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# Heater Pass Balancing using MPC on a Redundant DCS Node

## 91b

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## Abstract

A multivariable controller to balance heat distribution by adjusting individual heater pass flows, while maintaining upstream level control and managing other process constraints, was implemented in a redundant DCS node. The controller overcame various instrumentation issues including significant valve stiction to reduce heater pass imbalances, skin temperature excursions, and improve upstream level stability across a wide range of process flow rates. The controller was designed and implemented using Lin and Associates' Model-less Multivariable Controller, Deltum-XMC®, installed in the Honeywell Experion® control node, and commissioned in less than a calendar-week without step-tests or process modeling. The controller is running at a 2-second interval in a redundant control node.

# 1 Process Description

Heater pass balancing is industry best practice and has been implemented on the vast majority of fired heaters in industry. Pass balancing is an advanced process control (APC) strategy that adjusts the individual pass flow control valves of a multiple pass heater to achieve equal pass outlet temperatures. Equal pass outlet temperatures, as opposed to equal pass flows, is more effective at reducing overall tube fouling, coking, and excessive metallurgical temperatures.

The multivariable APC controller, in addition to balancing the pass outlet temperatures, typically has one or more additional combined control objectives, such as total flow control or level control of the feed or discharge vessel. In the application at hand, the combined objective is level control of the liquid-liquid extractor vessel that feeds the heater.

A multivariable pass balancing application may have additional constraints, such as minimum or maximum flow, valve position, or temperature. These are typically selected based on the likelihood and potential impact of faulty valve or temperature measurement behavior. In the application at hand, in addition to the pass balancing temperature targets (one for each of the four passes), a minimum flow constraint for each pass has been included in the controller matrix design.

Heater outlet temperature control typically works independently of pass balancing. However, where a heater has multiple fireboxes, pass balancing can also automatically balance the load (shift flow) between fireboxes, if one firebox becomes constrained, for example due to low excess oxygen or high burner fuel gas pressure.

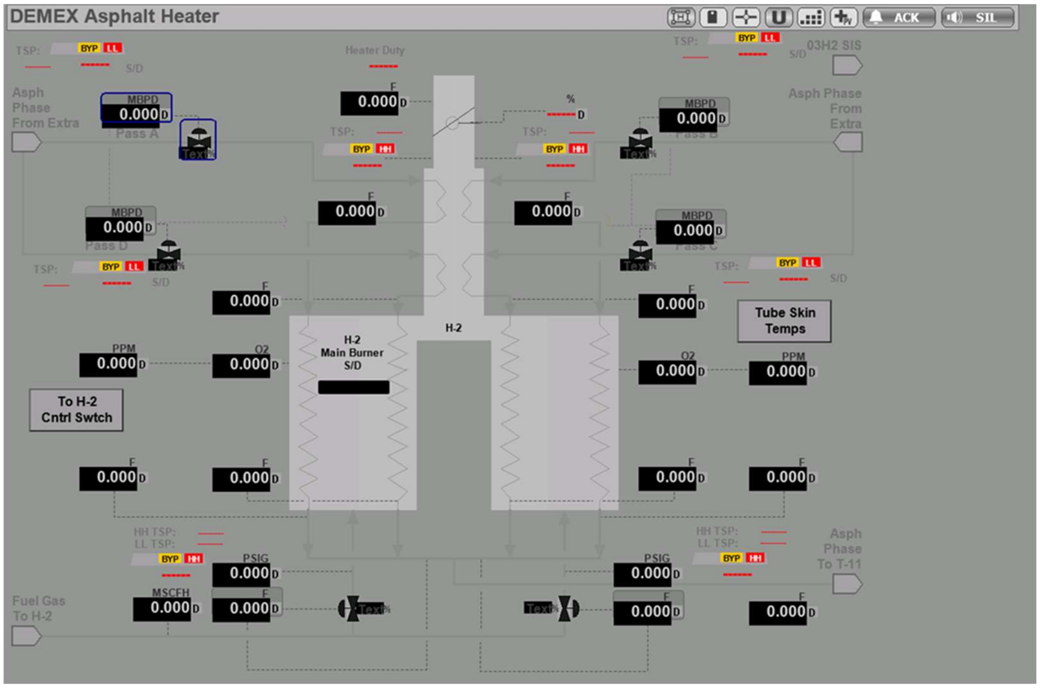


**Figure 1: DCS Heater Process Graphic**

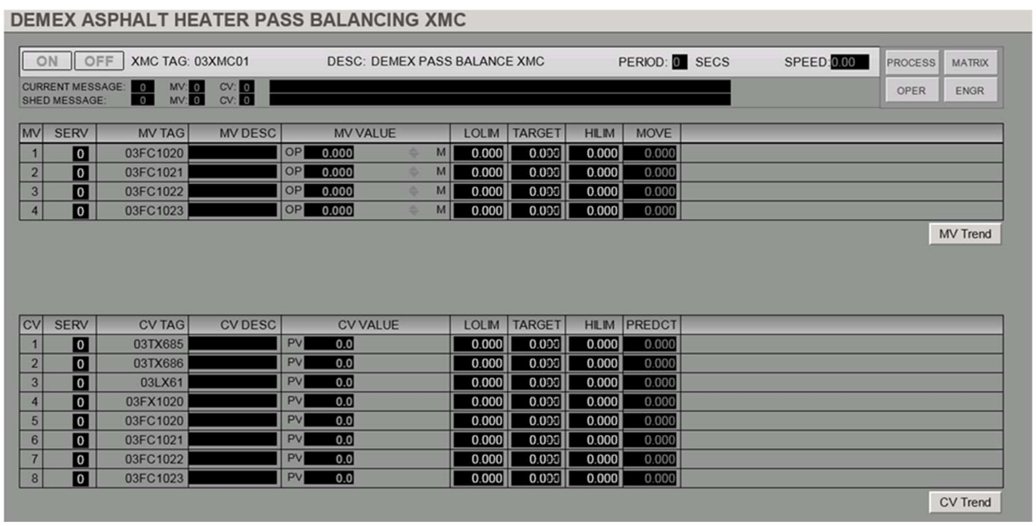


**Figure 2: DCS Deltum-XMC Operator Graphic**

## 2 Process Control Performance

Prior to installing an APC pass balancing application on the subject heater, process operation was very challenging in terms of excessive alarms, safety system demands, and excessive console operator resources. This was due to multiple factors, including the inherently noisy nature of the temperature and flow measurements on this process; frequently erratic behavior of the liquid-liquid interface level measurement; the severe service nature of the control valves – high temperature and very heavy material – which results in high valve stiction; and frequent heater swings due to changing rates.

As a result, this heater was a known refinery bad actor, in terms of alarms, safety system challenges, and operator demands, as described above, and this was further confirmed using loop intervention analysis, which showed that all seven involved control loops (four pass flows, one level controller, and two heater box temperature controllers) exhibited several hundred percent excess operator interventions relative to top quartile well-performing control loops.

After application of the multivariable APC controller, all related control loops immediately moved into the top-performing category and have remained there with no degradation of performance or application maintenance needs over a full year of operation.

| Controlled Variable | Standard Deviation Before | Standard Deviation After | Decrease in Variability |
|---|---|---|---|
| CV 1 (Cell 1 Delta T) | 82.22 | 6.945 | 91.6% |
| CV 2 (Cell 2 Delta T) | 63.87 | 5.85 | 90.8% |
| CV 3 (Extractor Level) | 40.85 | 1.44 | 96.5% |
| CV 4 (Cell Delta Flow) | 1.20 | 0.12 | 89.8% |

**Figure 3: Controlled Variable (CV) Performance**

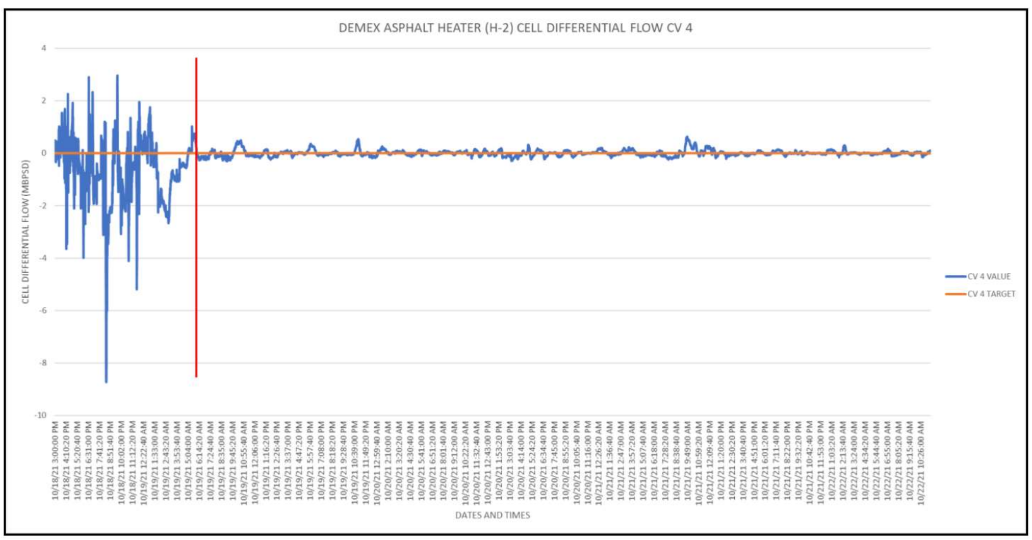


**Figure 4: Controlled Varaible (CV4) Performance**

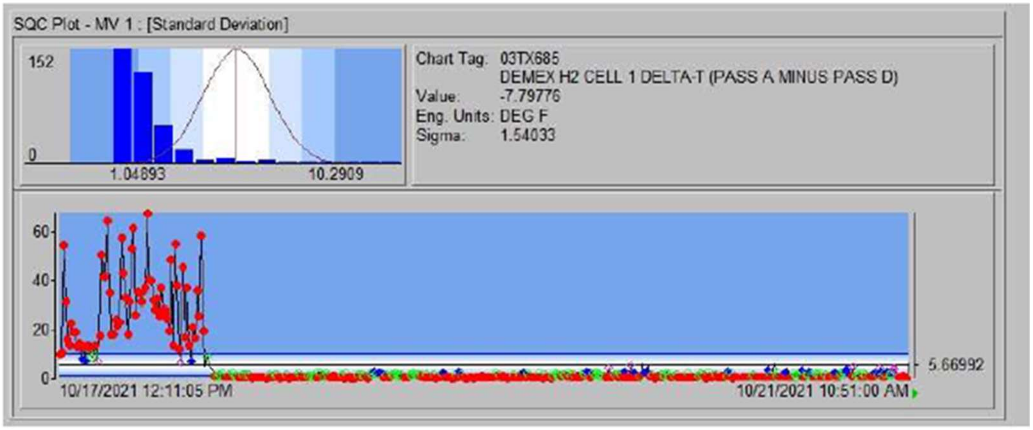


**Figure 5: Controlled Variable (CV) Performance (Standard Deviation)**

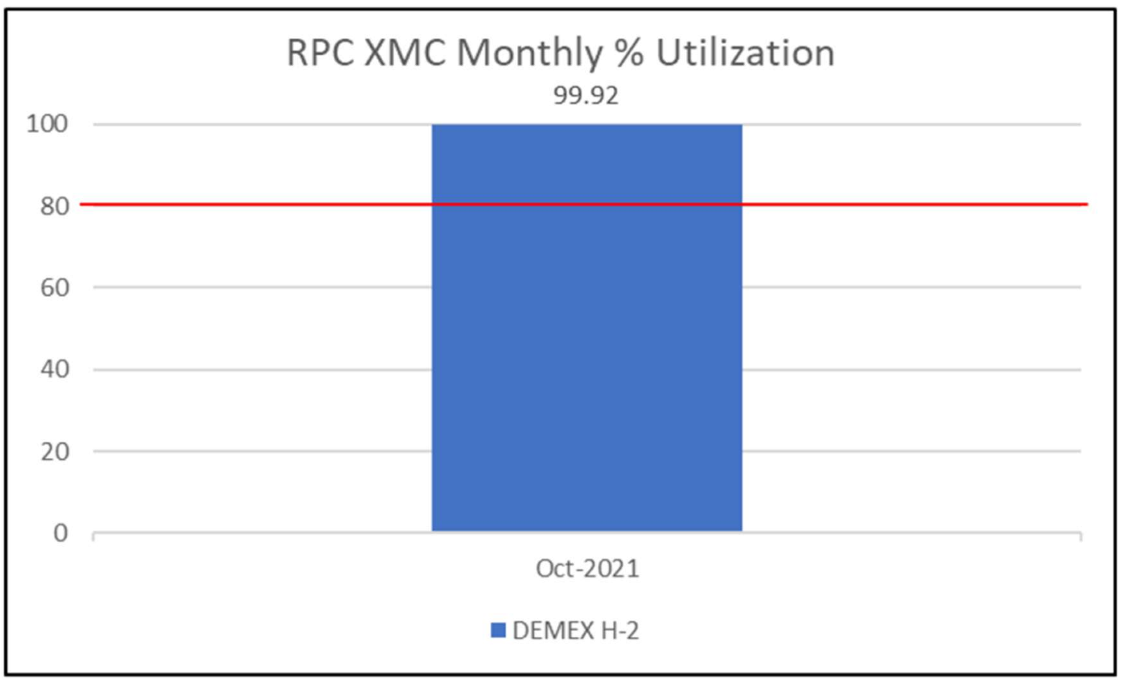


**Figure 6: Utilization History: October 18, 2021 – October 31, 2021**

| | 03FC1020 | 03FC1021 | 03FC1022 | 03FC1023 | 03LC6x | 03TC363 | 03TC373 |
|---|---|---|---|---|---|---|---|
| JUL | 167 | 236 | 131 | 120 | 102 | 303 | 265 |
| AUG | 7 | 90 | 5 | 0 | 61 | 97 | 105 |
| SEP | 1 | 10 | 31 | 0 | 67 | 60 | 68 |
| OCT | 209 | 158 | 152 | 288 | 74 | 437 | 417 |
| NOV | 2 | 1 | 1 | 5 | 1 | 137 | 46 |

**Figure 7: Loop Intervention Analysis Results of Related Regulatory Controllers**

Loop intervention analysis can be used to identify multivariable control loops that are "open" or in manual- mode. These loops are typically referred to as "bad-actor loops." Including these loops and appropriate constraints in the DELTUM controller allows the loops to be "closed" or operated in automatic mode.

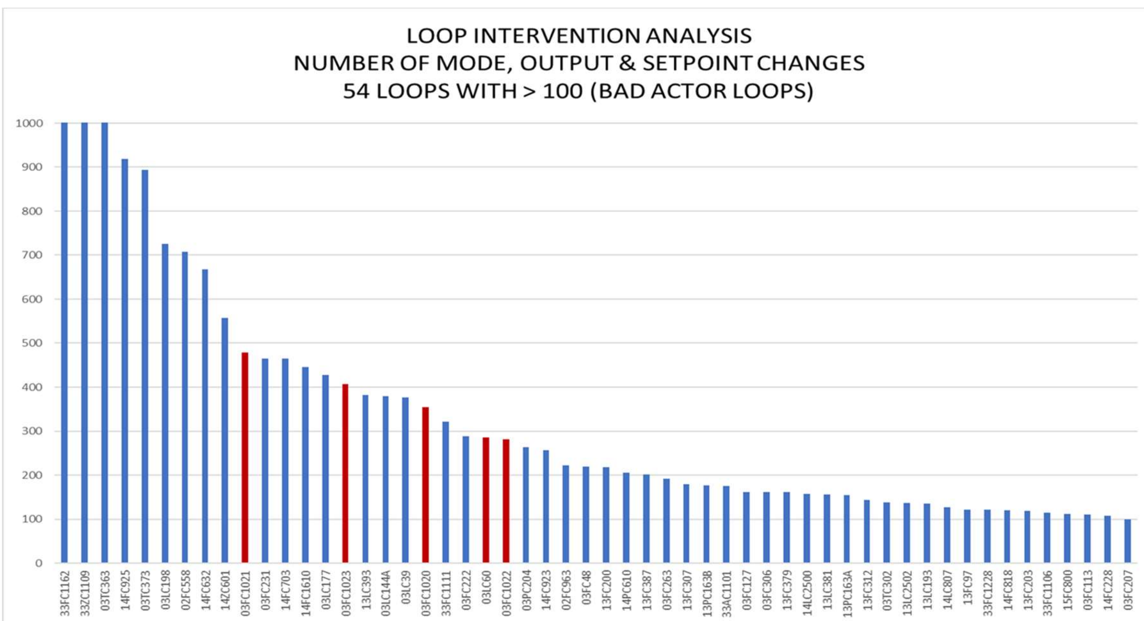


**Figure 8: Loop Intervention Analysis: Top 100 "Bad Actor Loops"**
**Used to identify needed/potential APC applications**

# 3 Benefits

This APC application had immediate tangible benefits, especially in terms of fewer alarms, less safety system challenges, and better use of console operator resources. Prior to installing the

APC application, many process upsets led to lengthy periods of continuous operator intervention to keep the process within bounds and avoid abnormal conditions and process trips. After applying APC, when process upsets occur, console operators now double check to assure the APC is fully enabled and allow it to handle all the ensuing control action adjustments to maintain stable and reliable process operation, while minimizing alarms, trips, and abnormal conditions. This has had a large tangible positive impact on process operation and console performance.

Another benefit of the APC technology that was employed is that it is model-less and resides directly in the redundant DCS level controller. This means that it is very cost and time effective to engineer, deploy, operate, and support. It was installed and tested on-site in under two days and began running continuously on the third day. A further benefit of the model-less technology is there are no models to degrade or maintain over time; no plant step testing up front; and no step testing going forward if it becomes necessary to add a new variable or troubleshoot some aspect of performance.

The fast controller execution period (2 seconds) and redundancy of this architecture – APC in the control layer – gives the Deltum-XMC controller additional ability to respond quickly to fast disturbances, and to meet high-availability automation requirements. Extractor level interface control has significantly improved, leading to overall more stable and reliable process performance.

Because Deltum-XMC deploys natively within the host DCS, as opposed to a traditional external APC host (or "supervisory") computer, it shares a common HMI scheme with all the other DCS operation graphics. Also, there are no separate applications to manage, and no foreign computers or servers to integrate, or associated cyber-security issues.

The application has now operated for over a year with essentially no downtime, additional tuning, or maintenance. The controller has performed equally well with process rate turndowns of 2:1.

# 4 Next Steps

The loop intervention analysis results can be used, along with plant input from operators, process engineers, etc., to identify groups of related base-layer controllers that constitute additional potential multivariable control applications, to capture this type of automation improvement throughout the refinery complex.