DOE-WPTO EWR Program

White Paper

A Coupled Energy–Water Storage Architecture for Resilient Urban Power and Water Distribution

Yang Chen, Computational Sciences and Engineering Division, Oak Ridge National Laboratory
Jian Sun, Buildings and Transportation Science Division, Oak Ridge National Laboratory
Contact email: cheny4@ornl.gov

Focal area

This white paper proposes a coupled energy–water storage architecture to enhance the resilience of urban power and water distribution networks. The concept leverages GLIDES concept (Ground-Level Integrated Diverse Energy Storage), which is a pneumo-hydraulic storage technology developed at Oak Ridge National Laboratory, to enable mechanically coupled, long-duration, and bidirectional energy exchange between electric and water infrastructures. By integrating high-pressure hydraulic storage with municipal water distribution systems through a controllable hydraulic transformer, the proposed approach enables co-optimization of electricity and water operations and providing cross-sector resilience during grid disturbances or water supply disruptions.

Existing Challenge

Energy and water are foundational pillars of urban infrastructure and essential for public health and community resilience. However, urban energy and water systems are increasingly strained by rising demand, aging infrastructure, and the growing impacts of extreme weather and grid disturbances. Many cities experience high peak electricity costs and vulnerability to cascading outages, where disruptions in one network will rapidly affect the distribution in another network.

Despite their interdependence, energy and water systems are still managed in silos, leading to inefficiencies, uncoordinated peak demands, and limited operational flexibility. For instance, pumping stations and reverse osmosis systems require steady pressure and flow to maintain efficiency and avoid equipment stress, yet their energy consumption often coincides with grid peak periods. Conventional electrochemical storage (e.g., batteries) can buffer electrical load but cannot directly stabilize hydraulic pressure and flow, which are critical to water network performance. Achieving energy–water resilience in urban systems therefore requires an integrated, multi-domain storage solution that can simultaneously buffer electrical and hydraulic energy to coordinate across both infrastructures.

Near-Term Opportunity

GLIDES (Ground-Level Integrated Diverse Energy Storage [1]) offer a transformative opportunity to bridge energy and water systems through hybrid mechanical–electrical storage. The GLIDES concept is shown in Figure 1. It was invented and prototyped in Oak Ridge National Laboratory. a GLIDES system typically consists of four main components: an atmospheric pressure liquid storage reservoir, prepressurized pressure vessel(s) containing a gas (e.g., air, nitrogen, carbon dioxide), a pump/motor, and a hydraulic turbine/generator, see Figure 2. In the charging process, the electricity drives the pump/motor to pump liquid from the liquid storage reservoir to the pressure vessel(s) until a certain pressure level is reached (less than allowable maximum level in the vessel). To recover the stored energy, the now high-head water passes through the hydraulic turbine (e.g., Pelton turbine), which spins an electrical generator to dispatch electricity [2].

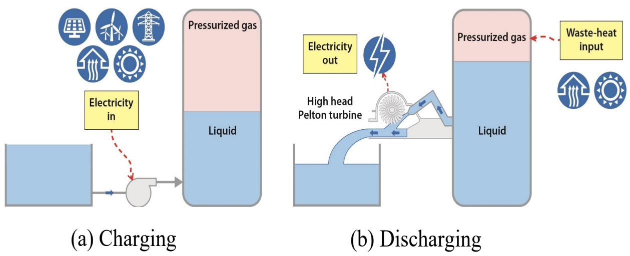

Figure 1. Basic layout and components of GLIDES concept system

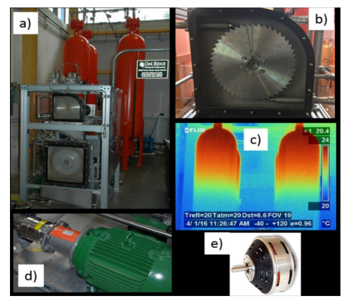

Figure 2. Prototypes of first-generation GLIDES,

Based on this concept, we propose the energy-water storage architecture coupled with the municipal water distribution system, see Figure 3. In charging mode, electricity from grid/renewables drives the water pump station to pump water inside the storage vessel with pressurization from hydraulic transformer. When power or water demand peaks, the compressed air pushes water back through the turbine to regenerate electricity to the grid or maintaining water network pressure. This storage stores energy as water pressure and compressed air, so it can prevents service interruptions and help both electricity and water system recover faster during outages.

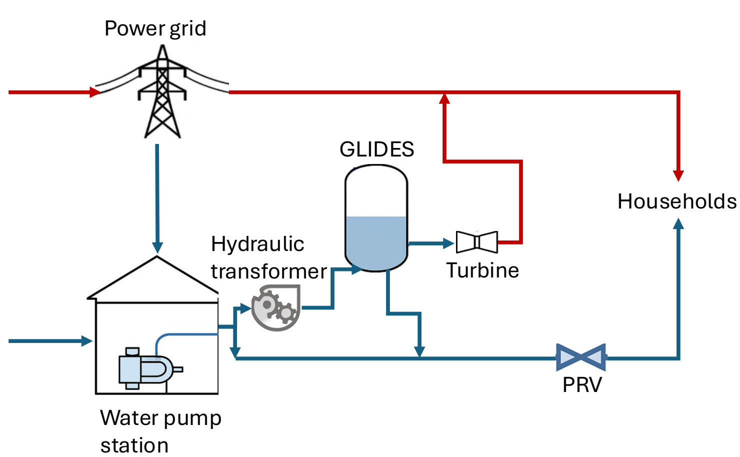

Figure 3. System scheme of coupled energy-water storage architecture

In urban settings where electric and water infrastructures are co-located, the proposed coupled energy-water storage architecture enables new synergies:

1. Enable dual-use infrastructure by coupling with existing tanks, reservoirs, or water distribution system to co-store water and energy, reducing redundant capital costs.
2. Stabilize renewable-powered desalination and treatment by maintaining near-constant pressure and flow for reverse osmosis and filtration processes, thereby reducing specific energy consumption (kWh/m^3) and membrane wear.
3. Shift pumping and distribution loads by absorbing surplus renewable power during low water demand and releasing hydraulic energy during peak hours to flatten grid and pressure fluctuations.
4. Provide safe, long-duration backup for water utilities by offering resilience during outages without fire or chemical risks associated with batteries.

The near-term opportunity lies in designing and demonstrating a pilot-scale GLIDES system integrated with a municipal or industrial water facility (e.g., desalination, water reuse, or pumping station) to evaluate multi-domain efficiency, load flexibility, and resilience performance.

Success Measures

Success of a near-term GLIDES–water integration pilot can be assessed using quantitative and qualitative metrics:

- Energy–Water Co-Optimization: Reduction peak grid load and stabilization of pressure/flow within optimal reverse osmosis operating range.
- Operational Efficiency: Reduction of specific energy consumption for desalination or water treatment.
- Resilience and Reliability: Sustained operation of critical water services for longer hours during grid disruptions.

References

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[2] Y. Chen, F. Dababneh, B. Zhang, S. Kassaee, B. Smith, X. Liu, and A. Momen. "Surrogate Modeling for Capacity Planning of Charging Station Equipped With Photovoltaic Panel and Hydropneumatic Energy Storage." ASME. *J. Energy Resour. Technol*. May 2020; 142(5): 050907. doi: 10.1115/1.4045733