

Development of Li-ion Battery Control Technology for HEV

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ABSTRACT

The mounting of lithium-ion batteries (LIB) in hybrid electric vehicles (HEV) calls for the configuration of highly robust control systems. When mounting LIBs in the vehicle, it is important to accurately ascertain and precisely control the state of the battery.

In order to achieve high durability, it is important to configure highly reliable systems capable of dependably preventing overcharging as well as to have control technology based on software that can contribute to extended battery life. The system configuration applies an overcharge prevention system that uses voltage detection with an emphasis on reliability. Furthermore, a method for varying the range of state of charge (SOC) control in the vehicle according to the battery state is implemented to assure durability.

In order to achieve this, battery-state detection technology was developed for the purpose of correctly detecting and judging the battery state. This battery control system is able to enhance the durability while obtaining the maximum battery performance.

This paper reports on the configuration of such systems, methods of state detection, and applications based on detection results.

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INTRODUCTION

Recently, various proposals have been made from a wide range of industrial sectors for the realization of a global low-carbon society. One such proposal is to increase automobile fuel economy, and there are demands for further enhancement of hybrid electric vehicle (HEV) efficiency and popularity of HEV. One device expected to help enhance HEV performance is the lithium-ion battery (LIB). Compared to nickel metal hydride (Ni-MH) batteries, LIBs feature higher efficiency, output, and are more lightweight.

Honda developed an LIB system consisting of 40 rectangular battery cells and applied it to a compact and lightweight parallel hybrid system (HONDA IMA SYSTEM) in 2011. Furthermore, Honda developed the two-motor SPORT HYBRID system to further increase fuel economy (Fig. 1).

The developed system has three system operation modes (Table 1).

In EV drive mode, EV driving is performed using the electric energy stored in the high-voltage battery. In HYBRID drive mode, the motor is driven by the energy generated by a generator coupled to the engine and the electric energy stored in the high-voltage battery. In Engine drive mode, the engine power is coupled directly to the wheels via the clutch. Driving can be performed using the battery and/or gasoline as the energy source in accordance with the driving state, and the system switches the mode as appropriate to enhance the

total energy efficiency. The developed system has a greatly expanded electric operation area compared to the previous HEV system as shown in Fig. 2.

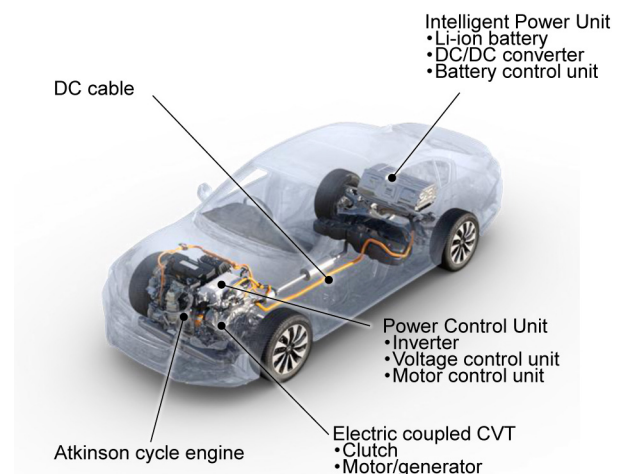


Figure 1. Overall system configuration

For this reason, the battery performance was enhanced and the weight of the battery module and battery box structures was reduced compared to the previous LIB system. This achieved a 20% increase in energy density [Wh/kg], an 85% increase in power density [W/kg], and further increased fuel economy compared to the previous LIB system (Fig. 4).

Table 1. Operation modes

EV Drive	HYBRID Drive	Engine Drive
Use electric energy from battery to drive motor	Use electric energy from engine generator to drive motor, with assistance from battery	Use engine to directly drive wheels

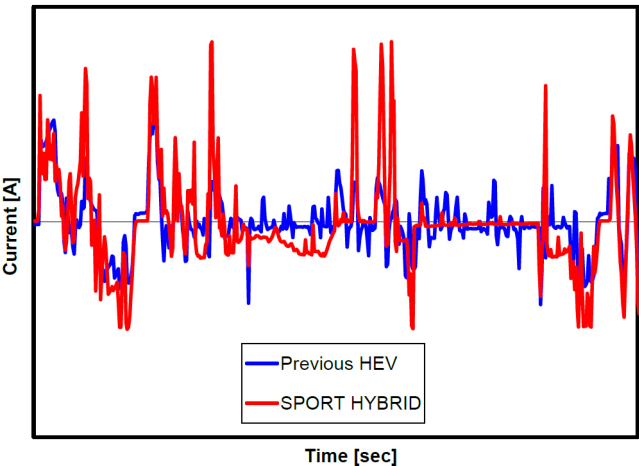


Figure 2. Time chart of battery current

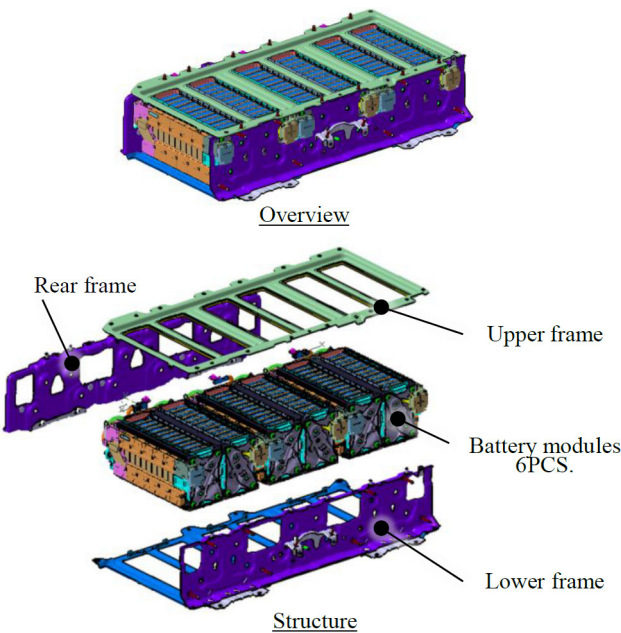


Figure 3. Battery pack

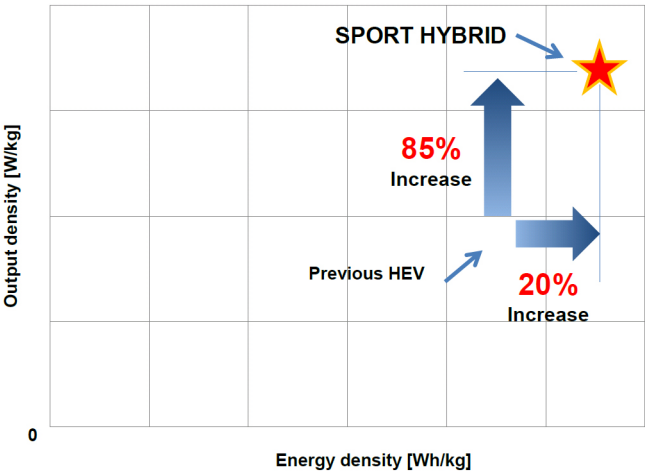


Figure 4. Pack characteristics

Figure 3 shows the structure of the developed battery pack. LIBs have high power density and energy density, so to implement LIBs in vehicles it is important to accurately ascertain and control the battery state. In addition, a highly dependable hardware system configuration that can reliably prevent overcharging and software-based control technology that can help increase battery life are needed to achieve high durability. This paper reports on these system configurations, methods of battery state detection, and applications based on the detection results.

SYSTEM CONFIGURATION

Battery Box Specifications

Table 2 lists the specifications of the developed battery box, and Fig. 5 shows the battery system diagram. The battery box developed for the two-motor SPORT HYBRID system consists of six 12-cell modules. The cell voltages of all 72 cells are constantly monitored by three cell voltage sensor units, each monitoring 24 cells, and controlled by a battery ECU. Contactors are located in the high-voltage output block. When the battery ECU detects an LIB error with the ECU internal control application and the voltage sensors, it operates the contactors to cut off the high voltage.

Battery Cell Specifications

The criteria for selecting the battery materials used were high thermal stability and high durability. Figure 6 shows the cell structure, and Table 3 lists the cell specifications. The developed battery utilizes a chemical compound for the positive electrode, which gives it high thermal stability specifications like previous LIBs.

Table 2. Comparison of battery box specification

Items	SPORT HYBRID	Previous HEV
Voltage/Number	259V/72Cells	144V/40Cells
Capacity	1296Wh	662Wh
Maximum Output	59kW	20kW

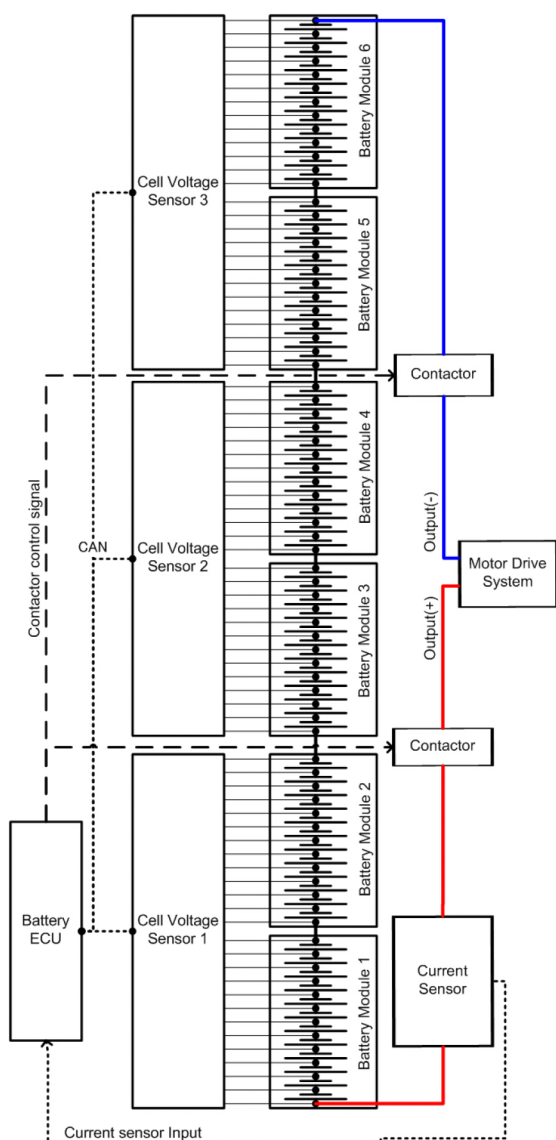


Figure 5. System diagram of developed battery

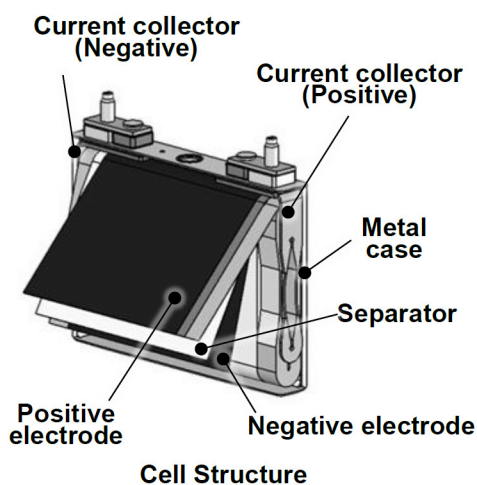


Figure 6. Construction of battery cell

Table 3. Battery cell specifications

Items	SPORT HYBRID	Previous HEV
Capacity	5.0Ah	4.7Ah
Voltage	3.6V	3.6V
Weight	0.28kg	0.28kg

TECHNOLOGY TO PROVIDE DURABILITY

Overcharge Prevention System

To increase the voltage value detection accuracy, the Ni-MH battery performs detection in 12-cell units as shown in Fig. 7. However, the LIB system has a cell voltage sensor for each cell and monitors each cell voltage value. The previous cell voltage sensor uses a system configuration that connects two voltage detection circuits with identical performance in parallel for each cell as shown in Fig. 8, and constantly monitors and compares the values from these circuits to detect voltage detection circuit failure based on the voltage difference between the two circuits. In addition, overcharge prevention reliability is further increased by selecting the higher of the voltage values measured by the two voltage detection circuits. The developed cell voltage sensor eliminates this duplex system of voltage detection circuits with identical performance. Instead, a self-diagnosis function is mounted that detects abnormal voltage detection accuracy using a voltage detection circuit, enabling increased reliability on par with the previous system (Fig. 9).

The battery voltage behavior for differing states of charge (SOC) is as follows. The Ni-MH charging efficiency drops in the high SOC range, and there is an SOC range in which the voltage does not rise even when charging is performed. In contrast, LIBs have characteristics such that the voltage rises together with the charging time even at high SOC. (The left graph of Fig. 7 shows the Ni-MH voltage characteristics and the right graph shows the LIB voltage characteristics.)

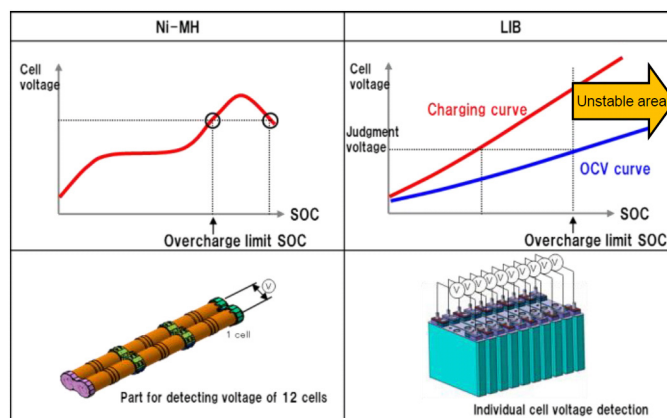


Figure 7. SOC characteristics and voltage monitoring unit