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HYBRIDIZATION OF GAS POWER PLANTS WITH THERMAL LDES

LOWER FUEL COSTS, ENHANCED OPERABILITY AND GRID RESILIENCY

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GE Vernova's Gas Power business engineers advanced, efficient natural gas-powered technologies and services, along with decarbonization solutions that air to help electrify a lower carbon future.

GE Vernova's Advanced Research business is a hub for innovation where research and development meets strategy creation, partnership building, and engineering genius. We're accelerating a new era of available, affordable, and sustainable energy and ambitiously tackling decarbonization, renewables, and electrification with the pioneering spirit to enable a zero-carbon future.

This presentation relates to an exploratory project at GE Vernova Advanced Research with estimated projections and does not represent a product offering

TES Integration with Gas Turbine Overview

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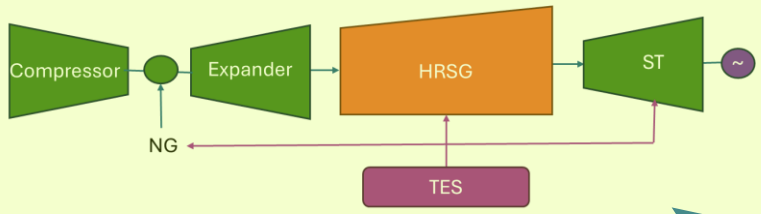
(Low pressure – lower risk implementations)

(High Pressure – higher risk implementation)

Bottoming cycle warming/Fuel heating

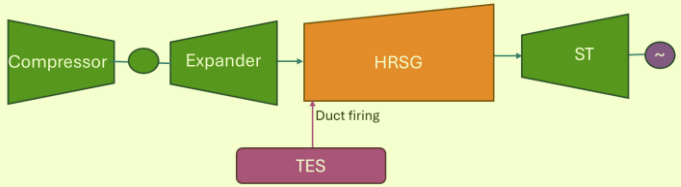
- Use TES steam output and connect into existing piping



TRL 5+

Current Presentation Content

TRL 5+



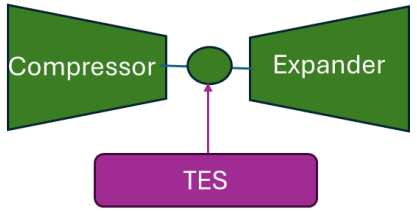
TES replacing duct firing

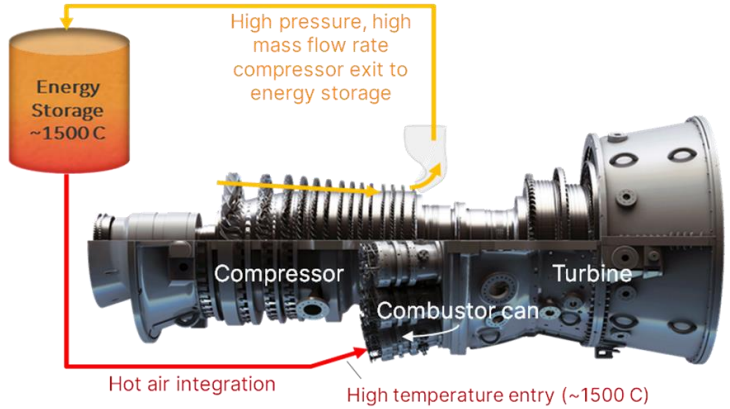
- Replace combustion air with TES hot air

TRL3

TES to replace combustion

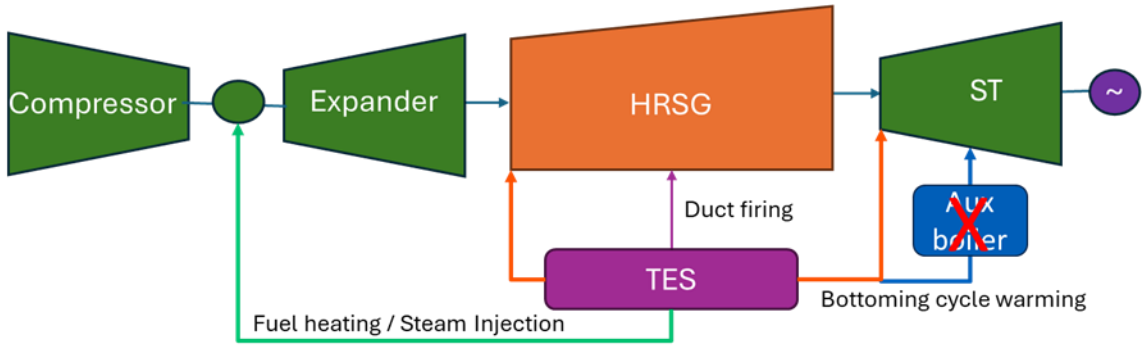
- Fully decarbonized





How does it work?

Current research at GE Vernova Advanced Research is targeting an end state in which GE Vernova's Gas Power business could offer an uprate for CCGT that would tie a TES system with advanced controls into the bottoming cycle allowing TES heat integration through steam piping.



Large Installed base of CCGT turbines

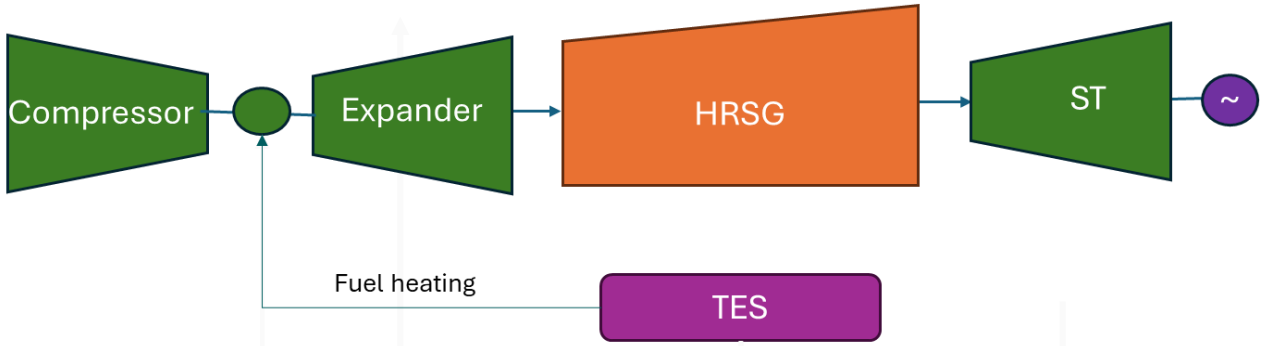
- E class ~ 500 units
- F class ~ 700 units

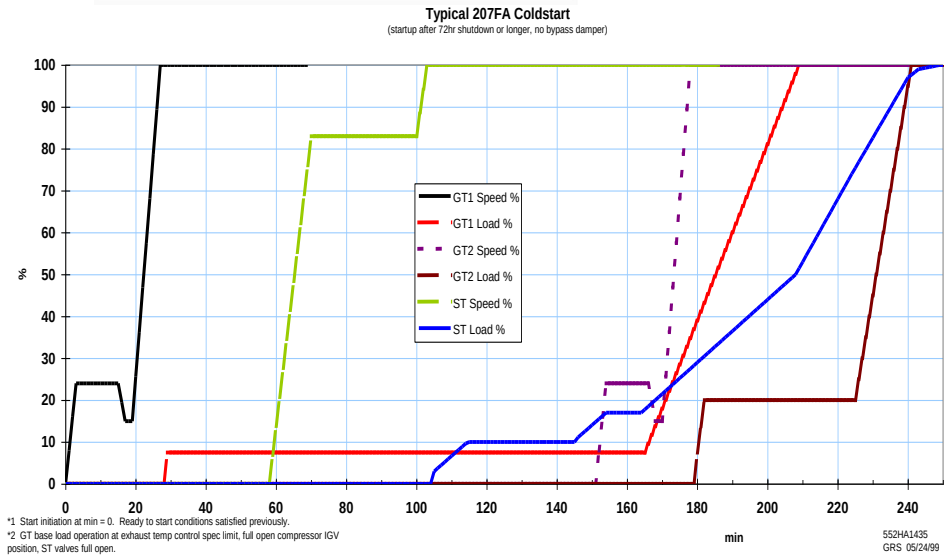
Multiple Value Streams:

- *Start-up fuel heating*
- *Bottoming cycle pre-warming for faster starts (elimination of Aux Boilers)*
- *Duct firing fuel replacement for GT flexibility and/or power augmentation*
- *Targeted "heat" soak for at risk components for transient thermal stress control*
- *TES charging integration into BOP electrical hardware for plant performance optimization and grid ancillary services like frequency control.*

Fuel Pre-heating

GT can use fuel pre-heating to increase efficiency. Typically steam from the bottoming cycle is used to provide the heat for fuel heating; however, that energy is not available during start-up unless provided by the TES system.

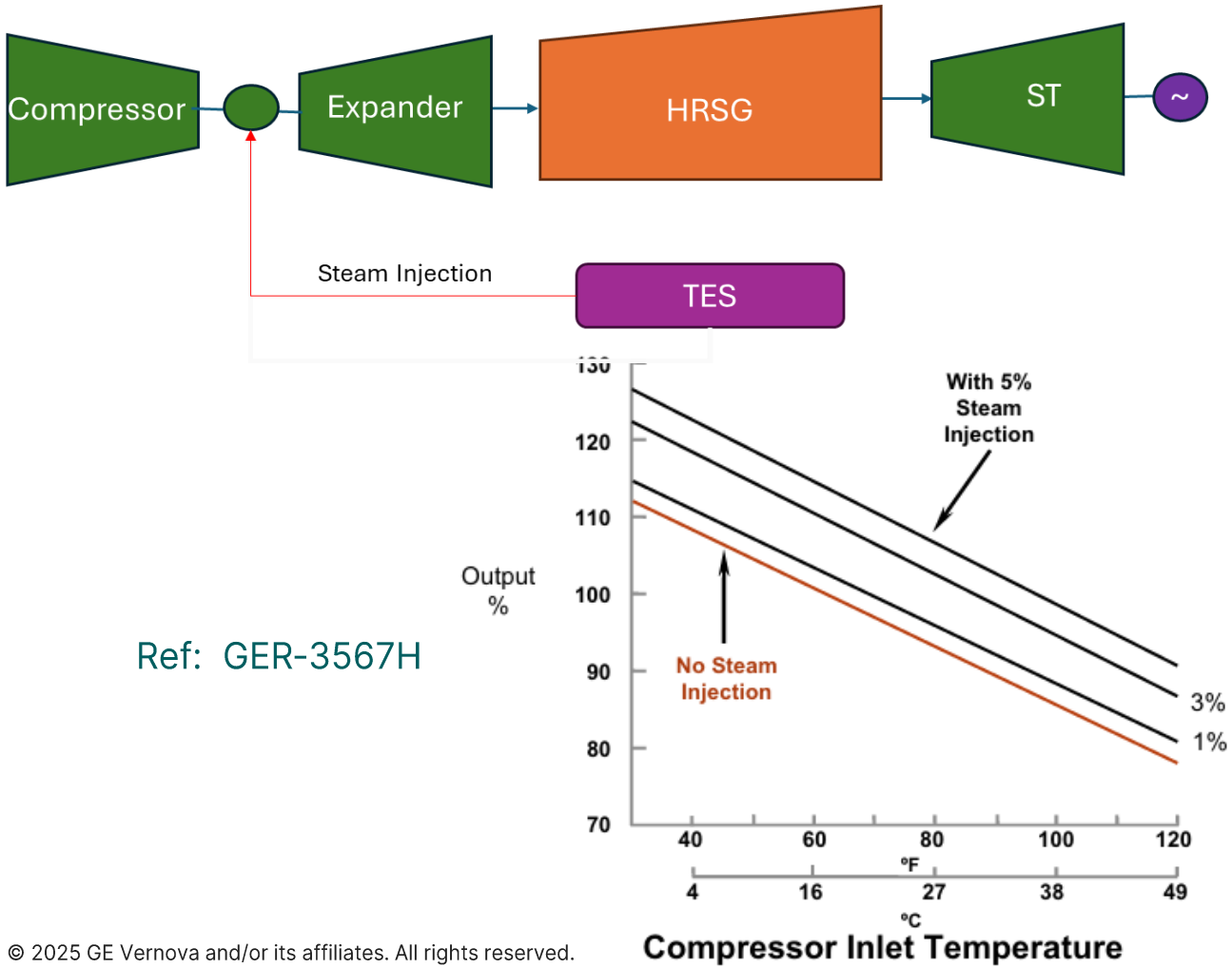




- Efficiency translates into reduced fuel and CO2 emissions
  - Estimated ~1300 lbs per hour reduced fuel consumption
  - Estimated ~1.7 tons per hour CO2 reduction
- Combined cycle benefit:
  - Cold start - >2 hrs w/o fuel heating
- Peaker benefit
  - Full benefit across operating time
- May require a combustion upgrade

Power Augmentation – Steam Injection

Steam injection into the combustion system is used as a power augmentation technique when additional grid energy is needed.

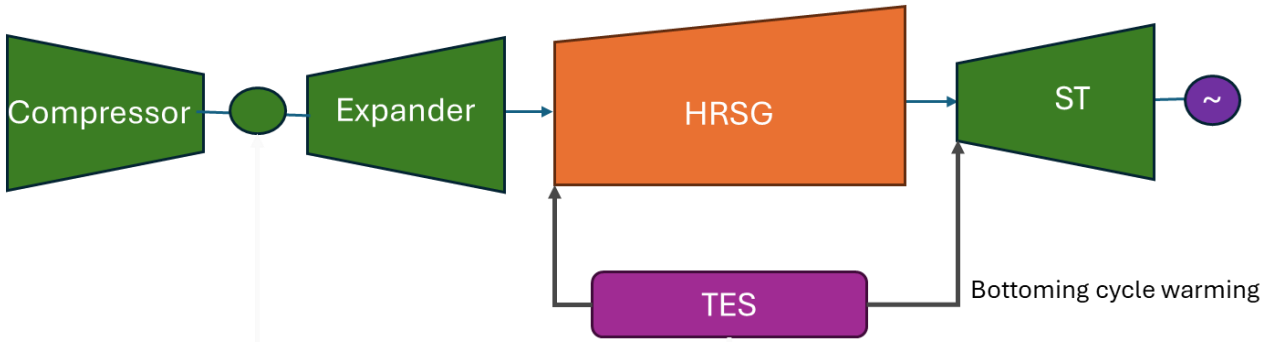


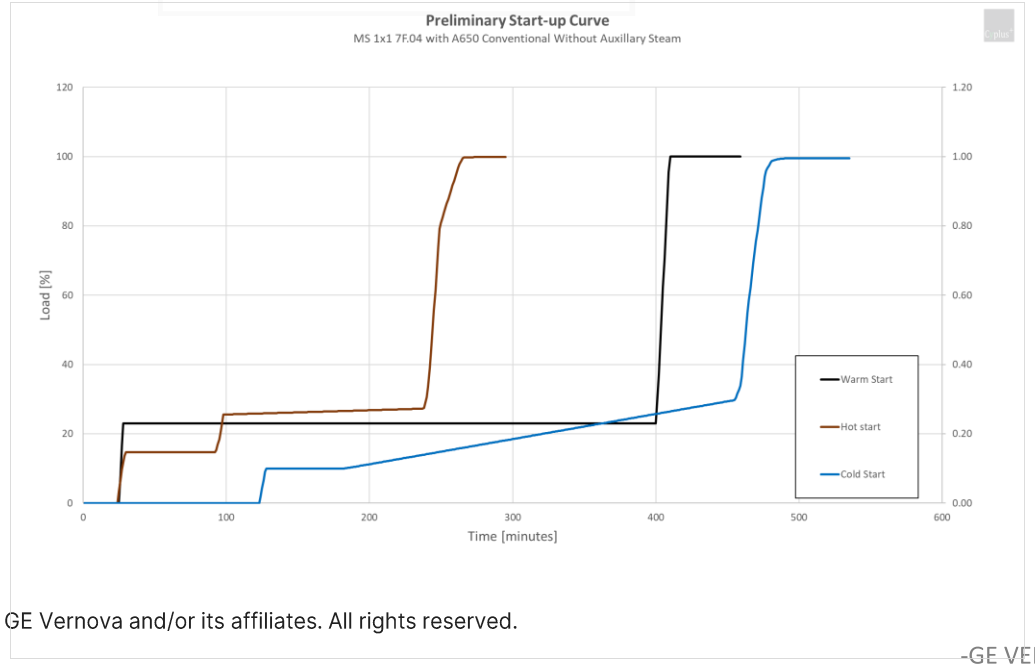
Ref: GER-3567H

- An available option of GE Vernova gas turbines
- Compressor discharge and/or combustion injection locations
- Traditionally would use an off-board source but can be supplied by TES
- Requires fuel level pressures and sufficient super-heat

Bottoming Cycle Warming

CCGTs can take 2-4 hrs or more to reach full load depending on start condition (hot restart, warm, cold start) This produces operator challenges in a highly flexible grid.

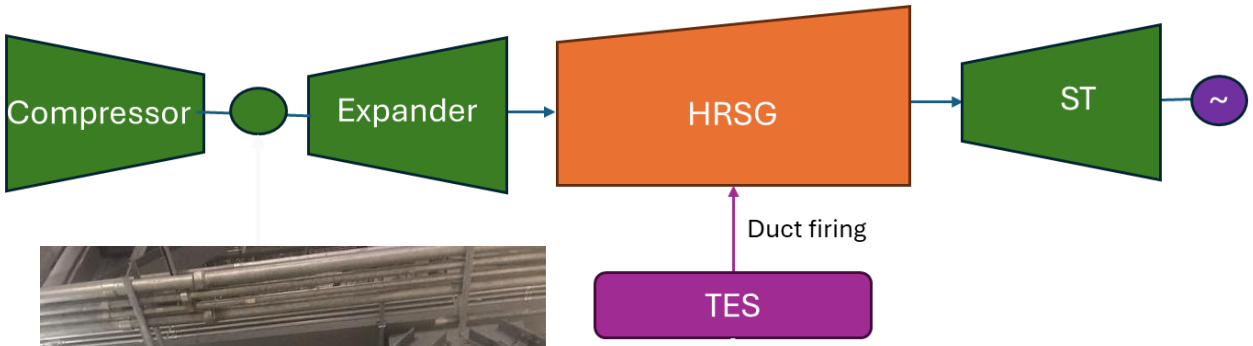




- GE Vernova already provides hardware that accomplishes a similar effect; however, all require energy input:
  - Electric ST blankets
  - Sparge steam
  - Electric hot air heaters
- TES can provide same functionality with lower cost:
  - Low-cost renewable energy
  - Better CAPEX than Li-Ion
- No additional hardware needed apart from TES integration. Control system programming modification

Duct firing

Traditional use of duct firing is for power augmentation. Additional fuel is combusted in the HRSG to boost energy into the steam cycle creating additional power. Recent EIA data is showing the additional use of duct firing as a method for additional flexibility.



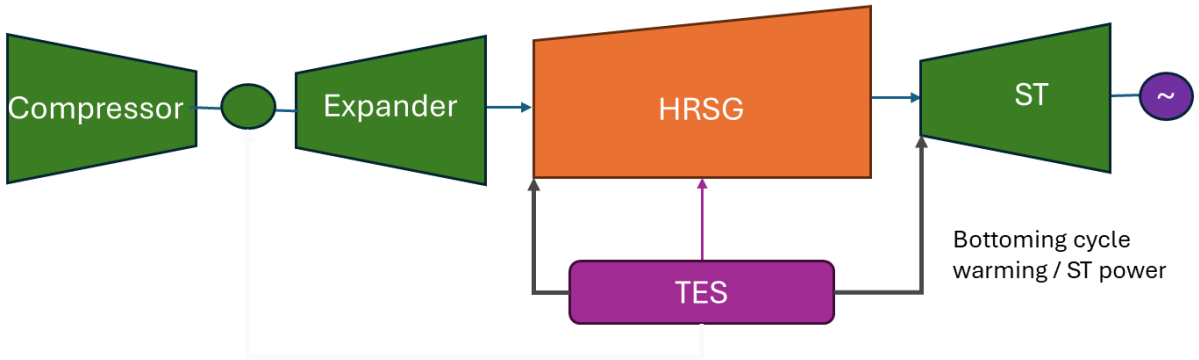
- 75% of US based CCGT have duct firing capability
- In 2024, the industry spent almost $2B in fuel for duct firing.
- When charge rates are <$20/MWh, an electrically charged TES has a cost advantage over natural gas
- Fuel and emissions free aspect could allow additional duct firing usage.

- TES for duct burning can allow customers that do not have duct burners installed to have the same functionality.

Ref: https://www.eia.gov/todayinenergy/detail.php?id=52778

Turndown enhancement

Current CCGTs are limited by the GT turndown capability to maintain emissions compliance. TES can be used for the joint function of bottoming cycle warming and supplying steam to the ST for low power output.



- Value proposition under development

Turbine	GT Turndown	TES enabled
HA	33%	7%
F	58%	7%
E	45%	7%

Summary

- All modalities are a connection of TES sourced steam to the existing bottoming cycle piping with control system modification
  - Low risk implementation that can be easily reversed
  - Based on customer operating characteristics, GE Vernova can develop the best available heat integration scheme.

- Value propositions are under development but highly driven by customer parameters.
  - TES does not compete with existing technology with NG fuel price
    - Need lower TES costs
    - Aux boiler provides this capability today with low cost NG
  - Emissions limited plants
    - Can provide additional capacity/dispatchability while lowering CO2 emissions

Open to potential demonstration partnerships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