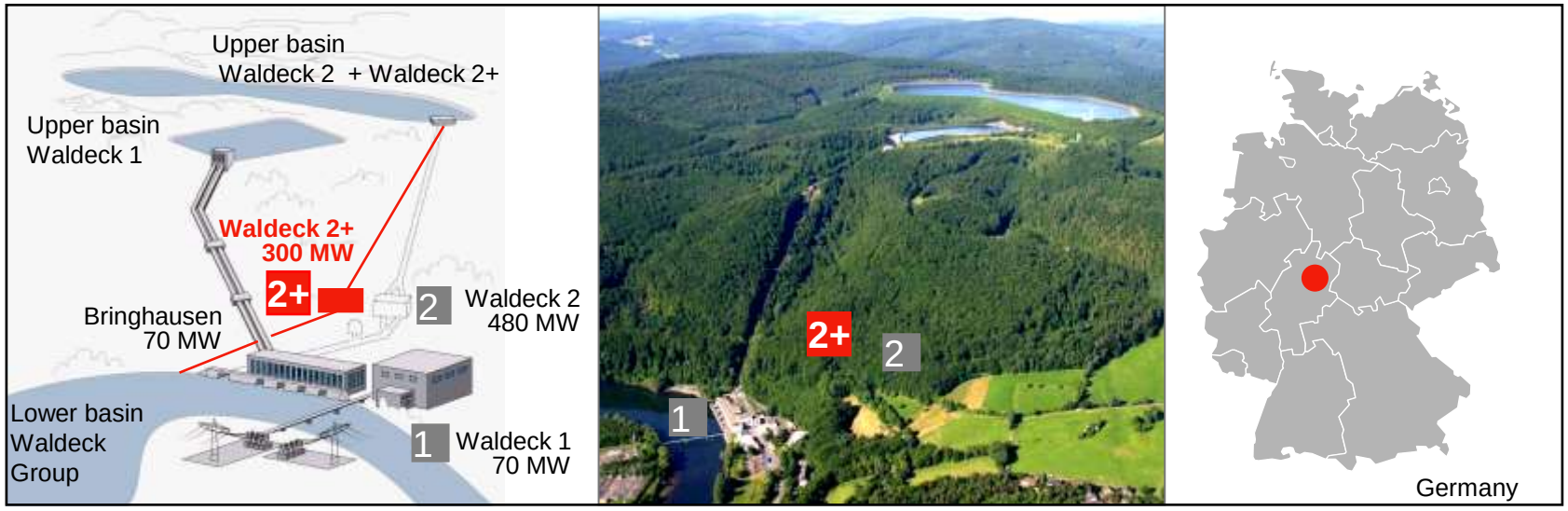

Extension of Pumped Storage Plant Waldeck 2 in Northern Hesse / Germany

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SHF Conference Grenoble
April 10, 2014

Agenda

Introduction

Existing facilities

Overview of the planned extension Waldeck 2+

Location of the new cavern Waldeck 2+

Machine concept and design capacity of the new plant

Cavern concept

Use of existing upper and lower basins

Project status and outlook

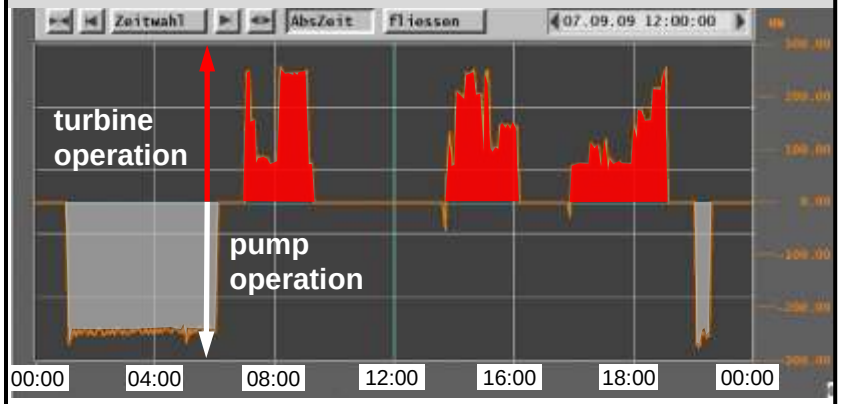
Introduction

- PSP were originally designed for providing peak-load and to profit from daily spreads
- Now PSP were increasingly used for the provision of system services
- Enormous construction of wind and solar powerplants are a result of the incentivizing renewal energy act (EEG) in Germany
- Storage of energy and a provision of high capacities on short notice is important to secure the power system and electricity supply

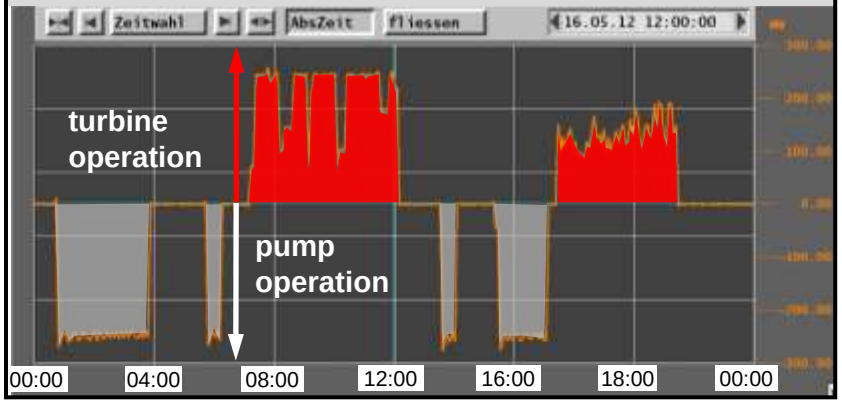
E.ON reviews the option to extend pumped storage power plant Waldeck 2

Pumped storage power plants in a changing climate

Typical operation in the past
One pump cycle and two to three turbine cycles per day

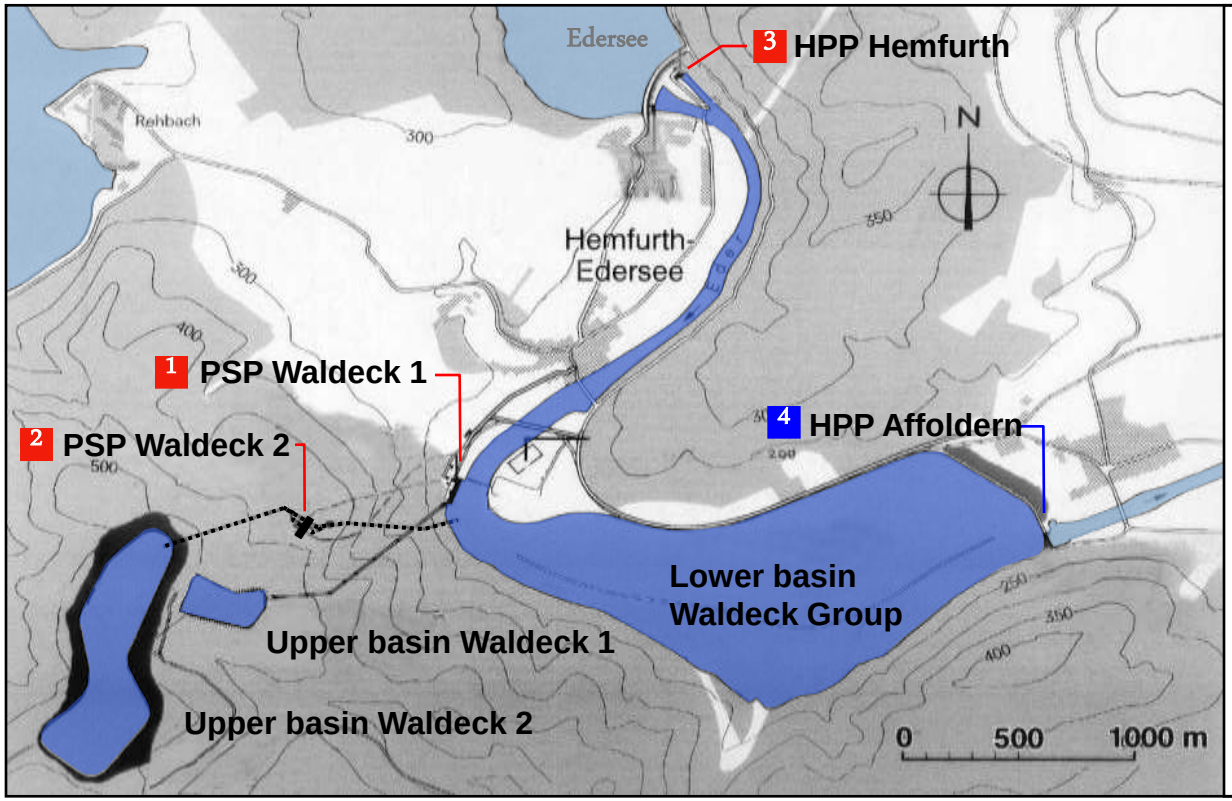


Typical operation today
Much more operating hours, a greater number of operating mode changes and pump operation in the afternoon



examples from operation Waldeck 2, engine no. 5

Existing facilities

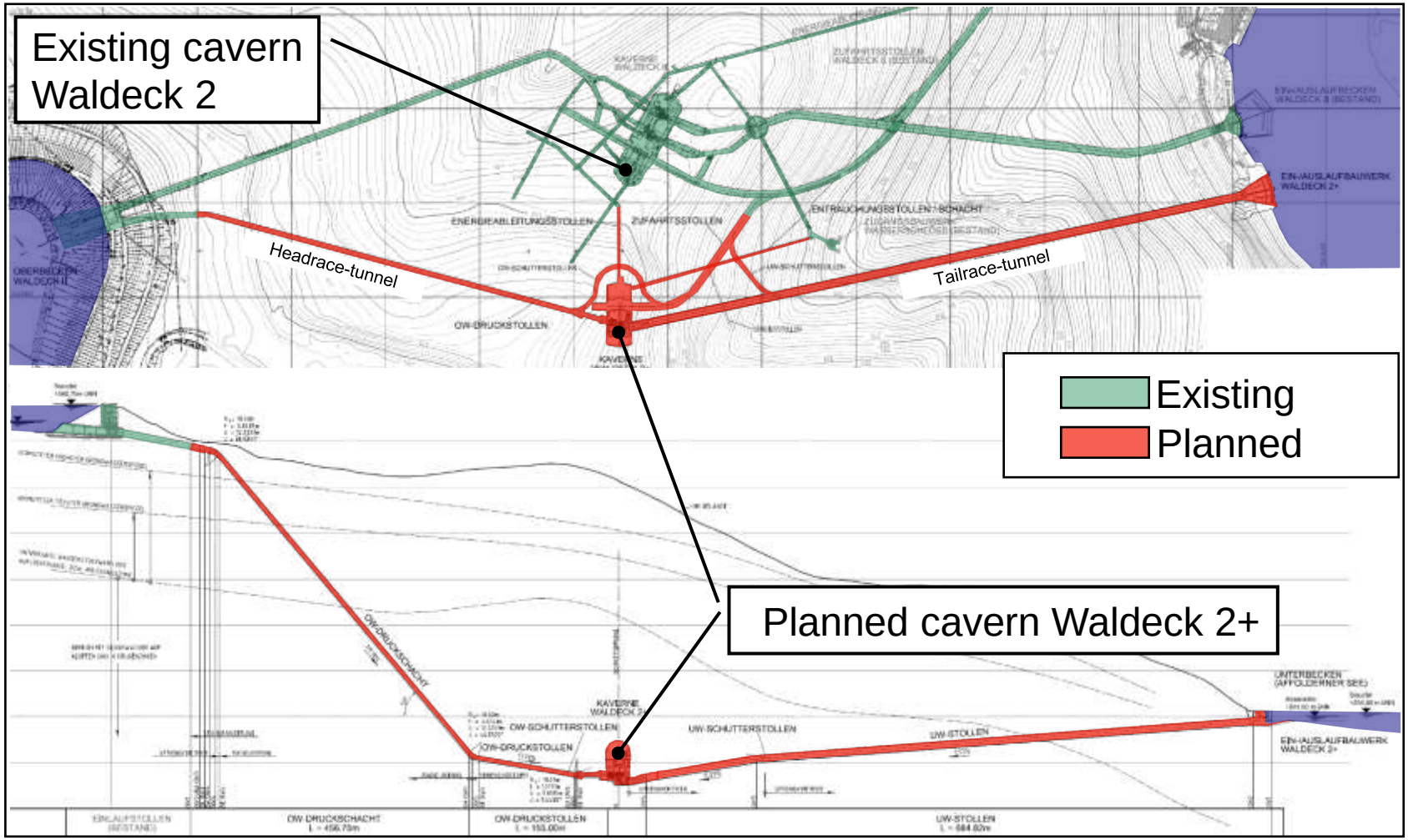


Deutschland

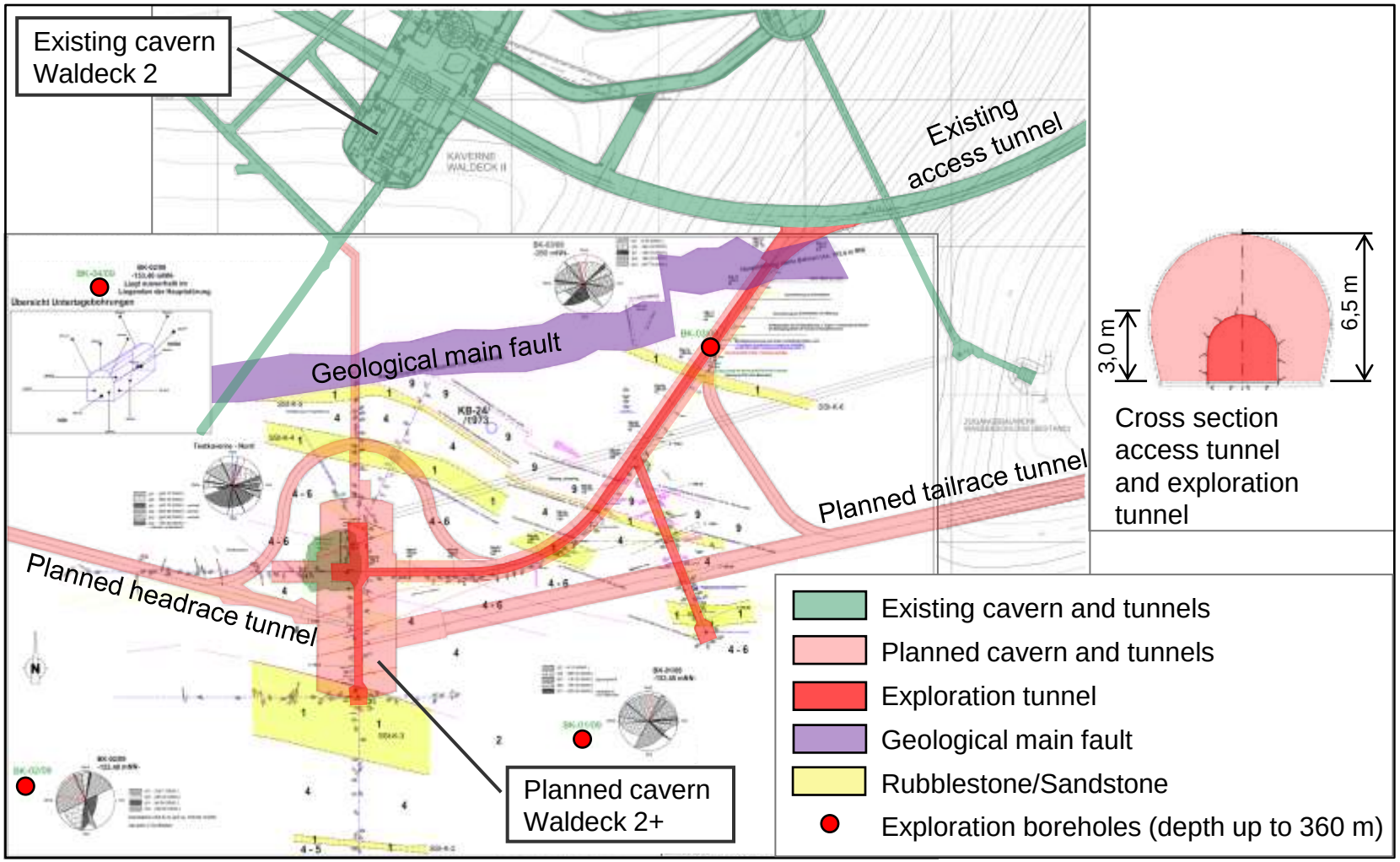
1 PSW Waldeck 1 (140 MW)
2 PSW Waldeck 2 (480 MW)
3 HPP Hemfurth (20 MW)
4 HPP Affoldern (2,8 MW)

When planning the Waldeck 2 scheme in the 1960s, a future extension of the plant had already been considered and the basins were designed accordingly.

Overview of the planned extension Waldeck 2+



Geological Investigations



Geological Investigations

Excavation of exploration tunnel, Feb 2012

Investigations confirmed
the geologists' assumptions

Machine concept and design capacity of the new plant

- Investigation of numerous layout and design options
- Parameters considered in detail
  - Design capacities between 200 MW and 400 MW
  - One- and two-machine concepts
  - Different design discharges (with or without extension of the basins)
  - Different types of machines:
    - pump-turbines with synchronous generator (without speed control)
    - pump-turbines with asynchronous generator (with speed control)
    - ternary machine sets (3-machine sets)
- Comprehensive studies of economic viability and technical feasibility

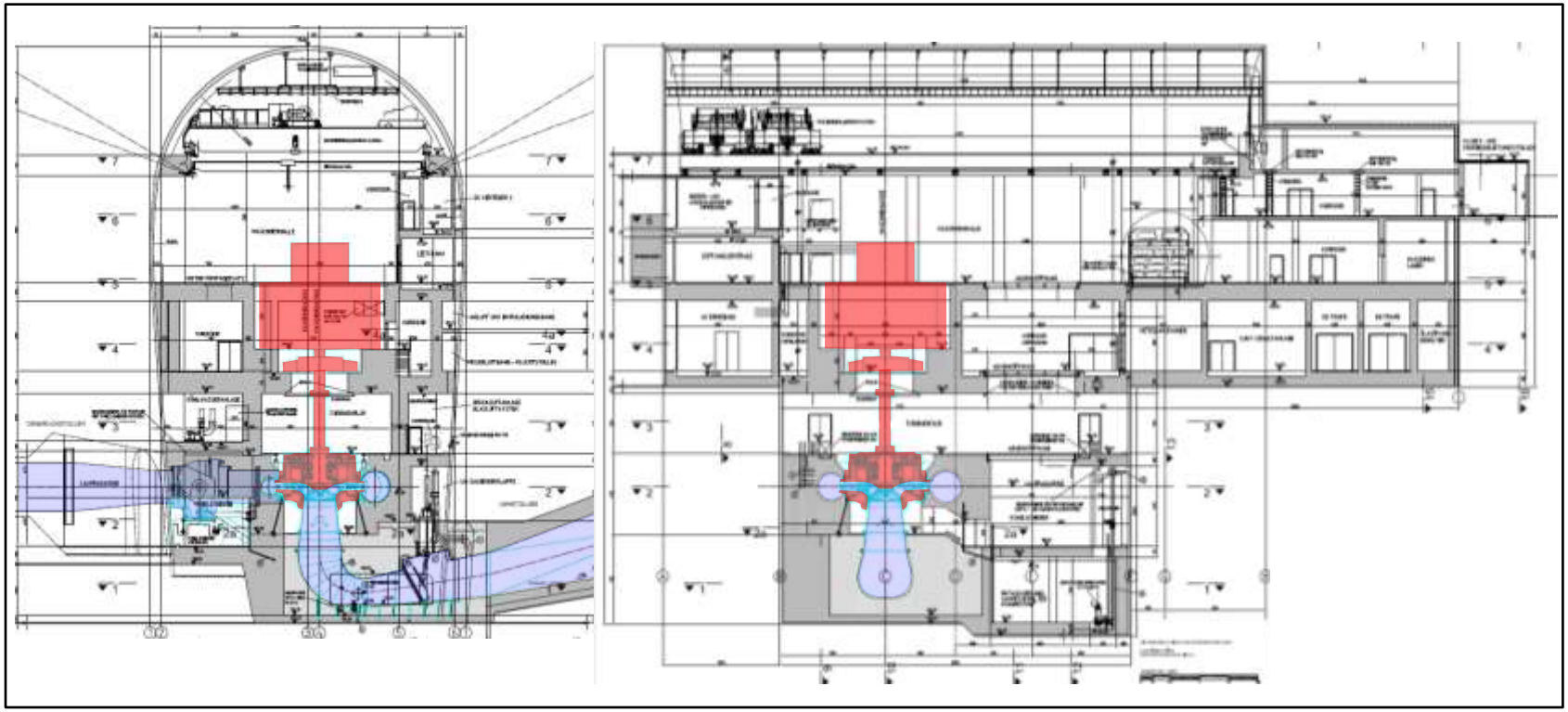
Optimal solution for Waldeck 2+:
Reversible, variable speed pump-turbine with a rated power of 300 MW

By combining the two existing ternary machine sets with the new variable speed pump-turbine the total system can be used much more flexible.

Machine concept and design capacity of the new plant

	Waldeck 2 (existing facility)	**Waldeck 2+ (planned facility)**
Pressure head	330 m	330 m
Design capacity	2 x 240 MW = 480 MW	300 MW
Machine type	2 ternary machine sets consisting of turbine, motor generator and pump	Reversible pump-turbine with asynchronous generator (pumping capacity variable between 200 and 300 MW)
rpm	375 min^{-1}	333 min^{-1}
Design discharge Q_{Turb}	2 x 80 m^3/s	105 m^3/s
Grid connection	380 kV	380 kV

Cavern concept



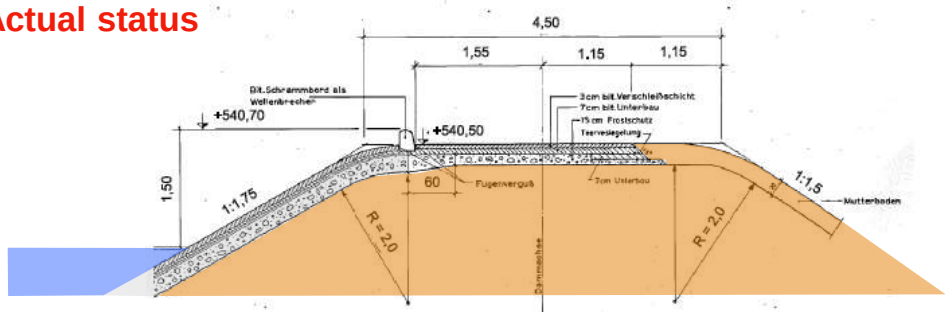
- Machine and transformer are housed in the cavern powerhouse
- Excavation volume of cavern could be considerably reduced from 89,000 m³ down to 55,000 m³ → dimensions now L/W/H = 68.00/27.00/48.45 m

Use of existing upper and lower basins

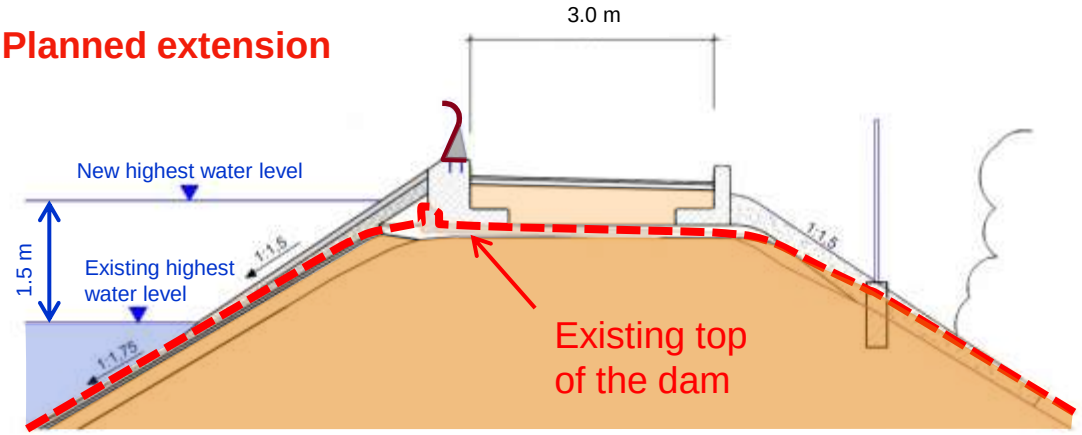
Upper basin

- Extension of water volume for 450.000 m³ (extension by 11 %)
- Maximum water level will be increased for 1.50 m
- Raising of the crest for 0.50 m
- Wave protection with steel parts on the crest

Actual status



Planned extension



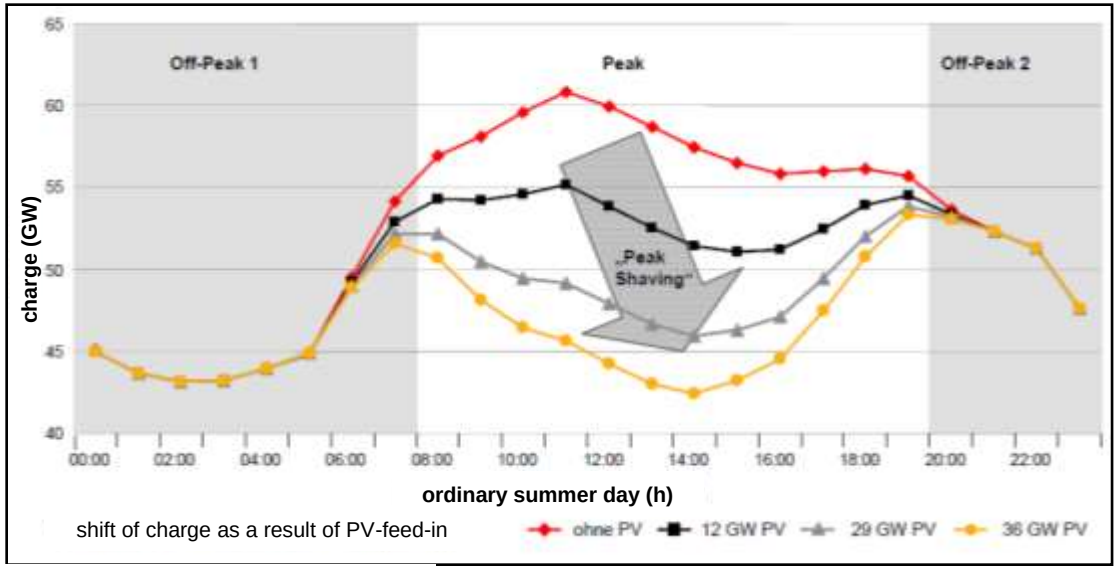
Lower basin

- Maximum water level is increased by 0.10 m, minimum water level is simultaneously reduced by 0.10 m

Project status and outlook

- The current German energy market does not provide sufficient investment security for the planned extension

  → E.ON has postponed the investment decision for the main project



„Peak-Shaving" due to feed-in of subsidized renewable energies reduce profitability of PSP dramatically

At present there is no market for system stabilization

Source: Godde + Engels (2013)

- However: The increase of the upper basin's dam will start as a first sub measure in May 2014