Project proposal: Design and fabrication of a pure electric hybrid vehicle (First version)

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***Abstract*—The *Facultad de Ingeniería Mecánica y Eléctrica* (FIME) of the *Universidad Autónoma de Coahuila* (UAdeC) wants to fabricate a pure electric vehicle for the didactic and the research purposes. It will be fabricated in many versions, moving from the simplest version to the complex one. This document identifies the requirements for the first version of such vehicle.**

I. Objective

The objective of this project is to model, design and fabricate an pure electric hybrid vehicle with the following functionality.

- Steep acceleration curves similar to the petroleum vehicles (PV).
- Maximizing the energy harvesting at all the times, i.e. during all kinds of the breaking routine.

II. Introduction

The electric vehicles were introduced in the early nineteenth century; these were holding a greater market in comparison to the internal combustion (IC) ones until the end of that century [1]. However, petroleum vehicles (PV) soon became more common on the roads later, which can be seen from the 2005 estimates, which indicate that the PV constitute a 97% of the vehicles [2]. Recently there is a growing interest in the hybrid vehicles (a hybrid of petroleum and electric) and pure electric vehicles (PEV) [3]–[5].

The *Facultad de Ingeniería Mecánica y Eléctrica* (FIME) of the *Universidad Autónoma de Coahuila* (UAdeC) wants to fabricate a pure electrical vehicle for the didactic and the research purposes. It is decided to fabricate various versions, the first version being a small capacity EV, i.e. $\approx 100\,\mathrm{kg}$ payload. This document presents a rough calculations to identify the specifications for the electric, electronic and mechanic devices. This allows to prepare an estimate for the first version vehicle. Also, it is decided to use a low velocity tricycle for the first version EV, which allows us to simplify the following complications.

- Implementation of differential wheel algorithm
- Safety associated with the braking mechanism
- Air resistance plays a major role in the calculation of power in high speed vehicles.

The structural design is **not** considered in this document.

III. Selection of storage type

Figure 1 shows the Ragone plot for the most common storage domains [7]. It is clear that combustion engines have high specific power and specific energy. In the context of automobiles, specific energy can be associated to the fuel autonomy measure, i.e. the distance it can move by consuming a unit fuel mass, and the specific power can be associated to the acceleration which it can achieve with a given unit fuel mass. So from Figure 1, we see that a petroleum based automobile have an advantage over any other domain. Also, we can see that a properly designed electric hybrid system can perform on par with combustion engines.

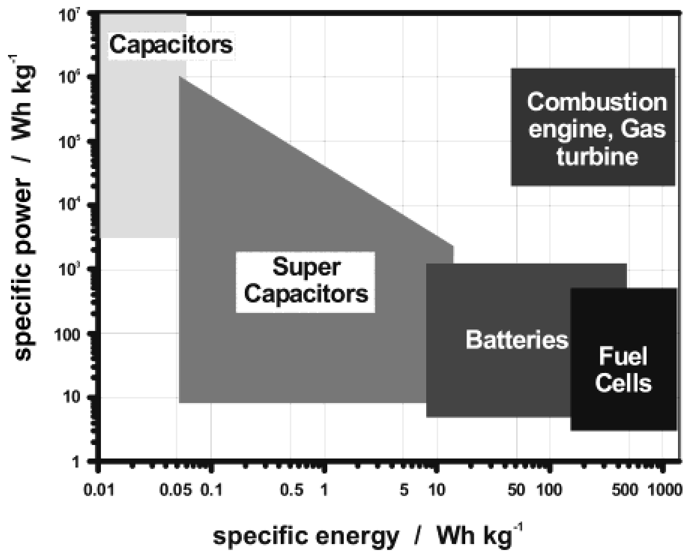

Figure 1. Ragone plot — Comparison energy density (specific energy) and power density (specific power) of most common storage domains [6].

Figure 2 shows the Ragone plot of electric storage devices. We can ignore the Li-primary batteries option because they are not rechargeable. So, the solution to achieve high specific energy and specific power is combining the positive trades of the super-capacitors (electrochemical capacitors) and the Li-ion batteries in an hybrid system.

IV. Power flow in an EV

At any given time a vehicle operates in one of the two modes, namely the driving mode and the braking mode. In an EV the wheel is coupled to the electric machine. Hence, in the driving mode the electric machine should act as a motor and in the driving mode it should act as a generator. Figure 3 and Figure 4 show the power flow diagram for an electric vehicle in the driving mode and the braking mode respectively.

Figure 5 shows a possible way of merging both modes of operations in a vehicle. In order to achieve this scheme, we need to satisfy the following conditions.

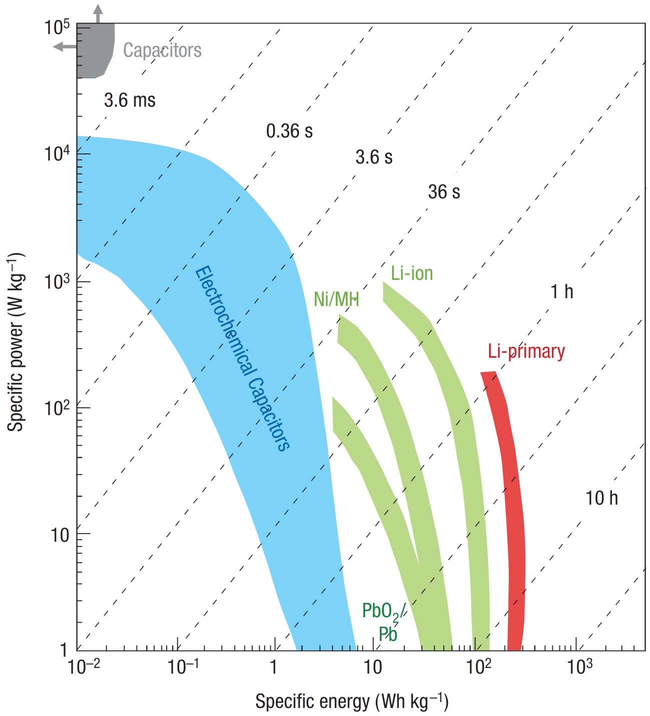

Figure 2. Ragone plot — Comparison energy density (specific energy) and power density (specific power) of various electric power storages [7].

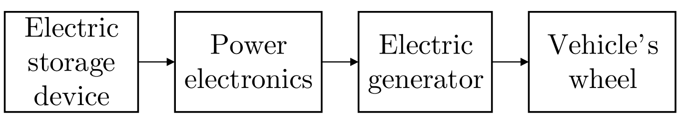

Figure 3. Power flow diagram of an EV in the driving mode

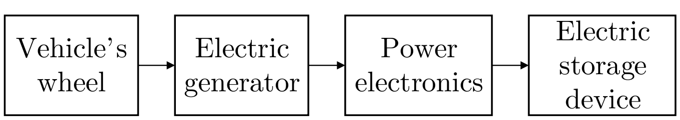

Figure 4. Power flow diagram of an EV in the braking mode

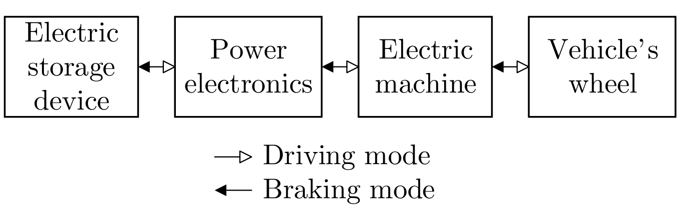

Figure 5. Schematic showing the EV's power flow diagram

Conditions

1) The coupling between electric machine and the vehicle's wheel should be bidirectional.
2) The same electric machine should work as a motor and a generator.
3) The power electronics should be bidirectional.

V. Selection of the Electric Machine

The electric machines capable of acting as both motors and generators are:

- AC induction motor
- AC synchronous machine
- DC machines

A. AC induction motor

An induction motor required a speed higher than the synchronous speed to act as a generator, hence this is not viable in our design.

B. AC synchronous machine

AC synchronous machine require the following power electronic modules.

- Rectifiers (AC to DC converters)
- Inverters (DC to AC converters)
- DC to DC converter (Buck–boost converter)

C. DC machines

DC machines require the following power electronic modules.

- DC to DC converter (Buck–boost converter)

We select DC machine to minimize the system complexity.

VI. System Design

Figure 6 shows the complete system scheme. Here for simplicity, one one direction of wheel movement is considered. We can notice that we need the following for the EV.

Requirements

1) DC machine
2) EV's mechanical structure
3) Buck-boost converter
4) Electronic switches and relays
5) High-speed controller with
   a) Digital IOs (inputs and outputs)
   b) Analog IOs
   c) Counter for encoder
6) Electronically actuated mechanical brake
7) Super-capacitors
8) Rechargeable battery

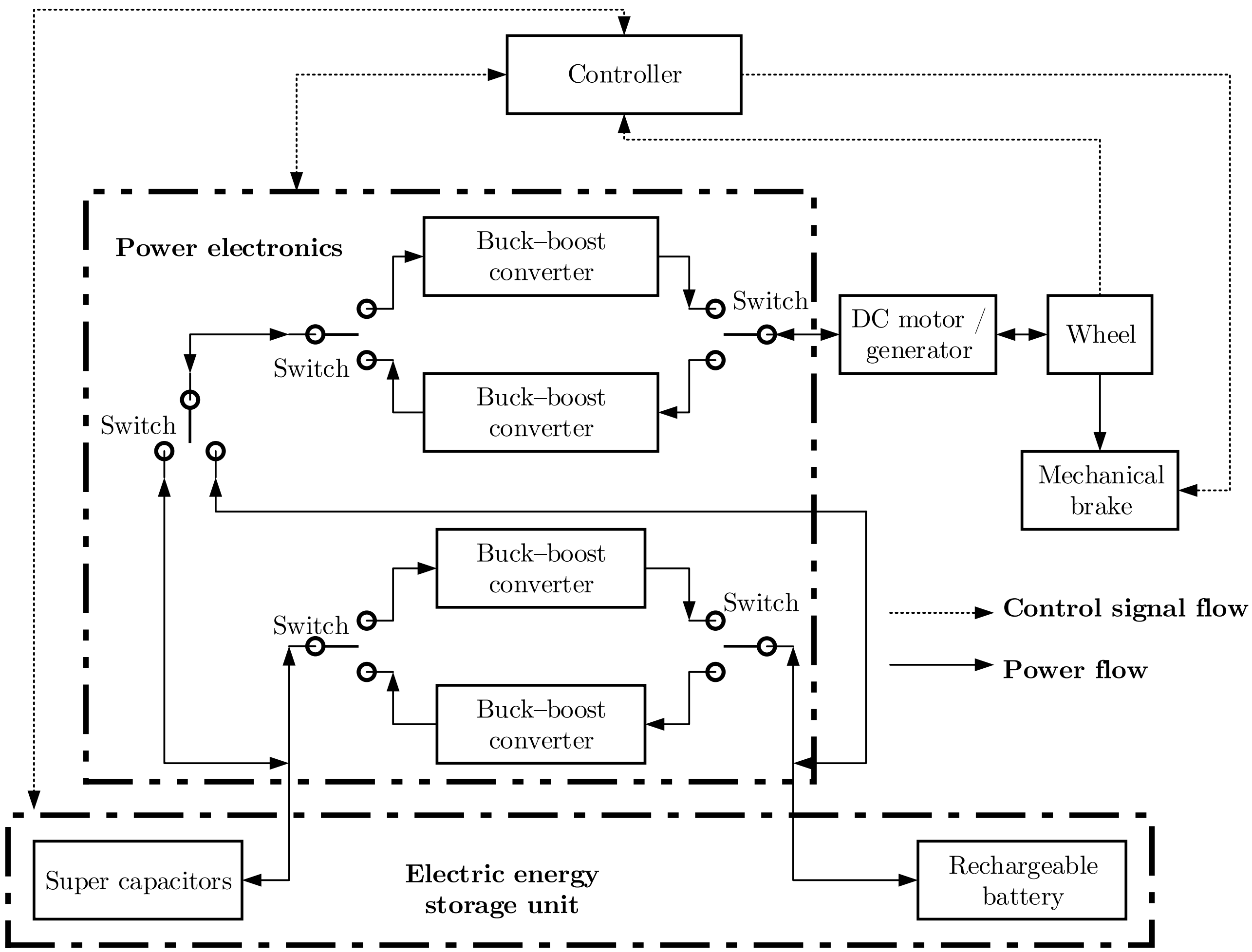

Figure 6. Schematic showing entire system

VII. Selection of DC machine

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