# PACE Magazine 2008 Zenith Award Submission

## "Moomba Gas Plant Throughput Maximisation" (Oil, Gas and Hydrocarbons Category)

Applicants: Sarah Perkins and Andrew Taylor of ProSys Engineering
Keith Humphris and Randall Yeates of Santos Ltd

## Background

The Moomba gas plant is located in the North East of South Australia and supplies gas products via pipeline to customers in South Australia and New South Wales. A liquid product line supplies the Santos Port Bonython Fractionation plant. Feed gas is also supplied to the Moomba plant via pipeline from the Santos Ballera plant in South West Queensland (SWQ). The plant is controlled via an Emerson DeltaV DCS system from a central control room.

The gas processing side of the Moomba operation essentially consists of:

- Field Compression to deliver hydrocarbon feed to the plant;
- Oil / gas separation and oil stabilisation prior to pumping to Port Bonython;
- Benfield CO2 Removal (six trains operating in parallel);
- Liquid Recovery Plant (two trains operating in parallel) which consists of:
  - Water Removal via adsorption;
  - DeMethaniser column which produces Sales gas;
  - DeEthaniser column which produces Ethane product with the bottoms product being routed to the Port Bonython Fractionation plant.

The nature of the plant design means that the gas throughput is set to meet customer demand and the liquid product yield is a function of the gas produced (i.e. the liquid product 'comes with the gas'). The ability to reinject sales gas into a storage reservoir provides an additional degree of freedom and the impetus to consistently maximise gas throughput to the limit of the plant equipment.

The plant design dictates that each of the major elements of the plant has explicit flow control provided. More specifically;

- Most field compressors are reciprocating machines which can be individually ramped up or down accordingly to load requirements. There are a small number of centrifugal machines which will adjust in a more automatic manner.
- The flow of feed gas from SWQ is set by the Ballera plant operations.
- All CO2 Removal trains have raw gas flow control (i.e. throughput control).
- Both Liquid Recovery Plant (LRP) trains have DeMethaniser feed flow control.

With this large number of flow control devices in parallel with groups in series, control of both the Moomba plant inlet pressure and the LRP inlet pressure was difficult and this task often resulted in relatively large moves being required on the flow controllers in order to keep system pressures within constraint limits.

These moves on plant flows introduced disturbances to the downstream equipment and the variation in plant pressures also has some detrimental effects upon plant performance and repeatability.

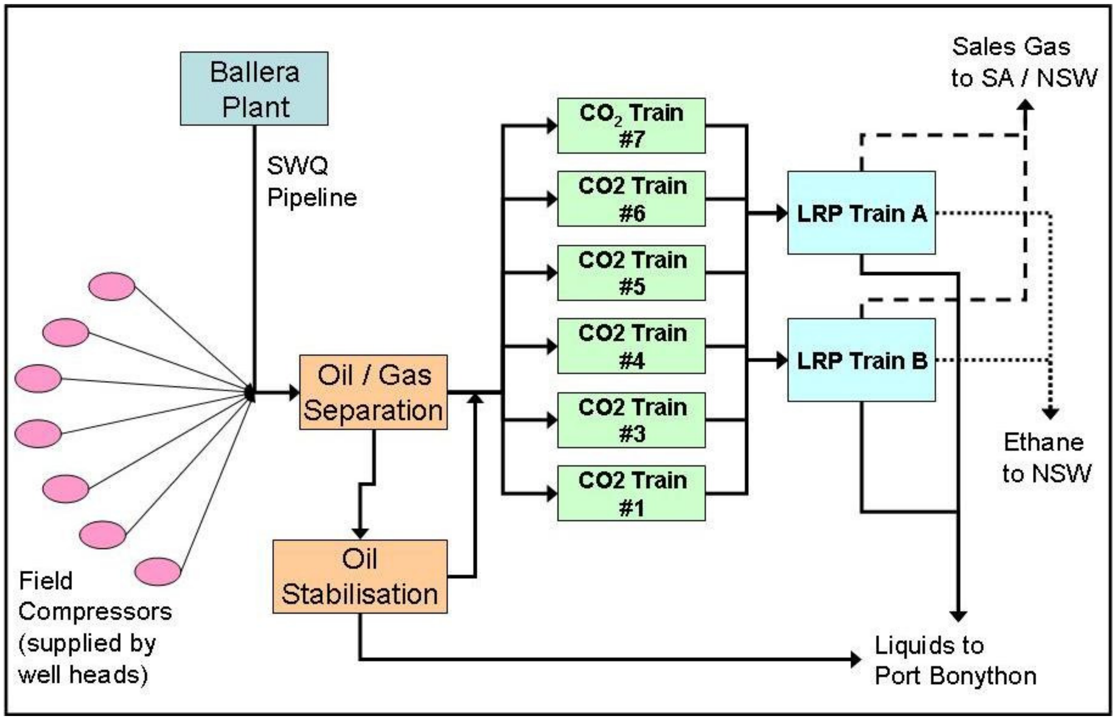


**Figure 1: Simplified Schematic of the Moomba Gas Plant**

The situation was exacerbated by the instances of CO2 Removal train trips which resulted in sudden loss of flow through an individual train. This sudden drop in throughput would result in rapid increase in DP across the online CO2 Removal trains and sometimes cause another train trip due to the resultant spike in flow causing foaming. This result was made harder to avoid by the highly non-linear characteristic of the raw gas flow controllers as they are butterfly valves (i.e. although the ideal operation would see the valves fully open, the need for the valve to quickly cut flow in the instance of a DP spike was inconsistent with the low gain characteristic at high valve openings). This phenomenon of cascading CO2 Removal train trips had a large impact upon plant stability and performance and encouraged the operators to run the plant very conservatively.

ProSys Engineering was engaged to assist the Santos engineers with process control improvement at the Moomba site in 2005. One of the initial objectives was to maximise plant throughput capacity and this was pursued via three primary mechanisms:

- Minimising DP across the CO2 removal trains;
- Minimising the LRP inlet pressure in order to facilitate a plant inlet pressure reduction. This provides immediate production improvement from all field compressors and provides an improved basis for reconfiguration of the reciprocating compressors to deliver more flow at constant power (and reduced field to plant inlet DP).
- Using the SWQ pipeline surge capacity to dynamically reduce feed gas supply to Moomba without reducing the production rate at Ballera. This helps eliminate spikes of high Moomba inlet pressure which would otherwise result in field compressor high discharge pressure trips.

In line with this objective, operating guidelines were changed to adopt this new operating paradigm and process control improvements were initiated in order to consistently achieve those goals.

**Figure 2: The Moomba Gas Plant**

## Technical Solution

The technical solution developed consisted of a suite of Multivariable Predictive Control (MPC) applications which managed the dynamic control needs of the plant to deliver maximum performance on a minute by minute basis. Although MPC technology is not a new tool within the oil refining sector, its application within the Oil & Gas sector has a relatively short history. The ability of MPC technology to optimise plant operations and improve reliability and operability is very attractive to Oil & Gas companies with product margins at all time highs and a focus on reliability being paramount.

The MPC applications built in the first half of 2006 included:

- Flow maximisers for the CO2 Removal trains (6 MPC applications): The objective here was to maximise the flow through the train to either a specified high limit (according to a process related capacity limit such foaming in the absorber) or valve saturation, which ever constraint was active first. This objective effectively minimises DP across each CO2 Removal train.
- LRP inlet pressure control (one MPC application with some challenging aspects): This application adjusts the LRP train feed flows in order to achieve a target LRP inlet pressure. The application provides flexibility to run with either single or dual LRP train operation.
- SWQ Pipeline Control (one MPC application): The objective of this MPC was to cut back the flow from Ballera when the Moomba plant inlet pressure was too high (generally a result of a CO2 Removal train trip). Although these instances were generally short term dynamic effects, it was important that the peaks of plant inlet pressure were reduced in order to allow the field compressors to be reconfigured for a lower discharge pressure in a robust fashion (i.e. without the risk of frequent high discharge pressure trips occurring).

The end result was more stable plant operation with a lower LRP and plant inlet pressure. This has facilitated the start of field compressor reconfiguration which will produce more feed gas for the same compressor power and increase the quantity of gas reserves by virtue of the lower suction pressures which would then be achievable.

Each of the MPC applications were developed and implemented using the following methodology:

1. Application scoping to define user/process needs, confirm the functional design specification and provide a basis for the Management of Change process approvals.
2. MPC software build to establish the application inputs/outputs (required before model building as the MPC software is used to perform the step testing).
3. Process step testing to collect process cause-effect data for dynamic model development.
4. Process model development and MPC controller generation.
5. Development and testing of custom logic to the support the required functionality.
6. Development of the custom operator interface graphic.
7. Development of Operator Guideline documentation.
8. Operator training and commissioning (including fine tuning of the MPC performance as required).

The following sections provide some details on the nature of the MPC applications commissioned:

***CO2 Removal Train Flow Maximisers***

Each train has a dedicated MPC application which is very simple in design but very effective at managing an often variable dynamic problem. One of the main challenges for controlling the CO2 Removal train feed flow was the desire to maximise the valve opening (in order to minimise DP) coupled with the need to quickly cut back the flow in the event of a CO2 Removal train trip (as the butterfly valve flow characteristic is such that the valve needs to cut back significantly below 100% before any flow reduction is effected). These conflicting objectives led the operators to run the CO2 Removal trains relatively conservatively in order to minimise the risk of cascading train trips.

In order to circumvent this issue and facilitate robust yet high performance flow controller tuning, the butterfly valves were linearised such that the MPC used a flow controller whose output was expressed in '% of flow capacity' instead of '% valve position'. This approach makes it feasible to run the valves fully open whilst also being able to control flow quickly in the event of a DP spike. Each CO2 Removal train feed flow valve was individually characterised using valve position / flow data normalised for DP changes – this revealed unique characteristics for each valve as the trains were built at different times (and thus the valves supplied varied widely).

The MPC design consists of a single manipulated variable (MV) being the feed gas flow controller with the linearised output and two constraints being the flow controller SP-PV error and the operator entered maximum allowable flow. The error constraint is important to protect against a cascade trip in the event of a large spike up in DP across the train. That is, having the flow setpoint just above the current flow means that the flow controller (with improved response due to the linearised output) will quickly bring the flow disturbance under control. The main value of the MPC in this instance is that it ensures that the setpoint tracks the actual flow as this is influenced by DP drift when the flow valve is saturated (i.e. the flow can go up and down with the valve fully open and the optimal response is to allow this if the flow is below the maximum set by the operator).

The operator can also set a maximum allowable flow in order to honour any process limits (e.g. foaming may occur beyond a certain flow rate) relevant for each individual train.

To assist the operators with managing the abnormal situation, the maximum flow constraint in each of the $CO_2$ Removal Train Maximiser MPCs are reset to the current flow in the event of a $CO_2$ Removal train trip. This allows the operator to assess the operation and make decisions about flow redistribution without the trains that were previously running below maximum flow (with saturated valves) suddenly increasing flow due to the DP increase bringing the valves back from saturation.

**Figure 3: DCS Operator monitoring the MPC applications**

***Liquid Recovery Plant Inlet Pressure Control***

The LRP Inlet Pressure Control MPC manipulates the two feed flows to the DeMethaniser columns to achieve the specified LRP inlet pressure target. A feed flow bias target allows the operator to skew the load to each train in a controlled manner (and absorbs the remaining degree of freedom).

The application needed to facilitate pressure control with either single or dual train operation. Unfortunately, the version of the MPC software implemented at the time did not allow for the case of a manipulated variable being dropped out of the application whilst it was online (i.e. all MVs needed to be active for the MPC to run). This forced the use of three separate MPC blocks (i.e. one for dual train operation, one for A train only operation and another for B train only operation).

The custom operator graphics and the MPC application were both significantly enhanced in order to manage the swapping between the three MPC blocks without the operators being affected by the added complexity. This resulted in a very flexible implementation which catered for all the likely operating modes whilst maintaining a very intuitive and robust operator interface.

The effect of the new MPC was quite substantial with the main benefits being:

- A significant reduction in operator intervention;
- Much reduced variance in LRP inlet pressure and a lower pressure target being sustained;
- Much smaller moves on the LRP train feed flows being automatically made by the MPC (improved stability within the LRP trains).

***SWQ Pipeline Control***

Previous operation of the pipeline involved co-ordination of the flow between the Ballera and Moomba plant operators – that is, the flow into the pipeline was requested by the Moomba operators and controlled by the Ballera operators without exploiting the 'line pack' characteristic (i.e. surge capacity) of the pipeline. This sometimes resulted in a lot of co-ordination between the two plants and deferred production during periods when the Ballera flow to the pipeline was less than maximum.

The new operating paradigm adopted with the implementation of the new MPC requires that the Ballera operators maximise the flow to Moomba unless the pipeline pressure becomes too high. Coupled with this, the valve at the Moomba plant inlet is left fully open unless the Moomba plant inlet pressure exceeds a maximum limit (generally due to a short term throughput reduction which can be resolved in a matter of hours). In this manner, the SWQ Pipeline MPC simply throttles in the feed flow from the pipeline to shave the peaks off the Moomba inlet pressure without impacting upon the production flow at Ballera. During this time, the flow imbalance causes an increase in the pipeline pressure. A reduction in production at Ballera is only required to honour the maximum allowable pipeline pressure if the flow imbalance is sustained.

The effect of the new MPC was significant with the main benefits being:

- A significant reduction in operator intervention;
- Much reduced maximum Moomba inlet pressure peaks which allow the field compressors to be reconfigured for higher throughput at lower maximum DP;
- A reduction in deferred production from Ballera as the pipeline is now operated as a surge tank with the pressure managed in an acceptable range.

***Customised Operator Interface***

For the MPC applications at Moomba, the standard operator interface provided with the MPC software was not used. Instead a custom interface was employed for the following reasons:

- The small dimensions of most of the applications (all bar one were single MV applications), meant that the standard interface was cumbersome for the operators to use.
- The CO2 Removal Train MPCs were displayed on a single view.
- Quick access links to the relevant process graphics and hyperlinks to the operator guideline documents for each MPC could be provided.
- It was possible to present the LRP Inlet Pressure MPC application simply without exposing the operator to the complication of the three MPC block approach and the required block swapping functionality.

Although this approach required significantly more engineering effort than simply using the standard MPC graphics, the benefits in terms of operator understanding and general operability of the system were substantial.

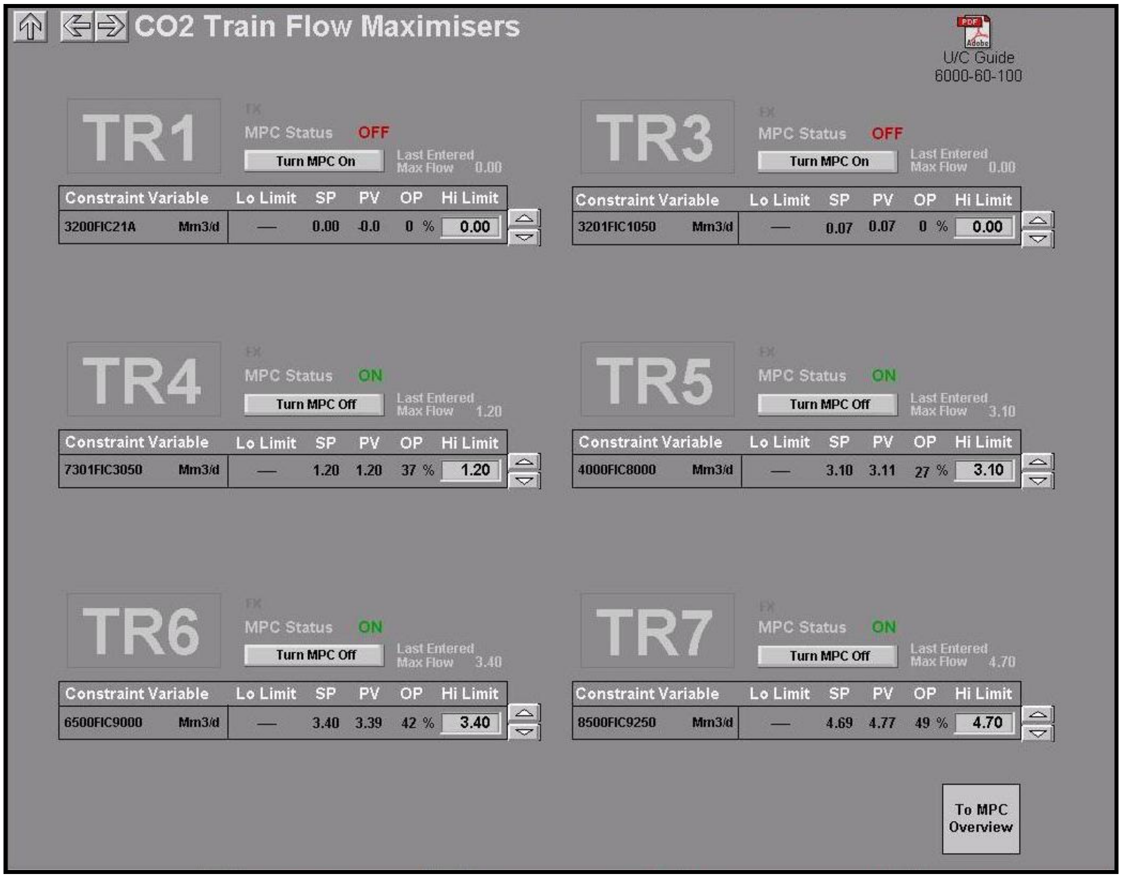


**Figure 4: CO2 Train MPC Operator Graphic (atypical operation shown)**

## Benefits Realised

The benefits of the combined suite of MPC applications were:

- More stable operation of the LRP trains with smaller and more regular moves on feed flows being delivered by the MPC.
- Lower incidence of cascading CO2 Removal Train trips due to the improved response of the online train flow controllers to a train trip.
- A more consistent and lower LRP inlet pressure coupled with more successful minimisation of CO2 Removal Train DP and elimination of plant inlet pressure spikes via judicious use of the SWQ pipeline surge capacity has delivered a more stable and lower maximum plant inlet pressure. This has three major impacts:
  1. An immediate increase in supply gas flow due to lower field compressor discharge pressure;
  2. The potential for further flow increases after reconfiguring the reciprocating compressors for higher flow at fixed compressor power and lower machine DP;
  3. A potential positive effect on reserves as the abandonment pressure for a well at end of life can be lower with the same compression power.

With the sustained reduction in plant inlet pressure achieved to date, Santos have quantified the benefits accrued from the first benefit and this has been conservatively quantified as a 0.5% increase in plant throughput. This benefit yields a simple project payback of *less than two months*.

The potential benefit from the second benefit source (i.e. after all the reciprocating compressors are reconfigured for the reduced discharge pressure) is estimated to be *a further four times the initial increase in plant throughput*. That is, the total throughput increase is estimated to be over 2.5% after all compressors are reconfigured.

The impact upon gas reserves has not been quantified to date.

The same operating concept of lowering plant inlet pressure to improve production has been employed at the Ballera plant (albeit without any process control improvements required for that specific plant configuration) and the immediate and potential throughput benefits were of a similar order (in terms of percent throughput improvement).

## Conclusion

This Plant Inlet Pressure Minimisation initiative undertaken by the ProSys Engineering / Santos team has been a good example of how application of appropriate process control techniques coupled with a strong understanding of the underlying process relationships and economics can deliver significant benefit to the bottom line. The new operating paradigm for the plant (i.e. running the CO2 Removal train valves as open as possible, controlling the LRP inlet pressure to a low target and peak shaving the inlet pressure spikes using the SWQ pipeline) would not have been feasible or sustainable without the use of the new MPC applications. The final result has been improved operability and economic performance of the plant to the benefit of the Moomba operators, engineers and Santos management.

This project illustrates how improved process control can deliver substantial plant performance improvement without the need for any process interruption or mechanical modifications, facilitating more efficient use of the existing equipment to deliver a highly effective debottlenecking of the plant.