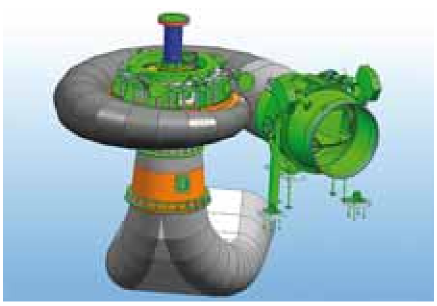
Favourable winds for pumped storage

Many countries in the world have announced plans to significantly increase electricity generation from fluctuating sources like wind and photovoltaics. This development will lead to a significant storage requirement for electrical energy. ANDRITZ HYDRO supplies conventional pumped storage plants and innovative decentralized solutions using variable speed electrical machines, both of which will play important roles in meeting future storage demands.

All electrical grids with a significant share of generation from volatile sources will be faced with storage problems. Germany, for example, aims 25% of generation from renewables by 2020, meaning that around 150 TWh is expected to come from fluctuating sources. A large share of non-dispatchable and highly intermittent generation will lead to a need for significant storage capacity, which will also have to cope with frequent high and fast load changes. By 2050, Germany will need over 100 times the storage volume of 2008 in order to be able to bridge a 10-day period of low wind.

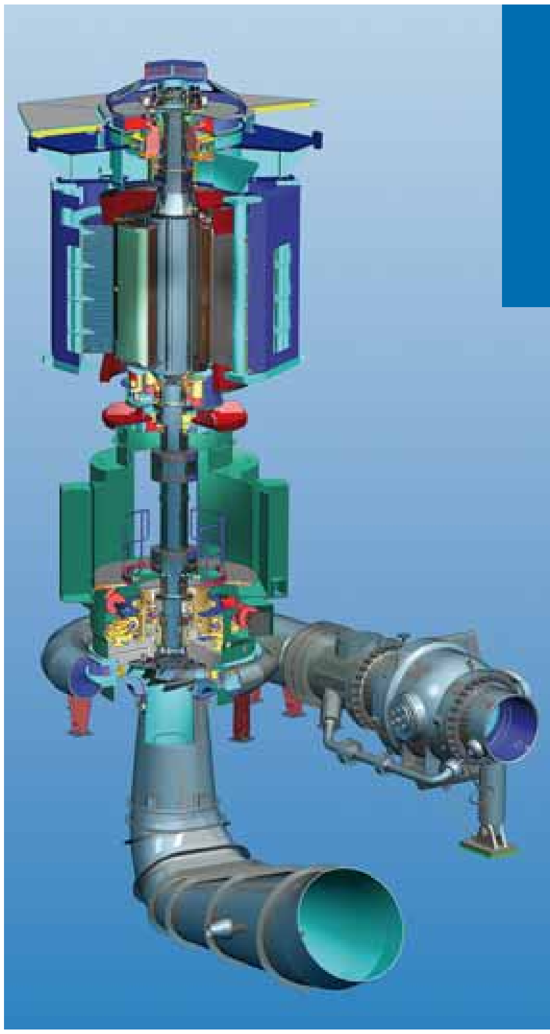
▼ Pump turbine Lang Yashan CAD model



On the other hand, days with strong winds and low demand will lead to oversupply. Several technologies are likely to contribute to meet these future storage requirements. Currently, compressed air energy storage (CAES), e-car battery clusters and electrolysis producing hydrogen are potential contenders in addition to conventional pumped storage. Due to the advantages in capacity, efficiency and overall storage cost, large scale pumped storage will remain the most important storage technology. However, it can hardly cover the expected demand alone. Since other more expensive and less matur e technologies will have to help in addressing the need for storage, pumped storage systems will be both, a technical necessity and an attractive investment in years to come.

Long history of pumped storage technology

As early as 1890, the town of Zurich, Switzerland connected the local river to a nearby lake with a small pumped storage plant. In delivering this unit, Escher Wyss, now part of ANDRITZ HYDRO, arguably supplied the world's first storage pump. The company has continued to provide groundbreaking pumped storage technology: the storage pumps of Provvidenza (Italy, 1949) as well as Limberg (Austria, 1954) were the world's largest, at the time of order, and Germany's largest pump storage plant in Goldisthal - the first variable speed pump storage plant outside Japan - commissioned in 2003 operates with electrical equipment from ANDRITZ HYDRO.



▲ Pump turbine and generator of Hintermuhr, Austria

▼ Pumped storage Lang Yashan in China. View of upper reservoir intake tower

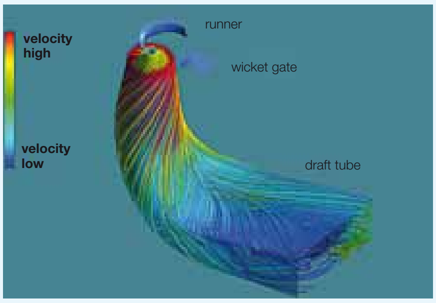
Research at highest level

Today, based on this long tradition, ANDRITZ HYDRO provides a pump turbine technology adapted to the specific requirements of each project. As a fullscale supplier of all electrical and mechanical components of pumped storage plants, the company designs individually developed hydraulic machines, e.g. for the upgrading of rehabilitation projects, or integrated systems including pump turbines and generators as well as all equipment necessary for automation and control. In response to the growing importance of pumped storage, ANDRITZ HYDRO has established a Center of Competence for pump turbines in Zurich, Switzerland, which coordinates global R&D activities.

Project	Head [m]	Power [MW]	Runner diameter [mm]	Speed [rpm]	Country
Tierfehd (Nestil)	1,066	142	2,263	600	Switzerland
Feldsee	548	73	1,919	1,000	Austria
Hintermuhr	518	74	1,870	1,000	Austria
Yixing	420	262	4,394	375	China
Goldisthal	338	325	4,593	333.33 / 300-346	Germany
Vianden M11	295	200	4,286	333.33	Luxemburg
Tongbai	289	306	4,802	300	China
Lang Yashan	153	166	4,700	230.77	China
Zarnowiec	128	188	6,008	166.67	Poland
Baixo Sabor Montante	100	77	4,112	214.29	Portugal
Foz Tua	99	125	4,837	187.5	Portugal
Baixo Sabor Jusante	35	18	3,948	150	Portugal

▲ Recent pump turbine projects delivered or under development

▲ Pump turbine Vianden M11: streamlines at rated operation (pump mode)



▲ Pump turbine Vianden M11: streamlines in the draft tube in turbine operation

▲ Model of the pump turbine Vianden M11 on the test rig

▼ Aerial view of upper reservoir of Vianden in Luxembourg

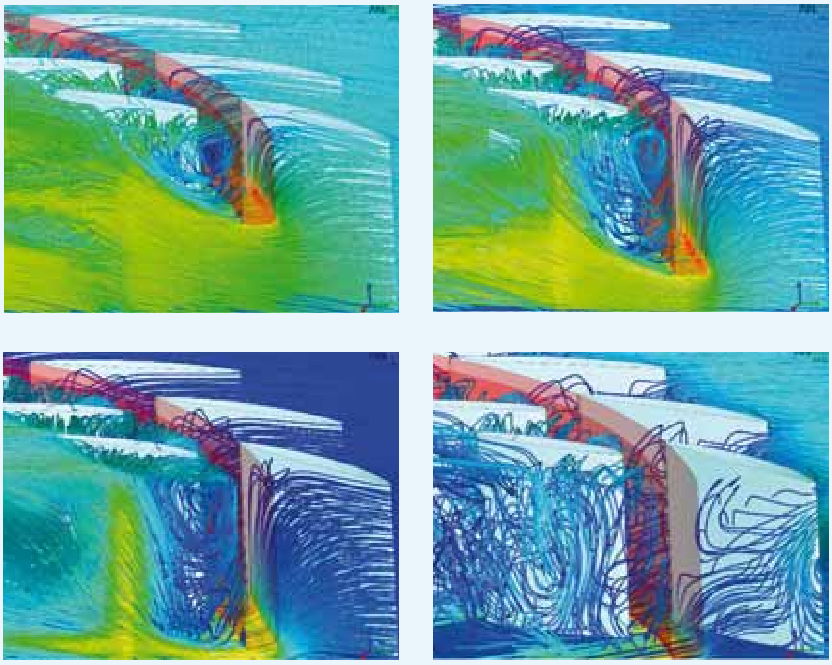
Flow calculations using unsteady computational fluid dynamics (CFD) as well as model measurements taken from one of the company's three pump turbine test rigs are essential for the development of a modern pump turbine technology prepared to fulfill changing requests. Today's grid regulation requires fast and frequent changes between pumping and generating modes as well as extended operation in off-design conditions. Understanding unsteady phenomena is crucial in developing pump turbines that can be operated with as few restrictions as possible.

Two main features of unstable behaviour in pump turbines are known. One shows in pump operation as a drop-in head as the flow is reduced (saddle type pump instability of head curve). The other sometimes occurs in generating mode at low load off-design operation close to runaway conditions (S-shape of the turbine characteristic) and may impede synchronization in turbine operation. Detailed investigations in cooperation with a Swiss university have increased the knowledge of this phenomenon. Unsteady CFD simulations in the very low load operating range of the pump turbine revealed a rotating flow separation between runner and wicket gates. The results of this research project contribute to minimizing these effects and to ensuring proper synchronization. CFD also plays an important role in the design of non-standard components, verifying and supplementing test rig measurements. For the Baixo Sabor power plant in Portugal ANDRITZ HYDRO optimized two pump

▲ Artist's impression of the power stations Baixo Sabor Montante...

▲ ...and Baixo Sabor Jusante, Portugal

▲ Baixo Sabor pump turbine runner during fabrication in the workshop



▲ CFD-calculated flow around the ring gate of Baixo Sabor Montante at 50%, 20%, 5% and 1% opening

turbines in the higher specific speed range, one of which is equipped with ring gates as shut-off devices. A CFD analysis combined with model measurements made it possible to evaluate both the forces acting on the ring gates and the flow in the ring gate area.

During the development of pump turbines, ANDRITZ HYDRO puts special focus on the aspects of hydraulic transients which lead to unsteady behaviour of the flow in the pump turbine. This rotor-stator interaction must be investigated hydraulically and the design of the components must consider the dynamic effects on the mechanical behaviour of the units. ANDRITZ HYDRO has fully examined the new pump turbine for the Vianden M11 pump storage plant (Luxemburg) using unsteady flow analysis and dynamic stress calculations in order to ensure safe and reliable operation in all required load ranges.

Innovative concepts

In a grid with a high share of installed wind power, the power produced will temporarily exceed current demand, meaning that power has to be extracted in or der to stabilize the grid frequency. The pumping operation of pumped storage plants can fulfill this need, but conventional fixed-speed pump units cannot change their pump input power. To follow wind energy's unpredictable load changes, the absorbed power -, that is, - the pump input power - should be varied continuously. Until recently this was only possible with large variable speed units (double-fed asynchronous motor-generators), which are rather expensive. Considering the specific challenges of balancing wind power, ANDRITZ HYDRO has developed an innovative concept tailored to future requirements. Small, decentralized pump storage plants consisting of standardized pump turbines equipped with a variable speed synchronous generator will be able to provide flexible local power storage adapted to operation close to larger wind or solar installations. With installed power lower than conventional pumped storage plants – a typical unit output will be between 10 and 25 MW – two to five such units will be able to balance a 50 MW wind farm.

▲ Goldisthal, Germany, underground machine cavern

Using a full sized electrical speed converter, the pump input power can be varied continuously over a wide range, and is then able to follow the load changes of the wind farm. The possible head variation of the hydraulic unit is large, and the efficiency characteristic in pump and turbine mode is very flat over a wide operating range.

With these new standardized pump storage units, the use of wind power can be increased in regions where grid stability would not allow a higher percentage of wind power. The combination of wind farms with local energy storage allows the local utility to generate a much more constant and predictable amount of electricity.

Furthermore, this new concept allows increasing renewable energy generation without needing substantial increase in the capacity of transmission lines between classical pumped storage plants in high mountains and wind farms and solar plants in the low lands.

Compared with other storage technologies used to supplement conventional pumped storage, such as CAES, batteries and hydrogen, this new ANDRITZ HYDRO concept provides electricity storage which is reliable, innovative and more economical than its competitors.

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▼ View of upper and lower reservoir of the Kaprun pumped storage power plant in Austria