NEWSLETTER

No. 4

PUBLIC OVERVIEW OF HESS PROJECT

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The pump storage system in mine shaft

One of the most important components of the HESS project – Hybrid Energy Storage System using post-mining infrastructure - is the preliminary design of an underground pumped-storage power plant integrated into a decommissioned mine shaft. This design includes an assessment of technical feasibility, the definition of functional and mechanical assumptions, and the configuration of the generating unit for further analyses and stakeholder consultations.

The concept assumes the use of the existing mine shaft as the lower reservoir, while a 5.3 MW Pelton turbine, a synchronous generator, a DN400 penstock, and hydraulic control systems are planned to be installed at the −900 m level.

System of the hydro turbine and generator with the shaft reservoir

The underground installation includes high-head Pelton turbine coupled with a medium-voltage synchronous generator. The unit operates with a head of approximately 900 m, a flow rate of about 0.71 m^3/s, and a rotational speed of 1500 rpm, corresponding to a rated power of around 5.3 MW. The three-nozzle turbine is supplied through a DN 400 pipeline, while the generator, directly coupled to the turbine, delivers power to a 6.3 kV grid, operating in parallel and meeting standard synchronization criteria (frequency, voltage, and phase angle).

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System components:

1. Vertical Pelton turbine
2. Turbine housing with distribution manifold
3. Control nozzle with deflector
4. Synchronous generator
5. Inlet pipe
6. Support pipe
7. Support structure
8. Pipe section
9. Gland-type expansion joint
10. Guiding support,
11. Supply pipe
12. Ball valve DN400, PN100
13. Hydraulic power unit.

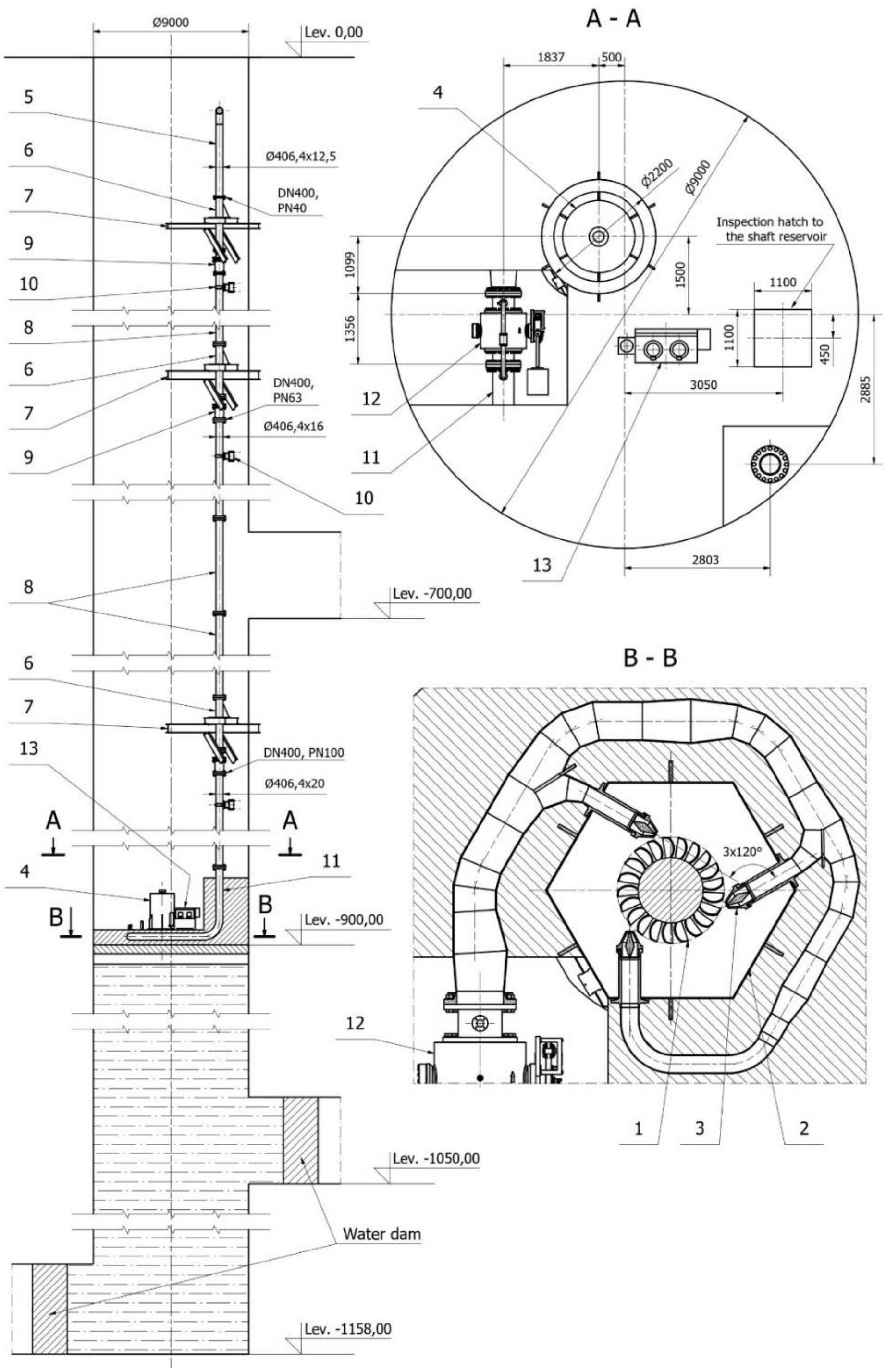

Fig. 1. System of the hydro turbine and generator with the shaft reservoir

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Key hydraulic and mechanical components

Pelton turbine runner

The Pelton turbine runner (fig. 2) used in the designed pumped-storage power plant constitutes the main component of the system responsible for converting hydraulic energy into mechanical energy. In the proposed solution, it has the form of a vertical wheel mounted on a shaft, which is directly coupled to a 6.3 kV synchronous generator. The runner diameter and the number of buckets were selected according to the design parameters—head of approximately 900 meters and flow rate of 0.71 m^3/s—in compliance with the characteristics of the Pelton turbine type PV3i-790/160.

The buckets, which are the actual working elements of the runner, have the shape of deep cups resembling two joined hemispheres separated by a central splitter ridge.

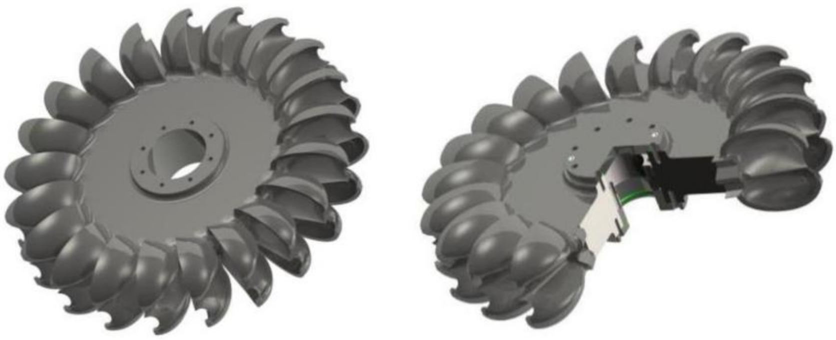

Fig. 2. Pelton turbine runner

Synchronous generator

The synchronous generator is directly coupled to a vertical Pelton turbine and operates at 6.3 kV and 1500 rpm (four-pole, 50 Hz). Its rated power slightly exceeds turbine rated power (approximately 5.3 MW), with a safety margin for stable operation. Cooling is provided by an IC81W forced-air system with water-cooled heat exchangers. Excitation is controlled by an AVR system with rectifier and rotor supply, ensuring voltage regulation, reactive power control, excitation-loss protection, and oscillation damping via a PSS. The generator is protected by comprehensive electrical and mechanical monitoring systems and is fully integrated into the plant's central automation system for remote control and grid-responsive operation.

Annular supply manifold for the turbines

The annular supply manifold is a key component of the Pelton turbine inlet system, evenly distributing high-pressure water from the DN400 penstock to three nozzles spaced 120°, ensuring uniform pressure, balanced runner loading, and minimized vibrations.

Made of high-strength steel, connected to the penstock via a spherical valve and to the nozzles through outlet flanges, it has a large cross-section and smooth geometry that reduce hydraulic losses and pressure fluctuations. Operating at about 8.4 MPa, it maintains even pressure, mitigates water hammer, supports turbine control, and also serves as a structural element protected against corrosion.

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Fig. 31. Cross-section of the casing with a view of the turbine supply manifold

Regulating nozzles and deflectors

The control system includes:

- three needle-type regulating nozzles,
- hydraulically actuated jet deflectors,
- 12-MPa hydraulic power unit.

Deflectors guarantee instantaneous power reduction without generating water hammer in the penstock.

Fig. 4. Needle-type regulating nozzle

Fig. 5. Jet deflector

Fig. 6. Hydraulic power unit

Penstock

The 900-m vertical penstock is divided into three pressure zones with increasing wall thickness:

Depth range	Pressure rating	Wall thickness
0.0 m to –326.5 m	PN 40 bar	12.5 mm
–326.5 m to –570.0 m	PN 63 bar	16 mm
–570.0 m to –900.0 m	PN 100 bar	20 mm

Additional elements include:

- support structures every ~80 m,
- guide supports ensuring radial stability,
- axial expansion compensators (±150 mm),
- welded pipe sections compliant with PN-EN 1092-1.

Hydraulic analyses show:

- temperature variations have minimal influence on pressure losses,
- internal roughness strongly affects net head – deterioration from 0.05 mm to 5 mm increases losses by >1.5 MPa,
- maintaining smooth internal surfaces is essential for long-term performance.

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<u>Technical service platforms and shaft infrastructure</u>

Two levels of technical service platforms installed in the shaft at the −900 m level.

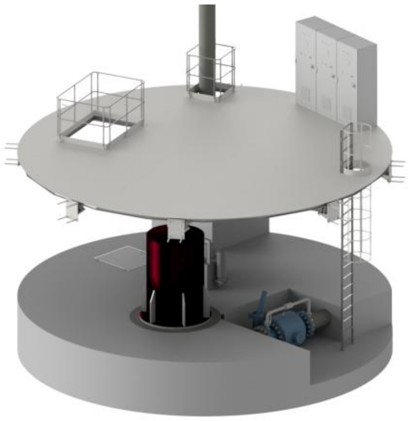

Fig. 7. Lower and upper levels of service platforms installed in the shaft

The upper platform includes:

- access for personnel and equipment,
- control cabinets,
- safety barriers and vertical ladder.

The lower platform originally planned as steel but replaced by reinforced concrete, which provides superior vibration damping, increases structural rigidity and lifetime, facilitates integration of auxiliary systems and improves alignment stability of the turbine-generator set.

<u>Shaft reservoir</u>

The lower reservoir of the pumped-storage power plant will be constructed in an abandoned mine shaft (approximately 9 m diameter and 1158 m depth) as the main water storage element, operating cyclically in generation and pumping modes. During generation, water descends from the upper reservoir through the DN400 penstock to the Pelton turbine and, after energy release, is received by the shaft reservoir; it must safely accommodate the entire working discharge ($Q \approx 0.71$ m³/s), maintain a stable water level in the inlet/outlet zone, and provide conditions that limit air entrainment and cavitation in the short turbine tailrace.

Using the existing shaft reduces civil works and provides a large natural hydrostatic head. Preparations include lining inspection and reinforcement, internal protective/sealing coatings (epoxy or membrane), installation of hydraulic connections (manifolds, valves), construction of water dams isolating unused workings, and structural/hydraulic monitoring. The reservoir must maintain water levels, prevent cavitation/air entrainment, ensure pump supply, and accommodate hydraulic transients.

Water pumping system from the lower reservoir

The pumped-storage power plant system installed in the shaft of the Budryk coal mine uses the existing main drainage infrastructure to transport water from the lower to the upper reservoir. A key component is the pumping station at the 700 m level, equipped with five pumps with a capacity of 315 m³/h each, operating in conjunction with two water reservoirs of different salinity levels. Water is discharged to the surface through two Ø350 mm pipelines routed via two successive shafts.

The lower reservoir is isolated from the underground workings by water-tight dams at the 1158 m and 1050 m levels, and pumping is carried out in a three-stage cascade: 1158 → 1050 m, 1050 → 700 m, and 700 m → surface.

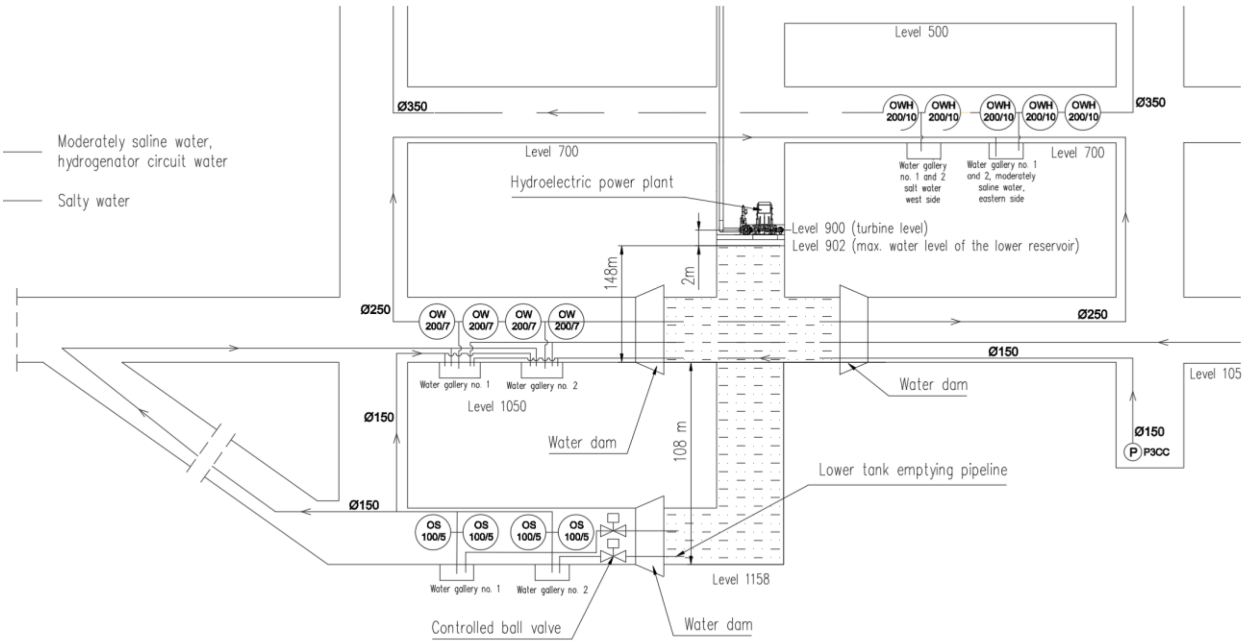

Fig. 8. Schematic diagram of pumping water from the lower reservoir

Upper reservoir

The upper reservoir is a key component of a pumped-storage power plant, serving as a storage facility for potential energy. During periods of surplus electrical energy in the system, water is pumped from the lower reservoir into the upper reservoir. During periods of increased power demand, energy is recovered through turbines, into which water flows under gravity.

The reservoir has been partially excavated into the ground, to a maximum depth of 1.1 m. The bottom of the reservoir slopes eastwards, towards the water intake. In the sections of the reservoir situated above ground level, the reservoir is surrounded by an embankment, with the crest located at an elevation of 2.9 m. The slope of the service ramps, providing maintenance personnel access to the reservoir basin, must not exceed 10°.

The project confirms the technical feasibility of using a mining shaft as a lower water reservoir integrated with an electrical power-generation unit. **The HESS project** demonstrates an innovative and scalable approach to repurposing mining infrastructure for energy transition needs.

The work resulted in deliverable ***D.3.1. The pumped storage systems in mine shafts***

We invite you to explore more details of the work on the HESS project website https://itpe.pl/en/hess/

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