The Stabilizing Role of the Energy-Water Nexus

Written by Amro M. Farid

Electric power is required to produce, treat, distribute and recycle water while water is required to generate and consume electricity. While many potential challenges emerge from this energy-water nexus, a systematic and intelligent approach to simultaneously plan and operate power and water infrastructure can lead to stabilizing effects in both.

Many of today's smart grid developments are driven by the need to achieve greater sustainability. Decarbonization, transportation electrification, and demand-side engagement all lead to a more sustainable future, as noted in **the recent IEEE Vision for Smart Grid Controls**. And yet, if we are to discuss the overall sustainability of the future smart grid, it also is important to consider the impacts on water.

Electric power is needed to obtain, treat, distribute and recycle water while water is needed to generate and consume electricity. These many interactions between the engineered electricity, water distribution and wastewater systems form an energy-water nexus that needs to be treated holistically. While the energy-water nexus often has been discussed as a grand challenge **a systematic and intelligent approach to simultaneously plan and operate power and water infrastructure** can lead to stabilizing effects in both.

Probably the most familiar of these interactions arises from the fact that water is readily stored and its associated potential energy can be used to stabilize power grid imbalances. The fast ramp rates of hydroelectric power facilities have long been exploited in grid dispatch and now, with the integration of variable energy resources, they are playing an even greater role. Thus, **Norway's hydroelectric capabilities provide storage and balancing for Denmark's wind**, helping the country lead in the world in building out a large wind sector. In each of the Gulf Cooperation Council nations (Bahrain, Kuwait, Oman, Saudi Arabia and the United Arab Emirates), the water distribution network is coupled to the power grid under a single combined utility; power-water co-production facilities provide the foundation for the arrangement. While these plants have tight process limits on the ratio of power generated and water produced, water storage allows them to be operated flexibly and follow load requirements. **New dispatching algorithms** have recently been developed to take advantage of this effect.

The stabilizing effect of water storage can be equally beneficial on the demand side as well. Consider the **water-heater pilot program recently initiated by PJM** and Steffes Corporation. Here, the duty cycle of a residential water heater can be tuned to provide an ancillary regulation service. Along the same lines, researchers at the University of Florida have developed control **algorithms to intelligently control swimming pool pumps**.

Any artificial water reservoir can, in theory, be used to provide such grid stabilizing capability. For example, the pumping energy in water distribution systems typically accounts for 5 percent of electric power consumption in a given region depending on its geographical topology. Considering that independent system operators typically maintain 7 percent in operating reserves, smart operation of water distribution systems can in principle have a significantly stabilizing impact.

Additionally, water distribution systems often suffer from double-digit water leakages. The World Bank estimates that 32 billion cubic meters of treated water are lost yearly. Utilities that already are making efforts to reduce leakages will have an incentive to go still further if they take into account the lost embedded energy and not just the lost water alone.

Finally, water infrastructure can play a stabilizing role in curbing peak load growth. In both hot and arid and more temperate climates, load duration curves are becoming increasingly steep because of ever greater reliance on air conditioning. In this context, district cooling presents an opportunity to achieve thermodynamic economies of scale that lead to an electric power reduction of 35-65 percent. Water is chilled centrally in a refrigeration cycle and then distributed to buildings that use the cold in central air systems.

The famous **Palm Jumeira development in Dubai, United Arab Emirates uses 921 MW of district cooling**. Because the peak load always coincides with air conditioning on hot and humid days, the choice of district cooling over distributed air conditioners represents an electric power saving that can be shaved directly off of peak load.

Active demand-side management can also be applied to water and wastewater treatment when it is managed as batch rather than continuous processes, so that it can be scheduled off-peak. In some cases, such processes also improve the quality of the end-product water. This growing possibility of distributed water treatment is promising as it allows for a more granular and more geographically distributed demand-side control of the power grid.

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Smart wastewater treatment can help on the supply as well as the demand side. Wastewater treatment often relies on biological processes that generate methane, a greenhouse gas 21 times more potent than carbon dioxide. Rather than emit it, wastewater utilities in San Diego and San Antonio have been harvesting the natural gas to fuel gas turbines. Doing so effectively installs distributed, fast-ramping and highly available peak load capacity that can directly contribute to the reliability and resilience of the smart grid as a whole.

To recapitulate, the energy-water nexus includes supply-side couplings, like hydroelectric and MSF (multistage flash distillation) desalination facilities, and demand-side couplings, like water-heaters and swimming pools. Furthermore, district cooling and water treatment facilities present opportunities to either reduce peak load or directly contribute to peak load generation capacity. Clearly, the degree and nature of these opportunities very much depends on the relative water abundance or scarcity in the region, on local policies, regulations and technical standards. Some rules may require significant revision to accommodate new applications.

I have advocated **holistic assessment approaches** to determine which opportunities are of greatest benefit. In any modern society, water and electric power are fundamental needs. We should figure out how to produce and use both well together.

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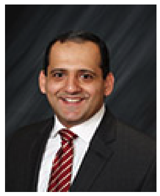

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