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Analysis of fuel cell vehicles with advisor software

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ABSTRACT

In this study, fuel cell systems in automobiles were modeled by ADVISOR, and those models were analyzed through making comparisons. Fuel cell systems are essential parts of vehicles. Thus, before constructing fuel cell systems in a vehicle, analyzing the coherence of the system with vehicle is important in terms of cost and security. ADVISOR which has been developed by National Renewable Energy Laboratory (NREL) facilitates making comparisons of those kind of systems. In this article, the utilization of the software was denoted by an example and through making comparisons of fuel cell types, and the obtained results were evaluated.

1. Introduction

Nowadays, due to increasing tendency to protect the environment, automobile manufacturers are challenged to come up with new solutions. Decrease in fossil fuels leads to more efficient energy use and use of renewable energy sources instead. Decrease in one of the most prominent energy resources, petroleum, and its increasing price widely affect transportation industry. As a consequence, R & D investments for those vehicles are also escalating. Those progresses lead to commercialization and use of vehicles driven by fuel cell. When the vehicles run by fuel cell are compared to the traditional vehicles run by fossil fuel, a significant fuel saving could be observed [1–5].

The most integral part of the vehicles run by fuel cells is fuel cell itself. Fuel cells are electrochemical devices that directly convert chemical energy into electrical energy. They are actively investigated as an attractive alternative to conventional fossil fuel combustion engines for cleaner power generation and are usually classified according to the type of electrolyte used in the cells such as PEMFC, AFC, MCFC, SOFC and PAFC [6]. There are tremendous amount of different fuel cells, and they are distinguished in terms of their performance and fuel type. Due to the fact that trying each type of fuel cells on real vehicles cost too much, the above mentioned comparisons are conducted through a software. The aim of this study is to compare the performances of the same vehicle run by a fuel cell fed by pure hydrogen directly and by hydrogen generated through reformation of petroleum.

2. Literature review for fuel cell vehicle modeling software

This chapter analyzes different fuel cell vehicle models and compares them with each other on a qualitative basis. Quantitatively, Hoefgen compares a subset of the models listed in Table 1. For the qualitative comparison in this dissertation work, first a metric of comparison was established [7].

The generic requirements for a fuel cell fuel vehicle model can be defined as follows and are not different than the requirements of other types of modeling work.

A fuel cell vehicle model has to be physically and mathematically sound. All relevant physical effects have to be considered and the model should be based on mathematically solid grounds. Unless these two conditions are fulfilled, we cannot rely on the results obtained. In addition to the soundness, the scope of the model should also be complete. Complete in this context means that it should enable the modeling of different types of vehicles (hybrids, non-hybrids and different forms of hybrids) and fuel cell systems for different fuels. The resolution of the modeling effort should be high enough to cover all the effects of interest.

After establishing the method of comparison, following paragraphs list the most significant (and most common) electric, hybrid and fuel cell vehicle modeling programs. Among those, only the UC-Davis hydrogen fuel cell vehicle model has been exclusively developed for fuel cell vehicle modeling. All the other programs incorporate functionality for the simulation of battery electric and IC hybrid vehicles.

In addition to the vehicle models listed in Table 1, other models are under development or already completed. Most of the other models that are not listed are either propriety of and internally developed by automotive manufacturers or contractors and only very limited information is publicly available or they are not completed yet. For this reason, these models are not discussed in this dissertation work.

Five different development lines could be identified looking at the

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Table 1
Overview about alternative fuel vehicle models.

Name	Source	Backwards/ Forwards	Fuel cell vehicles
HYZEM	Ricardo Consulting Engineers Ltd.	Forward	No
Elvis	Southwest Research Institute	Backwards	No
Path	Southwest Research Institute	Forward	No
PSAT	Southwest Research Institute and Argonne National Laboratories	Forward	Yes
Advisor	National Renewable Research Laboratory (NREL)	Backwards	Yes
Simplev	Idaho National Engineering and Environmental Laboratory	Backwards	No
Avte	UC-Davis, ITS	Backwards	No
UC Davis– Hydrogen	UC-Davis, ITS	Backwards	Yes

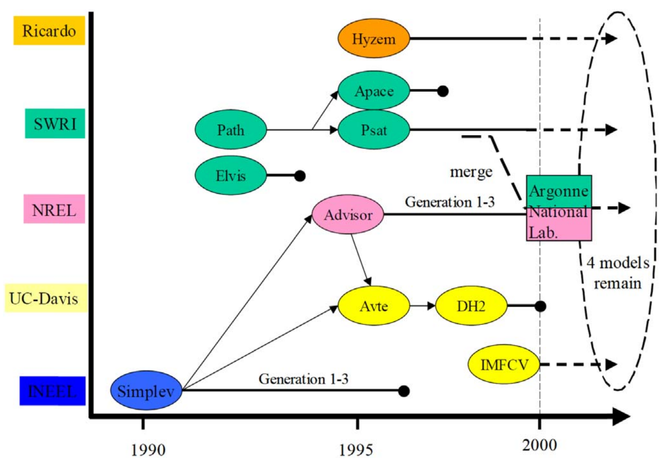

Fig. 1. Model evolvement and history [3].

model properties and the historical development of the models (Fig. 1). These are:

- Ricardo Consultants with the Hyzem program system [8,9].
- Southwest Research Institute (SWRI) with the modeling program systems Elvis, Path, Apace and their final product PSAT [10]. PSAT has been originally developed as the modeling tool for the Partnership of New Generation Vehicles but will be soon made public by Argonne National Laboratory for registered researchers.
- National Renewable Energy Institute with the program system Advisor [11]. Since recently, Argonne National Laboratories is responsibility for the development lines PSAT and Advisor and incorporates them into a single graphical user interface for the ease of use.
- UC-Davis starting originally with the Advanced Vehicle Test Emulator (AVTE) and an (AVTE based) direct hydrogen fuel cell vehicle model [3]. Both models are derived from Advisor. In addition to this modeling effort, UC-Davis started within the fuel cell vehicle modeling project a new forward looking fuel cell vehicle model that incorporates currently the fuels namely hydrogen, indirect methanol and indirect gasoline in hybrid and non- hybrid versions.
- Idaho National Engineering and Environmental Laboratory (INEEL) with Simplev. The program has only historical meaning - it was phased out in 1997 [12].

Several vehicle-modeling tools have been introduced and compared with each other. The points of comparison have been a list of generic requirements for mathematical modeling stated at the beginning of the chapter and restated in the first seven items in Table 2. These criteria define the theoretical potential of the modeling approach. Additionally, in the second half of Table 2 (items 8–10), the actual realized potentials of different models have been compared. Finally, the last row states the public availability.

Table 2
Benchmark (-negative or not possible, O neutral,+good).

Requirement	HY-ZEM	PSAT	Advisor	UC-Davis H2	Simplev
Theoretical soundness	+	+	–	–	–
Completeness	+	O	O	O	O
Flexibility	+		–	–	–
Expanded resolution through co-simulation	+	+	O	–	–
Validation supported through rapid prototyping	+(current version) - (1996 version)	–	–	–	–
Ease of use	O	O	O	O	O
Input data available	+	+	+	–	+
Realized fuel cell vehicle models (2000)	Indirect – methanol and direct-H2 in hybrid and non-hybrid Versions, no ultra-capacitor designs	Only battery hybrid fuel cell vehicles, no ultra-capacitor designs	Indirect- Gasoline and direct-H2 in hybrid and non-hybrid versions, no ultra-capacitor designs	Direct-H2 in hybrid and non-hybrid versions, no ultra-capacitor designs	–
Dynamic considerations	+	–	–	–	–
(Start up, reformer time constants)	Current version	Place holder model	Place holder model	Place holder model	
Modeling of emissions	+ (maps)	+(maps)	–	Not applicable	+ (maps)
Availability (October 2000)	–	+(free)	+(free)	–	–