MÄLARDALENS HÖGSKOLA
ESKILSTUNA VÄSTERÅS

Modeling of continuous processes like power plants and pulp mills for the purpose of process diagnostics

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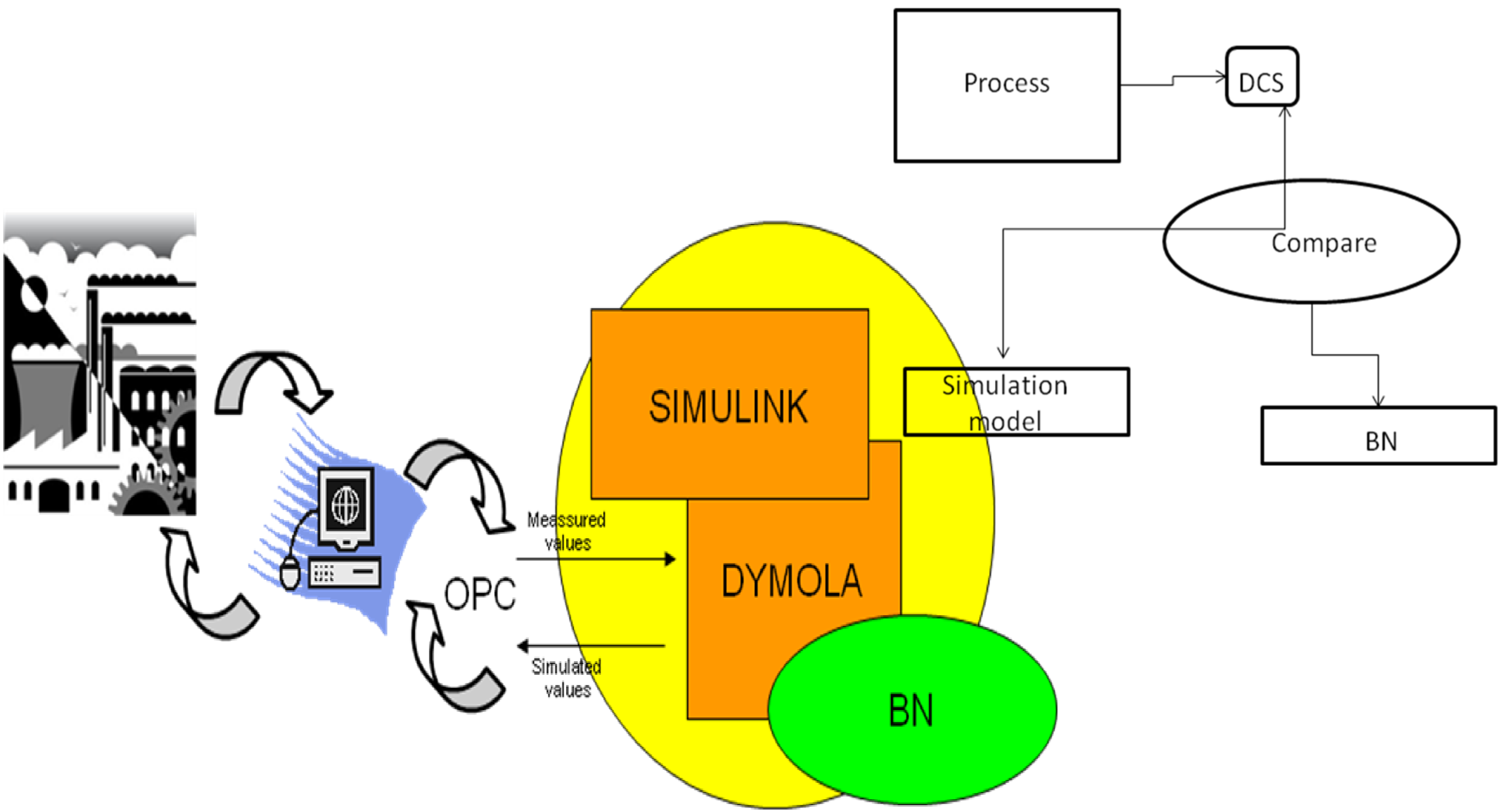
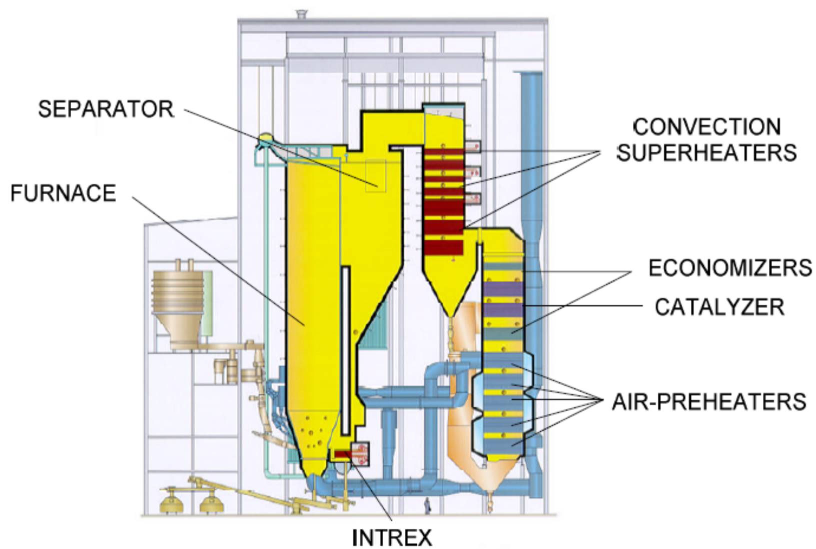
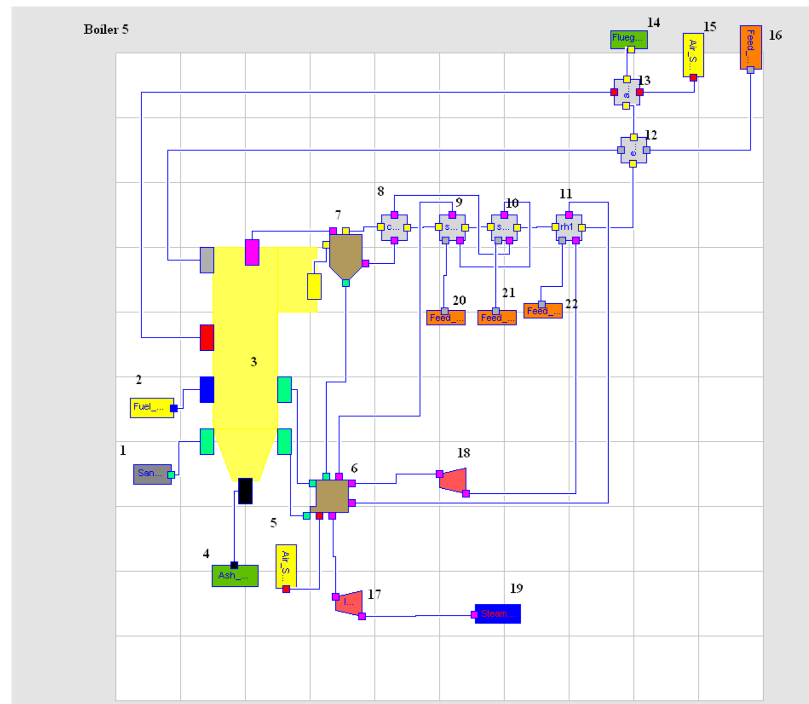
Application overview and Simulation in parallel with the process.



Mälarenergi CFB boiler





Material balances

$\partial m_{inventory} / \partial t = \sum m_{i,in} - \sum m_{i,out}$

where $m_{i,in}$ is the mass in-flow of each single component *i* ($C, H, O, N, CO_2, H_2O, NO_2$, ash) and $m_{i,out}$ is the corresponding out-flow. The change in concentration of each component *i* is given by c_i in the bed inventory:

$\partial c_i / \partial t = (\sum c_i * m_{j,in}$
$- \sum c_i * m_{k,out}) / m_{inventory}$

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Energy balances

The temperature $T_{inventory}$ in the inventory is calculated from the energy balance:

$\partial T_{inventory} / \partial t = = (\sum T_j * Cp_i * c_i * m_{j,in} - \sum T_k * Cp_i * c_i * m_{k,out}) + \Delta H - U*A*(T_{inventory} - T_{outside}))/ (m_{inventory} *(\sum c_i * Cp_i))$

Here ΔH is the energy released during combustion and U is the heat transfer number, A the area of the heat exchanger area and $T_{outside}$ the temperature at the other side of the heat exchanger surface – steam temperature vs exhaust gas temperature. Cp_i is the heat capacity for component *i*.

Effect of chemical reactions

$$\partial c_i / \partial t = (\sum c_i * m_{j,in} - k*[c_i]^a - \sum c_i * m_{k,out}) / m_{inventory}$$

k = a reaction constant and
a = an exponent giving the non-linearity of the conversion.

For components being removed c_i is decreasing while for those being created it is increasing.

Can be combustion, digestion or other reactions

CFB model verification

	$T_{st,befSH1}$	$T_{st,aftfSH1}$	$T_{st,befSH2}$	$T_{staftfSH2}$			
	376	473	444	489			
	389	475	459	498			
simulation	413	469		488			
T_{bed1}	T_{bed2}	T_{bed3}	T_{bed4}	T_{bed5}	T_{bed6}	T_{bed7}	T_{bed8}
842	807	815	837	821	804	805	835
869	830	837	863	847	831	828	863
simulation	879						
T_{fb1}	T_{fb2}	T_{fb3}	T_{fb4}	T_{fb5}	$T_{befSep1}$	$T_{befSep2}$	
521	690	726	796	803	772	767	
532	710	748	823	826	734	731	
Simulation	854				757	757	

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Model tuning

Part load (July 5, 2011) at 6.2 kg/s fuel, 30.1 kg/s air flow and 24 kg/s feed water flow

Variables	DCS	Prediction	Error%
Steam temperature after HPSH2 (oC)	434	439	1.0
Fluegas temperature after cyclone (oC)	550	566	2.9
Fluegas temperature before cyclone (oC)	551	576	4.6
Steam temperature after cyclone (oC)	366	353	-3.6

Full load (September 2011) 16.5 kg/s fuel, 79.8 kg/s air, 48.8 kg/s feed water

Steam temperature after HPSH2 (°C)	494	488	-1.2
Bed temperature (oC)	833	879	5.2
Fluegas temperature before cyclone (oC)	758	757	0
Steam temperature after cyclone (oC)	385	379	-1.5

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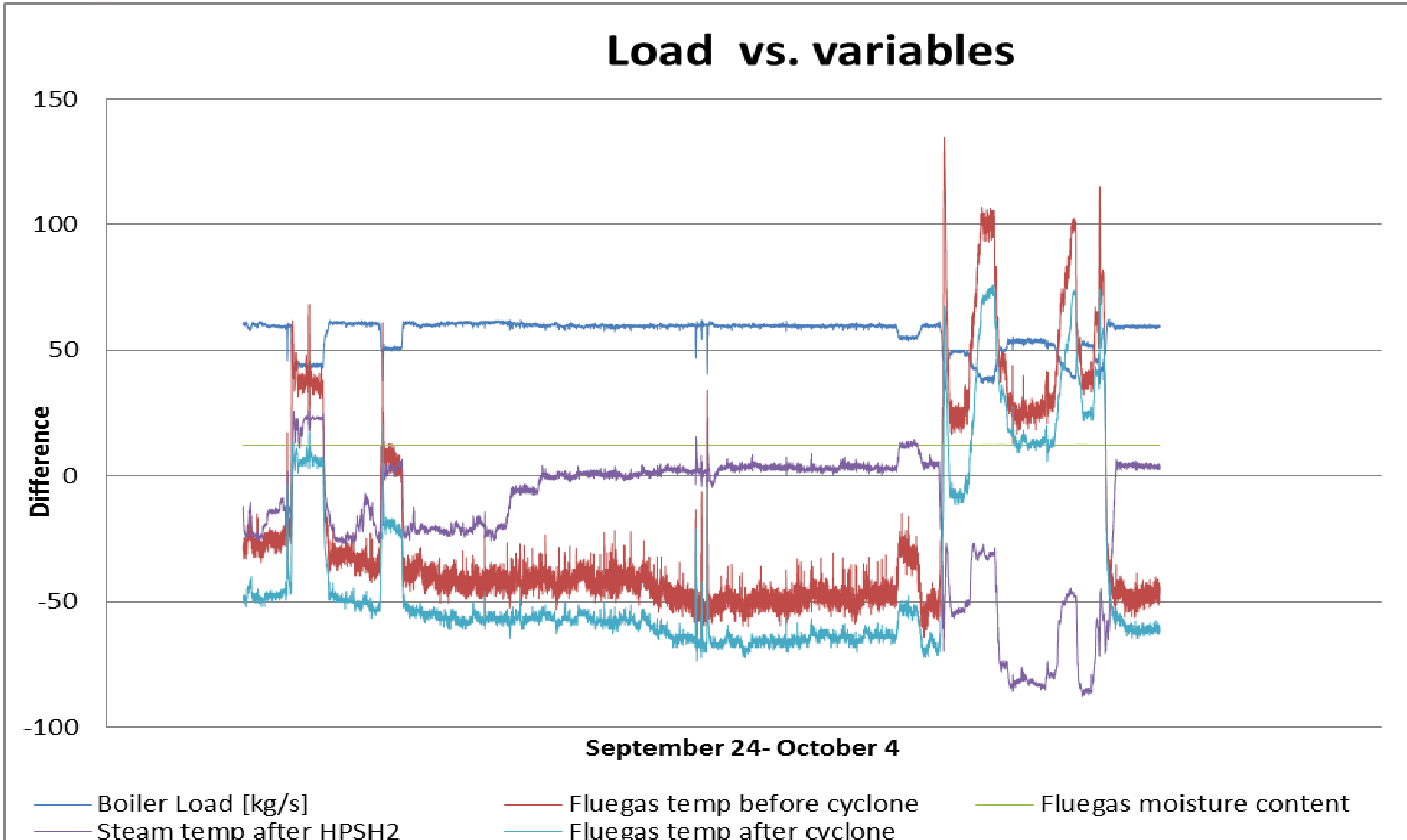
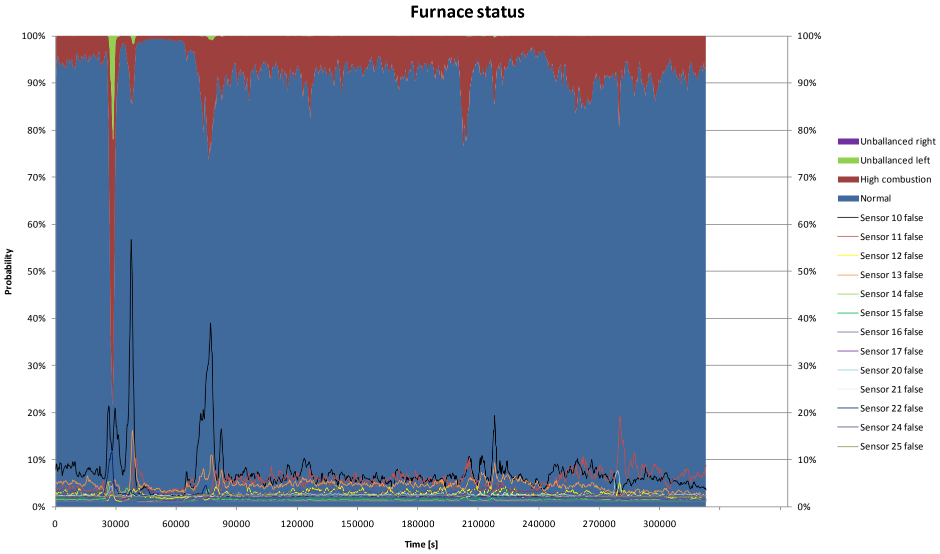
Simulated vs measured

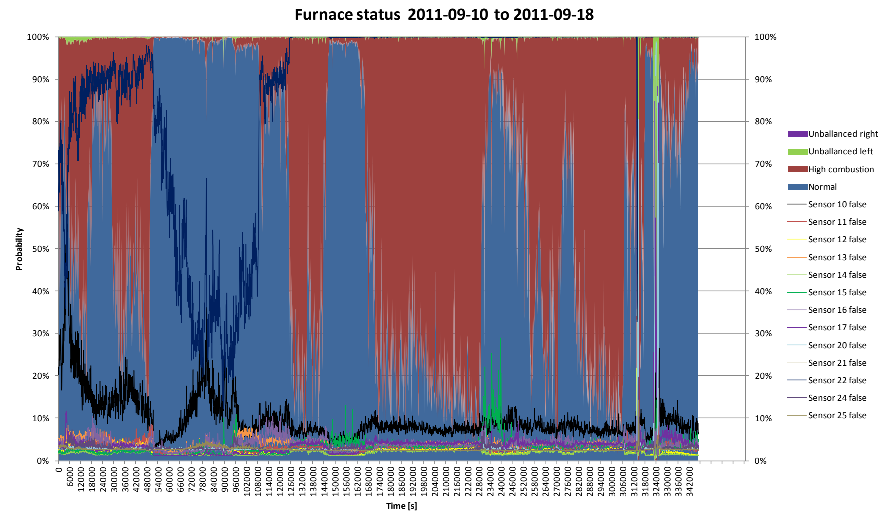


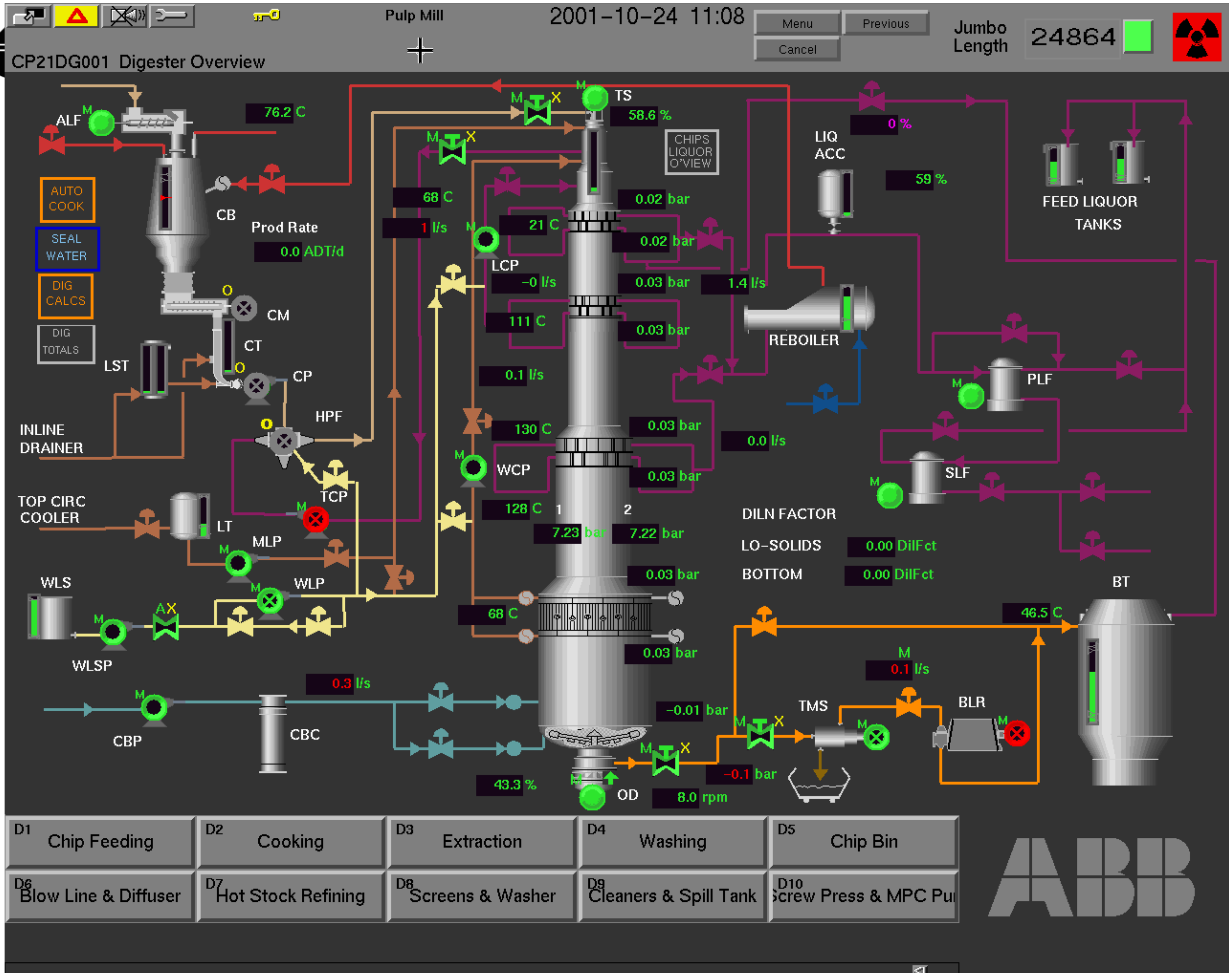
Diagnostics combined with BN

Probability for different type of faults in the CFB boiler for 16 variables as a function of time.
Variables to the right: Unbalanced right, unbalanced left, high combustion, 6 temperature sensors in the bed, 7 temperature sensors above the bed.

To the left – September 2010. To the right September 10 to September 18, 2011

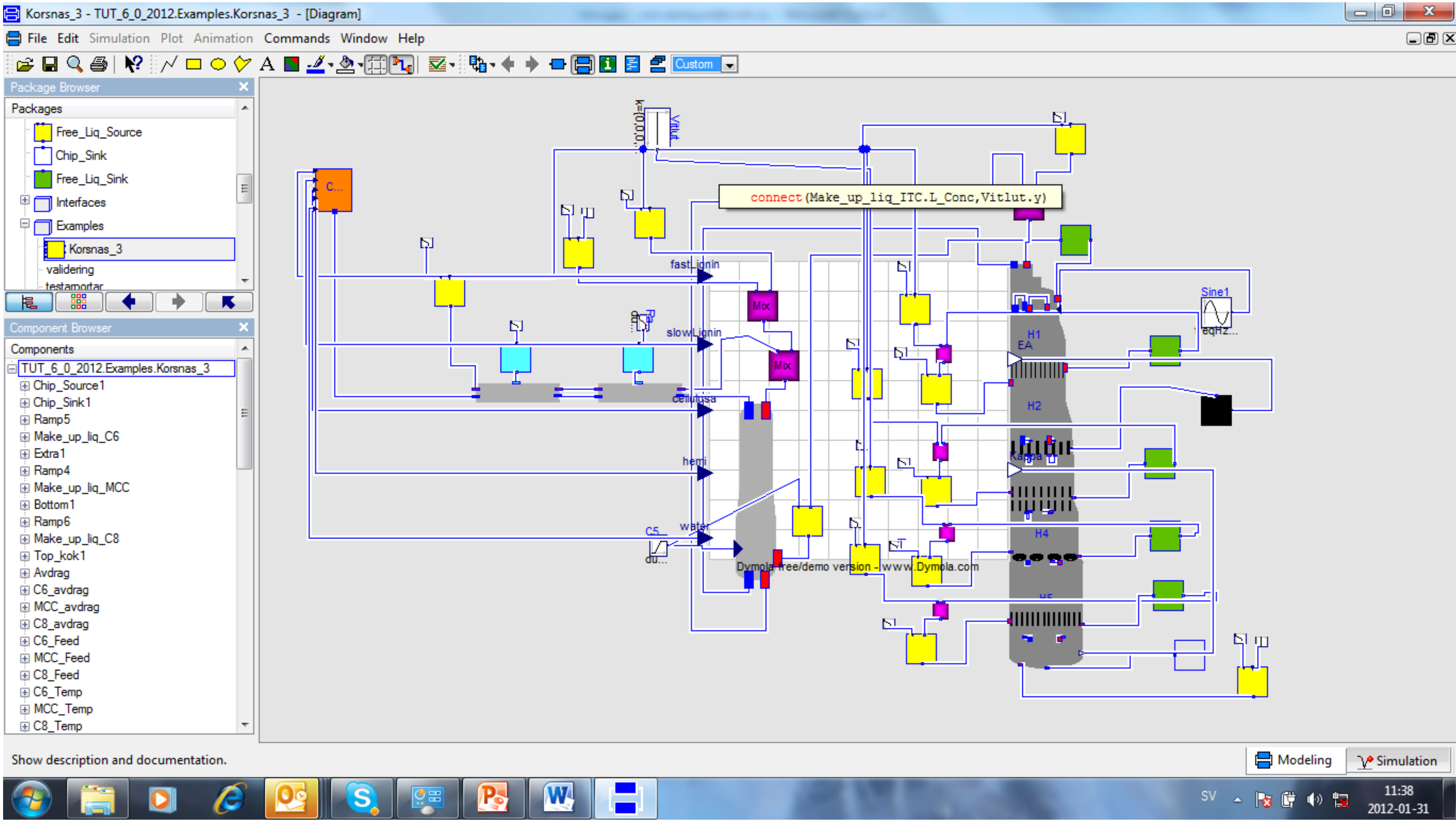




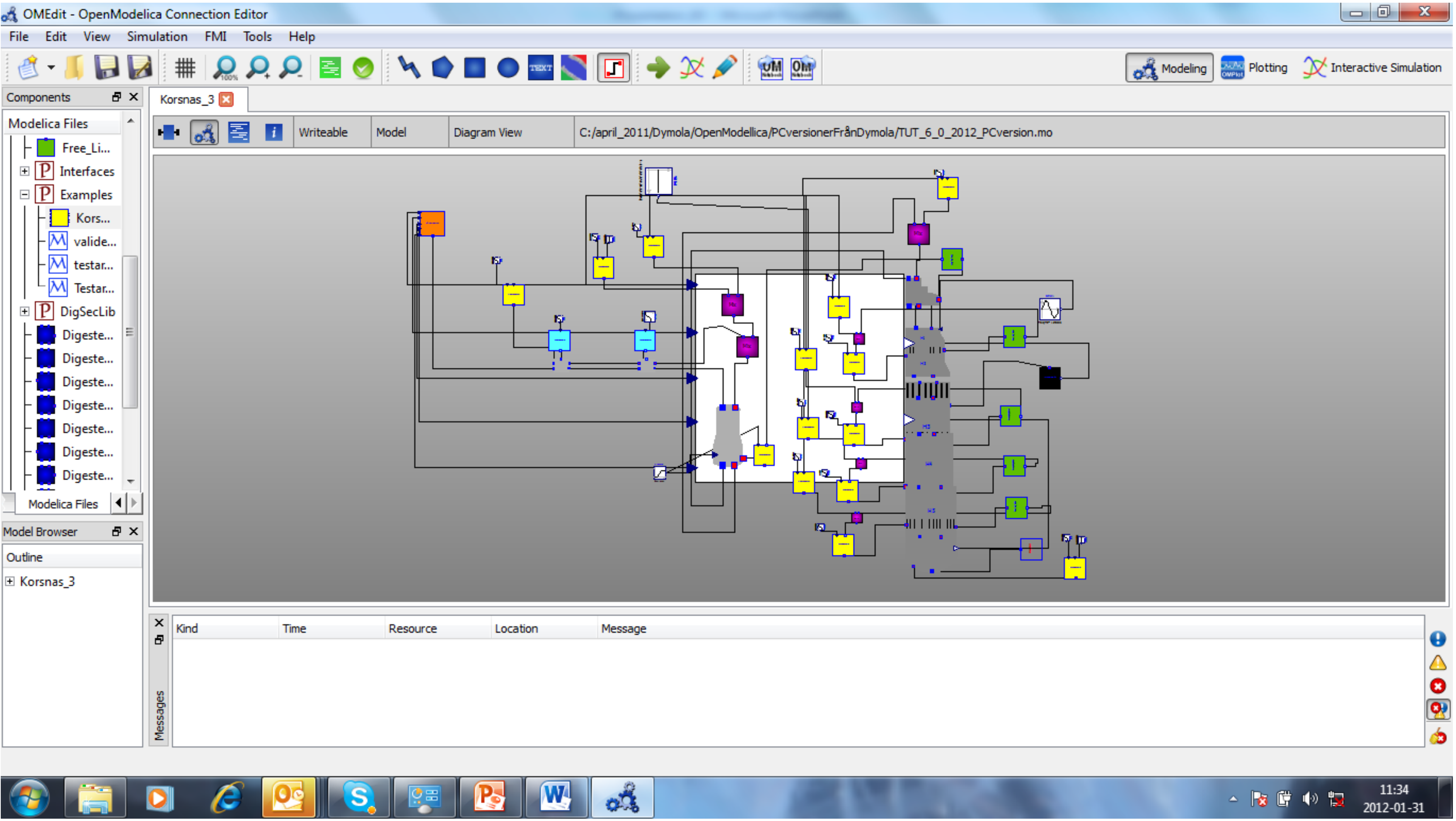


Pulp Mill
2001-10-24 11:08
Menu
Previous
Cancel
Jumbo Length
24864
CP21DG001 Digester Overview
ALF
76.2 C
TS
58.6 %
CHIPS LIQUOR O'VIEW
LIQ ACC
0 %
59 %
FEED LIQUOR TANKS
AUTO COOK
SEAL WATER
DIG CALCS
DIG TOTALS
CB
Prod Rate
0.0 ADT/d
68 C
1 l/s
0.02 bar
21 C
0.02 bar
LCP
-0 l/s
0.03 bar
1.4 l/s
CM
111 C
0.03 bar
REBOILER
CT
LST
CP
0.1 l/s
PLF
HPF
130 C
0.03 bar
0.0 l/s
INLINE DRAINER
WCP
0.03 bar
SLF
TOP CIRC COOLER
TCP
LT
128 C
1
2
DILN FACTOR
7.23 bar
7.22 bar
MLP
LO-SOLIDS
0.00 DilFct
BOTTOM
0.00 DilFct
0.03 bar
WLS
WLP
BT
68 C
46.5 C
WLSP
0.03 bar
0.1 l/s
0.3 l/s
TMS
BLR
-0.01 bar
CBP
CBC
-0.1 bar
43.3 %
OD
8.0 rpm
D1 Chip Feeding
D2 Cooking
D3 Extraction
D4 Washing
D5 Chip Bin
D6 Blow Line & Diffuser
D7 Hot Stock Refining
D8 Screens & Washer
D9 Cleaners & Spill Tank
D10 Screw Press & MPC Pu

Digester model in Dymola



Digester model in OM



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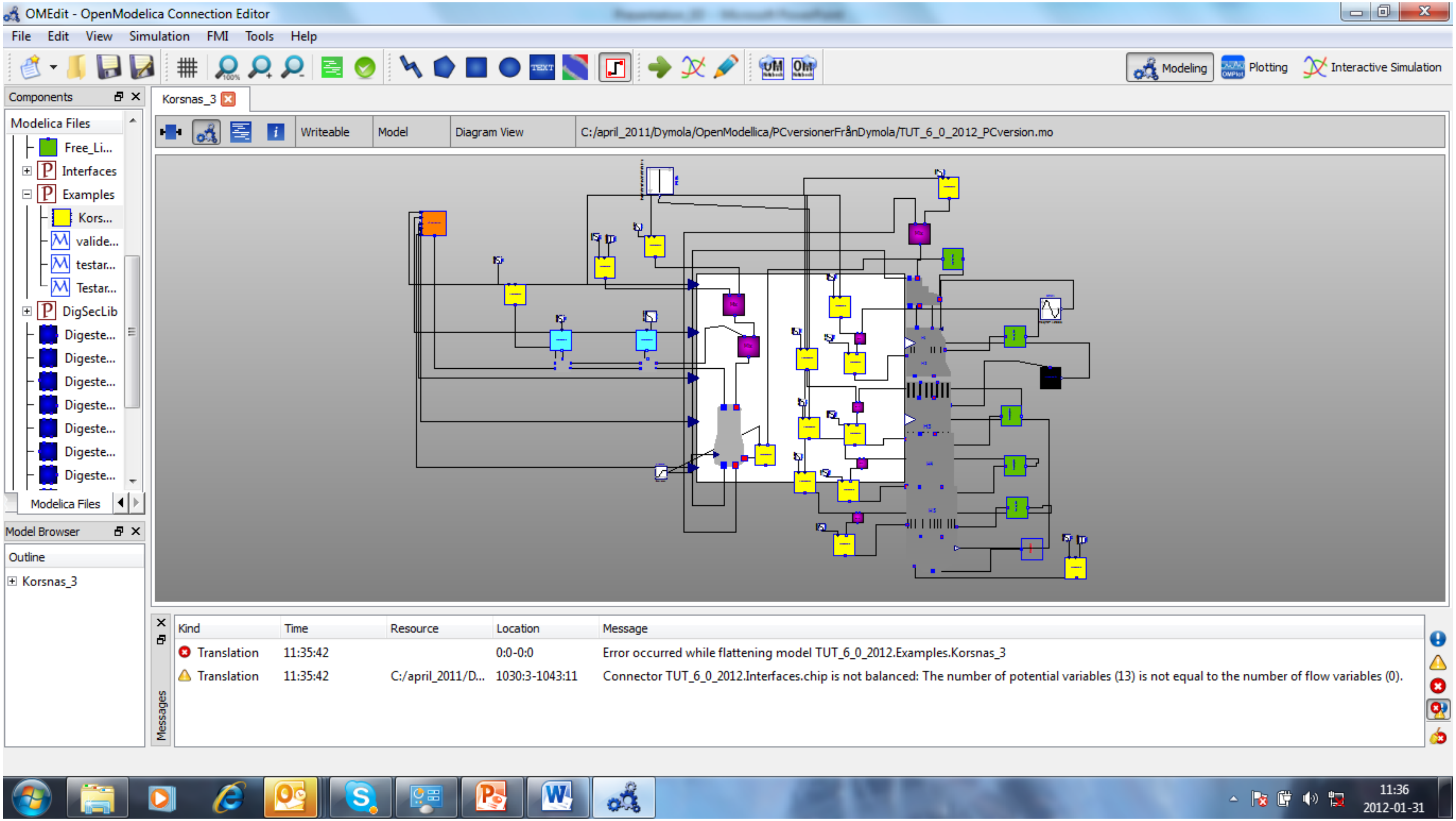
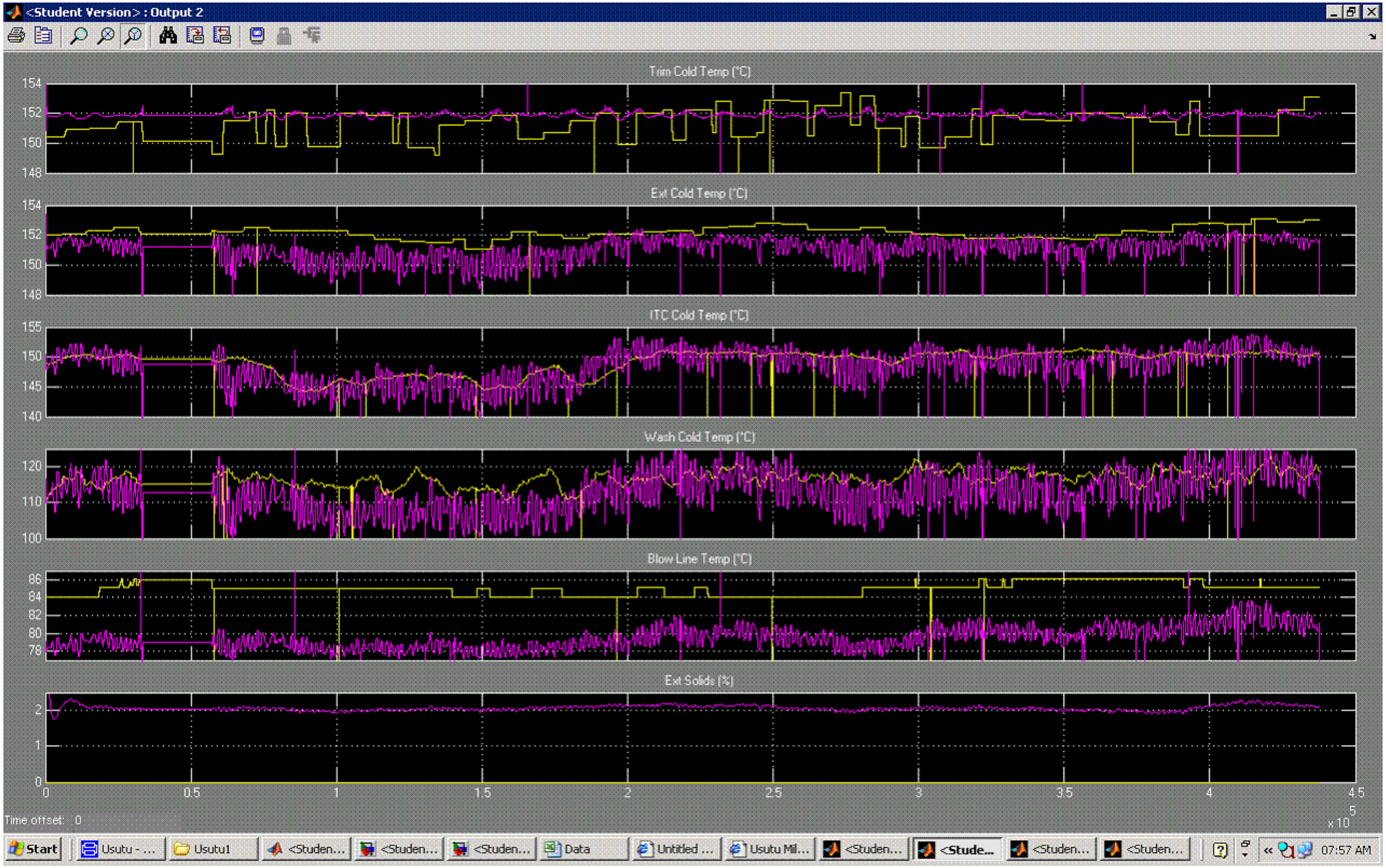
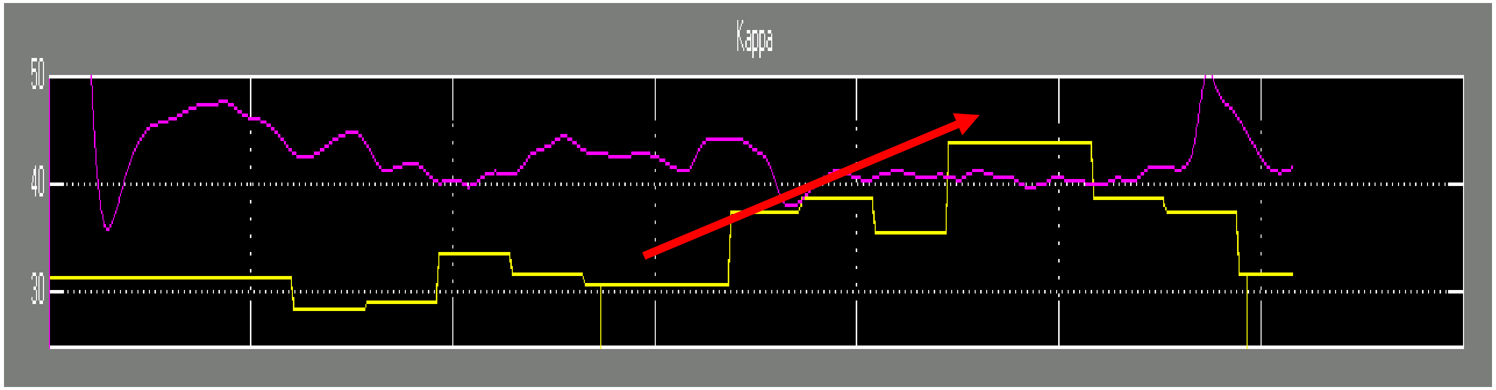
Crashing in OM



Diagnostics – comparing simulated to measured data on-line. Korsnäs and Usutu continuous digesters

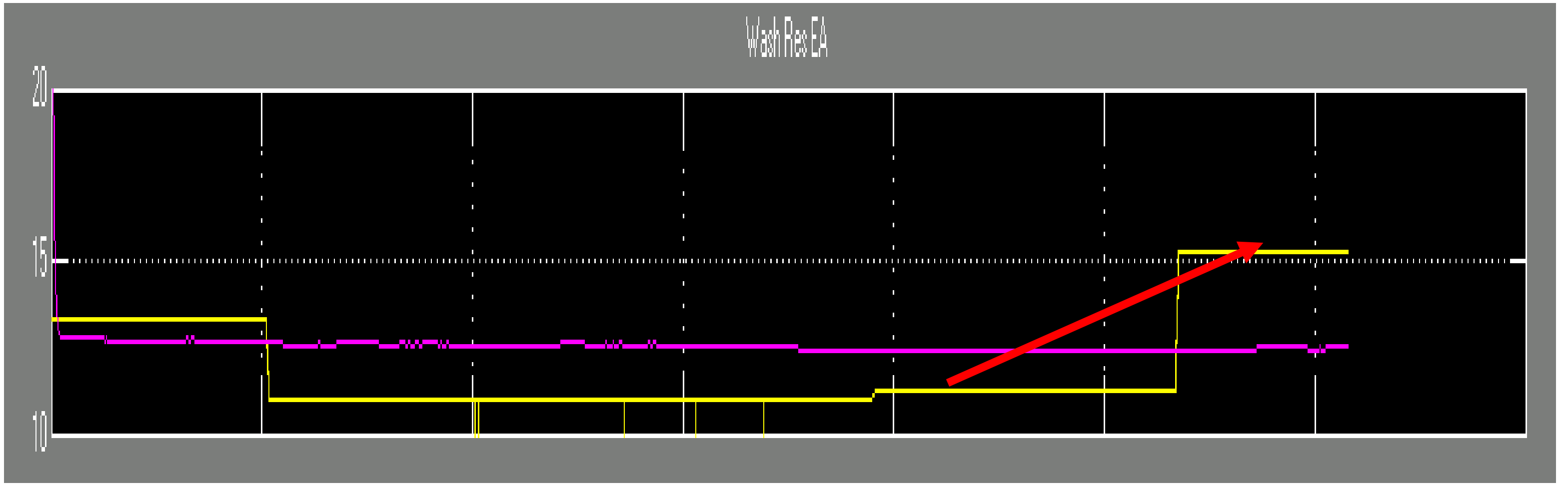


Channelling gave increased kappa number



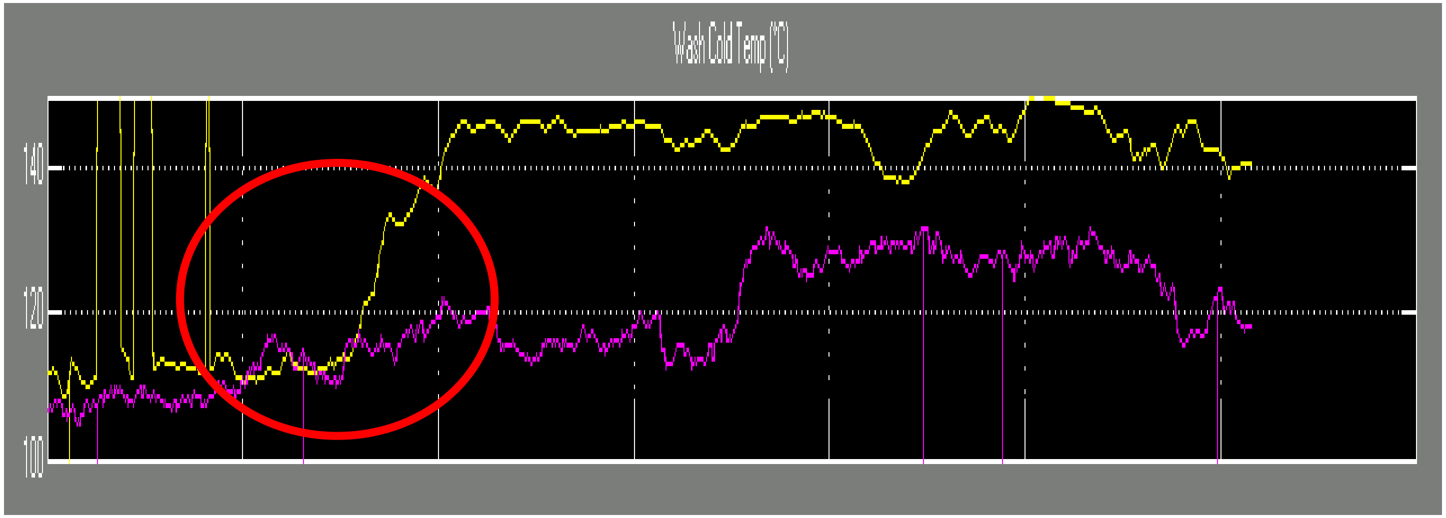
Kappa number during channelling :
- yellow curve = measured process value
- violet line = predicted value from simulation).

The alkali was higher than predicted during channelling.



Residual alkali in extraction flow during channelling:
- yellow curve = measured process value –
- violet line = predicted value from simulation.

The temperature was higher than predicted.



-Temperature in the extraction flow during channelling:
- yellow curve = measured process value
- violet line = predicted value from simulation

Conclusions

- We can transfer simpler models between Dymola and OM, but have problems with larger
- Takes longer to compile in OM than Dymola
- OM has develped enormously from a user friendliness perspective!
- Takes some time to understand the differences. We have not done so yet.
- Modelica is a very useful tool, and at least the Dymola version can be used on-line. Anyone with experience of using OM for on-line? Please contact us!

Dynamic simulation