The 2024 IERE-SwRI San Antonio Energy Transition Workshop
May 13–16, 2024

Overview of the Development and Demonstration of a Pilot-Scale Pumped Thermal Energy Storage Facility

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Keywords: *energy storage, thermal energy, turbomachinery, facility demonstration*

Abstract

Long-duration, grid-scale energy storage technologies provide a potential pathway to enable full penetration of renewable energy, like solar and wind, on the electricity grid. One of these technologies that leverages well-developed components is pumped thermal energy storage (PTES). PTES utilizes a heat pump to generate thermal energy stores and a heat engine to later discharge the stored thermal energy as power. PTES systems offer an advantageous solution with high potential system performance, no geographical barriers, and modularity for numerous use cases. This presentation provides an overview of a first-of-a-kind, small scale air-based PTES demonstration facility design with the with the objective to better understand the control strategies and operation of a full-scale system.

The PTES facility operates a simple-recuperated cycle for both the charge and discharge modes. Both modes share the thermal energy storage systems and the three heat exchangers but have individual turbocompressor drivetrains. The facility stores two hours of energy in a thermal oil at up to 350 °C and a water-glycol system at down to -10°C which is discharged through the 5kW turbocompressor.

The overall system layout is simple to others in the open literature and full-scale systems in commercial development. To minimize costs, off-the-shelf hardware was used as much as possible. However, to meet desired performance and operational goals, the turbomachinery did not exist and required bespoke designs for both the charge and discharge turbocompressors. Specific design features include bidirectional thrust capabilities, machinery heat mitigation strategies, and turbine aerodynamic flowpaths.

The performance of the system is described by steady state and transient data from both the charge and discharge modes during start-up, shut down, steady state, and system balance. Key operational and control strategy testing goals included cold start of sequencing, system power control, and storage media balance after repeated cycling. The data highlights the importance and methods of transient control tuning, the influence of ambient effects, and challenges associated with first implementation of a technology.