INTEGRATION OF AN SOFC WITH ORGANIC RANKINE CYCLE AND ABSORPTION CHILLER FOR DYNAMIC TRI-GENERATION OF POWER, HYDROGEN AND COOLING

OVERVIEW

SOFC's are a potential alternative technology which has high fuel to electricity efficiency, zero criteria pollutant emissions, and can be powered by renewable energy sources. Although SOFC systems exhibit high electrical efficiency, in practical applications almost half of the fuel energy is converted to heat. An Organic Rankine Cycle (ORC) can be used when low temperature waste heat is available making it a candidate as a bottoming cycle for an SOFC system. The integration of an absorption chiller and hydrogen separation unit with SOFC-ORC is studied to meet measured residential power, cooling and hydrogen fuel for fuel cell electric vehicle demands

GOALS

- Develop dynamic physical models for the SOFC, ORC, HSU and absorption chiller in MATLAB/Simulink.
- Verify the developed physical models by comparing to experimental data and literature studies.
- Simulate meeting the dynamics of actual buildings.
- Evaluate the combined system efficiency, capacity, cost, emissions, and dynamic operation and control.

SIMULATION

A spatially resolved dynamic model was previously developed to study dynamic characteristics of SOFC's. In this study, a dynamic model of an ORC consisting of evaporator, expander, condenser, and pump is developed (Figure 1). The heat source for the ORC system is SOFC exhaust gas. Figure 2 shows the system schematic.

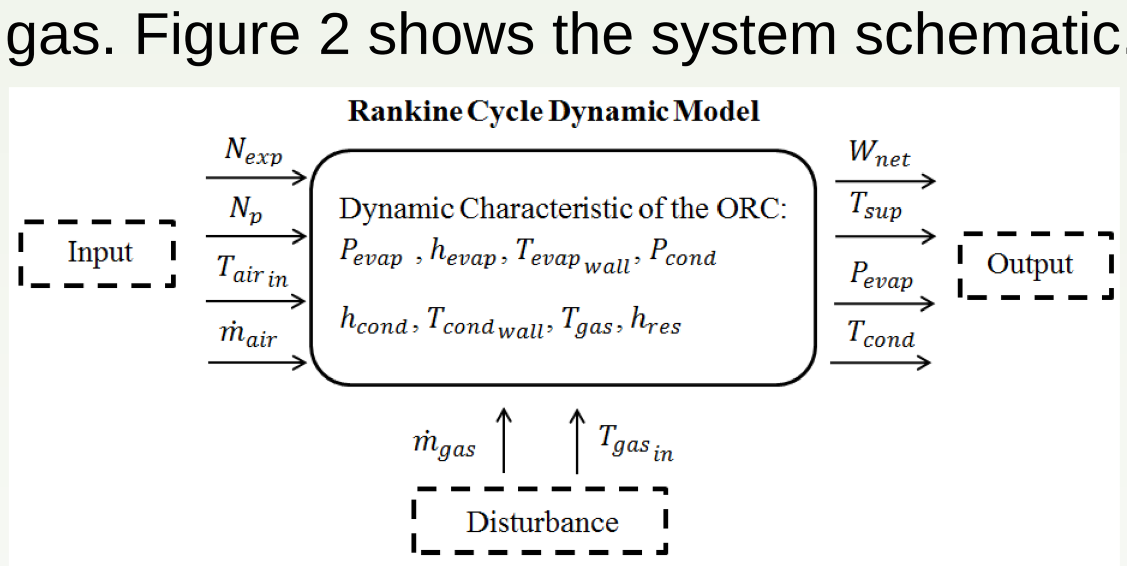

Figure 1: Information Diagram of the ORC Simulation Model

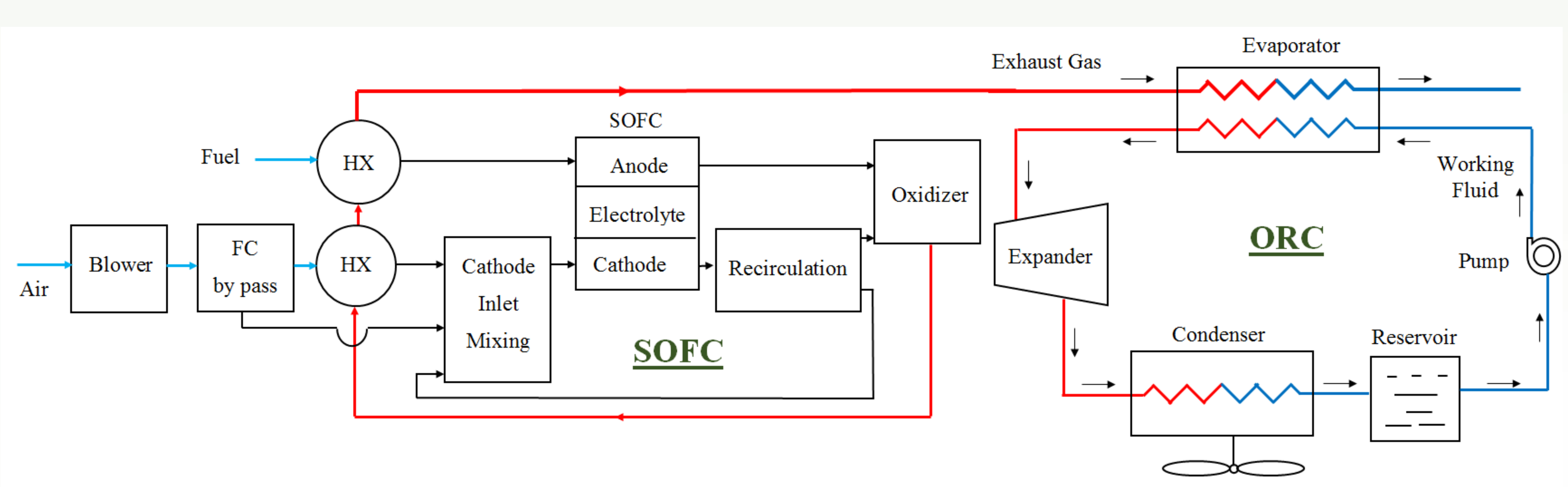

Figure 2: Configuration for SOFC-ORC System

VERIFICATION

To verify the developed dynamic model, the dynamic input data of the Zhang et al. study are used [1]. Figure 3 and 4 show the variation of output power in [1] and developed dynamic model response in two scenarios. The percentage root mean square error is 1.41% and 1.49% respectively.

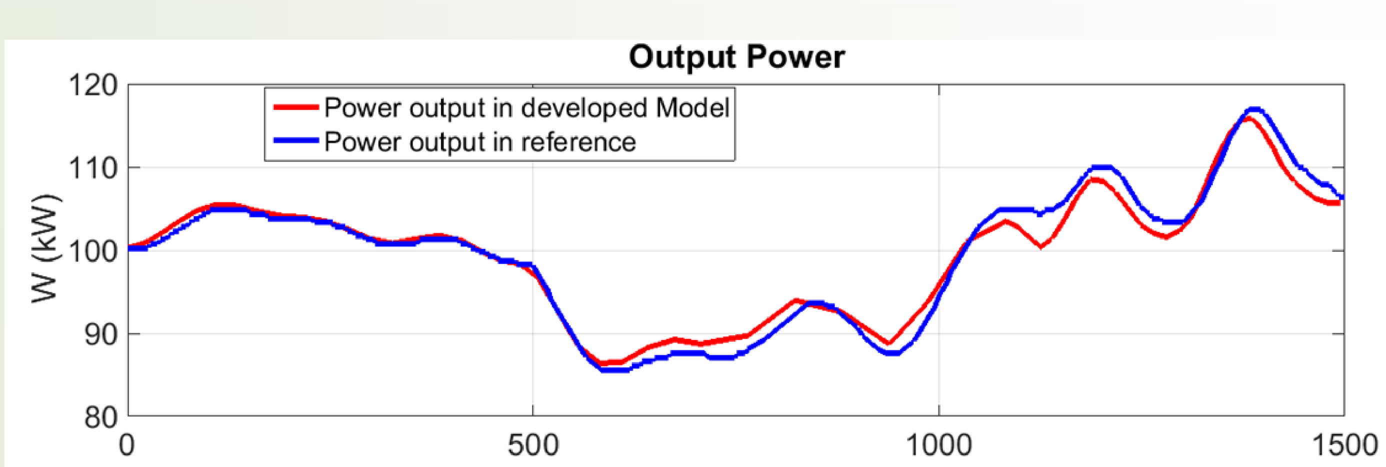

Figure 3: Output Power in Developed Model and in [1]: First Scenario

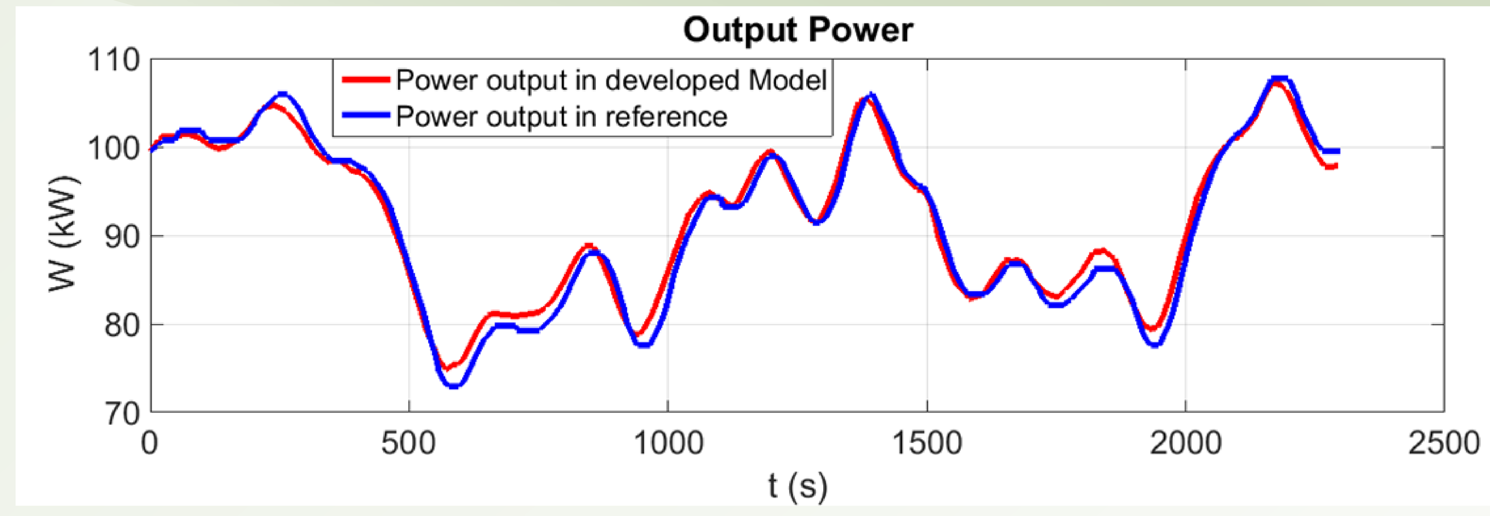

Figure 4: Output Power in Developed Model and in [1]: Second Scenario

RESULTS

Data from a residential complex in Verano Place (VP) in Irvine are used as an input to evaluate the dynamic SOFC-ORC model. Figure 5 shows the actual total power demand of the VP residential complex on July 30th for 24 hours with 15-minute resolution. Two different scenarios are considered in the SOFC-ORC model including actual and bounded PV power demand as shown in Figure 6.

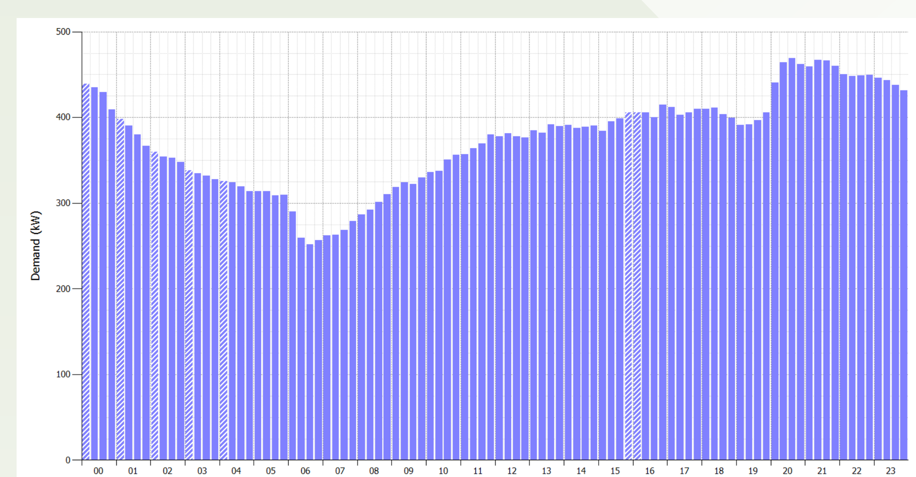

Figure 5: VP Electrical Demand

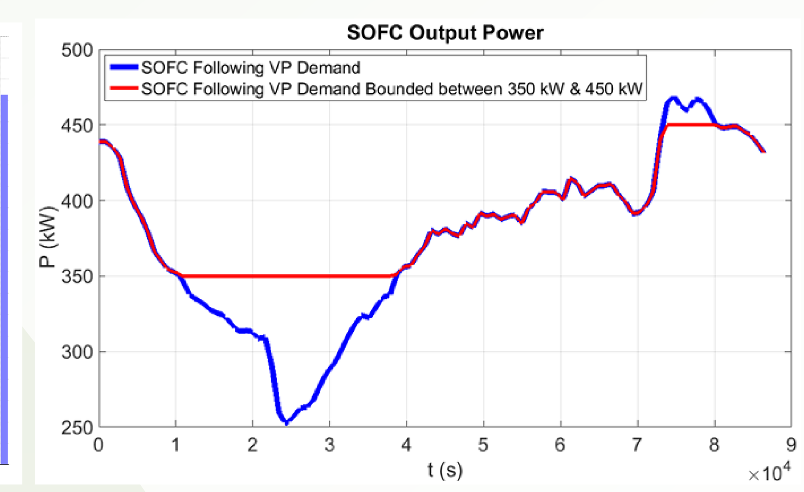

Figure 6: SOFC Output Power

Temperature and Mass flow rate of SOFC exhaust gas in the two scenarios are presented in Figures 7 and 8. The captured SOFC exhaust gas is considered as the dynamic input of the ORC model.

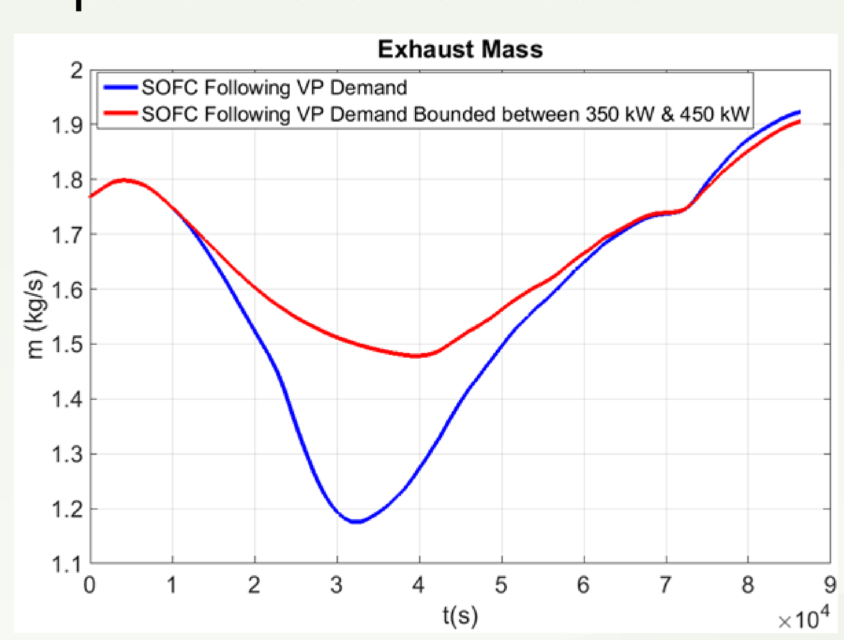

Figure 7: SOFC Exhaust Gas Mass Flow Rate

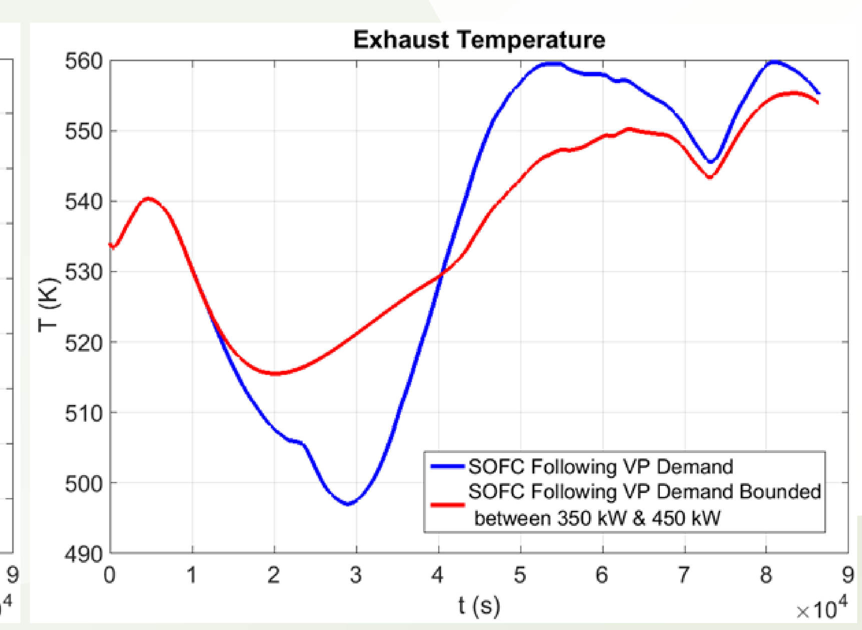

Figure 8: SOFC Exhaust Gas Temperature

The obtained ORC output power based on the dynamic exhaust gas in two mentioned scenarios are presented in Figure 9. The ORC system can generate power which is between 4 and 7 percent of SOFC generated power.
Even after transferring most of its energy to the ORC working fluid, the SOFC exhaust remains of sufficient quality for use in an absorption chiller. (Figure 10)

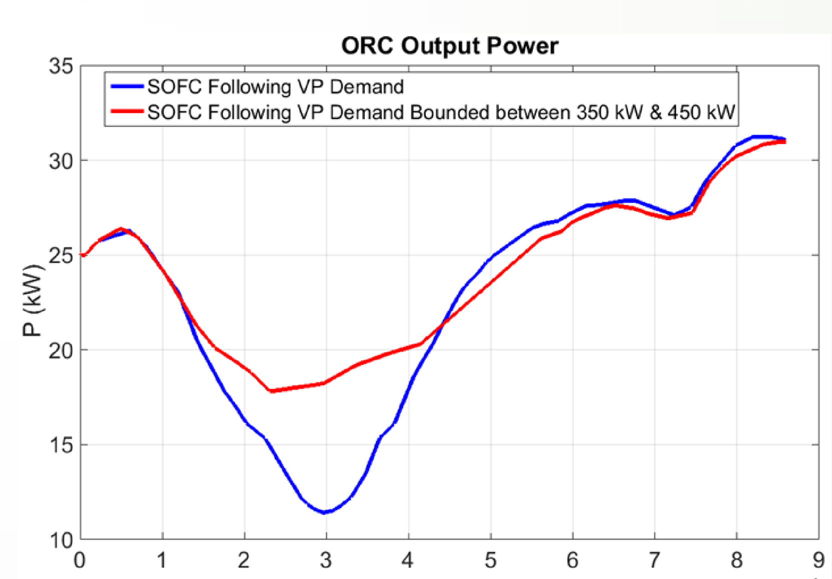

Figure 9: ORC Output Power

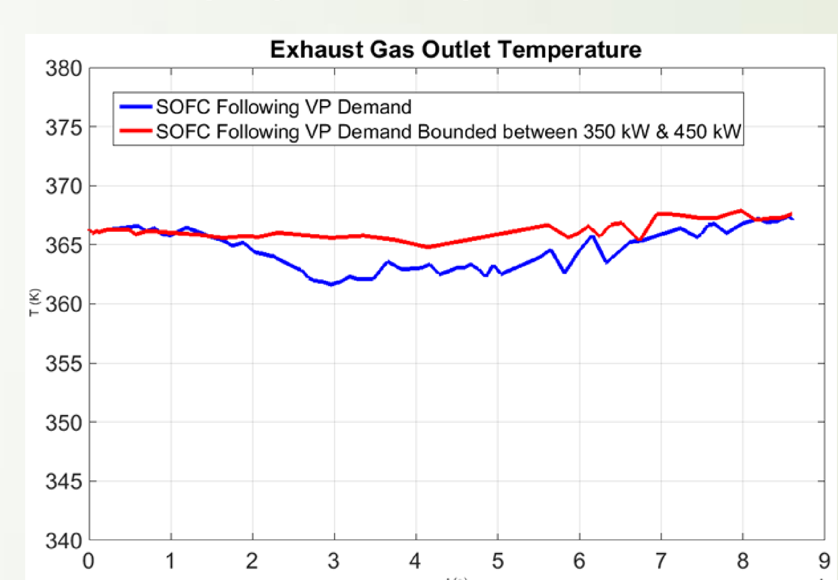

Figure 10: Exhaust Gas Outlet Temperature after Transferring Heat in ORC

REFERENCE

[1] Zhang, Jianhua, et al. "Modeling and constrained multivariable predictive control for ORC (Organic Rankine Cycle) based waste heat energy conversion systems." Energy 66 (2014): 128-138.

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