Flexible operation of Thermal Power Plants – OEM Perspective and Experiences

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- Capacity, Demand and Supply
- Market requirements for flexible operation
- Technical background: transient operation
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Technology development of steam parameters

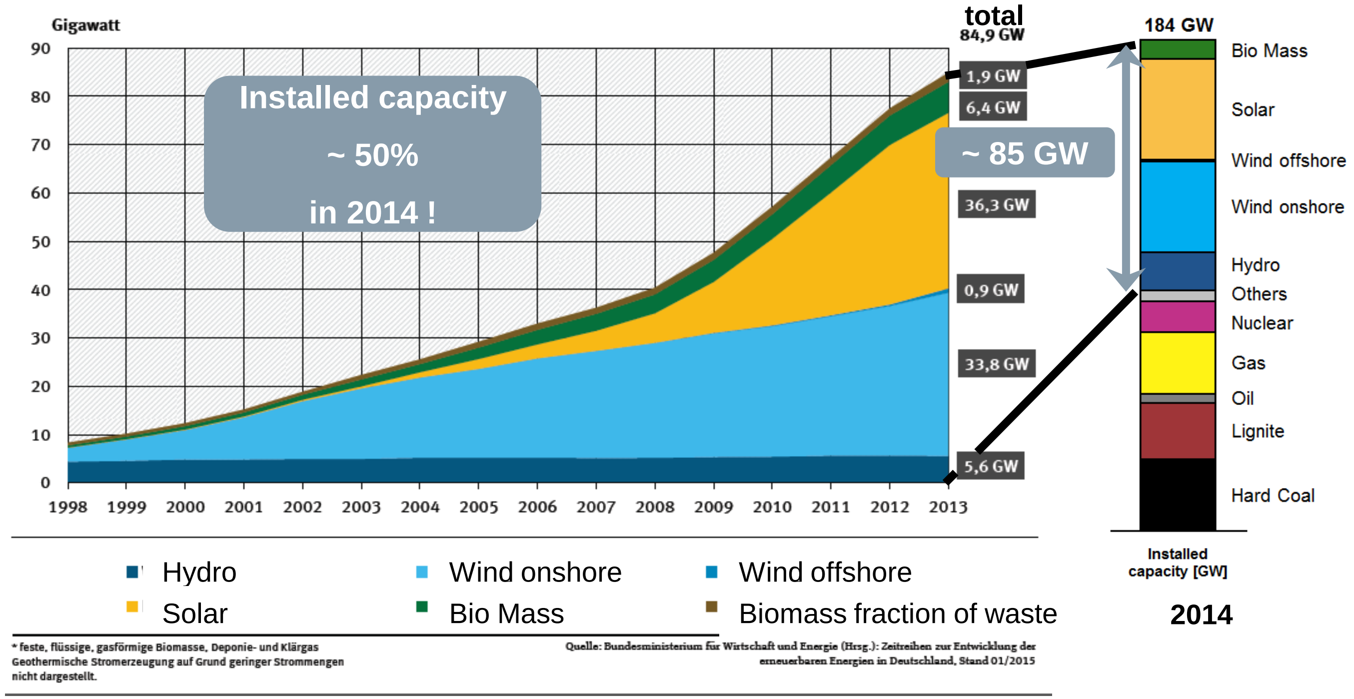
Reference examples state-of-the-art efficiency

1981	1996	2005	2013	> 2020
				
SPP Bergkamen 747 MW	**SPP Boxberg 906 MW**	**SPP Yuhuan 1,000 MW**	**Lünen 812 MW**	**Pingshan II - Double Reheat 1350 MW**
39% SPP efficiency	**42 %** SPP efficiency	**45%** SPP efficiency	**46%** SPP efficiency	**52+%** [1)] SPP efficiency
190 bar 530 / 530 ºC	**260 bar 540 / 580 ºC**	**262 bar 600 / 600 ºC**	**270 bar 600 / 610 ºC**	**325 bar 610 / 630 / 630 ºC**
				350 bar 700 / 720 ºC

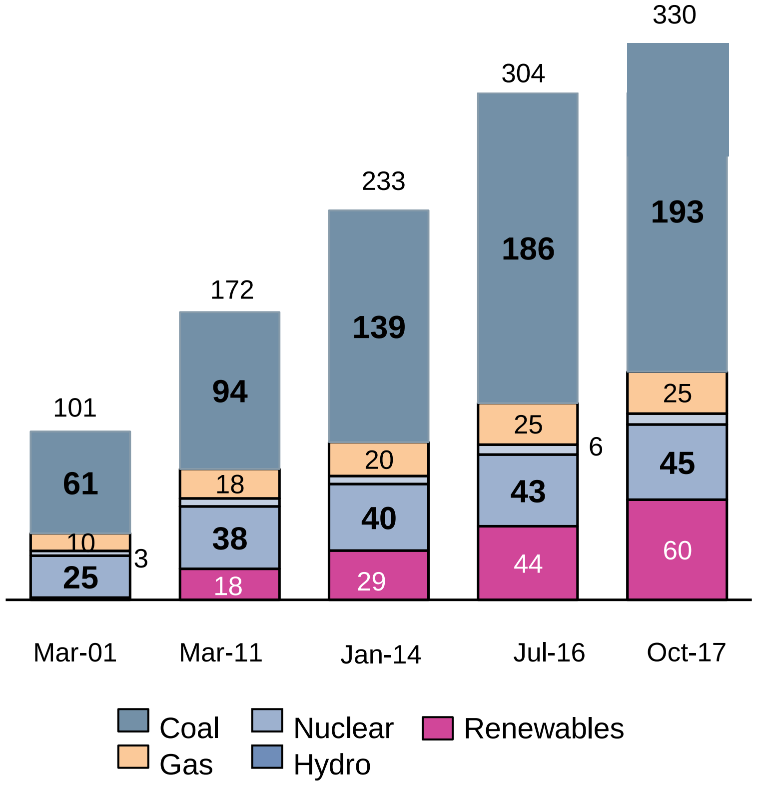
1) Gross efficiency achievable with this technology – offered

Market requirements
Generation scenario in Germany and India

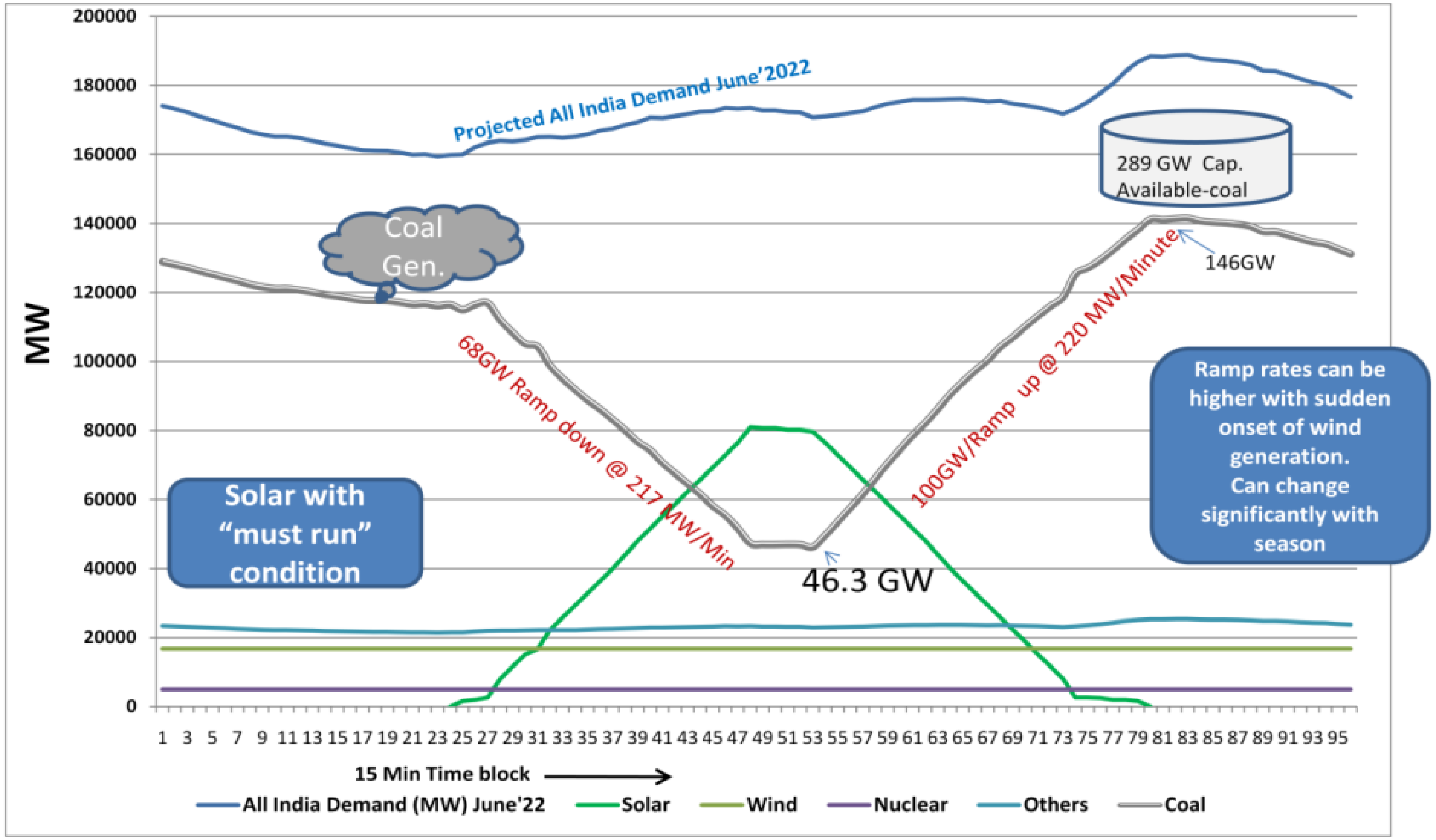
Development of capacity of renewables Germany



Installed Generation Capacity India (GW)



Anticipated Scenario in 2022 with 100 GW Solar & 60 GW Wind

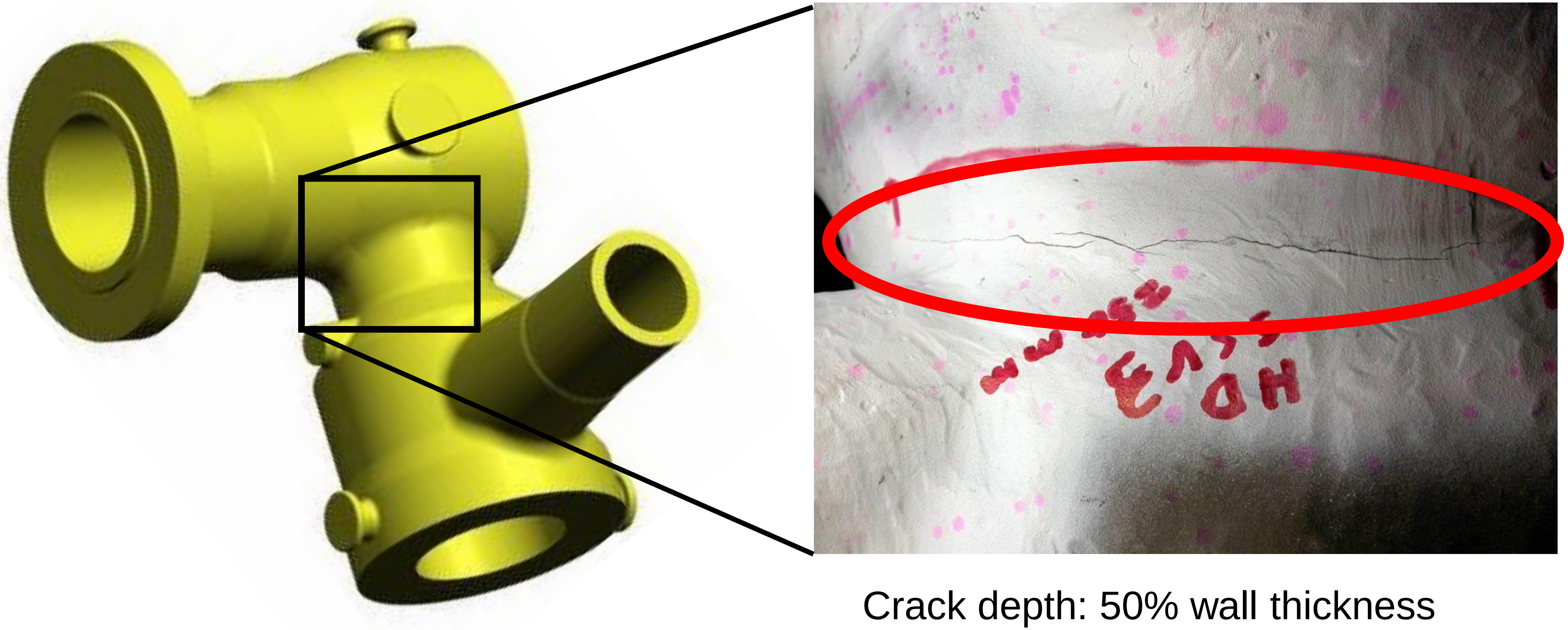


Lower Technical Minimum	Primary and Secondary frequency Control
Faster Ramp up	Faster Ramp down

Technical background: Transient Operation

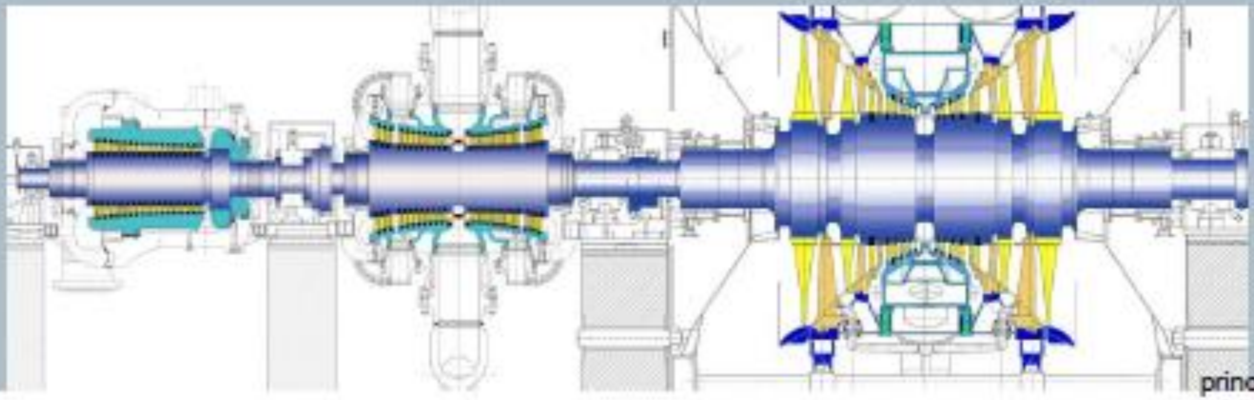
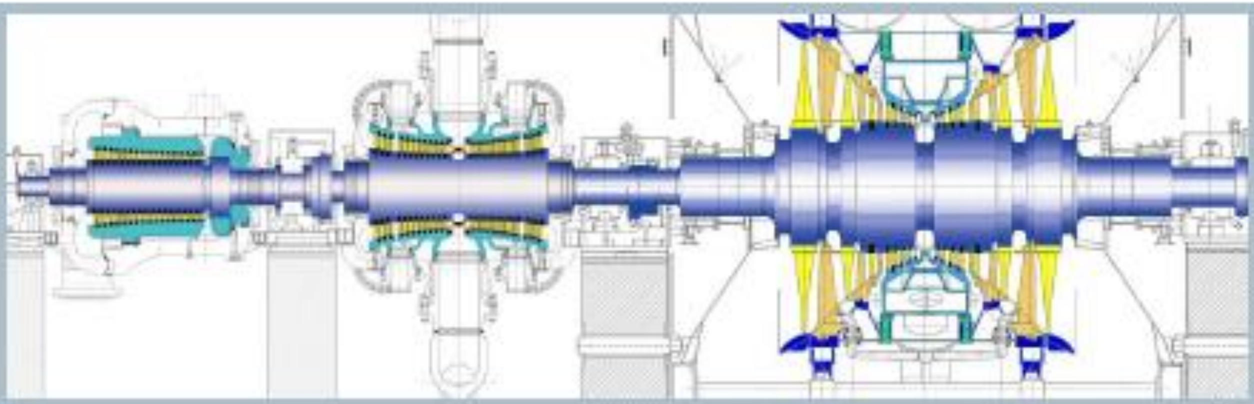
Recent Findings at a Highly Cycling Unit (operated outside limits)

Main steam valve



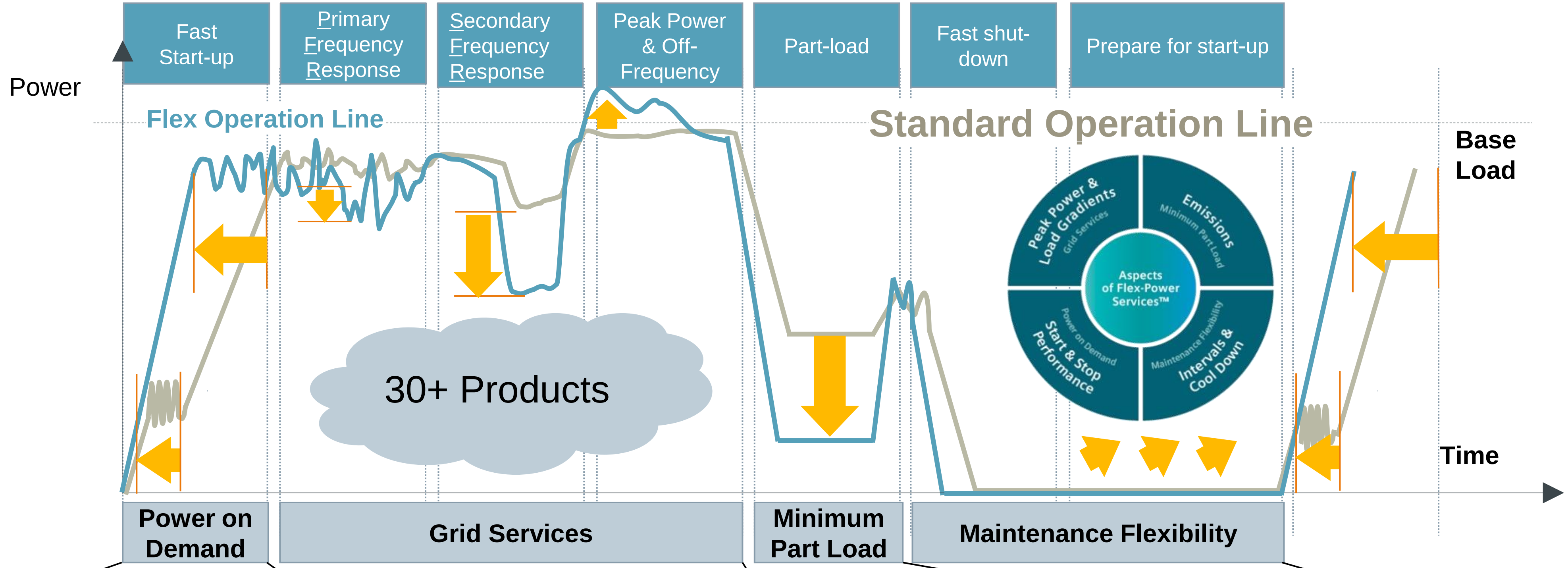
Crack depth: 50% wall thickness

Siemens Fleet in India

KWU 200 / 210 MW	HP	H30-25	
	IP	M30-25	
	LP	N30-2x5m^2	
KWU 500 MW	HP	H30-63 H30-100	
	IP	M30-50 M30-63	
	LP	N30-2x10m^2	

Modernize existing plant with flexible operation as key element to them

Market requirements:
Changed operational regimes require highly flexible products

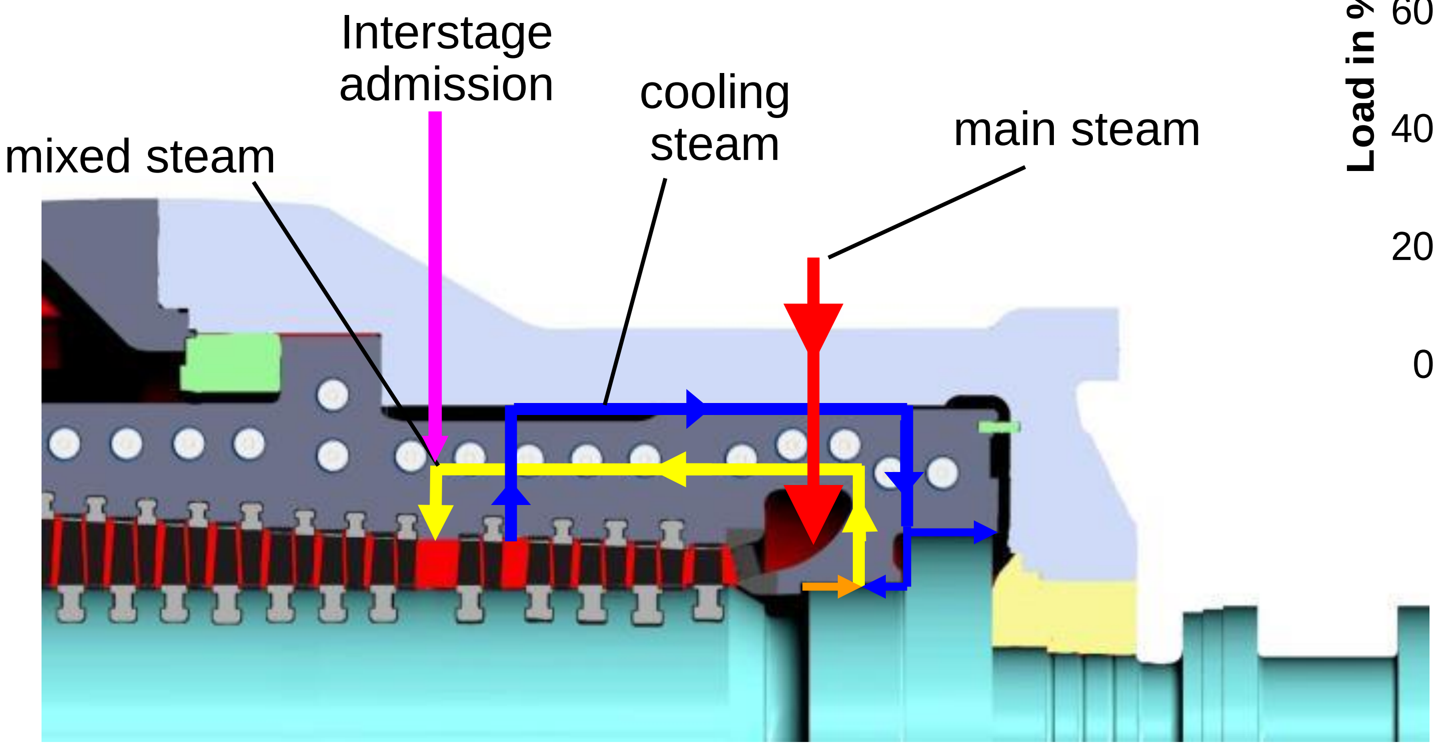


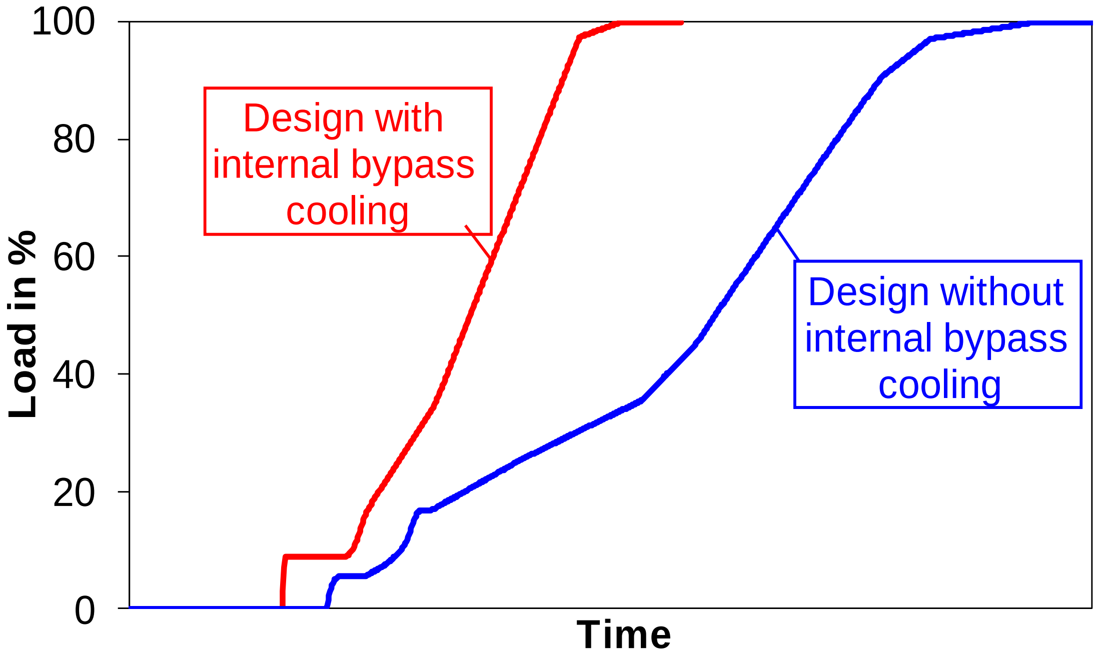
Power on Demand	Grid Services	Minimum Part Load	Maintenance Flexibility
• ST Stress Controller	• Advanced Fast Loading	• HP Turbine with Last MS-Valve	• Fast Preservation
• SPP Hot Start On The Fly	• Primary Frequency Response	• Partial Bypass Concept	• Fast Cooling
• HP internal bypass cooling	• Condensate 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			

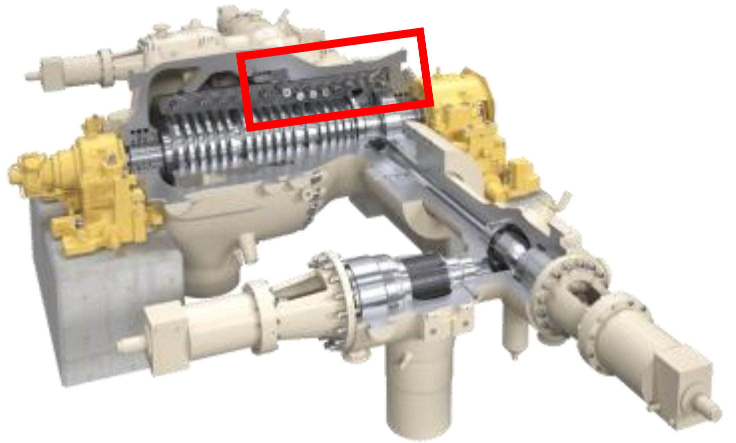
Reduction of Wall Thickness to Improve Start Up & Cycling Capabilities

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

Significant improvement in LCF



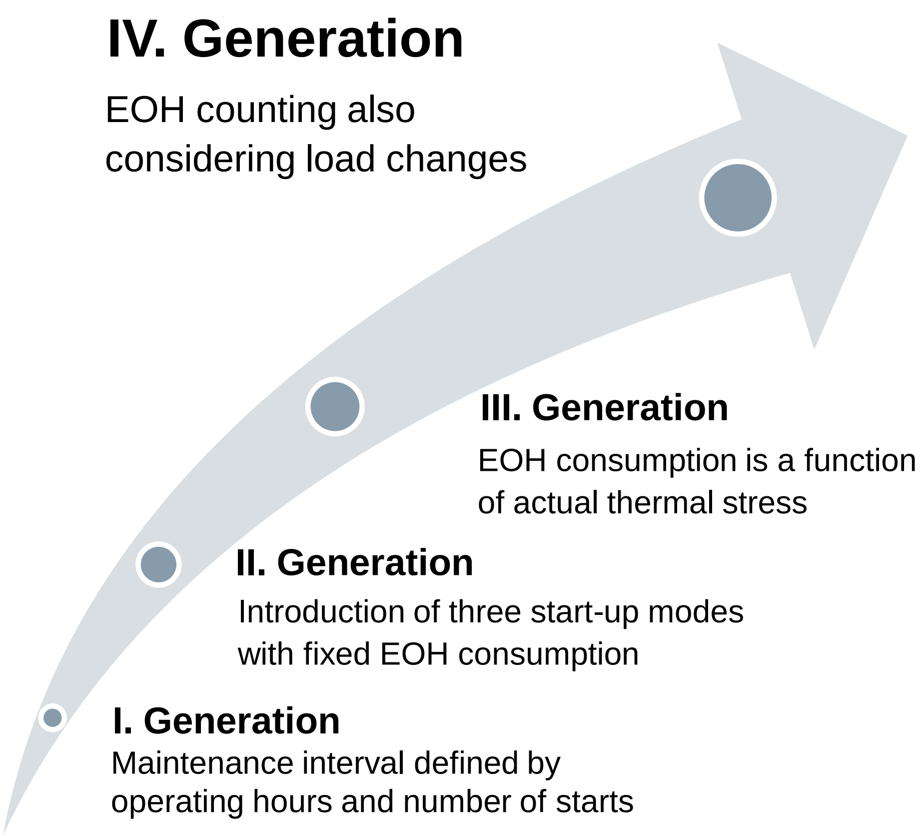




Power on Demand
Monitoring of flexibility consequences: steam turbine EOH counter 4.0

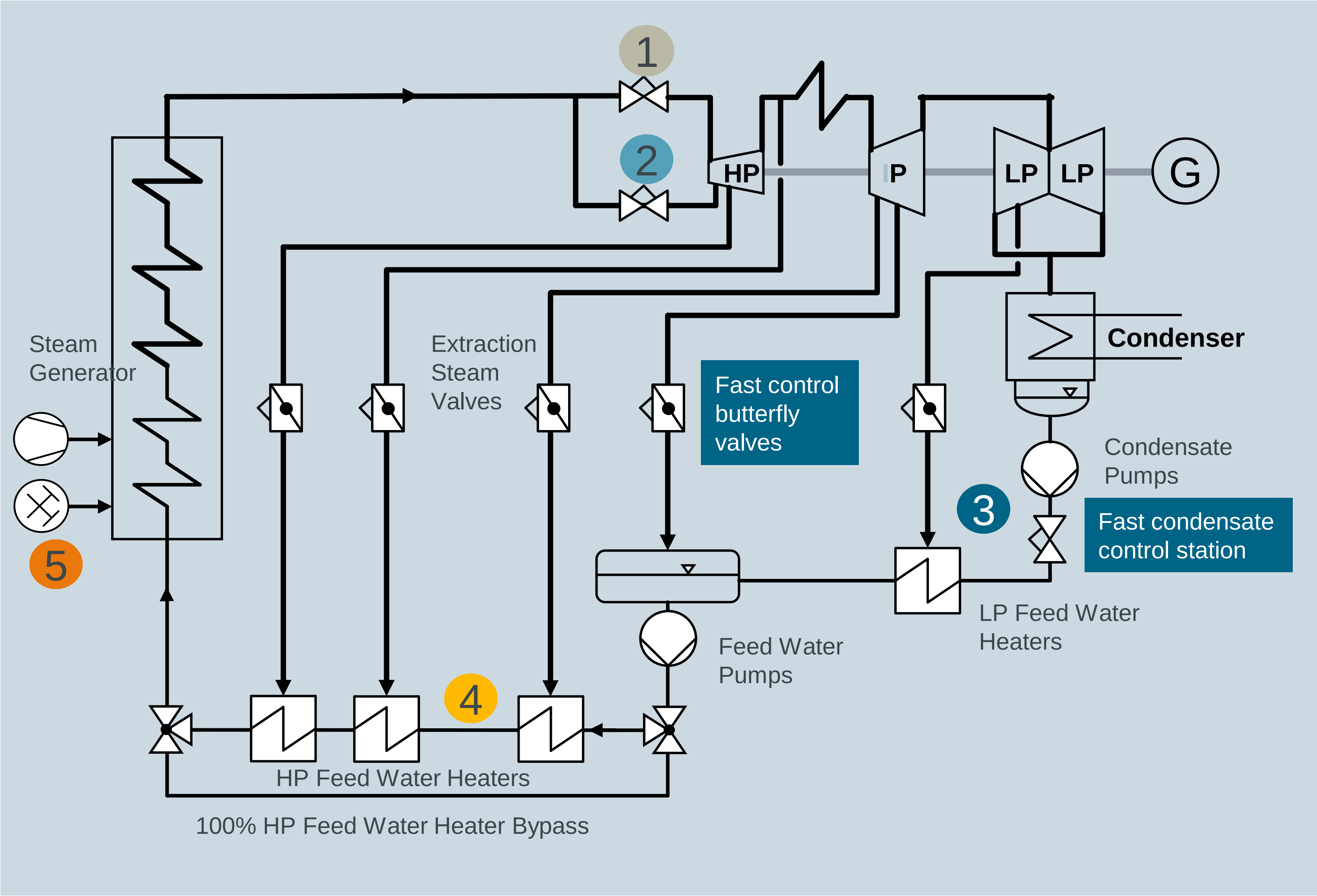
Task
- Part load may lead to steam temperature changes, especially hot reheat temperature
- Thermal stresses during operation are not considered in standard counting of equivalent operating hours (EOH counter)
- Maintenance needs may not be recognized

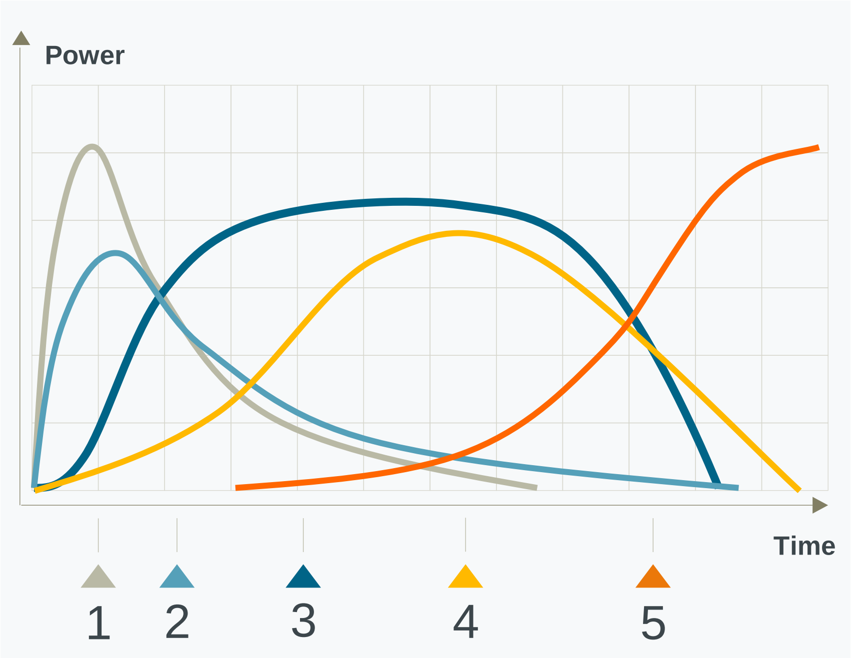
Solution
- Evaluation of operational history
- Implementation of a state of the art EOH counter considering load changes



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

Grid Services
Measures for fast load ramping

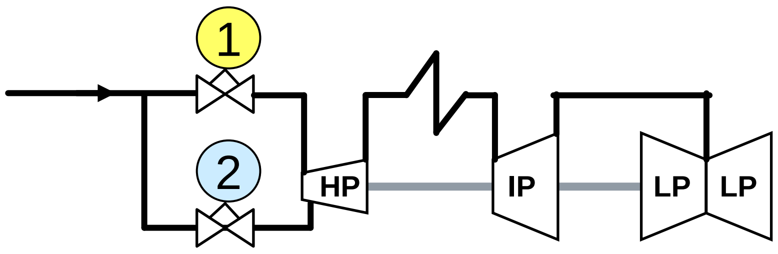




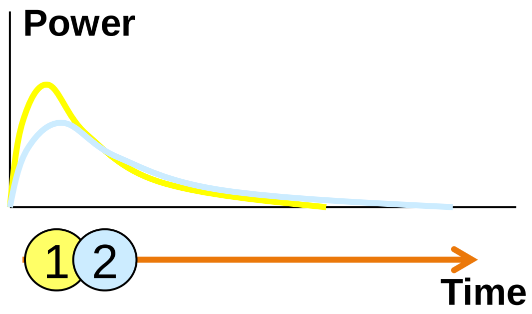
1 Throttling
2 Additional valve
3 Condensate throttling
4 HP heater
5 Fuel increase

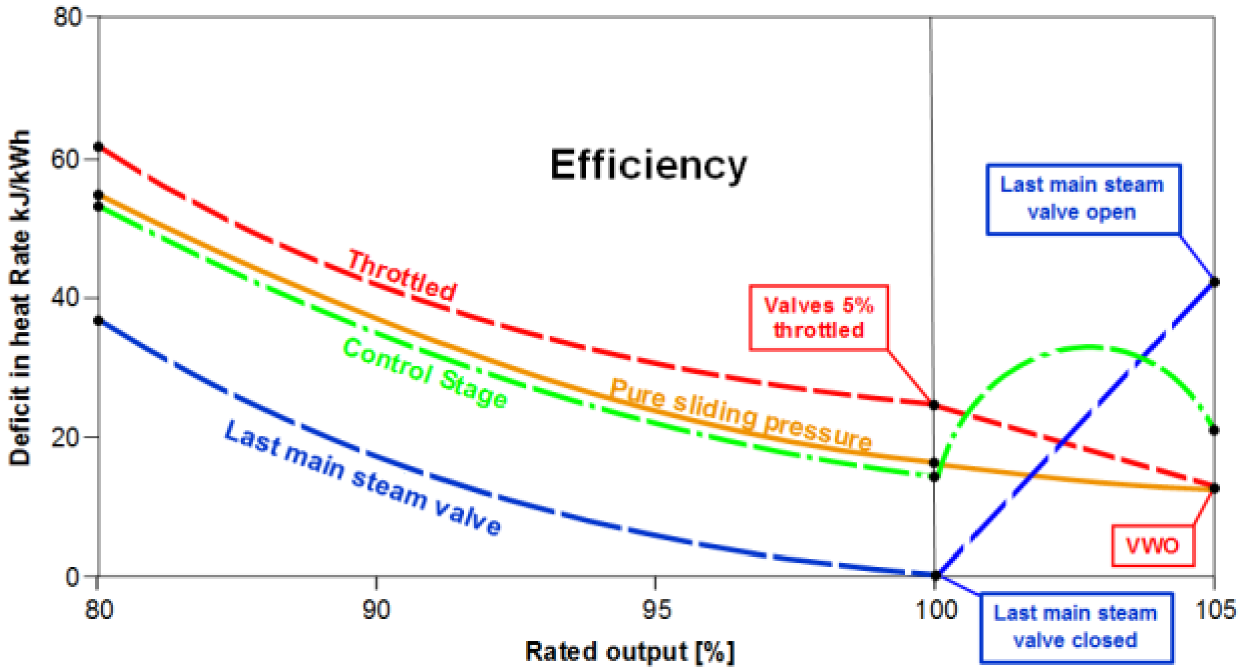
Grid Services

Increase turbine swallowing capacity to use boiler storage

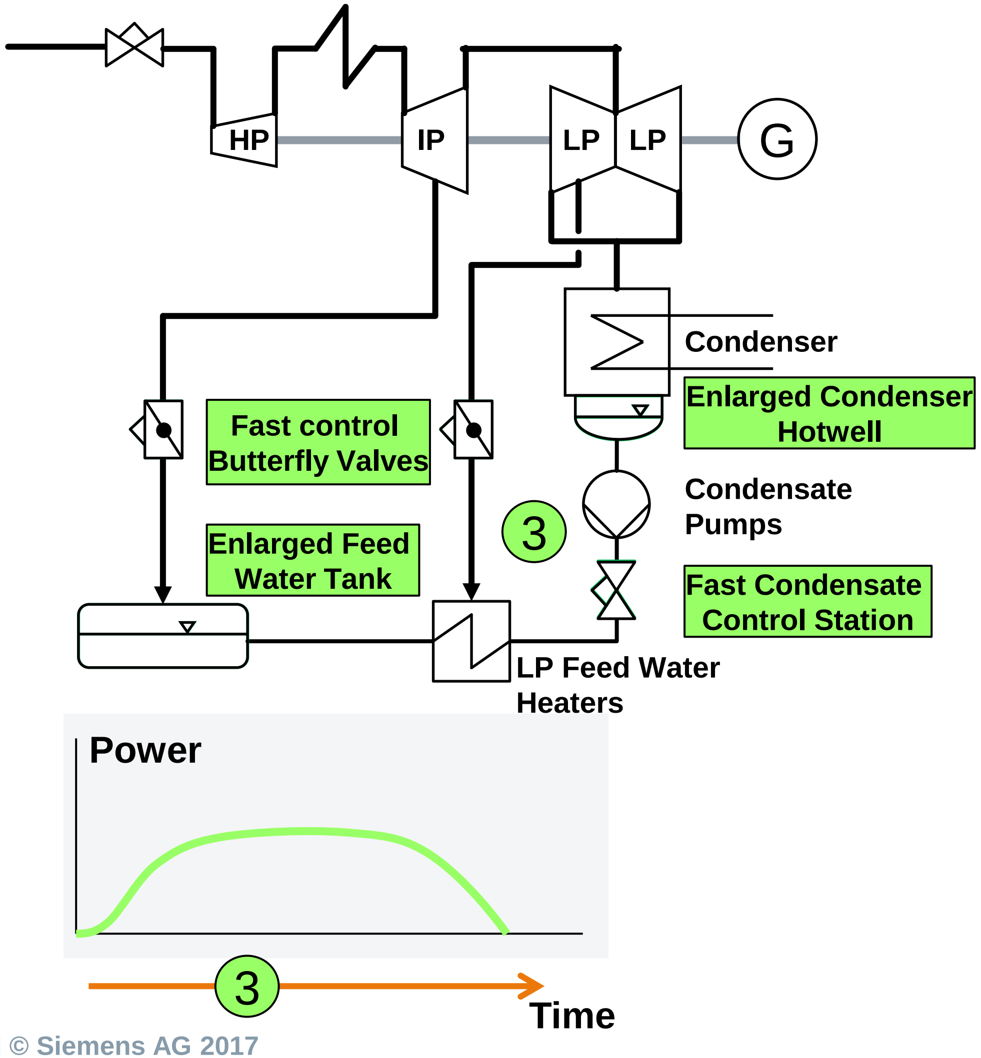


a. **Remove throttling of control valves**
b. **Opening of last main steam valve**





First Condensate throttling based primary frequency control in India

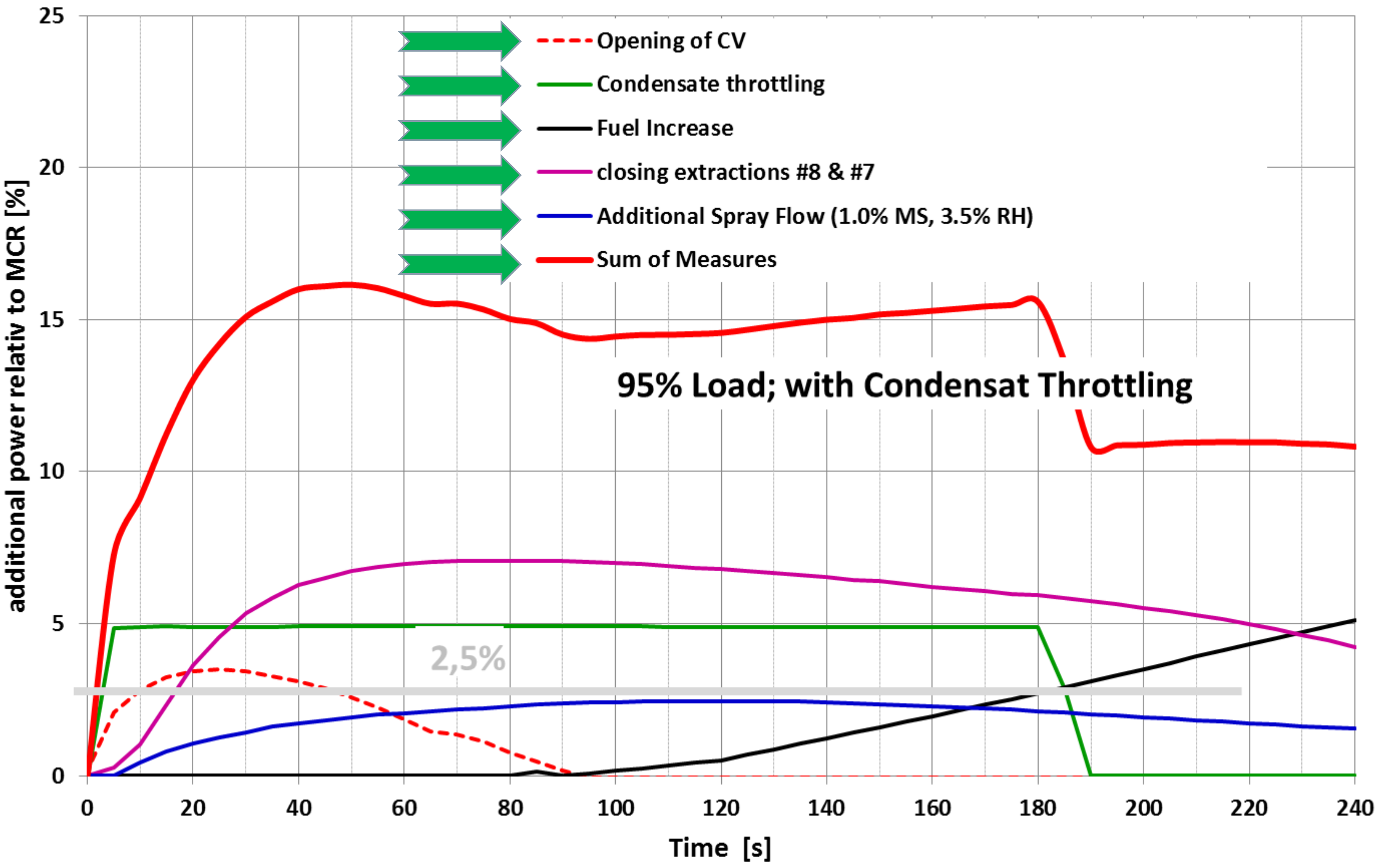


a. Enlarge storage volume
b. Fast condensate control valve
c. Fast control valves in LP extractions

NTPC Dadri Stage II – Unit #6 490 MW

Grid Services

Example for grid code compliance



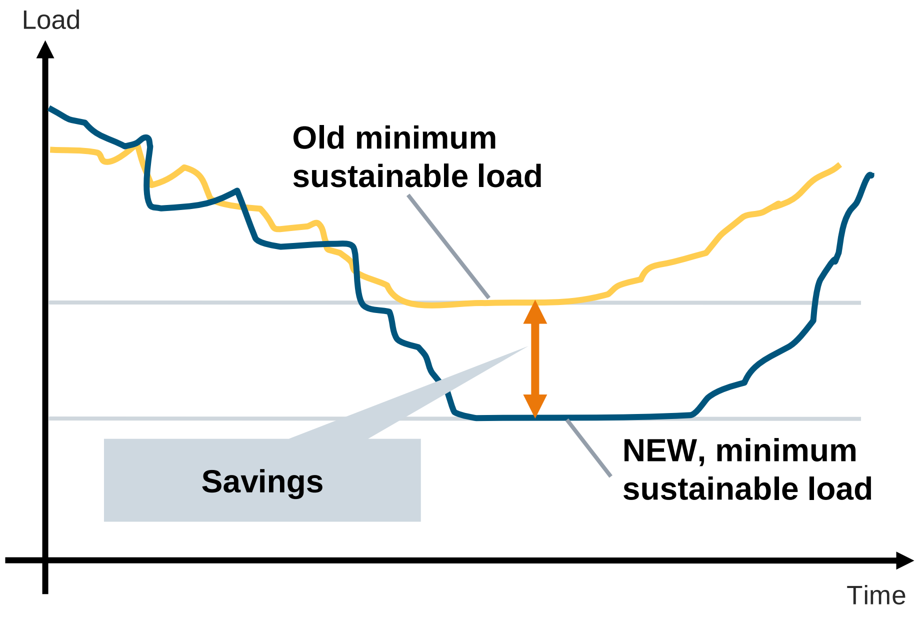
Further solutions for flexible operation
Minimum Load Reduction

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

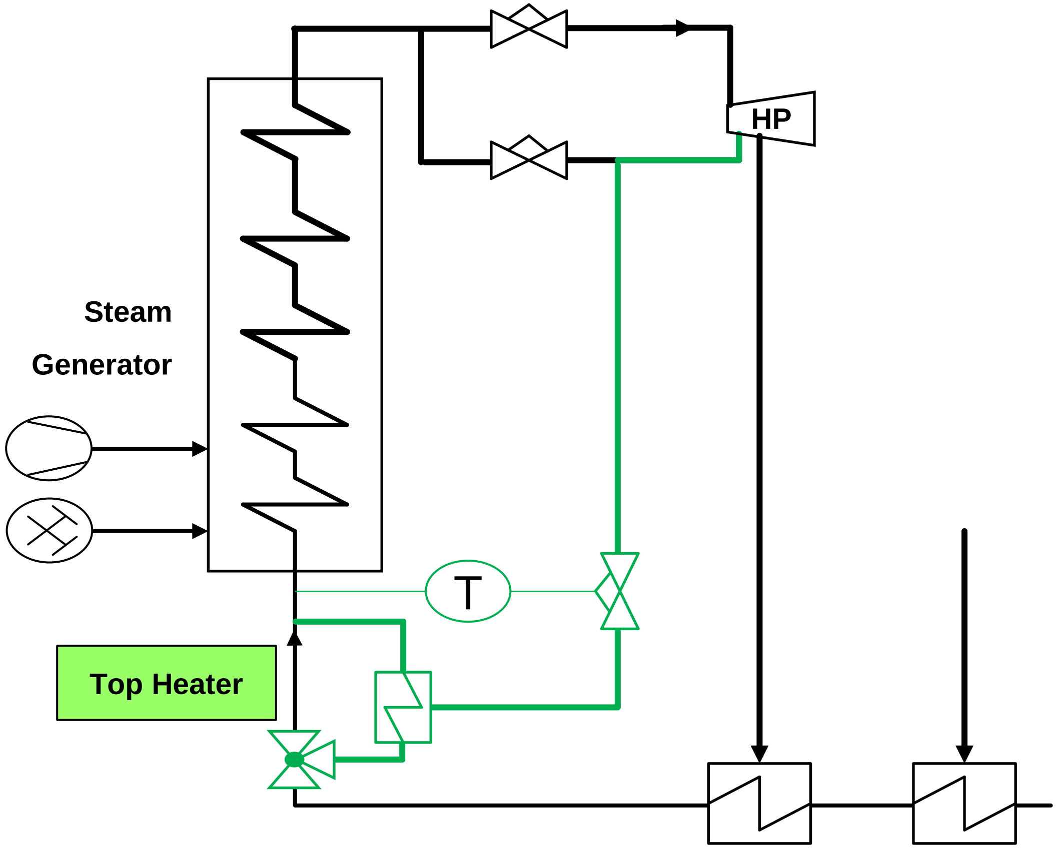
Benefits
- Reduced financial losses during off-peak periods
- Faster response to increased load demands as unit does not need to be shut down
- Avoidance of unnecessary startups and shutdowns

Minimum Load Reduction



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

Part Load: Efficiency improvement
Top heater for improved heat rate and lower NOx emisions



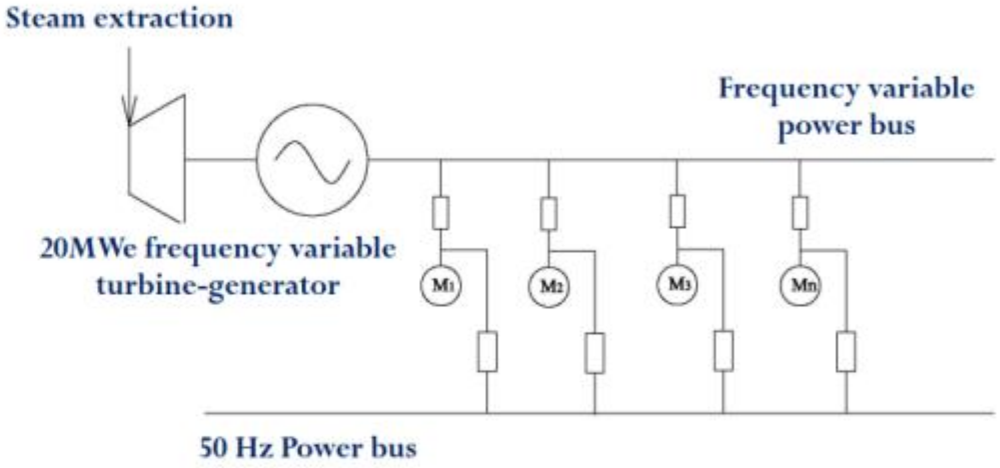
a. **Steam from stage bypass connection**
b. **Is activated at part load**
c. **Final feed water temperature vs. load constant or even increasing**
d. **HR improvement of ~ 0.6% @ 50% load**

Wai Gao Qiao 3, China 2008, 1040MW

Part Load Optimization: Centralized frequency variable power system

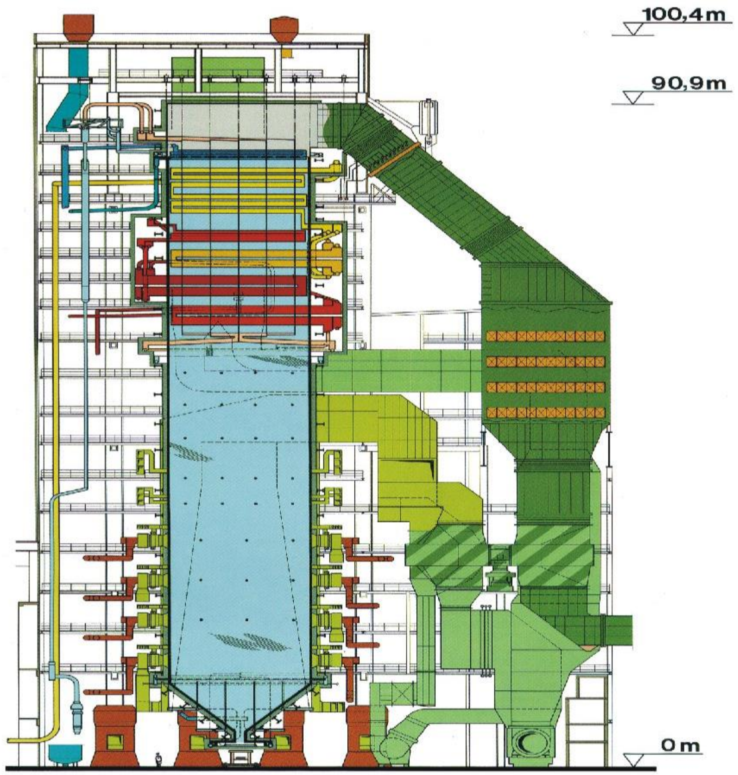
Solution: feed frequency variable turbine from main turbine extractions, supply frequency variable power to motors of fans and pumps.

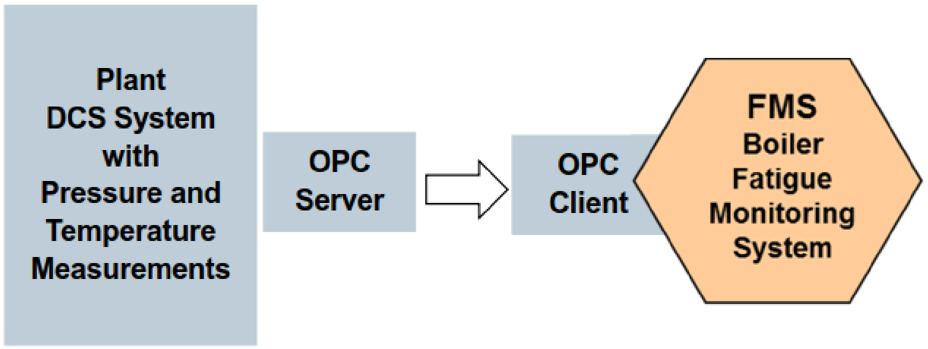
- House power rate has been reduced from 3.5% to less than 2% (SCR and FGD included)
- Higher reliability compared to conventional electronic frequency convertors



*) Huaibei Shenergy Power Generation Co.,Ltd

Maintenance Flexibility
Fatigue Monitoring System





<u>Typical components:</u>

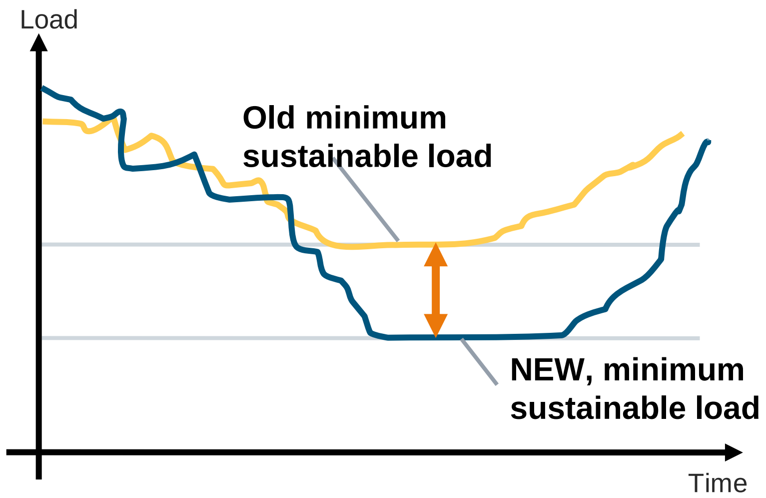
- Headers, Manifolds (HP superheater, Reheater)
- Drums
- Separators
- Piping (e.g. elbow after HP / HRH final stage attemperator)
- T-Pieces (e.g. HP bypass station)
- Y-Piece (e.g. before HP turbine)

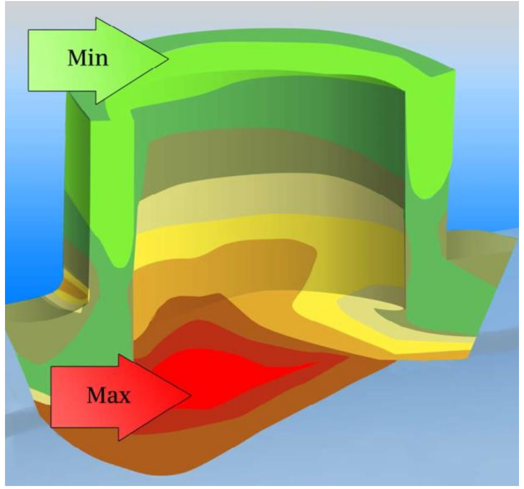
Online calculation of Boiler Fatigue Components is possible

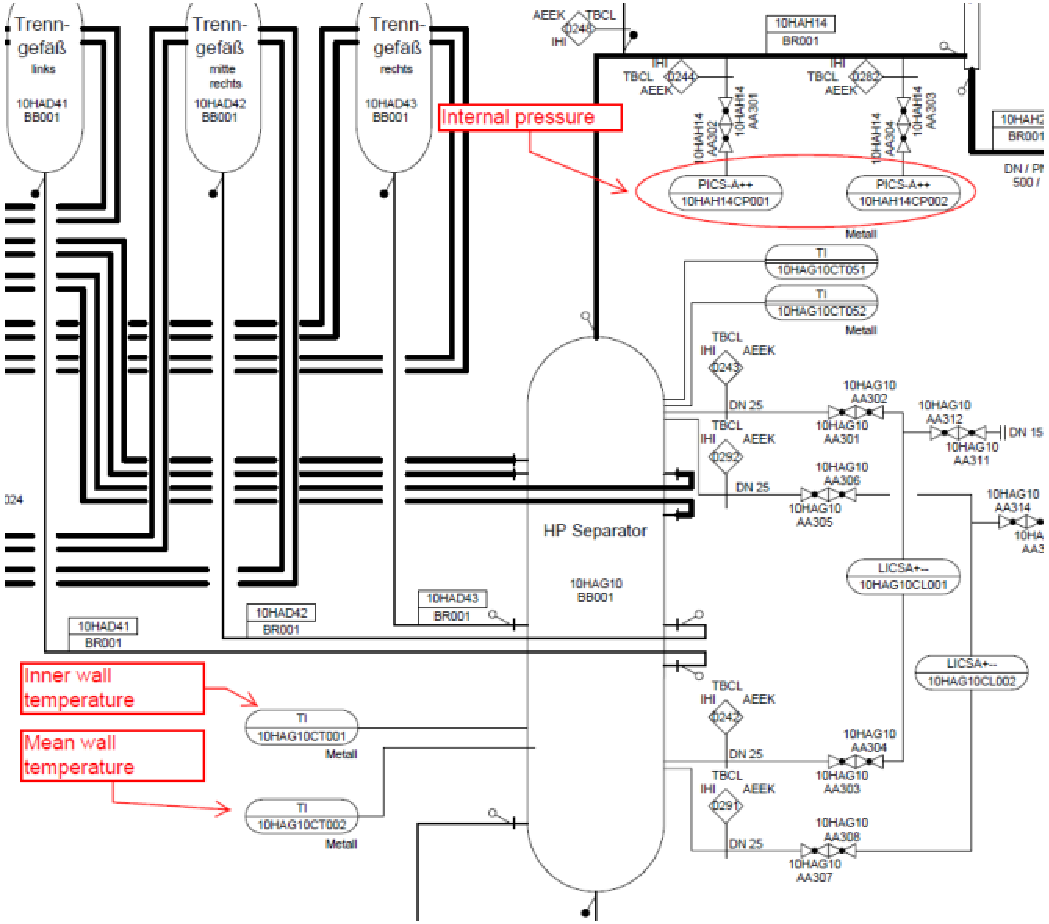
Both Creep Fatigue and Low cycle fatigue calculated

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

Maintenance Flexibility
Fatigue Monitoring System







How much fatigue is it?

Don’t Guess when you can actually measure it

Further I&C solutions for flexible operation

Reference case: DCS Retrofit in Neurath Units D and E

- 2 x 600 MW units, lignite fired
- Built 1975
- Originally designed and run as base-load plants

VORWEG GEHEN / SIEMENS

	starting situation	contract	proven (trial run)	further possible potential
Load gradient	5 MW/min	12 MW/min	15 MW/min ✓	20 MW/min
Minimum load (gross)	440 MW	290 MW	270 MW (w/o bypass operation) ✓	250 MW (with risks, e.g. minimum fire interlock)
Primary frequency control (PFC)	18 MW by throttling of inlet valves	18 MW by condensate throttling	45 MW	50 MW
Secondary frequency control (SFC)	n.a.	66 (75) MW	100 MW ✓	110-115 MW
Simultaneous PFC and SFC	n.a.	18 MW 66 (75) MW	18 MW 75 MW ✓	still under investigation

Contractual targets considerably exceeded!

Further I&C solutions for flexible operation
Selected references

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

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