Hydropower: Not So Renewable After All?

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See footnotes at end of text.

Arguably, hydroelectricity is the ideal renewable technology for power generation.[1] It can operate to meet power requirements ranging from baseload to peak, can be brought on-line almost instantaneously and is thus ideal for regulating supply from solar and wind, and has a negligible short run marginal cost. However, the past few years have witnessed significant drought conditions, virtually globally, and in many countries the resulting impacts on power generation have been both costly and disruptive. In particular, it can have major repercussions for the world's poorer nations that rely primarily on hydropower for their electricity, with blackouts causing lost production, water restrictions, and, potentially, social unrest.

The Tasmanian Energy Crisis 2016

Tasmania is part of Australia's liberalized National Electricity Market, being joined to the mainland via the Basslink underwater interconnector to Victoria. Its electricity generation is primarily hydro and, as a result, the state is highly dependent on rainfall for electricity generation. Peaking capacity is provided by four gas turbines, with base load capacity from a combined cycle plant, all of which comprise the Tamar Valley Power Station. Due to high water levels and the interconnector, the combined cycle plant was thought to be redundant and was decommissioned in 2014 with the intention of it subsequently being sold.

However, on 20 December 2015 Basslink had to be shut down due to a cable fault offshore. This event coincided with a particularly dry period, leaving dams severely depleted, which meant that Tasmania's security blanket for such times of drought had been lost. Actions taken to minimise the consumption of water from Hydro Tasmania's storages included:

- Recommissioning of the gas-fired Tamar Valley Power Station;
- Striking agreements with the three major industrial customers – the two Tamar Valley smelters Bell Bay Aluminium and TEMCO, and Norske Skog's paper mill at Boyer - to reduce their load by a combined 180 MW;
- Deploying up to 200 MW of portable diesel generators; and
- Bringing Hydro Tasmania's cloud seeding programme, usually scheduled to start in May each year, forward by a month.

Despite these actions, wholesale power prices surged by more than 350% as a result of the crisis, and the economic "hit" to the state was estimated to be in excess of A$560 million. Fortunately, the gas pipeline from the mainland was still operational so that emergency supplies for the gas-fired power plants could still be delivered.

The Brazilian Drought Crisis 2014-18

The 2014–18 Brazilian drought has been a severe drought affecting the southeast of Brazil, including the metropolitan areas of São Paulo and Rio de Janeiro. As over seventy percent of Brazil's electricity is generated by hydropower there has been a concern that a lack of water may also lead to energy rationing in addition to water rationing. Thermal plants were used to fill the energy gap, but the switch was very costly. In response to decreased hydroelectric power, rolling power cuts have also been instituted.

The Brazilian water crisis is due not only to lower precipitation levels, but also to mismanagement of multiple uses of water. Clearly, hydropower plants are water-intensive and their energy production has been negatively impacted by water scarcity, resulting in failure to meet contractual power generation targets, legal uncertainty, and higher energy prices. In order to address these issues and support sustainable water management, the Brazilian government is currently discussing regulatory measures, including the implementation of a water market, which will reallocate water use, and prioritize collective agreements among water users.

A novel approach to the problem was to install floating PV arrays on dams to generate power when water supplies were depleted. The logic behind placing solar panels on dams is that hydro acts as a back-up for the variable output of the PV, and utilizes the same transmission infrastructure. Thus, water is "saved" during daylight hours. In addition, one of the most expensive aspects of grid scale PV is its associated transmission requirements which are avoided in this situation.

Floating solar panels are more efficient than land-based arrays, largely due to the fact that they have water on hand to cool them down. "Floatovoltaics" is also appealing because it is cheaper to float panels over water than to rent or buy land. In addition, they can be constructed more quickly than land-based installations, and more easily tucked out of sight. Finally, floating arrays also shade the water and consequently reduce algae blooms and water evaporation. Brazil's first floating solar arrays with a capacity of 304 kW came on-line in 2017. A further 5 MW of capacity is at the planning stage.

Zambia's Drought

Zambia has experienced daily 8-hour power-cuts since July 2015. Low water-levels at the main reservoirs for hydroelectric generation have led to a power deficit of about one-third of electricity demand. With the country's historically sufficient power supply, the sudden crisis has exposed low diversification of the fuel mix and caught households and businesses unprepared and without alternative or back-up sources of electricity supply. Left without electricity many households have reverted to charcoal for cooking, causing a spike in prices and accelerating the rate of deforestation. While only 22% of the population has access to electricity, the entire population has been affected indirectly through negative impacts on the economy and public infrastructure services.

Zambia's shortage of power generation capacity has been estimated at about 1000 MW, and without significant inflows into the dams in the short term the situation is likely to get worse, as demand is growing by around 200 MW annually without matching increases in supply.

Short term measures to alleviate Zambia's electricity crisis are in limited supply and, where they do exist (such as diesel generators), are costly. The past heavy reliance on hydropower means that alternative technology back-up capacity is limited. In addition, imports are expensive and of limited availability given the overall electricity supply shortfall across Southern Africa.

Longer-term measures to avoid, or at least mitigate, the impact of future crises are readily available, but at a cost. In this context, of fundamental importance is "getting the prices right"! The current all-pervasive subsidies for electricity consumers encourage consumption, discourage investment, and divert government funds from more efficient avenues of allocation. Since 2014 the IMF has been negotiating the terms for a U.S.$1.3 billion bail-out package (i.e., budgetary support) for Zambia, but one of the conditions relating to the electricity sector was that all subsidies and support schemes be removed. Negotiations have stalled, largely due to Zambia's high level of external debt. However, the end of electricity sector subsidies has been promised by the government by year-end 2018.

On the demand side, there appears to be few attempts to introduce energy efficiency measures, such as mandatory energy labelling or minimum energy performance standards for both consumer and industrial products, which are commonplace in more developed economies.

The New Zealand Model

Hydroelectric generation contributes around 60% of New Zealand's total electricity supply, with many generators of widely varying sizes distributed throughout the country. Inflows (rainfall and snowmelt) can be stored in hydro lakes until needed. However, the lakes have quite limited operating ranges – for technical and resource consent reasons, each lake's level cannot be lowered below a certain point. It is not possible, therefore, to completely "empty" a hydro lake. In the absence of inflows, the lakes can only hold enough water for a few weeks of winter energy demand.

For security of supply purposes, hydro storage is divided into two categories: controlled and contingent storage. Generators can use controlled storage at any time, but contingent storage may only be used during defined periods of shortage or risk of shortage. During sustained dry periods, controlled and contingent storage are important indicators of overall supply risks. Storage is expressed in gigawatt-hours – GWh (a measure of the energy that can be produced using the water).

New Zealand has a liberalized power market, and therefore (the theory goes) as prices climb during periods of unusually dry conditions additional, fossil fuel, plants (currently moth-balled) would be encouraged to return to supplying the grid. However, at present, one of the generators is paid to keep a 500 MW gas and coal power station constantly in reserve, which is really in conflict with the liberalized market model. The correct approach would be to offer a backup dry-year supply determined by auction, but the market is probably too small to deliver a competitive outcome.

The New Zealand model clearly relies upon a surplus of generating capacity (and not just hydro), particularly for dry years. Nevertheless, drought-vulnerable countries could perhaps adopt the concept of controlled and contingent storage, or more generally the concept of water management, adapted for domestic conditions.

Pump Storage

Pumped storage projects store and generate energy by moving water between two reservoirs at different elevations. At times of low electricity demand, like at night or on weekends, excess energy is used to pump water to an upper reservoir. During periods of high electricity demand, the stored water is released through turbines in the same manner as a conventional hydro station, flowing downhill from the upper reservoir into the lower reservoir and generating electricity. The turbine is then able to also act as a pump, moving water back uphill.

The power used to move water back uphill would generally come from surplus generation capacity from inflexible technologies such as nuclear, brown coal, solar, and wind. In other words, technologies which cannot be easily ramped down during times of low demand, or those that are variable in output and generate power when conditions are favourable irrespective of demand.

According to the IEA, pumped-storage hydropower is the largest and most cost-effective form of electric energy storage at present.[2] It claims that the current global capacity of pumped-hydro storage could increase tenfold as some existing hydropower plants could be transformed into pumped-hydro storage plants.

In South Africa, the 1332 MW Ingula Pumped Storage Scheme commenced full operations in January 2017. The plant uses water from the upper reservoir to generate electricity during the peak demand periods of the day. At night, excess power on the grid generated by conventional coal plants and a nuclear power plant is used to pump water back to the upper reservoir. However, there are currently no plans to build pump storage hydropower elsewhere in hydro-vulnerable neighbouring countries, probably because the inflexible technologies mentioned above do not currently exist in those countries.

Conclusion

The lesson that can be learned from the above events is obvious: energy security is an essential element of any power system. In addition, diversity of energy technologies is an important aspect of energy security, as is diversification of supply sources. In the context of hydropower, however, the critical issue is effective and efficient water management.

Footnotes

[1] This paper does not enter the debate on whether a dam, as opposed to run-of-river, hydropower can indeed be classified as "renewable".

[2] International Energy Agency (IEA), *Renewable Energy Essentials: Hydropower (2010). www.iea.org/publications/freepublications/publication/hydropower_essentials.pdf*

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Julian Silk *(continued from page 18)*

18 The rebuttal for Minnesota is in https://fresh-energy.org/correcting-the-center-of-the-american-experiments-false-report-on-clean-energy/. But it does not cite a specific methodology for counting jobs gained in Minnesota, instead alluding to a generalized result from Massachusetts. An honest rebuttal would be to use IMPLAN, or some other sort of model, calculate the jobs without the mandate, calculate the jobs with the mandate, and show how the mandate created jobs, and in what industries.

19 For example, see Glenn Schleede, "Wind Farms DO NOT Provide Large Economic and Job Benefits (quite the opposite)", January 5, 2011, at https://www.masterresource.org/false-claims/false-wind-claims/.

20 See the Energy Information Administration (EIA), February 9, 2018, "Utilities continue to increase spending on transmission infrastructure", at https://www.eia.gov/todayinenergy/detail.php?id=34892.

21 Young, Lauren, 2015. "Concentrator Photovoltaics: The Next Step Towards Better Solar Power", IEEE Spectrum, August 31, 2015. https://spectrum.ieee.org/energywise/green-tech/solar/concentrator-photovoltaics-the-next-step-towards-better-solar-power.

22 Hamilton, Tyler, 2016. "Morgan Solar, One of the Last Remaining Concentrating PV Firms, Wins 10MW Project", Green Tech Media, May 11, 2016. https://www.greentechmedia.com/articles/read/morgan-solar-wins-10mw-project.

23 Wesoff, Eric, 2017. "SunShot $1 per Watt Solar Cost Goal: Mission Accomplished, Years Ahead of Schedule", Green Tech Media, January 25, 2017. https://www.greentechmedia.com/articles/read/Sunshot-1-Per-Watt-Solar-Cost-Goal-Mission-Accomplished-Years-Ahead-of-S. The installed costs are higher, and are discussed by Robert Margolis, David Feldman, and Daniel Boff, "Q4 2016/Q1 2017 Solar Industry Update", National Renewable Energy Laboratory, NREL/PR-6A20-68425, April 25, 2017, 48. Wiesenhoff, Maike, Simon Philipps, Andreas Bett, Kelsey Horowitz, and Sarah Kurtz. 2017. "Current Status of Concentrator Photovoltaic (CPV) Technology", Fraunhofer Institute for Solar Energy Systems ISE and National Renewable Energy Laboratory NREL, Version 1.3, April 2017. https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/cpv-report-ise-nrel.pdf.

24 Gilliland et. al., 2015. Ellen Gilliland, Nino Ripepi, A. Kyle Louk, Xu Tang, Cigdem Keles, Charles Schlosser, Joseph Amante, and Michael Karmis, "Differences in Adsorption Behavior for Three CCUS Pilot Tests in Unconventional Reservoirs of the Central Appalachian Basin and Implications for Enhanced Gas Recovery", presented to the Carbon Capture, Utilization and Sequestration (CCUS) meetings, Exchange Monitor Publications, April 30, 2015.

25 Personal communication to the author.

26 Gellerman, Bruce, 2016. "New England's Largest Battery Is Hidden Inside A Mass. Mountain", WBUR, December 2, 2016. http://www.wbur.org/bostonomix/2016/12/02/northfield-mountain-hydroelectric-station.