Cold-air bypass characterization for fuel cell thermal management in fuel cell turbine hybrids

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Long Abstract

Introduction

The hybridization of high temperature fuel cell and gas turbine allows to achieve very high efficiency and to extend the lifetime of the fuel cell component [1-4]. However, the interaction between the two coupled systems presents new significant challenges in terms of controls. In a hybrid system different variables, for instance turbine speed and cathode airflow, are strongly coupled, i.e. a change in one variable affects the second one and vice-versa. This aspect results in a more complicated control of the system. In particular, cathode airflow management is considered extremely important to keep cell temperature and temperature gradients in a safe range, but its variation affects several other parameters in the system [5, 6]. In this work, the effect of cathode airflow variation on the system dynamics was studied comparing two different scenarios: in the first case turbine speed was let free to change (open loop configuration), in the second one it was kept constant via manipulating the electric load imposed to the turbine (closed loop configuration).

The comparison between the two cases showed the coupling between turbine speed and cathode airflow, and consequently cell temperature. As such, cell temperature response was proved to be very different in open loop and closed loop. This aspect needs to be taken into account when a control strategy is developed.

1. Methods

Two experiments were carried out using Hardware In the Loop Simulation (HILS) approach. In this approach the hardware components of the Hybrid Performance (HyPer) facility, located in the U.S. Department of Energy, National Energy Technology Laboratory, are coupled with a numerical real-time model of a solid oxide fuel cell (SOFC). The SOFC model drives the only heat source of the real system, which consists in a recuperated gas turbine and two vessels that emulate the volumes of the fuel cell system. A schematic representation of the plant is presented in Figure 1, where all the dash lines represent the numerical model.

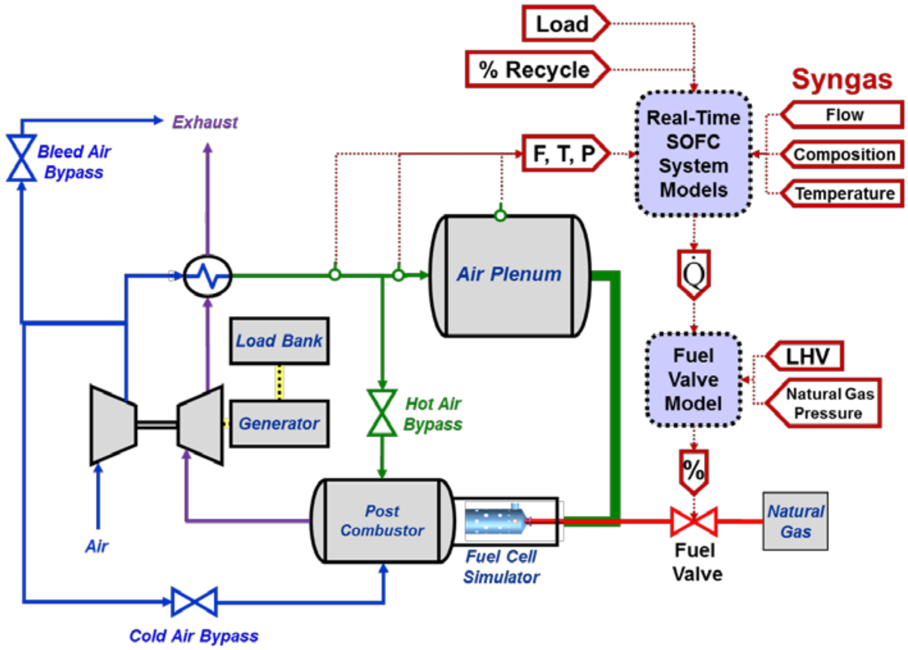

Figure 1. Hyper facility schematic diagram

The two experiments were carried out moving the cold air bypass valve, which bypasses the heat exchanger and the fuel cell volume diverting air to the turbine inlet, with a 15% step up from its nominal position. In the first case (open loop) no control system was applied to the turbine speed, while in the second case (closed loop) the speed was kept constant by varying the turbine load. The results showed the strong coupling between turbine speed and several other system parameters, such as cathode airflow and cell temperatures. When the speed was free to change, cathode airflow decreased significantly with a self-propagating effect, because of its coupling with the turbine speed, and the fuel cell temperature increased because of the reduction in the cooling flow. In the second case, when the speed was controlled, the cathode airflow variation was lower, and cell temperature showed a slight reduction. This was caused by a higher variation in turbine inlet and outlet temperatures than in open loop, which affected cathode inlet temperature, since cathode airflow was pre-heated in the heat exchanger with the turbine exhausts. Another important aspect was the different behavior of surge margin in the two cases. When the speed was kept constant, the variation in surge margin was smaller, suggesting that a larger freedom is possible in cold air valve position change in order to control cell temperature without affecting the system safe operability.

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