Flexible Operation of Steam Power Plants

Solutions from SIEMENS ENERGY

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Business Representation for Siemens Energy
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Changing energy market

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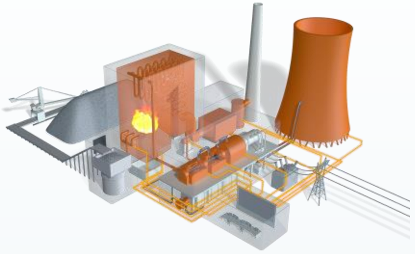
SOLAR WIND COAL & LIGNITE

	Renewable		Non Renewable	
2012 CEA	21	GW	125	
2022 CEA	114	GW	210	
2032 Niti Aayog	500 ↑	GW	200 ↓	More Retirals Less Additions
2047 Niti Aayog	650	GW	333	

Coal based power plants – will have to become

- Agile
- Handle minimum loads
- Improve efficiency
- Lower emissions -
  to remain operational

Siemens Power & Process Automation Modern control concepts for high profitability



Process engineering competence

600 GW installed,
10 GW operated
by Siemens

+

Automation competence

2500 systems based on proven Siemens technology

+

Power-IT competence

Role-based information supply for everyone in the power plant

Excellent control concepts form the basis for Process Optimization solutions:

- **Model-based, predictive feed forward structures**
- **Decoupling of highly intermeshed sub processes**
- **State space control**
- **Neuronal networks and fuzzy logic**

This makes it possible to achieve extremely stable, reproducible and flexible operating behavior -

The basis for high profitability

Siemens approach to reduce min. load up to 40%
There is no One Size Fits All !!!

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Answering Questionnaire

Information about thermal state of plant (degradation level), existing automation level, flamer scanner, combustion stability, start-up procedure etc. have to be provided

Providing of Process Data

Process data from one cold start-up, one ramp down to min load and one ramp up to full load will be analyzed from Siemens-Energy.

Alignment on min load tests

Siemens Energy suggests based on the provided information and the result of the data analyzation a test procedure to reduce min load.

Reducing min. load on site

Siemens Energy experts and the operators from the power plant reduce the min load according the agreed test procedure until first obstacle occurs.

Implementation and automation of min. load

Siemens Energy implements the identified measures to automate the load reduction and secure a stable operation during min load

Typical Questions – Identify improvement in specific areas

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Plant Configuration

- Boiler type (drum/once through)
- Number of mills ? Mill manufacturer/design ?
- Burner configuration (Tangential, wall, opposed wall, …)
- Boiler DCS manufacturer / Model ?

Efficiency & Emissions

- How often does the plant perform soot blowing in the economizer /evaporator/superheater / APH area?
- What is the furnace exit temperature ?
- What is the current HP steam temperature set point? & deviation ?
- What are current values for CO?
- What are current values for carbon in ash (LOI)?
- What are current values for NOx ?

Flexibility

- What is the current Minimum Load?
- What is the Minimum Load target for the future? What is the current technical limitation for more ? Minimum Load ?
- Would a higher part load efficiency add business value?
- Is it lucrative for the plant to increase the range of frequency control?
- What are the current load ramps?

Siemens approach to reduce min. load
Example - Test Plan

Time (IST)	Time (CET)	Load	Status	Procedure	Observation
10:30	07:00	290 MW	Min load, unit control normal operation, mills B-E in operation,one feedwater pump already out of operation (if possible), SCAPH already in operation	Select burner tilt, O2 and main steam pressure as found most suitable in last test	
10:30	07:00			If not done before: Put SCAPH in operation for increased APH flue gas temperatures.	
10:30	07:00			If not done before: Take feedwater pump out of operation as early as possible, and operate with 1 pump. If possible, before reducing load below actual min load.	
10:30	07:00			Take mill E out of operation. Operate with the minimum number of mills (three) that are required for this load. Use mills B, C and D.	
11:30	08:00	290 MW		Lower load slowly and in steps by adjusting the unit control setpoint. Load changes should be around 25 MW (equaling 5%). This can be achieved by reducing the load setpoint from 288 MW to 263 MW to 243 MW to 220 MW to 210 MW, using a slow slope (e.g. 0.5%/min). After each load reduction, wait about 30 minutes for stabilization	Drum level, SH&RH steam temperatures, combustion, ...
				After each load reduction, wait about 30 minutes for stabilization	Identify process instabilities.
				If no instabilities, reduce load further	Drum level, SH&RH steam temperatures, combustion, ...
				When instabilities can not be eliminated, go back to last safe load	
11:40	08:10	263 MW		Reach 263 MW	
12:10	08:40	263 MW		Setpoint to 243 MW	
12:20	08:50	243 MW		Reach 243 MW	
12:50	09:20	243 MW		Setpoint to 220 MW	
13:00	09:30	220 MW		Reach 220 MW	

Technological solutions to address the challenges

Solutions	Benefits
• Boiler → Slow-acting • Turbine → Fast-acting Solution: Enhanced Unit Controller that ensures better Coordination • Optimized Control of Key Operational Parameters → (a) Reheat Temperature b) Main SteamTemperature (c) Flue Gas (d) Feedwater circulation d) Intelligent soot blowing	1. Higher Load Ramps 2. Minimum human intervention 3. Improved Plant efficiency 4. Stable Operation at *"new"* sustainable minimum load
Smart Regulation of key Aux Equipment • Fans • Pumps • Mill Scheduler → coal mills } Auto ON/OFF	1. Improved Plant efficiency 2. Auxiliary Power consumption optimized. 3. Minimum Operator intervention.
Thick-walled boiler components are impacted with load ramps / thermal cycling. Fatigue life must be monitored. This is achieved through - Fatigue Monitoring System to monitor and determine residual lifetime.	Plant shutdowns can be planned to rectify / replace highly stressed components at the appropriate time – savings in unplanned outages

Omnivise P3000 Minimum Load Reduction
Reduced minimum load level

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Task

To upgrade the plant so that the specified minimum load level can be reduced and to make the plant capable of fast and low-stress load increases on demand in accordance with market requirements.

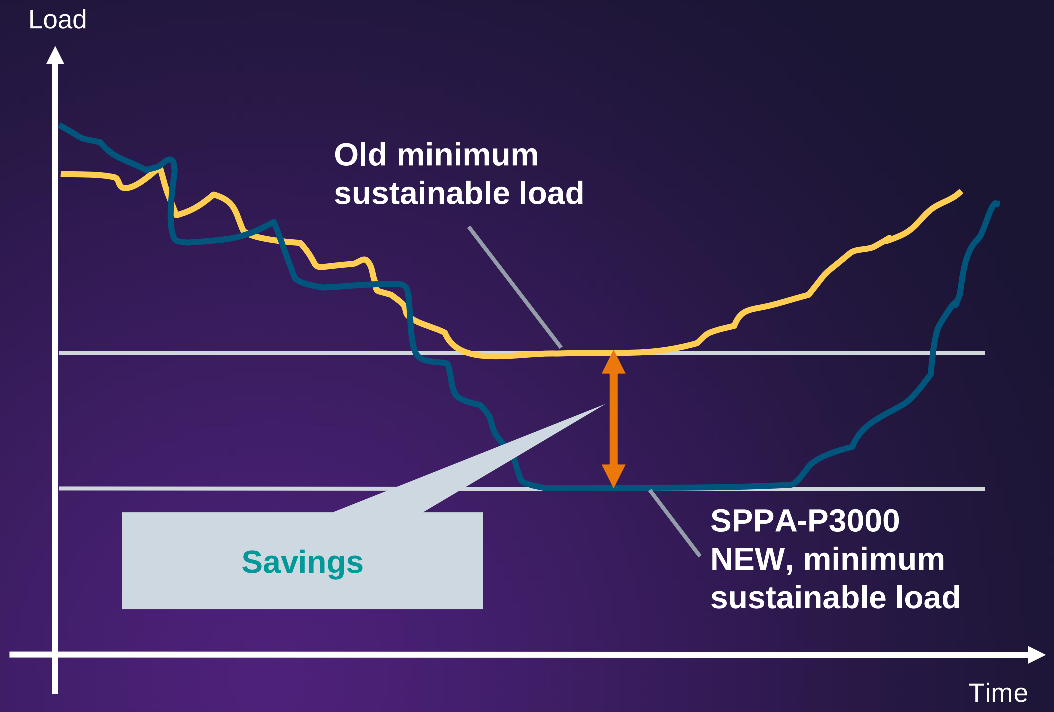
Solution

- Use of robust state space controller for unit control
- Adaptation, optimization and setting of lower-level controls for new minimum load level
- Adaptation or addition of control sequences, burner and mill scheduler
- Provision of additional instrumentation where necessary

Benefit calculation based on

- Reduced financial losses during off-peak periods
- Faster response to increased load demands as unit does not need to be shut down
- Avoidance of unnecessary startups and shutdowns

Minimum Load Reduction



The Minimum Load Reduction solution results in savings for minimum load operation through optimization of lower-level controls.

Omnivise P3000 Temperature Optimizer
Increased steam temperatures

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Task

To achieve maximum steam temperature without violation of material limits

Solution

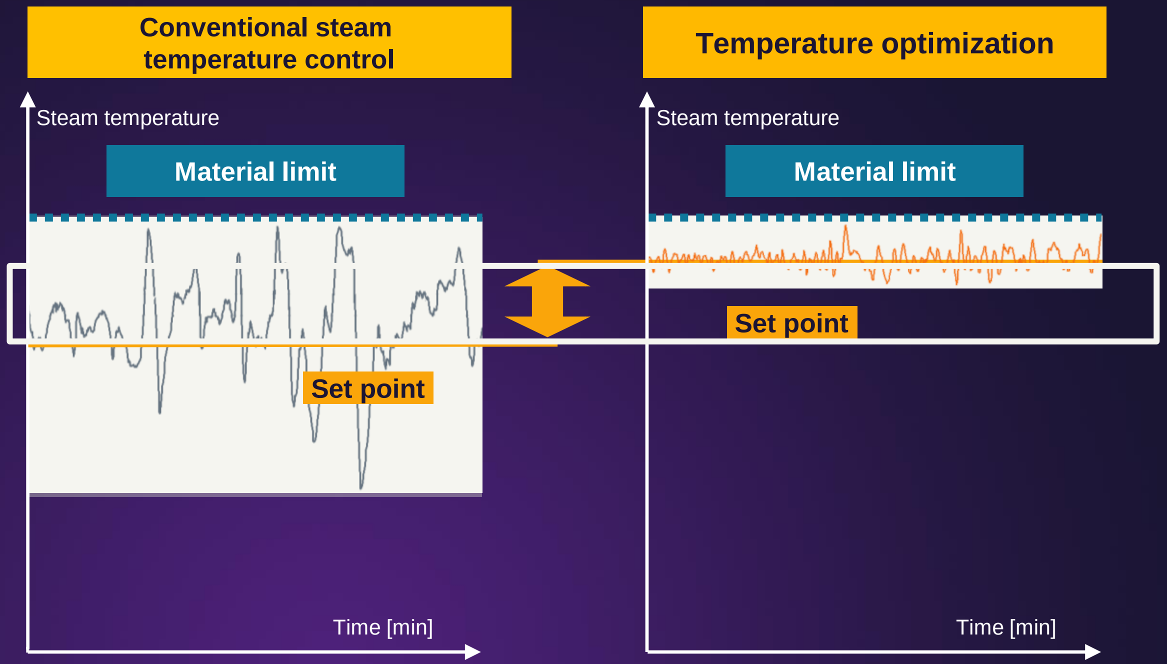
- Robust, easy to parameterize and adaptive state space controller with observer
- Where needed, use of entire control range through to injection into saturated steam
- Use on startup/shutdown and over the entire load range

Benefit calculations based on -

Increased efficiency thanks to

- Higher steam temperatures
- Reduction in reheater attemperation

Temperature Optimizer



The Temperature Optimizer solution increases the efficiency through higher steam temperatures and the use of appropriate control elements for reheater temperature.

Omnivise P3000 Sootblower Optimizer
Optimized operation of sootblowers

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Task

Condition-based, selective operation of individual sootblowers instead of manual or cyclical activation of entire groups of sootblowers.

Solution

Targeted control of key boiler operating parameters such as

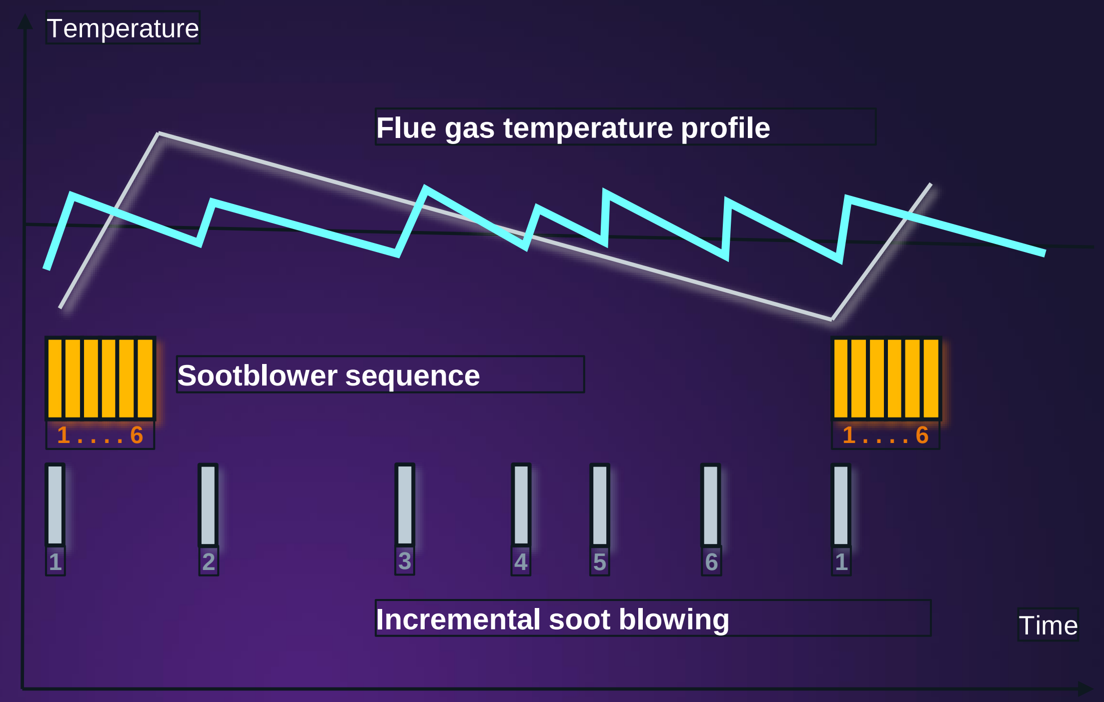
- Reheater attemperation
- Temperature imbalances
- Control range of HP feed water heaters
- Boiler slagging

Automatic activation of individual sootblowers

Benefit calculation based on

- Reduced fuel costs due to optimal operation of sootblowers
- Higher availability due to avoidance of unnecessary soot blowing

Sootblower Optimizer



The „Sootblower Optimizer“ solution enables the optimum operation of individual sootblowers.

Beyond classical "Intelligent" Sootblower Optimizers which only activate existing soot blower groups according to fouling

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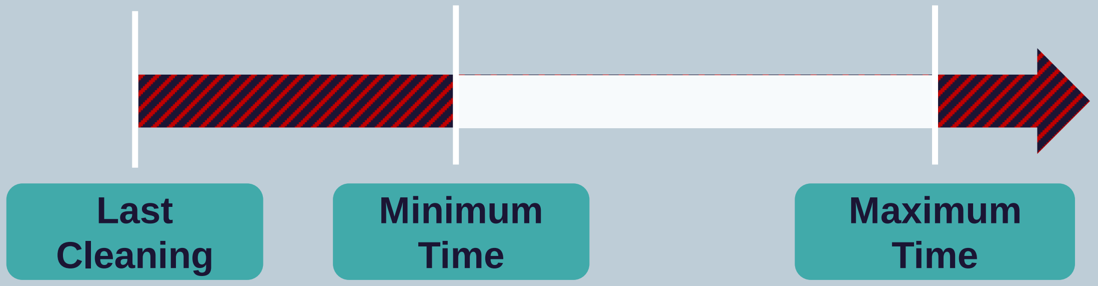
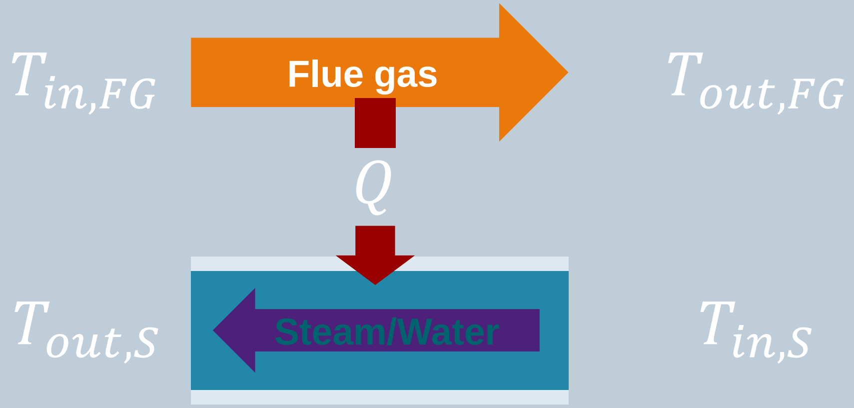


- Minimum Time prevents excessive cleaning
- Maximum Time ensure minimum cleaning cycle to avoid baking of residue
- Time is measured for **each sootblower individually**



Heat transfer: $Q = m_S * c_{p,S} * \left(T_{out,S} - T_{in,S}\right)$

$= m_{FG} * c_{p,FG} * (T_{in,FG} - T_{out,FG})$

Heat transfer coefficient: $q = \frac{Q}{\Delta T}$

Cleanliness factor: $CF = \frac{q}{q_{clean}}$

Fouling factor: $FF = \frac{1}{CF} - 1$

Omnivise -P3000 Frequency Control
Increased range for primary frequency control

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Task

To upgrade the unit so that it can provide primary frequency control and spinning reserve. Due to the fast load ramps that this service requires, it places very high demands on the dynamic control response of a power plant unit.

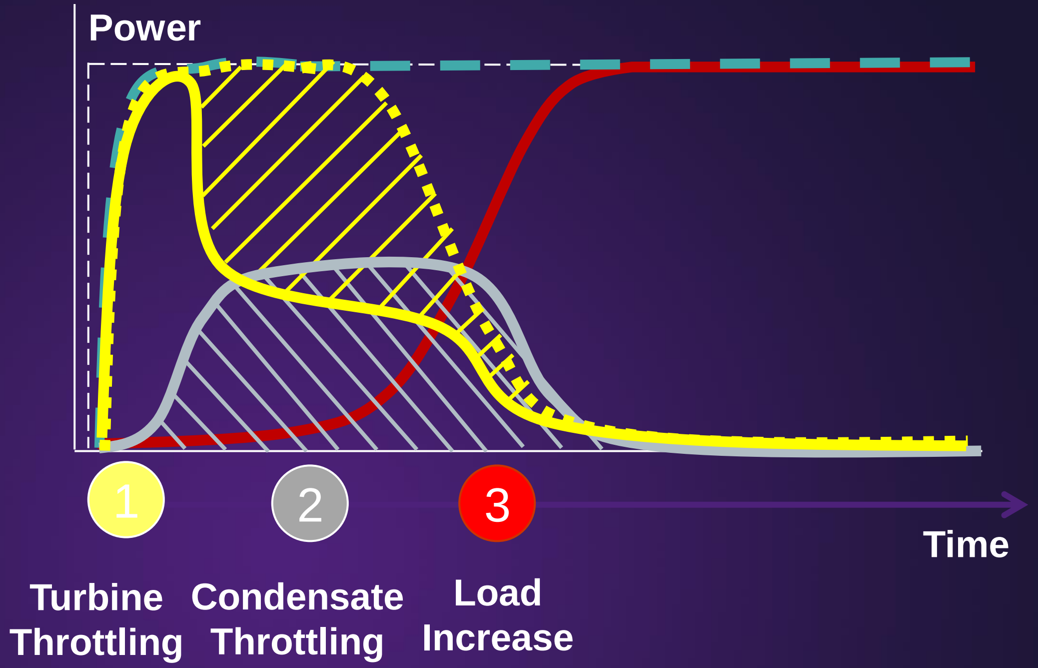
Solution

- Activation of the condensate throttling to mobilize energy storage and/or
- Throttling of turbine valves

Benefit calculation based on -

- Increased revenue from primary frequency control and spinning reserve services
- Avoidance of fiscal penalties for non-provision of contractually agreed primary frequency control and spinning reserve services

Frequency Response including P3000 Condensate Throttling (Efficiency):



Additional information about coal flow distribution as first step to avoid imbalances in coal flow, increase burner stability

The Issue

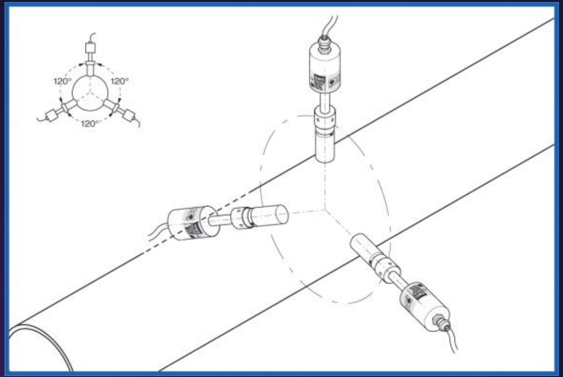
- Today imbalances of coal flow among the burners can be up to 30%)
- Cause poor combustion and possibly wall corrosion
- This means lower efficiency, more emissions, more material stress

The Solution

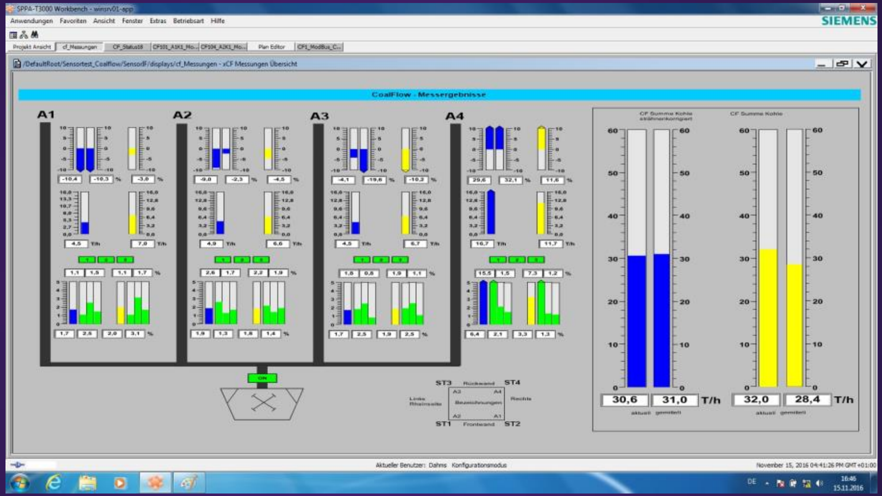
- Applying a microwave sensor system for coal flow measurement
- Balancing combustion
- Imbalances are equalized in short time periods

Benefit:

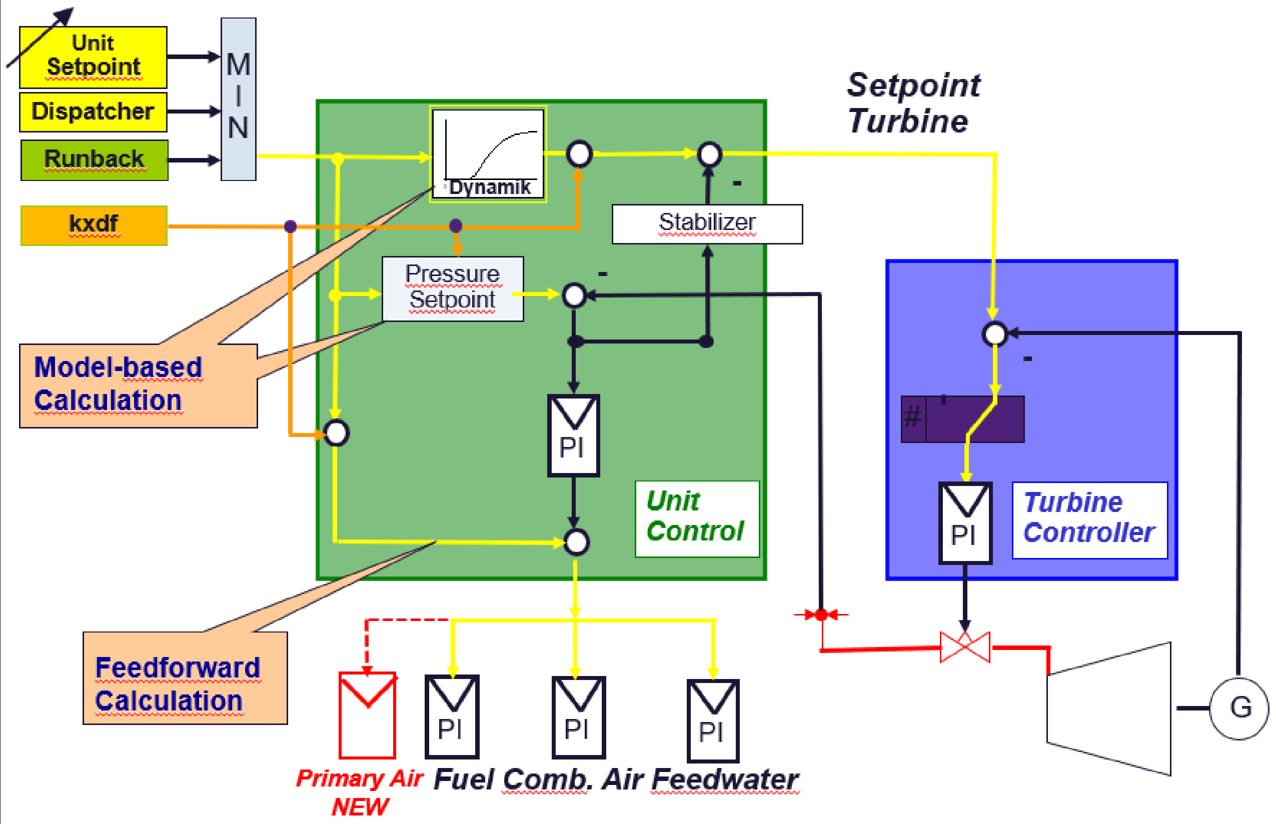
- Individual burner adjustment possible



Installations of 3 Sensors for pipes above 400 mm diameter to avoid inaccuracies from roping



Coal Flow Measurement System
Advantages for Flexibility & Efficiency



Expected Benefits and Results

- Improved mill and feeder control
- Higher plant stability during load changes
- Higher Load Ramps by using mill storage
- Improved dynamics during fuel demand with new Primary Air Setpoint

Boiler Fatigue Monitoring System (FMS)
Life cycle of Components
Online Evaluation--Possible

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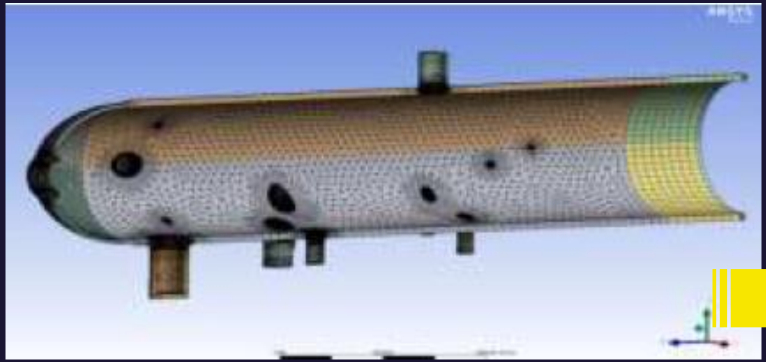
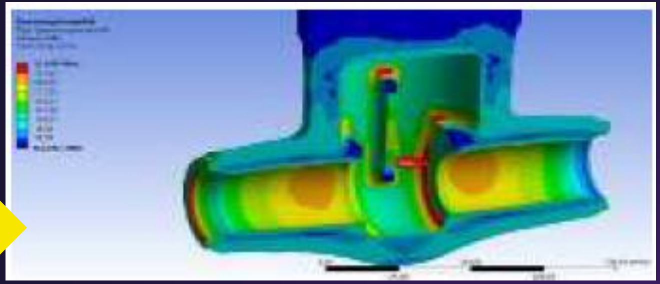
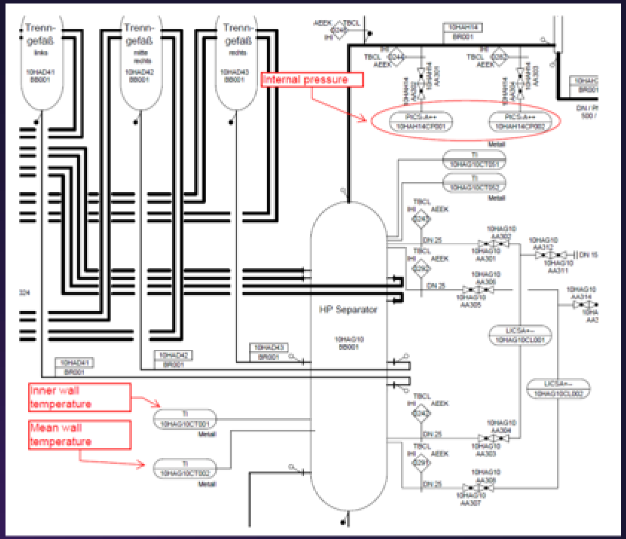
Online Fatigue calc and evaluation of lifetime limits and stresses







Component under Fatigue caused by Thermal cycling

How much fatigue is it ?

Optimization of process to regulate the parameters

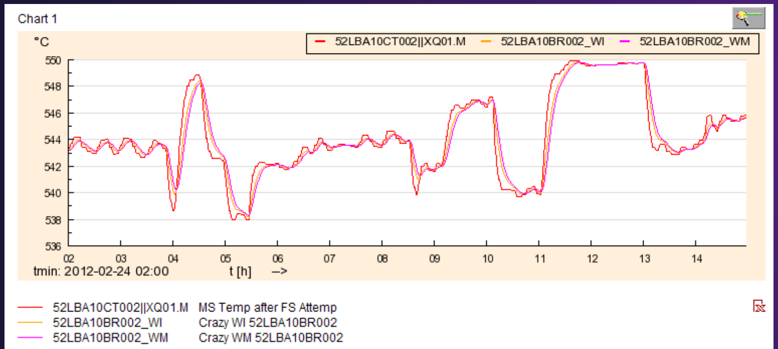
Don't Guess when you can measure it!!!

<u>Affected components</u>:

Headers, Drums,

Separator. Attemperators,

Piping



New fatigue control & Monitoring → Higher flexibility with check on Material Life

FMS - Overview
Max lifetime of components and theoretical lifetime --operating modes

Objective

- Calculation of boiler component's fatigue
- Early detection of deviations

Solution

- Online Determination of creep and low-cycle fatigue of critical components acc to EN 12952
- Online Residual lifetime & Theoretical Limits calculation (No. of cycles to crack initiation)
- Long term data storage→ for trends & comparison

Benefits

- Transparency in relation to impact of operating mode on residual life
- Detection and prevention of high-wear operating modes
- Optimum selection of point in time for requisite overhaul and inspection
- Enhanced power plant safety and reliability
- Utilization of component material reserves/spares and better planning.
- Cost-effective in-service monitoring and analysis

Successes in Technical Min assessment and Flexibility Interventions in India

Achieving better part load performance & ramp rates- SPP

NTPC Dadri 500 MW

Scope

Flexibility Assessment for 500 MW block for technical minimum and ramp rates.

Interventions to automate load reduction to 40%

- **Unit Control** to coordinate slow-acting boiler and fast-acting turbine
- **Reheat / Flue Gas / Main Steam Temperature Control**
- **Fatigue Monitoring System** to determine residual lifetime of highly stressed components
- **Replacing of the feed water recirculation valve** by a control valve
- **Mill Scheduler** to switch coal mills on/off automatically depending on the firing demand
  Next step: Installation of an Online Coal Flow Measurement System

525 MW IPP – East India

Scope

Flexibility Assessment for 500 MW block for technical minimum and ramp rates with **IGEF** and **VGB**

Customer Benefit

- **Technical minimum of 36%** established and 3% ramp rates
- Reduced CO_2 footprint

DVC Andal 500 MW

Scope

Flexibility Assessment for 500 MW block for technical minimum and ramp rates with **IGEF** and **VGB**

Customer Benefit

- New **technical minimum of 32%** established (**country's best**) and 3% ramp rates
- Reduced CO_2 footprint

Optimization solutions can be used with any DCS and are suitable for new plants and modernization projects

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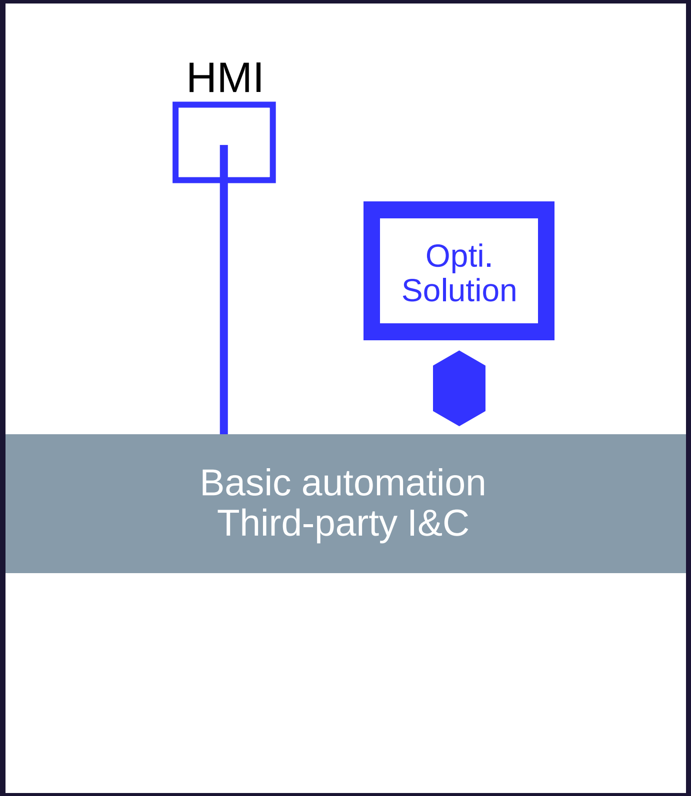
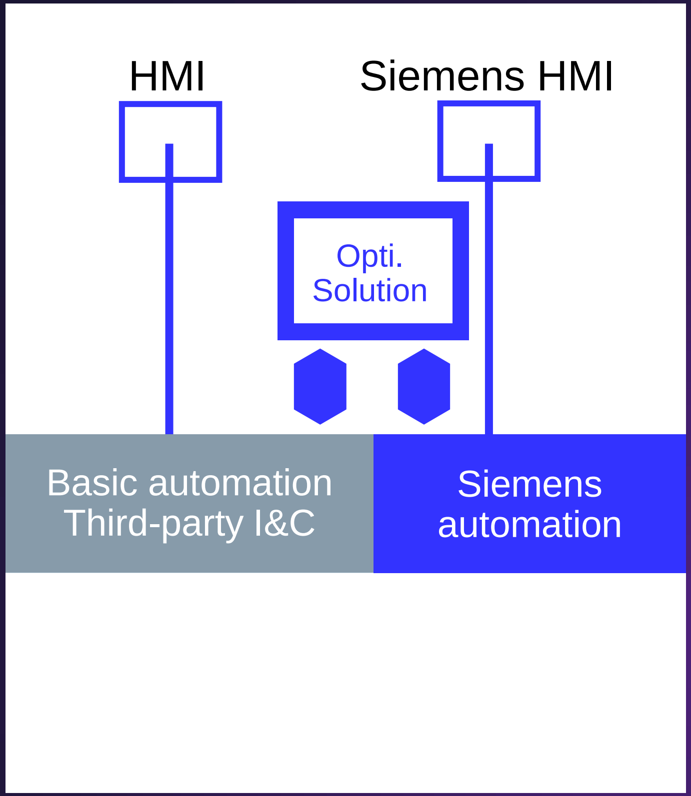
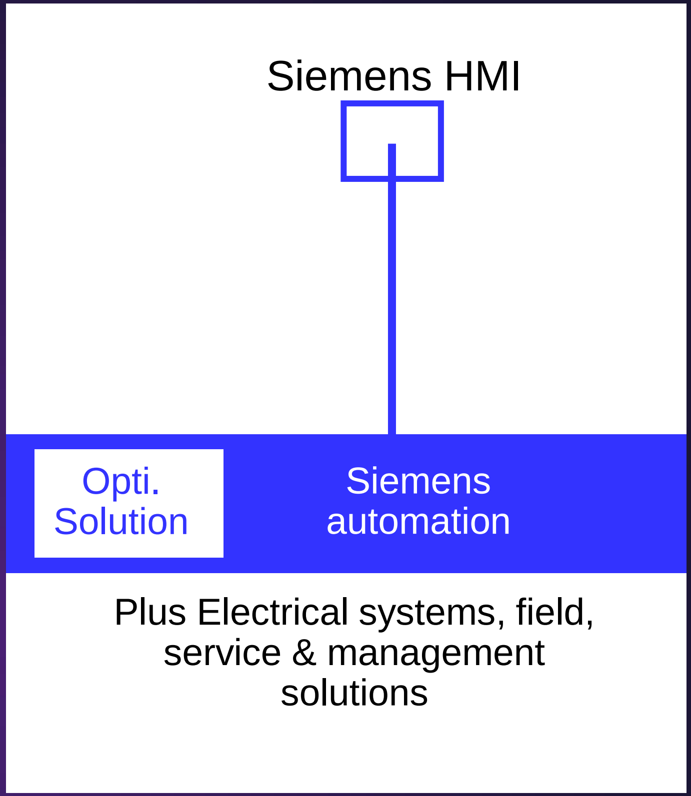
Optimization for third-party DCS



Optimization for third-party and Siemens DCS

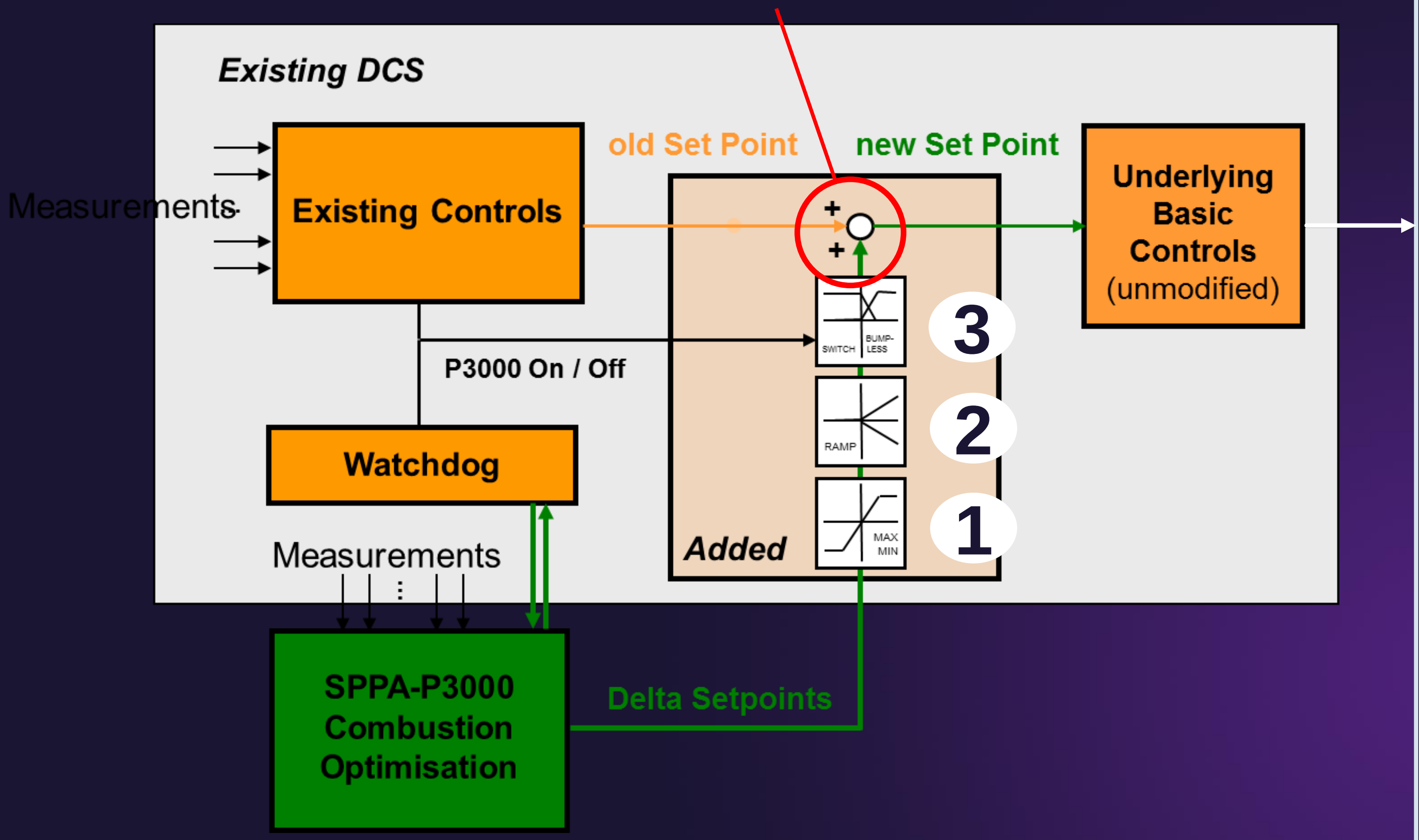


Optimization for Siemens DCS



Interface to the Plant DCS (Non Siemens)

Omnivise Optimization modules typically add a bias to the set point for existing basic controls to be more effective in the process.



Making communication with DCS safe:

A continuously circulating watchdog signal **monitors communication.**
=> biases are bumplessly fading out on DCS and Onivise side whenever communication fails.

Required **treatment of each incomming biases** from Omnivise in DCS (see drawing on the left):

1. Limiting biases to an agreed **minimum** and **maximum**,
2. Limiting speed of value change to an agreed **maximum ramp rate**,
3. **Switching on/off all biases bumplessly** within a given time when required (Master switch on/off, communication watchdog fails, ..)

Thank you for your attention!

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Q & A

Thank you for your attention

Please contact us for further information at

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Siemens Suite of Solutions
Higher profitability through intelligent solutions

- ✓ Runback Plus
- ✓ Life Time Plus
- ✓ Uptime Plus

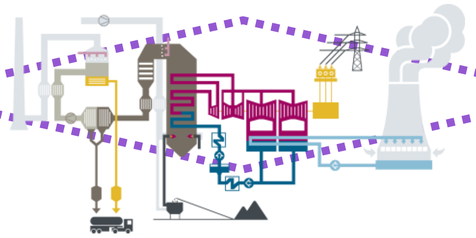
High Availability

Minimal mechanical changes

- ✓ Low Loss Start
- ✓ Combustion Optimizer
- ✓ Sootblower Optimizer

High Efficiency

- ✓ Temperature Optimizer
- ✓ Low Throttling
- ✓ Best Point



- ✓ Fast Start
- ✓ Fast Ramp
- ✓ Frequency Control

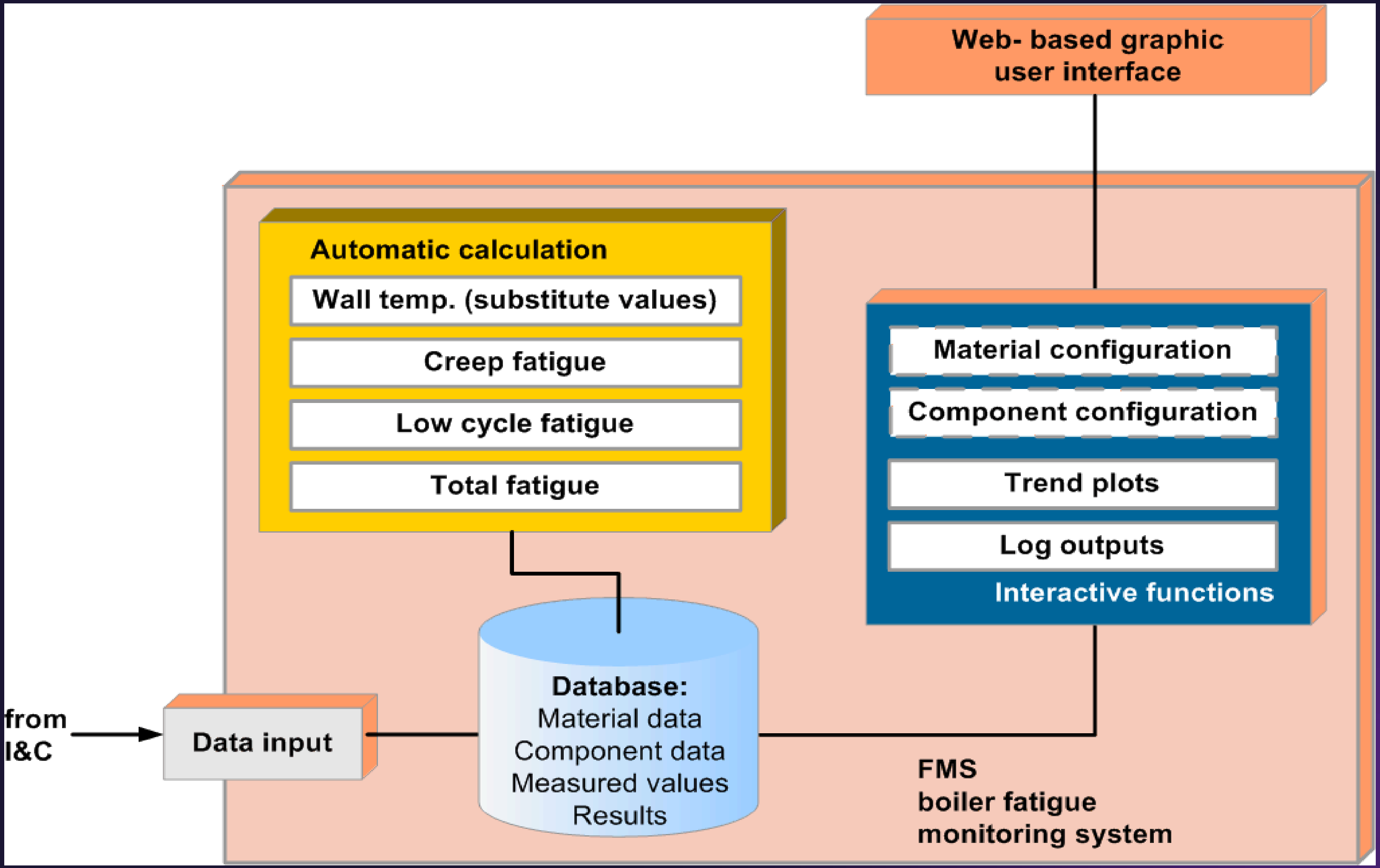
High Flexibility

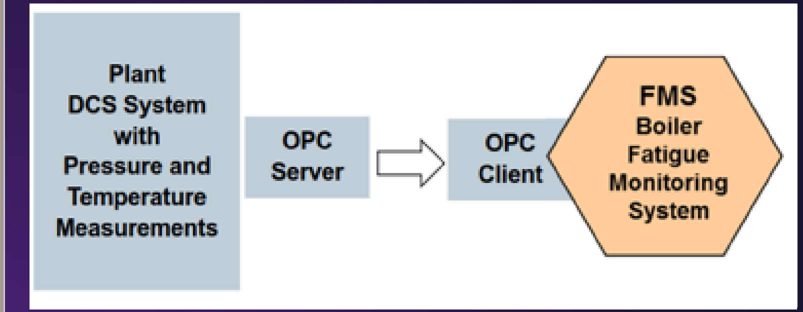
- ✓ Dispatch Control
- ✓ Minimum Load Reduction
- ✓ Maximum Load Plus
- ✓ Online Fatigue Monitoring System

Low Emissions

- ✓ NO_x Reduction
- ✓ CO_2 Reduction
- ✓ LoI Reduction

Boiler Fatigue Monitoring System (FMS)
System Architecture





Power on Demand
Monitoring of flexibility consequences: steam turbine EOH counter

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Task

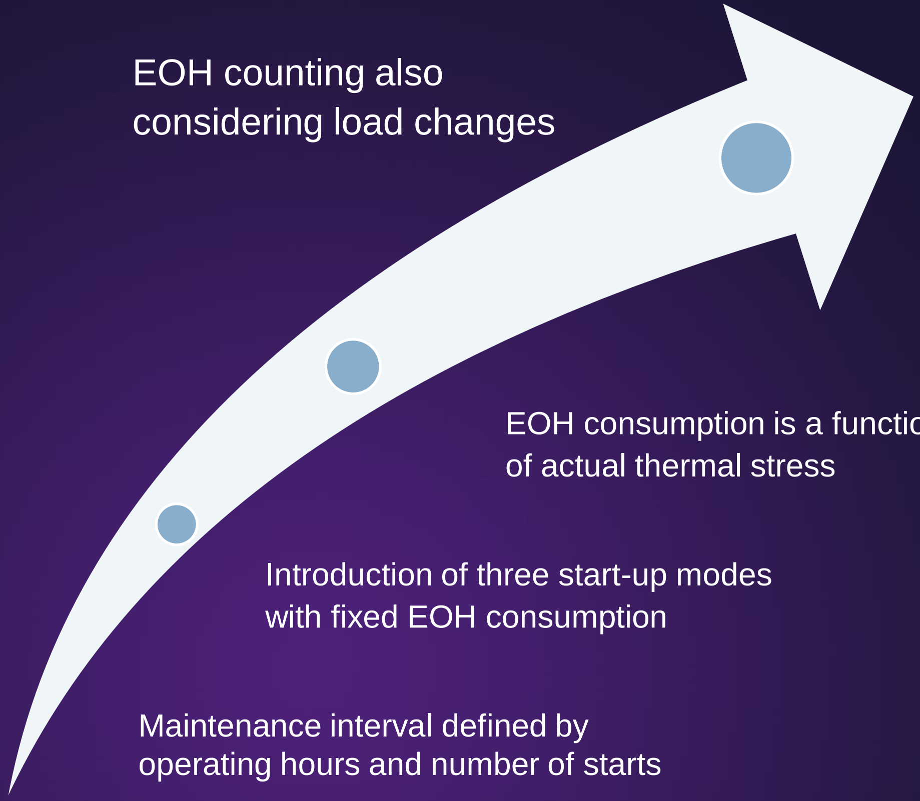
- Part load may lead to steam temperature changes, especially hot reheat temperature
- Thermal stresses during operation are not considered in standard counting of equivalent operating hours (EOH counter)
- Maintenance needs may not be recognized

Solution

- Evaluation of operational history
- Implementation of a state of the art EOH counter considering load changes

Benefits

- More accurate EOH counting
- Improved outage planning
- Enhanced operational flexibility



Advanced Coal Flow Measurement System
The consequent next step : Combustion Optimization

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The Digital Solution

New !! Support in Load ramps

Fuel flow Monitoring for

- *Calculation of average coal / biomass flow*
- *Detection of unbalanced coal / biomass flow situations*
- *Full transparency in coal / biomass flow in all pipes over all load cases*

Plant specific solution depending on monitoring results

- *Adjustment of control strategy*
- *Compensation of unbalances in air – fuel*

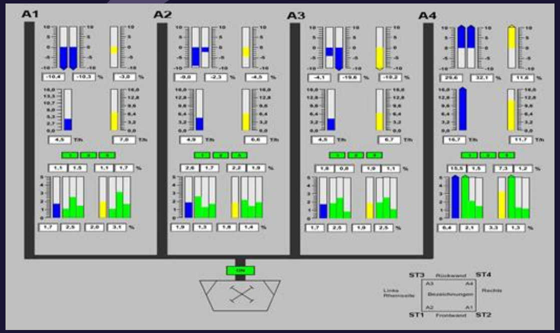
Optimized plant economy

- ✓ Better efficiency
- ✓ Reducing of emissions
- ✓ Potential Reduction of Min. load

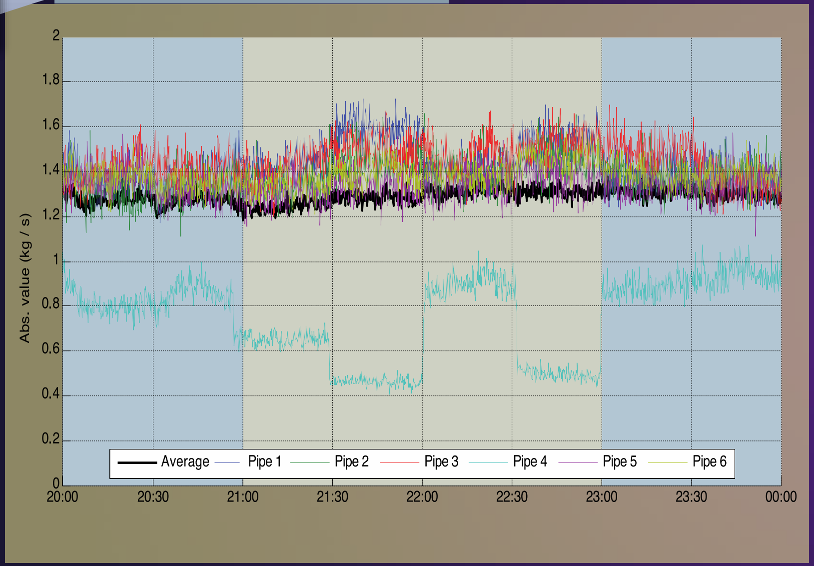
Flow Measurement per Mill

- *microwave sensor*
- *Hard coal and solid biomass fuels*
- *Roping detection by three sensor concept and compensation*

Measuring



Monitoring



Optimizing