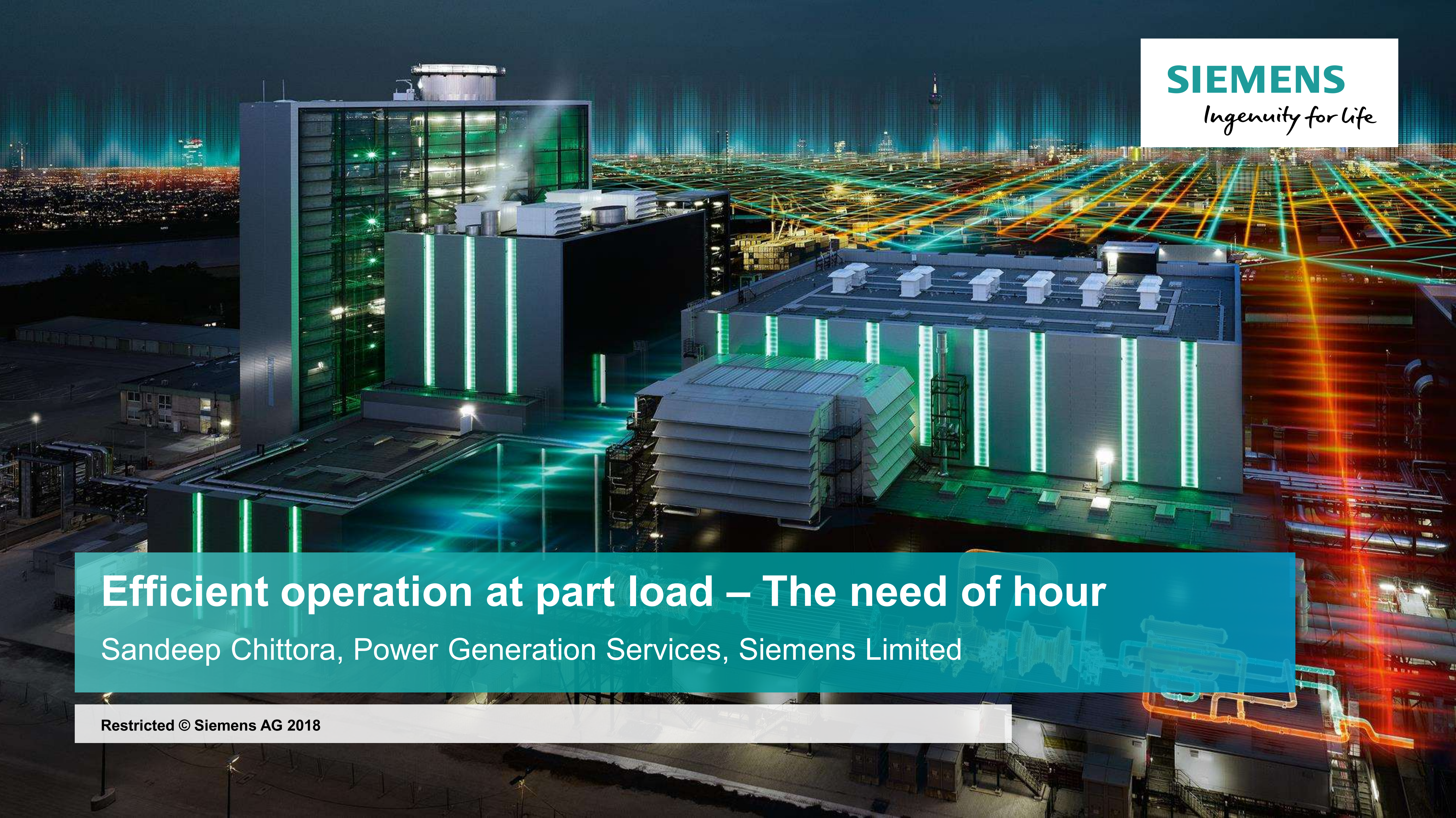

Efficient operation at part load – The need of hour

Sandeep Chittora, Power Generation Services, Siemens Limited

Plant Optimization

Flexibility is the new efficiency

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Reduced Electricity Production Cost and Increased Competitiveness *

Reducing technical minimum plant load

Down to 30%

Improved I&C and combustion for stable operation at lower loads

Increasing Efficiency and Performance (MW)

16 MW more

@ 75% load, including aging recovery effects by new hardware in HP and LP turbine at constant coal consumption

Improved Ramp Rates

3x higher

Higher ramp rates up to 15MW/min

Reducing CO_2 Emissions

Up to 5% lower

An improved efficiency leads to lower CO_2 emissions!

Reduced Costs for Starting and earlier Power Production

>60min earlier

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

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Balance of Plant (BoP) Assessment for Boiler, Condenser, Steam Turbine & Auxiliaries

Boiler
Fuel Supply
Instrumentation & Controls
Combustion Concept & Operation
Thermal Design
Fans and Pumps

Boiler Feed Pump (incl. Motor or turbine drive)

Feed Water Heaters

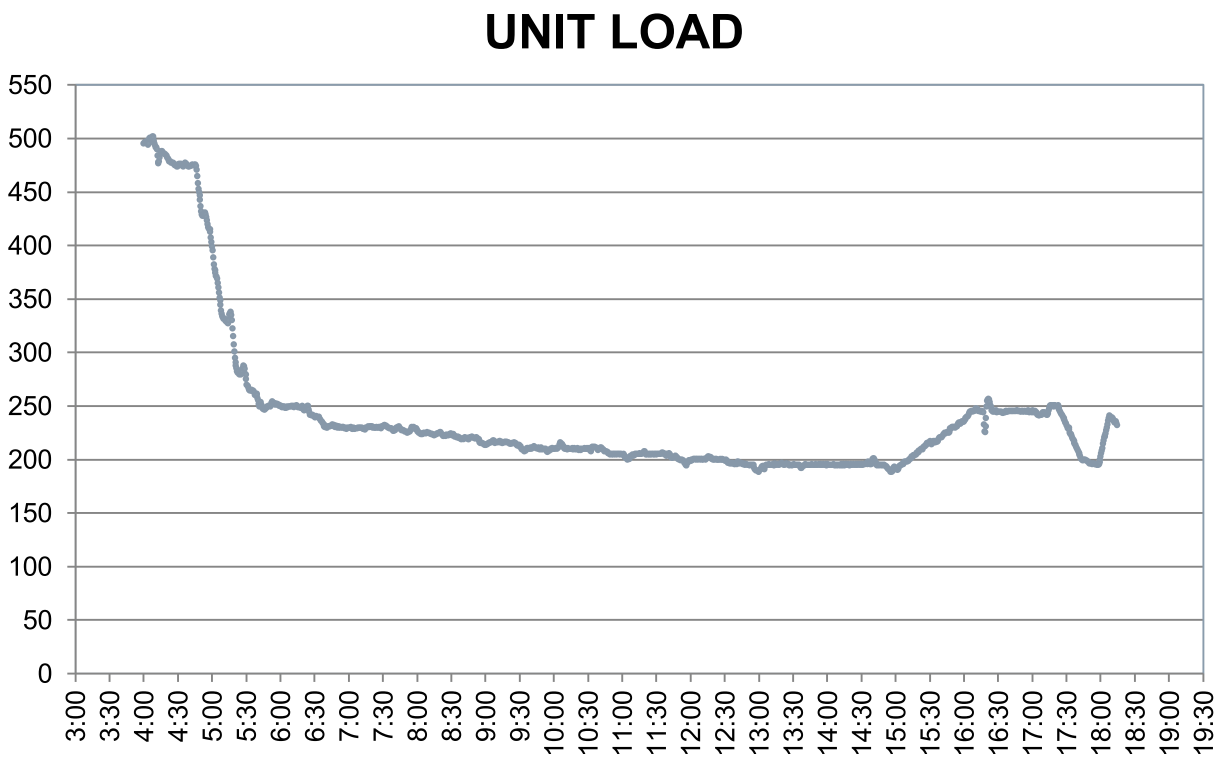
Turbine
Blading
Operation
Steam Seal
Drains

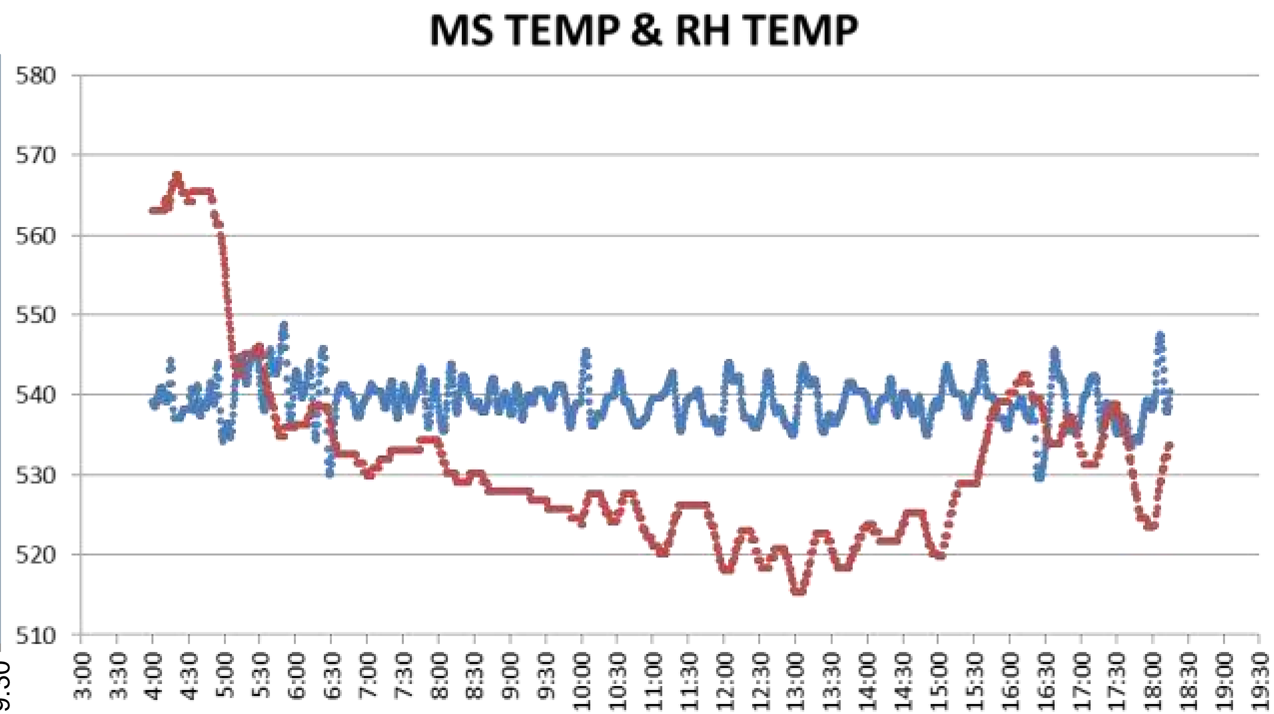
Condenser
Terminal Temperature Difference (TTD)
Condensate Pump

Steam Piping System

Cooling Water System

40% Technical Minimum is Possible – NTPC Dadri

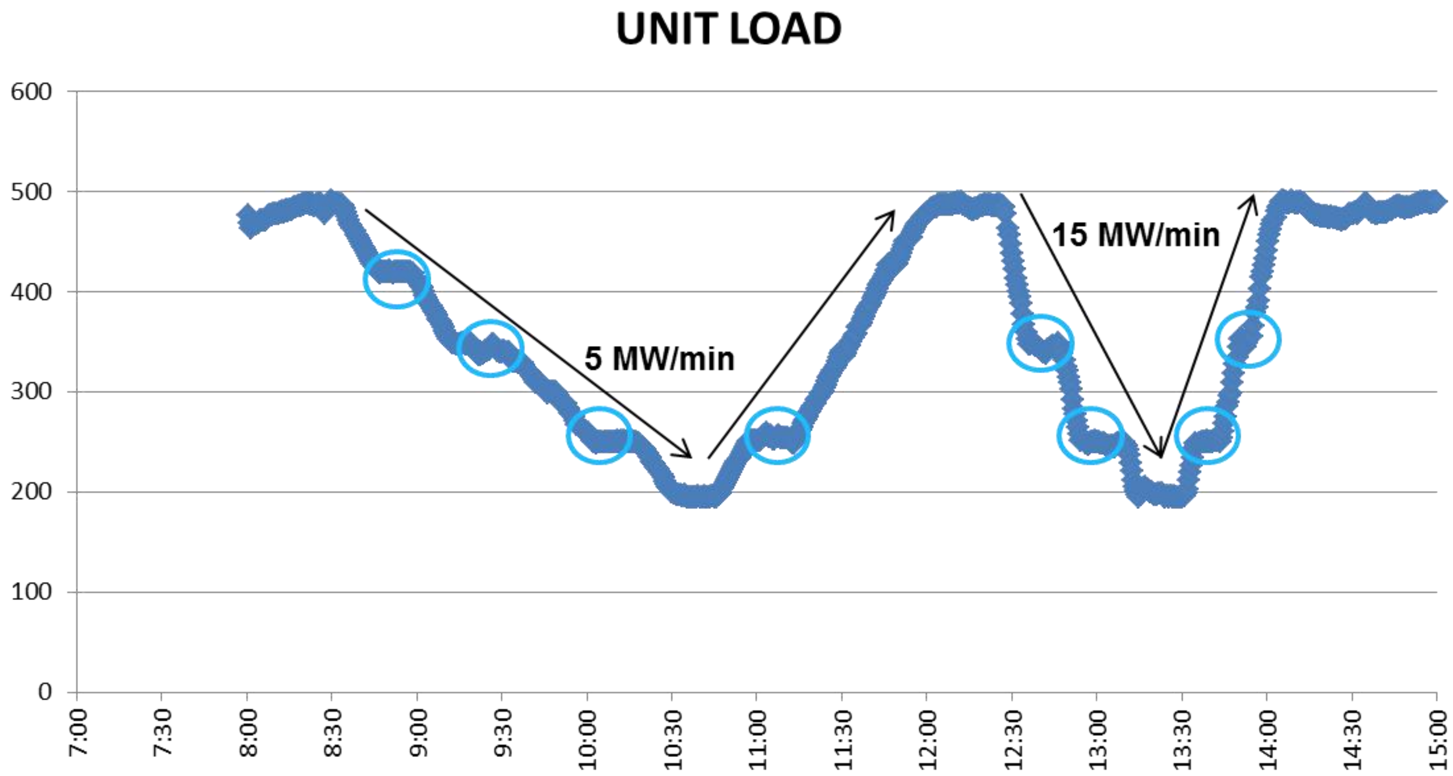


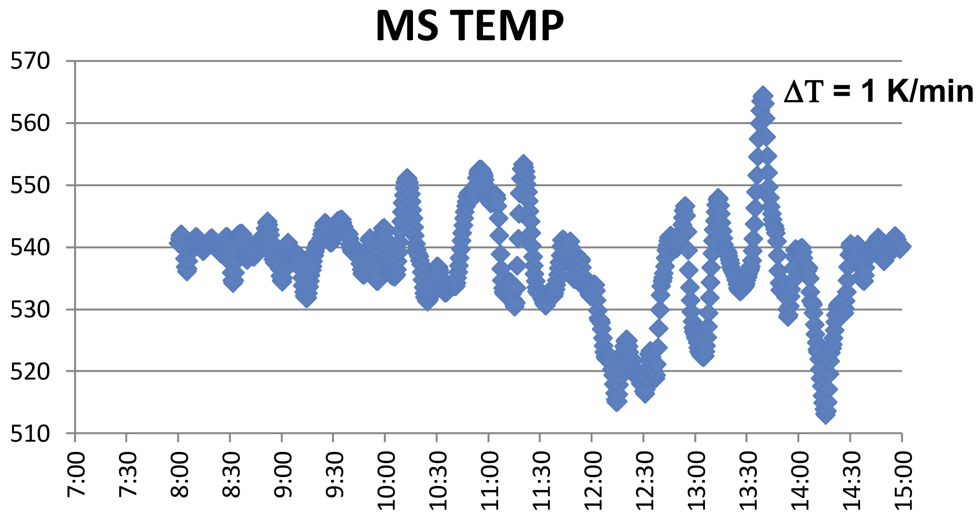


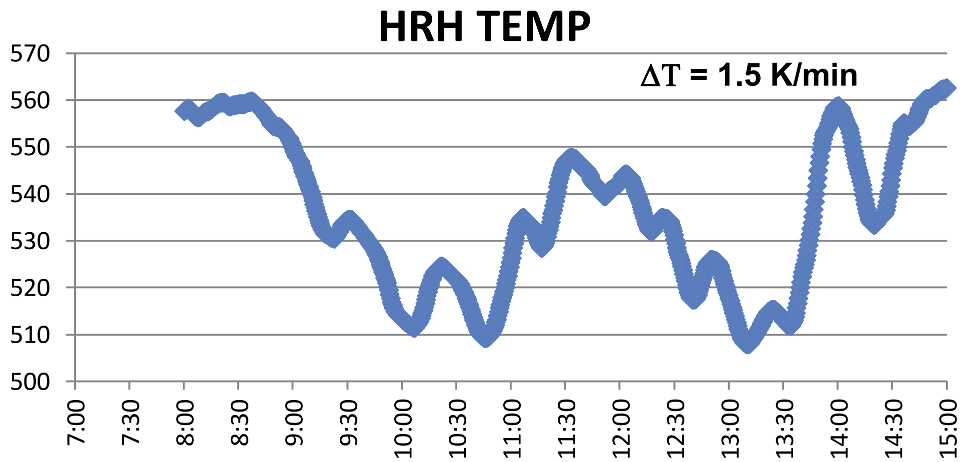
Cond.	M %	Ash%	C %	H %	N %	S %	O %
Air dried	4.03	37.29	43.63	3.26	1.01	0.35	10.43

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

Influence on Ramps on Temperature Transient



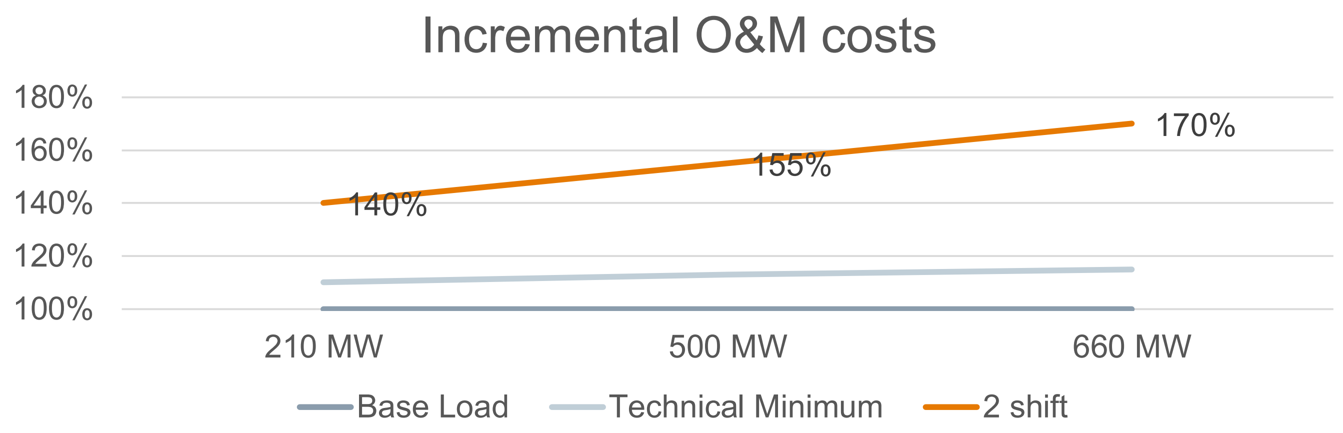




Lower technical minimum is better than two shift operation

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

Start	Life Consumption	IEC 45 permissive
Cold Start	23 – 75 hours	100
Warm Start	15 -17 hours	700
Hot Start	10 -12 hours	3000
Load Change	3 hours	-



Transient Operation (Ramp Up / Ramp Down)

increased temperature gradient results increased life consumption

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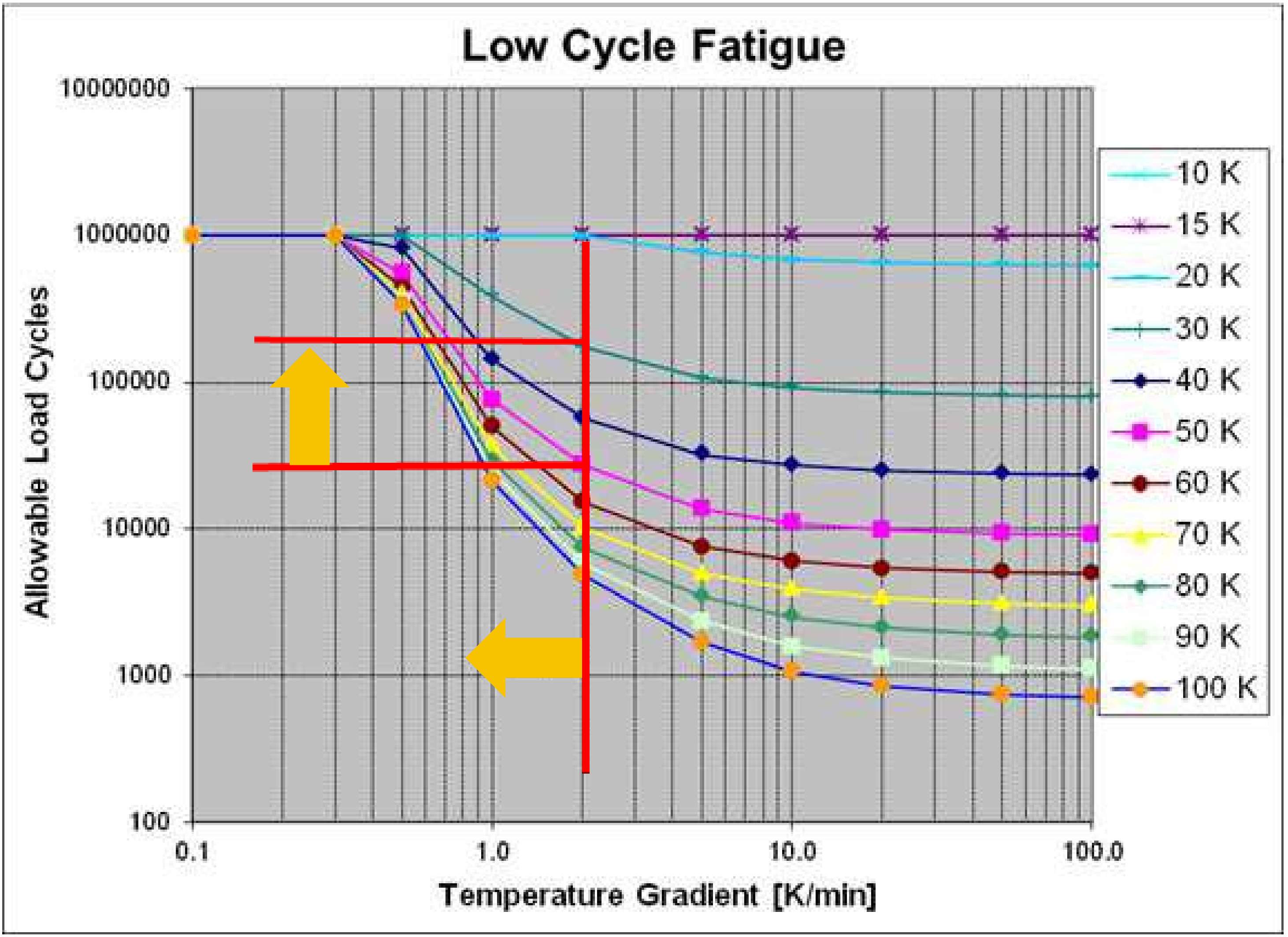
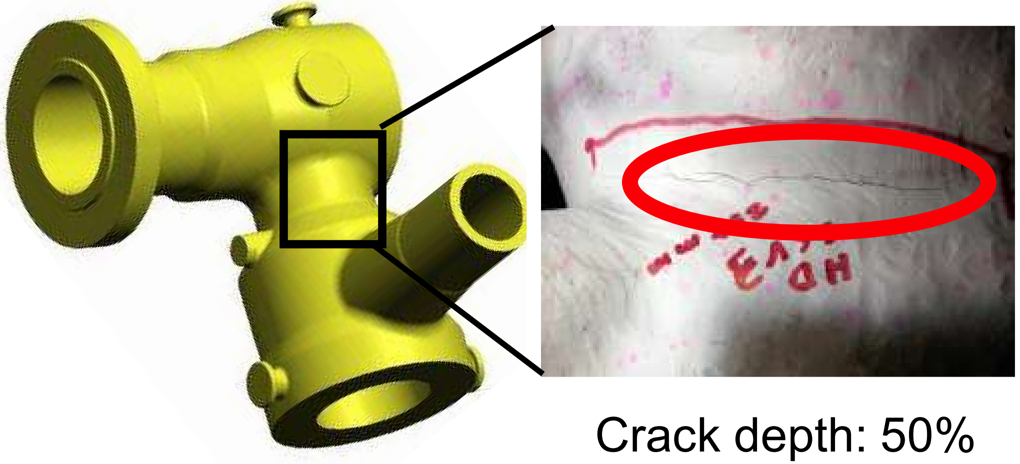
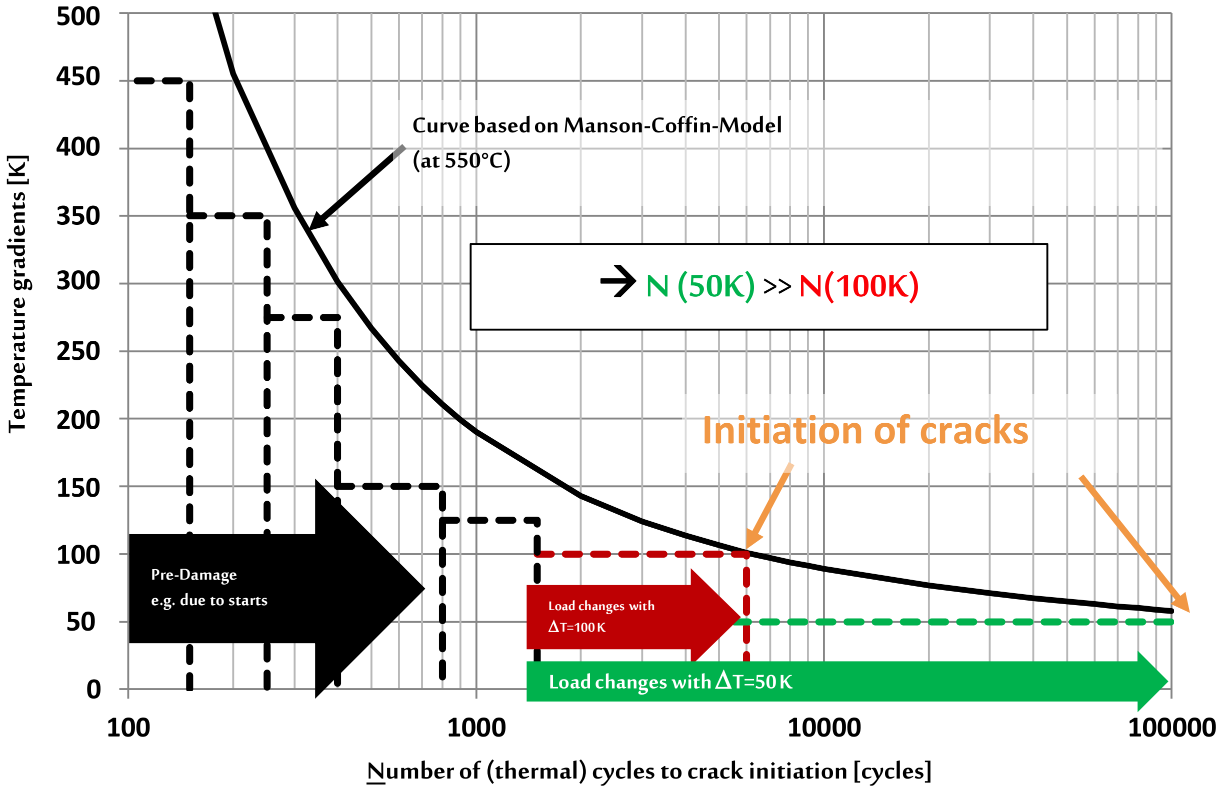


Main steam valve



Crack depth: 50% wall thickness

Time for crack initiation



Operational Strategy

- Part load may lead to steam temperature changes, especially hot reheat temperature
- Thermal stresses due to temperature changes across thick wall components are detrimental to life consumption
- Careful analysis and suitable modification would lead to improved fatigue behavior and reduce maintenance requirements

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

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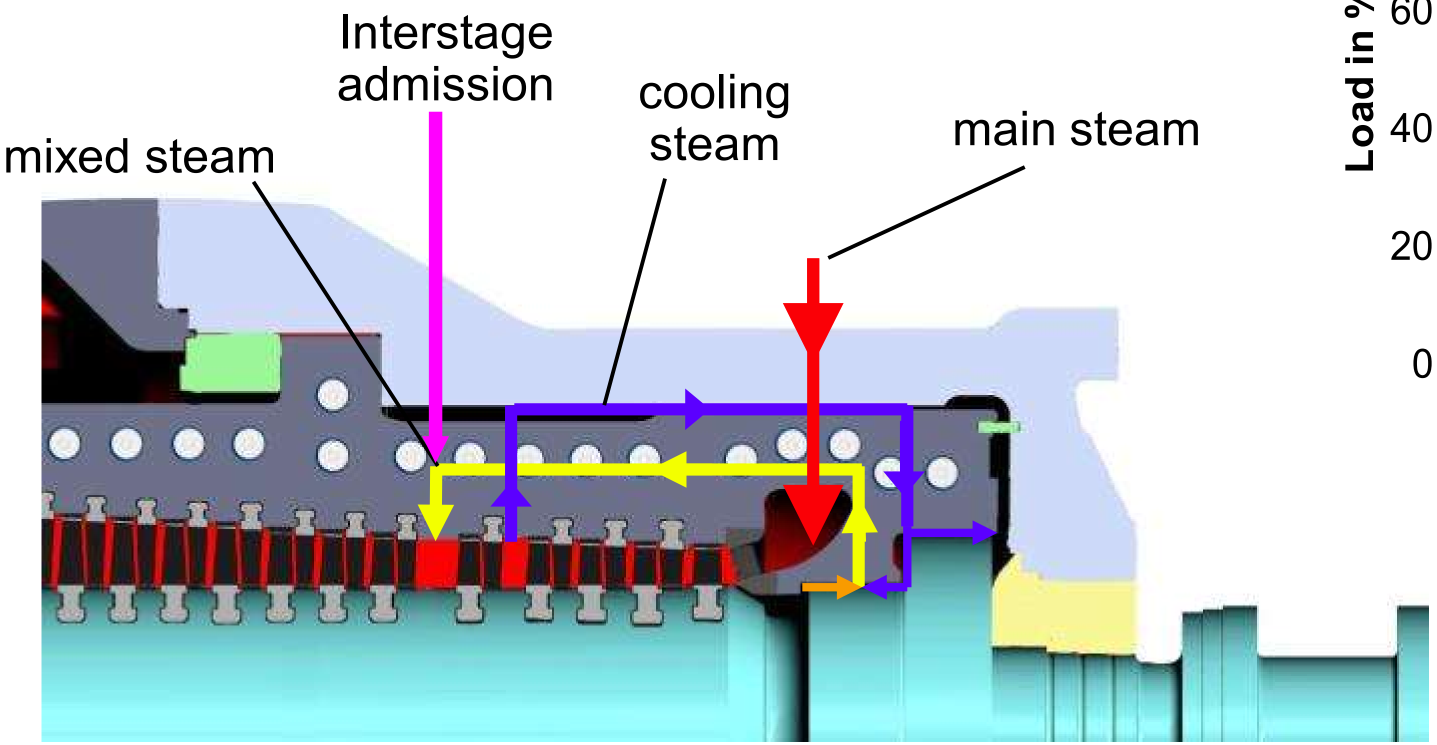
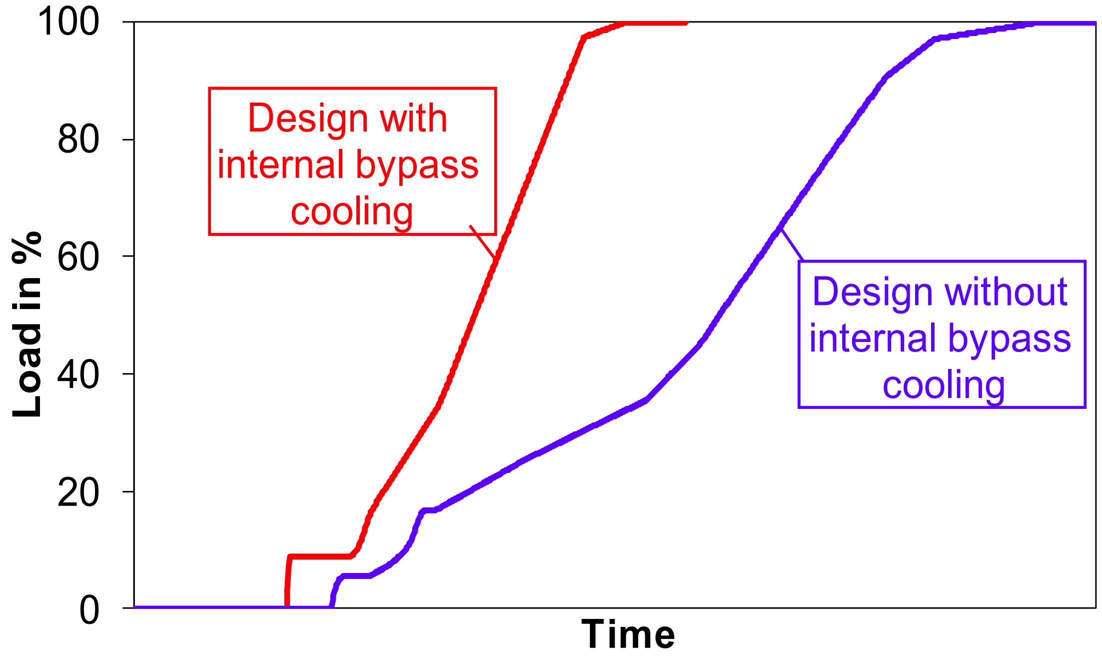
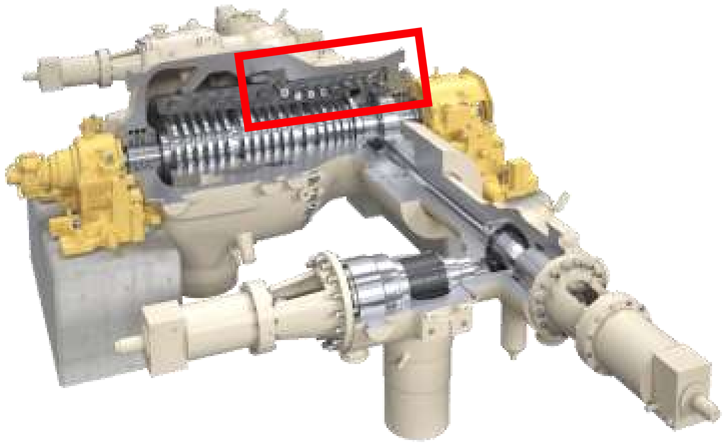
<u>Example:</u> Reduced Casing thickness & reduced thermal piston loading by HP bypass cooling

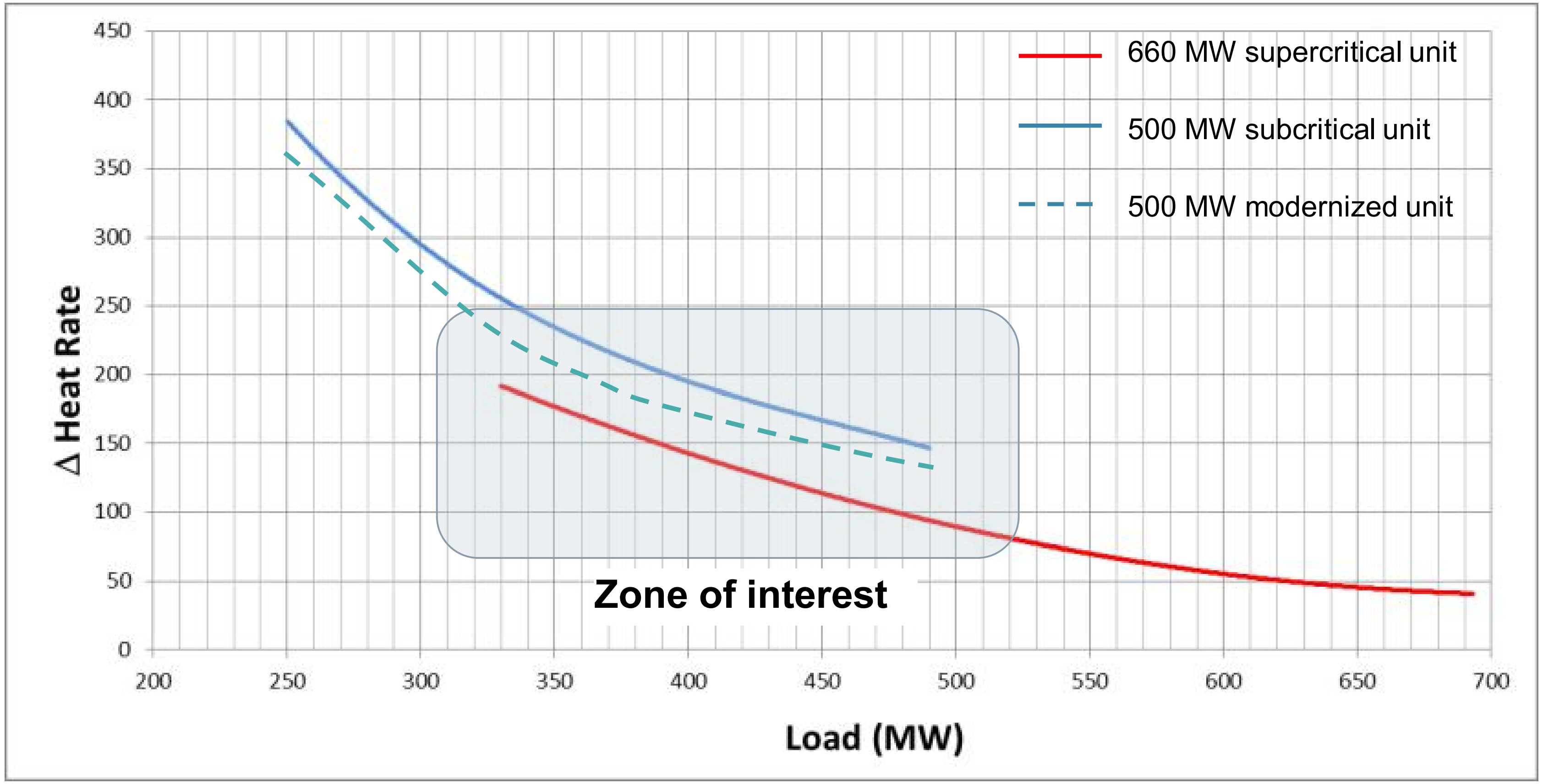
Significant improvement in LCF







Performance at lower part load factor



210 MW modernization leads to 25 paisa savings in cost of generation with payback period of ~3 years

Part Load Efficiency: Turbine hardware upgrade
HP Turbine

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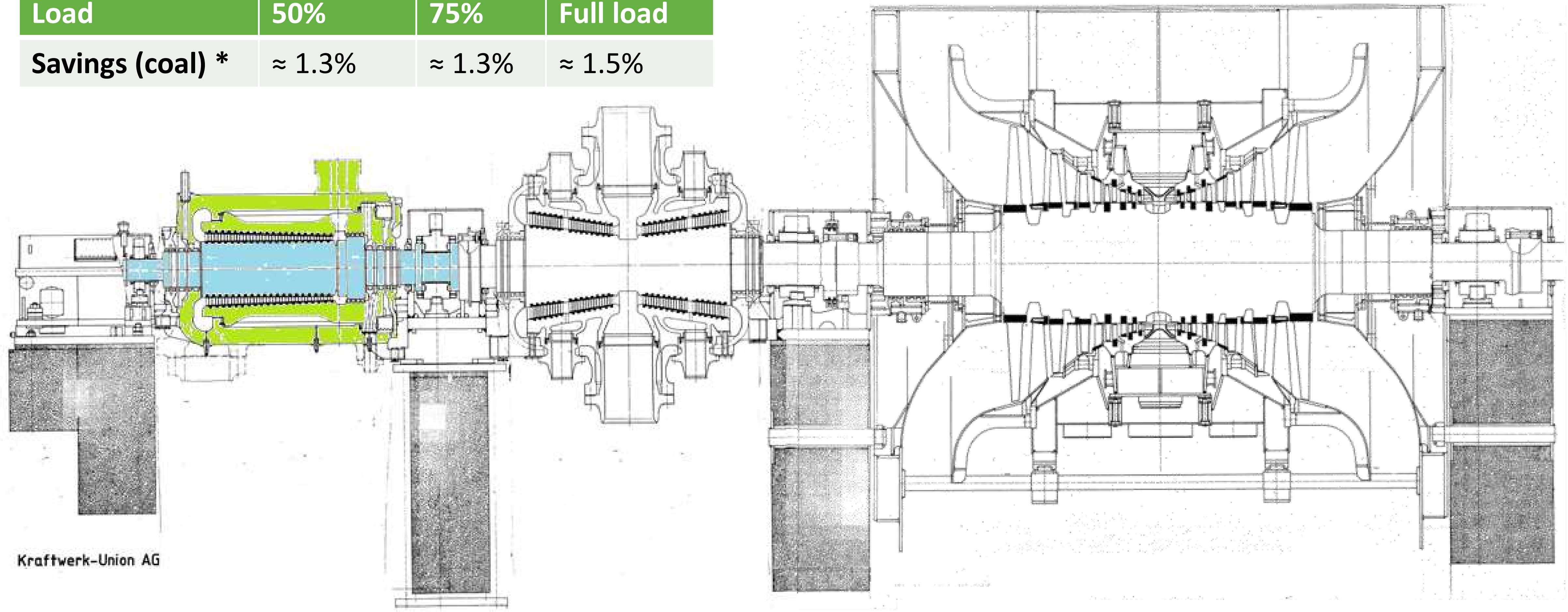
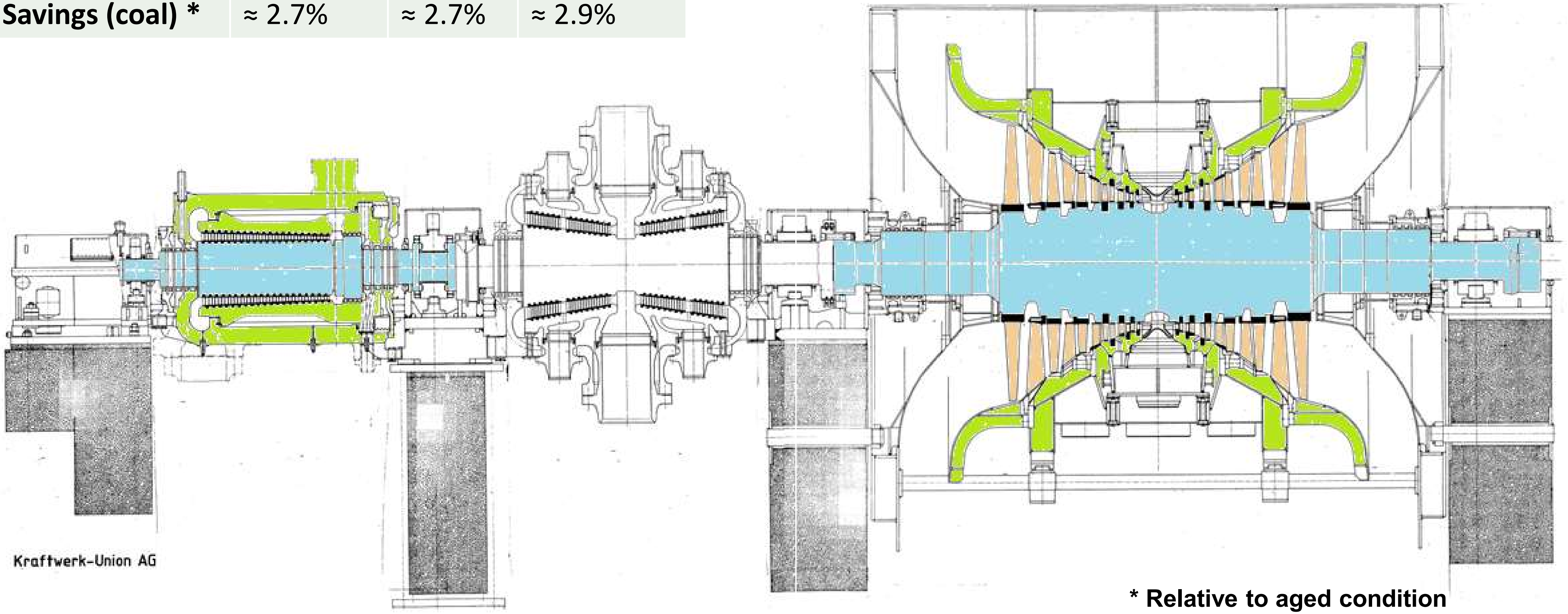
Load	50%	75%	Full load
Savings (coal) *	≈ 1.3%	≈ 1.3%	≈ 1.5%



*** Relative to aged condition (both in fixed pressure operation)**

Part Load Efficiency: Turbine hardware upgrade
HP + LP Turbine

Load	50%	75%	Full load
Savings (coal) *	≈ 2.7%	≈ 2.7%	≈ 2.9%



* Relative to aged condition (both in fixed pressure operation)

Part Load Efficiency: Turbine hardware upgrade

HP Turbine with control stage

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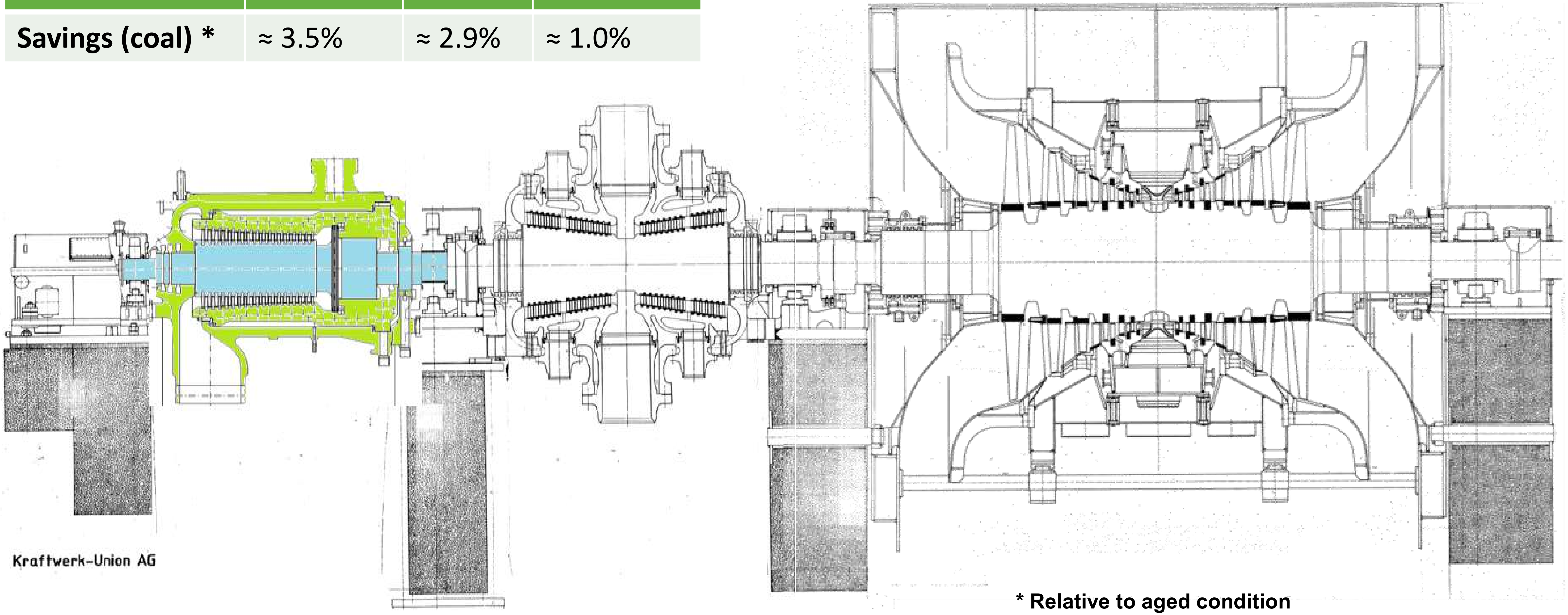
Load	50%	75%	Full load
Savings (coal) *	≈ 3.5%	≈ 2.9%	≈ 1.0%



* Relative to aged condition
(both in fixed pressure operation)

Part Load Efficiency: Turbine hardware upgrade with control stage

HP + LP Turbine with control stage

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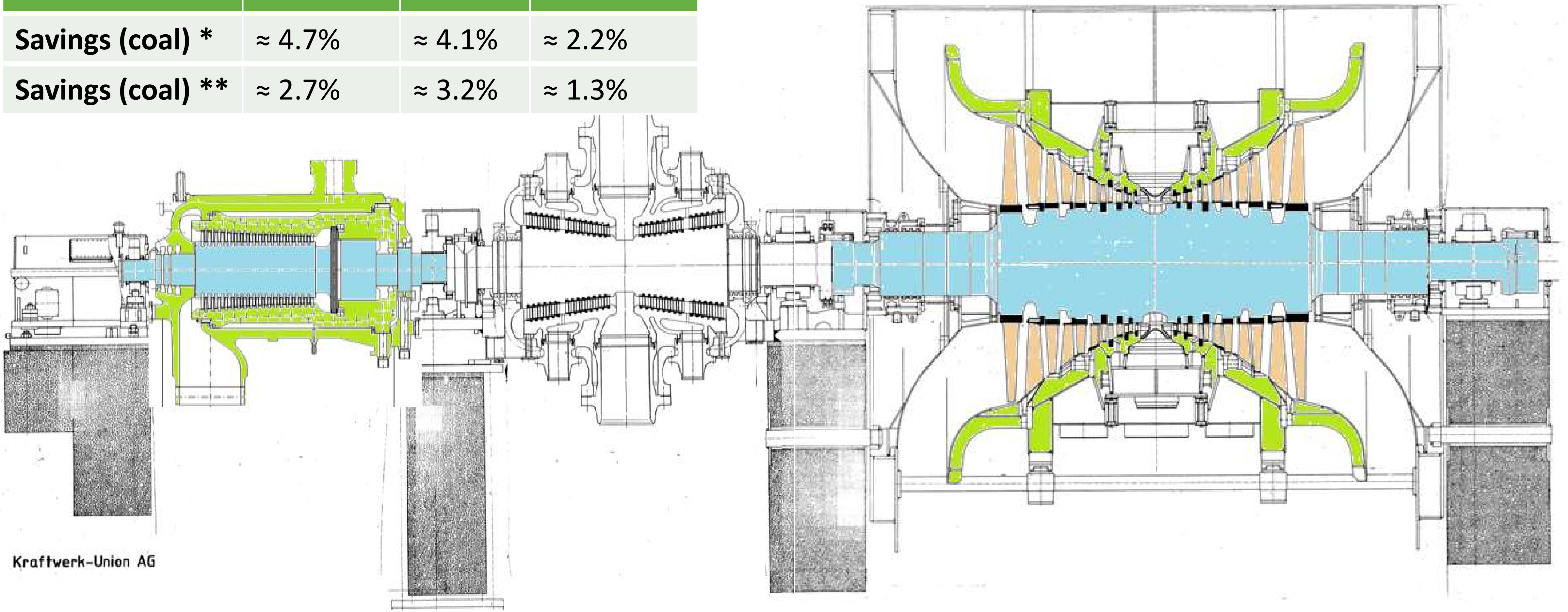
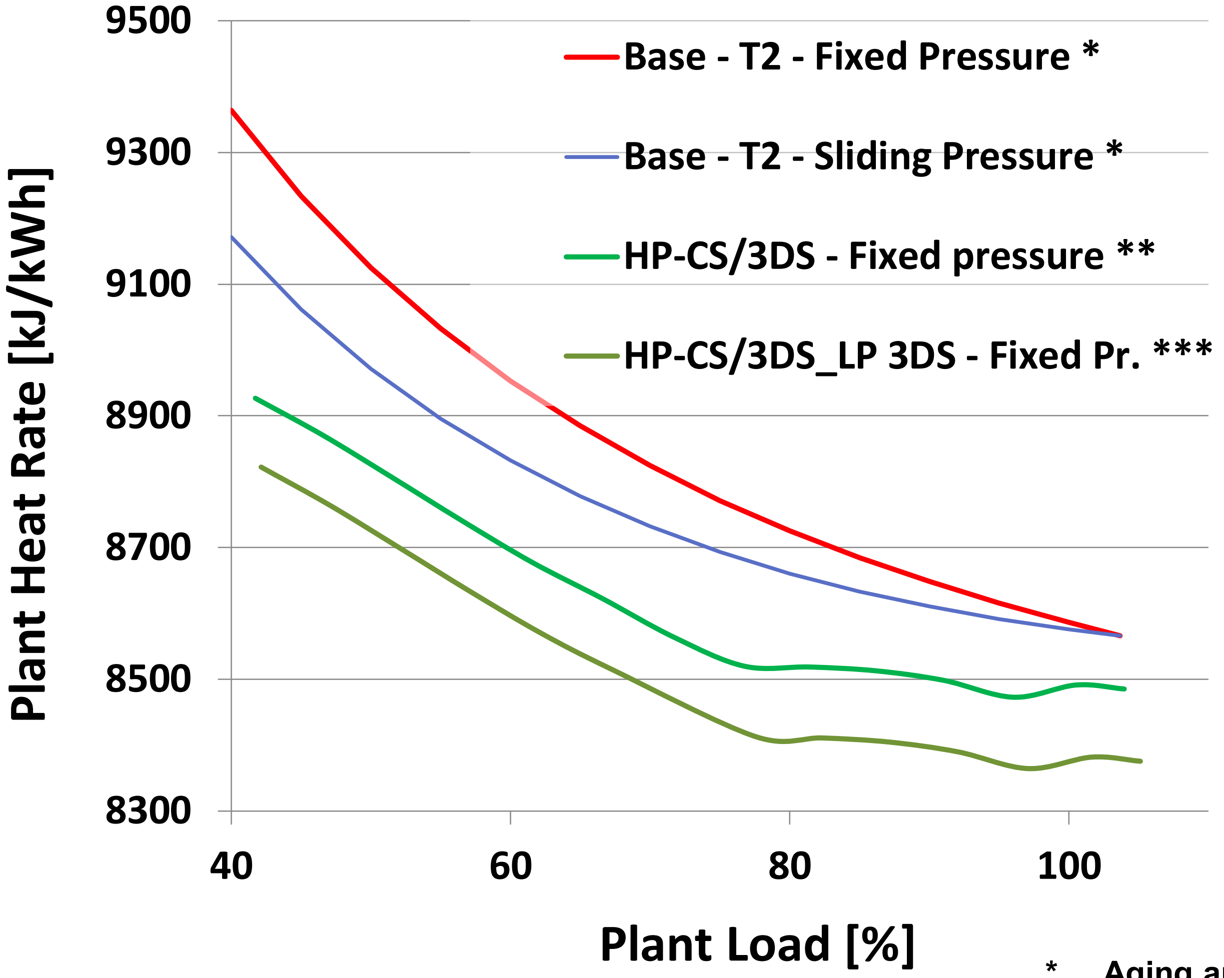
Load	50%	75%	Full load
Savings (coal) *	≈ 4.7%	≈ 4.1%	≈ 2.2%
Savings (coal) **	≈ 2.7%	≈ 3.2%	≈ 1.3%

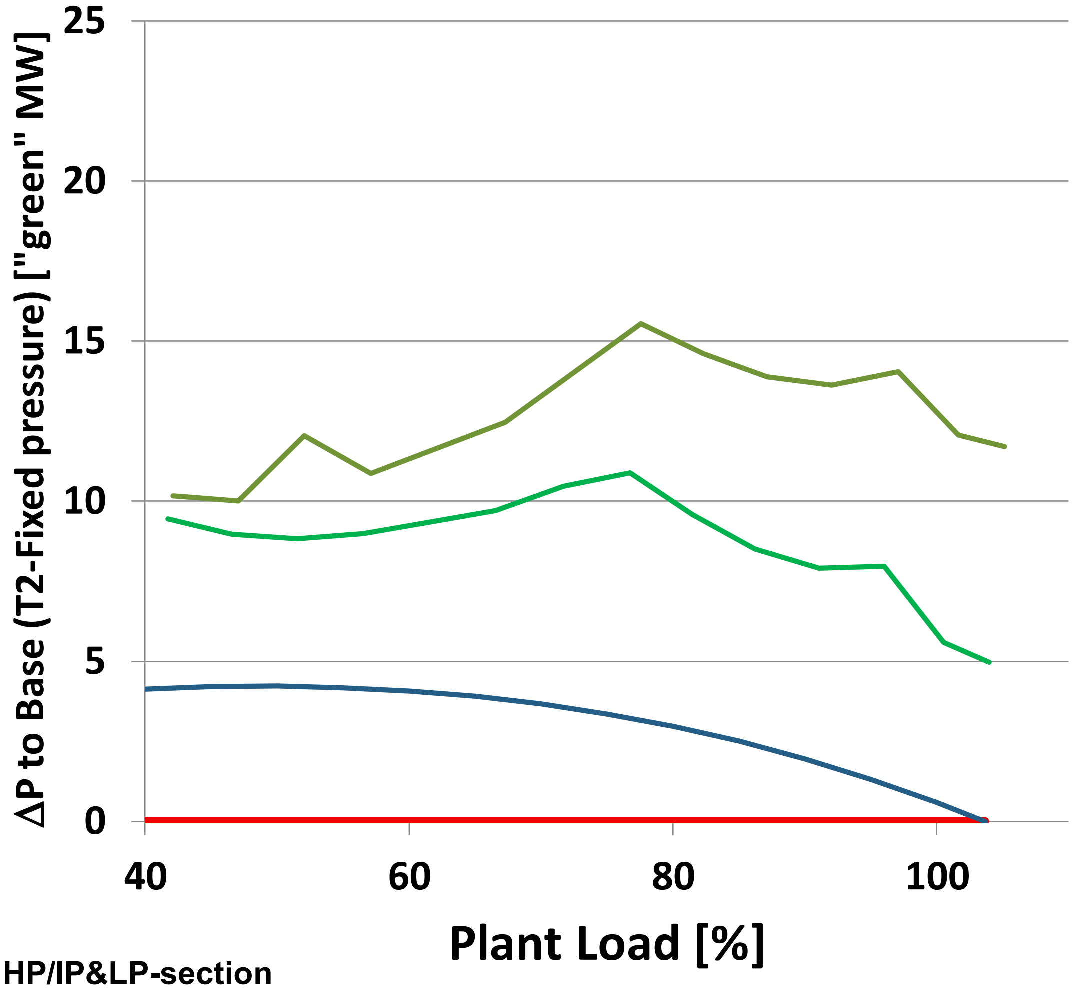


*** Relative to aged condition (both in fixed pressure operation)**
**** Relative to new and clean conditions**

Part Load Efficiency: Turbine hardware upgrade with control stage

HP + LP Turbine with control stage





* Aging applied to HP/IP&LP-section

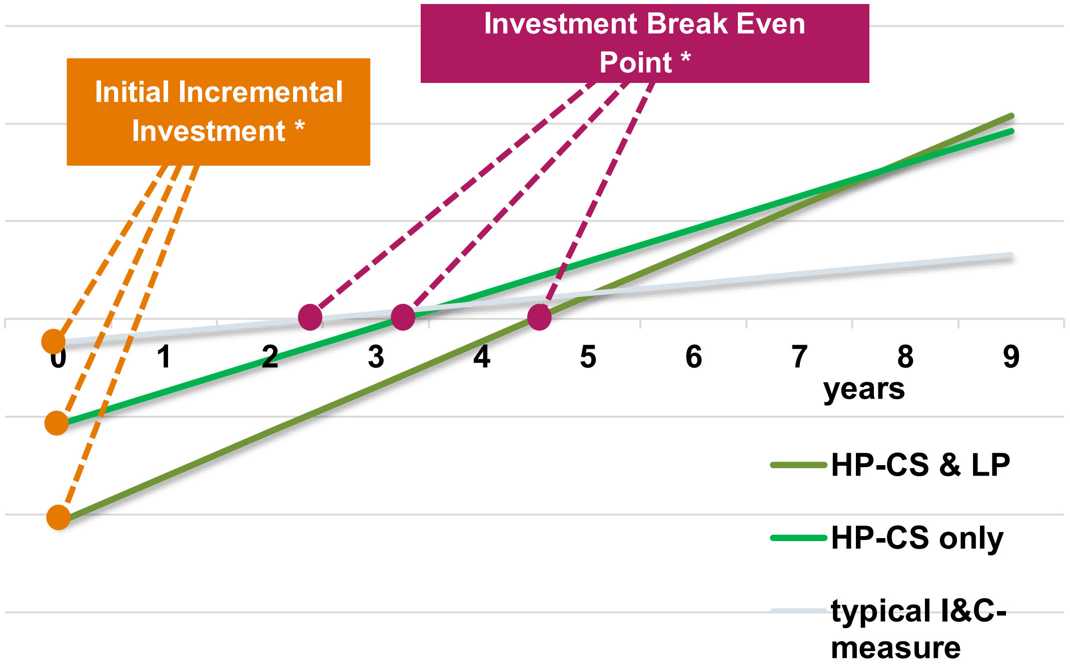
** Aging applied to IP/LP-section

*** Aging applied to IP-section

Return on investment with hardware upgrade
Potential Benefits

For the corresponding 500MW steam power plant the modernization of the Turbine Hardware (new HP module with control stage / new LP rotor and inner casing) would result in significant savings for coal.

Taking this into account, the return of invest period accounts to 4 - 5 years. Additional benefits like the avoided CO_2 and the enhanced ability for fast load changes are not even considered here.



* This example is based on a modernization of a 500MW-coal-fired power plant in India (KWU-design)

Reduced Startup-times: Heating blankets

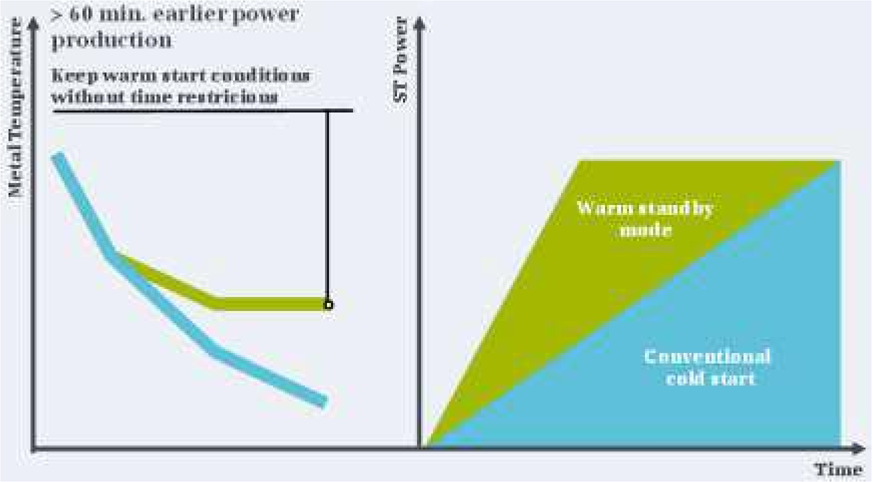
ST Warm Standby Operation to prepare for fast start-up

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 part load performance improvement is possible, unit specific changes needs to be applied
- Means of improving part load efficiency by upto 4% are available
- Need based R&M is the approach for part load performance improvement

Contact information

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Power on Demand

Monitoring of flexibility consequences: steam turbine EOH counter 4.0

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Task

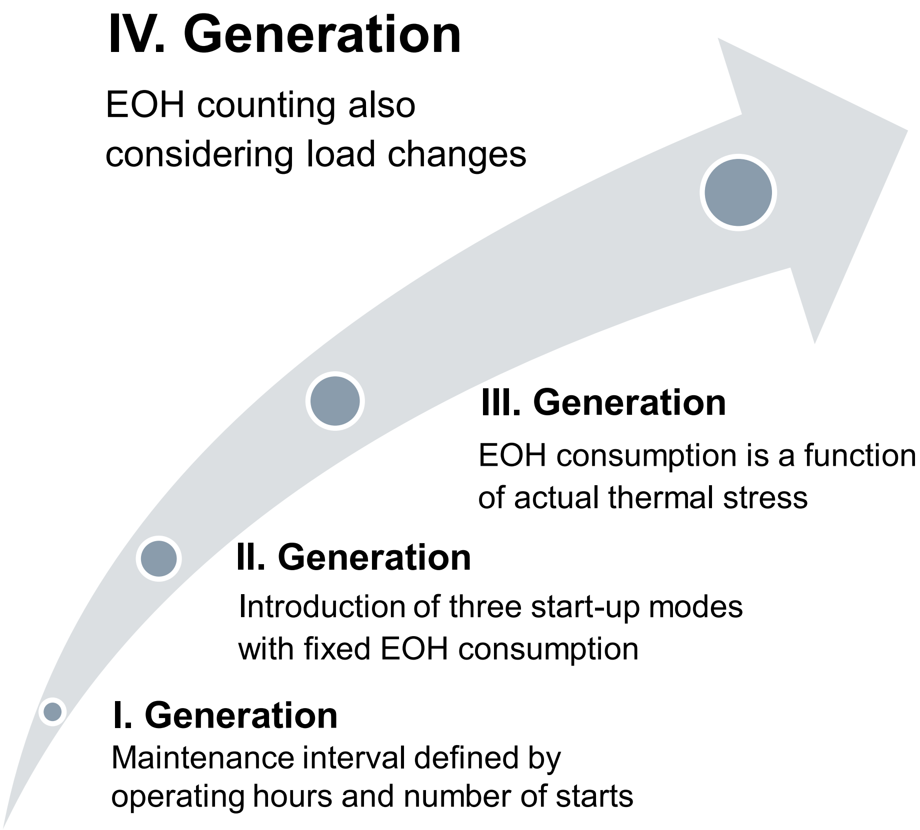
- Part load may lead to steam temperature changes, especially hot reheat temperature
- Thermal stresses during operation are not considered in standard counting of equivalent operating hours (EOH counter)
- Maintenance needs may not be recognized

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

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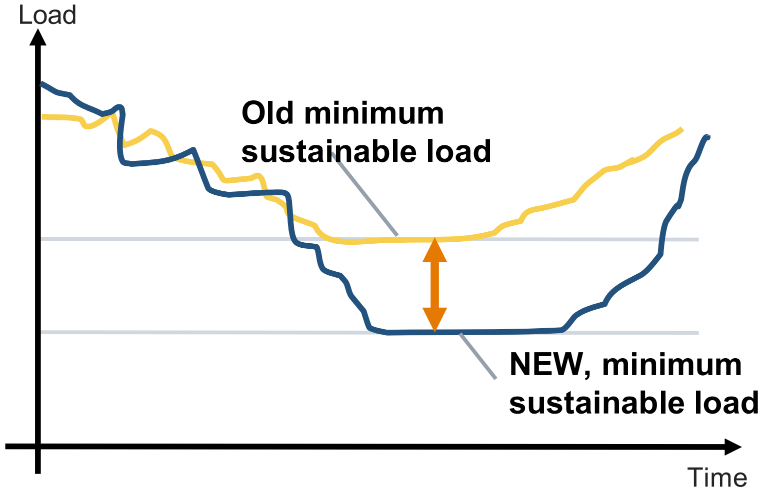

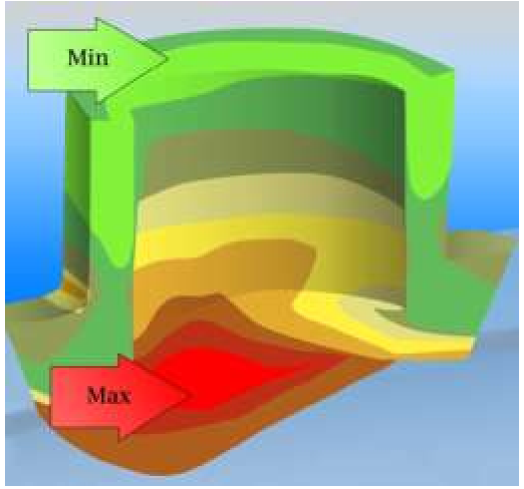

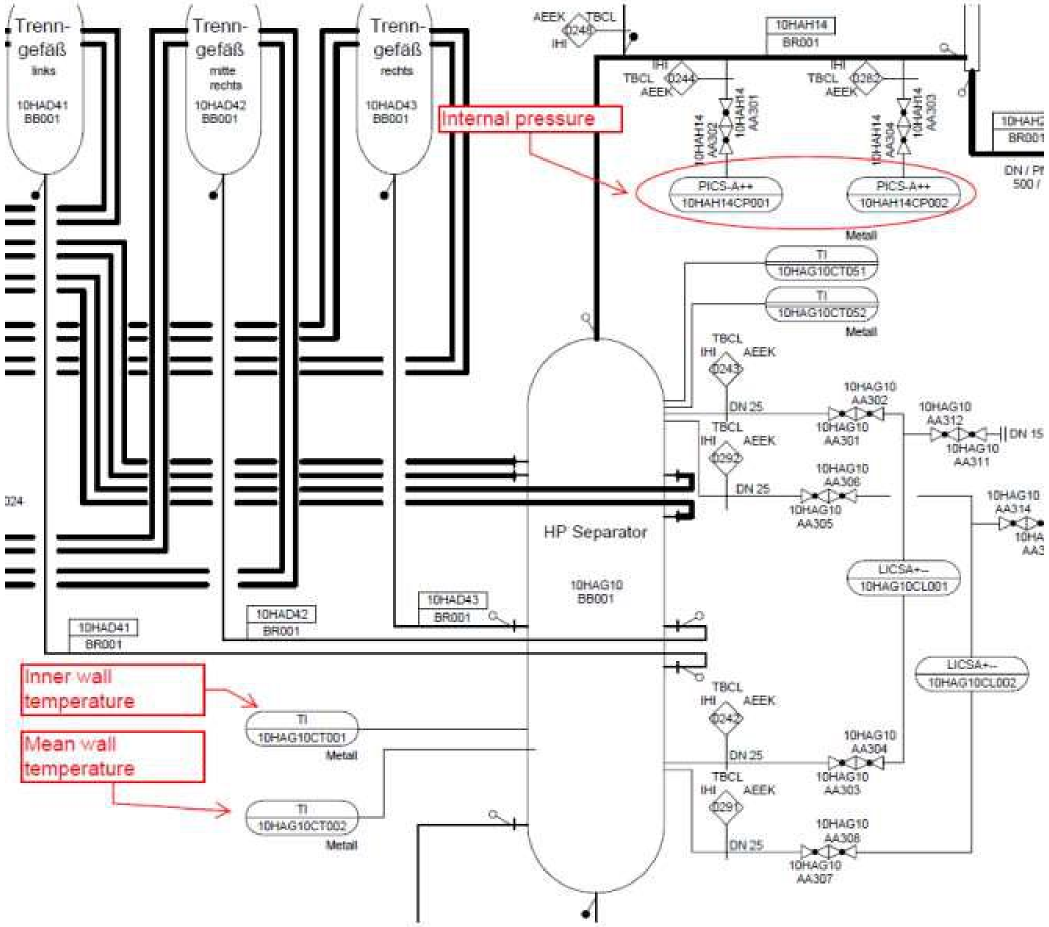

How much fatigue is it?

Don’t Guess when you can actually measure it

Maintenance Flexibility
Fatigue Monitoring System

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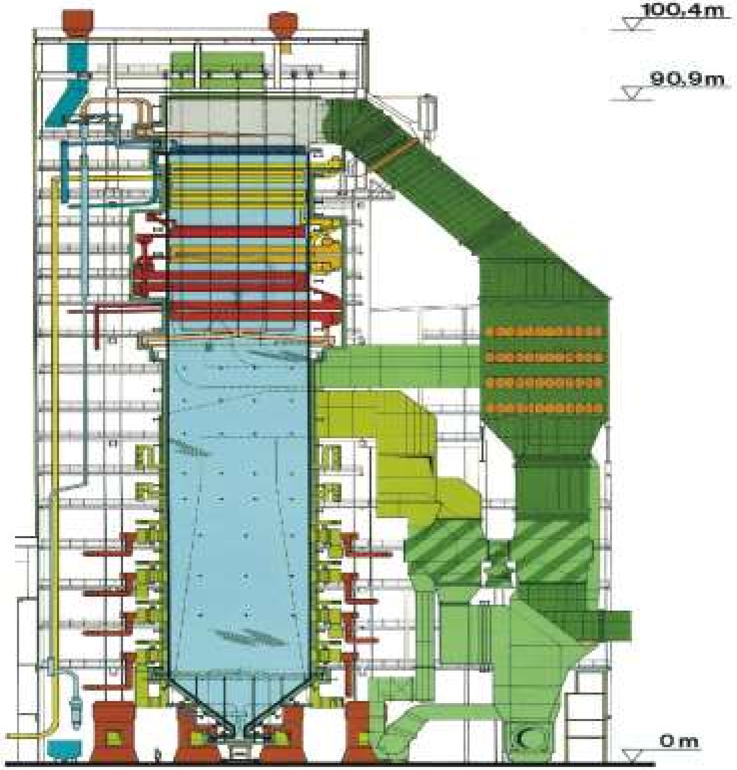

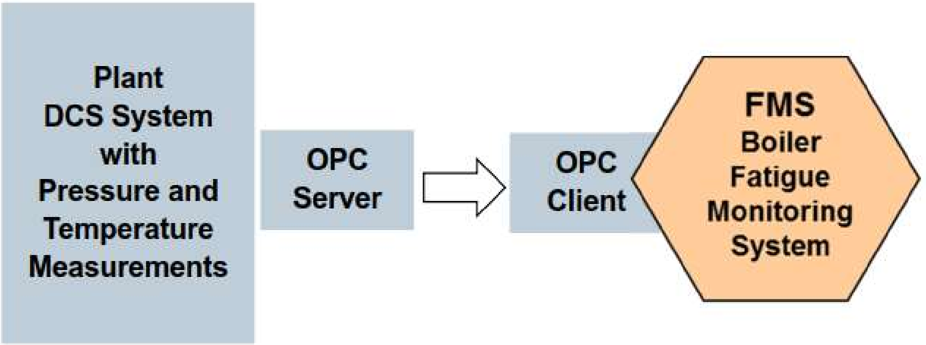

Typical components:

- 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