A new method for the dispersal of high-voltage energy stored in EV powertrains

Research Objectives

Chao Gong and Dr Yihua Hu are developing a discharge method to ensure the heightened safety of electric vehicles.

Detail

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Bio

Chao Gong is a PhD student with the Department of electronic Engineering of University of York. His research interests include EV safety and electrical machine design and control.

Yihua Hu is a Reader and Electrical Engineering programme leader at University of York. He is a Fellow of IET and was awarded Royal Society Industry Fellowship and Newton Advanced Fellowship in 2020 and 2019, respectively.

Funding

Newton Advanced Fellowship
Royal Society Industry Fellowship

References


Personal Response

Could the method you developed be used in other settings where batteries or capacitors are used?

The proposed method could be popularised in other electrified transportation systems, for example, in more electric ships or trains.
A new method for the dispersal of high-voltage energy stored in EV powertrains

Compared to traditional internal combustion engine (ICE) vehicles, electric vehicles (EVs) feature higher voltage and higher energy power systems. When EVs are involved in a collision, the voltage of the power stored in the DC bus capacitor must be reduced as quickly as possible. Chao Gong and Dr Yihua Hu from the University of York, UK, are working on the development of a high-safety, low-cost and high-reliability DC bus capacitor fast discharge method that relies on both the internal machine windings and external bleeder circuits. This will achieve fast dissipation of the electric potential, heightening the safety of EVs.

As of today, more than 10 million electric vehicles (EVs) have been sold worldwide, and it is expected that more than 40 million EVs will be circulating by 2030. As sales continue to grow globally, the safety of EVs has become one of the key factors manufacturers are considering.

Compared to conventional internal combustion engine (ICE) vehicles, EVs feature higher voltage and higher energy power systems. The electrical system of typical EVs consist of battery packs, which are used to store and supply power, a boost converter that can lift the voltage to very high levels, and a voltage source inverter (VSI), which converts the direct current (DC) power into the alternating current (AC) power, allowing the machine to operate. One of the most significant hazards in these systems is the extremely high voltage of the DC bus, which can result in electrical injuries to occupants and rescuers.

The electrical system of typical EVs features capacitor packs, which are used to store and supply power, a boost converter that can lift the voltage to very high levels, and a voltage source inverter (VSI), which converts the direct current (DC) power into the alternating current (AC) power, allowing the machine to operate. One of the most significant hazards in these systems is the extremely high voltage of the DC bus, which can result in electrical injuries to occupants and rescuers. Therefore, to avoid these risks, the EV requires the capacitor voltage to drop to safe levels of around 60V fast, ideally within 5 seconds of the crash.

Traditionally, a bleeding resistor (BR) is connected in parallel to the bus capacitor to dissipate the residual energy and discharge the capacitor voltage. In this ‘external-circuit discharge’ system, the power and current levels of the resistor should be high, while the resistance is supposed to be small to satisfy the requirement of quick discharge. A complication arising from this strategy is that it requires an excessively large size and weight for the bleeding circuit, affecting the compactness of the drive system. In practice, a compromise is achieved, and manufacturers opt for BRs that cannot reach the highest discharge rate, in order to keep the compact size of the drive.

Another discharge approach relies on dissipating the residual energy in the form of heating through the internal machine windings of the EV. A downside of this internal discharge approach is that occasionally a crash will not immediately activate the protection mode, failing to trigger the safe and fast discharge of the DC bus capacitor.

A DESIGNING A THREE-MODE HYBRID DISCHARGE STRATEGY

Gong, Dr Hu and their team are working on the design of a hybrid DC bus capacitor that can discharge within the five second time frame. The hybrid strategy relies on both the internal machine windings and external bleeder circuits to achieve the discharge while using the minimum bleeder size and weight for any EV. With the hybrid approach, the machine windings can be adopted as the auxiliary plant for the external bleeder circuits so as to reduce its size, achieving a relatively lightweight and compact design technique suited to any EV drives.

The team analysed the mechanism of the bleeder-based discharge method through mathematical modelling, considering the current level, resistance, size, and weight of the BR. This allowed them to build a robust theoretical framework for the combined discharge strategy and to demonstrate through calculations that the hybrid approach is highly advantageous. When designing the hybrid discharge system, the extreme condition at which the initial speed equals the maximum possible speed must be considered. In a realistic scenario, however, an emergency might occur when the machine operates below the maximum speed.

To verify the effectiveness of the model, experiments were conducted on a PMSM powertrain used for EVs under the three different discharge modes. The voltage of the DC power supply was set at 312V. According to the experimental results, the proposed full-power discharge algorithm, the partial-power discharge algorithm, and the bleeder-based discharge algorithm are accurate in predicting that the DC bus capacitor can achieve fast discharge within five seconds should an emergency occur.

CONCLUSIONS AND FUTURE PERSPECTIVES

Gong, Dr Hu, and their collaborators conducted research to investigate the risks linked to high-voltage energy stored in the powertrain of electric vehicles. They optimised strategies and safety design that can minimise the risk of electrocution in a collision scenario. The team developed various winding-based discharge methods, which were adapted for different safety-related conditions. By using the proposed winding-based hybrid discharge approach, Gong, Dr Hu, and their collaborators demonstrated that the residual energy stored in the EV powertrains can be dissipated within five seconds in a compact and cost-effective way.

Further investigation will be needed to address crash safety-related problems, both in relation to the safety of the occupants and the protection of the fragile components in the EV. This might involve the use of more algorithms to improve the reliability of the safety features. Also, considering that the powertrains are completely different in different EVs, more case studies should be employed in the future to validate the proposed model.
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