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LPG Fractionation Unit Advanced Control Revamp

Woodside Energy Ltd and ProSys Engineering Pty Ltd

Project Background

Woodside Energy Limited (WEL) recognised well before the commissioning of the new 4th LNG train in September 2004 that the additional LNG production and associated increase in LPGs would test the capacity of the Fractionation unit at the Burrup Peninsula site in Western Australia. At that time, the Karratha Gas Plant (KGP) consisted of three LNG trains, a domestic gas plant which supplies natural gas to the WA market via pipeline, a LPG fractionation plant which separates the NGL products, an offshore trunkline terminal and utility services. Although offshore field selection provides some scope to influence LPG product yields, this has a big impact upon condensate yields and KGP economics dictate that liquids production is maximised at all times.

Instances of De-ethaniser flooding with only three LNG trains online had signalled a production limit on the Fractionation Unit and a shift in engineering focus towards this constraint. WEL carried out operational reviews and test runs to verify the maximum throughput limits against De-ethaniser flooding limits.

WEL are mature users of advanced process control technology with a decade of experience in use of Multivariable Predictive Control (MPC) technology. This technology uses a dynamic process model coupled with an embedded optimiser to control multiple input – multiple output systems. Use of MPC has delivered substantial economic benefits to WEL's bottom line and set the company apart from most of their Oil & Gas peers. Seven MPC applications were commissioned on the Fractionation Unit in early 1997 with an immediate improvement in process stability and profitability. With gradual change in the process conditions due to throughput increases, the performance of the MPC had deteriorated. In addition, with the prospect of LPG production losses being suffered due to Fractionation Unit capacity constraints, a review of the MPC design with a capacity maximisation focus in mind was appropriate.

Early in 2004, WEL engaged ProSys Engineering Pty Ltd (PSE) to revamp the APC applications on the Fractionation Unit. PSE has a track record of success in design and development of MPC applications and, in particular, were very experienced in revamp of existing applications and the technology used at the KGP.

Process Context

The Fractionation Unit consists of two trains of De-ethaniser, De-propaniser and De-butaniser columns supplied by a common feed drum. The De-ethaniser condensing duty is provided by a propane refrigeration system whilst the downstream column condensers are air-cooled. All six columns have reboilers supplied by a common hot water system. The De-ethaniser bottoms product from the domestic gas plant is added to the Fractionation unit De-ethaniser bottoms before entering De-propaniser columns.

The Ethane product is routed to the Domestic Gas pipeline whilst Propane and Butane products are routed to storage for distribution via ship. Debutaniser bottoms are sent to condensate product which is sold as refinery feedstock and distributed via ship. High purity propane is produced in batch runs from either of the De-propansiers as required for refrigerant in the LNG production trains.

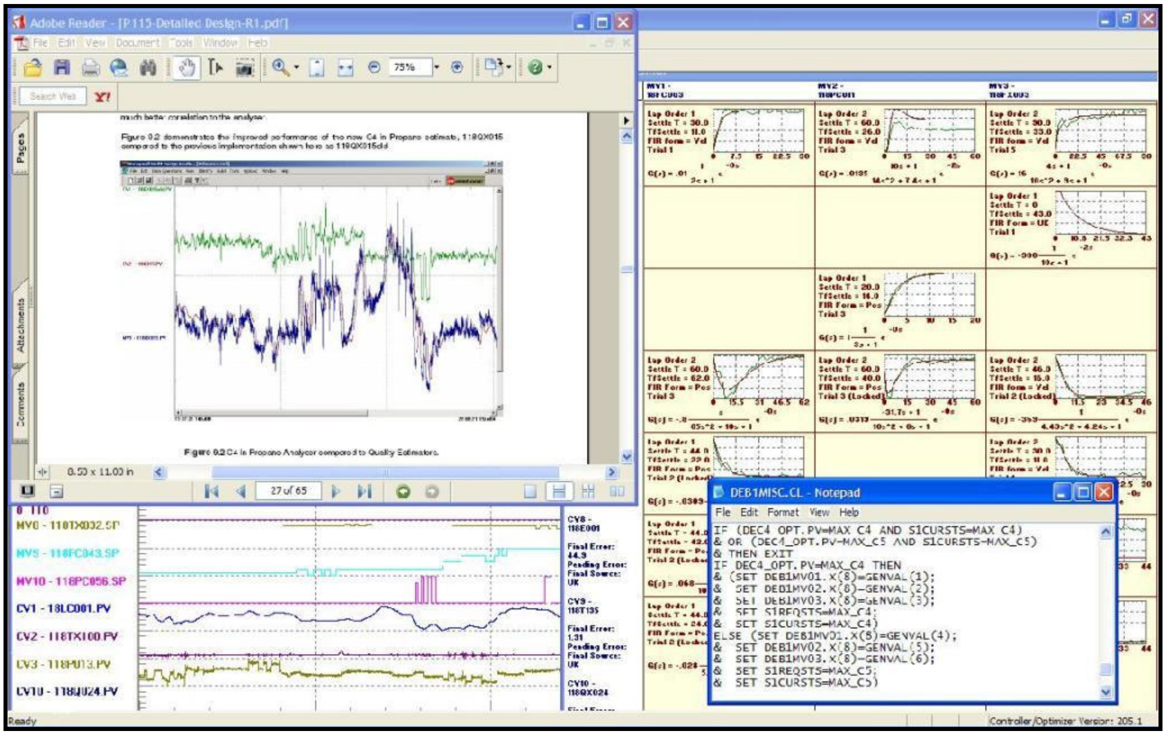
Project Process

The project was conducted by a hybrid team to maximise effectiveness and technology transfer – two consultants from PSE teamed up with a site control engineer for the project duration. The methodology used by the project team was as follows:

- Review MPC design: A new design was required to meet the process objectives for the current process context and improve the plant profitability. This phase involved a number of interviews with WEL operations, planning and engineering personnel to understand the user needs along with analysis of the performance of the existing MPC applications.
- Regulatory Control Review: As the MPC 'sits' on top of the regulatory control layer it is critical to the performance of the MPC that this basis performs well. Accordingly, a complete review of instrument performance, controller tuning and control design was conducted with a number of changes to the regulatory control layer implemented to improve its robustness and linearity.
- Process Step Testing: Sequences of perturbations were made to the MPC independent variables and the responses to the dependent variables measured. This testing was conducted on a 24-hour basis to provide a block of rich and contiguous performance data for model development.
- Model Development: The step test data was used to develop a dynamic model of the process using a least squares fit algorithm. Each cause-effect submodel in the independent – dependent model matrix was validated against the step test data collected and 'sanity checked' with process engineering judgement.
- MPC Simulation and Initial Tuning: The validated process model was used in a simulation environment to assist with initial tuning of the MPC and confirm that optimiser objectives were being met. MPC performance when subjected to model error (i.e. a change in process dynamics) was also be tested by using an imperfect model of the process whilst keeping the original model for the MPC.
- MPC Software Installation: Installation of the application specific MPC software on the MPC node and the DCS were managed such that minimal downtime was experienced by the operators during cutover of the new MPC applications. The new MPC operator interface was designed to improve the layout for ease of use.
- Commissioning of new MPC applications: Cutover of each of the new MPC applications was completed within a day. Fine tuning of the new applications and operator re-training was completed over a three week period. Testing of the MPC operation during a number of different modes of operation (including refrigerant mode on the De-propanisers) was also completed.
- Project Site Acceptance: At the end of the initial commissioning period (October 2004), site acceptance testing was completed to confirm acceptable performance, adequate operator training and handover to site support personnel.

As the throughputs experienced during the commissioning period were not as high as expected, a further site visit was warranted in November 2004 to review performance at the expected higher loads.

The new MPC was able to circumvent the De-ethaniser flooding limit to a greater extent than anticipated and loads were able to be further increased to the extent that Depropaniser flooding started to become an issue. This development was quite unexpected as the De-ethaniser capacity increases resulting from the MPC revamp were not expected to be so great. Therefore, a further commissioning trip was conducted to maximise production to Depropaniser flooding limits. This was completed in April 2005 with absolute maximum capacity being experienced subject to the true equipment constraints.



A variety of data analysis and software tools were used to build the Advanced Control solution

Project Challenges and Solutions

De-ethaniser Reflux Minimisation
Minimisation of De-ethaniser reflux ratio was paramount to relieving the flooding constraint. The original MPC design prevented propane migration to the top section of the De-ethaniser by using temperature limits in the upper section of the column (i.e. over-refluxing to avoid the difficulties associated with control of the process non-linearity). To facilitate a reduction in reflux ratio, the project team used a novel approach to allow the propane interface to be maintained at a much higher position in the column without loss of propane to the overhead product. This approach also unloaded the overhead condenser and associated refrigerant compressor.

As the De-ethaniser constraint was flooding of the bottom section of the column, short term and limited relaxation of the bottoms temperature target was also used to assist with instances of peak capacity requirements – this was made feasible by a complementary MPC application which managed the combined propane product C2% by regulating the cutpoint in the domestic gas plant De-ethanisers.

Exploitation of the Dual Train Operation
Another opportunity identified by the project team was degrees of freedom provided by the dual train operation: As the product streams were combined in tankage, any imposed quality giveaway on one train could be exploited on the other train to maximise yields whilst still honouring combined product quality specifications. Propane product quality giveaway was regularly imposed during refrigerant mode operations as a relatively small draw of high purity propane was drawn from the top of the column, whilst the remainder of the high purity propane product would be routed to propane product tankage.

This strategy delivered improved propane product yields when one De-propaniser was in refrigerant (high purity) mode by permitting higher impurity levels in the non-refrigerant mode De-propaniser. This became particularly important as Fractionation unit throughputs increased to the point that De-propaniser flooding became an active constraint and the higher purity operation added significant load to the column in refrigerant mode.

Biasing the feed to the two trains to maximise throughput whilst honouring the constraints was fundamental to the MPC design and a large portion of the project benefits. The original MPC design consisted of one application for each of the six columns and the feed drum whereas the revamped design included the feed drum and the first four columns in a single application – this allowed co-ordination and optimisation of the entire unit upstream of the De-butanisers. The De-butaniser columns were left as individual applications as they were traditionally operated significantly under capacity in a single mode of operation.

Provision of Unit Capacity Calculation

One of the difficult operational issues highlighted to the project team was the time delay between requesting changes in liquids volume from the offshore platforms and it actually arriving via the trunklines. This delay (of the order of 8 hours) makes it difficult for the DCS operator to ensure that the fractionation unit is at capacity at all times when changes in ambient conditions, LNG train operation and/or requirements to switch the Depropaniser(s) into refrigerant (high purity propane) mode can occur in a much shorter time frame.

The nature of the MPC operation further clouds this issue as the MPC will use excess capacity to increase fractionation and improve product yields. This makes it very difficult for an operator to easily interrogate the process operation and determine how much capacity is available before an absolute unit capacity limit is breached.

To assist the DCS operator with ordering of offshore liquids to maximise production, the project team developed a capacity estimator to assess the available capacity. This calculation involves interrogation of the MPC application to assess how close the process is to key constraints and to what extent the fractionation of the limiting column(s) can be reduced. Use of this calculation has been widely adopted by the DCS operators as a robust way of maximising fractionation unit production without exceeding constraints.

Woodside Energy Control Engineer (Kate Oxford) discusses the Fractionation Unit Advanced Control with DCS Operator (John Dingey)

Project Highlights

The project was highly successful on a number of different fronts. A major contributing factor was the support of the WEL site management and the enthusiasm and involvement of the site engineering and operations personnel. Some of the important aspects to emphasise are:

Command of leading edge technology

WEL has a strong tradition of supporting the process control engineering discipline and is an experienced user of MPC technology. High penetration of MPC application at the KGP has delivered significant economic benefits and secured support for the technology throughout the organisation. This developed understanding of the technology also lead to the decision to support appropriate revamping project work to capture eroded benefits and profit from potential evolution of the MPC design.

High value technology transfer

The decision to engage PSE consultants assisted with project resourcing, increased the experience pool to draw upon during all project phases, added structure and commitment to the project schedule and provided an excellent training opportunity for the site engineer. Involvement in a MPC development project provides a focussed training experience for control engineers who have previously been limited to supporting existing applications. The DCS operators also gained a lot of training value relevant to both the process and the MPC operation from the project execution.

Holistic approach to improving operator efficiency

Although the project team focussed primarily on improving the MPC performance, other complementary improvements were implemented to assist the operators to meet the site needs. For example, the layout of the MPC interface was improved, revised operating guidelines were issued and the excess capacity calculation was made available online.

Excellent project payback

The increase in production capacity experienced on the Fractionation unit following the MPC revamp greatly exceeded expectations and had a significant impact upon profitability of the entire KGP complex. The increase in fractionation unit capacity from the MPC revamp and associated process optimisation is estimated to be > 10%. This represents an excellent outcome from what is effectively a software upgrade with no hardware modifications or plant shutdown required.

Practical application of technology to improve efficiency of Australian primary industry

A recent survey of the use of process control technology in Australian process industries revealed a surprisingly low level of penetration and awareness. Local process control oriented journals reiterate this theme via a focus on instrumentation and PLC / SCADA / DCS system developments. This project illustrates how process control technology can do more than provide a building block for process plant compliance – it can deliver significant improvements in profitability.

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