Advanced Power Plant Flexibility

Simon Müller, Head of Unit, System Integration of Renewables

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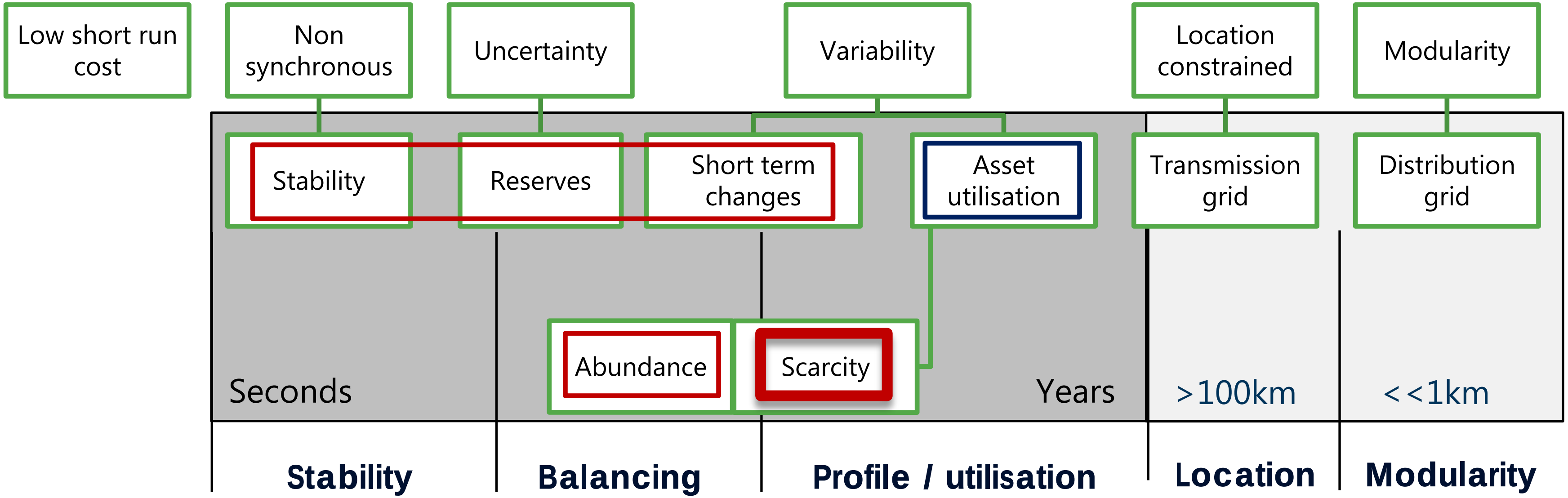
System integration - boosting power plant flexibility

- Flexible power plants are a major source of flexibility in all power systems
  - Biggest source in several leading countries
  - Key issues: minimum generation levels, start-up times, ramp-rates
- Significant barriers hinder progress:
  - Technical solutions not always known
  - Regulation and/or market design frequently favour running 'flat-out'
  - Contractual arrangements with manufacturers may penalise flexible operating pattern
- Campaign to be launched at CEM8

Example North-America
From baseload operation to starting daily or twice a day (running from 5h00 to 10h00 and 16h00 to 20h00)
Source: NREL

(Thermal) power plants as a flexibility option



In the short term: make room while keeping the lights on
In the long term: critical for bridging multi-day periods without VRE

Comparison with other flexible resources

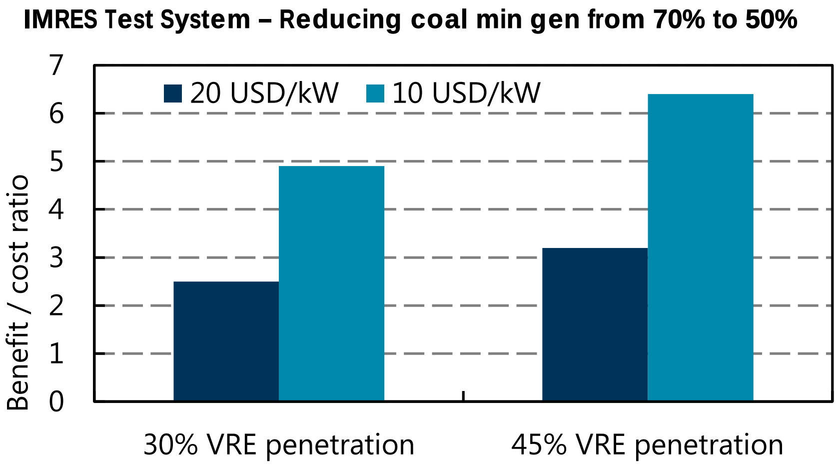
	Uncertainty	Variability			Location	Modularity	Non-synchronous
		Ramps	Surplus	Scarcity			
Transmission grids	✓	✓✓	✓	✓	✓✓	✗✗	✓
Distribution grids	O	✓	✓	O	✗✗	✓✓	✗
Interconnection	✓	✓✓	✓✓	✓	O	✗✗	✓✓
Dispatchable generation	✓✓	✓✓	✓✓ / ✗✗	✓✓	✗	O	✓✓
Distributed storage	✓	✓	✓	✓	✗	✓✓	O
Grid-level storage	✓✓	✓✓	✓	✓	✗	✗✗	✓
DSI small-scale (distributed)	✓	✓✓	✓✓	O	✗	✓	✓
DSI large-scale	✓	✓	✓✓	O	✗	✗✗	✓

Updated from IEA, 2014: The Power of Transformation

Flexible power plants compete with other resources across the full spectrum of flexibility requirements.

Cost-benefit analysis

- Robust information on cycling and retrofit costs are very hard to obtain
- Cited numbers for start-up costs diverge up to factor of ten
- Interventions highly plant specific



Retrofits of existing assets can be a cost-effective tool to enhance system flexibility.

Retrofits to Improve Flexibility-Real World Cases

Plant: Neurath 2x630MW
Manufacturer: Siemens

	Reference	Contract	Proven Results
Load Gradient	5 MW/min	12 MW/min	15 MW/min
Minimum Load	440 MW	290 MW	270 MW
Primary Frequency Control (PFC)	18 MW by Turbine Valve Throttling	18 MW by Condensate Throttling	45 MW
Secondary Frequency Control (SFC)	n.a	66 MW	100 mw
Simultaneously PFC+SFC	n.a	18 MW+66 MW	18 MW+75 MW
Efficiency	37%		38.10%
Start-Up Time	4hr and 15min		3hr and 15min

Plant: Steag Voerde 700 MW
Manufacturer: Siemens

	Reference	Proven Results
Minimum Load	280 MW (40%)	140 MW (20%)

Power Plant Flexibility- A Comprehensive Approach

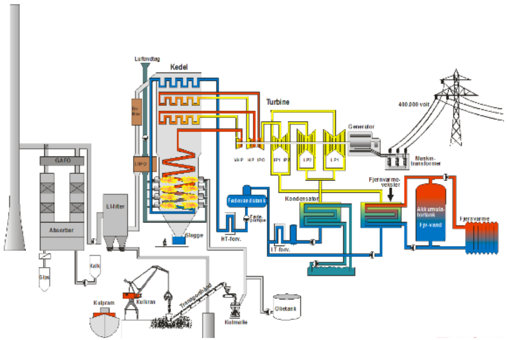
Unit-wide optimization

- Optimize load control ("gently" reach temperature and operational limits without violating them)
- Optimize flame conditions
- Optimize fuel supply
- Re-program DCS software
- Train staff

System-wide optimization

- Use advanced optimization software to optimize dispatch
- Make use of any storage capabilities to operate thermal plants more flexibly
- Dynamic DR programs
- Design appropriate markets

Coal Power Plant Flexibility



Make use of digital monitoring

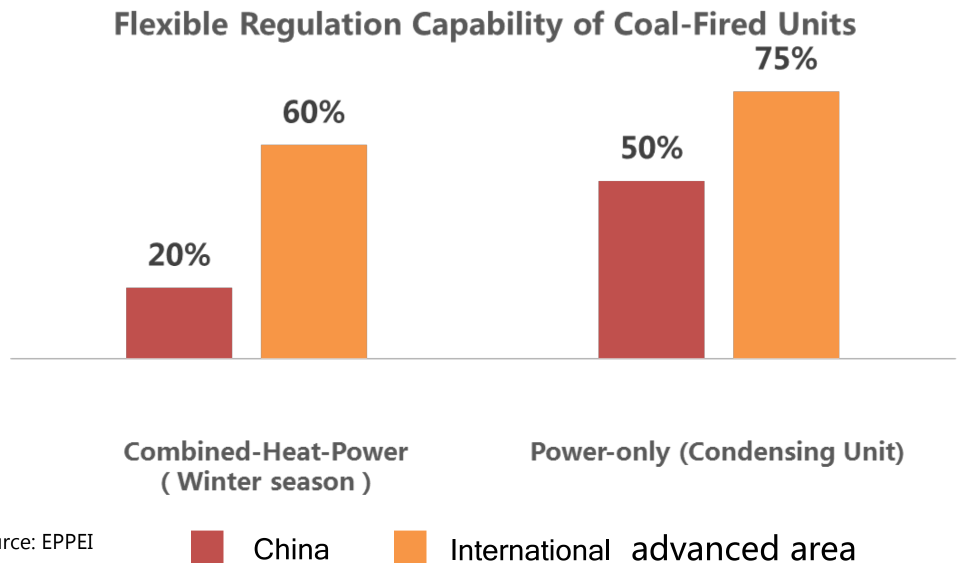
- Monitor T changes regularly
- Monitor flame conditions
- Monitor catalyst conditions

Replace components if needed

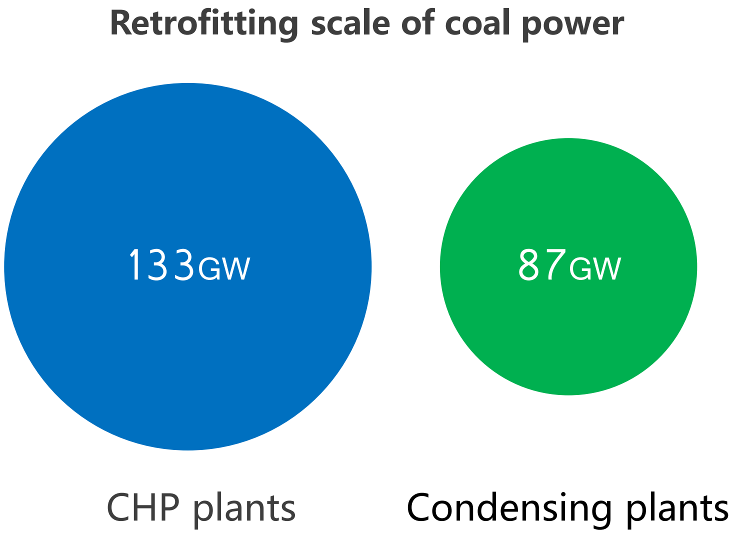
- Use materials designed for thermal cycling
- Use feed water pump designed for cycling

Power System Flexibility Enhancement & 13th FYP in China

- Huge potential of flexible operation ability for thermal power units in China.
- 133GW CHP plants and 86GW condensing power plants will be retrofitted by 2020, which is 20% of the overall capacity of coal power in China. A flexible regulation capacity of 46GW is expected to be achieved.



Source: EPPEI



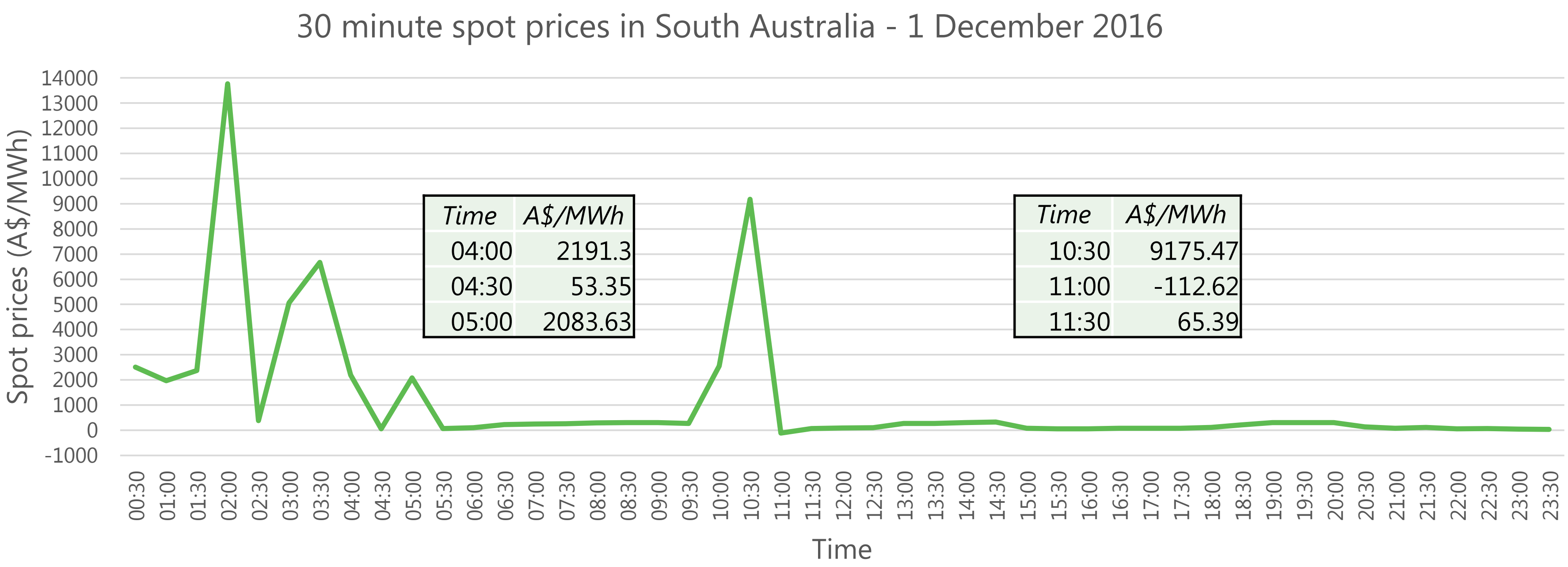
Regulatory frameworks to incentivise flexibility

- Carrots:
  - Provide incentives to leave the market or reduce market share
  - Allow very high prices during periods of scarcity

- Sticks:
  - Give priority to other generation resources (priority dispatch)
  - Allow very low / negative prices during abundance periods

- … and other tricks:
  - Consider flexibility potential when nominating must-run units
  - Remunerate new types of services (synchronous inertia, ramping capability)
  - Adjust KPIs for plant operators

Regulatory frameworks to incentivise flexibility



Price volatility – in particular periods of zero or negative prices – strong commercial driver to become more flexible.

ADVANCED POWER PLANT FLEXIBILITY

A Clean Energy Ministerial Campaign

Campaign Co-Leads

China

Denmark

Germany

Participating CEM Members

Brazil

Canada

EC

India

Indonesia

Japan

Mexico

Saudi Arabia

South Africa

UAE

COWI

DONG energy

enel

ENERGINET/DK

GE

J-POWER

SIEMENS

KYUSHU ELECTRIC POWER CO.,INC.

MAN Diesel & Turbo

Agora Energiewende

VGB POWERTECH

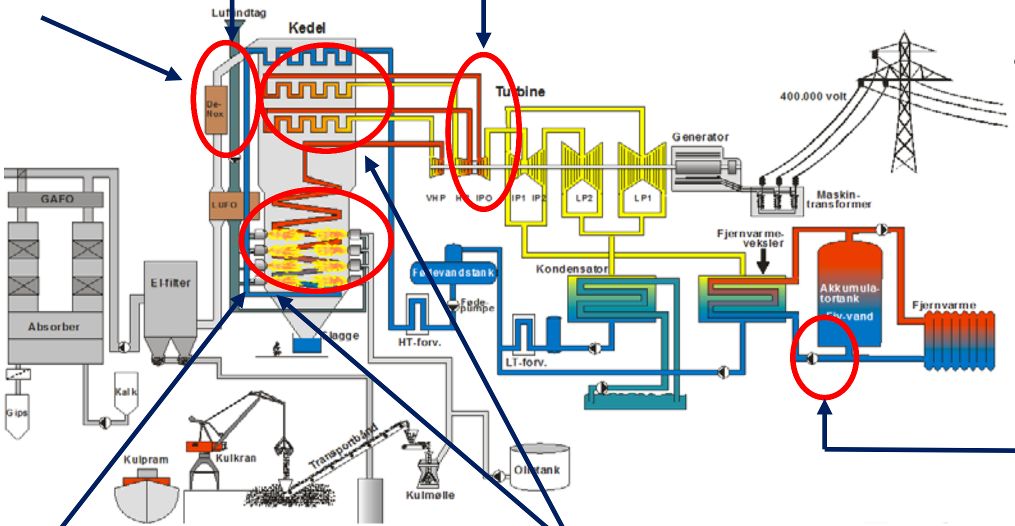
Challenges on Reducing min Load in Coal Power Plants

1) Low flue gas temperature

- Low-load operation reduces flue gas temperature
- Side effect: Poor performance of de-NOx catalyst

5) Drop in efficiency (expensive operation)

- During low-load operation steam volume and pressure are reduced
- Side effect: Bypass of HP turbine is required → reduced efficiency



4) Reduced load control options

- During low-load the amount of condensate water is reduced
- Condensate stop control is dying out

2) Unstable flame

- Maintaining flame stability is more challenging during low-load

3) Thermal stresses

- Thermal stresses are caused due to a) frequent cycling and b) unstable flame
- Power plant life time reduction

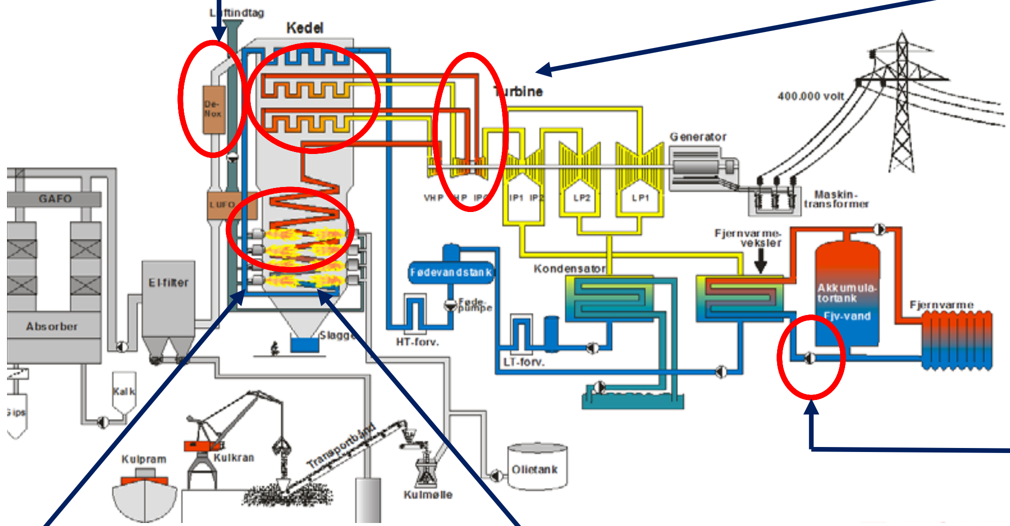
Technical Interventions to Reduce min Load in Coal Power Plants

1) Improving emission levels

- Dynamic supervision of conditions in the catalyst

5) Improving efficiency

- Optimization of all subordinated controllers to improve steam (pressure conditions)



4) Improving load control options

- Use alternative options:
- Alternative "fast control handle" is throttling of steam to HP turbine

2) Stabilizing flame temperature

- Dynamic measurement of flame conditions in the combustion zone
- Smart controls: Optimization of all subordinated controllers (e.g air, fuel, feed water)

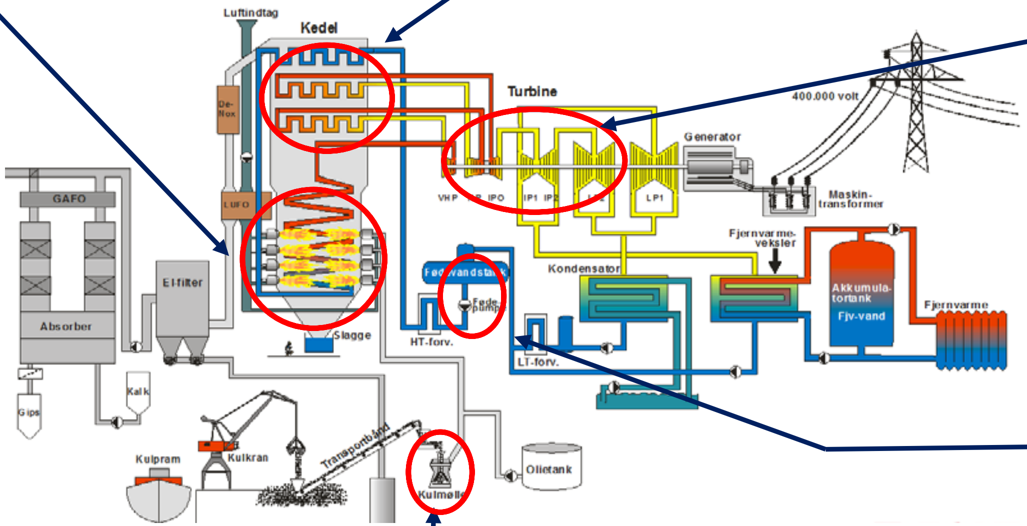
3) Reducing thermal stresses

- Dynamic monitoring of components for fatigue
- Smart controls: Optimized load control for more "gentle operation"
- Replacement of materials with ones designed for thermal cycling

Challenges on Increasing Power Plant Ramp-Rates

1) Maintaining optimal flame conditions
- During fast ramping it is more challenging to maintain optimal conditions in the boiler

4) Thermal stresses
- Temperature imbalance between firing and feed water
- Excessive temperature changes at turbine components



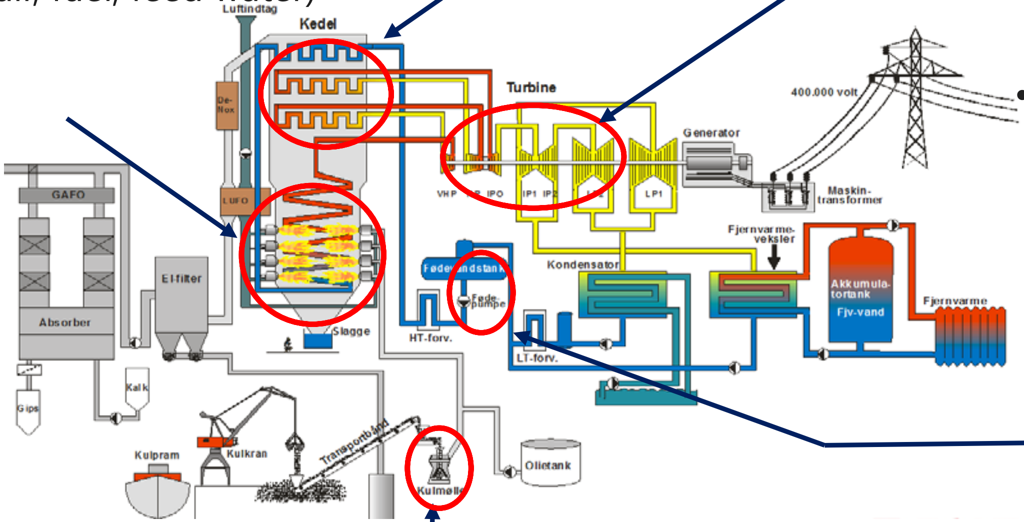
3) Unstable feed water circulation rate
- Changing pump operation during cycling causes water flow disturbances

2) Speed of fuel supply
- Fast ramping depends on the responsiveness of the fuel supply system

Technical Interventions to Increase Power Plant Ramp-Rates

1) Improving flame conditions

- Dynamic measurement of flame conditions in the combustion zone
- Smart controls: Optimization of all subordinated controllers (e.g air, fuel, feed water)



4) Reducing thermal stresses

- Continuous optimization of control =f (coal type, summer/winter soot blowing, operator dependence)
- Smart controls: Optimize operation to reach technical limits without violating them

3) Stabilizing feed water circulation rate

- Design pumps with favorable characteristics for fast cycling

2) Improving speed of fuel supply

- Optimize mill operation (shift between n to n+1 operation, use good mills for low load, use mills with high content of fine grain coal)

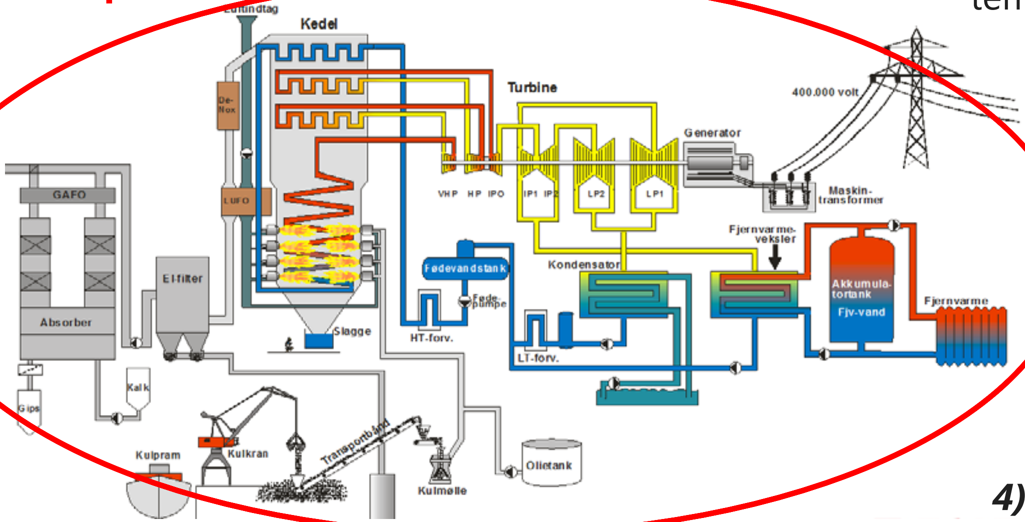
Challenges on Decreasing Power Plant Start-Up Times

1) Maintaining optimal flame conditions

5) Distributed control system and turbine controller bottle-necks

- Many times next-step in a start-up sequence is delayed until a temperature threshold is reached

All challenges related to increased ramp-rates are even more profound during start-up



4) Temperature alarms

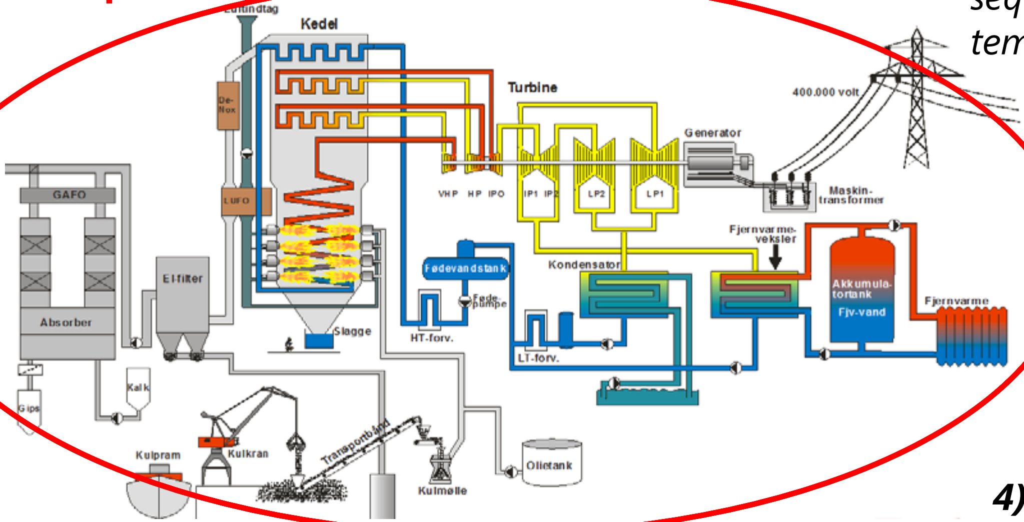
2) Speed of fuel supply

3) Unstable feed water circulation rate

Solutions to Decrease Power Plant Start-Up Times

1) Maintaining optimal flame conditions

All challenges related to increased ramp-rates are even more profound during start-up



5) Distributed control system (DCS) and turbine controller bottle-necks

- *Many times next-step in a start-up sequence is delayed until a temperature threshold is reached*

Solution: Re-program software; if not possible replace software

4) Temperature alarms

2) Speed of fuel supply

3) Unstable feed water circulation rate