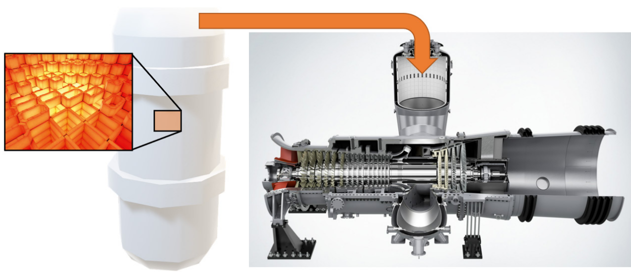
Gas Turbine Integration with High-Temperature Thermal Energy Storage



High-temperature thermal energy storage delivering heat to a gas turbine. Images courtesy of RHI Magnesia and Siemens Energy.

- Enhance flexibility and reliability by repowering gas turbines with high-temperature thermal energy storage
- Identify candidate technologies and gas turbine models that may be suitable and develop integration design strategies
- Estimate costs and performance of the integrated system
- Approach may be feasible for simple-cycle gas turbines, combined-cycle plants, or cogeneration

Key Research Question

Energy storage is a key enabler of a low-carbon future. As more variable renewable energy (VRE) in the form of solar and wind are installed and dispatchable thermal power generation is displaced, substantial energy storage will be needed to provide grid stability and reliability. Energy storage can shift energy in time, storing excess energy when available, and then provide it later when needed. Energy storage can also provide critical ancillary services, such as spinning reserve capacity and frequency response, and can contribute to system inertia.

One possible pathway to enable the deployment of energy storage and help decarbonize the power generation fleet is repowering existing natural gas (NG)-fired power generation and cogeneration facilities. Such plants can be converted from fossil-fuel units to electrically heated thermal energy storage (TES) plants. Developing a high-temperature, electrically-heated TES system that could heat air to high enough temperatures to replace the combustion of NG may enable low-cost, high-efficiency bulk energy storage. Combined-cycle gas turbine (CCGT) power plants burn NG at high temperature in a gas turbine (GT), then recover additional energy from the GT exhaust by generating steam and driving a steam turbine. Such facilities can achieve thermal conversion efficiencies near 60%. Simple-cycle GTs are lower efficiency but are prevalent as peakers and may also be candidate technologies for high-temperature TES. GT cogeneration facilities providing power and steam may also benefit from such a decarbonization approach. However, storing heat at typical turbine inlet temperatures (>1500°C) is challenging. Furthermore, the heat must be applied to pressurized air and subsequently delivered to the turbine for expansion to achieve effective Brayton cycle operation. This heat delivery problem represents an unsolved design challenge.

Objective

The objective of this project is to review multiple candidate high-temperature TES technologies and first perform a conceptual design for integrating them with GT systems, then cost and performance studies at selected host sites.

Approach

This supplemental project will be conducted in two phases. Members can join just Phase 1 or join Phase 1 and Phase 2 concurrently.

Phase 1: Design Framework and Performance. This phase will first identify candidate technologies suitable for storing heat at sufficiently high temperature to drive a GT. Several technologies will be evaluated in terms of maturity, expected performance, and suitability for meeting the desired conditions. Candidate technologies include TES systems utilizing ceramic beads, conductive refractory bricks, graphite, oxide minerals, and sand. GT models will also be evaluated for ease of integration with an external heat source. It is expected that GTs with silo combustors may be desirable to adapt for this application, but models with external combustor cans or even combustor rings will also be considered. A performance model of the integrated system will be developed utilizing industry-standard modeling software to estimate key performance metrics of the integrated system.

Phase 2: Cost Studies at Host Sites. This phase will develop feasibility studies for selected TES technologies integrated with a GT at a member host site. For each site, an independent techno-economic assessment (TEA) with an AACE Class 5 cost study will be performed. Results will include the process design, integration strategy with the GT unit, round-trip efficiency, estimated capital and operations and maintenance costs, and levelized costs.

Research Value

This project will provide detailed information and design strategies utilizing several technologies to repower GT plants with high-temperature TES.

In Phase 1, funders will obtain design information on multiple technologies and their potential integration to GTs, to better assess which technologies might be a fit in their portfolio and whether their GT units might benefit from such a low-carbon approach.

In Phase 2, the TEA will be specific to a particular GT plant and/or site in the member's system matched to a selected high-temperature TES technology, which could be the first step towards a demonstration at the site. Each member of Phase 2 will also obtain non-proprietary results from the other member's Phase 2 projects, with information provided so that they can be able to apply the technology for their own use case including factors such as labor rates, size, duration, depth of discharge, etc.

Ultimately, members of this project will receive valuable information to better prepare for which energy storage technologies to use in their portfolios to decarbonize NG-based power to help accommodate the drive towards increasing VRE required to meet future low-carbon goals in the most cost-effective way.

Deliverables

- Kickoff meeting
- Quarterly webcasts—including a closeout webcast after the final report has been published—to provide updates and lessons learned.
- Phase 1: Report describing the candidate technologies assessed and the GT models evaluated for TES integration. The report will include details on the conceptual process design, integration approach, relative ease of integration with various GT models, and expected performance of the integrated system.
- Phase 2: Individual reports on the TEA studies for each site host for their selected high-temperature TES technology and non-confidential results from all other TEA studies being performed in Phase 2. The reports will include details on the process design, integration approach, performance, capital costs, maintenance costs, and levelized costs.

Price of Project

The price to join Phase 1 of the project is $55,000. The price to join Phase 2 of the project is $130,000. The price can be paid over two years. SDF and TC can be used. Members can fund both now or make a decision at the end of Phase 1 whether they want to move into Phase 2.

Project Schedule

The projected start date for this project is November 2023. Phase 1 is expected to take 6 months to complete. Phase 2, which will start after Phase 1 is completed, is expected to take 12 months to complete.

Who Should Join

Members interested in evaluating low-carbon repowering strategies for their GT systems should consider joining this project to obtain information on possible high-temperature TES technologies and design approaches in Phase 1, and cost and performance in Phase 2.

Contact Information

For more information, contact the EPRI Customer Assistance Center at 800.313.3774 (askepri@epri.com).

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