Harmonizing wind and water energy: Frades II

A HIGHER PLANE

With energy demand on the rise, three key developments in pumped-storage technology are helping provide **greater flexibility and efficiency** to our grids.

As the mix of renewable energies in the world's electricity supply grows, so does the need for reliable, high-efficiency short-term storage of energy to reduce fluctuations in the grid. According to a 2011 study by Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the German grid will need more energy in the coming years for hourly and daily balancing of load fluctuations than it will for balancing over longer intervals, such as weekly, monthly and yearly (see chart on following page). "Over the long run, a minimum of 70 to 80 percent of the storage business will be short-term," explains Alexander Schechner, Head of After-Market Business at Voith Hydro in Germany.

Fortunately, hydropower pumped storage is already helping to meet the need for cost-effective grid-scale energy storage the world over. The design of the plants allows energy to be stored as water and then generate electricity: first, water is pumped up to an elevated reservoir; when electricity is required, it is released through turbines down to a lower reservoir.

In operation for more than seven decades, new developments to the various pumped storage applications, namely variable-speed systems, ternary systems and multi-stage pumps, are now making this technology more effective. So far, pumped storage was considered an ideal supplement to nuclear and thermal base-load power plants, since it is costly for those plants to reduce production, for instance overnight, even if demand changes.

"Because of the ability of a hydropower pumped storage plant to increase or reduce output within minutes, or even seconds, pumped storage is an all-rounder – it's the wunderkind on the block when it comes to power plants because it provides grid support and storage," says Schechner.

A differential is made between long-term and short-term storage, where short-term typically means a few hours, or 10 at most. Contrary to popular opinion, short-term storage is actually what is needed most, Schechner says. "Producers need maximum flexibility to combine stored energy with fluctuating renewable energies, such as wind and sun."

In Portugal, where the government is developing a further 5,400 MW of wind-power capacity, Voith is equipping a pumped storage plant called Frades II in the northern part of the country, featuring variable-speed pumped storage units that will help local wind power become more profitable and more reliable.

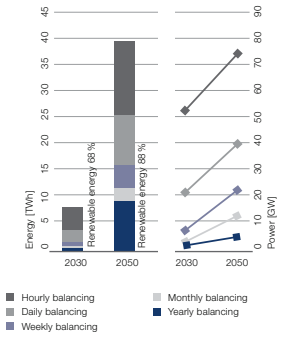
The plant, with two units of Francis vertical variable-speed pump-turbines, will be connected to the grid in 2015 ▷

Aerial view of the lower and upper reservoirs at Wehr, southern Germany.

Modernization work carried out on one of Wehr's generators.

Pumped storage to the fore

The growing need for short-term load balancing in Germany's power grid



Source: Fraunhofer Institute

▷ and produce a maximum of 383 MW per unit. It will use two asynchronous motor-generators to serve the grid.

Grid frequency, which must not vary more than +/- 0.1 hertz, is stabilized when the motor-generators react extremely fast to provide power to the grid or absorb power from it; they can react within milliseconds due to highly sensitive control systems that can tap the kinetic energy of the flywheel masses of the motor-generators.

For the project in Portugal, Voith is delivering variable-speed technology for pump-turbines, made feasible with asynchronous generators, namely double-fed induction machines.

Using an asynchronous generator to regulate pump speed and power is not new in industrial equipment. The machines operate independently of the network frequency as pump-motors with variable power, but also optimize turbine efficiency during generation at reduced speed at partial load.

In applying the concept to hydropower plants, the problem has always been the larger scale. Now, however, Voith Hydro has developed an asynchronous motor-generator for a large-scale pumped storage plant. This enables the pump-turbine to change its rotational speed, meaning the pump capacity can be adjusted using just the currently available amount of energy, allowing for highly efficient stabilization of the grid during pump and turbine operation.

"Typically, pump-turbines are connected via synchronous generators to the grid and cannot be regulated in pump mode – they always pump with the same power," comments Wieland Mattern, project manager for Frades II. "Using variable rotational speeds represents a new level of pumped storage that better meets requirements for electrical grids in the future. In addition to transporting variable power into the grid, as with synchronous pump-turbines, variable power can also be pumped out."

Two further advantages also exist, says Mattern. "Asynchronous pump-turbines are particularly suitable for dynamic peaks in grid load variation and they can be operated at optimum efficiency in both pump and turbine mode."

For plants that are already operating with synchronous generators, particularly smaller pumped storage plants, Voith is developing a full-scale convertor solution to provide similar functionality.

Elsewhere in Europe, Voith Hydro is also at work with another technology that has been further developed to improve the performance of pumped storage plants – ternary systems.

As the name implies, ternary systems are a three-part set: a turbine connected to a motor-generator on the one side and a pump on the other. As two separate hydraulic machines, the rotational direction of the motor-generator can be the same in both operational modes, giving considerable commercial value for a plant's operation. "The technology enables the highest flexibility between power delivery and power consumption modes," says Johannes Roest, Voith Hydro project manager.

For Forces Motrices Hongrin-Léman S.A., plant owner at Lac de l'Hongrin and Lac Léman in Switzerland, Voith provides two vertical multi-stage pump units as part of the plant's ternary units (together with the Pelton turbine and the motor-generator).

The technology has been recently refined so that customers can use both pump and turbine simultaneously to efficiently pump the water within a hydraulic short circuit. "Ternary systems are the most flexible. They are more expensive than standard technology but allow the plant to be customized to the operator's needs. Improving the application and use of hydraulic circuits enhances flexibility further," Roest says.

Across the border in neighboring Germany, at the pumped storage plant Wehr, the operator, Schluchseewerke AG, recently hired Voith to modernize the four horizontal motor-generators at one of the world's largest pumped storage facilities in the world. The 4x300 MVA ternary system was in operation for more than 40 years, providing high levels of reliability and flexibility. In recognition of Voith's expertise in this field, the company was asked to update the technology with the latest features.

The final piece in the development of pumped storage is multi-stage technology. With this concept, water is pumped to the upper reservoir in stages inside a single pump.

The pumps are built in a row (in five stages at Lac de l'Hongrin) because of a plant's location high up in the mountains or significant height differences between the upper and lower reservoirs. Overall grid efficiency is increased since multi-stage pumps can be used during times of over-production from renewable energies, consuming that excess energy to get the stored energy of the water into position in the upper lake to be released when needed.

The enhancement of these three technologies is bringing pumped storage to unprecedented levels of flexibility and efficiency. Trianel, a network of municipal utilities in the western part of Germany, is designing pumped storage plants in consultation with Voith and the group is optimistic about the efficiency gains and additional flexibility that the plants will provide.

"As the energy mix in Germany transitions to a high proportion of renewables, a flexible power supply is vital," states Christoph Schöpfer, project manager at Trianel. "In addition, it is now possible to design pumped storage plants so that they are adapted to the ecosystem. From the outset, designers work to minimize the impact of the power plant and keep in mind what plants and animals need to thrive." //