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Modelling and Simulation of Hybrid Electric Vehicle Based on MATLAB/ Simulink

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***Abstract:** Due to the more vigorous regulations on carbon gas emissions and fuel economy, Fuel Cell Electric Vehicles (FCEV) are becoming more popular in the automobile industry.*

This paper presents a neural network based Maximum Power Point Tracking (MPPT) controller for 1.26 kW Proton Exchange Membrane Fuel Cell (PEMFC), supplying electric vehicle powertrain through a high voltage-gain DC-DC boost converter. The proposed neural network MPPT controller uses Radial Basis Function Network (RBFN) algorithm for tracking the Maximum Power Point (MPP) of the PEMFC.

High switching frequency and high voltage gain DC-DC converters are essential for the propulsion of FCEV. In order to attain high voltage gain, a three-phase high voltage gain Interleaved Boost Converter (IBC) is also designed for FCEV system. The interleaving technique reduces the input current ripple and voltage stress on the power semiconductor devices. The performance analysis of the FCEV system with RBFN based MPPT controller is compared with the Fuzzy Logic Controller (FLC) in MATLAB/Simulink platform.

***Keywords:** Fuel cell electric vehicle, high voltage gain IBC, PEMFC, MPPT, RBFN etc.*

I. INTRODUCTION

As the green movement will increase in quality, additional and additional electrical vehicles (EVs) of all kinds from electrical scooters to cars to buses and product trucks can grace the roads.

Power designers are challenged to produce systems which will be tailored to a good type of differing types of batteries and vehicles with immensely numerous performance needs.

This report examines the key issues that square measure best suited to meeting the challenges of as well as battery performance, lifespan and, of course, safety whereas coming up with intelligent battery management and charging systems EV battery packs are created of multiple cell modules organized nonparallel and in parallel. organized round the battery pack and throughout the vehicle, the battery management system (BMS) is comprised of many elements, including observance elements close to the battery cells themselves, one or additional power-conversion stages dictated by the requirements of the vehicle, and intelligent controllers or embedded processors placed at strategic locations in the design to manage numerous aspects of the facility system.

This project introduces A battery observation computer circuit (BMIC) or cell-balancer device is often assigned to observe the voltage of every battery cell during a module, the temperature of varied points within the module and other conditions. This information is reportable to a cell management controller (CMC) and, counting on the quality of the system, on to higher-order processing parts, like one or a lot of battery management controllers (BMC).

The exactitude of these measurements and also the frequency of the communications from the BMIC to the CMC and BMC is essential to detective work a condition of concern early on and taking corrective action before it becomes hazardous. for instance, the BMC may stop regenerative charging or scale back the ability draw from a pack to come individual cell temperatures to an appropriate vary or the driving force of the vehicle might be alerted to such a condition through a “check engine” light-weight on the dashboard.

In any case, the BMICs should be capable of terribly correct measurements and strong communications with the CMCs so a BMC will take the correct corrective action during a timely fashion. associate degree electron volt is so terribly challenging in terms of planning a good communication network thanks to the abundance of electrical noise within the surroundings. Lithium-ion battery packs are the predominant energy storage systems in aircraft, electric vehicles, portable devices, and other equipment requiring a reliable, high-energy-density, low-weight power source.

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II. PROJECT METHODOLOGY

The designed EV motor driver is comprised by four sections such as battery, bi-directional dc-dc converter, FLC and dc machine as shown in Fig. 1

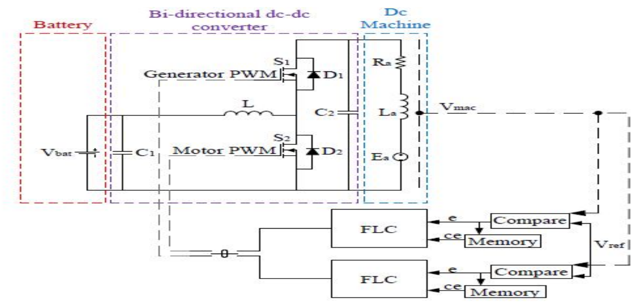

Fig. 1.Circuit diagram of EV machine driver with battery management

In this study, the starting voltage of battery is set to 378 V while the operating voltage of dc machine used in traction system is 500 V dc. The battery voltage is increased up to 500 V with bi-directional dc-dc converter in generator mode. The battery is discharged when dc machine is started acceleration. The motor mode simulation with various torque values are performed to observe battery parameters such as state of charge (SoC), current, voltage and voltage of the dc machine.

The voltage of the dc machine is decreased to 500 V with bidirectional dc-dc converter which is controlled with FLC. The battery is charged during the generator mode operation of dc machine. The FLC determines duty cycle of S1 and S2 to ensure charge and discharge of battery. The dc machine is comprised by brushes, armature core and windings, commutator, field core and windings. Armature circuit is comprised by series structure with inductor, resistance and counter-electromotive source.

Similarly, battery parameters such as SoC, current, voltage and voltage of the dc machine are observed in the generator mode simulation regarding to various torque values applied to dc machine. The battery specifications are given in Table 1.

Table 1 Battery Parameters

Parameter	Value
Battery Type	Lithium-ion
Nominal Voltage	350 V
Maximum Capacity	100 Ah
Exponential Voltage	378 V
Initial State of Charge	% 88
Cut off Voltage	262.5 V
Fully Charge Voltage	407.4 V
Nominal Discharge Current	44.5 A

III. SIMULATIONS AND RESULTS

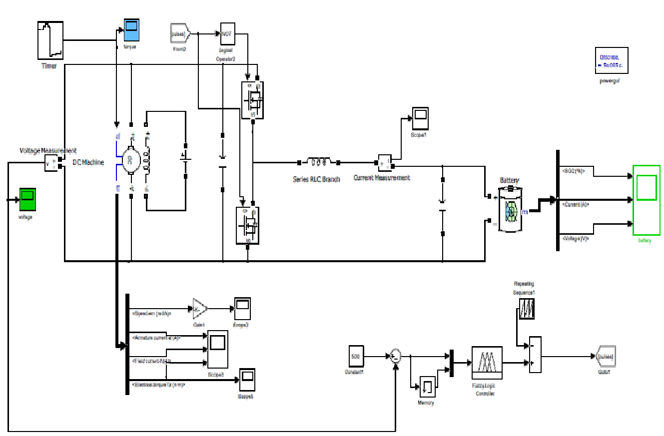

Figure 2. Battery current, voltage and SoC

While motor and generator torque value are shown in Fig. 7and voltage of the dc machine is shown in Fig.8. The dc machine is operated during first 25 seconds in motor mode and last 25 seconds in generator mode.

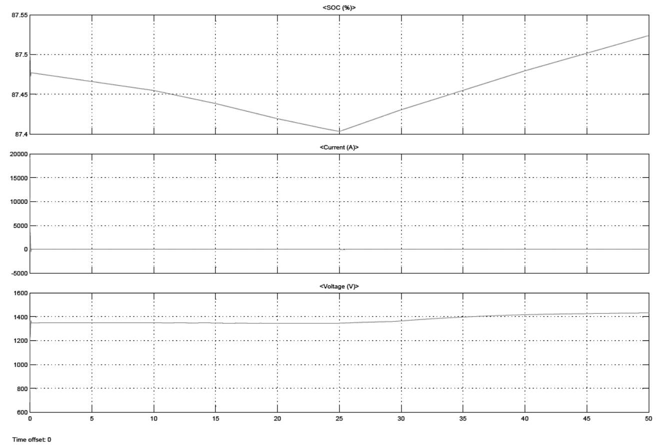

Figure 3. a) Battery voltage b) battery current c) SoC

Reference values of Motor and generator

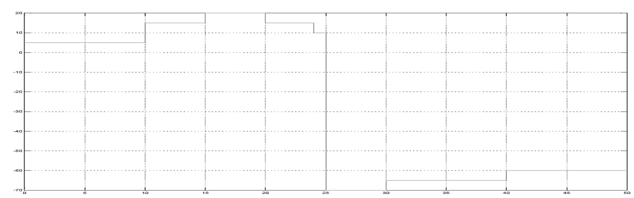

Figure 4. Motor and generator torque

Reference values of DC Machines

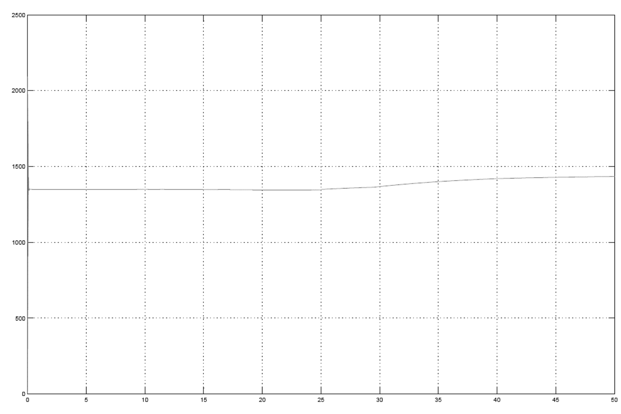

Figure 5. Voltage of dc machine

1) *Between 0 and 5 seconds:* The starting torque value which is implemented to the dc machine is set to 5 N.m and it is increased up to 15 Nm in fifth seconds. The current fluctuates between 26.7 A and 30.6 A is supplied by battery while battery SoC decreases from %88 to %87.505.
2) *Between 5 and 10 seconds:* The constant 15 N.m torque value is applied to dc machine during five seconds. The battery current is obtained to constant at 30.6 A and battery SoC reduces from %87.505 to %87.462.
3) *Between 10 and 15 seconds:* The torque value implemented to dc machine is enhanced to 20 N.m in the fifteenth second. The current of battery is observed between 30.6 A and 35 A. It is lower than discharge current of battery. The battery SoC decreases from %87.462 to %87.416.

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4) *Between 15 and 20 seconds:* The dc machine torque value is decreased down to 15 N.m in the twentieth second. The battery current is decreased from 35 to 26.25 A whereas battery SoC reduces from %87.416 to %87.375.
5) *Between 20 and 25 seconds:* The constant 10 N.m torque value is implemented to dc machine during five seconds. The battery current is observed as constant at 26.25 A and battery SoC reduces from %87.375 to %87.337. The battery voltage is stable at 377 V while the voltage of dc machine is constant at 500 V during first twenty-five seconds. When torque value is positive torque, dc machine is operated in motor mode and according to torque value, it is acceleration. Bi-directional dc-dc converter is operated between 0 and 25 seconds in Mode-I and Mode-II that are boost mode of bi-directional dc-dc converter. FLC generates duty ratio and it is compared with triangle waveform which has switch frequency and so switching pulse is generated for semiconductor switch. Voltage of dc machine is increased to desired value. As torque is increased, the dc machine current is increased up to discharged current of battery. On the other hand, as torque value is reduced, the current of battery is decreased.
6) *Between 25 and 30 seconds:* The torque value is decreased down to -70 Nm. in the twenty fifth second and increased to -65 N.m in the thirtieth second. The battery voltage is increased from 377 V to 381.9 V. The battery current fluctuates between 0 A and -18.47 A and battery SoC increases from %87.337 to %87.356. The voltage of the dc machines enhanced from 500 to 634 V.
7) *Between 30 and 35 seconds:* The torque value is implemented as constant -65 N.m. The voltage of battery is acquired as constant at 381.9 V while the current of battery is obtained as stable at -17.94 A. The SoC of battery increases from %87.356 to %87.381 and the voltage of dc machine is observed as constant at 634 V.
8) *Between 35 and 40 seconds:* The torque value is enhanced to -60 N.m in the fortieth second. The battery voltage is decreased from 381.9 V to 381.65 V. While current of battery is changed between -17.94 A and -15.62 A, the SoC of battery increases from %87.381 to %87.4 and the voltage of the dc machine is decreased from 634 to 625 V.
9) *Between 40 and 45 seconds:* The torque value is implemented as constant -60 N.m during five seconds. The battery voltage is acquired to constant at 381.65 V while the battery current is observed as constant at -15.1 A. The battery SoC increases from %87.4 to %87.426. The voltage of the dc machine is constant at 625 V.
10) *Between 45 and 50 seconds:* The torque value of dc machine is enhanced up to -55 Nm. in the fiftieth second. The voltage of battery is decreased from 381.65 V to 381.2 V whereas the battery current is changed between -15.1 A and - 12.78 A. The battery SoC increases from %87.426 to %87.445 and also the voltage of the dc machine is decreased from 625 to 615 V.

When torque value is negative, the dc machine is operated as generator mode and the battery is supplied by dc machine. The bi-directional dc-dc converter is operated between 25 and 50 seconds in the Mode-III and Mode-IV that are buck mode of bi-directional dc-dc converter. FLC generates duty ratio and it is compared with triangle waveform that has switching frequency and switching pulse is generated for semiconductor switch. The voltage of dc machine is reduced to desired voltage value. The battery voltage and SoC are increased according to variable torque value. When torque value is increased as absolute value, the SoC, voltage and current of battery are increased. On the other hand, as absolute torque value is reduced, the SoC, voltage and current of battery are decreased.

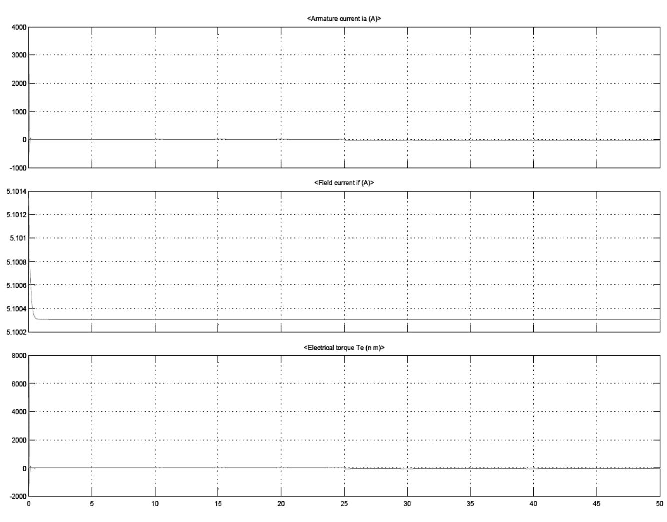

Figure 6. Current Measurement of the system

This project presents design and control bi-directional dc-dc converter for all-electric vehicle. The bi-directional dc-dc converter is controlled with FLC according to rules. When the battery is discharged, the dc machine is operated in motor mode and bi-directional dc-dc converter is operated in boost mode. Variable positive torque values are applied to the dc machine and condition of the battery is observed. According to simulation result, the battery SoC is reduced from %88 to %87.337 and voltage of the dc machine is constant at 500 V. When the battery is charged, the dc machine is operated generator mode and bi-directional dc-dc converter is operated in buck mode. Variable negative torque values are applied to the dc machine and effect on the battery is observed. According to simulation result, the battery SoC is increased from %87.337 to %87.445. In all-electric vehicle, regenerative breaking is occurred in this state. Charge and discharge states of the battery are the most essential for distance to determining.
The old battery management system (BMS) did not have a power control unit. Advanced battery technology consisting of lithium-ion require a power control unit to ensure the protection and long-time period overall performance of the battery percent. The power control unit also controls the battery recharging indicated by forwarding the recovered energy (i.e. regenerative braking) to the battery pack as shown in the figure.

The prescribed power control unit also works,

a) Protect the battery from complete damage.
b) Monitor cells, units and packages to ensure they operate within reasonable limits and to avoid operations such as short circuits, overvoltage, overcharging, over-discharge and excessive heat with special emphasis on Li-ion cells. Huh.
c) Ensure safe operation and extend battery life as long as possible.
d) Communicate with the vehicle supervisor and meet all requirements for the operation of the vehicle.
e) Balance cell groups during dynamic charging and discharging to ensure that the entire battery system is functioning properly.

Based on this work, the specific challenges faced by BMS and their solutions are the basis for future research. Depending on the specific situation, various strategies can be implemented to upgrade and optimize BMS performance in EVs.

IV. CONCLUSION

As batteries are the center fuel sources in EVs and HEVs, their presentation significantly impacts the attractiveness of EVs. Along these lines, producers are looking for advancements in both battery innovation and BMSs. Synthetic responses in the battery are liable to working conditions, and consequently, the corruption of a battery may shift in various conditions. Building up a complete and develop BMS is basic for makers who might want to expand the piece of the pie of their items. The significant worries of BMSs were examined in this paper. They incorporate battery state assessment, displaying, and cell adjusting, wherein the assessment strategies of battery status were seen as the pivotal issue.
Along these lines, related work on the SOC, SOH, and SOL of batteries were audited with examinations. A BMS system was proposed to manage the insufficiencies of momentum BMSs in both exploration and business items. In view of past work, explicit difficulties confronting BMSs and their potential arrangements were introduced as a strong establishment for future exploration. Because of shifting circumstances in certifiable applications, a standard arrangement was not needed. In view of the particular circumstance, various systems ought to be applied to improve and advance the presentation of BMSs in future EVs and HEVs.

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