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The computer-aided analysis for the driving stability of a plug-in fuel cell vehicle using a proton exchange membrane fuel cell

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ABSTRACT

In order to analyze the driving stability of a plug-in fuel cell vehicle (PFCV), a computer-aided simulator for PFCVs has been developed. PFCVs have been introduced around the world to achieve early commercialization of an eco-friendly and highly efficient fuel cell vehicle. The plug-in option, which allows the battery to be recharged from the electricity grid, enables a reduction in size of the fuel cell system (FCS) and an improvement of its durability. As such, the existing limitations of the fuel cell - such as its high cost, poor durability, and the insufficient hydrogen infrastructure – can be overcome. During the design phase of PFCV development, simulation-based driving stability test is necessary to determine the sizes of the electric engine of the FCS and the battery. The developed simulator is very useful for analyzing the driving stability of the PFCV with respect to the capacities of the FCS and battery. The simulation results are in fact very close to those obtained from a real system, since the estimation accuracy of PFCV component models used in this simulator, such as the fuel cell stack, battery, electric vehicle, and the other balance of plants (BOPs), are verified by the experiments, and the simulator uses the newly-proposed power distribution control logic and the pre-confirmed real driving schedule. Using these results, we can study which one will be the best in terms of driving stability.

1. Introduction

The world's major automotive and energy companies have focused on hydrogen fuel cell vehicles (HFCV) as one of the opportunities to solve the problems of conventional gasoline vehicles, such as greenhouse gas emissions and the depletion of fossil fuels. However, when it comes to commercialization, HFCVs face various limitations, such as their high cost, poor durability, insufficient hydrogen infrastructure, and so on. Electric vehicles (EV) constitute another eco-friendly opportunity. In the case of the EV, its battery charging time is too long and its energy capacity too low, even though their capital cost is lower and they are more durable than HFCVs. The battery's energy capacity is not sufficient for the entire driving range required, and then the battery cannot be easily recharged due to the long charging time. On the other hand, fuel cell hybrid electric vehicles (FCHEVs) require a relatively small fuel cell capacity because the required output power is

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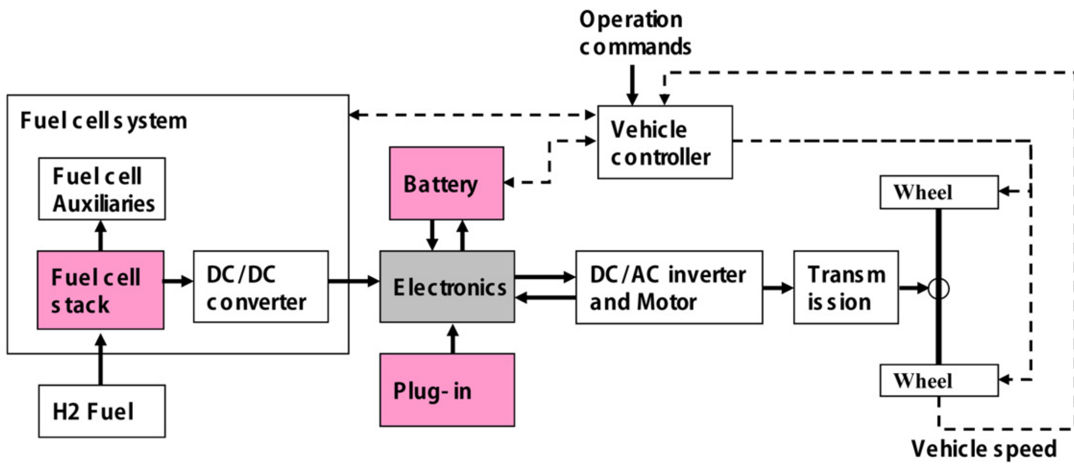

Fig. 1 – Configuration of the general plug-in fuel cell vehicle.

shared with a battery. However, the fuel cell is the source for charging a battery; thus, the fuel cell has to keep drive during a whole driving schedule. The short lifecycle of a fuel cell stack arises from the frequent start-up and long-time operation of the FCSs. The PFCV was proposed as the earliest commercialized product to solve such problems. The most important differences between the PFCV and the FCHEV are the battery charge source and the 'battery only driving mode'. The battery of the PFCV is charged by a home grid on a nightly basis, while the electricity required to drive the vehicle is supplied by only the battery within a certain range at first. If the vehicle is driven for a short distance almost every day, the operating time and the number of the starts of the fuel cell on the PFCV becomes shorter than that of the fuel cell in the FCHEV. The longer lifetime of the fuel cell on the PFCV can be ensured in that way. In addition, the PFCV brings about a decrease in the capital cost of the vehicle by reducing the capacity of the fuel cell compared to the FCHEV, while the operating cost of the PFCV is decreased by using excess nighttime grid power instead of hydrogen.

Recently, several research works on the PFCV have been conducted, as follows [1–5]. Suppes et al. introduced the conceptual design of the plug-in fuel cell hybrids as the best solution to achieve the early commercialization of the fuel cell-based vehicle [1]. Suppes et al. also verified that the cost and the performance of a plug-in hybrid with a regenerative fuel cell (RFC) are better than those offered by both the FCHEV and the plug-in hybrid electric vehicle [2]. However, Suppes

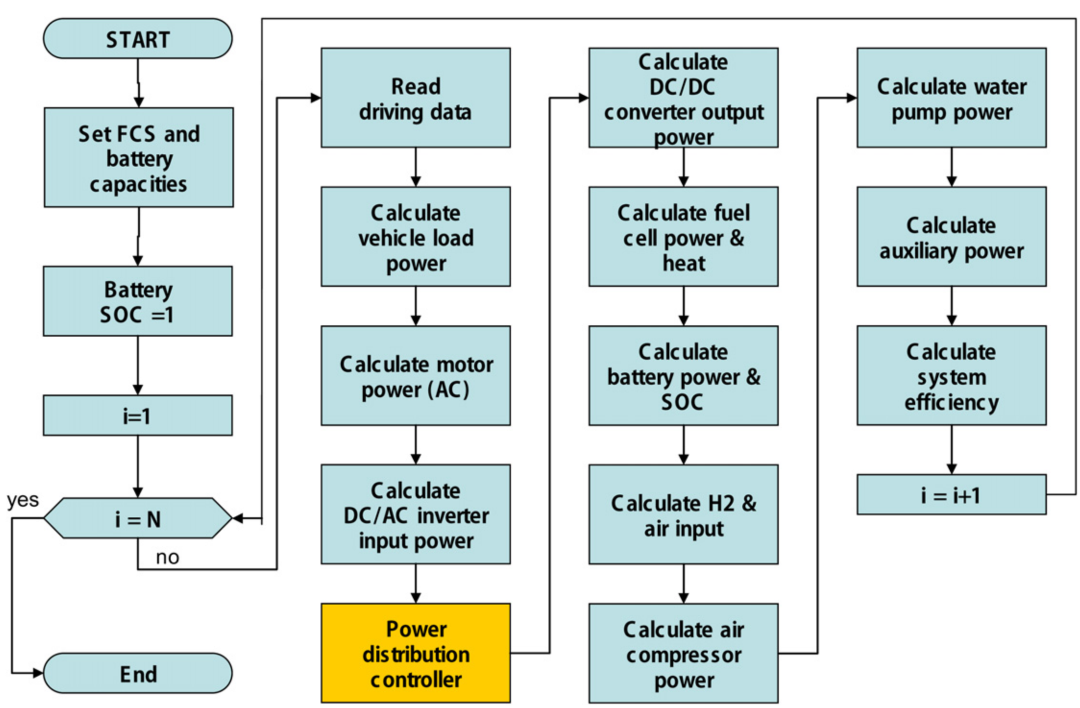

Fig. 2 – Algorithm of the proposed simulator.