Steam System Model Development in RTO Application

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Acknowledgement

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Overview

- Background
- Steam system modeling development
- Summary

Optimization Objective Function

- The objective function will be maximized as the revenue generated from product minus the cost of feed and utilities.

$$Profit = \sum Product_i \, C_{p,i} - \sum Feed_j \, C_{f,j} - \sum Utility_k \, C_{u,k}$$

$C_{p,i}$ = Revenue from Product *i*

$C_{f,j}$ = Cost of Feed *j*

$C_{u,k}$ = Cost of Utility *k*

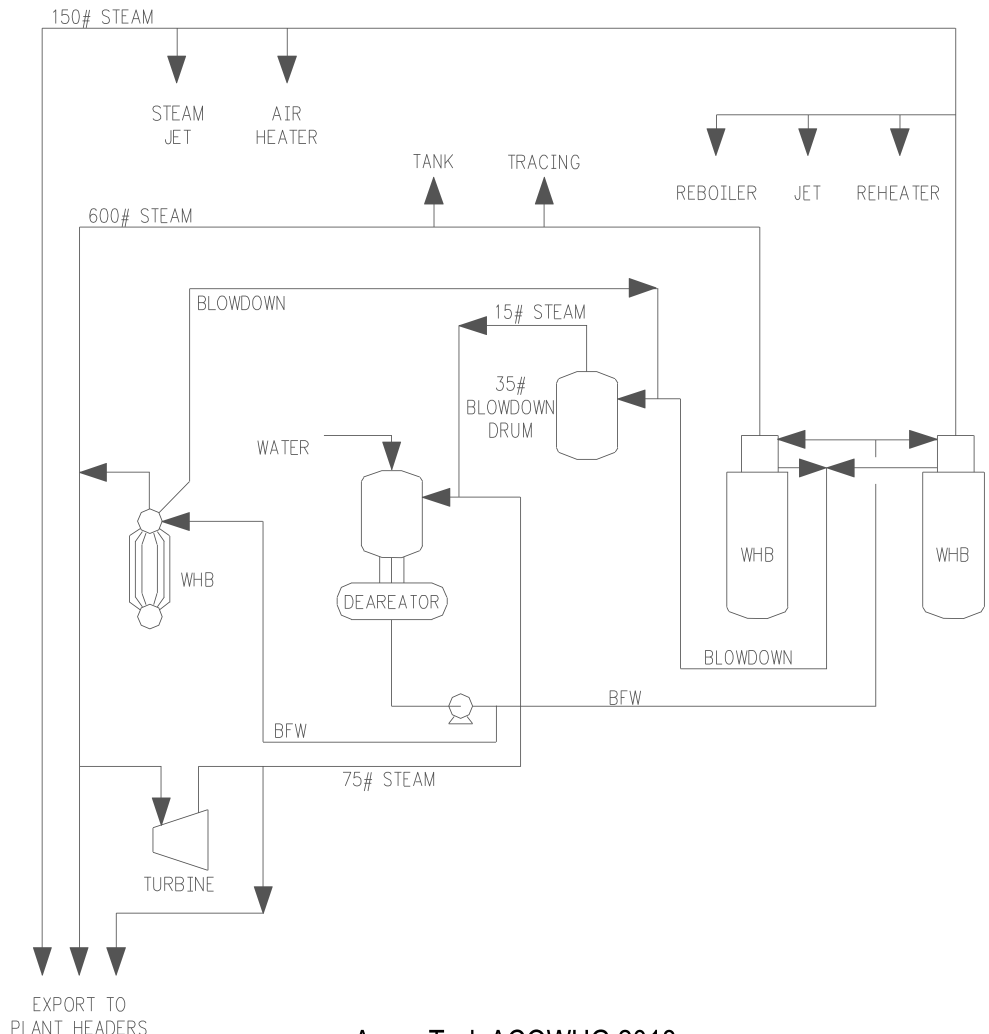
- Utilities imported will be treated as a cost with utilities exported as a credit.

Process Overview

- Five parallel reactor trains with associated cooling water and steam

- RTO benefits
  - ✓ Yield optimization
  - ✓ Optimal reactor load balancing

Steam System for one reactor train



Steam System Overview

- Each reactor train has three steam headers at three different pressure levels: HP, MP & LP
- HP, MP & LP headers are connected throughout the entire site
- LP header gets most of its steam from turbine letdowns
- All reactor trains can either import or export different pressure steams
- Each reactor train has a back pressure controller on the HP export line to maintain pressure in the reactor system

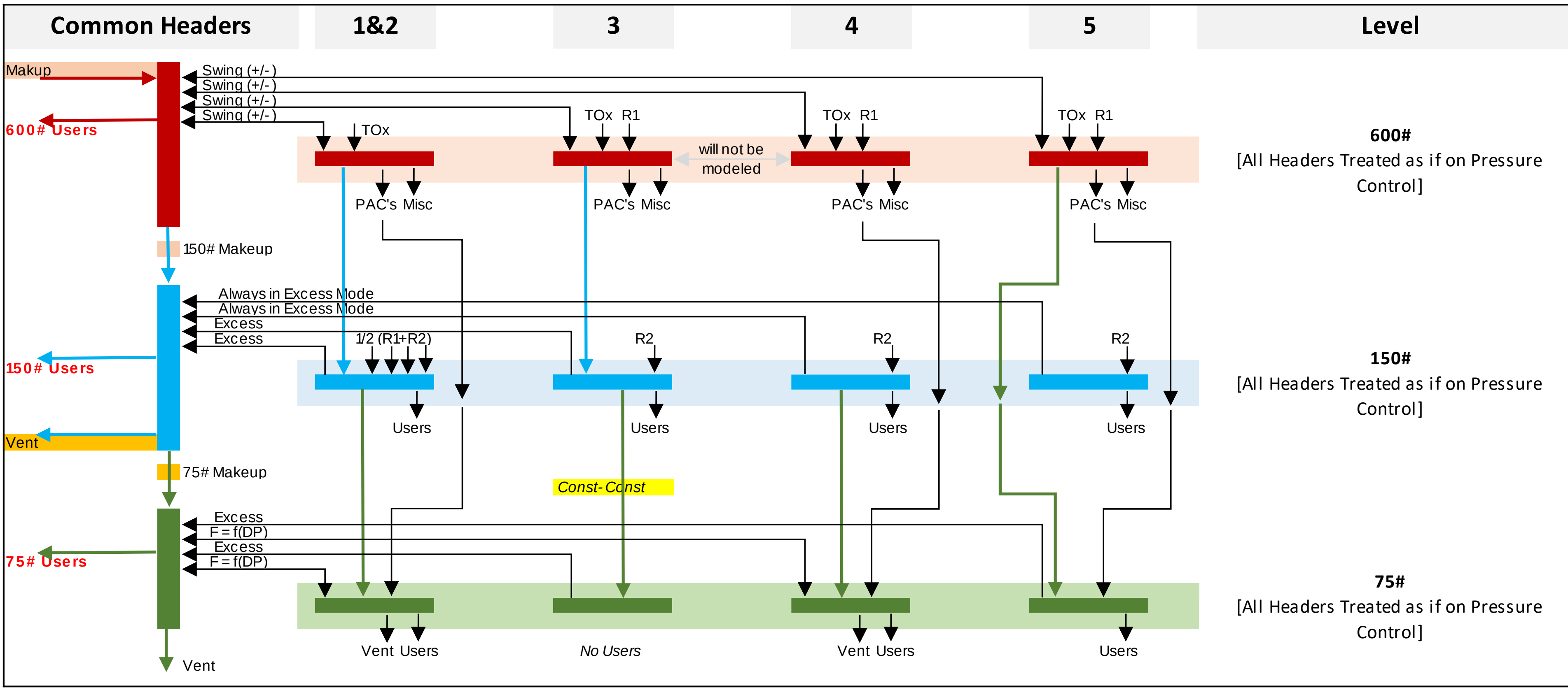
Steam Model Development

- Steam Model was developed using Aspen Plus Optimizer in equation oriented modeling environment
- Component material balance, energy balance and thermodynamics in the model with approximately 3,000 equations, 80 spec groups, 50 blocks, and 120 measurements.

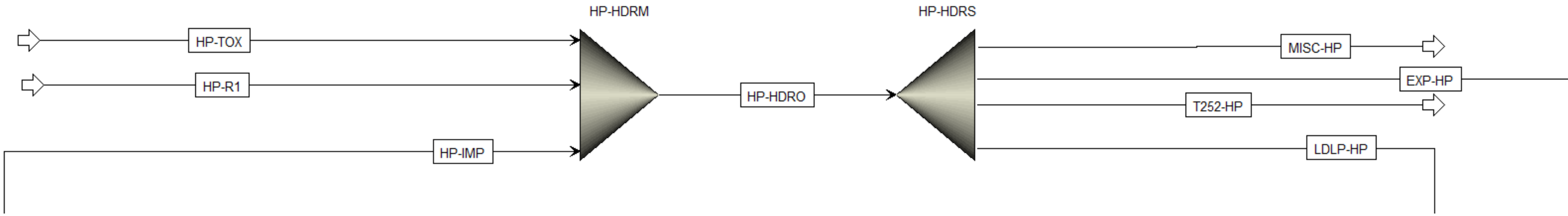
Modelling Guidelines

- Include the 600#, 150#, and 75# steam headers, the condensate return headers, deaerators, and the boiler feed water headers.
- The steam and boiler feed water sides of all heat exchange equipment are modeled within their respective process-side hierarchies.
- Makeup/letdown lines to/from the various headers to manage pressure control including logic as required (modeled using calculators).
- Lines to/from the scope of the utilities system to areas out of scope are be lumped together as required. The rates are estimated prior to solution.
- Boilers not modeled. Steam from the boilers is treated as an import line to the scope of the section and are priced appropriately.
- Steam to/from the battery limits of the scope of the integrated plant model are priced appropriately.

Overall Simplification of Steam System



HP Steam Header Model



HPSUPL = HP-TOX + HP-R1 (SUPPLY)

HPDMD = MISC-HP + T252-HP + LDLP-HP (DEMAND)

HPIMB = HPSUPL – HPDMD (IMBALANCE)

```
IF (HPIMB .LT. 0.0) THEN
        HP-IMP = - HPIMB + 1.0
        EXP-HP = 1.0
ELSE
        EXP-HP = HPIMB + 1.0
        HP-IMP = 1.0
ENDIF
```

Spec Groups for Pressure Control

Spec group: HP-PC

☑ Enabled

Description

600 PSIG HP STEAM HEADER PRESSURE CONTROL

List of variables

Variable	User spec
HP-HDRS.BLK.EXP-HP_MASS	Constant
HP-HDRS.BLK.HP-HDRO_MOLES	Calculated
HP-HDRM.BLK.HP-HDRO_MOLES	Constant
HP-HDRM.BLK.HP-IMP_MOLES	Calculated
HPHDRS.BLK.HP-IMP_MOLES	Constant
HPHDRS.BLK.HP-IMP_MASS	Calculated

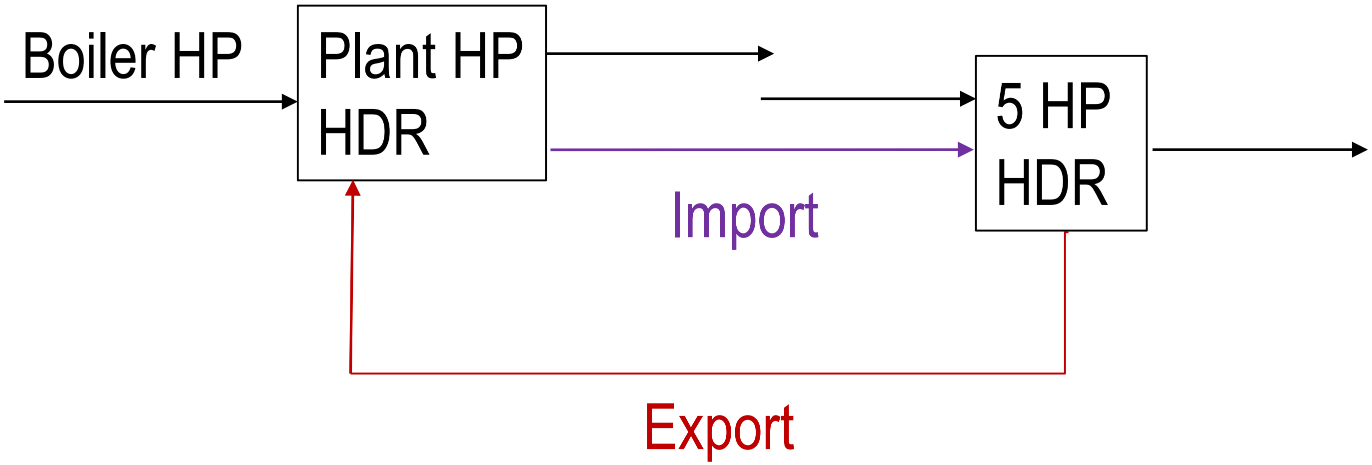
Steam Balance Results

Variable	Value (Export)	Value (Import)	Units
BLK.TOX_600_PISG_STM_GEN_F	89279.6	8927.96	LB/HR
BLK.R1_600_PISG_STM_GEN_F	78231.9	78231.9	LB/HR
BLK.HP_STM_SUPPLY	167511	87159.9	LB/HR
BLK.HP_STM_IMPORT	1	53552.9	LB/HR
BLK.HP_EXPORT	26801.8	1	LB/HR
BLK.MISC_HP_STM_USAGE_F	1999.7	1999.7	LB/HR
BLK.T252_STM_F	138711	138711	LB/HR
BLK.HP_STM_TO_LP_LD_F	1	1	LB/HR
BLK.HP_STM_DEMAND_F	140712	140712	LB/HR
BLK.600_PSIG_HP_STEAM_IMBALANCE	26799.8	-53551.9	LB/HR

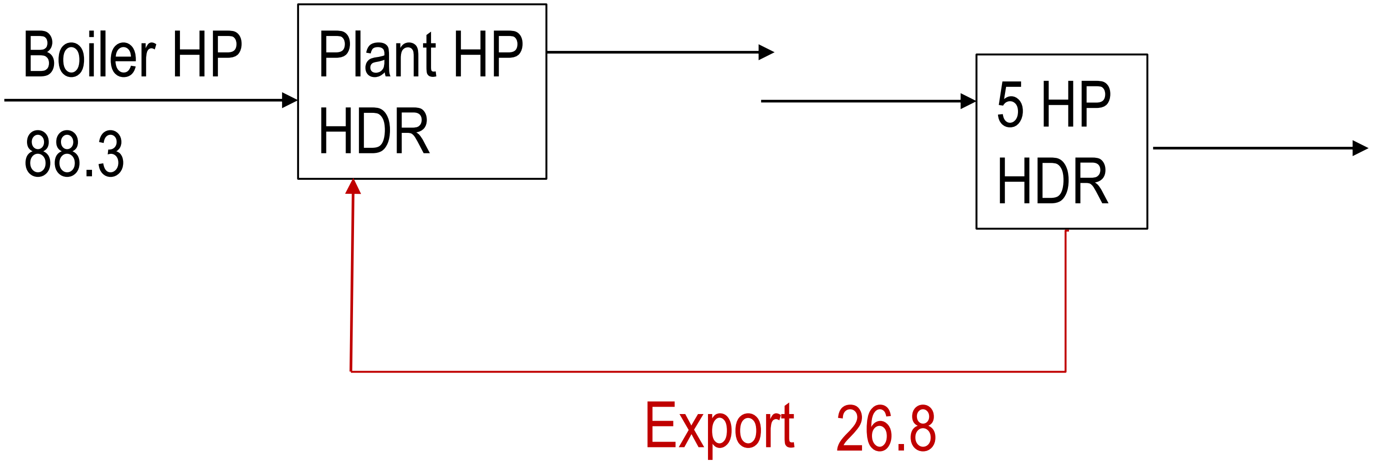
X 0.1

Export 2 Import

HP Steam Import/Export

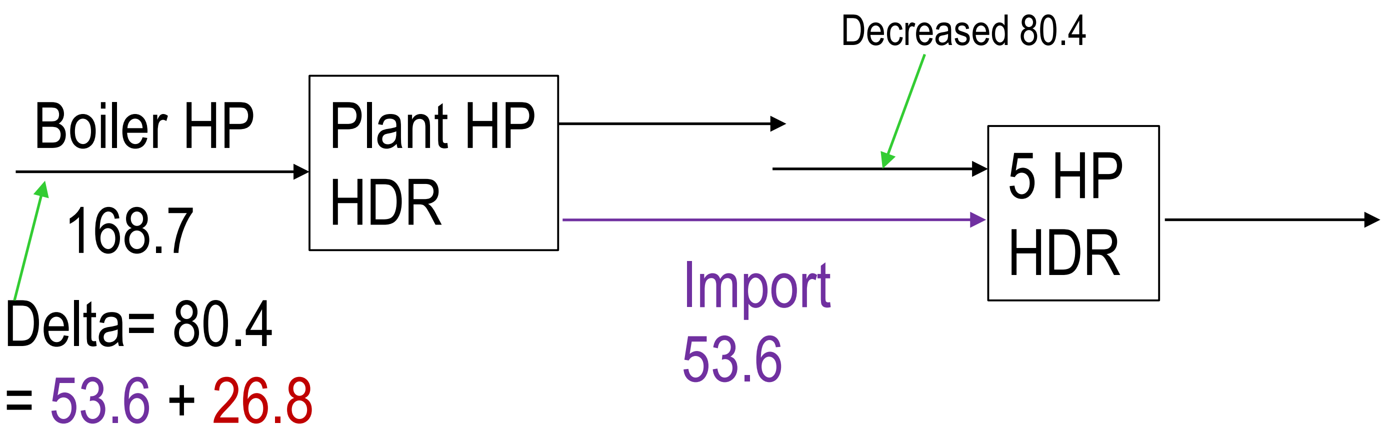


HP Steam Export



Unit: MLB/HR

HP Steam Import



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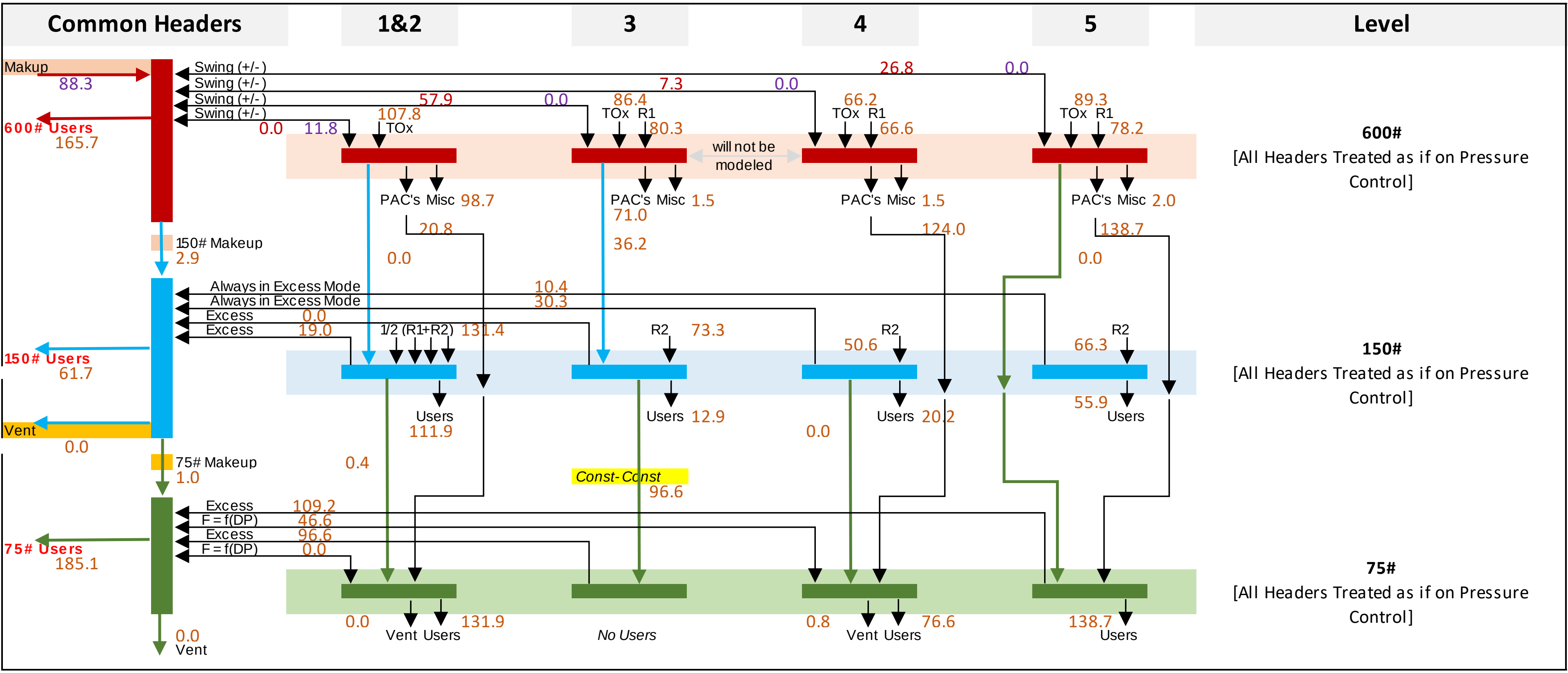
Overall Steam System Scenario Analysis Results



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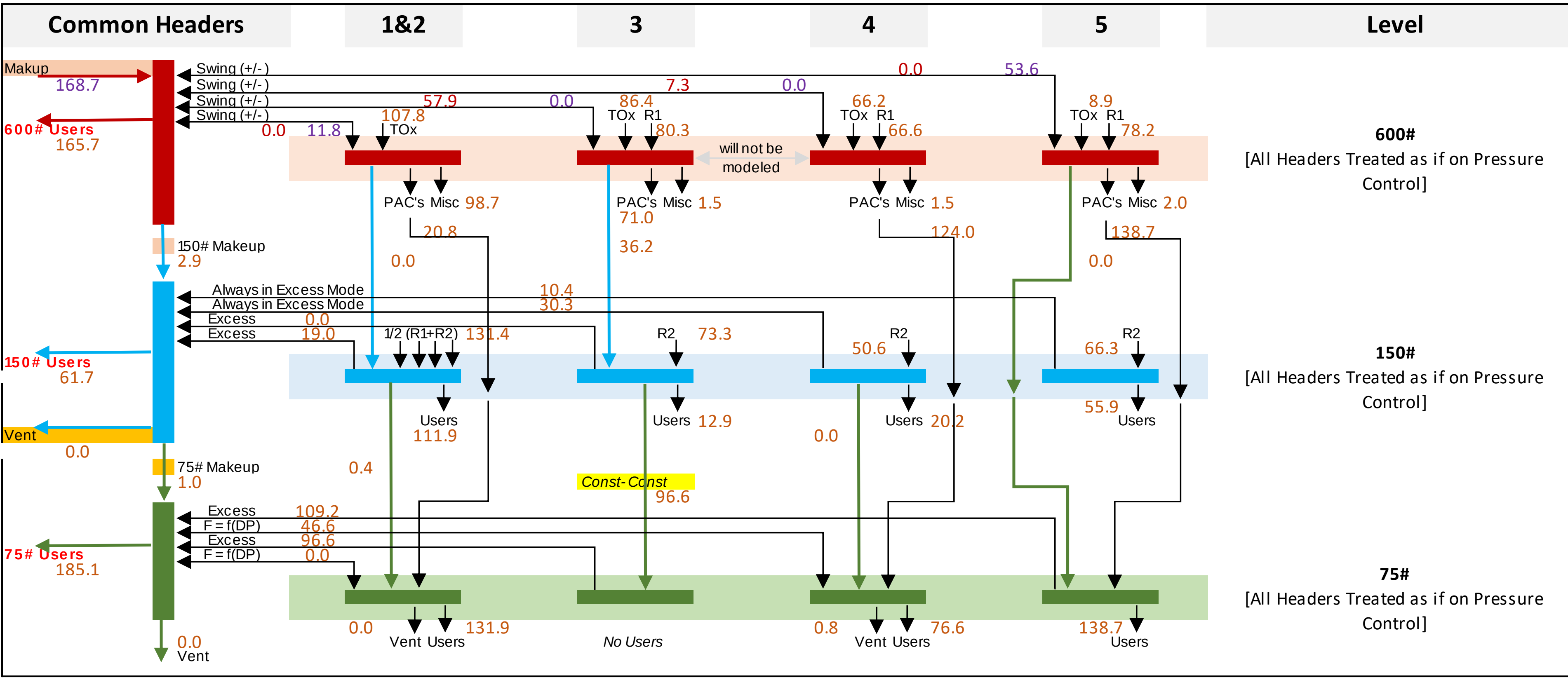
Overall Steam System Scenario Analysis Results (Cont'd)



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Summary

- Steam system modeling within a chemical plant optimizer is important to track and value the utility contribution to the objective function
- Appropriate simplifications are needed to ensure robustness for the optimizer without compromising the results
- An example of steam system model development for a chemical plant optimizer was demonstrated