Turbine Performance Monitoring and Optimization System

By

Debasish Patra
General Manager
System Technologies

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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 System for Turbine Performance Monitoring and Optimization System

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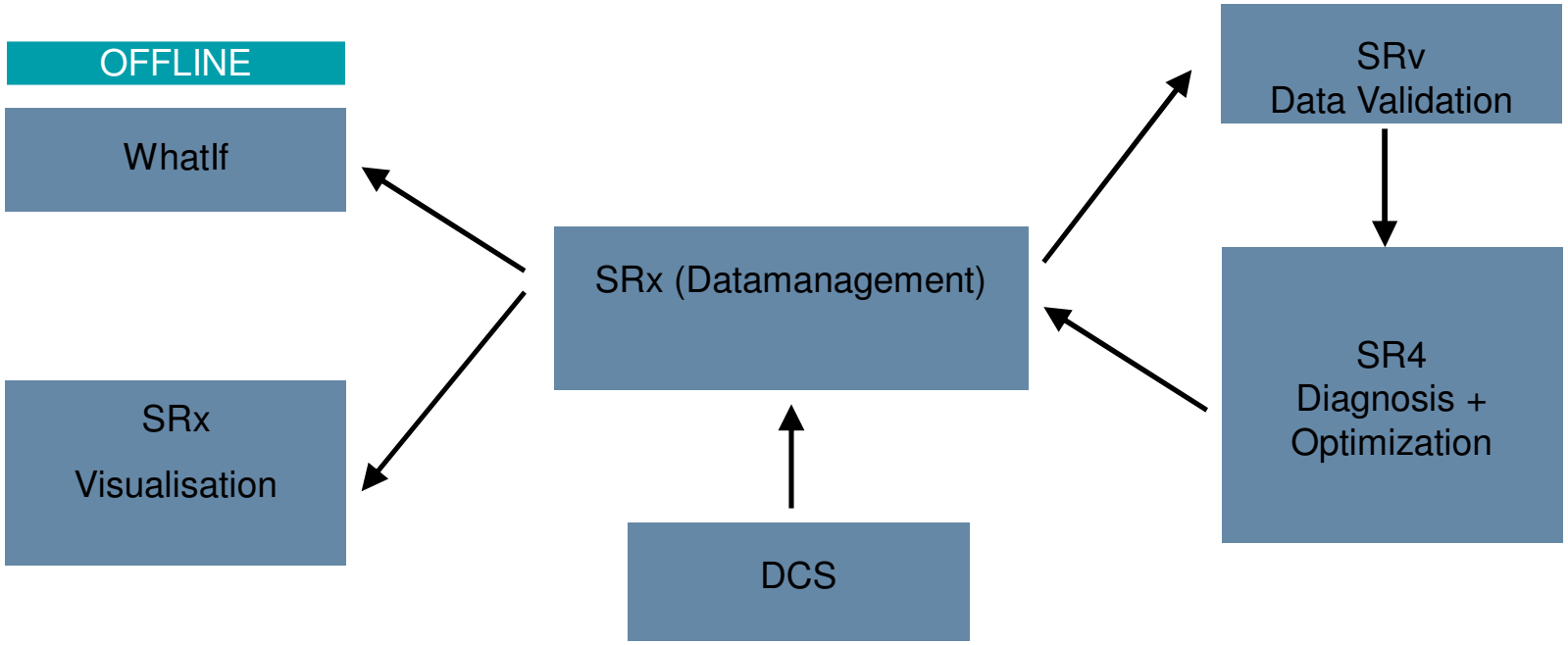
1. All relevant data from DCS which goes into calculation need to be validated i.e. all implausible values have to be replaced by plausible values

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

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83 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)

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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 (4X18 MW + 2X50 MW)
- 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
- NTPC Kudgi 3X800 MW

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 for Turbine Cycle

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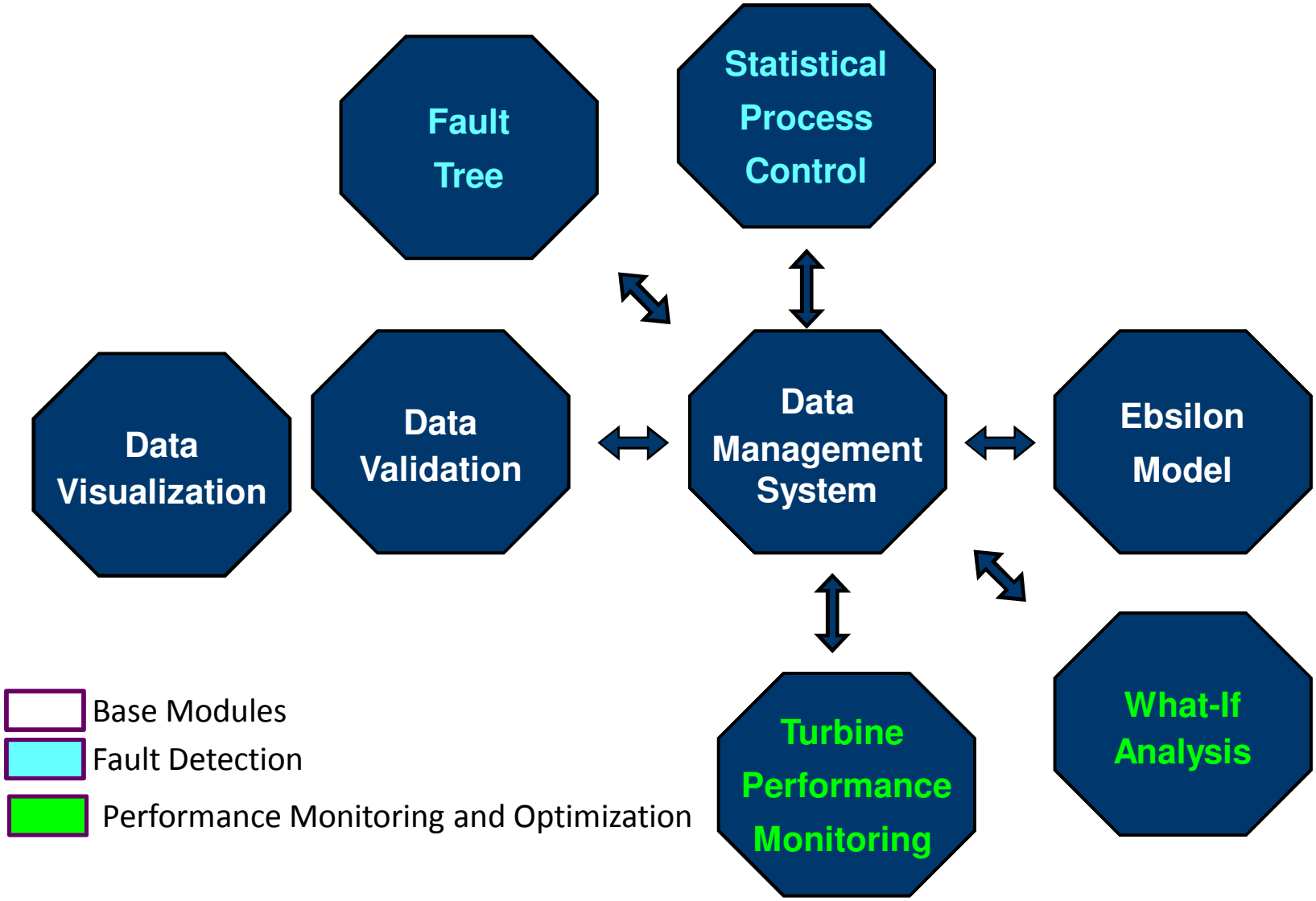

SR::x Data Management System

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

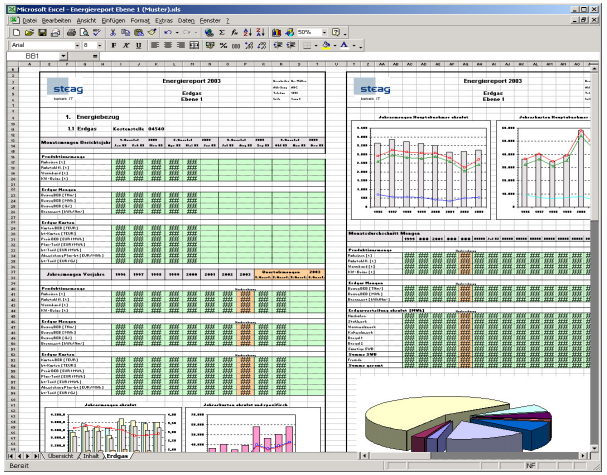
– Competitive server featuring a “state-of-the-art“ visualization

– 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



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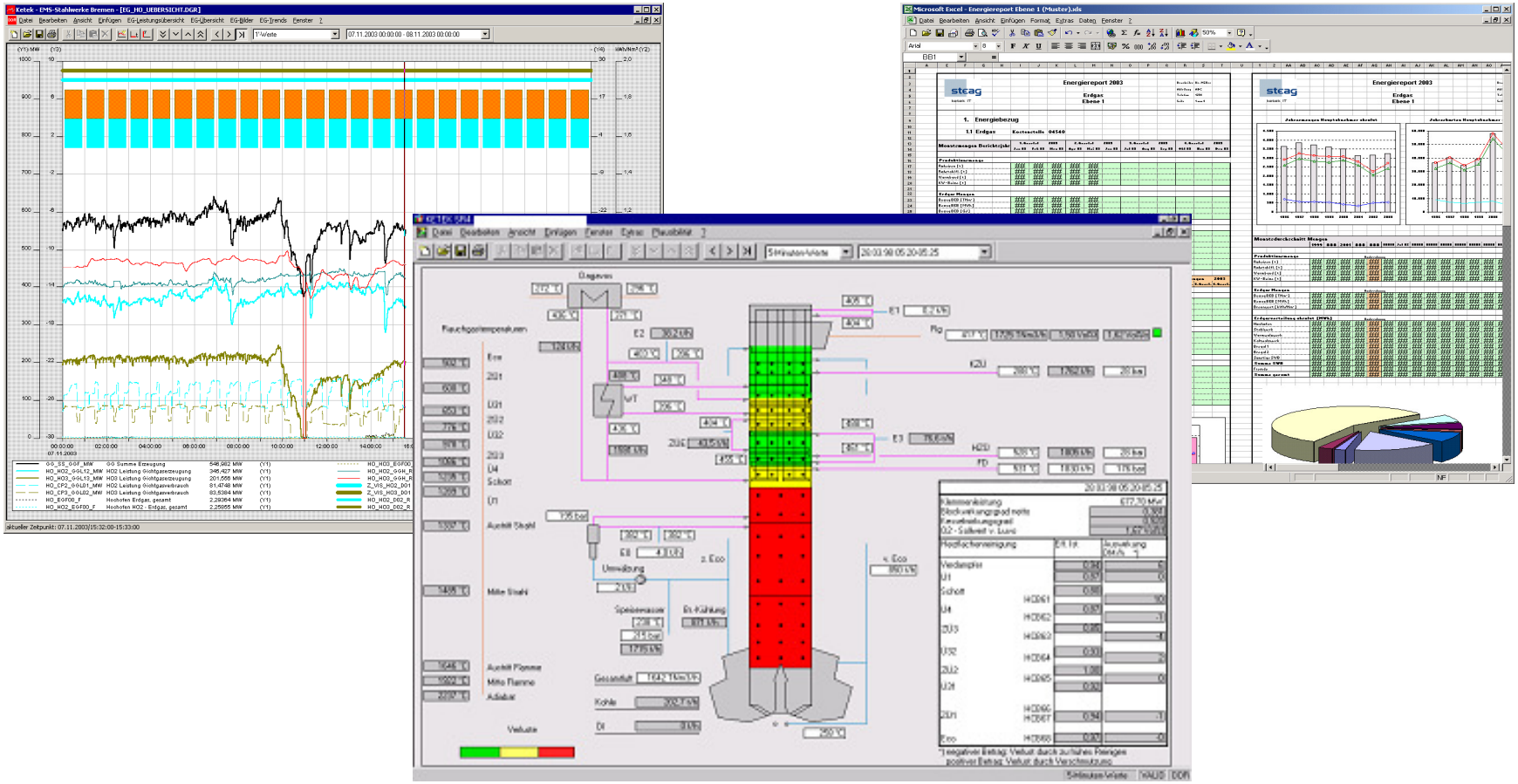

Data Validation System

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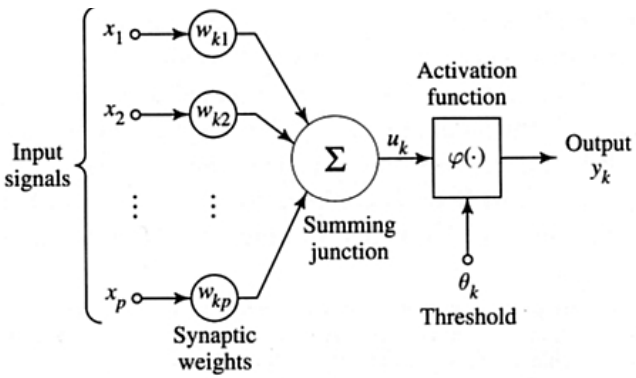
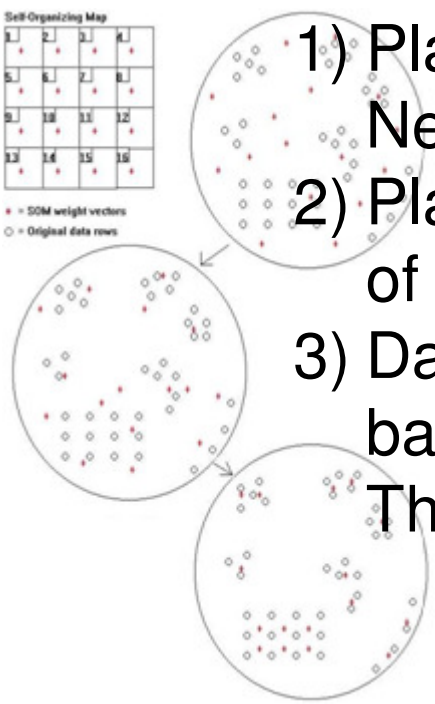
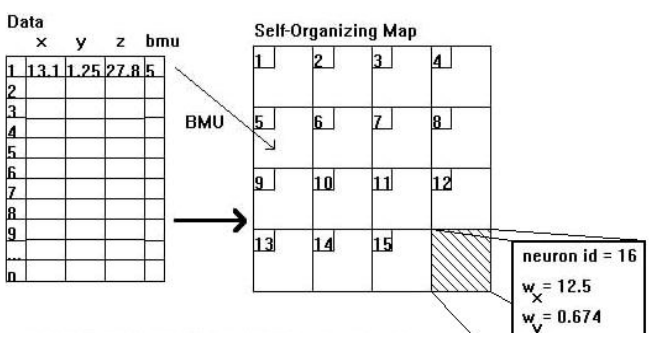
Data Validation to replace data errors due to defective sensor or cable problems:
Incorrect Data – Wrong results
No data – No results



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)

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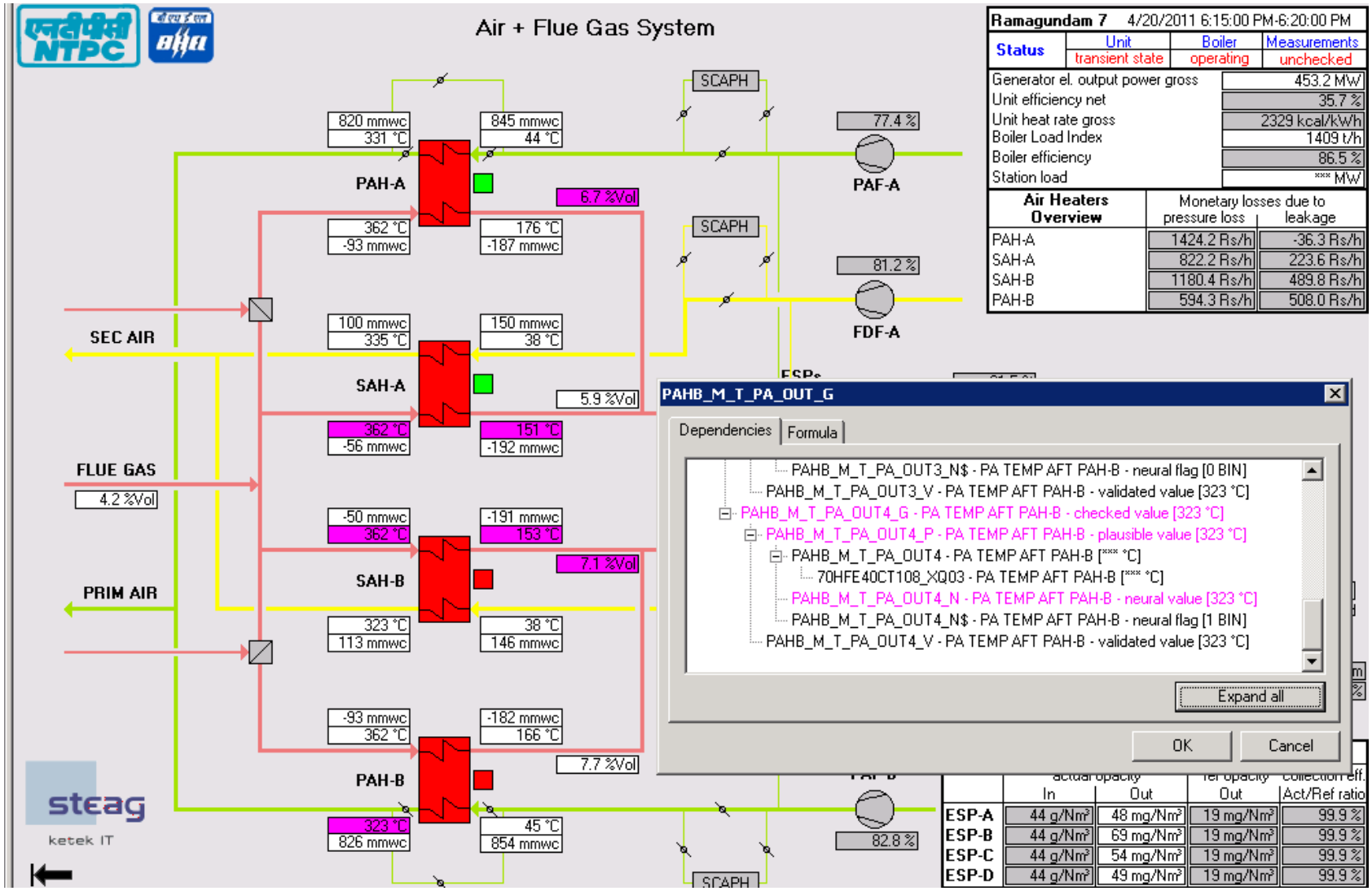
based on Neural Network…



Data Validation System (2)

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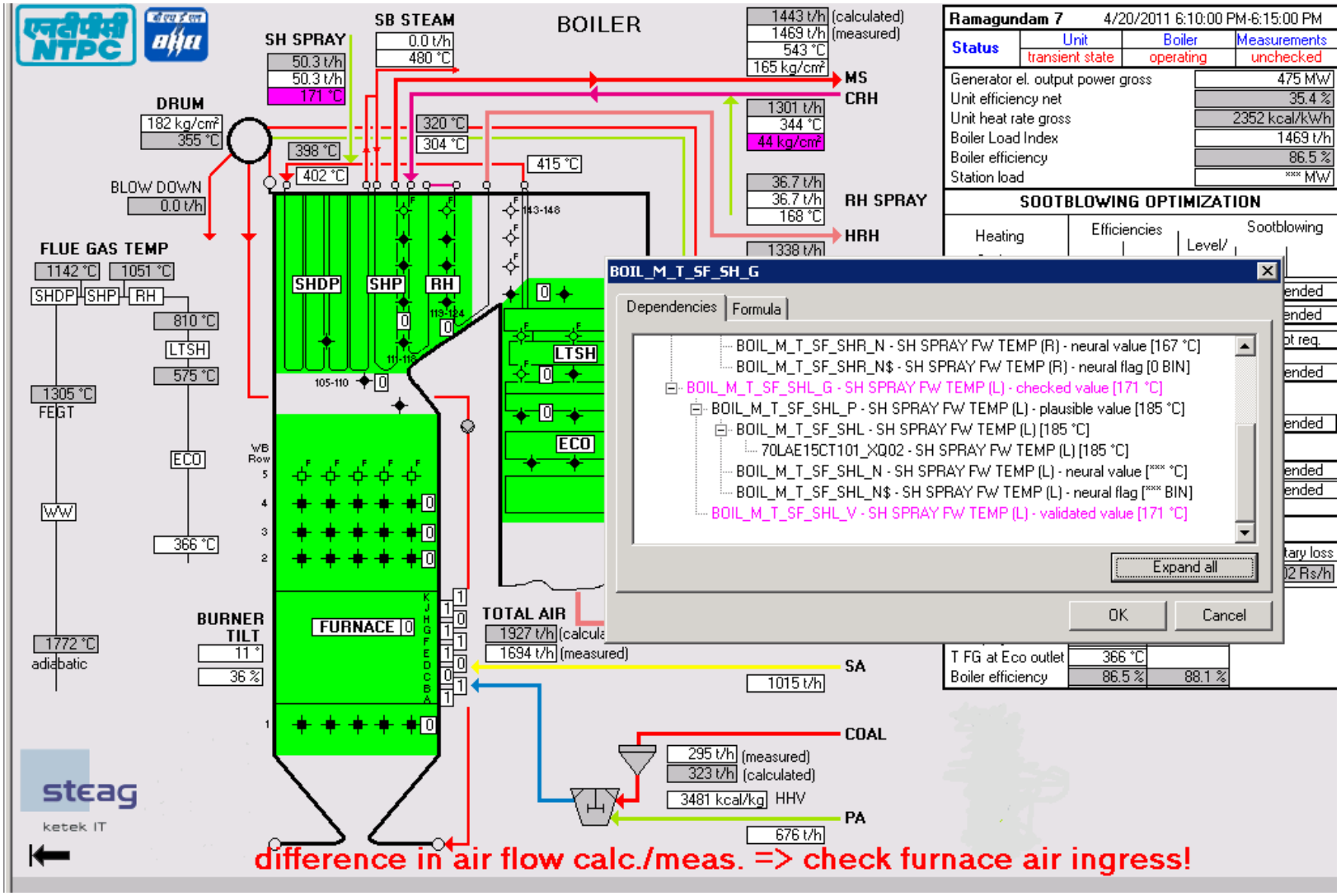
based on “First Principle Thermodynamics”…



Data Validation System (3)

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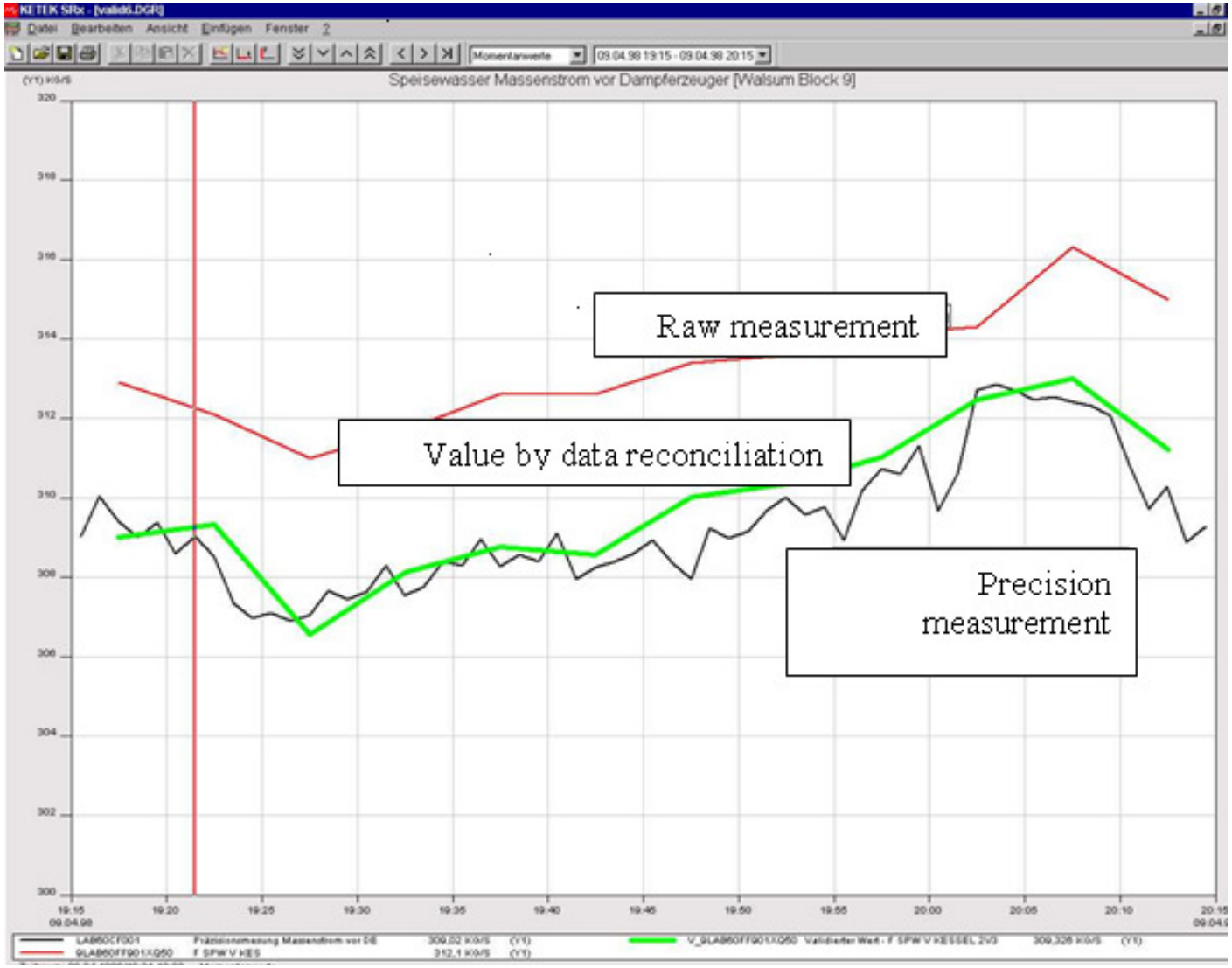
check the quality of measurements …



Implausible Value - detection

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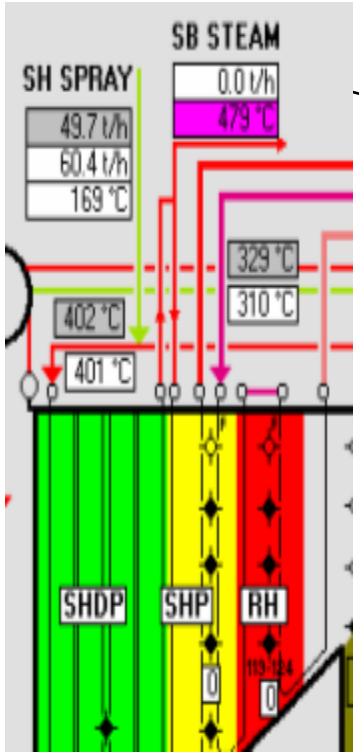

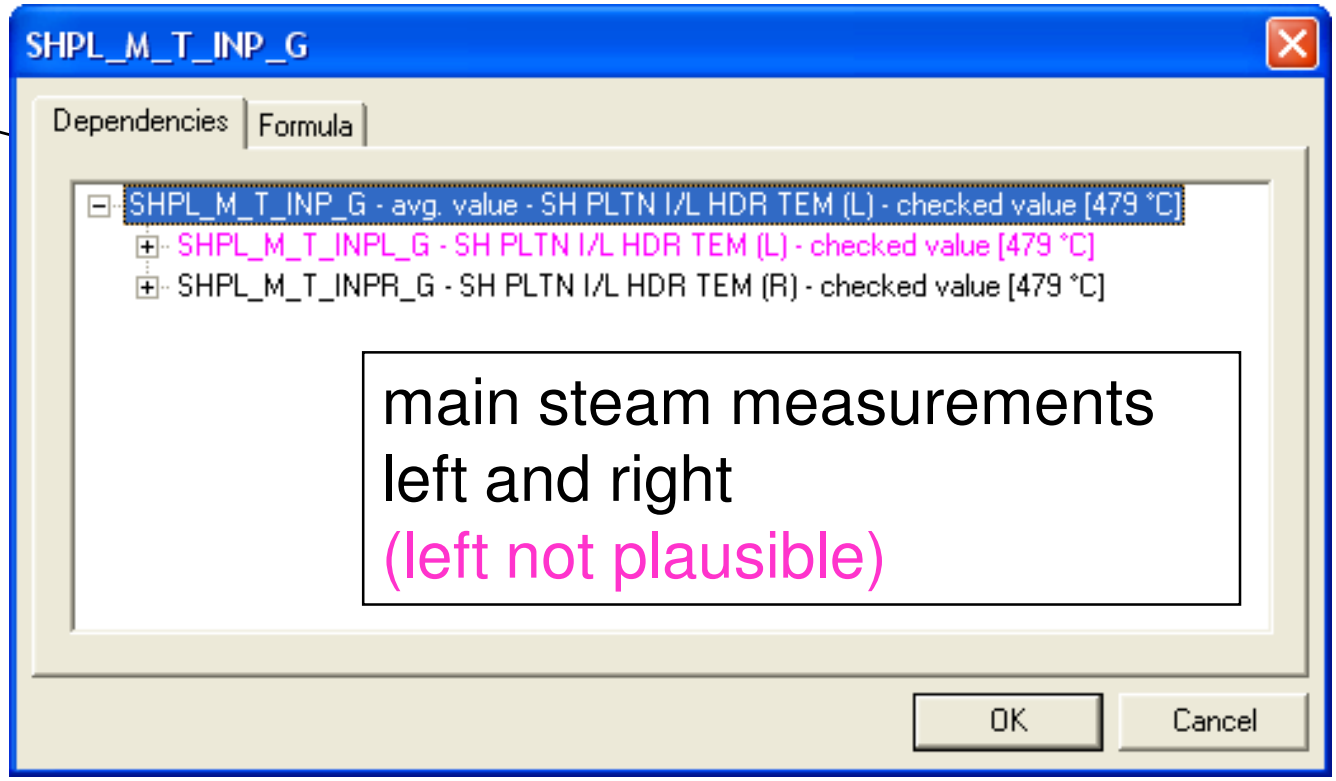

main steam measurements left and right
(left not plausible)

Implausible Value - replacement

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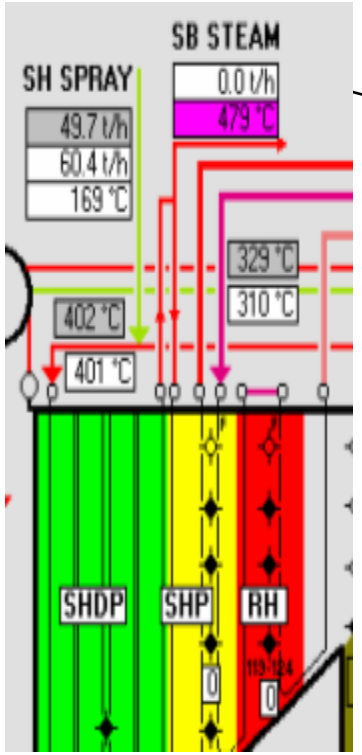

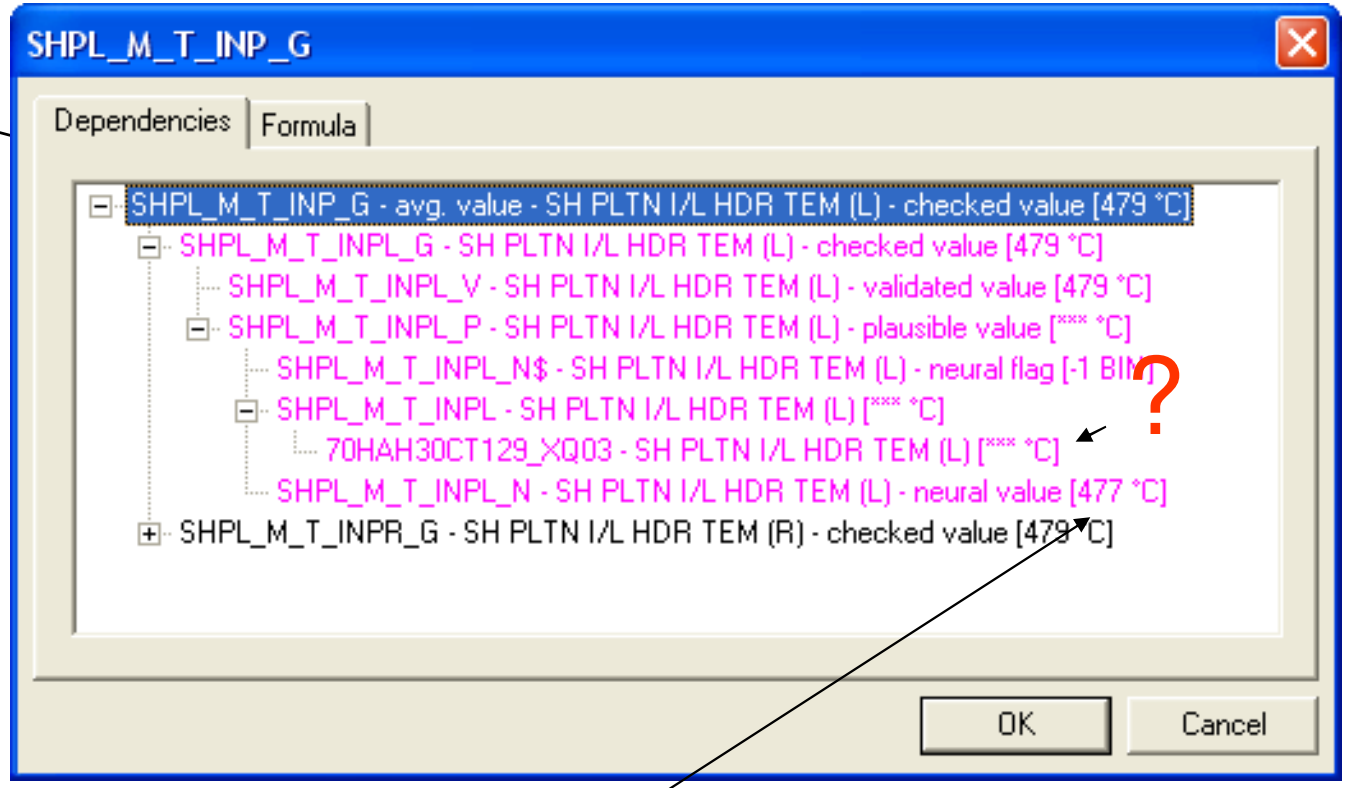

Neural network generated the value 477 °C for not available value of tag 70HAH30CT129_XQ03

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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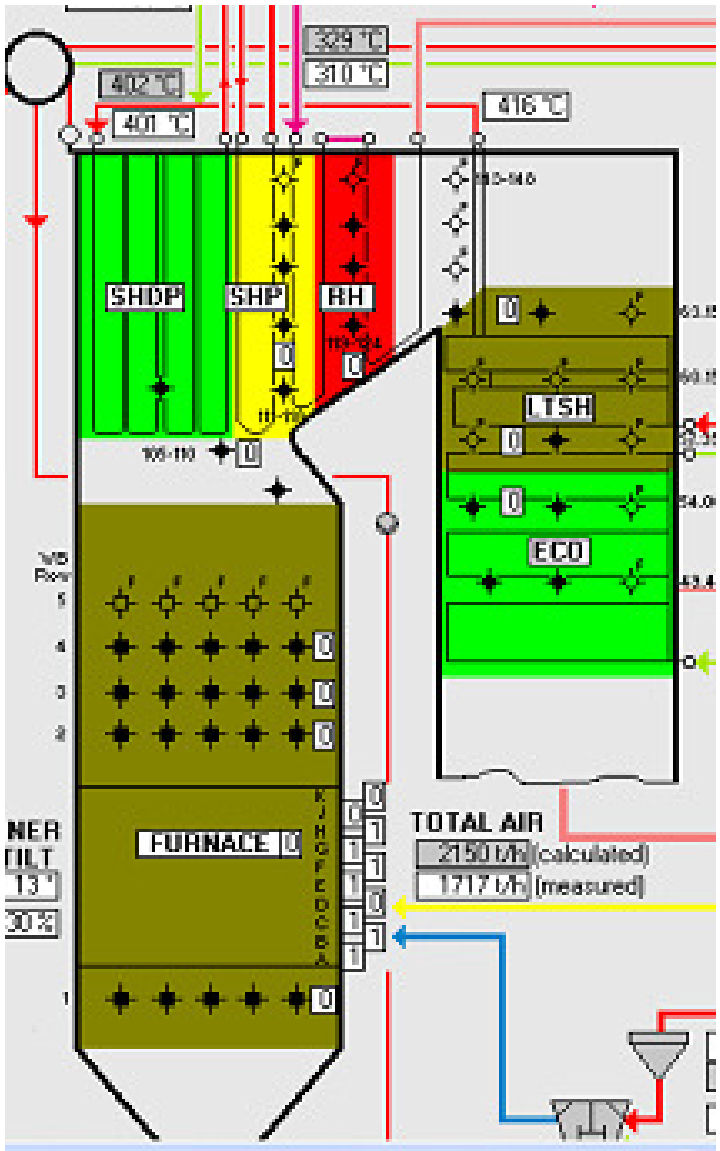

Red - Critical
Yellow - Suboptimal
Light Green – Optimal
Dark Green – Time gap to next action

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

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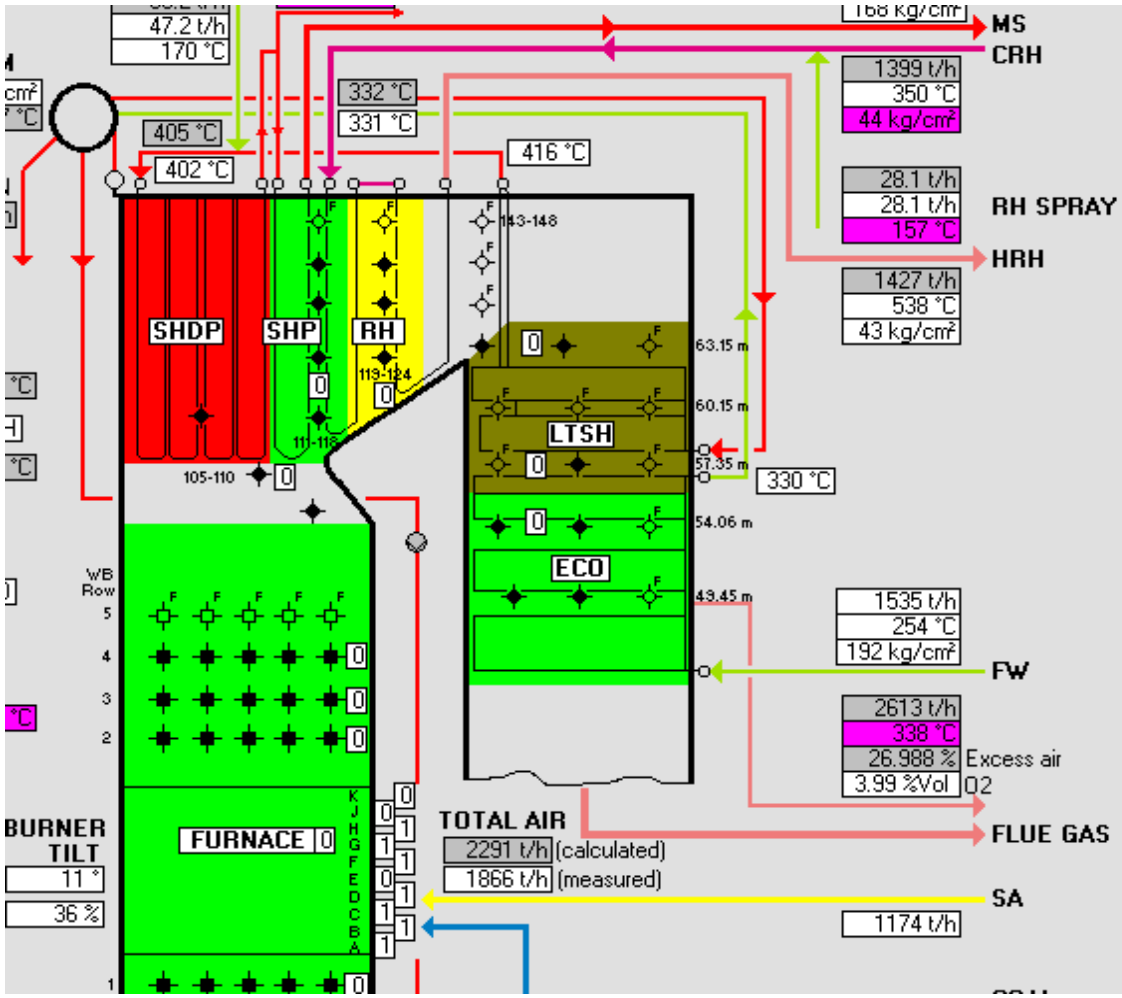


Generator el. output power gross	502 MW
Unit efficiency net	35.3 %
Unit heat rate gross	2363 kcal/kWh
Boiler Load Index	1567 t/h
Boiler efficiency	87.0 %
Station load	15.0 MW

SOOTBLOWING OPTIMIZATION

Heating Surface	Efficiencies Act	Efficiencies Min	Level/ SB No.	Sootblowing
Furnace/WW	91.7	80.1	Row 1-5	SB not req.
SH Division Pan.	88.9	85.0	105-110	Comp. SB
SH Platen	93.2	85.0	111-118	SB not req.
Reheater	79.0	79.0	119-124	Next SB
Low Temp. SH	106.2	85.0	63.15 m	Suspended
			57.35 m	
Economizer	97.0	85.0	54.06 m	Suspended
			49.45 m	SB not req.

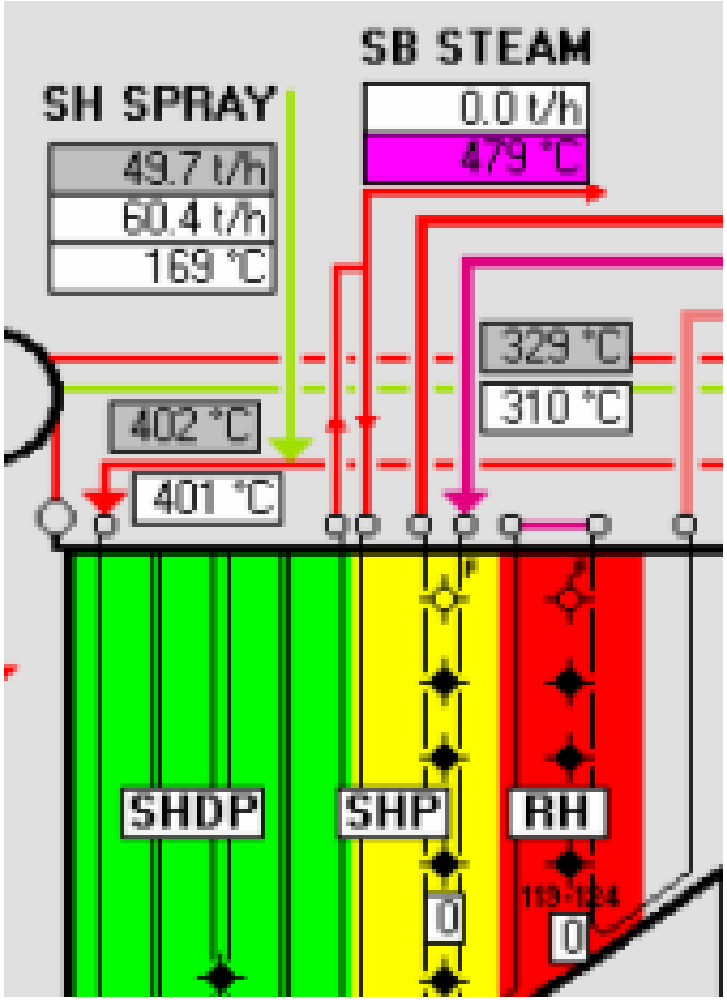
ACT-/REF-COMPARISON

	Act	Ref	Monetary loss
O2 at Eco outlet	3.99 %Vol	3.16 %Vol	0.02 Rs/h
Burner tilt	11 °	-4 °	
SH spray	36.2 t/h	0.0 t/h	
RH spray	28.1 t/h	0.0 t/h	
T FG at Eco outlet	338 °C		
Boiler efficiency	87.0 %	87.9 %	

Soot Blowing Legend

Compulsory SB

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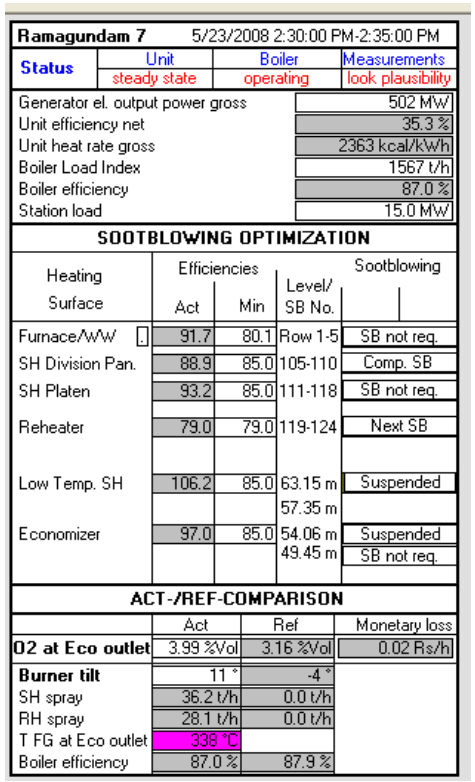
- Compares the actual values of critical parameters with the best achievable under current operating conditions.
- Shows monetary loss against each sub optimal operating parameter, defining the scope of improvement.



Ramagundam 7 5/23/2008 2:30:00 PM-2:35:00 PM

Status	Unit steady state	Boiler operating	Measurements look plausibility
Generator el. output power gross			502 MW
Unit efficiency net			35.3 %
Unit heat rate gross			2363 kcal/kWh
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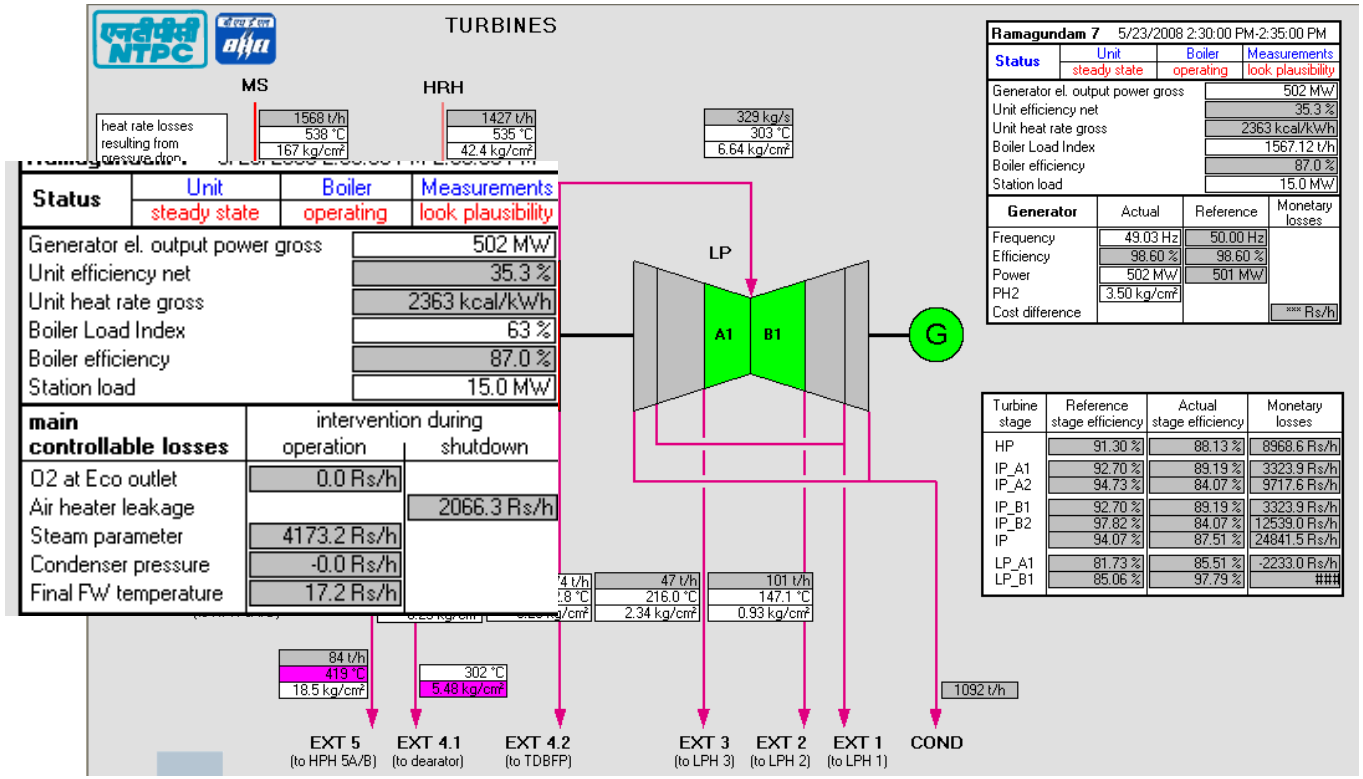

Ramagundam 7 5/23/2008 2:30:00 PM-2:35:00 PM

Status	Unit steady state	Boiler operating	Measurements look plausibility
Generator el. output power gross			502 MW
Unit efficiency net			35.3 %
Unit heat rate gross			2363 kcal/kWh
Boiler Load Index			1567.12 t/h
Boiler efficiency			87.0 %
Station load			15.0 MW

Generator	Actual	Reference	Monetary losses
Frequency	49.03 Hz	50.00 Hz	
Efficiency	98.60 %	98.60 %	
Power	502 MW	501 MW	
PH2	3.50 kg/cm²		
Cost difference			*** Rs/h

Turbine stage	Reference stage efficiency	Actual stage efficiency	Monetary losses
HP	91.30 %	88.13 %	8968.6 Rs/h
IP_A1	92.70 %	89.19 %	3323.9 Rs/h
IP_A2	94.73 %	84.07 %	9717.6 Rs/h
IP_B1	92.70 %	89.19 %	3323.9 Rs/h
IP_B2	97.82 %	84.07 %	12539.0 Rs/h
IP	94.07 %	87.51 %	24841.5 Rs/h
LP_A1	81.73 %	85.51 %	-2233.0 Rs/h
LP_B1	85.06 %	97.79 %	###

Status	Unit steady state	Boiler operating	Measurements look plausibility
Generator el. output power gross			502 MW
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Unit heat rate gross			2363 kcal/kWh
Boiler Load Index			63 %
Boiler efficiency			87.0 %
Station load			15.0 MW

main controllable losses	intervention during operation	intervention during shutdown
O2 at Eco outlet	0.0 Rs/h	
Air heater leakage		2066.3 Rs/h
Steam parameter	4173.2 Rs/h	
Condenser pressure	-0.0 Rs/h	
Final FW temperature	17.2 Rs/h	

Turbine Performance Monitoring

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- [TURBINE]

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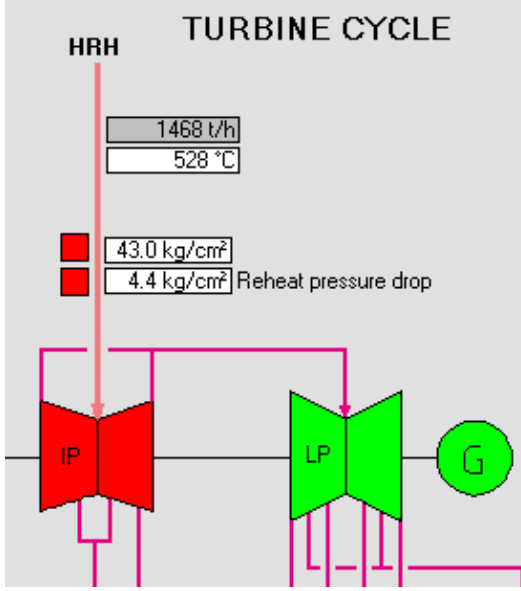
5'-values 5/23/2008 2:45:00 PM-2:50:00 PM



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

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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

Controllable Losses

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- [TURBINE]

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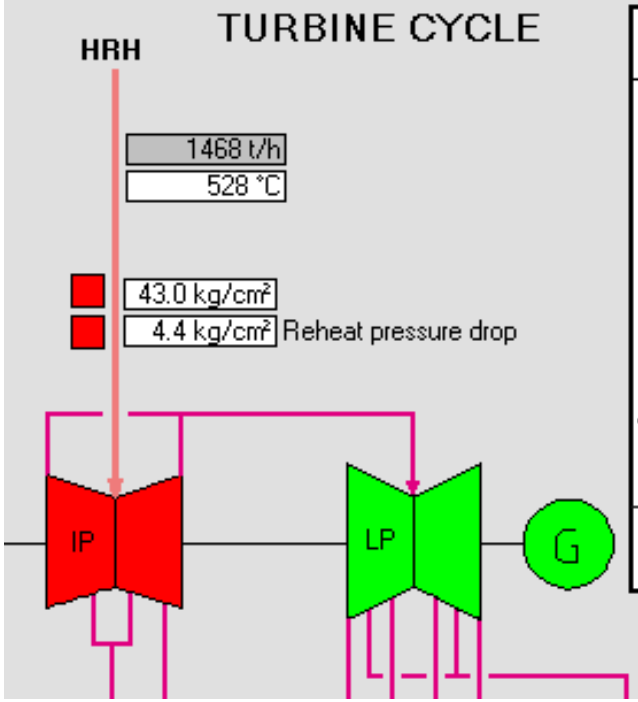

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TG heat rate gross, actual 2054 kcal/kWh
TG heat rate gross, reference 2051 kcal/kWh
TG heat rate net, actual 2117 kcal/kWh

Turbine Stage Efficiencies

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STEAG Ketek IT - PAD [redacted] INES]

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TURBINES

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Status	steady state	Boiler operating	Measurements look plausibility

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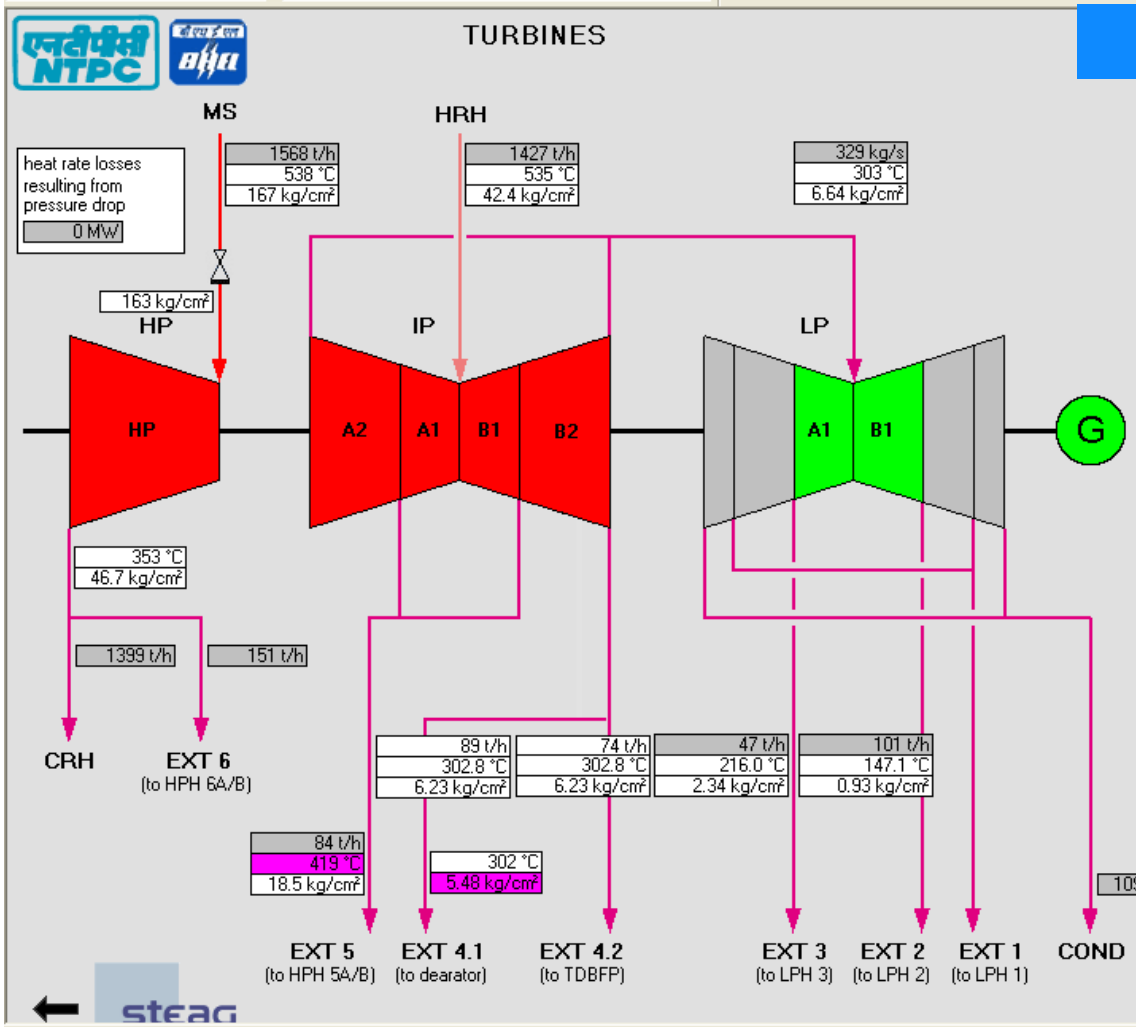
Cost difference			*** Rs/h



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IP	94.07 %	87.51 %	24841.5 Rs/h
LP_A1	81.73 %	85.51 %	-2233.0 Rs/h
LP_B1	85.06 %	97.79 %	###

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LPA1 C ML EFF

Condenser

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CONDENSER

Steam from LP Turbine

1016 t/h

Steam from BFP turbines — 73.9 t/h

1092 t/h

-644.455 mmHg
85.606 mmHga

Cooling Water total — 44.6 °C

Cooling Water left — 44.6 °C

Cooling Water right — 44.6 °C

53493 m³/h

33.7 °C — 33.7 °C — 33.7 °C

Condensate to hotwell — 183 t/h

6.6 t/h
DM MU flow

Condensate
48.4 °C

Condensate Extraction Pumps

	C	B	A
	off	on	on
	6.60 kV	6.60 kV	6.60 kV
	0 A	77 A	80 A
	*** %	73 %	70 %
	0 t/h	638 t/h	637 t/h

49.1 °C
27.7 kg/cm²
183 t/h

[redacted]

5/23/2008 2:30:00 PM-2:35:00 PM

Status	Unit	Boiler	Measurements
	steady state	operating	look plausibility

Generator el. output power gross	502.3 MW
Unit efficiency net	35.3 %
Unit heat rate gross	2363 kcal/kWh
Boiler Load Index	1567.12 t/h
Boiler efficiency	87.0 %
Station load	15.0 MW

	Reference	Actual
condenser vacuum	85.633 mmHga	85.606 mmHga
condensing temp.	*** °C	48.4 °C
efficiency	95.0 %	100.0 %
TTD	3.8 °C	3.8 °C

heat rate deviation	-0 kcal/kWh
heat rate deviation air ingress	0 kcal/kWh
heat rate deviation fouling	-0 kcal/kWh
monetary loss	-0 Rs/h

	pass - I	Pass - II
cw temp. rise	10.9 °C	10.9 °C
TTD	3.8 °C	3.8 °C
vacuum due to		
cw inlet temp.	81.1 mmHga	81.1 mmHga
cw flow	83.1 mmHga	83.1 mmHga
loss of vac. due to		
cw inlet temp.	5.1 mmHga	5.1 mmHga
cw flow/excess heat	2.0 mmHga	2.0 mmHga
dirty tube/air ingress	4.5 mmHga	4.5 mmHga
total loss of vacuum	11.6 mmHga	11.6 mmHga
depression	***	

CW diff.pressure	0.05 bar
Reference Pressure	0.97 bar

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HP Heaters

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STEAG Ketek IT - PADO

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5'-values 5/23/2008 2:30:00 PM-2:35:00 PM

HP HEATERS

EXT 6 151 t/h

EXT 5 84 t/h

EXT 4 89 t/h 302 °C 5.48 kg/cm²

DEAERATOR -55.2 mm 0.0 ppb O2 302 °C 5.5 kg/cm²

1275 t/h

FW to boiler 1535 t/h

TDBFP 37 t/h 2 t/h 37 t/h 2 t/h

BFP C B A

SH SPRAY 36.2 t/h

RH SPRAY 28 t/h

pump efficiencies *** % 74 % 74 %

M off on on

16 t/h 789 t/h 795 t/h

254 °C 195 kg/cm² 76.6 t/h 350 °C 44.6 kg/cm²

255 °C 195 kg/cm² 74.6 t/h 350 °C 44.6 kg/cm²

0 mm *** mm HPH 6A

-40 mm *** mm HPH 6B

77 t/h 213 °C

75 t/h 214 °C

206 °C 197 kg/cm² 40 t/h 418 °C 17.6 kg/cm²

209 °C 197 kg/cm² 44 t/h 418 °C 17.6 kg/cm²

-46 mm *** mm HPH 5A

-39 mm *** mm HPH 5B

117 t/h 176 °C

118 t/h 176 °C

172 °C 199 kg/cm²

172 °C 199 kg/cm²

768 t/h

768 t/h

5/23/2008 2:30:00 PM-2:35:00 PM

Status	Unit	Boiler	Measurements
	steady state	operating	look plausibility

Generator el. output power gross	502 MW
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High pressure heater		TTD actual	TTD reference
on	HPH 6A	3.06 K	0.02 K
on	HPH 6B	1.94 K	0.02 K
on	HPH 5A	1.24 K	0.19 K
on	HPH 5B	-1.31 K	0.19 K

High pressure heater	DCA actual	DCA reference
HPH 6A	6.93 K	4.92 K
HPH 6B	5.08 K	4.92 K
HPH 5A	3.92 K	4.77 K
HPH 5B	4.05 K	4.77 K

case	pump in operation	max load per pump	recommended load distribution
1	1	990 t/h	1 x *** t/h
2	2	990 t/h	2 x 800 t/h

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Ready

LP Heaters

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5'-values | 5/23/2008 2:30:00 PM-2:35:00 PM

LP HEATERS

5/23/2008 2:30:00 PM-2:35:00 PM

	nit	Boiler	Measurements
	steady state	operating	look plausibility

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Boiler Load Index	1567.12 t/h
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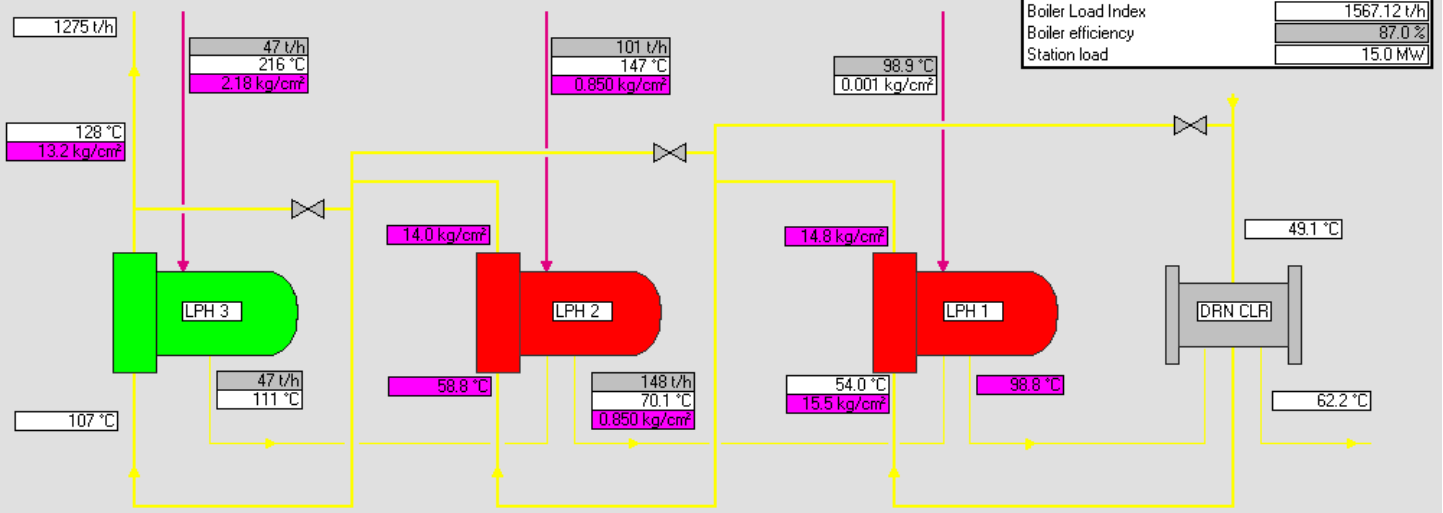
Station load	15.0 MW



Low pressure heater	TTD	TTD_REF	DCA	DCA_REF
LPH 1	40.03 K	2.99 K	44.85 K	15.60 K
LPH 2	10.11 K	2.92 K	11.32 K	4.87 K
LPH 3	6.78 K	2.90 K	4.17 K	4.97 K

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Ready

Statistical Process Control

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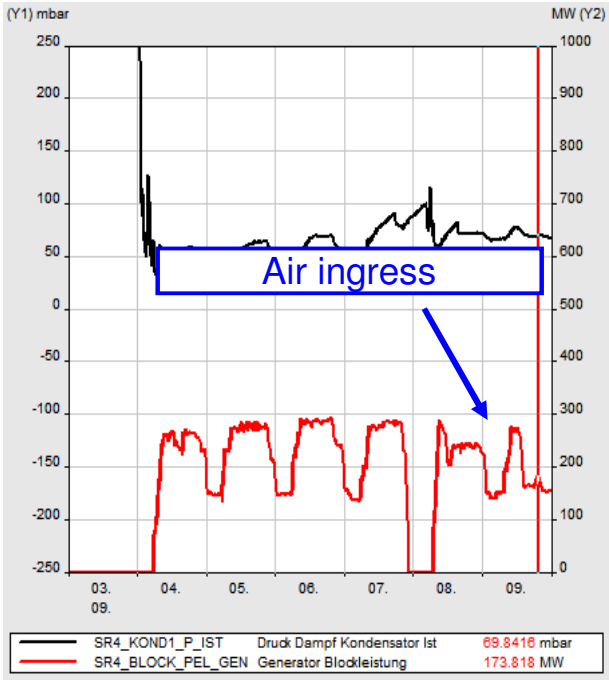
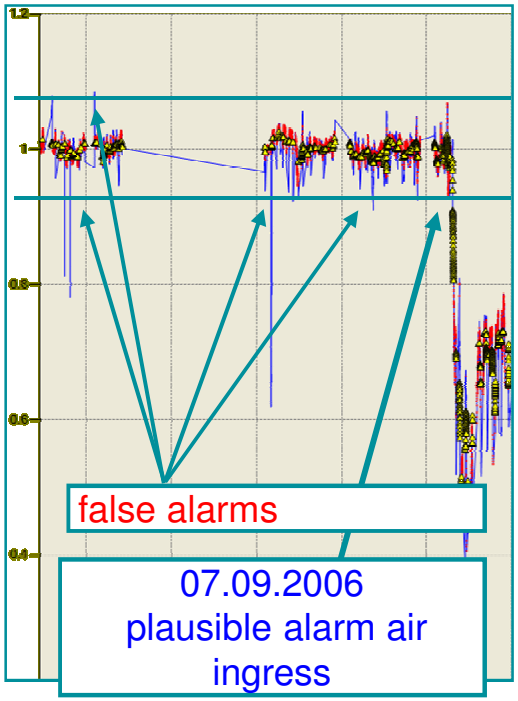
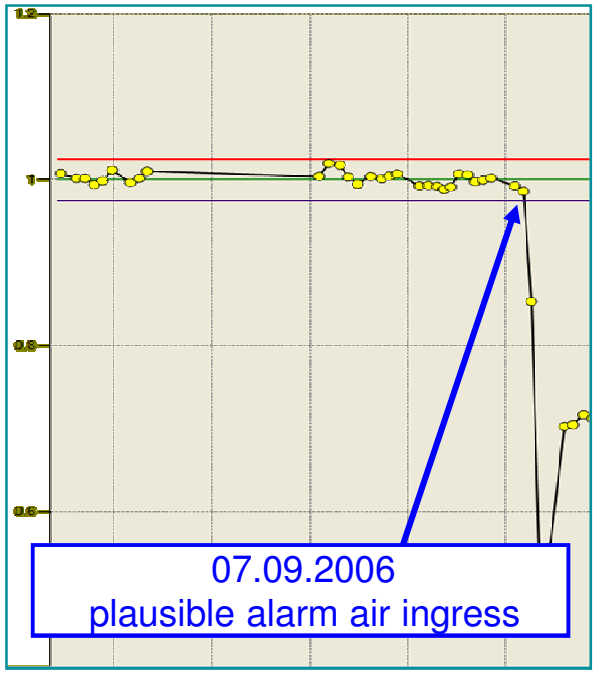
Statistical methods to evaluate partly automatic, early & reliable detection of changes where deterioration is slow.







Key Performance Indicators

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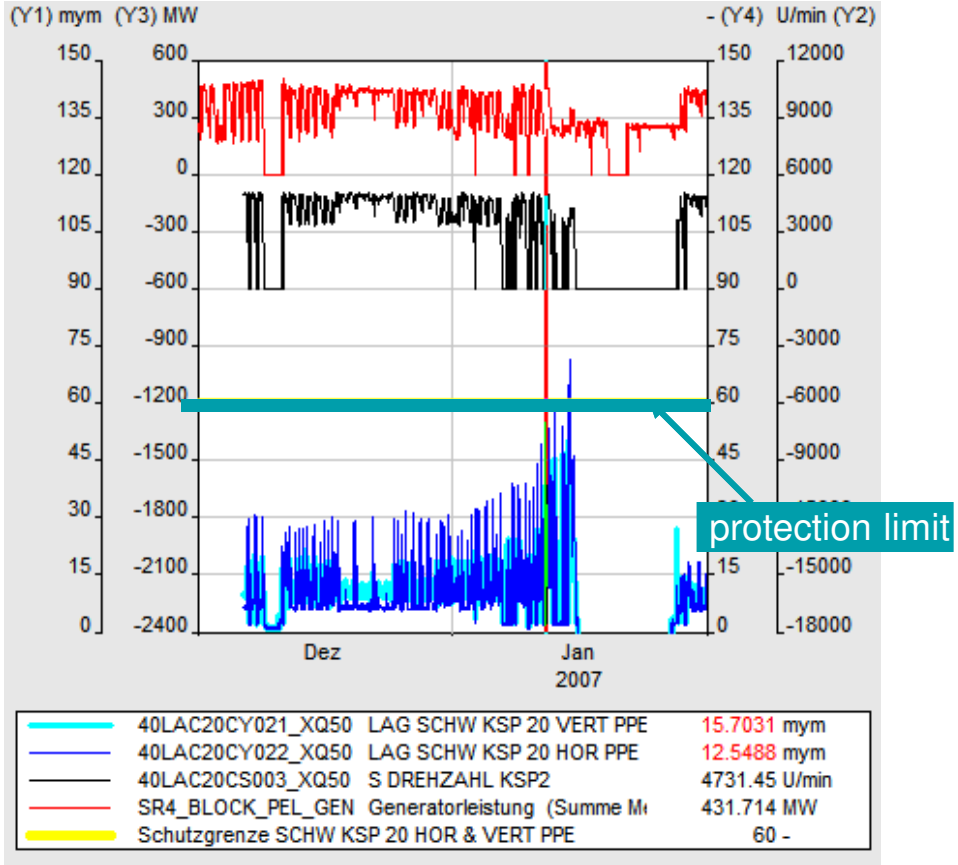
measured	calculated
vibration bearing temperature oil temperature power consumption …	heatrate Component quality factor efficiency …

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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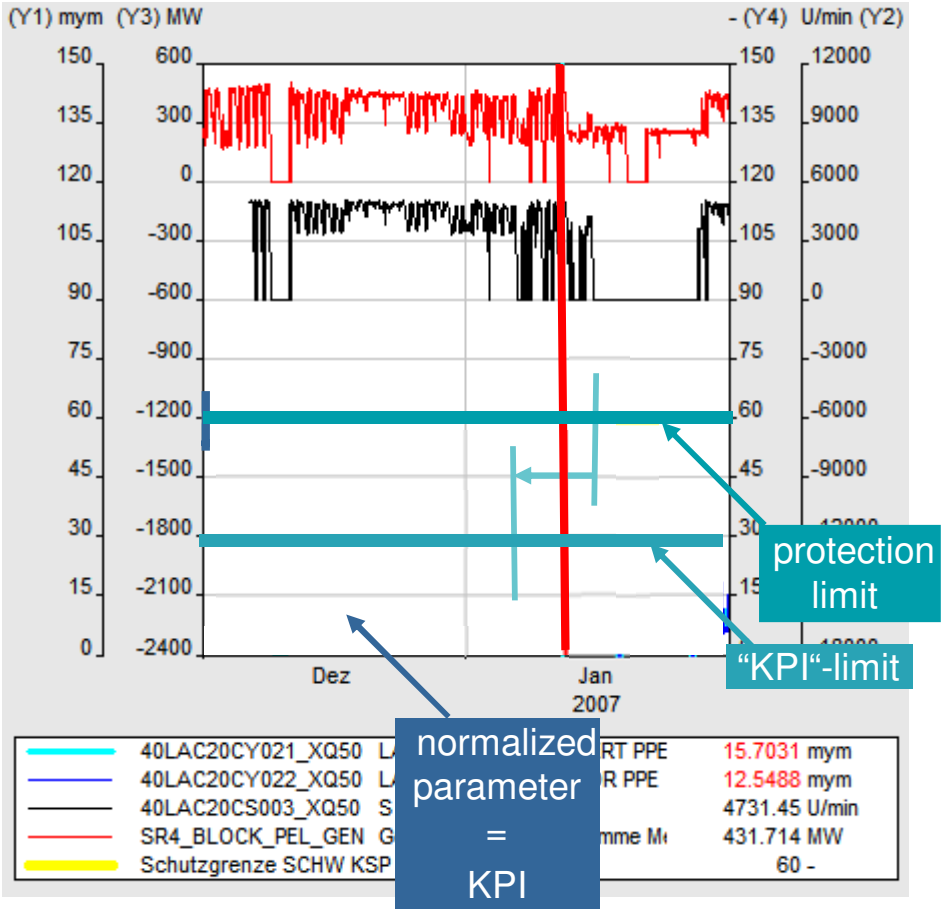
KPIs measure the qualitiy of the process / component.

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

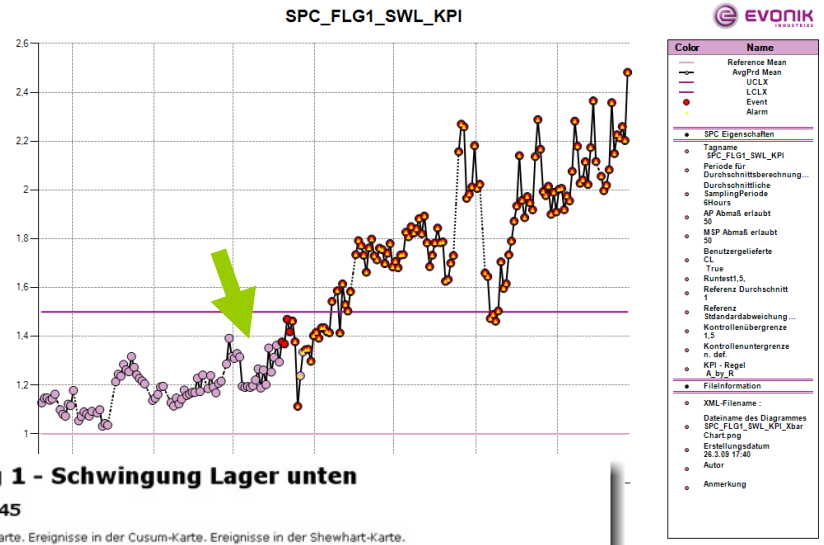
Zustandsüberwachung

Kesselspeisepumpe 1

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

Kesselspeisepumpe 2

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



SPC_SGZ1_SWU - Saugzug 1 - Schwingung Lager unten

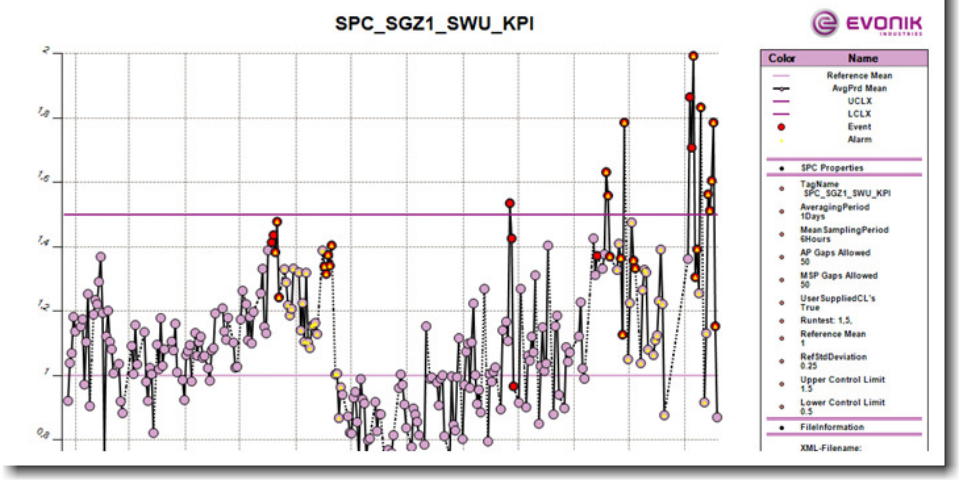
SPC Ergebnisse für 20.01.2009 15:45

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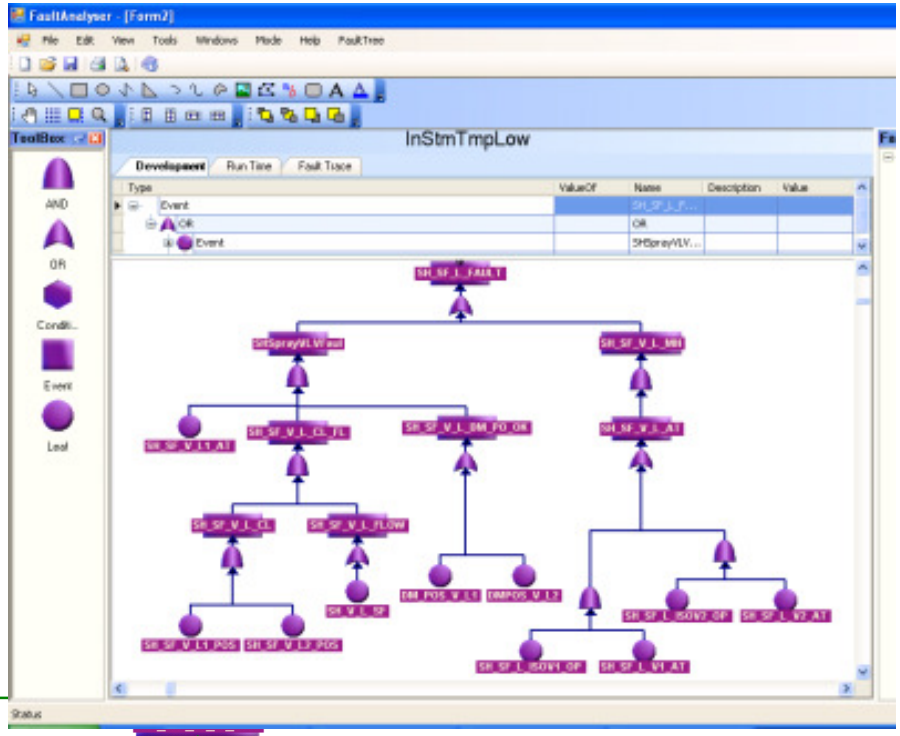
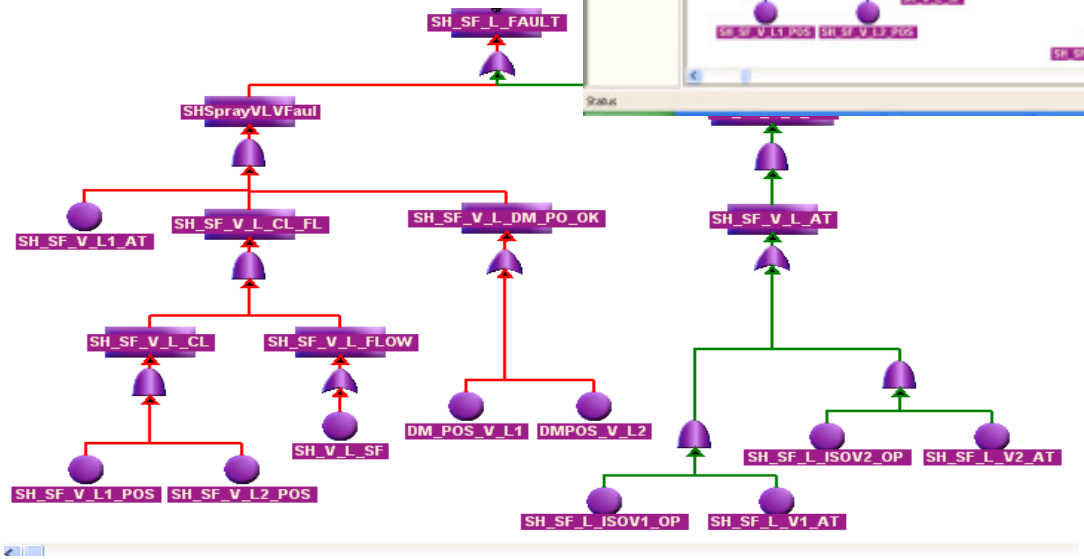
- Models and analyzes faults in the process.
- Composed of logic diagrams that display the state of the system and the states of the components
- Constructed using Drag & Drop technique
- Does not need programming expertise for building such trees.





Thank You

... Ideas & Solutions for Tomorrow

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