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General view of weir and intake of the Karasu hydropower plant

OPTIMISATION OF WATER INTAKES FOR EASTERN TURKISH CHAIN OF POWER PLANTS

The eastern Turkish provinces of Erzurum and Erzincan are home to five power plants operated on the River Karasu by a German-based financial investor. The facilities are located along a 60 km stretch of the river. Dissatisfied with the overall performance of their quintet of power plants, the operators turned to renowned planning specialists BERNARD Ingenieure in Hall in Tirol for a solution. The main causes of the suboptimal performance were quickly identified as problems at the intake, and the surrounding geological conditions. Based on the improvement measures worked out by the Tyrolean engineers, the facilities are now being modified to raise them to the desired performance level.

The adjacent provinces of Erzincan and Erzurum stretch across a mountainous region that includes parts of eastern Anatolia and the Black Sea region. The entire landscape is characterised by its distinctive, high-towering mountains with plenty of snow in the winter and some local ski resorts to match. But high mountain tops are not the region's only characteristic. It is also home to numerous lakes and rivers, which account for its high hydropower potential. This is one of the regions with the highest electro-hydrological utilisation potential in all of Turkey. To leverage this potential, a large number of new power stations have been built over the past few years. Among them were the five facilities on the River Karasu, which flows through the two provinces of Erzurum and Erzincan. (Incidentally, the Karasu is considered to be the northernmost headstream of the Euphrates.)
The Karasu power stations are all relatively new. The last of the power plant quintet to be opened was a 10-megawatt facility in the Erzincan province, in 2011. In total, this chain of power plants extends over 60 km along the river and has an installed capacity of 24.5 MW. The stated nominal annual output is 139.1 GWh. All five of the facilities were originally built by Turkish project developer Akfen Holding.

ANALYSIS AFTER ON-SITE INSPECTION

It was in the year after the start-up of the fifth power station that the German-based financial investor acquired the entire chain of facilities from Akfen Holding, along with several other hydropower stations. A few months later, however, it was obvious to the new owners that the performance of the plants was not quite up to scratch. Although well equipped technically, they all suffered clogging problems at the water intake structures, which caused a noticeable loss of production.
As a first reaction, the operators contacted Austrian planning specialists BERNARD Ingenieure, which has a long list of successful-

Inlet screen with manual cleaning equipment (insufficient)

General view of Channel comprising the geological problems

ly implemented projects, primarily in hydropower construction. The main tasks for the Tyrolean engineers were to identify the particular problems and to work out ways of solving them. "To be able to do that, it was essential for us to get there and take a look at the situation on-site," recalls BERNARD Ingenieure project leader Ernst Andergassen. A dedicated specialist for water intakes, he set off for eastern Turkey, together with his colleague, certified geologist Maike Weissflog. This project was to prove yet again how useful it is for BERNARD Ingenieure staff to be able to rely on in-house experts for cooperation.

RESTRICTED FLOW RATE AT THE INTAKES

"Our work consisted primarily in identifying the problems with the intake structures and the headrace channels. We were able to discuss the problematic influencing factors with the operators directly on-site," says Andergassen. Based on their proposals, BERNARD Ingenieure was assigned the task of working out detailed solutions for the necessary structural modifications. This required close cooperation with the contracted hydraulic steelwork engineering firm, Southern Tyrolean specialist Wild Metal.
There are only slight differences in design between the five intake structures. As a result, they all suffered from almost identical hydraulic and structural problems. "The main problem was that the intakes are arranged in a hydraulically unfavourable way, and to make things worse, there is a total lack of cleaning devices. This causes the intake to block up rather quickly with bedload gravel and floating debris, which reduces the flow of water to the turbines," as Andergassen explains. But that was not all: There was also a problem with the open headrace channels. Gravel, pebbles and sand keep sliding into the channels, reducing the flow velocity of the water and restricting the overall flow capacity. All that leads to a loss of power generating capacity. Another weak point of the existing structures was a poor drainage system along the headrace channel. As Andergassen explains, "The concrete structures at the headponds looked a little worn-out, and there were sediment deposits in some parts. But," he adds, "at least we didn't notice any leaks." The power house and its electromechanical equipment gave the engineers no cause for complaint either. All hydro-mechanical and electrical equipment was working.

MISSING TRASH RACK CLEANERS

Although the hydraulic problem analysis and development of corrective measures were performed only on the Karasu 1 power station, the results could be applied to the other four facilities accordingly. "At the intake of Karasu 1 we noticed that the four inlet openings were too small," says Andergassen. "A lot of debris was carried along with the headwater and sucked into the desilting chambers. This would quickly cause a blockage at the intake." This is a fundamental problem, especially since there are no trash racks, fine screens or trash rack cleaners installed. Also, there were no silt measuring devices installed in the desilting chambers, and the facilities were lakking any equipment for automating or monitoring the weir structures.

COMPREHENSIVE CORRECTIVE MEASURES

To improve the situation, the team from BERNARD Ingenieure suggested a whole set of measures: This included the implementation of a trash rack with a clear spacing of 250 mm. The individual removable round steel bars are to be put in place directly in front of the intake. A second suggestion calls for construction of a skimming wall to guide floating materials towards the sluice gate
Another measure consists in the implementation of two fine screens with 40 mm clear spacing, as well as a trash rack cleaner with flushing capability. Further items on the list of measures include the installation of silt gauging devices at all desilting chambers and implementation of an automatic flushing routine. Also, the two existing narrow sluice constructions are to be replaced by a single one with a radial gate on top for flushing floating materials downstream. Also on the list of improvement measures is the implementation of a data circuit for remote-controlling the water intake structures, along with water level measuring equipment and surveillance came-

Inside powerhouse, machinery

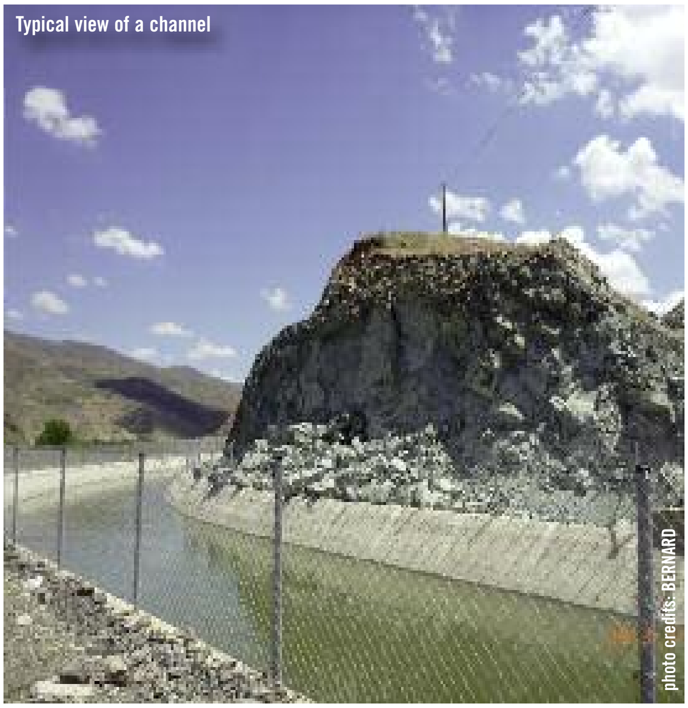
Planned installation of trash rack cleaning system

ras. Rounding off the package of improvement measures is the installation of groins in the backwater area as guiding device for the river channel.

Next, the team from BERNARD Ingenieure ZT-GmbH went on to work out in detail all the civil drawings, statical calculations and reinforcement drawings required for the modification of the Karasu 1 power station. The design of the modifications was tailored to the requirements of the hydro-steelwork supplier. By now, all plans and blueprints have been sent to Turkey, where the contracted construction firm will soon begin implementing the required measures. This means everything is set for the five Karasu facilities reaching their projected performance level in the near future.

RESEARCH STUDY AS A DECISION-MAKING AID FOR INVESTORS

The Karasu power plant project is only one of many Turkish hydropower projects that stand as proof of the professional competence of BERNARD Ingenieure. Another one of their reference projects in Turkey was for the Derya power station on the River Kizilirmak in the northern province of Corum. The Kizilirmak, which is Turkish for “red river”, is the longest river to have its source and mouth in Turkey. It is considered one of the country’s water bodies that are most intensely utilised for hydropower purposes. Contracted by a German-based financial investor, BERNARD Ingenieure conducted a comprehensive lender’s due diligence study. This included a hydrological analyses, a technical design evalutation, HSE (Health, Safety and Environmental) management, a legal and contractual evaluation, and an assessment of the overall power plant performance. Additional items on the agenda included an evaluation of existing studies on the environmental and social impact with respect to Equator Principles and IFC performance standards. The results were consolidated into an independent experts’



Typical view of a channel

Technical Characteristics

- Karasu 1: Design flow 2 x 7.5 m³/s, Net head 29 m, Power output 2 x 1.9 MW, 2 Francis turbines
- Karasu 2: Design flow 2 x 7.5 m³/s, Net head 23 m, Power output 2 x 1.45 MW, 2 Francis turbines
- Karasu 4.2: Design flow 3 x 6.95 m³/s, Net head 58 m, Power output 3 x 3.2 MW, 3 Francis turbines
- Karasu 4.3: Design flow 2 x 15 m³/s, Net head 15 m, Power output 2 x 1.77 MW, 2 Kaplan turbines
- Karasu 5: Design flow 2 x 10.0 m³/s, Net head 21 m, Power output 2 x 1.8 MW, 2 Francis turbines

report to the Lenders, including comprehensive information on all technical aspects of the project.

The power station has a net head of 20 m and an overall design flow rate of 115 m³/s. The two vertically aligned Kaplan turbines with an output of 10 MW each are designed to generate a total of 132 GWh of electricity in a normal year.

THE HALLMARK OF A TRUE EXPERT

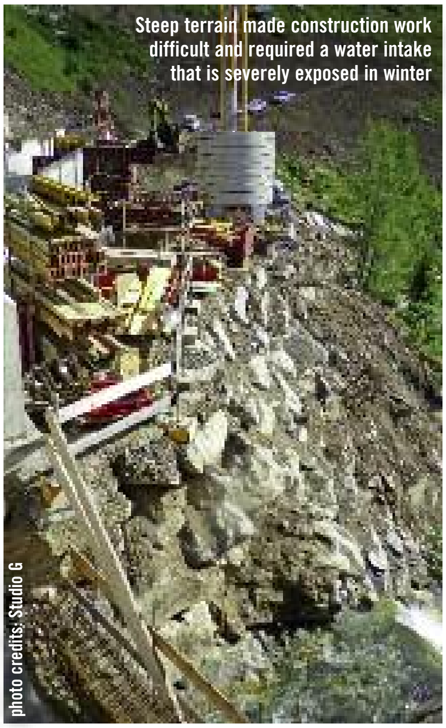
Whether for a due diligence study, as ‘trouble-shooter’ for existing facilities or general contractor for new power stations: whenever answers to complex problems in hydropower utilisation are required, BERNARD Ingenieure provides best solutions. Reference projects all over the world stand as proof to the firm’s success. Meanwhile there are several projects in the booming Turkish hydropower market that also bear the hallmark of the Tyrolean-based planning office.

With finished greening, the power house will blend in optimally with the surrounding scenery. Due to its semi-subterranean architecture, it is hardly audible at all

ODD PAIR OF TURBINES PROVIDE ALL-YEAR POWER IN SOUTH TYROL

On the 18 November 2013, Weitfeld Kons. GmbH officially commenced operations of their diversion power plant at Weitfeld in the Ahr valley in South Tyrol (Alto Adige) in Italy. The geologically tricky and rather steep terrain ranging up to 1,828 m (5,997 ft) above sea level presented the project management as well as the contractors involved in the erection of the plant with tremendous challenges. There was no room for delays in the tight seven month construction schedule. On the contrary: At this altitude, work is a race against time and the unpredictable weather of the Tyrolean Alps. As during the preparatory phases, experts had been critical about the schedule, completion in time before the onset of winter was all the more gratifying. Its most outstanding feature is the use of a pair of turbines of different types that was prompted by the strong seasonal variation in works water supply.

The Ahrn vally is a side arm of the Puster valley in South Tyrol (Alto Adige) near the Austrian border in Italy. Featuring high mountain ranges and countless tributary valleys, it is an impressive sight. The valley is surrounded by more than 80 3,000-meter (10,000 ft) peaks and more than 50 active shielings, many of them offering regional food and drinks in winter as well. The south side of the Ahrn valley borders on the Puster valley and the famous Dolomites. The steep, mountainous terrain with its numerous brooks and creeks makes it therefore attractive for hydroelectric projects. One of the most recent projects is the Weitfeld hydropower plant on the Schwarzbach upstream from Luttach (Lutago) near the Weitfeld shieling. The operators Weitfeld Konsortium GmbH awarded the planning contract to “Studio G“, a well-reputed engineering firm from Bruneck (Brunico). The service package included the submission project, implementation planning, the bidding procedure, construction supervision and miscellaneous proceedings with authorities. Upon finishing the planning and approbation phases, construction work commenced on 15 April 2013.



Steep terrain made construction work difficult and required a water intake that is severely exposed in winter

DIFFICULT GEOLOGY AND TERRAIN

The water catchment was situated at an altitude of 1,828 m (5,997 ft) above sea level. The water is led through a 2.7 km (1 2/3 mi.) pipeline made of ductile cast-iron pipes to the power house. Equipped with two Pelton turbines, this is situated at a 1,255 m (4,117 ft) altitude. What made the schedule as critical as it had been was the water catchment in extremely steep terrain. To facilitate the construction of the weir in this terrain at all, a wall 50 m (164 ft) tall needed to be built, says the vice president of Weitfeld Kons. GmbH. In the Beginning, the greatest challenge was finding the right pipeline route. Orographically to the right there are avalanche stretches with fissures several meters deep

The water intake was designed as a Grizzly Coanda-type rake from Wild Metal GmbH

all the way down to the valley bottom. To the left, there were house-sized boulders from previous rockslides. In spring, there is also an elevated danger of rock fall in this section. The best route was found during several site inspection surveys with the local forestry authorities. Safety for the workers, for access roads and the pipes had to be assured. To this end, two dams were erected for rock slide protection and several sections were protected using rock fall nets. As a side effect, this resulted in the creation of a safe and attractive hiking trail. Meeting the requirement for completion within only seven months also posed a challenge difficult to meet. The weather, on the other hand, was friendly. Following a lot of rain in spring, there was hardly any rain at all during summer and autumn so all work was finished before winter started.

WEIR DIFFICULT TO ACCESS IN WINTER

Due to the alpine winters and the aforementioned steep terrain, the water catchment is difficult to get to in winter. To avoid down times, its exposed situation needed to be taken into account in the planning. Even at the lowest temperatures, the weir needs to remain flawlessly operational and guide water to the turbine. This is why the time-tested Grizzly grid rake system from Wild Metal GmbH of Ratschings (Racines) was selected for its high reliability of operation. The width of the weir field is 4.5 m (15 ft). An additional 1.5 m (5 ft) is reserved for the dynamic residual flow output. The maximum developed water volume is set to 420 l/sec. The minimum volume for withdrawal in winter was set by the authorities at 5 l/sec. The works water is led across the Grizzly rake taking advantage of the Coanda effect with a 0.6 mm gap width mounted beneath the protective grid rake. In case of thick ice, the water is diverted using a winter inlet.

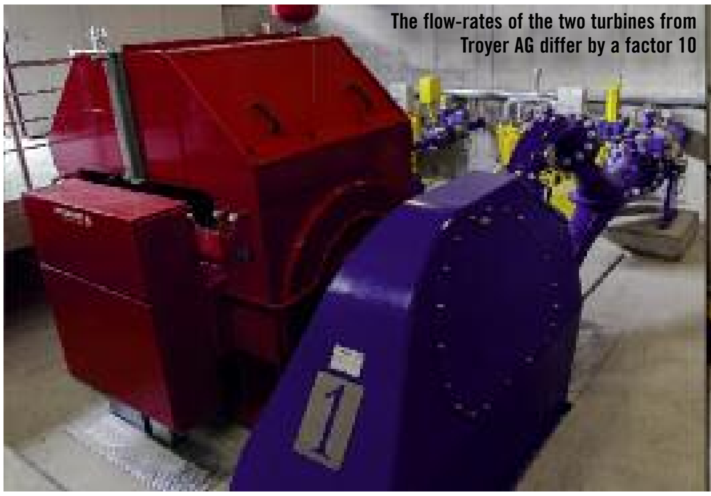
The water catchment can additionally be heated using a flow of warm air to avoid freezing. A tube sluice, an innovation from Wild Metal, allows flushing the basin upstream from the Grizzly. Its benefit is that no extra construction with implications on the scenery is required. The prefabricated elements for the sluice are delivered and installed with the inserts for the Grizzly.

A particularly rigid screen rake protects the weir from rock fall. The fixed portion of the residual water amounting to 23 l/sec is led off through a gauged pipe. On top of this, a variable volume of 25 % residual water is extracted via the weir field.

Sediments do not need to be taken into account as there is an elevated plain upstream from the weir in which most of the bed load settles out. From the plain to the rake, the water passes only steep, rocky terrain and does not gather any more bed load. To be on the safe side though, a sand trap was installed anyway.

DUCTILE CAST-IRON PIPES

The geology and the steep slopes made pipe laying a difficult undertaking. High-grade ductile graphite iron pipes with push and pull protected connectors from Tiroler Rohre GmbH proved suitable for this terrain. The pipe diameter was selected to provide the optimal tradeoff between cost effectiveness and minimised elevation losses. For the first half of the line, pipes with a nominal diameter of 600 mm (2 ft) were used, while for the second half, this diameter was reduced to DN 500 (20 in). The 2,700 m (1 2/3 mi) force pipe drops 575 m (1886 ft). Over the entire length, the pipes were laid underground with a minimum 1.2 m (4 ft) depth of coverage.



The flow-rates of the two turbines from Troyer AG differ by a factor 10

Turbine 2 was dimensioned for 40 l/s to effectively work at marginal water volumes in winter

photo credits: zek

Pressure loss was minimised to about 3.2 % of the nominal head of water.

SEMI-SUBTERRANEOUS POWER HOUSE

Building the power house, much attention was paid to landscape integration. The intent was to build it structurally inconspicuous and with minimal noise emissions. To this end, architect Elfriede Hofer designed a semi-subterraneous power house. Thanks to the integration with the slope, it has a natural noise protection at the back and on both sides. The visible outer walls were covered with a wooden front. Due to this wood panelling, the power house has a traditional appeal that as a result of the roof edge line and the position and shape of the windows is also very modern. The water return runner opens directly into the Schwarzbach stream. Due to its natural stone dressing, it is hardly discernible.

ODD PAIR OF TURBINES

In the power house, two Pelton turbines from Troyer AG produce electricity year-round. The first, larger generation features a 2-nozzle Pelton turbine with 40 l/min. Maximum throughput at a 556 m (1,824 ft) water head. Its power rating is 1,965 kW at a nominal speed of 1,000 rpm. It has a directly attached synchronous generator from Hitzinger with a 2,360 kVA power output. The design of the winter turbine is particularly remarkable. With a throughput of only 40 l/s, the single-nozzle Pelton turbine is rated ten times smaller than its bigger sister. It is meant to generate energy even if water supply in the Schwarzbach stream drops to 5 l/s in winter. The nominal power rating of this generating set is 195 kW at a speed of 1500 rpm. It has a directly attached Hitzinger synchronous generator rated at 240 kVA. With the maximum volume of developed water at 420 l/s, the power station has a bottleneck capacity of about 2 Megawatts. According to calculations, an annual six million Kilowatt-hours of electricity are expected to be generated.

SUCCESSFUL PROJECT

The geology and the steep terrain confronted engineers and construction workers with great challenges. "Timely completion of the power plant with all related infrastructure and their environment-friendly integration with the landscape were facilitated by commitment and consistent coordination on the side of the operators as well as the competent construction supervision and support from local authorities, above all the torrent regulation agency and the Steinhaus forestry office," the construction supervisors said.

Technical Data

Machine 1: 2-nozzled Pelton turbine

- Manufacturer: Troyer AG
- Flow Rate: 400 l/s
- Gross Head: 556 m
- Output: 1'965 kW
- Rotation Speed: 1'000 rpm
- Generator: Synchronous Hitzinger
- Output: 2'360 kVA

Machine 2: 2-nozzled Pelton turbine

- Manufacturer: Troyer AG
- Flow Rate: 40 l/s
- Gross Head: 556 m
- Output: 195 kW
- Rotation Speed: 1'500 rpm
- Generator: Synchronous Hitzinger
- Output: 240 kVA
- Average Energy output: 6 mill. kWh