

Development of a Smart Main Relay Assembly using IGBTs for xEV Battery System

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ABSTRACT

This paper proposes a smart main relay assembly or power relay assembly for xEV battery system. The role of main relay assembly is to connect and disconnect main high voltage battery and loads including the inverter. Current main relay is usually a special electro-mechanical relay which has a gas chamber to suppress electrical sparks between relay contacts for switching high current safely. The gas-chambered electro-mechanical relay is relatively too heavy and bulky to decrease design flexibility and may worsen fuel economy.

The proposed smart main relay assembly uses IGBT (insulated gate bipolar transistor) for transient states to switches on or off, and uses relays for steady states to connect or disconnect current. As no spark induces to relay contacts directly with the proposed method, conventional electro-mechanical relays without gas-chambers can be used. Therefore the mass and volume can be reduced to increase gas mileage and also reduce the material cost. Using a current sensor in the assembly, a fail-safe diagnosis function which detects and disconnects an abrupt change of high current up to a given limit, also can be implemented.

The prototype of the proposed smart main relay assembly was developed for 80A current load and tested for control and diagnostic functions. The prototype was installed to a hybrid EV and tested including driving conditions. The prototype's fail-safe diagnostic function disconnected high current successfully under the test conditions which include short-circuit to make the previous main relay assembly out of order permanently.

CITATION: Lee, T., Jung, B., Lee, S., Kim, H. et al., "Development of a Smart Main Relay Assembly using IGBTs for xEV Battery System," *SAE Int. J. Alt. Power.* 2(1):2013, doi:10.4271/2013-01-1764.

INTRODUCTION

The main power supply of xEV vehicle for the inverter of motor traction and the dc-to-dc converters of low voltage system is from the high voltage battery system. The main relay assembly or power relay assembly (PRA) connects and disconnects the battery and the inverter/converter wiring[1].

The main relay assembly consists of three high voltage/current relays, a resistor, and bus bars between the wiring terminals and relay terminals. The characteristics of the relays need to flow high current up to nominal load consistently, and cut off the abrupt current safely without any electric sparks. Conventional main relay assembly uses relays which have a gas chamber with inert gas surrounding the relay contacts to suppress the arcs. The chamber may increase the volume and mass of the relay which cause design inflexibility and poor fuel economy.

Past studies for the main relay and its control of xEV battery system had focused on finding and controlling faults using the output voltage of the battery management system (BMS) [2][3][4], and on monitoring status of vehicle in a view of abstract level point[5][6]. They added or enhanced a part of conventional main relay assembly's functions, but they were on basis of conventional structure of the system which has the same limits.

Other studies on the control of relays for high voltage and current loads showed partial switching using diodes[7] and partial switching using multiple relays for different loads[8] to reduce relays' burden. For alternating current system, composition of semiconductor TRIAC (triode for alternating current) and relays in series was proposed to minimize possible electric arc[9].

Recent study showed parallel connection of relay and semiconductor switch to suppress spark for direct current

system[10]. However it had not enough voltage and current capacity to apply realistic xEV vehicle's battery system.

This paper proposes a new main relay assembly compensating conventional methods using conventional relay and IGBT semiconductor for satisfying the requirement of the xEV battery system. The proposed method are implemented and tested with a hybrid vehicle for its feasibility.

Section 2 describes the design of the system including requirement and operational method of the system. Section 3 explains the implementation including hardware circuits and software. Section 4 presents the test setup and result in lab and vehicle test.

DESIGN OF THE SYSTEM

System Requirement

The role of PRA is a switch to connect or disconnect the battery to the loads as shown in Figure 1. The PRA is controlled by BMS using direct control signals for each connection status.

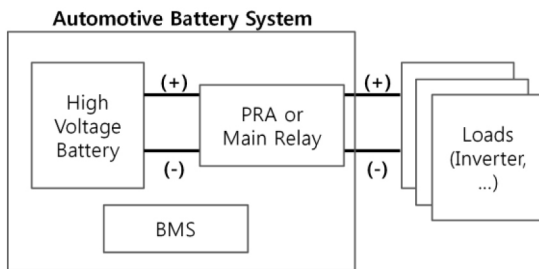


Figure 1. Role of PRA in the automotive battery system

The target requirement of the system is shown in Table 1. The system is to be used for a hybrid or an electric vehicle in passenger car grade, which has nominal current range 80 to 120 amps. The control inputs from BMS are separate +12V signals for precharging, main minus, and main plus connection. The system is supplied by +12VDC from BMS.

Table 1. System requirement of PRA

Parameter	Value
Output voltage	Nominal 450V
Output current	Precharging 10A Nominal load 80A Peak load < 170 A
Control inputs (from BMS)	Precharging connection on/off Main(-) connection on/off Main(+) connection on/off
Power supply	+12VDC

Smart PRA consists of two conventional relays, two IGBTs, a PTC, a current sensor, bus bars, and a controller PCB as block diagram shown in Figure 2. The current path is divided into three parts, the one of which is for precharging through precharging IGBT and PTC in series, and another is for normal loading through main (+) relay alone, and the other

is for cutting off the load through main cutoff IGBT. Main (-) relay is common return path of the current. The current sensor using the Hall effect measures flowing current via PRA, and is connected to BMS and PRA controller deciding operating mode.

Method of Operation

The operation of smart PRA is shown in Figure 3. The smart PRA has four inputs which are precharging control, main (-) control, main (+) control from BMS and current sensor signal, and four outputs which are on/off signals for main (-) relay, main (+) relay, precharging IGBT, and main cutoff IGBT. The BMS input signals can be substituted by an integrated main signal because the smart PRA is capable of sequential control.

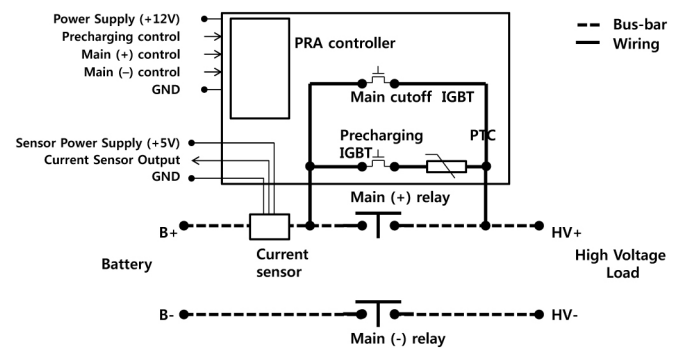


Figure 2. Block diagram of smart PRA

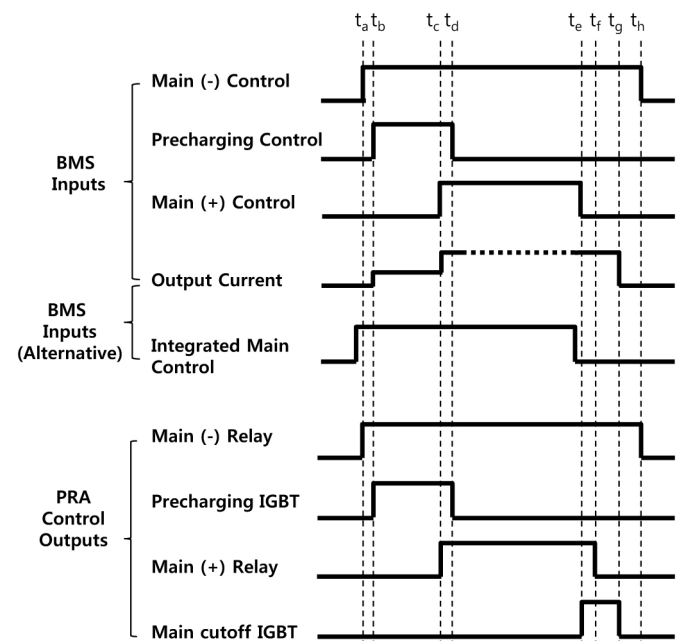


Figure 3. Operation of smart PRA

When BMS turns the main (-) control on at all off status, the smart PRA controller turns on the main (-) relay at t_a . After that, the precharging control on, the precharging IGBT