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Steam Power Plants as Partners for Renewable Energy Systems

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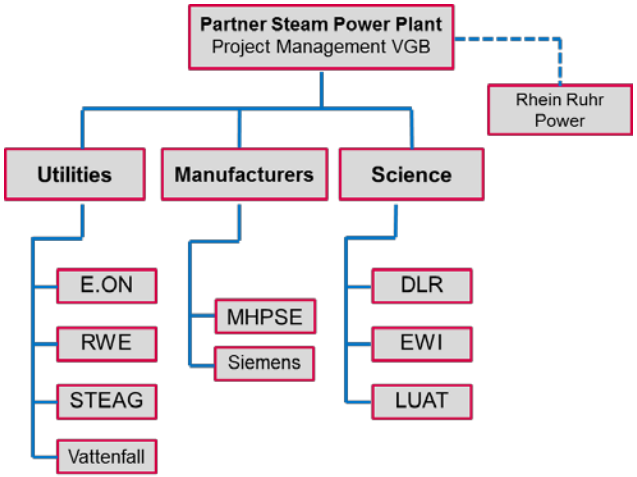
Steam Power Plants as Partners for Renewable Energy Systems

Overview of the partial projects

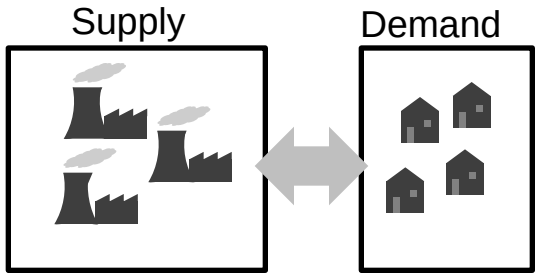


- Requirements for the future power plant mix (EWI)
- Definition of reference plants (STEAG)
- Simulation of thermodynamic performance (LUAT)
- Reduction of boiler load (MHPSE)
- Reduction of steam turbine start-up time and shut-down time (SIEMENS)
- Integration of storage systems in thermal power plants (DLR)
- Summary

Requirements for the future power plant mix (EWI)

Modeling of European power plant operation with *MORE*

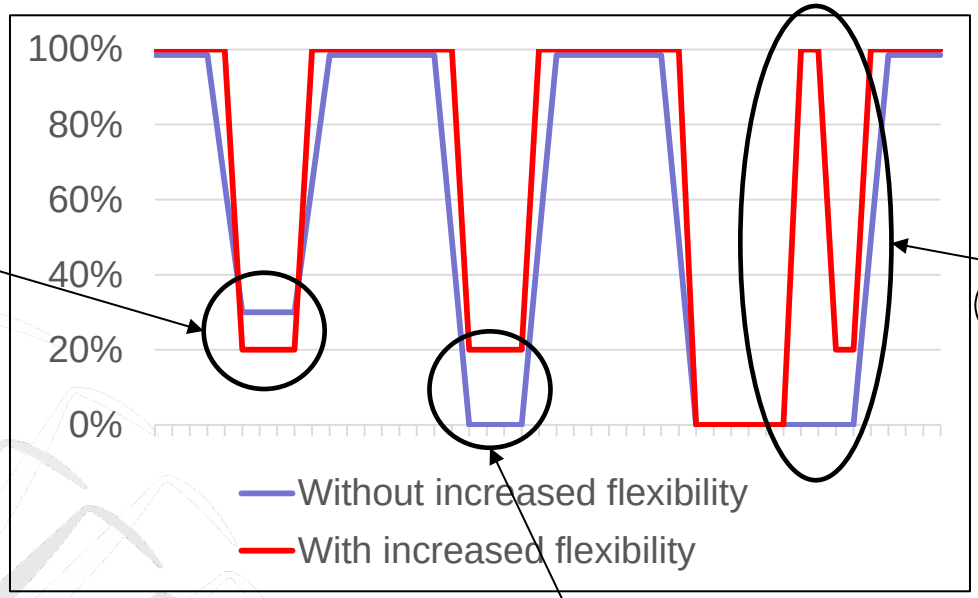
- Individual power plant blocks modelled in hourly resolution
- Detailed technical profiles for individual power plants
- Different flexibility options within the electricity market considered



- **Target:** Calculation of added value of flexibility within the overall European power plant system
- **Methodology**: Comparison of different model setups
- **Approach**: Variation of flexibility parameters for reference power plants
  - Reduction of minimum load by ~30-40%
  - Shorter startup time (by -50%) and lower costs (by -20%)

Requirements for the future power plant mix (EWI)

Effects of increased power plant flexibility



1 Lower minimum load …
… saves fuel (costs) and CO_2 emissions

2 Lower minimum load (instead of no load) …
… saves start-up costs and contributes to grid stability

3 Early start-ups…
will cover residual demand best

Increased flexibility can improve the technical, economical, and environmental performance of power plants

Definition of Reference Plants (STEAG)

- Criteria
  - Existing plants in Germany with sufficient remaining life time
  - Sufficient data available
  - Hard coal and lignite
- Power plant Schwarze Pumpe
  - Lignite
  - Two units of 800 MW each
  - Start of operation: 1997
  - Operator: Vattenfall
  - Net efficiency: 41,2%
- Power plant Voerde
  - Hard coal
  - Two units of 761 MW each
  - Start of operation: 1982 / 1985
  - Operator: STEAG
  - Net efficiency: 39,8%

Power plant Schwarze Pumpe. Source: Vattenfall

Power plant Voerde. Source: STEAG

Definition of Reference Plants (STEAG)

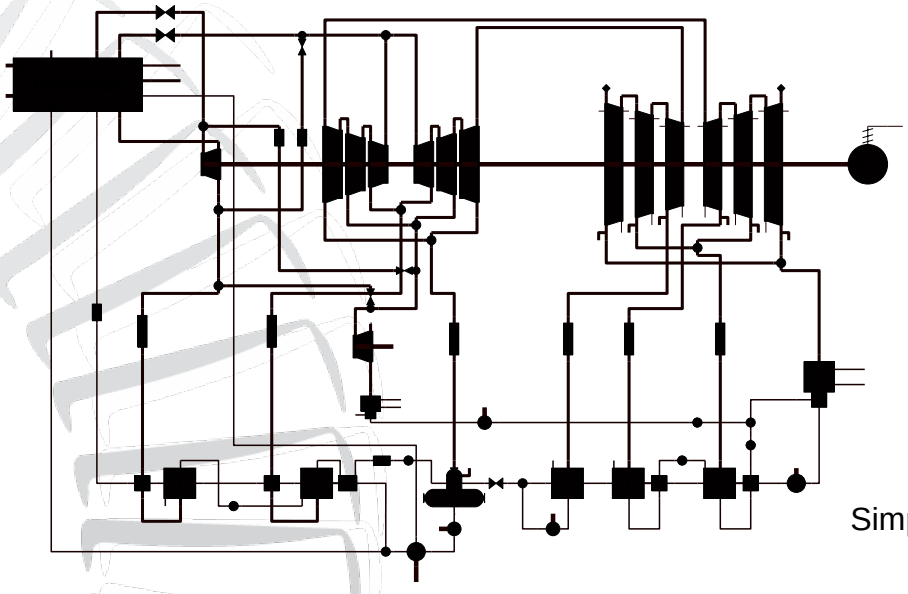
First results (STEAG)

- The Partner Steam Power Plant must meet increased requirements with respect to flexibility:
  - Lowest minimum power output possible
  - Lowest start-up costs possible
  - Sufficient fast power output changes
- Flexibility requirements
  - arise from the market
  - hence, are different for hard coal and lignite plants
- Different components limit flexibility
- Many limitations can be removed by using appropriate measures
- The result is a highly flexible power plant as a partner for renewable energies

Simulation of Thermodynamic Performance (LUAT)

Targets

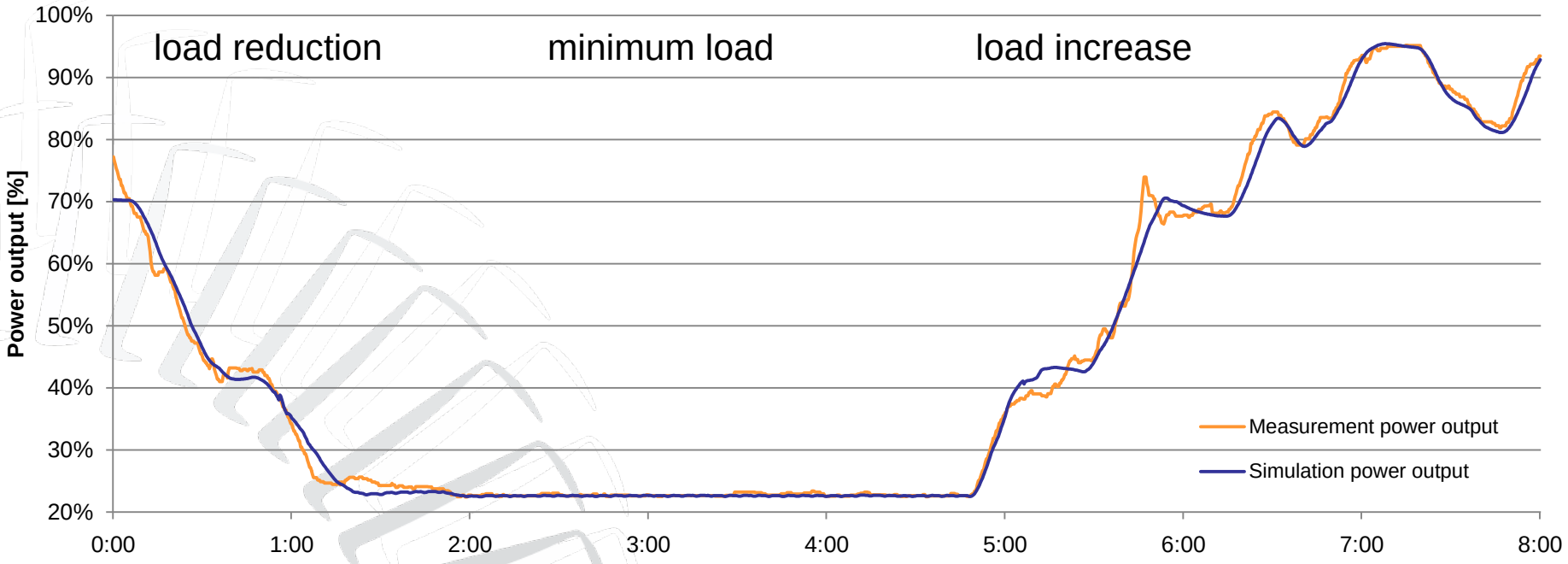
- Building of the stationary and dynamic overall system models
- Integration of thermal storages into the power plant process
- Simulations of several strategies/measures to increase the power plant flexibility (minimum load reduction, increasing load change rates, etc.)
- Applicability of the results to existing and new power plants



Simplified power plant scheme

Simulation of Thermodynamic Performance (LUAT)

Comparison of measurements and simulation results



- Good accordance between measurements and simulation results
- Basis for additional simulation studies

Reduction of Boiler Load (MHPSE)

Targets

- Development of technical solutions to reduce minimum boiler load
- Minimizing efficiency losses of the boiler system
- Realizing a quicker boiler response on the fluctuating load demand
- Optimization of boiler sub-systems and critical single components such as:
  - Firing system
  - Milling systems
  - Water – steam part
  - Thick-walled components
  - Material selection
- Concept studies on boiler operation characteristics

Reduction of Boiler Load (MHPSE)

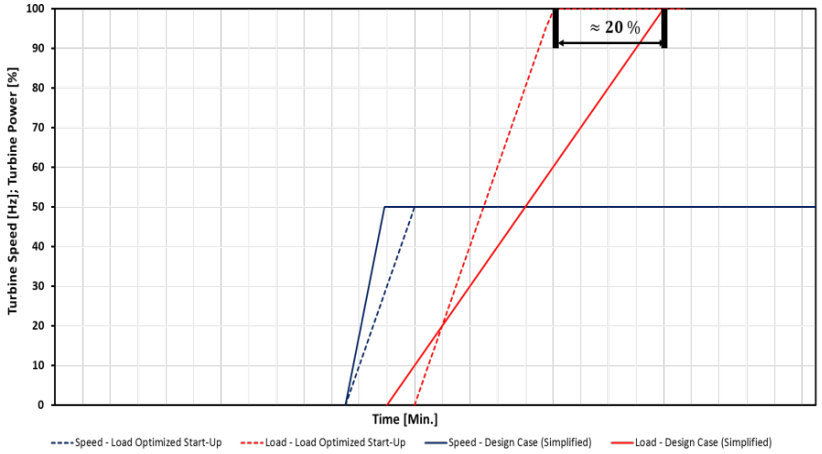
Some results from examined reference plant Voerde

- Increase of boiler load leads to a reduction of the classifier rotating speed
- Boiler load of 15% might be preferably achieved in 1-mill operation
- By installing 2 additional mills, it is possible to achieve a minimum load of 20% to 15%
- Through a replacement of the 4 existing milling systems by 6 smaller mills, it is possible to cover the total load regime
- Higher load ramp up/down rates can be achieved by installation of an indirect firing system
- Start up of the lower burner row by installation of an electrically heated burner nozzle may lead to considerable cost savings by decreasing auxiliary fuel consumption

Reduction of Steam Turbine Start-up Time and Shut-down Time (Siemens)

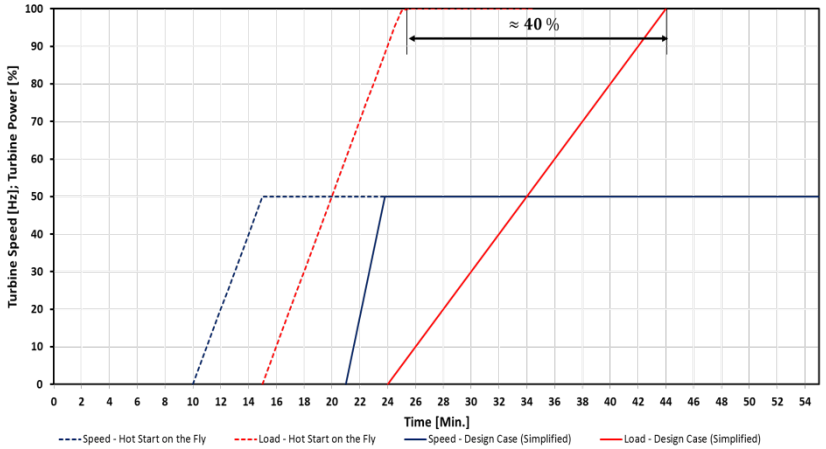
Improved turbine start-up time

- Start-up times can be reduced by about 20% for hot start conditions
- Main & re-heat steam temperatures are reduced for start-up
- This prevents excessive thermal stresses during start-up processes



Improved plant start-up time

- Overall plant start-up times can be reduced by about 40%
- In collaboration with project partners, steam turbine roll-off has been improved
- Focus was set on hot start-conditions



Reduction of Steam Turbine Start-up Time and Shut-down Time (Siemens)

Alternative Inspection Concept - HP turbine is replaced by an identical HP spare turbine

Benefits:

- Shorter inspection times (up to 50 %)
- Optimization of time and expenses projection for inspections
- Less risk of unexpected findings during inspections
- Increased lifetime of turbine components
- More flexible use of equivalent operating hours (EOH)
- Revolving change of components in similar power plants
- State of the art upgrades, so that
  - Optimization for changing operation principles are possible
  - The replaced turbine will have a better efficiency

Integration of Thermal Energy Storages in Thermal Power Plants (DLR)

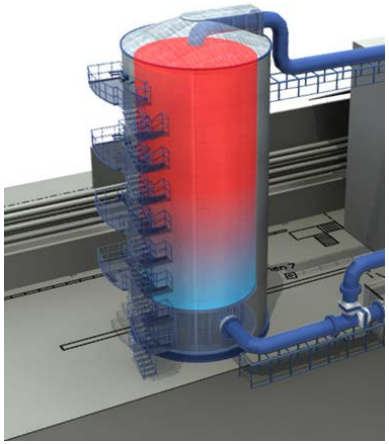
Storage technologies for power plant application

Liquid salts (commercial)

Steam storage (commercial)

Phase change materials
(pre-commercial)

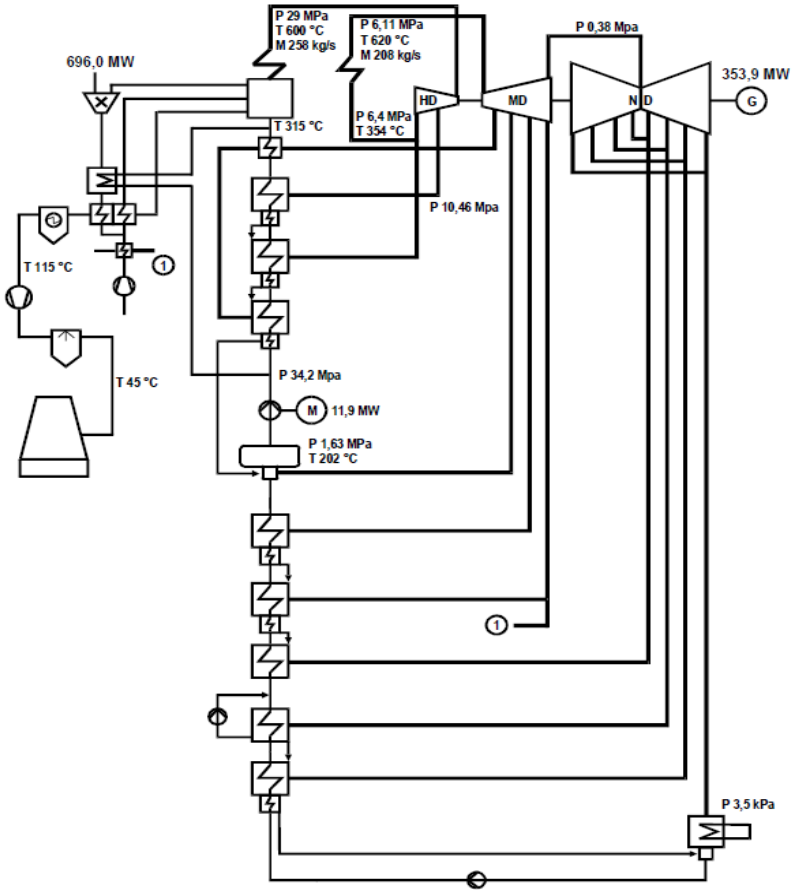
Solid materials
(demonstration stage)

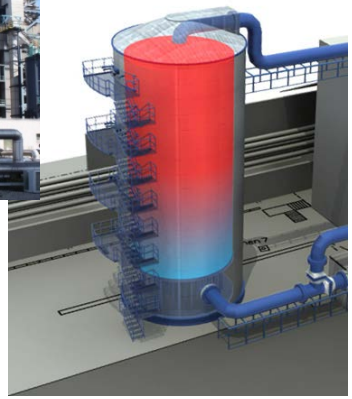


- Wide range of storage technologies for power plant applications available
- Adaptation for specific application necessary

Integration of Thermal Energy Storages in Thermal Power Plants (DLR)

Multiple purpose of storages in power plant operation





- Reduction of the minimum load ✓
- Improvement of load gradients ✓
- Accelerated start-up and shutdown ✓
- Decoupling of firing and power generation ✓

Steam Power Plants as Partners for Renewable Energy Systems

Summary

- Due to the remaining residual load security of supply on the basis of renewable energy sources (RES) is technically not feasible in the next decades
- Use of the existing fleet of thermal power plant capacity is an efficient solution to support an increased share of RES
- The mentioned flexibility measures need a new non-discriminatory market design with capacity provision remunerations and lead to increased economical and ecological efficiency and reduced CO_2 emissions
- Capacity markets work best in an integrated European market; UK and FR are pioneers and good examples that capacity markets are highly cost efficient

Transition to flexible operation already proceeded well, for satisfying the future demand additional options for flexibility have to be elaborated further