OVERVIEW

OF

Performance Analysis Diagnostics & Optimization (PADO)

How to Improve Efficiency ?

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First Step: low hanging fruits

- ❑ Improve efficiency by improving operation and maintenance

Next Steps:

- ❑ Audit or „map“ the plant using off line modelling tool e.g. Ebsilon
- ❑ Online optimization tool PADO
- ❑ Online fault detection system using SPC and Fault trees
- ❑ Online life time monitoring SR1 for better planning of inspections and maintenance

Why to use the PADO tools ?

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DCS also has the information needed to do the calculation of efficiencies & heat rates

But what are the limitations ?

1. DCS does not give the system wise efficiencies so you do not know where the losses occur

2. Data from I/O points e.g. Temperature, pressure mass flow could be wrong because of sensor errors, bad connectors etc. That makes calculation erroneous.

3. DCS does not give advice on what to do

PADO: Online Optimization Sequence

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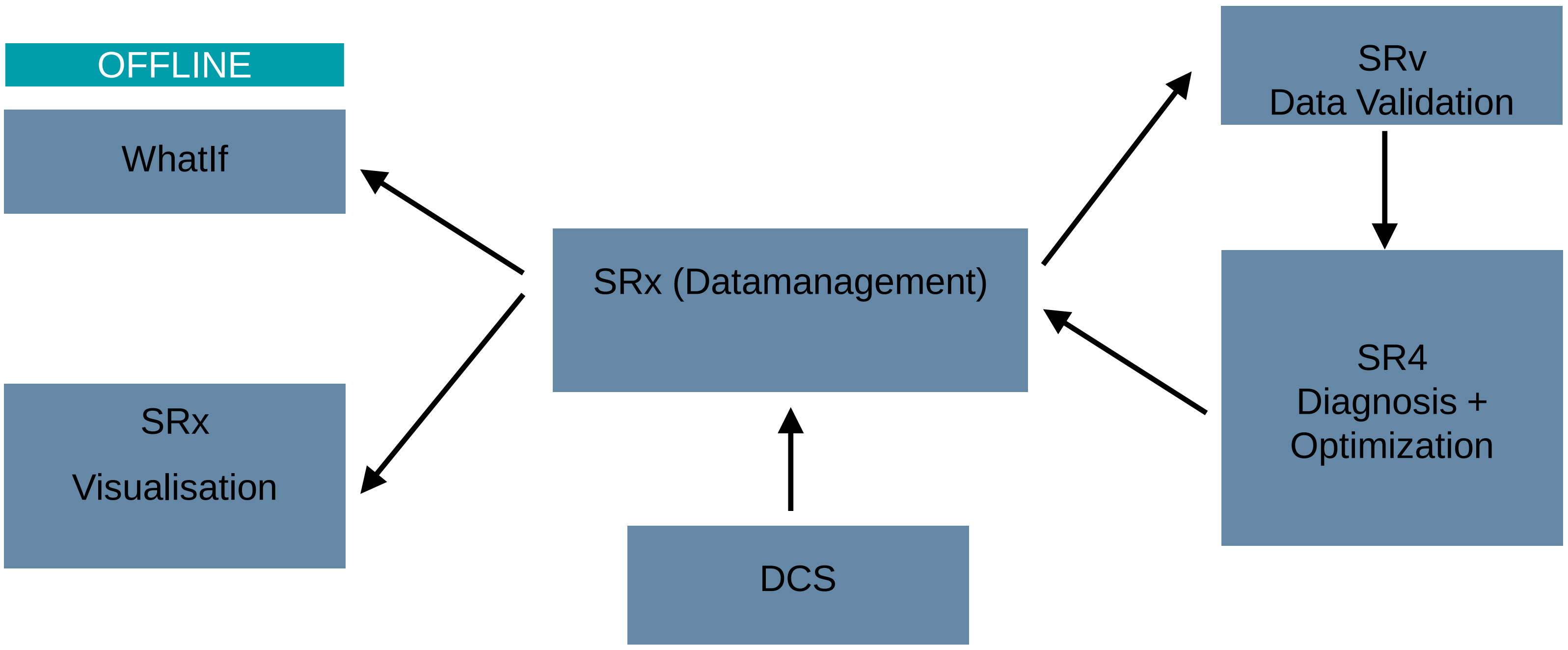
1. All relevant data from DCS which goes into calculation need to be validated i.e. all implausible values have to be replaced by plausible values

2. All calculations must be done every 5 minutes so as to continuously monitor component and heating surface efficiencies.

3. Results should be presented in user friendly manner: state of comonents indicated by green, yellow, red and losses expressed in monetary value per hour

PADO Functions



PADO in India

80 units order for PADO have been placed on SESI
27 units successfully commissioned till date

National Thermal Power Corporation (NTPC)

The largest power generating major of India generating power from Coal and Gas with an installed capacity of 34,194 MW, has standardised on Steag PADO for all future units including Super-Critical Units.

Bharat Heavy Electricals Limited (BHEL)

The largest supplier of power equipment with 70% of current installed market of Thermal Power Plants has a Framework Agreement with SESI for installation of PADO for all future units including Super-Critical Units.

PADO in India (2)

55 units where PADO is commissioned or under commissioning

- NTPC Simhadri 2x500 MW
- NTPC Ramagundam 1x500 MW
- NTPC Rihand 2x500 MW
- NTPC Talcher 4x500 MW
- NTPC Kahalgaon 3x500 MW
- NTPC Sipat 2x500 MW
- NTPC Vindhyachal 2x500 MW
- NTPC Korba 1x500 MW
- NTPC Dadri 2x500 MW
- NTPC Farakka 1x500 MW
- Mahagenco Khaparkheda 1x500 MW
- Mahagenco Bhusawal 2x500 MW
- NTPC Simhadri (stage II) 2x500 MW
- NTPC Jhajjar 3x500 MW
- KPCL Bellary (KPCL) 1x500 MW
- RVUNL Stage 1 and 2 Chhabra 3 x 250 MW
- Shree cement Ltd. RAS
- DVC Maithan 2x500 MW
- GEB Ukai 2x500 MW
- NTPC Korba Extn 1x500 MW
- NTPC Bongaigaon 3x250 MW
- TNEB North Chennai 2x600 MW
- CSEB Marwa 2x500 MW
- CSEB Korba 1x500 MW
- L&T Rajpura 2x700 MW
- L&T Koradi 3X660 MW
- Sterlite Jharsuguda 4X600 MW

Signing of Framework Agreement

Advantages of PADO

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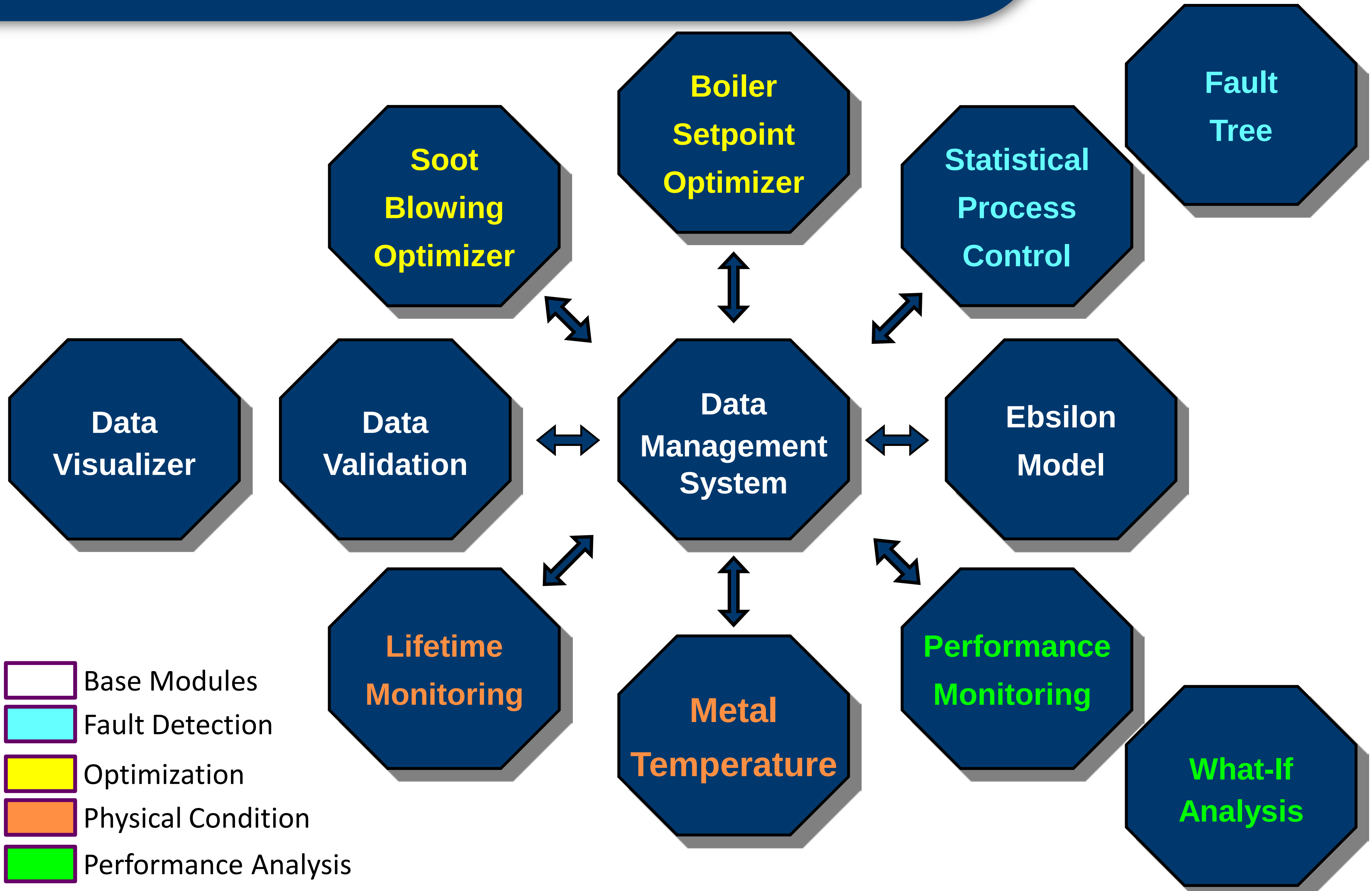
- Improving the quality of measurements by data validation
- Evaluation of boiler, turbines, condenser and other components
- Optimization of unit operation (sootblowing, setpoints)
- Calculation of what-if scenarios
- Generation of daily and monthly reports
- Enhance the efficiency of the power plant !

Modules of PADO System



SR::x Data Management System

SR::x is the central data management in the SR product family

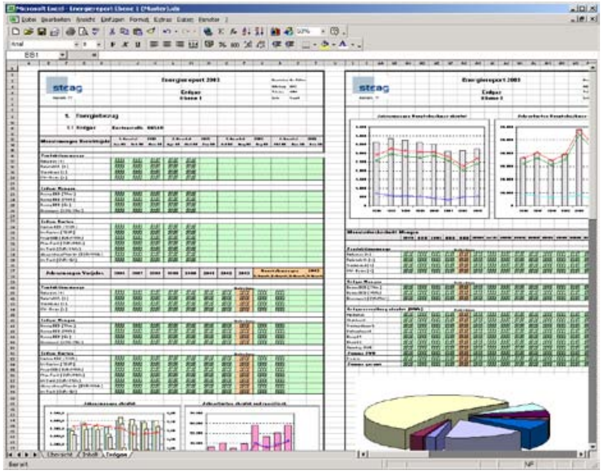
– Competitive server featuring a "state-of-the-art" visualization

– Long-term storage of measured and computed values in time-oriented archives;
base time class is 'minute values'

– Automatic aggregation to higher time classes such as 5'-, quarterly-, hourly-, daily-, monthly- or yearly-values

– Integrated mathematical formula editor

– Excel-Add-In and HTML-List Generator allow the generation of extensive reporting systems



SR::x Data Management System

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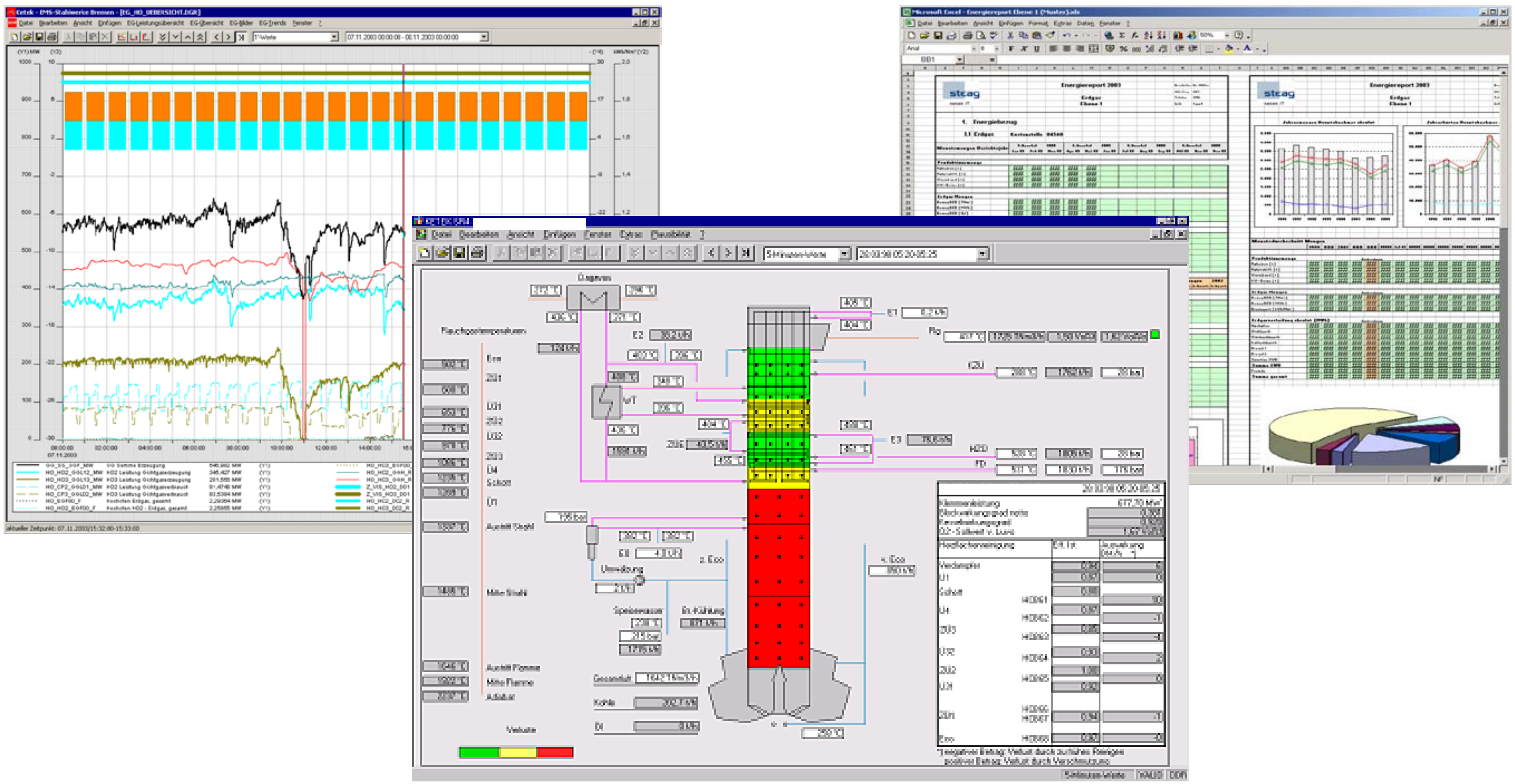
SR::x is the central data management with “state-of-the-art” visualization

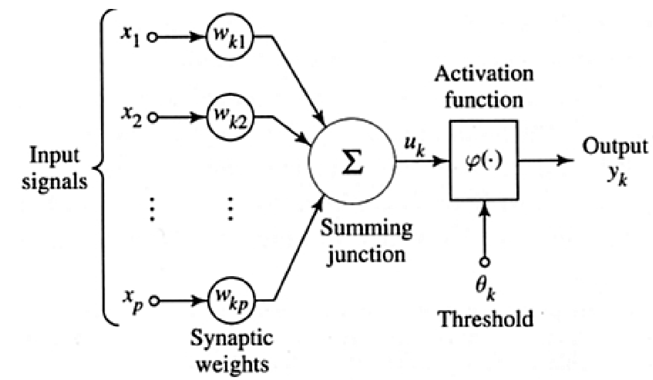


Data Validation System

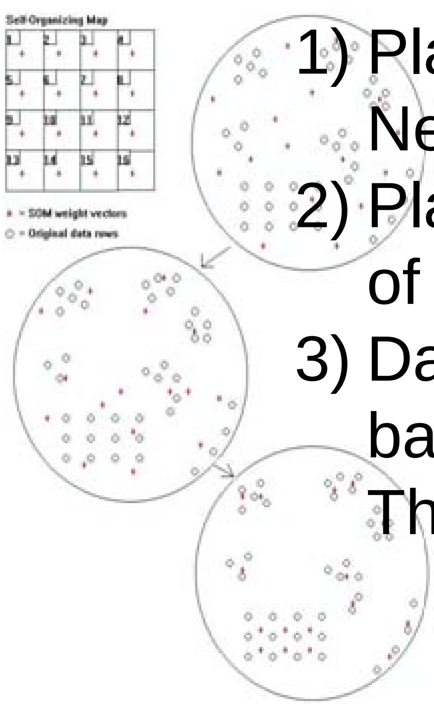
Data Validation to replace data errors due to defective sensor or cable problems:

Incorrect Data – Wrong results

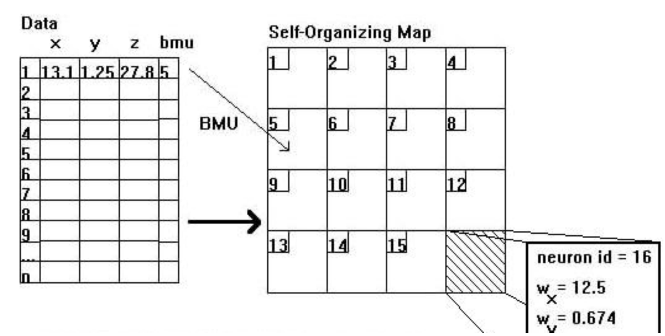
No data – No results



Validation – A 3 tier Process

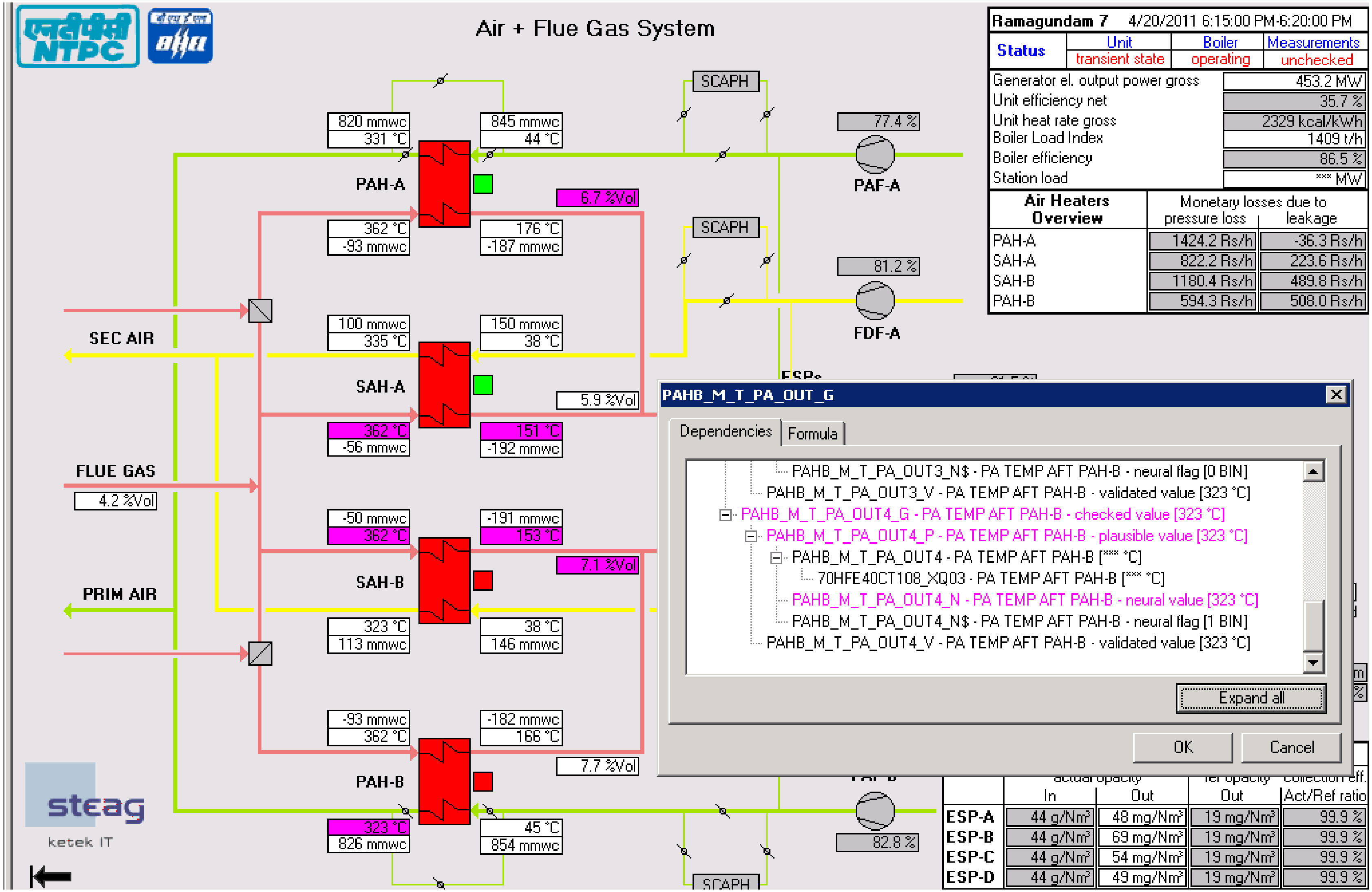


1) Plausibility Check using Neural Networks
2) Plausibility Check based on range of Values
3) Data validation / reconciliation based on “First Principle Thermodynamic” model



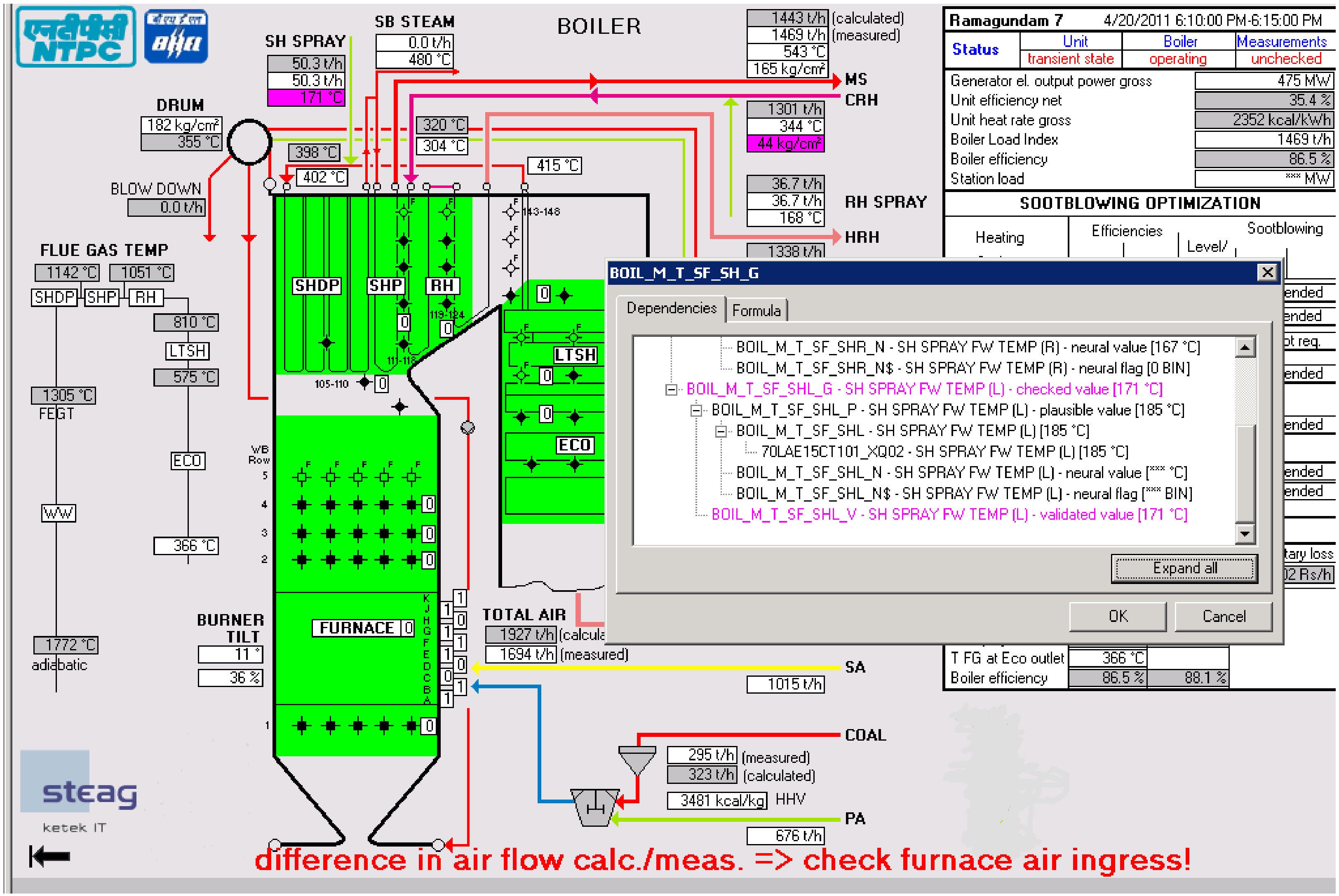
Data Validation System (1)

based on Neural Network…



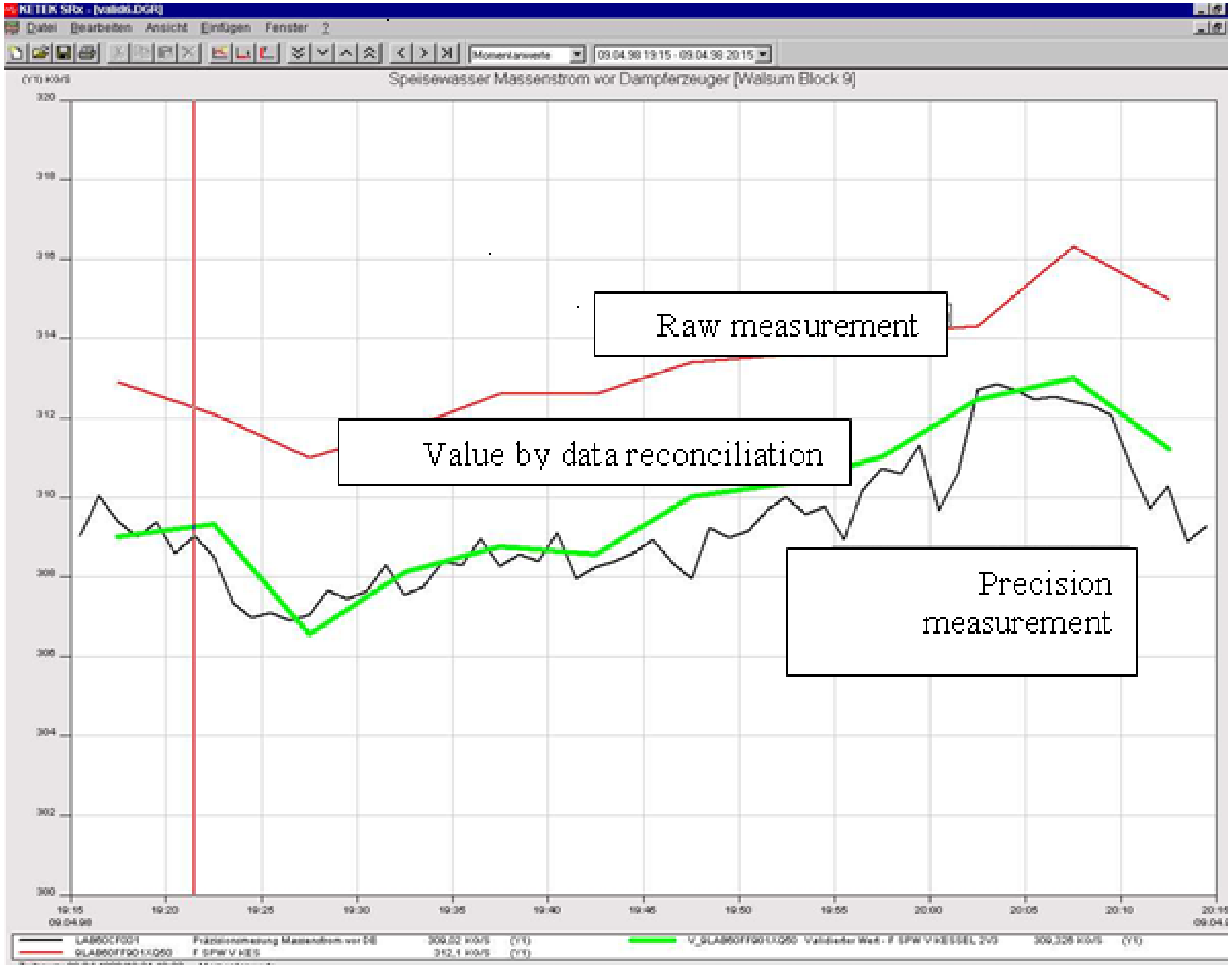
Data Validation System (2)

based on “First Principle Thermodynamics”…

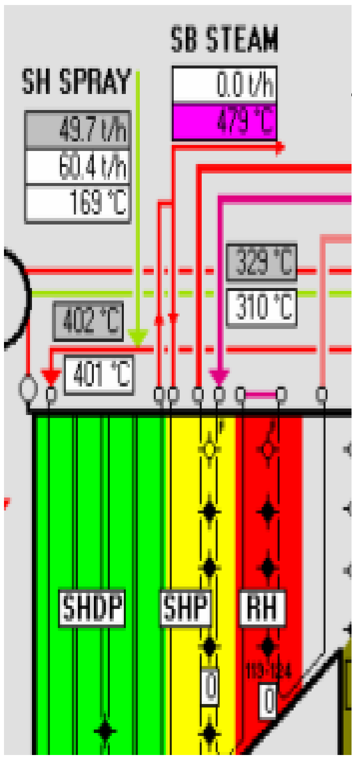


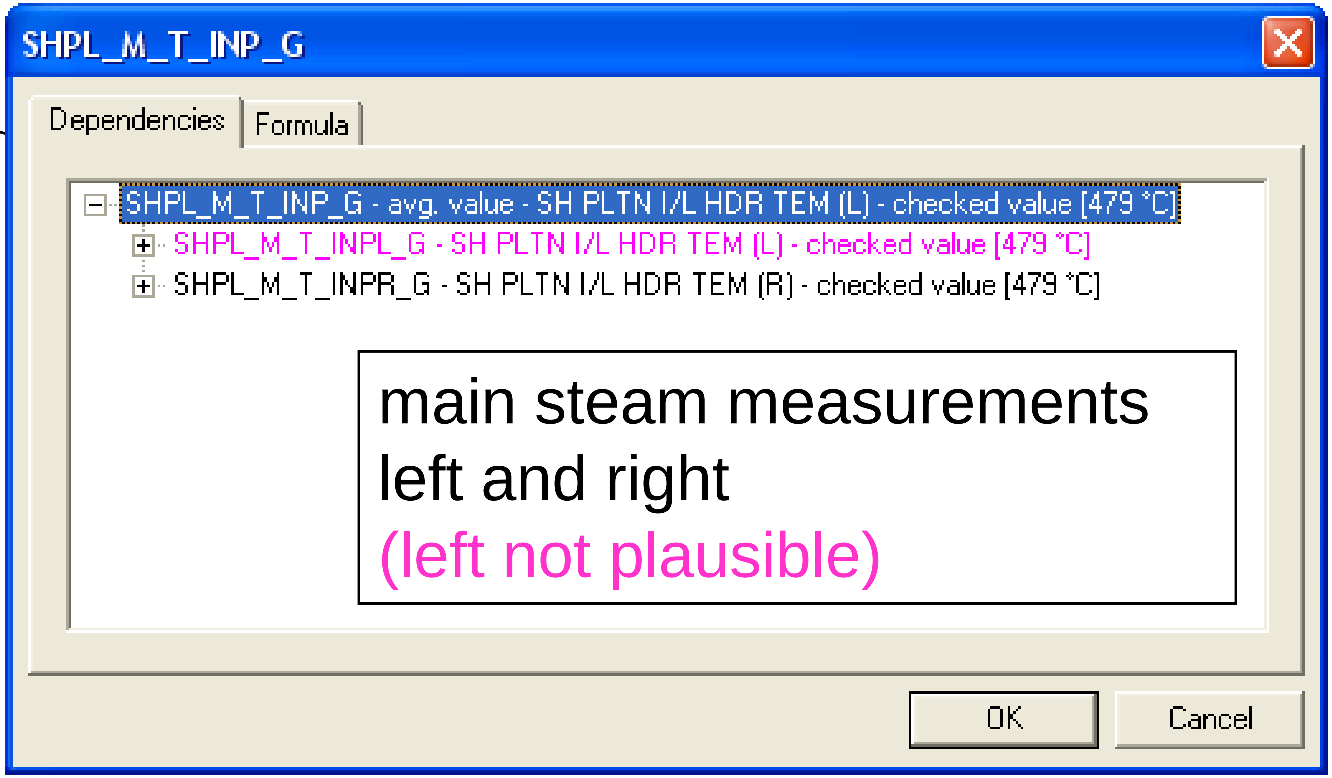
Data Validation System (3)

check the quality of measurements …



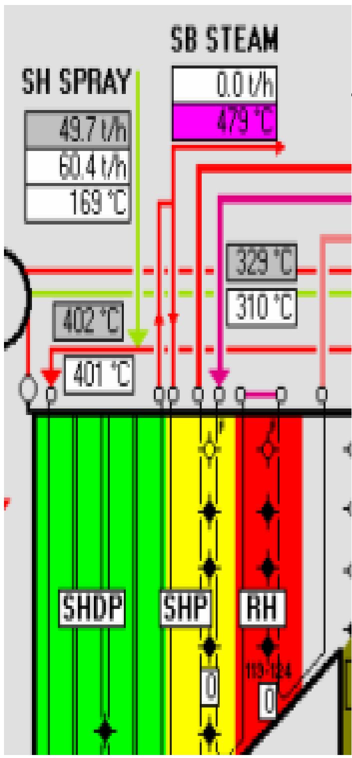
Implausible Value - detection

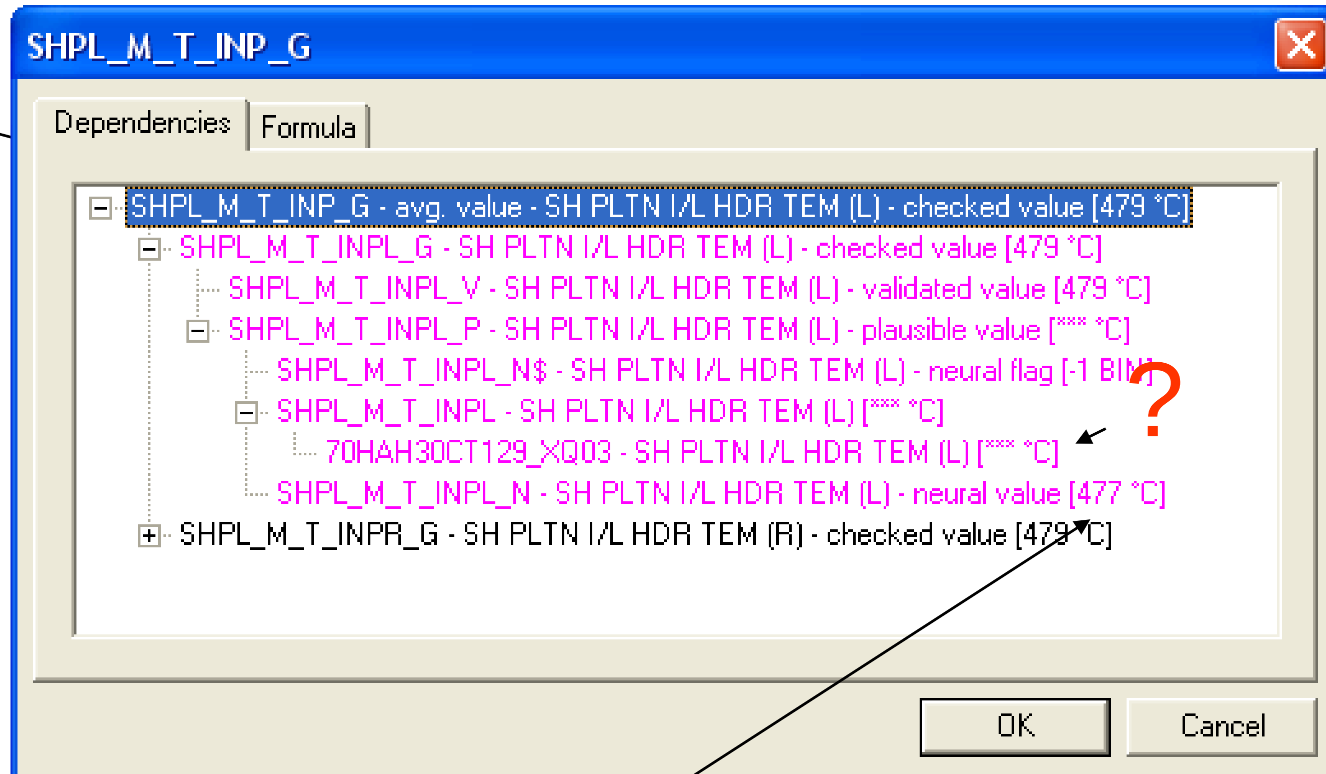




main steam measurements left and right
(left not plausible)

Implausible Value - replacement





Neural network generated the value 477 °C for not available value of tag 70HAH30CT129_XQ03

Data Validation Report

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point in time: 05.05.04 11:25:00

plausible value	data reconcilation successfull
implausible value	data reconcilation not successfull

datapoint	description	raw value	plausibility checked value	reconciliation data point	value from reconcilia
20HAC10CP101	plausib. value FW PRESS AT ECO I/L	196.3 kg/cm²	196.3 kg/cm²	20HAC10CP101_V	196.3 kg/cm²
20HAC10CT101	plausib. value FW TEMP AT ECO I/L	257.1 °C	257.1 °C	20HAC10CT101_V	257.1 °C
20HAD01CP101	plausib. value DRUM PRESS	190.4 kg/cm²	190.4 kg/cm²	20HAD01CP101_V	190.4 kg/cm²
20HAD01CP102	plausib. value DRUM PRESS	190.0 kg/cm²	190.0 kg/cm²	20HAD01CP102_V	190.0 kg/cm²
20HAD01CP103	plausib. value DRUM PRESS	189.7 kg/cm²	189.7 kg/cm²	20HAD01CP103_V	189.8 kg/cm²
20HAH21CT101	plausib. value SH DESH I/L TEMP (L)	400.0 °C	400.0 °C	20HAH21CT101_V	400.2 °C
20HAH22CT101	plausib. value SH DESH I/L TEMP (R)	401.1 °C	401.1 °C	20HAH22CT101_V	401.1 °C
20HAH23CP101	plausib. value SH DESH O/L PRESS (L)	184.1 kg/cm²	184.1 kg/cm²	20HAH23CP101_V	183.9 kg/cm²

Visualization Aid 1 : Traffic light coding system

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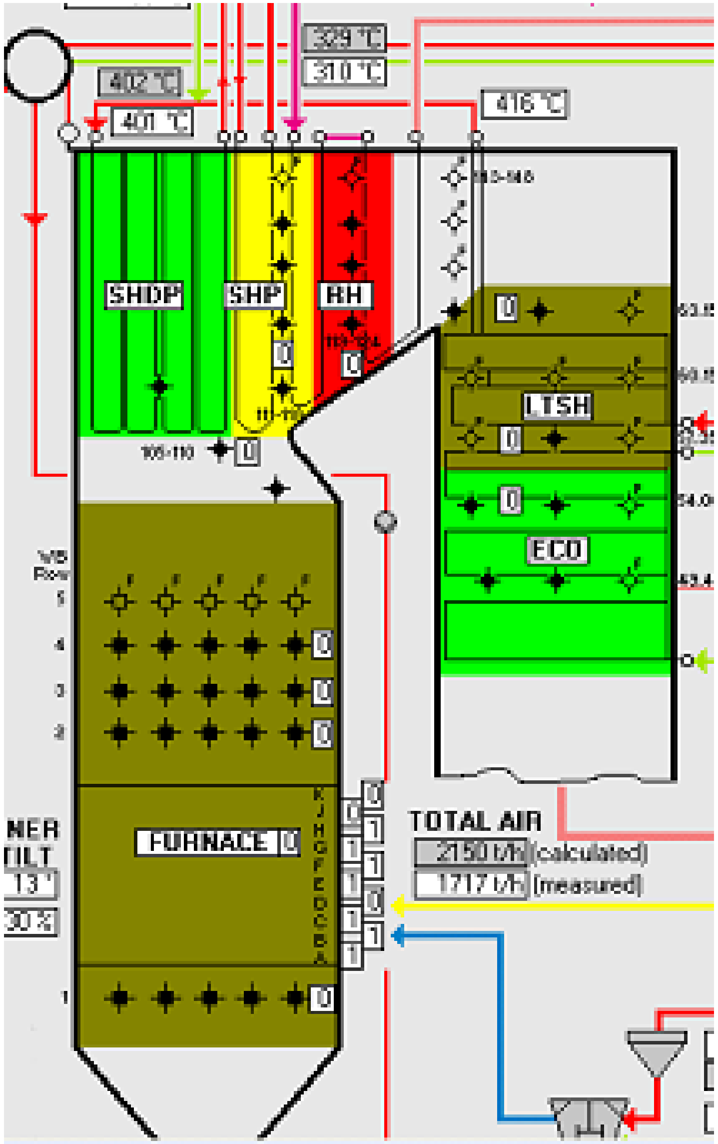


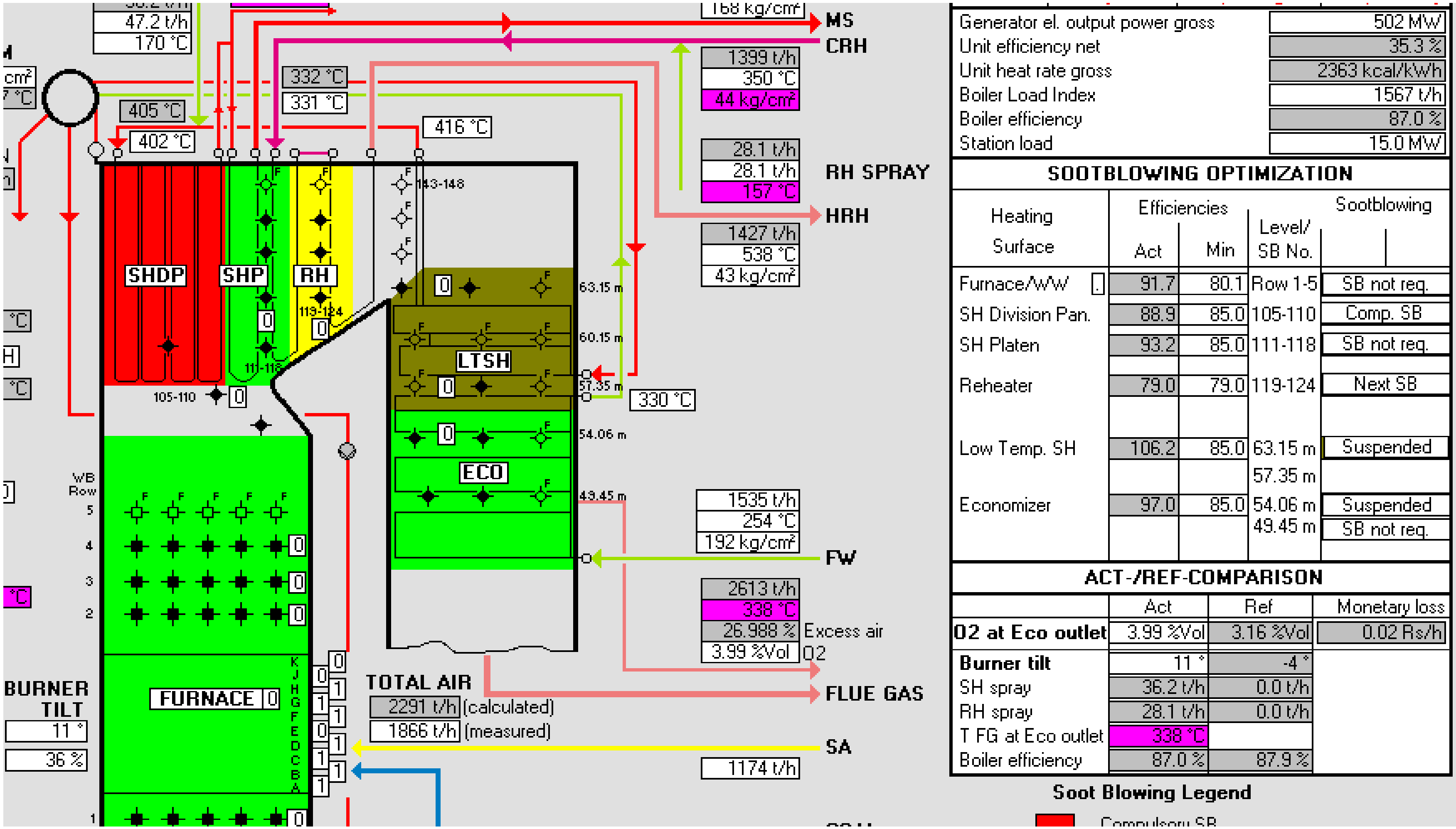
Red - Critical

Yellow - Suboptimal

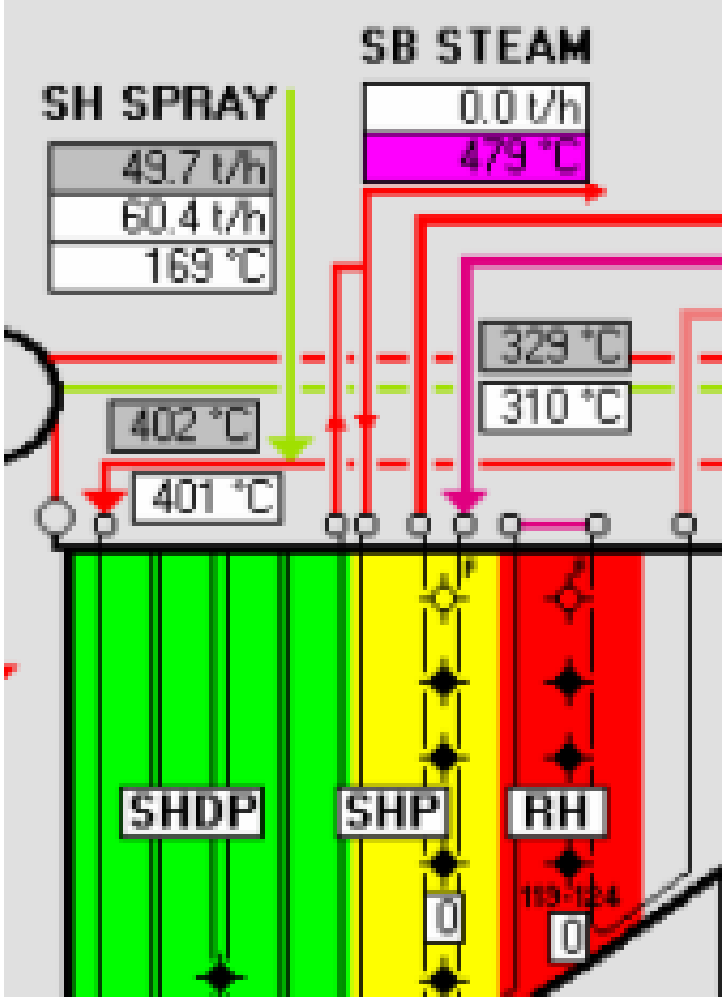
Light Green – Optimal

Dark Green – Time gap to next action

Visualization Aid 2 : Data values as tags & in tables with coded Background colors



Interpretation of Background Colors



White – Measured Value

Grey - Calculated Value

Violet – Replaced value (Originally non plausible or not available)

Performance Monitoring

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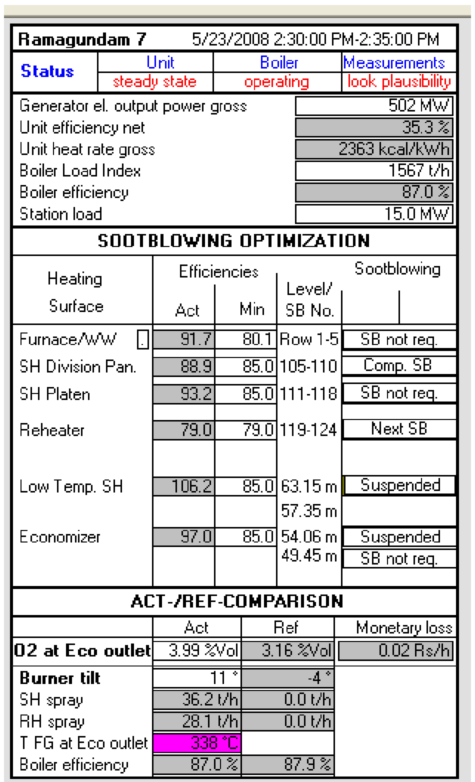
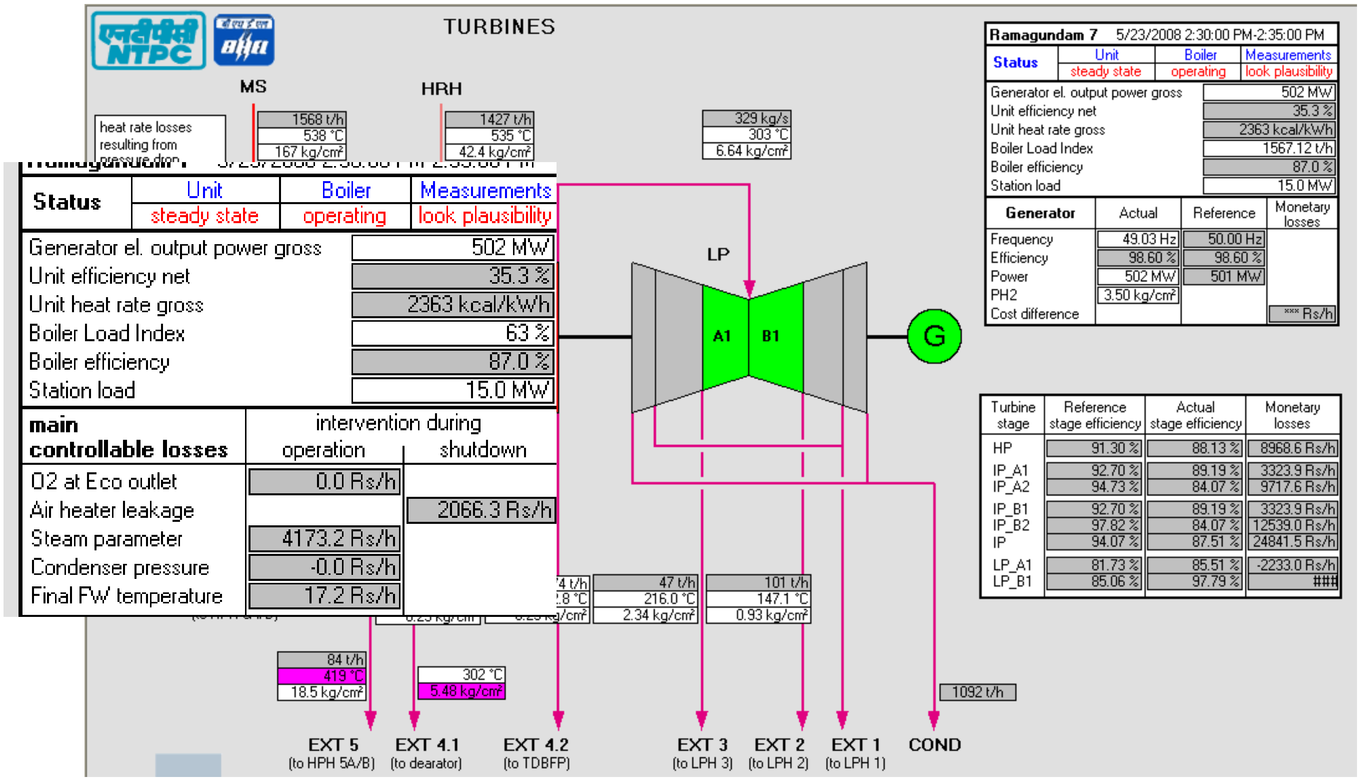
- Compares the actual values of critical parameters with the best achievable under current operating conditions.
- Shows monetary loss against each sub optimal operating parameter, defining the scope of improvement.





Turbine Performance Monitoring

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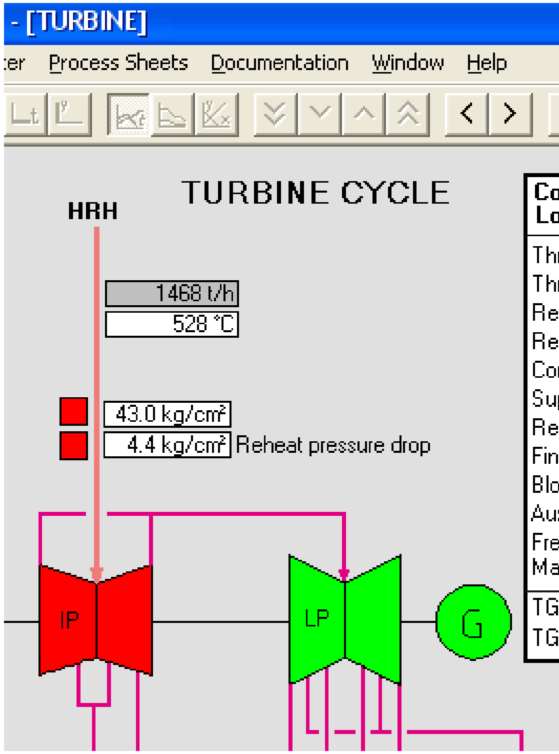

Controllable Losses	Actual	Reference	HR Dev. [kcal/kWh]	Losses expr. in extra fuel	Monetary loss [Rs/h]
Throttle temperature	538 °C	537 °C	-0.335	-0.1 t/h	-74
Throttle pressure	169 kg/cm²	170 kg/cm²a	2.879	0.5 t/h	634
Reheat temperature	528 °C	537 °C	4.997	0.8 t/h	1101
Reheat pressure drop	4.4 kg/cm²	4.5 kg/cm²a	3.672	0.6 t/h	809
Condenser back pressure	-0.87 kg/cm²	-0.87 kg/cm²	-2.965	-0.5 t/h	-1
Superheater spray flow	30.5 t/h	0.0 t/h	6.190	1.0 t/h	1364
Reheat spray flow	32.5 t/h	0.0 t/h	20.944	3.5 t/h	4614
Final FW temperature	255 °C	254.3 °C	0.346	0.1 t/h	76
Blow down flow	0.0 t/h	48.4 t/h	0.000	0.0 t/h	0
Auxiliary steam flow	13.6 t/h	10.0 t/h	8.449	1.4 t/h	1861
Frequency	49.38 Hz	50.00 Hz	0.042	0.0 t/h	23
Make-up flow	22.2 t/h	0.0 t/h	43.613	7.4 t/h	9608

TG heat rate gross, actual: 2054 kcal/kWh
TG heat rate gross, reference: 2051 kcal/kWh
TG heat rate net, actual: 2117 kcal/kWh

Boiler Performance Monitoring

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Boiler thermal performance data

Fluid temperature [°C] Inlet	Outlet	Fouling factor
259	331	0.86
359	359	0.89
359	415	0.89
401	478	0.90
478	542	0.79
322	545	0.90
		0.64

Coal analysis	
GCV [kcal/kg]	3481
Proximate	
Total moisture [%]	12.1
Ash [%]	38.1
Volatile matter [%]	23.0
Fixed carbon [%]	26.8
Ultimate	
Carbon [%]	36.3
Hydrogen [%]	2.6
Nitrogen [%]	0.8
Oxygen [%]	9.8
Sulphur [%]	0.4
Total moisture [%]	12.1
Ash [%]	38.1

Load [MW]	513
MS flow [t/h]	1596
MS temp [°C]	542
RH temp [°C]	545

Section	Flue gas temperature [°C] Inlet	Outlet
Economiser	578	362
Waterwalls	1794	1334
LTSH	826	578
Panel SH	1334	1173
Platen SH	1173	1076
Reheater	1076	826
Air heater	362	155

Coal mass flow [t/h]	325
Bottom ash removal rate [%]	20
Duct ash removal rate [%]	5
AH ash removal rate [%]	3
Fly ash removal rate [%]	72
UBC in ash [%]	0.4

Ambient air temperature [°C]	28
Relative humidity [%]	60
Flue gas oxygen at Eco outlet	3.68
Flue gas oxygen at AH outlet	6.23
Burner tilt [°]	11
Mills in operation	

Mill	Status
A	on
B	on
C	off
D	off
E	on
F	on
G	on
H	off
J	on
K	on

Maximum metal temperature [°C]
436 °C
527 °C
589 °C
612 °C

Heat balance	Act	Ref
Boiler efficiency [%]	86.89	87.99
Losses		
Dry gas [%]	5.64	4.28
H2O in fuel [%]	2.18	2.21
H2O from H2 in fuel [%]	4.21	4.21
H2O in air [%]	0.08	0.11
UBC [%]	0.32	0.32
Radiation [%]	0.11	0.12
Others [%]	0.68	0.76
Total losses [%]	13.21	12.01
Corrected Boiler Efficiency (%)	87.03	

Boiler Mapping

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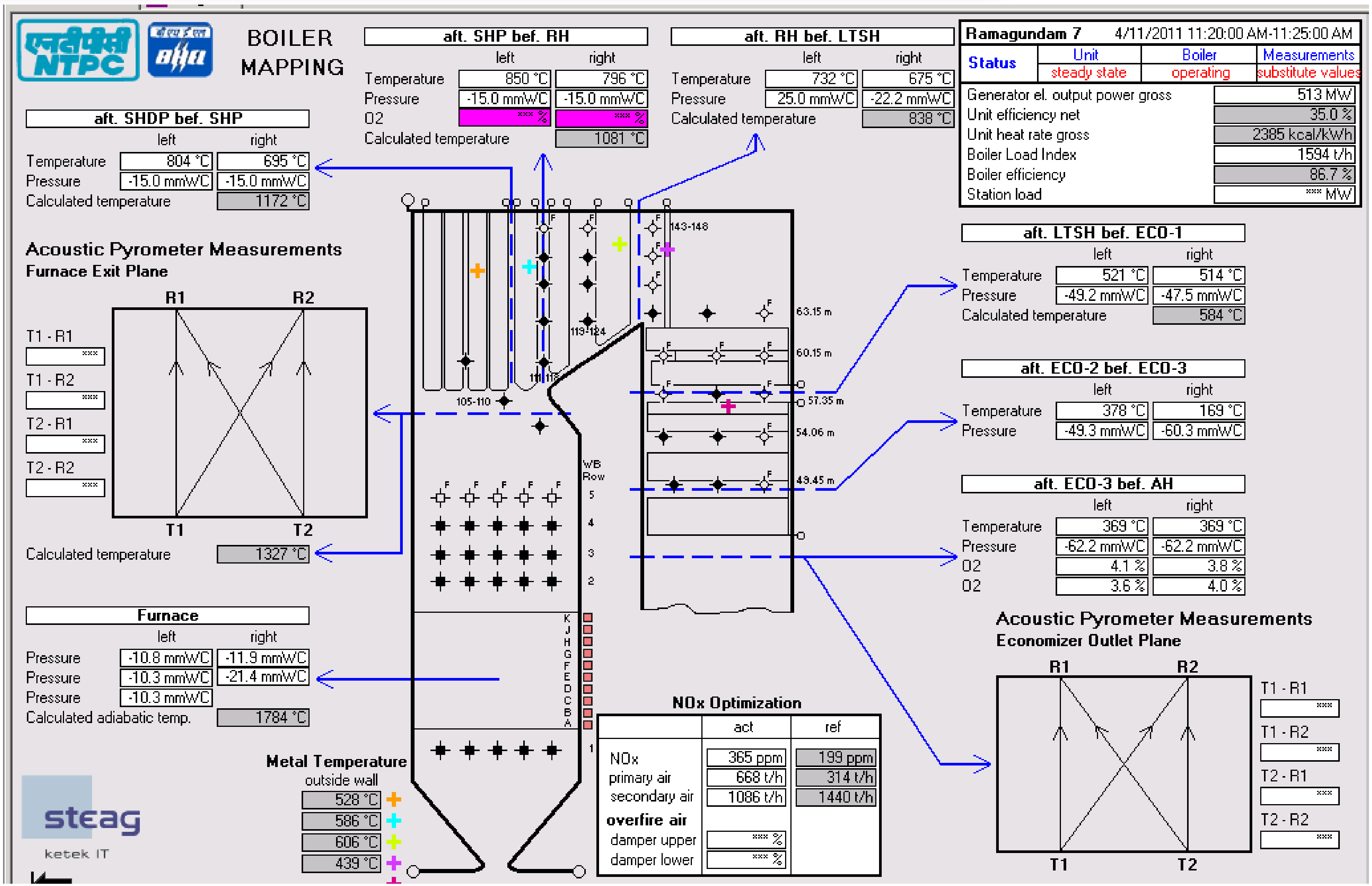

Soot Blowing Optimization

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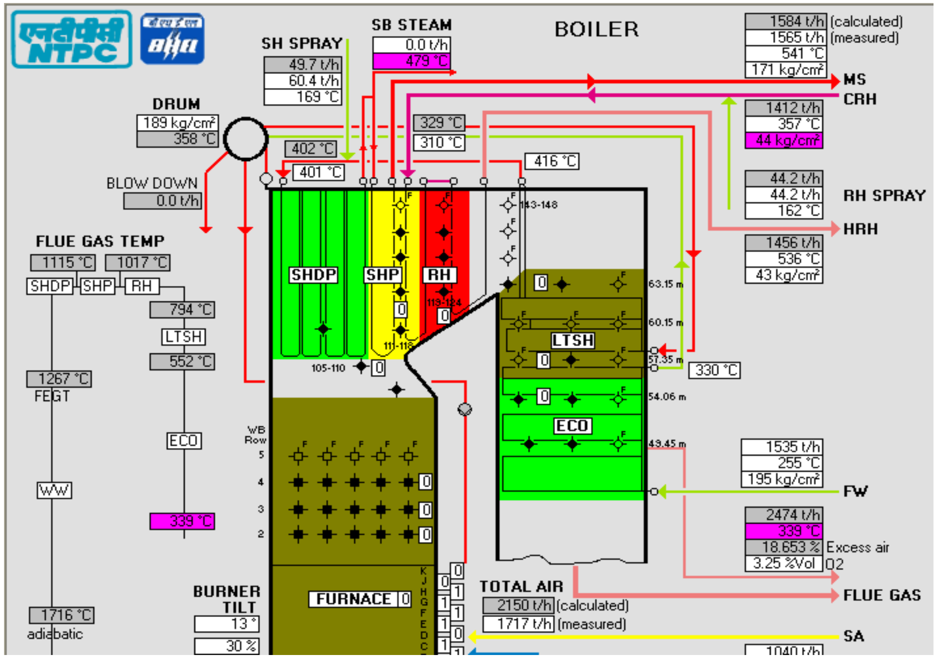
- **Fouling and Slagging of boiler heating surfaces cause…**
  - Loss of efficiency due to increased flue gas temperature.
  - Loss of efficiency due to increased Reheater spray flow.
  - Shutdowns for removing persistent slag.

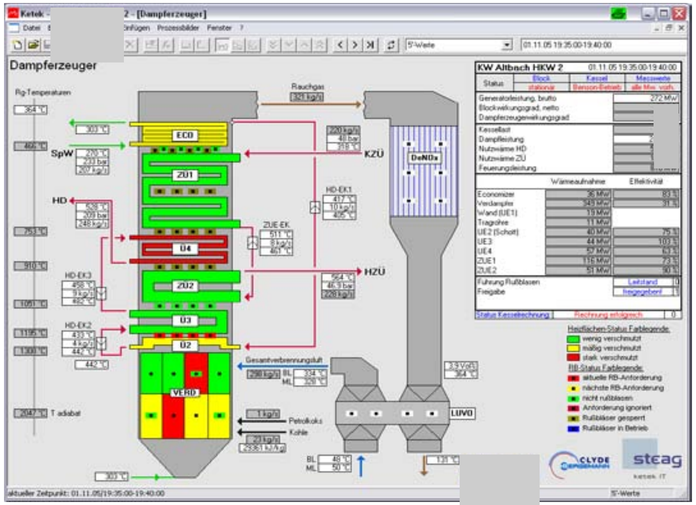
  - **Use of soot blowers…**
    - Causes costs (blowing medium, wear-and-tear...).
    - Impact on control actions.
    - Erosion of the heating surfaces.
    - May be prohibited or not reasonable in some operating states.

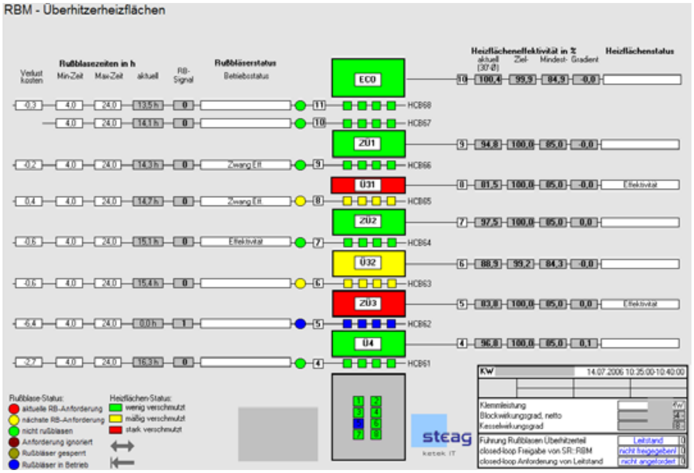


Soot Blowing Optimization

SR::EPOS::BCM is the SR product for optimizing the soot blowing

- Controlled by costs or other criteria the optimum points in time for activating the individual blower levels are calculated
- Closed-Loop application possible if desired
- Application of fuzzy technology





Criteria for Soot Blow Optimization

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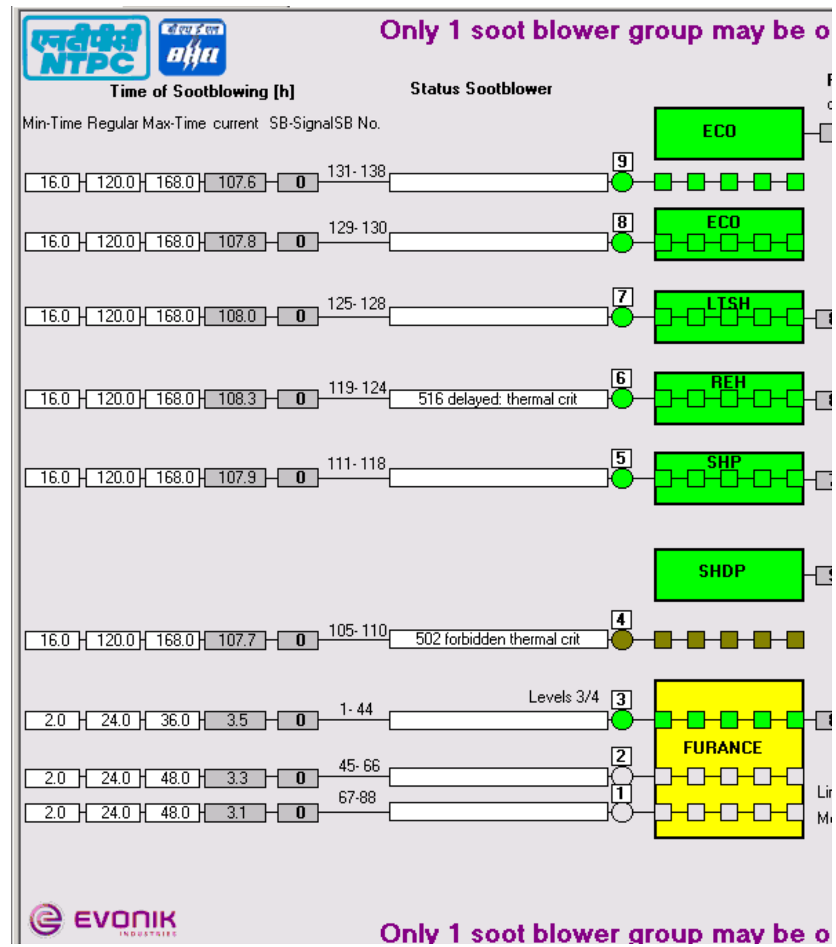
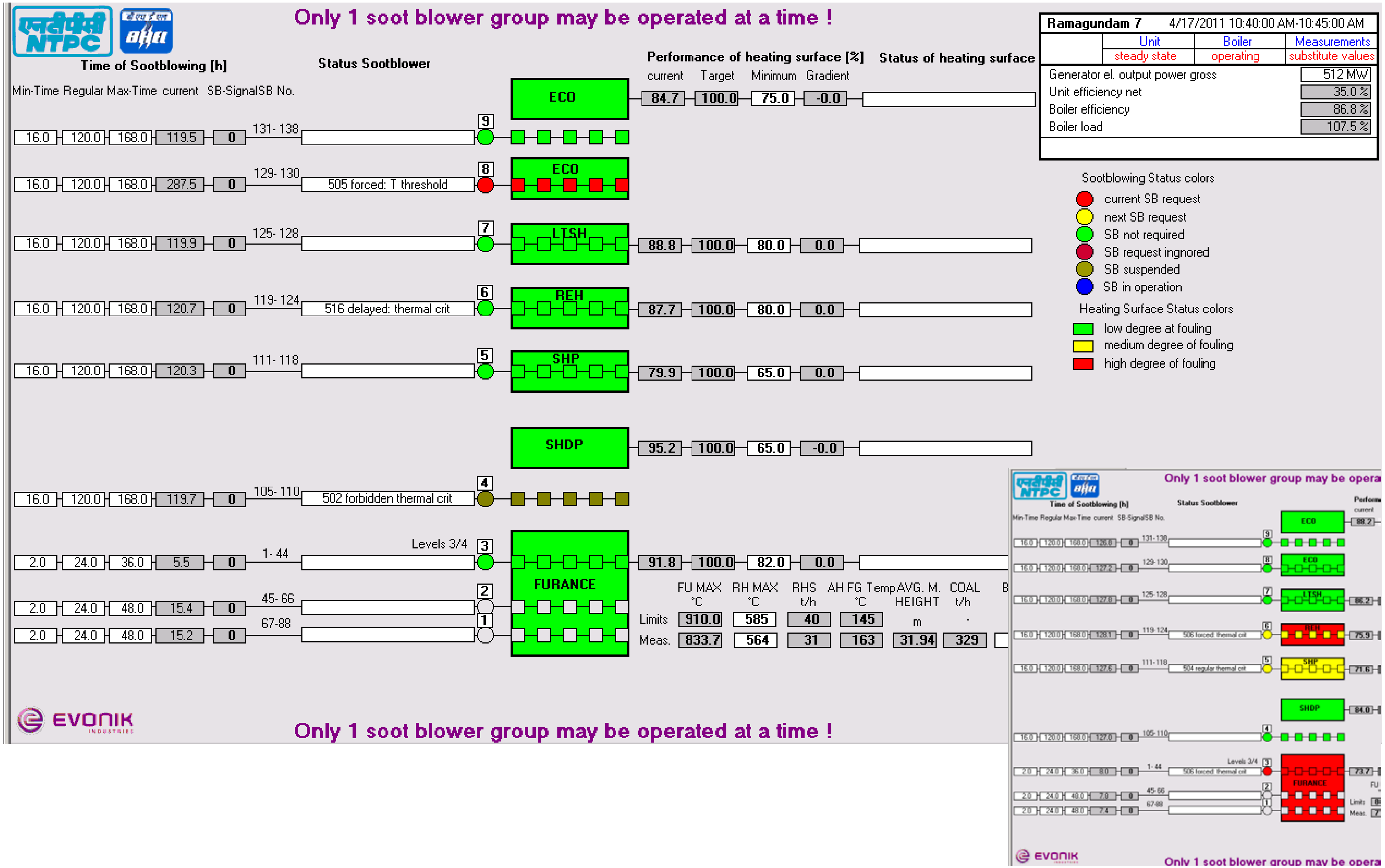
- Fouling/Slagging: Results from thermodynamic model - SR::EPOS
- Time intervals
  - Minimum frequency of soot blowing
  - Minimum-pauses
- Configurable priorities for each criterion
- Soot-blowing costs
- Process-engineering criteria, plant-specific
  - Reheat spray flow
  - Flue gas temperature before air preheater
  - Furnace exit gas temperature
  - RH Metal Temperature
  - Mills Combination
  - Coal mass flow
  - NOx-emissions



Soot Blowing Optimization



Boiler Setpoint Optimization

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Shows the optimal against current setpoints and improvement in heat rate.

Ramagundam 7
6/16/2010 11:10:00 AM-11:15:00 AM

Set point optimization

Boiler	Act value	Opt value
O2 at Eco outlet	3.62 %Vol	3.22 %Vol
Burner tilt	4.3 °	0.5 °

Turbine Cycle	Act value	Opt value
MS temperature	533.84 °C	537.42 °C
MS pressure	168.85 bar	170.00 bar
Reheat temperature	530.97 °C	533.32 °C
Unit Heat Rate gross	2368 kcal/kWh	2365 kcal/kWh

Mill optimization

	Current Status	Opt Status	Current Load	Opt Load
MILL K	1	1	55.39 t/h	22.00 t/h
MILL J	1	1	50.38 t/h	22.00 t/h
MILL H	0	0	0.13 t/h	0.00 t/h
MILL G	0	0	0.00 t/h	0.00 t/h
MILL F	1	0	43.67 t/h	0.00 t/h
MILL E	0	0	0.04 t/h	0.00 t/h
MILL D	1	1	42.71 t/h	38.09 t/h
MILL C	1	1	38.23 t/h	38.38 t/h
MILL B	1	1	42.08 t/h	47.63 t/h
MILL A	1	1	42.68 t/h	55.01 t/h

Unit Critical Calculated Outputs

Superheater Spray	13.5 t/h
Reheater Spray	56.5 t/h
Furnace Exit Flue Gas Temp	1296 °C
PAPH-A Leackage	11.713 %wt
SAPH-A Leackage	12.743 %wt
PAPH-B Leackage	17.147 %wt
SAPH-B Leackage	16.596 %wt
Platten SH Max Metal Temp	585 °C
RH Max Metal Temp	600 °C
HPH-5A Drain O/L Flow	130 t/h
HPH-5B Drain O/L Flow	132 t/h

Transient State Status

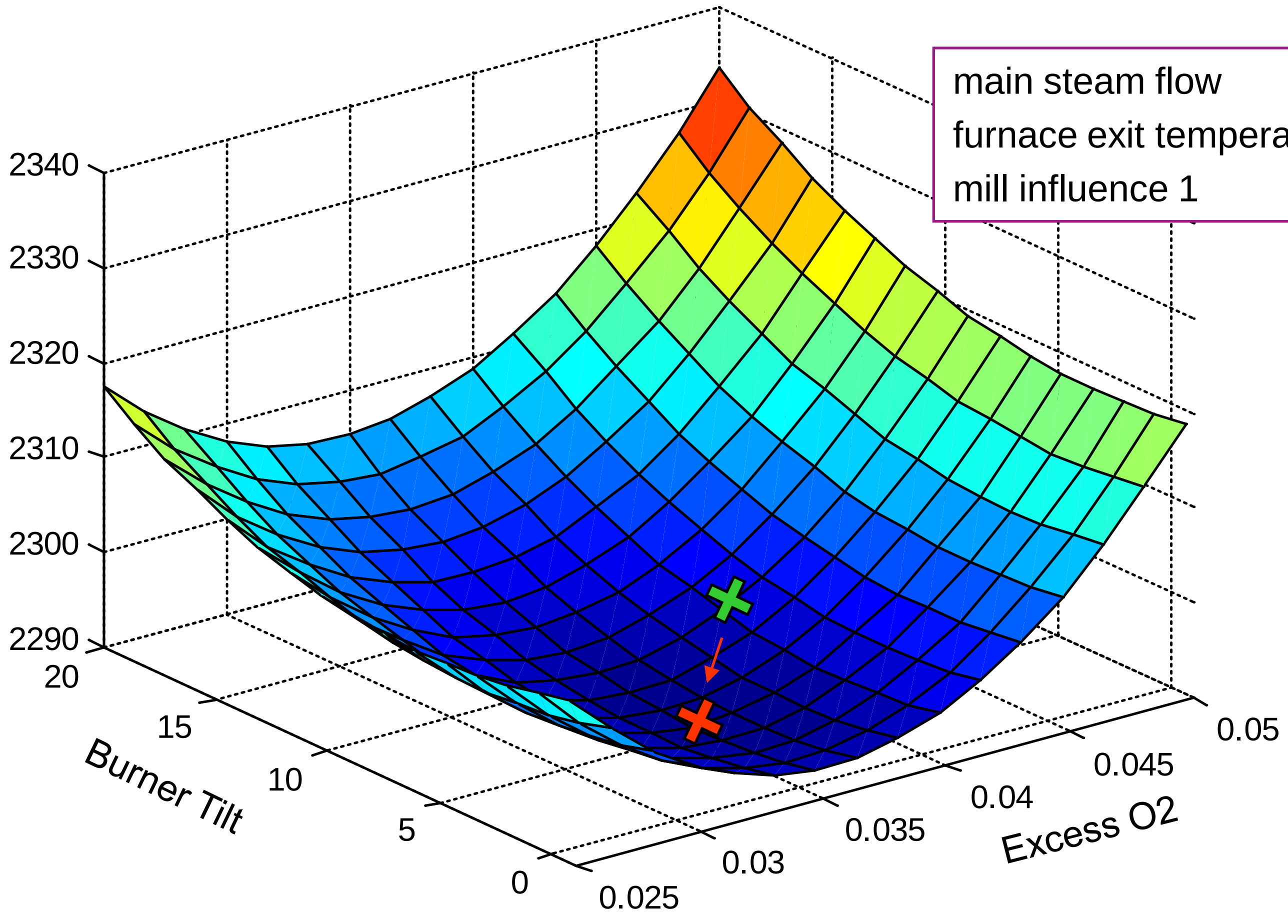
Model solved	1
Plant in steady state	1

Top3 Mills Status

Model solved - Constraints on top 3 mills relaxed	0

Total consumption of pumps	9947.7 kW
Total consumption of mills	2264.9 kW
Total consumption of fans	7031.7 kW
Total consumption of aux. consumers	19244.3 kW
Unit load	516.9 MW
FH1 OPT	30.86

Optimized Heat Rate



main steam flow	= 450.33 kg/s
furnace exit temperature	= 1242.7 °C
mill influence 1	= 33.38

In this case the optimum means to move

- the burner tilt down from the current 9 degree to 4.5 degree and
- the excess O2 from the current 4% to 3.55%.

Metal temperature Module

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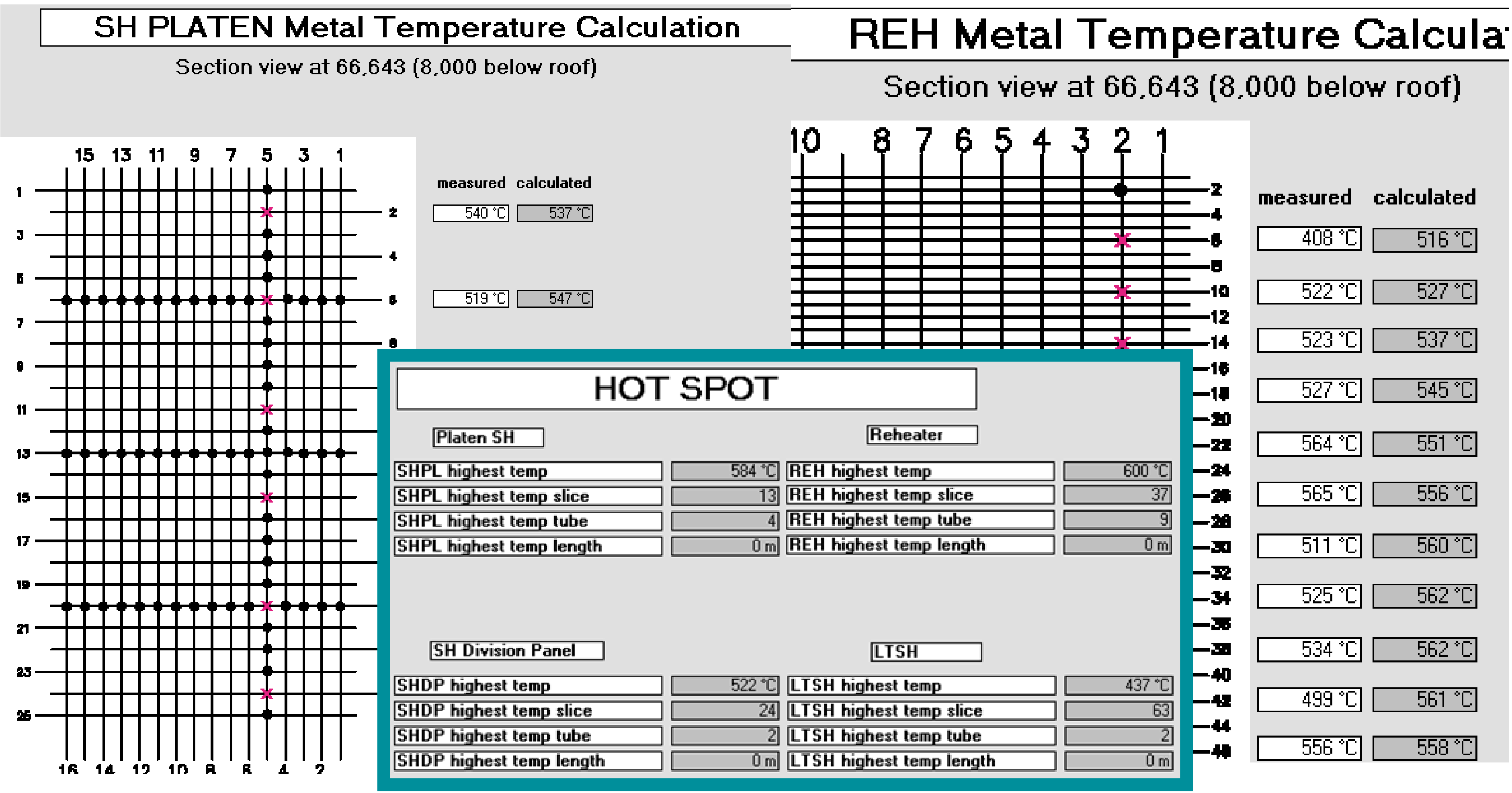
Shows the temperature profile of individual tubes of various heating surfaces of boiler and identifies the Hot spots.



Lifetime monitoring module

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module aims to calculate the remaining life of thick walled components in boiler

steag SR1
ketek IT

BHEL Ramagundam 70
Allowable Operating Parameters

4/20/2011 5:00:00 PM-5:00:30 PM

Component	Pressure allowable	Pressure current	Temperature allowable	Temperature current	Difference of Temperature upper allow.	Difference of Temperature current	Difference of Temperature lower allow.
1. Drum 1, upper side 70HAD01	200.0	185.6	370	360	14	0	-45
2. Drum 1, lower side 70HAD01	200.0	185.6	370	360	11	0	-48
3. HRH1, outled header, tee, upper side 70LBB01	52.0	43.5	540	548	26	-0	-34
4. HRH1, outled header, tee, lower side 70LBB01	52.0	43.5	540	548	26	-0	-34
5. HRH1, outled header, middle, lower side 70LBB01	52.0	43.5	540	548	26	-0	-33
6. HRH1, outled header, left, upper side 70LBB01	52.0	43.5	540	548	26	-0	-33
7. HRH1, outled header, left, lower side 70LBB01	52.0	43.5	540	548	26	-0	-33
8. MSH1, outled header, tee, upper side 70LBA01	186.0	167.7	540	540	25	2	-34
9. MSH1, outled header, tee, lower side 70LBA01	186.0	167.7	540	540	25	2	-34
10. MSH1, outled header, left, upper side 70LBA01	186.0	167.7	540	540	25	2	-34
11. MSH1, outled header, left, upper side 70LBA01	186.0	167.7	540	540	25	2	-34
	52.0	43.5	540	548	25	0	-34
	186.0	167.7	540	540	15	2	-27
	186.0	167.7	540	540	25	2	-34

steag SR1
ketek IT

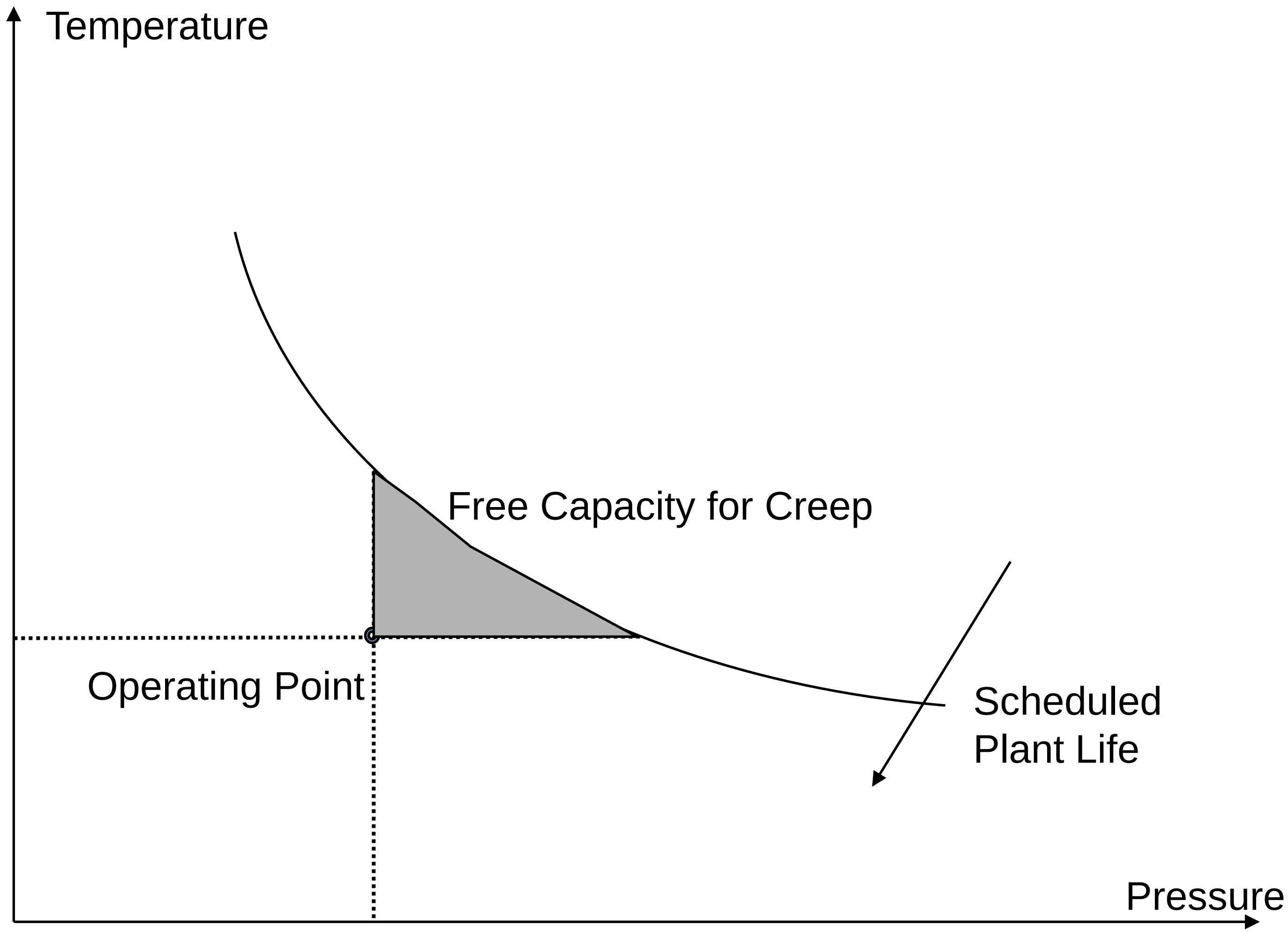
BHEL Ramagundam 70
Overview Degradation

4/20/2011 4:30:00 PM-5:30:00 PM

Component	operating time [h] monitored	operating time [h] down time	life time consumption [%] creep	life time consumption [%] fatigue	life time consumption [%] total	life time consumption [%] increment (24h)
1. Drum 1, upper side 70HAD01	35604.3 h	7765.5 h	5.201 %	0.238 %	5.439 %	0.000156 %
2. Drum 1, lower side 70HAD01	35604.3 h	7765.5 h	5.926 %	0.278 %	6.204 %	0.000178 %
3. HRH1, outled header, tee, upper side 70LBB01	35604.3 h	8653.6 h	1.868 %	0.000 %	1.868 %	0.000069 %
4. HRH1, outled header, tee, lower side 70LBB01	35604.3 h	8653.6 h	2.016 %	0.000 %	2.017 %	0.000075 %
5. HRH1, outled header, middle, lower side 70LBB01	35604.3 h	8653.6 h	6.354 %	0.000 %	6.354 %	0.000232 %
6. HRH1, outled header, left, upper side 70LBB01	35604.3 h	8653.6 h	3.822 %	0.000 %	3.822 %	0.000141 %
7. HRH1, outled header, left, lower side 70LBB01	35604.3 h	8653.6 h	6.354 %	0.000 %	6.354 %	0.000232 %
8. MSH1, outled header, tee, upper side 70LBA01	35604.3 h	7766.6 h	2.546 %	2.349 %	4.895 %	0.000102 %
9. MSH1, outled header, tee, lower side 70LBA01	35604.3 h	7766.6 h	7.974 %	2.349 %	10.322 %	0.000276 %
10. MSH1, outled header, left, upper side 70LBA01	35604.3 h	7766.6 h	27.202 %	0.937 %	28.138 %	0.000882 %
11. MSH1, outled header, left, upper side 70LBA01	35604.3 h	7766.6 h	27.202 %	0.937 %	28.138 %	0.000882 %
12. YP 1, 70LBB01	35604.3 h	8471.3 h	3.086 %	0.032 %	3.118 %	0.000119 %
13. YP 1, 70LBA01	35604.3 h	7766.6 h	2.634 %	4.881 %	7.515 %	0.000127 %
14. MSH 1, outlet header, tee, lower side 70LBA01	35604.3 h	7766.6 h	7.974 %	2.349 %	10.322 %	0.000276 %

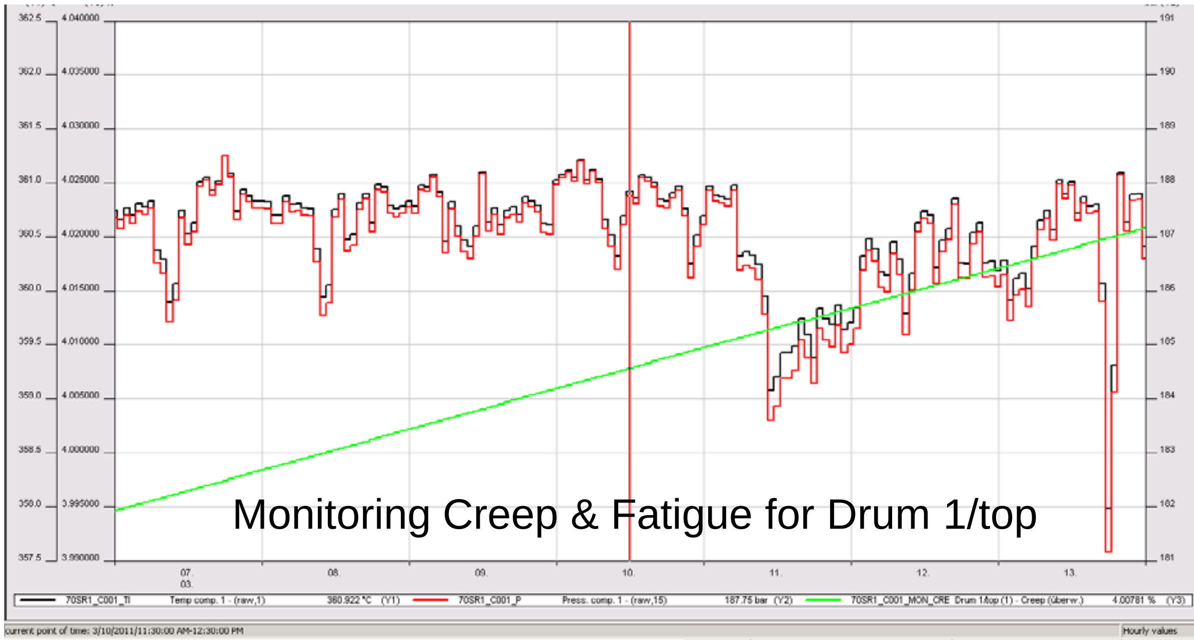
the consumed life of an equipment could be different from the actual age of the equipment

Lifetime monitoring module



Lifetime monitoring module

depends upon how stressful the life of equipment has been so far in terms of temperature and pressure which effect fatigue and creep.



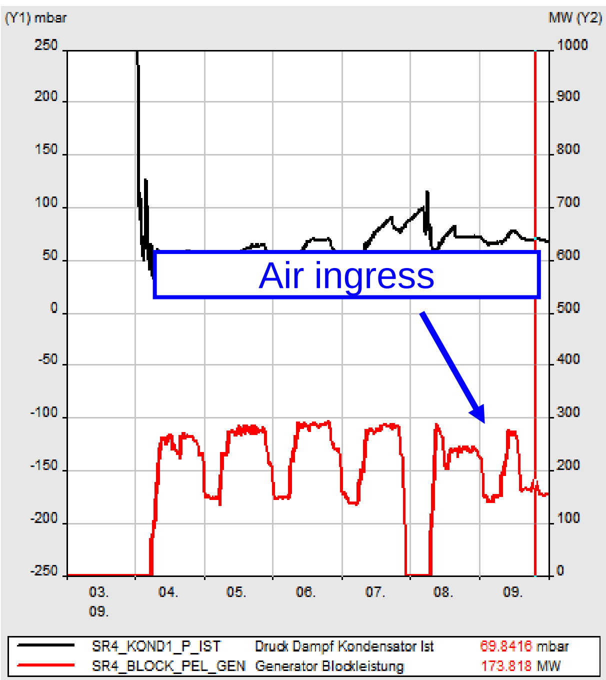
ry

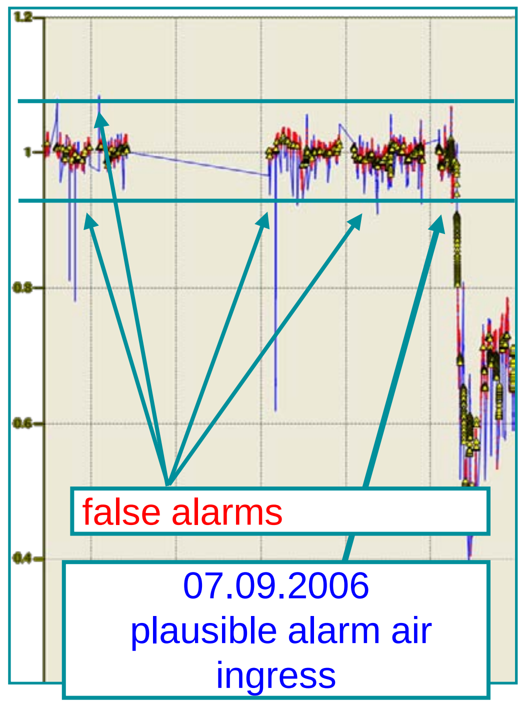
Date: 20.04.2011
Time: 17:30:00

					Degradation			
				ailure	Fatigue	Creep	Total	Rem. Peaks
				65.5h	0.238%	5.201%	5.439%	1.331%
				65.5h	0.278%	5.927%	6.204%	0.691%
70.3	HRH 1/t-top	35605.3 h		8653.6h	0.000%	1.868%	1.868%	0.000%
70.4	HRH 1/t-bot	35605.3 h		8653.6h	0.000%	2.017%	2.017%	0.000%
70.5	HRH 1/m-bot	35605.3 h		8653.6h	0.000%	6.355%	6.355%	0.000%
70.6	HRH 1/l-top	35605.3 h		8653.6h	0.000%	3.822%	3.822%	0.000%
70.7	HRH 1/l-bot	35605.3 h		8653.6h	0.000%	6.355%	6.355%	0.000%
70.8	MSH 1/t-top	35605.3 h		7766.6h	2.349%	2.547%	4.895%	16.718%
70.9	MSH 1/t-bot	35605.3 h		7766.6h	2.349%	7.974%	10.323%	16.718%
70.10	MSH 1/m-bot	35605.3 h		7766.6h	0.937%	27.202%	28.139%	4.984%
70.11	MSH 1/l-bot	35605.3 h		7766.6h	0.937%	27.202%	28.139%	4.984%
70.12	YP 1/lbb	35605.3 h		8471.3h	0.032%	3.086%	3.118%	0.064%
70.13	YP 1/lba	35605.3 h		7766.6h	4.881%	2.634%	7.515%	4.207%
70.14	MSH 1/t-bot	35605.3 h		7766.6h	2.349%	7.974%	10.323%	16.718%

Statistical Process Control

Statistical methods to evaluate partly automatic, early & reliable detection of changes where deterioration is slow.





Key Performance Indicators

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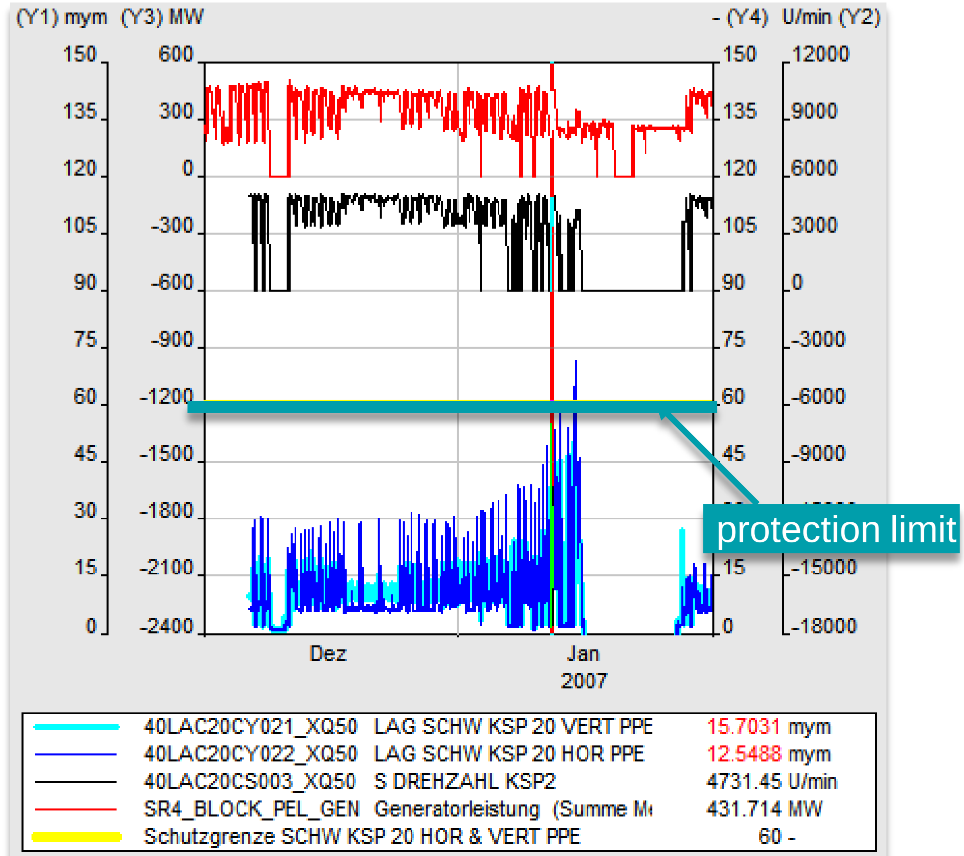
measured	calculated
vibration bearing temperature oil temperature power consumption …	heatrate Component quality factor efficiency …

Key measurements in power plants usually depend on
- load,
- operation mode
- fuel quality
- ambient conditions
- etc.
And are superposed by noise



key performance indicators by Act / Ref-comparison (KPI)

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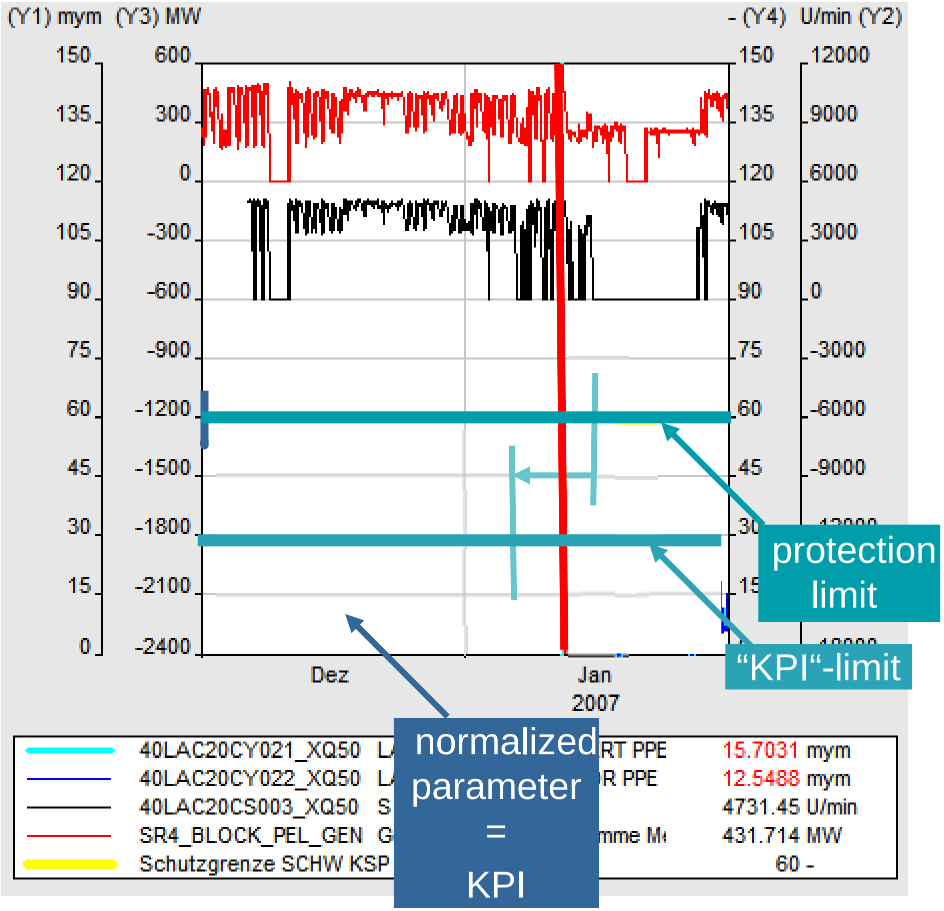
KPIs measure the qualitiy of the process / component.

They do not depend on external disturbance variables

KPI = act-value / ref-value



SPC – Alarm Control Centre

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STATISTISCHE PROZESSKONTROLLE

04.11.2007 00:00:00 - 12:00:00   Blockstatus: In Betrieb   SPC-Status: unbekannt   Pel,brutto: 9477 MWh

Prozessgüteüberwachung

	SPC	KPI	Shewhart
SPC_KOND, Kondensatorgüte, KPI (SR::EPOS)	0	0,95	0
40HLC10CP001_XQ50, Druckverlust Luvo, luftseitig (TEST)	0	1,12	0
SPC_LVW_HYDR, LUVO Druckverlust, KPI (SR::EPOS)	0	0,94	0
40LBB0_CT001_XQ50, Dampftemperatur ZÜ-Austritt	6144	0,99	0

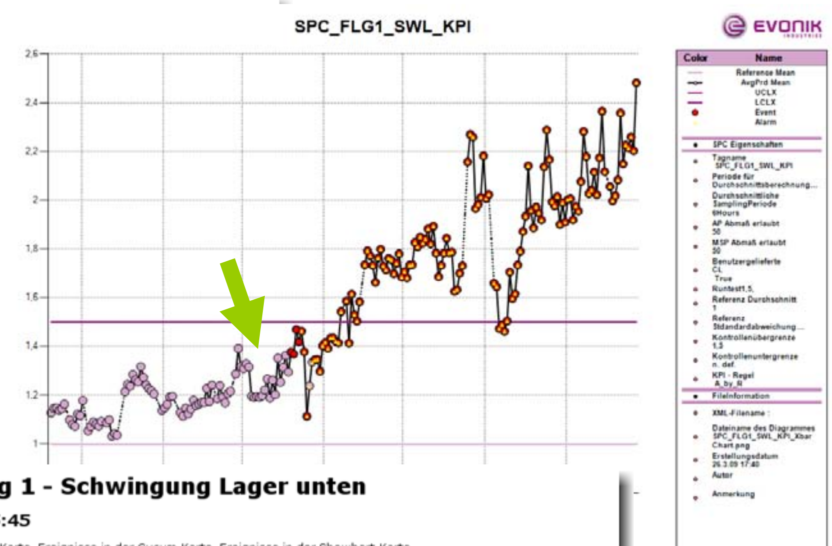
Zustandsüberwachung

Kesselspeisepumpe 1

	SPC
40LAC10CY021_XQ50, Lagerschwingung vertikal	0
40LAC10CY022_XQ50, Lagerschwingung horizontal	0
40BBA03EW383_XQ50, Stromaufnahme	0

Kesselspeisepumpe 2

	SPC
40LAC20CY021_XQ50, Lagerschwingung vertikal	0
40LAC20CY022_XQ50, Lagerschwingung horizontal	0
40BBB03EW383_XQ50, Stromaufnahme	0



SPC_SGZ1_SWU - Saugzug 1 - Schwingung Lager unten

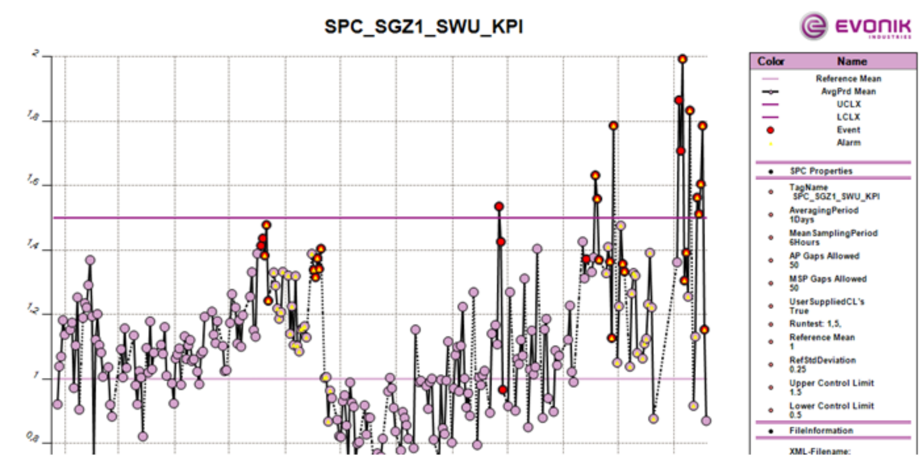
SPC Ergebnisse für 20.01.2009 15:45

Aktueller KPI-Wert ist NaN. Ereignisse in der Shewhart-Karte. Ereignisse in der Cusum-Karte. Ereignisse in der Shewhart-Karte.
Alarm ist aktiv.

Shewhart

Test 1 (Kontrollgrenze überschritten) war positiv.
Test 5 (2 von 3 Werten liegen im äußeren Kontrollbereich) war positiv.

Mittlerer Referenzwert ist 1.
Standardabweichung ist 0,25.
Kontrollbereich ist 0,5 bis 1,5.
Der äußere Kontrollbereich ist unter 0,67 bzw. über 1,33



Fault Trees

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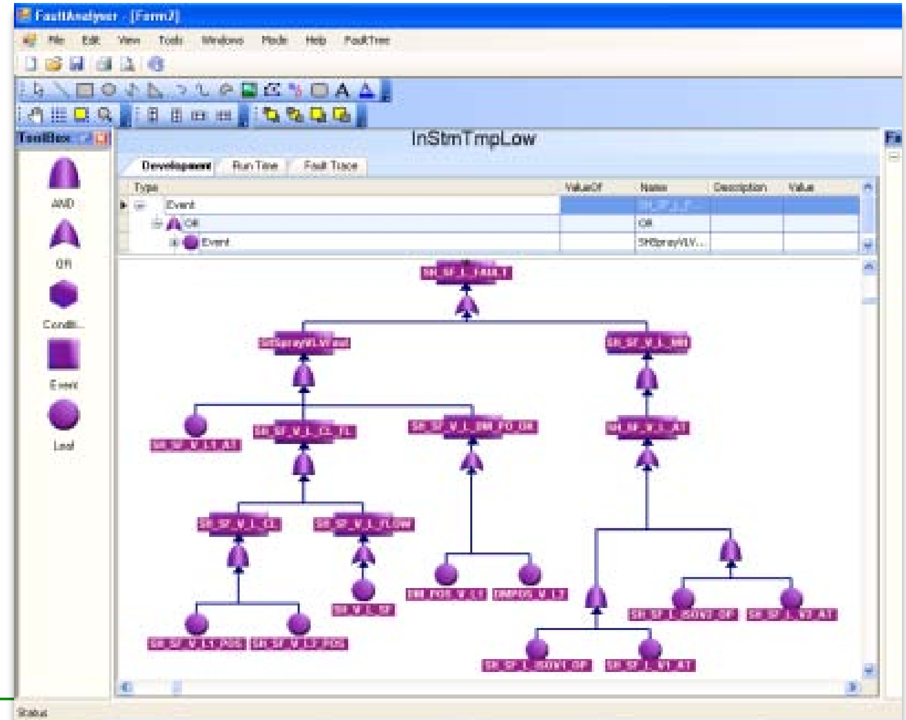
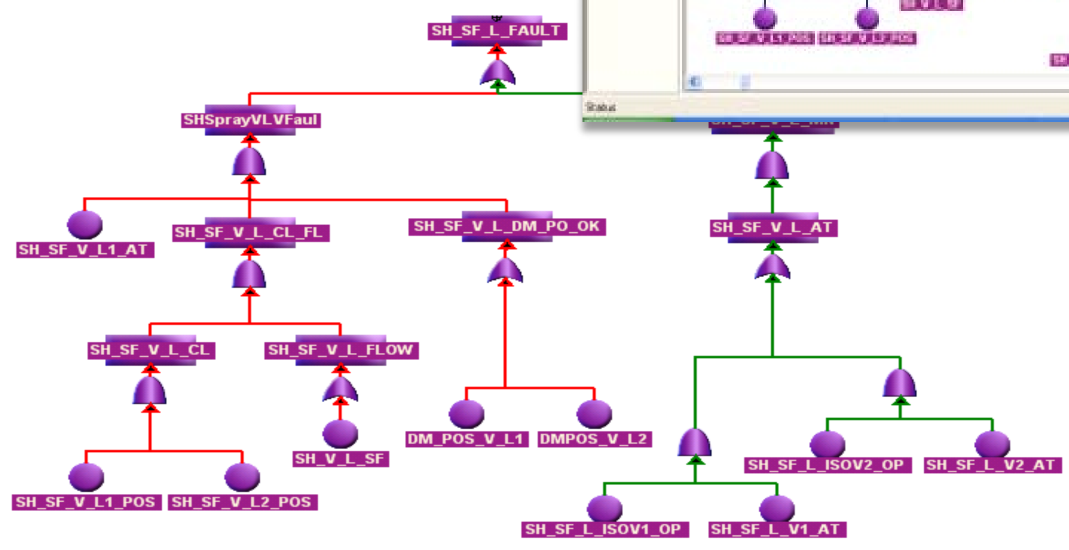
- Models and analyzes faults in the process.
- Composed of logic diagrams that display the state of the system and the states of the components
- Constructed using Drag & Drop technique
- Does not need programming expertise for building such trees.





Thank You

... Ideas & Solutions for Tomorrow

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