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Flexibilization of thermal power plants - need of hour

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Market requirements:
Changed operational regimes require highly flexible products

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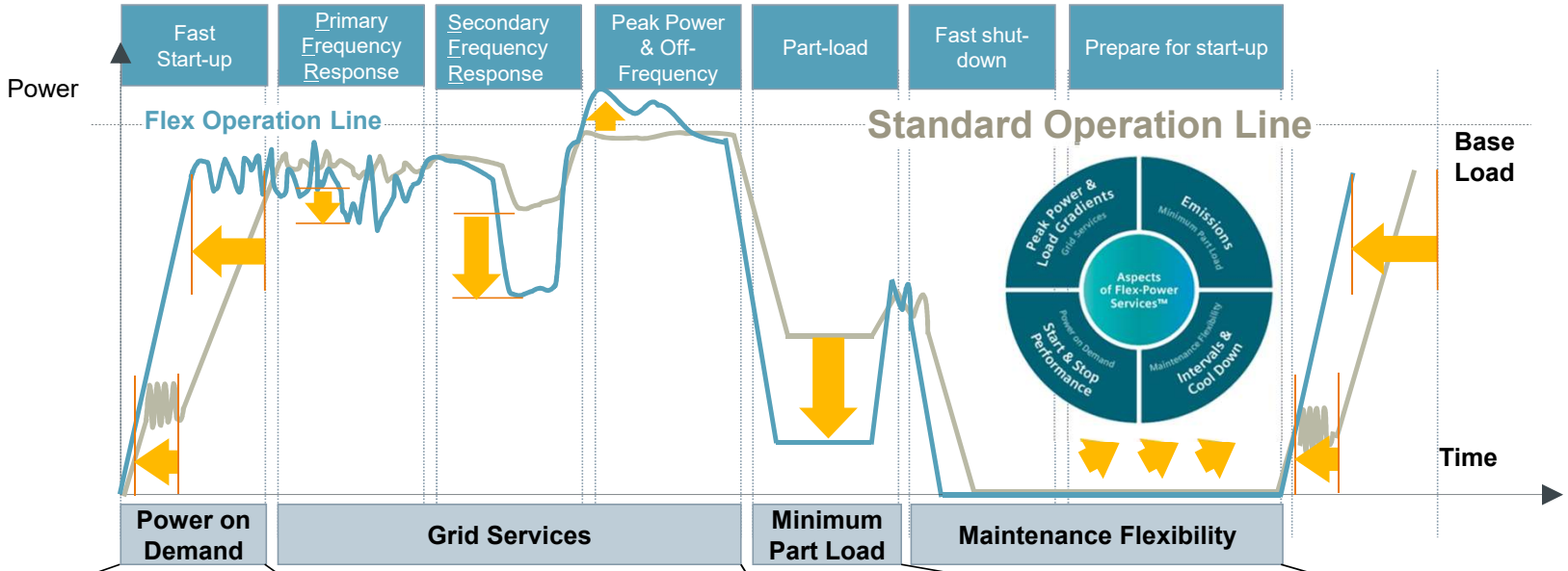

• ST Stress Controller	• Advanced Fast Loading	• HP Turbine with Last MS-Valve	• Fast Preservation
• SPP Hot Start On The Fly	• Primary Frequency Response	• Partial Bypass Concept	• Fast Cooling
• HP internal bypass cooling	• Condensate throttling	• Part Load Optimization Package	• ST Hot Standby
• Advanced Fast Loading	• Dispatch Control	• Minimum Load Reduction	• FMS
• ST EOH Counter 4.0	• Maximum Load Plus	• Top Feedwater Heater	
• Low Loss Start			
• Fast Start / Hot Start			

Flexibility Road Map

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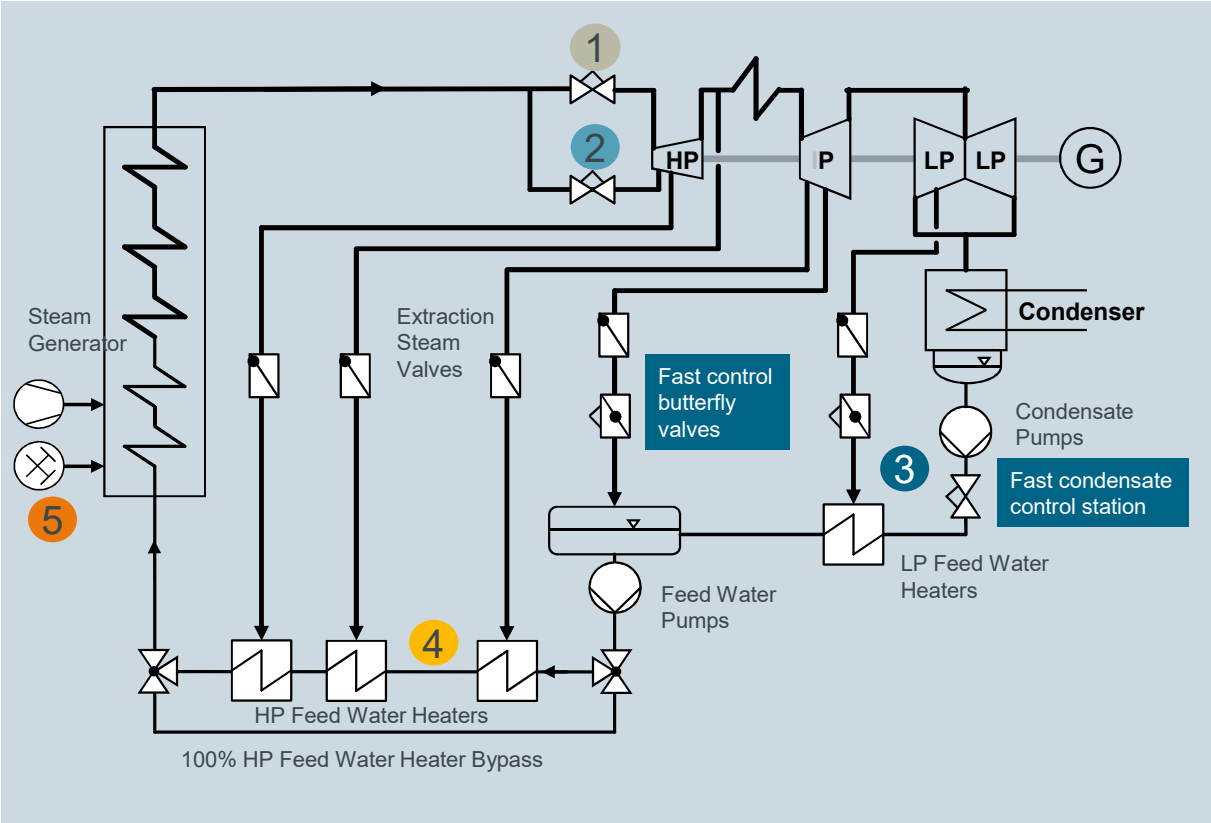
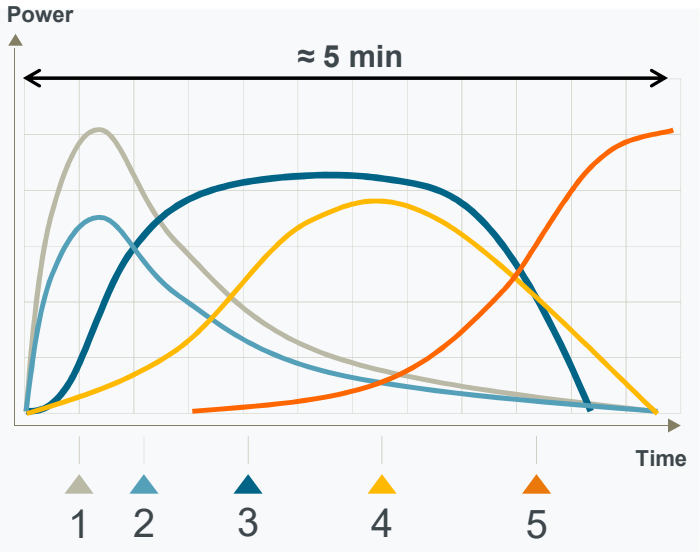
Controls and Optimization	Lifetime consumption & Monitoring	Retrofit and Modernization
Advanced Process Control • Temperature Control Optimization • Soot Blower Optimization • Combustion Optimization • Frequency Control • Fast Ramp	• Fatigue Monitoring • Equivalent Operating hours • Performance Monitoring • Last Stage Blade Vibration	• Steam Turbine Modernization • Boiler Retrofit • Fast Start

Technical Minimum + Higher Ramps + Efficiency

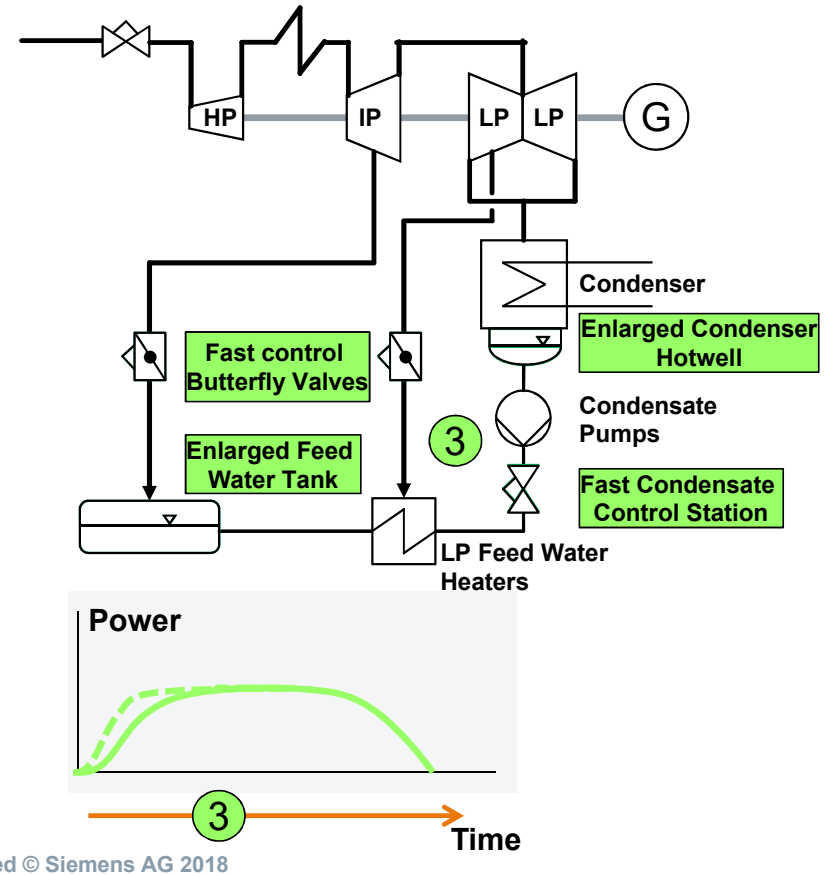
Measures for fast load ramping
Overview





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

Let P3000 Condensate Throttling increase your profitability by providing state-of-the-art frequency response (2/3)

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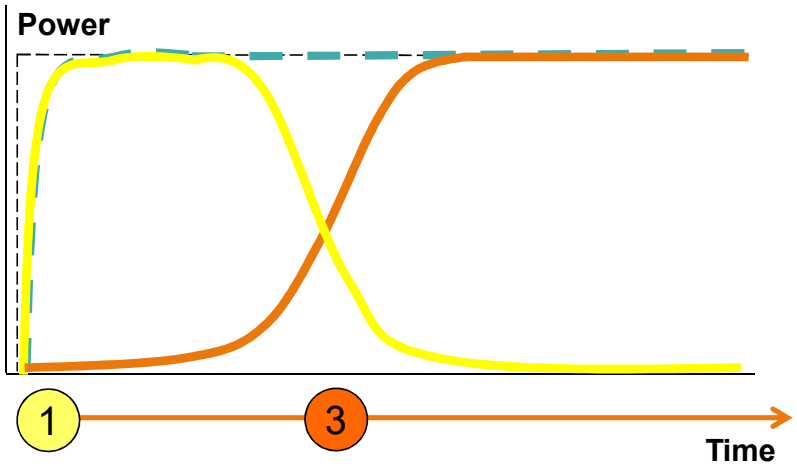
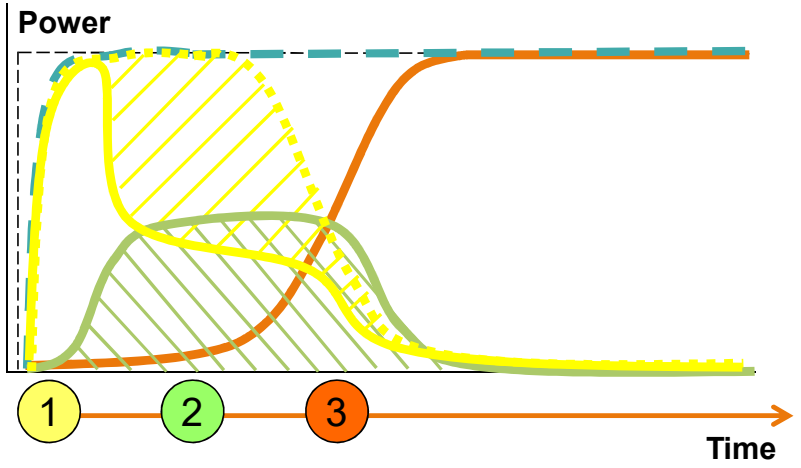
Frequency Response without P3000 Condensate Throttling :



Frequency Response including P3000 Condensate Throttling (Efficiency):



Let P3000 Condensate Throttling increase your profitability by providing state-of-the-art frequency response (3/3)

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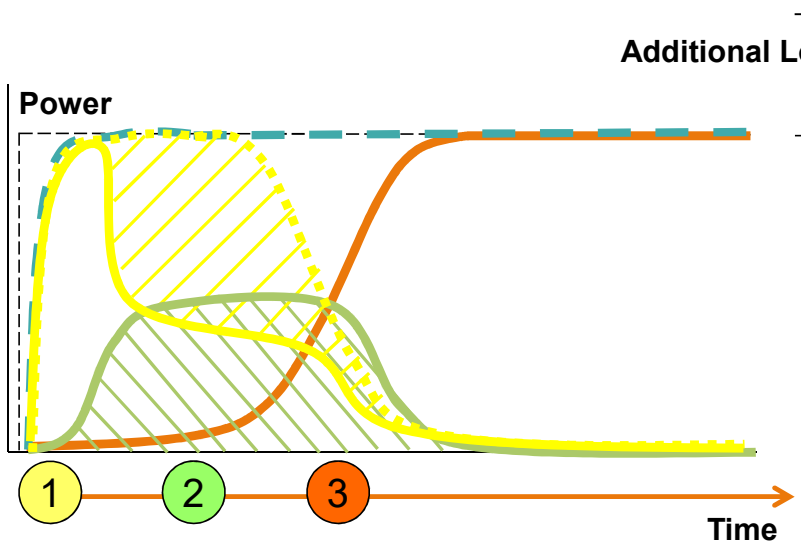
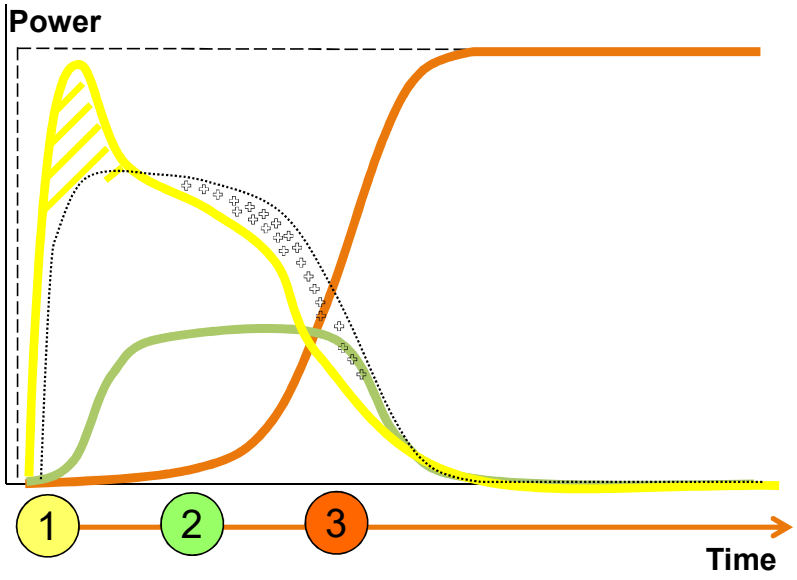
Frequency Response including P3000 Condensate Throttling (Efficiency):



Frequency Response including P3000 Condensate Throttling (Load Additional):



SPPA-P3000 Minimum Load Reduction
Reduced minimum load level

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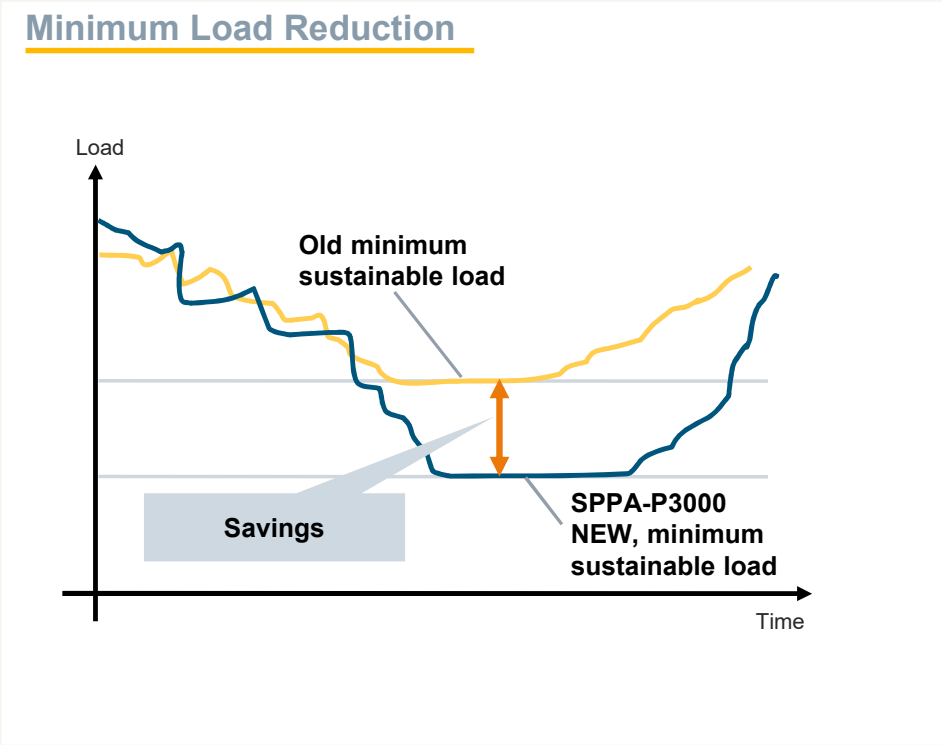
Task
To upgrade the plant so that the specified minimum load level can be reduced and to make the plant capable of fast and low-stress load increases on demand in accordance with market requirements.

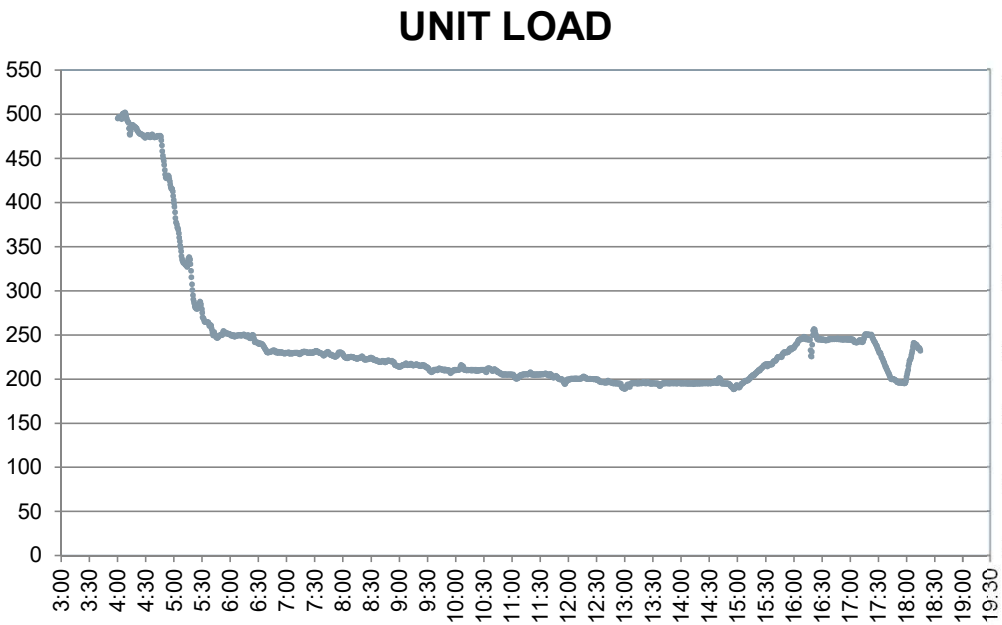
Solution
- Use of robust state space controller for unit control
- Adaptation, optimization and setting of lower-level controls for new minimum load level
- **Adaptation or addition of control sequences, burner and mill scheduler**
- Provision of additional instrumentation where necessary

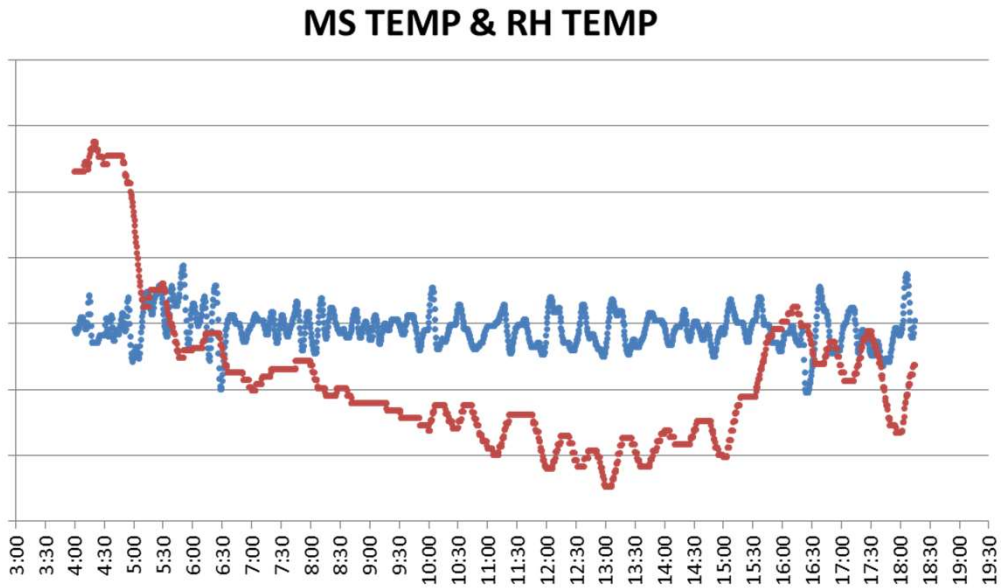
Benefit e.g. 500,000 €/a → Benefit calculation
- Reduced financial losses during off-peak periods
- Faster response to increased load demands as unit does not need to be shut down
- Avoidance of unnecessary startups and shutdowns



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

40% Technical Minimum is Possible



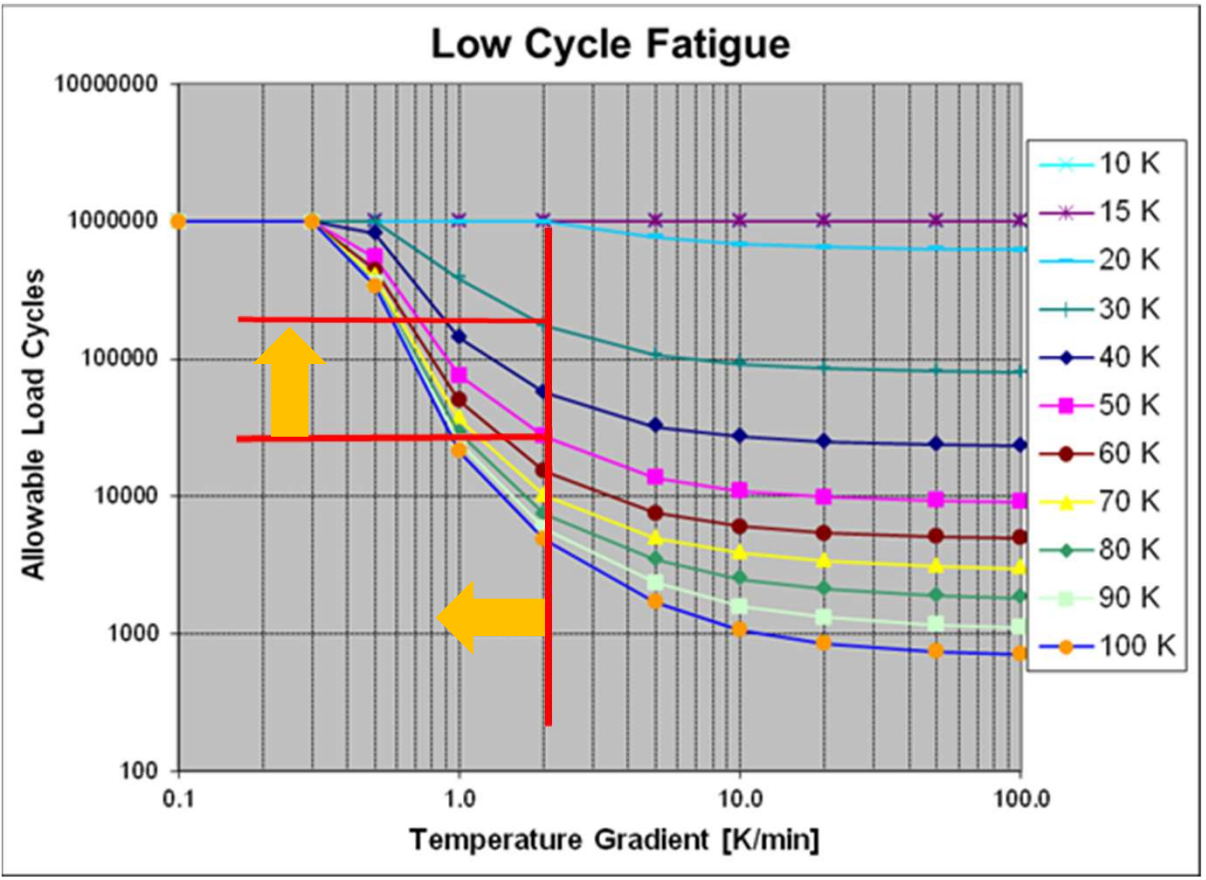


Cond.	M %	Ash%	C %	H %	N %	S %	O %
Air dried	4.03	37.29	43.63	3.26	1.01	0.35	10.43

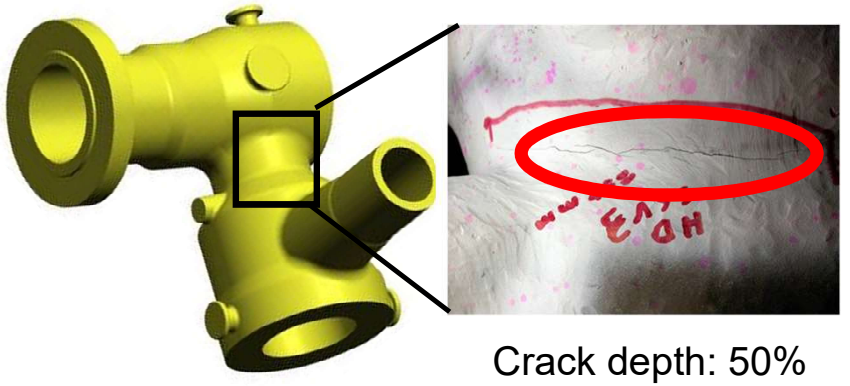
GCV (kcal/kg)	VM%	Ash %
3000	22%	35%

Transient Operation (Ramp Up / Ramp Down)

increased temperature gradient results increased life consumption

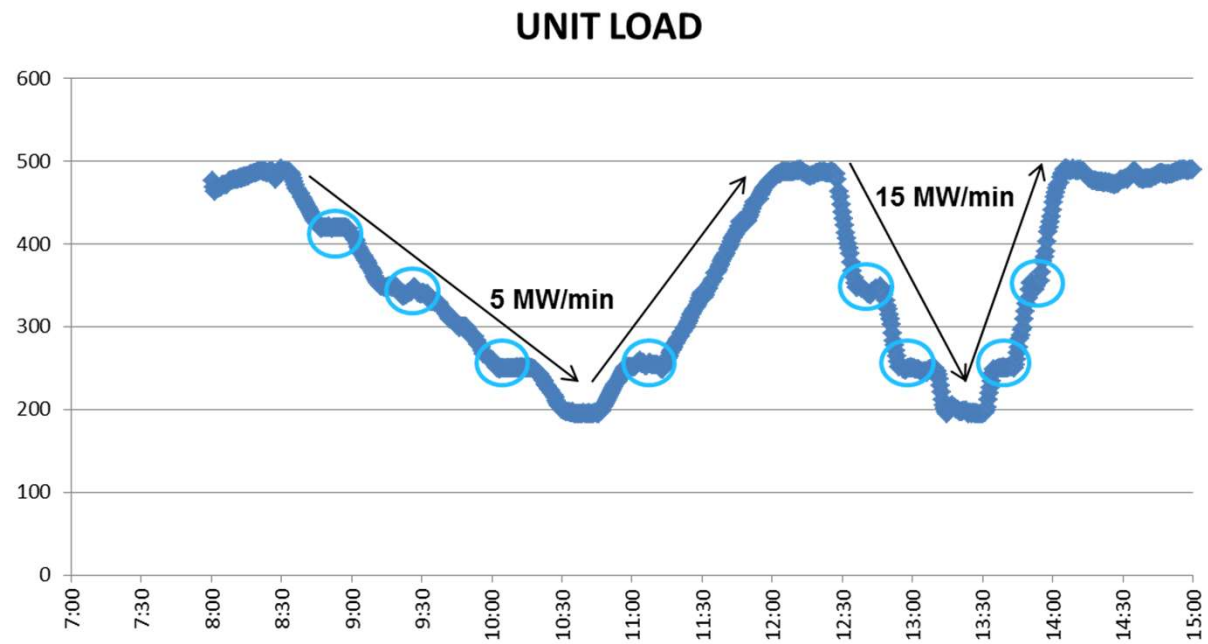


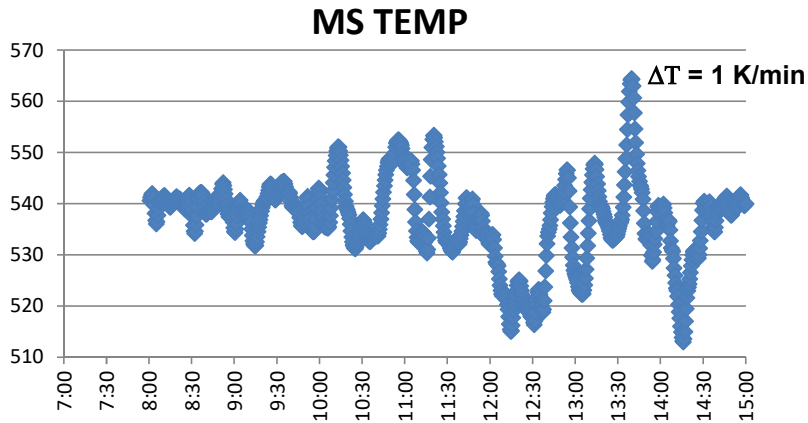
Main steam valve

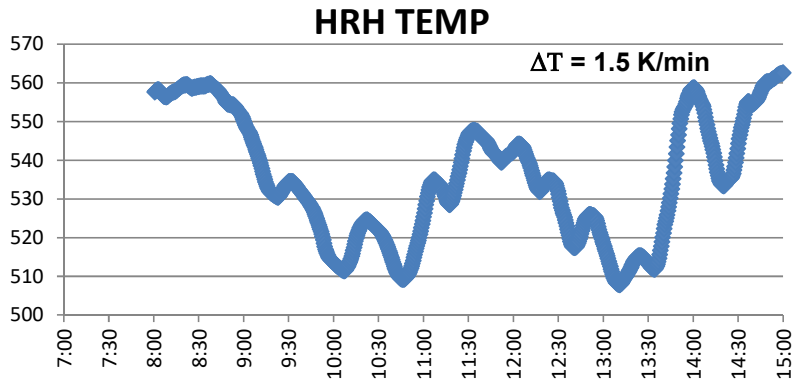


Crack depth: 50% wall thickness

Influence on Ramps on Temperature Transient







SPPA-P3000 Temperature Optimizer
Increased steam temperatures

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Task

To achieve maximum steam temperature without violation of material limits

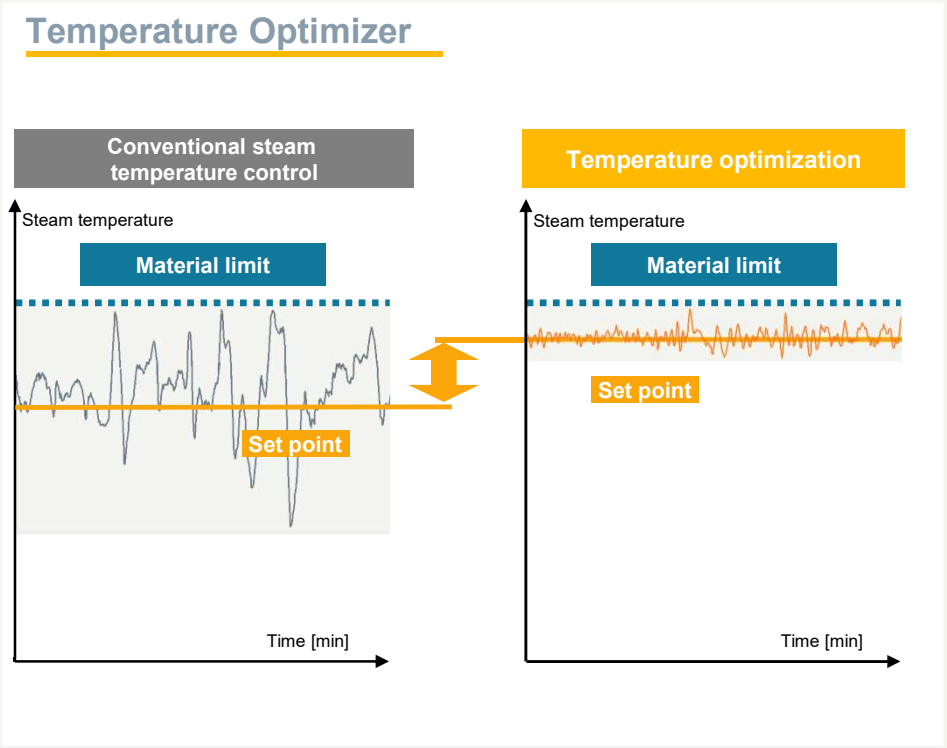
Solution

- 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
- 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

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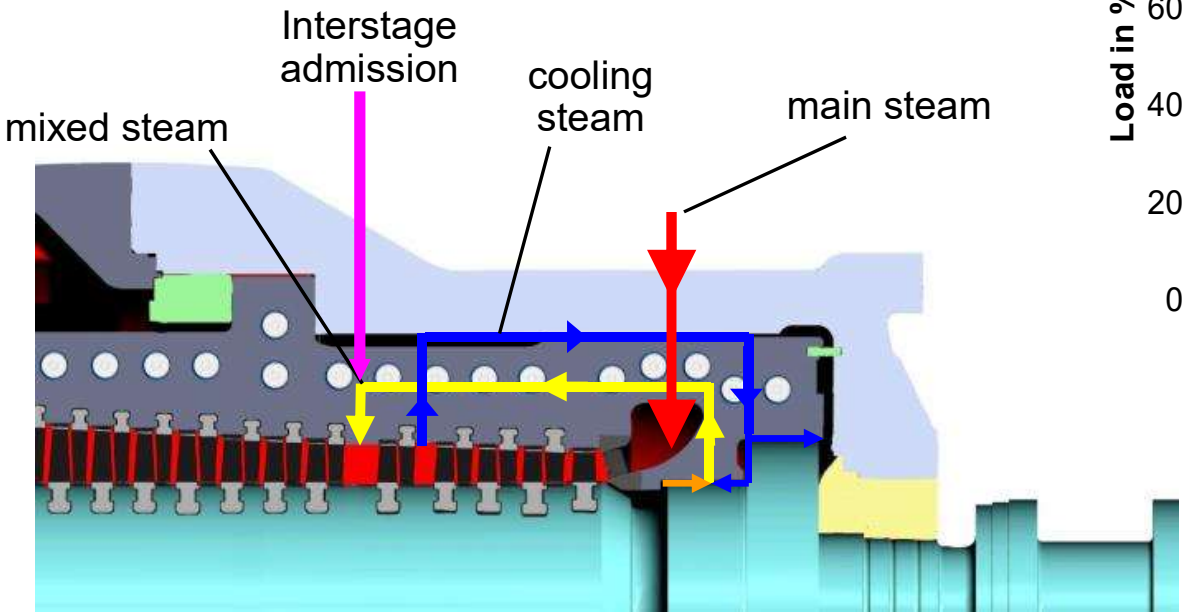
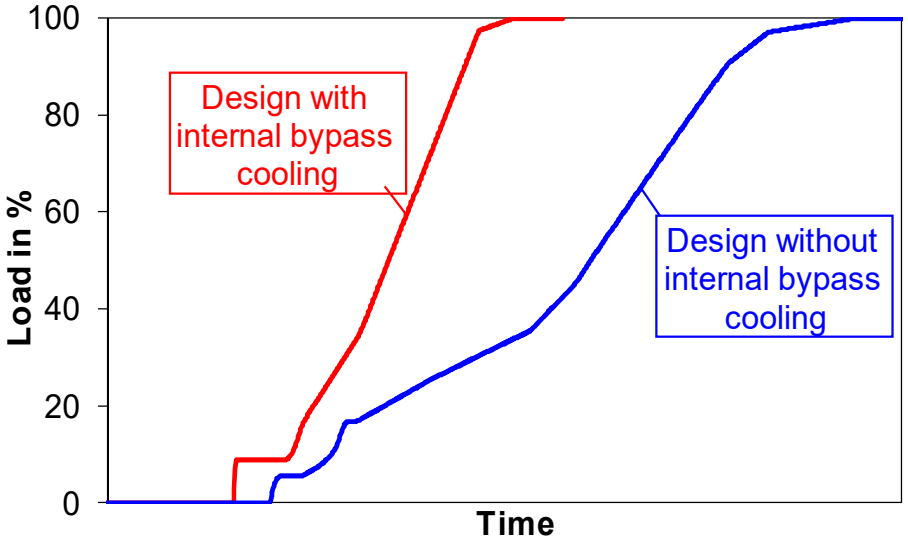
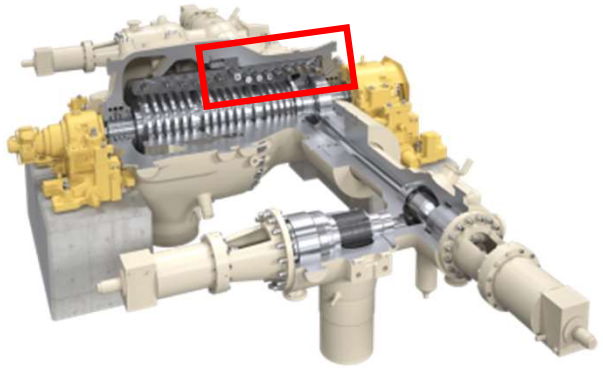
Example: Reduced Casing thickness & reduced thermal piston loading by HP bypass cooling

Significant improvement in LCF







Measures to improve transient operation

ST Warm Standby Operation to prepare for fast start-up

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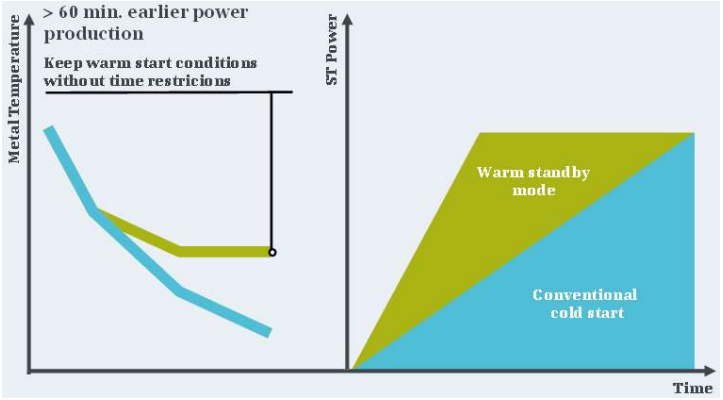
Technology

- 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

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

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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