Flexible Operation of Thermal Power Plant: A Bridge to Decarbonized Energy System

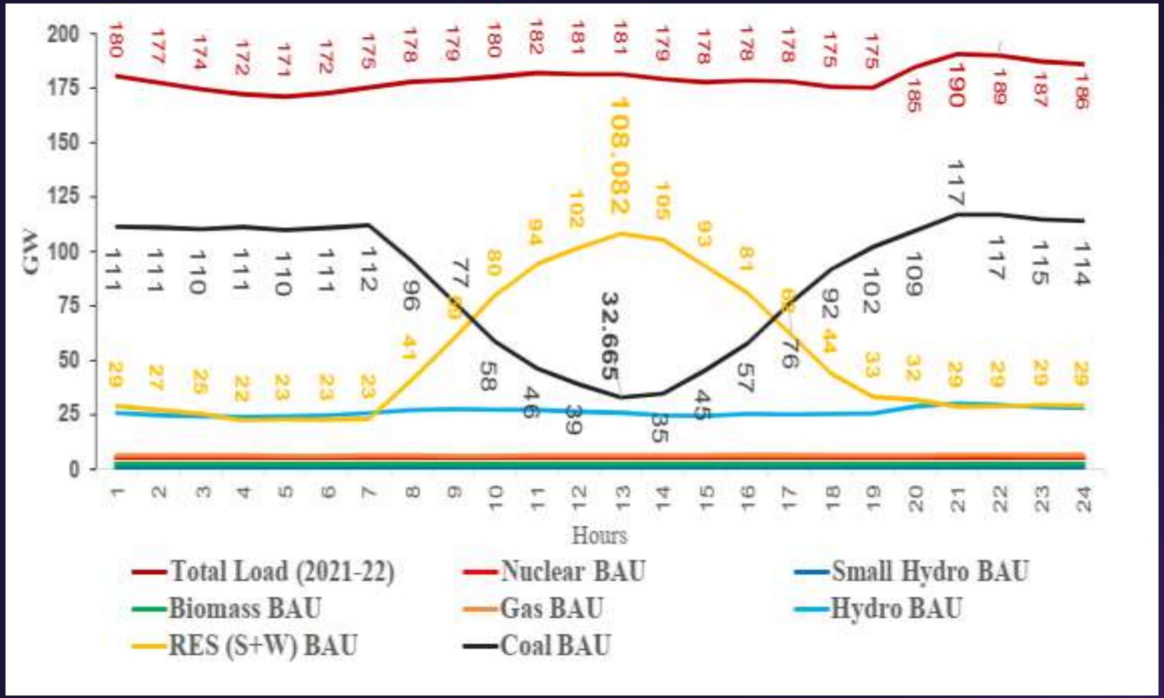
Flexibilization of your Power Plants - Role of Controls

Ian Rebello

12 Oct 2023 – EEC Workshop , Raipur

Changing energy market

SIEMENS energy



Demand & Generation on a critical day

Solar Power – Pipeline status 08th Oct'23

(Source: CEA's report "flexible operation of thermal power plants for integration of renewable generation")

(Source: https://iced.niti.gov.in/energy/electricity/generation/pipeline-capacity/solar)

Events timeline – Flexibilization of Thermal Plants in India

SIEMENS energy

Aug’22

CEA – draft Regulation on Flexible operation of Thermal Plants

Jan’23

CEA – Gazette Notice “ Regulation on Flexible operation of Thermal Plants”

May’23

CEA – Announces phasing plants for plants.

4 phases from 2024 - 2030

July’23

CERC notice on compensation methodology for flexible operation of Thermal Plants

July’24….

Phase 1
Jul’24 – Dec’26
Phase 2
Jul’26 – Jun’28
Phase 3
Jul’28 – Dec’29
Phase 1
Jul’24 – Dec’26

Dec’30

Phase 4
Jan’30 – Dec’30

CEA Notification dated 30 Jan 2023

7. **Ramp rates capabilities of coal based thermal power generating units for flexible operation**.- (1) The coal based thermal power generating units shall have ramp rate capability of minimum three percent per minute for their operation between seventy percent to hundred percent of maximum continuous power rating and shall have ramp rate capability of minimum two percent per minute for their operation between fifty-five percent to seventy percent of maximum continuous power rating.

(2) The coal based thermal power generating units shall achieve ramp rate capability of minimum one percent per minute for their operation between forty percent to fifty-five percent of maximum continuous power rating as per phasing plan mentioned in the sub-regulation (2) of regulation 5 of these regulations.

IMPLICATION ON GENERATION COMPANIES

Generation Companies are expected to conduct MIN Load tests & evaluate their units for potential to meet the CEA requirements

Generation companies are expected to implement the necessary interventions to meet the CEA notification requirements as per the phasing plan , which has been published by CEA in May’23

CEA Phasing Plan May 2023

SIEMENS energy

Phase and time period	Sector	No. of units	Capacity (MW)	Time (year)
Pilot May,2023-December,2023	Central	4	1990	1
	State	3	2260	1
	Private	4	2190	1
		11	6440	1
Jan,2024 - Jun,2024	Performance analysis and modification, if required.			
1st July,2024-Jun,2026	Central	32	20110	2
	State	28	16410	2
	Private	39	20030	2
		99	56550	2
2nd July,2026-Jun,2028	Central	27	11850	2
	State	24	10980	2
	Private	66	30495	2
		117	53325	2
3rd July,2028-Dec,2029	Central	8	2630	1.5
	State	35	10800	1.5
	Private	36	12055	1.5
		79	25485	1.5
4th Jan,2030-Dec,2030	Central	79	26760	1
	State	104	23227.5	1
	Private	24	7657	1
		207	57644.5	1

Subsequently a draft phasing plan has been prepared for achieving 40% technical minimum load at coal based generating units. Different factors such as pit-head/ non-pithead, RE concentration, units having latest control system, CFBC technology, ball & tube mill, vintage units, cost etc. have been taken into account during preparation of phasing plan.

(Source: CEA notification on phasing plan dated 01 May 2023)

CERC Draft Regulation July 2023

2. Measures required for achieving lower Minimum Power Load

For achieving minimum power load (40%) and higher ramp rate, Coal based power plants may require few modifications by way of improved control systems etc and also required to be compensated for the loss of life and increased variable cost due to regular part load operation.

The primary focus of the utility shall have to be on the existing control system optimization and improvements in some of the areas like achieving automated control operation which includes proper tuning of operation so as to avoid temperature and pressure excursions. Control optimization shall also include main/reheat steam temperature control, boiler feed water recirculation control, flue gas temperature control. Better combustion control include, optimum fuel to air ratio, fuel to load coordination, furnace pressure control, burner tilt control and proper flame monitoring at low loads are essential. Condition monitoring of

Primary focus while enabling flexible operation of thermal plants is expected to be on optimizing existing plant control systems

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

SIEMENS energy

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

SIEMENS energy

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

SIEMENS energy

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 – APC based solutions

SIEMENS energy

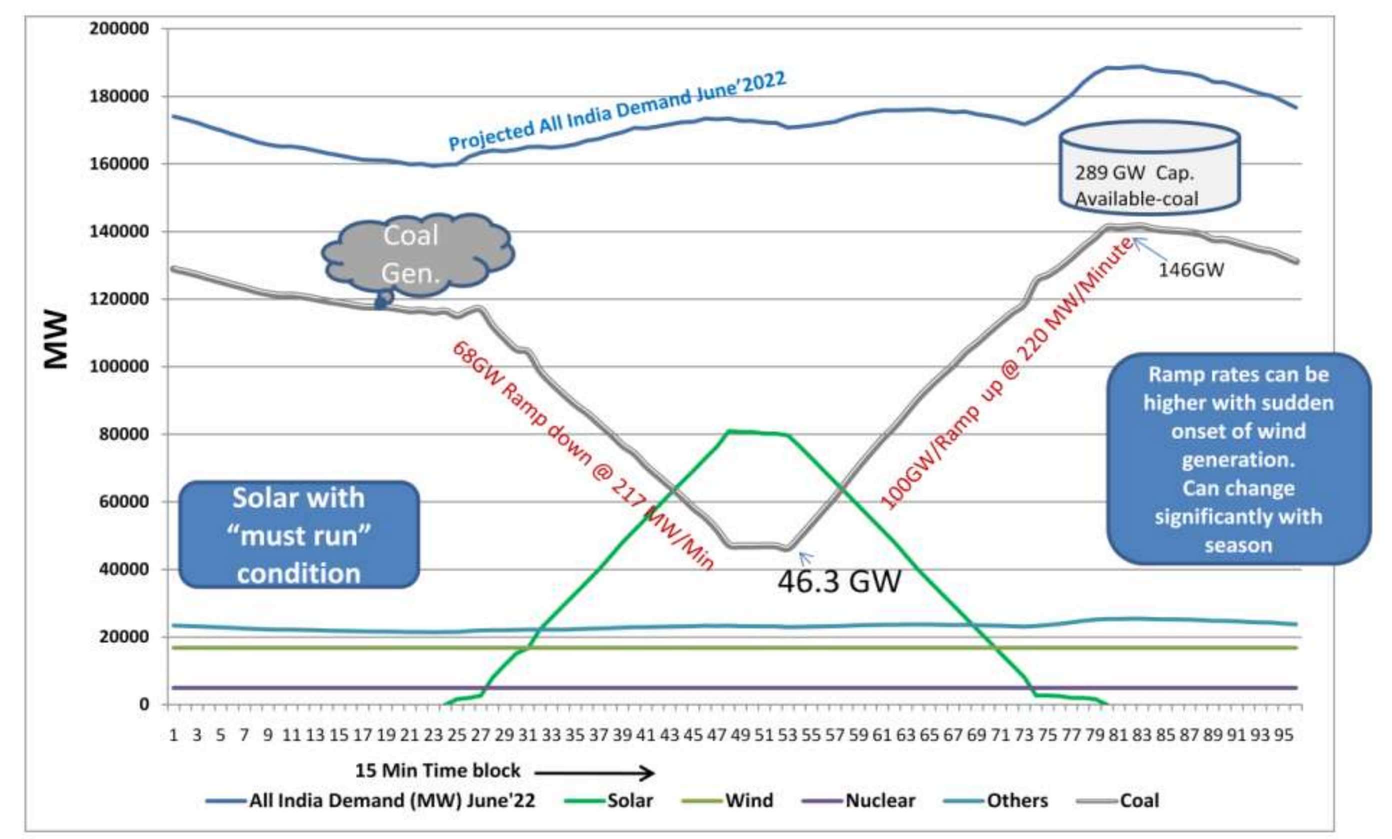


Fig-4:Anticipated Indian Scenario in 2022,*with 100 GW Solar & 60 GW Wind*

Source: CEA's report "flexible operation of thermal power plants for integration of renewable generation")

Flexibility Road Map
Solutions based on Digital interventions.

Advanced Process Control / Thermal twins

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

We choose the best approach for each solution to maximize plant performance

SIEMENS energy

Digital Twin (DTT)

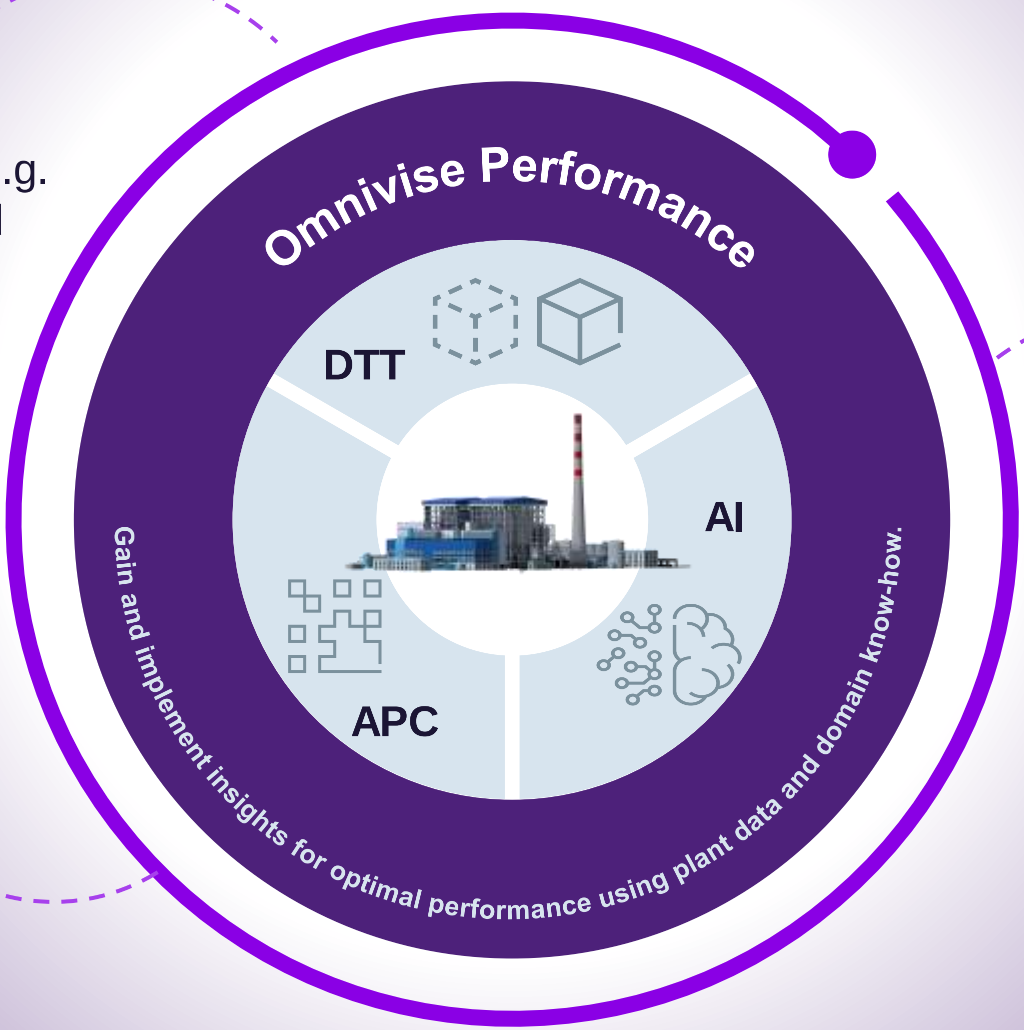
Digital thermal twin using first principal equations, e.g. conservation of mass and energy …

to add background knowledge to plant data

Advanced Process Control (APC)

Dynamic digital twins used in non-linear model predictive control (NMPC), state space control ...

to exploit plant limits beyond historic operation



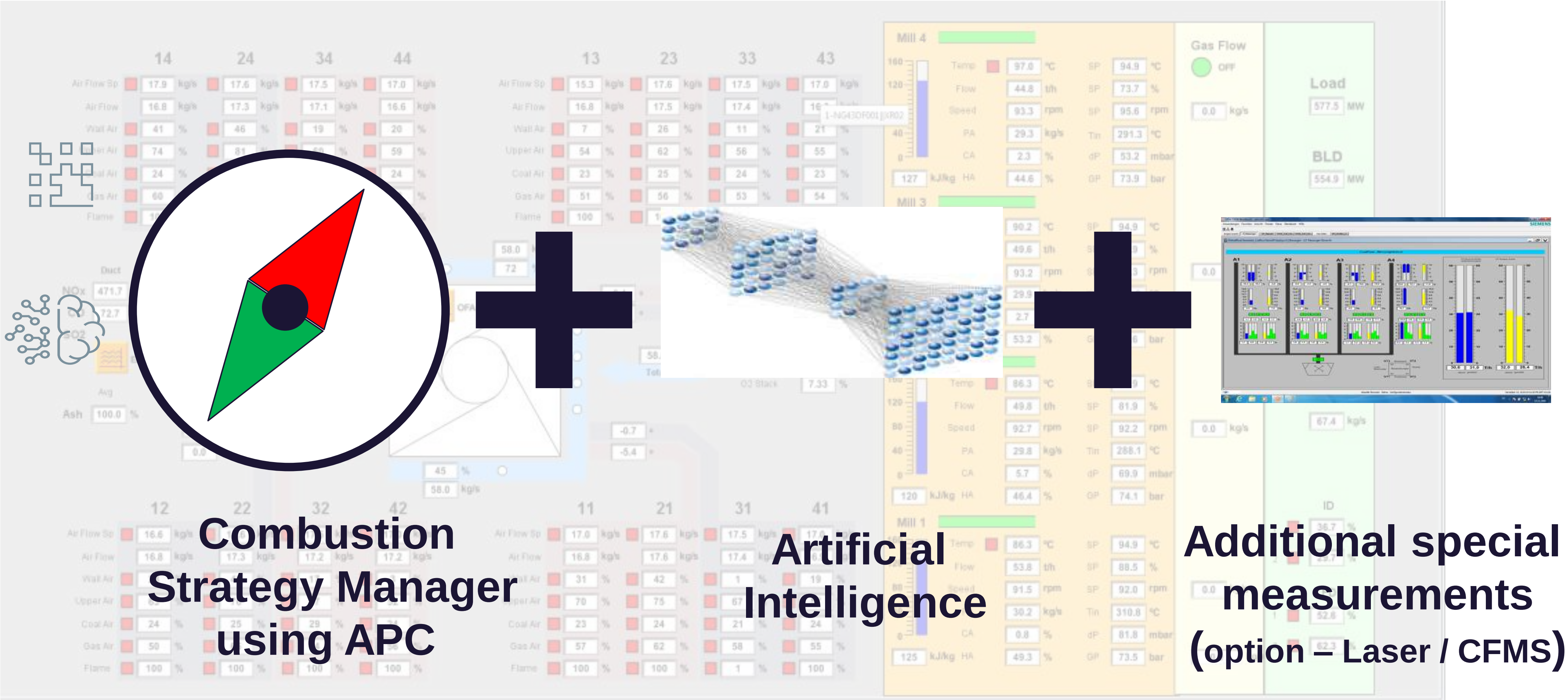
Artificial Intelligence (AI)

Machine learning, neural nets, fuzzy logic …

to exploit historic plant operation

Hybrid combustion optimization – combining APC and AI advantages to increase efficiency and reduce NOx

SIEMENS energy



Combustion Strategy Manager using APC

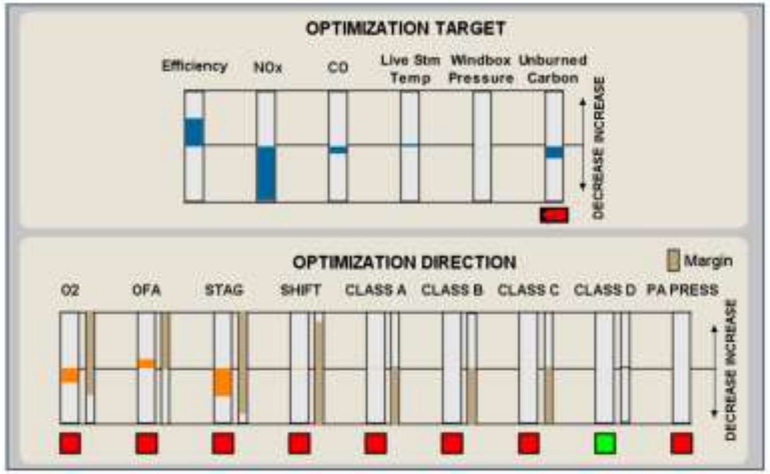
+

Artificial Intelligence

+

Additional special measurements (option – Laser / CFMS)

Our answer: Combustion Strategy Manager (APC) to exploit limits of plant beyond current operation and …



Targets and constraints
- Efficiency
- NO_x
- CO
- …

Strategy Manager
- modular
- Using APC
- Using AI (option)

Possible strategies
- VAS - Vertical Air Staging,
- VFS - Vertical Fuel Staging,
- MOOS – Mill out of service,
- Burner Tilt,
- CO/NOx control including CO Excursion Control Strategy
- Biasing of FD, PA and ID fans

Measurements
- O_2 at boiler end
- Air flows
- Temperature/ O_2 /CO profiles?
- ..

Controllers/Actuator
- OFA set points
- Fuel/air staging set points
- O_2 setpoints
- …

Omnivise P3000 Minimum Load Reduction
Reduced minimum load level

SIEMENS energy

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.

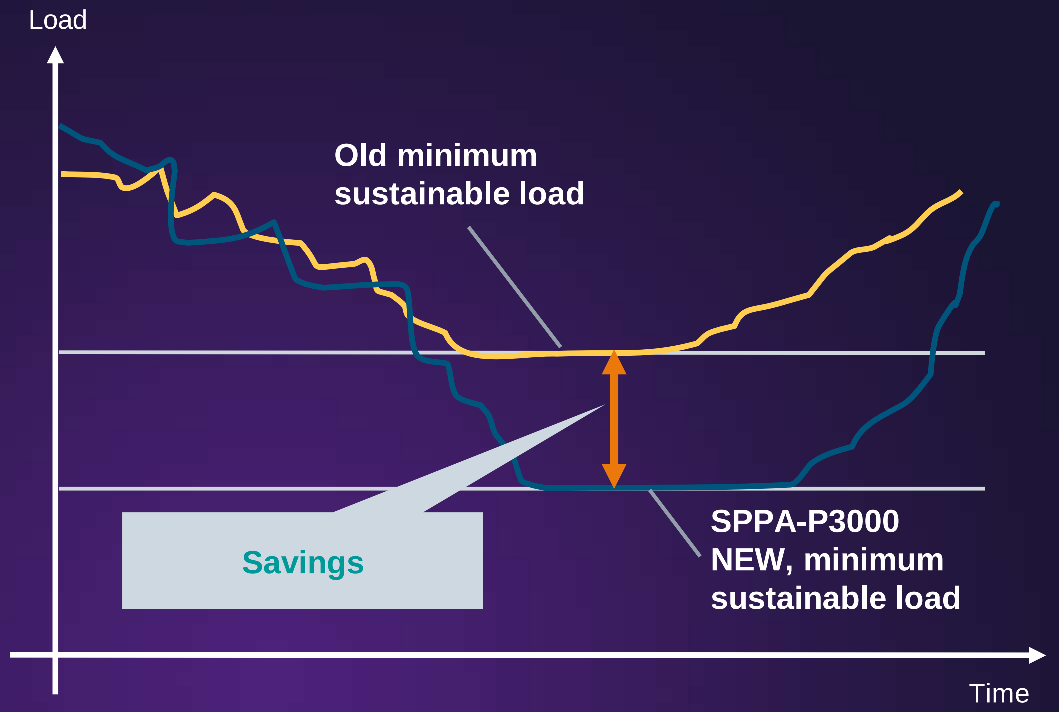
Solution

- 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

Task

To achieve maximum steam temperature without violation of material limits

Solution

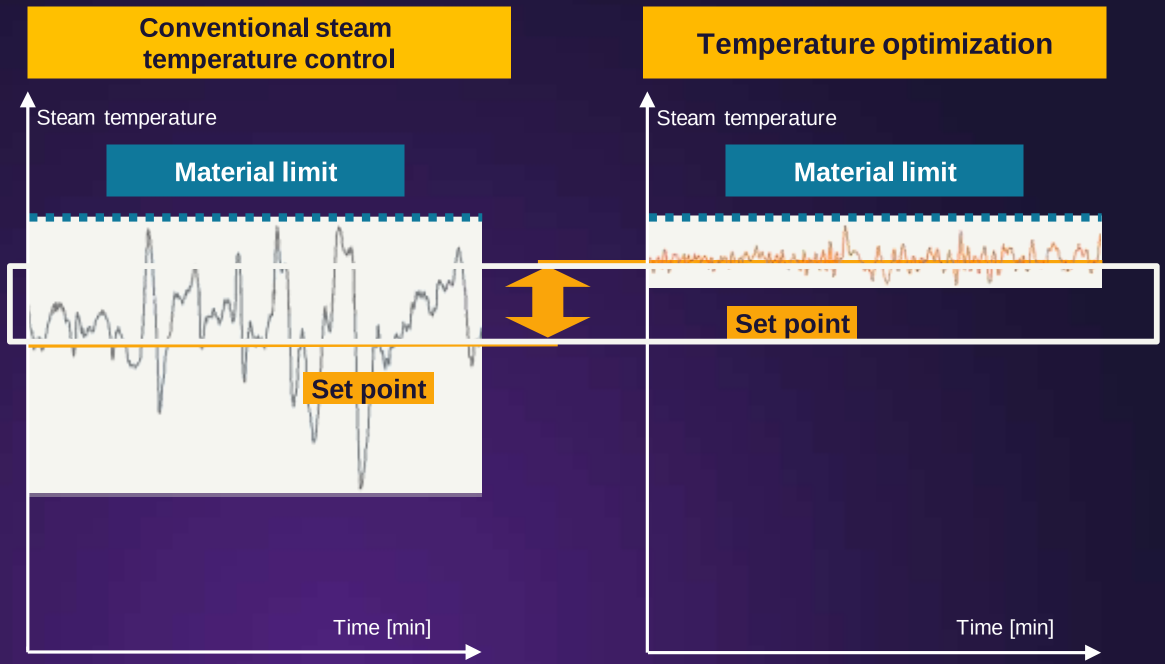
- Robust, easy to parameterize and adaptive state space controller with observer
- Where needed, use of entire control range through to injection into saturated steam
- Use on startup/shutdown and over the entire load range

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

SIEMENS energy

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

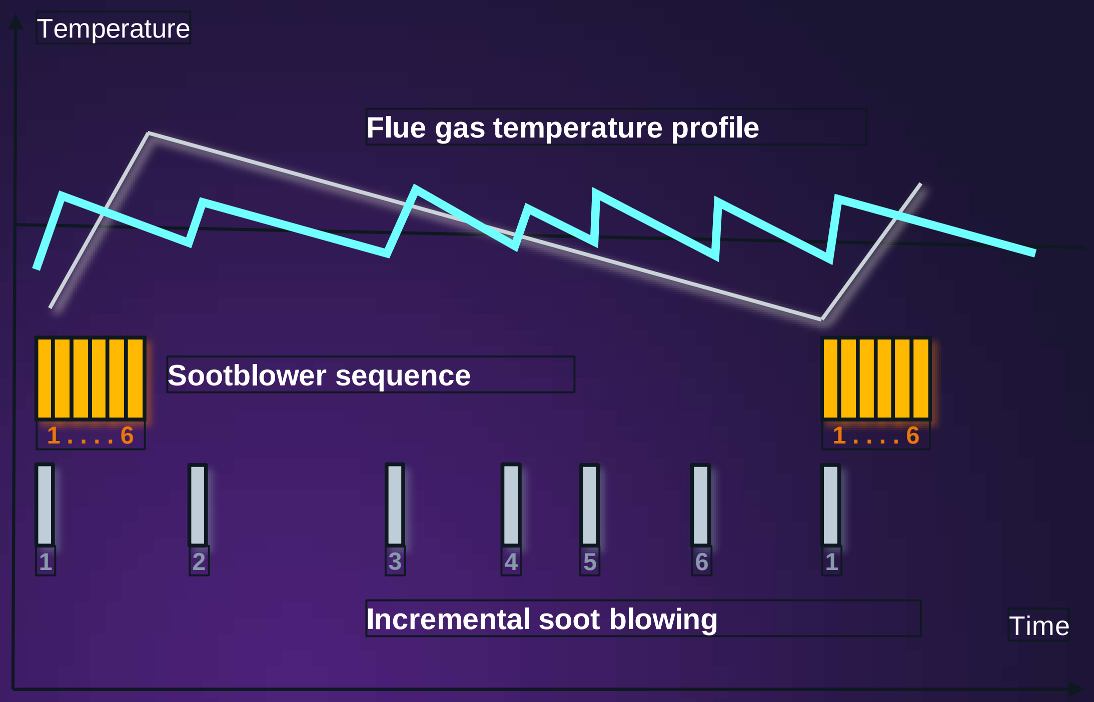
- Reheater attemperation
- Temperature imbalances
- Control range of HP feed water heaters
- Boiler slagging

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.

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

SIEMENS energy

The Issue

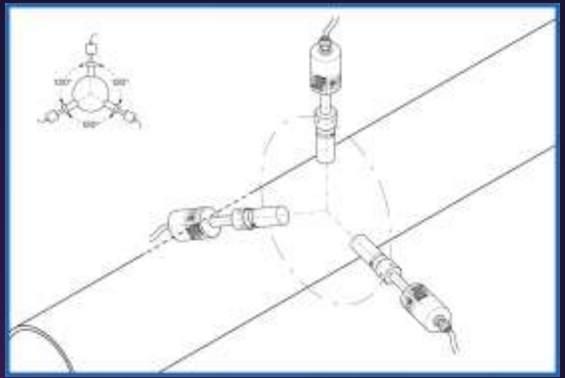
- Today imbalances of coal flow among the burners can be up to 30%)
- Cause poor combustion and possibly wall corrosion
- This means lower efficiency, more emissions, more material stress

The Solution

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

Benefit:

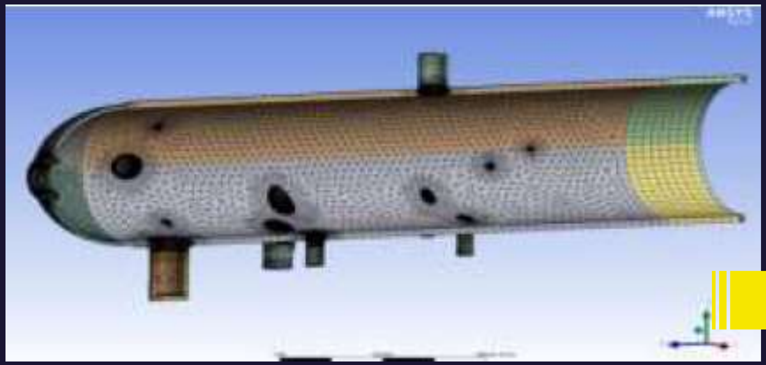
- Individual burner adjustment possible

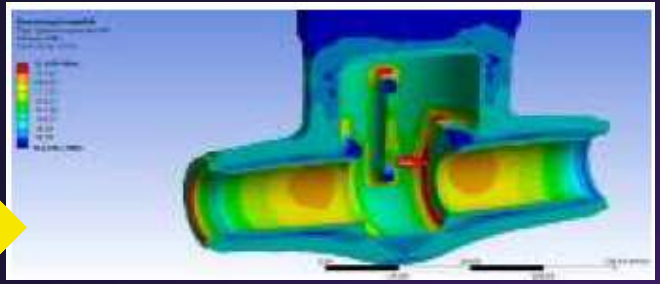


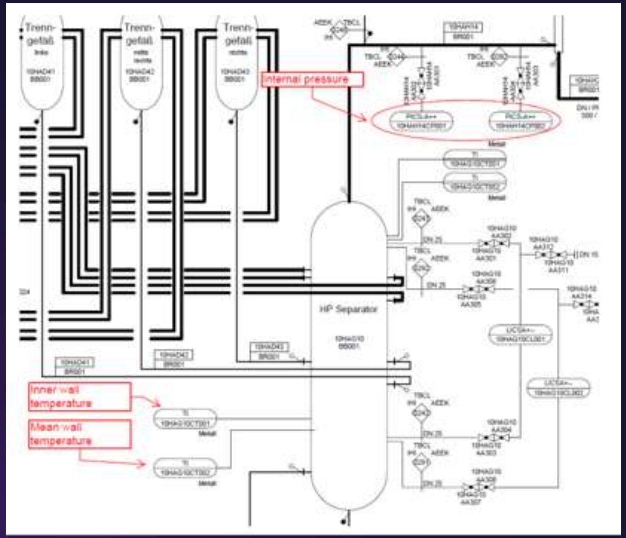
Installations of 3 Sensors for pipes above 400 mm diameter to avoid inaccuracies from roping

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

Online Fatigue calc and evaluation of lifetime limits and stresses







Component under Fatigue caused by Thermal cycling

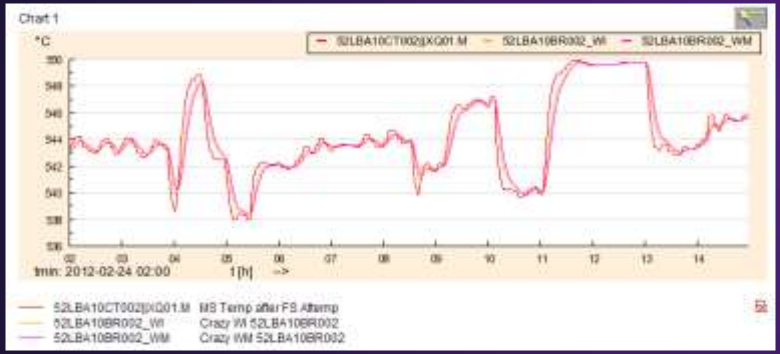
How much fatigue is it ?

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

APC / Digital solutions to address the challenges

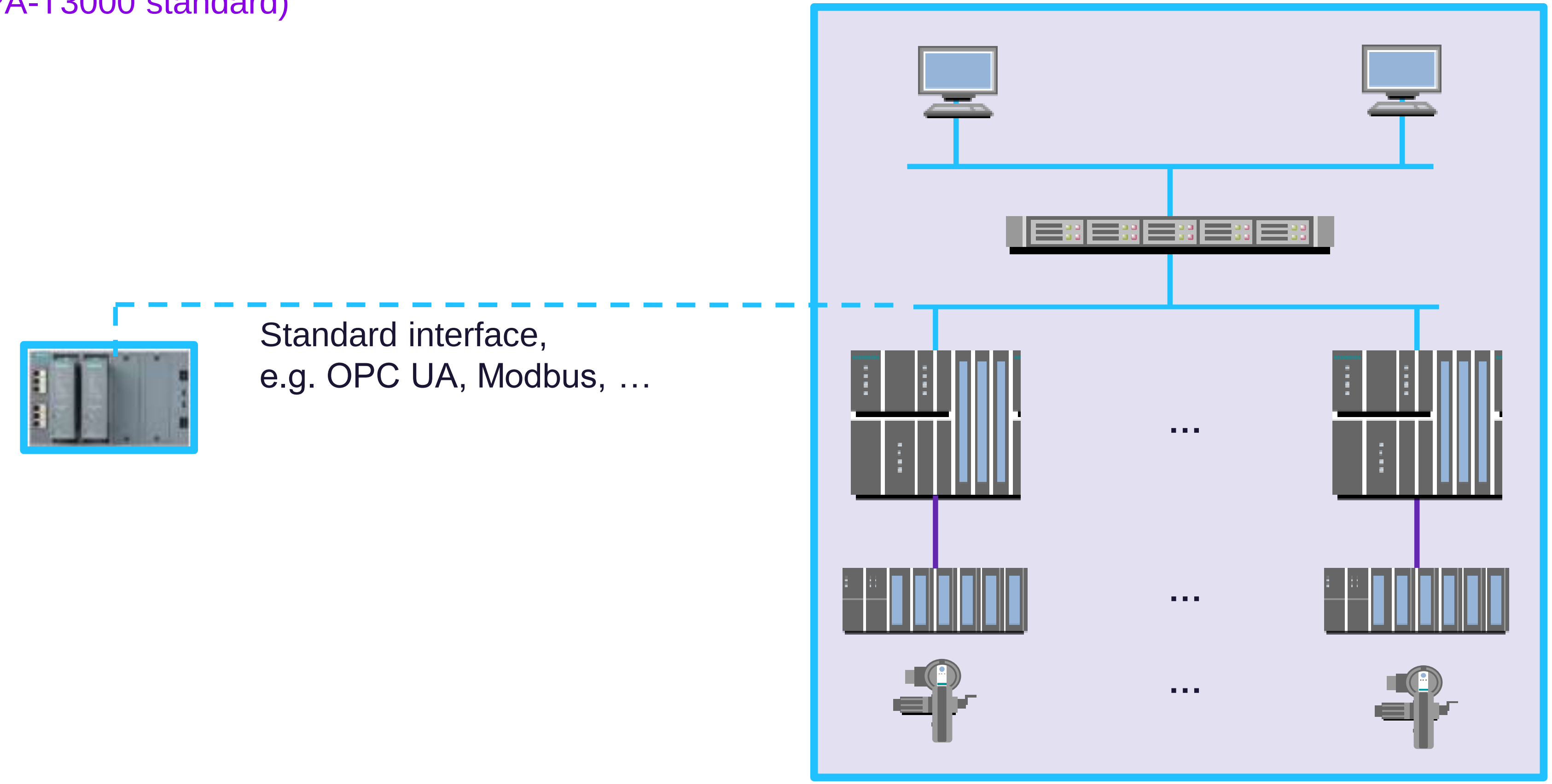
SIEMENS energy

Challenges	Solutions	Benefits
Low Ramp Rate Combustion / Flame issues Operator interventions	Enhanced master controls Low load controls tuning	Higher ramps Operator intervention Better efficiency
Aux Power Single Stream Operation	Auto Cut In/Off Of Auxiliaries Mill Scheduler	Reduced aux power Operator intervention Better efficiency
Impact on components Unscheduled outage	Fatigue Monitoring System Life consumption	Low stress operations Shutdown planning

Easy hardware integration: Interface to plant control system using standard interfaces

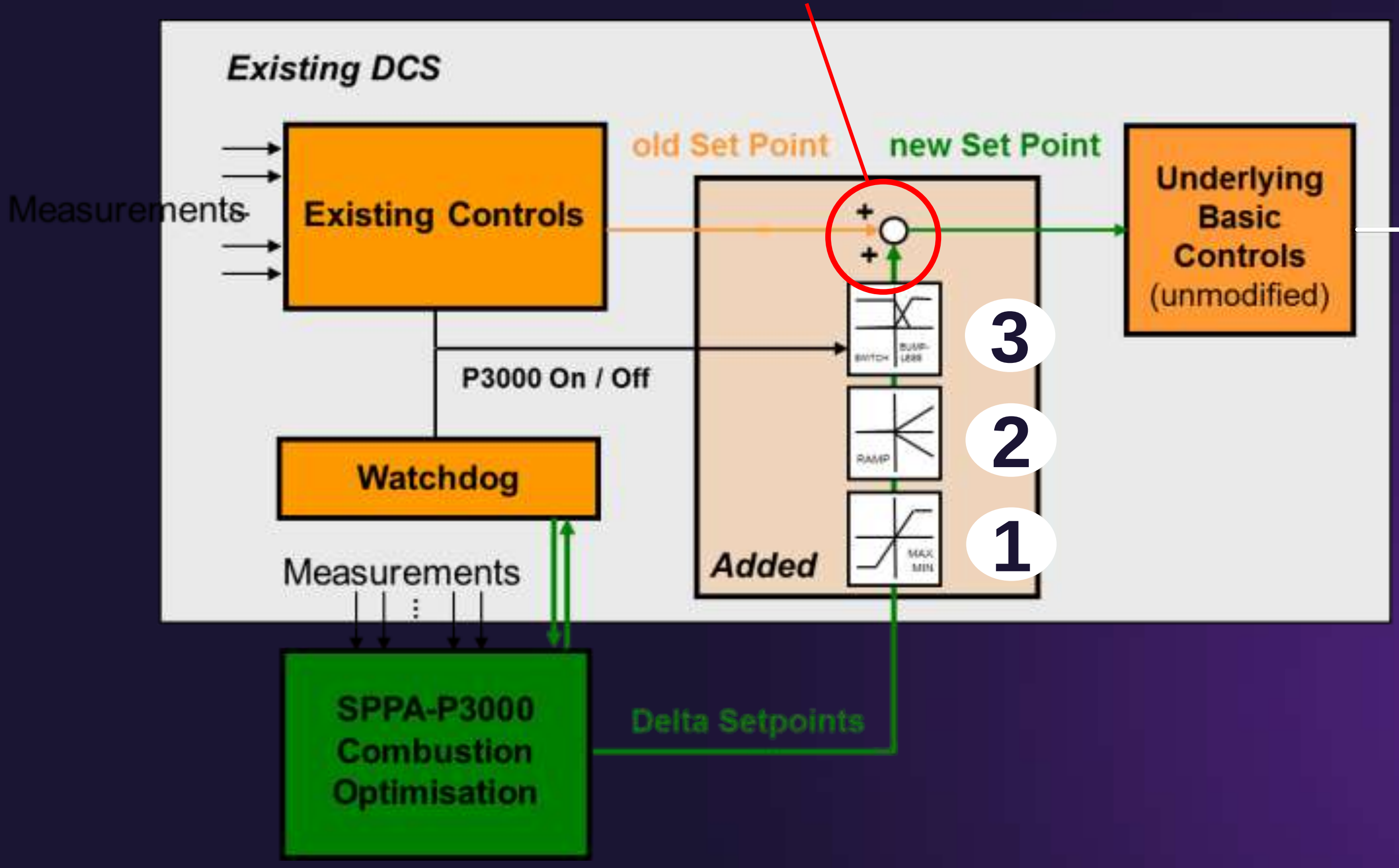
Omnivise
Performance Server
(SPPA-T3000 standard)

DIstributed control system
(SPPA-T3000 or 3rd party)



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:

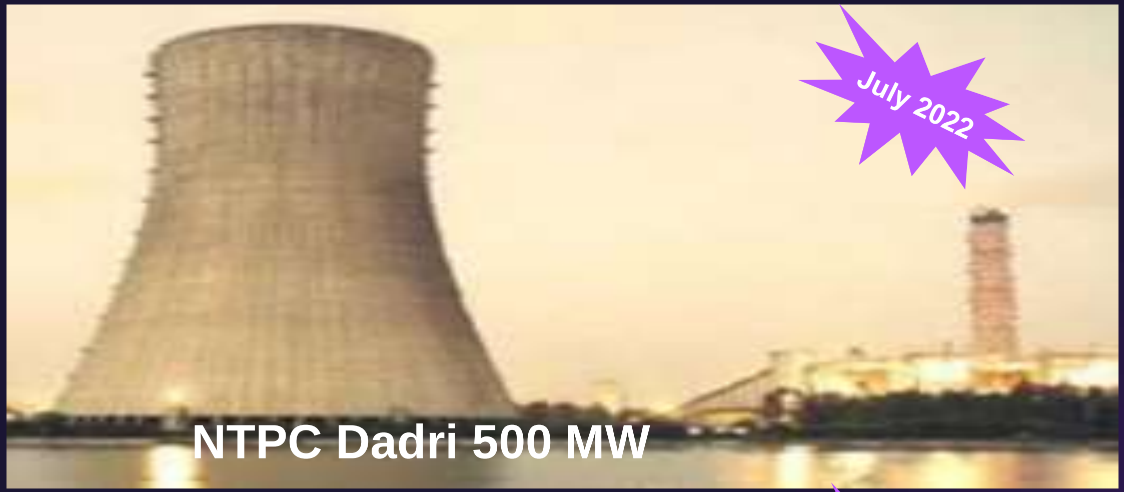
A continuously circulating watchdog signal **monitors communication**.
=> biases are bumplessly fading out on DCS and Onivise side whenever communication fails.

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, ..)

Successes in Technical Min assessment and Digital based flexibility Interventions in India

SIEMENS energy



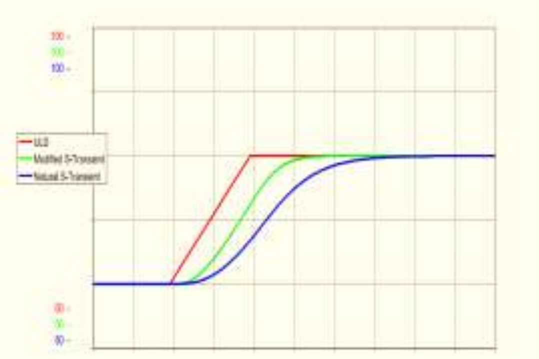
- **Min Load Tests - Flexibility Assessment for 500 MW block for technical minimum and ramp rates. July 2018**

Interventions implemented to automate load reduction to 40% and ensure stable operation

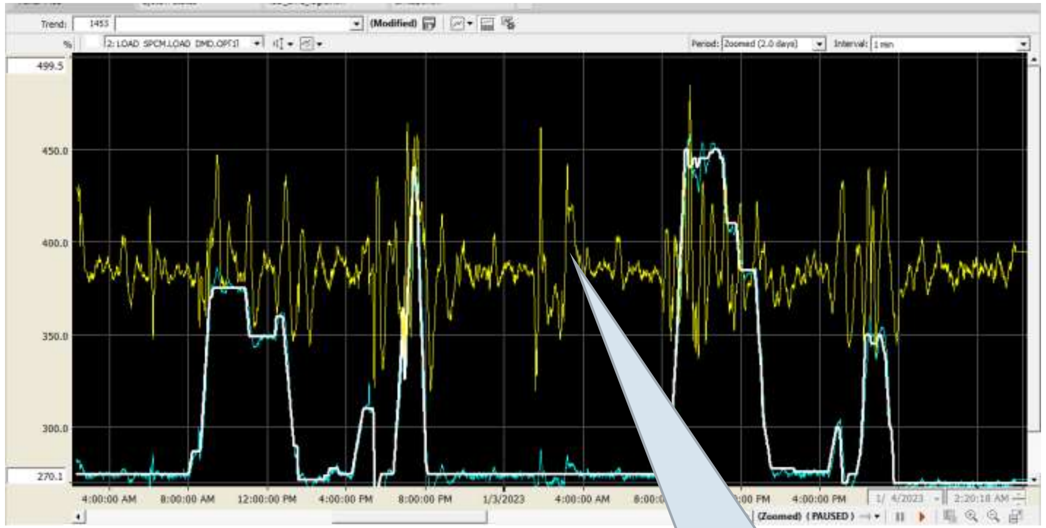
- Enhanced Unit Control
- Reheat / Flue Gas / Main Steam Temperature Control
- Fatigue Monitoring System
- Mill Scheduler
- Replacing of the feed water recirculation valve by a control valve

- Implementation of “Dispatch Control” and “Temperature Optimizer”
- Improve the flexibility of the plant

Results for Load Ramp - 500MW Plant in West India

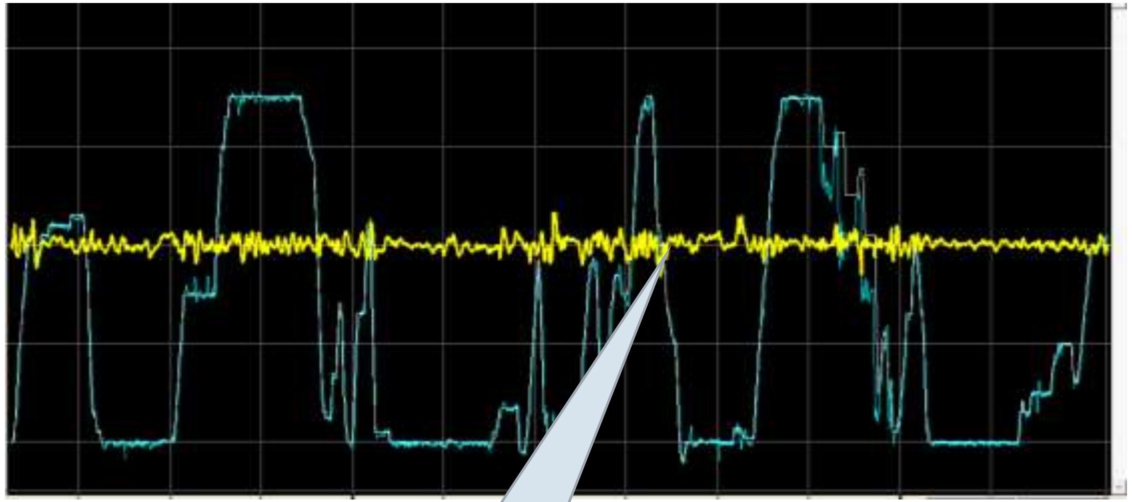


BEFORE



HIGH VARIATIONS IN BOILER MASTER DURING RAMPS

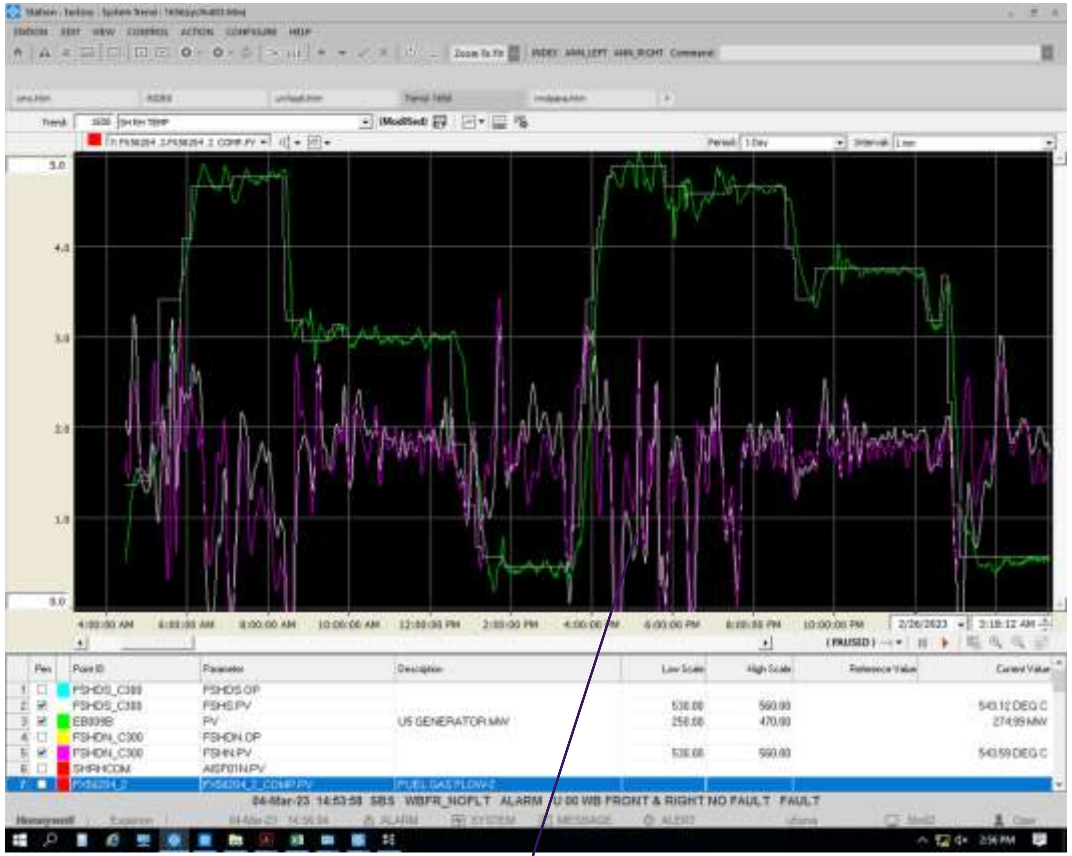
AFTER



LESS VARIATIONS IN BOILER MASTER DURING RAMPS

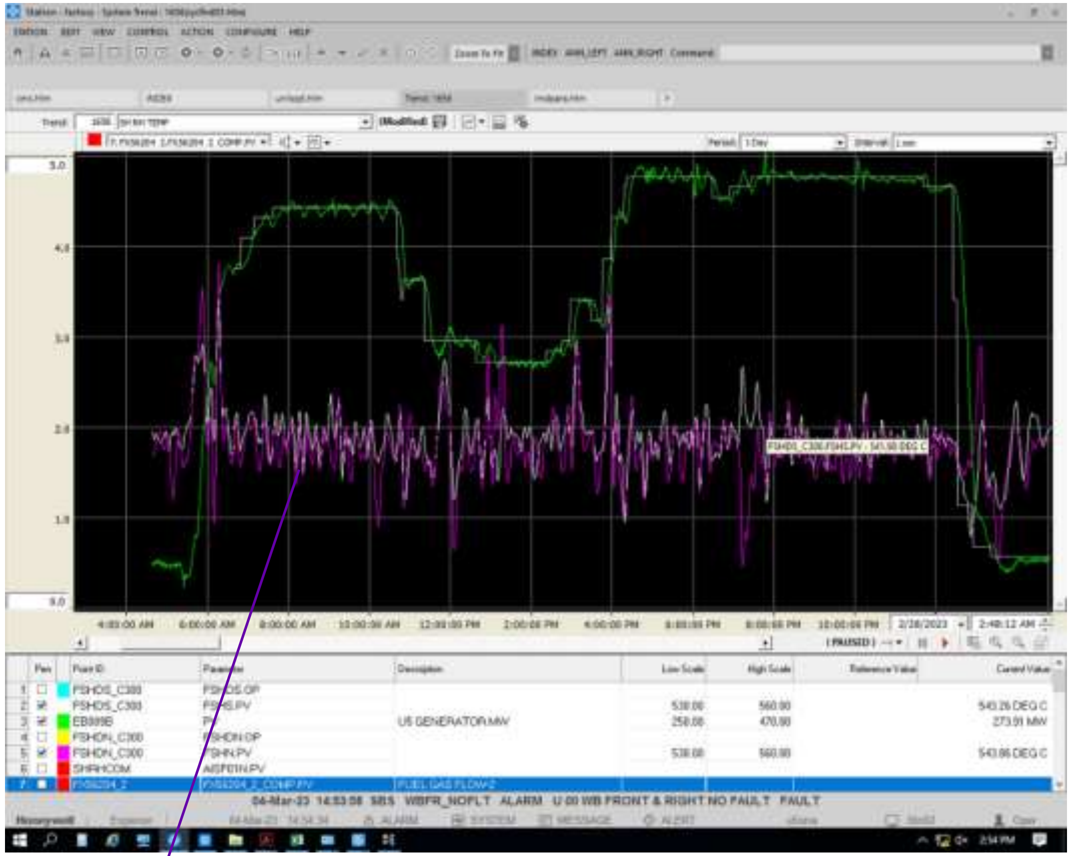
Results for Temperature Optimizer - 500MW Plant in West India

RESPONSE OF STEAM TEMPERATURE ON LOAD RAMP(BEFORE)



HIGHER TEMP VARIATION ON LOAD RAMP

RESPONSE OF STEAM TEMPERATURE ON LOAD RAMP(AFTER)



LOWER TEMP VARIATION ON LOAD RAMP

Summary or results – 500 MW Plant West India

Process Parameter	Status before Project Execution	Target	Achievements
Load Ramp	5 MW/Min	7 MW/Min	8.475 MW/Min
Deviation of SH Temp	+/- 15 Deg C	Steady State:+/- 7 Deg C	Steady State: Max +/- 1.8 Deg C(SD)
		Transient State:+/- 12.5 Deg C	Transient State: +/- 2.75 Deg C(SD)
Deviation of RH Temp	+/- 25 Deg C	Steady State:+/- 9 Deg C	Steady State: Max +/- 1.8 Deg C(SD)
		Transient State:+/- 12.5 Deg C	Transient State: +/- 4.75 Deg C(SD)

Summary or results – 500 MW NorthIndia

Process Parameter	Status before Project Execution	Achievements
Load Ramp	1.9 %	3.6 %
SH Temp dev	Steady State: Max +/- 5 K	Steady State: Max +/- 3 K
	Ramp +/- (12 – 15) K	Ramp +/- 8 K
Technical Min Load	55 %	40 %
Condensate Throttling	7% increase in load in 20 seconds * 5% from ST CV throttling & 2 % from Condensate throttling	

Thank you for your attention!

Ian Rebello

Siemens Energy

Service & Digital
Lead- Flexibilization &
Process Optimization
Mobile: +91 9820737004
ian.rebello@siemens.com

SPPA-P3000 Combustion Optimizer: Approach
APC / Laser / CFMS