CASE STUDY: **HYDROPOWER SOLUTIONS**

Linthal 2015

Variable Speed Pumped Storage Plant

Guaranteeing the future electricity supply for central and north-eastern Switzerland

Country:..... Switzerland
Project: ..... Linthal 2015
Customer:..... Kraftwerk Linth-Limmern AG
Scope of supply:..... 4 x 250 MW variable speed pump turbines, 4 x 280 MVA variable speed motor generators, power electronics.
Electrical output: ..... 1,450 MW
Commercial operation: 2015

PROJECT HIGHLIGHTS

- Stores energy to immediately and effectively bridge production bottlenecks
- Enables power regulation even when the plant consumes electricity to pump water to the upper reservoir
- Facilitates the integration of renewable energies that will require balancing services during the night, when most pumped storage plants are pumping water to the upper reservoir

Linthal 2015 hydropower plant

In 2009, Kraftwerk Linth-Limmern AG (KLL) decided to extend its power station and granted Alstom a contract to provide four new 250 MW variable speed pump turbine and motor generator units, **boosting the plant's output** from 450 MW to 1,450 MW. This output is on a par with the Leibstadt nuclear power plant and it's about equal to the average power **consumption of 1 million homes.**

The new pumped storage plant (PSP) will be used to pump water from Lake Limmern back up to Lake Mutt which is 630 m higher. The altitude differences found in the Swiss Alps provide a particularly favourable environment to use pumped storage power plants. Because Linthal 2015 is a storage plant, water from the upper reservoir can be released to provide power **rapidly to supply peak electrical demand**.

Pumped storage plants also play a key role in **regulating the frequency of the electrical grid**. Variable speed pumped storage plants can provide power regulation to the grid **in both generation and pumping mode** whereas traditional PSPs can only regulate in generation mode. Variable speed technology also **enables sites with head variations greater** than those that can be accommodated by traditional PSP.

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TECHNICAL SPECIFICATIONS

PROJECT FEATURES:	LINTHAL 2015
Rotatational sychronous speed (RPM)	500 +6%/-7.5%
Pump: Delivery net head Max/Min (m)	709/560
Turbine: Rated net head (m)	623
Turbine: Rated output (MVA)	250
Generator rated output (MVA)	280

VS-PSP generator mock up, Linthal

Alstom **currently has the most variable speed projects under execution**. In addition to Linthal 2015, Alstom is designing and manufacturing equipment for two other variable speed pumped storage plants – Nant de Drance in Switzerland and Tehri in India.

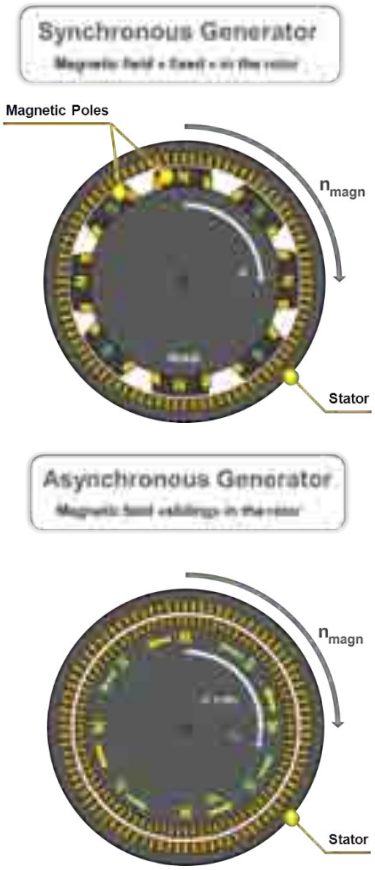
VARIABLE SPEED TECHNOLOGY

With variable speed units the power absorbed in pumping mode can be varied by approximately 30% over a certain range, depending on the head. This enables the power station operator to regulate grid frequency in pump mode and deliver services such as frequency regulation to the grid operator while filling the upper reservoir. Conventional PSPs can only deliver this service while in generation mode.

For fixed operational speed, the top of the efficiency hill charts is generally not within the operating range. Variable speed permits **operation closer to the optimal efficiency operating points in both turbine and pump modes**. Generally, efficiencies are higher compared to the fixed speed and the same nominal speed, particularly at partial loads.

The **additional flexibility** provided by the speed variation also enables sites with a wide head variation to be equipped. The operating range of fixed speed pump turbines is limited to a ratio of about 1.25 between maximum and minimum head while Linthal's ratio is above **1.26**. Varying the pump rotation speed enabled Alstom to overcome this head range limitation.

Double fed induction machines with static frequency converters feeding the rotor are the preferred concept for motor generators in variable speed PSPs with unit outputs above 50 to 100 MW. The rotor design of double fed induction machines is significantly different from conventional synchronous machines because the rotor of a double fed induction motor-generator **has a three-phase rotor winding wound into a cylindrical rotor**. By feeding the rotor with a low frequency AC current, a magnetic field rotating at the right speed is created to compensate for the turbine's speed variation. As a result, it generates a magnetic field rotating at a constant speed – a fraction of the grid frequency- in the stator.



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