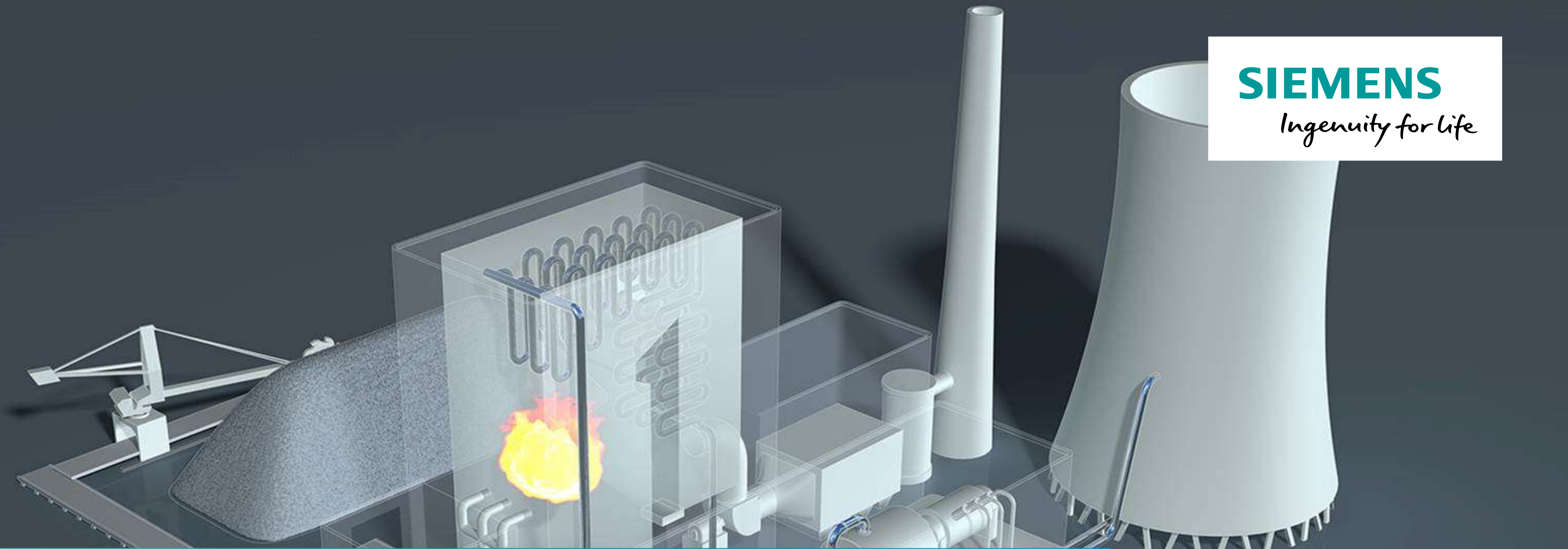

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Steam Power Plants / Steam Generator

Enabling flexibility: thermal feasibility studies and condition monitoring

EEC Conference, New Delhi, 30th Nov 2018

Contact page

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Overview – Topics

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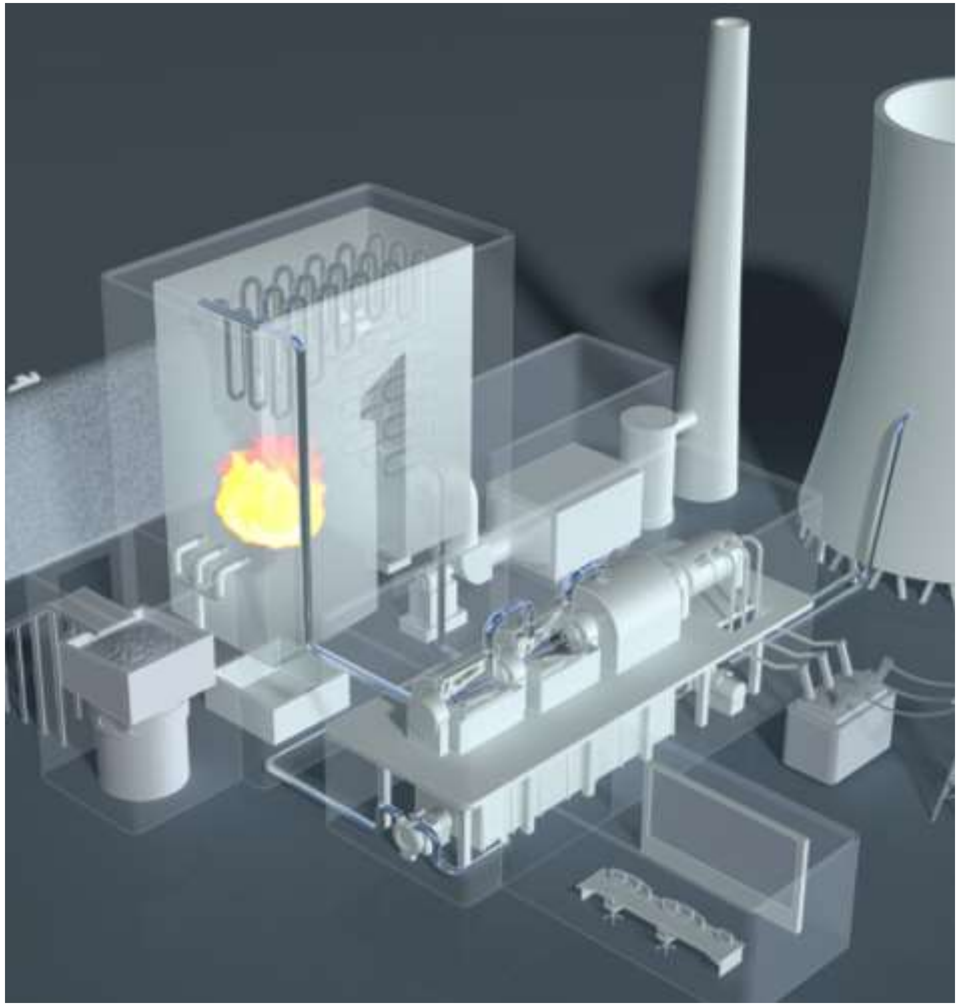

1. Partload Issues for fired Steam Boiler
2. Part Load Test in Dadri 6 (NTPC Plant)
3. Results and recommendation

3.1 Thermal Feasibility Study

3.2 Boiler/BOP Fatigue Analysis

3.3 Optimization of Existing Controls
Condition Monitoring incl.
Boiler Fatigue Monitoring System (FMS)

1. Partload Issues for fired Steam Boiler

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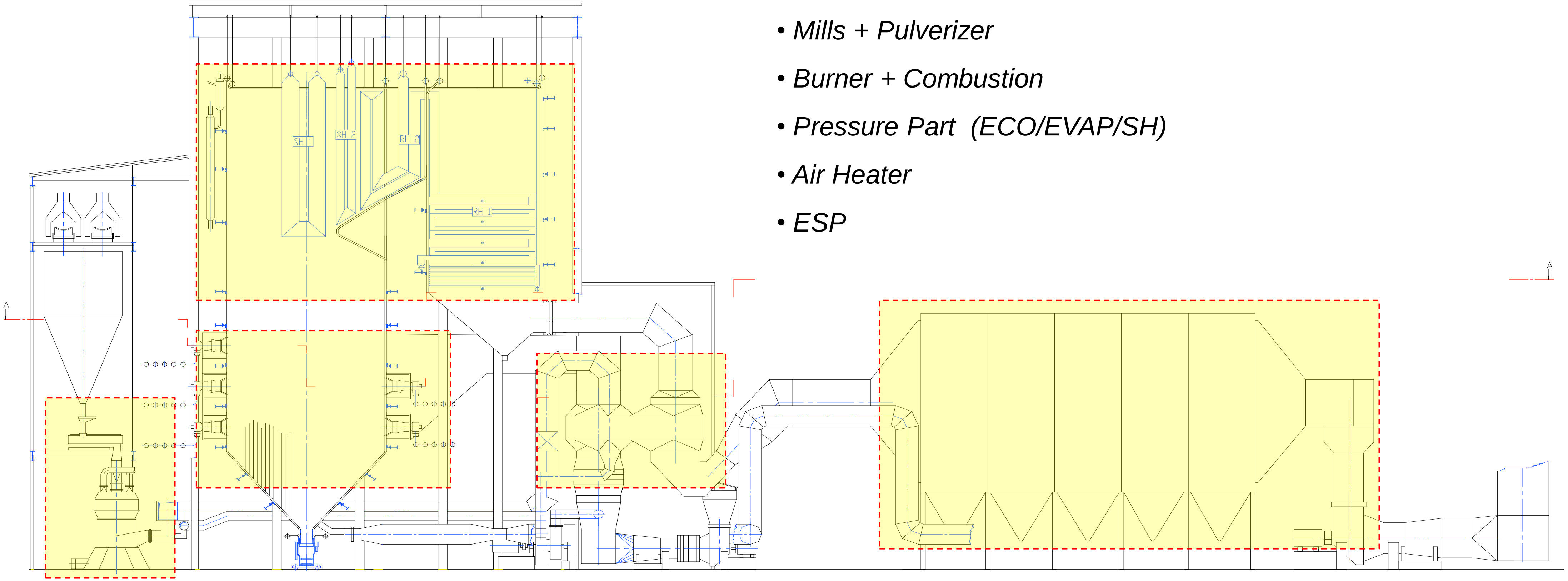

- *Mills + Pulverizer*
- *Burner + Combustion*
- *Pressure Part (ECO/EVAP/SH)*
- *Air Heater*
- *ESP*

Part Load Technical Issues

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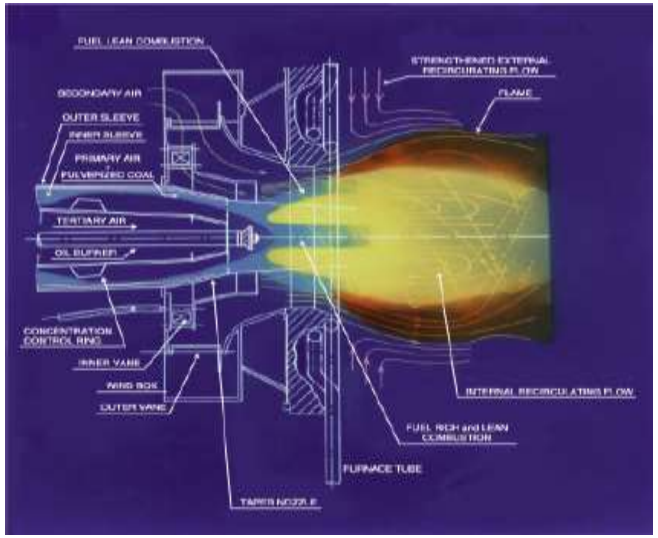
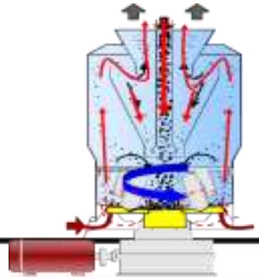
<u>Part Load Challenges:</u>

1. Fuel Composition (knowledge of the fuel composition and of the fuel properties incl. ash is very important for the steam generator design)
2. Fuel supply system (Mill operation diagram, Mill operation concept, Pressure drop, Air bypass flap, Control system, Mill classifier behavior, Mechanical restrictions of mill etc.)
3. Combustion (Fuel composition stability, Temperature/O_2/Concentration inturbulances, Symmetry of flame, Aerodynamics, Combustion efficiency, Emissivity, Support fuel)
4. Evaporator Stability (at first Benson Evaporator, Activated Burner Level) / ECO Stability for possible ECO outlet steaming
5. Boiler Outlet Parameters (HP/RH Temperature, Control system, Flue gas damper, Activated Burner Level, Attemperator)
6. APH (Water/Sulphur dew point), Flue gas pollution (ESP efficiency)
7. SCR (Operation temperature window)

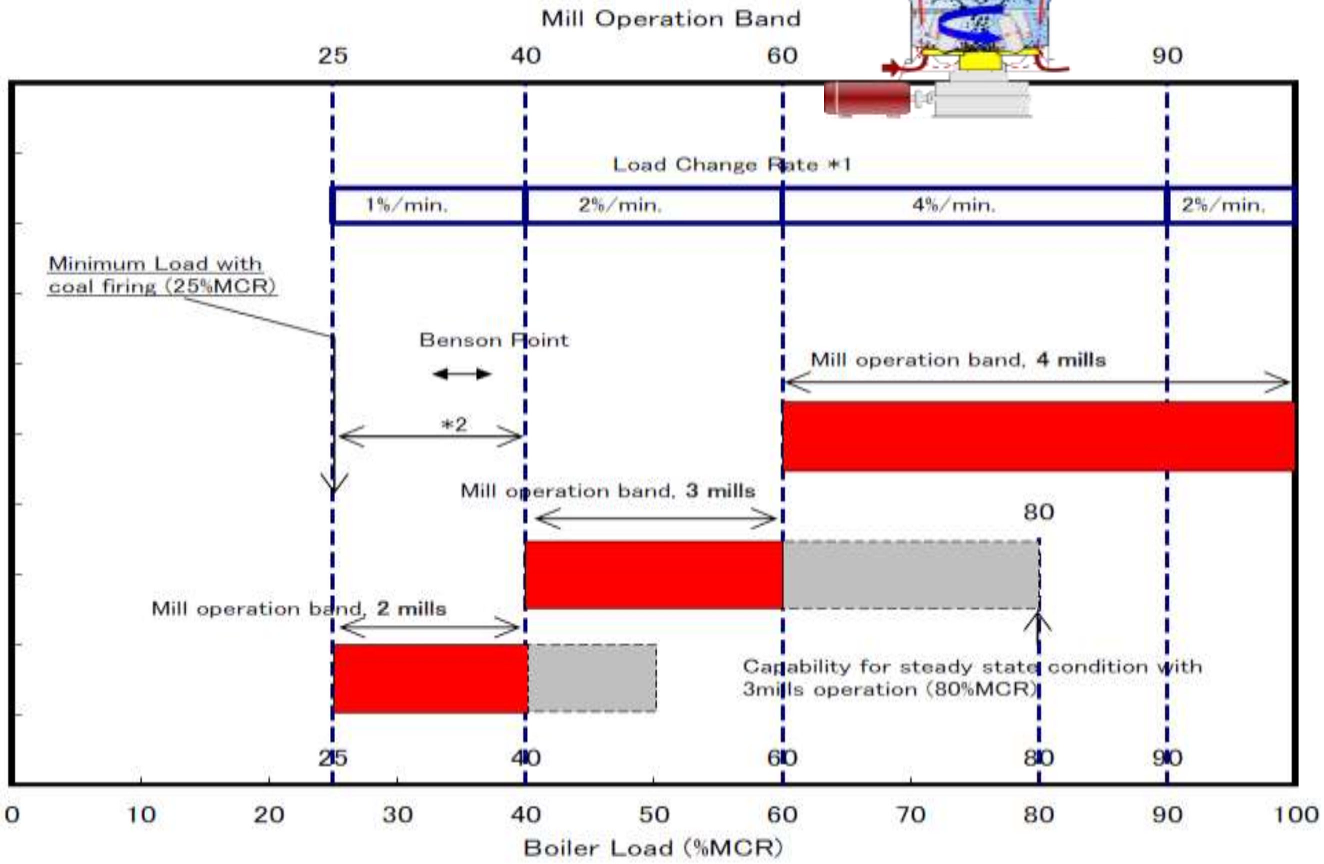
Example of mill operation diagram (4 mills, Once- through boiler)

Low-NOx Vortex Coal Burner





Bowl Mill



Mass Flux Range in Drum- and Once-through (Benson) Boilers

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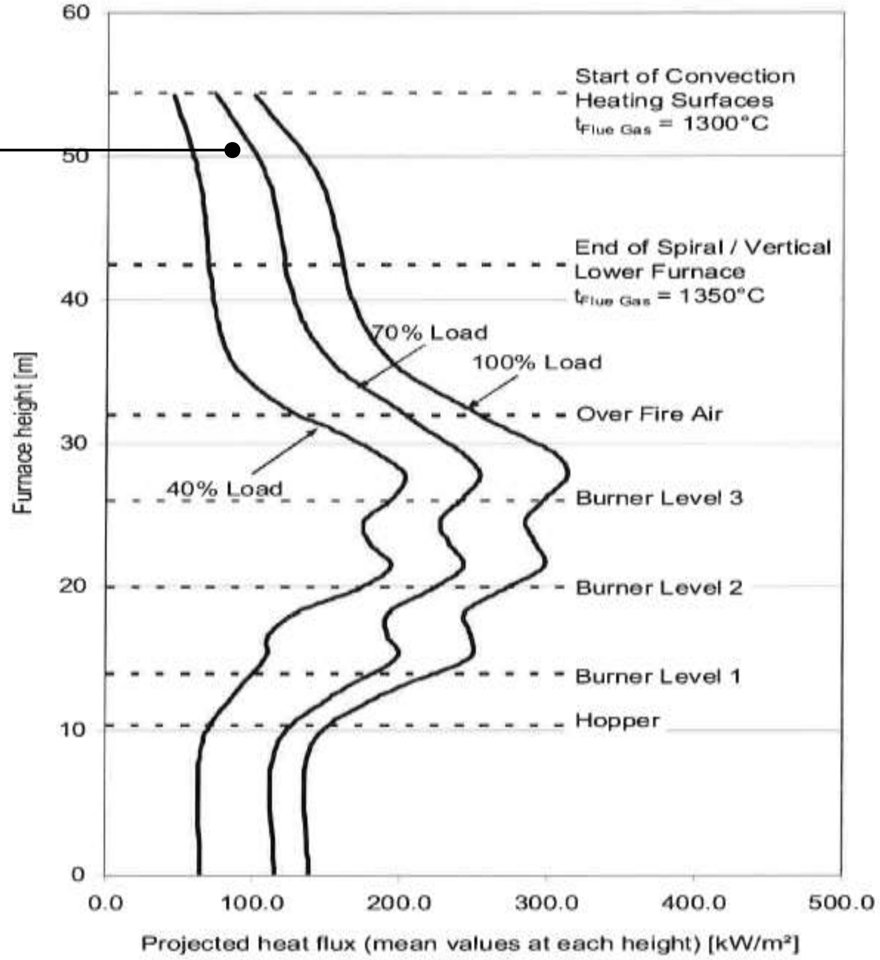
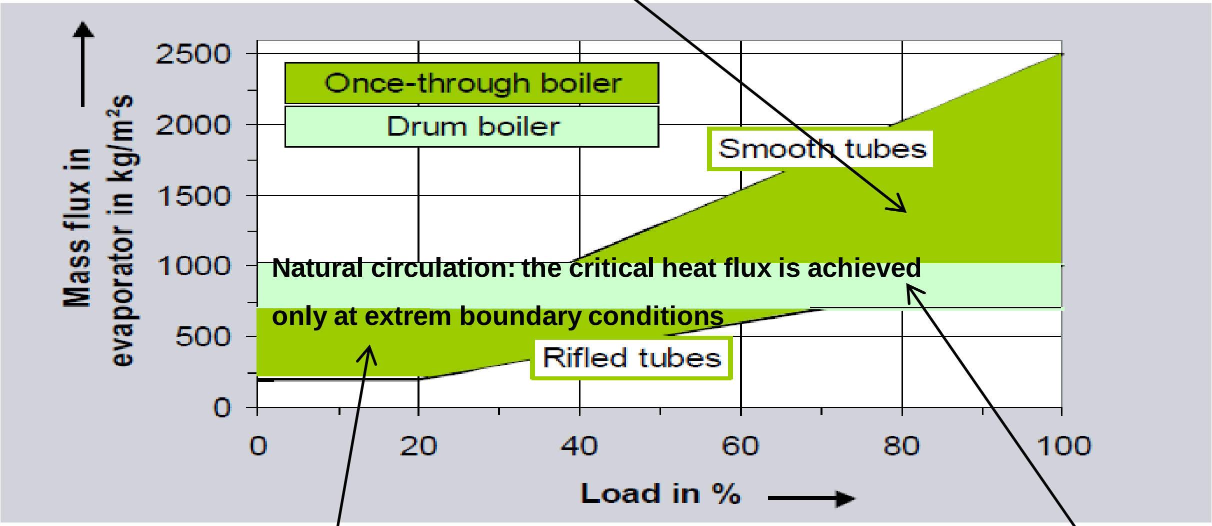
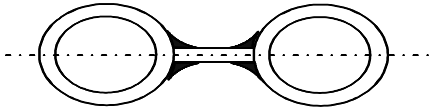
Heat flux profile for:

- Base Load
- 70 % Load
- 40 % Load







Possible Solutions for pressure part (Evaporator/ECO/Superheater)

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Measures	Effect
Design optimization of heating surfaces in heat flux critical zone Rifled tubes	Reduction of thermal stress • Increase of allowable heat flux • Prevention of boiling crisis (DNB – Departure from Nucleate Boiling)
Retrofit / Re-design of attemperators	Improvement- / Increase of spray water mass flow Better water mixing (evaporation distance)
Orifice at Inlet / Outlet ECO, ECO Recirculation	Establishment of smooth and uniform flow distribution in the tubes
Orifice at Evaporator Inlet	Improvement of dynamic stability
Pressure compensation header in Evaporator	
Upgrade of Superheater drains	Effective removal of condensate during start-up
Increase of RH outlet temperature for Part Load	Implementation of RH slide pressure curve, Activation of upper burner level, Activation of positive tilting of burner

2. Part Load Test in Dadri 6 (NTPC Plant)

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Part Load Test in Dadri 6 (NTPC Plant)

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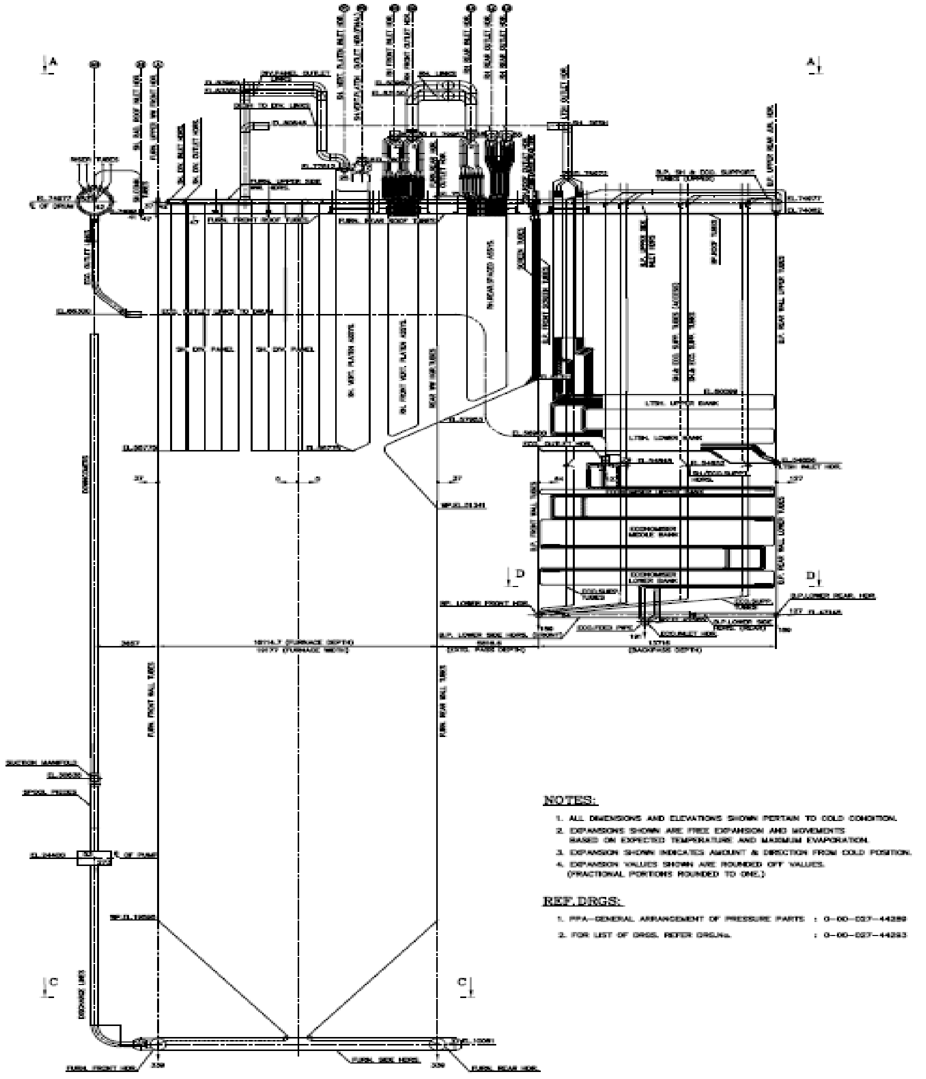
In 2006 the Indian Prime Minister and the German Chancellor established the Indo-German Energy Forum (IGEF) to promote an energy dialogue.

Various initiative and efforts were suggested and implemented in cooperation with the **Excellence Enhancement Centre (EEC)** – promoting Energy Efficiency and Energy Security in the Indian Power Sector.

As a part of this effort, NTPC aims at reducing minimum load in several power plants, including Dadri units 5 & 6.

A **team of EEC/VGB/Siemens representatives** were given the opportunity to test minimum load in **Dadri unit 6** on June 21st and June 22nd, 2018.



Test for Boiler part stable load reduction
Load regime during the minimum load tests

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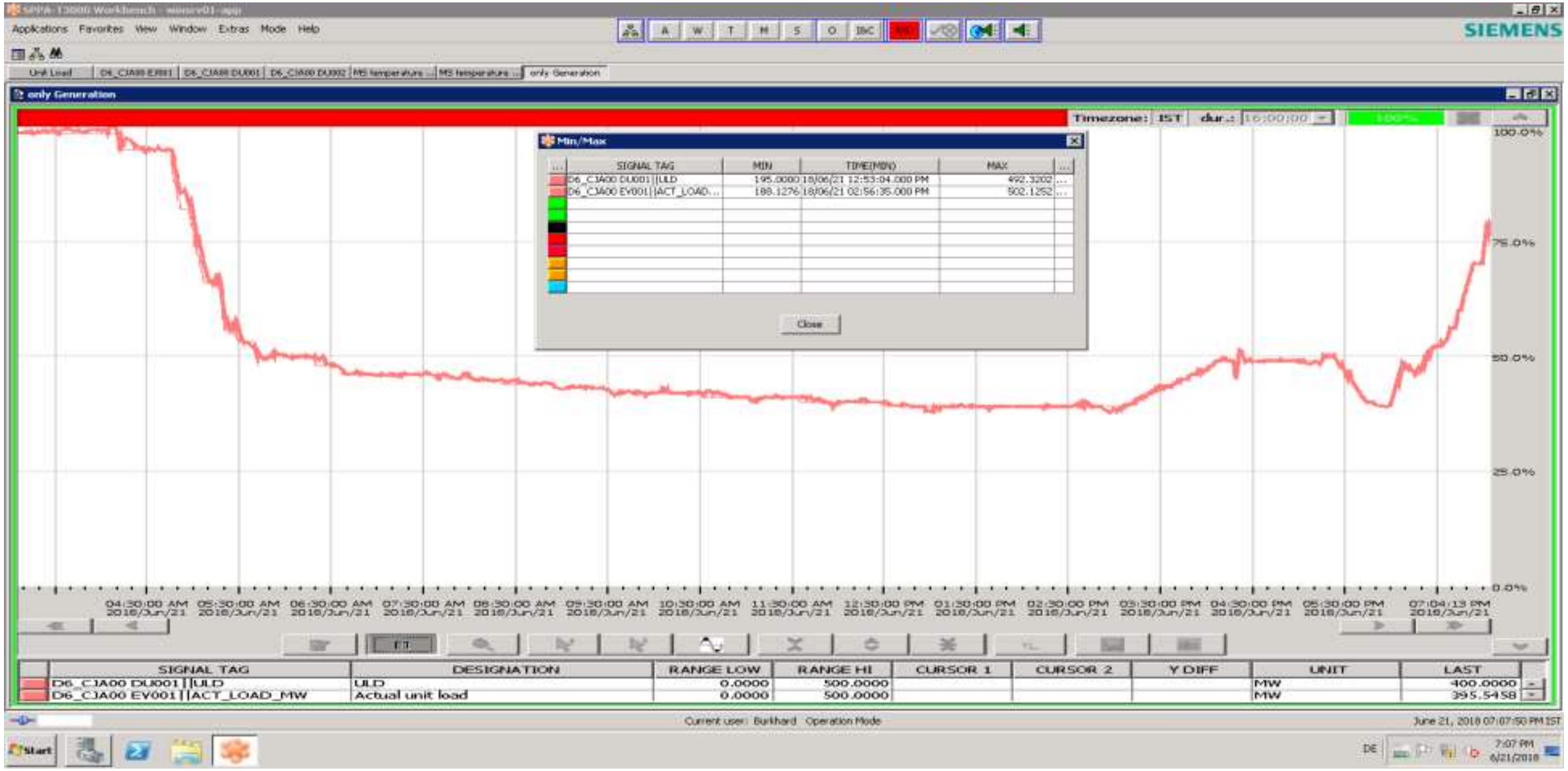
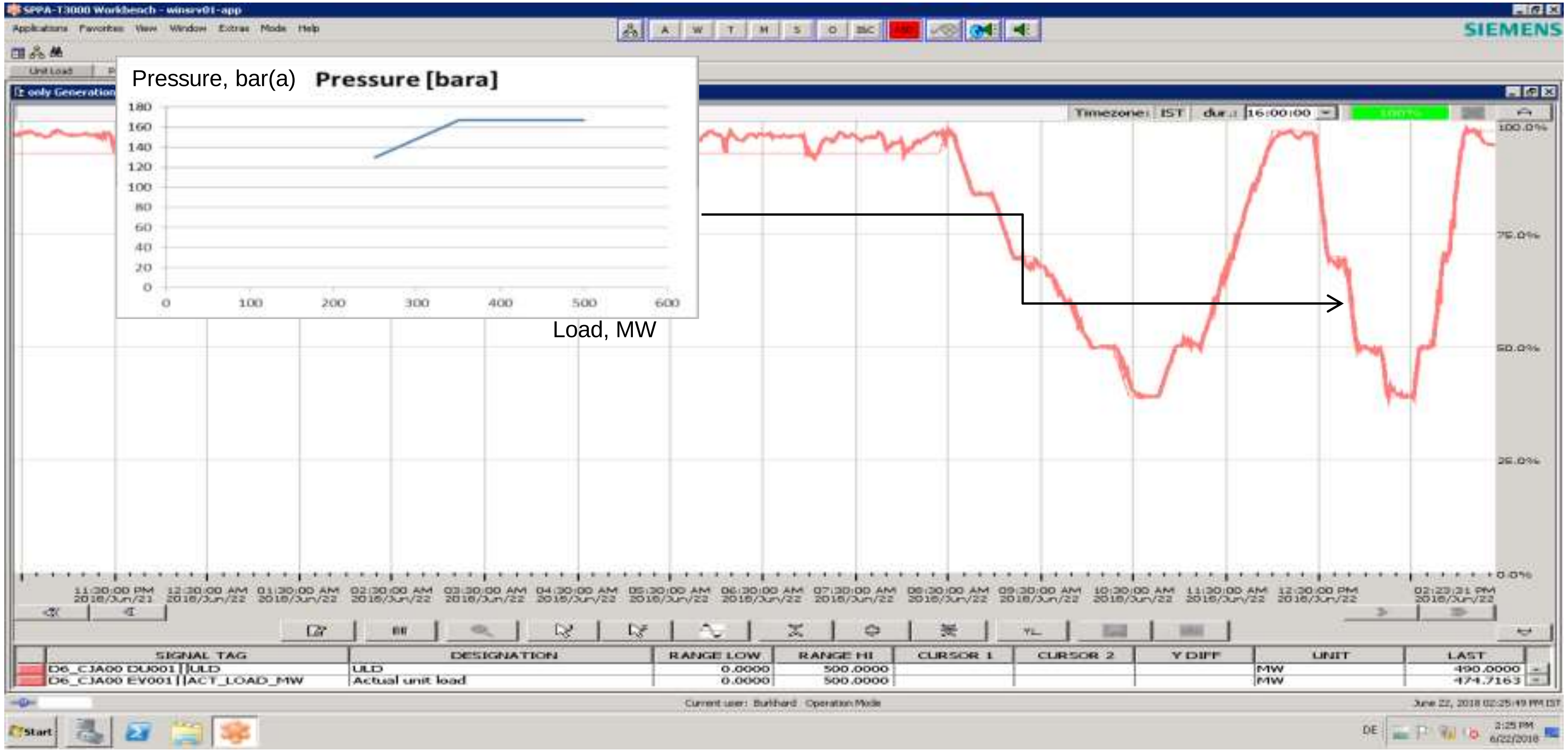


Test for faster load Ramp up / Ramp down between min and base loads
Load regime during the ramp tests



3. Results and recommendation

Results and recommendation

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During the both tests, there were **no major thermal/mechanical restrictions** of the mills, combustion, air flow and flue gas, main steam/RH pressures and temperatures, drum level and economizer.

Recommendations:

1. **Thermal Feasibility Study**

2. **Fatigue Analysis** (FEM calculation)

3. **Optimization of Existing Controls** (Control and Automatic Mill Operation, fans, boiler feed pumps and mills automatically into operation, Main Steam Temperature Control, Reheat Steam Temperature Control, Flue Gas Temperature Control)

4. **Condition Monitoring incl. Boiler Fatigue Monitoring System** (Condition monitoring systems should monitor highly loaded boiler and piping components against creep and fatigue. Such a system monitors the temperature differences, pressure, and signals when the allowable limits during load changes have been exceeded)

3.1 Thermal Feasibility Study

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A thermal feasibility study of the boiler and the turbine for minimum load based on test data is required in order to avoid long-term damages and limitations to the boiler and turbines systems.

Such a study would involve the evaluation of process limitations and an assessment of the influences of low load operation and temperature- and pressure gradients on the boiler and turbine components and equipment. Thermal and mechanical models of the plant will be constructed, calibrated with test measurement data and applied.

Since other Indian power plants are built with the same setup, these models can be used for the rollout into the 500 MW fleet.

Boiler thermal calculation software DEFOS

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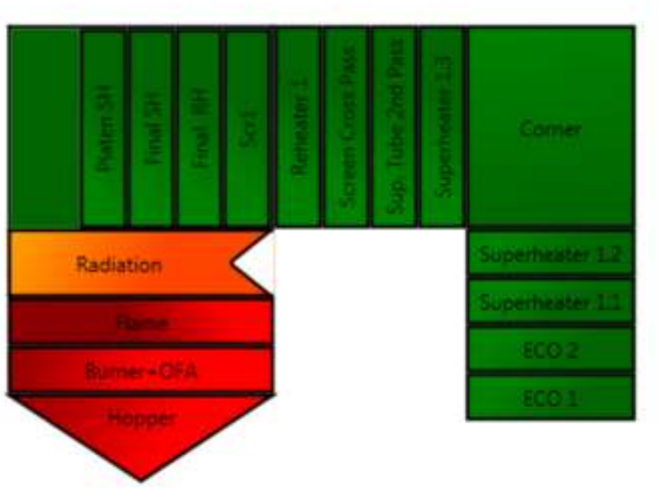
The thermal boiler model is constructed by using computer software **DEFOS** (boiler performance calculation tool developed under BENSON license), which permits a detailed representation of the thermodynamic and heat transfer processes across the complete boiler system based on engineering principles and analysis.

Boiler thermal model of flue gas segment:



Boiler thermal model of water/steam system:

Check of relevant firing boiler components during Feasibility Study

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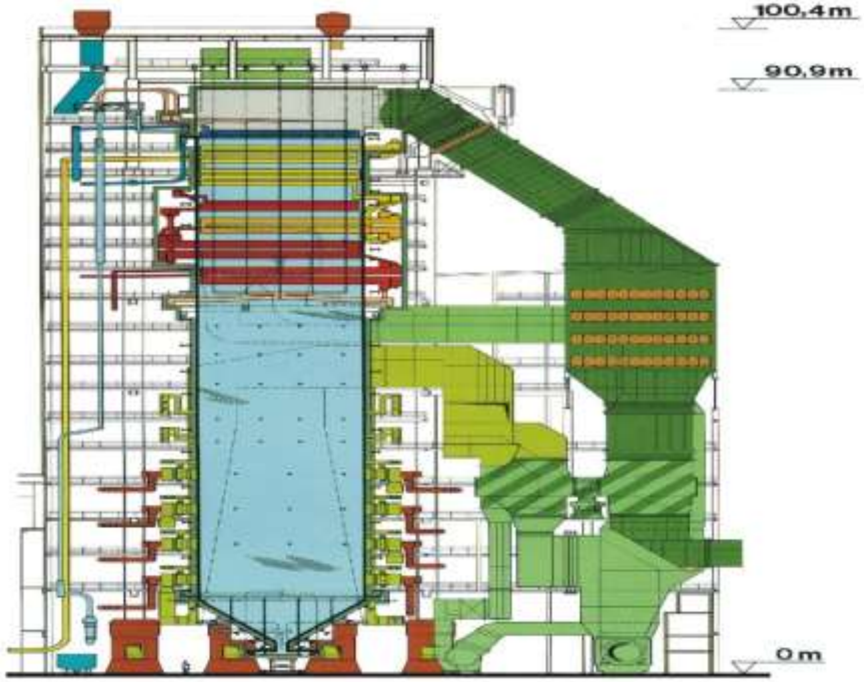
- Heating surface SH (thermodynamical, hydraulical, mechanical)
- Piping (thermodynamical, hydraulical, mechanical)
- Drums/separator and evaporators (thermohydraulic, Benson)
- ECOs (thermodynamic, hydraulic, bypass)
- Flue gas part (slaging, fouling, velocities, abrasion, pressure drop)
- ID/FD/PD- fans and other components
- Water desuperheaters, temperature control
- Casing; casing insulation
- APH
- Control valves, Safety valves
- I&C
- Pumps
- Flashtank



3.2 Boiler/BOP Fatigie Analyses
Two origins of boiler fatigue

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Fatigue from cyclic operation

- During Start / Shutdown / Loadchanges: Changing steam pressure and steam temperature
- Result: Alternating Stresses at boiler pressure parts
- **Cracks** occur after a certain **number of cycles** depending on Stress variation range

Creep fatigue

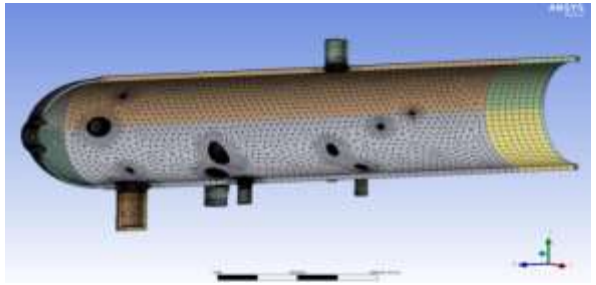
- Material strength reduces during steady state operation at high temperature and at high pressure
- **Cracks** occur after a certain **operation time**

At Siemens MTEC we calculate the percentage of fatigue with

FEM-Simulations

Boiler/BOP Fatigue Analysis
What are FEM-Simulations?

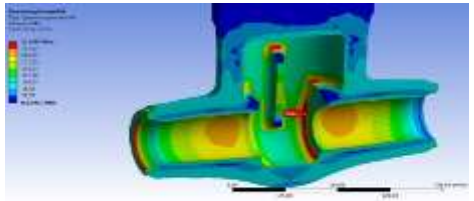
FEM = Finite Element Method



- FEM is a numerical method to compute the physical
- The system is split into small sections, which "Finite Elements"

General fields of application

- Mechanical Simulation: Stresses, deformations, …
- Thermal Simulation: Heat conduction, temp. fields, …
- Fluid Dynamics: Flow distribution, flow velocities, …
- Modal Analysis: Resonance frequencies, …
- Electromagnetic Analysis: Magnetic fields, …
- etc.



Our Approach and Advantages of FEM-Simulations

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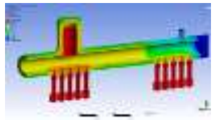
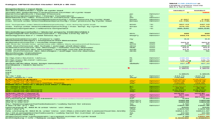
Our Approach

① **Thermal-Transient** Simulation to calculate the temperature distribution during Start & Shutdown

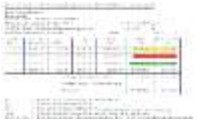


② **Static-Mechanical** Simulation to calculate stress trends from thermal and mechanical stress

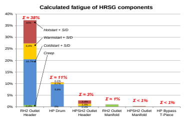
③ Evaluation of stress variation range according to DIN EN 12952-3 to calculate the **fatigue of one loadcycle in %**



④ Calculation of **creep fatigue** according to DIN EN 12952-4 with the software Probad



⑤ Extrapolation of current and future component fatigue based on startup-counting and future load regime



Advantages compared to simplified method

- More accurate boundary conditions
- More precise stress calculation
- Assessment of welds possible
- „Complicated geometries“ possible

Selection of SPPA-P3000 References
Profitable, reliable and flexible plants - worldwide

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Parish, USA
- Low Loss Start
- Minimum Load Reduction
- Fast Ramp

ValesPoint, Australia
- Fast Ramp
- Temperature Optimizer
- Minimum Load Reduction
- Low Throttling

Callide, Australia
- Fast Ramp
- Maximum Load Plus
- Temperature Optimizer
- Dispatch Control

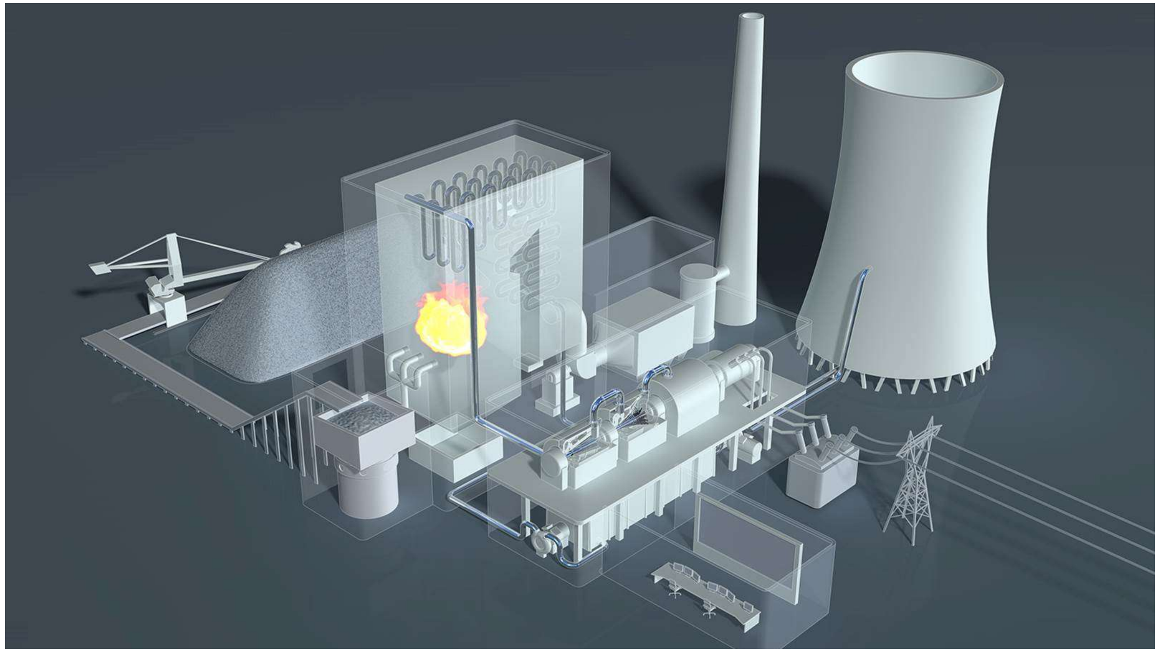
Neurath, Germany
- Frequency Control
- Dispatch Control
- Low Throttling
- Minimum Load Reduction

Elverlingsen, Germany
- Combustion Optimizer
- NO_x Reduction

Altbach, Germany
- Frequency Control
- Sootblower Optimizer
- Lifetime Plus

Dingzhou, China
- Dispatch Control
- Temperature Optimizer
- Lifetime Plus

Cottam, UK
- NO_x Reduction



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Subject to change without prior notice.

The information in this document contains general descriptions of the technical options available which do not always have to be present in individual cases. The required features should therefore be specified n each individual case at the time of closing the contract.

3.3 Optimization of Existing Controls
Condition Monitoring incl. Boiler Fatigue Monitoring System (FMS)

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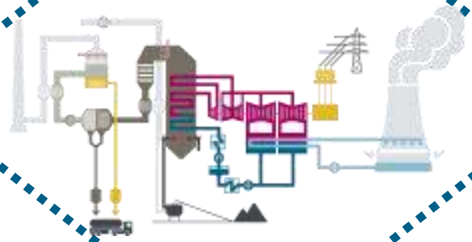
The situation:

A power plant unit needs to be operated at the most profitable operating point at all times. This generally calls for greater **flexibility**, higher **efficiency**, better **availability** and lower **emissions**.

High Availability

Minimal mechanical changes

High Efficiency



High Flexibility

Low Emissions

Our solution:

SPPA-P3000 Process Optimization solutions

SPPA-P3000 Minimum Load Reduction
Reduced minimum load level

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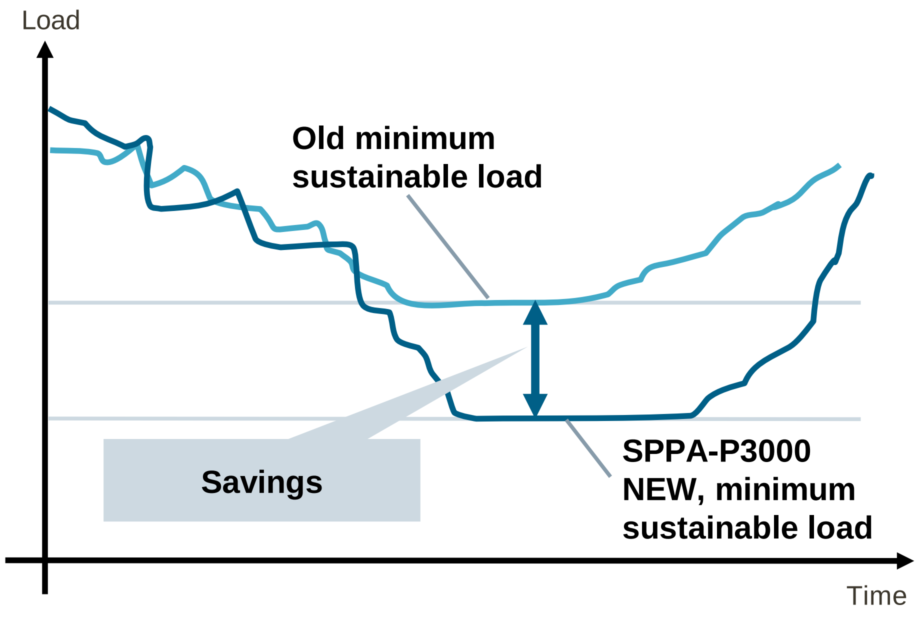
Task
To upgrade the plant so that the specified minimum load level can be reduced and to make the plant capable of fast and low-stress load increases on demand in accordance with market requirements.

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 e.g. 500,000 €/a → Benefit calculation
- 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.

SPPA-P3000 Best Point
Optimum steady-state plant operation

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Task

To ensure fast provision of information about deviations from optimum operation and to calculate consequential costs for detection of improvement potentials

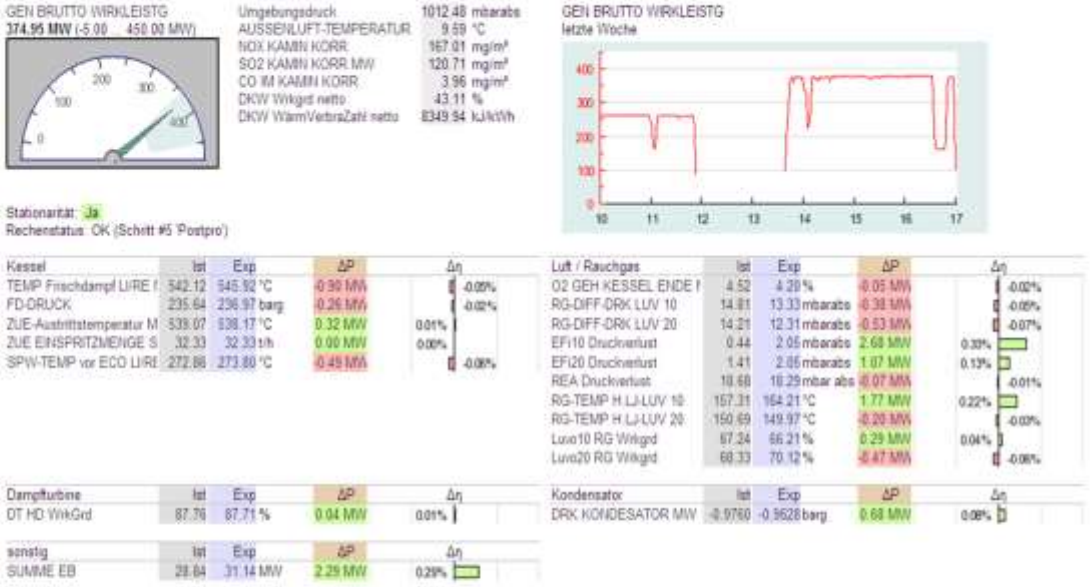
Solution

- Online calculation of key process data on the basis of a thermodynamic process model
- Validation of process data
- Interactive process analysis for "what if?" scenarios for the purposes of optimized operation and investment decisions

Benefit, e.g. 100,000 – 300,000 €/a → Benefit calculation

- Early detection of malfunctions and deviations from optimum operating point
- Reduced maintenance costs through qualified problem analysis
- Reduced power generation costs

Best Point



A thermodynamic plant model generates significant indicators for profit-optimized plant operation.

SPPA-P3000 Uptime Plus
Early detection of emerging damage

Task

Extensive condition monitoring of the plant processes to maximize availability and avoid costly reductions in performance and outages

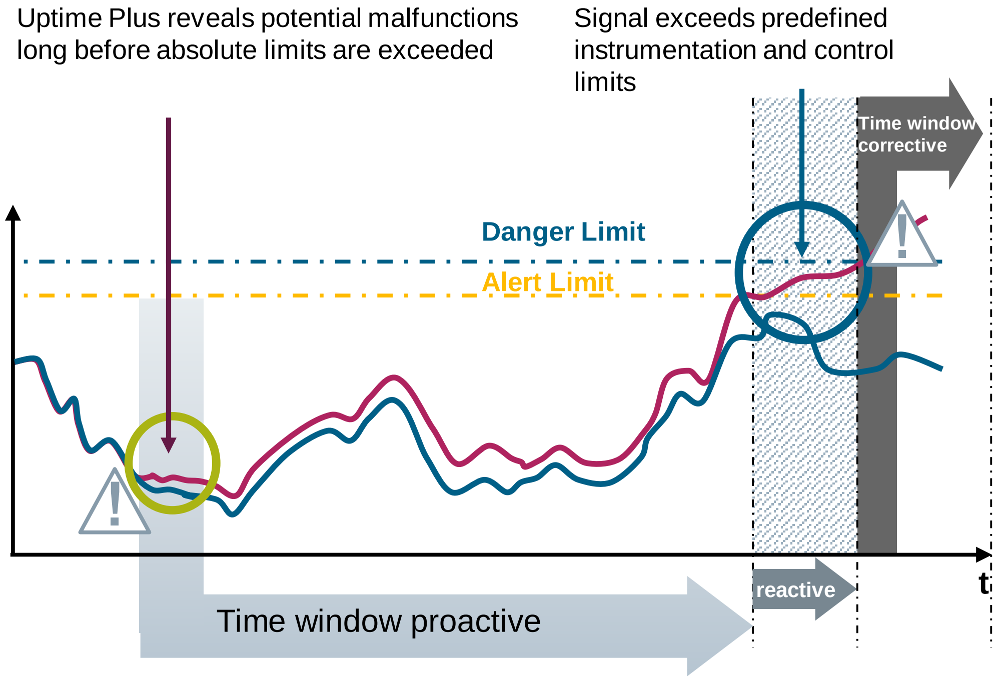
Solution

- Earliest possible damage detection based on empirical values from plant's operating history
- Rapid and precise localization of an event thanks to alarms in the DCS
- Monitoring of all plant components and processes, also in quasi-steady-state conditions
- Individual model generation for your plant

Benefit, e.g. 180,000 €/a → Benefit calculation

- Prevent unscheduled downtime
- Shorten scheduled outage times
- Plan maintenance and repair work in a proactive and anticipatory manner
- Minimize load on machines and components

Uptime Plus



Condition monitoring with Uptime Plus *detects possible damage at the earliest possible moment and thus creates more time for proactive measures*

Boiler Fatigue Monitoring System (FMS)

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Customer Challenge:

- Ensure maximum lifetime of HRSG and adapt operating modes to accordingly

- **Calculation of the total theoretical lifetime of highly stressed components based on creep fatigue and low-cycle fatigue**

Solution

- ➢ Determination of creep and low-cycle fatigue
- ➢ Component specific calculation acc to EN 12952
- ➢ Online calculation
- ➢ Long-term data storage

- ➢ 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
- ➢ Cost-effective in-service monitoring and analysis
- ➢ Integrated into „T3000“