Session 4: Evaluating the Benefits of Hydropower

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Understanding power systems

To maximise the value from hydroelectric schemes it is necessary to plan and configure them to provide optimum support to the electricity grid. Hence hydro engineers and developers need to understand the changes that are taking place on power systems, and the role that hydropower will play in supporting future grids.

Energy transition

The world's power systems are in the middle of an energy transition, moving away from traditional fossil fuelled generation to low-carbon alternatives. While the pace varies from nation to nation, change is happening everywhere, and it is being driven largely by economics rather than legislation.

In many countries solar and wind are already the cheapest sources of electrical energy. Recent tenders for solar energy are as low as US¢1.3 per kWh in Portugal and Abu Dhabi. In the United States, sub-US¢2.0 per kWh for wind energy is common, although these prices are subsidised; without subsidies it would be around US¢3.0 per kWh. Few, if any, other generation technologies can compete with these price levels.

The price for solar and wind energy are significantly higher in many countries, but often it is caused by barriers and impediments to development, rather than poor resources.

Legislation, environmental concerns and public sentiment are also driving the energy transition. National commitments under the 2015 Paris Agreement require most countries to decarbonise their electricity sectors. Public pressure for cleaner environments and concerns about climate change are making governments retire thermal generators, especially old and inefficient coal fired plant.

Shape of future power systems

Traditionally the daily network demand has been relatively predictable, varying according to regular patterns during the day, with predictable variations at weekends, on public holidays and according to seasons. Electricity system operators (ESOs) had to be prepared for sudden variations due to transmission trips and unusual events, such as TV pick-ups, but these were generally small in size relative to overall system demand.

Electricity supply traditionally came from despatchable technology or "always-on" nuclear plant. Balancing the system with predictable demand and dispatchable generation was easy.

The power systems of the future will be very different. Behind-the-meter generation, such as roof-top solar, is outside the control of the ESO, effectively varying net demand in an unpredictable manner according to cloud cover or wind speed. Smart grids, where appliances are switched on and off by the grid, and vehicle to grid (V2G) may help to smooth demand, but this technology development and widespread deployment is a long way off.

To compound the problem of demand variability, most decarbonised generation is non-dispatchable – the level of output varies with the solar, wind or hydro resource, or in the case of conventional nuclear plant, is always on.

Of existing low-carbon generation options, only storage hydro and biomass are fully dispatchable. Concentrating solar and hydro with pondage have some dispatchability, and green hydrogen plant, carbon capture and storage (CCS) and molten salt nuclear are dispatchable prospects for the future.

Without dispatchable generation, storage technologies such as pumped storage and batteries offer the best low carbon options to supplement variable renewable energy (vRE) and achieve grid security. Of these only pumped storage has the realistic capability of storing enough energy to back-up vRE.

Balancing demand and supply on an hourly or half-hourly basis, used to be the primary concern of the ESO. However the future grid imposes new challenges: sub-second balancing or frequency response, power factor control, rate of change of frequency (RoCoF) management through system and virtual inertia and a range of other parameters need to be managed as a result of the variability and predominance of asynchronous generation on the future grid.

Valuing energy

We have traditionally traded electricity, both wholesale and retail, on the basis of energy. In future this will not be practical. Consumers are minimising the amount of energy they purchase from the grid by behind-the-meter generation. The small amount of energy they need to buy, during times of high consumption or low self-generation, will not be enough to pay for their share of grid costs.

On the wholesale side, most future generation will have low or negative marginal cost. Also the costs and benefits to the grid (and consumer) of different generation technologies is very different due to the nature and location of the plant. Variable generation requires back-up and possibly storage headroom at times of surplus; large units require standby capacity in case they fail; asynchronous generation requires separate provision of inertia to control RoCoF; reactive power, and to a certain extent inertia, are location-specific, and hence need to be in the right place.

All energy is not equal!

Benefits of hydropower

Hydropower plant, and especially pumped storage, is able to provide most of the ancillary services required by the ESO to balance the grid and provide security and stability services. Importantly many hydro schemes, including most pumped-storage, Pelton plant and Francis units equipped with blow-down, can provide these services at zero-load. They can run in synchronous condenser mode, synchronised to the grid providing inertia and ready to provide frequency response and fast ramping without displacing vRE from the system.

In addition to low-carbon energy and ancillary services, well-planned hydropower reservoirs can provide multi-purpose benefits such as flow regulation, agricultural, industrial and domestic water supply, flood control, water quality management, navigation, control of saline intrusion, leisure facilities and fisheries.

Expenditure on hydropower construction, often with high domestic supply-chain content, can provide major economic benefits in terms of Gross Added Value (GVA) to the economy. During operation economic benefits accrue through provision of reliable electricity supply, imported fuel displacement and the supply chain for operation and maintenance.

How to value the benefits

Traditionally hydropower has been valued on the basis of its energy cost, using the levelized cost of energy (LCOE) or the tariff required. However comparing energy costs, as discussed above, is no-longer useful.

Valuing hydropower in terms of the market value of its benefits is one approach, but does not work well since many of the benefits cannot easily be monetised at present. For example few ESOs are purchasing inertia, although this is now happening in Ireland and Great Britain. In small quantities, ancillary services can be provided as a by-product from existing generators, and therefore the price at the start of the market does not reflect the true long-term cost of provision.

The best approach would be to assess the net economic value of a hydropower scheme to the nation, evaluating all of the benefits and negative impacts on an economic basis.

Power and energy benefits can be assessed using least cost system planning software, comparing the net present value of operating the future power system, including opex and capex costs, over a long time horizon. The residual value of hydro at the end of the planning horizon needs to be taken into account to value hydro's longevity. Unrealistically high discount rates should not be used, as these work against high capex / low opex investments.

Ancillary services are harder to value. They only have a value if they are needed, and the situation is dynamic. For example many power grids have ample system inertia for control of RoCoF. However as more asynchronous vRE is added to the grid, a tipping point is quickly reached where there is insufficient inertia at times of high vRE output, and inertia needs to be purchased. An indication of the value can be derived from the cost of providing the service from a stand-alone facility. However the cost to the grid is complex: for example a pumped storage unit may provide the same inertia as a steam unit, but while the pump-turbine can provide this at zero load, the steam unit must run at 40% of capacity, potentially displacing vRE from the grid and reducing the value of its service.

In addition to the electricity benefits, reservoir hydro schemes are increasingly being optimised for multi-purpose benefits. Again economic analysis is required to value these benefits, and also to value the detrimental impacts. The methodology for economic analysis of most water resource benefits is well-established, and can readily be incorporated into the analysis of multi-purpose schemes.

Conclusions

The valuation of hydropower benefits has become more complex as a result of the changing nature of electricity systems. The methodology traditionally used in least cost system development plans is no-longer valid, since it only values power and energy benefits.

Improvements in the methodology for valuation of ancillary benefits are needed, and studies are underway on a number of power systems to develop a better understanding.

Valuing the electricity benefits, including power, energy and ancillary services needs to be complemented by more comprehensive analysis, including GVA benefits to the nation, and valuation of multi-purpose benefits, and of course, negative impacts should also be taken into account.

The Author

Mike McWilliams is a renowned industry expert with over 40 years of experience specialising in power planning, renewable energy, hybrid systems and commercial aspects of generation. He is currently Head of Energy at CEBR, one of London's foremost economic consultancies, Senior Advisor to the Global Solutions Group on Hydropower and Dams of World Bank, where Mike advises on projects, strategy and planning, on the Board of hydropower developer SN Power of Norway and Advisor on hydropower to Mott MacDonald..