Improving Cost and Efficiency of the Scalable Solid Oxide Fuel Cells Power System

Project ID: DE-FE0031941
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Project Objective
Improving cost and efficiency of the scalable SOFC power system

Overview

1. 3 year/$3.25M Project

2. Project Objectives
   1. Develop analytical models and tools to optimize the Balance of Plant (BoP) design of a SOFC system.
   2. Design and develop the 20kW range FCPS and build the small scale SOFC power system.
   3. Demonstrate the performance and durability of the 20kW FCPS for 5000 hours in a real-world environment at the University of Connecticut.
   4. Develop a cost model, complete techno-economic analysis (TEA) and demonstrate pathways to achieve sub-$1000/kW goals.

3. Deliverables
   1. BP1 (Jan’21–Jun’22): 20kW System design, build and commissioning for demonstration at UConn
   2. BP2 (Jul’22–Dec’23): 5000-hour demonstration, post-test analysis and TEA demonstrating pathways to achieve sub-$1000/kW goals
Solid Oxide Fuel Cell and Stack Technology

- Cummins SOFC technology is a proprietary metal supported cell design.
- 20 kW range Fuel Cell Power System will be built using demonstrated cell and stack technology (TRL 5)
- Flow channels have been optimized for flow uniformity and low pressure drop to achieve low parasitic losses

Data from 500-hour test conducted at Hudson Valley Community College (HVCC) in Malta, NY


170 cell stack used in the 50-kW system test
# Project Milestones

## Timeline and Budget
- **Project Start Date:** January 1, 2021
- **Project Duration:** 36 months
- **Total Project Budget:** $3,251,307
  - **Total DOE Share:** $2,601,046
  - **Total Cost Share:** $650,261
- **Total DOE Funds Spent**: $630,150
  - **Total Cost Share Funds Spent**: $157,536
  * As of September 30, 2021

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<th>Task</th>
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| 1.0  | M1: Project kick-off | Completed | Updated Project Management Plan  
Project kick-off presentation |
| 2.0  | M2: System Requirements review and architecture definition | Completed | System Requirements Report  
Architecture definition complete |
| 3.0  | M3: Calibrated SOFC System Model | Completed | System model calibrated to Baseline stack and system performance |
| 3.0  | M6: Computational Fluid Dynamics (CFD) analysis complete | Ongoing | Flammable gas analysis  
Flow distribution Analysis  
Thermal Analysis |
| 3.0  | M7: Structural Analysis complete | Ongoing | Hot and cold side BOP analysis  
Skid Analysis |
| 4.0  | M4: Power Electronics design qualified | Ongoing | Power Electronics design verified and validated |
| 5.0  | M5: System Catalysts Defined | Ongoing | CATOX and CPOX catalyst specification defined |
| 6.0  | M8: Demonstration System Design Complete | Ongoing | System design drawings and model released. |
| 6.0  | M9: Demonstration system assembly complete | Ongoing | 20kW range Cummins SOFC power system build complete for demonstration  
End-of-line testing complete |
| 6.0  | M10: System Commissioned at UConn  
Go/no-Go to BP2 | Ongoing | System commissioned at the host site demonstrating the functionality and meeting Beginning-of-Life (BOL) specifications |
| 7.0  | M11: 5000-hour test complete | Ongoing | 20kW Cummins SOFC power system Demonstration Report – FCPS demonstration complete at the UConn test facility |
| 8.0  | M12: TEA complete | Ongoing | Complete TEA with costs for high volume manufacture demonstrating pathways to achieve sub-$1000/kW goals |
|      | M13: Deliver Final Report to DOE | Ongoing | Final Report |
1. A full SOFC system Simulink model has been developed, incorporating various components including fuel cell stack, heat exchangers, burner, catalysts. Each component model will solve mass transfer, heater transfer and chemical reactions mathematically.

2. The percentage differences in stack performance and temperature is within 5%. Meanwhile, the differences in pressure and anode out gas composition is also reasonable.
CFD model development

1. Stack CFD model has been developed to predict the cell-to-cell flow distribution across the stack consisting multiple fuel cells.

2. CFD model includes detailed electrochemistry of solid oxide fuel cell, which can be used to predict performance.

3. The model input parameters are calibrated and validated against the test data. Results show model predictions match well when compared to the test data.
1. The ALD process has been set-up to study different mounting strategy for the stack

2. As example, with four additional mounting supports (iteration 2), stress values in the skid were seen to reduce as compared to the iteration 1.
Power electronics development

**Verified operation**

- Inverter creates 3-phase sine wave output and supports the load
- PE controls interface with Battery BMS for pre-charge and contactor closing sequence
- Battery DC-DC regulates HVDC voltage by boosting battery low voltage
- FC DC-DC provides current to HVDC link per FC BOP control current command sent over BOP CAN to control board
- When there is additional current available after supporting the load, FC DC-DC charges battery simultaneously
- FC current can ramp up to support the needed load (customer load + battery charge)
- In a test, battery can pick up 6 kW transient load in < 20 ms
Catalyst development

3 catalysts components:

- **CatOx**: Catalyst selection and sizing completed
- **CPOx**: Characterization work completed. Model development ongoing.
- **Reformer**: Development ongoing.
System design

- Design and development of a 20kW range FCPS using the principles of Analysis Led Design (ALD) and targeted testing to optimize Balance of Plant (BOP) design. Baseline design has completed.

- Key Features of the Balance of Plant architecture includes:
  1) Anode Gas Recirculation (AGR) eliminating need of a steam generator
  2) Start-up burner and catalyzed partial oxidation (CPOx) to assist in start-up and shut-down
  3) Heat recovery from exhaust gases
  4) Catalytic Oxidation (CatOx) to clean the exhaust gases before venting to environment
  5) Leveraging automotive-derived components for the desired reliability and cost
Next steps

- Complete system design and build
- System commissioning and 5000-hour demonstration at University of Connecticut.