Decentralized pumped storage systems

TO INCREASE THE ELECTRIC MOBILITY

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As a consequence of the integration of renewable energy systems, energy storage has become a necessity for the operation of stable grids. Nowadays Pumped Hydro is the only technique providing large amounts of power and capacity at good efficiency and low specific storage costs [1]. According to the National Hydropower Association (NHA) [2] 270 Pump Storage Systems (PSS) are existing worldwide with 127 GW of total installed power. As shown in Figure 1 only 15% of the installations are applied in the range of < 80 MW, producing a power output of only 1% of the worldwide installed capacity. The problem with this small power installations is that PSS which operate in the small MW range cannot compete with a power plant of the high capacity classes if they are rated by specific costs per installed MW [3].

For the Pump Turbine a reversible, multistage and speed variable system is applied. This enables a very compact machine setup with a wide application area. The modular structure on the hydraulic side uses four basic components:

- **Electrical supply modules**: The electrical modules, especially the frequency converter modules have to be adapted to fit the generator.
- **Motor Generator modules**: Depending on the power input needed in the pump mode the motor-generator can be customized by choosing a number of stator and rotor discs.
- **Pump Turbine modules**: The variation of the installation head and power is possible by adapting the number of stages of the reversible multistage pump turbine.
- **Spiral Casing**: Connects penstock and runner of the last stage, creates the needed pre-rotation in turbine mode and raises the static head by decelerating in pump mode.
- **Refeeding Channel**: Links the runners while leading the flow to the inlet of the subsequent, creates the necessary pre-rotation in turbine mode and de-swirls in pump operation.
- **Runner**: Converts mechanical energy into static pressure raise for pump operation and vice versa in the turbine mode after changing the rotation direction.
- **Draft Tube**: Connects the first runner and the tail water penstock, provides a uniform velocity distribution in pump mode and converts kinetic energy into static pressure raise in the turbine operation.

As basic modules the spiral casing and the draft tube are used. An adaptation to the required boundary condition is done by choosing the number of stages and corresponding arrangement of runners and refeeding channels. To meet the basic idea of modularity, the design for the runner and the refeeding channel of each stage is identical and uniform. This enables standardized components to be developed and used which leads to a considerable cost reduction. All the components were investigated and developed in numerous CFD (Computational Fluid Dynamics) studies. They have been performed for the single components and also coupled to study the interaction between the up- and downstreaming elements.

**Application**

Customized for low discharge and high heads, the concept is designed for the use of already existing artificial water reservoirs. In the alpine area such reservoirs are used for snow production and irrigation purpose. These applications are particularly preferred because no extra costs for the headwater reservoir have to be considered, which is an enormous economic advantage. An internal study shows the high potential with some hundred artificial reservoirs in the investigated area (see Figure 2).

By combining the individual components to a machine with up to five stages, the adjustment to the boundary conditions can be made. In combination with a fully speed variable motor-generator this allows an application range from roughly 200 m up to 1000 m pumping head and approximately 1 m³/s to 2.5 m³/s of discharge (Fig. 3). Depending on the pump duration chosen, this can lead to reservoir sizes from 10000 m³ up to 100000 m³ for the use as daily storage and even bigger reservoirs for weekly storage systems [5]. Such small solutions are not used for PSS, yet.

**Motivation**

An economic application of PSS in the power range of small hydro applications is currently not possible. Cost reduction of the electromechanical equipment is the basic prerequisite for such an application [6]. A modular approach can enable such a cost reduction by providing standardized components which can be produced in a small batch and an additional reduction through faster planning processes in the implementation. The modular concept is a combination of three machine components, each adaptable modular:

- **Spiral Casing**: Connects penstock and runner of the last stage, creates the needed pre-rotation in turbine mode and raises the static head by decelerating in pump mode.
- **Refeeding Channel**: Links the runners while leading the flow to the inlet of the subsequent, creates the necessary pre-rotation in turbine mode and de-swirls in pump operation.
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**References**


**Figure 1**: Relationship between the number of pump storage systems and capacities from 1960-2007, Data from [4].

**Figure 2**: Artificial lakes for snow production in the investigated area.

**Figure 3**: Calculated characteristics for 1 to 5 stages.

**Figure 4**: Artifical lakes for snow production in the investigated area.