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Review Article

INTELLIGENT CONTROL STRATEGY FOR ENERGY MANAGEMENT SYSTEM WITH FC/BATTERY/SC

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Abstract

The Hybrid Electric System (HES) is a desirable issue by integrating different, hopeful technologies like Fuel Cell, a Battery and a Super Capacitor. Because of its reliability, this system is configured for electric vehicle purposes. In this paper hybrid system performance is analyzed and evaluated by using MATLAB /Simulink.

Based on a multi-input and multi-output state-space model, a model comprising a battery, a proton exchange membrane fuel cell (PEMFC), and super-capacitor were developed. A reliable energy management system for hydrogen fuel usage, and state fluctuations throughout the super-capacitor or battery were analyzed and assessed to regulate load demand and to examine supply sources. The simulation outcomes could substantially confirm overall performance using MATLAB / Simulink environment.

Keywords: hybrid system, Fuel cell, battery, super capacitor, power management

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INTRODUCTION

The use of more cars creates serious challenges for the environment and / human life, air pollution, global warming and the rapid reduction of fossil fuel reserves on earth are now becoming services. Electric vehicles, hybrid electric vehicles and fuel cell electric vehicles have been continuously designed to change traditional cars in the coming days. Most hybrid and electrical electrical structures use multiple energy storage projects, one with high level energy storage capacity and the other with high energy capacity and reversibility, called "rechargeable energy storage system". It provides long range and offers great acceleration and regenerative braking. Energy storage or power supply strategies differ in their output voltage based on load or state of charge (SoC) and the high voltage of the DC bus connection creates significant challenges for vehicle engineers when the power is on. integrated or storage equipment with DC-DC traction converters. limit the elements in the powerplant by increasing or cutting the voltage levels. Due to the limitations of the locomotive, the power converters must be lighter, more reliable, of lower volume, higher productivity, less electromagnetic interference and less ripples of voltage and current [1] [2-8].

An electric vehicle uses a combination of three different energy storage devices, such as fuel cells (FC), batteries and supercapacitors (SC) to power an electrical drive scheme. In electric vehicles, one or more energy storage devices help the main energy source [9-14]. Therefore, the system cost, mass and volume can be reduced and a substantially improved yield can be obtained. Two frequently used energy storage tools are batteries and SC [15]. They can be connected to the Ffuel Cell stack in many approaches. A simple design consists of directly connecting two devices in parallel (FC / battery, FC / SC or battery / SC). The impedance of the system will depend on several factors such as soc, health, temperature and at the point of operation. Each project could work in an incompatible condition, such as efficiency and health [12-16].

The voltage characteristics of both devices must be completely balanced and for example only a small part of the device's working range. In the configuration of the fuel cell battery n, the fuel cell must almost always supply the same power due to the fixed voltage of the battery and the battery / Super capacitor

The supercapacitor design can only use a portion of the supercapacitor's energy exchange capacity. This is again due to the almost constant electricity of the battery. After designing the DC / DC converters, we can determine the voltage deviations of the devices and control the power of each device.

In general, the hybrid / FC / SC battery performs better than other hybrid electrical sources, since the Supercapacitor can more efficiently support the fuel cell to / satisfy the transient power supply and the transient current demand in which the charged a high concentration and / / the discharge of the battery will affect its duration.

An FC / battery / SC hybrid offers long battery life. It can be seen that the use of high power DC / DC converters is necessary for EV power systems. In addition, the power of the DC / DC converter differs from the characteristics of the vehicle, such as the maximum speed, the acceleration time from 0 to 100 km / h, the highest torque, the power profile and the weight.

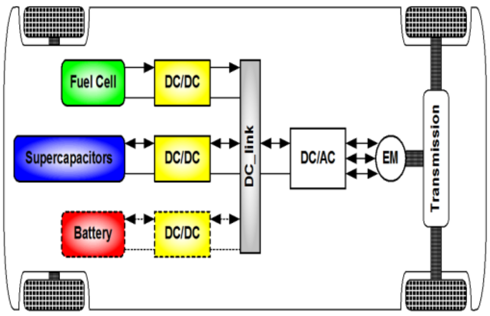

Fig 1: Hybrid electric power system block diagram.

HYBRID ELECTRIC VEHICLE SYSTEM

Description

Figure 2 demonstrates a detailed RES that combines multiple subsystems to work together and maintain the correct functioning of the system. RES uses the Fuel Cells (FC) subsystem as the main power source to provide the required electrical charge. The goal of this subsystem is to ensure full energy demand.

Includes a supercapacitor (SCS) subsystem to monitor transient energy events. A battery subsystem is integrated to reduce the difference between the required charge power and the generated FC power. A controlled chopper is connected to each component of the system.

The fuel cell is supplied with a unidirectional pulse converter. In the meantime, the battery and a part of the Supercapacitor are connected with a bidirectional to balance the energy demand and conserve unsupported energy. Indeed, a PMU is designed for energy management consumption and to intelligently increase system efficiency. Therefore, the proposed algorithm aims to "improve the reliability and efficiency of the device based on the rate of hydrogen consumption" and the state of the Super capacitors / Battery charge (SoC), respectively.

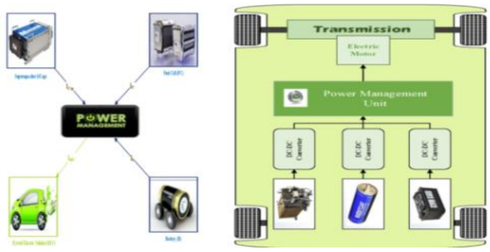

Fig 2: Hybrid electric power system

Subsystems Of HES

1) Fuel cell
2) Battery
3) Super capacitor
4) DC-DC Converter Quality Check

Fuel Cell

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel and a corroding agent into electricity through a pair of redox reactions. Fuel cells are different from most batteries in making a continuous source of fuel and oxygen to sustain the chemical response, whereas in a battery the chemical energy typically comes from metals and their ions or oxides that are usually present in the battery, except in flow batteries. Fuel cells can generate electricity constantly for as long as fuel and oxygen are provided [7].

There are several kinds of fuel cells, but they all comprise of an anode, a cathode, and an electrolyte that allows ions, frequently positively charged hydrogen ions, to move between the two sections of the fuel cell. At the anode, a catalyst causes the fuel to undertake oxidation reactions that produce ions (often positively charged hydrogen ions) and electrons.

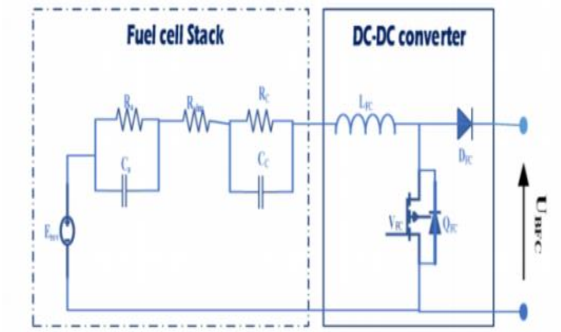

Fig 3: Fuel cell electrical system

Battery

Energy storage systems, typically batteries, are necessary for hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and all-electric vehicles (EVs)[3][4].

The chemical responses in the battery develop the electrons at the anode. This results in an electrical difference among the anode and the cathode. You can think of this change as an unsteady build-up of the electrons. The electrons want to reorganize themselves to get rid of this difference.

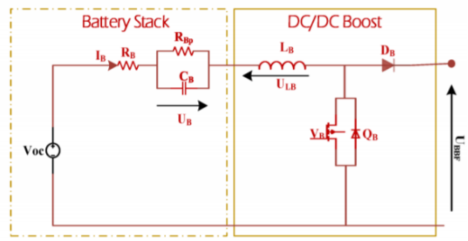

Fig 4: Battery Electrical system

The function of the battery as an energy storage device has been demonstrated in various compositions and applications. Lithium ion batteries are a smart proposition for use in high performance electric vehicles. Unlike other rechargeable batteries, the lithium ion offers specific energy of the highest level and a greater amount of charge and discharge phases. The cost is also acceptable. Therefore, a lithium ion battery, specially designed for high-level equipment and transportation [8]..

Super capacitor

A SC (or ultra-capacitor) varies from a common capacitor in two important ways: its plates efficiently have a much larger area and the distance between them is much lesser, because the separator between them operates in a different way to a traditional dielectric [10][17-24].

The capacitance of a capacitor rises as the area of the plate's increases and as the distance between the plates reduces. In an outer layer, super capacitors get their much better capacitance from a mixture of plates with a bigger, efficient surface area (as of their activated charcoal structure) and less distance between them (as of the very effective double layer) [5][25].

A Super condenser is chosen to handle daily charging and disc harge pulsations, which include the power constraints of hybri d vehicles. The charging / discharge pulse characteristics are h ighlevel currents (up to 600A), and millisecond to second intervals.

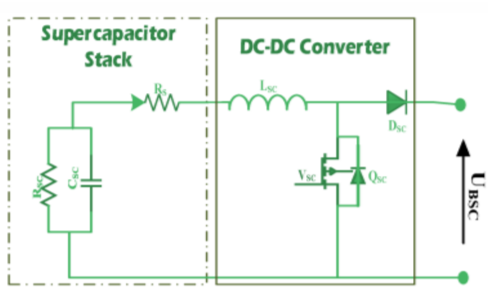

Fig 5: Super Capacitor Electrical Scheme

DC-DC Converter Quality Check

For electric system functions such as a power converter, DC power source, etc., several power electronic converters are often used. AC to DC Converter/ Rectifier, DC to AC Converter/ Inverter, AC to AC converters, DC to DC Converters, etc. can be classified as the power electronics converters. If we compare DC to DC, these are known as DC to DC buck converter, DC to DC boost, and DC to buck-boost converter, Switch from DC to DC.

The DC/DC converter output voltage is much higher than the input voltage. The voltage from these converters is used to meet the load demand. The correlation between the load and supply could be managed by using a power electronic switch in the DC/DC converter design[6].

A DC/DC converters design consists of a transistor or a diode to regulate the output and energy storage elements like capacitors and inductors and these converters can be used as voltage regulators. DC/DC converters are utilized to supply DC power to electrical systems[27].

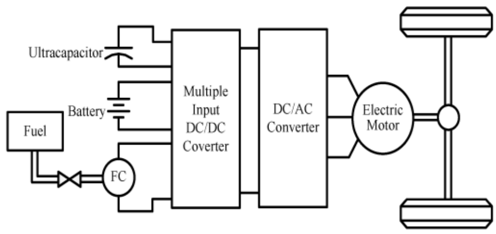

Fig 6: Converters connection in HEV

POWER MANAGEMENT UNIT AND CONTROL

In today's world, Hybrid Electric Systems (HESs) are becoming increasingly popular worldwide. There is a growing interest in the design and development of successive control solutions for successful HEV drive systems. In this regard, the control of the power flow between different energy sources in the vehicle is one of the most critical problems.

The development of an efficient control approach to the energy organization is essential to an effective HES after identification for the vehicle design and size of the modules. Energy management control shall ensure that the operations and physical properties, such as road level conditions, vehicle loading times and accelerations, or braking controls are carried out under fluctuating operating conditions of vehicles.

The control aims primarily to meet the driver's load demand continuous operation. The driver energy requirement should be converted into the torques which the power assets of the car can generate while also achieving a variety of other objectives. The planning use and minimization of the fuel and the control of the battery SOC can be demonstrated. Different restrictions, for example the torque-demand and the speed of the vehicle supplier, should be met by the control.

With the progressive effects on the degradation of air conditions and declines in oil reserves, the advancement of safe, clean and high-efficiency transport is of great importance. The most encouraging solutions to land transport problems are the electric vehicles (EV), hybrid power systems (HES) and hybrid electric fuel cell vehicles (FCHEV). Hybrid electric vehicles are considered to increase the good potential as they show progress in the use of fuel with less extra expenditure.

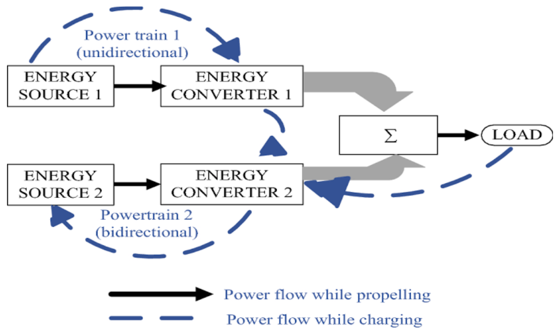

Fig 7: Power flow diagram in a HEV

Operation of the RES module is usually based on the consumpt ion of hydrogen fuel and the battery charging condition.

These parameters are used to control the system's actions by d ividing the system into two PMU controlled operating modes.

The basic functions of the mentioned modes are described as follows:

PM-Mode 1 : In this mode, the FC and the SC work together to adequatelymeet the demand for load and simultaneously control the transient event.

PM-Mode 2: In this mode, the Battery and the SC work under combinatin to supply the demand for electrical load when the amount of hydrogen is insufficient to support the smooth working of the FC.

Start PMU Mode1:

STATE 1: Active Subsystem "FC Power Generation P_{FC}"
For $P_{FC>=}P_{Load}$
If $P_{FC>}P_{Load}$
STATE 2: Put SC Subsystem on (Charging Mode)
If $P_{FC=}P_{Load}$
STATE 3: Switch off SC Subsystem
If $P_{FC<}P_{Load}$
STATE 4: Start SC Subsystem (Discharging Mode)
End PMU Mode1

Start PMU Mode2
STATE 5: Switch on Battery Subsystemfor $P_{B=}P_{Load}$
STATE 6: Deactivate SC Subsystem
If $Pb_{<}P_{Load}$
STATE 7: Switch on SC Subsystem / (Discharging Mode)
End PMU Mode2

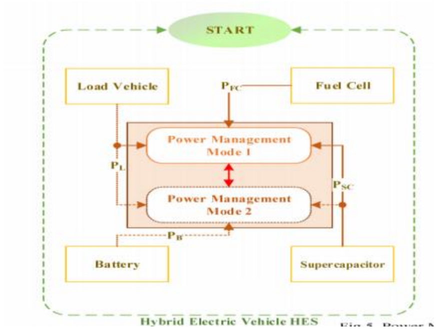

Fig 8: Power Management Block Diagram

SIMULINK MODEL

In this project, we have created a simulation version of an alternative energy system based on fuel cells of the hybrid electrical system. As pollution increases day by day, HES plays a very important role in reducing pollution [11].

Hybrid electric vehicles and PEM FC-based hybrid electric systems are more efficient thanks to their excellent autonomy. This typical model represents an alternative approach to emergency energy based on fuel cells, batteries and supercapacitors [13].

This project explains the development of a static hybrid energy system that includes a proton exchange membrane fuel cell (PEMFC), a super capacitor and a battery system. We developed a load of fuel cells with a proton exchange membrane and energy management for the hybrid electrical system and developed a Simulink model. The Simulink model is used to analyze the execution and efficiency of the hybrid electrical structure, through the use of various energy management methodologies. The system mainly comprises three parts: PEMFC control, power management and a Simulink model.

The fuel cell is the main energy source of the system. It is connected to a type of boost, i.e. a DC / DC booster converter, which improves the low / level DC voltage produced by the traction fuel cell for the DC bus system.

As a complement, a rechargeable lithium ion battery and a supercapacitor are used as sources of energy. The battery produces additional energy during accelerations and recovers energy during braking. Due to its high dynamic reaction, the supercapacitor produces / uses the maximum power that neither the fuel cell can supply, nor the battery can produce / store and make available the DC bus voltage control.

The supercapacitor is connected to a bidirectional pulse type DC / DC converter that increases the small DC voltage produced by the traction supercapacitor for the DC bus and distributes an energy flow in both directions, from the supercapacitor to the bus. CC. The battery is connected to a two-way DC / DC buck converter which reduces the high DC voltage supplied by the battery to the traction DC bus and allows for power movement in both directions, from the battery to the DC bus and vice versa [14]

The fuel cell-based hybrid electric vehicle consists of a hybrid electric system in which the primary source fuel cell is connected to a unidirectional DC / DC converter to provide the stable exchange channel for transferring energy between the DC bus. and also the load request. The lithium ion battery works as a secondary power source that connects between the DC bus and the load request, which is responsible for replacing the fuel cell energy in various situations such as:

a. Condition like the state of charge(SOC) of battery is high
b. Condition like the hydrogen level is insufficient and can't meet the load demand.
c. When ultra-capacitor is fully discharge

Otherwise, the super capacitor is attached directly to a bidirectional converter which designed to manage the fast-occurring peak power during super capacitor slow dynamics.

The connection between these three sources is safeguarded by an energy management system which makes it effective to serve the delivery power and the hydrogen reduction.

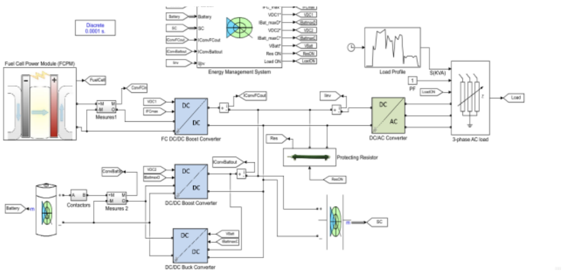

Fig 9: Simulink Diagram

The above figure shows the Simulink connections of various components like proton exchange membrane fuel cell, battery system and a super capacitor. All these three sources serve as power supplement sources to meet the load demand.

All the three sources are connected to DC/DC converters in order to step-up the voltage from low voltage level to high level so that it is easy to meet load and DC/AC converter in order to convert DC voltage to AC voltage because the majority of the loads in the real world applications are AC source applications. The load connected is a 3-phase AC load, so we must convert the available DC supply to required AC supply by using DC/AC converter.

A load profile describes how a load uses the power over a period. It is designed utilizing measurements of a customer's energy usage at regular periods, usually one hour, thirty minutes or fifteen minutes, and offers a precise description of a customer's usage patterns.

RESULTS AND DISCUSSION

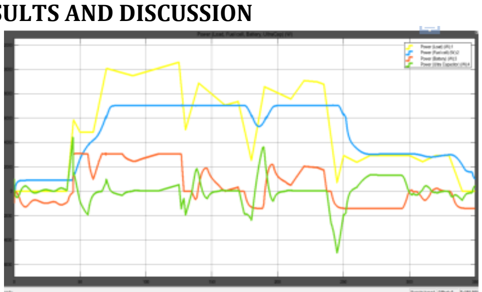

Fig 10 : Power output curves

The above curves describes the power's of fuel cell stack, battery, a super capacitor and load. During initial period the fuel cell alone supplies the power according to the load demand. So it is considered as primary source of the system. In later stages the load demand is shared by super capacitor and battery sub systems. The three sources collectively supply power to meet the demand.

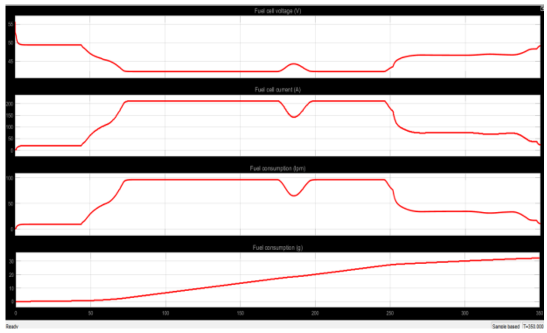

Fig 11: Voltage, current and consumption of fuel cell

The Fuel cell graph describes about the amount of fuel consumed per time in line 3 and 4 , the voltage and current ratings of fuel cell in line 1,2.

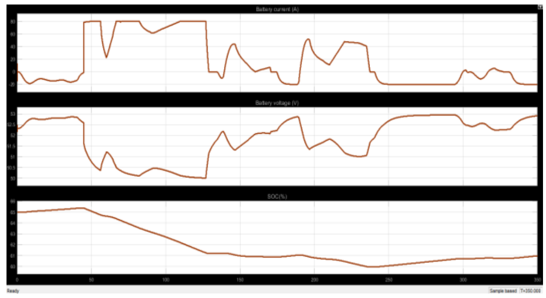

Fig 12: Voltage, current and SOC curves of battery

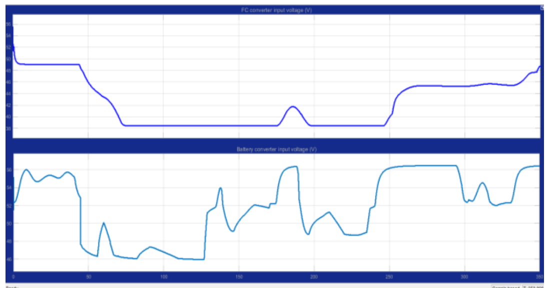

Fig 13: Voltage curves of fuel cell converter and battery converter

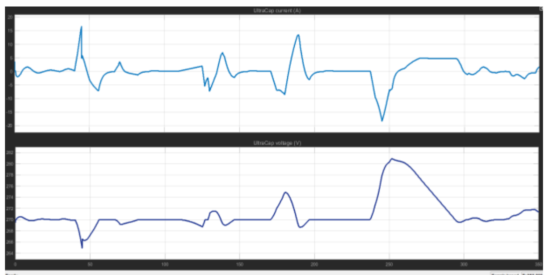

Fig 14: Curves of current and voltage of super capacitor

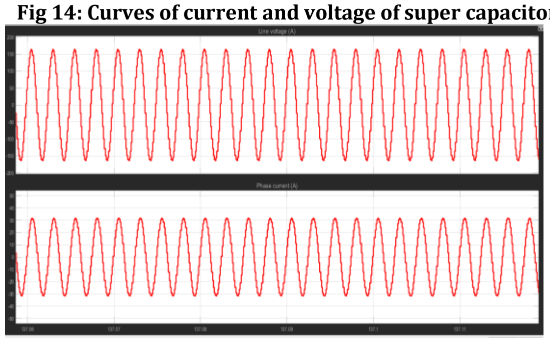

Fig 15: Line voltages and phase currents of load

CONCLUSIONS

In this project we analysed the proposed HES FC, SC and battery combinations to ensure a requirement for power load demand with a precise PMU. The device evaluation was based on the energy consumption profile proposed. The included PMU was also arranged according to the FC source's current inputs. The suitability of this hybrid vehicle's predictive control has been shown in the simulation results. Based on these findings, it is evident from them that the demand for vehicle power is met.

When the approach is stable, the major benefit of FC efficiency is attributed to the FC's operating on maximum efficiency. Our model was evaluated using the simulation results.

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