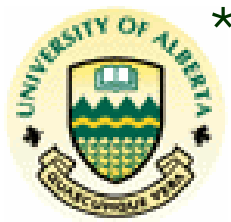


MPC Monitoring of KHU & NHU



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Matrikon
Solutions for Industrial Agility

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1. Introduction
2. Summary of Model Quality Analysis
3. Performance Analysis of KHU MPC
4. Performance Analysis of NHU MPC
5. Concluding Remarks

Introduction

Motivation

1. DMC+ is the model predictive control (MPC) technology of choice at Suncor-upgrading.
2. How to assess model quality is still an open question?
3. NHU and KHU DMC+ controllers are not working as well as when they were initially commissioned. Performance analysis is needed together with the diagnostics of why performance has degraded.

Simulation VS Prediction

1. What is simulation (or unbiased prediction)?

$$u(1), u(2), \dots, u(t) \rightarrow \boxed{\text{model}} \rightarrow \hat{y}(1), \hat{y}(2), \dots, \hat{y}(t)$$

2. What is 1-step ahead prediction (or biased prediction)?

$$\begin{array}{l} u(1), u(2), \dots, u(t) \\ y(1), y(2), \dots, y(t) \end{array} \rightarrow \boxed{\text{model}} \rightarrow \hat{y}(t + 1|t)$$

What is model fit?

1. A widely used model fit is defined as:

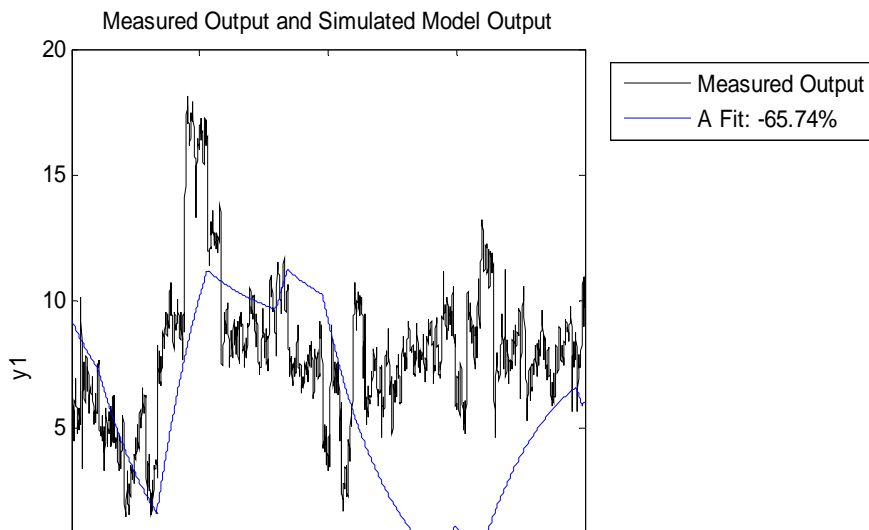
$$\text{model fit} = 1 - \frac{\text{norm}(y - \hat{y})}{\text{norm}(y - \bar{y})} = 1 - \frac{\sqrt{\sum (y_i - \hat{y}_i)^2}}{\sqrt{\sum (y_i - \bar{y})^2}}$$

2. \hat{y}_i can be either from simulation or prediction
3. '1' indicates perfect model
'0' indicates same performance as using the mean value to predict.
'<0' indicates bad model

Example: Simulation VS Prediction

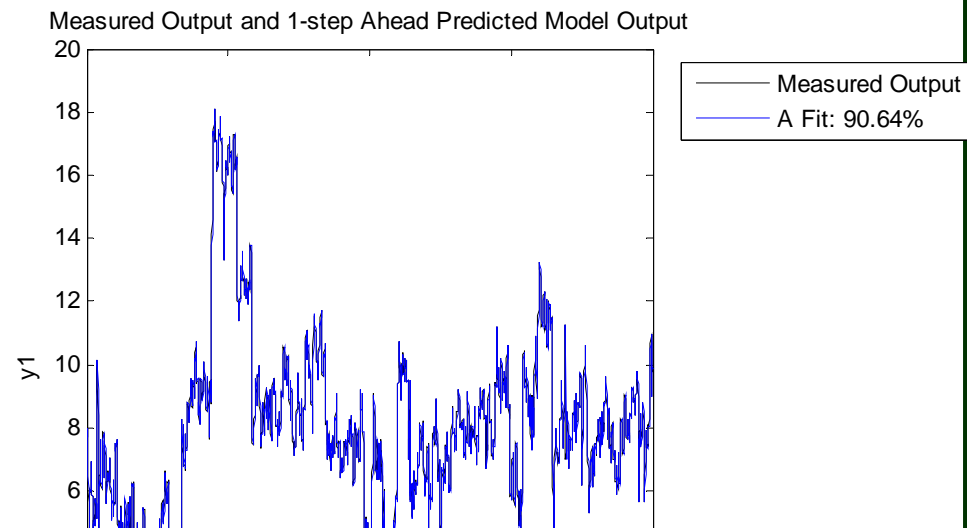
1. 4000 data points from real plant
2. A simple ARX(1, 1, 1) model: $y(t) = B(q) / A(q) u(t-nk) + 1 / A(q) e(t)$

Simulation



BAD model
in terms of simulation

One-step ahead prediction

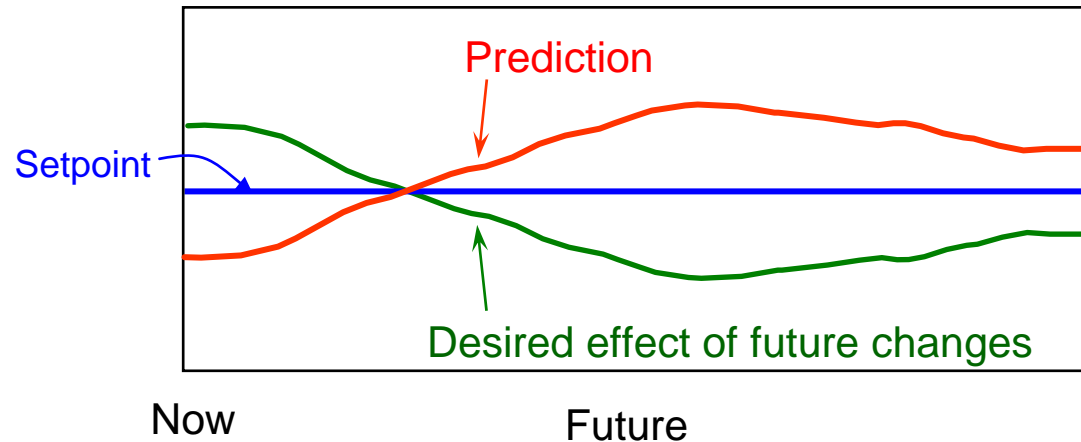


GOOD model
in terms of prediction

Roles of simulation & prediction in DMC+

1. For each execution of DMC+, there are two key steps:

Prediction



Optimization

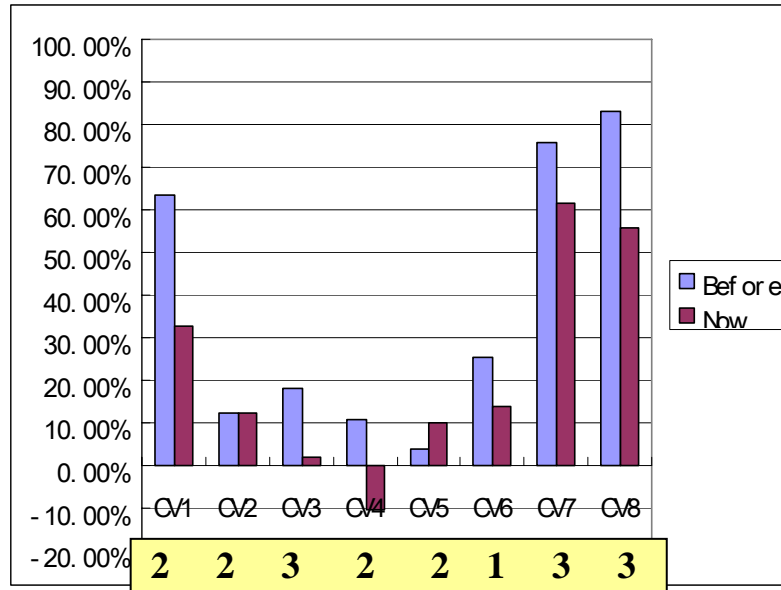
$$u_{future} = G^{-1}y_{desired}$$

Considering constraints and limits

Summary of Model Quality Analysis

Model fit of NHU MPC

Simulation fit

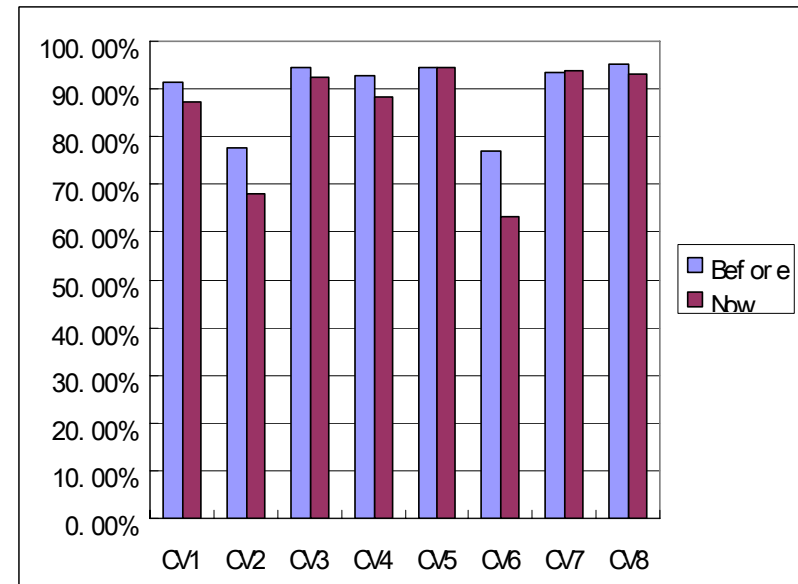


Sensitive to model change.

Sensitive to disturbance.

May give false alarm.

Prediction fit

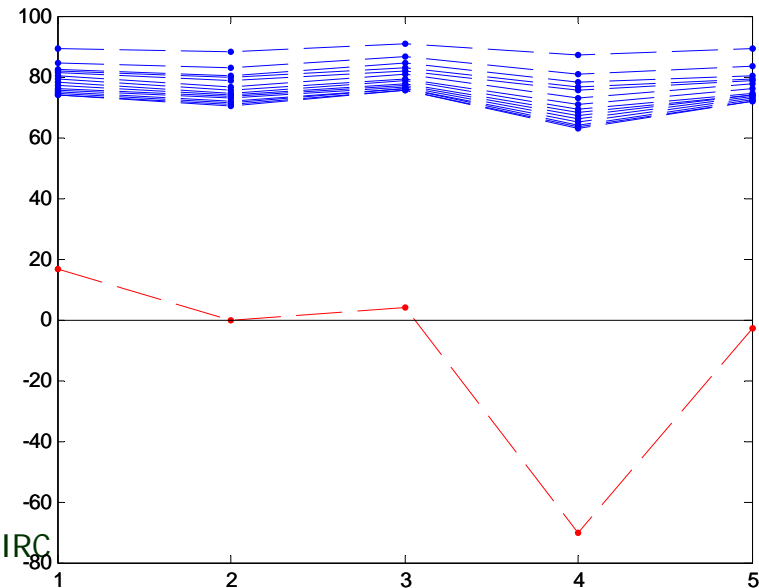
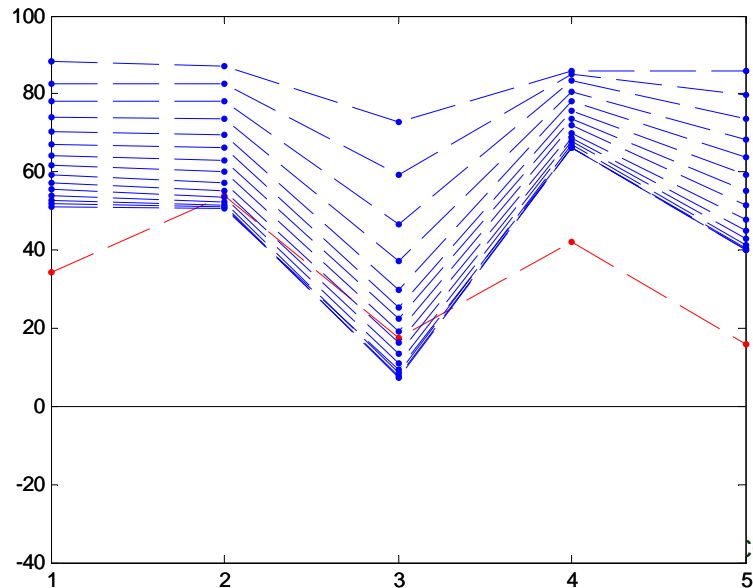
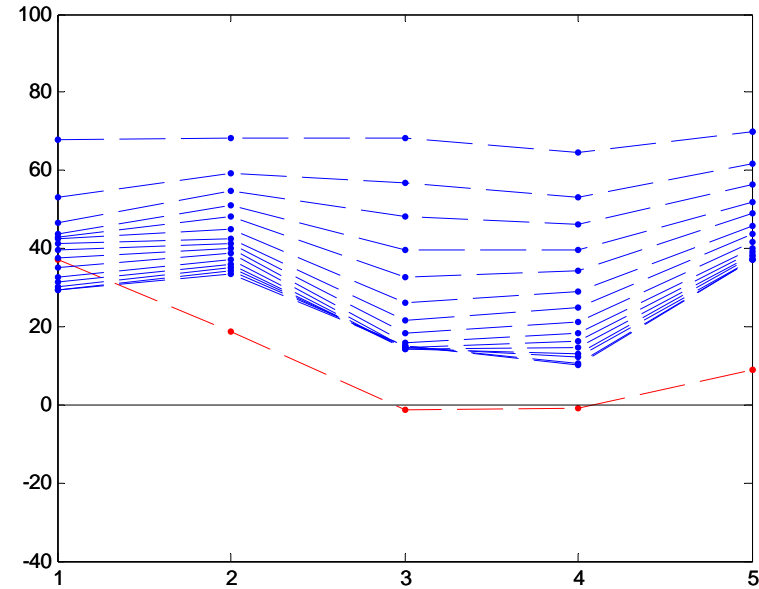
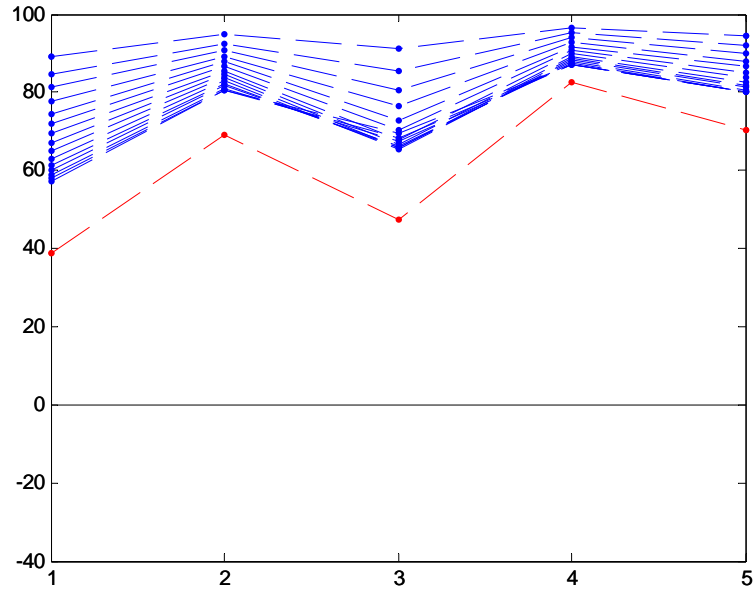


Not sensitive to disturbance.

Not sensitive to model change.

May be misleading.

k -step ahead prediction



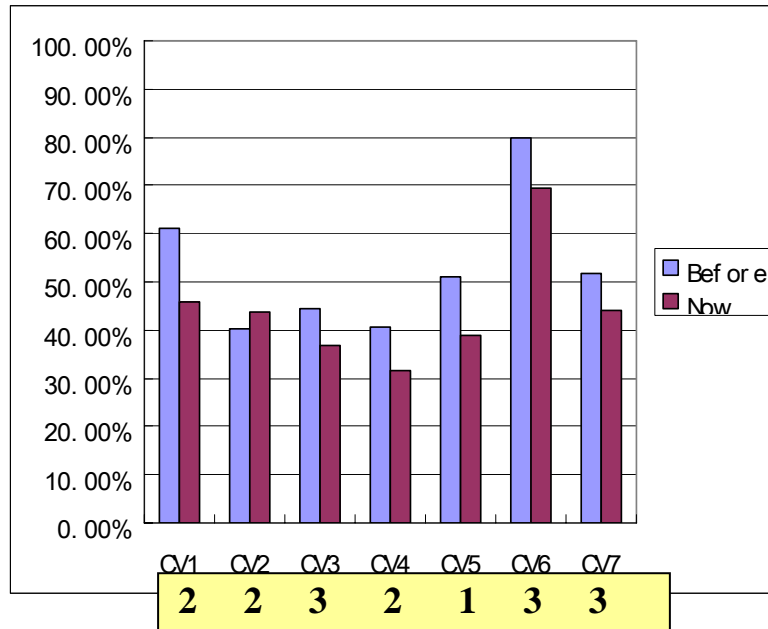
Our experiences...

1. Good prediction fit does not necessarily mean a good model.
2. Bad simulation fit does not necessarily indicate bad model.
3. k -step-ahead predictions are useful to judge the model quality.
4. **Bad** k -step-ahead predictions + **bad** simulation is a sign of **bad** model.
5. New idea:

$$\frac{(\text{average fit of } k\text{-step ahead predictions}) + \text{simulation fit}}{2}$$

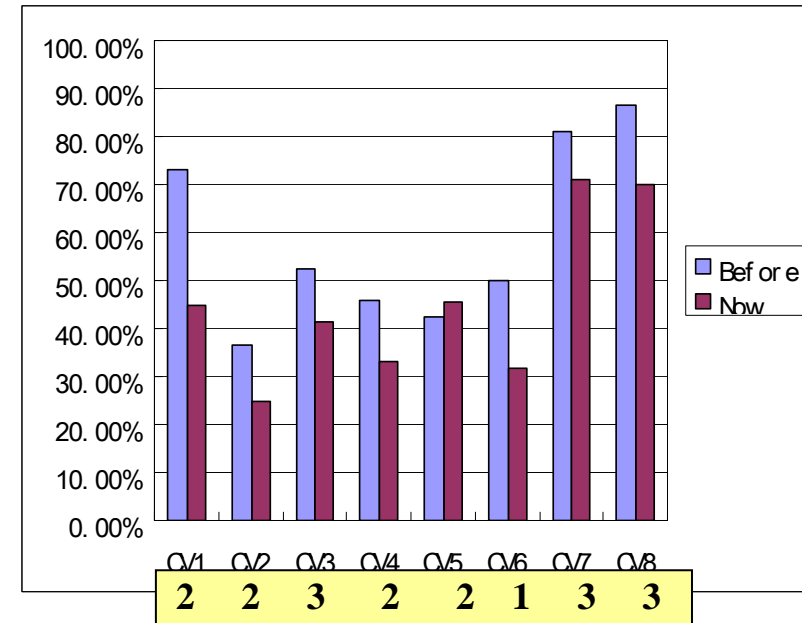
New index for KHU & NHU

KHU



CV4 has the lowest index.

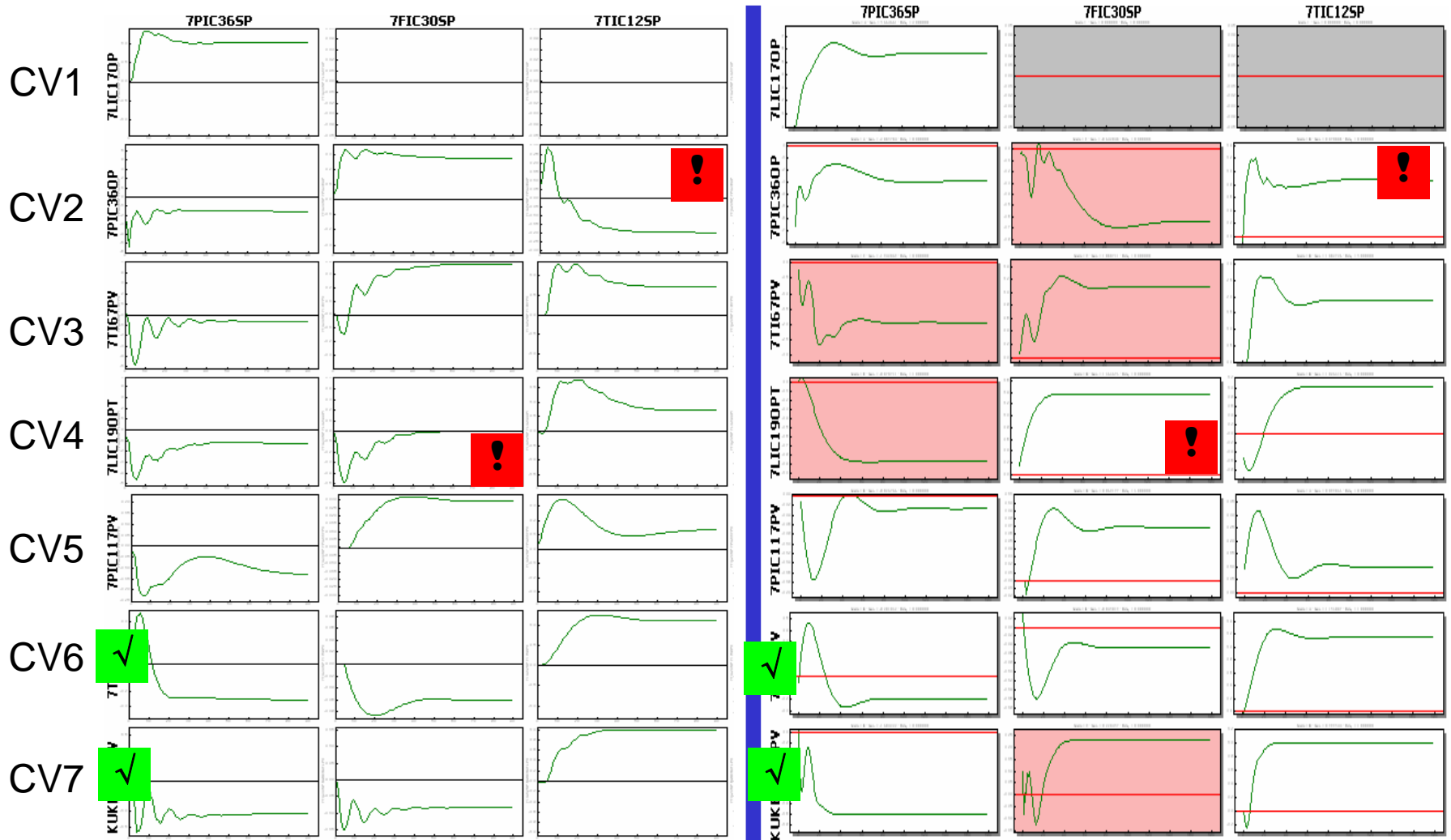
NHU



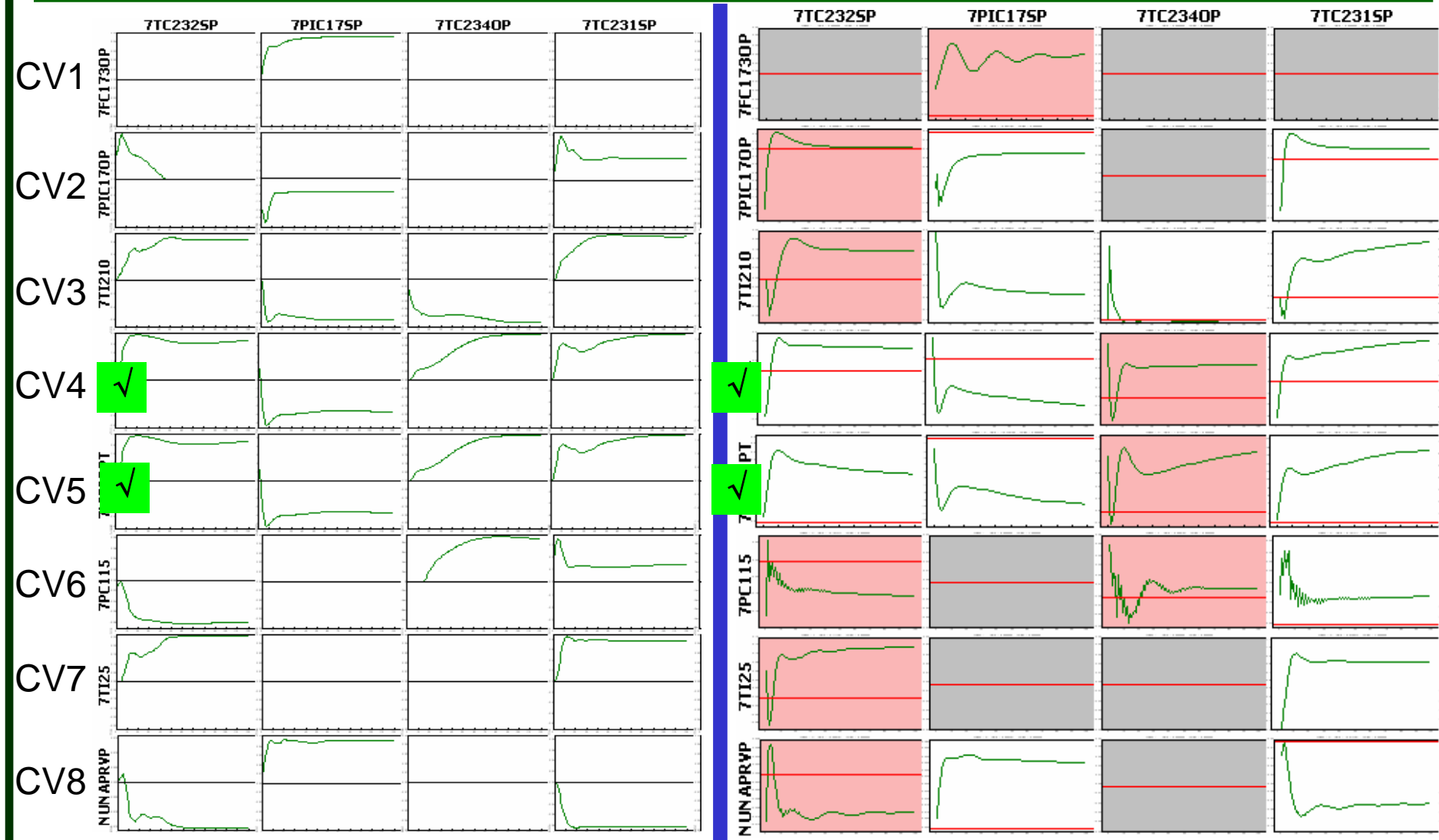
CV2 has the lowest index

Index for CV6 has dropped significantly

Tai-Ji Identification for KHU

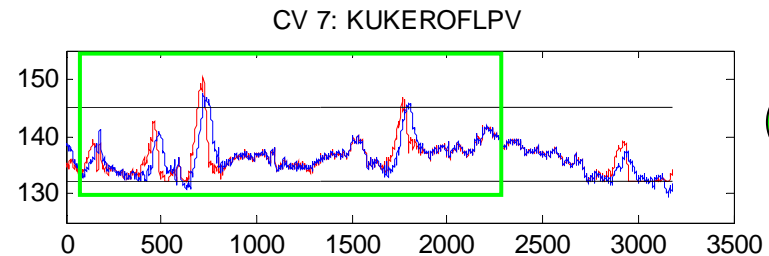
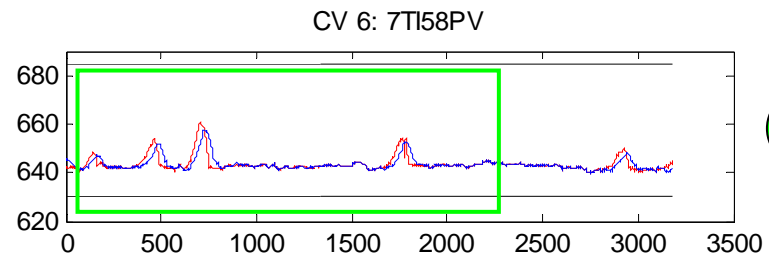
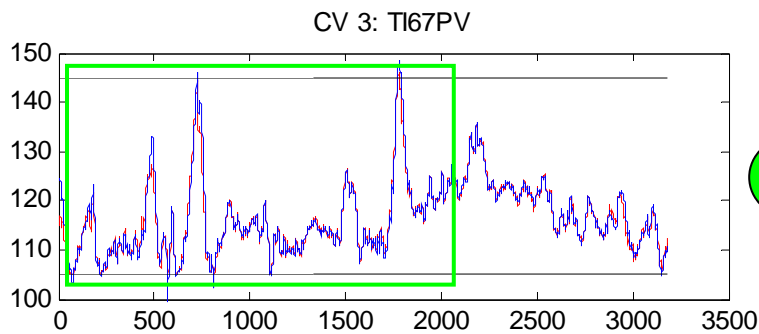
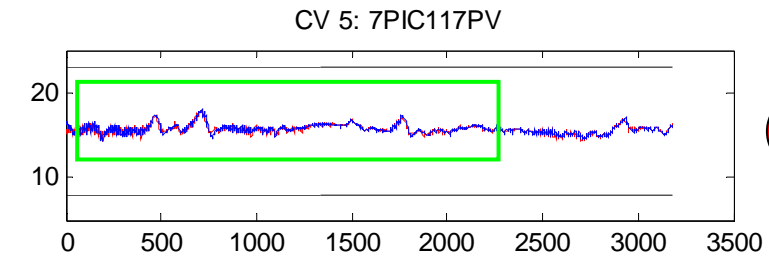
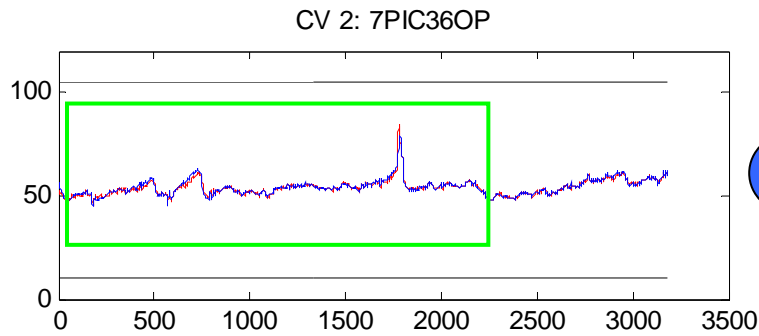
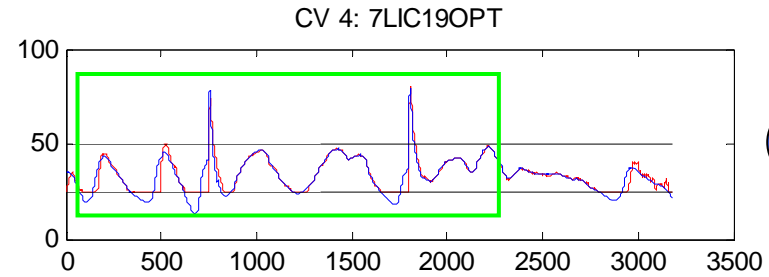
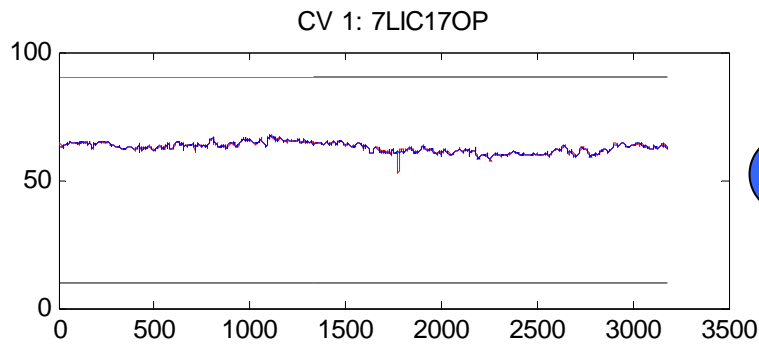


Tai-Ji Identification for NHU



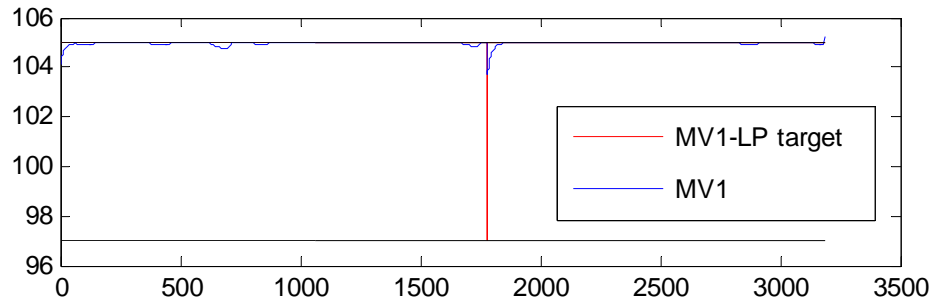
KHU Performance Analysis

Control Objective: (1) CV4 & CV7 to be at low limit,
(2) the other CVs between their limits.



MVs

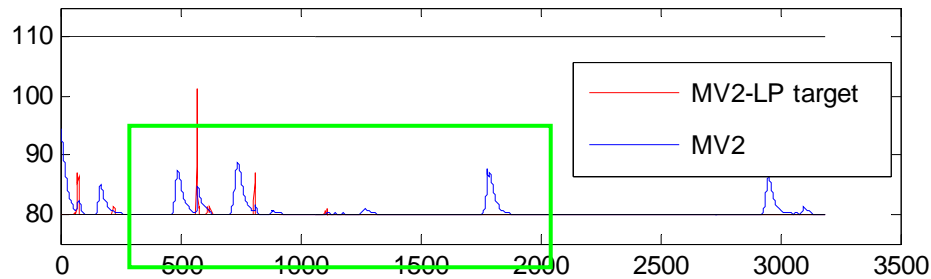
MV 1: 7PIC36SP



MV1 Cost Action: Maximize

99.76% of LP target is at high limit

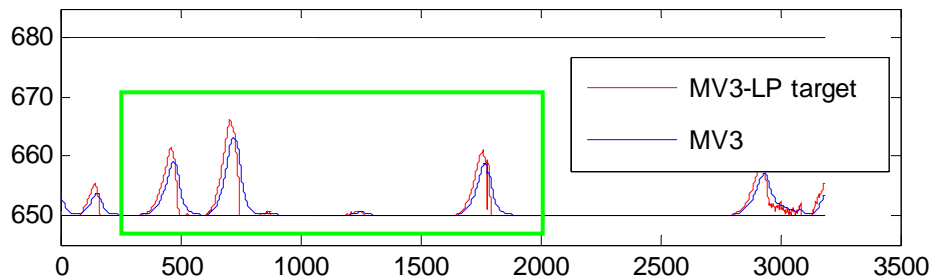
MV 2: 7PIC30SP



MV2 Cost Action: Minimize

98.16% of LP target is at low limit

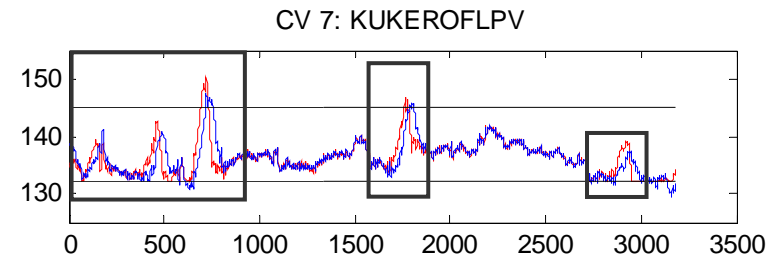
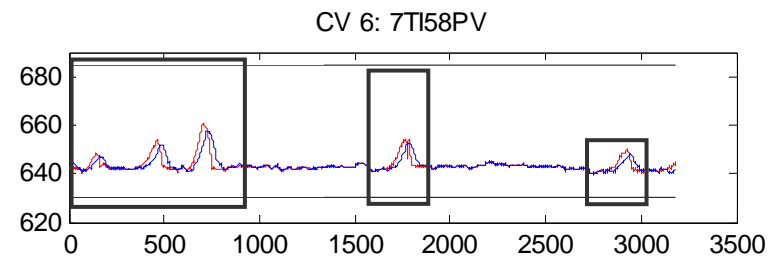
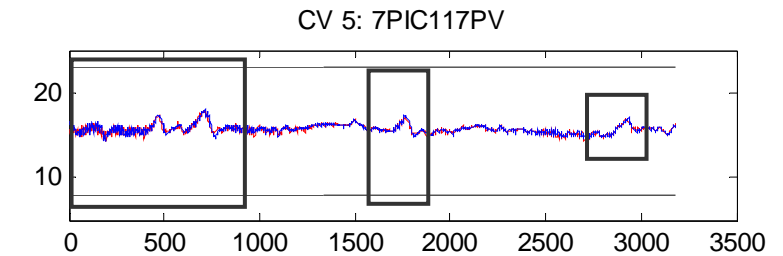
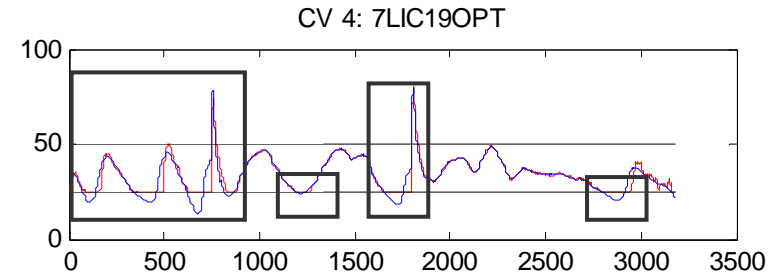
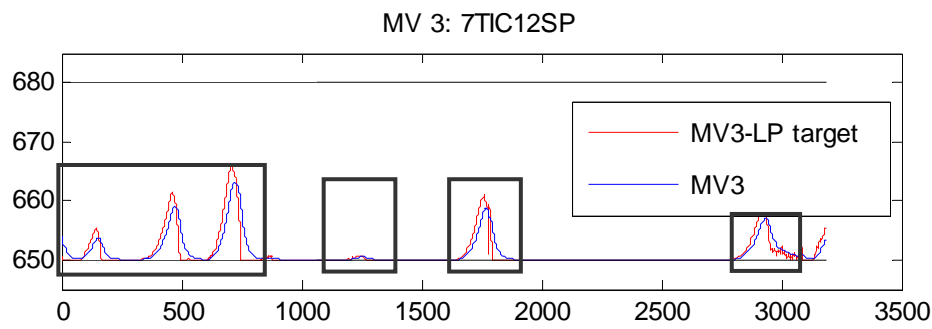
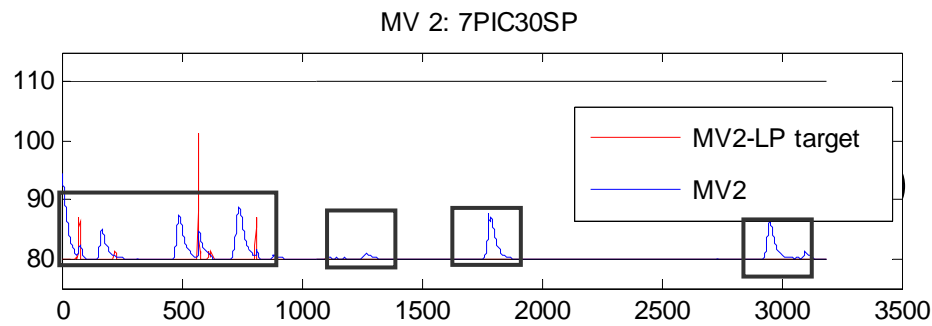
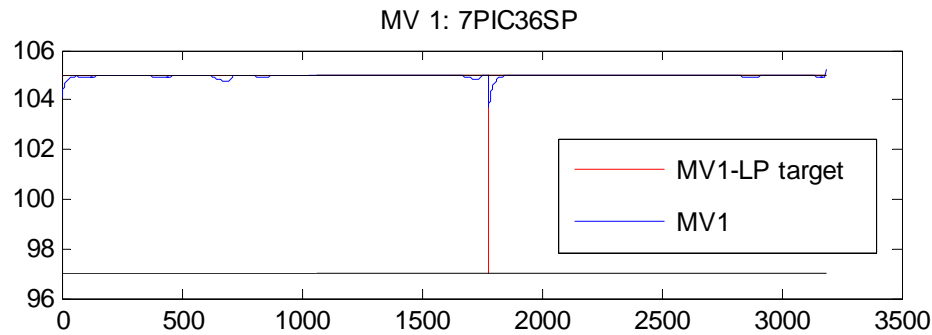
MV 3: 7TIC12SP



MV3 Cost Action: Minimize

74.95% of LP target is at low limit

When CV4 out of limits



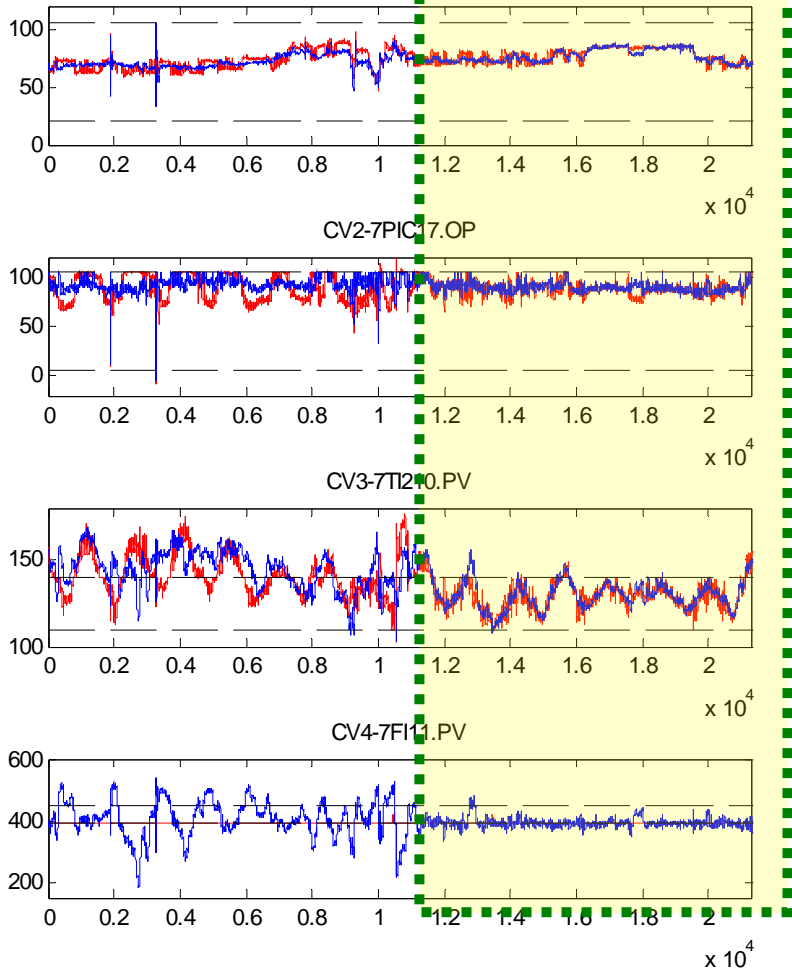
Diagnosis of KHU MPC

1. The MVs were pushed to their limits before the MPC could achieve the control objectives.
2. Current limits do not allow MPC to achieve optimal performance.
3. LIC19 PID controller is not able to control the level well.
4. First recommendation is to check the limit setting.
5. Second recommendation is to tune the PID controller.

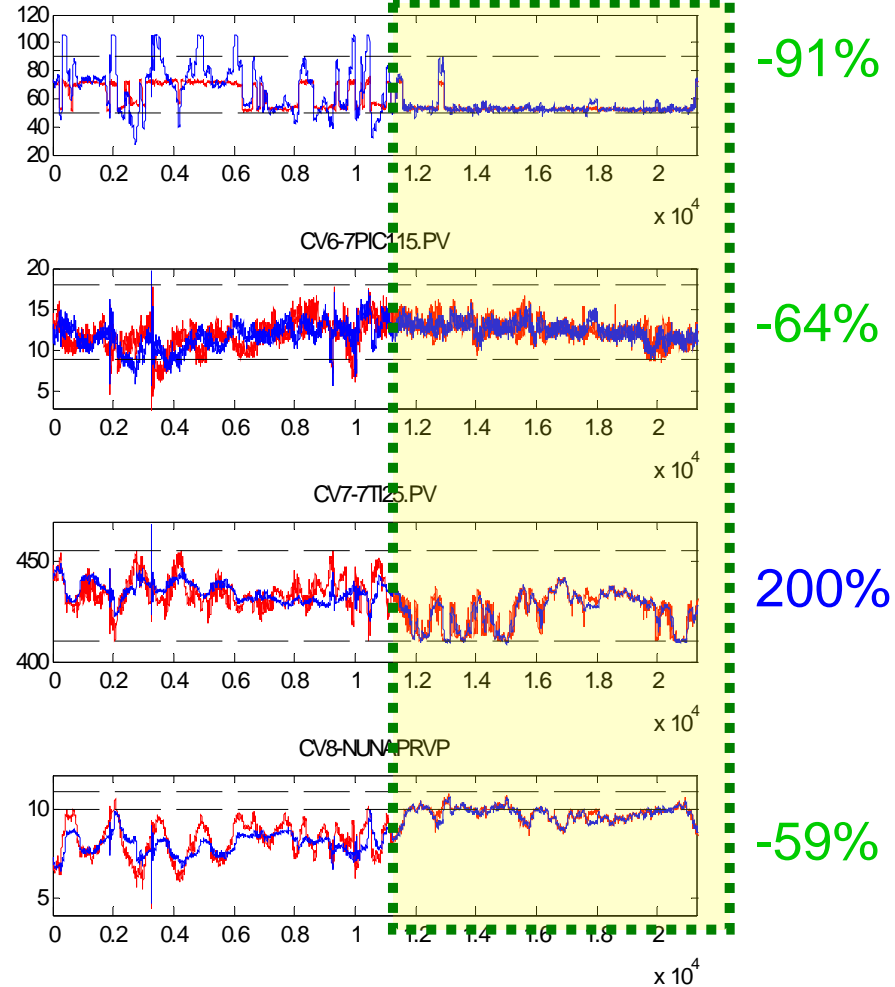
NHU Performance Analysis

Control Objective: (1) CV1, CV2 & CV6 to be at high limits,
 (2) the other CVs between their limits.

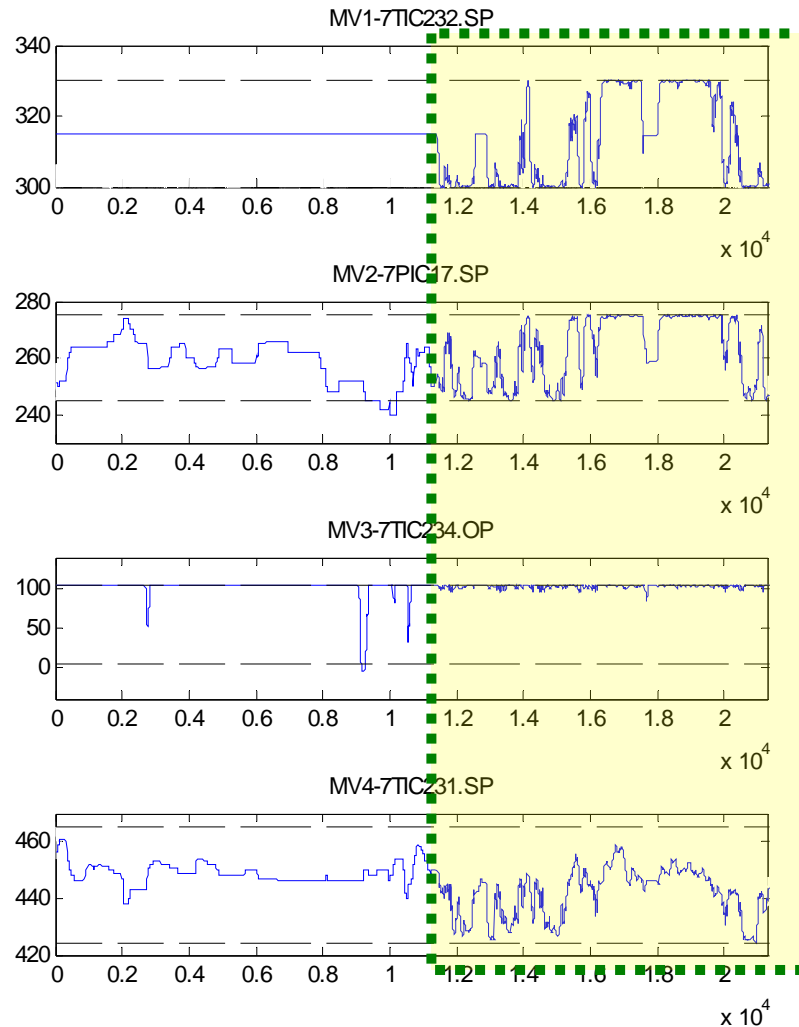
MPC on



MPC on



MVs



- MV3 stays at its high limit most the time.
- The other MVs still have freedom to move.
- This limit setting is better than the setting for KHU.

Diagnosis of NHU MPC

1. The process performance with DMC+ on is much better than when DMC+ was off.
2. 3 CVs are close to their limits, while the other CVs are within their limits. This indicates that the DMC+ was operating well.
3. The performance was acceptable, but not optimal.

Concluding Remarks

1. Model quality assessment in terms of prediction and simulation has been discussed. A new model index has been proposed.
2. Adjusting limits could allow KHU MPC to perform better.
3. One PID loop in KHU caused limit violation.
4. NHU MPC shows acceptable performance.
5. Tai-Ji identification has been shown to be useful for model re-identification using routine operating data.

Acknowledgements

1. Bruce Wilson, Barry Ledrew, Foon Szeto for providing data and technical information about the process.
2. Rohit Patwardhan from Matrikon for many useful suggestions.
3. Mridul Jain from Matrikon for help with Control Performance Monitor.
4. Ramesh Kadali and Trevor Hrycay for all the help during my stay at Suncor.
5. NSERC-Matrikon-Suncor-iCORE for financial support.