Hydropeaking mitigation measures - planning, realization and operation of the first Swiss hydropeaking compensation basin in Innertkirchen BE

M. Müller, Y. Keller, P. Billeter
IUB Engineering Ltd.
Belpstrasse 48, Postfach
CH-3000 Bern 14
Switzerland

R. Kaderli, M. Gehri
BKW Energy Ltd.
Viktoriaplatz 2
CH-3013 Bern
Switzerland

M. Kost
Kraftwerke Oberhasli AG
Grimselstrasse 19
CH-3862 Innertkirchen
Switzerland

Abstract

Sudden opening and closing operations of the turbines produce highly unsteady flow in the river downstream of hydropower plants. This so-called hydropeaking is the major man-made hydrological alteration in Alpine rivers and may disturb the ecological quality and the natural abiotic structure of ecosystems. Since 2011, the Swiss Law on Water Protection prescribes to improve the quality of Swiss waters, including hydropeaking mitigation. When the existing hydropower scheme Innertkirchen 1 was enhanced by the construction of parallel waterways as well as an additional cavern power house Innertkirchen 1E, the plant owner Kraftwerke Oberhasli Ltd. included planning and realization of constructive hydropeaking mitigation measures. To reduce the negative impact of the increased turbine discharge on the downstream Hasliaare River, a new compensation basin and a new 2.1 km long reservoir tunnel were implemented at the downstream end of the enhanced scheme.

Preliminary design included laboratory tests on outlet structure capacities as well as hydrological calculation with the definition of the necessary storage volume and the definition of target hydropeaking rates. In the detailed design phase, 1D numerical simulations allowed analyzation and optimization of the system behavior and led to a final hydropeaking mitigation concept consisting of a compensation and regulation basin and a regulated tailrace tunnel. The corresponding regulation control was implemented based on a robust volume balance, taking into account the as-is state as well as a forecast of the expected operational changes from the power plants. Multiple boundary functions guarantee a safe system operation and a continuous compliance with the target hydropeaking rates. The relatively small storage volume, the forecast uncertainty and the oscillations in the downstream hydraulic system presented special regulation challenges.

Commissioning tests took place in autumn 2015 and spring 2016 and allowed verification and optimization of the system regulation performance. Prototype characteristics such as head-discharge relations for the different regulation gates, effective storage volumes and free flow slopes were measured and compared to results from preliminary calculations and hydraulic modelling. On August 8, 2016, the enhanced system has been officially handed over for commercial energy production, after some four years of construction works and about nine months of testing the electromechanical equipment as well as the storage volume regulation aiming a future hydropeaking mitigation.

The paper gives a short overview on the “Tandem” enhancement project, its possible ecological consequences on the downstream river reach and the objectives of this very first compensation basin in Switzerland implemented within the scope of hydropeaking mitigation. Then, it emphasizes on the planning and construction challenges of the regulation system under the severe exploitation conditions and safety constraints. The results from the in-situ testing phase as well as the consequent adaptions of the regulation system are presented and discussed.

1. Background

In the framework of the upgrading program KWOplus, the so called “Tandem” project consisted in the construction of parallel systems to the two existing high head hydropower plants Innertkirchen 1 (Inn1) and Handeck 2 (Ha2, Müller et al. 2014). This enhancement allows reduction of head losses in both existing and new pressurized tunnels and shafts, with a corresponding gain in energy production of 70 GWh/a. The overall installed capacity has increased by 240 MW and the new additional turbines lead to an increased operational flexibility of the two plants.

Initially, water from the Inn1 cavern power house was released through a 1,330 m long tailrace tunnel (UW_{best}) into the small Gadmerwasser River and some 50 m downstream into the Hasliaare River (Fig. 1). Consequently, the downstream river reach was altered by discharge variations caused by the plant operation. While the minimum residual flow in the Hasliaare River is $Q_{Hasliaare,min}$ = 3 m^3/s, the initial maximum turbine capacity was $Q_{Inn1,max}$ = 39 m^3/s. In addition, water from the existing Innertkirchen 2 power plant (Inn2, $Q_{Inn2,max}$ = 30 m^3/s) was restituted directly into the Hasliaare River through a 40 m long tailrace channel.

The Innertkirchen 1E/S (Inn1E) enhancement project included the construction of a second hydropower system located at some 50 m of the existing plant. From the upstream hydropower stage Ha2, a new parallel headrace pressure tunnel leads the water toward the surge tank. A new parallel steel-lined pressure shaft connects the extended surge chamber to the new Inn1E cavern power house, where a Pelton turbine with a nominal discharge of $Q_{Inn1E,max}$ = 25 m^3/s and a capacity of 150 MW is installed. Without hydropeaking mitigation measures, the increased discharge from the power plants and the increased operational flexibility would have considerably altered the ecological conditions in the Hasliaare River by inducing highly unsteady flow phenomena. As the Swiss Law on Water Protection inter alia prescribes to improve the quality of Swiss waters, including hydropeaking mitigation by constructive and eventually operational measures, the plant owner Kraftwerke Oberhasli Ltd. (KWO) aimed an ecological enhancement of the downstream river reach. To reduce the negative impact of the foreseen increase of the turbine discharge, a new compensation and regulation basin (BB) and a new 2.1 km long tailrace tunnel (PUW) were implemented at the downstream end of the existing Inn1 and the new Inn1E plants.

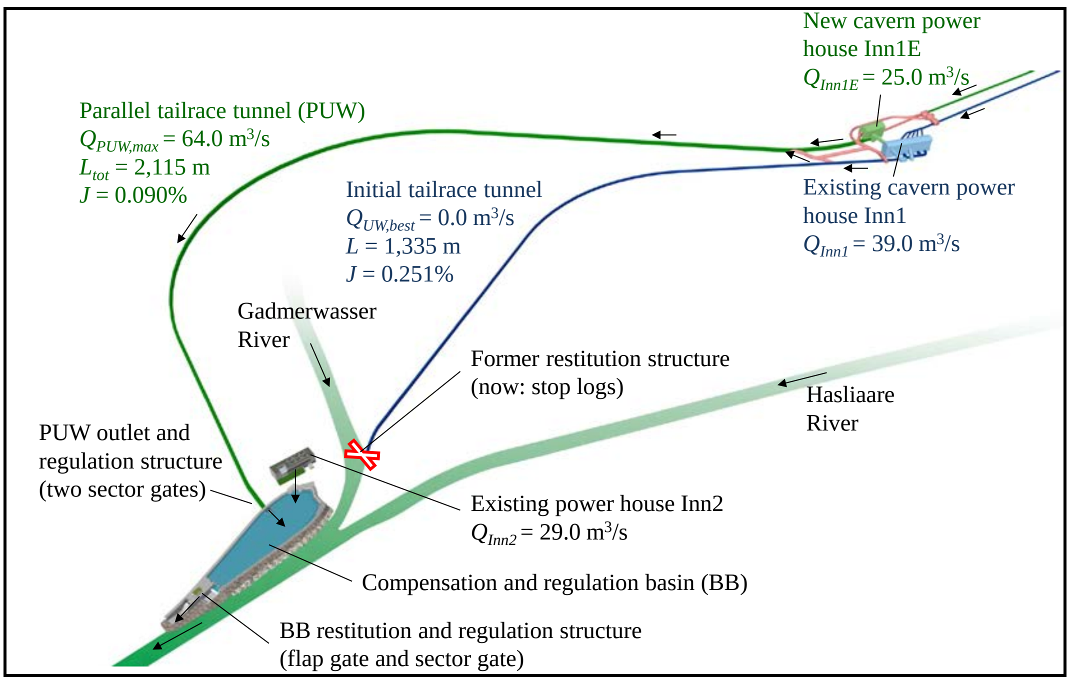


Fig. 1. Schematic overview of the enhanced hydropower scheme Innertkirchen 1 & 1E, area between the two cavern power houses and the water restitution into the Hasliaare River.

2. Objectives

In a preliminary hydrological study, the flow up- and down-ramping rates were estimated for the initial conditions and the situation after the “Tandem” realization (Schweizer et al. 2013a). Simulations revealed that a volume between V = 50,000 and 100,000 m^3 would allow increasing future ecological conditions, not only compared to the future situation without mitigation measures, but also compared to toady's situation. Based on a cost-benefit-analysis, an expert panel of environmental specialists, engineers, representatives of cantonal and federal authorities as well as the plant owner selected a volume of V = 80,000 m^3 as the most convenient compromise, acceptable for all of the involved partners (Schweizer et al. 2013b).

Relevant up- and down-ramping rates defined as target values for the detailed design are summarized in Table 1. As during winter season natural base flow from the catchment area is low and therefore hydropeaking impact is most critical, the calculations were carried out for operational data from four consecutive winters (December to March, 2009/2010 to 2012/2013). Regulation performance was evaluated with the 95%-percentile of daily maximum values.

Table 1. Up-ramping rates (+), down-ramping rates (-) and down-ramping rates during base flow $Q < 8.1$ m³/s (-) for the initial and the enhanced hydropower system (Bieri et al. 2014).*

Hydropower system configuration	**Hydropeaking rates [m^3/s/min]**		
	Up-ramping (+)	**Down-ramping (-)**	**Down-ramping for $Q < 8.1$ m^3/s (-*)**
Initial configuration (before "Tandem" project)	1.36	1.21	0.70
"Tandem" without storage volume	1.43	1.35	0.70
"Tandem" with storage volume of $V = 80{,}000$ m^3	0.70	1.33	0.14

For the case of increasing water depth in the downstream river reach, the target up-ramping rate is +0.70 m^3/s/min for the entire discharge range and a maximum rate of +2.50 m^3/s/min must not be exceeded. Down-ramping rate for base flows higher than $Q = 8.1$ m^3/s is limited to -1.33 m^3/s/min. For very low base flow ($Q < 8.1$ m^3/s), the critical down-ramping rates is -0.14 m^3/s/min, corresponding to a flow depth variation of -0.5 cm/m/min and ensuring conditions required for the juvenile brown trout in the downstream gravel bars reach (Baumann et al. 2012).

3. Hydropeaking mitigation concept

3.1 Boundary conditions

Due to the narrow on-site conditions of the valley floor in Innertkirchen, the BB could only provide a volume of about $V_{BB} = 20{,}000$ m^3. Therefore, the new PUW between the Inn1E power house and the basin was designed with a length of almost $L_{PUW} = 2.2$ km and a very large cross section to provide extra volume. The existing tailrace tunnel has been connected to the new system and its downstream end has been closed by stop logs. Thus, the entire water from the existing Inn1 and the new Inn1E power house is now evacuated through the new PUW. The two schemes are conceived to still enable the separate exploitation of only one plant, in case of major revision works on the neighboring system.

During detailed design, the hydraulic functioning of the combined system PUW & BB was analyzed and optimized in 1D-simulations (MIKE URBAN, DHI) for several exploitation scenarios. The storage volume management was refined with an adopted regulation algorithm, taking into account not only the afore mentioned critical up- und down-ramping rates from the preliminary design, but also a multitude of safety and operation constraints required by the plant owner. For example, neither the entire system nor a single storage component is allowed to empty or overflow. Simultaneously, a sudden opening to maximum discharge or a short term closing of the turbines have to remain possible for a flexible energy production. System safety, maximum and desired up- and down-ramping rates as well as operation flexibility are prioritized in the regulation algorithm to manage the retention volume.

3.2 Parallel tailrace tunnel

The parallel tailrace tunnel (PUW), which initially was conceived for free surface flow conditions, presents a width of $B_{PUW} = 7.42$ m, a height of $H_{PUW} = 6.0$ m and a very low longitudinal slope of $J_{PUW} = 0.9‰$. This geometry induces flow depths of some $h = 4.50$ m and a remaining free height below the Pelton wheel of some 3.40 m. Under free surface flow conditions, the PUW would have provided a maximum storage of $V_{PUW} = 60{,}000$ m^3, which together with the basin was judged sufficient according to preliminary results. However, numerical calculations considering additional operation and safety boundary conditions revealed the need of an active regulation of the PUW in order to provide additional storage volume and achieve the given target rates while guaranteeing a safe and flexible plant operation.

To actively contribute to compensation of flow variations from the turbines, the PUW is now regulated by two sector gates of $B = 6$ m width which allow increasing the active PUW storage capacity up to $V_{PUW,max} = 73{,}000$ m^3, depending on the instantaneous system discharge and regulation possibilities. The 1D-simulations allowed verification of the adequate system functioning under the altered hydraulic conditions of partially pressurized flow.

Admissible flow depths at crucial system points and especially below the turbines are still satisfied. However, new ventilation elements were required to assure air exchange during transient flow phenomena.

3.3 Compensation and regulation basin

The compensation and regulation basin (BB, Fig. 2) represents the "bottleneck" at the very downstream end of the entire KWO hydropower system. On one hand, the PUW opens out into the BB and on the other hand, water from the Inn2 plant is not released directly in the Hasliaare River any more, but also flows through the BB. In the detailed design, the basin provides an active storage volume of $V_{BB,max}$ = 19,800 m^3 and is regulated by a flap gate and a sector gate of B = 12.5 m and B = 10.0 m width, respectively.

Fig. 2. Aerial view of the compensation and regulation basin Innertkirchen. Up right: Inn2 power house. Centre: PUW outlet and regulation structure. Low left: BB restitution and regulation structure into the Hasliaare River. Along the right image border, the Gadmerwasser River and the initial restitution structure upstream of the railway bridge are visible.

The capacity of these restitution and regulation gates, the planned geometry of the stilling basin as well as the impact of the new water release into the natural Hasliaare River reach were studied and optimized in a physical model at the Laboratory of Hydraulic Constructions (LCH) at the Ecole Polytechnique Fédérale de Lausanne (EPFL). Test results revealed an evacuation capacity of about Q = 100 m^3/s for both outlet structures under normal flow conditions in the Hasliaare River (LCH 2014). Consequently, redundancy of the regulation gates is assured. During flood events, when high downstream water levels lead to imperfect overflow, high BB water levels are required to still guarantee evacuation of the maximum discharge from the power plants. Flood safety along the considered river reach is not altered by the implementation of the BB and its regulation structure.

4. System regulation

4.1 Challenges

The biggest challenges met during the elaboration of the regulation algorithm which is facing a multitude of constraints and system components are listed hereafter:

- From the power plant operation, discharges from Q = 0 to 64 m^3/s (Inn1 & Inn1E) flow into the PUW and Q = 0 to 29 m^3/s (Inn2) directly into the BB. Theoretically, this corresponds to an inflow rate up to ΔQ = 93 m^3/s/15 min, or ΔQ = 6.2 m^3/s/min. For water release back into the Hasliaare River, target rates are lower by one order of magnitude.
- The PUW system and the BB interact and build a storage volume sensible to wave motions. The regulation must not excite or amplify such volume oscillations.

- The regulation has to assure the minimum free height below the involved turbine wheels at all time. However, adjustments at the regulation gates downstream of the PUW are observable in terms of a changing water level in the upstream part of the tunnel only after some minutes.
- The instantaneous volumes and discharges are calculated based on measured water levels and gate positions. There are only few points in the system which deliver reliable data for any given operation.

4.2 Approach

The target values for up- and down-ramping rates can be achieved with the relatively restricted regulation volume only if the system composed by the PUW and the BB is prepared for expected operation changes. Consequently, it has to be gently filled or emptied toward anticipated filling levels, reason why discharge forecast becomes a key element in the regulation algorithm.

For the transfer point at the switchyard between the hydroelectric schemes of KWO and the high-voltage grid, nominal effective power is predicted several hours in advance. This schedule of power production or absorption allows a general forecast on the discharges expected to enter the storage system. However, the forecast is subject to the following uncertainties:

- Knowledge about which machineries in the entire KWO scheme are going to produce the future nominal power is available only after a manual start command in the control system. Depending on which power house is producing, the expected inflow to the storage system PUW & BB is either almost nil or very high.
- In pumping mode of other KWO plants, the nominal effective power at the transfer point is basically decreasing. However, discharge into the storage system can increase if the pumping activity is compensated elsewhere by turbine mode.
- The volatility of the energy market leads to significant short-term modifications within the 15-minutes regulation forecast. Such modifications cannot be anticipated.

Simulations during the dry commissioning phase showed that the storage regulation including an inaccurate and temporary wrong forecast still leads to better hydropeaking behavior than an algorithm without any forecast.

4.3 Realization

Regulation of the total system is based on robust volume balances of the tailrace tunnel, the basin and the total system. Instantaneous water level measurements and the geometrical characteristics allow determining the as-is state. The target volume is calculated for a 60-minutes forecast of the expected discharge changes from the power plants. If high discharge is predicted the regulation aims a high retention volume to assure sufficient volume for a very smooth release into the Hasliaare River in case of a sudden discharge decrease from the power plants.

Discharge forecast relies on several images of the existing plant controllers. These clones are fed with values from the forecast nominal effective power and from the actual power production. They deliver the future target in terms of power production of the relevant power houses Inn1, Inn1E and Inn2, allowing to estimate the future discharge released into the storage system. Multiple global and local boundary functions are implemented to assure an adequate and safe behavior of the system, even in case of forecast errors, short-term changes in the production schedule, manual operations or malfunctions.

Calculated target discharges from the storage system are controlled by two sector gates at the downstream end of the PUW and a flap gate and a sector gate at the downstream end of the BB. An adequate head-discharge-relation and a variable adjustment speed are key elements to the correct behavior of these regulation gates. Water level measurement stations have been installed below the turbines, at the upstream and the downstream ends of the new PUW, in the BB as well as in the Hasliaare River downstream of the restitution structure.

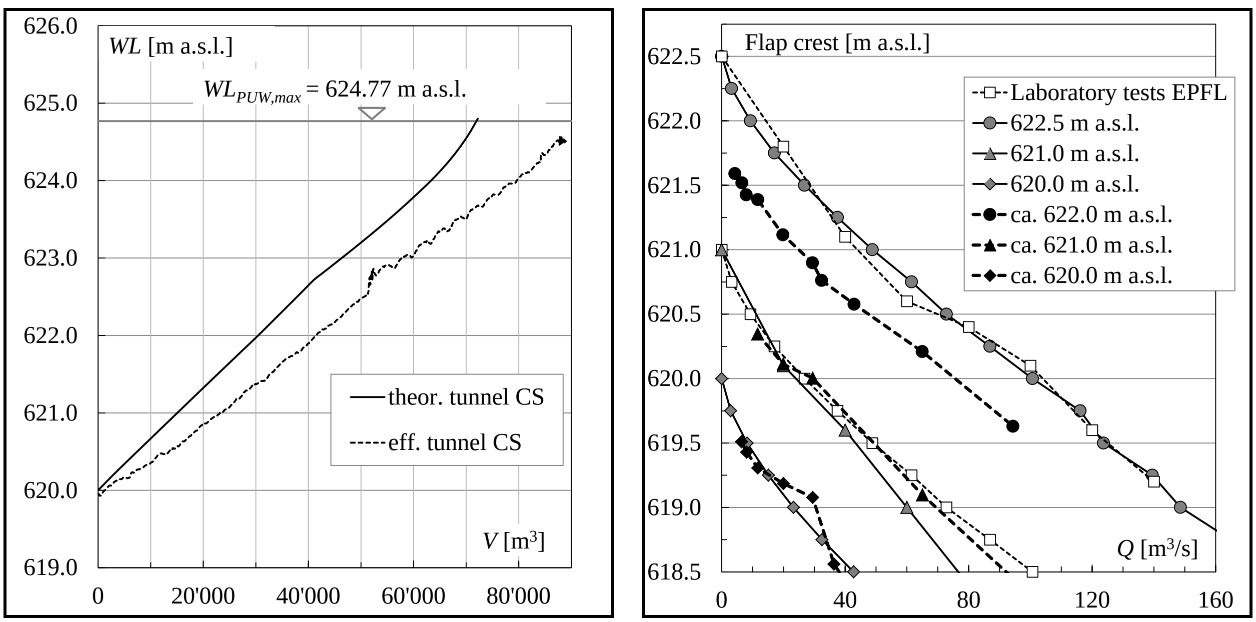
The primary functions such as discharge forecast, volume balance and system boundary conditions are implemented in redundant computer units of the existing plant control system. Two automation devices at the downstream end of the PUW and at the water restitution into the Hasliaare River host local functions such as discharge regulation, gate positioning and additional limiters. The latter assure the compliance with the critical water levels regarding system safety concerns. The sampling stations, the regulation structure as well as the system controller are basically insensitive to external impacts and malfunctions.

5. Commissioning phase

In October and November 2015, a first commissioning phase took place with tests on the new hydropeaking mitigation system with water from the existing power plants Inn1 and Inn2. All sampling stations were already operational and allowed recording water levels in the PUW and the BB. Discharge data from the power plants were available as well as the regulating variables from the four regulation gates. Based on the commissioning tests, the safety and operational functions of the controller and the technical boundary conditions of the system could be verified. From March to May 2016, the second phase of commissioning tests included operation of the new power plant Inn1E. These tests allowed gathering additional information about hydraulic particularities and the functioning of the control device under future exploitation conditions.

5.1 System characteristics

During the very first filling and emptying tests, the effective storage volumes of the two components PUW and BB were determined. The active storage volume of the basin is about $V_{BB,eff}$ = 17,000 m^3, while the tailrace tunnel (including the UW_{best} blocked by stop logs) provides some $V_{PUW,eff}$ = 89,000 m^3. In fact, after excavation of the PUW, the owner, the project engineers and the geologists decided not to proceed to a shotcrete lining of the tunnel cross section, reason why the storage volume is increased by up to 25% depending on the water level (Fig. 3a). The bigger cross section is theoretically increasing the hydraulic capacity of the PUW, however, the modest shotcrete cover as well as the bare rock implicate a relatively high roughness. Free surface flow slopes were measured for steady state conditions in order to determine the effective tunnel roughness and evaluate minimum and maximum available storage volume depending on the actual discharger from the plants.



a) *b)*

Fig. 3. Comparison between results from preliminary studies, detailed design and commissioning phase: a) water level WL vs. total (PUW & UW_{best}) storage volume V for the theoretical (continuous line) and effective (dashed line) PUW cross section for the storage PUW and UW_{best}, b) Flap crest vs. discharge Q for the flap gate at the BB restitution structure according to calculations (grey), physical modeling (white) and prototype measurements (black).

In addition, the prototype measurements allowed verification of the head-discharge-relation of the regulation gates, which were previously calculated and determined in laboratory tests (Fig. 3b). For basin water levels above $WL_{BB} \geq$ 621.0 m a.s.l., prototype measurements confirm the capacity values from calculations and laboratory tests. For lower filling levels of the BB, prototype capacity start diverging significantly from calculations and physical modeling results. In fact, due to the BB geometry and the location of the outlet structures from the PUW and the Inn2 plant, a main current develops along the side wall next to the Hasliaare River. This current is especially pronounced for low water levels in the basin and leads to excessive approach velocities upstream of the flap gate which is no longer characterized by the commonly used head-discharge-relations from literature but presents a considerably higher evacuation capacity. This circumstance caused a constant slow sink of the basin level. The sector gate is not affected by this main current and presents quite uniform and low approach velocities. The measured capacity of this regulation gate corresponds well with values from literature and physical modeling.

Detailed data analysis revealed important temporary oscillations in the two connected storage volumes. The PUW is especially affected by oscillation phenomena after manipulations at the two sector gates, with amplitudes up to +/-15 cm and a period of some 13 minutes. Dampening of these oscillations to amplitudes less than +/-5 cm takes more than 1.5 hours. How such system oscillations affect the regulation and the resulting hydropeaking rates will only be known after a certain period with real continuous plant operation.

5.2 Regulation functions

Commissioning of sensors, regulation actors and boundary functions took place without major problems. However, the definition of the primary functions resulted more difficult as the tunnel system and the BB are influencing one another and are subject to oscillations. The first tests with the superordinate regulation very often ended with a slow but continuous emptying of the basin. With the implementation of the effective system characteristics (storage volumes and capacities of regulation gates), stable regulation conditions could be reached. In addition, the propulsion of the regulation gates was optimized after the first commissioning phase in autumn 2015, as the positioning needs to act as slowly and uniform as possible under normal exploitation, but very fast when local boundary functions are activated. At the end of the second commissioning phase in spring 2016, the system regulation has proved to perform well. The dampening effect of the new hydropeaking mitigation measure is illustrated in Fig. 4 and will be monitored further on. The behavior of the system will be followed-up over the next months and years to continuously gather more operational data and optimize the regulation concept if necessary.

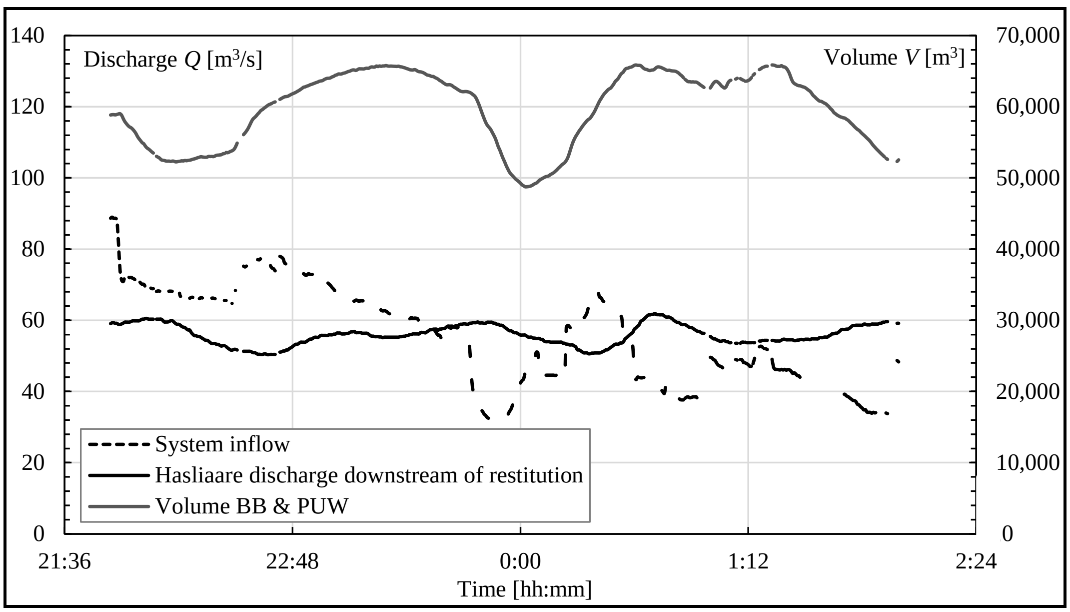


Fig. 4. Operation data for the period from June 16, 21:36 h to June 17, 02:24 h. Total system inflow Q from plants Inn1, Inn1E and Inn2 (black, dashed), discharge released into the Hasliaare River (black, continuous) and corresponding development of the storage volume (grey). The dampening effect of the hydropeaking mitigation measure is clearly visible.

6. Conclusions and outlook

The realization of the first Swiss compensation and regulation basin especially conceived as a hydropeaking mitigation measure showed that on-site conditions as well as safety and operation boundary conditions imposed by the plant owner are to be considered already in early design phases, especially for the estimation of storage volumes and target up- and down-ramping rates. In the case of the “Tandem” enhancement project, the requirements could be achieved by the implementation of additional active storage volume in a very long regulated new parallel tailrace tunnel. The development of a coherent regulation strategy was subject to important challenges due to the interconnected storage volumes, the multiple global and local boundary conditions and the uncertainties in forecast of power production (and consequently inflow in the compensation and regulation system) for a very complex hydropower scheme. Detailed system analysis and prototype measurements during commissioning tests allowed optimizing the regulation algorithm and first results reveal satisfactory behavior of the implemented hydropeaking mitigation measure. Monitoring during the upcoming years of exploitation will allow evaluation and further improvement of the system performance.

References

1. **Baumann, P., Kirchhofer, A. and Schälchli, U.**, "Sanierung Schwall-Sunk – Strategische Planung: Ein Modul der Vollzugshilfe Renaturierung der Gewässer", Report. Umwelt-Vollzug, Berne, Switzerland, 2012. (in German)
2. **Bieri, M., Müller, M., Schweizer, S. and Schleiss, A.J.**, "Flow restoration in Alpine streams affected by hydropower operations – A case study for a compensation basin", *Proceedings*, River Flow 2014 – the 7th International Conference on Fluvial Hydraulic, EPFL, Lausanne, Switzerland, 2014.
3. **Laboratory of Hydraulic Constructions (LCH)**, "Auslassorgane Beruhigungsbecken Innertkirchen – Hydraulische Modellversuche", EPFL-LCH, Lausanne, LCH Report Nr. 2/2014, 184 pages. Unpublished report owned by KWO (Authors: Ferràs, D., Zeimetz, F. and Pfister, M.), 2014. (in German)
4. **Müller, M., Zahno, M., Keller, Y, Billeter, P., Stamm, J. and Kost, M.**, "Building new power plants under continuous exploitation of neighboring hydropower schemes - planning and construction challenges of the "Tandem" enhancement project in the Central Alps of Switzerland", *Proceedings*, HYDRO 2014 – Building on recent development progress, Como, Italy, 2014.
5. **Schweizer, S., Bieri, M., Tonolla, D., Monney, J., Rouge, M. and Stalder, P.**, "Schwall/SunkSanierung in der Hasliaare – Phase 2a: Konstruktion repräsentativer Abflussganglinien für künftige Zustände", Wasser Energie Luft 2013(4), 267–274, 2013a. (in German)
6. **Schweizer, S., Schmidlin, S., Tonolla, D., Büsser, P., Maire, A., Meyer, M., Monney J., Schläppi, S., Schneider, M., Theiler, Q., Tuhtan, J. and Wächter, K.**, "Schwall/Sunk-Sanierung in der Hasliaare – Phase 2b: Ökologische Bewertung von künftigen Zuständen, Wasser Energie Luft 2013(4), 275–285, 2013b. (in German)

The Authors

Dr. Michael Müller graduated in Civil Engineering from the École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, in 2007. Between 2007 and 2012 he was a research assistant at the Laboratory of Hydraulic Constructions (LCH) at EPFL, and obtained his doctorate in science in 2012 on the subject of reservoir sedimentation in pumped-storage reservoirs. Currently he is working for IUB Engineering Ltd. in Berne as project engineer for hydropower and hydraulic engineering as well as river training and flood protection.

Roland Kaderli graduated in Electrical Engineering from the Higher Technical Institute FH Burgdorf near Bern. Between 1990 and 2010 he worked as project engineer in controls, regulations and protective devices for various hydropower stations in Switzerland. Since 2010 he is the head of department of process automation in the engineering department of BKW Energy Ltd.

Yves Keller graduated in Civil Engineering from the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland, in 2003. He is currently working as project manager at IUB Engineering Ltd in Berne, Switzerland, and is involved in the design of hydropower schemes and river engineering projects as well as water supply, flood protection, and feasibility studies. Since 2012 he is the head of the hydraulic engineering and power station construction department of IUB.

Matthias Gehri graduated in Civil Engineering from the ETH in Zurich, Switzerland, in 1998. Between 1998 and 2001 he worked as project engineer in gas pipelines with B+S Ltd. Since 2002 he works as senior engineer and project manager for hydro power engineering BKW with specialty in design concept and optimization of hydro power schemes.

Dr. Peter Billeter graduated in 1987 in Civil Engineering from the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland. In 1988 he joined the Laboratory of Hydraulics, Hydrology and Glaziology (VAW) at the ETH as research assistant and was appointed head of the hydrodynamic section in 1992. He received his PhD in 1998 with a thesis on flow-induced vibrations of gates. From 1998 to 2000 he held a position as senior project manager in the field of structural dynamics at Gruner Ltd. in Basel. Since 2000 he is working for IUB Engineering Ltd. in Berne as project manager for hydropower and hydraulic engineering. He currently is President of IUB and member of the board of directors.

Markus Kost graduated in Mechanical Engineering from the Higher Technical Institute FHZ Lucerne. Between 1984 and 1991 he commissioned large steam power plants worldwide for BBC/ABB. After 1992, he worked as head of operation and maintenance at a hydropower plant in Switzerland during 20 years. Since 2012 he is the responsible project manager for the upgrade of the Innertkirchen 1 power plant at KWO.