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Analysis of the control strategies for fuel saving in the hydrogen fuel cell vehicles

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ABSTRACT

A hydrogen fuel cell vehicle requires fuel cells, batteries, supercapacitors, controllers and smart control units with their control strategies. The controller ensures that a control strategy predicated on the data taken from the traction motor and energy storage systems is created. The smart control unit compares the fuel cell nominal output power with the vehicle power demand, calculates the parameters and continually adjusts the variables. The control strategies that can be developed for these units will enable us to overcome the technological challenges for hydrogen fuel cell vehicles in the near future. This study presents the best hydrogen fuel cell vehicle configurations and control strategies for safe, low cost and high efficiency by comparing control strategies in the literature for fuel economy.

Introduction

On account of find a way out the global warming problem in the world, it is utmost importance to minimize demand for fossil fuels and reduce emissions [1–9]. Thanks to sustainable fuel nature of hydrogen, hydrogen fuel cell vehicles (HFCEVs) are inevitably more advantageous than other conventional vehicles. Since the energy efficiency of the hydrogen fuel cell is high, replacing the internal combustion engines with hydrogen fuel cell vehicles will contribute to the developing technology. With this precaution, the trend towards hydrogen fuel cell vehicles in the transportation sector is increasing rapidly [8–12]. In general, hydrogen fuel cells are environmental friendly technology that transforms incoming hydrogen into electricity and contributes to renewable energy [13–23]. They are promising and renewable energy sources with high energy efficiency and low emissions [24–26].

The hydrogen fuel cells are designed to take the place of conventional internal combustion engine vehicles [11,27–29]. In addition to these advantages, there are disadvantages of having lower power density and slower power response [26,30,31]. In order to reduce these disadvantages, supercapacitors (SCAPs) and batteries (BATs), energy storage systems, can be used together with the fuel cell (FC) [20,26,32–34].

However, to achieve the advantages of HFCEVs and to mitigate disadvantages is needed that robust control strategies. The ability of the batteries to have higher energy than the supercapacitors and the supercapacitors to have higher power

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than the batteries should be used appropriately in the control strategies [20,26,31,32,35–41]. Moreover, it is necessary to design controllers when these control strategies are developed. For this, the design of the electronic power circuits in the system should increase the efficiency of the system and satisfy other needs [42–46]. Controllers control the flow and sharing of energy in energy storage systems by supplying energy from the system [47–52].

Proper control of the power and energy variables is required to control the vehicle's equivalent hydrogen consumption and maintain the efficiency of the vehicle along the way. To achieve high charging efficiency, the battery (BAT) must operate at the optimum operating range and a control strategy must be designed for it [31,42,53–55]. The current, voltage and power ratings of an FC must be adjusted by checking BAT charge status of the BAT. In addition, to achieve good system performance, the supercapacitor (SCAP) control strategy must be identified and must have a gradual control cycle with the FC control strategy [24,26,32,33,52,56–62]. In order to apply these control strategies to FC and hybrid vehicles, a controller should be used to establish and implement a control strategy based on data from the traction motor, FC, BAT and SCAP. After determining the characteristics of all these energy storage technologies according to the energy and power demand of the vehicle (P_{demand}) and establishing a system, it is necessary to apply the control strategies and make comparisons between them and determine the most appropriate one in terms of many features.

The first part of the study describes the vehicle configuration and gives an overview of various control strategies and then, these control strategies are examined, compared and interpreted. In the last section, the results are presented in an explanatory manner.

The configuration of the vehicle

As developments in the automotive sector increase, automakers are beginning to produce vehicles that are technologically advanced. It is necessary to determine their configuration before launching these vehicles to the market. The configuration of the hydrogen fuel cell vehicle (HFCEV) is clearly indicated in Fig. 1. In this configuration, the control mechanism has consisted of FC, BAT, SCAP, DC/DC converter and inverter [30]. In addition, the vehicle composes of three-phase traction motor, auxiliary devices, DC-bus, and energy storage systems. The power-energy changes and balances required by the vehicle are provided by the healthy functioning of all these elements. The control strategy should be determined to prevent any damage to the system from occurring.

The primary energy source for HFCEV is FC [32,63,64]. FC converters serve as an intermediate layer for connecting FC to the DC-bus [60–64]. FC converter maintains the voltage regulation of BAT [65–68]. The battery generates extra power for both the DC-bus and FC when the fuel cell's power (P_{FC}) is not enough. BAT converter is operated to preserve the voltage regulation of SCAP [20,39–41,69]. SCAP controls DC-bus voltage and it generates specific power that FC and BAT cannot generate to provide the vehicle's sudden power demand. SCAP converter is involved in regulating a DC link voltage [69–74]. The inverter is used to produce any desired output voltage for the traction motor and to control the output of FC-BAT-SCAP.

Control strategies of the hydrogen fuel cell vehicles

Control mechanisms in HFCEVs usually include FC, BATs and SCAPs. Various controllers have been developed and applied to provide energy management in the vehicle. The most common control strategies used by these controllers are given below.

1. Peaking Power Source Strategy (PPSS)
2. Operating Mode Control Strategy (OMCS)
3. Fuzzy Logic Control Strategy (FLCS)
4. Equivalent Consumption Minimization Strategy (ECMS)

When control strategies are defined, common characteristics should be considered in common, and the main backbone of control strategies must be shaped accordingly. The strategy should be established by determining the current and power limit values for the charge and discharge states of BAT. In the event of sudden charging and discharging of SCAP, the

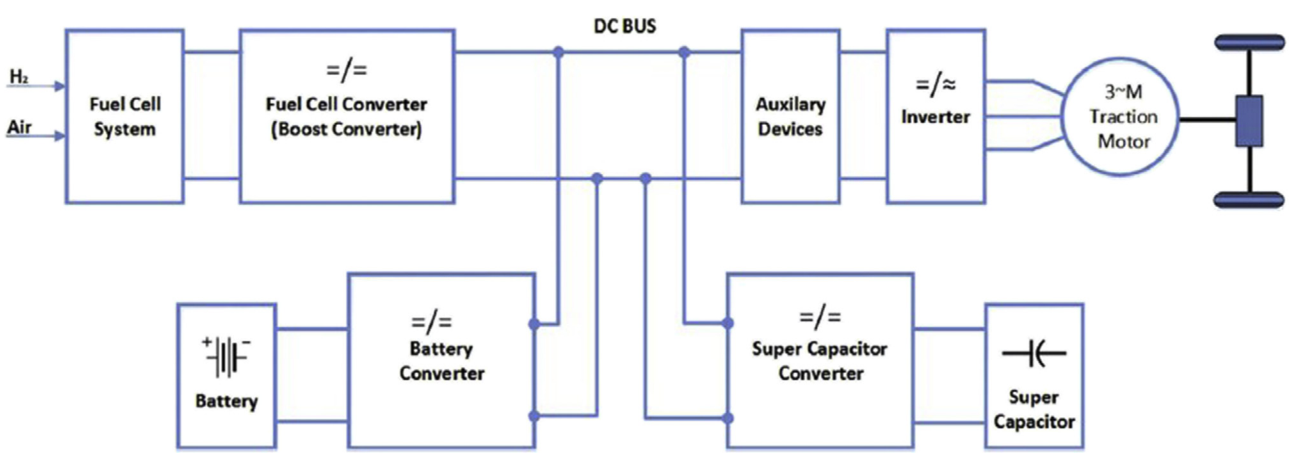

Fig. 1 – The configuration of the vehicle [Adopted from Ref. [11]].

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