

Technological innovation in the field Hydropower

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Imagination at work

Renewable Energy will continue to grow

Global renewable energy installations

Cumulative (GW)



Market:

- ✓ Continue to drive towards CO2 free energy
- $\checkmark\,$ Most renewable energies now at grid parity

<u>GE</u>:

- Broadest and deepest Renewables technology portfolio in the industry
- ✓ 370GW of installed base (>20% of total)
- Access to stronger resources to scale quickly & foster leadership
- ✓ More visibility and accountability towards customers & shareholders

GE: leader in the fastest growing Energy market segment



Hydro Industry Main Development Trends



Maximising flexibility

- Power regulation in turbine & pump
- Increased cycling

Increasing Hydropower production

- Efficiency increase in refurbishment
- New projects

Maximising storage dissemination

- Overcoming equipment limitation
- New plant concept

Environmentally friendly solutions

- Reducing use of oil
- Fish friendliness



Variable renewable integration





Power regulation need increase





Increase of unit cycling





Fatigue in Motor-Generators

Life time analysis on structural design

Design criteria

- Start up to rated speed (HCF)
- Acceleration to runaway speed (LCF)

Calculation methods

- Finite element calculations
- Assessment of fatigue strength and maximum number of cycles









Extension operating range





Variable Speed PSP



Advantages

- Adjustable pumping power
- Turbine global efficiency
- Compatible with more challenging sites
- Faster power adjustment



PSP in Europe



199 plants, 48,8 GW turbine capacity 537 machines with a pumping mode (representing)

a pumping mode (representing a turbine capacity of 46,6 GW)

Source: eStorage

Feasible sites for new PSPs









Non-realisable potential



Clusters of potential sites

- <u>S.</u>
 <u>Norway:</u> 54%
 of realisable
 capacity
- <u>Alps:</u> 13% of realisable capacity
- <u>Pyrenees:</u> 5% of realisable capacity

Source: eStorage

Environmental Friendliness



Hydropower continues innovating so that renewable power remain renewable:

- Further improving its flexibility
- Increasing its production
- Maximising the dissemination of storage technology
- Minimising its environmental impact



