drive using hydrogen from natural gas is twice as high as that of a conventional internal combustion engine [4]. Using pure hydrogen as fuel can reduce vehicle emissions, especially in densely populated urban environments.

The dependence of PEM on high-purity hydrogen reactant requires novel hydrogen generation and storage technologies. Fuel processors that reform hydrocarbon fuel into gas rich in hydrogen are currently considered a near-term solution to the hydrogen generation problem [7]. Controlling fuel processors to provide hydrogen on demand can mitigate problems associated with hydrogen storage and distribution [8], [9]. In the long term, hydrogen generation by means of water electrolysis based on renewable energy from wind, waves, and sun, or reformed hydrocarbon fuel through biomass will help reduce the current dependence on fossil fuels.

The principle of electricity generation from a PEM-FC is straightforward when the correct material properties, cell structure, and hydrogen are in place. The FC power response, however, is limited by air flow, pressure regulation, heat, and water management [10]. Since current is instantaneously drawn from the load source connected to the FC, the FC control system is required to maintain optimal temperature, membrane hydration, and partial pressure of the reactants across the membrane to avoid detrimental degradation of the FC voltage, which can reduce efficiency. These critical FC parameters must be controlled over a wide range of current, and thus power, by a series of actuators such as valves, pumps, compressor motors, expander vanes, fan motors, humidifiers, and condensers. The resulting auxiliary actuator system, shown in Figure 2, is needed to make fine and fast adjustments to satisfy performance, safety, and reliability requirements that are independent of age and operating conditions. These requirements create challenging spatial and temporal control problems [11]. In this article we assume that compressed hydrogen is available, and we concentrate on the challenges associated with the temporal characteristics of the air (oxygen) supply. The overall FC system and relevant variables are shown in Figure 2.

We use control design techniques based on a dynamic model developed in [12] and [13]. A similar modeling

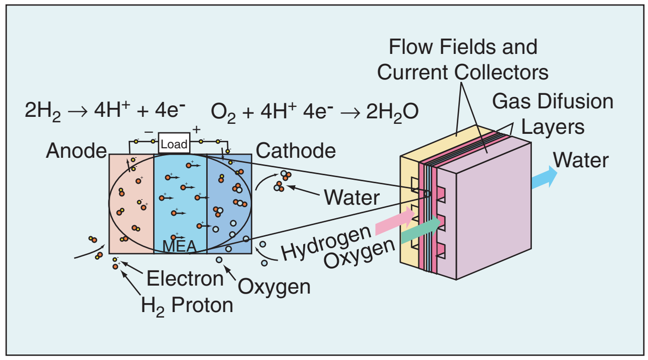

Figure 1. *PEM FC reactions and structure. Water, electrical energy, and heat arise through the combination of hydrogen and oxygen. Although the concept is simple, its implementation requires a complex structure, sophisticated materials, and accurately controlled conditions.*

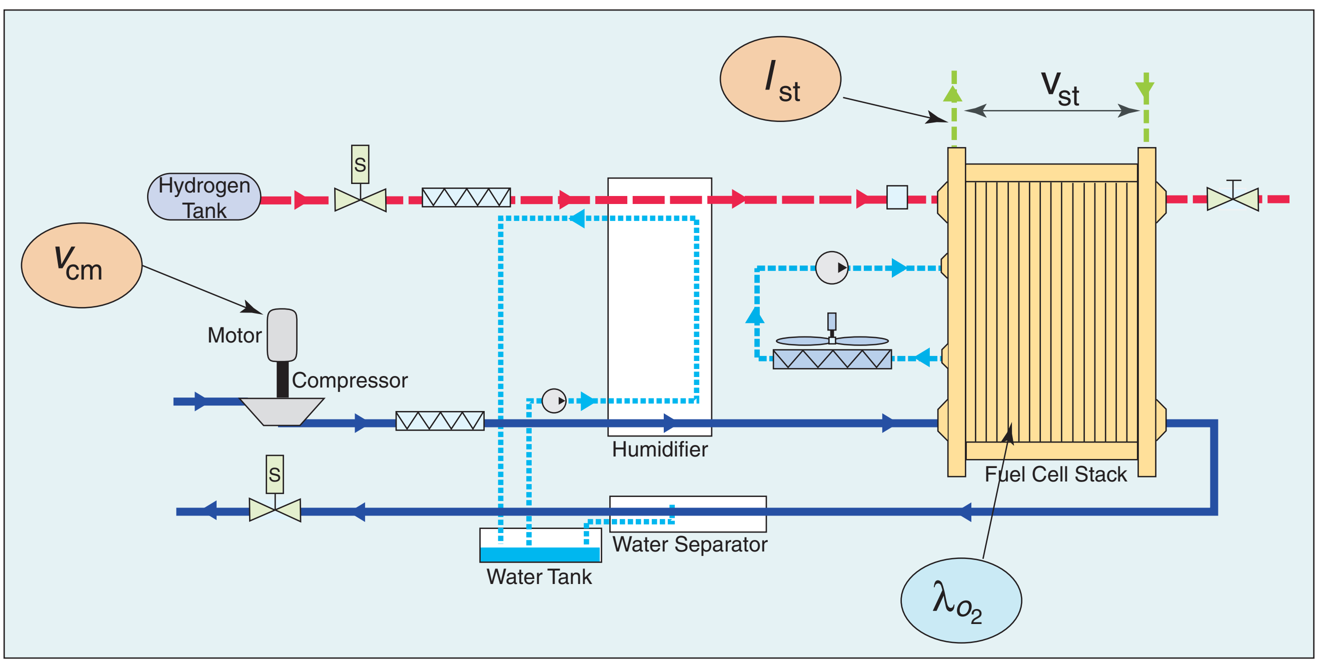

Figure 2. *FC system with major control subsystems. A fuel cell system includes four subsystems that manage the air, hydrogen, humidity, and stack temperature. The humidification and cooling are sometimes combined in one subsystem. The figure also shows the control inputs and outputs of the air subsystem.*