THE CONTRIBUTION OF HYDROPOWER TO STORAGE OF ELECTRIC ENERGY

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ROLE OF HYDROPOWER

Hydropower provides 16% of electric power needs in Europe, and continues to be a cornerstone of Renewable Energy concepts

1. Run-of-River Hydropower
- Predominantly but not necessarily low head
- Frequently combined with navigation
- High load factor MWh (energy) / MW (output)

Rheinkraftwerk Iffezheim (Germany, France)

Iffezheim
Old scheme 4 x 28 MW
Extension 1 x 38 MW

Electricity for 250,000 households
ROLE OF HYDROPOWER

2. Storage Hydropower
- Most frequent concept, daily / weekly / yearly storage
- Increasing importance in new energy systems

New Lysebotn Norway

\[ P = 2 \times 185 \text{ MW} \]
\[ H = 685 \text{ m} \]
New Underground Powerstation
Existing reservoirs
Output increase
Construction 2013 - 2018
ROLE OF HYDROPOWER: PUMPED STORAGE FOCUS

3. Pumped Storage

With affordable electricity supply from Renewables

⇒ Role of Hydropower shifts from **GENERATION → FLEXIBILITY SERVICES & STORAGE**

Pumped Storage is most flexible, economically feasible for large amounts of electricity, medium / longer time
VALUE OF PUMPED HYDRO STORAGE

- Pumped Storage is a mature industry
- First installations ~ 20 MW/unit in Germany: Köpchenwerk (Ruhr), Niederwartha (Elbe)
Commissioning ~ 1929

Global Pumped Storage capacity 153 GW
Expected increase next 5 years: +26 GW (IEA)

Goldisthal - Upper Reservoir  Source Vattenfall/// - pA- dpa

Typical overview on Storage technologies
VALUE OF PUMPED HYDRO STORAGE

FLEXIBILITY solutions:
STORAGE & ANCILLARY Services

- Inertia
- Frequency regulation
- Reserve
- Reactive power
- Black start
- Isolated grid operation
- Low voltage ride through (LVRT)

Balancing
- Frequency control
- Storage capacity if reservoir present
- Near zero-carbon backup for variable output RES

Fast load changes (Ramping)

Main concept: Single Stage Reversible Francis Pump Turbine (up to H=800 m)
See examples (later)

Special concepts (even faster):
Ternary units (Pump / Turbine separate)
Variable speed applications

Ancillary Services

Reactive power
- Voltage stabiliser
- Loop flow control
- Bottleneck control
- Short circuit capacity

Black Start
- Power system reconstruction

Obervermuntwerk II, Austria (2x180 MW) / ANDRITZ HYDRO – EDF HYDRO / PUMPED STORAGE / SEP 2019
Pumped Storage References

Goldisthal – Germany: Fixed + Variable Speed

- Customer: Vattenfall Europe
- In operation since 2002
- 4x 265 MW Reversible Pump-Turbine units
  H = 330 m
- 2 units with variable speed
- Main equipment supplied by Andritz and Voith

- Double Fed Induction Generator
- Reversible Pump-Turbine
- Pump-Turbine runner welding in Ravensburg
PUMPED STORAGE REFERENCES

Vianden – Luxemburg

Customer: SEO / RWE

- Pumped storage plant from ~1960
- Total output increased to 1290 MW
- Original scheme: 9 x 100 MW ternary units, horizontal shaft
- Two extensions:
  1 + 1 $P = 195$ MW
  Reversible units, vertical shaft

Operation mode became very dynamic (balancing wind power)

Lower reservoir: River Our
Three separate powerhouses
PUMPED STORAGE REFERENCES

Bajo Sabor Jusante & Montante - Portugal

Increased Flexibility for entire River Douro Scheme

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<thead>
<tr>
<th></th>
<th>Jusante</th>
<th>Montante</th>
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<tbody>
<tr>
<td>Power</td>
<td>2 x 18 MW</td>
<td>2 x 76 MW</td>
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<tr>
<td>Head range</td>
<td>34.5m – 25m</td>
<td>104m – 89.4m</td>
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<tr>
<td></td>
<td>(67.5m)</td>
<td>(67.5m)</td>
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<tr>
<td>Commissioning</td>
<td>2016</td>
<td>2016</td>
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Very large operating range
PUMPED STORAGE NEW PROJECTS

Hatta – United Arab Emirates (Dubai)

Customer: DEWA

Plant Capacity: 250 MW for 6 hours
Head variability: 125 – 175 m
Lower reservoir already existing
2 reversible Francis units, variable speed

UAE has an ambitious and strategic program of Solar Power Storage capacity provided by Batteries + Pumped Storage

Engineer: EDF Hydro

Contract Award Aug. 2019 to Strabag – Özkar – Andritz
PUMPED STORAGE NEW PROJECTS

La Coche PSP extension project – EDF, France

Additional Turbine – Generator unit
1 Pelton turbine  240 MW : largest Pelton unit in France
H = 908 m

- La Coche : 1 of the 6 EDF Hydro PSP installations
  (T : 5 GW ; P = 4,2 GW)
- Extension of an existing Pumped storage plant, additional output for peak operation
- Plant Output increase from 320 MW to 400 MW
- Reduction of repair and maintenance work on existing multi-stage pump turbines (impact of sediments)
- Increased flexibility due to flat efficiency curve and fast load changes of the Pelton turbine
- Additive Manufacturing (Microguss) in Ravensburg
  2 Pelton runners D1 = 2840 mm
- Construction 2015 – 2019 : Project is on time & on budget !!
The potential of Hydro PSP is very important

- On existing or partially existing sites: possibilities to connect existing reservoirs, while limiting:
  - Important additional CAPEX
  - Environmental footprint of installations

- European Joint Research Center (JRC) study (2013): potential is in between 3.5 to 10 times the existing PSP capacity, only considering sites with 1 or 2 existing reservoirs

- In France:
  - Technical potential > 20 GW, incl. existing or green-field sites
  - RTE vision by 2035: +1 to 3 GW of PSP would be needed

- A new emerging solution: Marine Hydro PSP

- The reality of future PSP projects will depend on the capacity of power market to reveal the global value of PSP on the grid

Theoretical PSP potential in Europe considering sites with 1 existing reservoir
Source: JRC (2013):
Overall cost of Pumped Storage is favorable, even more when considering stored energy (GWh).

Source: HydroWIRES, U.S. Department of Energy, July 2019
ADVANTAGES / DISADVANTAGES OF PUMPED HYDRO

ADVANTAGES

➢ Hydro: excellent Energy Payback ratio
➢ Very low cost of stored energy (GWh) over entire lifetime,
➢ Very low CO2 emission
➢ High cycle efficiency (up to 80%)
➢ Almost zero losses during storage
➢ No degradation over lifetime
➢ Low maintenance cost
➢ Proven technology
➢ Additional benefits (ancillary services)
➢ Many possible sites

DISADVANTAGES

➢ Market not (not yet) adapted to reveal the real value of PSP to the grid
➢ Long planning and approval period
➢ Long time for construction
➢ High investment cost, long payback period
➢ Incertainty of revenues over long time
➢ No big support for new developments
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