Efficiency Improvement on Steam Power Plants at Flexible Load Conditions

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Today’s and tomorrow’s Load Requirements

Energy from Renewables has feed-in priority in the grid

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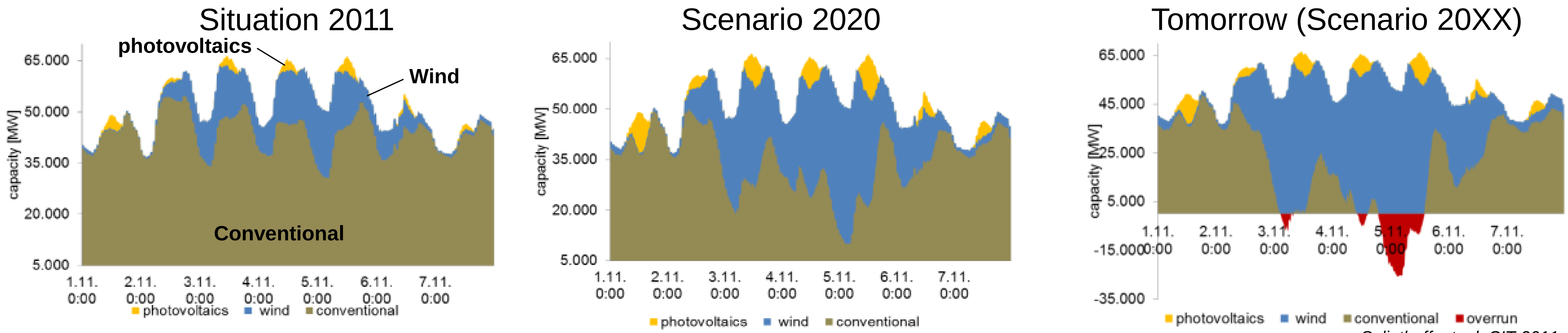


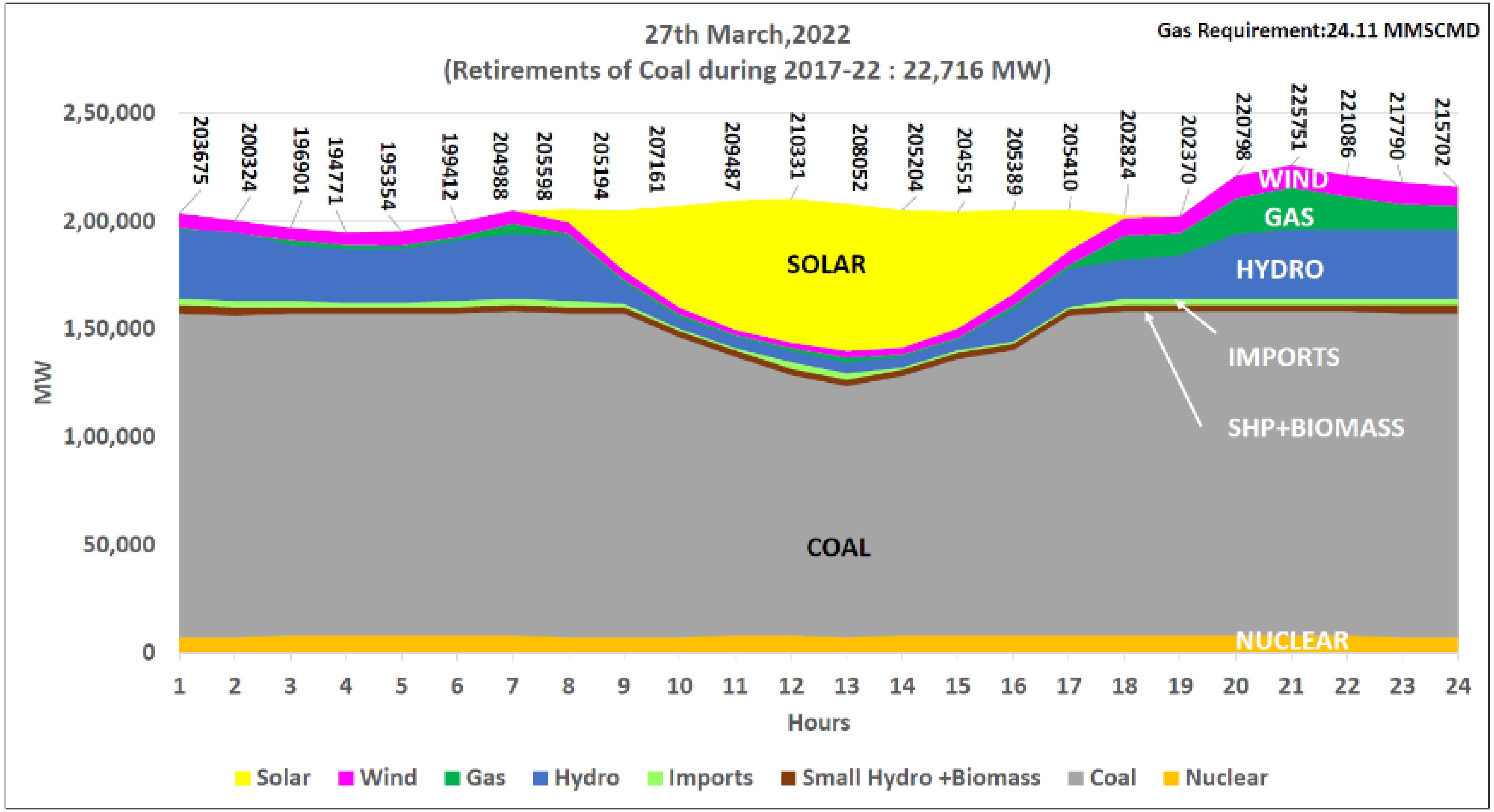
source: Spliethoff: et. al, CIT 2011

	Nuclear	Hard Coal	Gas
2011	Base Load	Base - Intermediate Load	Intermediate Load
2020	Intermediate Load	Intermediate Load	Peak load
20XX	Phase out	?	?

Energy market of tomorrow requires flexible fossil fired power plants

Conventional Power Plants need to be able to supply full power demand in times of non-availability of renewable energy

India Demand Scenario for 2022



Market requirements:
Changed operational regimes require highly flexible products

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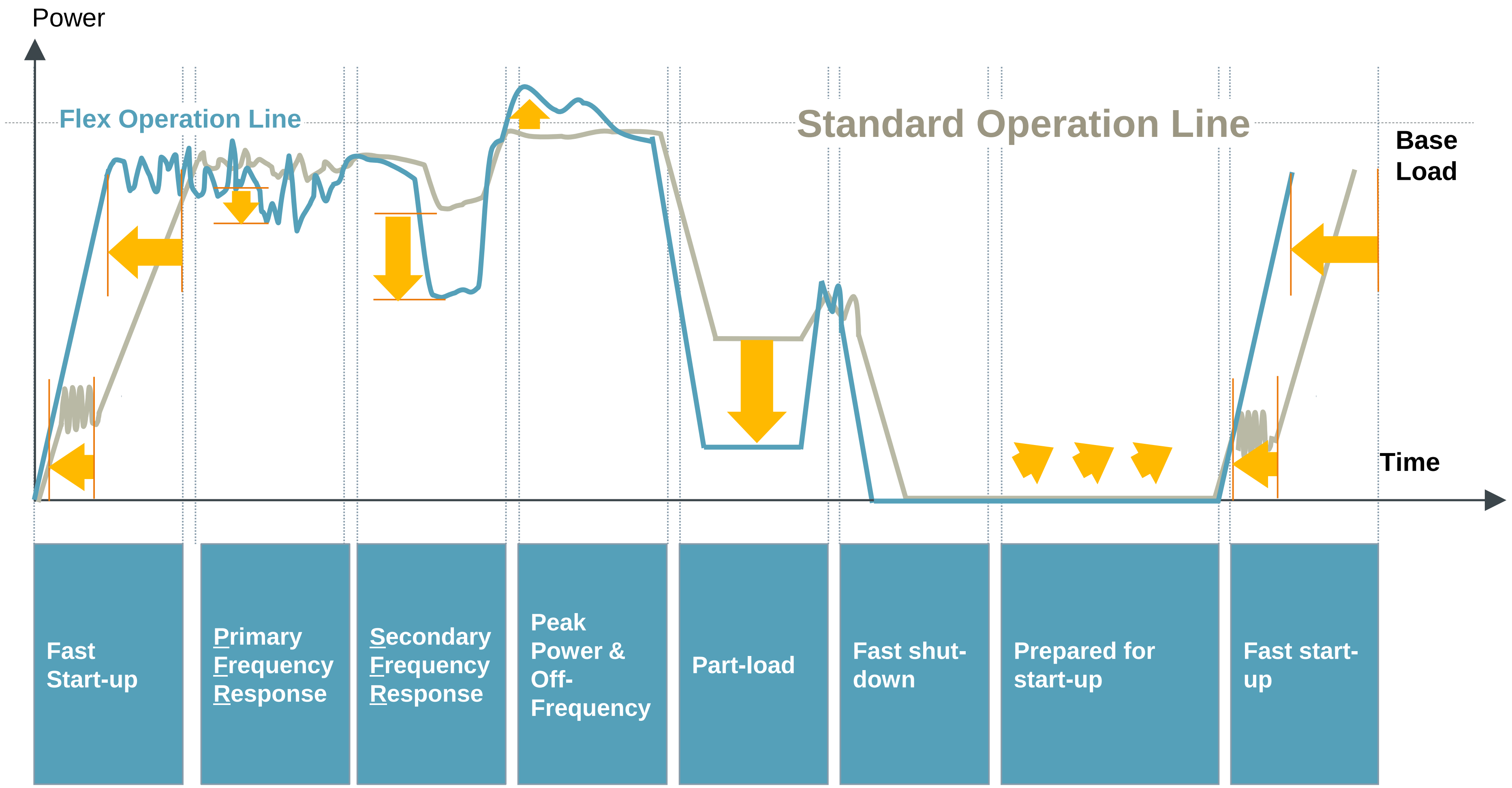

Increased flexibility leads to two main issues for Steam Power Plants

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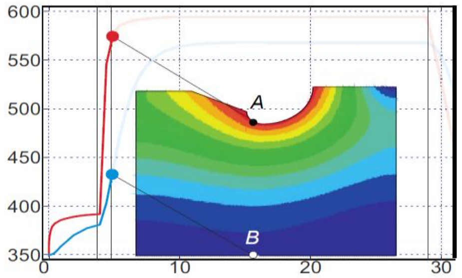
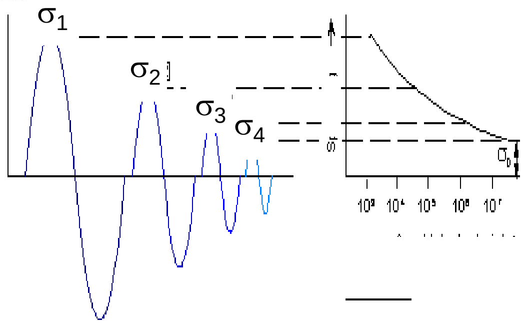
Increased number of starts & load changes

- High stress in component
- Increased wear and tear
- Reduced Reliability & Availability
- Increased maintenance cost





Decreasing number of generated Power

- Low efficiency in Part Load
- Lower number of generated MW
- Lower income

Steam Turbine Modernization can increase Part Load Efficiency and provide higher stress resistance

Steam Turbine configuration for 500MW coal-fired power plants (KWU-design)

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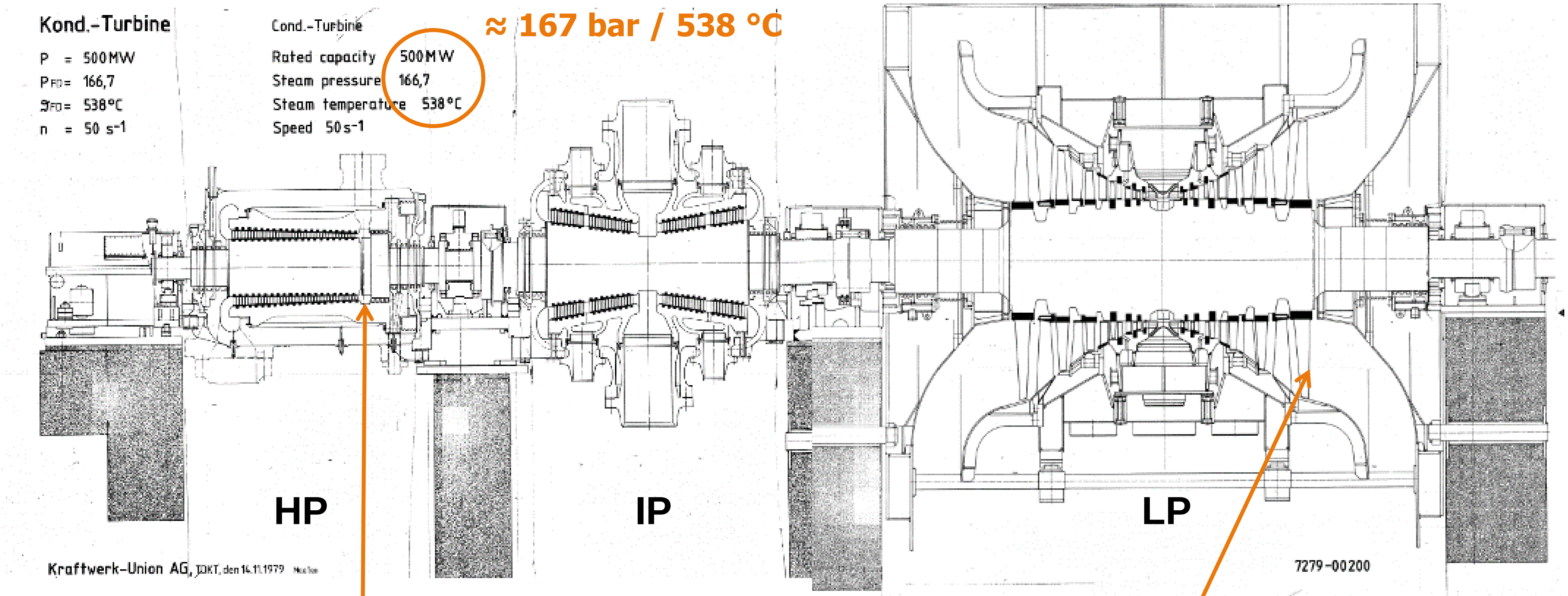
Turbine initially designed for fixed pressure operation !

≈ 167 bar / 538 °C



4 valves and inlets

2x10m²

Full Arc HP at Fixed Pressure Operation
Heat Rate loss of approx. 200 ckal/kwh at 40% load

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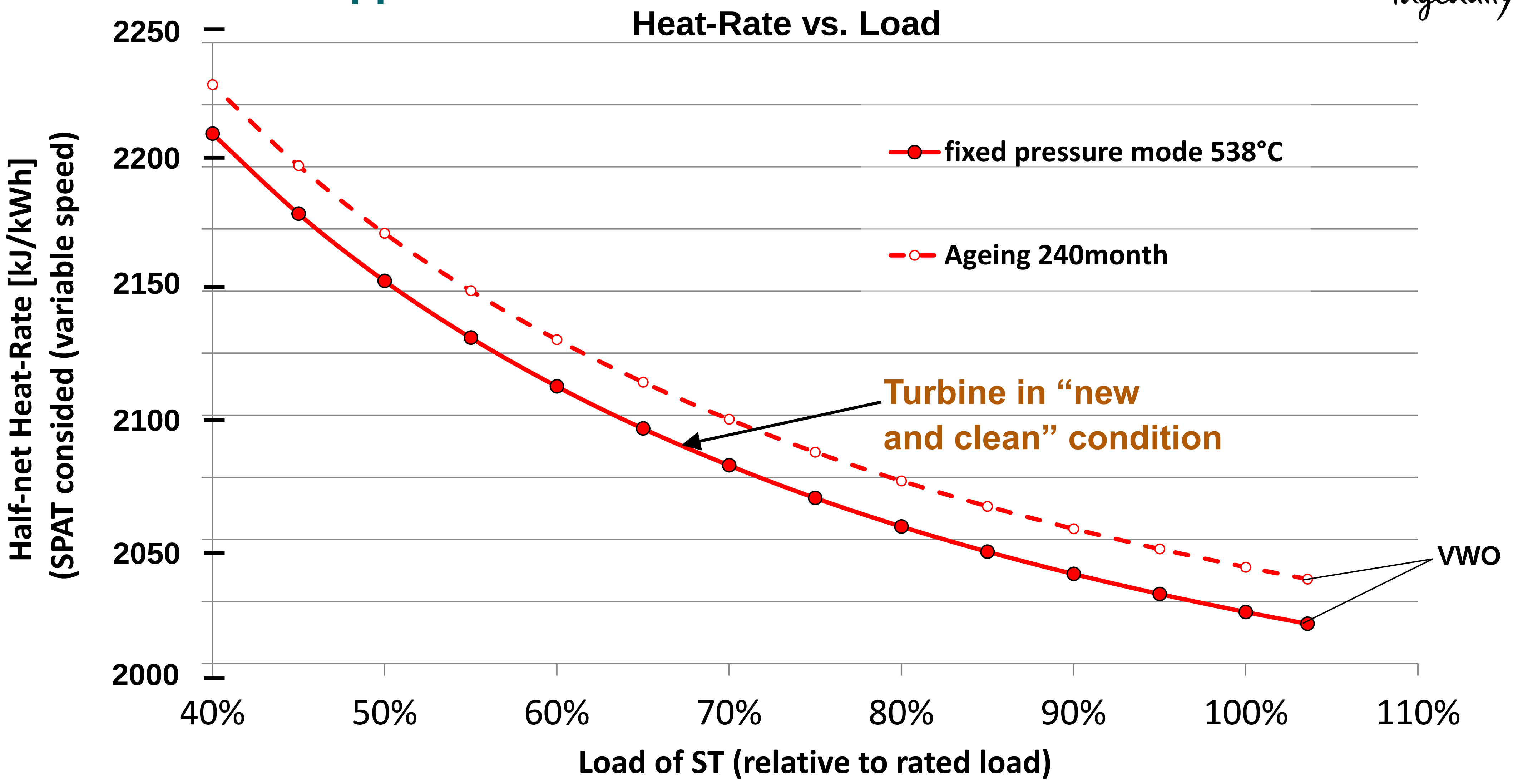

Water-Steam-Cycle
- Full load

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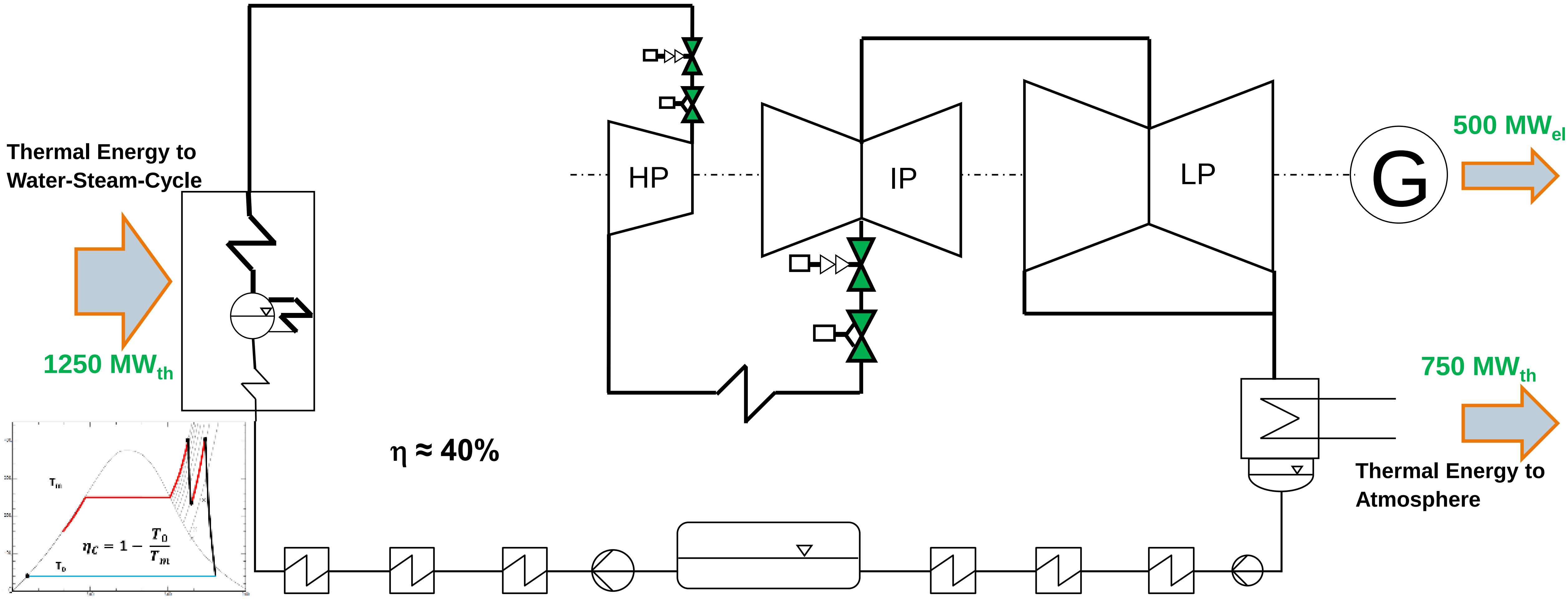

Water-Steam-Cycle
- Part Load (40%) with Fixed Pressure Operation

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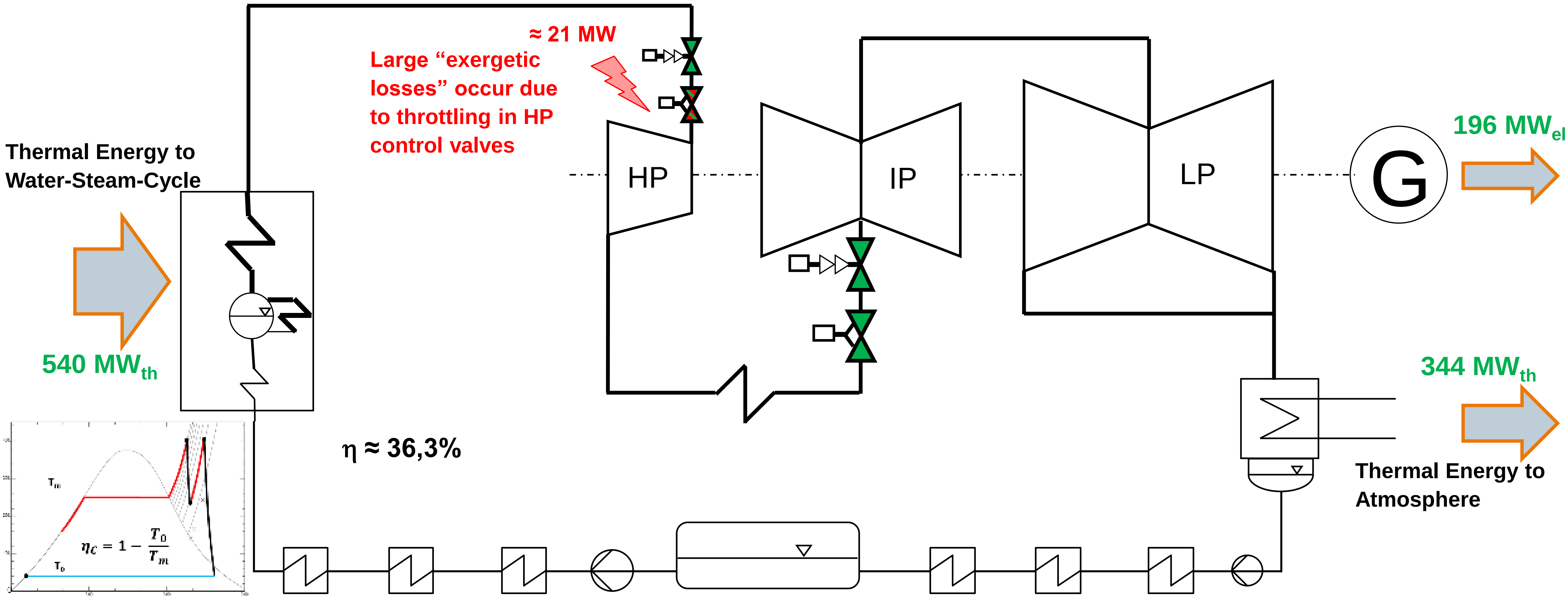

Water-Steam-Cycle
- Part Load (40%) with Sliding Pressure Operation

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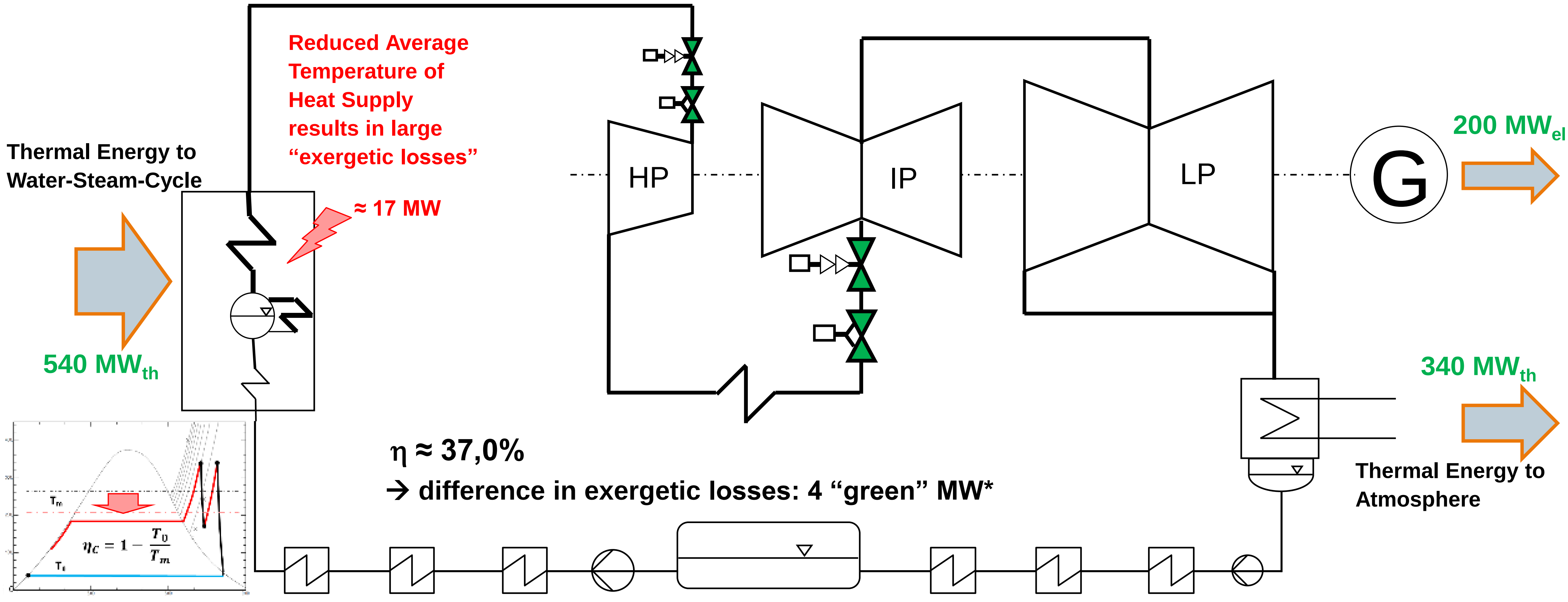

η ≈ 37,0%

→ difference in exergetic losses: 4 “green” MW*

*** compared to fixed pressure mode**

Heat-Rate vs. Load (Fixed-pressure vs. Sliding pressure)

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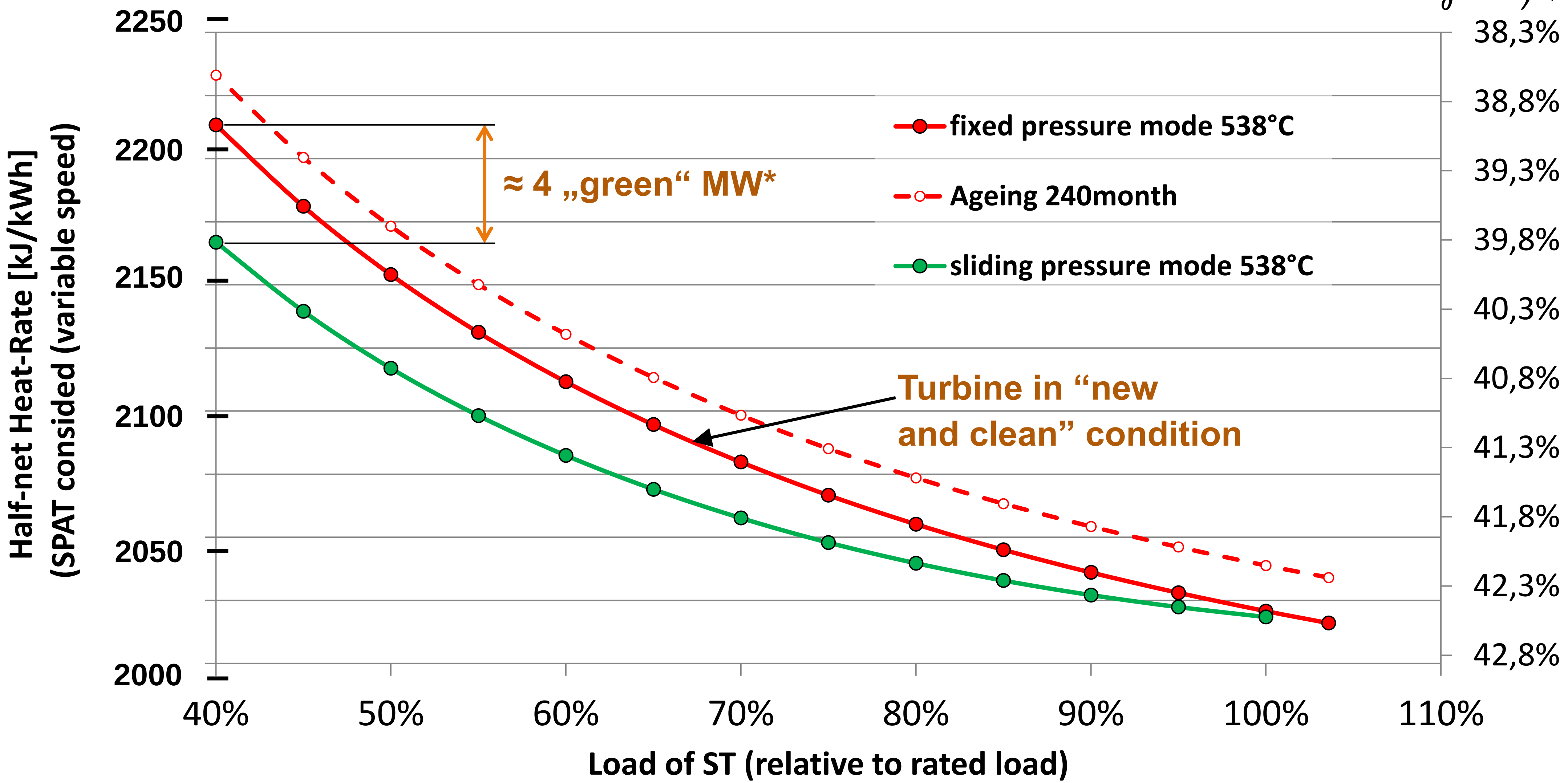
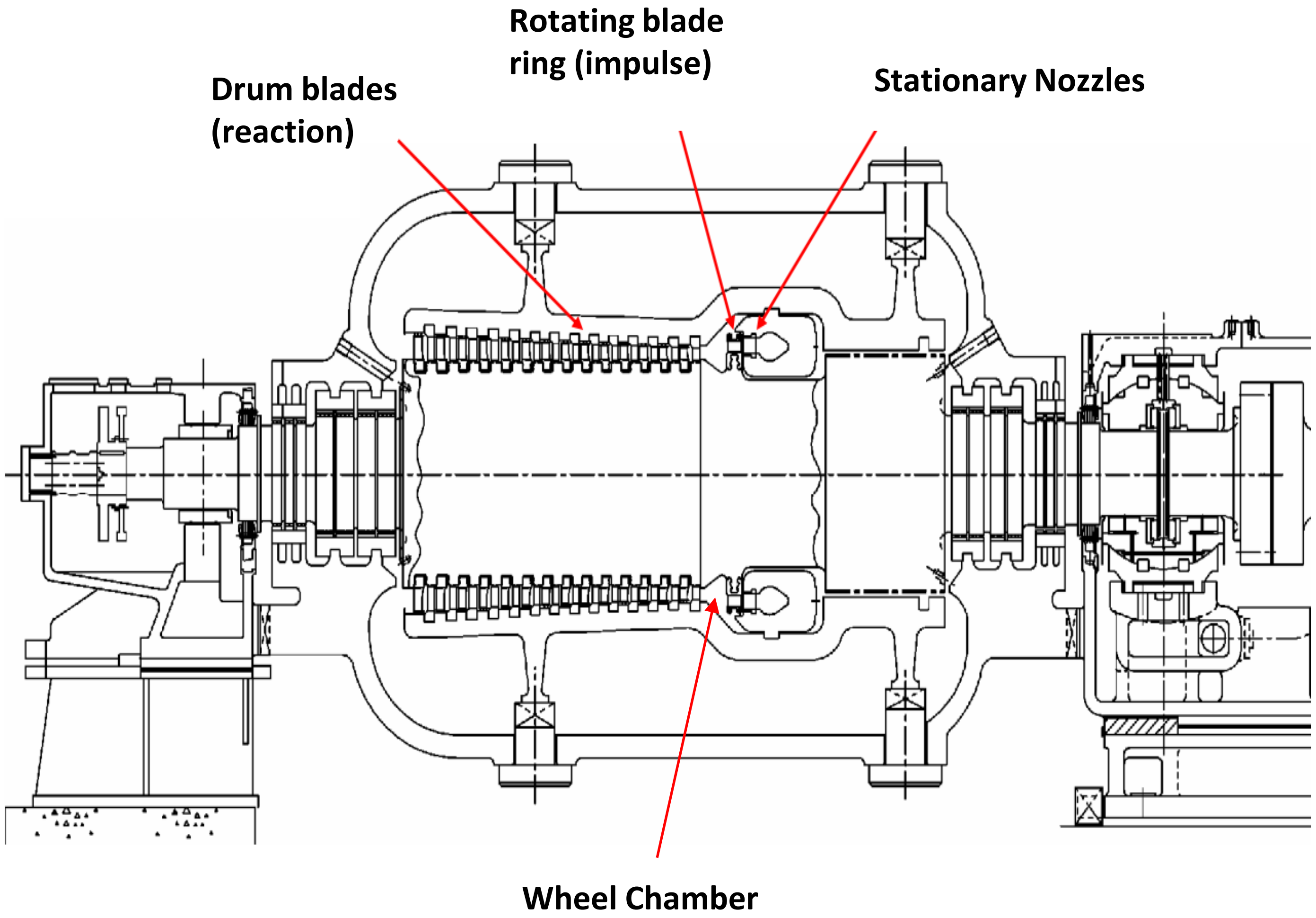
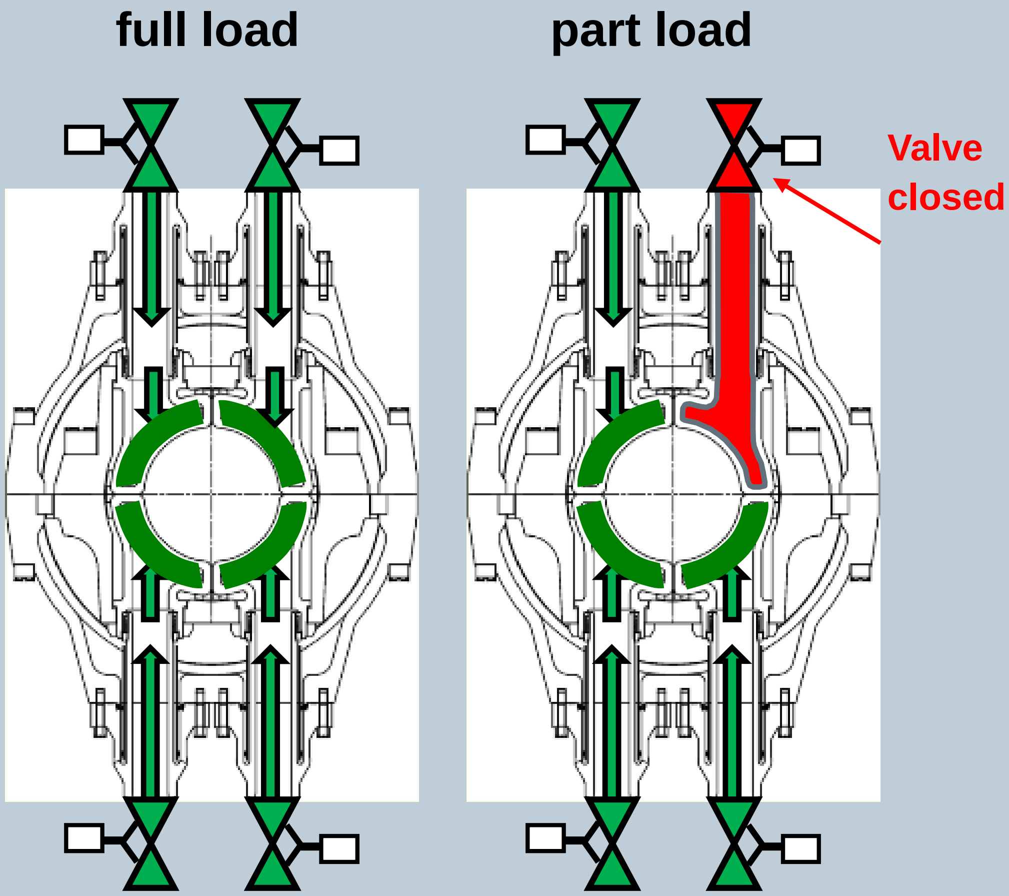


* Additional Power output due to better performance

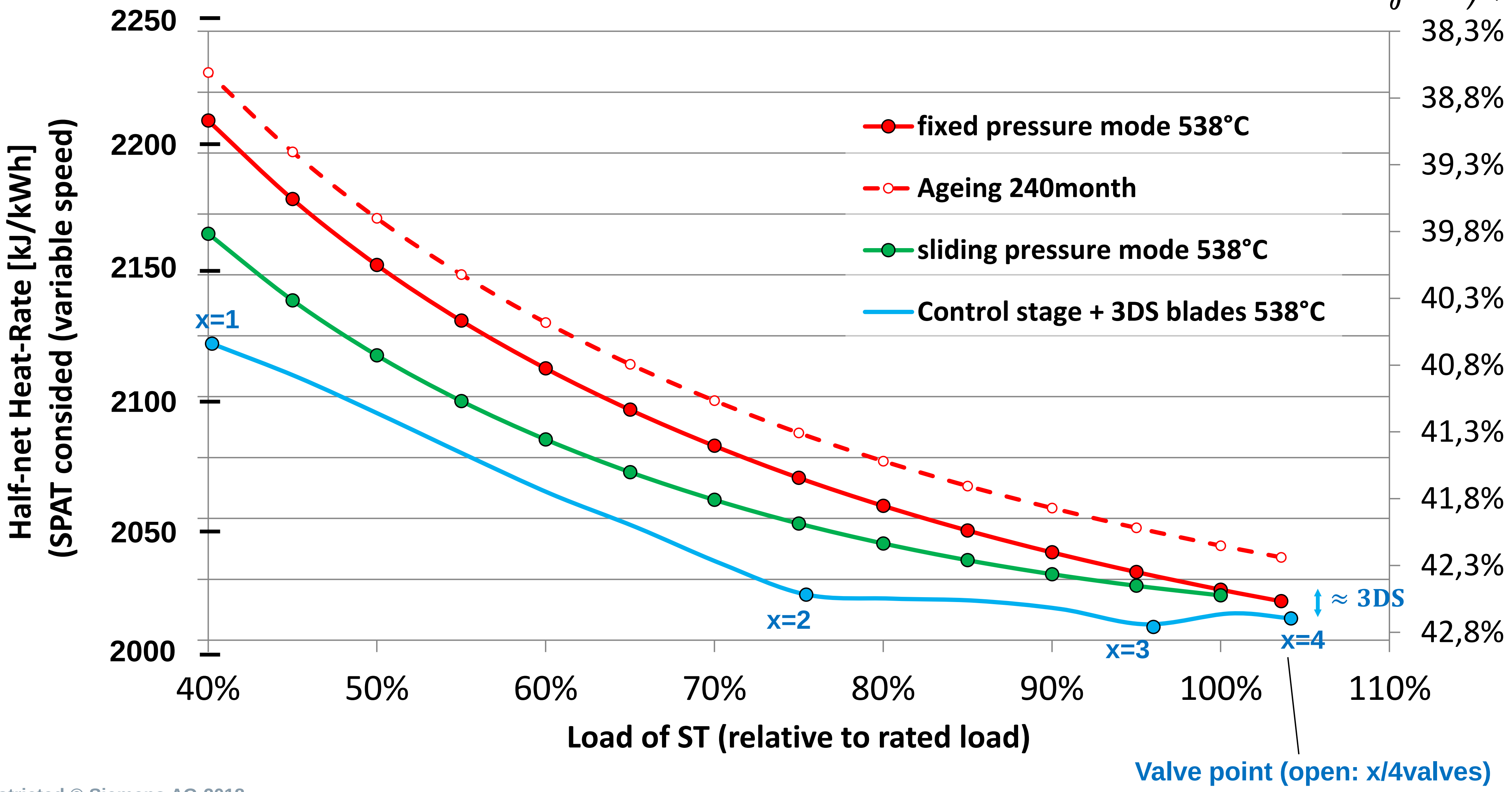
HP Steam Turbine with Control Stage



Valve operation Full Arc vs. Control Stage

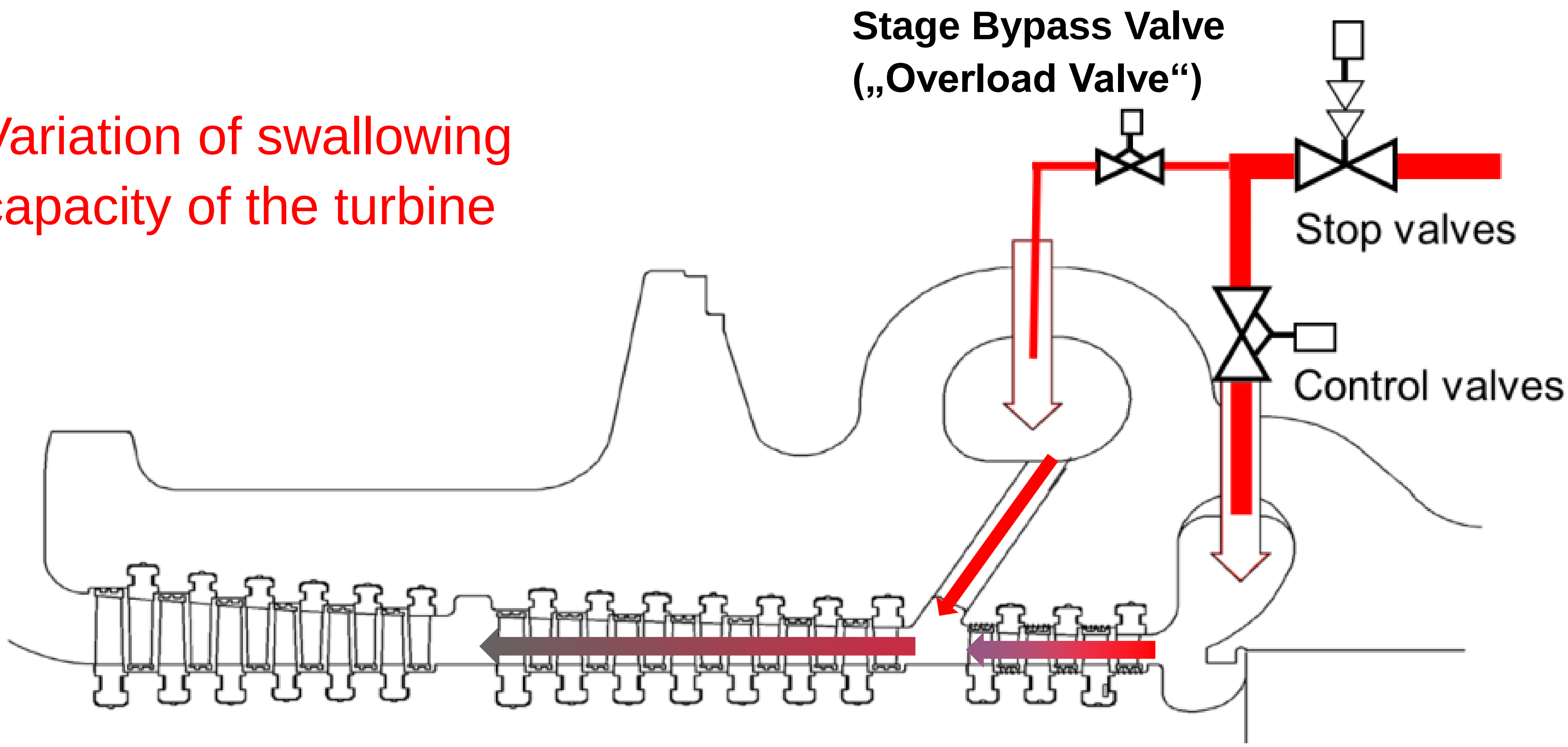


Heat-Rate vs. Load (incl. Control Stage)

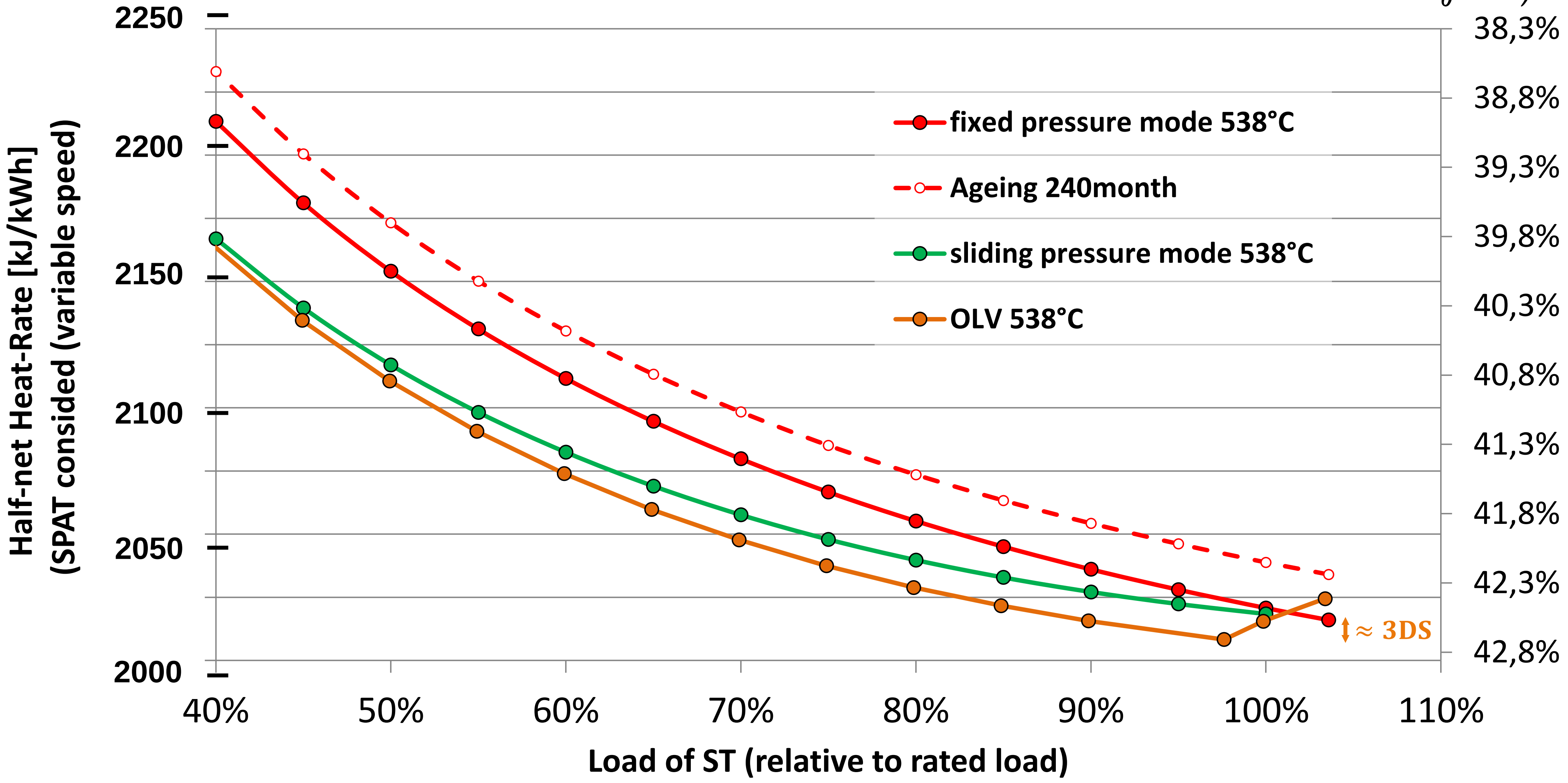


HP Stage Bypass Valve

→ Variation of swallowing capacity of the turbine



Heat-Rate vs. Load (incl. Stage Bypass)



Heat-Rate vs. Load (incl. Stage Bypass & Control Stage)

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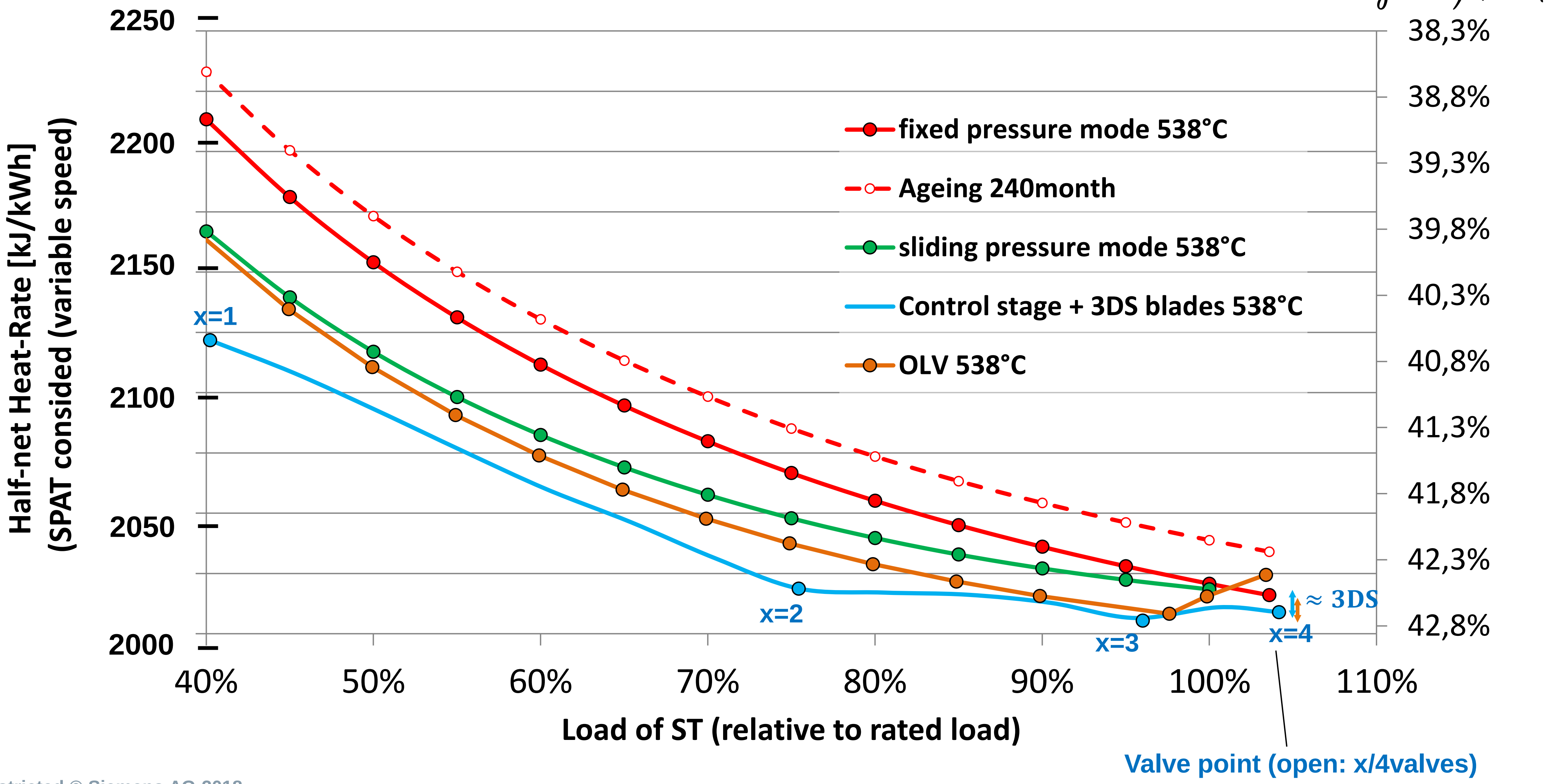

Additional “green” power (sliding pressure and Control Stage) can save up to 55.000 tons CO2 emission / year

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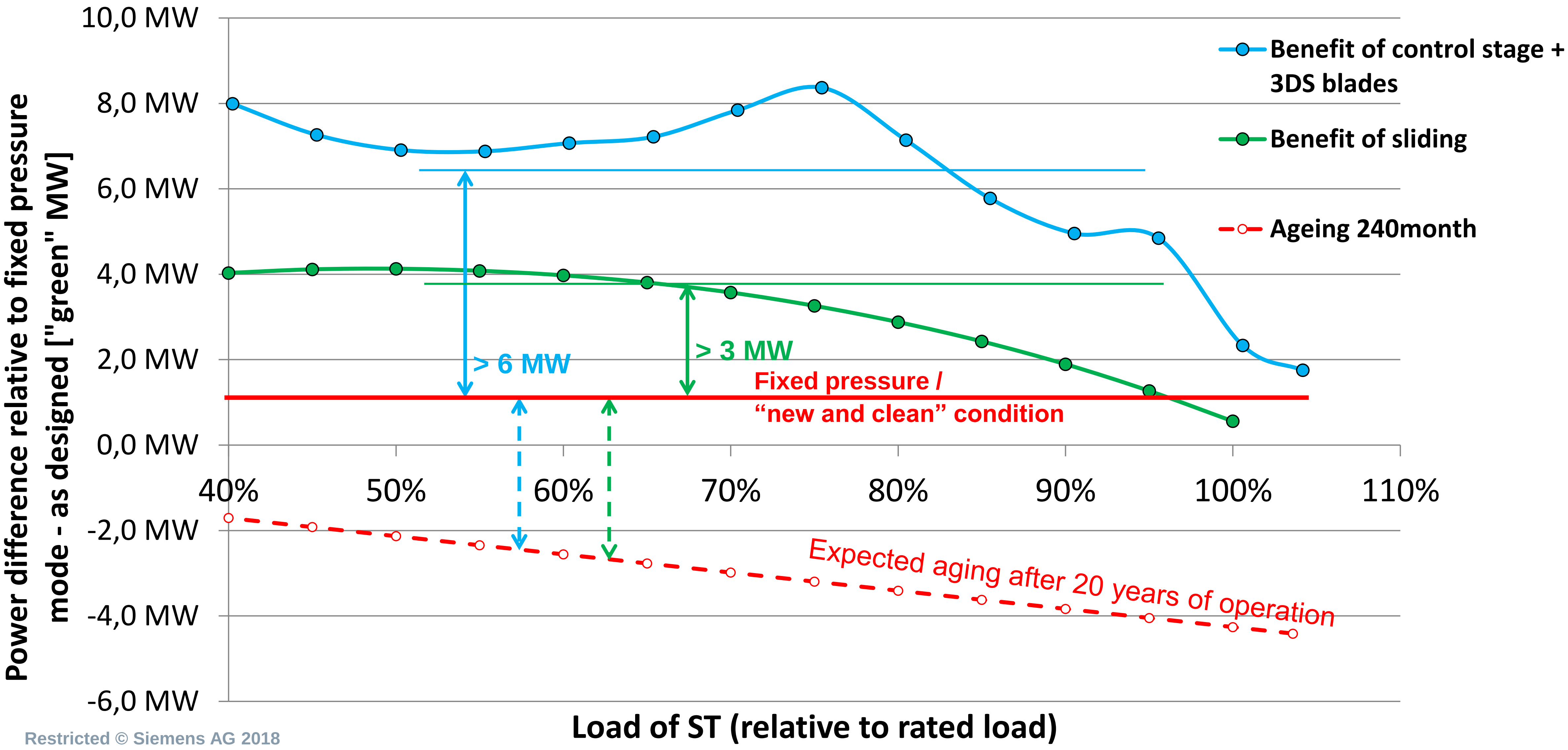

Scenario: Control Stage

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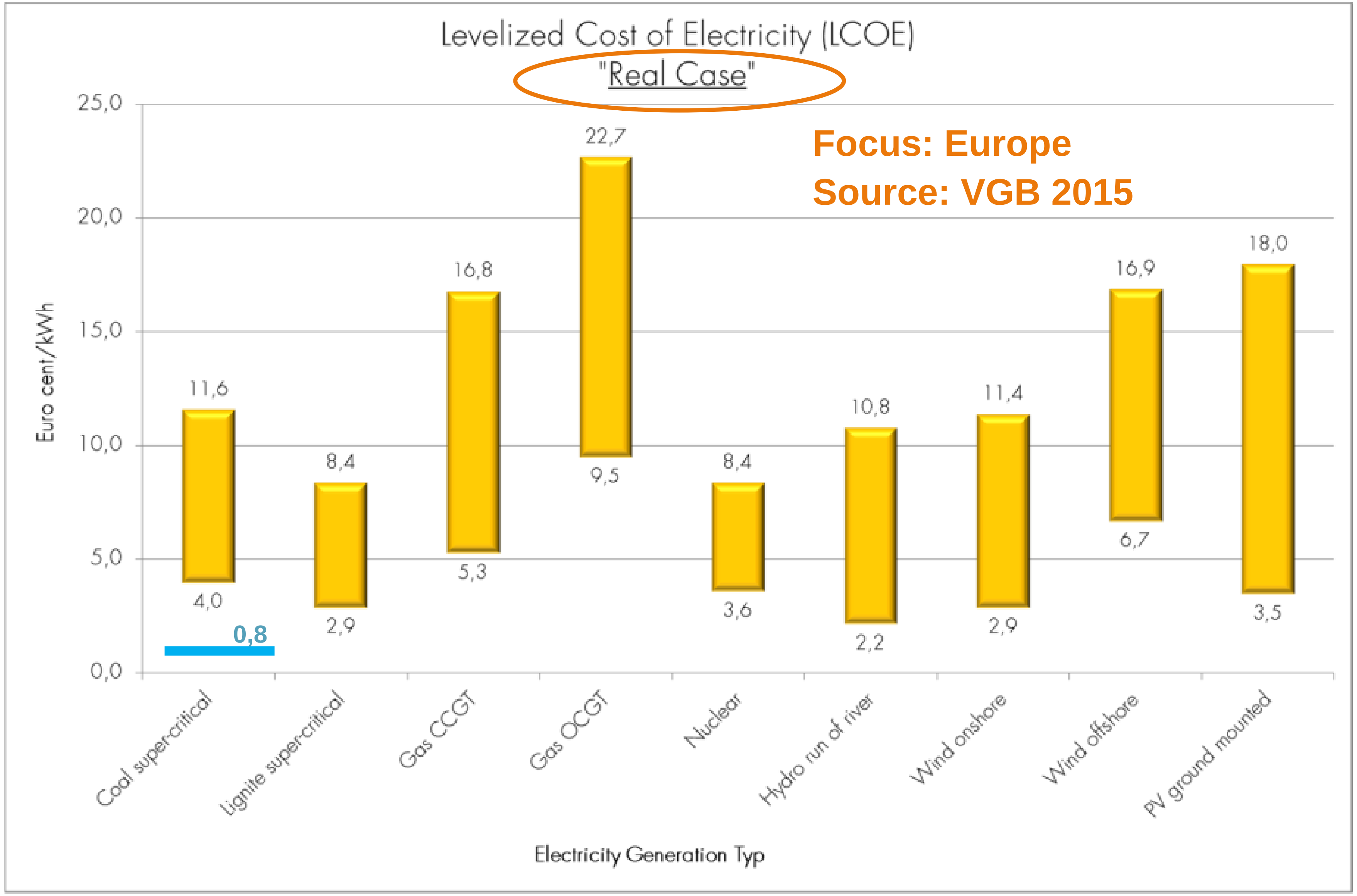
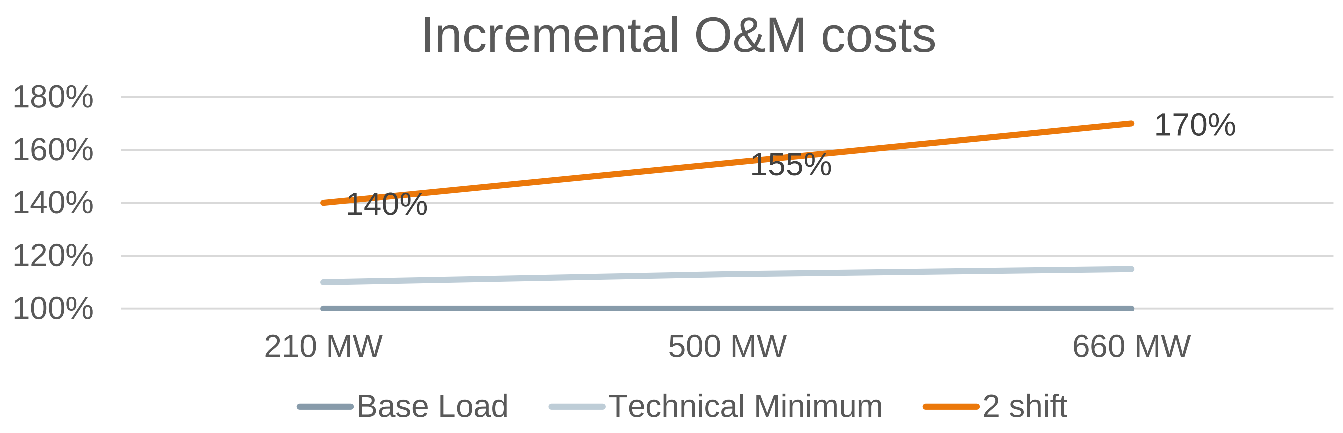


Costs of additional gained „green“ Electricity much lower compared to new power plants

Lower technical minimum is better than two shift operation

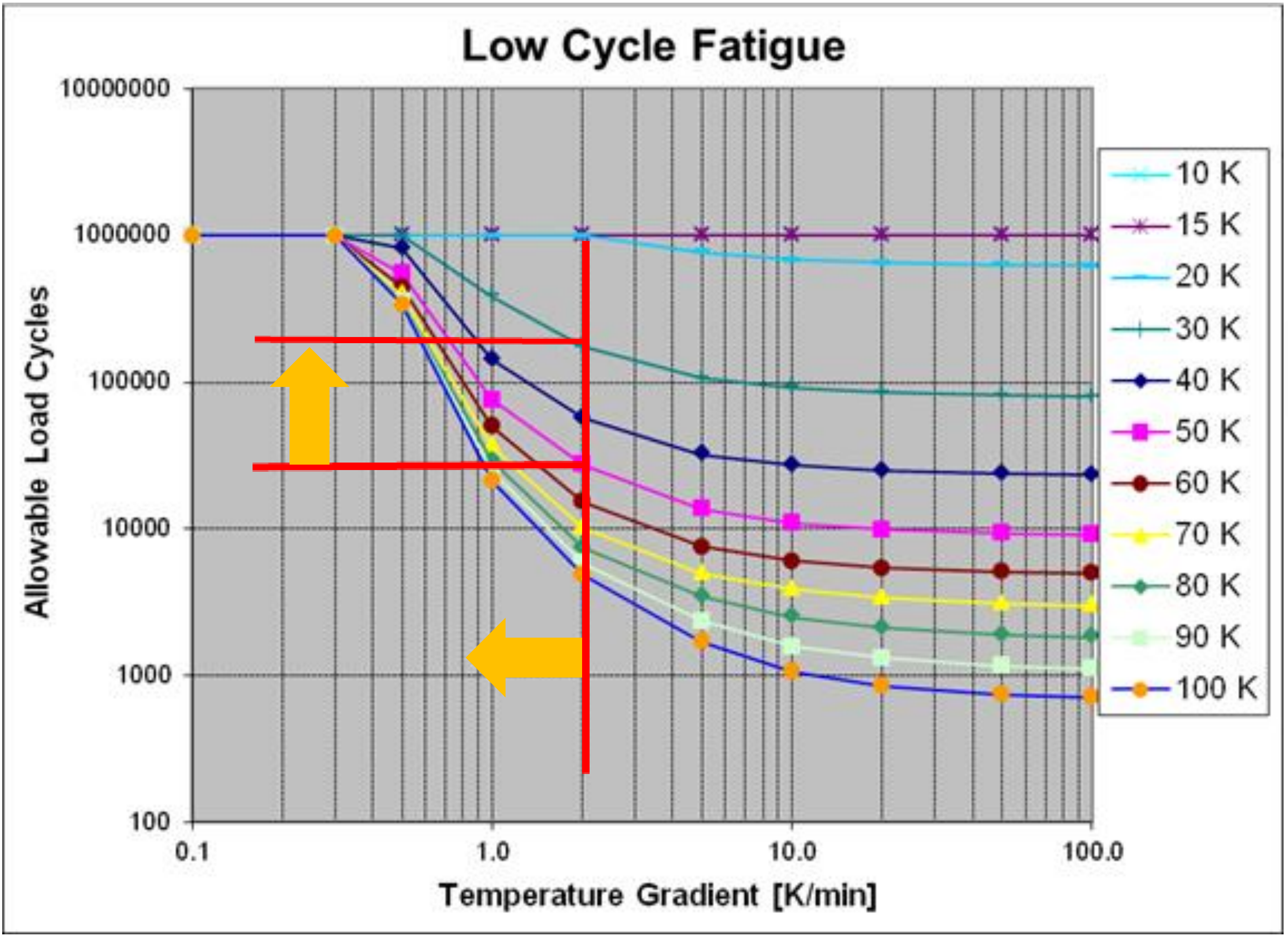
Comparison of life consumption based on cold, warm and hot start

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	-	

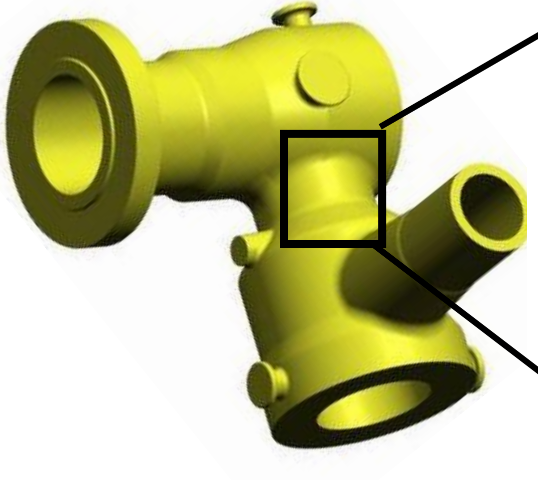


Transient Operation (Ramp Up / Ramp Down)

increased temperature gradient results increased life consumption



Main steam valve



Crack depth: 50% wall thickness

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

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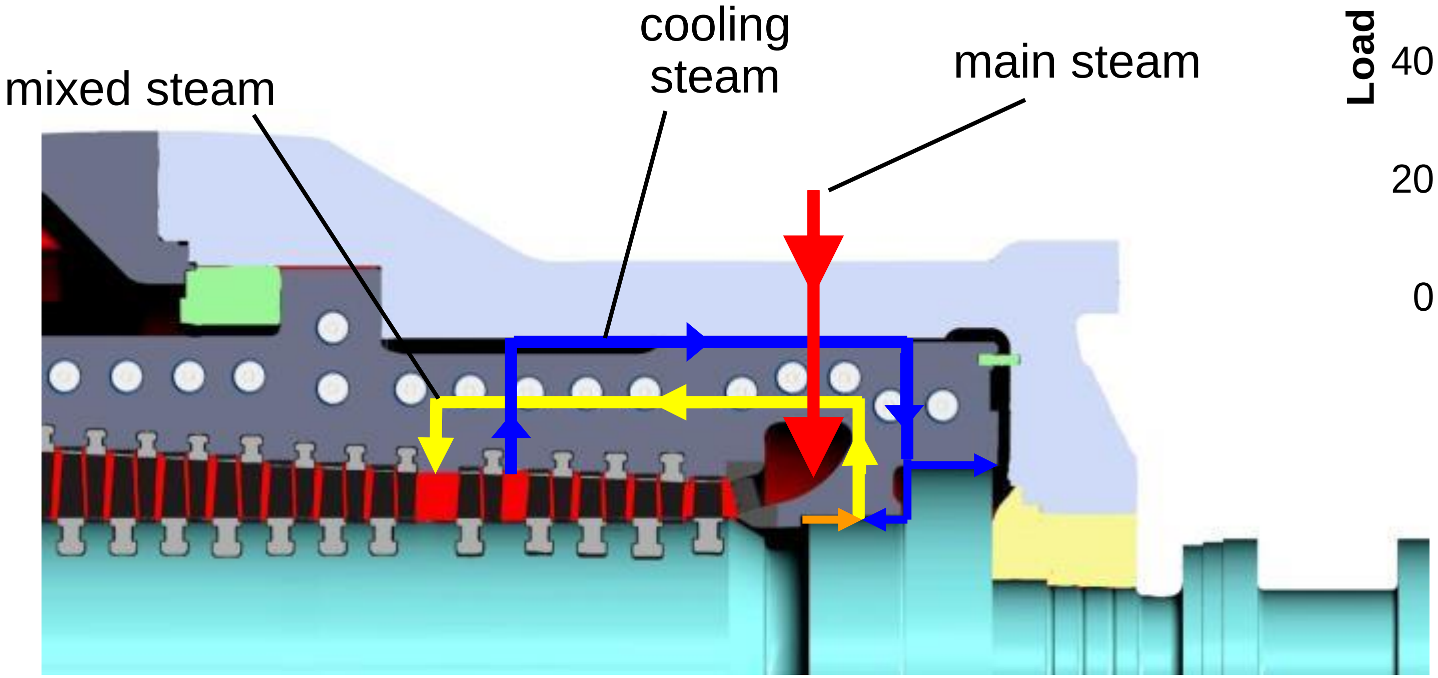
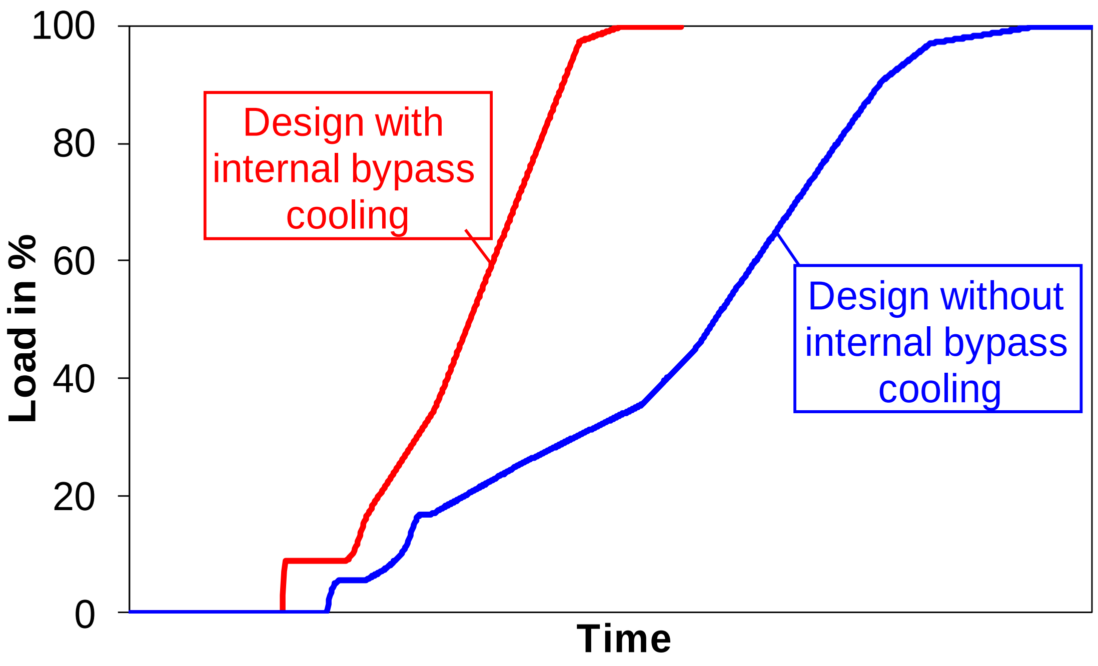
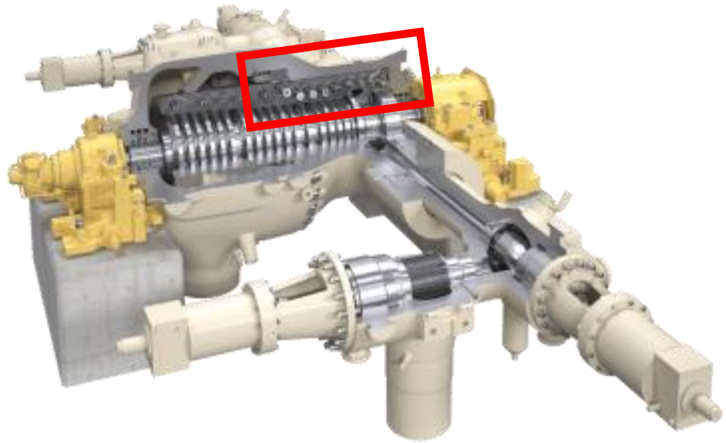
Example: Reduced Casing thickness & reduced thermal piston loading by HP bypass cooling

Significant improvement in LCF







Primary Frequency Control
- Situation in Germany

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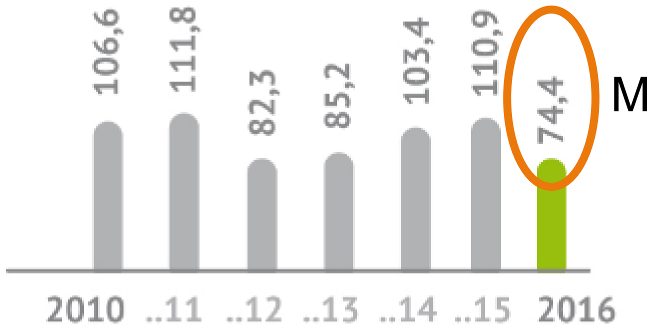
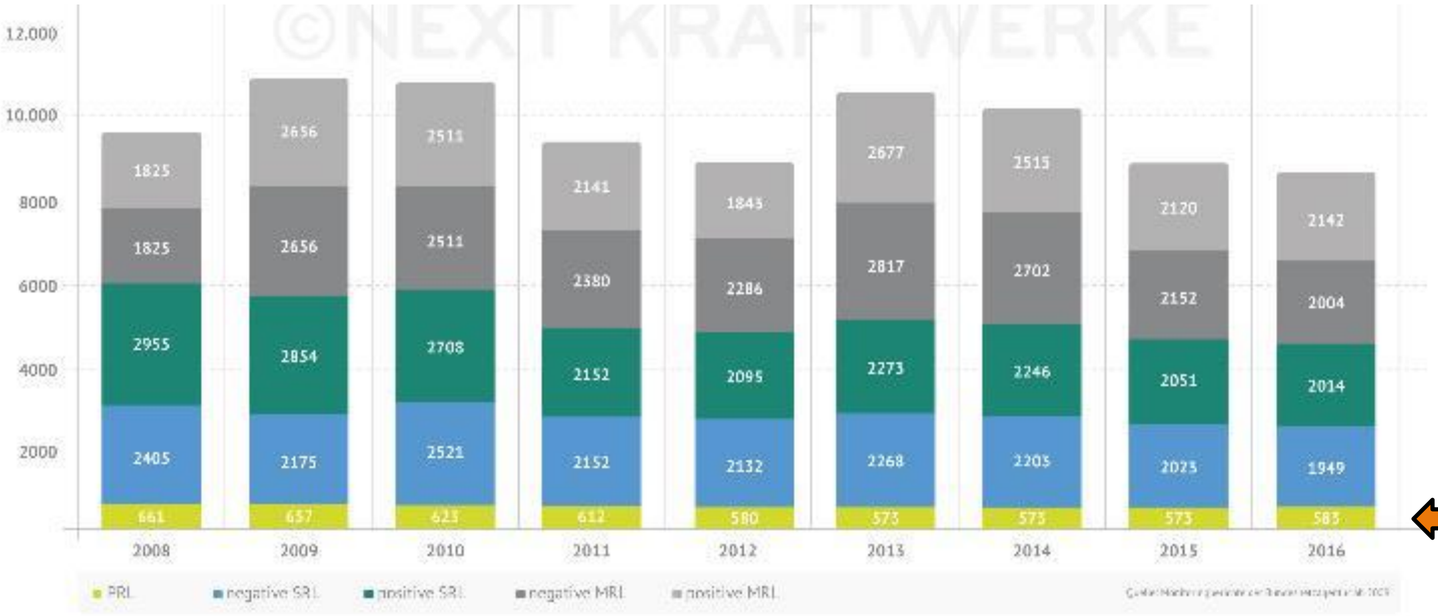


Cost for Primary Control Power
(weekly e-auction)



Demand ≈ 600MW
(for Germany)

PRL „Primary Control Power“ → to be activated within 30 seconds

For allocating (positive and negative) Power for Primary Frequency Control specific prices of 2000 – 2500 € per MW and week are paid.

HP Steam Turbine Solution

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- The Heat Rate increases in part load operation which results in higher CO_2 emission and coal consumption
- Boiler Sliding Pressure Operation reduces the losses, however to the disadvantage of controllability.
- HP with Control Stage provides the lowest heat rate losses and maintains controllability.
- HP Modernization is required to implement the Control Stage
- With a HP Modernization the aging will be reversed and additional efficiency improvement can be gained by using state of the art blading and sealing technology.
- HP design update can reduce the stresses in cycling operations.
- The return of investment for the Steam Turbine modernization is lower than all other Cost of Electricity measures.
- Condensate throttling allows for fast load ramp rates.
- ST Mods and Flex-Power Services™ solution (e.g. I&C) can provide additional improvement in Flexibility and Efficiency