SMOOTH AND SAFE START-UP OF A MID-SCALE LNG PLANT IN CHINA USING AN EMULATED OPERATING TRAINING SIMULATOR

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ABSTRACT

Operator Training Simulators (OTS) are of key importance for operating companies. They allow operators to familiarize themselves with the various units prior to the initial start-up and to maintain their skills over the lifetime of the plant.

Technip, as Contractor, and RSI, as OTS provider, have developed a collaborative approach for plant OTS development and implementation.

In 2009, Technip was awarded the design and construction of the Ningxia Hanas LNG Plant, the largest built in China to date and Technip and RSI developed an emulated OTS for this project.

This plant uses SMR liquefaction process technology from Air Products. Testing confirmed that the OTS realistically reflects plant behavior over the full range of various scenarios including start-up phase and shutdown sequences.

Despite the short project schedule, the emulated OTS was successfully delivered to site early enough to play a significant part in training. To the owner’s satisfaction, training began on site in July 2011, 8 months prior to gas-in.

The training provided using the OTS was of upmost importance, in particular because this plant was the first of its kind in the HANAS Group. With the OTS, operators better understood the effects of their actions on the dynamic response of the plant and thus improved efficiency and safety, in particular for emergency situations.

The purpose of this poster is to present the key elements of success in the development of the high fidelity OTS for the Hanas LNG plant.

INTRODUCTION

Ningxia Hanas LNG is the largest LNG plant built in China to date. It is located in Yinchuan, capital city of Ningxia Hu autonomous region in China and has two LNG trains with a capacity of 400,000 tons/year each, using SMR[1] liquefaction technology from Air Products. The plant was put in operation in March 2012.

The contract for the design and construction of the plant was awarded to Technip in 2009.

In addition, Ningxia Hanas New Energy Group contracted Technip and RSI in 2011, for the development of a high fidelity Operator Training Simulator (OTS) for their plant. The OTS needed to be delivered to site early enough to allow complete operator trainings and plant familiarization before gas-in. The training provided by
the OTS was of upmost importance in particular because the plant was the first of its kind in the HANAS Group.

In the past, most OTS’s have relied on plant’s DCS database with the consequence of often having been made available very late to the trainees, sometimes only after plant initial startup, meaning that this important advantage of early training was often lost.

To overcome this problem, the OTS of the Ningxia Hanas LNG plant was developed using a different approach. Instead of relying on the DCS database and a so-called stimulated OTS, a separate DCS emulator was used. Even though the emulated version of the OTS does not require DCS database, it is still a true full replicate of DCS in terms of graphics and functionality.

Beyond the advantage of faster delivery track, an emulated OTS could be also used during normal operations to assist in plant improvements such as the design and development of Advanced Process Control (APC) systems, Process Surveillance and Engineering studies.

**TYPICAL DYNAMIC SIMULATOR BENEFITS**

The OTS is used for the training of the operators prior to and after plants start-up in order to meet the following main objectives:

- Increase operator awareness, skills and readiness,
- Familiarize operators with plant dynamic response and behavior,
- Train operators to plant operating procedures,
- Validate real plant control logics, alarms configuration, etc.,
- Increase level of safety for equipment and personnel by avoiding operator mistakes,
- Reduce plant start-up and shutdown times,
- Reduce environmental impact of the plant through better mastering of operations,
- Avoid unnecessary plant trips,
- Increase plant availability,
- Allow testing new operational parameters (controller set points, flow, temperature, pressure)

In order to achieve the above objectives, the operator training simulator shall aim at the following:

- Simulate plant start-up with dynamic process behavior,
- Increase the operators process experience and develop their process diagnostics skills to recognize and respond to emergency and/or upset situations, resulting in increased plant safety and availability,
- Familiarize the operators with the Work Stations, the Process Control System, Process Shutdown System, the Emergency Shutdown System and the Fire and Gas system,
- Train the operators on system responses and/or complex sequences of events,
- Train the operators on the concept of an operational team.

**OPERATOR TRAINING SIMULATOR COMPLEXITY**

Nowadays high-fidelity customized OTS can be developed for almost all the LNG supply chain, from well heads to LNG terminals.

However, the advances in OTS technology should not hide the fact that OTS engineering is always a challenge.
To date, the purpose of OTS has always been to provide a training environment, replicating with high fidelity the following main components of the plants:

- The process, represented by individual equipment items such as column, compressors, coolers, etc.,
- The field instrumentation such as manual valves, level gages,
- Distributed Control System (DCS) or Programmable Logic Controllers (PLC) that can either be emulated or stimulated,
- Sequential logic and Emergency Shut Down (ESD) that are usually implemented in dedicated PLCs,
- Control room operator consoles.

**STIMULATED AND EMULATED**

OTS Stimulated implies the DCS is a standalone software (and Hardware) package that works exactly as it does in the plant. DCS code for the simulator and plant are the same.

Stimulation option is characterized by the fact that “Dynamic Process models” and “controls” are separate applications. Dynamic Process models are generally simulated by the OTS VENDOR software but “controls” (including ESD, FGS, PLCs) are simulated (stimulated) through proprietary DCS VENDOR software, reproducing actual DCS controllers behaviors.

As a consequence, standard architecture implies communication between the DCS controllers replica servers and the Process models servers before sending the signal to end users on their screen.
Since, a stimulated OTS requires the DCS database to be completed, it is often very difficult to have it available before the real plant is started.

On the other hand, the Emulation option is characterized by the fact that both “Dynamic Process models” and “controls” are coupled and handled within one single system and one VENDOR.

In an Emulated OTS, the DCS controllers and operator station graphics are implemented within the OTS application by the OTS vendor. It is designed to give the same functionality as the plants DCS vendor software.

In a standard architecture, a set of servers takes care of everything (process models & controls).
Real plant DCS and emulated OTS schedules are disconnected. OTS can therefore be supplied several months before the real plant completion. However, any modifications to plant DCS must also be made to the OTS.

From an OTS user point of view, it is difficult if not impossible to discern the emulated application from one interfaced to an actual DCS.

Cost savings from using an emulated approach are significant (50% to 75% savings depending on complexity of the model), both in terms of initial cost for the OTS and ongoing maintenance costs of the system.

An Emulated OTS can be supplied within 7 months to 1 year after contract award, depending on number of units. While stimulated OTS can require 2 years for the same scope, since the DCS has to be delivered beforehand.

DATA REQUIREMENTS

The process model constitutes the heart of the dynamic simulator. A high fidelity dynamic simulator accurately simulates the physico-chemical process using rigorous thermodynamics and detailed process control models.

To achieve such high fidelity, OTS projects require a large quantity of process input data, including heat and material balance, process flow diagrams, main equipment and instrument data sheets, as well as detailed engineering data such as piping and instrumentation diagrams (P&IDs), input/output lists, control narratives, alarms set points, sequential charts, and cause and effect diagrams.

Considering the amount of information required to engineer those complex process models, meeting the execution schedule is a challenge, requiring significant specialized resources.
Good engineering practices for the DCS database is also a major prerequisite to a successful development of OTS.

Traditional phases needed to develop an OTS are shown below.

**OTS Project phases and information requirement**

**NINGXIA HANAS LNG PLANT EMULATED OTS SYSTEM**

The Ningxia Hanas LNG plant OTS consists of the following major components:

- Simulation Computer,
- Dynamic Process Models INDISSTM,
- Instructor Station,
- Emulated Operator Stations

RSI emulated the Emerson DeltaV DCS for the Basic Process Control (BPC) and Safety Instrumented Systems (SIS) such as ESD and FGS.

The OTS model included the following process sections:

- Feed gas and compression
- Natural gas treatment sections
- Liquefaction and refrigerant compression (AP-SMR Process)
- Boil off gas compression
- LNG storage
- Hot oil system

The Emulated Operator Stations closely resemble the DCS including monitors and keyboards. The man-machine-interface is faithfully represented for all operator related activities including operating groups, trends, alarms, graphics, keyboard functions, etc.

The graphic displays exactly duplicate the actual DCS configurations and integrate them into the Emulated DCS format with all the functional features such as windows and control targets.
The overall result is a very high-fidelity representation of the operator work station similar to the ones available in the control room.

This product allows the operator training to occur with maximum realism as well as engineering applications since the control algorithms are simulated in detail. The realistic OTS performance gives the operators the opportunity to better understand not only the operations but also the dynamic response of the plant.
Prior to site delivery, the OTS steady state and dynamic performances were tested by experienced personnel's with process and operation background. The thermodynamic configuration used for INDISS™ model was reviewed and adjusted when necessary. Various scenarios were analyzed including plant overall start-up and shutdown.

Testing confirmed that the OTS realistically reflected the plant behavior over the full start-up and shut-down sequences as well as during stable operations, in particular for the complex interactions between the operating parameters such as the refrigerant operating pressures, refrigerant compositions all around the process, temperatures profiles within the MCHE [2], JT[3] valves opening, etc.

Despite the short schedule, the emulated OTS was successfully delivered to site in July 2011, 8 months prior to gas-in.

OTS use began on site early enough and thus it played a significant part in operators training. It allowed operations personnel to understand the way the plant works and how sensitive it is to changes. Simulation of start-up sequences and trip scenarios could be practiced extensively.

**EMULATED OTS PERSPECTIVES**

New perspectives are arising from additional uses of emulated OTS. Process surveillance is one of them which is of great interest. The constant improvement of computer performance make this a realistic option.

Today, OTS can achieve without any problem a “x2 real time” speed factor, which leads the operator to act faster than required by the real operations. Starting from a given process state, an emulated OTS allows forecasting of near future events and trends in a very short time. Starting from actual process conditions uploaded from the DCS (if necessary, via a real time database), the operator might be able to predict, at any time during plant operation, how the true process will evolve on a 24 hour or 48 hour horizon.

For example, should the pressure on any equipment exceed a certain value, the operator would extract a snapshot of the process variables from the DCS and launch the accelerated simulation to perform “what if” analyses and to test possible control actions to force the process to come back to steady state.

New improvements in speed factors (from real time to 2, 3, 4 or even x5 factor) can facilitate using the OTS in this way. Considered for a couple of years now and more and more frequently required on new large EPC projects, this capability is becoming a new incentive for implementing OTS, in addition to the possibility of cross checking DCS databases and intensively training operators.

This new way of using emulated OTS may also be of interest to Safety and Maintenance Departments. Simulating process disturbances or malfunctions of some equipment items can allow anticipating major consequences far ahead. As an example, simulating pumps or multi-equipment failures through multiple scenarios allows better understanding of the consequences on the process. There is a clear benefit from testing the feasibility of fallback procedures and improving plant maintenance schedules using these tools.

**CONCLUSION**

Innovative use and development of an Emulated OTS have been successfully performed for Ningxia Hanas LNG plant. The early and fast development of an Emulated OTS allowed operators training well before the actual start-up of the first LNG train.

Personnel and plant safety was greatly improved thanks to increased operator awareness, skills and readiness. Plant operating procedures have been tested well in advance of gas-in.
Emulated OTS can be accessible to plant engineers, e.g. from office PC via the office network and or on stand-alone office PC and can be used as stand-alone tool for engineering studies by COMPANY, during plant normal operation.

Additional uses such as Process surveillance and design development may add even more value to the OTS.

Emulated OTS approach allows significant cost savings, both in terms of the initial cost and ongoing maintenance costs of the system. Delivery time is also significantly reduced.

Notes:

[2] MCHE: Main Cryogenic Heat Exchanger