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Conceptual Design and Modelling of Solar Hydrogen Electric Vehicle

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Abstract There is large demand for better fuel economy on vehicles, researching different hybrid methods is necessary. The objective of this research is to use clean fuel for transportation like hydrogen & solar energy and to reduce the drawbacks of fossil fuels. The main drawback of fossil fuels is that they produce Green-house gases, non-sustainable, and having higher cost. The awareness for the environment has induced the development of different types of electric vehicles. While hydrogen & solar both are free in nature, sustainable energy, and are having zero emissions. These vehicles will be quite and eco-friendly without losing the power or range of the actual ones. We propose a hybrid energy system which combines both solar panel and hydrogen gas which will be a better alternative for conventional source of power generation to run the vehicle. All the more critically, there is poor air quality related with fossil fuel burning and the approaching issue of man-made environmental change. Due to this reality it is essential that we create transportation strategies so that we don't depend on fossil fuel as the primary source.

Keywords- Hybrid vehicles, *Fuel cell vehicles, Energy management, Hydrogen consumption, Photovoltaic cell, Solar energy, Battery, Electric Vehicle, Modelling*

I. INTRODUCTION

As climate change has become more widely recognized global problem, electrical propulsion of vehicles appears to be a promising solution to cut green-house gases emissions. Existing vehicles are often powered either by batteries only, solar panels and batteries, or fuel cells and batteries, with range and performances dependent upon solar radiation and hydrogen storage capacity. This study emphasis on electric propulsion system for a vehicle, encompassing battery, solar panels and a hydrogen fuel cell, which provide higher range and better flexibility of use.
Automotive power trains are evolving at a rapid rate. While the efficiency and emissions of conventional gasoline and diesel powered vehicles continue to improve, consumers are now starting to see departures from the conventional combustion vehicle, with gasoline-electric hybrids and fully electric vehicles being offered by many Original Equipment Manufacturers (OEMs). Hydrogen vehicles are also available in limited markets. Barriers to commercialization of hydrogen vehicles currently include their higher relative cost, level of reliability and refinement, public acceptance of hydrogen as a fuel, and the limited availability of hydrogen fuelling infrastructure. Nevertheless, some Original Equipment Manufacturers (OEMs) will have a commercial fuel cell vehicle in the market by 2020. OEMs are continuing to develop new ways to meet ever more stringent fuel economy standards while maintaining the overall experience that consumers have come to expect form car ownership. Vehicle performance, range, interior space, purchasing cost, maintenance costs, and long-term reliability are all considerations that factor heavily into a buyer's decision making process. It can be challenging to meet buyers' expectations in these areas when developing a vehicle powered by alternative fuels. Our project is going to deal with designing and modelling of vehicles using renewable energy sources is with the aim to demonstrate how current technology can provide alternative fuels power trains that still meet the demands of automotive consumers.

The relevance on research of this nature is obvious in today's global context when people are coming to realize that oil dependency is a threat at many levels. The awareness of this issue has already arisen widely among the automobile industry as well as in the power production sector. In this sense, our project is truly unique since it benefits from a strong university based research and development and aims at encompassing multiple renewable energy sources in order to offer operation performances as high as those of a traditional combustion engine while making optimized use of electrical sources.

The major difference between electric vehicles and conventional internal combustion vehicles is over the energy storage (i.e. battery instead of a liquid fuel such as gasoline) and the engine (i.e. an electric motor instead of an internal combustion engine). From an environmental standpoint the use of batteries is preferred over liquid fuels, for "zero emissions". Although gasoline engines generate pollutants and are inefficient, efforts are being made to increase its efficiency; also fuel can be conveniently stored in reasonable quantities in the vehicle and is made readily available on demand. Furthermore, this kind of vehicle can be conveniently and quickly refuelled. On the other hand, batteries are currently inherently limited in terms of both operating range and recharge rate.

In order to circumvent the two above mentioned drawbacks of traditional electric vehicles (indirect pollution and restricted range due to battery capacity limitation) other technologies have been incorporated into this propulsion system.

Photovoltaic (PV) panels supply emission free and directly available electricity to an extent related to the available radiation from sun. A hydrogen fuel cell (FC) produces electricity from hydrogen through an electro-chemical reaction (that is further described in the report). The main advantage of fuel cells versus batteries is that the energy concentration per weight unit is much higher with hydrogen when the latter is stored under certain conditions.

Combining those two electric sources enables the vehicle to make very limited use of pre-charged batteries and even of hydrogen when the sun intensity is sufficient. An optimized energy management hence will allow the vehicle to run with a very low or no carbon footprint. It is important to note that if renewable energy sources - such as wind, solar or hydro - are used to produce the hydrogen and to recharge the batteries, the propulsion system of the SHEV becomes 100% emission free.
In this research work we aim to design a suitable electric propulsion system enabling to reach required speeds and offering suitable range while consuming as little hydrogen and energy from the pre-charged batteries as possible. The propulsion system components have consequently been selected with this objective in mind together with weight constraints. The entire propulsion system will be monitored and the data stored for subsequent analysis. A computer-based model of the system will be built in order to simulate various driving schemes, study and predict energy flows and consumptions. All work carried out in the scope of the present research will serve as a knowledge foundation for the choice of technology and design of the propulsion system.

II. BRIEF LITERATURE REVIEW

This research being partly based on experimental work in a relatively pioneering field, it could not be fundamentally based on previous scientific publications, these being still few in the field. Here under is an overview of the scientific papers, books and websites about projects and experiments whose scopes are to a wider or lesser extent related to the present topic. They are referred to in the relevant sections where they have been of use. Reading and consulting those as well as conducting a comprehensive electric vehicle market study was of great help when it came to choosing the right technological options in order to design the propulsion system as well as to model it or carry out other specific tasks within the scope of this research.

Wee (2006) [1] summarizes the prospects of Proton exchange membrane fuel cells (PEMFCs) technology considering their current status and a review of the latest research on their applications. There are several issues to be solved before PEMFC can be properly commercialized. The first is the stable and economical supply of high-purity hydrogen. The second is on the scale of the application object, i.e. whether there is sufficient space for satisfying the first issue. The third is the existence of more efficient competitive power sources than the PEMFC system. The fourth is social viewpoints such as the health and environmental benefits as well as the infrastructural aspects of traditional power supply and demand.

Thou thong *et al.* (2009) [2] presents a control strategy for employing PEM fuel cell, known as slow dynamic device, as main power source and supercapacitors, known as high dynamic storage elements, as auxiliary power source for dc distributed system. The main point is to regulate the dc bus, and the important constraint is to avoid speedy operation of fuel cell current. Therefore, fuel cell is simply operating in almost steady state conditions in order to ensure a good synchronization between fuel (hydrogen and oxygen) flow and fuel cell current and to lessen mechanical stresses. The proposed control is based, first, on the regulation of the dc bus voltage through the control of the power delivered by the supercapacitors, and second, on the control of the supercapacitor voltage by the operating of the fuel cell. To validate control algorithms, hardware system is realized by analogical current loops and digital voltage loops (dSPACE). This paper studies carefully the energy management of fuel cell/battery/super-capacitor hybrid power source for vehicle applications. They point out that the 5 fuel cell/battery hybrid source can effectively function to meet the electric vehicle demand and the proposed system has achieved an excellent performance

Elnozahy and Salama [3] studied the feasibility of using PV (Photovoltaics) electricity to charge PHEVs (Plug-in hybrid electric vehicles). Results showed the feasibility of using it for a short period as it can fulfil partially the needed energy by PHEVs. However, in the long operating periods, PV arrays will face difficulty to supply the increased demand for energy and storage devices should be implemented to fill the gap. This paper fills the gap by developing a probabilistic Monte Carlo (MC)-based benchmark that can be used to assess the resulting impacts when PV arrays are used to charge PHEVs. Finally, the authors compare the resulting aggregated impacts with those resulting when PHEV charging demands are met solely from the medium voltage network, in order to draw conclusions on the feasibility of such a charging alternative.

Larminie et al. (2003)[4] cover all aspects of fuel cell technology known at the publishing time. While the fuel cell itself is the key component and an understanding of its features is essential, a practical fuel cell system requires the integration of the stack with fuel processing, heat exchange, power conditioning, and control systems. The importance of each of these components and their integration is rightly emphasised in sufficient detail for the chemical and engineering disciplines to understand the system requirements of this novel technology. This book offers those new to fuel cells a comprehensive, clear exposition and a review to further their understanding; it also provides those familiar with the subject a convenient reference.

Catarina Dinis *et al.* (2012) [5] describes a computational application that allows analyzing the effect of placing photovoltaic panels on board of an electric vehicle. In particular, it calculates the autonomy of the vehicle (number of km) and emissions of greenhouse gases associated to the power generated by the PV system. With this platform, it is possible to include numerous databases for the following parameters:

- vehicle type,
- vehicle location,
- slope of the route,
- solar radiation for different locations and months of the year, and
- type of photovoltaic panel.

From these data, the computational application can deliver results based on different assumptions and combining different type of factors allowing analyzing several parameters such as: characteristics of the PV module; energy balance for urban, extra urban and combined routes; pollutant emissions; and, energy consumption of the vehicle. The platform is under continuous development, and will also include the ability to analyze the vehicle performance for different energy storage systems (such as batteries and fuel cells) and the estimation of the braking energy.

Hybrid and fuel cell vehicles are considered more fuel efficient when compared to conventional vehicles. In addition, fuel cell vehicles are considered carbon-free vehicles, especially if the hydrogen used is extracted from renewable or clean energy sources such as solar, wind and nuclear energy by C.C.Chan [6]. With the more stringent regulations on emissions and fuel economy, global warming, and constraints on energy resources, the electric, hybrid, and fuel cell vehicles have attracted more and more attention by automakers, governments, and customers. Research and development efforts have been focused on developing novel concepts, low-cost systems, and reliable hybrid electric powertrain. This paper reviews the state of the art of electric, hybrid, and fuel cell vehicles. The topologies for each category and the enabling technologies are discussed.

Deep information about the hydrogen research and development as well as market is given in reference [7] by Solomon et al. (2004) provide further information about hydrogen and other fuels. Several factors have led to growing interest in a hydrogen energy economy, especially for transportation. A successful transition to a major role for hydrogen will require much greater cost-effectiveness, fuelling infrastructure, consumer acceptance, and a strategy for its basis in renewable energy feedstock's. Despite modest attention to the need for a sustainable hydrogen energy system in several countries, in most cases in the short to mid term hydrogen will be produced from fossil fuels. This paper surveys the global status of hydrogen energy research and development (R&D) and public policy, along with the likely energy mix for taking it. The current state of hydrogen energy R&D among auto, energy and fuel-cell companies is also briefly reviewed.

Markvart et al. (2003) [8], addresses the need for a book that summarises the current status of know-how in this field. It represents a detailed source of information across the breadth of solar photovoltaics and is contributed to by top-level specialists from all over the world. Over 1,000 references, bibliographies and web sites guide the reader to further details, be it specific information for industrial production and research or a broad overview for policy makers. Thirty-seven chapters in the handbook cover topics from fundamentals of solar cell operation to industrial production processes, from molecular photovoltaics to system modelling, from a detailed overview of solar radiation to guidelines for installers and power engineers, and from architectural integration of solar cells to energy payback, C02 emissions and photovoltaic markets. Appendices include extensive bibliography and lists of standards, journals and other sources of information which can be found in a printed or electronic form.

Mebarki et al. [9] have studied a hybrid power system composed of a PEM fuel cell and a battery storage system to supply an electric vehicle. In this paper, a study of Hybrid power system to supply energy to an electric vehicle is presented. The hybrid system is used to produce energy without interruption and it consists of a proton exchange membrane fuel cell (PEMFC) and a battery bank. PEMFC systems work in parallel via DC/DC converter and the battery bank is used to store the excess of energy. The mathematical model topology, the identification of each subsystem and the control supervision of the global system are the contribution of this paper. Obtained results under Matlab/Simulink and some experimental ones are presented and discussed.

An environmental analysis of the impact of FCVs is a popular topic for research, and has appeared frequently in recent literature. Fletcher et al.[10] have even discussed the energy management strategy to optimize both fuel consumption and PEM fuel cell lifetime in a hybrid vehicle. The cost and reliability of fuel cells are major obstructions preventing fuel cell hybrid electric vehicle (FCHEV) from entering the mainstream market. However, many of the degradation methods are strongly affected by the operating conditions of the fuel cell and therefore can be mitigated by optimisation of the Energy Management Strategy (EMS). The major causes of fuel cell degradation are identified from the literature and a model is produced in order to estimate the effect of the EMS on the fuel cell degradation. This is used to produce an optimal strategy for a low speed campus vehicle using Stochastic Dynamic Programming (SDP). The SDP controller attempts to minimise the total running cost of the fuel cell, inclusive of both fuel consumption and degradation, each weighted by their respective costs. The new strategy is shown to increase the lifetime of the fuel cell by 14%, with only a 3.5% increase in fuel consumption, largely by avoiding transient loading on the fuel cell stack.

III. CONCLUSION

The ultimate aim of our project was to design a suitable electric propulsion system enabling to reach required speeds and offering suitable range while consuming as little hydrogen and energy from the pre-charged batteries as possible, so that our vehicle can be at par with conventional vehicles that will be "zero emissions" as well. The propulsion system components have consequently been selected with this objective in mind together with weight & safety constraints. A computer-based model of the system has been built in order to simulate various driving schemes, study and to predict energy flows and consumptions. All work has been carried out with the aim to present this research to serve as a knowledge foundation for the choice of technology and design of the propulsion system of the real scale SHEV.

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