A NOVEL ATTEMPT TO SUSTAIN MCHE TEMPERATURE PROFILE THROUGH AUTOMATED MIXED REFRIGERANT (MR) AUTOMATION

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ABSTRACT

Malaysia’s PETRONAS LNG Complex (PLC) in Bintulu, Sarawak, comprises of MLNG (1983), MLNG DUA (1995) and MLNG TIGA plants (2003) with a combined LNG production capacity of 25.7 MTPA. The three (3) plants were originally designed with Air Products and Chemicals Inc. (APCI)’s Propane Pre-Cooled Mixed Refrigerant (MR) process.

The heart of the LNG process lies in the Main Cryogenic Heat Exchanger (MCHE) where the natural gas is liquefied to become LNG. APCI’s MCHE is designed to achieve the highest efficiency with minimum delta temperature between the natural gas stream and the MR system. Therefore, a stable and optimized MR system is vital to sustain maximum LNG production.

MLNG have successfully implemented a novel automated MR composition control, which utilizes Distributed Control System (DCS) sequential logic program, in all of its eight (8) LNG modules. This first of its kind application maintains stable MR composition that reduces the specific power for the liquefaction process, directly improves the overall process efficiency. In addition, intangible benefits have also been realized especially in minimization of manual intervention and human capital development in the areas of technological innovation.

The novel invention is protected as PETRONAS patent and filed in Intellectual Property Corporation of Malaysia in March 2011.

The paper describes the experiences during the implementation of the automation control including the driving factor for automation, project milestones, benefits, project enhancement, as well as project challenges.

1 INTRODUCTION

1.1 PETRONAS LNG Complex

PETRONAS LNG Complex is located in Bintulu on the Malaysian side of the island of Borneo. The complex consists of three LNG plants namely MLNG, MLNG DUA and MLNG TIGA. MLNG, which consist of 3 LNG modules; Module 1, Module 2 and Module 3 was incorporated in 1978 and delivered its maiden cargo to Japan in January of 1983. Growing demand of LNG and vast reserve of natural gas from the central Luconia basin open ways for establishment of MLNG DUA Module 4, 5 and 6 in 1994 and MLNG TIGA Module 7 and 8 in 2003. All plant facilities are located in one area which spreads over 276 hectares land (refer Figure 1) with the total combined production of 25.7 million tonne per annum of LNG.
1.2 Process Description

The plant can be divided into 4 main sections: upstream facilities, gas treating, liquefaction and storage/terminal. The upstream facilities receive gas via 125km pipeline from offshore and separate the condensate from the gas. The gas is metered and enters the individual train gas treating section.

The first part of the gas treating section removes CO₂ and H₂S to meet product specification and to prevent freezing in the liquefaction section. Amine-based solvent with absorbed acid gases are regenerated in regenerator column at high temperature and low pressure. The acid gases are then incinerated before being discharged safely to the environment. The final process of gas treating is the removal of water and mercury up to 1 ppm and 10ng/sm³ respectively.

The natural gas is then ready to be liquefied by using Air Products and Chemicals Inc. (APCI) licensed process which uses 2 types of refrigerants: propane and mixed refrigerant (MR) composition i.e. mixture of Nitrogen (N₂), Methane (C₁), Ethane (C₂) and Propane (C₃). Natural gas is first pre-cooled by propane before it is finally chilled to −160 degC in the Main Cryogenic Heat Exchanger (MCHE) by the MR. Finally, LNG is routed to the tank farm for storage at atmospheric pressure. LNG is loaded into LNG tankers from the tank through loading arms at the jetty head.

2 PROBLEM STATEMENT

Between December 2008 until March 2009, maximum capacity test was conducted in order to identify potential gaps in sustaining MLNG production at its maximum capacity. Instability of MR composition which translates into difficulty in maintaining stable MCHE temperature profile and subsequently resulted in loss of LNG production has been identified as one of the potential gap.

Thus, a multi-disciplinary task force (Operations, Technologists, Process Control and Engineering personnel) was formed to explore the possibility of automating the MR composition control in MLNG.

3 SOLUTION AND FINDINGS

3.1 Project Development

Module 1 of MLNG has been selected as Pilot plant for this initiative. The project started with feasibility study where two options; Rule Based DCS System and Advanced Process Control (APC) had been identified as the potential method of automating the MR compositions. Considering the pros and cons of both options from different perspectives including process limitation, risk and cost of the project, the team has identified Rule Based DCS System as the best approach to automate the MR composition control in MLNG.

Upon completion of the feasibility study, the team continued with the project development from June 2009 until August 2009. During this phase, development of the rule based logic was carried out where best practices of experienced panel man were gathered together and combined with in-depth appreciation of LNG
process theory to formulate the desired control strategy. Detail instrumentations checks on the related valves and transmitters were also done where the transmitters’ calibration and valves’ stroking were carried out. It was then followed up with Hazard and Operability Study (HAZOP) where any potential risks associated with the implementation of the new automation were identified.

After confirmation of technical acceptability, commissioning of MR composition automation control was successfully carried out in Module 1 on September 2009. The new automation had gained almost immediate panel operator acceptance with high controller uptime, an indicator that the automation worked perfectly. Continuous improvement was done thereafter and was being documented properly for future reference.

3.2 Project Benefits

Post Implementation Review (PIR) has been conducted to measure the effectiveness of the new automation. Data utilized from Process Information (PI) database was compared before and after the automation. Focus of the data analysis was given on to the control stability of the MR composition, MCHE temperature profile and impact to LNG production.

It was observed that the Standard Deviation (STD) for all MR composition; N\textsubscript{2}, C\textsubscript{1}, C\textsubscript{2} and C\textsubscript{3} has been improved significantly (Refer Figure 2).
Consistency in the MR composition has helped to stabilize the MCHE temperature profile (refer Figure 3) which then translated to sustained and higher LNG production (refer Figure 4). Besides, the automation has also managed to shift the repetitive action done by panel man to supervisory control.

**Figure 2**

Improvement of N₂ composition STD by 92%

Improvement of C₁ composition STD by 83%

Improvement of C₂ composition STD by 88%

Improvement of C₃ composition STD by 74%
With encouraging results from Module 1 Pilot i.e. higher sustainable LNG production, MR Automation application was customized taking into consideration the uniqueness of liquefaction design and process behaviour of the individual plant and was subsequently implemented in all remaining seven (7) modules in PETRONAS LNG Complex in 2010 - 2011.

4 PROJECT ENHANCEMENTS

4.1 Additional Capacity Improvement

Realizing the potential benefits of this application, further enhancements were developed and implemented in MLNG in 2012 for additional capacity improvements. The improvement done involves integration of the MR automation application to existing MCHE APC in Module 1, 2 and 3. With this integration in place, both MR flow and MR composition was linked to control the same economic objective which is sustaining optimum MCHE temperature profile.
4.2 Plant Reliability Improvement

In April 2012, a feasibility study for MLNG has been conducted to measure the impact of improper control of MR composition during final cooling down to the overall cool down quality i.e. combination of temperature rate of change and cooldown duration. The data analysis involved more than 20 final cool downs from Year 2004 until February 2012. The analysis had shown significant impact of improper adjustment on the MR composition to the overall cool down quality especially on the impact to the excessive LNG cooldown duration and MCHE thermal shocks.

Thus, an initiative has been identified to expand the automation from focusing on plant capacity improvement to plant reliability improvement. The automation logic was enhanced to adjust the MR composition at the initial of final cooling down until LNG rundown. Upon completion of the project enhancement, commissioning of MR automation during final cool down operation was carried out at Module 3 on May 2012, which was the Pilot plant for this expansion project. With the success in stabilizing the MR composition profile during Module 3 final cool down process, the automation has been continued to the remaining 2 modules in MLNG.

Major benefit realized from implementation of MR automation during plant start up was stability in the MR composition control which then eased the control of MCHE temperature profile to follow the recommended temperature rate of change from APCI. This has resulted in minimization of MCHE thermal shock together with optimization of LNG start up duration measured by reduction in excess LNG cooldown duration from an average of 7 hours to an average of 1.85 hours (refer Figure 5). In addition to this, proper control on the MR composition has also led to saving of MR refrigerant consumption due to minimization of venting and draining of the refrigerant during the final cool down process. A standardized method of adjusting the MR composition was also established and panel operators’ attention was shifted to more challenging job.

![Figure 5](image)

5 PROJECT CHALLENGES

A lot of efforts have been put to overcome the challenges to ensure successful implementation of this application in all modules in PETRONAS LNG Complex. One of the identified main challenges was in terms of the selection of technology used for the automation. The automation of MR composition using Rule Base DSC System has never been done and was the 1st of its kind in LNG industry.

Another identified challenge was paradigm shift of panel operators’ mind set to operate the MR composition in automatic control after almost 30 years it has been operated in manual control. However, with direct involvement of OPS personnel from initial development of project until commissioning together with proper training and continuous improvement done on the application, it gained high acceptance and buy in from Operation personnel.

It was also a challenge for MLNG to continuously customize the controller design detail of the MR automation to tailor to each plant’s requirement due to the uniqueness of their liquefaction design and
process behaviour. With the support from management and high buy in from Operation, continuous improvement and full implementation to all modules were completed in less than 3 years.

Successful outcome in improving plant capacity has brought to new challenging task which was to come out with more robust application that can be utilized during module start up operation. Through positive mind set and tremendous effort, the application is now able to bring benefit to support plant reliability improvement in addition to additional capacity improvement.

6 FUTURE ENHANCEMENTS

A study to enhance further the system through integration of the MR automation between plant modular via Real Time Optimizer (RTO) application is currently on going. This enhancement is expected to help managing the refrigerant consumption on plant basis. Upon successful outcome of this enhancement, it is planned to extend the integration to manage the refrigerant consumption of whole plants in PETRONAS LNG Complex.

CONCLUSION

Application of MLNG MR Automation is proven as an effective tool to assist plant operators to achieve stable MR composition resulting in higher sustainable in LNG production. It is also recognized as a tool to assist plant operators during module start up operation resulting in optimization on LNG start up duration and minimizing of MCHE thermal shock. Its success is contributed to few elements: teamwork of MLNG personnel from relevant disciplines and background, persistently continuous improvement and enhancement, full implementation to all modules in PETRONAS LNG Complex together with good support from MLNG management.