Hardware design multi-sources light electric vehicles

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ABSTRACT – Combination of battery, proton exchange membrane fuel cell (FC) and super-capacitor (SC) as energy sources for light electric vehicle (LEV), or better referred to as multi-sources LEV has the purpose to improve vehicle performance and surpass battery drawbacks. Power coordination is designed by implementing intelligent switching hardware in energy management system (EMS) control circuit board. The EMS hardware circuit is integrated with dSPACE/ DS1104 down-scaled model for LEV. The accumulated results show that multi-sources LEV delivered better power efficiency than a single-powered battery LEV. This research could be beneficial to automobile industries in the future.

1. INTRODUCTION

Implementation of renewable energy in EV has becomes an important subject for research and study in both academic and industrial fields. Existing Battery Electric Vehicle (BEV) technology as a single-source EV has flaw to maintain good performance since its electrical characteristics depend heavily on its state of charge (SOC), self-discharge and life cycle [1]. The maximum current limitation differs between a brand-new battery and a battery, which already undergoes many life cycle [2]. Due to this, power performance of LEV will decline over time and thus becoming a hurdle to enter consumer market. Thus as an alternative to deliver acceptable power range, a multi-sources LEV is proposed [3]. Two additional sources that are suggested for implementation in the test bench model are FC and SC.

A small scale test bench model is designed by using dSPACE DSP DS1104 [4]. The hardware is built of EMS control board being connected to multi-sources signals, which is embedded on dSPACE interface signals and then linked to a computer. The output of the EMS control circuit is then linked to dSPACE for data acquisition.

2. HARDWARE DESIGN METHODOLOGY

The Figure 1 illustrated the model of EMS hardware control circuit. Components of the circuit include a voltage regulator, relay SONGLE, power MOSFET, half-bridge driver, speed pedal variable resistor, I/O hex buffers and PWM signal inverters. Additionally, an ampere meter is placed in series due to the fact that current is measured in term of voltage by the current sensor.

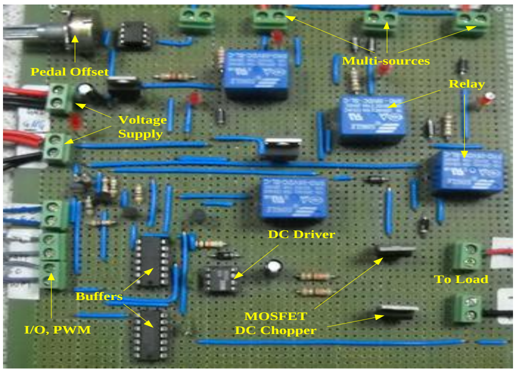

Figure 1 EMS hardware control circuit

2.1 *Pedal Sensor through Variable Resistor*

The vehicle throttle function is being replaced by a variable resistor. A voltage divider is attached to the variable resistor and its tapped voltage is assumed as pedal offset value.

2.2 *Relay Triggered Circuit*

SONGLE relay 5 VDC is used for multi-sources power switching. It has capability to hold 24 VDC with maximum current of 10 A. An NPN transistor of type BC184 is used to drive current flow into the coil inside the relay. A buffer is connected to base transistor via a 1 kΩ resistor. At the emitter end of the transistor, a resistor of 47 Ω is connected to the ground. Minimum current flow value to the coil must be greater than 70 mA.

2.3 *MOSFET Drive Circuit*

Power MOSFET IRL2703 is a fast switching speed of logic gate drive which has capacity of drain to source voltage, V_{DSS} of 30V and drain current, I_D of 24 A. Both pulse width modulation (PWM) signals from dSPACE DSP DS1104 are attached to the gate MOSFET with a series of resistor to avoid short circuit current. A half bridge driver circuit is designed to deliver load current.

2.4 *Pedal Sensor through Variable Resistor*

Current transducer LTSR-15 is used to measure load current and battery current for SOC value. The measured current in range of -5A to 5A. The output current is detected in voltage range of 0 - 5V with 2.5V being the 0A point. The output signal is filtered with cut-off frequency, f_c of about 2 Hz.

2.5 Power Efficiency and Dissipated Energy Calculation

The power efficiency is calculated by how accurate the vehicle is able to trail the drive cycle. The under speed LEV from the drive cycle will be deducted. This power efficiency can be calculated as follows:

$$PowerEfficiency = \frac{DriveCyleArea}{TestDriveCycleArea} x100\% \quad (1)$$

The dissipated energy, E_{diss} used to trail drive cycle is calculated from the measured load current, I_L multiplied by rated voltage, V_{rated} and time, t as shown in below equation:

$$E_{diss} = V_{rated} \cdot I_L \cdot t \quad (2)$$

3. RESULTS AND DISCUSSION

The experiment is conducted by executing several test runs under ECE-47 and ECE-15 drive cycles. The speeds of drives cycle are extended to 33% (with ext) from their original speed for better analysis of the vehicle performance. The test runs are applied on both multi-sources (MSLEV) and single-source/battery (BLEV) systems to enable comparison between these two systems. The collected data for vehicle performance and energy consumption are evaluated and presented in Table 1.

Table 1 Test result of BLEV and MSLEV

Drive Cycle	BLEV PE (%)	MSLEV PE (%)	BLEV DS (Ws)	MSLEV DS (Ws)
ECE-47	~98%	~98%	1680	1699.2
ECE-47 ext	92%	97.9%	1940.4	1966.8
ECE-15	70.2%	~98%	2461.8	2700
ECE-15 ext	90.7%	97.2%	2893.6	3040.8

PE-Power Efficiency; DS-Dissipated Energy; Ws-Watt-second

Both BLEV and MS-LEV manage to follow ECE-47 drive cycle with high precision, with both systems achieved power efficiency of 98%. The dissipated energy for both is around 1690Ws. Since maximum speed of ECE-47 is the average power of energy sources, extended speed of 33% is necessary to investigate capabilities of the vehicles. For the extended ECE-47 test, battery condition is no longer new and test runs when battery SOC is at about 70%. BLEV showed a drop in power efficiency to 92% while MSLEV was able to stay at 98%. During the test, SC is triggered in MSLEV to maintain the maximum speed. The consumed energy for MSLEV is 1966.8Ws and BLEV is 1940.4Ws.

The next test executed is for the ECE-15 drive cycle or urban drive cycle. For this test, battery SOC is only at around 50-55%. During this test drive cycle, FC was activated in MSLEV whenever SOC level is below 50%. Meanwhile in BLEV, it is battery powered only when SOC goes beyond 50%. The performances of BLEV dropped to 70.2% while MSLEV still managed to maintain 98%. Less power efficiency of BLEV leads to less energy consumption as well. Therefore, dissipated energy for BLEV is 2461.8Ws while for MSLEV, it is at 2700Ws. The ECE-15 test is included with extended speed of 33%. For this test, battery condition is set at 65% and this condition is better than previous test. At this test drive cycle, BLEV improved its power efficiency to 90.7%, while MSLEV almost maintained its value at 97.2%. The dissipated energy of MSLEV is 3040.8Ws and for BLEV, it is at 2893.6Ws.

The overall results show that battery's electrical characteristics will be decreased by its SOC level and lifecycle numbers. This is obvious to be observed especially when the test was conducted at half of SOC level. During high load current, battery current will be reduced in time until it is maintained at average current. For MSLEV, SC will be triggered to maintain high current load. In the case where battery reaches half of SOC level, FC will take over and continue to power the vehicle.

4. CONCLUSIONS

This paper is concerned in developing hardware and control algorithm for MSLEV. The EMS hardware prepares signals from I/O peripherals of dSPACE DS1104 to select energy source and sensing system. The system performance is evaluated through ECE-47 and ECE-15 drive cycles. The experiment result shows that MSLEV had successfully follow the drive cycle even during low battery condition and urgent power demand. The test result also proves that MSLEV is superior to a BLEV. Thus this system has potential to be implemented in in future vehicle applications.

5. REFERENCES

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