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Outrush Current Control by Hot Swap Controller for Battery Protection in Electrical Vehicle

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Abstract

This paper focuses on problem-solving for large outrush current from DC power supply to capacitive load in an electric vehicle. This outrush current occurs during a pre-charge state of traction battery to cause high spike peak and consequently damage the main switching contact and the battery cell. In this paper the current control to gradually increase the outrush current by hot swap controller was proposed. The responses of the proposed control and the classical control were compared and investigated. With the proposed control technique, the impact of harmful outrush current can be reduced. As a result, the hot swap controller gave satisfactory responses and provided good stability.

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Keywords: capacitive loads: hot swap: pre-charge: outrush current

1. Introduction

The most critical component of the electric vehicle is a set of traction batteries used for on-board electric motor drives. The need for the traction battery results in increasing both its energy and power rating. In general, the price of a battery is effectively about half of the electric vehicle capital cost. Due to such an expensive traction battery, it is necessary to pay more attention in such a way that the battery efficiency is maximized while any harmful risks

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during its operation are minimized. To extend the life of the battery, limiting its transient current at the start-up can prevent an unexpected damage that might be occurred. In electric vehicle propulsion systems, filtering capacitors are connected to their DC link. Therefore, the outrush current is drawn intrinsically during either making or breaking the main power supply contact. This may result in an electrical arc, which may damage the battery main relay contact.

Consequently, to use the traction battery in the above mentioned circumstance, a pre-charge system may be required to limit the current surge. This surge typically takes several seconds, depending on the system property. An old fashion system used resistors by connecting in series with its load at the beginning to reduce the outrush current and then bypassing the resistors after the outrush current died down.

This paper presents a hot swap control method by using the MOSFET. A controlled current is kept constant by adjusting its voltage at the MOSFET's gate pin. Section 2 explains the classical control design of resistors for the pre-charge system. Our proposed design of the hot swap control is presented in section 3. Section 4 provides the results of the pre-charge and the hot swap controls, and the conclusion is in the last section.

2. Classical control design

The pre-charge control is commonly used in most electric vehicles. The pre-charge circuit diagram can be shown in Fig.1. The resistor is connected in series with the pre relay to bypass the positive relay for limiting the outrush current. Basically, the pre-charge circuit operates as described in the following steps. The system is shutdown, all the relay contacts are switched off. When the system is back to service, the pre relay and the negative relay are both switched on to bridge the pre-charge circuit energizing the load through the pre-charge resistor. If the outrush current is measured or estimated somehow, the positive relay is switched on when the outrush current decreases to an unharmed value. The load is now energized from the battery by two parallel paths. Therefore the pre relay is switched off after a certain delay to terminate the pre-charge state.

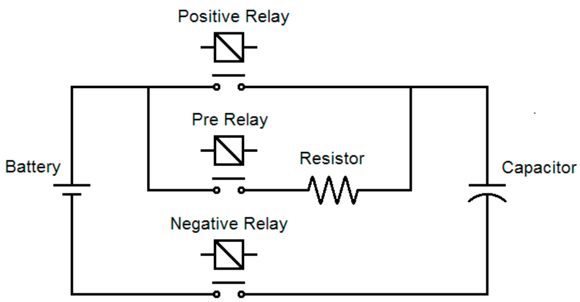

Fig. 1. Pre-charge control circuit

The resistance of the pre-charge resistor is chosen based on the capacity of the capacitive load and the desired pre-charge time [1]. The capacitor voltage (V_C) at time *t* during the charging period is given as:

$$V_C = V_S\left(1 - e^{-\frac{t}{RC}}\right) \tag{1}$$

Where:

V_C is the voltage across the capacitor

V_S is the supply voltage

$\tau = RC$ is the time constant of the RC charging circuit