SIEMENS
Ingenuity for life

Improved Ramp rates of steam power plant

Sandeep Chittora, Service and Digital, Siemens Limited

Imagine you are in 1950s

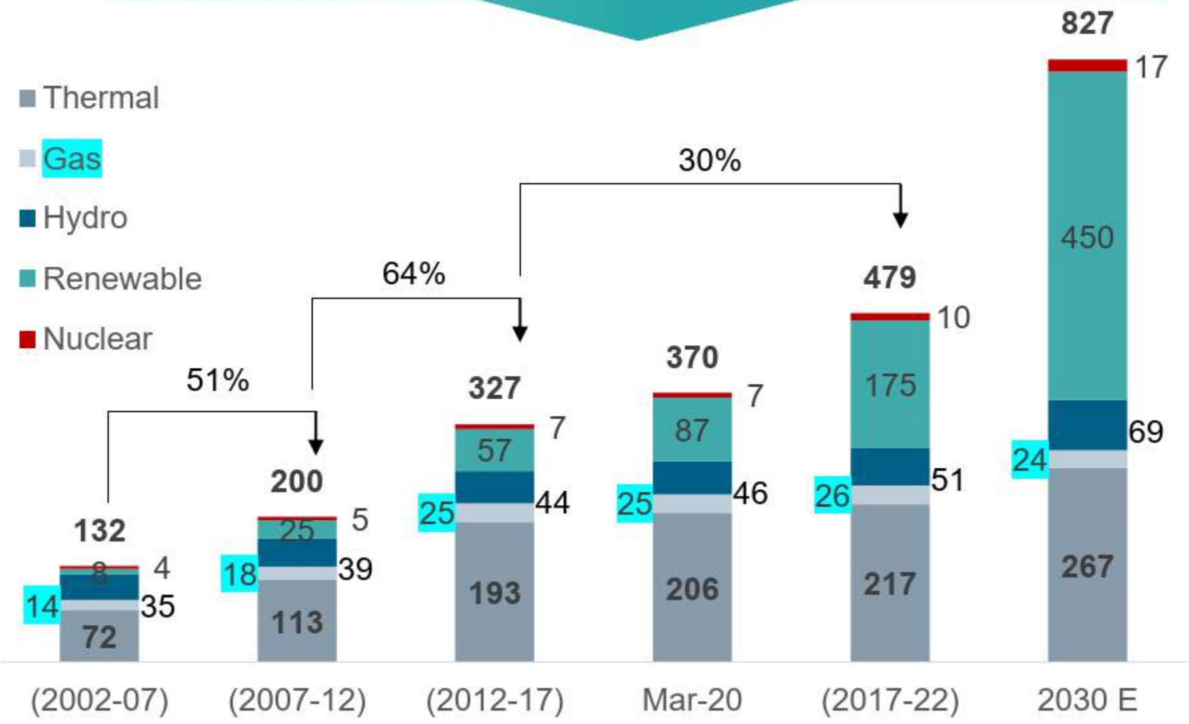
- If you were required to bring the fuel from thousands of kilometers to produce power
- If the quality and quantity of fuel was uncertain
- Scarce resource like water, land would have been must to generate power
- You needed proven material to operate at 3000 rpm with less than a tenth of a millimeter clearance
- You would have to build hundreds of meters high stack to avoid pollution in local community
- You needed trained staff to operate such machinery and required regulatory hurdles to cross

Yet we build Steam power plants

Market requirements
Generation scenario in India

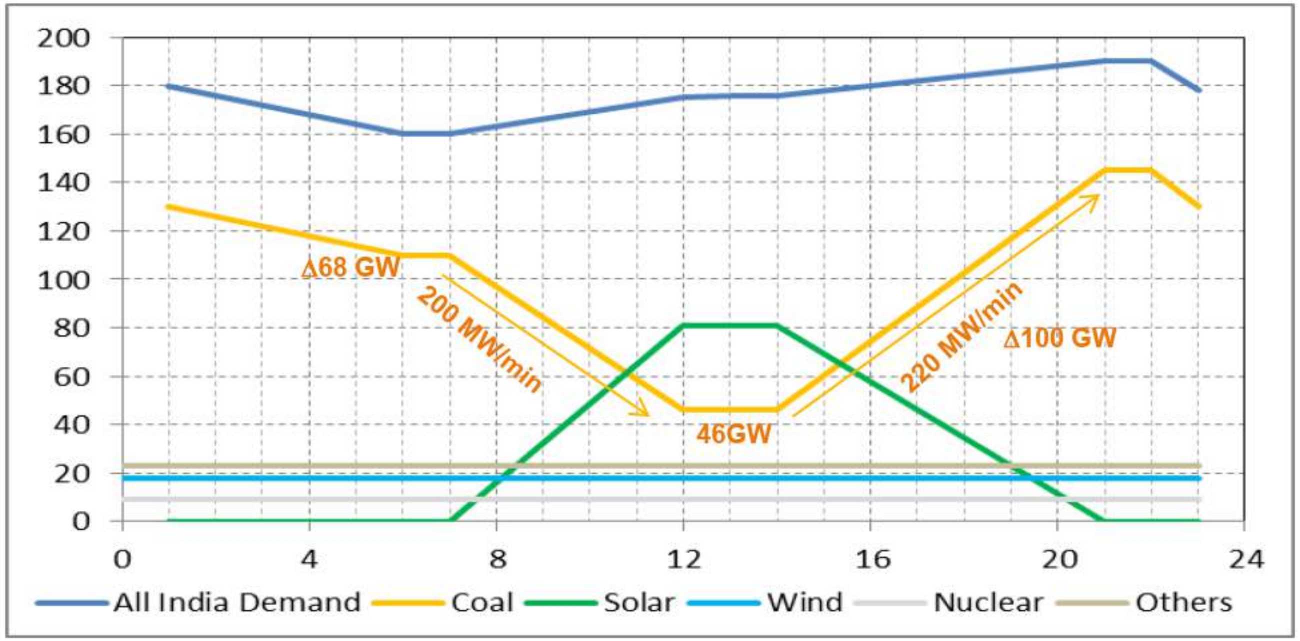
SIEMENS
Ingenuity for life

Installed Generation Capacity India (GW)



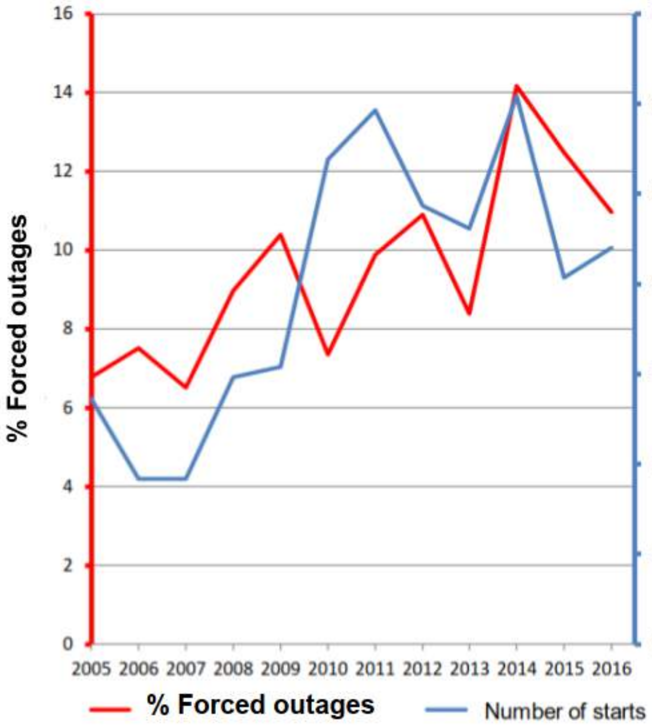
Capacity installed upto March 20 indicates thermal capacity target for 2022 is practical to achieve but 175 GW of renewable is likely to get missed.

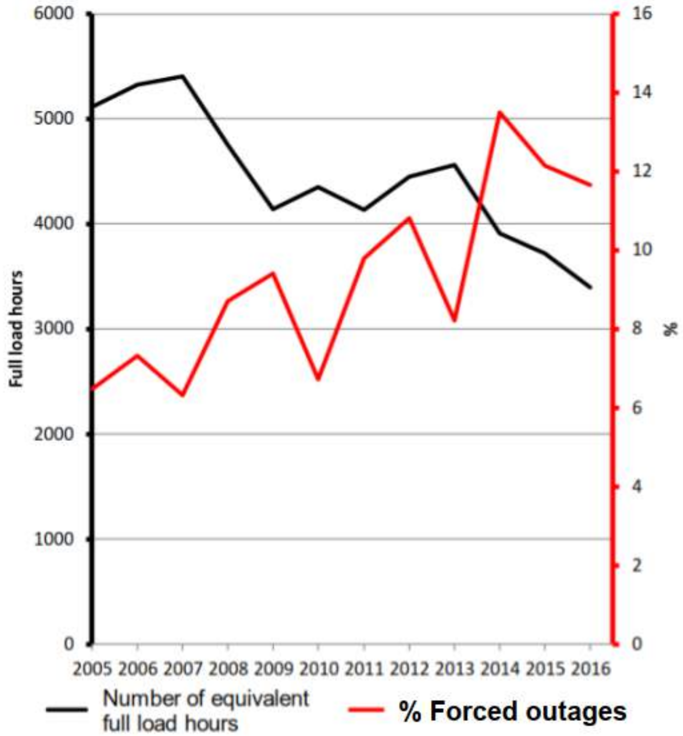
Generation Scenario on a typical day of 2022



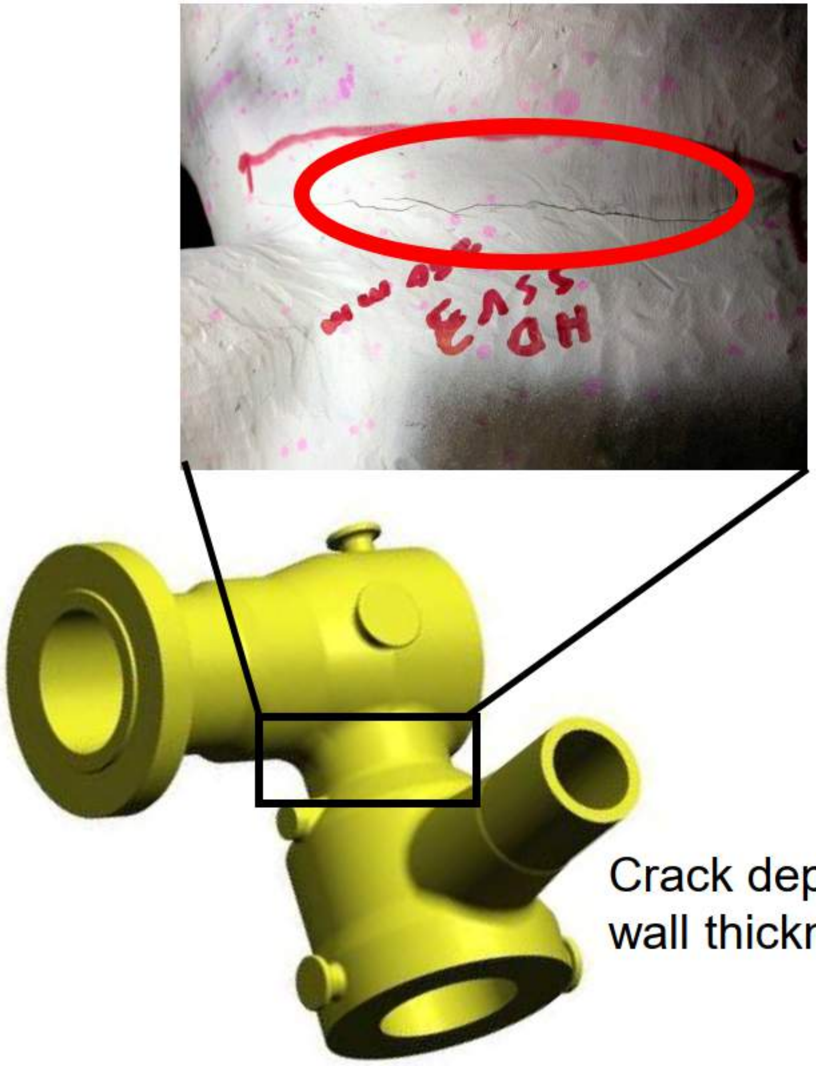
Lower Technical Minimum	Primary and Secondary frequency Control
Faster Ramp up	Faster Ramp down

Increased forced outages





Source: VGB study for flexible operation



Crack depth: 50% wall thickness

Lower technical minimum is better than two shift operation

Comparison of life consumption based on cold, warm and hot start

Start	Life Consumption	IEC 45	VGB R105M
Cold Start	23 – 75 hours	100	200
Warm Start	15 -17 hours	700	400
Hot Start	10 -12 hours	3000	1600
Load Change	3 hours	-	

Plant Optimization

Flexibility is the new efficiency

SIEMENS
Ingenuity for life

Reduced Electricity Production Cost and Increased Competitiveness *

Reducing technical minimum plant load	Increasing Efficiency and Performance (MW)	Improved Ramp Rates	Reducing CO_2 Emissions	Reduced Costs for Starting and earlier Power Production
Down to **30%**	**16 MW** more	**3x** higher	Up to **5%** lower	**>60min** earlier
Improved I&C and combustion for stable operation at lower loads	@ 75% load, including aging recovery effects by new hardware in HP and LP turbine at constant coal consumption	Higher ramp rates up to 15MW/min	An improved efficiency leads to lower CO_2 emissions!	Reduced startup-times and earlier power productions by improved I&C and hardware measures

A Balance of Plant (BoP) Optimization makes a significant contribution to economic values

* Values are based on a 500 MW reference steam power plant

Plant Optimization

Total Plant Evaluation is key for successful operation in deep part load

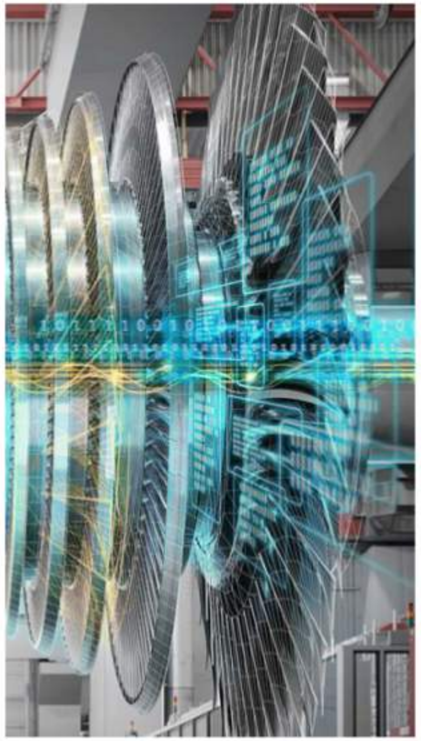
SIEMENS
Ingenuity for life

Plant Assessment for Boiler, Condenser, Steam Turbine & Auxiliaries

Boiler
- Fuel Supply (Mills/Pulverizer)
- Instrumentation & Controls
- Combustion (Burner) & Operation
- Thermal Design (Pressure Part)
- Air Preheater/ Fans / Pumps

Boiler Feed Pump (incl. Motor or turbine drive)

Feed Water Heaters



Turbine
- Blading
- Operation
- Steam Seal
- Drains

Condenser
- Temperature Termial Difference (TTD)
- Condensate Pump

Steam Piping System

Cooling Water System

SIEMENS
Ingenuity for life

Part Load Technical Issues

Part Load Challenges:

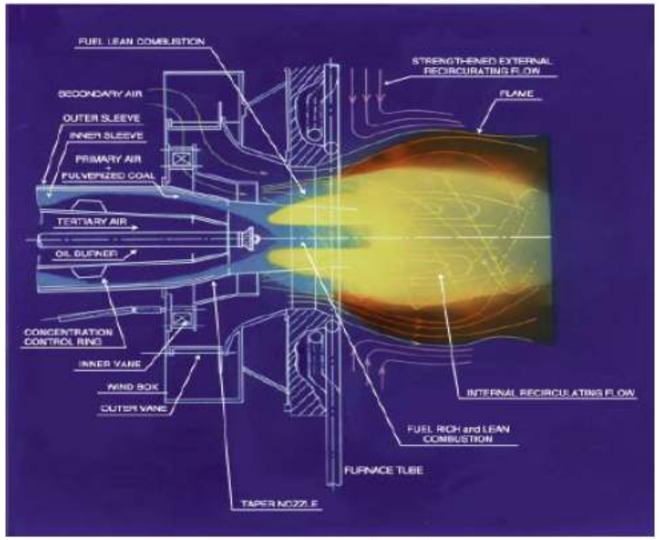
1. Fuel Composition (knowledge of the fuel composition and of the fuel properties incl. ash is very important for the steam generator design)
2. Fuel supply system (Mill diagram & operation concept, Pressure drop, Air bypass flap, Control system, Mechanical restrictions of mill etc.)
3. Combustion (Fuel composition stability, Temperature/O_2/Concentration inturbulances, Symmetry of flame, Aerodynamics, Combustion efficiency, Emissivity, Support fuel)

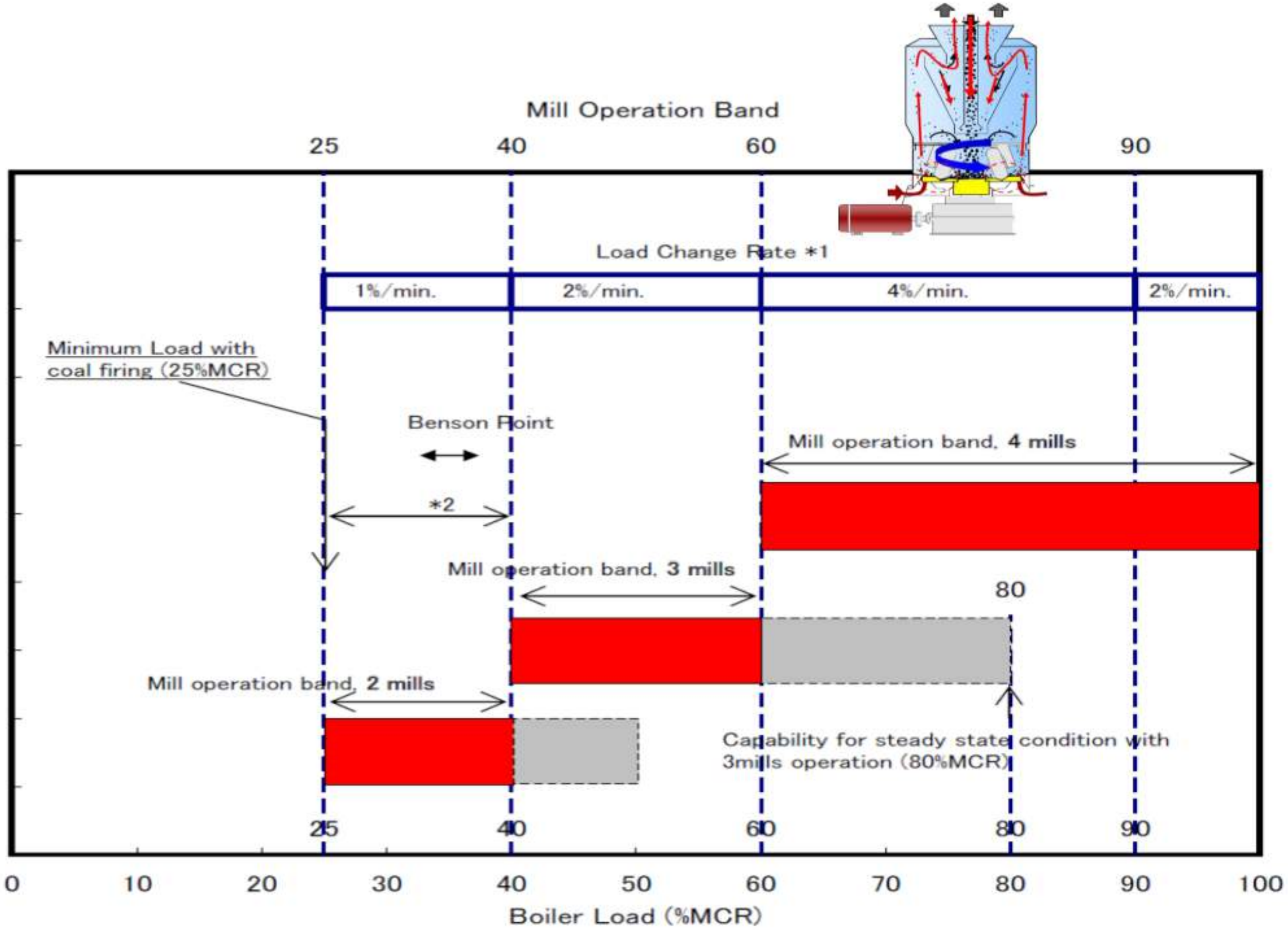
Combustion quality detoriates at lower loads

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)

SIEMENS
Ingenuity for life

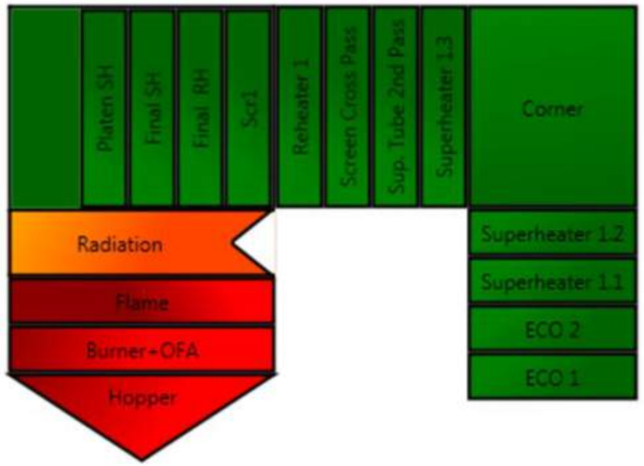




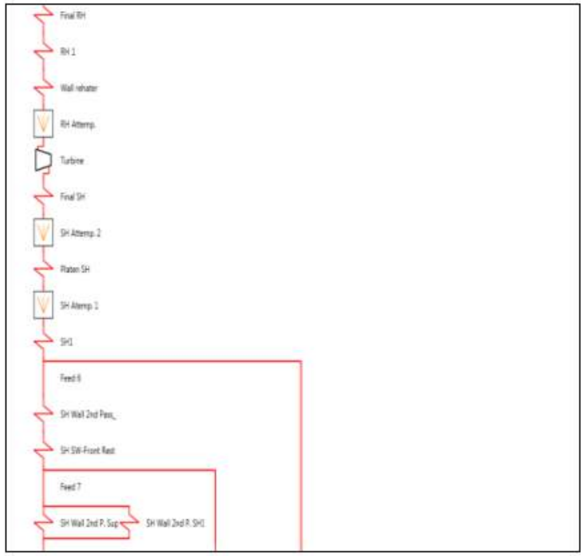
Boiler thermal calculation software DEFOS

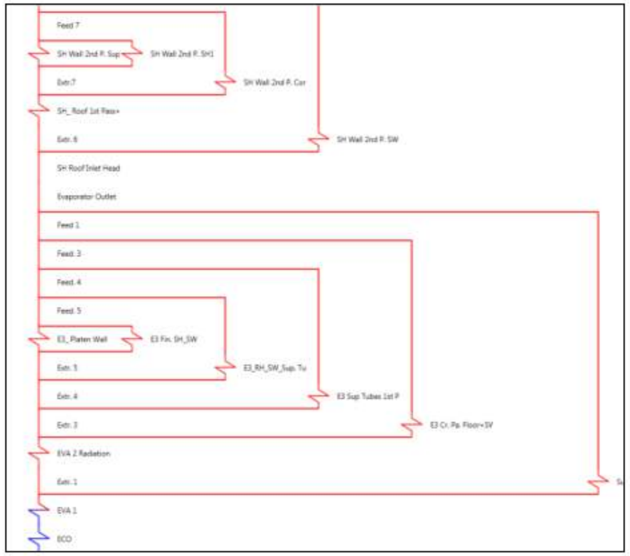
The thermal boiler model is constructed by using computer software **DEFOS** (boiler performance calculation tool developed under BENSON license), which permits a detailed representation of the thermodynamic and heat transfer processes across the complete boiler system based on engineering principles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

Boiler thermal model of flue gas segment:



Boiler thermal model of water/steam system:

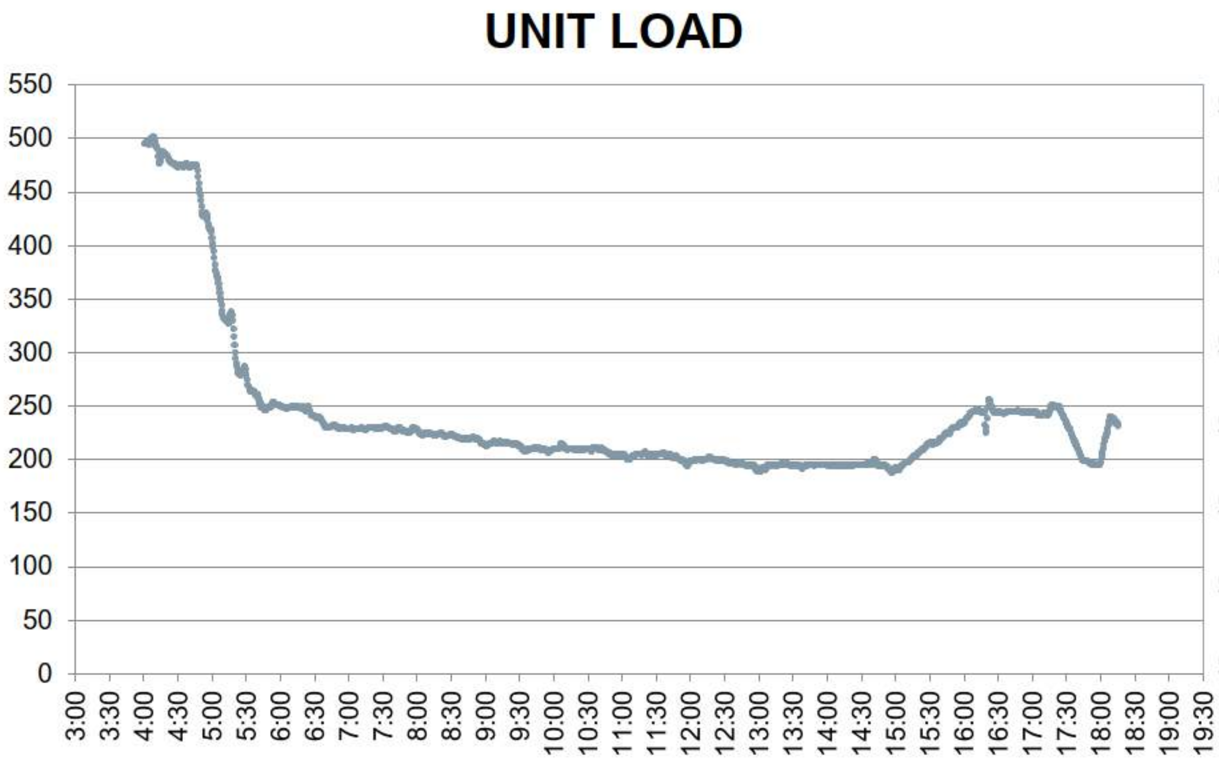


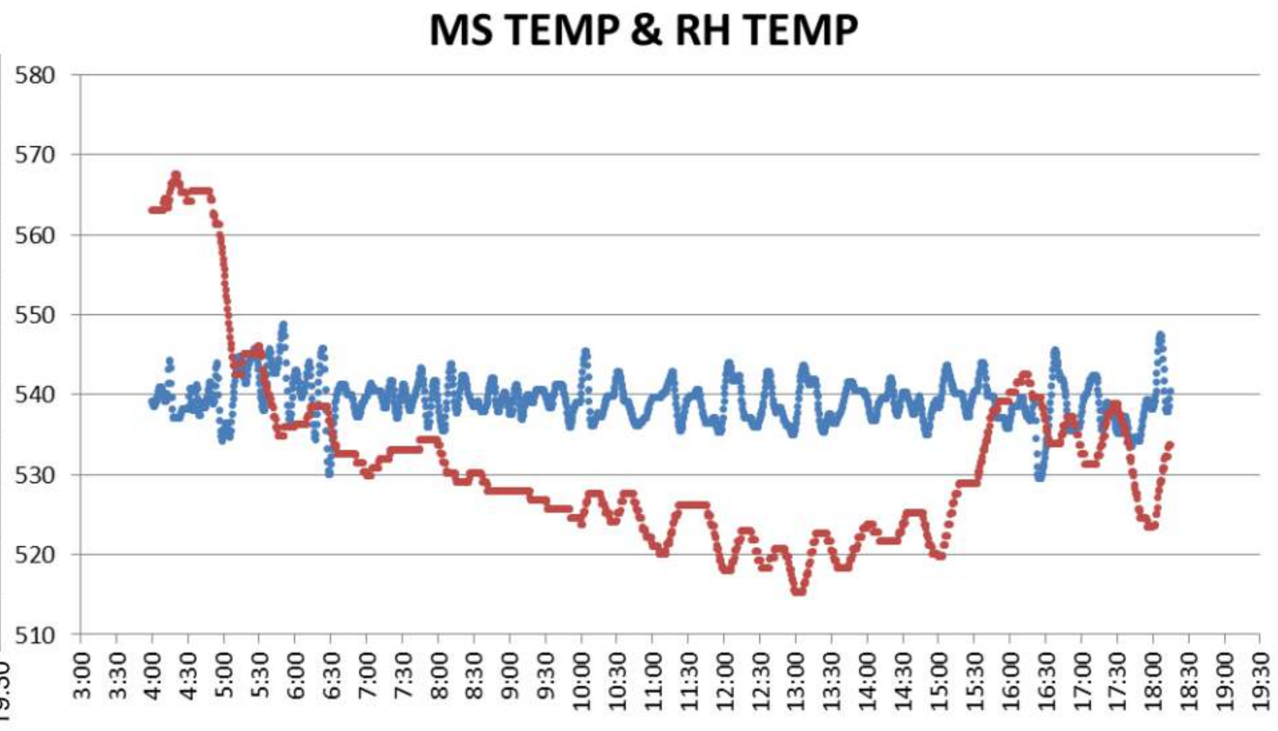


Test Results at NTPC Dadri

SIEMENS
Ingenuity for life

40% Technical Minimum is Possible



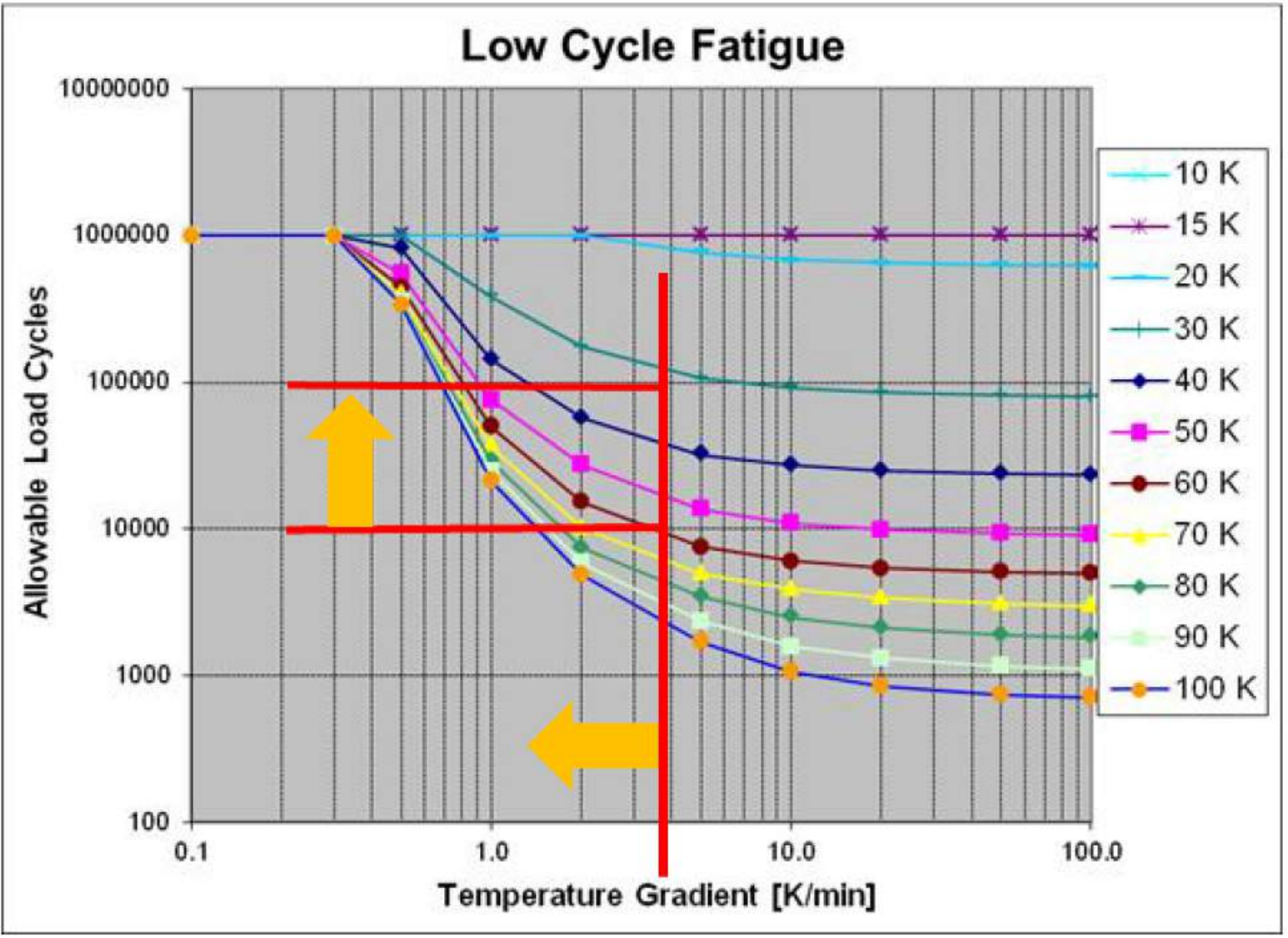


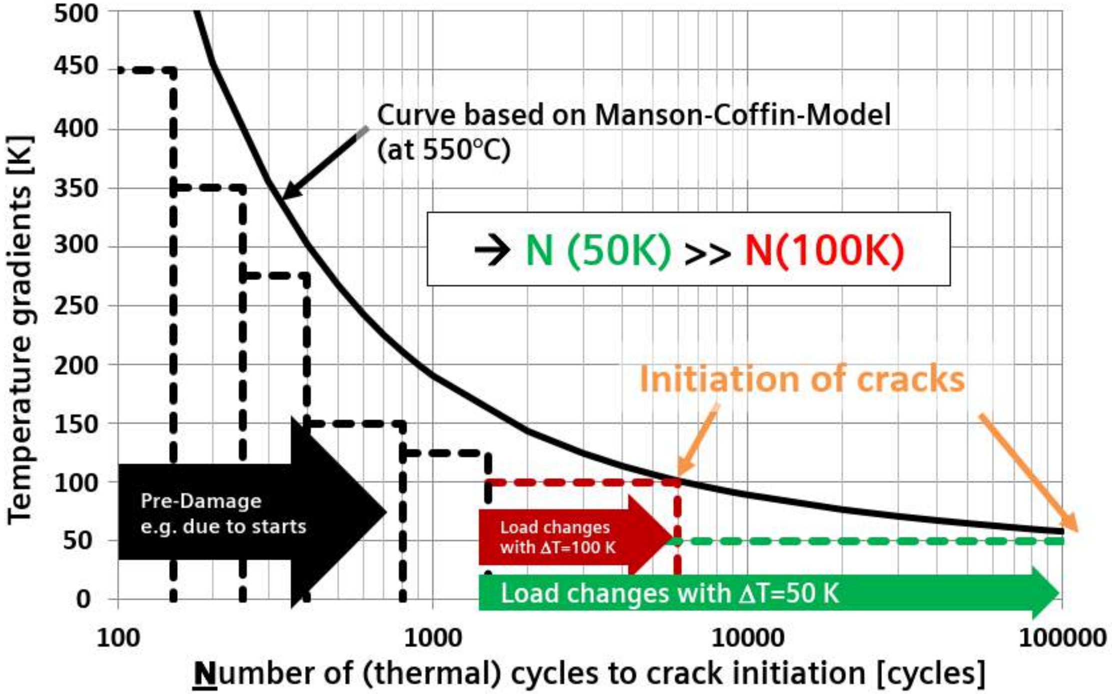
Cond.	M %	Ash%	C %	H %	N %	S %	O %
Air dried	4.03	37.29	43.63	3.26	1.01	0.35	10.43

GCV (kcal/kg)	VM%	Ash %
3000	22%	35%

Transient Operation (Ramp Up / Ramp Down)

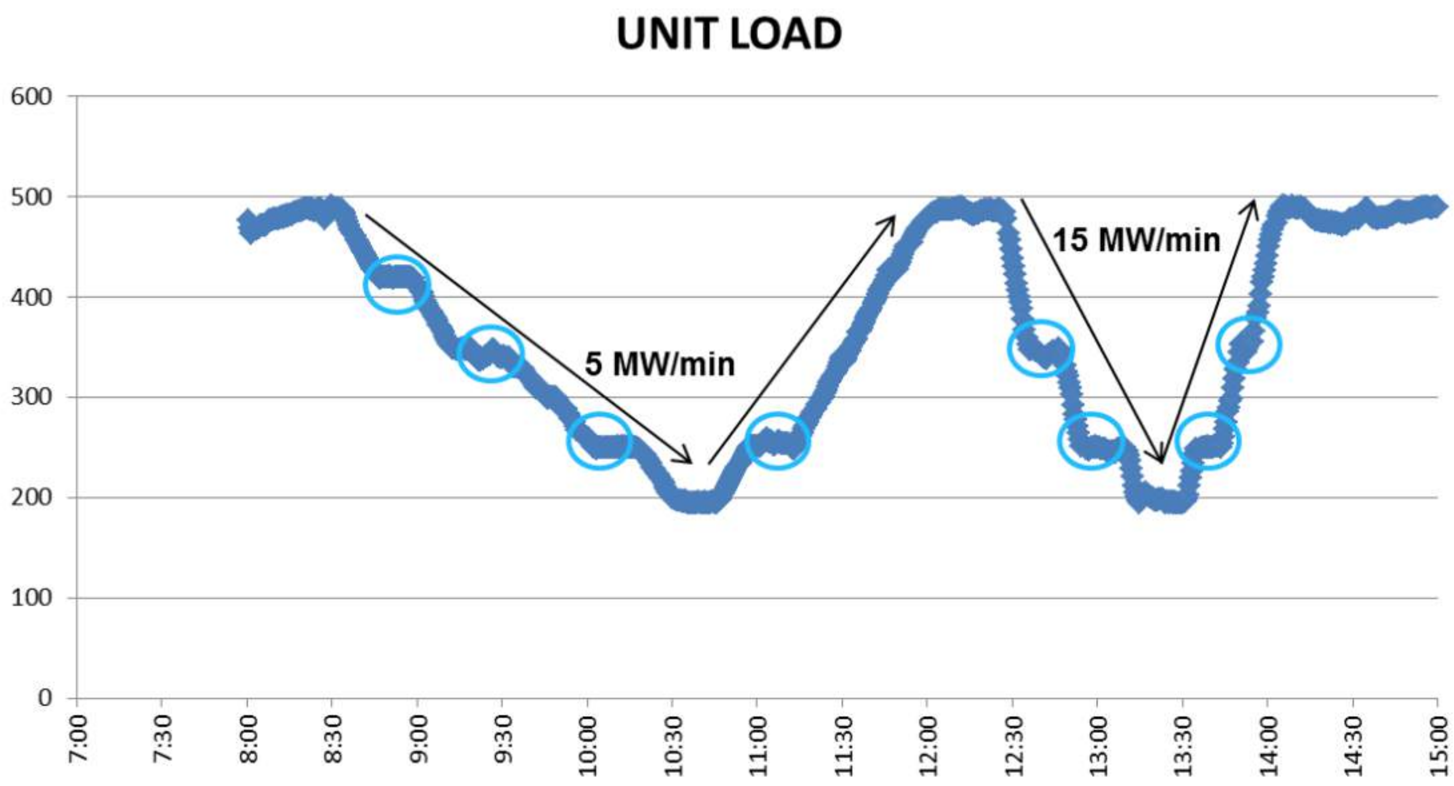
increased temperature gradient results increased life consumption

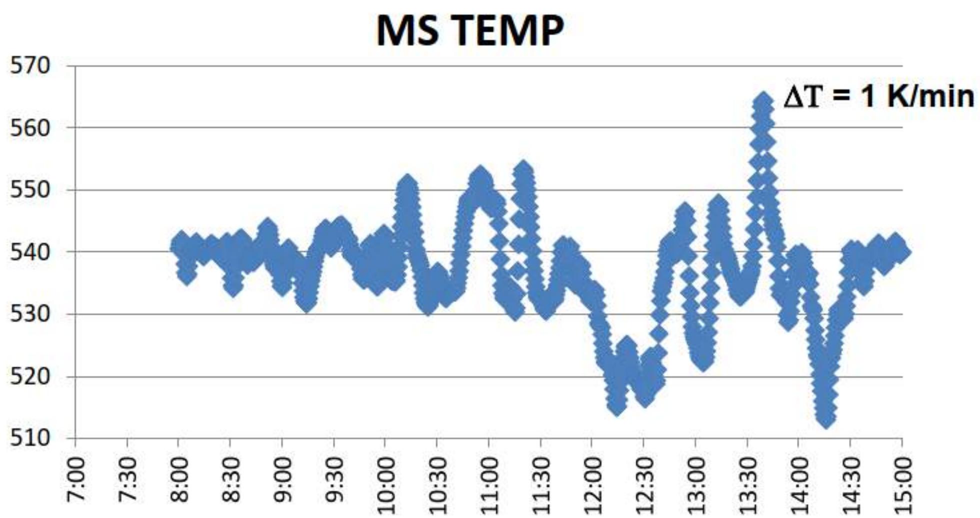


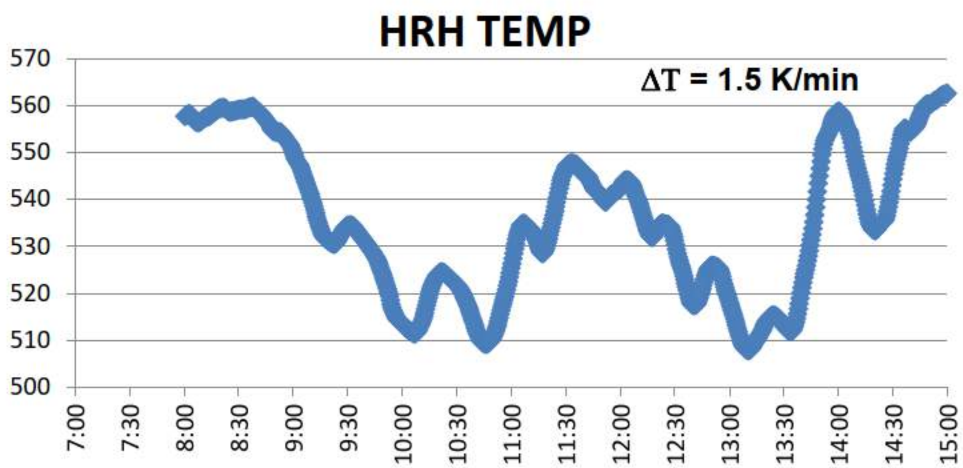


SIEMENS
Ingenuity for life

Influence on Ramps on Temperature Transient







SPPA-P3000 Temperature Optimizer
Increased steam temperatures

Task

To achieve maximum steam temperature without violation of material limits

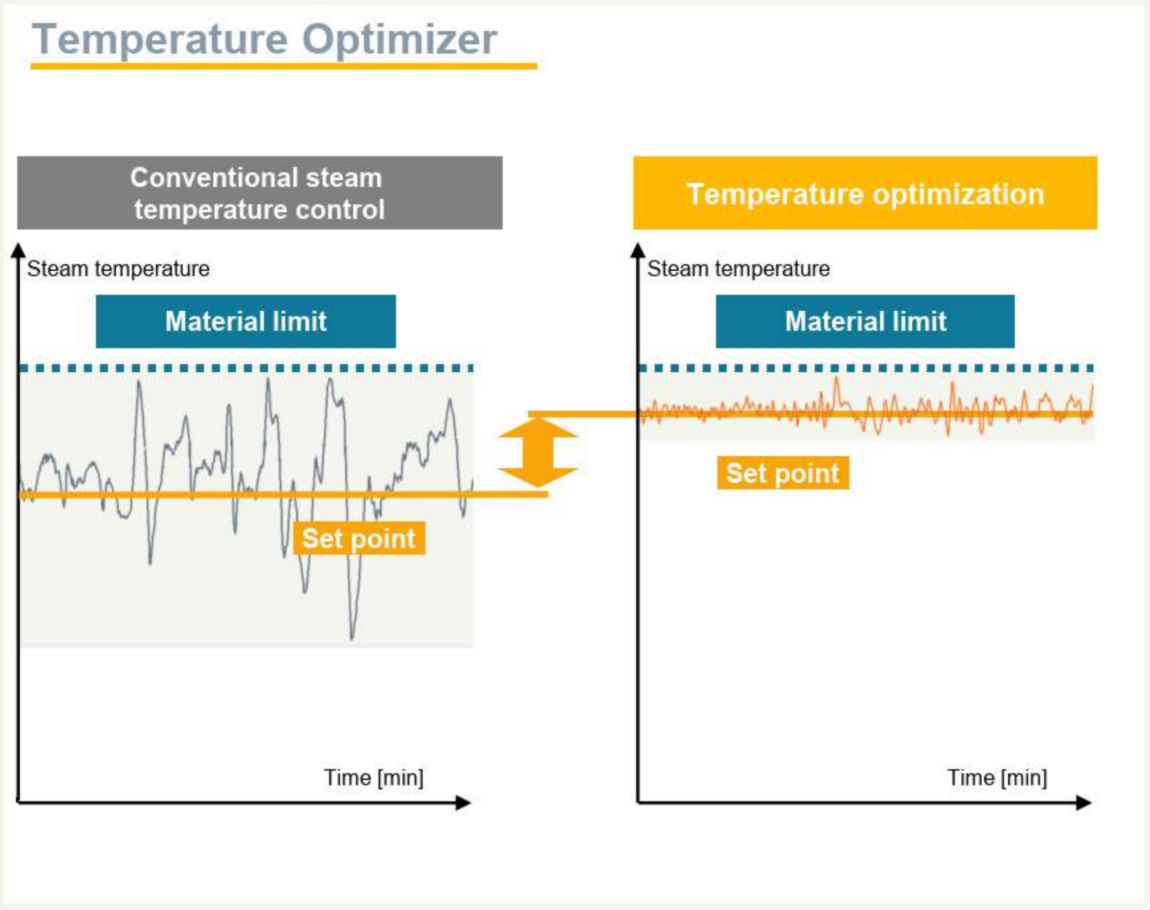
Solution

- 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
- Use of flue gas recirculation and biflux or triflux valves to control reheat steam temperature

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

Increased efficiency thanks to

- Higher steam temperatures
- Reduction in reheater attemperation

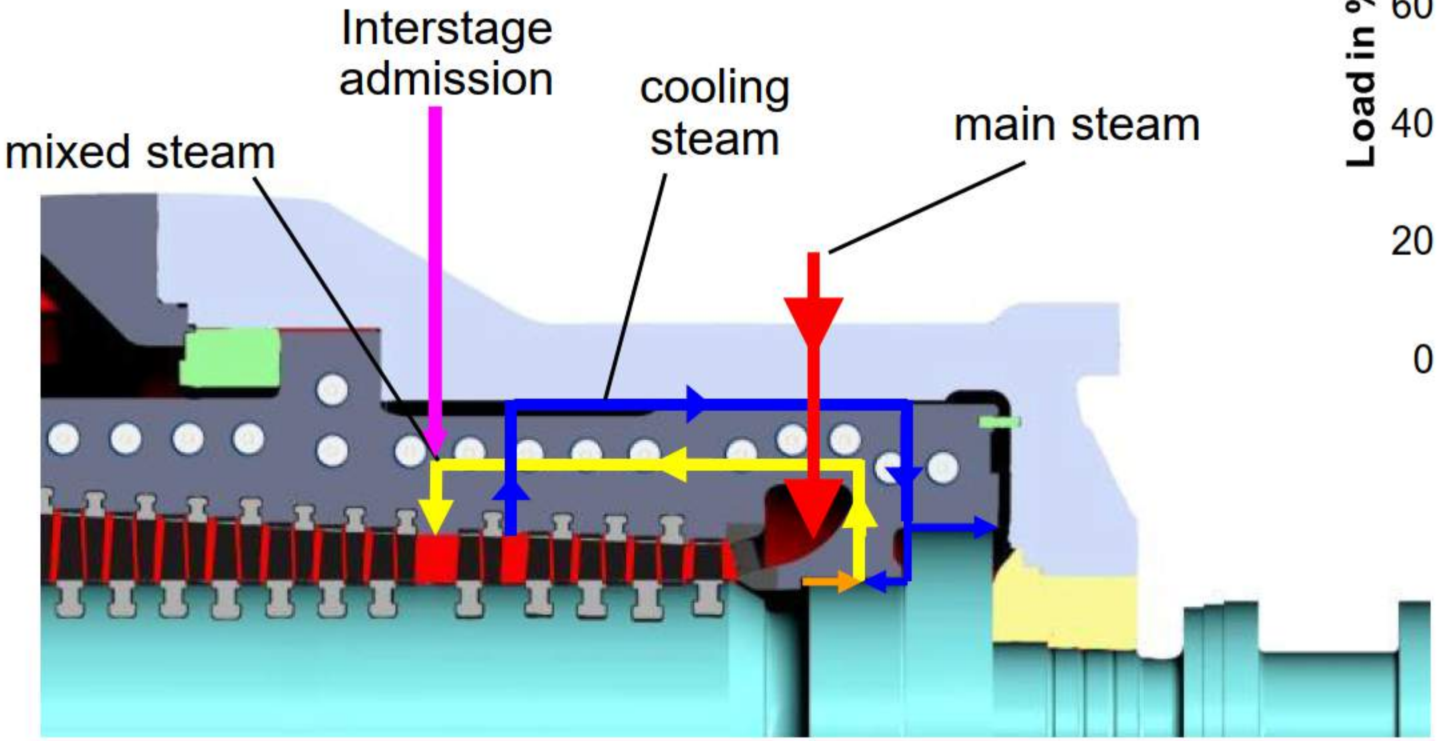


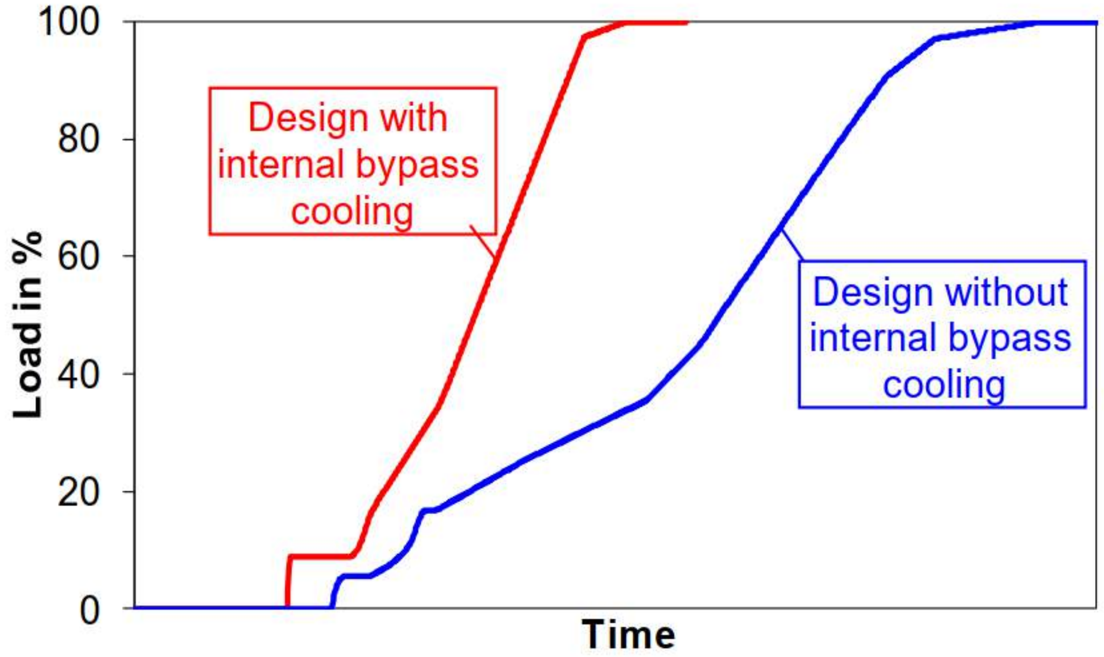
The Temperature Optimizer solution increases the efficiency through higher steam temperatures and the use of appropriate control elements for reheater temperature.

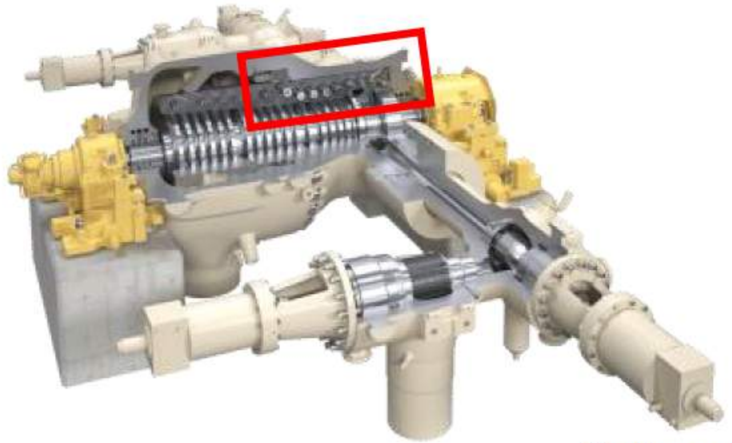
Power on Demand
Reduction of Wall Thickness to Improve Start Up & Cycling Capabilities

<u>Example:</u> Reduced Casing thickness & reduced thermal piston loading by HP bypass cooling

Significant improvement in LCF







Reduced Startup-times: Heating blankets
ST Warm Standby Operation to prepare for fast start-up

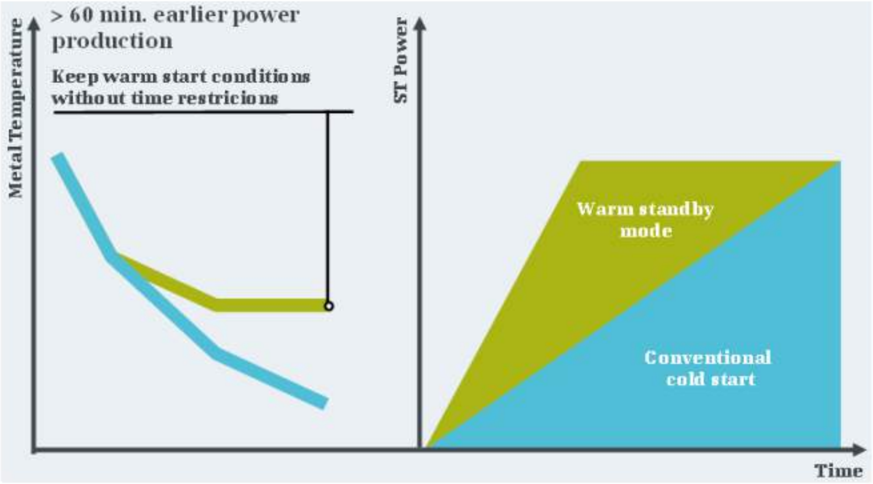
SIEMENS
Ingenuity for life

Technology

- Electrical heating system for ST in turning gear
- Maintains rotor shaft temperature at warm startup conditions

Benefit

- Significant reduction of startup time
  - > 60 min. earlier power production
- Reduction of EOH consumption per start
- Less energy is bypassed to condenser
  - Reduced costs per start up



Electric heating coils to keep HP/ IP Turbine casing and shaft in warm start conditions

Power on Demand

Monitoring of flexibility consequences: steam turbine EOH counter 4.0

SIEMENS
Ingenuity for life

Task

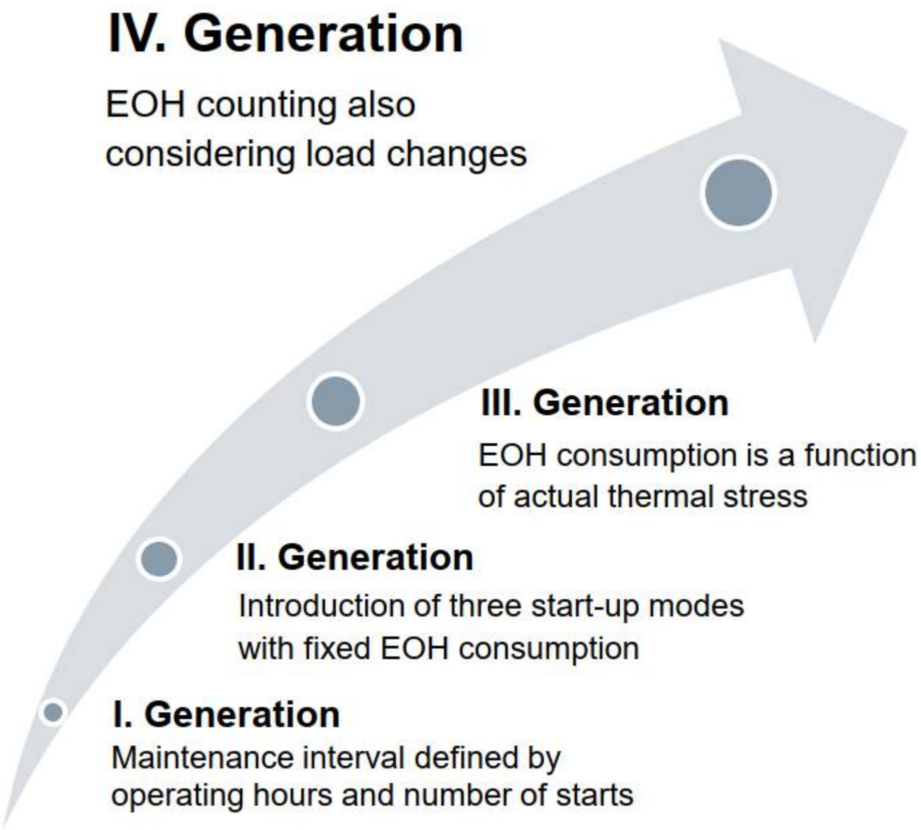
- Part load may lead to steam temperature changes, especially hot reheat temperature
- Thermal stresses during operation are not considered in standard counting of equivalent operating hours (EOH counter)
- Maintenance needs may not be recognized

Solution

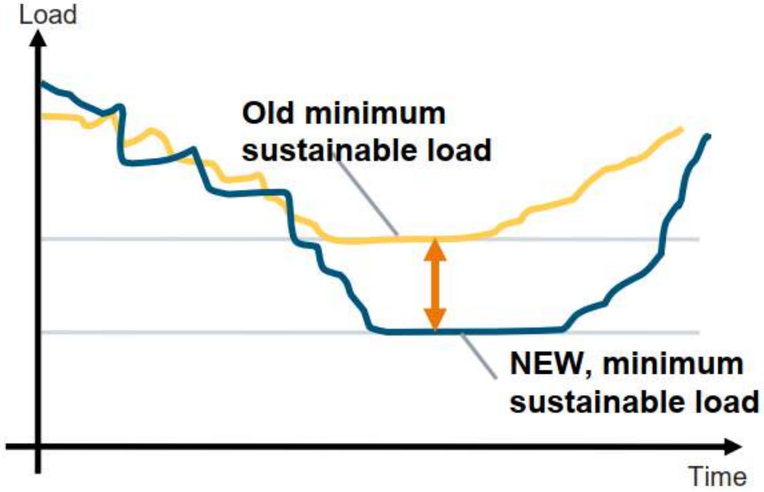
- Evaluation of operational history
- Implementation of a state of the art EOH counter considering load changes

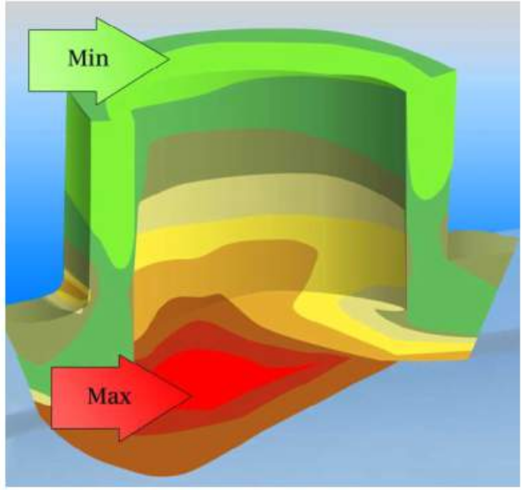
Benefits

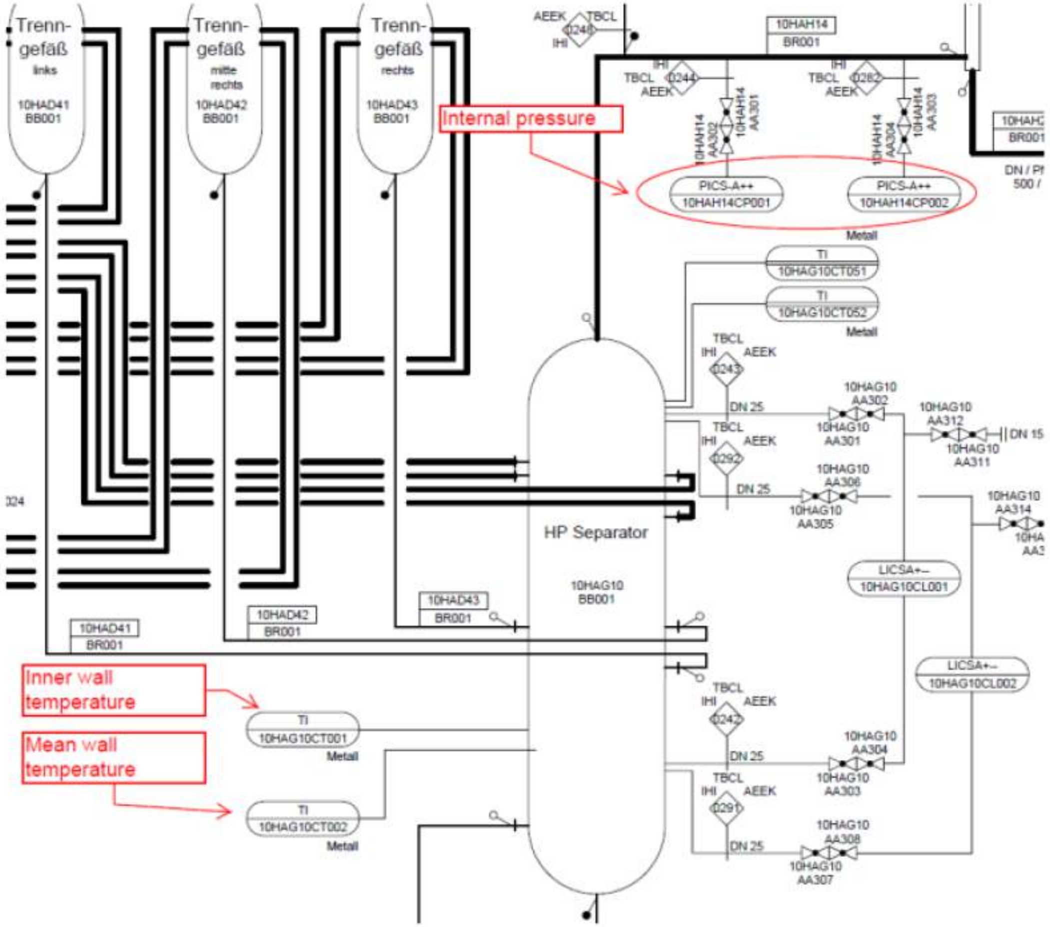
- More accurate EOH counting
- Improved outage planning
- Enhanced operational flexibility



Maintenance Flexibility
Fatigue Monitoring System





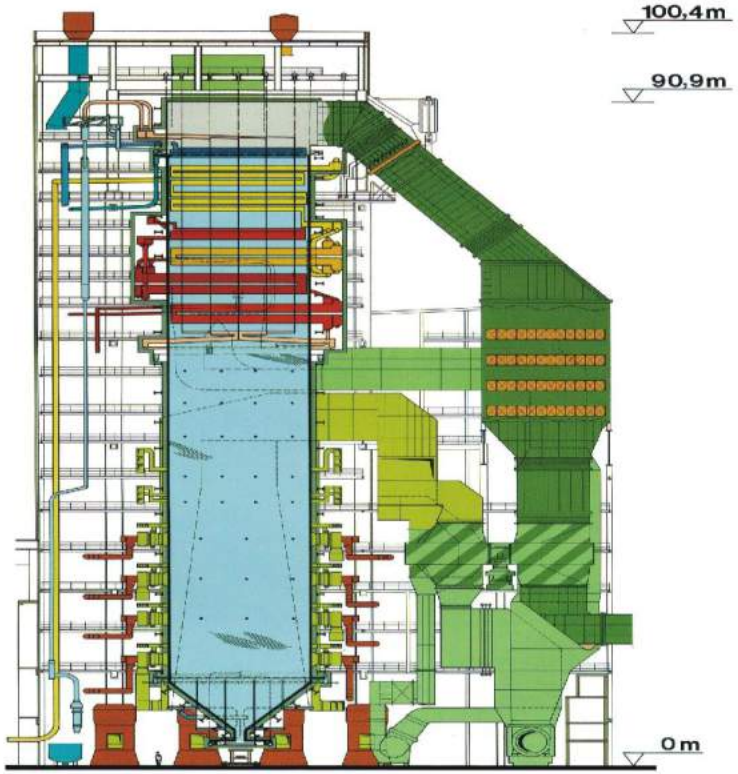


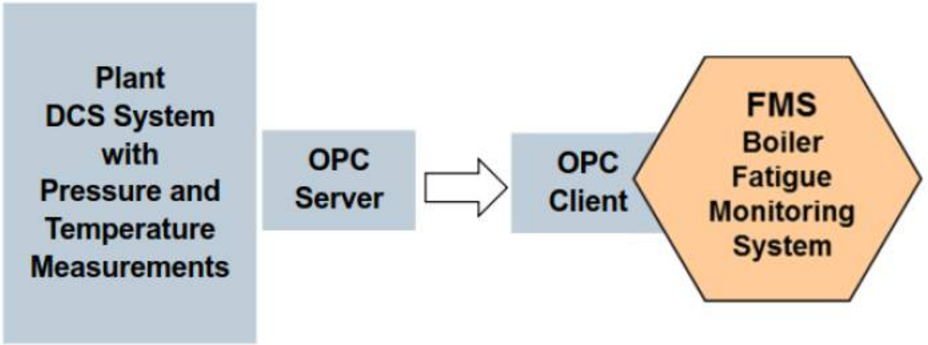
How much fatigue is it?

Don't Guess when you can actually measure it

Maintenance Flexibility
Fatigue Monitoring System

SIEMENS
Ingenuity for life





Typical components:

- Headers, Manifolds (HP superheater, Reheater)
- Drums
- Separators
- Piping (e.g. elbow after HP / HRH final stage attemperator)
- T-Pieces (e.g. HP bypass station)
- Y-Piece (e.g. before HP turbine)

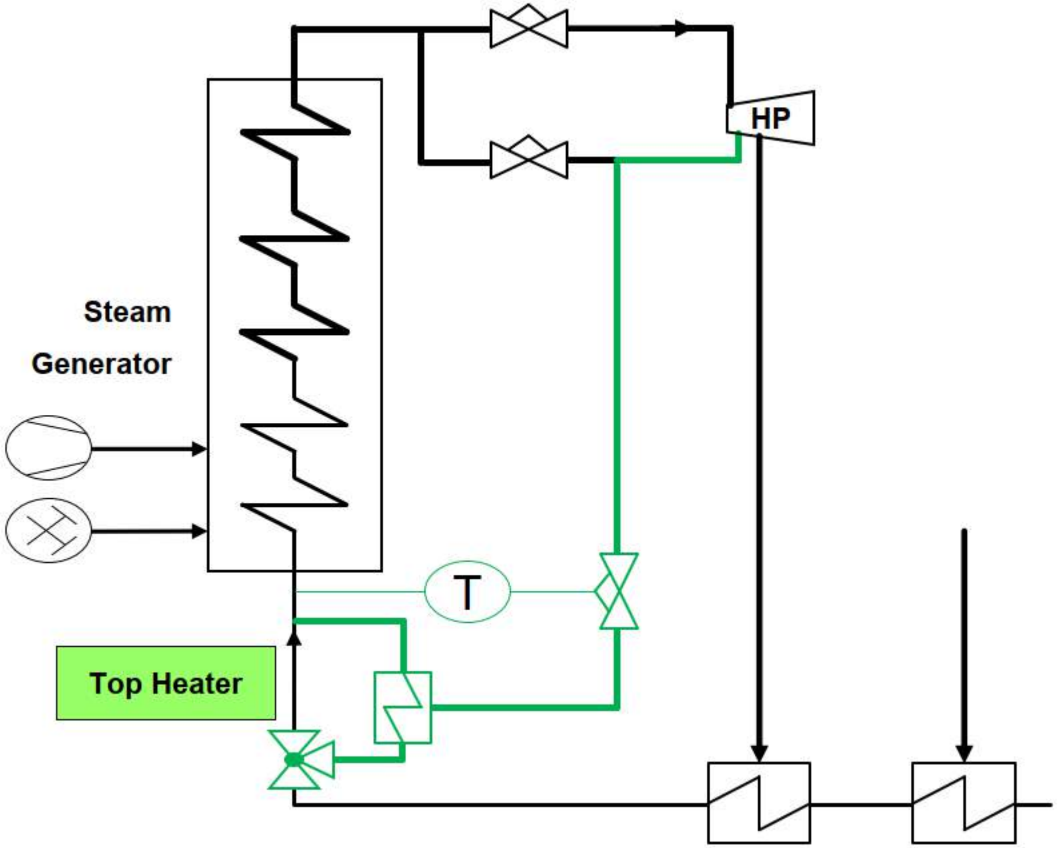
Online calculation of Boiler Fatigue Components is possible

Both Creep Fatigue and Low cycle fatigue calculated

Depending upon the actual operating mode, residual life of critical components is determined

Part Load: Efficiency improvement

Top heater for improved heat rate and lower NOx emisions



a. **Steam from stage bypass connection**

b. **Is activated at part load**

c. **Final feed water temperature vs. load constant or even increasing**

d. **HR improvement of ~ 0.6% @ 50% load**

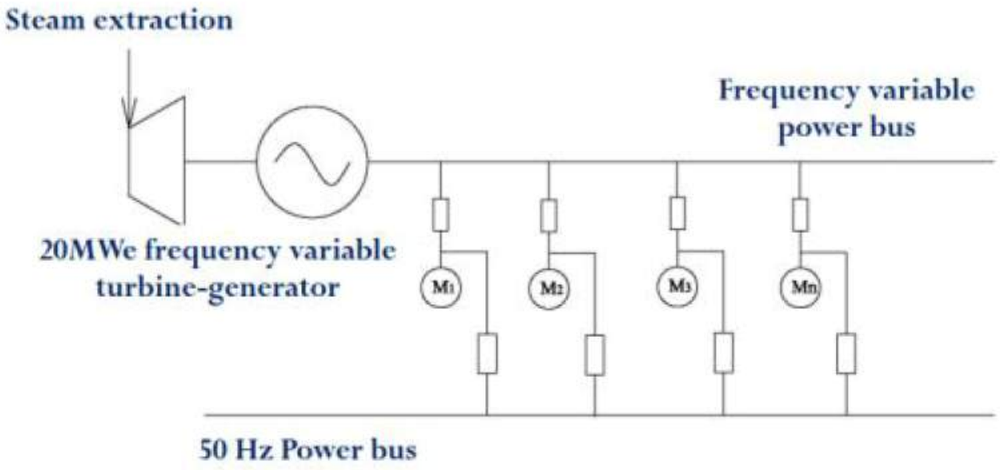
Wai Gao Qiao 3, China 2008, 1040MW

Increased Auxiliary Power Consumption: Centralized frequency variable power system

SIEMENS
Ingenuity for life

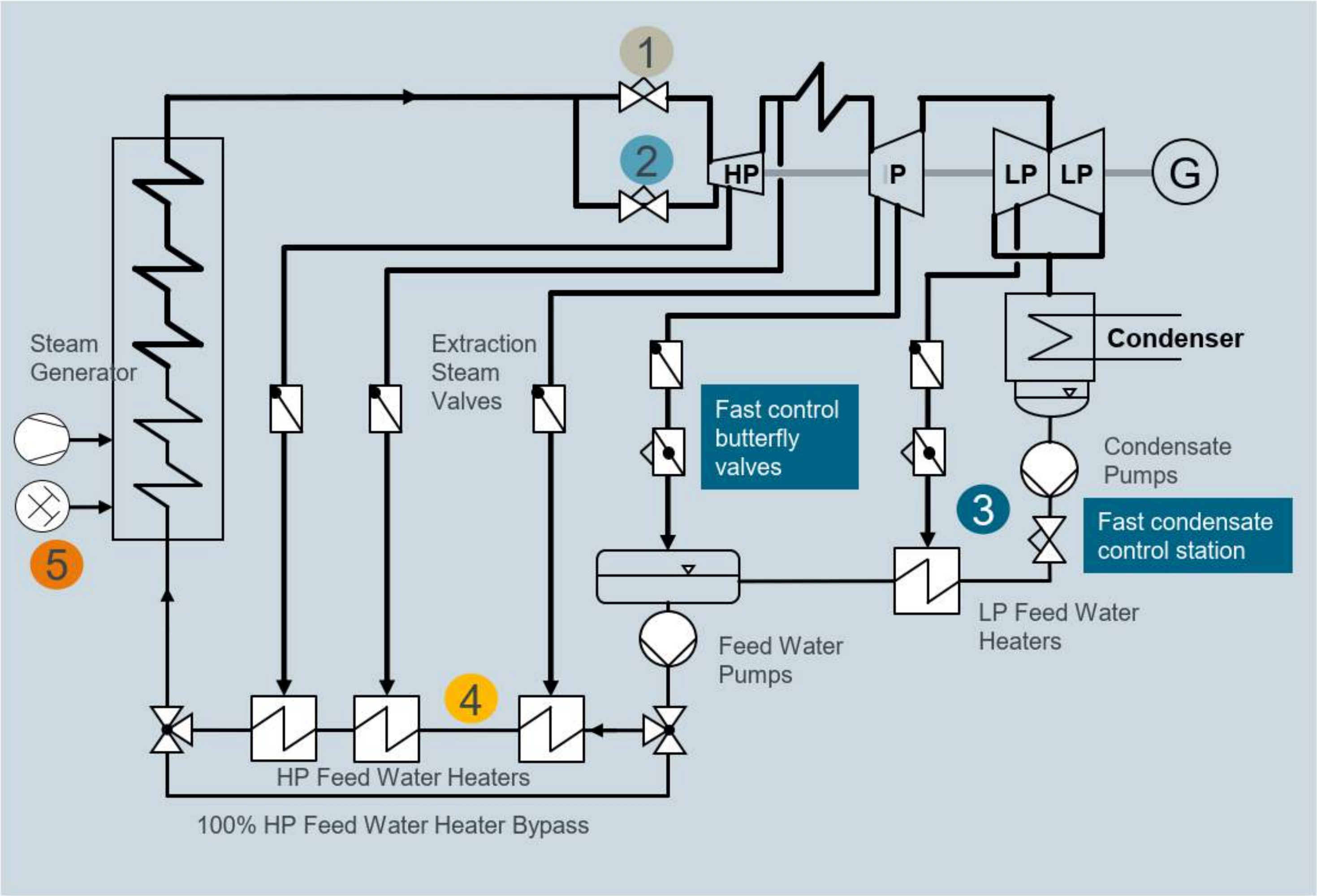
Solution: feed frequency variable turbine from main turbine extractions, supply frequency variable power to motors of fans and pumps.

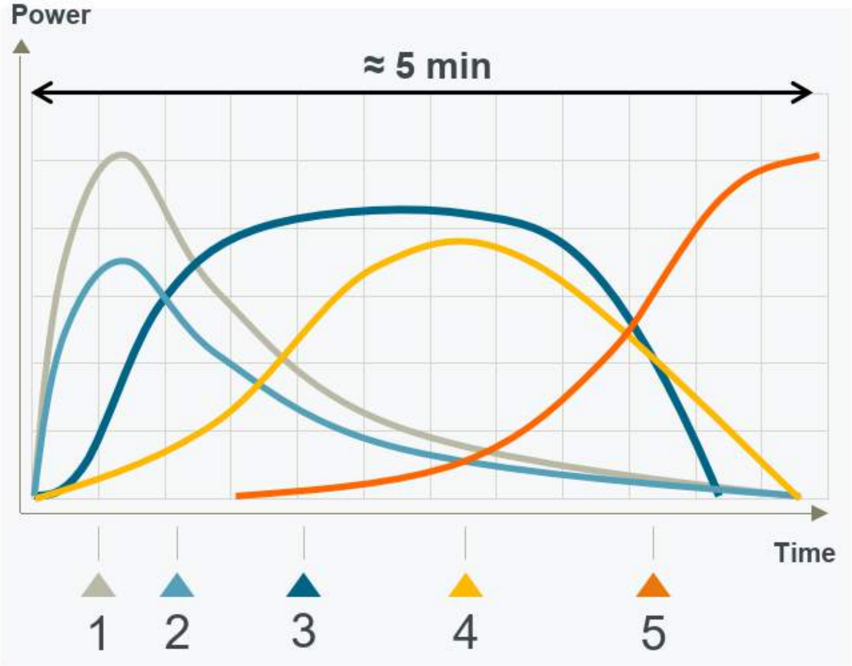
- House power rate has been reduced from 3.5% to less than 2% (SCR and FGD included)
- Higher reliability compared to conventional electronic frequency convertors



*) Huaibei Shenergy Power Generation Co.,Ltd

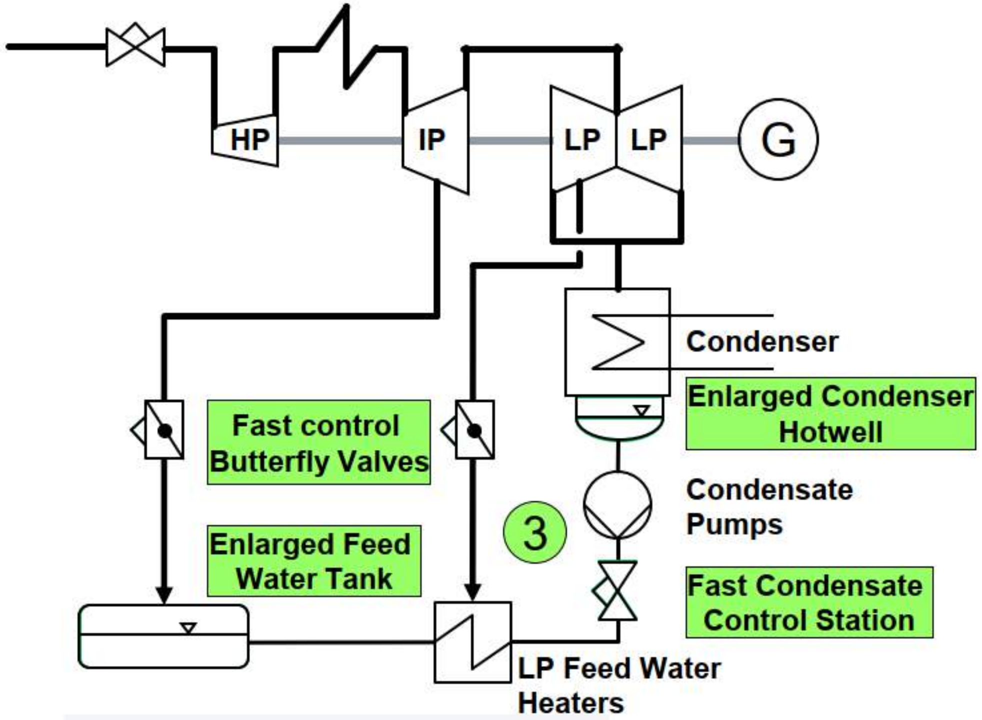
Measures for fast load ramping
Overview





1 Throttling
2 Additional valve
3 Condensate stop
4 HP heater
5 Fuel increase

"Condensate throttling" controls storages in the water steam cycle to increase ramp rates

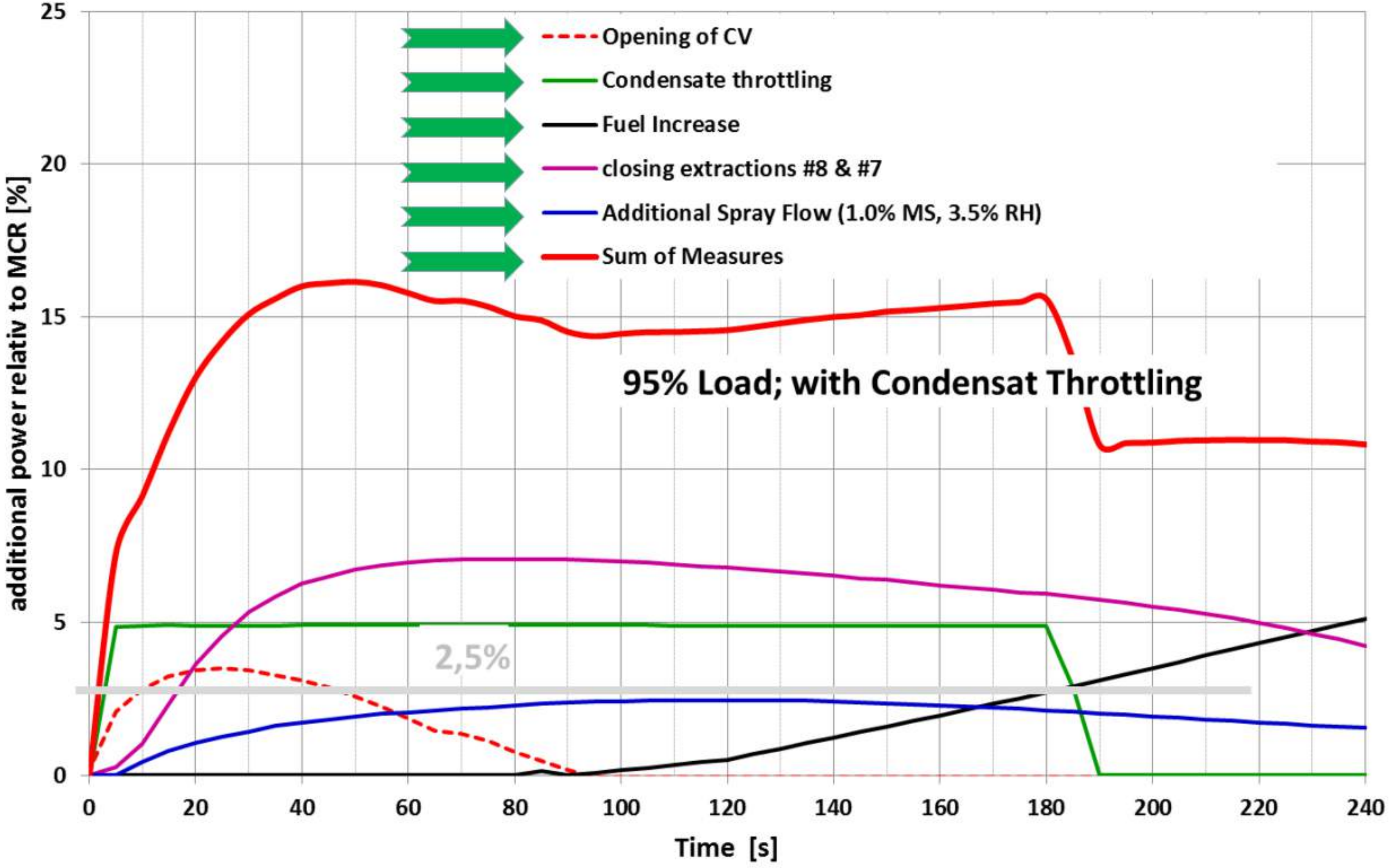


Iskenderun, Neurath, Luenen and NTPC Dadri

a. **Enlarge storage volume**
b. **Fast condensate control valve**
c. **Fast control valves in LP extractions**

NTPC Dadri Stage II – Unit #6   490 MW

Grid Services
Example for grid code compliance



Key Takeaway

- Lower Technical Minimum is better operation than two shift operation
- Subcritical fleet is more suitable for flexible operation with respect to loss in performance
- Lower Technical Minimum with advanced control systems is possible, unit specific changes needs to be applied
- Means of improving part load efficiency by upto 1% are available
- Maintenance planning is to be adapted based on actual life consumption during flexible operation
- Thermal power utilities will play a key role in Indian grid for renewable grid

Further I&C solutions for flexible operation
Selected references

SIEMENS
Ingenuity for life

Frequency & Dispatch Control

Altbach, Germany
420 MW, hard coal:
5% in 30 s up to 100% load
(with turbine & condensate throttling + partial deactivation of HP preheaters)

Dingzhou, China
600 MW, hard coal:
Boiler delay reduced from 180s to 40s for load ramps up to 4%/min (with throttling)

Dadri, India
490 MW
35 MW (~7%) in 20 s
(with condensate throttling + HP reserve)

Reliable and efficient start-ups

Franken I, Germany
383MW, gas, built 1973:
20% reduction of start-up costs

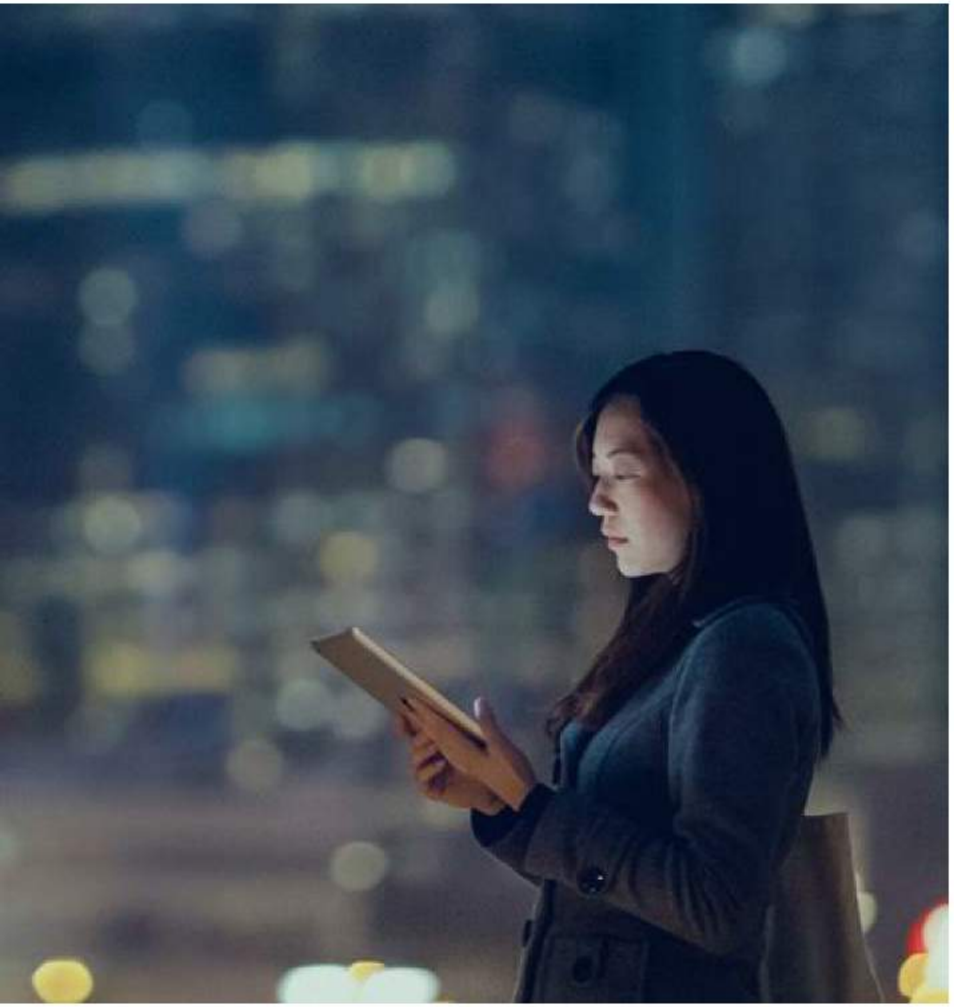
Reduced minimum load

Steag Voerde, Germany
700 MW, hard coal, built 1985:
Minimum sustainable load w/o oil support and bypass reduced
from 280 (40%) to 140 MW (20 %)

Increased Maximum Load

Callide, Australia
420 MW, hard coal:
Max. load +10 %
1,400 h/year max. load through controlled HP bypass deactivation

Contact information



Sandeep Chittora
Head – Portfolio Consulting
Siemens Limited, India
Phone: +91 124 2842650
Mobile: +91 9971170337

E-mail: sandeep.chittora@siemens.com