Integration of Thermal Energy Storage with a Combined Heat and Power System

Agreement Number: 34626

Argonne National Laboratory/Capstone Turbine Corporation

Project Period: 03/01/2019 - 02/28/2021

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Overview

Project Title: Integration of Thermal Energy Storage with a Combined Heat and Power System

Timeline:

Project Start Date: 03/01/2019

Budget Period End Date: 02/28/2020

Project End Date: 02/28/2021

Barriers and Challenges:

- High thermal resistance barrier in current phase-change material (PCM) storage systems; hence precludes their usage
- Need for a rapid charge/discharge thermal energy storage system
- Large footprint for current thermal energy storage technology such as hot-water storage

AMO MYPP Connection:

- Combined Heat and Power (CHP) Systems
- Waste Heat Recovery Systems

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$380,000	$393,000	$773,000	50.8
Approved Budget (BP-1&2)	$380,000	$393,000	$773,000	50.8
Costs as of 3/31/19	$13657	$435	$14,092	3*

*Number low since the project start was delayed, expected to increase in coming months

Project Team and Roles:

- Dileep Singh (ANL, PI): overall project progress, deliverables, and reporting
- Donald Ayers (Capstone): overall efforts at Capstone
- Munidhar Biruduganti (ANL): integration of thermal energy storage system (TESS) prototype with C65 combined heat and power (CHP) unit
- Wenhua Yu (ANL): simulations, experiment design, and experimental testing
- David M. France (ANL): system analysis and experiment design

Background

- There is a strong push to recover the thermal energy from engine exhaust gases and use it to perform useful work:
  - About 30-40% of the combustion energy from a typical heat engine is lost through exhaust gases

- There is an imbalance for turbine operation between daytime and nighttime

- Argonne has developed at Thermal Energy Storage System (TESS) technology that can help in efficiently balancing the energy loads for the CHP system

Project Objective(s)

- Integrate a TESS with Capstone C65 CHP unit for storing heat during power generation and releasing the stored heat on demand

- Target - TESS with a 4-hour nighttime thermal load

- Key Tasks
  - Simulating TESS operation with C65 CHP unit
  - Building a lab-scale TESS prototype and integrating with C65 unit
  - Testing thermal performance of the TESS, and transferring the TESS technology for manufacturing

Technical Innovation

- **State-of-the art:**
  - Current commercial TES technologies being used in concert with CHP are PCM and hot-water storage
- **Limitations:**
  - Limited charging and discharging abilities due to high thermal resistance for PCM storage
  - Large footprints for hot-water storage
- **Proposed Approach:**
  - Using the proven ANL technology, TESS, that comprises of PCM/foam composite as the storage medium
    - Large storage density with PCM infiltrated into high-porosity foam
    - Fast heat transfer rate from high-thermal conductivity foam
    - High round-trip exergy efficiency
- **Alternate Approach:**
  - Using metal-based PCM
    - High thermal conductivity
    - High melting points and expensive

Technical Approach

- Optimize PCM/foam combination as the storage medium for operation with C65 CHP unit
  - PCM: appropriate melting temperature, high latent heat of fusion
  - Foam: high thermal conductivity, low cost
- Design heat exchanger with PCM/foam and exhaust gas
  - A tube-PCM/foam-fin module structure
- Laboratory-scale module testing using ANL's existing C65 unit
- Key challenge: optimized system design with minimized cost
- Multidisciplinary team roles
  - ANL will lead: PCM/foam selection and experimental testing
  - Capstone will lead: test module fabrication
  - ANL and Capstone will collaborate on heat exchanger design
- TESS technology will be marketed through Capstone's leadership position on CHP systems

Results and Accomplishments

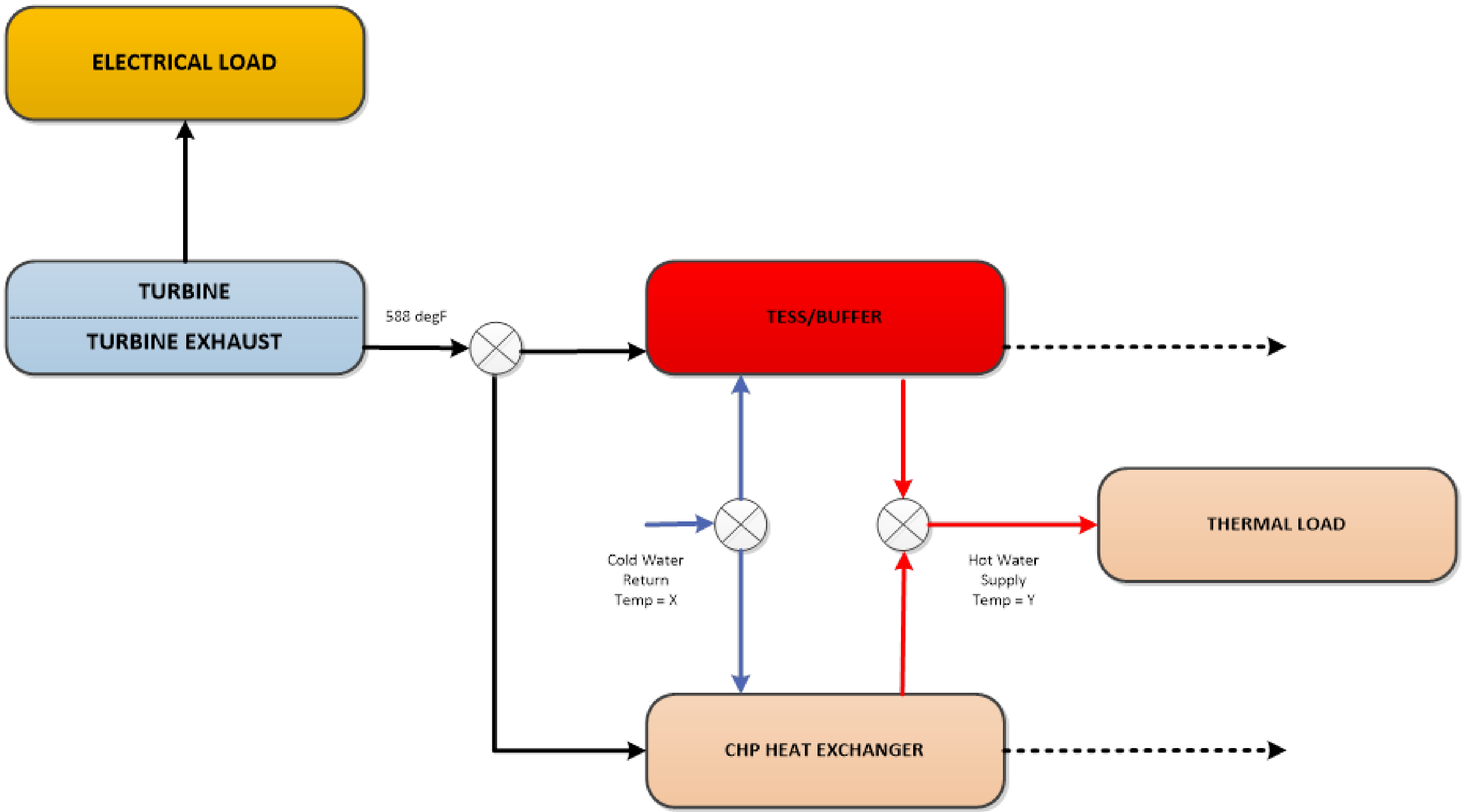
Project Initialization

- Project selected for funding – September 2018
- ANL team members met with Capstone at ANL for laying out the overall project goals – October 2018
- ANL team members inspected the existing C65 unit at ANL on its instrumentation and readiness for the project testing - October 2018
- CRADA signed - 02/28/2019
- ANL team members visited Capstone for in-depth discussions of the project path forward – April 2019
  - Current heat recovery unit of C65 CHP (without storage function)
  - Overall design approach of the TESS: similar to the current heat recovery system

Results and Accomplishments

Overall Operation Principle

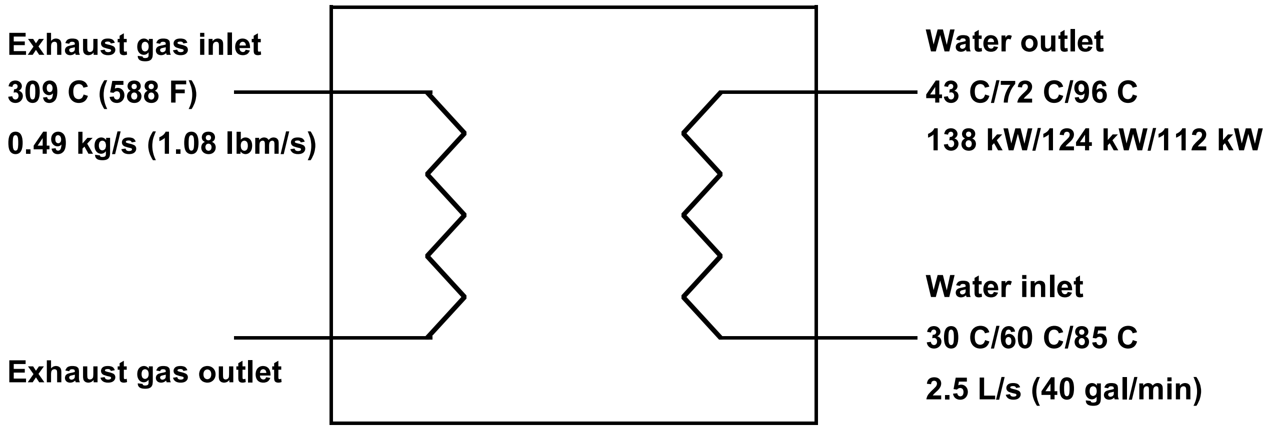
- TESS, a separate component, works in parallel with heat recovery



Results and Accomplishments

Design Criteria

- Current heat recovery operation conditions



- TESS requirements:
  - Water inlet and outlet temperatures: 30 °C and 43 °C
  - Water flow rate: 2.5 L/s (40 gal/min)
  - Heat transfer rate: 138 kW
  - Required night thermal load time: 4 hours
  - Total stored thermal energy: 1987 MJ

Results and Accomplishments

Preliminary PCM Selection and Calculations

- Based on 4-hour nighttime thermal load

	Pure Temp 151/foam
Total energy (MJ)	1987
Melting temperature (°C)	151
Heat of Fusion (kJ/kg)	217
Water flow tube ID (inch)	0.402
Water flow tube length (feet)	9
Required PCM mass (kg)	10774
Solidification radius (inch)	16.190
Required water flow tube number	8

Results and Accomplishments

Milestones for BP-1

Milestone 1: Collect CHP C65 and Heat Recovery Module Specifications – Month 1-2 (completed)

Milestone 2: Establish cost/performance benefits of the integrated system – Month 2-4 (ongoing)

Milestone 3: Complete thermal simulations of the TESS optimized module, design parameters, and predictive performance specifications – Month 5-8 (ongoing)

Transition

- Technology readiness level (TRL) of 5 is anticipated by the end of the project
- ANL will work with Capstone and/or a third party vendor for licensing and transferring of the TESS technology for manufacturing
- Demonstrated TESS technology will be applicable for other waste heat recovery applications and such opportunities will be explored