Pump storage hydro power plant (PSKW) Reißeck II

A challenge in high-altitude mountains

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Short description
The new pump storage power plant (PSKW) Reißeck II represents an expansion of the already existing group of power plants, Malta and Reißeck/Kreuzeck in Carinthia. The new plant will link the hydraulic systems of this power plant group and better exploit the available resources. The existing annual storage reservoir Groß'r Mühldorfer See will be used as the upper reservoir, and the existing reservoirs Gößkar and Galgenbichl as lower reservoirs.

All of the plants will be built underground with the greatest possible consideration for nature and ecological balance. No additional reservoirs or stream collecting works are required. The entire construction area runs a length of approx. 7 km in the Mühldorfer Graben area; headings are located between 600 and 2,400 m above sea-level. The length of the new headrace is approx. 5 km on the whole and consists in detail of a 3.3 km long headrace gallery as well as 0.8 km pressure shaft with a 42° gradient which flows into the new hydropower cavern over the 0.6 km lower horizontal section and the upstream distribution pipeline.

There the two machinery units will be installed underground with an output of 215 MW each. The headrace is connected to the existing gallery system for the Malta power plant group through the downstream distribution pipeline and a 0.3 km underwater gallery. The power plant will have a power output in turbine and pumping operation of 430 MW. Commissioning is planned for 2014.

In the following report we will describe the full project and discuss the particular technical and logistical challenges of this high-altitude mountain construction site.

Technical data for pump storage power plant Reißeck II (chart 1)

<table>
<thead>
<tr>
<th>Turbine type</th>
<th>reversible Francis pump turbine, vertically installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median gross head</td>
<td>595 m</td>
</tr>
<tr>
<td>Number of machinery units</td>
<td>2</td>
</tr>
<tr>
<td>Max. turbine output</td>
<td>2 x 215 MW</td>
</tr>
<tr>
<td>Max. pumping power</td>
<td>2 x 215 MW</td>
</tr>
<tr>
<td>Max. metered flow per turbine unit</td>
<td>40 m³/s</td>
</tr>
</tbody>
</table>

Contract
The consortium PSKW Reißeck II, consisting of the companies G. Hinteregger & Söhne, Öst-Stettin, Porr Bau GmbH and Swietelsky Tunnelbau, were awarded the contract in spring 2010 by the Verbund Hydro Power to carry out the primary works. The contract at hand encompasses all of the primary works for the new power plant. Total construction time is projected at 4.5 years. A half year for the ground opening, two years for excavation and structural work, and two additional years for the complete expansion. At the time of contract conclusion in May 2010 the contract volume was approx. 100 m euros.

Geology
The project area of PSKW Reißeck II lies in the area of the overthrust of the Glockner nappe (upper schist shell) over the Storz nappe and the upper Central Gneiss Core (crystalline basement). The Glockner nappe system is a macro-tectonic unit of the Pennine nappes of the Tauern window.
The project lies for the most part in the area of the Central Gneiss Core. Mostly granite and augen gneisses are encountered, while band gneisses played a subordinate role in excavation. In the course of the tunnel drive operations high-strength rock was observed but also high quartz and mica content, and thus very high abrasiveness of the rock.

**Site installation area, organisation**

The construction site in Mühldorfer Graben stretches over 7 km and an elevation difference of 1,800 m. The main site installation is located in Mühldorfer Graben at 1,500 m over sea-level (Illustration 2). In addition to the construction office for the client and contractor, the living cabins for approx. 300 men, a central workshop, a concrete mixing plant, a storage area for materials handling and a site canteen are also located there.

A somewhat smaller site installation was set up at Schoberboden at 2,200 m over sea level for the high-pressure side of the headrace. There is an additional repair shop in this area.

**Site accessibility, access roads**

The 12 km long Burgstall access road runs from the valley to the site installation in Mühldorfer Graben. The existing road had already exceeded its useful life and was rebuilt over the entire length while maintaining traffic operations. The Schoberboden access road with a length of 6 km is connected to the Burgstallstraße at Mühldorfer Graben and runs to the Schoberboden construction area at an elevation of 2,200 m. This road was realigned and built anew.

In the following we describe the individual construction areas, in particular the penstock from the intake structure at Großer Mühldorfer See via the cavern up to the connection to the existing gallery system of the Malta power plant.
The portal cut for the ventilation structure is at an altitude of 2,400 m above sea level in a 35-40° steep high-alpine terrain. The construction ground is blocky colluvium and permafrost soil (Illustration 7).

The 150 m high plumb shaft was excavated in a shaft-sinking process from the top downwards. The excavated diameter is 6.55 m. Stabilisation was implemented with three-cord arch lattice girders, 25 cm reinforced shotcrete as well as norm anchoring of 4 m long injection drill anchors. A 35 cm thick and reinforced in situ concrete shell is planned for the inner lining. The foundation for the ventilation structure will be the shaft inner-shell.

Schoeroboden surge chamber

The Schoeroboden surge chamber is located at the high pressure side of the headrace and forms the transition between the pressure gallery and the penstock. In detail, this surge chamber consists of a ventilation structure, riser duct with restriction, ramp gallery with lower chamber as well as the transition to the penstock (Illustration 6). Excavation was done in conventional blast drive. Tunnel lining, adapted to the encountered rock, was done with three-cord arch lattice girders, 25 cm shotcrete, two-layers reinforced, and a norm anchoring of 6 m long mortar or injection drill anchors. The lining of the lower chamber is a circular, strongly reinforced in situ concrete shell with 7.1 m inner diameter.
Penstock
The 817 m long penstock reaches from the Schoberboden surge chamber lower tank to the shaft bottom in the lower horizontal section. The excavation of the 42° gradient penstock was carried out by conventional shaft-sinking methods from the top downwards. The rock was loosened by drilling and blasting. The loosened debris was loaded in hoppers and taken out of the shaft head with a winch (Illustration 9). Via an intermediate heading it was possible to perform the excavation over two headings. The excavated diameter is 4.3 m.

The penstock is lined with armoured steel and has a 3.6 m inner diameter. The annular gap between the excavation soffit and the steel tube is grouted with highly flowable concrete. Concreting sections are as a rule 14 m long. A self-compacting highly flowable concrete was used. For that purpose, a trapezoidal sheet-steel chute was installed over which the concrete flowed. The composition of the concrete was previously submitted to large scale tests and optimized with respect to its installation characteristics.

Lower horizontal section
The high-pressure side of the headrace is connected to the power cavern via the penstock over the approx. 600 m long lower horizontal section and the upstream distribution pipeline. This section was also provided with an inner armoured steel lining.

Power and transformer caverns with power transmission
Two power caverns 58 m long, 25 m wide and 43 m high were excavated out of the inside of the mountain for the two machinery units, each with 215 KW power output (Illustration 11). For construction and safety technical reasons, the two machine transformers were installed in separate chambers, in the so-called transformer cavern. This is 59 m long, 15 m wide and 15 m high. For the two caverns a total of approx. 65,000 m³ of rock was excavated (Tab. 2). The caverns were constructed with conventional drill and blast methods. Tunnel lining was done with three-cord arch lattice girders, 30 cm shotcrete, two-layers reinforced, and a norm anchoring of 6 m long mortar anchors and 15 m long permanent single-rod anchors.
Illustration 11: Cut through the power and transformer caverns
Image: PORR

Illustration 13: Interior work, power cavern
Image: PORR

**Comparison of the two cavern excavations (chart 2)**

<table>
<thead>
<tr>
<th>Cavern Type</th>
<th>Rock Excavation (Solid)</th>
<th>Length</th>
<th>Width</th>
<th>Max. Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Cavern</td>
<td>51,000 m³</td>
<td>58 m</td>
<td>25 m</td>
<td>43 m</td>
</tr>
<tr>
<td>Transformer Cavern</td>
<td>14,000 m³</td>
<td>59 m</td>
<td>15 m</td>
<td>15 m</td>
</tr>
</tbody>
</table>

Power is transmitted from the transformer cavern to the relay station in three steps. At the beginning, the energy transmission runs 820 m underground over the Burgstall access gallery and the energy transmission gallery. From the portal of the energy transmission gallery up to the existing machinery chamber of the Hattelberg penstock, the energy transmission is run along the Burgstall access road into an 830 m long accessible cableway. Then comes a 1,750 m long cable duct parallel to the existing Hattelberg pressure pipeline down into the valley, to the existing outdoor switchgear bay of the 220 kV Malta main stage relay station (Illustration 14).

The special challenges in constructing the cableway are the steep terrain, supplying the site via the aerial railway as well as the short construction time.

Illustration 14: Power transmission along the existing pressure pipeline, supply via the aerial railway
Image: PORR

**Headrace, low-pressure side**

**Underwater galleries**

The underground gallery with a length of 230 m links into the existing Hattelberg gallery of the Malta power plant at a right angle. Excavation was done by blasting. As with the headrace gallery, the interior was provided with an in situ concrete shell with inner diameter of 6.2 m, which connects in the invert area to a tubbing segment.

The connection to the existing Hattelberg gallery will be made only following completion of the underwater area in the summer of 2013. For that purpose, the existing steel armouring in the connection area will be cut open and linked to the underwater gallery.

**Burgstall surge chamber**

The Burgstall surge chamber is located on the low pressure side in front of the connection of the underwater gallery to the existing Hattelberg gallery.
It is constructed as a double-chamber differential surge chamber with nozzle restrictor and rising shaft widening. In detail, this surge chamber consists of an upper chamber with a ventilation structure, riser duct with restriction and widening as well as a lower chamber with the connecting shaft to the underwater galleries (Illustration 15).

Excavation was done in blast drive. The excavation diameter in the 120 m high rising shaft is 6.55 m and in the area of the widening 14.1 m ("backpack", height 35 m). A mucking shaft with 1.8 m diameter was constructed first with raise boring. The shaft was then widened from the top downward.

Illustration 15: Overview of Burgstall surge chamber
Image: PORR

Headrace injections
Following concrete work on the headrace, systematic injections will be carried out. We differentiate:

- Injections in concrete-lined parts as well as
- Injections in steel armoured parts of the headrace

In addition to the mandatory first-contact injection, an additional high-pressure injection into the mountain will be carried out in the concrete-lined parts of the headrace. On the one hand, the purpose of this injection is to assure contact between the mountain and the lining, on the other hand to reduce the porosity of the mountain rock as well as to increase rock stability, and furthermore to achieve a marginal pre-stressing of the mountain rock and lining. The injection is carried out with bore holes, the number and length adapted to the excavated rock. In addition to a pure concrete suspension, a cement-bentonite suspension is also used as injection material. Injection pressures are up to 20 bar.

Where the injections are carried out in steel armoured parts of the headrace, an additional annular gap "steel armour concrete" is injected in addition to the already described injections. These injections are made via nipples in the steel armour. The injection pressure is matched to the respective sheet metal gauge and lies between 6 and 10 bar.

Special challenges in the project implementation
The main challenge in the excavation phase was the production of the 42° gradient and approx. 820 m long sloped shaft with conventional shaft-sinking.

The extraordinarily comprehensive and tight construction programme as well as the large number of headings represent special challenges to the site management and logistics. On account of the location in the high-alpine area, in addition to the daily construction operation challenges, diverse difficulties in supplying the construction areas and hazards of the high-altitude mountain area also have to be mastered. A special avalanche warning system is also in operation for the construction site in the winter months.

The existing power plants are a tourist attraction and there are many visitors in the summer months. These traffic flows through the construction site area also have to be organised.

Final remark
Excavation work was completed for the most part in the autumn of 2012. Concreting work at the headrace and in the caverns will be completed by the end of 2013. After that, construction will only be auxiliary and finishing works. If no delays occur in the following works, nothing stands in the way of commissioning the two machines in 2014.

Hydro-energy is among the most important renewable energy resources. The Reißeck II pump storage power plant was designed as a balancing and backup power plant and thus contributes to a sustainable energy production.

Project data (chart 3)

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total investment of which construction work at the signing of the contract</td>
<td>EUR 385 m EUR 100 m</td>
</tr>
<tr>
<td>Start of construction</td>
<td>June 2010</td>
</tr>
<tr>
<td>End of construction</td>
<td>September 2014</td>
</tr>
<tr>
<td>Cumulative length of tunnelling operations</td>
<td>9 km</td>
</tr>
<tr>
<td>Total excavation</td>
<td>510,000 m³</td>
</tr>
<tr>
<td>Shotcrete</td>
<td>40,000 m³</td>
</tr>
<tr>
<td>Anchors</td>
<td>40,000 pcs.</td>
</tr>
<tr>
<td>Structural concrete</td>
<td>120,000 m³</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>4,000 t</td>
</tr>
</tbody>
</table>