CAPTURING AND SUSTAINING THE BENEFITS OF ADVANCED PROCESS CONTROL

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Abstract: The paper describes the application of an advanced process control (APC) strategy to a complex Fluid Catalytic Cracking, two Vacuum Distillation Units and a Crude Distillation Unit located at Galp Energia Sines Refinery (Portugal). The paper describes the strategy and methodology adopted in the projects, specifically focusing on the best practices related to the implementation and maintenance of large multivariable controllers. The technologies, tools and procedures adopted to keep the applications at their top performance are described in detail. The benefits are shown based on data of rigorous post-audits. *Copyright © 2005 IFAC*

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1. OVERVIEW OF GALP ENERGIA

Galp Energia is the largest contributor to the Portuguese economy. Their activities go from exploration, production , supply, refining and distribution., with revenues in excess of 6.9 billion Euros and a net income of 114.5 Million Euros in 2002. Galp Energia operate two refineries, one locate near Porto and one in Sines. Galp Energia Sines refinery is their largest production plant, built in 1978 with a capacity of 225,000barrels/day corresponding to 10.4 Million Tons of crude processed per year. The production is mainly focused on gasoline, aviation fuel, diesel, LPG and targeted to the Spanish, Portuguese and African markets.

The business objectives of Galp Energia at Sines refinery are:

- Maximise income
- Maximizing throughput while adhering to regulation compliance
- Identifying improvements in real-time operations at the plant and enterprise levels

In this context an extended automation plan has been started several years ago at Sines in different steps:

1. Field instrumentation upgrade
2. Installation of a Distributed Control System
3. Installation of a Corporate wide Information system
4. Implementation of Advanced Process Control on major units
5. Potential Implementation of real time optimization on specific units

The first multivariable controller at Sines refinery was implemented in 1993 on the Continuous Catalytic Reformer (CCR) and Crude Distillation Unit (CDU) using SMCA technology.

In early 2000 the CDU controller was revamped and migrated to DMCplus together with a new controller on the Deisopentaniser unit.

In 2002 the FCC and Gas Concentration Unit multivariable controllers were completed. In 2003 the VDU1 and VDU2 multivariable control strategies were implemented.

Figure 1: location of Galp Energia Refineries

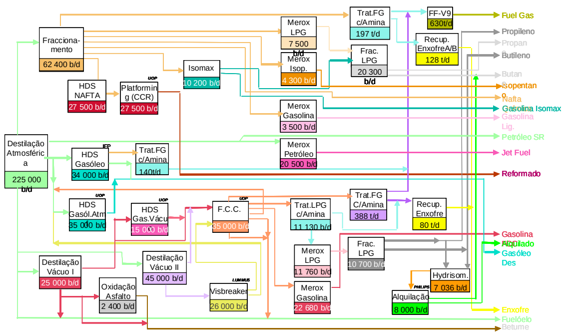

Figure 2: overview of Sines Refinery

2. ADVANCED PROCESS CONTROL OBJECTIVES

The process control objectives are summarised below for the most important units.

Crude Distillation Unit.
The APC stragey is implemented on the preheat train, 4 heaters, main fractionator, gas fractionation section and deisopentanser.

The main objectives are:

- Maximise Feed
- Maximise most valuable products
- Quality control
- Automatic Crude switching

Fluid Catalytic Cracking and Gas Concentration
The APC strategy covers the preheat section, reactor and regenerator, main fractionator and gas concentration unit.

The APC strategy is designed to meet the following objectives:

- Maximise Feed
- Maximise LPG production

Vacuum Distillation 1 and 2
The APC strategy is implemented on the preheat train, heater and vacuum column of both units.

The objectives of APC are:

- Maximise Feed
- Maximise VGO Yield
- Quality control (Asphalt mode)

Currently there are installed 7 multivariable controllers, divided in 16 subcontrollers. The total number of variables manipulate by DMCplus exceeds 100 and the total number of controlled variables is approximately 210. In the several strategies implemented there are more than 30 qualities inferred through process measurements

The technologies used at Galp Energia are:

- DMCplus™ for multivariable control
- AspenIQ™ for inferential development and deployment
- AspenWatch™ for performance monitoring
- Production Control Web Server for operator and engineer interface
- DMCplus for TDC3000 package for operator interface
- Cimio for OPC to connect to the Honeywell TDC3000

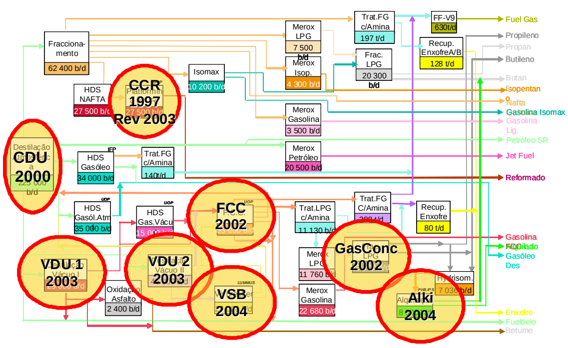

Figure 3: overview of APC applications

3. SUMMARY OF BENEFITS

The benefits on the major units were calculated based on rigorous post-audits of the controllers. The reference base case is determined based on 6 months of operation without advanced process control.

In the following paragraphs a brief summary of the results is presented.

3.1 Crude Distillation Unit

The following table shows a comparison of the benefits obtained through the application of APC to the CDU. The results are based on 6 months of operation of the multivariable controller and compared to the expected results in the reference base case.

<u>Table 1: summary of the benefits on the CDU (6 months of operation)</u>

	Estimated	*Obtained*
Feed increase	*2.4%*	*>4%*
Kero Yield increase	*0.53%*	*1%*
HGO Yield increase	*0.25%*	*0.8%*
Heavy naphtha 5% ASTM (Standard deviation)	*<3.2degC*	*1.5degC*
HGO evap 360degC (standard deviation)	*<2.9%*	*2.2%*

Feed maximization was also evaluated with a performance run during which the APC strategy was turned OFF and the operator maximised feed for 24 hours. Then the controller was turned back on it maximised the feed.

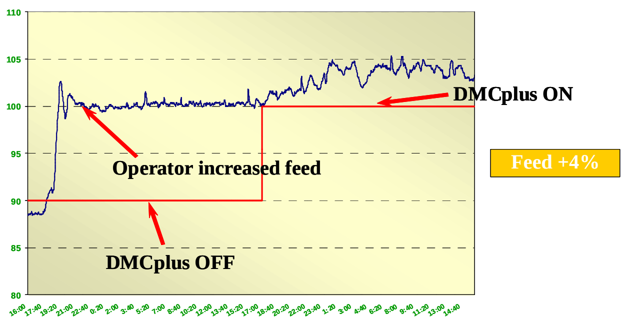

Figure 4: CDU feed maximization - performance run results (100%=base case average feed)

3.2 Fluid catalytic Cracking and Gas Concentration Unit

The main benefit in the FCC and Gas Concentration are coming from feed maximisation.
The following figure compares 6 months of operation with and without the controller.
The average feed increase obtained with DMCplus was greater than 5%.

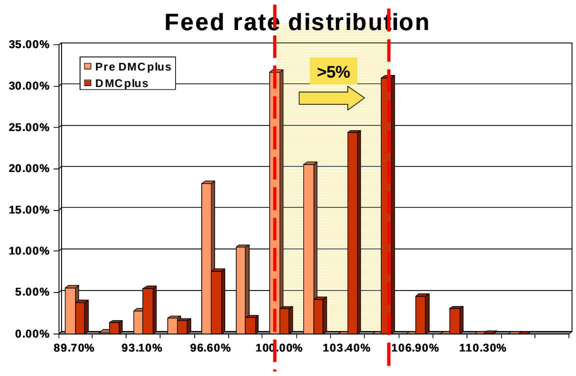

Figure 5: FCC feed distribution with and without APC (100% = base case average feed)

3.3 Vacuum Distillation #1

The main benefits in VDU #1 are obtained through the maximisation of throughput and maximisation of VGO yield. The following figures show the distribution of feed and VGO yield with and without APC.

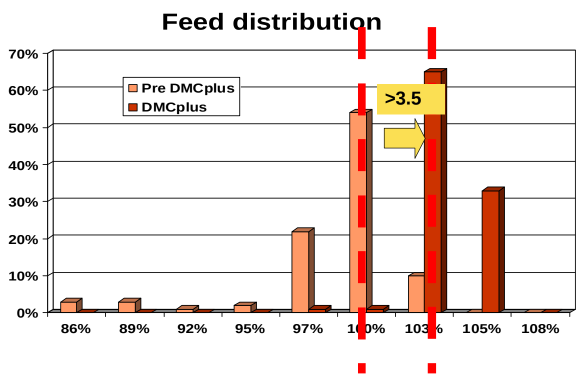

Figure 6: VDU#1 feed rate distribution (100%=base case average feed)

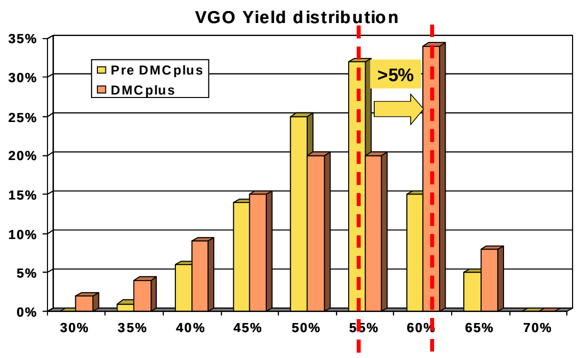

Figure 7: VDU1 VGO yield distribution (%)

4. SUSTAINING THE BENEFITS

The benefits obtained with the application of APC are substantial and keeping the applications at their top performance becomes a critical business objective. A small reduction in overall performance of the controllers can lead to substantial financial losses.

Causes of controller performance degradation are attributable to one or more of the following factors:

- Changing plant economics - values of products, feeds and utilities may vary over time. These impact the costs used in the advanced process control embedded Quadratic or Linear Program within the controller. Often, however, these costs are not updated and the controller pushes constraints which no longer maximize profit.
- Changing plant operating point - the controller may be operating at a different operating point to the one it was commissioned at due to seasonal or permanent factors. Often this can be rectified through re-tuning of the controller at the new operating point, providing the model error is not great. However this can also lead to performance degradation due to reduced model accuracy.
  - Turnaround modifications - after turnarounds this mismatch may suddenly become substantially greater due to significant process plant modifications. There are also inevitably a number of small plant process and instrumentation modifications during turnarounds (new valves, exchanger bundles etc) that will cause the new post-turnaround plant to behave dynamically differently to the original model. Sometimes small changes in the regulatory control structure of the plant will result in the existing model becoming invalid for large parts of the controller, due to the embedded dynamics of the old regulatory controls within the advanced control model.
  - Process hardware and operational changes – these can alter the dynamic and steady-state characteristics of a process. This may cause a degradation of performance.
  - Plant-model discrepancies - with all multivariable controllers there is a continuous and gradual increase in "plant-model" discrepancy beginning soon after controller commissioning. The actual plant dynamics drift away from the dynamic model of the plant as captured during the original controller project. This is due to many factors such as fouling, minor and major plant modifications, instrumentation changes etc. Without continuous monitoring, training and maintenance the controller performance degrades with significant resulting loss of benefits.
- Mobility of staff - it is common for staff to be moved from one function to another, or from one plant to another. Successful support of an application requires continuity of technically skilled effort and familiarity with the process.
- Operator training - as a result of expert staff limitations and mobility the skills of operators in understanding and driving the Advanced Process Control application may decrease. This can result in operators setting wrong or sub-optimal controller manipulated and controlled variable limits. This is due to a changing plant operating point and loss of knowledge by the operators about what, why or how the controller is doing what it does.

As an example the performance of the CDU controller slowly went down in a few years after implementation.

Even though the controller has a service factor greater than 99%, the operators started to clamp the limits on the manipulated variables thus limiting the degrees of freedom of the controller and reducing the benefits.

Figure 8 shows the distribution of the degrees of freedom when the analysis of the controller performance was audited again in 2003, three years after it was implemented. The value went down to approximately 33% from the starting values of 80% at commissioning time.

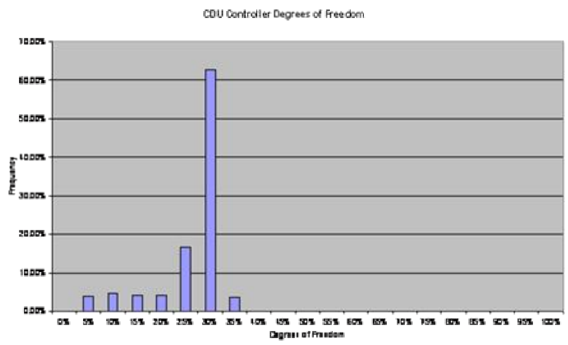

Figure 8: degrees of freedom of the CDU controller

A detailed investigation of the reasons why the controller performances went down over time lead to the following conclusions:

- The operating point of the unit has changed since the commissioning of the APC strategy;
- The performance of the tower have changed (change in feed composition, quality targets, fouling and possible tray damage);
- Operator had changed and the new operators had less confidence in the APC strategy

4.1 Procedures for sustaining the benefits

Sustaining benefits on multiple APC applications can be a challenging task that has to be approached in a systematic way.

The following factors were identified as key factors for maintaining APC applications:

- Availability of a reporting tool. A tool that easily created reports for management and control engineers is essential for day to day operations of the controller
- APC application historian. The plant historian is useful to trend key variables but doesn't provide all the information required for troubleshooting. A tool that allows to go back in history to see all the APC application parameters (limits, tuning parameters etc.) is essential for understanding behaviour and troubleshooting the application
- Remote connection. The control engineers need to monitor the application even when they are not in the control room. A safe connection to the on-line server is essential to monitor the controller performances. Remote connection is also important if performances have to be monitored from third parties

Galp Energia selected AspenWatch as a reporting tool and APC historian.
The controllers are published on the refinery Intranet using the Production Control Web Server, so that process and control engineers can monitor the applications using their Internet Browser. Remote connections are done through Webex meetings.

Galp Energia and Aspen Technology formed a joint team with clear responsibilities and activities.
Galp Energia team takes care of day to day monitoring of the applications, troubleshooting etc.
The AspenTech team performs as part the Aspen Sustained Value (ASV) program regular remote checks and site visits every 3 months.
On request remote check are also performed on an as needed basis.

5. CONCLUSIONS

Advanced Process control applications have resulted in significant ongoing benefits to Galp Energia.

Rigorous post audits of the application have proven to be essential to prove the importance of APC applications installed and to increase focus on these applications especially after commissioning.

A systematic approach for sustaining the benefits of the application has been essential for keeping the application at their top performance.