Mining towards renewable energy

Stantec examines how pumped storage can be an ideal solution at mine sites

The Dinorwig pumped storage scheme in north Wales, UK

Mine sites can offer the ideal infrastructure for the development of pumped storage hydropower projects post closure and have the potential to add a considerable amount of renewable energy to the power grid.

Pumped storage is the modified use of conventional hydropower technology. Projects store and generate energy by moving water between two reservoirs at different elevations, as shown in Figure 1. The system is a 'closed loop', which eliminates the need to dam a river.

Pumping the water uphill for temporary storage creates a 'rechargeable battery'. During periods of high electricity demand, water is released back through the turbines to generate energy like a conventional hydropower station.

Pumped storage projects are viable as they often use low-cost excess 'grid' power to pump and generate power when the arbitrage price of power exceeds the cost of pumping.

PROVEN TECHNOLOGY

According to the International Hydropower Association, pumped storage accounts for over 94% (9,000 gigawatt hours) of installed global energy storage capacity, and retains several advantages, such as lifetime cost, levels of sustainability and scale.

Pumped storage is available at almost any scale. The largest operating pumped storage plant is just over 3,000MW and the smallest plant is less than 1MW. Storage volumes and generation times range from several hours to a few days.

"Pumped storage accounts for over 94% of installed global energy storage capacity"

Other renewable energies, such as wind and solar energy, tend to stop and start abruptly, causing steep MW per second ramp rates to occur. When the power grid is not in perfect supply and demand balance, frequency or voltage problems occur.

However, pumped storage allows grid operations to manage the grid response to changes almost instantaneously, to generate power when needed and to be a load consumer in times of oversupply.

As governments push for higher renewable penetration percentages, the need for ultra-fast energy storage response becomes crucial to the reliability and security of the power grid. In fact, the existing 161,000MW of pumped storage capacity is currently forecasted to grow by 78,000MW by 2030.

EXISTING MINE SITES

Due to the infrastructure, location and water storage capacity at existing mine sites, private developers are proposing that a significant portion of the global pumped storage capacity be used at these sites.

As seen in Figure 2, existing mine sites offer a unique opportunity to evaluate the potential of mine pits post closure for use as flooded reservoirs for pumped storage. Current pits that were developed for coal, aggregate and gold resources are being evaluated and considered for pumped storage.

Post closure, the presence of either one or two pits offers mining companies the opportunity to consider the value-added opportunity of the pits for use as upper and lower reservoirs at new pumped storage projects. Many mine sites around the world are being considered for use as pumped storage sites, with generation output typically ranging from 1MW up to 1,300MW.

Planning for pumped storage at existing mine sites has already begun in some cases. For example, Stantec, along with SCI, is involved in the development of pumped storage projects on abandoned and operating mine sites located on First Nation lands throughout Canada. The joint venture has agreements with 11 First Nations to manage the development (design, permitting, financing, construction management and operations) of seven pumped storage projects, which if developed will deliver 6,400MW of generating capacity.

A notable example is the 1,728MW Dinorwig pumped storage scheme in north Wales (UK), as seen in the lead image. Fully commissioned in 1984, the station is a prime example of an abandoned slate quarry being utilised to develop pumped storage generation.

The Dinorwig pumped storage scheme includes an underground powerhouse that supplies the National Grid in the UK. When the plant officially opened in 1984, it was regarded as one of the most imaginative engineering and environmental projects in the world, and to this day, it remains the largest project of its type in Europe.

A WIN-WIN

The main attraction for developing a pumped storage scheme at an open-cast mine site is the utilisation of the existing infrastructure. Underground tunnels and caverns can be used for the storage, although these are not as common as open-cast sites. Positioning an upper storage pond on the surrounding elevated positions at an existing mine site can help to develop a differential head with the main pit. Using the main pit as the lower storage reservoir eliminates the need to construct a dam to form the lower storage. The greater the difference in elevation profile and net hydraulic head, the less water is required to generate the same energy output.

As a result of previous mining operations, mine sites have a good chance of already being understood geologically and geotechnically. Additionally, the lithology, structural and hydrogeological aspects of mine sites are typically documented as well, which can expedite studies.

The transformation of a mine site to a pumped storage facility may also present an opportunity to restore the land to a safe, stable and self-sustaining condition with due consideration to the surrounding environment and communities.

Mine sites often have in place suitable access, an electricity transmission grid connection and other site services, offering significant cost and permitting benefits. Although development costs will be required to establish the upper and lower storage reservoirs, the offset rehabilitation costs could be substantial, and an ongoing beneficial asset is created. The development of a pumped storage scheme could become a central feature of the mine closure plan.

Leveraging synergies between mine operations and the development of the potential pumped storage facility can help reduce capital costs and minimise the lapse between completion of mining activities and the commissioning of the plant. Using the mine fleet to cut back the pit slopes as they develop to a profile that meets the long-term civil engineering design parameters will likely cut costs compared to revisiting and stabilising the steep mine cut slopes at the end of mine operations.

The costs of additional work done by the mine fleet should be taken into consideration when evaluating pumped storage economics. For example, utilising the mine fleet to place waste rock material in locations favourable to the construction of the pumped storage structures, such as an upper reservoir embankment, could offer cost savings.

Integrating mine planning with hydropower planning for a pumped storage scheme will help address some of these issues but could become complex. A clear understanding of both aspects is necessary to ensure a successful project. The critical path for hydropower projects typically passes through civil construction of the powerhouse, installation and commissioning of the electromechanical plant and equipment. If the earliest commissioning date possible is the target for an active mine site and it is possible to commence civil construction prior to completion of mining activities, it is possible that the critical path may shift to completion of the mining activities, construction of the lower reservoir intake structure and completion of the tailrace conduit.

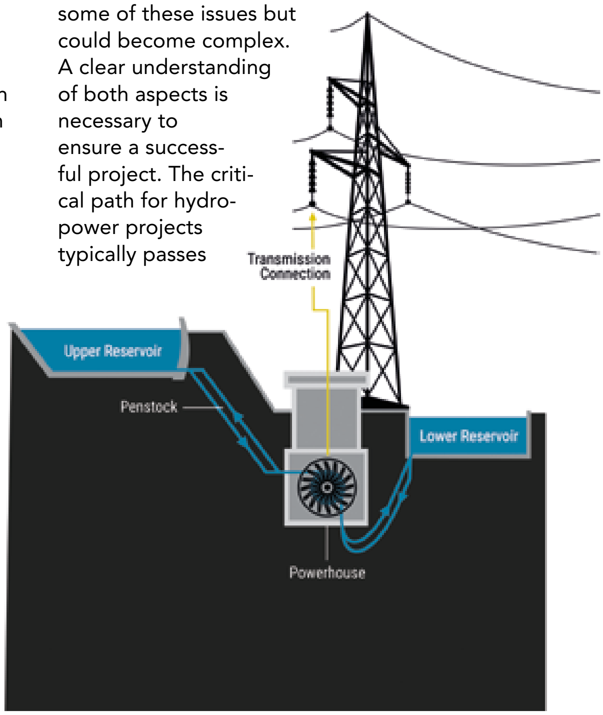

Figure 2: Pumped storage potential at existing mine sites

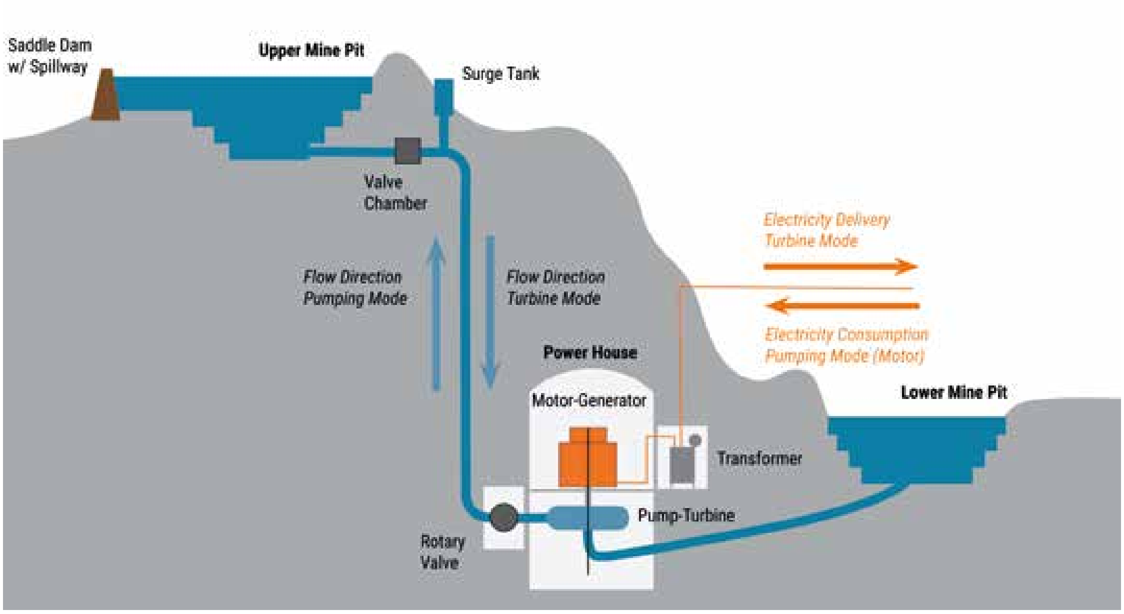

Figure 1: A schematic of a project storing and generating energy by moving water between two reservoirs at different elevations

The image of the Rocky Mountain pumped storage project in Georgia, US showcases the elevation differentiation needed for a successful pumped storage project

IDEAL PUMPED STORAGE SITE

The below table lists 10 basic criteria that can be used by mine operators to identify potential sites and to rank one site versus another. Some of these may not apply to a given site, but in general all of them should be considered. For example, topography would apply to a mine site where only one pit exists; the other reservoirs must be created but would not be as critical compared to a mine site with two pits with suitable elevation differential. All of the 10 criteria should be given additional attention as budget permits.

AN OPPORTUNITY

The efficient use of energy resources is a significant societal demand. While the benefits of this energy are recognised, achieving these aims within an integrated electricity grid poses a number of technical challenges. These challenges are often mitigated by grid operators through systems planning, and management via pumped storage hydro.

Other forms of energy storage, such as lithium batteries, lack the reliability that grid operators depend on. Mine sites come with preceding site data and offer ideal infrastructure for the development of pumped storage projects post closure.

Landowners are beginning to give these sites considerable interest as they may be able to extract additional revenue from their investment.

Characteristic	Preferred Situation	Rationale
Length to head ratios	Length to head – the smaller the better; less than 10 preferred. Gross head – the larger the better. Ideal 200m to 600m (minimum 100m, maximum 700m).	Total waterway length from upper to lower reservoir intake, divided by gross head (average upper reservoir water elevation minus average lower reservoir water elevation). Minimises costs and project footprint.
Topography	Varied topography.	Allows for reservoir construction with minimal excavation or embankments.
Geology	Sound, unfractured, consistent, limited faulting.	Limits reservoir leakage and foundation preparation requirements; provides suitable local construction materials.
Power capacity	Maximum megawatts.	Increases revenue potential. Pump loads are greater than generation.
Energy storage potential	MWh, increases revenue potential and operational flexibility. Typical minimum hours of storage is four hours, average is 6-8 hours, but can be 24 hours or more.	Product of plant capacity in MW and the hours of available storage (MWh); or potential energy associated with the upper body of water in relation to the lower storage space.
Construction	Powerhouse can be in a shaft or in a cavern. Water transfer pipe can be a tunnel or surface buried line.	Below 100MW often can have a shaft powerhouse. Larger schemes require a cavern.
Water availability	Plentiful, available, and nearby. First fill important, and annual top up for evaporation.	Reduces costs and risk exposure for first filling and replenishment water.
Environmental, regulatory and land use	Closed loop, limited environmental exposure, desirable land ownership.	Reduces costs, risk exposure, permitting requirements and development duration.
Electrical power transmission	Nearby and available transmission capacity. Higher the kV class of line the better.	Reduces potential costs of new T-lines and/or grid upgrades.
Power marketing	Large spreads, suitable partnership opportunities, multiple offtakers.	Increases revenue potential and ease of marketing; reduces risk exposure.