Siemens Energy Solutions

Flexible Operation of Steam Power Plants and Life Cycle

Ian Rebello
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Business Representation for Siemens Energy

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Siemens experience in the Field of Flexibilization
Journey of Thermal Power Plants

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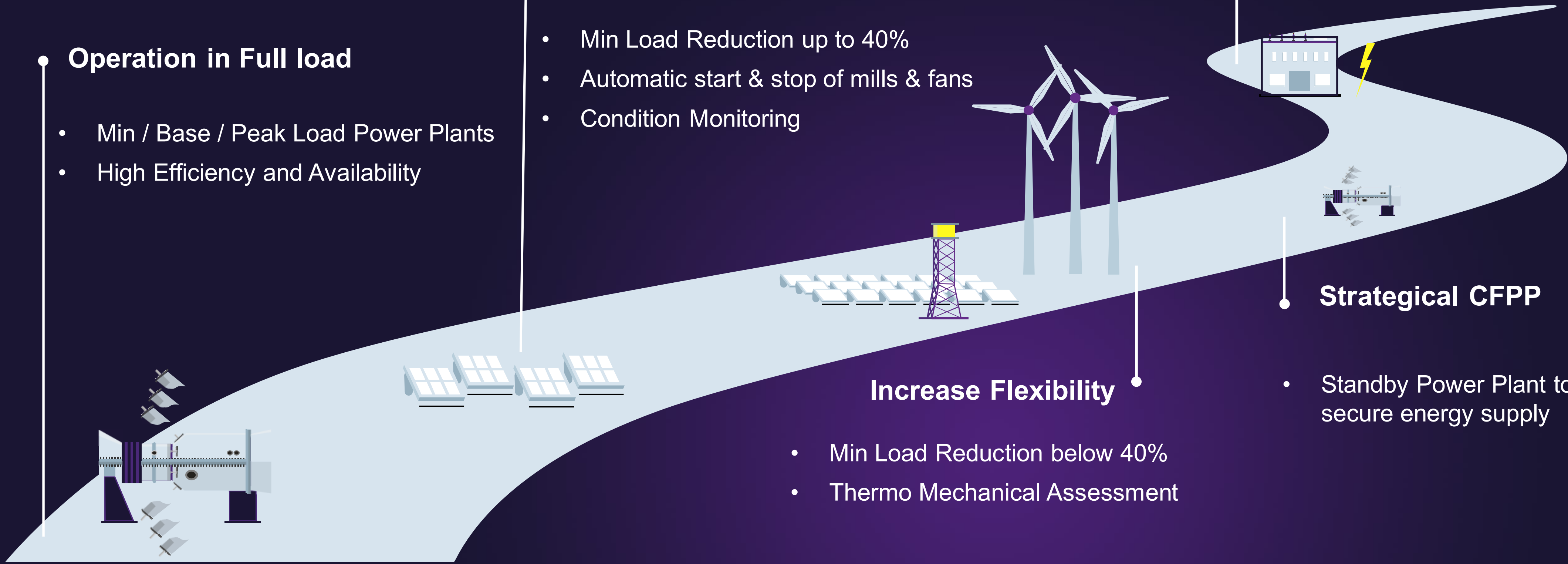

Operation in Full load
- Min / Base / Peak Load Power Plants
- High Efficiency and Availability

Flexible Operation
- Min Load Reduction up to 40%
- Automatic start & stop of mills & fans
- Condition Monitoring

Increase Flexibility
- Min Load Reduction below 40%
- Thermo Mechanical Assessment

Strategical CFPP
- Standby Power Plant to secure energy supply

Conversion of CFPP
- Synchronous Condenser (reactive Power)

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
- **Possible to achieve extremely stable, reproducible and flexible operating behavior**
- **The basis for high profitability**

Flexible Operation in Thermal Power Plants – India Story
CEA Letter - Flexible Thermal Generation

- ✓ CEA has addressed the utilities in June 2020 & followed it by a reminder in October 2020 on the topic of Min Load tests.
- ✓ CEA has recommended that Thermal Units conduct low load & ramp tests , identify the gaps if any, and implement the recommendations

- ✓ Siemens is proud to share that we have conducted MIN Load tests at 2 Important Thermal Power Plants – NTPC – Dadri (500 MW) & MPL Maithon (525 MW)

Siemens Experience in the field of Flexible Operation
Successful Min. Load Tests at *NTPC Dadri CFPP Unit 06*

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Capacity : 500 MW
Boiler : BHEL

Type : Drum Boiler
Number of mills : 9
Total coal dust pipes : 36
Turbine : BHEL-KWU design

Min Load Test on June 21, 2018

- Load reduction from 490MW to 250MW
- Changing from four to three mills operation
- Load reduction in steps of 5 MW
- 195 MW achieved and maintained for 2.5 hours

Our esteemed partners:

Recommended measures 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

Under construction

Next step:
Installation of an Online Coal Flow Measurement System

Siemens Experience in the field of Flexible Operation

Second Min. Load Test at *Maithon CFPP*

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Capacity	: 525 MW
Boiler / Steam Turbine	: BHEL / BHEL - Siemens design
Type	: Drum Boiler
Number of mills	: 8
Result of data analysis	: No limitations identified
Siemens Questionnaire	: Flame instability during minimum load

July 2021: Test to identify min. load

- Load reduction to 40% min. load 210 MW
- Load reduction further to 36% min. load 190 MW
- Report with recommendations has been submitted to the customer

Our esteemed partners:

igef Indo-German Energy Forum

vgbe ENERGY IS US

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Siemens approach to reduce min. load up to 40%

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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

Siemens approach to reduce min. load
Example - Test Concept

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	

Generation scenario in India
Flexibility Road Map - Controls and Optimization

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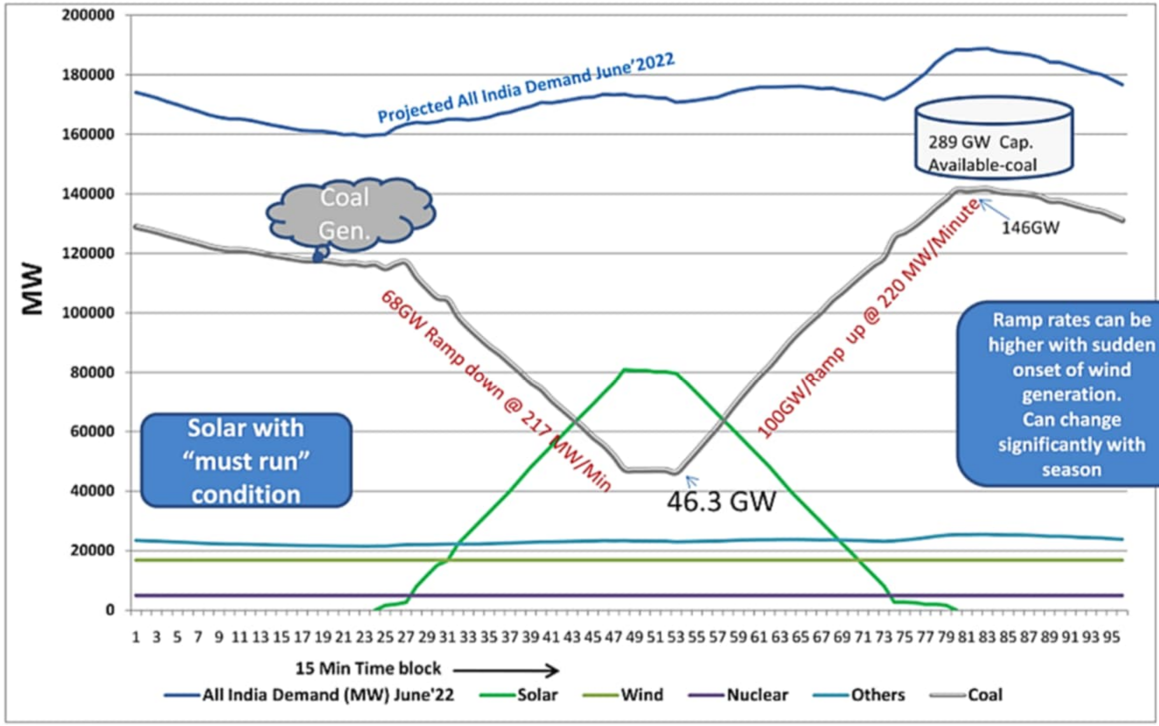


Fig-4:Anticipated Indian Scenario in 2022,*with 100 GW Solar & 60 GW Wind*

Lower Technical Minimum	Primary and Secondary frequency control
Faster Ramp up	Faster Ramp down

Flexibility Road Map Solutions based on Controls and Optimization

Advanced Process Control

- ✓ Temperature Control Optimization
- ✓ Soot Blower Optimization
- ✓ Combustion Optimization
- ✓ Frequency Control
- ✓ Minimum load reduction
- ✓ Fast Ramp
- ✓ FMS

SPPA-P3000 Temperature Optimizer
Increased steam temperatures

Task

To achieve maximum steam temperature without violation of material limits

Solution

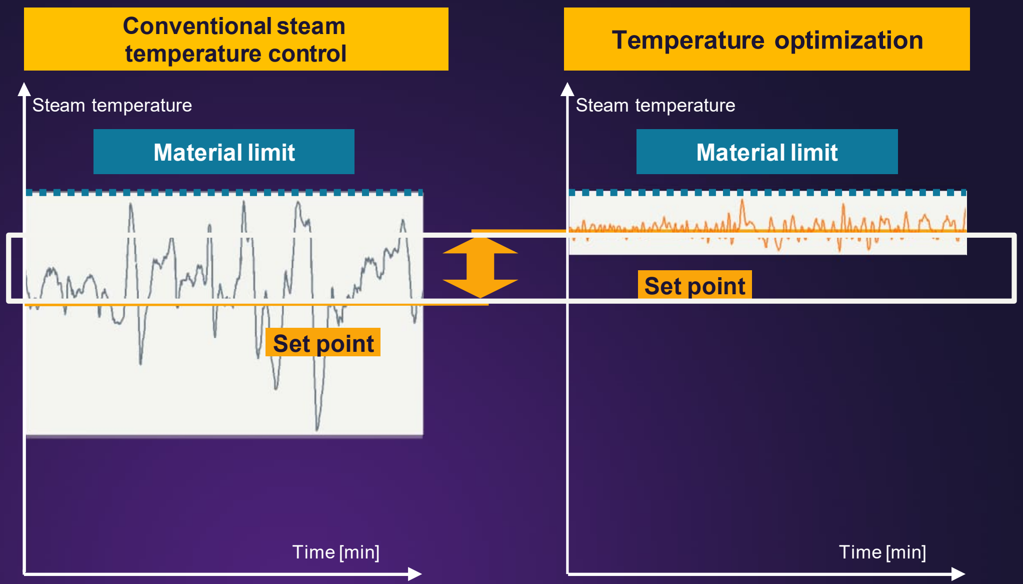
- Robust, easy to parameterize and adaptive state space controller with observer
- Where needed, use of entire control range through to injection into saturated steam
- Use on startup/shutdown and over the entire load range

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.

SPPA-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

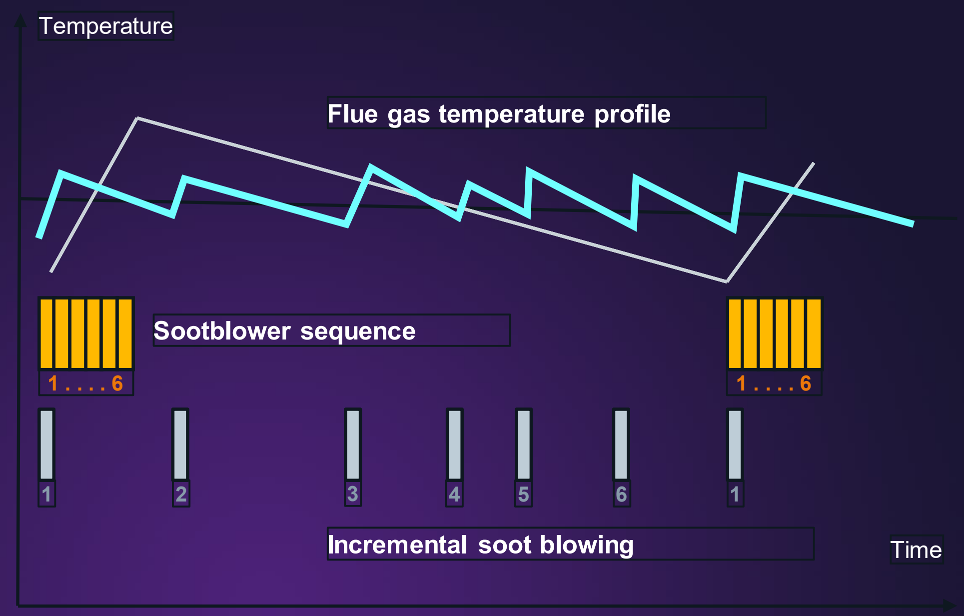
- Reheater attemperation
- Temperature imbalances
- Control range of HP feed water heaters
- Boiler slagging

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.

SPPA-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.

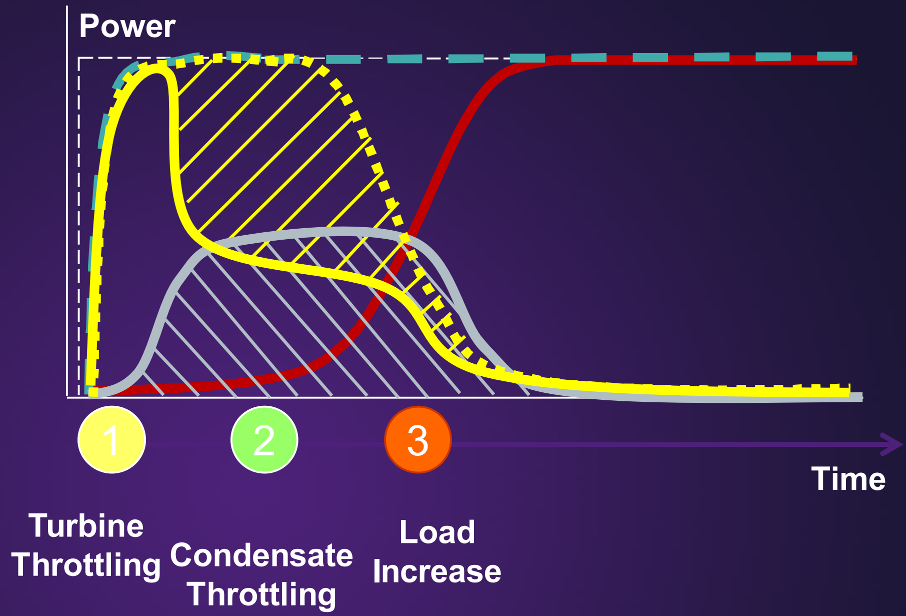
Solution

- 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):



SPPA-P3000 Minimum Load Reduction
Reduced minimum load level

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.

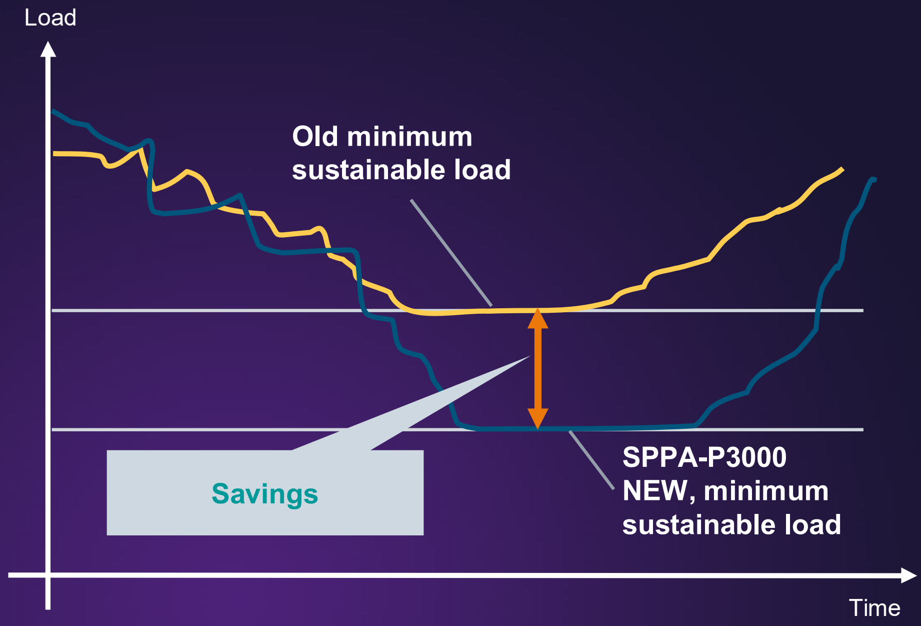
Solution

- 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

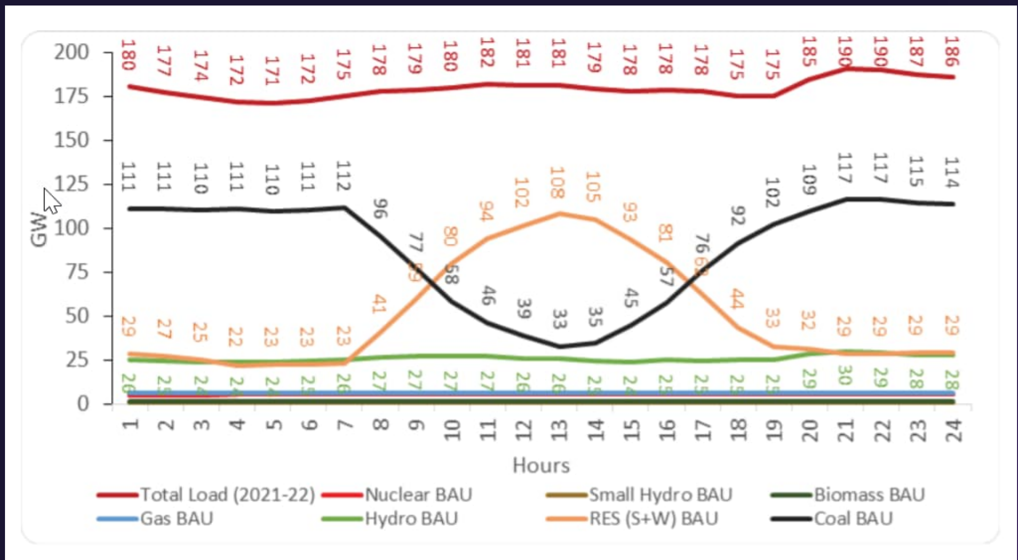
Minimum Load Reduction



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

Boiler Fatigue Monitoring System (FMS)
A. Why FMS ?—Effects of Thermal Cycling

Increase of Renewable energy Power generation as mandated by Govt regulation leads –175 GW by 2023



*Constant flexing of Thermal power plants—
79 GW in 6 hours de-load + load cycle ~ 220 MW/min

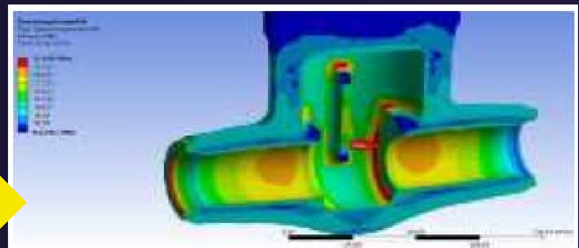
CEA report→ Max ramp rates on typical day—379 MW/min

*Note : CEA report on **FLEXIBLE OPERATION OF THERMAL POWER PLANT FOR INTEGRATION OF RENEWABLE GENERATION**

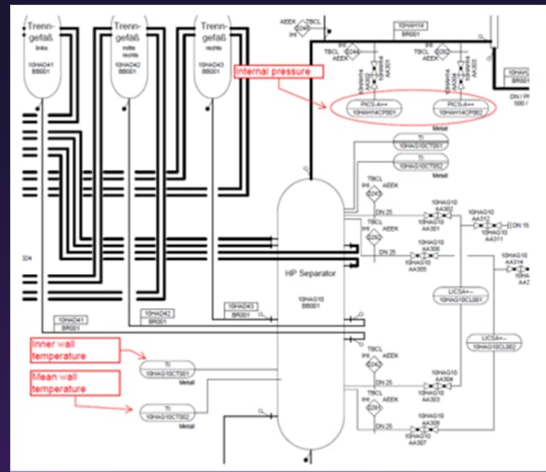
Boiler Fatigue Monitoring System (FMS)
B. Life cycle of Components
Online Evaluation--Possible

Component under Fatigue caused by Thermal cycling

Online Fatigue calc and evaluation of lifetime limits and stresses



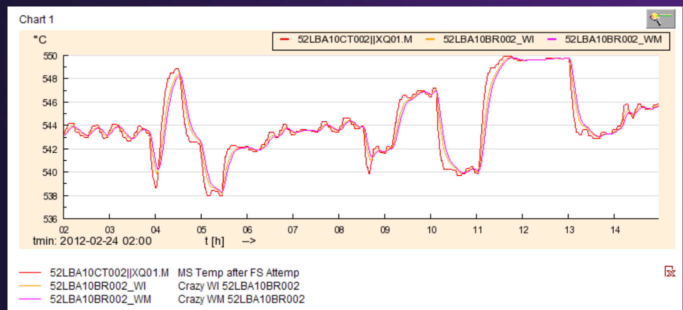
How much fatigue is it ?



Optimization of process to regulate the parameters

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

Affected components:
Headers, Drums,
Separator. Attemperators,
Piping



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

C. Objective→
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

Boiler Fatigue Monitoring System (FMS)
D. Types of Fatigue and Theoretical Service Life

Fatigue from cyclic Operation

Oper. Mode : During Start / Shutdown / Load changes→ Changing steam pressure and steam temperature

Result : Alternating Stresses at boiler pressure parts

Finding : Cracks occur after a certain number of cycles depending on Stress variation range

Creep Fatigue

Oper. Mode : Cont Operation at high Loads

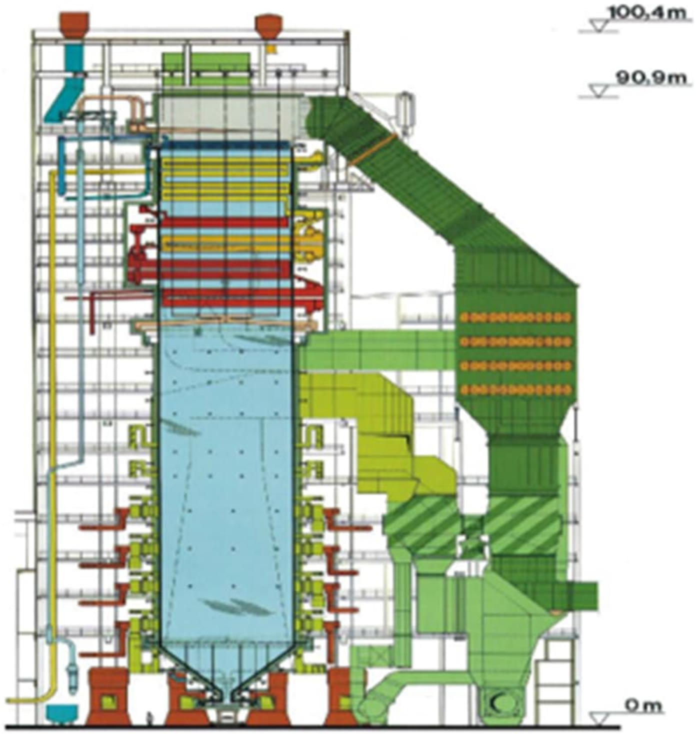
Result : Material strength reduces during steady state operation at high temperature and at high pressure

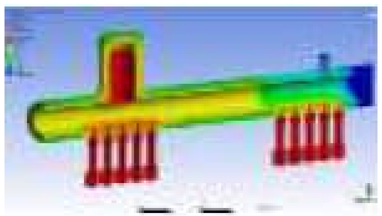
Finding : Cracks occur after a certain operation time

The **theoretical service life** of a component is precalculated for a **specific design loading**.

Operating conditions outside the design parameters→
lifetime attained may be longer or shorter than design.

Actual anticipated time until failure of the component at the current operation time→ **residual lifetime**.





Boiler Fatigue Monitoring System(FMS)
E. Methodology of Calculation

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1. Component design
2. Measuring point selection & Parameter classes
3. Theoretical lifetime & Creep fatigue calculation
4. Number of cycles to crack initiation calculation
5. Low-cycle fatigue calculation
6. Analysis of the current list of remaining extrema
7. Determination of the total fatigue

F. Types of Fatigue Calc---Theoretical Lifetime Calc

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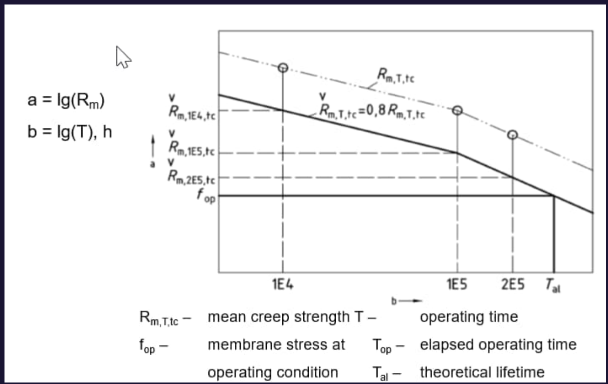

Lifetime (Limits) per class (in h)

Type: Cylinder T-branch - butt joint, GMAW, no void	
Material:	10CrMo9 10 - DIN 17 175 (<= 80 mm)
Outside diameter (Parent part):	290 mm
Wall thickness (Parent part):	70 mm
Outside diameter (Branch):	88.9 mm
Wall thickness (Branch):	8 mm

Temp. -> pressure	450	450 460	460 470	470 480	480 490	490 500
< 10	3.0e18	1.6e18	4.3e17	3.3e16	9.4e15	2.6e15
10 - 20	1.7e17	9.5e16	2.7e16	2.5e15	7.5e14	2.2e14
20 - 40	1.2e15	7.4e14	2.4e14	3.0e13	1.0e13	3.3e12
40 - 60	3.4e13	2.1e13	7.3e12	1.2e12	4.3e11	1.5e11
60 - 80	3.1e12	2.0e12	7.4e11	1.4e11	5.3e10	1.9e10
80 - 100	5.2e11	3.4e11	1.3e11	2.8e10	1.1e10	4.18e9
100 - 120	1.3e11	8.4e10	3.4e10	7.91e9	3.18e9	1.24e9

Many highly-loaded components of the water and steam piping systems with limited service life are implemented in power plant boiler construction.

Thus, for each class (pressure-temperature-combination) the theoretical service life is calculated, which may be achieved, if the component is operated in this class only.

Input data:

- Geometry of the component
- Material properties (mean creep strength values)

Result:

Matrix of the theoretical service life.

F. Types of Fatigue Calc--- Creep Fatigue Calc

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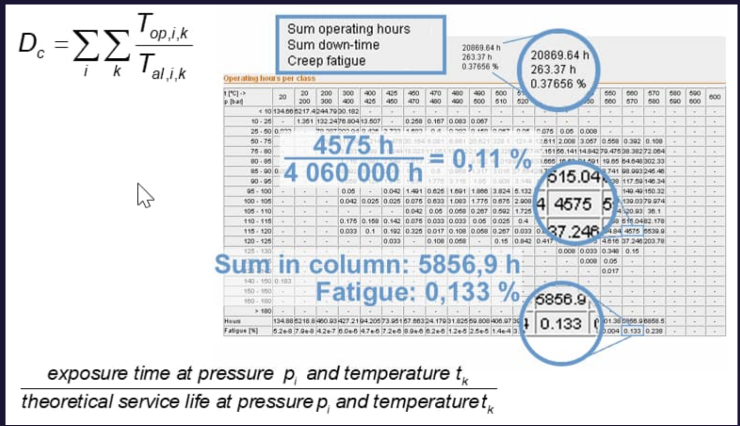
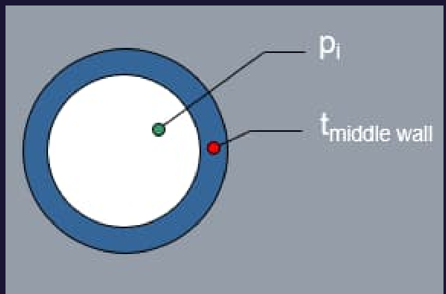




Methodology:

The measured value for mean wall temperature t_{mw} is increased by f_z (temperature addition). This corrected wall temperature and the inner pressure are the input for the class selection.

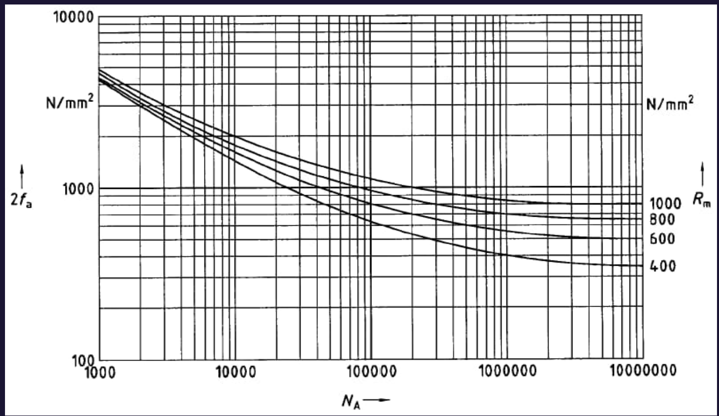
Input required

- Geometry of the component.
- Material information/database
- **Plant measurements →Mean wall temperature t_m and Internal pressure p_i**

Result:

Matrix of service time (operating hours per class)

F. Types of Fatigue Calc--- Low Cycle Fatigue & No. of Cycles to Crack Initiation

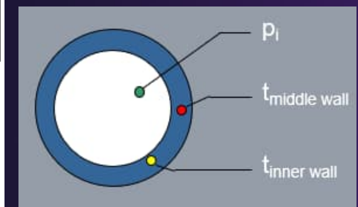


Number of load cycles N_A for crack initiation as a function of the stress range $2f_a$ (R_m fatigue stress)

Number of cycles to crack per class

Type: Cylinder T-branch - butt joint, GMAW, no void	
Material:	10CrMo9 10 - DIN 17 175 (<= 80 mm)
Outside diameter (Parent part):	290 mm
Wall thickness (Parent part):	70 mm
Outside diameter (Branch):	88.9 mm
Wall thickness (Branch):	8 mm

Temp. -> σ	450	450 460	460 470	470 480	480 490	490 500
850 - 900	4143.7	4143.7	4143.7	4143.7	4143.7	4143.7
950 - 1000	3498.0	3498.0	3498.0	3498.0	3498.0	3498.0
1000 - 1050	2995.7	2995.7	2995.7	2995.7	2995.7	2995.7
1050 - 1100	2596.8	2596.8	2596.8	2596.8	2596.8	2596.8
1100 - 1150	2274.5	2274.5	2274.5	2274.5	2274.5	2274.5
1150 - 1200	2010.1	2010.1	2010.1	2010.1	2010.1	2010.1
1200 - 1300	1790.4	1790.4	1790.4	1790.4	1790.4	1790.4



Methodology:

The number of load cycles to crack initiation is calculated according cyclic stress range for the component. The cyclic stress range is temperature corrected, so the number of load cycles to crack initiation is independent from temperature.

Input data:

- Geometry of the component
- Type of welding connection
- Material properties
- **Plant Measurements →Inner wall temperature t_{iw}** (temperature at inner wall surface) , **Mean wall temperature t_{mw}** (equivalent to t_m in creep fatigue) & **Internal pressure p**

Result:

Matrix of load cycles to crack initiation (cyclic stress range –temperature -classes)

Boiler Fatigue Monitoring System (FMS) System Architecture

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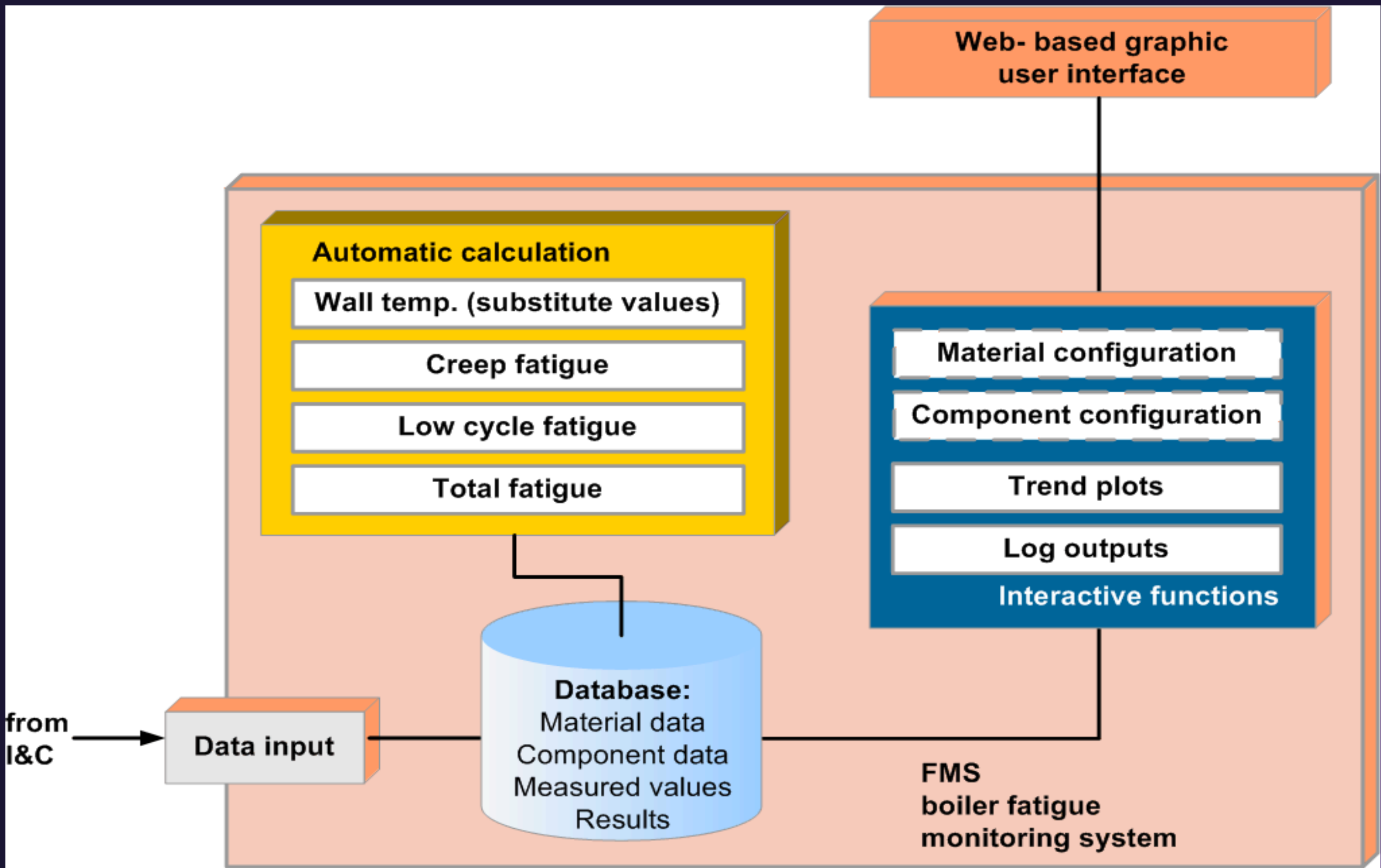

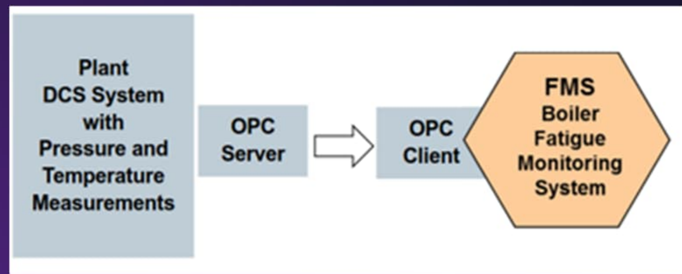

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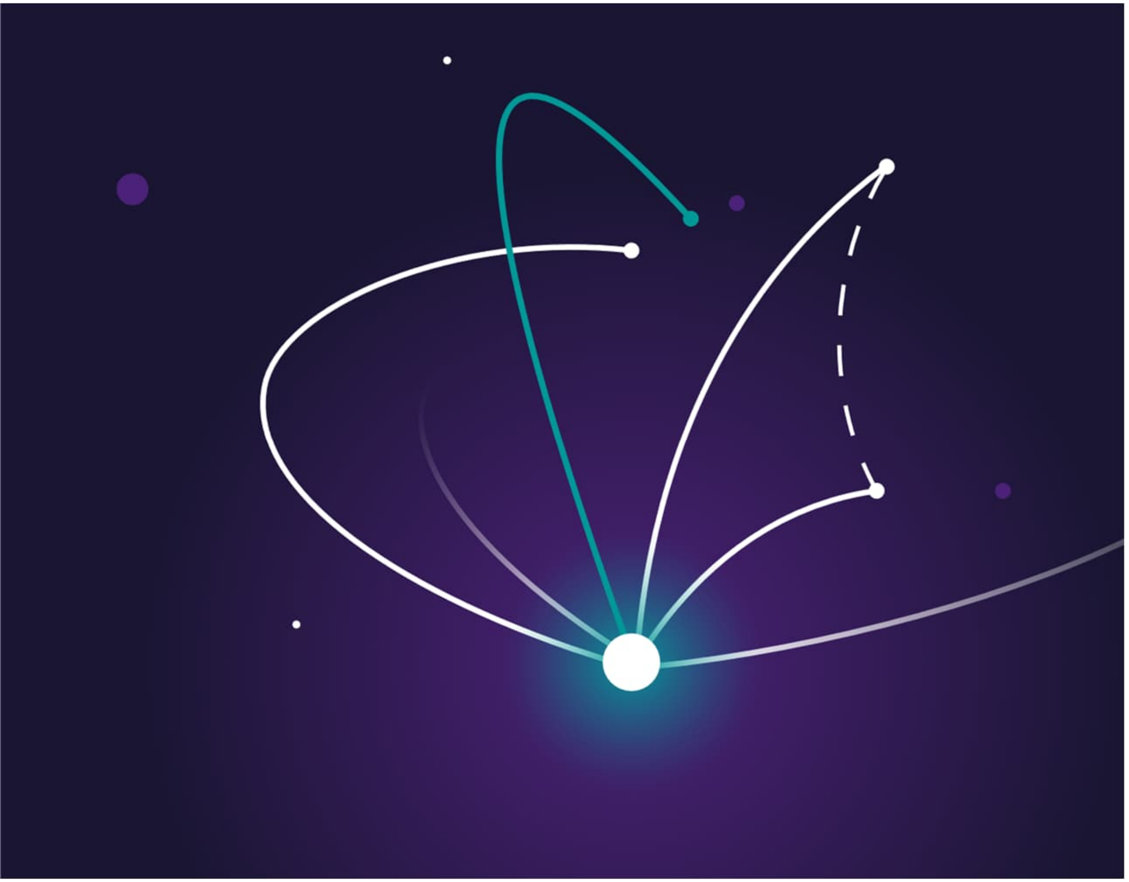

Ian Rebello

Siemens Energy
Lead – Process
Optimization
India
Mobile: +91 9820737004
ian.rebello@siemens.com

Aravind Shankar

Siemens Energy
Digital Solutions, Sales
Mobile: +91 9971777048
aravind.s@siemens.com