Giga-Watt Generation Panel Session

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Hydro Generators
August 2008

Content

- Recent developments in pumped storage energy
- Answers to questions asked for in the panel session

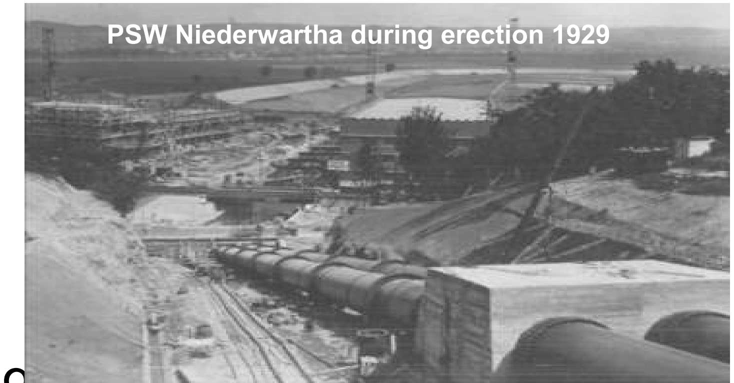
History of Pumped Storage Energy

The first pumped storage power plant was already built at the beginning of the last century

PSPP Niederwartha (Commissioning 27.11.1929)
A great achievement of engineering skills

Development to highest performance after World War II

- 1961 - Cruachan, Scotland – more than 100MW
- 1970 - Vianden, Luxemburg – more than 200MW
- 1974 - Chiotas, Italy – multi-stage, more than 1000m head


PSW Niederwartha during erection 1929


PSW Shi San Ling 900 MVA, China, 1995


PSW Tian Huang Ping 2000 MVA, China, 1998

Why Pumped Storage Energy?

Energy storage
Unique technology to store huge quantities of energy at reasonable efficiency (cycle 80%)

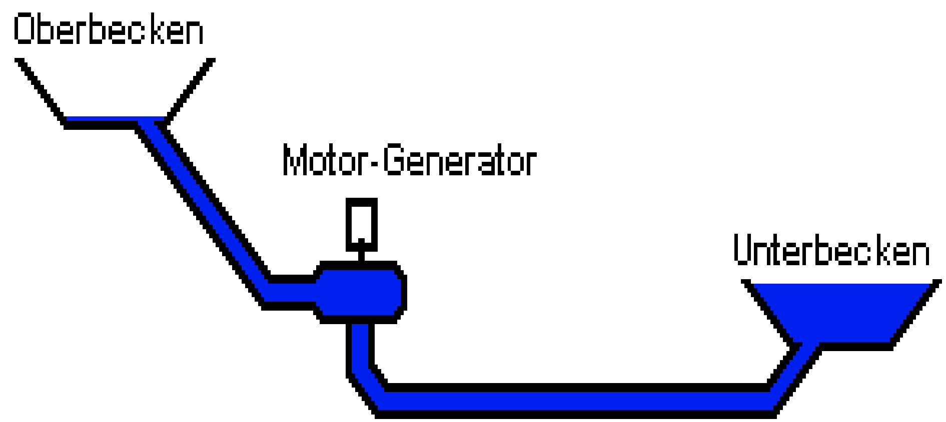
Balancing energy production and demand in electrical grids

Pumped storage power plants provide or absorb electrical energy quickly

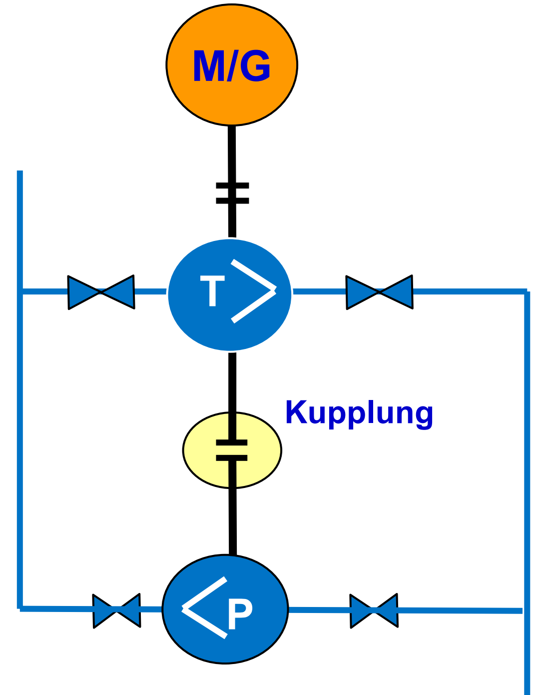
Compensation of excess capacities (e.g. nuclear power plants)

Free of emissions

Improvement of efficiency of thermal power plants



Technology 1 – Group of 3 machines (ternary units)



Advantages:

- Quick transition
  Turbine ←→ Pump
- Pump start filled with water without problems
- High turbine and pump efficiencies
- Possibility of direct hydraulic short-circuit
  (regulating power up to ±100 %)

Disadvantages:

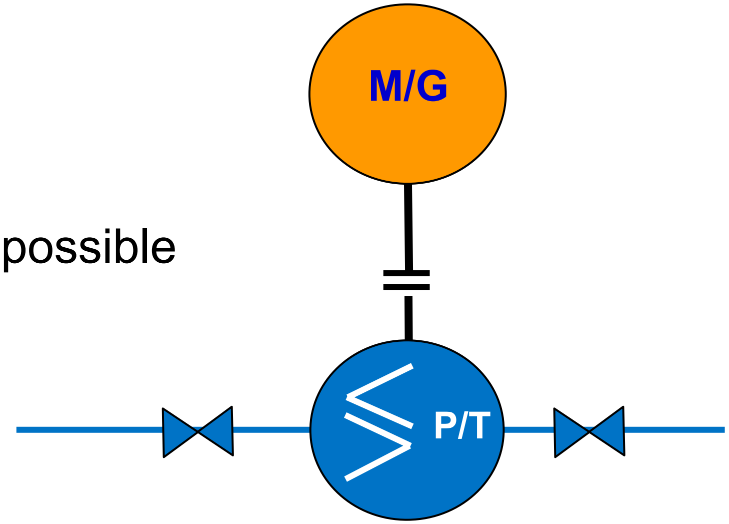
- High equipment costs
- Additional requirement on space
- More valves


PSW Häusling 400 MVA,
Austria, Commissioning 1986

Technology 2 - Reversible (Francis) Pump Turbine

Advantages:

- Compact power house
- Cost-effective solution
- Indirect hydraulic short-circuit possible



PSW Goldisthal
VAR Rotor 350 MVA

Disadvantages:

- Long transition times
  Turbine ←→ Pump
- Start-up in pump mode requires high power or blowing-out water

PSW Vianden
Blade wheel 220 MW

Preferred method for starting in pump mode

- electrical „back to back“
- with static frequency converter (SFC) in air

Variable speed principle - Developments

1970 First theoretical analyses

1990 Japan – first variable speed pump turbine

Yagisawa (1 x 85 MVA, 156…130 rpm)

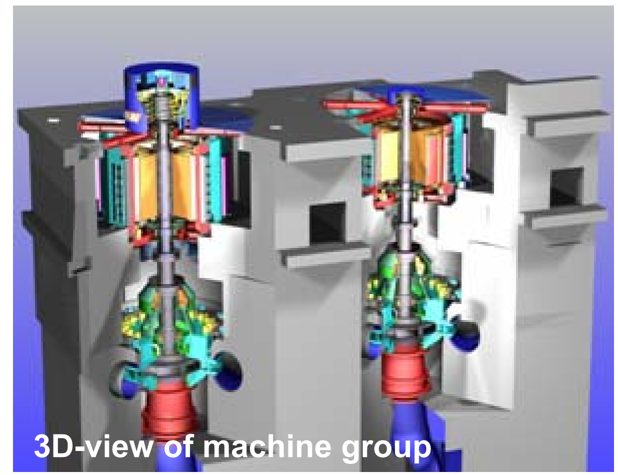
1995 Japan – largest variable speed pump turbine

Ookawachi (2 x 395 MVA, 390…330 rpm)

2003 Germany – largest hydro power plant of Germany

Goldisthal (2 synchronous and 2 asynchronous units, total output 1060 MW)

PSW Goldisthal 1060 MW



3D-view of machine group

IGCT

Goldisthal / Germany

Client: Vattenfall Europe

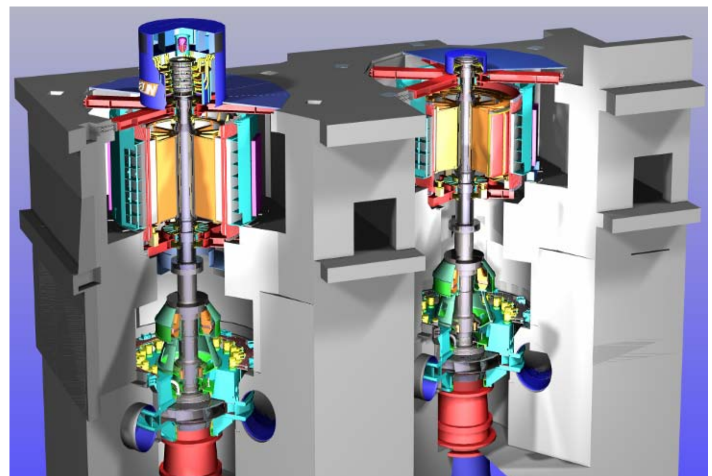
Equipment:

- 2x300 MW and 2x261 MW 1-stage reversible pump turbines, 2x340 MVA and 2x331 MVA motor generators, AC-excitation and start-up - SFC
- Mean head 302 m
- 300..346 rpm and 333 rpm

Project Highlights

- 2 rotor-fed asynchronous and 2 conventional synchronous units
- Central position in UCTE grid

Successfully in operation since 2003

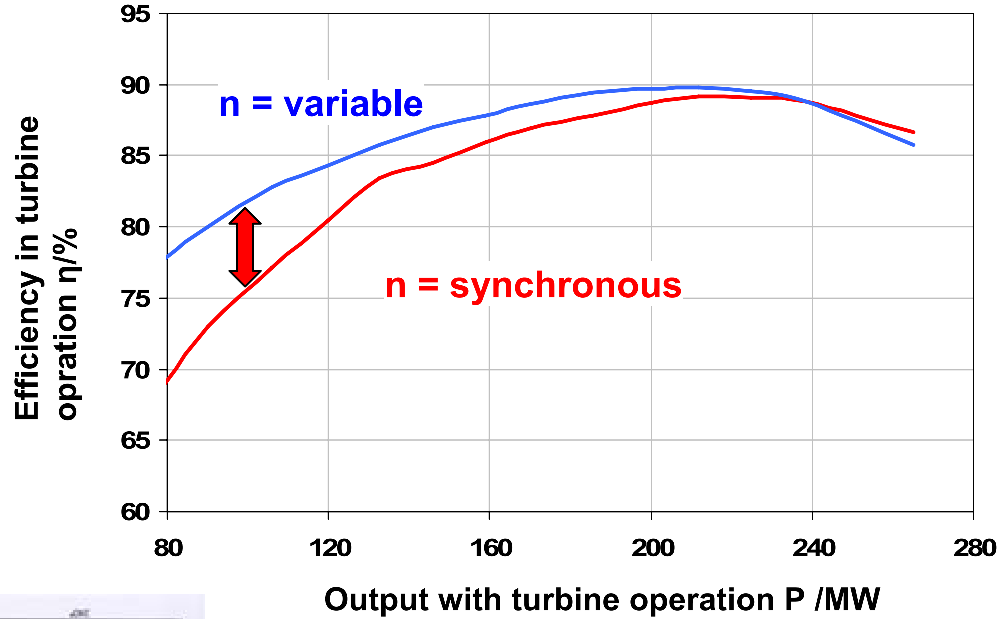


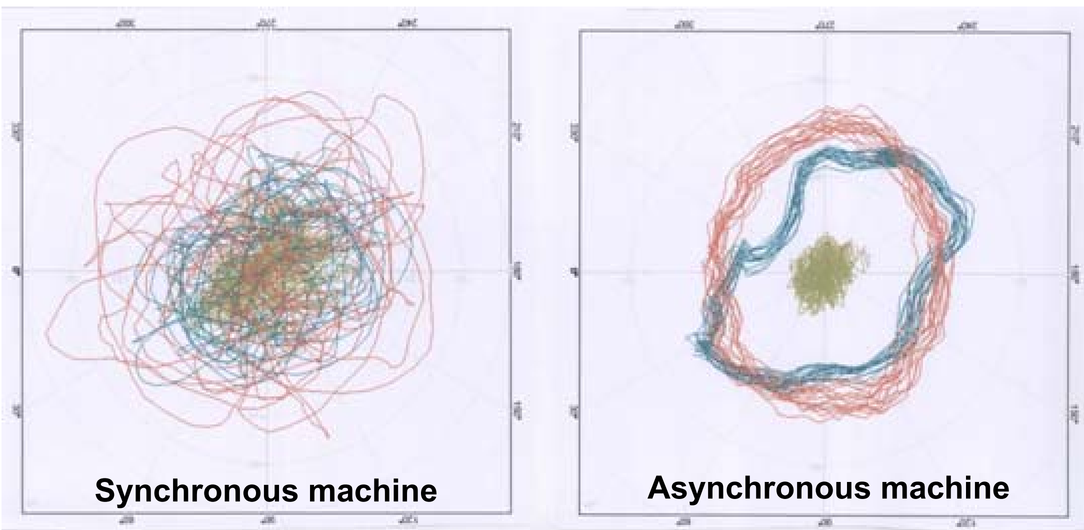
First variable speed pumped storage power plant in Europe

Variable speed principle – Main advantage for pump turbines

Advantages of efficiency in turbine operation caused by shifting of operating point in more favourable ranges of the characteristics curve

Continuously variable output control in pump operation within certain limits





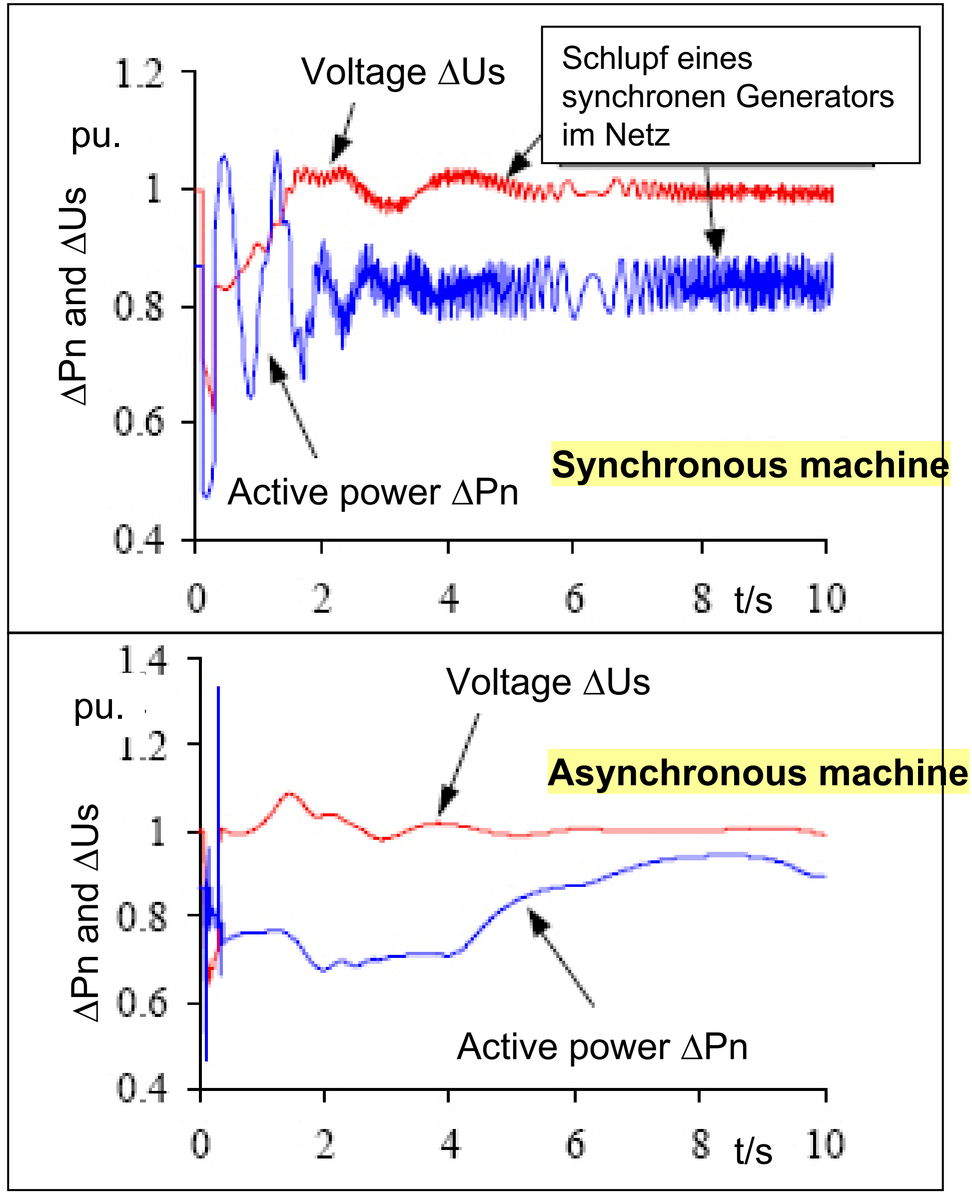
- Extended head range
  - Ratio head H_{max} to H_{min} within 1.25 to 1.45
  - For fixed speed max. approx. 1.25
- Smooth running (reduced vibration)
- Increased life endurance

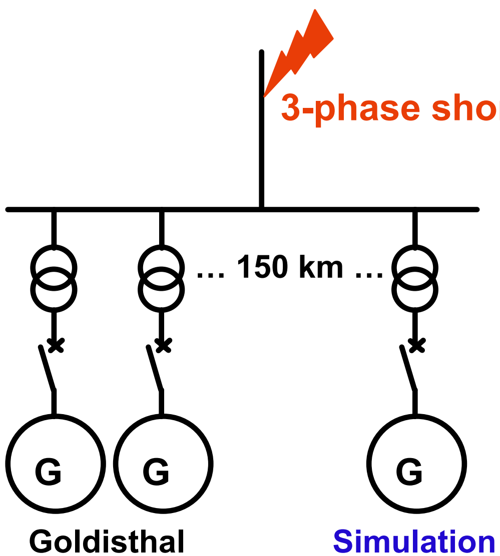
Variable speed principle – Main advantages for grid

Simulation

- Short-circuit in the grid
- Voltage drop by approx. 30%
- Synchronous generator in approx. 150 km distance
- Dynamic behaviour
- Comparison of stability

Asynchronous units stabilize synchronous generators in the same grid





Quelle: 15. Triennial World Congress, I.Ehrlich, TU Duisburg, U. Bachmann, VEAG

UCTE-grid - tomorrow

Supply of electrical energy to approx. 800 Mio. people (today 450 Mio.)

Approx. 850 GW installed capacity (today 625 GW)

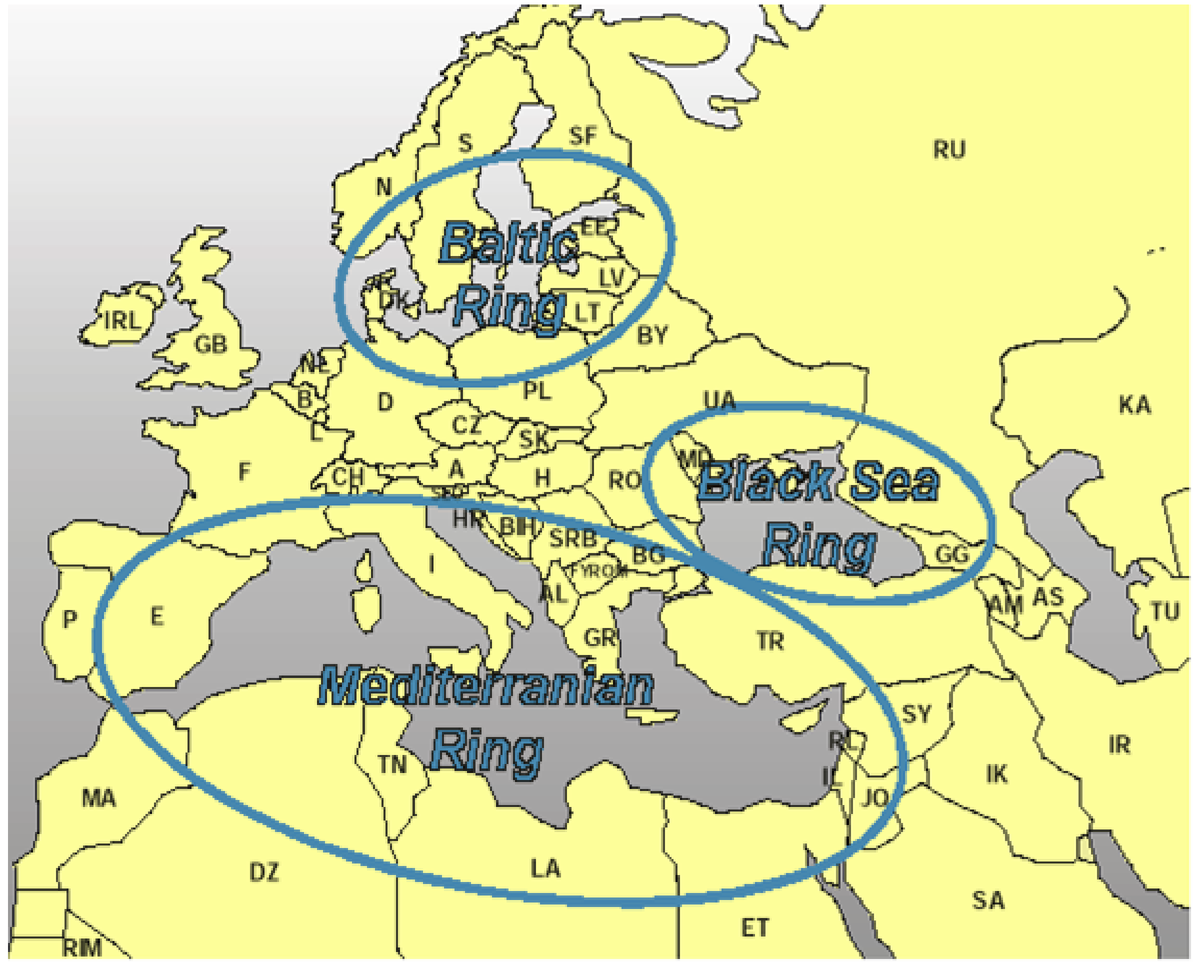
Increase of grid stability

- Pumped storage as stabilisation factor

Grid oscillations

- Pumped storage as attenuation factor

UCTE grid - **U**nion for the **C**oordination of **T**ransmission of **E**lectricity



Wind energy in grid

Wind energy has increasing importance in European “electricity mix” with rising tendency

39 GW installed wind capacity

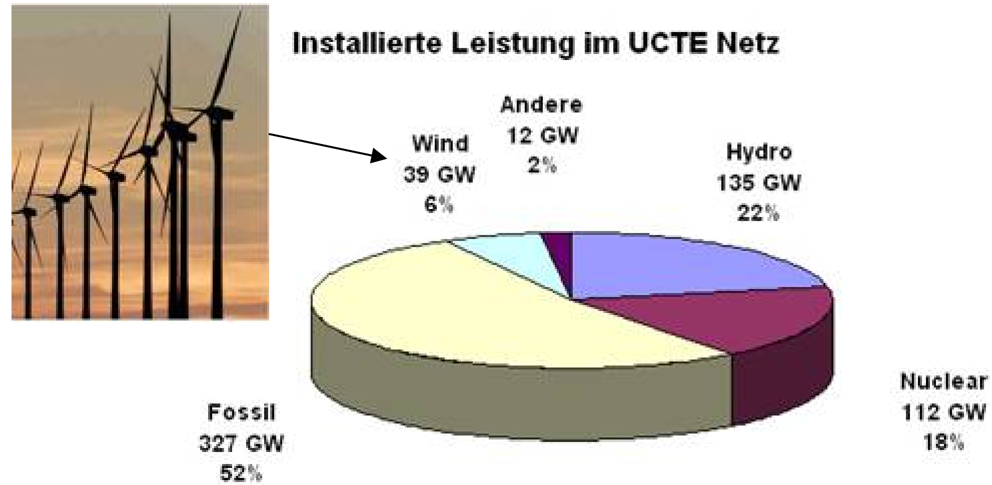
- Germany, Spain, Netherlands and Denmark

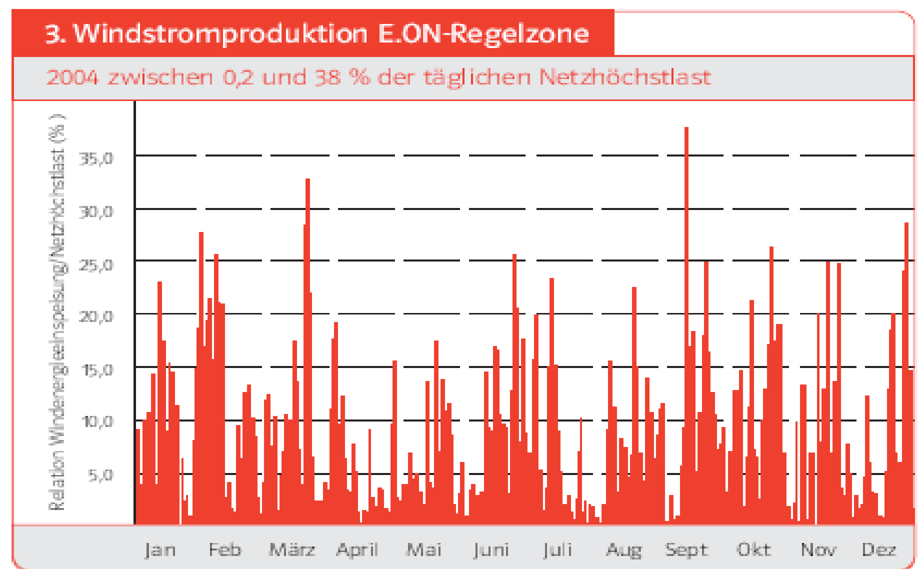
0.2..38% of daily grid peak load

Typical characteristics of wind

- Very volatile
- Low predictability
- Low reliability
- Operation difficult to be planned

Balancing is required ⇨ PSPP

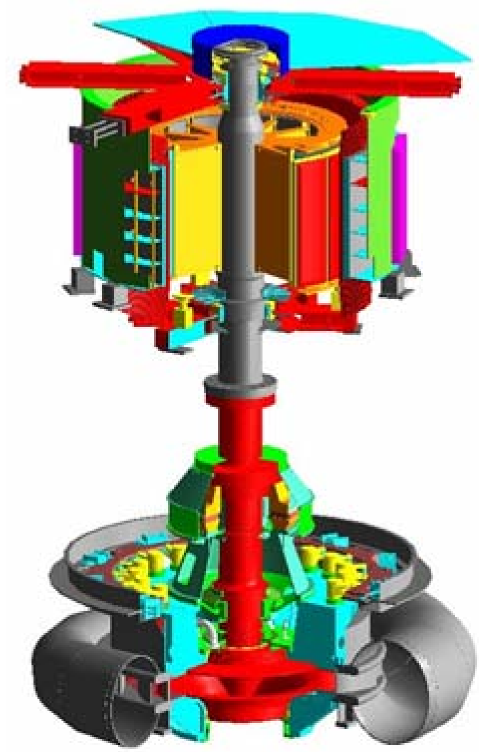




Quelle: e.on-Netz Windreport 2005

Pumped Storage Energy - Summary

- Most economical method to store large energy quantities
- Particularly important when considering the entire energy system
- Ensures energy balancing and improves stability in the grid
- Essential because of development of volatile wind energy
- Remarkable comeback in Europe
- Investments in Pumped Storage Energy rise all over the world
- Benefits from technological improvements in hydraulic and electrical engineering and automation
- Due to the future world-wide largest synchronous grid Europe becomes global trendsetter for Pumped Storage Energy



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1.4.a) What are the largest nuclear (4 pole) and fossil (2 pole) generator that you are developing/ have recently developed?

- None

1.4.b) What are the largest Hydro units developments in the categories given in section1.4 below that you are developing/ have recently developed?

- Hydroelectric generators with a diameter over 11 meters
  - Bemposta 212 MVA/ 115 rpm
- Hydroelectric generators with a nominal speed over 300 rpm and over 100 MW.
  - Limberg 270 MVA/ 428 rpm
  - Beles 130 MVA/ 375 rpm
  - Nestil 165 MVA/ 600rpm
  - Kops 180 MVA/ 500 rpm
  - Gerlos II 165 MVA/ 375 rpm
  - Nagjari 166 MVA/ 375 rpm
  - Ermenek 177 MVA/ 375 rpm
  - Tong Bai 334 MVA/ 300 rpm
  - Cruachan 144 MVA/ 500 rpm
  - Teesta Urja 245 MVA/ 375 rpm

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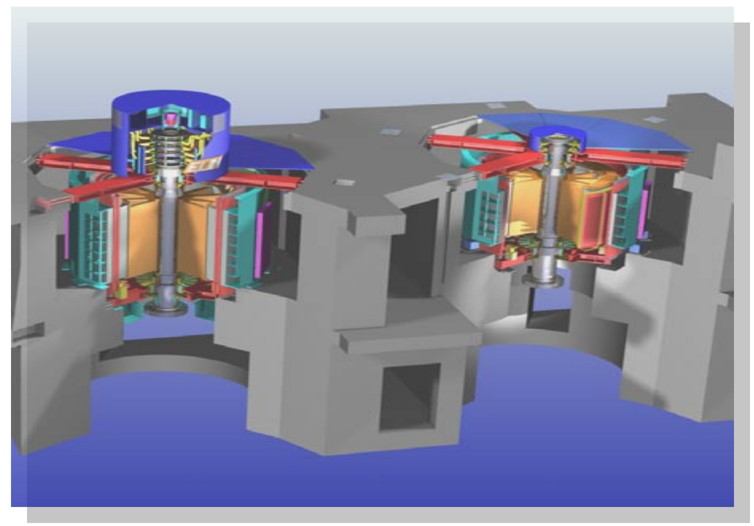
- Hydroelectric generators with
  - Francis turbines larger than 300 MVA
    - Goldisthal 331 MVA/ 333 rpm
    - Tong Bai 334 MVA/ 300 rpm
  - Kaplan turbines larger than 150 MVA
    - None
  - Bulb turbines larger than 50 MVA
    - Santo Antonio 82 MVA/ 100 rpm
  - Pelton turbines larger 200 MVA
    - Teesta Urja 245 MVA/ 375 rpm
  - large double fed asynchronous machines
    - Goldisthal 341 MVA/ 300-346,6 rpm



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1.4. c) What are the main design features that were applied to achieve the larger design? How is transportation solved?

- Stacking and winding at site
- Laminated rotor rim stacked at site
- Sliding box for statorframe-foundation connection

1.4 d) What design feature have you applied in the generator to enhance the reliability required on such a large unit?

- Expandable stator frame (sliding box) against core buckling
- Shrink fit for laminated rim
- Elastic winding embedding EWB
- FEM for electromagnetic and mechanical design
- CFD for ventilation

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1.4. e) What design assessments have been carried out to ensure the reliability and long term integrity of the generator?

- Design reviews for the electromagnetic, ventilation and mechanical design
- FEM
- CFD

1.4. f) What special consideration will users need to give in the running and maintenance of these large units?

- No special consideration as compared to smaller units

1.4. g) What considerations have been given to ensure stable operation on the gird?

- This is normally investigated by the client, as a supplier we are only occasionally involved.

1.4. h) State of the art in the developments of Hydro and Thermal Turbine Generators.

- Use of
  - FEM for electromagnetic and mechanical design
  - CFD for ventilation design
  - Highly developed insulation system and winding embedding system