Development of Improved CHP Systems utilizing Improved Gas Turbine and sCO2 Cycles Using Additive Manufacturing (AM)

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Siemens/Oak Ridge National Laboratory

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Anand Kulkarni, Siemens Corporation
Arindam Dasgupta

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Overview

Project Title: Demonstration of Improved CHP Systems utilizing Improved Gas Turbine and sCO2 Cycles Using Additive Manufacturing (AM)

Timeline:

Project Start Date: 10/01/2018

Budget Period End Date: 04/30/2020

Project End Date: 09/30/2021

- **Barriers and Challenges:**
- Integration of the different technologies so that operating conditions and system component sizing is optimized for waste heat recovery
- Identification of cost-effective materials for the primary heat exchanger thatdo not degrade prematurely in high-moisture exhaust gas at 550°C
- Design for a secondary heat exchanger that can tolerate sCO2 on one side and saturated steam on the other

AMO MYPP Connection:

- A CHP system consisting of a high- efficiency gas turbine and sCO2 bottoming cycle will be suitable for many small and mid-size manufacturing facilities with both electrical and thermal loads. The increased gas turbine cycle efficiency will improve the business case for the installation of such CHP systems in the 5-10 MW size range.
- Flexible CHP systems that can provide grid services are expected to be financially attractive investments in markets with high penetration of intermittent renewable resources, such as California, Texas, and several Midwestern states.

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$1,125,000	$375,000	$1,500,000	25.0%
Approved Budget	$1,125,000	$375,000	$1,500,000	25.0%
Costs as of 3/31/19	$38,280	$14,447	$52,727	27.4%

Project Team and Roles:

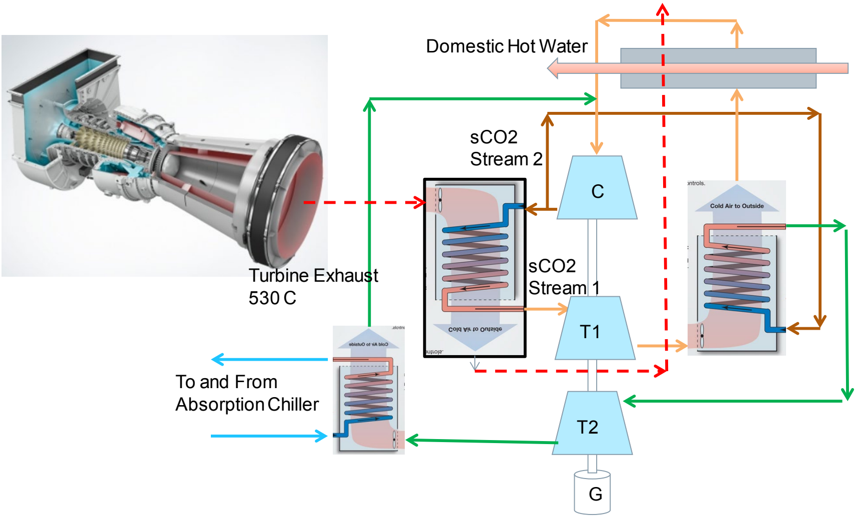
Team Member	Skills/ Roles
Principal Investigator: Dr. Anand Kulkarni	Materials needs for fuel-flexible environments, Additive Manufacturing
Siemens Team: Dr. Arindam Dasgupta, Mr. Doug Willham, Dr. Bradley Lemke, Mr. Chris Junod, Ms. Colleen Pavlicek, Dr. Wes Harris, Mr. Rae Gold	Thermo-economic studies of power systems including CHP systems Combustion, Aero-thermal design, aero-derivative gas turbines manufacturing, operation and testing.
ORNL Team: Dr. Sebastien Dryepondt, Dr. Bruce Pint, Dr. Michael Kirka, Dr. Patrick Geoghegan	High temperature materials and Corrosion, Heat exchanger design and testing, Additive manufacturing (AM) of high temperature structural components.

Project Objective(s)

- Strongly support AMO's initiative to conduct research and development activities to further the utilization of cost-effective, highly efficient combined heat and power (CHP).
- Target - Electricity generation component of a 1-20 MWe CHP system - Gas turbine based CHP system must be able to operate at a fuel to electricity generation efficiency of 25% and must demonstrate a total CHP efficiency of 85% at 50% rated electrical capacity.
- A supercritical CO_2 bottoming cycle will meet this requirement due to the size of its turbomachinery and demonstrated factory assembled design, however the cost of heat exchanger needs to be addressed.
- The project seeks to enable a new type of a flexible CHP system by adding a supercritical carbon dioxide (sCO_2) bottoming cycle and a steam injection system to an existing 5.3 megawatt (MW) gas turbine to increase its peak electrical efficiency to 50% and maintaining 30% electrical efficiency at 50% of load.

Technical Innovation

- The new CHP system configuration will use an existing 5.3 MW aero-derivative gas turbine as its starting point. It is a proven turbine with capability for fast cold-starts, fast ramping up and down, and multiple starts and shutdowns per day.

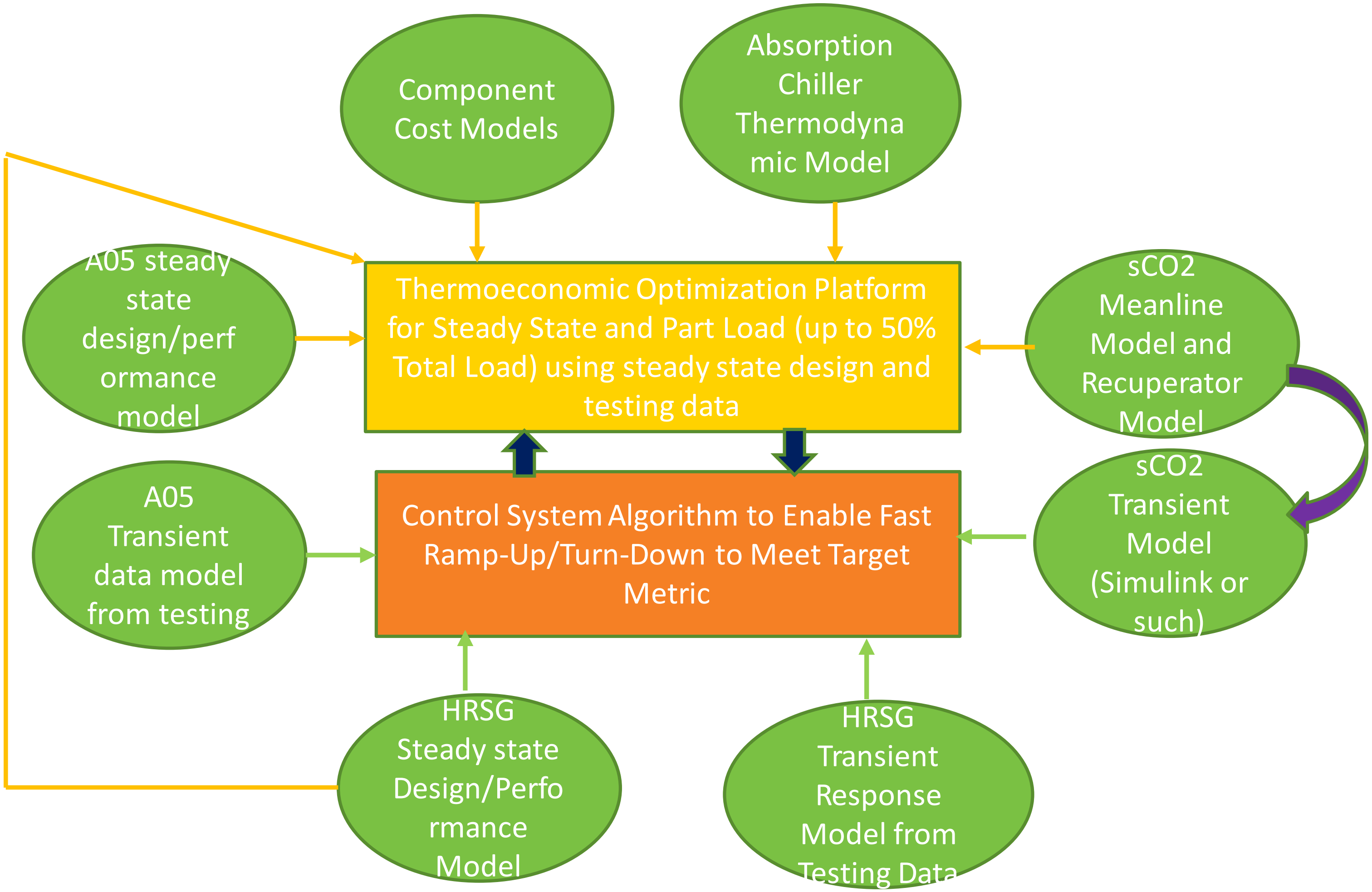


- The turbine currently has an electrical efficiency of 32% at rated power, but with additional steam injection this efficiency can be increased to approximately 37%. Incorporating a sCO2 bottoming cycle will increase total electrical efficiency to around 50%. Special emphasis will be placed on thermo-economic optimization of the cycle, to ensure commercial viability and marketability of the developed system.

Technical Innovation

- To inject additional steam into the turbine, a new fuel nozzle variant will be designed, built, and tested. Additive manufacturing approaches, which allow intricate designs not feasible with conventional manufacturing technologies, will be utilized to build the modified nozzle.
- A major focus of the project will be the development and demonstration of novel heat exchangers. To achieve project goals, a new heat exchanger design is needed for the primary cycle between the gas turbine and the sCO_2 system as well as the secondary cycle between the sCO_2 and process steam systems. The new advanced heat exchanger designs need to be optimized for low pressure drops, have the ability to withstand multiple cycles at high temperature and pressure, include integrated control systems, and be cost effective.

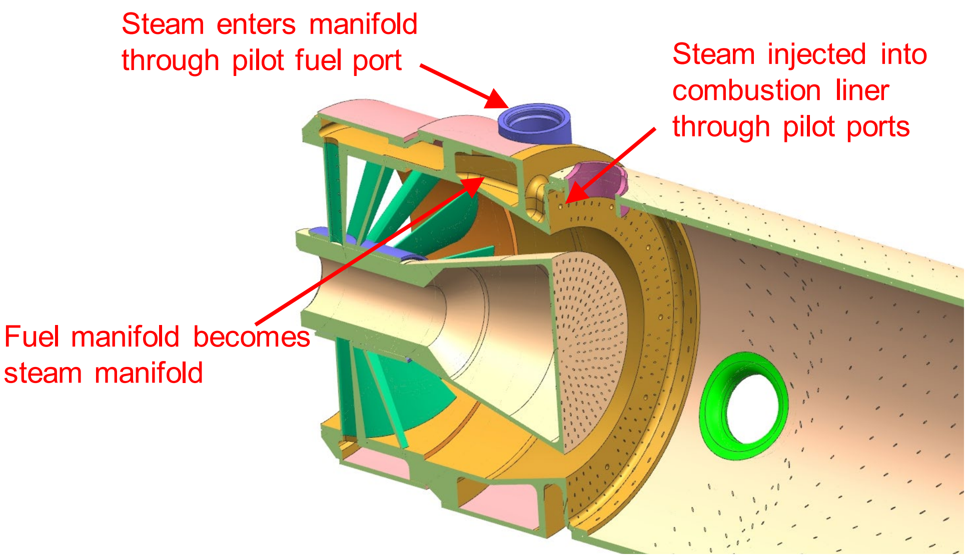
Technical Approach



Siemens and Oak Ridge National laboratory (ORNL) have unique Infrastructure and Expertise for detailed thermodynamic simulation of cyber-physical systems for optimization of cost/performance for desired targets

Technical Approach

Steam Injection Planned at Pilot Manifold (after starting) for Potential Emissions Improvement



Hardware/Software Changes Needed:

- Steam manifold
- Valves for fuel shutoff and steam manifold switch
- injected into combustion liner through pilot ports
- Control system for fuel and steam valves

ORNL/Capstone 65kw Microturbine Testing Facility

- Microstructure and mechanical properties of the AM HX materials
- Exposure in ORNL SCO2 rigs at 400°C-600°C and 200-300 bars for duration up to 2,000h to compare Determination of AM HX lifetime and ORNL lifetime model in SCO2

Integrated/Synergistic approach for technology advancements

Results and Accomplishments

- DOE award signed 21st Dec 2018, Siemens management executed Jan 11th 2019, Program kicked off
- Siemens and ORNL researchers had kick off meeting to discuss the detailed technical plan, sCO2 heat exchanger interaction with SGT-AO5 gas turbine for optimal cycle studies.
- Efforts initiated for Steady State Modeling Framework and Initial System Architecture Exploration for cyber-physical simulations for thermodynamic modeling
- Performance models on current Siemens A05 gas turbine model were run to generate thermocycling data points, performance and exhaust conditions across various loads
- Materials/Coatings test matrix being put together for high temperature corrosion studies in sCO2/Combustion environments
- FY19 milestone: Initial selection of CHP system components and modeling to confirm feasibility of system design meeting electrical efficiency goal of 50% at rated power

Transition (beyond DOE assistance)

- The developed CHP system will build on an existing 5.3 MW Siemens gas turbine that has a proven track record of service and more than 1,600 installed units worldwide. Marketing a new, advanced version of an existing gas turbine is expected to be easier than a completely new system design. Besides small and medium-size manufacturing facilities, likely host sites for the developed system include large hotels and apartment complexes, hospitals, and universities.

- The Small Engine Business (SEB) division in Siemens Gas and Power, located in Indianapolis, has expressed interest in developing and demonstrating new technologies for these advanced hybrid cycles in CHP mode. The whole engine design/engineering team is intricately involved in the project.