BMS

Part 02

Developing Technologies for Battery Management

Dynamic Switch Control for Maximum Battery Performance

Advances in motor vehicle electrification and in self-driving technology are increasing the demand for 12-volt (12V) batteries that use Li-ion cells. This kind of 12V battery is a stable power supply to the electrical load (the load) of a vehicle (●Fig. 1) because it includes a battery management system (BMS).

The BMS operates a switch, e.g., a relay or field-effect transistors (FET) on a charge-discharge path at appropriate times to prevent overcharge or overdischarge of the 12V battery. Specifically, the BMS opens the switch when the voltage or state of charge (SOC) of the 12V battery is outside a prescribed range to block the charge-discharge path, or closes the switch when the voltage or SOC is within the range to maintain the state where current flows through the 12V battery. Switch control by the BMS should allow maximum battery performance while suitably protecting the components of the 12V battery.

This article will use two scenarios to explore the technical concepts developed at GS Yuasa for optimizing switch control based on the state of the vehicle.

Scenario 1: Is the Vehicle Running or Parked?

The 12V battery supplies power to loads such as the lights, the steering system, and the brake system, and communicates with the vehicle ECU. When no power is being supplied to the loads from the high-voltage battery in an electric vehicle (or, the alternator in an ICE vehicle), it is the 12V battery that supplies the power to these loads. Additionally, power from the 12V battery is used to start up the high-voltage battery system or the engine.

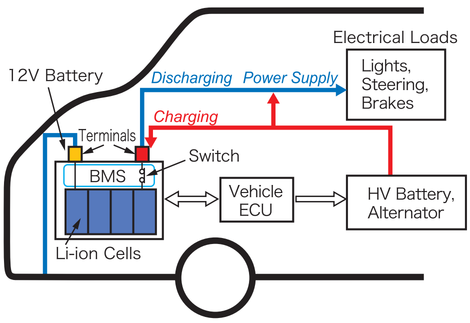
While the vehicle is running, when no power is being supplied from the high-voltage battery due to some kind of failure, the BMS should keep the switch closed so that as much power as possible can be supplied from the 12V battery until the vehicle can stop in a safe location. Therefore, a voltage threshold (or, an SOC threshold) that serves as a requirement for whether to open the switch must be set to a low value.

In contrast, while the vehicle is parked, when the switch remains closed, a small amount of current (dark current) flows from the 12V battery to the load, and the SOC of the 12V battery gradually deteriorates, and this is likely to hinder start up of the high-voltage battery system or the engine. Consequently, the threshold for opening the switch should be set to a relatively higher value when the vehicle is parked. Here, we want to preserve the power that can be used to restart in the 12V battery by opening the switch when the voltage of the 12V battery is relatively high.

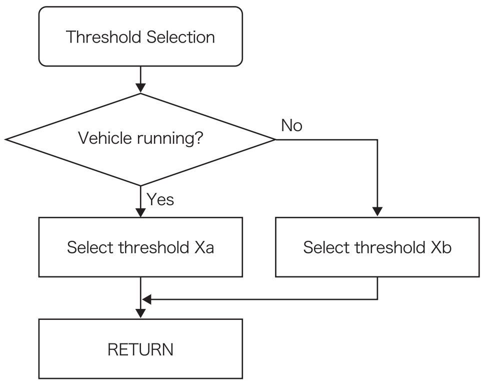
Therefore, we devised the idea of selecting the threshold that serves as the requirement for opening the switch based on whether the vehicle is running or is parked[1]. The BMS determines whether the vehicle is running based on, for example, the current flowing through the 12V battery or the frequency of communication with the vehicle ECU. If the vehicle is running, then the BMS selects threshold Xa. If the vehicle is parked, then the BMS selects threshold Xb which is higher than threshold Xa (●Fig. 2).

Thus, by changing the requirement for opening the switch based on the state of the vehicle, it becomes possible to more properly utilize battery's features.

●Fig. 1 Automotive Power System Block



●Fig.2 Flowchart for Selecting Thresholds



Scenario 2: Switch Control during External Short Circuit

The 12V battery has one pair of external terminals (a positive terminal and a negative terminal). An external short circuit may occur when a technician mistakenly connects the external battery terminals via a metal tool when installing the 12V battery (see ●Fig. 3). The switch should be opened when this happens to block the charge-discharge path and protect the components in the battery, e.g., the Li-ion cells, from the large current (excess current) that flows through the battery at that time. In the same way the switch should be opened when a short circuit occurs in any of the loads (●Fig. 1) being supplied power by the 12V battery.

A straightforward implementation would see that the 12V battery has a current sensor that is provided on the charge-discharge path, and a counter that is provided to the BMS to measure time. The current sensor can be used to detect that an excess current exceeding a current threshold flowed through the battery, and the counter can be used to measure the duration of time that the excess current flows; therefore, when the excess current continues to flow for a prescribed time, the BMS can determine that an external short circuit has occurred and open the switch.

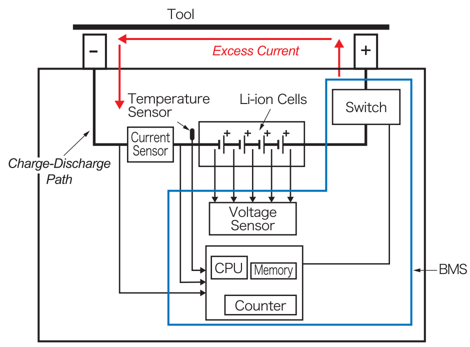
However, in some cases, the excess current due to an external short circuit may occur over multiple, non-consecutive time intervals. In the method described above, the switch would remain closed when the duration of the excess current is less than a prescribed time during a single occurrence. Consequently, the components of the battery may be damaged when that kind of excess current flows on the charge-discharge path for multiple, non-consecutive time intervals. If the duration of the excess current —which is to serve as a requirement for opening the switch— is set to be short, then the switch will open when a large current is discharged to an instantaneous load, which still needs to happen, and thus the battery loses the ability to stably supply power to the load.

Therefore, we devised the idea of totaling the durations of excess current when the current threshold is exceeded, and opening the switch when the total exceeded a total-time threshold[2]. Let us consider a case where the excess current, i.e., current that exceeds the current threshold occurs for three non-consecutive time intervals (●Fig. 4). From time t1 to t2, this excess current flows on the charge-discharge path (top, ●Fig. 4), and the count increases, i.e., rises to the right, due to the totaling by the counter (bottom, ●Fig. 4). From time t2 to t3, although the instantaneous current falls below the current threshold, because time X23 is shorter than reset time TR, the count is maintained and is not reset. Then, the excess current flows continuously and at time t6 when the count reaches the total-time threshold, the switch is opened and the charge-discharge path is blocked.

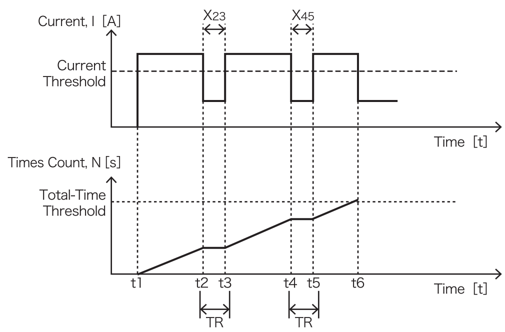
Thus, by totaling the durations of the excess current over the multiple, non-consecutive time intervals, and using this in the determination of whether to open the switch, it becomes possible, in an even more flexible manner, to protect the components of the 12V battery from damage due to external short circuits.

In this article we discussed techniques for switch control of the BMS for the purpose of bringing about maximum performance of the 12V battery while appropriately protecting it. GS Yuasa will continue to utilize our substantial knowledge of the special qualities of Li-ion cells to provide even more advanced battery management technology as we create the future of energy.

●Fig. 3 Block Diagram of the 12V Battery



●Fig. 4 Totaling the duration of excess current over non-consecutive time intervals.



1. Japanese Patent No. 6807018, US Patent No. 10,615,616, Chinese Patent No. 201710907101.0, German Patent Publication No. 102017217547 (filed in 2016)
2. Japanese Patent No.7528926, US Patent Publication No.2022/0200307, Chinese Patent Publication No. 113597718, German Patent Publication No. 112020001393 (filed in 2019)

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