Low-Cost Sulfur Thermal Storage for increased flexibility and improved economics of fossil-fueled electricity generating units

FE0032007

Total Project Cost: $250,000 (Federal Funds: $200,000 + Cost Share: $50,000)

Project Duration: 12 months

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Project Team

Lead Organization

Sub-Recipient
Motivation

- Fossil-fueled units subjected to increased demand for operational flexibility
  - Due to variable renewable penetration

- Constant cycling results in higher operational expenses
  - Wear and tear on thermal equipment
  - Unstable boiler chemistry leading to excessive pipe corrosion

- Operate at minimum load for long periods of time
  - Decreases plant efficiency and revenue
  - Increased emissions per kWh

Low-cost thermal energy storage (TES) is critical to increase the utilization, improve flexibility and economics of fossil fuel asset

Illustration of frequent cycling of fossil-fueled plants

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1Lew et al., The Western Wind and Solar Integration Study Phase 2, NREL/TP-5500-55588
Use of **low-cost molten sulfur** as the heat storage fluid

Innovation/Novelty

Benefits of Sulfur

- **Dirt cheap** (~$0.04/kg - $0.08/kg)
- **Highly abundant**
- **Chemically stable**
- **Low freezing point** (~105 °C) compared to SOA solar salt (~220 °C), ensures low parasitic load and low O&M cost

For heat in the temperature range of 100 °C – 400 °C

*In the comparison chart, bottoming temperature for molten salt and sulfur is chosen to be 20 °C above their freezing point.*

Sulfur TES Design & Performance

- Single tank design that involves HTF tubes located within molten sulfur bath.
- Natural convection currents enable efficient storage and retrieval of heat from sulfur thermal storage.
Sulfur TES Technology Development

**Current Projects**
(funded by California Energy Commission)

- Skid-mounted 350 kWh molten sulfur TES prototype in small-scale combined heat and power unit with natural gas microturbine
  - Adds flexibility for improved reliability and economics
  - Design, CFD characterization, and testing completed in-house by Element 16, fabrication by PCL Industrial Services

- Waste heat capture for energy efficiency improvement in an industrial facility
  - Energy and water savings, Emissions reductions

- Molten sulfur TES as Carnot battery for electricity storage
  - 1500 kWht molten sulfur TES prototype
  - Charge using electric heater and discharge using Rankine cycle
Project Objectives & Impact

- Quantify the value of sulfur thermal energy storage (TES) integrated with fossil fuel assets.
  - Increase in plant utilization, Cost savings, Emissions reduction, etc.

- Complete feasibility study to establish economically viable TES integration scenarios for responsive operation of conventional fossil fuel assets.
  - Charge and discharge heat rates, Discharge duration, Levelized cost of storage, etc.

- Project Impacts:
  - **Security**: Increased reliability of power plants improves grid resiliency
  - **Environment**: Decreases greenhouse gas emission intensity by enabling coal plants to operate at the highest efficiency
  - **Economy**: Decreases fuel cost and O&M expenses, Energy arbitrage

![Diagram of sulfur thermal energy storage (TES) system]
Integration with fossil-fueled assets

Coal EGUs respond to grid demand without increased thermal cycling stress

- Boost steam production during peak demand without ramping thermal equipment
- Capture thermal energy and reduce power production when value of electricity is low or negative
- Capture overgeneration from external energy resources
- Repurpose retiring fossil power plants

Schematic illustration of sulfur TES for generating steam or preheating feedwater in a fossil fuel electricity generating units (EGUs)

Dynamics of flexible power plant operation

Flexibility Toolbox: “Compilation of Measures for the Flexible Operation of Coal-Fired Power Plants”, VGB Power Tech, VGB-B-033, March 2018