BOG Facility	Compressor	8	12,000m^3/hr/unit (96,000m^3/hr)
	Flare Stack	1	130 ton/hr
LNG Pump	Low Pressure	34	150 ton/hr/unit (3,600 ton/hr)
	High Pressure	27	120 ton/hr/unit (3,120 ton/hr)
Vaporizer	ORV	8	180 ton/hr/unit (1,440 ton/hr)
	SMV	18	90 ton/hr/unit (1,170 ton/hr)
Recondenser		4	30 ton/hr/unit (120 ton/hr)
High Pressure Compressor		2	20 ton/hr/unit (40 ton/hr)
Metering Station		3	~4,440 ton/hr
Co-generation Facility		3	9MW/unit (27MW)

3. INFORMATION INTEGRATED MANUFACTURING FOR LNG FACILITIES

Modern manufacturing processes are becoming more complicated for general operators to understand completely due to the complexities of the processes and their automation. In order to maintain plant safety and enhance the processes availability, the sophisticated manufacturing processes need the information management system and the operating support systems. In the past two decades, the information added automation systems have been rapidly developed and improved. Due to the information integrated manufacturing environment, the recent manufacturing plants have been operated with many advanced technologies such as on-line fault diagnosis, APC (Advanced

Process Control), on-line optimization, scheduler, *etc*. In this paper we propose the configuration of the information integrated manufacturing environment for LNG facilities, as shown in Fig. 2, based on the typical CIM (Computer Integrated Manufacturing) structure. KOGAS has developed the Operating Information System (OIS), operation support system, and data reconciliation system in Incheon LNG receiving terminal for the information integrated manufacturing environment.

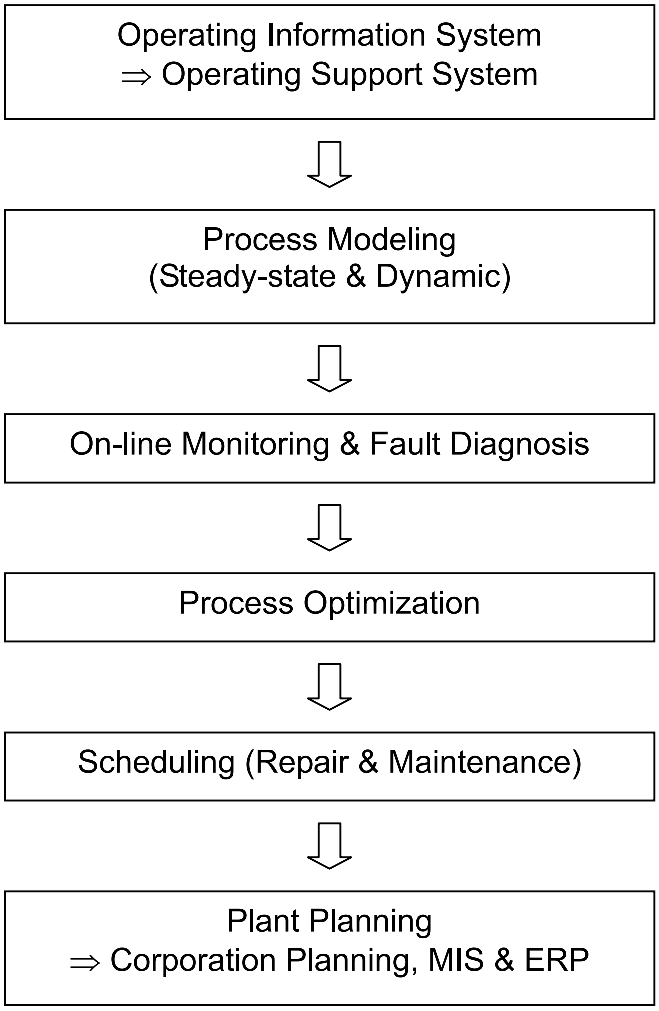

Fig. 2 Configuration for information integrated manufacturing in LNG facilities.

The basic functions of the OIS are to gather and re-distribute the plant information. Based on the functions of the OIS, there are many valuable applications including process monitoring, productivity and operability management, *etc*. The OIS also shares the process information with many applications such as optimization, scheduler, and so on. Therefore the OIS affords the managers an office automation using the auto-report forms based on the operating information and makes the various value-added applications possible as follows:

- Data Reconciliation
- ACS (Advanced Control System)
- On-line Fault Diagnosis
- On-line Optimization
- Supervisory Control
- Scheduling and Planning

The concept of the OIS is not just logging information supplier. The OIS provides the environment for the process analysis and modeling, and then increases the process reliability due to the information sharing. Fig. 3 Shows the concept of OIS infrastructure for productivity and operation safety in LNG terminal.

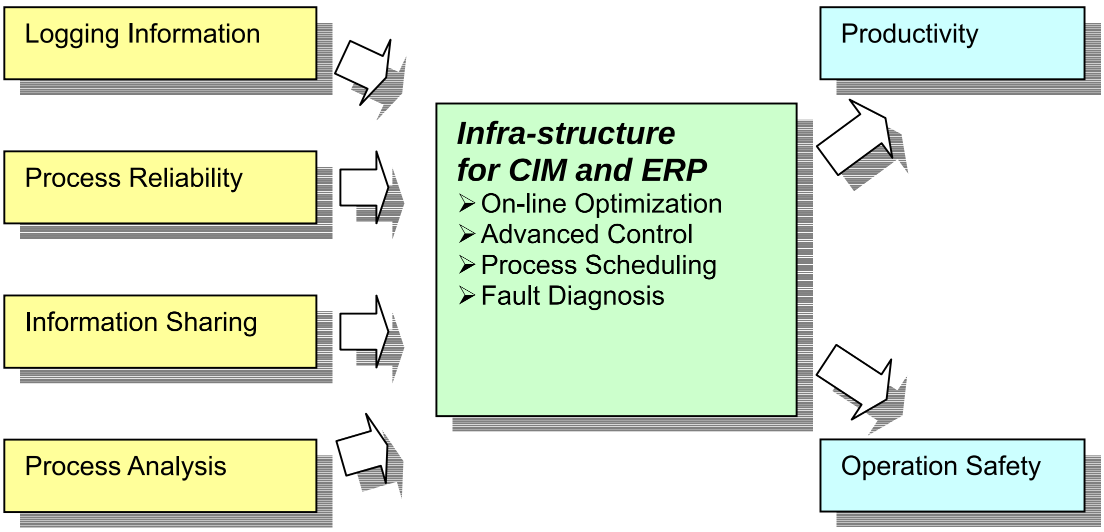

Fig. 3 Concept of OIS Infrastructure for Productivity and Operation Safety in LNG Terminal

4. OPERATING INFORMATION SYSTEM IN INCHEON LNG RECEIVING TERMINAL

The OIS in Incheon terminal has been developed based on the concept of the information integrated manufacturing mentioned above. The integrated environment for the future operating support applications also has been considered. Therefore the OIS becomes the central database as a realtime supplier of the process information for all facilities in the terminal.

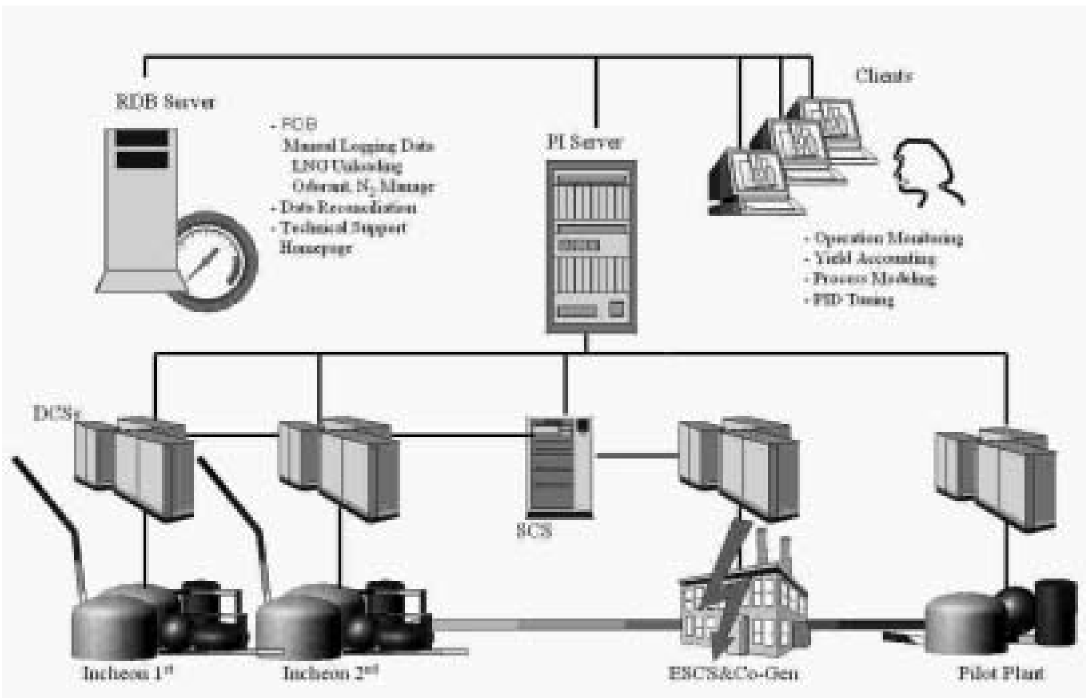

Fig. 4 Overall structure of the operating information system for Incheon LNG receiving terminal.

For the efficiency of the computation and network environment, we have developed the system based on the 3 Tier Client/Server Architecture, which consists of a database layer, an application layer, and a presentation layer independently. There are realtime database (RTDB) and relational database (RDB) in the server layer; a data reconciliation system and a pipe analysis system in the application layer; process viewers and spreadsheet programs in the presentation layer in the developed system. KOGAS plans to integrate the OIS with other applications and databases such as Facility Management System and LNG Heating Value Management System.

Fig. 4 depicts the overall structure and the connected systems. Users could monitor the plant and analyze the process data through the process viewers and the spreadsheet programs.

The RTDB stores and re-distributes more than 12,000 points of realtime process variables and 633 points of analysis data calculated in Supervisory Control System. The RTDB stores them every minute. The RTDB server also generates the calculated variables such as total flowrates, the number of running equipments, and running time accumulation of rotating equipments, and then stores them.

The RDB (relational database) has been developed to handle the manual data that were not collected automatically from the instruments and the control systems. The RDB system treats LNG unloading data, odorant and nitrogen storage management, LNG density management, fuel gas consumption management, and so on. There are 7 tables of relational databases in the RDB system.

4.1 Operating Support System

The operating support system for the management of productivity and operability is presented in this section. The system has many functions including on-line process monitoring, auto-reporting and data reconciliation. The auto-reporting function generates logging sheets, prompt reports, and the analysis reports of BOG (Boil-off Gas), *etc*. The data reconciliation system improves the confidence on measurements and computes the yield accounting of the plant. Fig. 5 shows the architecture of the monitoring and auto-reporting functions.

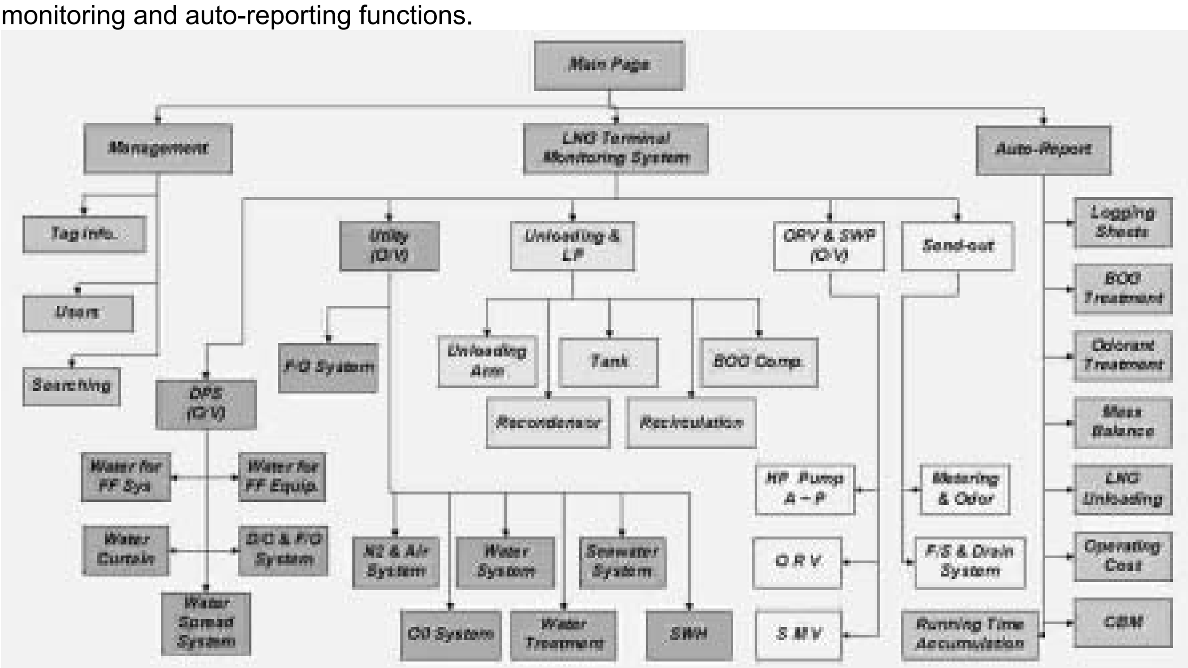

Fig. 5 Tree architecture of monitoring and auto-report system for operating support.

4.1.1 On-line Monitoring and Reporting

The primary objective of the OIS is an on-line monitoring. The operating data colleted from DCSs (distributed control system) are reserved in the RTDB server, and displayed on the screens of users. A number of schematic diagrams have been provided for process monitoring, and the structure of the monitoring system consists of three levels: overview, sub-area overviews and detail diagrams. Fig. 6 shows the sub-area overview for the unloading and LNG storage facilities as an example of the monitoring system.

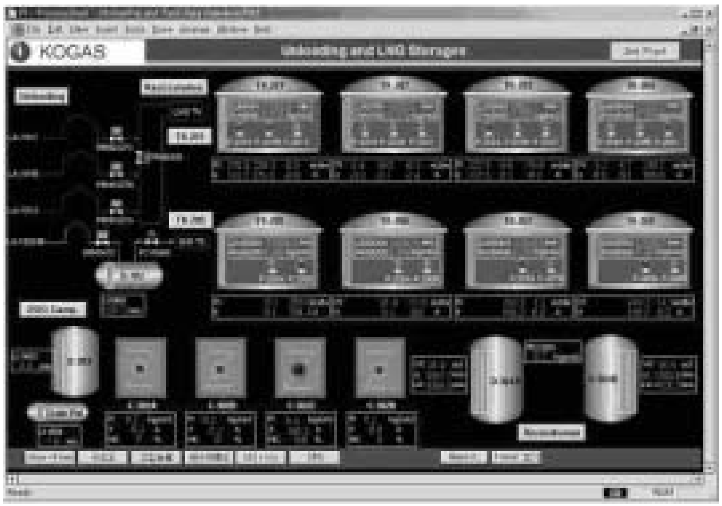

Fig. 6 Sub-area overview for the unloading and LNG storage facilities.

For the operating assistances, several documents and manuals are linked into the monitoring page associated. The linked documents are as follows:

- Environmental, Health and Safety Management System (EHSMS)
- ISO 9001
- Equipment Photographic
- Operating Manual
- Equipment Specification

KOGAS has provided various auto-report forms including the operation logging sheets and the reports for equipment maintenance, mass balance, LNG unloading, operating cost analysis, boil-off treatment, *etc*. Attaching the trend charts into the report forms, the process managers could easily catch what happened in the processes.

In the LNG receiving terminal, there are a lot of rotating equipments such as LNG pumps and air compressors, and operators have to monitor them carefully. The operators could check the running time of every important rotating unit using the running time accumulation report. Therefore they could determine the period of repair or replacement based on the information.

KOGAS has provided a lot of reports, more than 40 sheets, as follows:

- LNG Cost Analysis Report
- Electric Power Consumption Report
- Fuel Gas Consumption Report
- Unit Operation Cost Report
- Daily (Hourly) Cost Analysis
- LNG Unloading Report
- BOG (Boil-Off Gas) Treatment Report
- Odorant Treatment Report
- Running Time Accumulation Report for Rotating Units
- Yield Accounting Report
- CBM (Conditional Based Management) Report

Table 3 shows the overall configuration of the schematic diagrams and auto-report forms for the Incheon LNG receiving terminal.

Table 3 Configuration of the Schematic Diagrams and Auto-report Forms

Item	Plant 1	Plant 2	Pilot Plant	Etc.
Schematic Diagrams	46 Files	37 Files	4 Files	73 Files
Auto-report Forms	51 Files			
Manual Input Forms	6 Items			

4.1.2 Data Reconciliation System

The calculation accuracy of the yield accounting depends entirely on the precisions of the field instruments such as temperature, pressure and flowrate sensors. Therefore the precise field instruments are essential to not only the safety of plant operation but also the improvement of the plant. Regular maintenances for the field instruments are essential because the installation conditions of the field instruments and the operation environment influence their precisions. But, each instrument has its hardware limit on precision, so the plant data are commonly imperfect. In this study, we have focused on the mathematical model based approaches to reconcile the plant data.

Data reconciliation is the procedure of optimally adjusting measured data so that the adjusted values obey the conservation laws and other constraints (Crowe, 1994). In this study, the least square method is used to reconcile the plant data.

4.1.3 Technical Supports with Web System

Users including operators and managers get the information through the monitoring viewers and auto-report forms. The Incheon LNG terminal has been extended in its processes and tanks, consequently not only the schematic diagrams in monitoring viewers but also the outlines and computing ways of the auto-report forms have to be modified. Especially in the cases of auto-report forms, if the computing ways, such as density calculation method or basic factors of the calculation, are changed then the analysis methods are modified in the forms. The web server for technical support manages the modified schematic diagrams and the auto-report forms. The main functions of the web server are to notice the system upgrades and to propagate those files. The web server also introduces the basic concept of the OIS and supplies the tutor and manuals of the system. The Q&A part is also available for various solutions concerned with the OIS. The OIS web server supplies various services as follows:

- Tutor of the OIS: Introduction of the OIS
- Notices for Users: News related to the system
- Q and A (Question and Answer)
- Upgrade Information
- Manuals: for Beginner, Expert, and Developer
- Technical Information: Technical reports, Articles

The web server also sends Emails about recent news to the users using the electrical mailing list.

4.1.4 PID Auto-Tuning Package

A LNG terminal is a large plant that consists of many processing units (LNG storage tanks, pumps, vaporizers, etc.), integrated with one another in a systematic and rational manner. During its operation, the terminal has to satisfy several requirements imposed by its designers and the general technical, economic, and social conditions in the presence of ever-changing external influences (disturbances). Therefore, process automation and control are essential for the safety and economical operation of the terminal process.

PID (Proportional, Integral, and Derivative) controller is popularly used in the processes of a LNG terminal. The process information and complex control knowledge are required to tune the P·I·D values, therefore a lot of control loops have been left out of proper tuning because of the complexity of the tuning works. KOGAS has developed the PID auto-tuning package to tune automatically PID controllers. The PID auto-tuning package consists mainly of model identification (1st step) and PID tuning parameter calculation (2nd step). The first step, model identification, receives the actuator and process variable data and then builds automatically up process model by least square method (Åström and Wittenmark, 1990). This resulting model would be used in the second step, PID tuning parameter calculation. DCLR (Desired Closed-Loop Responses) is applied to the calculation method of the PID tuning (Lee et al, 1998).

KOGAS has developed the package based on the MS Excel^{TM} environment, exactly *xla* form, so the field engineers could use the package without any expression of discontent. The performance of the package has been proven through the successful cases in the various control loops. Fig. 7 shows an example of PID tuning using the package.

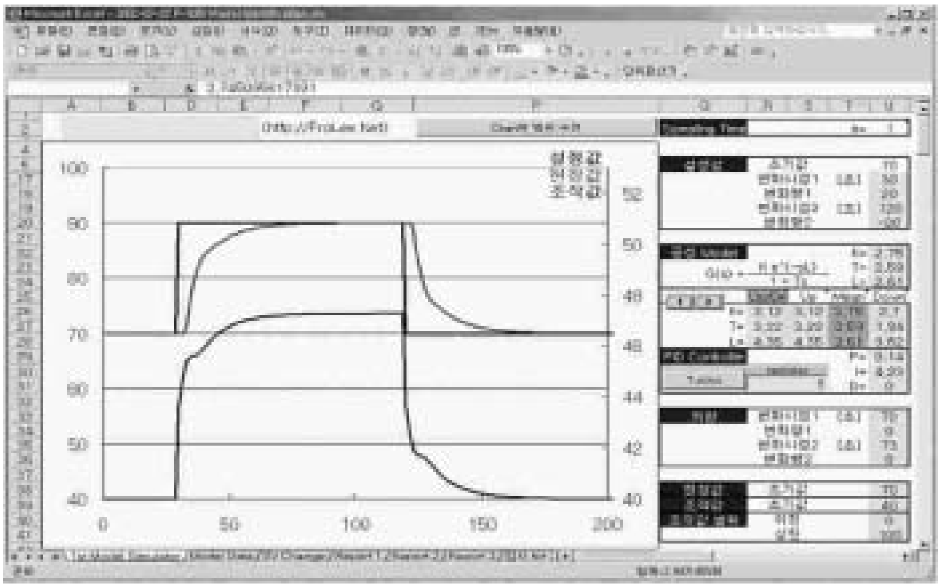

Fig. 7 Auto-PID tuning package screen.

The package and its manual can be downloaded in http://ProLee.Net.

4.2 Improvements of Process and Operation

Not only process operators but also process engineers and researchers could get the various plant information about Incheon LNG receiving terminal through the OIS. Therefore they could diagnose sensors in the field, manage the yield accounting, and analyze the utility consumption.

KOGAS has improved the processes and utilities such as a vaporizing process, an air supplier, and a seawater heater, and diagnosed the low temperature sensors in the LNG storage tanks and the temperature sensors in the safety detection system. If the low temperature sensors, which indicate the LNG leakage, in the tank in the LNG storage tank had not been diagnosed, the KOGAS might have deconstructed the roof of large tank at a great cost.

4.2.1 Fuel Gas Consumption Analysis

There are many parallel alternative processes in Incheon LNG receiving terminal as expressed in table 2. The vaporization process, which consists of the open rack vaporizers (ORVs) and the submerged vaporizers (SMVs), is the typical parallel alternative process

The ORVs and the SMVs are the facilities vaporizing cryogenic LNG into natural gas. The fuel gas is used in the SMV for the vaporization of LNG, and the seawater is used in the ORV for heat exchange.The ORV needs the seawater heater, which uses the fuel gas, to raise the temperature of the seawater when its temperature is below 5 ºC. Usually the ORV, which uses the seawater, is operated to vaporize LNG in the Incheon terminal, so the SMVs are backup processes in case of very low temperature of seawater.

According to the fuel gas consumption analysis, the operation mode, which uses the seawater heater to raise the temperature of seawater, is not efficient during the winter. Therefore we have changed the operation concept, which makes the SMVs to be major processes during the winter. In other words, the vaporizing process has been optimized in the operation using the OIS.

The Fig. 8 shows the result after the modification of the operation mode. The chart represents the proportion of the fuel gas consumption amount to the natural gas production. In the chart, the dashed line indicates when the operation mode was modified. After the modification, more than 31,000 m^3/day of fuel gas could be saved.

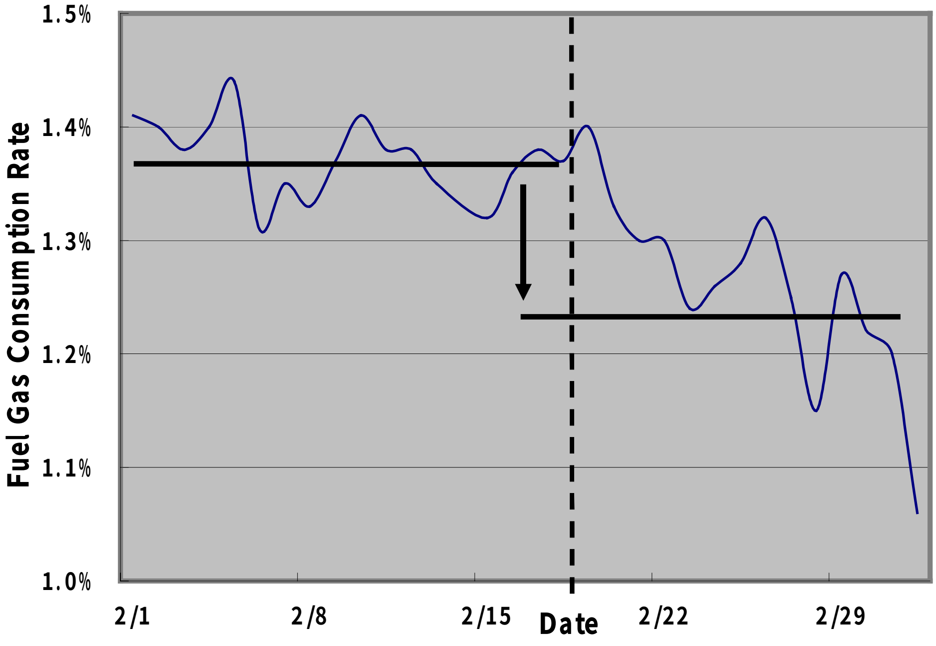

Fig. 8 Improvement of fuel gas consumption after the modification of operation mode in vaporization process.

4.2.2 Air Consumption Analysis

In Incheon LNG receiving terminal, there are a lot of air compressors. A compressor continuously supplies air into the dryer process and the purge process that includes the flame detector purge, the pilot fuel pipe purge, the igniter cooling, *etc*. After consumption analysis of the process, KOGAS could modify the process to decrease the air consumption. More than 8,000 m^3/day of compressed air could be saved due to the modification.

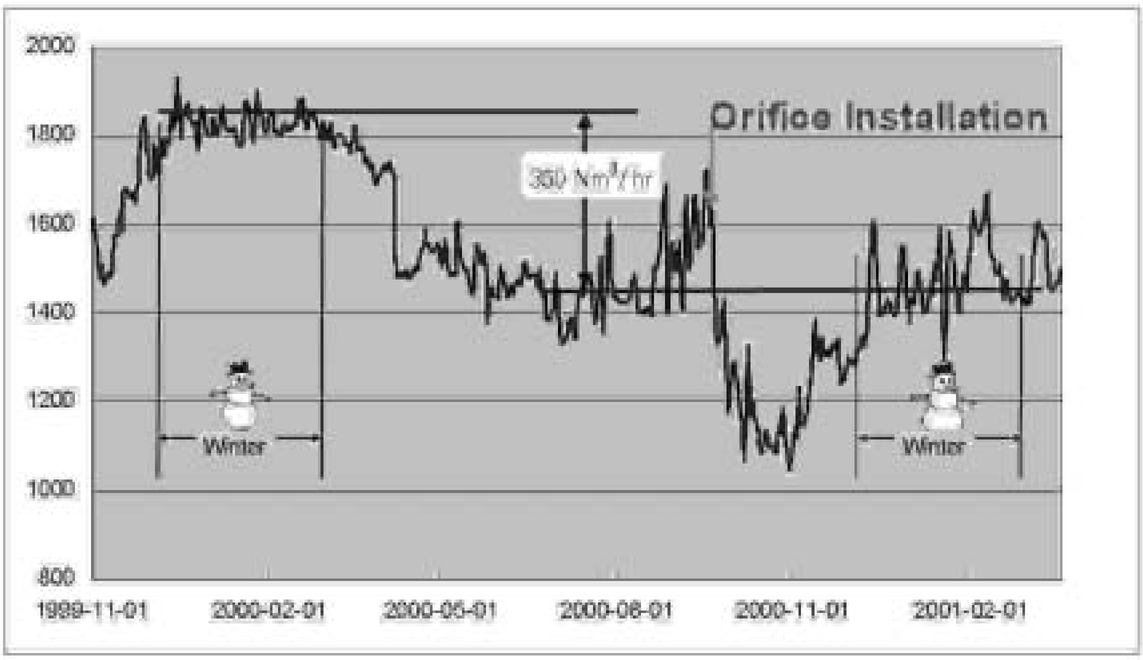

Fig. 9 Improvement of air consumption after the process modification

5. TOTAL OIS (OPERATING INFORMATION SYSTEM) FOR KOGAS

KOGAS has three LNG receiving terminals and trunklines as mentioned before. Fig. 10 shows the locations of the LNG receiving terminals in Incheon, Pyongtaek, and Tongyong on the map of South Korea. The heavy lines on the map express the trunklines (main LNG supply lines). KOGAS plans to build the Operating Information Systems for other two terminals and the central control system that controls the trunklines.

Fig. 10 LNG receiving terminals and trunkline network in Korea

KOGAS is the only LNG provider in Korea. Therefore, as shown on the map of Korea, all facilities of KOGAS seem to be a single plant in South Korea, because all terminals are connected by the trunklines. Fig.11 shows the overall structure of total OIS after the implementation. There are five OISs in the plan. The OIS in the head office integrates those information for the production plan, yield accounting, OAS (Open Access System), *etc*. This integrated information will help KOGAS manage the LNG supply chain networks, and make the important decisions in business activities.

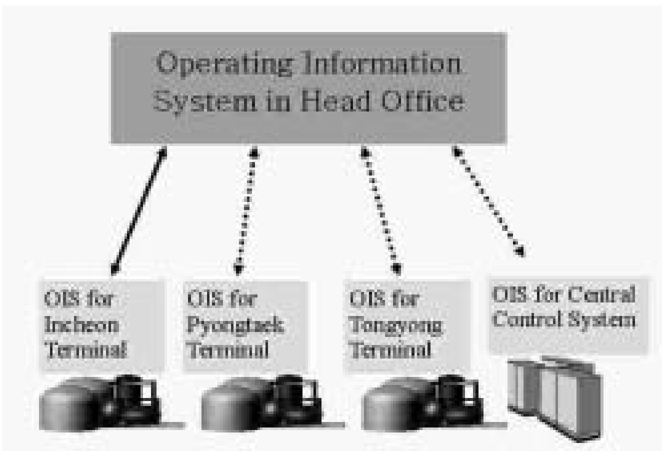

Fig. 11 Overall structure of total OIS.

6. CONCLUSIONS AND KOGAS PLAN

KOGAS has built up the enterprise-wide standardization of manufacturing information system based on the Operating Information System (OIS), and the OIS was developed for the safety and the operability in Incheon LNG receiving terminal. The OIS is composed of 5 parts: *Realtime Database* for realtime process variables; *Relational Database* for manual-logging data; *Operation Assistant System* for monitoring and operation reports; *Data Reconciliation System* for sensor validation and yield accounting; *Information Support System* for data communication with long distance such as the head office.

KOGAS has improved the process operabilities in Incheon terminal using the OIS. The improvement of the processes of vaporization and air supplier could save a lot of operating cost.

The basic structures and the operation concepts of other LNG receiving terminals in KOGAS are very similar to those of Incheon terminal, so KOGAS will transfer the technologies to other terminals.

KOGAS plans to implement a total OIS (Operation Information System) that can integrate all plant information of all LNG terminals and central control office. This integrated information will help KOGAS maintain a clear picture of the business plan, create optimal LNG supply chain scenarios, and make quick adjustments and decisions for the business plan. Therefore not only the operators but also the managers can achieve the better business activities based on the operability and safety.

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