No batteries required: pumped hydro for solar energy storage

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Kidson Pumped Hydro Project

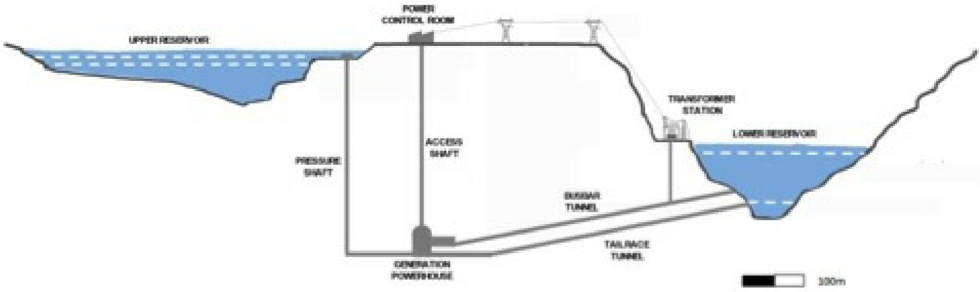
With the change-over from centralised fossil fuel power to distributed renewable energy, there is intense interest in battery storage to cope with intermittency of solar PV and wind power. There is no doubt that batteries will have a major part in the transition. Apart from flow batteries, however, the opportunities for multiple-hour storage and discharge at scale over a period of hours is still unresolved. It is implemented for cars and household storage and indeed the first steps to access power stored in the batteries of Electric Vehicles have already been taken.

The interesting thing about accessing EV batteries by the grid, is that the capital costs of these batteries have already been covered to provide transport. Hence the storage costs involve only accelerated wear and tear on the batteries which occurs when charging and accessing power (whether at home or wherever the vehicle gets connected to the grid). The amount of power available from a fully implemented EV program is astonishing. This is not yet realised as there are not enough EVs. Furthermore, the technology for accessing and managing this power is not yet implemented.

There is a complementary energy storage system that is well established globally, with ~143GW of storage currently accessed in 40 countries. This power can handle massive capacity requirements and also allows seasonal storage. This is pumped hydro and it is attractive because it involves recycling of water between adjacent upper and lower reservoirs which have a substantial height differential. The cycle efficiency of modern pumped hydro is ~80 per cent, which compares favourably with CCGT (Combined Cycle Gas Turbine) cycle efficiency of 30-60 per cent.

Most of these facilities involve flow-through water (i.e. they involve damming waterways); these were essentially all built more than 25 years ago.

Pumped hydro can also involve cycling between two storage systems that are not connected to a waterway. New generation reversible pumps/generators simplify the engineering and capital costs. Also variable speed pumps allow great flexibility in power capture/generation. Business models for implementing this type of storage are somewhat limited at this time.



Schematic for pumped hydro

Here I review an example of a corporate play in this space. It involves a small company listed on the Australian Stock Exchange, and gives a flavour of how this emerging industry might play out.
I also make some comments about what is happening around the world.

Genex Power (ASX:GNX) Kidson project

Australia has three well-established pumped hydro facilities: Tumut 3 in NSW (0.6GW), Wivenhoe in Queensland (0.5GW) and Shoalhaven in NSW (0.24GW). Genex Power plans to build the fourth significant pumped hydro project in Australia.

As envisaged when the company listed on the ASX in July 2015, the plan was to develop a 330MW pumped hydro project on the old Kidston gold mine, involving water transfer between two pits at different altitudes. Queensland is a good place to develop such a project as peaking power is primarily provided by gas turbine generators. With substantial increases in gas prices expected, this makes the project financially interesting.

The transactions involved in setting up the company for ASX listing are complex. The Kidston mine and associated infrastructure were acquired from the world's largest gold miner, Barrick Gold Corporation (NYSE:ABX). There is a 20GL dam, which was built to service the mine, 18km away. The Kidston project owns piping between the dam and the mine and it has water rights of 4.6GL annually should there be a drought.

The basic plan was to connect two dams which are located at ~190 metres vertically from each other. The initial plan involved 3 x 110MW reversible pumps, which will pump water from below to the top dam when there is excess power, or generate electricity via water from the top dam entering the lower dam. There is already a 132kV transmission line providing connection to the North Queensland grid and this will be enhanced with a further 275kV line.

There is also a planned 50MW solar PV farm, and this will be the highest quality solar resource in Australia, with strong community support. A binding agreement with Ergon Energy has been announced for power uptake. The planning for the solar PV farm in the old tailings area, can now proceed with the certainty that the power produced is sold into the grid and there is the possibility of extending this solar PV farm to 150MW.

The existing 132kV line from Townsville to Kidston means that no augmentation of the infrastructure power lines will be needed to service the solar PV project. The solar aspect of the project is advancing rapidly, as Genex has very recently entered into a debt-funding mandate with Societe Generale, which will cover most of the funds required for the project. Equity and grant funding through ARENA is actively being explored to cover the gap from financing provided through the Societe Generale agreement. Genex plans to commence construction of the solar facility in late 2016 and to generate first cash flow within 12 months of construction commencement (i.e. in 2017).

The close relationship between a solar PV farm and a pumped hydro project in the Genex business model is reminiscent of combined solar park/hydro facilities in China and Chile. Many pumped hydro projects are located in rugged terrain that is not suitable for solar farms, so the Kidston project is unusual in having elevation difference combined with a flat tailings area close by.

Since listing on the ASX last July, the pumped hydro project has developed significantly due to involvement of a key investor in the project, HydroChina, one of the largest hydro electrical and mechanical equipment manufacturers in China. HydroChina has a 3GW hydro equipment manufacturing capacity annually and it has installed 200 medium and large-scale turbine generators in 20 countries. It is a top three hydro equipment and service supplier (along with GE-Alstom and Andritz).

Experienced hydro consulting group Entura, which is owned by Hydro Tasmania, has been involved in consulting on project development, with really interesting results. The upshot is that a revised plan will deliver not 330MW (1.65 GWh) of power storage, but up to 450MW for 5 hours (2.2 GWh) depending on the final configuration. This involves building a new upper storage facility that is 35-40 metres higher than the originally envisaged facility, making the vertical drop 225-230 metres.

The new dam will be a cheap "turkey nest" construction that is lined to prevent seepage. A turkey nest dam is cheap to construct as it is shallow (5 metre depth), but has large capacity due to covering a large flat area. The cost of building 5 metre walls is dramatically different to a conventional dam construction where the water pressure of an elevated wall means substantial construction costs. An additional advantage of the revised plan is that less concrete is required due to the proximity between the new upper and lower dams. The plan also leaves an existing dam for storing excess water and for flood mitigation.

A critical issue for a pumped hydro project is that the project has strong state and federal Government support. ~$A2 million has been advanced through convertible notes to ARENA (Australian Renewable Energy Agency) towards the cost of the pumped hydro feasibility study. The project has been given "State Prescribed Project" designation and this has facilitated discussions with various Queensland government departments in the development phase. The solar PV aspect of the project already has environmental approval to proceed.

Of considerable interest is that Genex has identified as many as 12 other mining sites around Australia that may allow pumped hydro projects based on former mines. Of course each location has specific conditions that need to be addressed, so no single project is easily replicated. However there is no doubt that the experience of completing a major project of this type builds a knowledge base to take on additional projects.

So the Kidston site is a proof of concept that can probably be replicated. The scale of these storage opportunities suggests that if a funding model can be sorted out, pumped hydro can offer a substantial and complementary energy balancing opportunity to battery storage. There is a substantial report (2014) from the University of Melbourne Energy Institute detailing pumped hydro opportunities in Australia. This references a ROAM (2012) report which started with 100,000 potential sites and identified 68 sites for detailed analysis (53 freshwater and 15 seawater sites).

Identifying a site which is basically set-up, and using the best engineers to scope out the project, the Genex facility looks like it will be substantially cheaper than the generally accepted construction costs of $US1.5-2.5 million for 1MW storage capacity (assuming large capacity of ~1GW). If the Genex project is now an up to 450MW (instead of a 330MW) project that will cost ~$A300 million, this looks like a very cost-effective pumped hydro project, costing ~$US0.5 million/MW. Note that the construction cost includes an additional 275 kV line to the grid. Genex's goal is to complete the feasibility study for the pumped hydro facility in Q3 2016 and to begin power storage in 2019.

Pumped hydro in Europe

The first pumped hydro systems were installed in alpine Switzerland, Austria and Italy in the 1890's.

As one has come to expect from Europe in the renewable energy space, there has been substantial work done on assessing prospective sites for substantial pumped hydro power facilities.

A recent European Commission project addressed economically viable solutions to support large scale integration of intermittent renewable energy production into the EU electricity grid. The detailed 2016 report on pumped hydro storage identified paired water masses that were close together and separated by sufficient height to make substantial power storage and generation feasible (at least 1 GWh) in EU-15 countries, plus

Norway and Switzerland. The report is thorough and has been prepared with significant industry input. No realisable pairs were found in Denmark, Ireland, Luxembourg or the Netherlands. Only one or two pairs were defined in Belgium, Finland, Germany and Greece, due to insufficient slope (head divided by distance between the water bodies).

The report identified 6,924 GWh of substantial (more than 1 GWh storage) theoretical new pumped hydro power storage available in Europe, of which 2,291 GWh was classified as realisable potential. There were 714 paired water bodies identified as theoretically feasible, with 117 being chosen as realisable.

The grounds for defining realisable potential varied between countries, including issues concerning permitting and the granting of concessions. Decisions for inclusion included a combination of computer modelling and input from national hydro experts.

Note that the report only addresses situations where both water bodies already exist and therefore excludes situations where a second water body needs to be built. Notably this means opportunities where the sea might be one water body are excluded.

Unfortunately the most prospective pumped hydro regions in Norway, the Alps and the Pyrenees did not coincide with locations of major power generation or power requirement . However, the report notes that Europe's interconnected market allows power to be distributed between countries.

The report indicates that the pumped hydro storage identified is 7 times current installed European pumped hydro capacity and is equivalent to 95 million lithium ion batteries of the size used for electric vehicles. Three areas comprise 72% of the potential capacity : 54% Southern Norway; 13% The Alps (Austria, France, Italy, Switzerland, Germany); 5% the Pyrenees (France & Spain).

Since these sites are prospective it allows current best practice to be implemented, most notably this would involve use of variable speed reversible pumps/generators.

What is happening in the US?

While there are 40 pumped hydro facilities in the US, which provide 22GW of power storage, virtually all of this capacity was built more than 25 years ago. For example, Duke Energy (NYSE:DUK) has two substantial pumped hydro facilities, Bad Creek (1.06GW, commercial 1991) and Jocassee (0.71GW, commercial 1973), both in South Carolina.

In recent years, damming natural waters has become essentially impossible. However the realisation that burgeoning solar PV and wind power needed balancing has meant a resurgence of interest in pumped hydro; there are now 60 pumped hydro projects involving 51GW of power in the FERC (Federal Energy Regulatory Commission) queue for licensing and permitting.

Two large-scale opportunities (both in California) have permits and these have been under development for a very long time; they are struggling to raise capital. In fact there is doubt that either will proceed. Sourcing water to provide initial water supply and then annual replacement for seepage and evaporation are critical issues for these projects in California, which is experiencing a long-term drought.

There is a project starting out on the FERC approval process, Gordon Butte Pumped Storage based in Montana, that seems quite similar to the Genex project, although Gordon Butte uses a natural geological feature rather than an old mine.

Gordon Butte Pumped Storage will be located on private land. It is a closed loop facility that will access water from a nearby irrigation system, so (apart from denying water to irrigators, who presumably will be paid) the water source is not controversial. The head of water is ~300 metres and the dams will be connected by a steel-lined underground concrete shaft. The project requires 4000 acre feet of water to fill the lower dam and then ~400 acre feet of water annually to replenish water lost by evaporation and seepage. The facility will have 400MW/~3.6GWh installed capacity and an annual power supply/consumption of up to 1,300 GWh.

Major turbine manufacturer Alstom will supply the variable reversible pump/generators and the facility will be able to deliver power within seconds. Smart hydraulic short circuit pump technology, with pump and generator operating in the same shaft rotating in the same direction, will allow the system to pump water upwards and at the same time generate power. This will allow rapid balancing of renewable power, as well as increasing grid stability in Montana. This will be the first hydraulic short circuit pump installed in the US.

Japan

Japan's Okinawa Yanbaru pumped hydro facility, built in 1999, is the world's first system that uses sea water as the lower reservoir. It is small (30MW) and the water head is 150 metres. (How far this technology has moved is indicated by recent environmental approval in Chile for a 300MW facility with 600 metre head that has received environmental approvals and construction is planned to be completed in 2020. Like the Genex project, it will be coupled with a 600 MW solar PV facility.)

Japan had the world's largest installed pumped hydro capacity of 27.4GW in 2014.

Japanese Okinawa Yanbaru pumped hydro facility

China

China, with 21.5 GW pumped hydro, eclipsed the US (20.9 GW) in 2014.

While China only installed 1.2GW of pumped hydro storage in 2015 (compared with 18.2 GW of conventional hydro power added), interesting things are happening in coupling hydro power with renewable energy. In 2015 China implemented the second phase of its 850 MW Longyangxia solar park by coupling the power generation directly to one of four turbines at a nearby 1,280MW hydropower station. The advanced controls on the hydro turbine allowed variable solar power supply to be dispatched as firm power to the grid.

China plans to have 100 GW pumped hydro by 2025!

Conclusion

Like much of the renewable energy transition, finding appropriate business models to enable this major transition is not straightforward. This isn't a problem for a 'command and control' economy, and so China is powering on. Well-planned economies like Europe and Japan also have pumped hydro strategies well in hand. In the US there are still not clear investment opportunities for pumped hydro storage currently, but in free enterprise US there are a number of major projects emerging. Perhaps the coupling of solar PV (or wind) with pumped hydro is the way this will play out. Australian company Genex is an interesting example.

This article stems from my research on the latest developments in the Genex project. I liked what I saw so much that I recently bought some shares. So I declare an interest in Genex Power.

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