Range-Extended Hybrid Electric Vehicle Project

L. Breziner, P. Strahs, J. Weaver, C. Garrant, K. Shaffer, G. Diloyan, P. Hutapea
Department of Mechanical Engineering, Temple University, Philadelphia, PA, USA

Abstract

The objective of this project is to design and assemble the powertrain of an electric vehicle, using a hydrogen fuel cell stack (FC) and small internal combustion generator (ICGen) for range extending capabilities. The idea behind this particular hybrid layout is that the battery pack is sized to give the vehicle an all-electric range suitable for short trips (about 20 miles). For greater range, either the ICGen or the FC operates, depending of certain factors such as power load requirements, emissions and noise restrictions, and fuel availability.

Powertrain

As shown in Fig. 1, the vehicle is propelled by a high-torque three-phase induction motor and controlled using an integrated power inverter that allow regenerative braking.

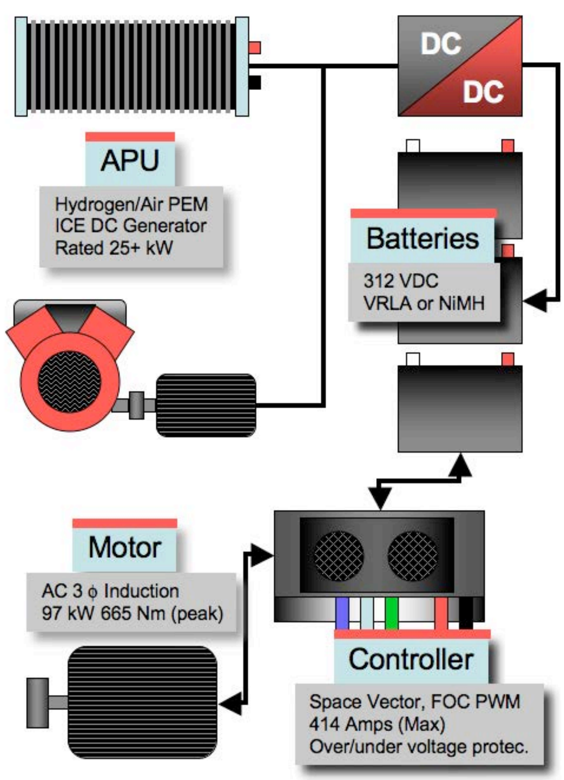

Figure 1: Series Hybrid Powertrain Diagram.

The electric energy is stored in a bank of deep-discharge lead acid batteries (VRLA or Gel) with the option of upgrading to the NiHM technology. The range-extended capability is provided by the *Auxiliary Power Unit* (APU), which is composed by the ICGen and FC stack. This unit is operated at their peak efficiency based on the factors mentioned before by means of an automated control system.

Vehicle Description

For this project, a 2000 Audi TT Quattro was selected as the platform for the project due to its compact size, weight, aerodynamic parameters, and good driving dynamics. The car has been stripped down of all unnecessary components, and the drivetrain is currently being redesigned using some of the original components (Fig. 2.)

Figure 2: Image of the actual vehicle (before and after removal of components.)

In addition, a numerical simulation for the performance and energy consumption of the vehicle (using current EPA urban and highway driving schedules) was implemented using LabVIEW®. Based on very conservative parameters, the vehicle specifications and performance results are listed in Table 1.

Table 1: Simulation parameters for the proposed powertrain. (*) Average Propulsion Power required using EPA driving schedules.

Parameter	Value
Gross Weight	1825 kg (4015 lbs)
Coefficient of Drag	0.34
Frontal Area	2.15 m^2
Motor Peak Power/Efficiency	97 kW / 0.88
Final Gear Ratio	3.15:1
Acceleration (0-60 mph)	10.6 sec
¼-mile Acceleration / Speed	17.9 sec / 71 mph
Top Speed	92 mph
Avg Power (City/Highway)*	4.46 / 9.94 kW

The motor and controller is purchased from Azure Dynamics (Woburn, MA). The motor air-cooled AC motor is capable of producing an astonishing 490 ft-lb of torque, allowing good acceleration, gradeability, and top speed without using a multi-gear transmission. This also results in better powertrain efficiency and overall weight reduction.

The battery bank has a nominal voltage of 312VDC, it is air-cooled, and sized to provide an all-electric range (estimated) of 22 miles in the city and 23 in the highway using current VLRA lead-acid technology.

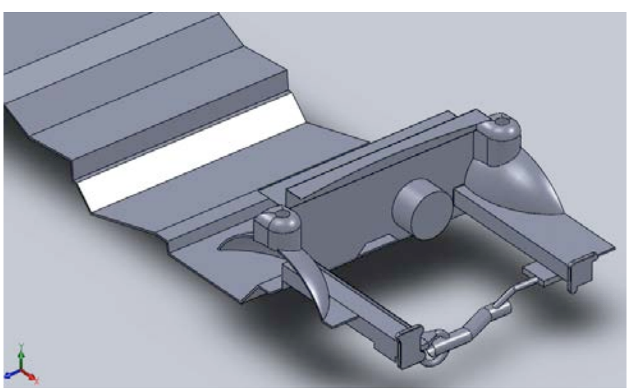

Figure 3: Current CAD model of the front end of the car for component design and optimization.

The APU is designed to provide at least 20 kW of power to the traction batteries in order to sustain highway speeds of 70 mph and charge the batteries at the same time. The specifics of the APU are still to be determined and a few options are being considered at this time, including diesel or gasoline powered generator, and a micro gas turbine in conjunction to a small hydrogen fuel cell stack (less than 15 kW). In addition to this, there is also the option of having a single 20+ kW fuel cell stack as the solely component of the APU.

Funding Support

The Pennsylvania Department of Environmental Protection

References

1. G. Diloyan, L. Breziner, P. Hutapea, "Development of a PEM Fuel Cell Powered Scooter," Journal of Fuel Cell Science and Technology, 9(3), 034502, 2012.
2. P. Strahs, J. Weaver, L. Breziner, C. Garant, K. Shaffer, G. Diloyan, P. Hutapea, "Development of a Proof of Concept Hybrid Electric Fuel Cell Vehicle," Journal of Renewable and Sustainable Energy, 4, 033107, 2012, doi: 10.1063/1.4718369
3. G. Diloyan, P. Hutapea, "Platinum Dissolution in Polymer Electrolyte Membrane Fuel Cell Under Mechanical Vibrations," Proceedings of ASME 2011 5th International Conference on Energy Sustainability & 9th Fuel Cell Science, Engineering and Technology Conference, Washington, DC, August 7-10, 2011.
4. G. Diloyan, P. Hutapea, "PEM Fuel Cell Loses due to Vibration," 6th Fuel Cells Durability & Performance, Knowledge Foundation, Boston, MA, December 9-10, 2010.
5. L. Breziner, P. Strahs, J. Weaver, C. Garrant, K. Shaffer, G. Diloyan, P. Hutapea, "Development of a Hybrid PEM Fuel Cell Vehicle Utilizing Multiple Power Sources," ASME 8th Annual Fuel Cell Science, Engineering & Technology Conference, Brooklyn, NY, June 14-16, 2010.
6. L. Breziner, P. Strahs, P. Hutapea, "Influence of Vibration on the Liquid Water Transport of PEM Fuel Cells," ASME International Mechanical Engineering Congress and Exposition, Lake Buena Vista, FL, November 13-19, 2009.