HYDROELECTRIC

# A new role for pumped hydropower storage?

**Hydropower is beginning to find a new role in expanding and complementing variable renewable energy sources through its flexibility capabilities, writes *Will Henley* from the International Hydropower Association.**

Floating photovoltaics at the Alto Rabagão pumped storage reservoir, Portugal
*Photo: EDP 3*

Unless greenhouse gas emissions fall by 7.6% each year between 2020 and 2030, the world will not halt the rise in global warming to 1.5°C. This was the stark assessment of the United Nations *Emissions Gap Report 2019*, published last November. Even more worryingly, at our current trajectory we are heading for a 3.2°C temperature rise, according to the report, which then called for a significant upscaling in decarbonisation and investment in renewable energy.

Despite the scale of the challenge, there is reason to believe that policymakers are beginning to grasp what needs to be done. There is momentum both in terms of reducing carbon emissions and also in preparing for – and increasing resilience to – the impacts of climate change. The European Union has already set a minimum target of achieving at least 32% of its energy share from renewables by 2030 and is now targeting a 'climate neutral' continent by 2050.

Such an ambitious policy agenda is spurred by dramatic cost reductions in variable renewable energies (VRE), such as solar and wind power, which are now competitive with thermal power sources. But as countries seek to replace coal, and in some cases even nuclear, in favour of solar and wind power, national authorities are recognising that massive VRE deployment brings its own unique challenges. Put simply, when the wind isn't blowing and the sun isn't shining, another energy source needs to kick in.

### Accommodating intermittence

With comparatively low levels of VRE penetration, power networks can easily manage and balance fluctuations in supply using low impact and existing conventional generators. However, as investment in VRE continues to expand (and in some countries displaces conventional generators) grid operators need to manage much higher uncertainty and variability.

This means alternative sources of dispatchable, flexible power generation and storage need to be found to accommodate the intermittency of VRE. As a result, attention is now turning to a trusted, if often overlooked, old friend: hydropower.

For decades, run-of-river and storage-based hydropower stations were seen as the workhorses of power grids, providing reliable, continuous baseload electricity as well as providing vital freshwater management services. In the modern age, however, hydropower plants are increasingly playing a more sophisticated role, responding to peaks and troughs in supply and demand, in particular from the more volatile VRE sources.

Hydropower offers natural flexibility to a modern power grid as operators can vary water flow through turbines to control generation and support imbalances in the system caused by an influx of solar and wind energy. Crucially, hydropower can also perform the role of a battery through pumped hydropower storage (PHS).

### Rechargeable water batteries

PHS works by pumping water up to an upper reservoir from a lower source, and then releasing the water on demand through a turbine to generate electricity. As battery forms go, few are cleaner or more reliable than these.

PHS is seen as a renewable integration tool because of its unique attributes, such as its wide operating range and its ability to deliver massive amounts of power within seconds – and for durations up to an entire day. By storing excess energy at periods of low demand, PHS is by far the leading form of energy storage used worldwide.

First developed at the turn of the 20th century, it wasn't until the Second World War that major PHS projects began to be constructed. The majority were built in the 1960s and 1980s. However, since the early 2000s there has been renewed interest in PHS from a number of countries – most notably China, which has added 15 GW since 2010 – as well as other emerging economies and the EU.

In the modern age, the vast storage capacity provided by PHS will be critical as countries continue to invest in VREs. The International Hydropower Association (IHA) estimates that PHS accounts for over 94% of global installed energy storage capacity, at 160 GW, with

9,000 GWh in current storage. In comparison, the total energy stored within the fleet of utility-scale batteries deployed is estimated at just 7 GWh. By 2030, IHA predicts an additional 78 GW of PHS capacity will have come online, with more than 100 projects in the pipeline around the world.

### Interconnections

The huge potential for pumped hydropower to support variable renewables is becoming increasingly clear in today's interconnected world. With the development of regional power pools, electricity can now be traded between power systems to adapt to regional variances in supply and demand.

This means that changing weather patterns, leading to rapid decreases or increases in solar and wind power generation, can be easily accommodated using the storage provided by hydropower reservoirs elsewhere. Equally, VREs can help reduce the impact of droughts on hydropower production, allowing water to be conserved for agricultural or municipal use.

For example, through Nord Pool, the European power exchange consisting of Nordic and Baltic countries, Norway's large hydropower capacity provides load balancing for Danish wind power generation. Denmark can therefore export electricity generated by wind power during times of oversupply and import hydroelectricity from Norway in times of low wind production.

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### Hybrid projects and 'floatovoltaics'

At the local level, the complementarity of wind, solar and hydropower also extends to siting installations in close proximity. This has resulted in a rising number of co-located projects involving the hybridisation of two or more renewable energy sources in a single power station (wind-hydro, solar-hydro or solar-wind-hydro).

A notable example of a hybrid project is the solar PV-hydro system at Longyangxia, on the Yellow River in China. This hydropower station was originally designed and commissioned in 1992 as the first load-peaking and frequency regulating power plant for the country's north-western power grid. Then, in 2013, a solar PV park was commissioned and connected to the grid via the hydropower station.

The Longyangxia reservoir supports a 1,280 MW power station with four 320 MW turbines, while the PV plant has an installed capacity of 850 MW, covering a 27 km$^2$ area, and is directly coupled to one of the turbine units by a 330 kV transmission line.

This project pioneered the development of a joint hydro/PV operation control system, which allows for almost instantaneous compensation between hydropower and PV generation. The power output of the PV plant is adjusted using the hydropower turbine to achieve a smooth and stable output curve and provide dispatchable, reliable power to the grid.

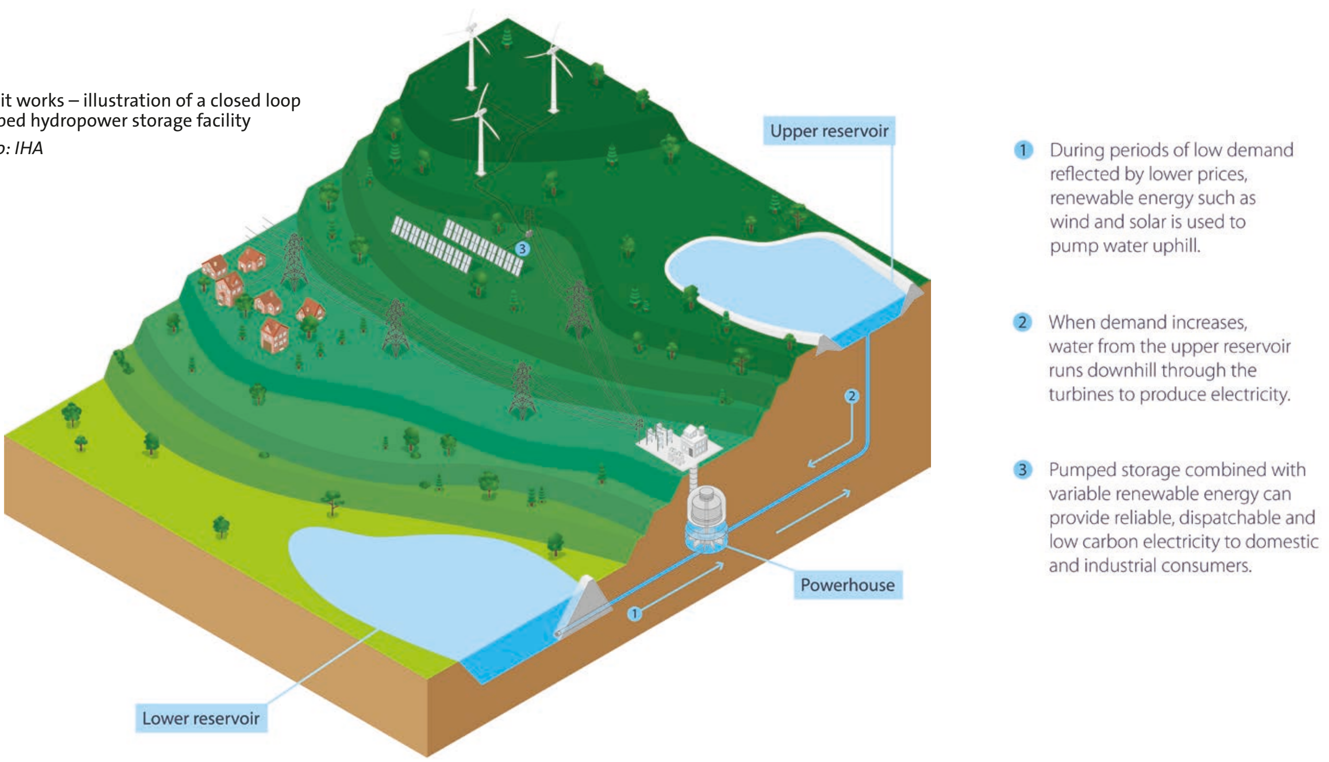
Another emerging trend involving co-location is the retrofitting of floating PV, or 'floatovoltaics', on hydropower reservoirs. This can bring a range of additional benefits such as increasing PV panels' efficiency on the water surface and improving the utilisation rate of existing transmission assets. Worldwide installed capacity in floatovoltaics grew from 10 MW at the end of 2014 to more than 1.3 GW by the end of 2018.

One of the pioneers of floating solar was Energias de Portugal (EDP) which successfully demonstrated the technical feasibility of retrofitting floatovoltaics at its Alto Rabagão pumped storage project in northern Portugal. The pilot project comprises 840 solar panels occupying a total area of 2,500 m$^2$, with an installed capacity of 220 kW and estimated annual output of 300 MWh.

From project conception to commissioning, the deployment process took only a year and a half, and just three months for assembly and construction. The pilot also verified that the floating photovoltaics installed on the Alto Rabagão dam were more efficient than photovoltaics situated on land at a conventional terrestrial solar plant in nearby Pousada de Alto Rabagão.

The Natural Heritage Institute (NHI) suggests that, with almost 6,000 major hydropower reservoirs operating around the world, the total global potential for retrofitting floating PV at hydropower reservoirs could be enormous. To encourage solar augmentation of hydropower, it is looking to develop a rapid assessment tool to identify,

How it works – illustration of a closed loop pumped hydropower storage facility
*Photo: IHA*



## Cutting-edge hydropower technologies

The European Commission, together with a consortium of 19 organisations – including utilities, equipment manufacturers, universities, research centres and consultancies – has announced a €18mn energy innovation project to demonstrate the viability of emerging hydropower technologies and approaches that enhance integration with renewables.

The Hydropower Extending Power System Flexibility (XFLEX HYDRO) project was launched at the UN Climate Conference (COP25) in Spain last December. It aims to test the limits of hydropower beyond traditional operating standards, while mapping the flexibility requirements of modern grid systems with higher penetrations of renewables.

Technology demonstrations are taking place at seven hydropower plants in France, Portugal and Switzerland over a four-year period. Key to the project is a new smart control system to monitor turbine dynamics and optimise energy performance, which uses algorithms to simulate and automate control of hydraulic turbines in real-time.

The project will see the installation of a battery hybrid at a run-of-river hydropower plant, adding energy storage capabilities to enhance turbine control. Measures to extend the operating range of generation-only, reservoir storage hydropower sites will also be demonstrated. Variable speed pump-turbines will be trialled, using high-powered double fed induction machines at one site, and a full-size frequency converter at another. Hydraulic short circuit, which involves simultaneous pumping and generating, will also be tested at both fixed-speed and variable-speed sites.

The XFLEX HYDRO project will result in technical and policy recommendations for operators, markets and governments. Innovations will be presented in Costa Rica in May 2021 at the next World Hydropower Congress.

Powered by almost 100% renewable energy, including 80% from hydropower, Costa Rica is an example of a country that has delivered clean, reliable and affordable energy to all, thanks to hydropower and variable renewables working together. Indeed, all countries that have come close to achieving this milestone – Costa Rica, Iceland, Paraguay and Norway – have a large portion of hydropower in their energy mix.

assess and rank the suitability of existing hydropower reservoirs for floating PV deployment.

### Today's technology

Looking to the future, record global investment in solar and wind power has clearly captured the attention of the public and raised hopes for the transition to a greener energy future. Amid this excitement, some sceptics have sought to cast hydropower as 'yesterday's technology', while others have even advocated replacing hydroelectric dams entirely with solar or wind installations.

But without hydropower's flexibility and storage services, countries risk returning to fossil fuel-based power plants or less environmentally friendly battery sources to support demand from variable renewables. Working in concert with solar and wind, renewable hydropower can help the world make good on global decarbonisation goals and close the carbon emissions gap.

Will Henley is Head of Communications at the International Hydropower Association (IHA).