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## REHABILITATION AND UPGRADING OF A SMALL HYDROPOWER PLANT IN THE AUSTRIAN ALPS

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### ABSTRACT

The reconstruction of the more than one hundred years old small Untertweg hydropower plant in the Austrian Alps faces technical difficulties due to the steeply sloping terrain and lack of accessibility. The economic constraints require an increased efficiency and creative solutions in order to meet the project budget and time constraints. Tourism requirements on the downstream lake and a fish breeding project on the lower course of the river are further challenges for the planning and execution of works. Finished in August 2015, the lessons learned shall be the focus of this paper.

### 1. Introduction

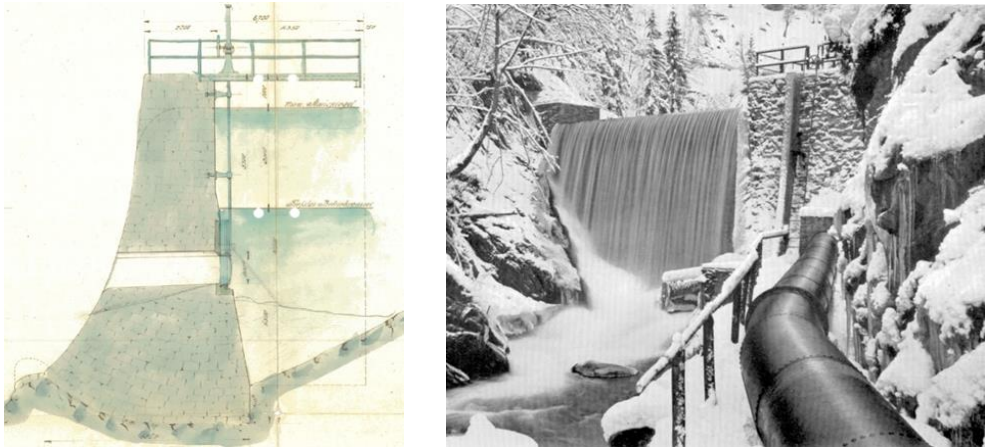
The Untertweg Hydropower Plant is situated in the Austrian federal state of Carinthia. It was built more than a hundred years ago, in order to fuel the start of an upcoming magnesite mining industry in the very beginning of the 20th century. The plant then consisted of a 10 m high dam, an about 600 m long riveted steel penstock and a single Francis turbine.

The ravages of time, especially corrosion of the riveted steel penstock and increasing silting-up of the headpond, required a major overhaul of the plant. Also, rockfall posed a threat to the safe operation of the penstock, which was only partially covered by wood logs. The silting up of the reservoir was a consequence of increasing constraints, regarding the flushing of the weir, in recent years. Not only a public lido, just next to the water mouth at 7 km downstream Millstättersee, but also an ambitious fish-breeding project, on the lower course of

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the river, were the limitations regarding turbidity of the water. The flushing of the weir was not permitted from September to April, during the spawning season. The bathing season on Millstättersee lasts from June to early September. In the remaining time flushing was only possible given a minimum flow. Thus, the first project foresaw the excavation, removal and disposal of a few thousand cubic meters of sediments.



**Fig. 1. Weir and water intake of the old HPP Untertweg (foto © RHI AG)**

Due to the limited accessibility to the gorge part of the penstock alignment (about 400 m), it was considered to use an inliner to rehabilitate the steel penstock. It was also reflected to backfill the whole penstock with concrete, to ensure rock-fall and corrosion protection. Both concepts however had to be given up due to relatively high costs given an only limited increase of the service lifetime of the plant.

It was then decided to replace the whole penstock and build a new from GFRP, backfilled with reinforced soil. The decision to use GFRP pipes with not fully restraint couplings also for the 38° steep headrace before the powerhouse was backed by the experience from a recently completed project where similarly connected cast iron pipes were used. The disassembly of the existing penstock, however, remained a problem, due to the limited accessibility, and was foreseen to transport the pipes off by helicopter. For the new penstock only short pipes with limited diameter would have to be used. Due to the comparatively low weight of GFRP pipes they can also be transported with small machinery.

Due to the fact that an existing water right permitted the full use of water resources, while a renewed plant would have to provide a sufficient biological minimum flow in the river, a concept had to be found to still increase the energy generation of such a new plant, in order to prove the economic viability of the project. Due to the very limited space on the gorge part of the penstock alignment, a significant increase of the pipe diameter, in order to raise the rated discharge, was not considered feasible. Thus, it was reflected to increase the head of the hydropower plant. The powerhouse of a chain of two power plants is situated 400 m upstream of the existing intake. However, in the middle of this stretch a small plant was derivating parts of the water.

As this small private power plant was also in no good condition, an agreement was found to compensate the former owners for its closing down. This way, the head of the new powerplant was increased by 22 m. By using the existing intake and connecting directly to the

upstream powerhouse, the necessary investment for the new project was reduced. Due to the new layout, the old headpond would not be needed any more and the sediments could be secured in their place such that they would not have to be transported off for landfilling.



**Fig. 2. Steel penstock protected by logs from rock-fall**



**Fig. 3. Former SHPP Obertweng**

The new configuration required the installation of two turbines in the powerhouse, such that the existing structure had to be expanded. Due to the difficult connection to the existing foundation and the necessary widening of the tailrace channel, it was found that a complete reconstruction of the powerhouse would be the most economical solution.

Beginning with the renovation of the penstock and the emptying of the reservoir, the project thus developed into the almost 100% reconstruction as well as an upgrading of the powerplant. One more technical challenge was to minimize the construction time in such a way so that the existing plant to operate as long as possible.

## **2. Execution and Technical Challenges**

Starting from the collecting tank and continuing downstream for almost exactly one kilometer to the new powerhouse, several technical problems were to be solved in order to reconstruct and extend the Untertweng hydropower plant.

In order to minimize the standstill time, the works were divided into two phases. In the fall of 2014 the collecting tank and the first 400 m of the penstock were to be erected. Before that a 600 m long access road had to be established in difficult terrain and the existing small hydropower plant Obertweng had to be dismantled. From November to March no works were allowed in the river bed, so that all works on this part of the penstock had to be finished before.

The second phase included the replacement of the powerhouse and the existing part of the penstock. During this time the powerplant was out of operation. The upstream powerplant had to stop operation for only 40 hours during the whole construction period.

### *Collecting Tank*

The powerhouse of the upstream Tieferbach power plant is situated very much next to the river on a steep slope below a federal road. The collecting tank for the new Untertweng power plant had to be built attached to it. The 10 m high slope support for the construction pit, made from reinforced shotcrete and rockbolts, was finished just before a major precipitation

event. Although the whole slope would be backfilled in the end and the executed securing works were thus of only temporary purpose, this event proved the necessity of the structure.

In order to minimize the standstill time of the Tieferbach powerplant, a temporary tailrace opening was cast into the powerhouse side wall.



**Fig. 4. Slope support and temporary outflow during construction time**

All the works in this area could only be performed with walking excavators and required the constant dewatering of the construction pit. However, for the hard rock excavation below the river level, a heavier excavator was required in order to efficiently excavate the pit. This excavator had to be transported to the site along the river bed and a ramp was required down into the pit.

Lesson learned: Prefer rock excavation over water derivation. It is probably more efficient to execute additional quantities of rock rather than to further derivate the river and dewater the construction pit as rock excavation can be performed no matter which meteorological conditions have to be faced.



**Fig. 5. Collecting tank bottom plate**



**Fig. 6. Penstock placing in the river bed**

#### *Penstock in the river bed*

The part of the penstock executed in 2014 had to be built in the river bed and had to cross the river with a duct about 100 m before the old head pond. Construction was stopped

twice by high water and river flow was generally significantly higher than the long term average. Due to the fact that solid rock was encountered on most parts of the penstock alignment, it was decided on site to rather excavate the penstock into the rock than to place it above and protect it with rip-rap, as initially foreseen by the tender design. By using fibre reinforced concrete it was possible to excavate the pit for two pipes of 6 m each, place the pipes and backfill them with concrete, all in one day. The costs for the additional rock excavation and the concrete were outweighed by the savings on rip-rap and backfill material, the faster pace, as well as the fact that pipes already placed wouldn't be damaged in case of floods.

This construction method further allowed to postpone the re-vegetation to a low discharge period in the following year and focus on finishing the penstock placing works before the trout protection period, starting in November.

Lesson learned: A lump-sum contract allows for wide scale optimizations regarding the execution of works if the designers are flexible enough to quickly execute changes in the design.

### *Penstock in the gorge*

The initial design envisaged demolishing the existing dam in order to access the gorge section of the penstock. Due to the geological condition of the left slope of the reservoir, the following deepening of the river bed by several meters would induce the risk of slope failure. After consultation with the competent administrative bodies, it was decided to leave the dam in place and keep the accumulated sediments as a counter weight. The consequence of this decision was that the 100-year old dam had to be rehabilitated, while a new access to the penstock alignment had to be built. By excavating a ramp into the left buttress of the dam, it was possible to get access and start with the works on the penstock even before the end of the trout protection period.



**Fig. 7. Penstock before / while dismantling; installation of slope support system; reinforced earth at access road**

Given this new access road, it was considered to use bigger equipment also in the gorge part, where the old penstock was placed on saddles while the maintenance catwalk for large

parts was already protruding over the hillslope. The first ideas of a large scale building up with reinforced soil, as it was used for the access road to the dam, or bridging the slope with precast elements were skipped because of the time needed for their execution. Due to the fact that the penstock could only be built with one team from the furthestmost point back to the dam and the difficult task to dismantle the existing penstock before, these works were very much on the critical path of the project.

The solution found was an umbrella-like slope support system that can be backfilled and loaded just after the anchor grout had hardened. The system consists of a metal cross holding a wire net-cum-geotextile that is secured in place by a rock anchor. For this particular application segments of 2.5 m x 2.0 m were used. Due to the difficult terrain, anchors had to be drilled in by hand. As the system has a finite service life time it was clear from the beginning that the purpose would be limited to the building up of the access road. The penstock had to be placed into the slope on solid rock so that it would not be affected by possible long time settlements of the backfilled access road.



**Fig. 8. Installation of slope support system**

Again the execution of this solution was not part of the initial tender, where precast concrete elements and a much smaller access road were envisaged.

Also, in the gorge part of the penstock alignment it was decided to place the penstock in fibre-reinforced concrete. This was necessary in the parts stabilized with temporary slope support, but proved to be quicker and thus more efficient, compared to building up a backfill from reinforced earth, as envisaged in the tender, as well as on the remaining penstock alignment.

A single trench crossing the penstock route was filled up with soil material and thus had to be bridged by a 15 m long reinforced concrete slab to ensure the sound foundation of the penstock in this part, too.

Lesson learned: The first support elements were initially fixed to a rock nail and secured to the rock anchor with a steel wire. As this wire was loose, a settlement of few centimeters would occur when the rock nail corrodes and the load is transferred to the rock anchor. This installation technique is appropriate for avalanche protection and protective hydraulic engineering but has to be adapted where settlements matter.



**Fig. 9. Access road on top of slope support**

*Steep penstock section*

Before the powerhouse the penstock faces a  $38^\circ$  decent over 70 m altitude difference. This part is divided from the gorge section by a 32 m long pipe bridge and a following 35 m long mostly flat section. The pipe bridge was only build 15 years ago, after a landslide on the former penstock route. Thus it was rehabilitated and forms the only remaining part of the old power plant incorporated into the new unit.



**Fig. 10. Penstock placement in the steep section before the powerhouse**

All the pipes, concrete and building material had to be carried over the steep incline before installation. This was solved by a sledge built for his purpose, operated by a winch where the steel wire was deflected on the walking excavator, which itself was operating on a winch secured to a rock anchor



**Fig. 11. Steep slope section of the penstock before hydro seeding; hydro seeding machinery**

The tender design envisaged a flexibly placed penstock with cross brackets every 12 m which would fulfill majorly a sealing-up function. Due to the encountered shallow rock line, this concept was changed to placing the penstock fully embedded in concrete. Thus, the concrete also had to be transported with a sledge to the place of installation. For the concreting of the anchor block at the transition from flat to steep inclination, the concrete was pumped as the required consistence did not allow the transportation in a sledge. A special concrete mixture had to be used to be able to pump the concrete up. While the concreting itself was finished in a few hours, the mounting and demounting of the pipes on the steep incline was a matter of several days.

In order to stabilize the topsoil layer, tree trunks were placed for providing temporary stability until this function can be taken over by the vegetation. To ensure a fast growth on this steep slope, prone to washing out, hydro seeding was used.

Lesson learned: Always double check the foundation conditions of existing retaining structures.

### **3. Solutions and Findings**

The findings from the deconstruction of the old steel pipes prove that the decision to replace the existing pipes with a new GFRP penstock was correct. Moreover, the rehabilitation of the more than one hundred-year old dam seemed to have happened at due time. Even the comparatively new pipe bridge already showed commencing corrosion inside the pipe while some weldings were badly made from the beginning. Thus, the overall rehabilitation of the project was necessary, from a retrospective point of view as well.

The foreseen technical solution was widely optimized during the execution due to the encountered geological conditions and potentials to speed up the works. This was facilitated by the lump-sum contract and the comprehensive authority to decide of the contractors'

construction manager. A qualified site supervisor intensively communicating with the client's own design office was a prerequisite just as well.

As stated before, due to tourism and fish protection, turbidity caused by the construction works was a major issue during the works. Besides the projection period, when works in the river bed were forbidden at all, also during the remaining time works had to be optimized in this regard. To allow the start of construction works on the powerhouse in early spring, side wall and tailrace channel had to be left out at the beginning and all water pumped from the pit had to be percolated. In order to not mobilize the sediment in the head pond when emptying the reservoir, for building the penstock and rehabilitating the dam, a dedicated derivation was built, from the beginning of the backwater to the bottom outlet, already in 2014. The emptying procedure itself was coordinated with all stakeholders and precisely monitored by the public authority. A continuous monitoring of water parameters was also performed during the execution of penstock placing in the river bed. Most importantly stakeholders were regularly informed about the state of works, especially as there were also other construction activities further upstream.

Optimized turbine equipment permitted abandoning the surge tank. On the other hand, key structures such as the dam and the pipe bridge were renovated and integrated into the new system. The previously mentioned slope support system permitted the access to the penstock route without the use of helicopters for transportation. Where access was still not possible, a combination of transporting pipes on sledges, as in the old days, with modern concrete pumping technology and construction machinery, was efficiently deployed.

## 4. Summary and Outlook

As rehabilitation projects usually necessitate the standstill of an otherwise productive unit, construction time is the key for the successful execution of such works. New construction techniques have to go hand in hand with in-depth knowledge of the structures to be rehabilitated. Where access is difficult and costly, replacement can then be more effective than renovation if the latter cannot provide an equally long extension of lifetime. Only if design and execution are flexibly adjusted to conditions encountered on site, works can be optimized. Comprehensive site supervision by the client is therefore just as important as a contractor's construction management holding the required authorization to decide.

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# РЕХАБИЛИТАЦИЯ И НАДГРАЖДАНЕ НА МАЛКА ВЕЦ В АВСТРИЙСКИТЕ АЛПИ

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*Ключови думи: рехабилитация, малка ВЕЦ*

## РЕЗЮМЕ

ВЕЦ „Унтертвенг“ е изградена през 1907 г. с цел подпомагане на развитието на минната индустрия за добив на магнезит в Източните Алпи в австрийската провинция Каринтия. Отпечатъците на времето, особено корозията на нитования тръбопровод и затлачването на напорния басейн, наложиха основна реконструкция на централата. Стръмният терен, където до тръбопровода имаше достъп само пеш, обуслови само една от многото технически, но също така и икономически трудности, които трябваше да бъдат преодоленни при реконструкцията.

Реконструкцията на ВЕЦ „Унтертвенг“ започна през юли 2014 г. и наскоро беше завършена. Изпълненото решение включваше вграждане на по-малка централа и пряка връзка с изтичалото 400 m нагоре по течението. Спестявайки от разходите за ново или възстановено водоземане, напорът беше увеличен с 22 m и застроеното водно количество беше увеличено с 50% за компенсиране на необходимия оводнителен дебит от 250 l/s. Друго техническо предизвикателство беше изграждането на нов стъклопластов тръбопровод с наклон от 38° пред централата.

За минимизиране на изпускането на отложените наноси в старата водна камера беше изградена специална деривация преди изпразването му. Наложително беше и ремонтирането на 108-годишната стена. Оптимизираното ново турбинно оборудване позволи премахването от схемата на водната кула. Допълнително беше реконструиран и съществуващият мост-канал с отвор 32 m. Увеличеното водно количество и новата техническа концепция наложиха инсталирането на две Франсис турбини, докато старата беше само една. Нова сграда на централата беше изградена с готови елементи само за 4 месеца. ВЕЦ „Унтертвенг“ сега представлява част от каскада от три централи с едно единствено водоземане, които могат да се експлоатират напълно автоматизирано.

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