



# **Load Cycling of Thermal Power Plants: Advanced Control Technology as Cost-Efficient Enabler**

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# Agenda

- 1 Who we are
- 2 Motivation for flexible coal operation
- 4 Coal fired power plant: A time-dependent system
- 5 Enhanced live steam temperature controller
- 6 Enhanced power plant load controller
- 7 Extended control system
- 8 Summary

# Uniper at a glance

## Our operations

- Power Generation
- Commodity Trading
- Energy Storage
- Energy Sales
- Energy Services



We operate in 40+ countries. Around the world.

€1.7bn  
EBITDA in 2017

100 years  
Experience

~36 GW  
Generation capacity

## Main activities

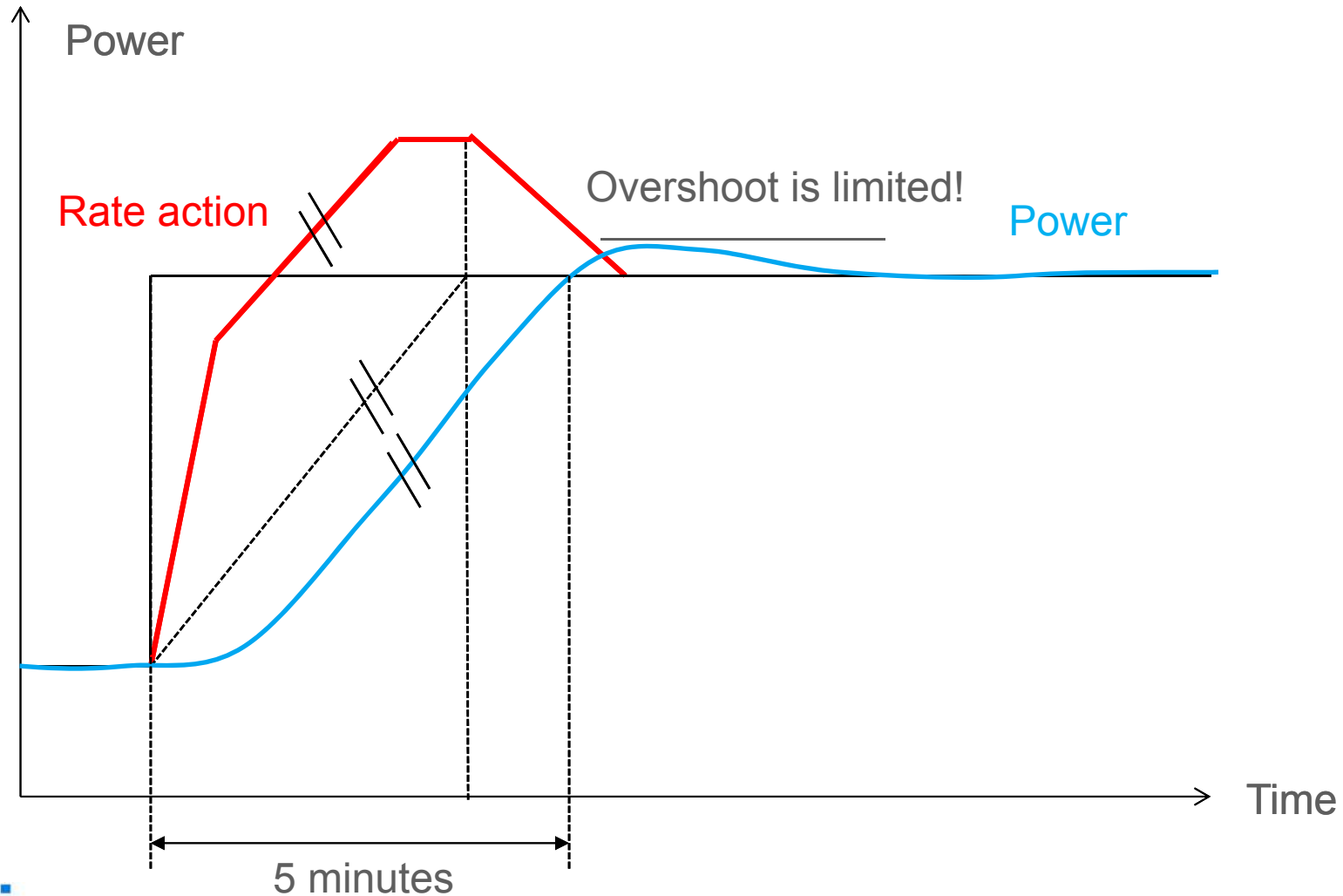


# Challenging requirements for coal flexibility

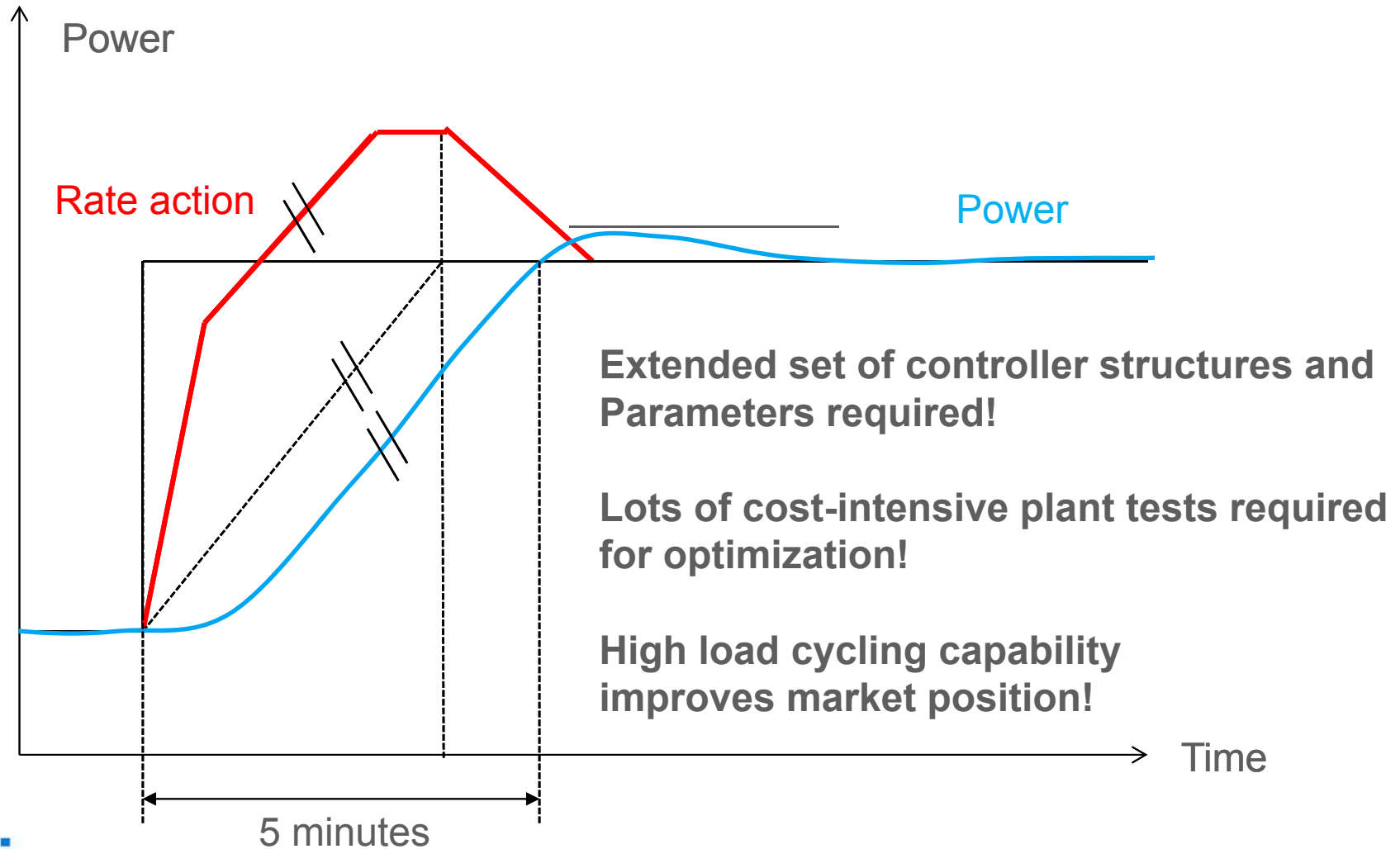
- Increasing network impact of intermittent renewable generation
- Variable load following & faster ramp rates
- Start-up & shutdown cycling
- Longer periods off-load and in standby operation
- Bigger swings between maximum and minimum load requirement
- More competitive market conditions and pricing
- Drivers to burn a changing or broader mix of coal types



# Load cycling in coal-fired power plants: Secondary control response



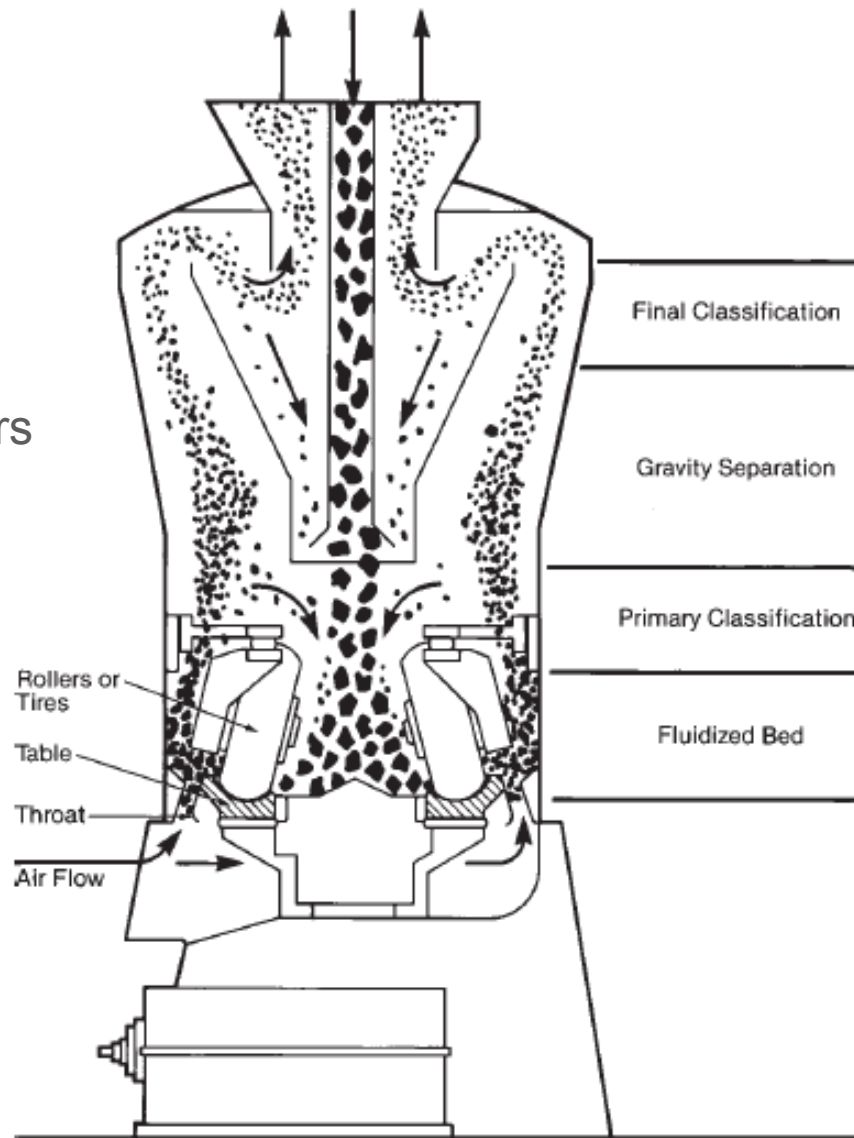
# Load cycling in coal-fired power plants: Secondary control response



# Coal Mill Operation

Mill behavior depends on

- Coal quality
- Mechanical wear
- Plant layout
- Mill operation parameters
- Mill load
- Degree of automation
- ...



Source:  
Steam and its  
generation and use

# Coal Mill: A time-variant system



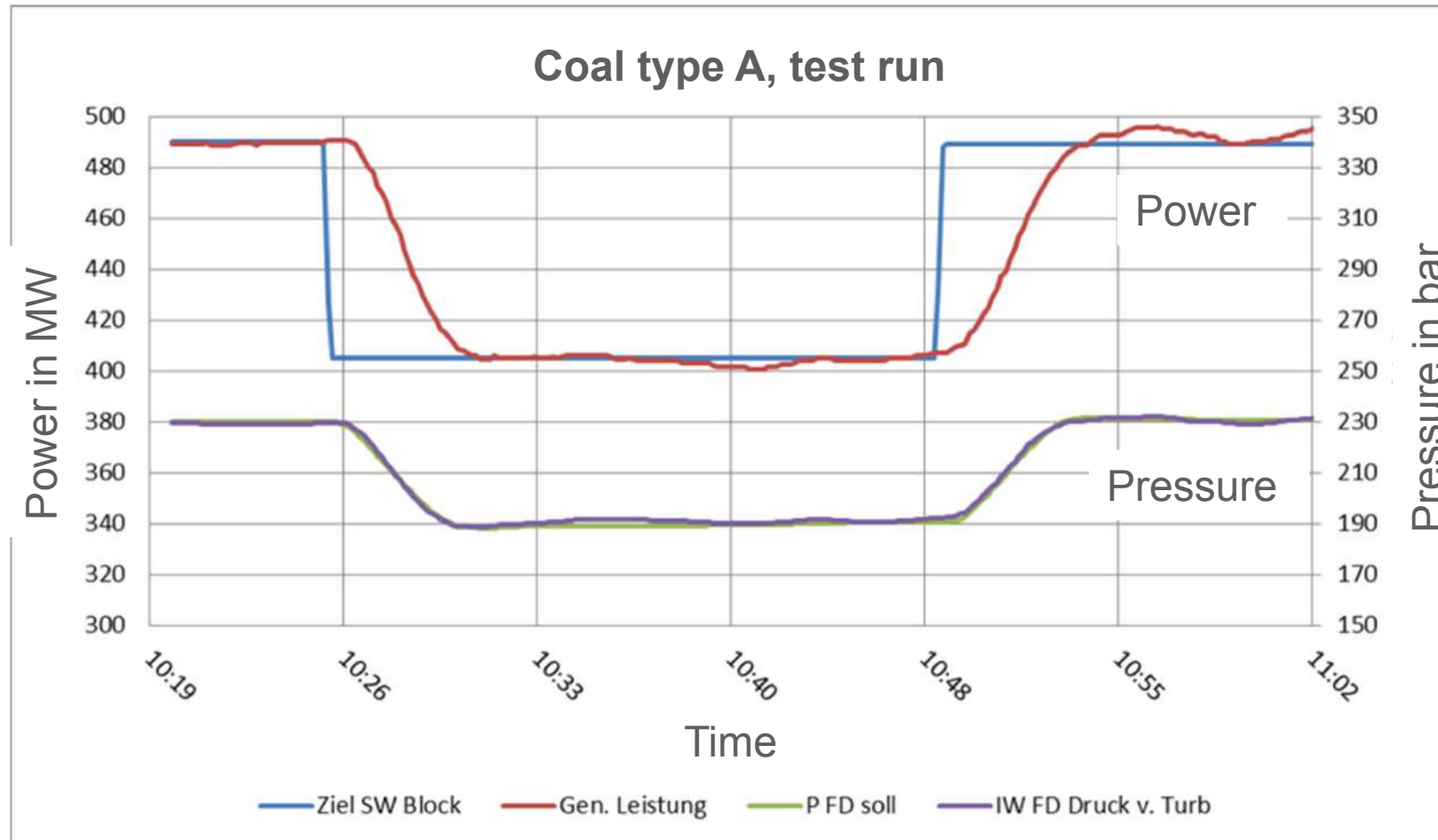
**New grinding roller**



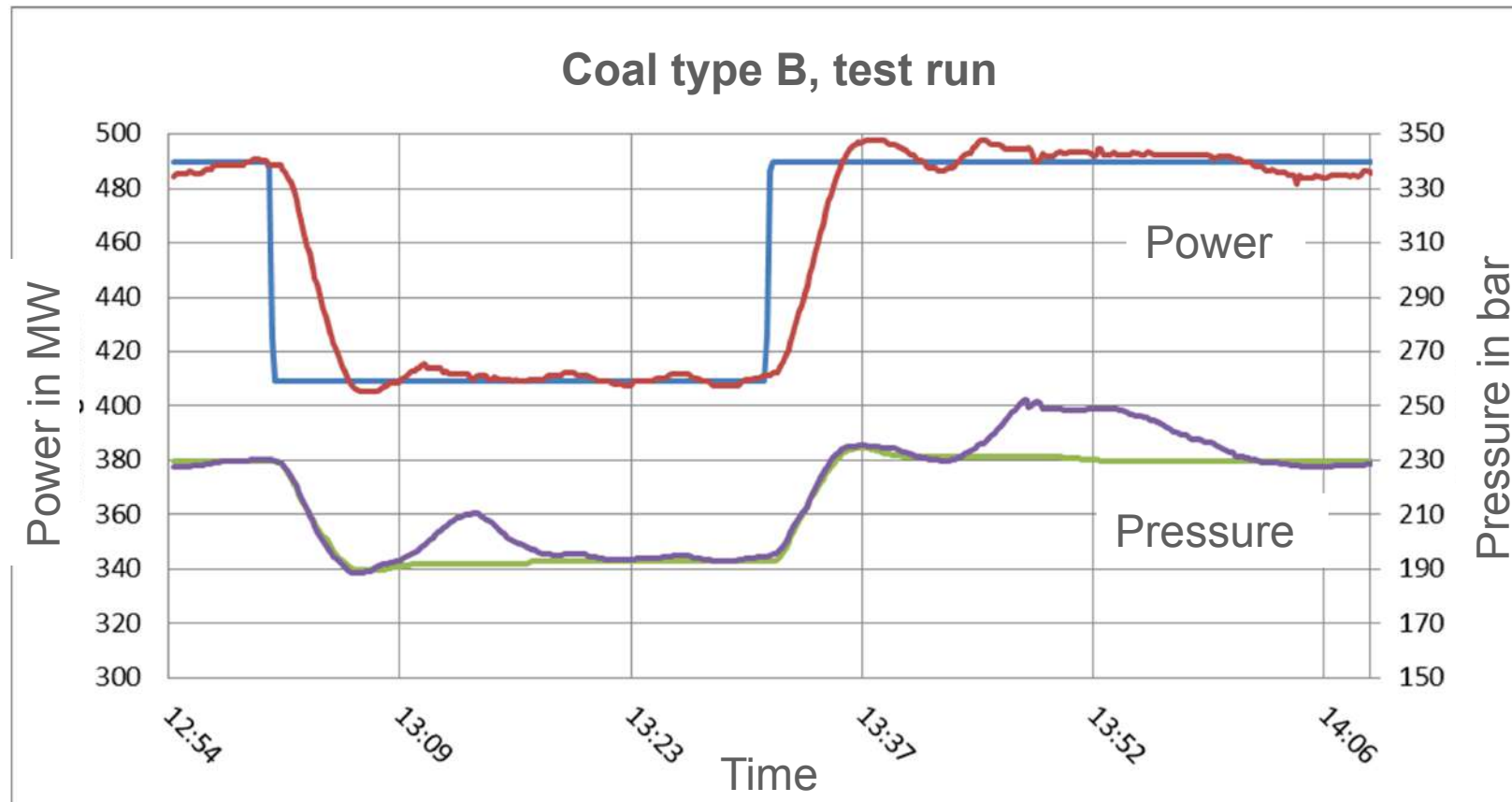
**Worn grinding roller**



# Coal Power Plant: A time-variant system

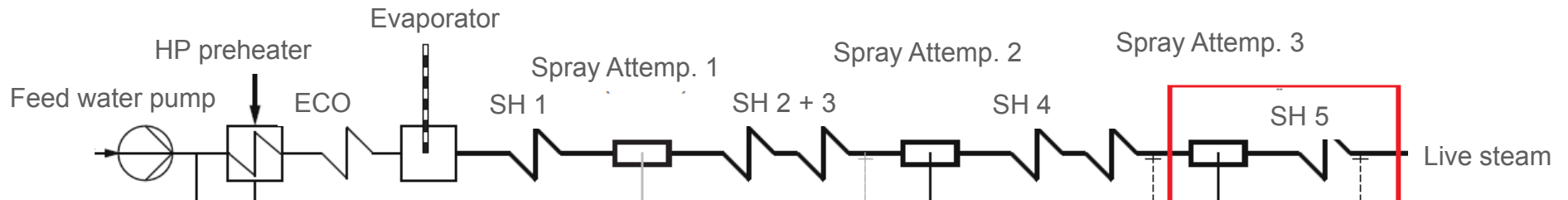


# Coal Power Plant: A time-variant system



Each coal type needs a separate control parameter set.  
The parameter set depends on the maintenance status of the mill.  
Lots of expensive plant tests for parameter optimization are required.  
**How about a controller that can adapt the parameter set automatically?**

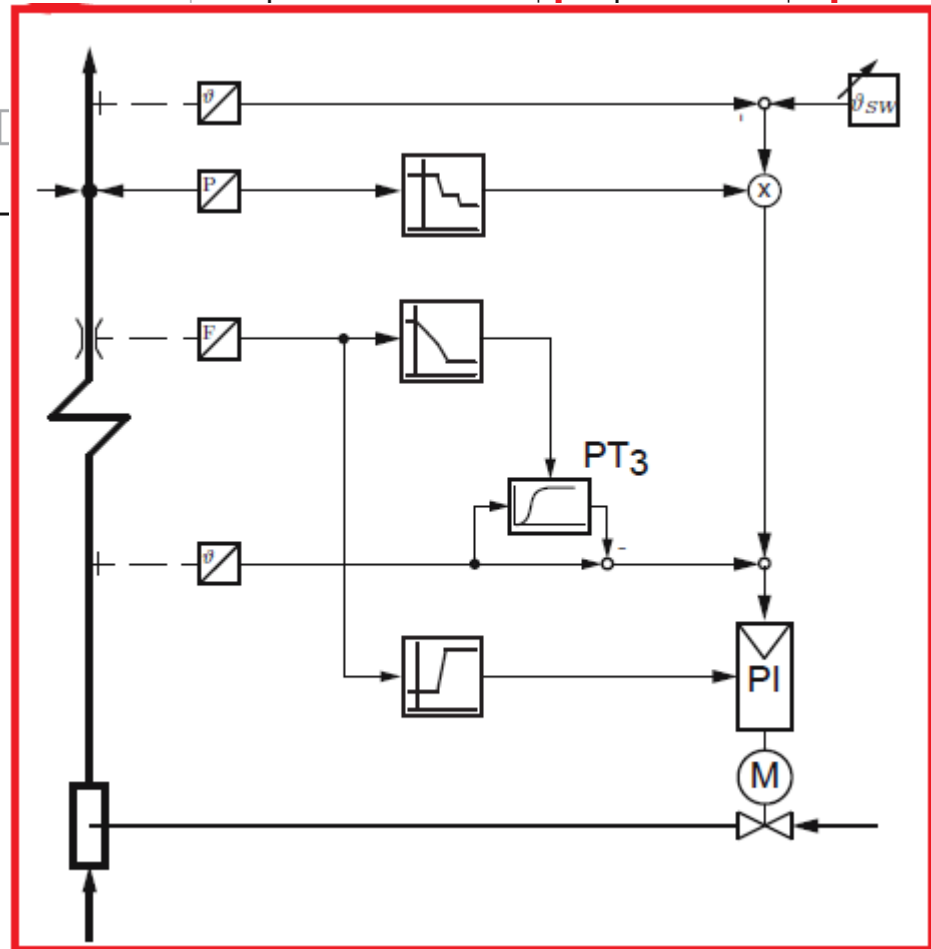
# Live steam temperature control: Static PI controller



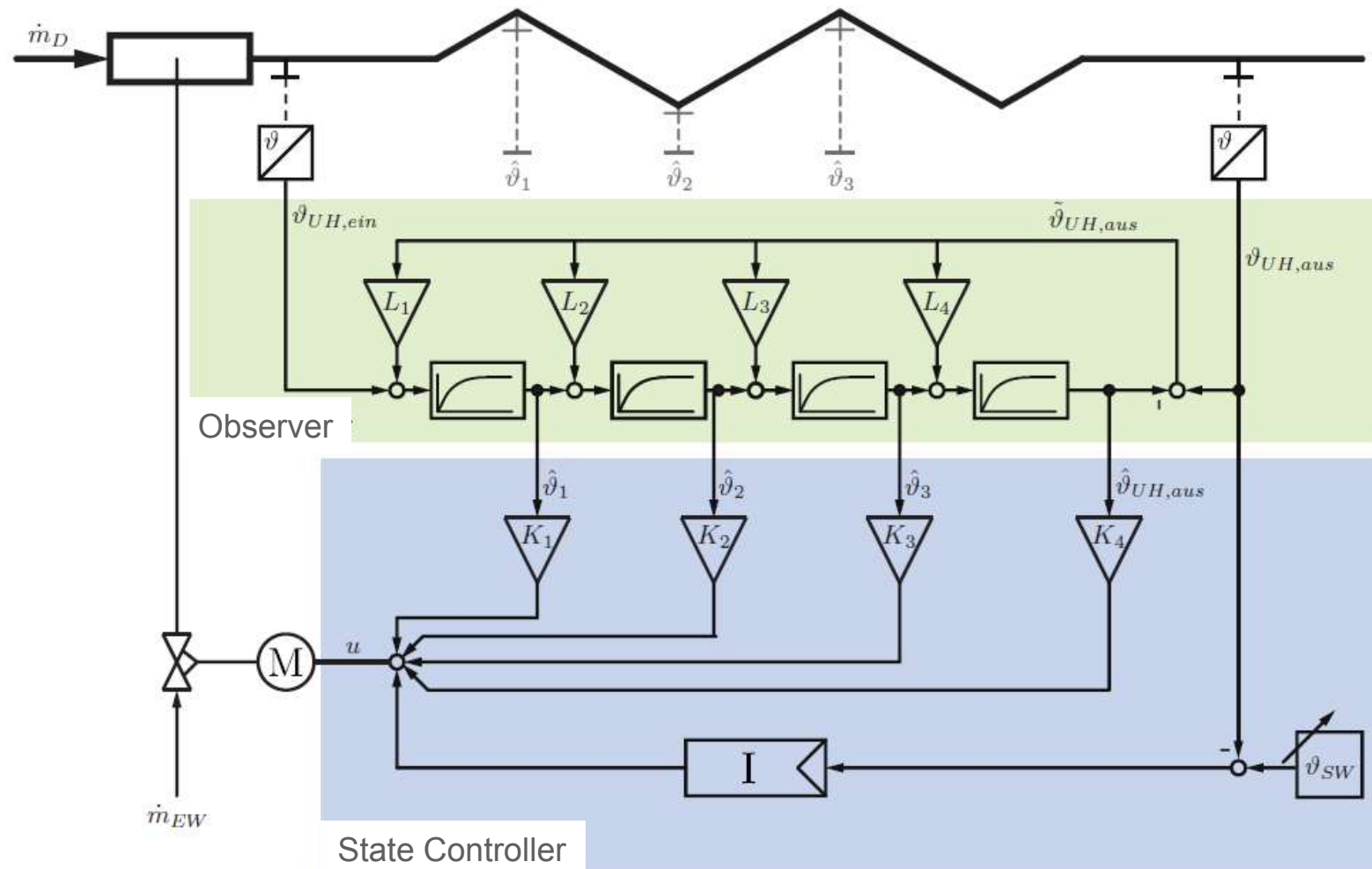
Time behavior of SH5 depends on

- Load (mass flows)
- Coal type
- Fouling and slagging

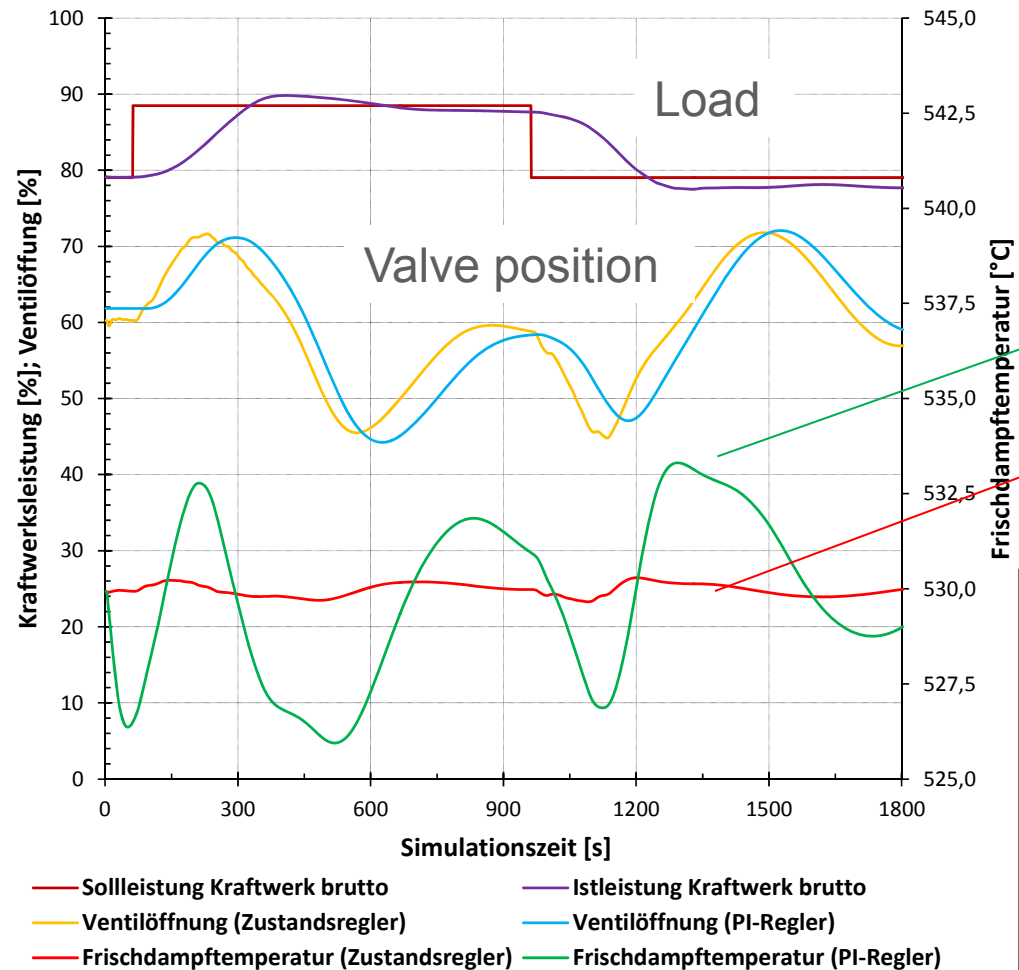
Only measurements upstream and downstream of the SH are available.



# Live steam temperature control: State controller adapts to changing system behaviour



# Live steam temperature control: Comparison of control concepts

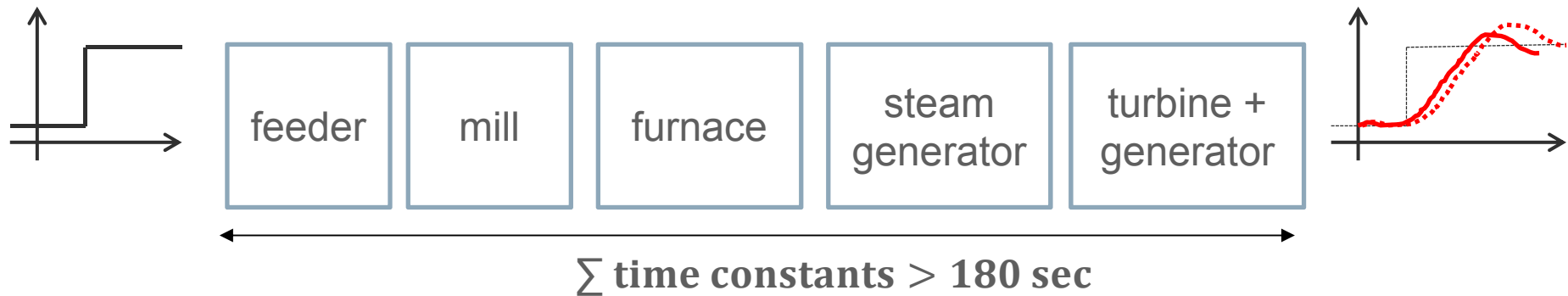


Temperature (PI controller)

Temperature (state controller)

- **Setpoint deviation of the state controller is significantly smaller.**
- **Reason is that the state controller anticipates control deviations by considering intermediate states.**

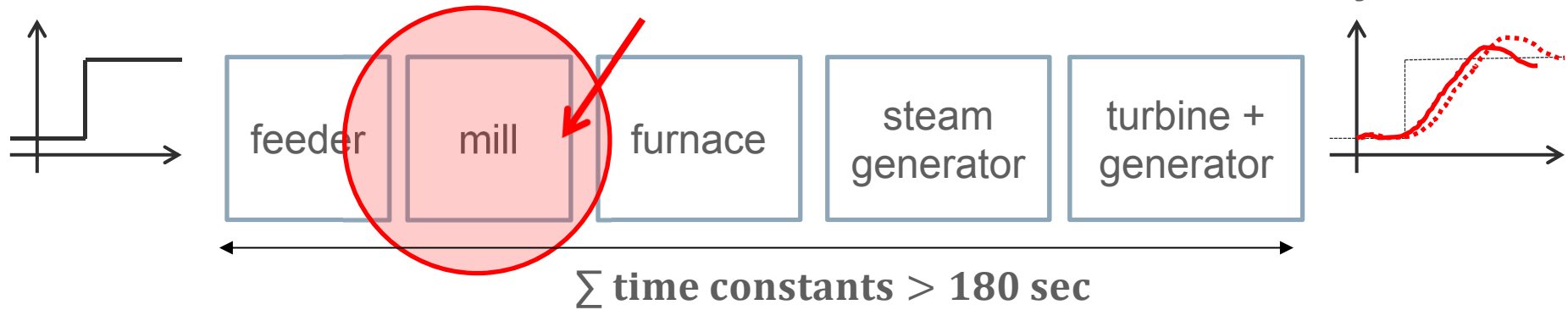
# Power plant load control: Controlled system



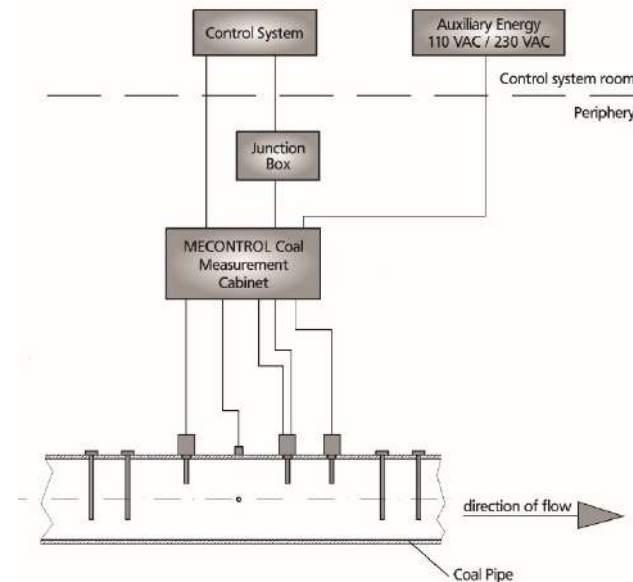
- Slow-reacting system,
- Disturbance on the controlled system cannot be identified.
- Measurement of a state variable in the middle of the controlled system would help.

# Power plant load control: Controlled system

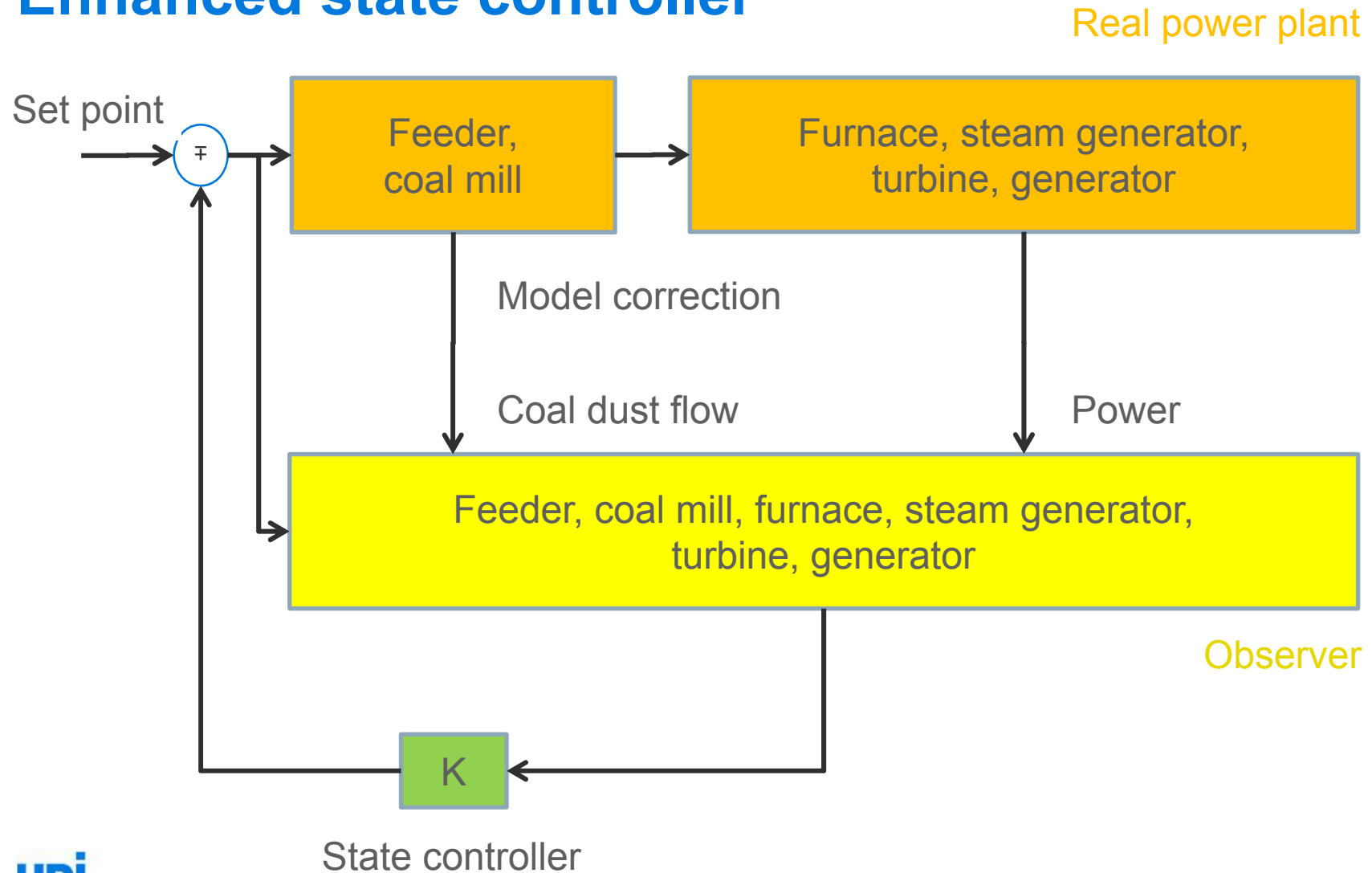
New state variable:  
**Promecon Coal dust measurement system**



- Measurement of absolute coal mass flow in kg/sec using microwave resonator technology
- Direct identification of mill disturbance, small time constant
- Signal processing of coal measurement in Kalman filter for control use, capturing mill dynamics



# Power plant load control: Enhanced state controller





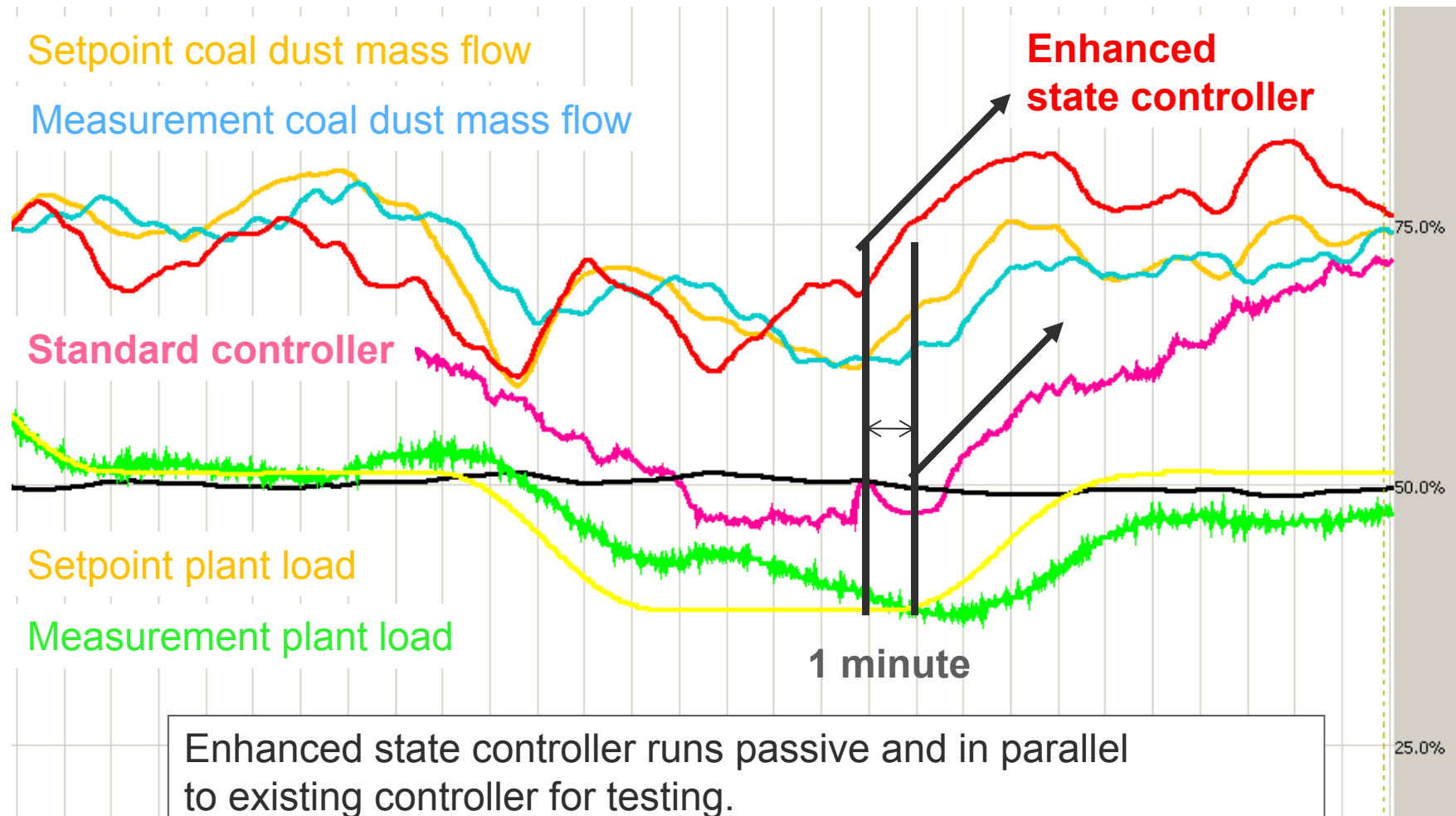
# Reference: Wilhelmshaven Power Plant, Germany



The image consists of two main parts. On the left is a map of Europe showing the North Sea to the north and the Atlantic Ocean to the west. Three red location markers labeled A, B, and C are placed on the northern coast of Germany. Marker A is at Wilhelmshaven, marker B is at Bremerhaven, and marker C is at Bremen. On the right is an aerial photograph of the Wilhelmshaven Power Plant, showing a large industrial complex with several tall chimneys and buildings situated along a waterfront. In the foreground, there are green fields and several wind turbines.

Wilhelmshaven Power Plant	
Commissioning	1976
Power gross:	820 MW
Fuel:	Hard Coal

# Comparison of load controllers in real plant



Enhanced state controller runs passive and in parallel to existing controller for testing.  
Coal dust mass flow deviation is identified earlier!  
**Enhanced state controller reacts approx. 1 minute earlier!**  
**Load cycling capability will be increased!**

# Conclusion

- **Enhanced state controller delivers 50% increase in secondary response capability (from 10% to 15% MCR) for the reference plant.**
- Power plants are time-variant systems, which require adaptive controllers with automatic parameter adjustment for optimum load-cycling performance.
- The coal dust measurement can be used to measure an additional state variable in the power plant and improve control.
- State controllers with observer are very effective in response to process variation and disturbance of the coal mills.
- State controller can be implemented independently from local DCS-OEM system using external control box.

# Thank you for your attention!

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