HYDROPOWER | WATER MANAGEMENT | ENVIRONMENTAL PROTECTION | INLAND NAVIGATION | ENERGY RECOVERY

ENERGETYKA WODNA

10 years

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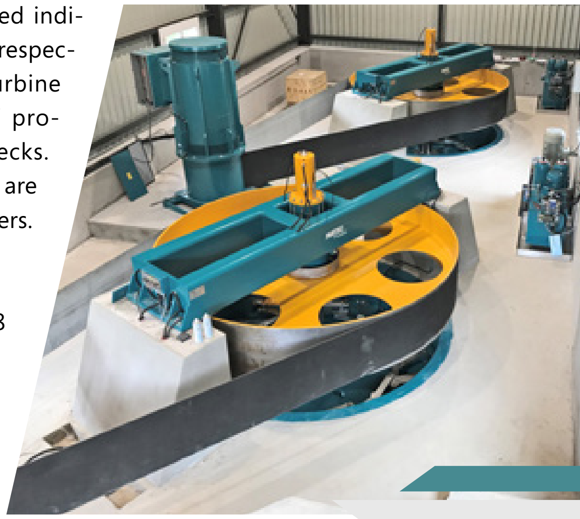
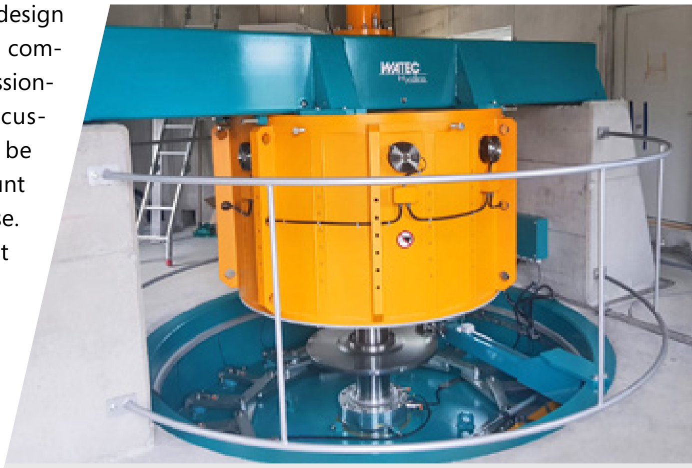
TRMEW

Competent with company **WATEC-Hydro** into the year 2023

Dear readers and friends of hydropower, we look forward to welcoming the year 2023 together with you.





Hydropower – energy for our future

Hydropower is viewed the cleanest and safest of all energy sources. Nevertheless, the generation of regenerative energy by hydropower can still be considerably expanded both at home and abroad. This can be done both by building new hydropower plants and by modernizing and increasing the output of existing plants. We offer electricity production that is ecologically compatible without CO_2 emissions and without the consumption of fossil fuels. The longevity of our plants also guarantees a long-term environmentally friendly and sustainable power generation.

Insight

WATEC-Hydro manufactures modern vertical-axis Kaplan turbines with runner diameters from 0.4 m to 2.50 m for the customer and offers comprehensive know-how for the successful implementation of a wide range of hydropower projects. Thanks to the support of many employees, fitters and external processors, the company made a successful start from 2002 onwards. Together, the company has succeeded in realizing over 320 turbine projects all over Europe in the last 20 years.

In this context, four different variants of a Kaplan turbine were installed:

- KDP Kaplan turbine, double regulated with permanent magnet synchronous generator,
- KSDP Kaplan spiral turbine, double-regulated with permanently excited synchronous generator and full spiral,
- KDD Kaplan turbine, double-regulated with direct-coupled V1 generator,
- KDR Kaplan turbine, double governed with belt drive.

In addition to the new construction of small hydropower plants in the power range from 10 kW to 1,000 kW, WATEC-Hydro has also specialized in the conversion and modernization of hydropower plants. WATEC-Hydro has got the knowledge and experience to provide manufacturing of formwork construction, steel hydraulic engineering as well as control and regulation technology. For the customer / client remains the whole variety of support within one company.

Production on site

The turbines are manufactured to order. This means that each turbine is produced individually and custom-made for the respective location. In this process, a turbine passes through various stages of production with constant quality checks. Installed materials and components are selected mainly from German suppliers.

WATEC company structure

WATEC-Hydro employs a total of 18 skilled workers in Heimertingen such as external fitters and design engineers. Sales for European-speaking countries are handled directly from Heimertingen. With this staff, the entire process is handled, from ordering and design to logistics, assembly and completion, including commissioning. A wide variety of customer requirements can be explicitly taken into account during the planning phase. A comprehensive insight into the processes can be taken from the newly designed website www.watec-hydro.de.

If you are interested or have any questions, please contact WATEC-Hydro directly at **info@watec-hydro.de** or **+49(0)8335-989339-0**

www.watec-hydro.de

From The Editorial Office

The topic of pumped storage power plants in Poland is getting louder and louder. Even the mainstream media are already writing about the renaissance of this energy storage technology and late last year we witnessed two important events, which we write about in the News.

The first was the presentation by the Ministry of Climate and Environment of a special act draft on the preparation and implementation of investments in pumped storage power plants. Granting these projects the status of public purpose investments is expected to ensure faster implementation and thus improve energy security by significantly increasing the energy storage capacity of the Polish electricity system. This state of affairs should generally be a cause for great satisfaction, but one should not forget the overly large spoon of tar in this barrel of honey. In Poland, the issue of pumped storage power plants has been meticulously neglected for decades, leading to the fact that the knowledge of designing such facilities has become almost forgotten. Whole decades of delays are impossible to catch up with, which may now be hiccuping us, especially given the pace of change in the national energy mix. Let's hope that the special act will increase the pace of new investments enough to prevent more serious problems in balancing the power system.

The second important information concerns the signing of a cooperation agreement on the construction of "Młoty" PSH plant between PGE Polska Grupa Energetyczna and the National Fund for Environmental Protection and Water Management. Currently, a feasibility study is being prepared to resume the construction of this power plant. Its results and further decisions on "Młoty" PSH plant can be expected in June, while according to the schedule, the investment is planned to be completed in 2030.

On the following pages of this issue, we remain on the topic of energy storage thanks to M.Eng. Ewelina Bogacka, project group coordinator at Instytut OZE, who summarizes the October training trip to PSP Nant de Drance, organized by our editorial team. For my part, I would like to add that the interest in the visited power plant, as well as other facilities of this type, pleasantly surprised us, and we are planning another training trip to a selected facility in Europe this year. If you would be interested in participating, you are cordially invited to contact our editorial office.

Another topic on energy storage relates to the idea of using the excavation and heap resulting from the exploitation of a lignite deposit, for the Turów thermal power plant. The possibility of constructing a pumped storage power plant as part of the reclamation works planned for the future and the possible parameters to be achieved are analyzed by PhD Leszek Opyrchal and PhD Aleksandra Bąk. The implementation of such a project on a brownfield site will entail numerous engineering challenges, but nevertheless having an energy storage facility in Poland with a substantial capacity of nearly 140 GWh stimulates the imagination.

Finally, I would like to announce an article in which Eddie Rich, director general of the International Hydropower Association, dissects the most important myths and misunderstandings about hydropower that the organization encounters on a daily basis. Disinformation and the spread of myths about the environmentally harmful role of hydropower and technical development of rivers is a phenomenon present also in the Polish media. Aware of the lack of reliability and bias in the transmission of information to the public about hydropower and motivated by the approval of industry representatives, we decided to give this article the rank of the issue's topic.

I wish you a pleasant reading!

Michał Kubecki
Editor-in-Chief

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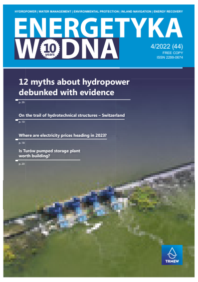

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Editorial office:
Michał Kubecki – Editor in Chief
Michał Lis – Managing Editor
Aleksandra Wołowiec – Editor
Dominika Wójtowicz – Editor
redakcja@energetyka-wodna.pl
mobile: +48 518 304 194

Subscription and advertising:
Monika Grzybek
biuro@energetyka-wodna.pl

DTP:
Gustaw Nowak
grafika@energetyka-wodna.pl

Printing house:
Agencja Wydawnicza „ARGI"
ul. Żegiestowska 11
50-542 Wrocław

Program council:
Wojciech Majewski
Janusz Steller
Bogusław Puchowski
Ewa Malicka
Radosław Koropis
Robert Szlęzak
Andrzej Grześ
Małgorzata Stolarska
Michał Krzyszkowski

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Publisher:
Polish Association for Small Hydropower Development (TRMEW)
ul. Królowej Jadwigi 1
86-300 Grudziądz
phone: +48 (56) 46 49 644
e-mail: biuro@trmew.pl
www.trmew.pl

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Special Act for pumped storage hydropower plants

The Ministry of Climate and Environment has presented a draft law on the preparation and implementation of investments in pumped storage hydropower plants. Granting them the status of a public purpose investment is expected to ensure faster implementation and thus improve energy security by significantly increasing energy storage capacity in the Polish electric power system.

Explaining the need for new regulations for pumped storage hydropower (PSHs), the Ministry of Climate and Environment stresses that, despite the many advantages of pumped storage hydropower plants in the context of stabilizing the electricity system and the dynamic development of RES and distributed generation in Poland, no new power plant of this type has been built for many years (we have had 6 such facilities in the country for many years with a total capacity of 1765 MW). New regulations and the granting of special status to investments in PSHs are expected to help change this state of affairs.

The catalog of public purposes contained in the Real Estate Law does not include the construction and maintenance of an PSH. Thus, under the current state of the law, the construction of an PSH is not a public purpose - unlike the transmission or distribution of electricity. The new legislation is expected to change this.

A barrier, the climate ministry points out, resulting from the multi-phase and size of PSH investments, is a series of restrictions and administrative requirements contained in various legal acts, which lead to a significant lengthening of the investment process. These include the need to obtain a decision on environmental conditions, a water consent, a decision on approval of a geological works project and geological documentation, and a construction permit. The new regulations are expected to result in the integration of these proceedings.

The draft law prepared by the Ministry of Climate and Environment also provides for:

- introducing a new definition of a pumped storage hydropower plant;
- confirm the regulatory exemption of electricity storage tariffs;
- abolition of double billing of network charges – electricity tariffs in settlements with storage facilities for services rendered (transmission or distribution) provide for deduction from the energy consumed by the storage facility from the grid of the power utility of electricity injected into the grid of the utility from the storage facility, based on the indications of metering and billing systems;
- making the obligation to obtain a license/registration dependent on the total installed capacity of the electricity storage facility, regardless of its capacity;
- obligation to register (OSD/OSP) a storage facility with a total installed capacity of more than 50 kW;
- obligation to license warehouses with a total installed capacity of more than 10 MW;
- exemption from half of the fee for connection of a storage facility to the grid with simultaneous regulation in transitional provisions of pending matters (submission of an application for determination of connection conditions, payment of an advance);
- introducing the possibility of drawing energy from the grid by a storage facility that is part of the RES without losing rights to certificates and entitlements under other support schemes;
- introducing RES source metering obligations and making certificate rights and entitlements under other support schemes conditional on proper storage metering;
- exemption from the obligation to present certificates of origin for cancellation, including from RES, cogeneration and energy efficiency certificates, of energy taken from the grid by the storage facility for the portion that was subsequently fed into the grid after storage;
- exemption from the transition charge, capacity charge, and co-generation charge (in the part of electricity consumption for storage) of electricity storage;
- amending the definition of final buyer, which excludes from excise duty the purchase of energy by a storage licensee.

The draft law on Nov. 3, 2022 was sent for public consultation.

GRAMWZIELONE.PL

Editorial office
gramwzielone.pl

Agreement on cooperation in the construction of "Młoty" PSH plant signed

PGE Polska Grupa Energetyczna and the National Fund for Environmental Protection and Water Management will cooperate on the "Młoty" Pumped Storage Hydropower Plant project. Implementation of the "Młoty" PSH project will support the national energy transition and ensure the future stability of the National Power System's (NPS) operation.

Pumped storage hydropower plants are the only large-scale energy storage technology to date. In the past four years alone, Poland's installed renewable energy capacity has increased from 8.7 GW in 2018 to 20.3 GW in 2022. Therefore, the implementation of the „Młoty" PSH project will not only support the national energy transition, but is also crucial to maintaining the stability of the National Power System's operation in southern Poland - says Wojciech Dąbrowski, CEO of PGE Polska Grupa Energetyczna - PGE is the leader in hydropower in Poland. Our share in the domestic market for pumped storage power plants is about 90 percent. Therefore, we want to use our experience and develop this technology in cooperation with the National Fund for Environmental Protection and Water Management in the construction of "Młoty" PSH plant. – Wojciech Dąbrowski adds. – Power from renewable energy sources in the National Electricity System is growing rapidly, but unfortunately the storage capacity is not. Power plants are still one of the best large-scale energy storage facilities, and we need them not only to develop RES, but also because they support Poland's energy security in emergency situations. The potential of energy storage facilities makes it possible to accumulate energy from renewable sources and, in a very short time, launch a large energy resource to meet the demand for electricity," says Dr. Przemysław Ligenza, CEO of the National Fund for Environmental Protection and Water Management. - The implementation of the PGE project will allow the use of modern yet uncomplicated technologies and long-term, fully "green" energy production. The project also has an important socio-economic dimension - as a result of its implementation, it will be possible to save on coal consumption for energy needs, stimulate the local labor market and increase the investment attractiveness of the municipality," adds CEO Ligenza.

The "Młoty" Pumped Storage Hydropower Plant, with a planned total capacity of more than 750 MW, is the most advanced PSH construction project in Poland. The project is based on mining work begun in the 1970s, which was suspended in the early 1980s. Completion of this investment was considered by local authorities in the second decade of the 21st century, as a result of which the investment was included in the Study of Conditions and Directions of Spatial Development of the town and municipality of Bystrzyca Klodzka from 2013 (updated in 2018 and amended in 2020), the Development Strategy of the Lower Silesian Voivodeship 2020, as well as the Spatial Development Plan of the Lower Silesian Voivodeship. As part of the investment, two water reservoirs are to be created, which, thanks to their specific functioning, would additionally perform flood control functions in the Bystrzyca Klodzka municipality. The power plant will be connected to the NPS by a 400 kV high-voltage power line, increasing the energy security of the region. Technical analyses carried out by the PGE Group show the possibility of continuing the work and implementing this project. In August this year, a feasibility study was launched for the resumption of the construction of a pumped storage power plant in Młoty. Its purpose is to obtain information on the work to be done to continue the investment, a detailed technical concept for the power plant, as well as the total investment outlay.

The results of the study and further decisions in the Project are expected in June 2023. The results received will be key information for taking the next steps towards the implementation of the construction of the "Młoty" PSH plant. According to the schedule, the project is scheduled for completion in 2030. The "Młoty" PSH project is part of the task of Order No. 351 of the Prime Minister of December 28, 2021, on the establishment of an Expert Team for the Construction of Pumped Storage Hydropower Plants. The team aims to develop solutions to foster the development of new energy storage facilities, through regulatory and technical support.

Press office
PGE Group

Calendar

27–28.02.2023 Warsaw, Poland	**23th POWERPOL Energy and Heating Congress** Organizer – European Business Center	www.powerpol.pl
8–9.03.2023 Kielce, Poland	**25th International Power Industry and Renewable Sources of Energy Fair ENEX and 23rd Environmental Protection and Waste Management Expo EKOTECH** Organizer – Targi Kielce	www.targikielce.pl
16–17.03.2023 Warsaw, Poland	**Polish Climate Congress 2023** Organizer – European Foundation for Sustainable Investment	www.polskikongresklimatyczny.pl
30–31.03.2023 Salzburg, Austria	**RENEXPO INTERHYDRO Hydropower trade fair** Organizer – Messezentrum Salzburg GmbH	www.renexpo-interhydro.eu
13–14.04.2023 Warsaw, Poland	**37th Energy Conference EuroPOWER & 7th OZE POWER** Organizer – MMC Polska	www.konferencjaeuropower.pl
16–18.05.2023 Poznan, Poland	**International Renewable Energy Fair GreenPOWER 2023** Organizer – MTP Group	www.greenpower.mtp.pl

News of the Polish Committee of Large Dams POLCOLD

A year has recently passed since the day when the Polish Committee of Large Dams – POLCOLD returned to life and membership in the International Commission of Large Dams (CIGB – ICOLD). During this time, POLCOLD's activities have focused on renewing contacts with ICOLD authorities, heads of technical committees, as well as the presidium of EuCOLD – ICOLD's European club.

Over the past several months, POLCOLD has established representatives on ICOLD's technical committees. Already, Poland has representatives in the committees on Dam Safety, Levees Technical Committee, Historical Water Structure Water Heritage, Young Engineers and soon more POLCOLD representatives will join the Tailings Dams & Waste Lagoons Committee. As another activity, we foresee the establishment of a team of Polish experts ready to act in the new EU hydropower program ETIP HYDROPOWER (2022–2025), which will be led by EuCOLD. The project has a budget of about EUR 1 million and will run for the next 3 years. The main objectives are:

1. to launch a financially stable organization to support and represent hydropower and dams in the European Union,
2. to communicate, disseminate and present hydropower as part of the SET Plan (Strategic Energy Technology Plan – a committee of representatives of member countries planning an energy system for the EU),
3. to facilitate direct implementation of research results and strategic activities by promoting and supporting cooperation in industry.

Those interested in cooperation are welcome to do so. Also not to be missed is the news of the attacks on dams in Ukraine. Let's remember that people are dying there not only from bullets and bombs, but also as a result of catastrophic damage caused by flooding of areas below the damaged hydropower structure. The problem of war damage to the economy and hydropower will be of particular concern to ICOLD and the national committees. Let's hope that 2023 year will bring good news from the East, and a time of proper development for Polish hydrotechnics.

Piotr Śliwiński
President
Polish Committee of Large Dams POLCOLD
ul. Podleśna 61, e-mail: piotr.sliwinski@imgw.pl
mob.: (+48) 781 774 107

Przeworno reservoir renovation completed

The renovation of Przeworno reservoir in Lower Silesia has been completed. The investment by State Water Holding Polish Waters Department in Wroclaw was carried out in two stages. The facility was readapted for permanent water damming. Its retention and effectiveness in counteracting the effects of drought in an area of 162 km² increased. In addition, flood protection in the municipalities of Przeworno and Strzelin improved.

As part of the renovation, the ground under the block of discharge facilities was reinforced, reinforced concrete structures were constructed, and the existing structures were reinforced with a reinforced concrete jacket. The dam was sealed with an anti-filtration screen and an outflow channel. Maintenance was carried out and bolt chambers were reconstructed, and a working platform and a lifting and cleaning mechanism were installed to operate the bottom discharge grates. The control and measurement networks and the ventilation system of the bolt chamber are new. Gradual filling of the water reservoir to an appropriate level of damming is currently underway (the rate depends on the level of rainfall in the Krynka River valley). The maximum volume of the 81-hectare facility is 851,000 m³. There is a fish ladder in the body of the front dam. The renovation of Przeworno reservoir began at the turn of 2018/2019, with the first stage completed in autumn 2020. Its most important element was the sealing of the dam with a vertical anti-filtration screen along a 500-meter section. It prevents water from seeping through the ground. The work for about PLN 4.5 million was carried out by Keller Poland. The second stage included the repair of the tower and other works to restore the reservoir's retention capacity. The work was carried out from spring 2021 to autumn 2022. The task was carried out by HZbud for nearly PLN 8.9 million. Technical acceptance took place on December 9. The front dam of the Przeworno reservoir on the Krynka River was put into operation in 2006. Already in the first years there was a problem with waterlogging of the forebay and significant filtration through the subsoil of the structure. Despite the renovation in 2009, it was impossible to maintain permanent retention.

Wojciech Kwinta
inzynieria.com

Plan to build a reservoir on the Czarna Woda river resumed

The earliest construction of the Kątki flood control reservoir in the municipality of Marcinowice in Lower Silesia will begin in 2024. In the near future, State Water Holding Polish Waters intends to resume design work, starting with an update of the decision on environmental conditions, which, as reported, has expired due to the implementation of other urgent tasks.

The task "Czarna Woda - Kątki reservoir, Marcinowice municipality" is included in the Program of Planned Investments of the State Water Holding Polish Waters. It involves the construction of a dry flood control reservoir on the Czarna Woda at km 37+700. The realization of this idea, the communiqué reads, will make it possible to secure the valley of the Czarna Woda over a length of 35 km, up to the mouth of the Bystrzyca River. The maximum damming level at the control flow will cover a flooded area of 55 hectares. Polish Waters also reported that the construction of the reservoir has additionally been recommended for the long-term program "Management of Water Resources in Poland" for 2023-2031. A dry reservoir on the Czarna Woda is necessary due to the fact that flash floods often occur in the area during the summer seasons. The polder is intended to protect villages such as Kątki, Zebrzydów, Szczepanów and Strzelce. An update of decisions and agreements is expected in 2023, and construction work is expected to begin in 2024. It says that given the urgent need to strengthen the protection of the residents of this municipality, their property and local infrastructure, it is necessary to resume design work starting with an update of the environmental decision.

Łukasz Madej
inzynieria.com

TRMEW news

Another year spent together is behind us. We feel immense gratitude for your support, not only financially, but also substantive assistance in the creation of various positions and proposals for changes in legislative documents. We have a growing sense of agency and awareness that our opinion meets with the recognition of those in power. And what happened in the last quarter?

Let's start with the issue of ending the support system for hundreds of hydropower plants. The moment we so feared, through high electricity prices on the market, turned out to be very kind to us. However, we still need to keep our hand in, we continue to push for the introduction of operating support for power plants without a support system, which will compensate for the costs of running the business and ensure a stable future for the power plants. Modernization legislation is also getting closer to enactment. In the last days of December 2022, another version of the draft amendment to the RES Act regulating these issues was released.

At the end of September 2022. Ewa Malicka attended a meeting at the Ministry of Development and Technology on the direct line. One of the project's main features is the exemption of distribution-related fees in exchange for a so-called solidarity fee. However, the project is controversial, and it is difficult to say what solution will eventually be implemented. Quite late, on November 4, 2022, the Decree of the Minister of Climate and Environment dated October 31, 2022 on the reference price of electricity from renewable energy sources and the periods applicable to generators who won the auctions in a given year was published in the Journal of Laws of the Republic of Poland (Dz. U. 2022 poz. 2247).
Prices for hydropower plants are:

- for installations with a total installed electric capacity less than 500 kW – PLN 770/MWh;
- for installations with a total installed electrical capacity not less than 500 kW and not more than 1 MW – PLN 705/MWh;
- for installations with a total installed electrical capacity greater than 1 MW – PLN 675/MWh.

Meanwhile, TRMEW's 7th Hydro-Forum was held in early December 2022. Conference speeches focused on changes in the electricity market in the short and long term. There was also a debate with the participation of invited guests representing the Lewiatan Confederation, Dentons, BNP Bank Poland, and the TRMEW Board of Directors. The second day of the meeting was entirely devoted to visiting the hydroelectric power plants in Starogard Gdański and Kolincz.

We would like to thank you for participating in the event, both our speakers, power plant owners for making their facilities available to visitors and our guests! In 2023, our Association will celebrate a remarkable 35th anniversary. I believe that together we will celebrate TRMEW's birthday already in June!

Once again, I would like to sincerely thank all our members for their support and good word. We are happy that there are more and more of you. See you around!

Monika Grzybek
TRMEW office manager

Myczkowski reservoir restocked

PGE Energia Odnawialna, has conducted stocking of Lake Myczkowskie. The reservoir, located near the Solina Pumped Storage Hydropower Plant, received 150 kg of brook trout. This is another action this year organized by the company, in addition to the energy facilities it owns, to restore the population of various fish species.

The two-year-old fish were reared at the Polish Angling Association's Fish Stocking Center in Folusza. They were transported to the site by a specialized vehicle equipped with a pool with a water aeration system and a so-called "sleeve" for directly dropping the fish into the water. – PGE Energia Odnawialna has long been involved in restocking campaigns. This year, for the first time, we decided to carry out such an action on Lake Myczkowskie. By doing so, we can help restore the trout population, and thus contribute to the growth of natural diversity and the improvement of the entire aquatic ecosystem", says Krzysztof Majcher, director of the ZEW Solina-Myczkowce Branch.

Importantly, as part of its efforts to support the brook trout population, PGE Renewable Energy was also involved in the restoration of historic spawning grounds on the San River. This was necessary because this process could not take place naturally. The San is a river baffled by dams, which means that the water is unable to move the stones and gravel that make up the spawning grounds on its own. Therefore, in order for the fish to spawn freely, it was necessary to apply dozens of kilograms of construction material. Restocking of Lake Myczkowskie is another such action organized by PGE Energia Odnawialna in 2022. At the end of October, thanks to the company's involvement, half a ton of fish of three species, i.e. tench, carp and common carp, were delivered to Lake Raduszeckie and Lake Dychowskie.

Lake Myczkowieckie, with an area of 200 hectares, is an artificial reservoir created by damming up the waters of the San River. It serves as a daily equalization tank for the Solina Pumped Storage Hydropower Plant.

Press office
PGE EO

From Around the World

31.10.2022 Eesti Energia has received €584,950 in funding for development of Estonia's first pumped storage project

The joint agency of EAS and KredEx approved the funds to help prepare construction of the 255 MW facility at the Ida-Virumaa mine site. Plans for the project are moving at a good pace, Eesti Energia said, with the preliminary environmental assessment of the site expected to be complete in early 2023. According to plans, the project's upper reservoir will be built on a tailings structure, and a closed mine will be used as the lower reservoir. The project is expected to start operating in 2026.

02.11.2022 Ukrainian hydrotechnical facilities damaged as a result of rocket attacks

Rockets reportedly hit hydropower plants, electric substations and heat generation plants, with the Ministry of Defence in Russia confirming that it had targeted energy systems. Power and water supplies in Ukraine were affected following the attacks, the energy minister said, while urging residents of unaffected areas to reduce electricity use where possible to help restore power to blacked out areas. According to elektrovesti.net, the hydro plants hit during the attacks include the Dnprovskyi facility and the Dniester dam and hydro plant.

08.11.2022 Conduit hydropower could add 1.41 GW of new hydropower in US, says report

A new report has suggested that there are potential opportunities in all 50 states in the US to generate hydropower from existing water infrastructure.

In a first-of-its-kind analysis, researchers at the US Department of Energy's Oak Ridge National Laboratory estimates that conduit hydropower, which uses water from structures such as water supply pipelines and irrigation canals, has the potential to add 1.41 GW of electricity to the country's power grid – enough to power more than a million homes.

The process for municipalities and other stakeholders to develop conduit hydropower would be relatively easy. Without the need to build new dams, facility operators could install hydropower generators at locations with excess hydraulic head. This could be coordinated with planned facility upgrades that replace aging infrastructure with more energy-efficient systems. Rural communities may benefit by adding small hydropower generation to their existing infrastructure for net metering, making them less dependent on the external grid.

Since conduit hydropower taps into existing infrastructure with minimal environmental impacts, the permitting process has been streamlined. Through the Hydropower Regulatory Efficiency Act of 2013 and its amendments in America's Water Infrastructure Act of 2018, the federal regulatory approval process can be completed in 45 days. To date, more than 350 conduit hydropower projects have been permitted or constructed, with more to come.

09.11.2022 UK and Kenya agree to fast track dam project following COP27 meeting

During the COP27 climate summit, UK Prime Minister Rishi Sunak and Kenyan President H.E. William Ruto agreed to fast-track six green investment projects worth KES 500 billion, including the Grand High Falls Dam project.

The leaders agreed on the six projects which span green energy, agriculture and transport to accelerate the flow of climate finance into Kenya. These investments will become flagship projects of the UK-Kenya Strategic Partnership – an ambitious five-year agreement that is unlocking mutual benefits for the UK and Kenya. Grand High Falls includes a KES 425 billion investment. It will be a Public Private Partnership on the Tana River that will generate 1,000 MW of hydroelectric energy capacity and irrigation for 400,000 hectares of farmland. Led by UK engineering firm GBM, the project is envisaged to include both a Power Purchase Agreement for clean energy and a Water Purchase Agreement for agricultural irrigation.

22.11.2022 Hydropower could provide additional 1 GW of energy for UK says report

Hydropower can realistically provide an additional 1 GW of energy for the UK under the right policy framework within a quick timeline, according to a new report.

The Energy Informatics Group at the University of Birmingham was commissioned by the British Hydropower Association (BHA) to assess the future potential of hydropower in the UK. The report, which is released to coincide with the start of the BHA annual conference in Glasgow, concludes that hydropower can provide an additional 50% increase from its existing installed base of 2 GW. Lead author Dr Grant Wilson from University of Birmingham's School of Chemical Engineering, said: "This report provides evidence and data that makes it clear hydropower has had long-standing benefits to help decarbonise the UK's electrical system, and with the right policy support can continue to do so. "

The report brings together data from various sources of the installed capacity and location of hydropower installations in the UK and compares these against the values forecast in previous reports. This has been complemented by a survey of BHA members and invited non-BHA members to consider the appetite for further investment in hydropower and the hurdles faced by the sector.

23.11.2022 Yusufeli dam project inaugurated in Turkey

The 558 MW Yusufeli Dam project in Turkey's northern Artvin province was officially inaugurated yesterday by President Recep Tayyip Erdogan. The Yusufeli dam and hydroelectric power project is located on the Çoruh River, upstream of the Borçka, Muratli, and the Deriner hydroelectric power plants. The project comprises a 275 m tall double curvature concrete arch dam and a power plant equipped with three 186 MW vertical-axis Francis turbine units. Each turbine unit is designed to operate at a rated head of 191 m and a rated discharge of 107 m³/sec.

The Yusufeli Dam created a 33.63 km² reservoir area with a total storage capacity of approximately 2.2 billion cubic metres. The maximum crest elevation and the crest length of the dam are 715 m and 490 m respectively.

05.12.2022 Rio Tinto completes Kemano hydropower project

Rio Tinto has commissioned a second tunnel to carry water into the Kemano Powerhouse in British Columbia, Canada, marking completion of the 960 MW Kemano T2 hydropower project.

The new 16 km tunnel was filled up with water and produced its first megawatt of electricity in July 2022 after its construction was completed in May 2022. Both T1 and T2 are now operating together, ensuring the long-term reliability of the power supply for Rio Tinto's BC Works aluminium smelter in Kitimat and neighbouring communities. Rio Tinto estimates the project contributed approximately $850 million to the BC economy and employed approximately 340 people at its peak.

06.12.2022 European Commission approves funds for pumped storage project in Finland

The European Commission has approved, under EU State aid rules, a €26.3 million Finnish aid measure to support Suomen Energiavarasto Oy (SEVO) in the construction of an underground hydroelectric pumped storage facility. The measure will increase the share of renewables in Finland's electricity generation in line with the EU's European Green Deal objectives. At the same time, it will help reduce dependence on Russian fossil fuels and fast forward the green transition in line with the REPowerEU Plan. Finland notified the Commission of its plan to support SEVO, a subsidiary of EPV, in the conversion of a non-active mine located in Pyhäsalmi into a pumped hydroelectricity storage facility. The storage unit will participate in the electricity spot markets, as well as in electricity balancing markets.

The pumped storage facility will have a capacity of 75 MW and 530 MWh and is expected to generate between 60 and 160 GWh of clean electricity per year. The facility is envisaged to start operating by the end of 2025.

07.12.2022 Farahantsana hydroelectric plant inaugurated in Madagascar

Tozzi Green Hydro Madagascar has just completed the construction of its largest hydroelectric power plant to date - the 28 MW Farahantsana plant. Currently operational and connected to the interconnected grid of Antananarivo, the plant is located on the Ikopa River, in the rural municipality of Ambohimasina in the Itasy region. It is equipped with four Francis turbines with a capacity of 7 MW each. The Farahantsana plant draws 66 m³ of water per second from the Ikopa River on a nominal head of about 42 m and generates an annual output of 135 GWh of electricity, enough to cover the average consumption of about 65% of the population of Antananarivo. The development of the project started 10 years ago, with construction starting in 2018 with the collaboration of companies from Madagascar, Italy, and the Philippines.

13.12.2022 OMVS inaugurates Gouina hydroelectric dam in Mali

The Organization for the Development of the Senegal River (OMVS) has announced that inaugurated on 3 December its third hydroelectric dam – the 140 MW Gouina dam project, located in the district of Diamou. Constructed upstream from Kayes, work began on the run-of-river power plant back in November 2016. The project has already been supplying electricity for several months as it was connected to the electricity network of Mali, the Mauritania and Senegal last March.

The project, which follows on from the Manantali and Felou dams, was built by Chinese firm Sinohydro. More than 80% of the project was funded by Eximbank of China.


Photo. View on upper and lower reservoir of Nant de Drance PSP

On the trail of hydrotechnical structures – Switzerland

You have already had the opportunity to read about the Nant de Drance pumped storage plant (PSP) in the Quarterly as part of investment review. In this article, I will report on a training trip organised by "Energetyka Wodna" with designers and hydropower specialists who had the opportunity to tour the facility in question in October 2022, expanding their niche knowledge of PSP operation, design and construction.

As a reminder, the Nant de Drance PSP was commissioned after 14 years of construction in September 2022. In the implementation of the EUR 2.2 billion investment, state-of-the-art technology was used to achieve over 80% efficiency, one of the highest values for PSPs. What is also impressive is the scale of the facility, which stores 20 GWh and achieves an installed power of 900 MW, obtained from the operation of six turbo pumps. Numerous technical and organisational challenges were faced during implementation, making Nant de Drance an attractive training and tourism facility.

Purpose of the trip

Due to the energy transition and the increasing need for renewable energy storage, Poland is starting to enter a period of increased demand for storage facilities. Pumped storage plants, among others, are intended to be the solution. For Polish designers, this is a return after a break of more than 40 years to designing such distinctive buildings. The editors of "Energetyka Wodna", responding to the market demands, organised a training trip that provided us, hydropower designers and specialists, with an excellent opportunity to learn about out-of-the-box investments, design and implementation issues and practical ways of solving them. At the same time, it was a great opportunity to interact directly with people involved in the construction and operation of the plant and, in so doing, gain information on technological solutions and first-hand experience of this type of facility in the various sectors: hydrotechnical, control and measurement equipment and automation, construction, geological, electrical and power engineering.

Sightseeing and some interesting facts

The October visit to Nant de Drance began with a presentation of the construction process and the problems encountered at various stages of the construction work and their out-of-the-box solutions. I would like to present a few of them below:

- the location of the plant itself posed a challenge – the facility is located in a high mountainous area with varied terrain. Such geomorphology means extremely harsh conditions and presents many of the construction difficulties that had to be overcome when building the infrastructure for evacuating power from the plant directly on the slopes of the mountains.
- The project envisages the upwards extension of the existing dam by about 20 m,


Photo. Trip participants in the power house cavern (Nant de Drance PSP)

increasing the volume of the reservoir by as much as double, thereby raising the water level to an ordinate of 2225 m above sea level. The issue was complex in terms of both design and construction. The height of the existing dam had to be lowered beforehand to correct its shape, and then extend it upwards. The method of height reduction is interesting – initially explosives were used for this. However, this solution proved too problematic. Ultimately, the creativity of the engineers led them to the idea of creating a device that pulled off the individual layers of concrete from above in the same way asphalt is scraped off the road.

- The construction of a water intake on the lower reservoir was also innovative. For weather-related reasons, construction took place on the shore when the water level was low. It was then transported by barge to its final location after the water level in the reservoir rose to cover the structure.
- Altitude at which the plant is located is impressive, with the Emosson reservoir at 1,930 m above sea level and Vieux-Emosson 2,225 m above sea level. The 32 m x 52 m x 200 m plant chamber was built in the heart of an alpine mountain range at a depth of 600 m, using drilling and blasting techniques.

An indication of the size of the structure are the adits used for transport, which are a total of 17 kilometres long. There are picturesque views from the foot of the dam on the Vieux-Emosson reservoir, making the location of the NDD even more attractive as a tourist destination.

Presentation

After the tour of the PSH plant, our team was invited to a presentation by GE Hydro, which was the contractor for the electromechanical work. Thanks to the courtesy of the representatives, we had the unique opportunity to exchange engineering experiences, inquiring about the most intriguing details of the investment, such as how to operate and select variable-speed turbines, the use of which increases the efficiency of the power plant. We were able to obtain information not only regarding Nant de Drance, but also other projects of a contractor experienced in the field, such as Malta Oberstufe or Reisseck II in Austria. An example of another Swiss pumped storage plant, for which GE Hydro used four variable-speed turbo pumps with a total power of 1,000 MW, is the Limmern plant. Its construction took about seven years and cost 2 billion Swiss francs. It was commissioned at the end of 2016/17. The plant pumps water from Lake Limmern to Lake Mutt, which is located 630 metres higher, and then uses it to generate electricity on demand. In the case of PSH plant Limmern, the drop of 700 metres is particularly interesting. The gravity dam of the upper reservoir is the longest in Switzerland at 1,054 metres and the highest in Europe. After its construction, the volume of water storage increased from 9 to 23 million m³. The lake's original natural water level of 2,446 m above sea level has risen to a dammed water level of 2,474 m above sea level. GE Hydro is also contributing to the modernisation of the technological part of our Polish Porąbka-Żar pumped storage plant.

Conclusions

The training gave our project staff the opportunity to confront engineering challenges encountered during construction, lessons learned during design, operation and maintenance, the impact of climate change on hydropower plants construction processes, the interdependencies between hydropower and other RES technologies. Given the relevance of the issue of energy independence, participation in such events is particularly important for hydropower specialists. The knowledge gained provides valuable input for the designers on my team working on facilities in Poland similar in scale to the Nant de Drance PSP, in which we are involved. Thus, it is undeniable that offsite training at similar facilities organised by "Energetyka Wodna" will add great value to our daily work.

I would like to take this opportunity to express my appreciation and gratitude to the "Energetyka Wodna" team for a very professionally organised trip, perfected in every detail and for the invitation received to participate in the training. At the same time, we are grateful to Nant de Drance S.A. and GE Renewable for their incredible generosity in sharing their knowledge and experiences.

M.Eng. Ewelina Bogacka
Project group coordinator
Instytut OZE Sp. z o. o.

Photos come from the archive of **Instytut OZE Sp. z o.o.**

Reconditioning and modernisation of water turbine rotors

Exposure of water turbines to the weather and mechanical wear and tear cause surface irregularities to build up and thus reduce efficiency. Belzona composite materials recondition the damaged steel surface by extremely reducing the roughness coefficient and preserve it, protecting it from further damage.

The energy of the actual fluid in the flow is systematically dissipated, increasing the energy losses arising in hydraulic systems. Losses in the flow can arise locally or be linear. Linear losses are caused by molecular interaction forces between fluid molecules and wall surface molecules (impeller, steering wheel, pipeline, etc.) and between fluid molecules throughout the fluid volume (mass). Local losses, as the name suggests, arise at specific points, areas of the flow, such as the leading edge of a vane, an orifice, a valve, or are caused by an abrupt change in the shape of the duct. Clearly, flow losses are a significant contributor to the operating costs of hydraulic machinery.

Surface roughness

In water turbines, from a technical point of view, every material (steel, alloy steels, special alloys) from which the rotor and the guide vane are made has a rough surface. The surface roughness depends on the degree of manufacturing accuracy of the component, but even if one reduces the roughness and other irregularities at great expense, the surface roughness still increases with service life due to corrosion and mechanical wear, including cavitation erosion (photo 1). By determining the average height of the irregularities at various points on the duct surface as the roughness value, a certain value is obtained, which is referred to as absolute roughness in flow loss calculations (in the literature it is usually referred to by the symbol k and is expressed in mm). In new ducts, the value of this coefficient can vary between 0.02 and 0.1 mm, while for ducts after many years of operation, these values can reach up to 3 mm (corrosion, cavitation pits, caking, etc.). In practice, the more important value is the so-called relative roughness ε, i.e. value related to the cross-sectional area of the duct. The more turbulent the flow, the more important the duct roughness is. This regularity is expressed in the linear resistance coefficient λ and includes the type of fluid movement (Reynolds number) and the ductl surface roughness. As a guideline (to simplify calculations), the value of the energy loss in the flow over the length L can be calculated by assuming a duct with a circular cross-section of diameter D and applying the Darcy-Weisbach equation:

$$h_{str} = \lambda \frac{Lv^2}{D^2 g} \quad (1)$$

where:
h_{str} – energy loss value [m];
λ – linear resistance coefficient;
L – length [m];
v – average flow velocity [m/s];
D – diameter of circular cross-section [m];
g – acceleration due to gravity [m/s²].

For an arbitrary cross-section, the hydraulic radius R_h is most often used as the linear dimension characterising the cross-section according to the definition:

$$R_h = \frac{F}{O_{zw}} \quad (2)$$

where:
R_h – hydraulic radius [m];
F – cross-sectional area of the duct [m²];
O_{zw} – length of wetter perimeter [m].

Taking into account (2), equation (1) takes a more general form for a circular section *(R_h=D/4)*:

$$h_{str} = \lambda \frac{Lv^2}{4R_h 2g} \quad (3)$$

The calculation of the value of the linear resistance coefficient λ for any non-circular R_h enables the Colebrook-White equation to be used with a fairly high degree of accuracy:

$$\frac{1}{\lambda} = -2\lg\left(\frac{2.51}{Re\sqrt{\lambda}} + \frac{k}{3.71 \times 4R_h}\right) \quad (4)$$

where:
R_h – hydraulic radius (wetted) [m];
Re – Reynolds number;
k – roughness height [m].

Based on calculations, it can be shown that an increase of a few tens of percent in the deformation of the duct compared to a perfectly circular one results in an increase in the λ-value of a few percent. In view of the above, there will also be an increase in hstr line losses.

Reduction in surface roughness

Therefore, in order to reduce energy losses in the flow through the ducts of a hydraulic machine, taking into account the directly proportional influence of the λ factor, it is necessary, above all, to reduce the roughness of their internal surfaces and to ensure that this surface

Photo 1. Surface area of Kaplan turbine vanes after years of operation (River Oder)

Photo 2. Water turbine inlet with Belzona® 1341 coating

Photo 3. Reprofiling of rotor surfaces – filling of pits and irregularities with Belzona®1111 composite

Photo 5. Application of Belzona® 1341 coating

Photo 6. Water turbine rotor with Belzona ® 1341 coating

shows resistance to corrosion and erosion processes including cavitation erosion. A proven method is to coat the metal surfaces of the inlet duct, steering apparatus ducts and rotor with Belzona® 1341 composite coating (photo 2). The polymer layer of Belzona® 1341 is not only very smooth (roughness coefficient k=0.0078 mm), but is above all hydrophobic and practically unaffected by the corrosive processes to which steel surfaces are exposed (general corrosion, pitting, crevice, intergranular, biological corrosion, etc.).

The service life of Belzona® 1341 coatings under operating conditions in water turbines is estimated at 10–15 years. Taking into account the physicochemical properties of the surface of the composite coating and its effect on improving flow efficiency (reduction of hydraulic losses), it can be said that the coating of the channels of a water turbine is a kind of efficiency upgrade of the machine, as the effect of these measures will always be to reduce the expenditure of energy required to overcome the (mainly linear)

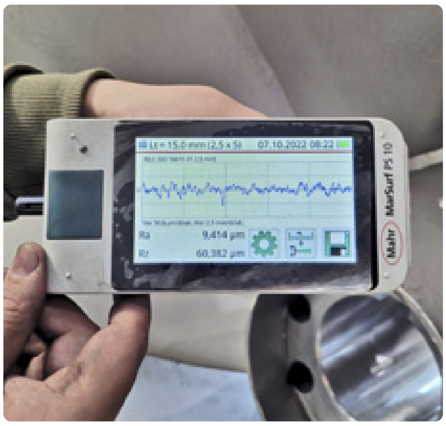


Photo 4. Surface roughness profile – measurement

resistance in the flow. Obviously, the coating reduces surface roughness, but it is also important that the surface is even, i.e. without indentations, offsets, cavities, perforations, etc., which appear especially in parts already in service and sometimes even in new castings or welded structures. When using polymer composite surface reconditioning methods, the levelling of any irregularities with paste composites such as Belzona® 1111 and Belzona® 1311 (ceramic R-metal) is applied prior to the application of the final coating of Belzona® 1341 (photo 3).

Steel reconditioning using composites

At a time when steel is very expensive and waiting times for new parts have increased dramatically, and given the more than 80% higher energy intensity of the process of making new parts compared to remanufacturing them, reconditioning with composites is not only becoming readily available, inexpensive, but is also a low-carbon method. The most applications confirming the above performance apply to centrifugal pumps of various designs and capacities, which were upgraded with Belzona® coatings between 1992 and 2022. Higher efficiency and durability confirmed by operation for at least 10 years applies to a huge number of pumps used in waterworks, power stations, chemical plants, nitrogen plants, refineries, mines and many other enterprises in Polish industry. Given the many similarities that exist in the operation of different types of hydraulic machinery, it seems natural to apply reconditioning using composites to the overhaul and modernisation of water turbines analogous to the methodology previously used in the repair and modernisation of pumps. Increasing the energy efficiency of the turbine and the longevity of its components, especially in terms of the impact of corrosion and cavitation erosion on its scope, were the reasons behind the decision to upgrade the Francis turbine rotor at Enerko Energy, a professional hydraulic machinery repair company. The rotor, with a diameter of ø1720 and a hub diameter of ø1027 and at a height of 950 mm, underwent a reconditioning and subsequent coating upgrade. Prior to application of the composites, the rotor surface was blasted to an optimum roughness of average 60-75 µm (photo 4). It guarantees good wetting of the surface with the polymer, a prerequisite for good adhesion. Corrosion pits, cavitation pits and macroscopic surface irregularities were filled and levelled with a paste composite, I.e. Belzona® 1111. Application of the Belzona® 1341 base coating to the rotor surfaces is carried out using a rigid brush (less frequently by spraying) and in a two-layer system (photo 5).

One day after completion of the coating, the rotor is ready for assembly and operation (photo 6). For the application in question, the rotor speed is 108 rpm at a flow rate of 10.5 m³/s in a turbine with a rated output of 288 kW. The hydropower plant, where the upgraded rotor was installed, has been in operation since 1930.

Roman Masek
Technical Director
Belse Sp. z o.o.

Photos come from the archive of **Belse Sp. z o.o.**

The need for a unified European hydropower voice

The new EU project ETIP Hydropower (September 2022 – August 2025) will closely link the EERA Joint Programme Hydropower to the new European Technology and Innovation Platform (ETIP) for hydropower. It succeeds the HYDROPOWER EUROPE project (2018–2022) which created a forum for more than 600 stakeholders representing all sectors.

A European Technology and Innovation Platform is a community whose primary purpose is to define Research & Innovation priorities for its sector. The secondary purpose is to overcome barriers to the deployment of R&I outcomes: e.g., industrial strategy, market opportunities, exploitation of research results, international cooperation, education, environmental and social impacts. A variety of ETIPs exist and they have the task to work together to contribute to the Net Zero Economy and help solve the energy crisis. The ETIP HYDROPOWER is managed by a consortium of six international organizations with the support of two communication agencies.

Helping to unify the voices of hydropower in Europe

There is a need for unified industry representation to be recognized at a European level. The HYDROPOWER EUROPE Forum provided a first opportunity to gather 650 stakeholders representing all the sectors of the value chain. Under ETIP HYDROPOWER, the hydropower forum will continue to grow and offers an ideal opportunity to help unify the voices of hydropower in Europe.

Facilitating Research Supporting Hydropower in Europe

Facilitating R&I actions and funding is of immediate interest and value to many hydropower industry organisations, helping them to overcome barriers in hydropower deployment. Hence a unified R&I focussed organization, where the hydropower industry could get rapid answers to urgent R&I questions through collaborative funding efforts, will be implemented by ETIP HYDROPOWER. It is not intended to duplicate existing funded research programmes, but rather, to facilitate European industry collaboration on priority issues not yet being funded, or not yet prioritised or funded enough. Hence this new unified R&I organization should complement and extend existing R&I actions. For instance, more innovation is needed for preserving biodiversity and improving river ecosystems by taking advantage of synergies within multi-purpose projects.

Implementing Strategic Actions Supporting Hydropower in Europe

There were 3160 NGOs amongst 11,800 organizations advocating their interest to European Union (EU) decision-makers and officials in 2019 generating 24,894 jobs and a budget larger than €3 billion/year. New hydropower deployment in Europe is often discussed as being very controversial. However, hydropower is the vital pilar of flexibility and storage within the new electricity system in the Net Zero Economy. ETIP HYDROPOWER will help in raising awareness and dispelling myths about hydropower in Europe. Hence, in the energy crisis, the task is to demonstrate how hydropower is contributing to the overarching priorities of European citizens: RePowerEU, Climate change adaptation, Green Deal, Circularity. Hydropower and the other renewable resources recently gained legal support from the European Parliament for accelerated permitting.

Personal commitment of all stakeholders in 2023

During a webinar on 25th January 2023, the vision of ETIP HYDROPOWER, its objectives, the suggested project structure and its foreseen work program were presented and discussed. This webinar is an introduction to a wider consultation process with the purpose of collecting stakeholders opinions on the services that the ETIP can provide to them and for proposals on working groups that the ETIP should implement. Any stakeholder can become a member of ETIP HYDROPOWER which entails being registered online, sharing the ETIP HYDROPOWER vision and mission and bringing a positive contribution to the ETIP. All members will be invited to participate to the first online General Assembly planned during the newly created 'HYDROPOWER DAY' which will be held in Brussels during the period 25-27th April, 2023. The members can then elect their representatives for the Governing Board of the ETIP HYDROPOWER. Any member can suggest the creation of a new working group with drafted terms of reference on any particular topic and submit it to the Governing Board. Members will be invited to join a WG when such a group is created.

In conclusion

ETIP HYDROPOWER will help to ensure that hydropower can play the vital role of a catalyst and enabler in the transition to a clean and safe energy system in Europe by being a reliable supplier in order to overcome the actual energy crisis as well as the achievement of climate neutrality by mid-century.

Acknowledgement

The HYDROPOWER EUROPE Forum and the ETIP HYDROPOWER are supported by a project, funded by the European Commission under Horizon Europe call HORIZON-CL5-2021-D3-02-15. Project partners are: International Commission on Large Dams (ICOLD), European Association for Storage of Energy (EASE), European Renewable Energies Federation (EREF), Association of European Renewable Energy Research Centres (EUREC), International Hydro-power Association (IHA), Samui France SARL (SAMUI), VGBE energy (vgbe) and ZABALA Brussels SPRL (ZABALA).

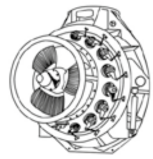
Jean-Jacques Fry
J-JFRY Consulting

Janire Garcia
Zabala Innovation

Mark Morris
Samui France

Anton J. Schleiss
Ecole polytechnique fédérale de Lausanne (EPFL)

Industry catalog



Water in technological processes

An increasing emphasis on environmental protection, resource conservation, as well as the current imperative of economic efficiency resulting from climate change are the most important challenges facing all industrial plants, translating into savings of goods, resources and capital.

The wastewater generated by industries and processes related to human activities is an indispensable aspect of water resource use. Wastewater is a by-product that is highly damaging to the environment, so proper treatment processes are essential to ensuring it does not pose a danger when returned to natural reservoirs.

Process water

Depending on the process, raw (untreated) water may contain, in addition to natural constituents, corrosion products or fine impurities from pipelines and installations. Visual assessment and chemical composition analysis make it possible to define the quality parameters of water used for all kinds of technological processes. This information enables assessment and selection of the most appropriate treatment methods.

Water treatment, i.e. the appropriate adjustment of physico-chemical properties to the requirements imposed by its intended use, involves determining the effectiveness of the removal of impurities present in the water and selecting the appropriate filtration equipment. In any process water circuit it is necessary over time to remove suspended solids caused by instrument corrosion and other factors. Continuous water filtration is required to reduce costs as much as possible. In order to meet growing demands for water and wastewater treatment, continuous improvement of these processes, based on a wealth of know-how and advanced technological solutions, is essential. This is where HYDAC Engineers can help. We have been supporting production plants and industrial wastewater treatment plants with sustainable, reliable solutions for 30 years on the Polish market (photo 1).

Photo 1. Process water filter, RF3-5 type, Q = 1500-2450 m³/hour

HYDAC group offer

HYDAC automatic self-cleaning filters with backwashing function are often chosen because of their smaller installation size, continuous filtration process even during backwashing, as well as low operating costs (no need to change filter cartridges, low energy consumption). An additional advantage is the durability of HYDAC devices, documented by many years of uninterrupted, efficient operation.

The circulating water filtration process extends the life of equipment and protects:

- heat exchangers,
- nozzles,
- valves,
- static seals,
- pumps,
- shaft seals

and many other components of industrial installations.

Automatic self-cleaning filters can also perform another important function - the treatment of sewage treated at wastewater treatment plants as a part of process water production (photo 2). Wastewater treatment plants need a large amount of water for washing and rinsing equipment with spray nozzles. The use of tap, i.e. potable water, is expensive as well as environmentally and economically unjustified. Hence the use of treated wastewater as an abundant and inexpensive source of water at each treatment plant.

The purpose of HYDAC self-cleaning filters at sewage treatment plants is to remove solids from treated sewage after it has passed through the secondary settling tanks, enabling it to be used for many on-site applications:

- in the screen hall – to wash screens, screen presses and sand separators, to rinse floors and wash containers;
- in the receiving station for incoming sewage – washing slurry tanker wheels, rinsing the yard adjacent to the receiving station;
- for sand separators – rinsing aeration nozzles, water for bed spraying in biofilters; in the sludge pumping station – rinsing pipelines;
- within closed and open fermentation chambers – foam rinsing;
- in the sludge dewatering building – washing sludge dewatering belt presses, washing chamber sludge presses, washing decantation centrifuges;
- in the polymer dosing station – coagulant and polyelectrolyte solution preparation;
- in sludge drying – for washing and cooling equipment.

Inadequate or insufficient water treatment can result in a number of problems, such as: deterioration of heat transfer; narrowing of pipe cross-sections leading to pressure losses; clogging of pipes, nozzles and valves; malfunction of measurement sensors and pumps, increased corrosivity resulting in a reduced equipment and installation life cycle.

Savings from the use of filtration of treated wastewater using HYDAC type RF4W filter for an average filter capacity of 10 m³/h:

- example demand of 10 m³ of water per hour of treatment plant operation
- average cost in 2022 year PLN 6.00 per m³ of potable water
- daily expenditure for drinking water PLN 1,440.00
- annual expenditure for drinking water: PLN 525,600.00

Photo 2. RF4W-3 filter - HYDAC Process Technology, Germany

Automatic self-cleaning filter RF4W-3

- flow Q_{max} 450 l/min
- design pressure p_{max} 10 bar / 16 bar
- filtration accuracy 25 – 1000 μm
- body and cartridges – 316 alloy steel
- backwashing with filtered medium
- dedicated for most process waters
- electric or electro-pneumatic control

HYDAC in Poland

Efficient operation of cleaning and filtration processes is therefore key to improving process efficiency and reduce servicing and maintenance costs, thus lowering the energy intensity and costs of the entire process. It is essential to use professional and proven equipment in order to carry out filtration effectively and efficiently. This is possible thanks to the use of filters from HYDAC's product range. HYDAC service provides support and assistance during commissioning and start-up, and remains at your disposal as needed. HYDAC solutions, backed up by extensive references, have been complementing and supporting filtration processes for many years and can certainly do the same for you.

Adam Grabowy
HYDAC Sp. z o.o. Mikołów

Photos come from the archive of **HYDAC Sp. z o. o.**

Range of HYDAC process filters with a wide spectrum of applications

- self-cleaning filters
- single in-line filters
- dual, switchable in-line filters

Advantages:

- compact, durable design
- low energy consumption
- low pressure losses
- small build-up area
- ergonomic operation
- operation over a wide temperature and pressure range
- wide material specification

HYDAC

Where are electricity prices heading in 2023?

The past year has brought many changes to the electricity market in Europe, and thus in Poland. From the generators point of view, after a promising first half of the year and recorded price records in August, there was a slump, due to the intervention of the European Union, introducing price caps for generators. Considering the significant influence of geopolitical factors, it is difficult to predict what 2023 will bring to the energy industry. However, based on observed trends, one may be tempted to outline two forecasting options.

Last August, electricity prices recorded record highs. In Poland, at its peak, the price of the BASE Y23 index was quoted above PLN 2,500/MWh, and the TGeBase daily index on the twenty-third of August 2022 achieved the highest price in the history of trading at PLN 1,953.49/MWh (figure 1). At the same time, Germany's Y23 annual contract was trading above €1,000/MWh. How much electricity and gas prices were the product of uncertainty and speculation, could be seen from the speeches of politicians, including the deep intervention of European Union member states announced by European Commission President Ursula von der Leyen and announced at the end of August 2022. Since then, we can observe a significant reduction in electricity and gas prices. To a lesser extent, these trends have translated into coal and CO_2 prices.

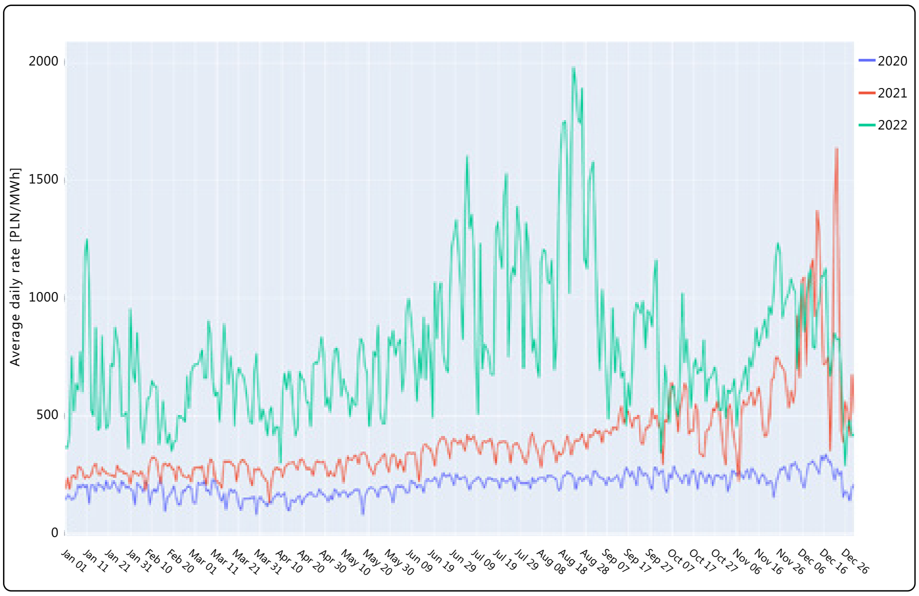


Fig. 1. Graph of the TGeBase Index on an annual basis

Energy market regulations

The regulation announced at the European level was introduced on October 6, 2022, in the form of a Council Regulation (EU)[1], which introduced price caps for RES generators until June 30, 2023 at €180. In Poland, price cap restrictions for RES generators and trading companies were introduced by the Law of October 27, 2022 on emergency measures to limit the amount of electricity prices and support for certain consumers in 2023. In December 2022, the law and the Decree of the Council of Ministers setting price limits for entities covered by this regulation were amended. The Polish law, unlike the European one, introduced price limits of PLN 345/MWh for wind installations and PLN 395/MWh for photovoltaic installations. The smallest price cap, however, has been applied to hydropower installations, at PLN 270/MWh[2]. The duration of the national restrictions is also longer than the European ones and will be in effect until December 31, 2023. However, the most significant impact on the price level from October 2022 was the introduction of the Ordinance of the Minister of Climate and Environment dated September 27, 2022, amending the Ordinance on detailed conditions for the operation of the electric power system. This regulation changed the rules for pricing the cost of PSE's purchase of forced energy and introduced a maximum price in the balancing market. Since then, there are no longer sharp price increases in the balancing market, which has translated into lower prices in the SPOT market. The decline in prices of basic energy commodities observed since September 2022 has also had an impact on the significant decrease in the index price in the futures market.

Prices for energy products

The reduction in gas consumption in Europe, mainly due to the very warm winter and the reduction in gas-fired power generation, had the most significant impact on the reduction in gas prices. At the same time, in mid-January 2023, gas storage facilities were filled to 79% of capacity, equivalent to about 900 TWh, which was 78% higher than in the same period last year.

Increase in the amount of electricity from RES installations

In the daily energy mix, there is a high variability in the share of RES generation in relation to the demand of the National Electricity System (NES). The more the daily share of RES generation increases, the greater the price drop in SPOT markets. Figure 3 clearly shows this correlation. The first two decades of December 2022 were characterized by a low share of RES, not exceeding 10% of NPS demand, resulting in an average FIX 1 price of about PLN 980/MWh. The turn of the year was a period when the share of RES increased to 28% of the NPS demand, resulting in a reduction of the average FIX 1 price to PLN 580/MWh.

In 2023, we will see another increase in the installed capacity of RES installations, primarily photovoltaic installations. The total capacity of these installations including prosumer installations has exceeded 12 GW in Poland. This growth is observed in the increase in electricity generation from these installations, which has tripled over the past two years.

Electricity prices in 2023

The estimation of electricity prices in the current year should be carried out in two variants. One of them assumes that there is no significant impact of the war

[1] COUNCIL REGULATION (EU) 2022/1854 of 6 October 2022 on emergency intervention in order to address high energy prices

[2] Limit values apply to installations with a capacity of more than 1 MW

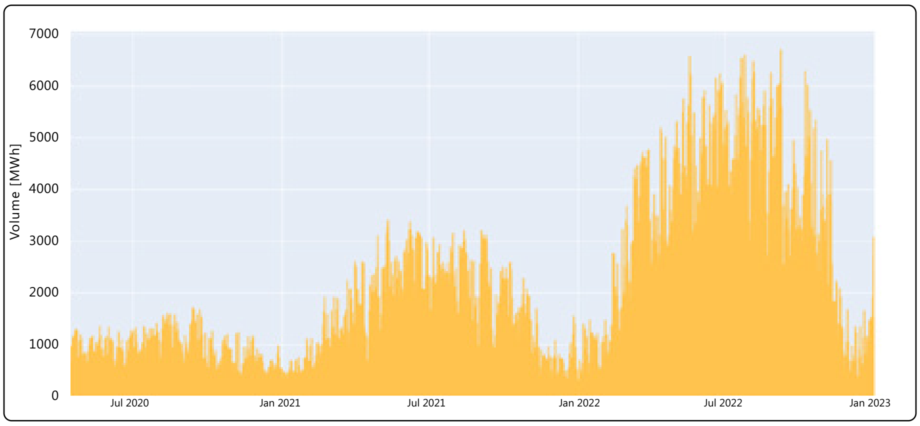


Fig. 2 Production in PV installations on a daily basis for the period 01.03.2020–31.12.2022

Source: Own study based on ENTSOE data

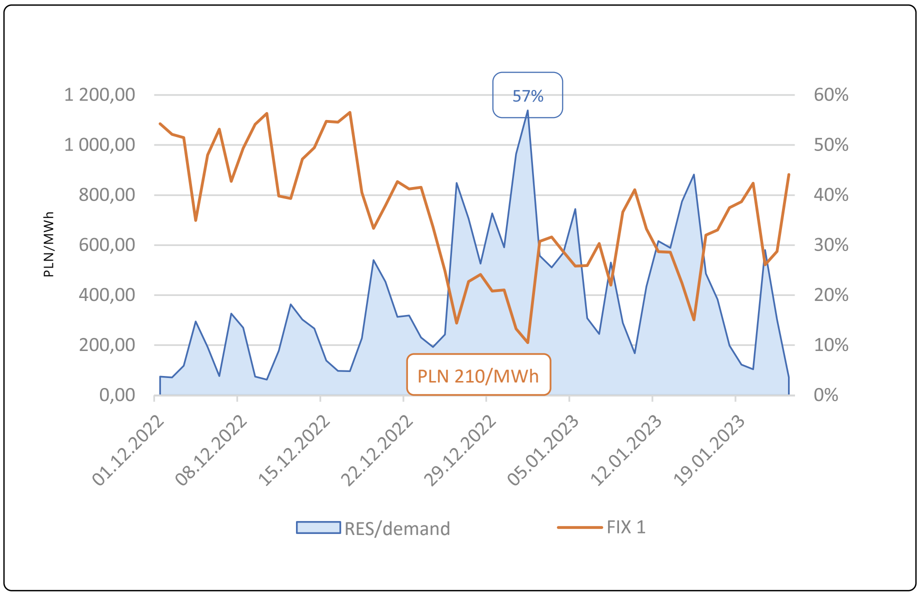


Fig. 3 Dependence of the FIX 1 price on the share of RES in the NPS in the period 12.2022–20.01.2023

Source: Own study based on POLPX data

in Ukraine on the price of basic energy resources, including primarily gas. In such a situation, it should be assumed that electricity prices will depend primarily on the level of demand, weather conditions and the amount of electricity generated by RES installations. The current warm winter will result in reduced energy demand, but at the same time the lack of precipitation will result in significant reductions in the amount of water in rivers during the summer, which will affect the production of electricity at some conventional power plants. The same period will see a significant increase in electricity from photovoltaic installations.

However, a periodic increase in prices may be caused by increased hostilities in Ukraine, which lead to a complete shutdown of natural gas supplies from Russia. This situation may affect electricity prices due to the anticipated increase in coal prices and CO_2 emission allowances at such a time. An additional factor increasing electricity prices may be further changes related to the market for CO_2 emission allowances, which will be a consequence of further legal changes planned in the near future. Electricity prices in 2023 in Poland will therefore depend on a number of geopolitical factors and on the share of generation from RES installations in relation to the projected demand in the NPS. If the increase in generation from RES installations is higher than the increase in demand for electricity, with no increase in energy commodity prices at the same time, we should expect average annual electricity prices to be above PLN 600/MWh with pronounced daily price volatility in quarters II and III (i.e., during periods of increased generation from photovoltaic installations).

Radosław Koropis
RENPRO Sp. z o. o.

Is Turów pumped storage plant worth building?

Carbon dioxide is blamed for the apparent climate change taking place on Earth. Therefore, the European Union, using the mechanism of high charges for CO_2 emissions, expects a significant increase in electricity generation from renewable energy sources, i.e. those that do not produce this gas.

In our country, renewable energy is mainly generated from wind using wind turbines and from solar radiation using photovoltaic panels. In Poland, the total installed capacity of solar power plants at the end of May 2022 was 10.22 GW [1] and 7.67 GW for wind power plants [2] (end of August 2022). Further development of electricity generation from renewable energy sources (RES) is planned. For example, the Orlen Group intends to build a wind farm in the Baltic Sea with an installed capacity of 7 GW [3]. In August 2022, the share of renewable energy sources in domestic electricity production was 17.5%.

While the cleanliness of RES-generated electricity production is clearly an advantage, its instability is a significant drawback. When there is no wind or insufficient sunshine, it becomes necessary to compensate for the shortfall in energy production. In contrast, when RES produce more electricity than demand, the problem of storing surplus electricity arises. Electricity is mainly stored in two ways: in batteries, as chemical energy, and in water reservoirs, as potential gravitational energy. The latter is known and used in pumped storage plants (PSPs).

Turów power plant

The Turów thermal power plant (photo 1) has recently become very high profile, mainly due to the Czech Republic and rulings by the Court of Justice of the European Union demanding a halt to open-cast lignite mining, which provides fuel for the Turów power plant. The case has sparked widespread discussion in our country about the legitimacy of its operation.

No matter how large the lignite deposit is, it will still be depleted at some point, and the area after the open-cast mine will need reclamation. Nor can it be ruled out that

Source: iStock, Castka

Photo 1. Turów power plant

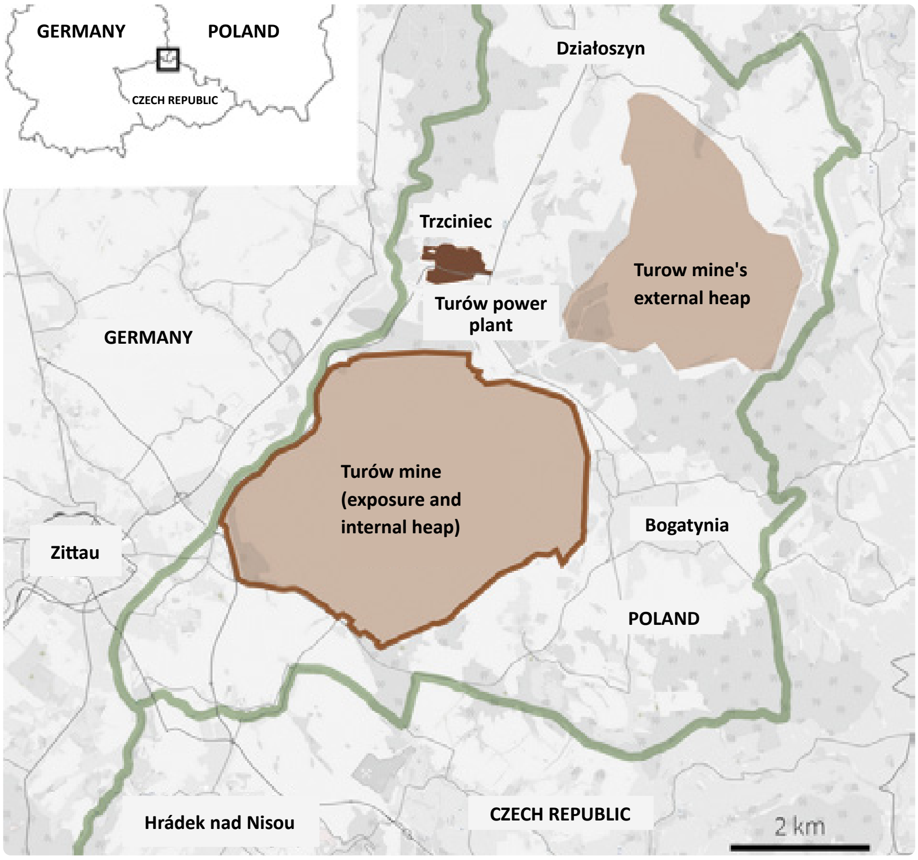
mining operations will cease before the lignite reserves are exhausted, and reclamation will have to start much earlier.

The Turów lignite mining operation has resulted not only in mine workings of approximately 2,400 ha and over 150 m deep but also a spoil heap (figure 1) close to the mine (approximately 2 km), which at present rises some 240 m above the adjacent terrain [4]. This location of the workings and the heap suggests the construction of a pumped storage plant, with the lower reservoir in the workings and the upper reservoir on the adjacent heap, where appropriate embankments would still need to be built.

Estimates

Based on the measurements made via Geoportal 2, let us assume the following approximate data for the estimates:

- average elevation of the area around the workings: 220 m above sea level,
- maximum workings depth level: -5.0 m above sea level,



Source: Instytut Gospodarki Surowcami Mineralnymi i Energią PAN, OpenStreetMap

Fig. 1. Turów mine and external heap

Source: Geoprtal 2, OpenStreetMap

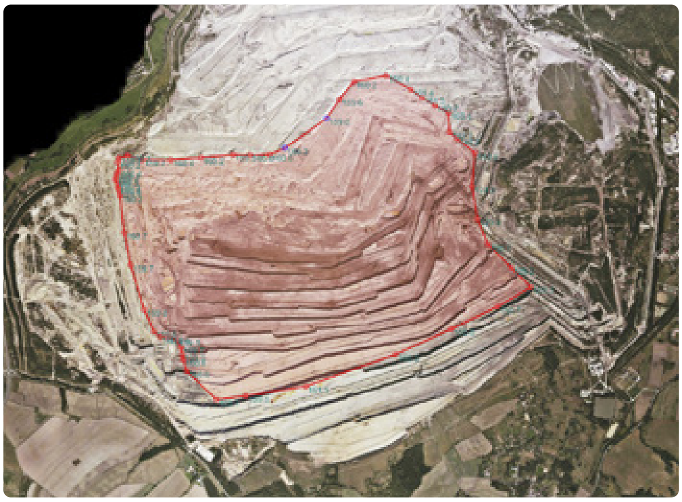


Fig. 2. Proposed location of the lower reservoir. Water level at 160 m above sea level, marked area is 933.03 ha.

Source: Geoprtal 2, OpenStreetMap

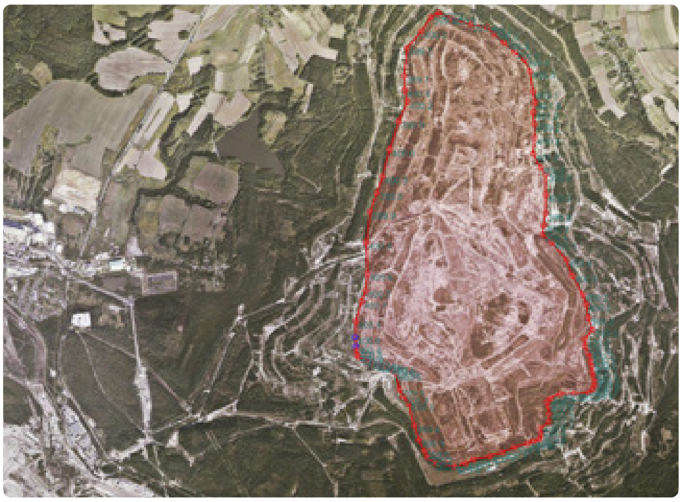


Fig. 3. Proposed location of the upper reservoir. Reservoir bottom level at 400 m above sea level, marked area is 657.58 ha.

- tailwater level WD of the lower reservoir (figure 2): 160 m above sea level,
- water surface area of the lower reservoir A_d: 933.03 ha,
- bottom level DG of the upper reservoir (figure 3): 400 m above sea level,
- water surface area of the upper reservoir A_g: 657.58 ha,
- filling height of the upper reservoir embankments h_g: 30 m.

Comparison of upper and lower reservoir capacities

Assuming for the sake of simplicity the verticality of the upper reservoir embankment walls, the volume of the upper reservoir V_g is approximately:

$$V_g = A_g \cdot h_g =$$
$$= 657.58 \cdot 10^4 \ m^2 \cdot 30 \ m =$$
$$= 19.73 \cdot 10^7 \ m^3$$

The volume of the lower reservoir will be calculated as the volume of a cone whose height hd is equal to the difference between the WD and the deepest point of the workings:

$$h_d = 160 \ m \ a.s.l. -$$
$$-(-5 \ m \ a.s.l.) = 165 \ m$$

$$V_d = \frac{1}{3} A_d \cdot h_d =$$
$$= \frac{1}{3} \cdot 933.03 \cdot 10^4 m^2 \cdot 165 \ m =$$
$$= 51.32 \cdot 10^7 m^3$$

The result indicates that the assumptions made about the volumes of the upper and lower reservoirs are correct, as the volume of the proposed upper reservoir is less than that of the lower one. Therefore, there will be no overfilling of the lower reservoir in the event of a complete discharge of water from the upper reservoir.

Calculation of stored energy

The stored potential energy of the water in the upper reservoir is:

$$E_p = m \cdot g \cdot H = \rho \cdot V_g \cdot g \cdot H = \gamma \cdot V \cdot H$$

where:

E_p – potential energy
m – mass of stored water
H – height of centre of gravity of the water mass
g – gravitational acceleration 9.81 $m \cdot s^{-2}$
ρ – water density 1000 $kg \cdot m^{-3}$
V_g – upper reservoir volume
γ – water specific weight 9.81 $kN \cdot m^{-3}$

The centre of gravity of the water is at half the height of the embankment, so the amount of potential energy resulting from the damming is:

$$H = WG - DG + \frac{h_2}{2} =$$
$$= 400 - 160 + \frac{30}{2} = 255.0 \ m$$

Hence, the stored potential energy in the upper reservoir is:

$$E_p = 9.81 \cdot 10^3 \frac{N}{m^3} \cdot 19.73 \cdot 10^7 m^3 \cdot 255 \ m =$$
$$= 49.36 \cdot 10^{13} J$$

This is thirty-eight times greater than the largest, Polish Żarnowiec PSP – in which the stored energy is 3.66 GWh = 1.3*10¹³ J [5] and almost three and a half times greater than the world's largest, Chinese Fening PSP, which stores the energy of 40 GWh = 14.4*10¹³ J [6].

Feasible supply times for the energy system

If it is assumed that the installed capacity P will be 1 GW and, assuming an overall power plant efficiency = 0.7, it will be possible to supply the power system for:

$$t = \eta \frac{E_p}{P} = 0.7 \cdot \frac{49.36 \cdot 10^{13} \ J}{10^9 \ W} =$$
$$= 34.55 \cdot 10^4 s = 95.8 \ h$$

That is to say, almost 4 days!

On the other hand, comparing with the installed capacity of RES installations, which was 20 GW in 2022, we get that the power supply by the planned Turów PSP will replace RES installations for:

$$t = \eta \frac{E_p}{P} = 0.7 \cdot \frac{49.36 \cdot 10^{13} \ J}{20 \cdot 10^9 \ W} =$$
$$= 1.73 \cdot 10^4 s = 4.8 \ h$$

However, if we design the plant for the maximum power demand recorded on 12 February 2021, which was 27.6 GW [7], then the feed-in time for the entire domestic power system would be almost 3.5 hours:

$$t = \eta \frac{E_p}{P} = \frac{49.36 \cdot 10^{13} \ J}{27.617 \cdot 10^9 \ W} =$$
$$= 1.25 \cdot 10^4 s = 3.48 \ h$$

Current opportunities for PSP construction

The construction of the proposed Turów PSP can only be implemented once the mine is closed, but even at present, existing opportunities can be exploited. The water supply system for the Turów power plant comprises three reservoirs: Niedów Reservoir, at which the water intake is located, Zatonie Reservoir and the Daily Levelling Reservoir. The main water storage, located at the base of the heap, is the Zatonie Reservoir (figure 4).

A possible solution is to build an upper reservoir on the heap and use the existing Zatonie Reservoir as a lower reservoir. This solution does not interfere with the current purpose of the reservoir, which is to store water for the Turów thermal power plant. The capacity of Zatonie Reservoir is $V = 2 \cdot 106\ m^3$, the normal water level (NWL) is 303.00 m above sea level, and the maximum damming height is 34.5 m [8]. Let us continue with the previous assumptions, i.e. the bottom level of the upper reservoir at 400 m above sea level and that a dam will be built on the heap to allow a damming up of the upper reservoir of 30 m. Then the potential energy will be calculated from the centre of gravity of the Zatonie Reservoir to the centre of gravity of the upper reservoir.

Level of the centre of gravity of the upper reservoir:

$$400.00\ m\ a.s.l. + \frac{30\ m}{2} =$$
$$= 415.00\ m\ a.s.l.$$

The centre of gravity of the lower reservoir can be approximated as follows:

$$303.00\ m\ a.s.l. - \frac{34.5\ m}{2} =$$
$$= 285.75\ m\ a.s.l.$$

Hence, the amount of potential energy:

$$H = 415.00\ m - 285.75\ m = 129.25\ m$$

By substituting these figures, we conclude that the stored potential energy would be:

$$E_p = \gamma \cdot V \cdot H = 9.81 \cdot 10^3 \frac{N}{m^3} \cdot 2 \cdot 10^6\ m^3 \cdot$$
$$\cdot 129.25\ m = 25.36 \cdot 10^{11} J$$

This means that if the installed capacity is 1 GW and the efficiency = 0.7, the feed-in time for the domestic power system will be 1.775 s, or 0.5 hours.

Conclusions

The presented estimates show that it is economically feasible to use the workings and heap after mining operations cease for the construction of a PSP. It is also important to note that a significant proportion of the costs required to build the PSP have already been incurred. The land where the PSP would be located belongs to a state-owned company. Therefore, no substantial land purchase costs will be involved. An enormous cost, and one that has already been incurred, has been the excavation of the workings, the piling of the heap and the construction of a filter screen to shield the workings. The core PSP elements are already in place. Preparation of the slopes of the workings and the construction of the upper reservoir on the heap remain. Abandoning the construction of a hydroelectric power plant and rehabilitating the post-mining area would be a simple waste of the money invested. Of course, building a PSP involves a number of issues that will need to be resolved. The upper reservoir would be founded not on native soil but anthropogenic soil. We do not have research on what the deformation of this soil would be due to variable water loads. There is enough time to conduct such research and possibly propose appropriate reinforcements. Another problem would be that of water management. On the one hand, there would not be the existing water loss that currently occurs in the cooling towers; on the other hand, there would be increased evaporation from the lower and upper reservoirs. Could this loss be balanced by the current intake? If not, where to get the additional water supply?

Fig. 4. Location of Zatonie Reservoir

Source: Geoprtal 2, OpenStreetMap

There are many problems. The authors of the article believe that it would be a mistake not to take up the challenge of building a Turów PSP. As demonstrated, the construction of this PSP would be a very profitable investment. Let us keep looking for new electricity generation technologies. Let us make an effort to build nuclear power plants. But above all, let us seize the opportunities that already exist.

PhD Leszek Opyrchał
PhD Aleksandra Bąk
Faculty of Civil Engineering and Geodesy
Military University of Technology

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Siphon turbines – a cost-effective solution for ultra-low heads

Until now, locations with low heads have been considered unattractive and for this reason have often not been developed in terms of energy. In order to exploit this undeveloped potential, IOZE hydro has developed a compact technology that is designed for deployment in locations where the use of traditional turbines proves uneconomic. Dedicated ultra-low-head technology, high electricity selling prices and a fixed feed-in tariff system mean that now is a very good time to implement such projects, thus allowing them to be marketised and provide satisfactory profitability.

Despite the significant technical potential of ultra-low-head locations (i.e. locations with a difference in level between high-level reservoir and low-level reservoir of less than 2 m), few of these sites have been developed for hydropower so far, due to the negative results that financial analyses indicate for them. This state of affairs is caused by the fact that commercially available solutions for low heads and high water flow rates, such as the Archimedes screw, VLH turbine, horizontal-axis Kaplan turbine or vertical-axis Kaplan turbine, among others, are not able to provide acceptable profitability. The inadequate profitability is due to the relatively high cost of purchasing the technology and carrying out the construction work relative to the profits generated. The use of traditional technologies in this type of project usually results in a payback period of more than 10 or even 15 years, making them unattractive.

With a view to significant development opportunities in ultra-low head and high water flow locations, IOZE hydro has developed the siphon turbine technology, thanks to which SHP investments projects that were previously considered uneconomic have a chance of being realised. The simplicity and reliability of the design, the relatively low investment cost and the minimal construction work with the high efficiency of the siphon turbine's power generation make it the most cost-effective solution on the market, capable of providing a payback period of up to several years.

Operation of the siphon turbine

The operation of the siphon turbine is based on the phenomenon of the water siphon, which is based on the transport of liquid by gravity from the high-level reservoir to the low-level reservoir, overcoming an obstacle whose peak is above the liquid surface in the high-level reservoir. It is nothing more than a pipeline with submerged ends in the high-level and low-level reservoirs, working as a water siphon with an impeller inserted inside, driving a power generator through a transmission system. Such a system must be properly primed and is unable to excite itself until the high-level reservoir is higher than the highest point of the siphon. To make this happen, the easiest way is to reduce the pressure inside the turbine by pumping air out of it. An important element in the proper functioning of the turbine is the tightness of the system. Any leaks, whether on the casings, suction pipe, turbine structure, connections, etc., will cause air to enter, which will result in at least a reduction in output and, in extreme cases, make the unit inoperable.

Design and foundation

The main advantage of siphon turbines is their foundation. Due to their design, they do not require deep excavations and significantly reduce the need for reinforced concrete work. The two basic foundation elements are the mounting blocks for the inflow chamber and the suction pipe. The siphon turbine can be "flipped" over the fixed dam without interfering with its construction. In addition, all turbine components can be made weatherproof, allowing the power station building not to be constructed and further generating investment savings.

Mechanically, the turbine design is also uncomplicated. The whole machine is housed in a steel casing, in which the main shaft is supported in two roller bearings and terminated by a rotor. A significant advantage is that the entire rotating system is mounted in a structural component that is assembled in the workshop, and assembly on site is limited to inserting it into the pre-mounted inflow chamber and suction pipe. This allows the entire system to be set up precisely in the workshop, tests to be performed and assembly

Photo. Assembly of siphon turbines

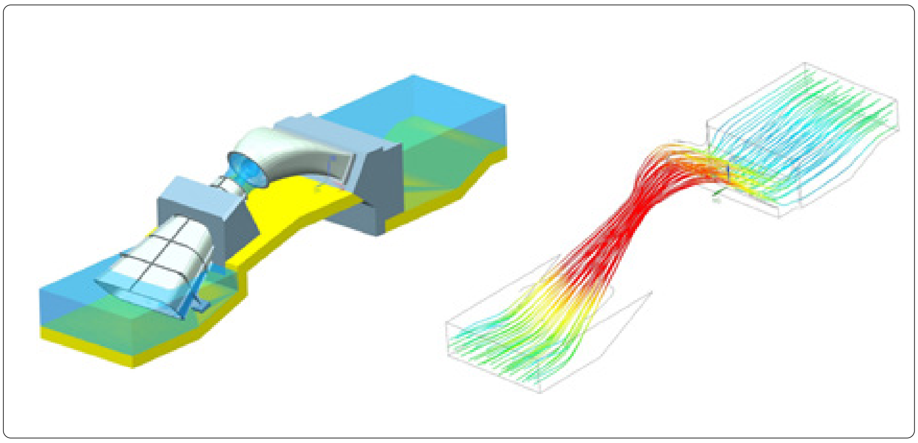


Fig. CFD simulation of a siphon turbine flow system

Operating parameters of Sulejów SHP

- installed capacity of the SHP: **200 kW**
- power generation over 3 months: **366 MWh**
- capacity factor: **83%**
- actual power generation efficiency of the SHP: **75%–85%**

Parameters recommended for the siphon turbine

- Head: 1–3 m
- Flow: 10–40 m³/s

errors to be avoided. The shaft transmits torque to the generator connected to it via a belt transmission. These components are also mounted directly on the turbine structure in the workshop.

The flow system of a siphon turbine consists of an inflow chamber, a fixed or movable steering system, a rotor chamber and impeller, and a suction pipe. Although the overall technology is simple and functional, it is proving to be a major challenge to design the flow system in such a way that the water flow is as orderly and laminar as possible, which has a key role in achieving adequate efficiency. The flow systems of the IOZE hydro siphon turbines have been modelled and simulated in a CFD programme to guarantee the highest possible efficiency of the hydrosets.

Methods of regulating water flow

A siphon turbine can be designed as a propeller turbine. This means that neither the rotor vanes nor the guide vanes are movable. The operator can control the flow in the SHP by switching individual turbines on and off. This solution results in much lower manufacturing costs for the machines, so that the affordability of the turbines increases significantly and the waiting time for an order is much shorter than for individually designed and manufactured turbines. In justified situations, siphon turbines can also be equipped with double control or the option to control the guide or rotor vanes. The correct and automatic operation of the deployed plants is supervised by an IT system, which ensures optimal utilisation of the available hydropower potential. Before deciding on the target configuration of the plants (number of turbines and method of control), in order to select the machines in a technically and economically justifiable manner, a curve of the sum of flow durations must be developed.

SHP Sulejów II – implementation in practice

IOZE hydro has successfully implemented a pilot project using siphon turbines installed on a water barrage on the Pilica River. The resulting small hydropower plant, Sulejów II, is located adjacent to the artificially created Sulejowski Reservoir. The reservoir was created between 1969 and 1974 by damming the Pilica River with a 1,200-metre-long and 16-metre-high concrete and earth dam. Just 500 metres below the dam is a water barrage that stabilises the riverbed below the Sulejowski Reservoir. The difference between the high-level reservoir and low-level reservoir in this case is 1.1–1.8 m, depending on hydrological conditions.

IOZE hydro carried out the investment project as general contractor. The works included the complete construction of a small hydropower plant with the installation of hydrounit and the necessary infrastructure to ensure efficient power generation. The works included the installation of 4 siphon turbines with a diameter of 1170 mm, with a total installed capacity of 200 kW. Significantly, the simplicity of this technology, its modularity and the existing water dams meant that the cost of the civil works for this project only accounted for about 10% in the total cost structure. The stage of operation demonstrated the high efficiency and effectiveness of the equipment – the power generation efficiency calculated at the generator terminals, depending on the head and flow, is in the range of 75%-85%. The installed turbines successfully generate power even with a head of 1 m. In this case, the high production and relatively low implementation costs of the project allowed the project to achieve high profitability. The return on investment is estimated at 2–3 years, which is a very good result in the hydropower industry.

Conclusions

IOZE hydro's proprietary solution allows for the efficient, both energy and cost-effective development of the lowest damming, whose investment viability has so far been questioned. Advantages of the siphon turbine include uncomplicated and low-failure design, short on-site installation time, small scope of construction work required, high efficiency of power generation, and short technology delivery time. In addition, the simplicity of the equipment also affects the ease of operation and servicing.

IOZE hydro is a technology company which manufartures highly efficient water turbines on the basis of proven proprietary technology. With a comprehensive product portfolio we deliver complete solutions for mini and small hydropower plants.

Łukasz Kalina
Department of Development
IOZE hydro

Graphics come from the archives of **IOZE hydro**


Source: iStock, Daniel Balakov

12 myths about hydropower debunked with evidence

"There is only one thing in the world worse than being talked about, and that is not being talked about" said Oscar Wilde. We should therefore take it as compliment that so many people talk incorrectly about hydropower. It shows that we are relevant. Eddie Rich, CEO of the International Hydropower Association, writes about the most common misconceptions and myths about hydropower that the organisation deals with daily.

Myth 1: Renewable energy is all about wind and solar.

Reality: Hydropower, as the "forgotten giant of renewables", is the world's largest source of low-carbon electricity.

In 2021, hydropower generated around 16% of the world's electricity(~4,252 TWh) – about the same as all other renewables combined. Recent growth, which has been overwhelmingly led by China, has added nearly 50 GW over the last five years. See the Hydropower Status Report 2022 for the full picture on hydropower development worldwide.

Myth 2: Wind and solar can power the planet alone.

Reality: Variable renewables like wind and solar need a reliable backup.

Wind and solar are growing faster than hydropower. It is beyond doubt that both technologies are crucial to making progress on climate change. But what happens when the wind doesn't blow and the sun doesn't shine? Do we fall back on fossil fuels? Do we face blackouts? Or do we look towards reliable, dispatchable, firm energy in the form of hydropower? For this reason, both IEA and IRENA say we will need to double hydropower capacity in the next 30 years to stay on track with net zero pathways. Hydropower's role will increasingly shift to enhancing system flexibility and supporting variable wind and solar. In other words, hydropower is ready to fill the hole left by coal.

Myth 3: All the available hydropower has already been built.

Reality: Potential hydropower capacity exists in abundance in all regions of the world.

Academic studies indicate there is more than enough global potential to achieve 1,200 GW more hydropower by 2050, even allowing for economic, social and environmental constraints. Tapping into this will be key to unlocking our net zero ambitions.

IHA's Hydropower 2050 report reviewed potential capacity in all regions. It found large potential in areas where hydropower is relatively underdeveloped; for example, 89% of Africa's hydropower capacity is untapped. And these figures do not include pumped storage, where there is great potential for additional expansion.

Myth 4: We need new technology to deliver net zero.

Reality: We have the technology; we are just not deploying it.

When it comes to addressing climate change, there is a lot of lazy talk about how the transition to net zero requires new technologies, innovations yet to spring from the imagination of a new generation of inventors. Don't believe a word of it. While innovation should always be encouraged, our net zero ambitions do not rely upon it. We already have the tools to do this job, right now. Variable renewable energy in the form of wind and solar, supported by storage – batteries, pumped storage hydropower and green hydrogen – can take us to a zero emission energy world. Pumped storage, as the "world's water battery", is the perfect natural complement to wind and solar. It already accounts for over 90% of storage capacity and stored energy in grid scale applications globally. New technologies, and refinements to existing ones, will of course emerge – whether it is bigger and better batteries and electrolysers, smarter turbines, or the creation of virtual power plants to name just a few. But right now, the single most important priority should be the planning and construction of long duration electricity storage (LDES) in the form of pumped hydro.

By using excess wind and solar at zero or low cost to pump water to an upper reservoir and dropping it down through turbines when there is a shortage of wind and solar, pumped storage is a brilliant example of renewables working together. The current storage volume of PSH stations is at least 9,000 GWh. Batteries will be important, but at the moment they amount to just 7–8 GWh. 40 countries have PSH capacity, but China, Japan and the United States alone are home to over 50% of the world's installed capacity. We can do more. A study by Australia National University has identified over 600,000 potential off-river PSH sites globally. That's 23,000 TWh of potential storage. Without using at least some of this, the energy transition is in danger of stalling just as it should be accelerating.

For more insights on PSH, visit the IHA and US Government-convened International Forum on Pumped Storage Hydropower.

Myth 5: Old hydropower plants need decommissioning and removal.
Reality: Hydropower is a forever resource.
There is over 600 GW of aging hydropower around the globe. While a few plants should be decommissioned and/or removed, the vast majority can be modernised. IHA has undertaken studies on the potential for modernisation in Asia and Latin America, and we are just finishing a similar study in Africa. The evidence is clear that upgrading our existing fleet is a massive opportunity for low-impact green electricity. And it is yet another reason why we do not need to develop new technology to make progress towards our net zero targets.

Myth 6: All dams are hydroelectric.
Reality: Less than one in five reservoirs worldwide are powered.
Most of the world's hydroelectric dams provide a range of multi-purpose services, such as flood and drought control, irrigation and water supply. Conversely, the 80% of unpowered dams around the world represent a significant potential for retrofitting.

Myth 7: Hydropower is unsustainable.
Reality: Demonstrable sustainability is not just possible; it is an expectation of the sector.
IHA members – who represent one third of the world's installed hydropower capacity – adhere to the San José Declaration on Sustainable Hydropower which says that "Going forward, the only acceptable hydropower is sustainable hydropower." New projects are to be independently certified by the multi-stakeholder designed and governed Hydropower Sustainability Standard, which is the first standard of its kind in the renewables sector. In this way, projects should enable healthy ecosystems, prosperous communities, resilient infrastructure and good governance. The Standard is aligned with the World Bank and IFC Sustainability Frameworks and with the Climate Bonds Initiative requirements for green bonds.

Myth 8: Drought will render hydropower unusable.
Reality: To mitigate against drought and floods we need more hydropower, not less.
Isn't it funny how we only notice hydropower's massive role in providing green electricity when we don't have it? With volatile weather conditions becoming more frequent, water management and mul-

The position of representatives of the Polish hydropower industry

Disinformation and dissemination of myths about the environmentally harmful role of hydropower and technical development technical development of rivers is a phenomenon present also in the Polish media. Therefore, the publication on the pages of "Energetyka Wodna" the position of the Managing Director of the International Hydropower Association by Mr Eddie Rich, in which he clarified 12 myths about Hydropower met with the approval of industry representatives. Among them included the chairman of the board of CEO of Hydroinvest Sp. z o. o., Mr Dariusz Gronek, M.Sc., said. –*Taking into account the position of the IHA and understanding the neglect and needs of both hydropower and water management Poland and knowing the importance and role of water for the country's economy of the country, I would like to stimulate reflection from those who know the state and understand the issues both in terms of water quantity and quality. I also hope that the article will provoke reflection from those who should feel responsible for spreading myths and misinformation, and strengthen the resolve of those who, by virtue of their duties, are responsible for the development of water management and hydropower*" – he said.

Photo. SHP Zabrzeż, Poland – by using the topography of the area in an appropriate way, the hydropower plant does not require the use of typical damming, thanks to which the river has retained its natural character and enables full fish migration.

ti-purpose reservoirs will be more important than ever in future. Countries like Spain are only able to cope with drought today because of massive investments in water infrastructure in the 1970s.

Hydropower is the answer. While coal and nuclear use up vast volumes of water, hydropower can use the same drop over and over again. The IHA Climate Resilience Guide provides a blueprint for hydropower operators to withstand the growing volatility in weather patterns.

Myth 9: Hydropower is expensive.

Reality: Hydropower is, over its full life cycle, the second cheapest form of renewable energy.

The latest IPCC report states that the levelised cost of electricity (LCOE) for hydropower is lower than the cheapest new fossil fuel-fired option, and that hydropower is one of the lowest-cost electricity technologies in existence. For a lifetime of 40–80 years for a hydropower project, the costs for operation and maintenance were found to be 2–2.5% of the investment costs per kW yr-1.

Myth 10: Hydropower causes excessive greenhouse gas emissions.

Reality: Only wind and nuclear power have lower median lifecycle greenhouse gas emissions than hydropower.

Independent research suggests that use of hydropower instead of fossil fuels for electricity generation has helped to avoid more than 100 billion tonnes of carbon dioxide in the past 50 years alone. That's roughly equivalent to the total annual carbon footprint of the United States for 20 years. Nonetheless, all energy sources, even renewables, produce carbon emissions in their lifecycle, due to the emissions caused by their manufacture, construction or operation. The IPCC report noted that only wind and nuclear power have lower median lifecycle greenhouse gas emissions than hydropower. It states that hydropower has a median greenhouse gas (GHG) emission intensity of 24 gCO_2-eq/kWh. By comparison, the median figure for gas is 490 gCO_2-eq/kWh. The G-res Tool, the reservoir emissions calculator, can help hydropower developers and operators to measure their emissions.

Myth 11: Hydropower is yesterday's technology.

Reality: Hydropower technology has been developing at fast pace.

Hydropower may be the oldest of the renewable technologies, but it is also one that is evolving swiftly with the times and delivering important climate innovations. The changing energy mix places increased demands on hydropower to provide flexible, reliable power services in order to adapt to supply and demand. New advancements in hydropower technology are helping to integrate variable renewables such as wind and solar power and batteries into the energy system. XFLEX HYDRO is an ambitious €18 million energy innovation project demonstrating how more flexible hydropower assets can help countries and regions to meet their renewable energy targets.

Myth 12: The market will deliver for hydropower.

Reality: The future of the sustainable hydropower sector is a matter of political will and choice.

Markets do not naturally reward electricity beyond generation. Hydropower does not get compensated for its wider system and other roles, such as flexibility, reliability, storage, floods and drought control, water supply and irrigation. Energy markets need to be adapted to reflect this, especially to allow pumped storage to become mainstream in the market.

Furthermore, proportionate, streamlined license/permit processes are needed to rapidly scale up hydropower to deliver on net zero.

Governments must also act to enablement investment into maximising their existing infrastructure through modernisation, the retrofitting of non-powered dams, and the integration of floating solar panels into hydropower reservoirs. And all parties – governments, financiers, operators and NGOs – should advocate for widespread adoption of the Hydropower Sustainability Standard.

The San José Declaration says that "sustainable hydropower is a clean, green, modern and affordable solution to climate change". I believe that we can make net zero a reality #WithHydropower.

International Hydropower Association

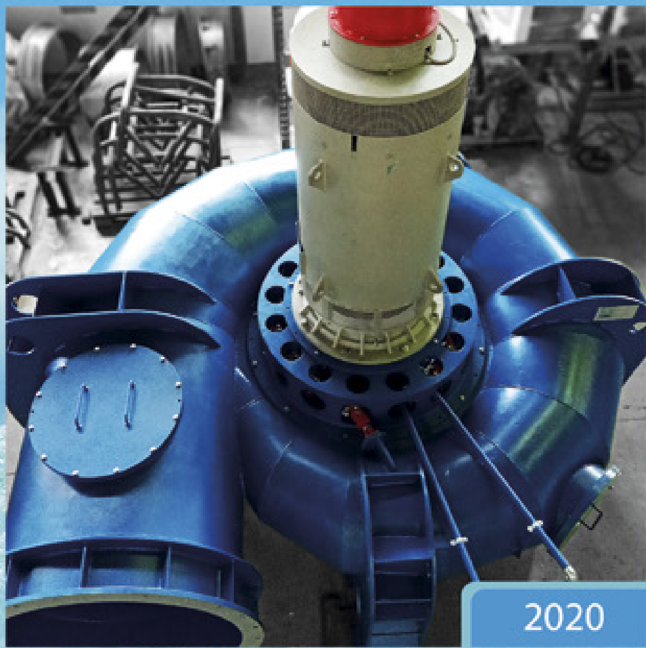
..................we believe in the power of nature

WTW Poland sp. z o.o. is a leading Polish manufacturer of water turbines as well as mechanical and electrical equipment for Small Hydroelectric Power Plants. We have been present on the Polish market since 1989 and so far we have produced 209 turbines with a capacity of> 15.5 MW. Our turbines also work in Italy, Estonia, Ukraine, Belarus and Germany. We provide high efficiency of turbines, professional advice on the selection of devices for a specific location, as well as warranty and post-warranty service. We design and supply Kaplan turbines for heads from 1.5 m to 24 m in many different configurations. Please visit our website where detailed information about our offer is available.

WTW Water Turbines Works

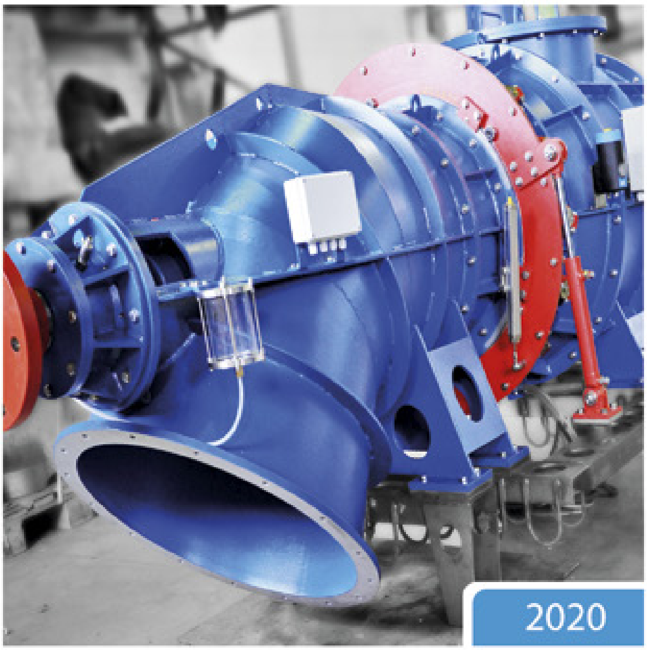
SHP Glebocko, Poland

6x136 kW (d=1090mm, H=3.1m)



SHP San Secondo, Italy

1x92 kW (d=720mm, H=5.4m)



SHP Naviglio, Italy

1x84 kW (d=560mm, H=7.6m)

SHP Chancza, Poland

1x177 kW (d=590mm, H=11.9m)

+48 695 639 657

info@wtw-poland.com

ul. Konopnickiej 2 F
11-200 Bartoszyce, POLAND

www.wtw-poland.com

Untapping potential of marine renewable energy

Discarding our dependence on fossil fuels will require massive investments in renewable energy sources. This however comes at usually high cost in terms of required land area. The region where renewable energy potential has been so far untapped is our seas and oceans. Although this trend is starting to change. What are the options?

Humankind mastered ways of generating electricity across the globe and beyond it from various sources. In the International Space Station, solar PV panels were constructed. Wind turbines are being built in the Arctic region. However, one source for electricity is still largely untapped to this day — it is our seas and oceans. Sophisticated marine energy technologies could play a significant role in the transformation of the current energy system. It is estimated that the global theoretical wave energy potential alone is 29,500 TWh [1]. The exploitable global offshore wind energy potential in shallow waters was calculated as 64,845 TWh [2]. It means, that, in theory, marine renewables could easily meet electricity needs for the growing world (the global electricity consumption oscillates around 24,000 TWh).

Possibilities of the complementarity

Recent scientific studies show that possibly best way to utilize marine renewable energy is to combine various generators into one system. The main reason behind this is the variable nature of such energy sources. Therefore, the use of the different renewable energy sources can not only increase the amount of generated energy from the single marine area, smooth the power output, but also decrease the installation, operation, and maintenance cost due to the utilization of common infrastructure such as electricity cables or substructure.

Diverse options are being studied by today's scientists and engineers to combine various marine renewables. Wave energy converters can be located outside of the offshore wind energy farm resulting in increased weather window for the operation and maintenance. This can be achieved by using the so-called shadow effect when wave energy converters are shielding the wind turbines from the harsh sea conditions. By shielding wind turbines from incoming waves and additionally generating electricity, wave energy converters can provide a less energetic wave climate within the wind farm, increase the number of weather windows to carry out maintenance work, and decrease the downtime due to delays of maintenance and repairs [3].

Floating solar energy farms can be located inside the offshore wind energy farms. Floating PV farms concept is still relatively new, but rapidly evolving opportunity for the renewable energy sector. It is already proven that they can be installed at lakes, hydropower reservoirs and irrigation channels. Nevertheless, solar PV farms in the offshore environment are still a question for the future. Here floating solar PV panels must face the saltwater and marine climate dynamics not suitable for the currently available floating photovoltaic systems. Still, this synergy is already being studied in such areas as Asturias (Spain) due to the climate patterns. Here the energy output from the wind turbines in the winter doubles the summer values, while the energy output from floating solar panels is three times higher in the summer months [4].

Although, the tidal stream energy resources are the smallest of all available offshore marine energy resources in Europe, their possible synergy with offshore wind energy is being assessed. The idea is to create a hybrid system of one tidal stream turbine on a single wind turbine monopile or two tidal turbines on a single wind turbine monopile. The drawback here is that floating offshore wind turbines are designed for working conditions at the sites where current is slow to avoid additional investment to reduce the risk of overturning. Meaning that the site where this idea was tested - the Pentland Firth, United Kingdom – where average flow reach 4 m/s is unsuitable conditions for conventional offshore wind energy turbines. The monopile of the offshore wind turbine needs to be strengthen by using the thicker steel. Fortunately, the simulation showed that the overturning moment at the base of the monopile even with two


Source: Author archive

Photo 1. Wave Star wave energy converter prototype. Designed to use the same foundations as wind turbine

tidal stream turbines is only 8% larger than for wind turbine alone in an environment with strong currents. Overall finding of the study is that the increased cost of infrastructure is small relative to the increased generation of energy [5].

Application perspectives

Green ports

75% of all goods to or from the EU are carried by ship. Therefore, ports play a crucial role in distributing the products of global economy. Unfortunately, by doing this they contribute up to 3% of the global greenhouse gases emissions. There are several ways for the seaports to cut these emissions. The energy which is consumed in container, bulk, passenger, and other terminals can come from local marine renewable energy sources. The ships, that have already docked could switch to electrical power that could be provided to the ship in order to turn off the main and auxiliary engines. This service is already provided in number of European ports such as Port of Kiel in Germany [6].

Oil rigs

The energy demand for petrochemical industry is very high. It consumes approximately 10% of its total production. The constantly increasing demand for oil, petrol and other products will only increase the industry's energy needs. One way to mitigate such impact is to power the oil rigs with one or several marine renewable energy sources. It was calculated that if the wind farm could operate in parallel with gas turbines at the oil rig in the North Sea it could lead to reduction of 54,000 tons of CO_2. Additionally, it could save up to 5.7 mln EUR annually as lesser amount of the pollution taxes would have to be paid and there would be lesser demand for fuel [7]. Other benefits could be that such power systems could reduce heat and noise emissions into the marine environment.

Aquaculture

Offshore and near-shore fishery farms are one of the fastest growing areas of animal food production in the world. As they usually are located far from power lines, the marine renewable energy sources can serve as alternative to the conventional electricity generators that use fossil fuel. One of the processes with high electricity consumption that is used in aquaculture is aeration. As dissolved oxygen is constantly needed to prevent from substantial losses in production. The optimal configuration of marine renewable energy system could significantly reduce the cost of energy for aquaculture farm.

Source: Dr. Jie Yan, North China Electric Power University

Photo 2. Offshore wind farm. Possible future site to combine various marine renewable energy sources.

Energy islands

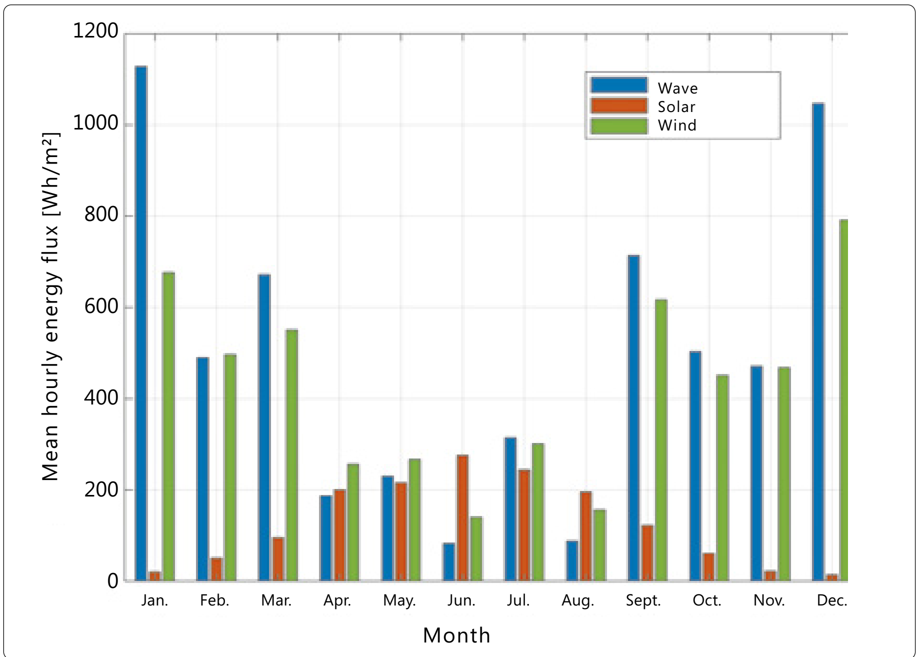
The area for deployment of new solar and wind parks in Europe is limited. As energy sources they require a significant surface to deliver certain volume of energy. Once we run out of low value land in continental Europe the energy industry will be forced to move at least part of its operation to the marine environment. One of the possible solutions is called an energy island. This concept assumes that large scale solar, wind and in particular wind parks are being built in the offshore locations. Subsequently generated from them electricity is not transferred via DC links to the mainland, but it consumed on-site to produce green hydrogen. This later can be compressed and used to fuel hydrogen ships or can be shipped to the harbours to meet the continental energy needs for example in the steel industry. First such island is planned by Denmark, and its estimated time of completion is 2033.

Possibilities for the Baltic Sea

The Baltic Sea does not have tides or marine currents that could be used for electricity generation. But the combination of solar, wind and wave energy can be utilized here in the future. The figure 1 shows the typical distribution of solar, wind and wave energy theoretical resources over the course of the year in an offshore location of the Baltic Sea. It can be clearly seen that the joint utilization of wind and wave energy resources in one Baltic Sea area could considerably increase the output of generated electricity during the colder season. Meanwhile, if to the same system floating photovoltaics could be added, the considerable amount of electricity could be generated throughout the whole year. Still, this is very early and rough estimation of what possibilities lay in the Baltic Sea for renewable energy generation. Further and more detailed research on this topic is needed.

Egidijus Kasiulis
Department of Water Engineering
Faculty of Engineering
Vytautas Magnus University

Jakub Jurasz
Faculty of Environmental Engineering
Wrocław University of Science and Technology



Source: Own study

Fig. 1. Offshore theoretical marine renewable energy resources in the Baltic Sea

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Determinations of laboratory methods for determining the hydraulic conductivity for soils granulation mixtures

In hydrotechnical facilities, where it is necessary to incorporate geomaterials with the declared parameters, it is also necessary to indicate test methods that allow for the control of this process. In terms of water permeability, the basic parameter is the hydraulic conductivity t, which, according to Darcy's linear law, expresses the relationship between the hydraulic gradient and the filtration speed of the water. In the case of analyzes of hydraulic damage, it is also important to define the so-called filter resistance, related to the structure and grain size of the soil. A necessary addition to the requirements in this regard may be the soil granulation treatment.

To determine the water permeability of the soil, the hydraulic conductivity is used. It represents the relationship between the hydraulic gradient and the velocity of water flow in the soil [1]. Many different methods are used to determine the hydraulic conductivity, including field methods (e.g., conducting pumping test, flooding methods), laboratory methods (described further below), and indirect methods – based on empirical formulas.

The choice of the appropriate method depends on the purpose of the study, the projected changes in soil and water conditions, and technical and economic feasibility [5]. Determination of the soil hydraulic conductivity using only one method is often unreliable due to the limitations of individual methods and numerous factors affecting the quality of the result obtained. The results obtained by correlation and field methods are worth comparing with the results of laboratory tests, during which the boundary conditions of the conducted test can be controlled in the spatial state of stress and strain [5].

Taking into account the course of the test and the quantities measured during the test, as well as the equipment and measuring instruments used to determine the hydraulic conductivity, laboratory methods can be divided into four main groups [11]:

- group I – includes instruments in which the measurement is carried out at a constant differential pressure of water flowing through the sample (so-called constant-head);
- group II – the study uses instruments in which the measurement is carried out with a constant change in the pressure of water flowing through the sample (so-called falling head);
- group III – these are methods in which instruments are used that take advantage of the capillary properties of soils and physicochemical phenomena that occur at the contact of the solid and liquid phases;
- group IV – includes instruments whose operation is based on the use of the principles relating to the instruments of the previous groups.

In the presented study, the determination of the hydraulic conductivity was carried out by two methods: constant-head (group I) and falling-head (group II) using different test apparatus. Falling head is recommended for fine-grained soils with medium and low permeability [2] (range of hydraulic conductivity t from $1x10^{-5}$ to $1x10^{-9}$ m/s) and constant head for coarse-grained soils ($k=1\div1x10^{-5}$ m/s).

All the results obtained (regardless of the method chosen) of the hydraulic conductivity were related to the temperature of 10°C using the empirically written equation of the relationship:

$$k_{10} = \alpha \cdot k_T$$

where:

k_{10} – hydraulic conductivity t at water temperature of 10°C [m/s]

k_T – hydraulic conductivity t at ambient temperature [m/s]

T – water temperature at the time of testing [°C]

α – correction factor calculated according to:

$$\alpha = \frac{1.359}{1 + 0.0337 \cdot T + 0.0002 \cdot T^2}$$

When analyzing hydraulic damage, it is important to determine the so-called filter resistance, linked to the structure and grain size of the soil [1]. A necessary complement to the requirements in this regard may be the procedure of batching. Granulation of soil material allows the use of potentially unusable material, such as from excavation or demolition, or waste from a mine. The procedure of graining applies to coarse-grained soils and is aimed at supplementing the local soil with missing fractions (usually dust or clay fractions) in order to achieve the desired parameters, e.g. compaction.

The article presents tests of the hydraulic conductivity t by laboratory methods of coarse soil with a negligible (less than 1%) content of fine fraction and its particle size distribution in the amount of 10% and 30%, in order to assess the suitability of the methods used.

Research material

Material for granulation soil

Slag and ash sand, produced from by-products of coal combustion, from lime desulfurization methods, from by-products associated with the production of mineral binders and cement, was used as the material for granulation. The particle size distribution is mainly the silt fraction, which, depending on the adopted classification, is 60–69% (table 1).

Reference soil and granulated soil 10% and 30%

Naturally occurring medium sand (MSa) with C_U = 2 was selected as the reference material. This soil is genetically included in the complex of fluvial formations from the Mazovian interglacial period. The medium sand used was granulated at 10% and 30%. The grain size compositions of granulated mixtures were determined with the sieve method in accordance with PKN-CEN ISO / TS 17892-4: 2008 [8]. Based on the obtained particle size distribution curve, the following parameters were determined: d_{10}, d_{17}, d_{20}, d_{50}, d_{60} (grain size [mm] corresponding to 10, 17, 20, 50 and 60% by weight passing through the sieves) (fig. 1).

Source: Own study

Percentage fraction (%)				Density of solid particles (measured)
Clay	**Silt**	**Sand**	**Corase and gravel**	2.17 *(g/cm³)*
<0.002 mm	*0.002–0.05 mm*	*0.05–2 mm*	*>2 mm*	Soil type acc. to PN-B-02480:1986 [7]
1	60	39	0	***Sandy silt***
<0.002 mm	*0.002–0.063 mm*	*0.063–2 mm*	*>2 mm*	Symbol of soil acc. to PN-EN ISO14688-2:2006 [9]
1	69	30	0	***saSi***

Tab. 1. Summary of the results of the grain size analysis for slag-ash sand

Source: Own study

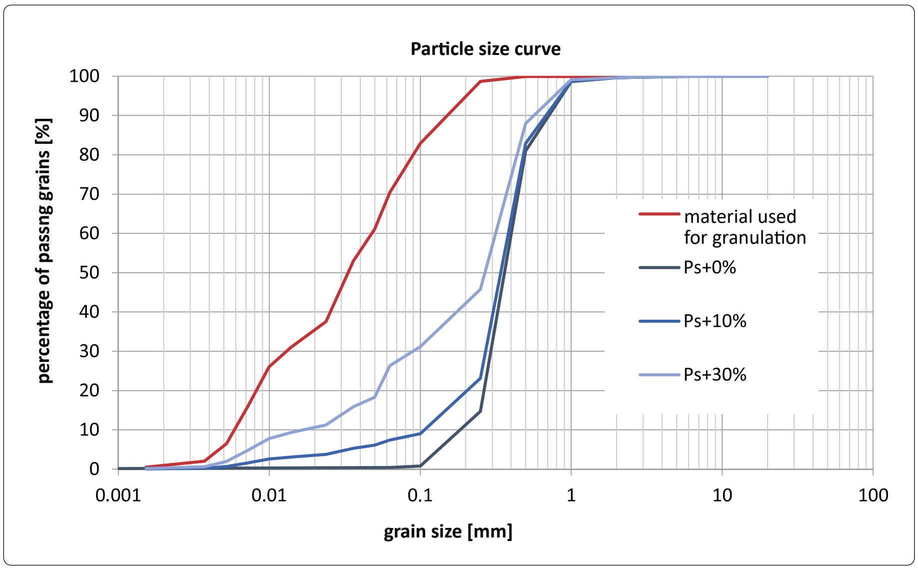

Fig. 1. Graph of the graining of the reference soil (+ 0%) and particle size (+ 10%, + 30%) and the material used for granulation (slag and ash sand)

Photo 2. Bipartite mold and membrane for forming samples at a given pressure

Photo 1. Set for testing the hydraulic conductivity t at specified pressure and constant head

Research methodology

Material used for granulation

For the indicated soil for granulation, the hydraulic conductivity t was determined with a constant head [10] in the apparatus for testing filtration at a specific effective pressure (photo 1). The test was carried out with the water flow "from bottom to top" for samples formed at optimum moisture content. To form a sample with a homogeneous density, bipartite molds were used, in which a membrane was stretched inside (photo 2).

Specially prepared nets with a mesh diameter of 0.063 mm were used (instead of pore stones) (photo 4), the porosity of which ensured free flow of water through the sample and better fit to it. The rings, in which the described meshes were mounted, were made on their own (3D printing). After the specimen of a given density was formed, a vacuum was applied to the interior of the specimen by means of a vacuum pump in order to maintain the shape and structure of the specimen after removing the mold. The chamber was then flooded with water and closed by applying pressure to the chamber. This treatment allows for further preservation of the unchanged structure of the sample. The difference between the pressure in the chamber and the equalizing pressure should not be greater than the effective stress, but it should not be less than 5 kPa (the difference of 10 kPa is taken as optimal for various types of soil, and the deformation of the sample is avoided at this value).

Deaerated water was used to saturate the sample. Soil samples were saturation with water in the "bottom-up" direction in order to force the air out of the pore space. The applied equalizing pressure by means of hydraulic controllers was to increase the solubility of the gas (bubbles) in the water. Equalizing pressure with various values from 5 kPa to 200 kPa was used. The saturation state was controlled by measuring the Skempton B parameter. The saturation was carried out to a state where its value was ≥ 0.95. For this purpose, the valve connecting the sample with the controller controlling the volume of water in the pores was closed, and then the pressure values in the chamber of the apparatus were increased by a predetermined value. After the saturation step, the sample was consolidated until 95% of the excess pore pressure dissipated (*u*> 95%, where *u* is the pore pressure read at a given time). Consolidation of the soil sample is essential to establish the desired stress state and apply the appropriate effective stresses prior to the filtration stage. During consolidation, the valve it remains open to allow drainage and dissipation of excess pore water pressure. When the consolidation step was completed, the values for the volume index and the pore pressure were recorded. Pressures were set to obtain the required effective pressure and hydraulic drop, and then the bottom-up hydraulic conductivity was started.

The water temperature during the test was constant at 22°C. Three determinations of the hydraulic conductivity t were made on one consolidated sample, with an effective stress (σ'c) value of 50 kPa. The results of the determination of the hydraulic conductivity (k) at constant head and the value of the hydraulic conductivity (k_{10}) at the reference temperature T=10°C are shown in table 2.

Granulated soil

For granulated soils, the hydraulic conductivity was determined by the constant- and falling-head method at different concentrations (I_D = 0.30 – loose state, I_D = 0.50 – medium-compacted state, I_D = 0.70 – compacted state, I_D = 0.90 – state very dense).

The determination of the hydraulic conductivity was performed with the use of equipment compliant with the standard PKN-CEN ISO / TS 17892-11 [10] with the water flow direction "from top to bottom" (photo 3). Samples of granulated soils were formed by compacting them directly in the test device at a certain moisture content order to achieve a specified dry density of solid particles.

Source: Own study

Sample data:	**Sample diameter: 100 mm**	**Sample height: 100 mm**	**Degree of saturation B: 0.95**
Hydraulic gradient I [–]:	Hydraulic conductivity k [m/s]	Hydraulic conductivity k_{10} [m/s]	Mean k_{10} [m/s]
2	$3.7{\cdot}10^{-7}$	$2.7{\cdot}10^{-7}$	
4	$2.1{\cdot}10^{-7}$	$1.5{\cdot}10^{-7}$	$1.6{\cdot}10^{-7}$
6	$2.4{\cdot}10^{-7}$	$1.8{\cdot}10^{-7}$	

Table 2 Results of determination of hydraulic conductivity material used for granulation

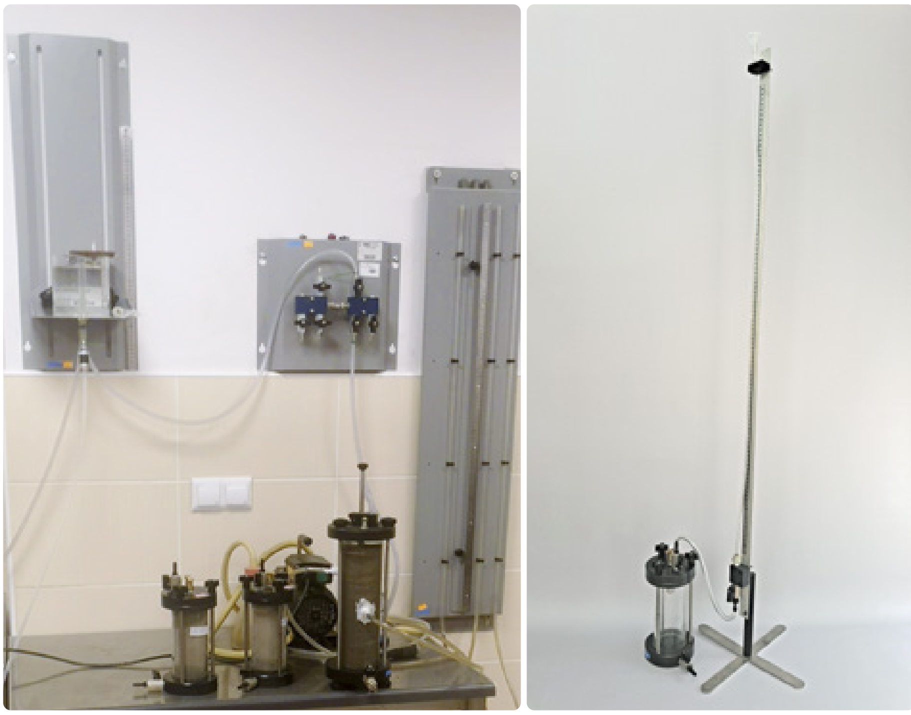

Photo 3. Set for testing the filtration with a constant head (left), next to the apparatus for measuring the hydraulic conductivity with a falling head

In order to form samples in a loose dense, the sub-compaction method [6] was used, consisting in dividing the target mass of the sample into a certain number of equal parts, e.g. five, bringing them to a moisture content of approx. 3%, at which the volume occupied by the soil significantly increases, and then tamping layers to specific heights, so that each successive layer in a controlled manner contributes to the compaction of the underlying layers. After the samples were formed into the cylinder, a vacuum pump was connected (to deaerate the sample) to a supply line in the top cover of the cylinder (closing all valves and outlets to create a vacuum). After about 15 minutes of deaeration, a water supply (deaerated) was connected to the bottom valve in the base in order to saturate the sample. The pump was turned off when the cylinder was full of water. In the chamber (with three outlets) for filtration tests, with a constant head with a constant drop in the place where the tubes were attached, home-made filter meshes glued to the rings printed with a 3D printer had to be used in order to prevent the soil from escaping from the sample. It was observed that in the case of determining the filtration of coarse-grained soil in a loose dense, a vacuum pump should not be used, because undesirable initial soil compaction occurs.

The determinant of the end of the deaeration stage of the sample is the observed steady, continuous flow of water (without disturbances related to air bubbles). Removal of air from the sample requires an appropriate time, depending on the type (grain size) and condition of the soil in the sample (from several minutes to even several hours for soils with a higher proportion of fine fraction) [4].

At least 4 determinations of the hydraulic conductivity were performed on one sample for a given density index. The determi-

Photo 4. Nets replacing pore stones

Source: Own study

Lp.	Share of granulation [%]	Porosity n [–]	Density index I_D [–]	Average hydraulic conductivity k_{10} [m/s] determined by the laboratory method:	
				Constant head	Falling head
1	+ 0	0.34	0.90	1.00E-04	4.81E-04
2	+ 0	0.36	0.70	1.16E-04	7.34E-04
3	+ 0	0.39	0.50	1.89E-04	8.88E-04
4	+ 0	0.41	0.30	2.18E-04	6.32E-04
5	+ 10	0.27	0.90	3.21E-06	2.21E-06
6	+ 10	0.30	0.70	5.13E-06	3.19E-06
7	+ 10	0.33	0.50	6.37E-06	4.50E-06
8	+ 10	0.35	0.30	2.13E-05	1.70E-05
9	+ 30	0.26	0.90	2.91E-07	3.28E-07
10	+ 30	0.30	0.70	5.10E-07	4.98E-07
11	+ 30	0.33	0.50	1.20E-06	1.03E-06
12	+ 30	0.36	0.30	1.43E-06	1.38E-06

Tab. 3. Summary of the results of determining the hydraulic conductivity t of granulated soils

nation of the hydraulic conductivity with a falling head was made according to the formula:

$$k = \frac{al}{At}\ln\left(\frac{h_0}{h_t}\right)$$

where:

- a – pipe cross-sectional area in which the lowering of the water column takes place, [cm²; m²];
- l – sample height [cm; m];
- A – sample cross-sectional area [cm²; m²];
- t – time of falling water column [s];
- h_0 – initial height of the water column (at the start of the test) [cm; m];
- h_t – height of the water column in time t [cm; m].

The general formula for determining the hydraulic conductivity with a constant head is as follows:

$$k = \frac{Ql}{A\Delta h}$$

where:

- Q – flow rate [cm³/s; m³/s];
- l – distance between measurement points [cm; m];
- A – sample cross-sectional area [cm²; m²];
- Δh – hydraulic height difference [cm; m].

Research results

The test results presented here allowed an evaluation in terms of the potential influence of the test method and compaction of the material, depending on the degree of granulation, on the results of the determination of the hydraulic conductivity *t*. A summary of the test results obtained (average values) using the laboratory method is provided in table 3. A total of 4 to 5 replicates were performed in each group at a given density index (i.e., about 70 determinations).

The obtained results of the hydraulic conductivity t determination indicate that the hydraulic conductivity t decreases with the increase of the fine fraction. In natural soil, the value of this parameter was 10^{-4} m/s, the granulation in the amount of 10% reduced the value of the hydraulic conductivity t to 10^{-6} m/s, and the granulation of 30% to the value of 10^{-7} m/s, regardless of the selected group of methods laboratory tests (groups I – constant head and II – falling head). Both methods gave the most similar results when filtering the granulated material in the amount of 30%.

The data presented in table 3 and fig. 2 also show a clear relationship between the changes in the hydraulic conductivity (k) and the effective pore diameter caused by the increase in the density index (I_D). This indicates an additional need to take into account the soil condition when estimating the value of the hydraulic conductivity [3, 4].

Conclusions

Soil granulation caused a change in the value of the C_U coefficient of uniformity. The value of this coefficient changed from $C_U = 2$ to $C_U = 4$ for 10% granulated material and $C_U = 19$ for 30% granulated material.

The obtained values of the hydraulic conductivity have the same order of magnitude regardless of the chosen research methodology, however, the scatter of the results in the case of the falling head method is greater (fig. 2). Based on the obtained results of determining the hydraulic conductivity, in the case of granulated soils with a hydraulic conductivity of ≥ 10^{-7} m/s, due to the described conditions of the measurement technique, it is recommended to use constant head methods. Standard methods, using the falling head technique, do not ensure full control over the test performed, and more precisely the control of boundary conditions, due to the flow rate (it is impossible to exclude the so-called privileged filtration paths and the

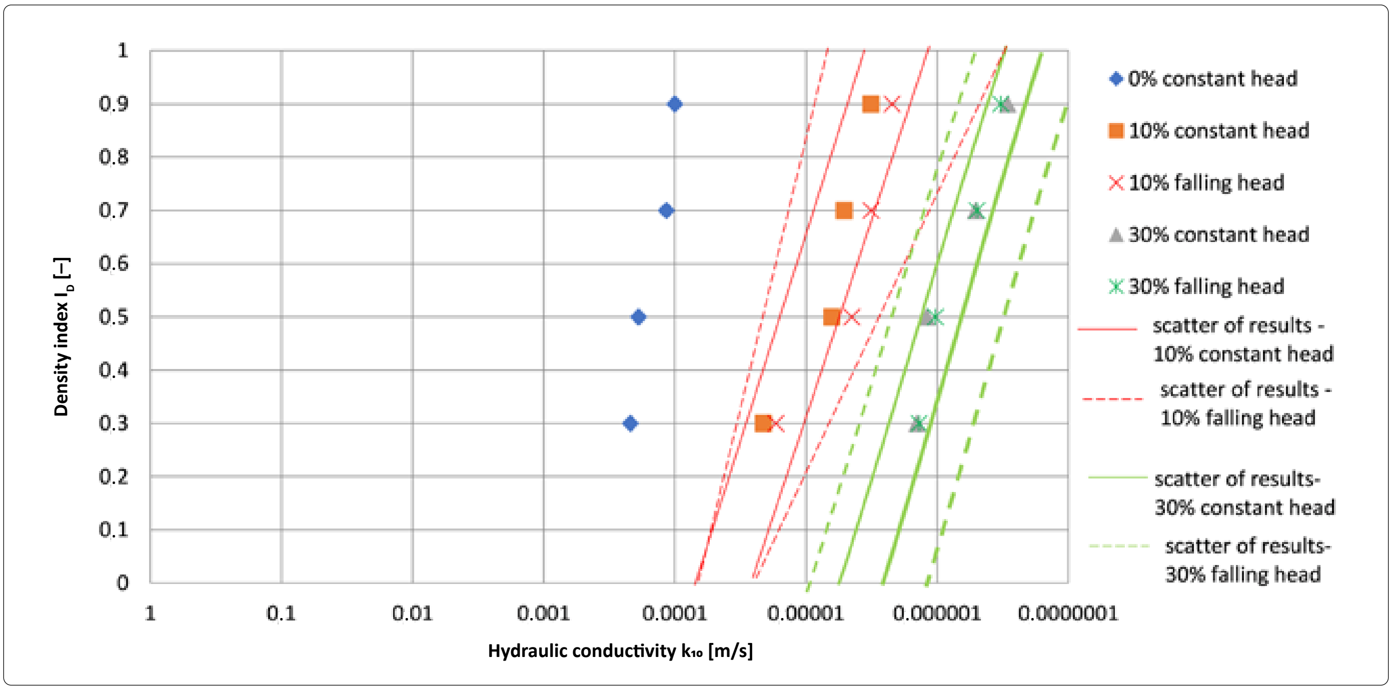

Fig. 2 Distribution of the determination of the hydraulic conductivity by the constant- and falling head method for 10% and 30% granulated materials, distinguishing the mean of the determinations.

possibility of incomplete saturation of the sample with water) [12]. Another limitation is the long duration of the test itself.

In addition, a good alternative to the above. The method is the method of stabilizing gradient at a fixed flow (the so-called flow-pump technique), in which a constant velocity of water flowing through the sample is forced, and the pressure difference at the ends of the sample is measured [12].

In conclusion, it is important to remember the appropriate choice of test methods that will ensure the correct estimation of the value of a given parameter at the stage of design and implementation of structures. In this aspect, in design practice, the determination of the direct hydraulic conductivity of soils is much less frequently indicated than other strength or deformation parameters, despite the fact that limit states for hydraulic damage are as important as bearing capacity or stability [13].

In the case of coarse-grained soils in large projects (class I-II hydrotechnical facilities, drainage of deep excavations, etc.), field methods are used due to the fact that they take into account the heterogeneity of the graund, and their result is usually the upper estimate of the filtration parameter, which is more important due to the design of the drainage [12]. In the case of objects of lower rank and with a limited scope of impact, often only empirical formulas are used, which have certain limitations and application ranges that must be strictly adhered to [3]. It is a rare practice to use laboratory tests, especially in the field of coarse-grained soils, due to the described issues of sample preparation and testing. These activities, as shown in the article, are subject to rationalization, because taking into account the purpose of the test and the characteristics of the material, it is possible to apply the optimal test method. In addition, as our own experience shows, a necessary condition for the correct determination of the filtration of a given medium is the collection of a representative sample, and in the case of testing reconstructed or granulated samples, it is also necessary to obtain information about the density index in which a given soil is or to what state it will be compacted.

BEng. Krystyna Jaśkiewicz
phD, DSc Tomasz Godlewski, prof. ITB
Building Structures, Geotechnics and Concrete Department, Building Research Institute, Warsaw, Poland

Photos come from authors archives.

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Environmental disaster on the Oder

In the past year there have been many publications attempting to explain the ecological disaster on the Oder River. Unfortunately, many of them were incomplete and often unreliable, placing the responsibility for the ecological disaster on hydraulic infrastructure and the navigational use of the river or natural phenomena. In order to present the ecological problems of the Oder in a reasonably objective manner, it is essential to present facts related to the current use of the river for various purposes.

The public would like to know what the basic cause of the massive fish death was. The Oder has been used for navigation purposes for many years. This is evidenced by the 187 kilometer long, canalized upper section of the river, which has 17 navigation locks, and the 459 kilometer long trained section that has free surface flow. In order to discuss in detail the water quality problem that has occurred, it is necessary to present the conditions of the river's development, as well as hydrological and hydraulic conditions.

Source: Wikipedia, Hanno Böck

Photo. The massive fish death in Odra river

Determinants of an environmental disaster

Any major disaster is usually the simultaneous confluence of many factors that create an unpredictable phenomenon. These singular factors usually cause the situation to worsen, but do not cause the disaster. This was the case with the environmental disaster on the Oder. The unfavorable hydrological condition of the river (low water levels) was compounded by high discharges of nutrients and saline waters, causing the formation of dangerous toxic compounds that resulted in massive fish deaths . In the absence of reliable information about this disaster, many people expected that full information about the situation will be provided. I will try, to the best of my knowledge, to present at least a brief version of the course of the disaster. I will begin by presenting the characteristics of the Oder and its basin and how it was used.

The Oder is the second largest river in Poland. Its total length is 854 km, of which we have 742 km (85%) in Poland. The mouth of the Oder is in the Szczecin Lagoon, and its source is located in the Czech Republic in the Sudeten Mountains, at an altitude of 634 meters above sea level. The transboundary section with Germany is 162 km long. The average annual discharge at the mouth of the Oder into the Szczecin Lagoon is 535 m³/s. The area of the Oder basin is 119 thousand km² (106 thousand km² – 89% in Poland). The Oder basin in Poland covers 34% area of the country. The Oder is divided into 3 sections: the upper – from its sources to Kędzierzyn-Koźle (the beginning of the navigation channel), the middle to the mouth of the Warta River, and the lower to the mouth of the Szczecin Lagoon. The Oder basin is located on the territory of 6 voivodeships and 5 Regional Water Management Boards. In the upper section there are more than a dozen barrages with navigation locks of various parameters. On a considerable length the river is trained (built up with groynes) and flows freely. Regulatory structures are partially destroyed. The parameters of the Oder and its basin indicate that Poland and its organizational management units are entirely responsible for this river. The Oder basin consists of more than 20 catchments located mainly in Poland. Within these catchments there are 19 retention reservoirs.

The total volume of these reservoirs is 805 hm³, which is 4.8% of the average annual outflow of the Oder into the Szczecin Lagoon. This is less than the average for Poland as a whole (6.5%). The Oder is not a water-abundant river, but it has very often experienced significant surges and flood levels (1997 flood of the century). The Oder is a river with a very diverse character. There is a large flood control reservoir Racibórz (commissioned in 2020) on the upper Oder. Also to be considered in the Oder system is the 42 kilometer long Gliwice Canal, connecting Kędzierzyn-Koźle with Gliwice. It served a very important transportation function.

A very important piece of information can be drawn from the 2022 cataclysm. Taking into account the quantities of dead fish that appeared after the cataclysm, it can be assumed that the fish state of the river was very good, despite the existence of many hydraulic structures of various kinds on tributaries and on the main channel of the Oder. For many years, environmentalists have presented us with information that any technical interference with the river will cause a deterioration in the state of biodiversity and the state of the river's fish stocking. The state of fish stocking of the Oder is a clear proof that, in contrary to what environmentalists suggest, fish have been able to adapt quickly to the changed conditions of the aquatic environment caused by hydraulic engineering structures (training or canalization).

In 2017 Poland signed and ratified the AGN Convention committing to transform the Oder into the E30 international navigation waterway. This was a very important challenge, committing Poland to many changes on this river. There were plans to create a navigation canal linking the Oder with the Danube, to build the Silesian Canal linking the Oder with the Vistula , to increase the transit depth of the Oder to 4.50 meters, or to open a number of ports and inland transshipment facilities. These were plans far beyond our financial and implementation capabilities. More recently, as a result of the war in Ukraine and perturbations in the economy, inland water transport has lost its priority.

In summary, it can be stated that over the many years that have passed, the Oder has undergone modernization for inland navigation purposes, and there were extensive plans for further use of the river for these purposes. Recent developments in world and economic politics have significantly changed the approach to this problem.

Climate change and its consequences

In water management, we usually have three different water crises depicted by the following aphorism **WATER: too much, too little, too dirty**

So far, we have most often had the following situations: too much water - surges and floods, too little water – droughts. Nowadays, the third situation becomes increasingly common: water too polluted. This situation occurs at low flows, when the amount of polluted discharges is constant and, relative to the low flow in the river, causes significant pollution, which can be very harmful. At high flood flows, there is uncontrolled water runoff collecting a lot of pollutants. Thus, despite the high flow, the amount of pollution can also be significant and dangerous.

Current climate change is making the occurrence of extreme situations more frequent. Such a situation was encountered in July 2022 on the Oder . There was a period of very low flows caused by low rainfall. Unfortunately, the water authorities conducting measurements on the rivers did not react properly by demanding a reduction in the volume of polluted water discharges. The situation was not specified in detail and the amount of polluted water according to the water permit was referred to the average flow, not the actual flow. Thus, the discharge of wastewater containing nutrients (phosphorus and nitrogen) caused a significant increase in phytoplankton. The discharge of saline industrial and mine water may have caused the proliferation of so called golden algae, which produce toxins that kill fish and other aquatic fauna. This has caused massive fish deaths. Increased water temperatures as a result of high air temperatures exacerbated adverse processes in the aquatic environment.

In summary, it can be clearly stated that the ecological disaster on the Oder in no way results from the natural hydrological conditions, over which we have no control, or from the hydraulic development of the river, but from the irresponsible discharge of sewage and saline water on these changed conditions. This is the responsibility of the relevant organizations that exist within State Water Holding Polish Waters.

Future actions on the Oder

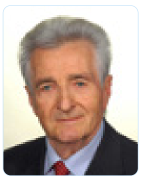
First of all, the river should be cleaned of dead fish as soon as possible, as their decaying remains cause an additional threat to the Oder waters. The second very important action will be to bring the quality of the Oder's waters to a good state. It is imperative to stop, or at least minimize, the discharge of polluted and saline waters. After that, it will be possible to think about restoring the river's fish stocking status. In the current situation, there are proposals from environmentalists to renaturalize the river, even to demolish of some hydraulic structures. I believe that the proposed renaturalization of the river and its tributaries will not benefit neither nature nor the economy. It will not improve hydrological conditions or equalize river flows over time, which we must be prepared to expect with climate change. When proposing the demolition of certain hydraulic structures, the question should always be asked: what purpose is this demolition to serve, what effects will it bring, and who is to pay for this costly activity?

The future of freight shipping on the Oder

Poland signed and ratified the AGN Convention in 2017, committing to bring the Oder as the E30 navigation route up to international standards. In view of the currently very low inland traffic in Poland, a thorough economic, social and ecological analysis should be made: whether we should continue this activity, or postpone it, or abandon it altogether even in the long run.

The future of water management in Poland

Poland has very modest water resources, either overall or per capita. Only in the interwar period the government of that day understood the importance of this branch of the economy by undertaking a number of significant investments. In the post-war period, water management did not find an important place in the country's economy by any government. The only brighter period in the development of water resources management was the period of operation of the Central Office of Water Management (CUGW) from 1960 to 1972. However, for unknown reasons, the CUGW was dissolved and water management was parcelled out to a number of ministries leading to its demise. Currently, in accordance with the Water Law, there is a National Water Holding "State Waters", which is under the Ministry of Infrastructure. As the cataclysm on the Oder has shown, the Polish Waters has not been able to properly approach this problem. Under Polish conditions, water management should be a separate ministry. If Poland does not take appropriate measures in the near future for the development of water management and its importance in the country's economy, a series of various kinds of costly disasters may await us, in the face of expected climate change.



Prof. Wojciech Majewski
Institute of Hydro-engineering
Polish Academy of Sciences in Gdansk
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