Modular Battery Management System (BMS)
(Technical Paper)

Chevy Bolt Battery Fires: Impact on the Perception of Battery-Electric Vehicles
(STS Paper)

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Prospectus

Introduction

In a debacle expected to cost General Motors (GM) over $2 billion dollars, the Chevrolet Bolt battery-electric vehicle has made headlines for multiple vehicles spontaneously catching fire. GM has had to issue three recalls, expanding the scope of the vehicles affected each time. The issue is serious enough that the scale of the recall now affects all Bolts ever produced, numbering approximately 141,000 units from model years 2016 to 2022 (Voelcker, 2021). GM attributes the root cause of the battery fires to manufacturing defects in the battery pack by its supplier, LG Chem, which result in a higher risk of fire occurring when the batteries are nearly fully charged or discharged too low. In this project, the impact of these battery fires and the handling of the resulting recall will be analyzed.

As the Bolt fires stem from issues with the battery pack, the functionality and safety of the battery system in a battery-electric vehicle like the Bolt is critically important. The architecture of a battery-electric vehicle generally consists of a conglomeration of battery modules that are individually managed by a battery management system (BMS), with each module containing individual battery cells. In addition to the battery modules themselves, the BMS is also a critical component of any battery-electric vehicle design. Modular and scalable BMS designs can help provide flexibility in allowing for different module and cell configurations for different vehicle applications, such as cars, e-bikes, and scooters. The design of such a modular BMS will be the focus of the technical portion of the project. The proposed technical project makes use of multiple modular BMS “cell” nodes managing individual sets of two battery cells and a primary main BMS node that manages the individual “cell” nodes.

Technical Topic

Battery electric vehicles (BEVs) have recently gained popularity as a "green" alternative to fossil fuel vehicles (Xu & Cao, 2015). The battery is an essential component of BEVs and its performance determines the driving range, while a BMS is needed to prevent the battery from overcharging or drawing too much electrical current, which can reduce battery lifespan. In addition, a BMS can report important battery information such as the state of charge (SOC) and further extend battery lifespan via cell balancing (Brandl et al., 2012). However, many BMSs can only be used for certain battery pack configurations with a maximum number of cells. This project proposes a modular BMS design that can handle many different pack types and sizes, while still providing essential BMS functionality.

The proposed technical project is a modular BMS designed to monitor, protect, and efficiently use battery packs in electric vehicles. This modular system will be a network of BMS boards that will be usable for battery packs of many sizes. The BMS will provide charge and discharge protection, display the state of charge of the battery pack, use active cell balancing and have a user interface to set parameters and view data. To help reduce the additional space overhead of the BMS, each individual BMS module will be compact enough to directly attach onto 18650 cells, rechargeable lithium-ion cells that are commonly used in electric vehicles.

A popular BMS used in industry is the Orion BMS, which provides a user interface that has features such as monitoring battery temperatures, setting electrical current limits, configuring device parameters, and logging live data (*Orion Li-Ion Battery Management System*, 2019). However, a major disadvantage of the Orion BMS is that it lacks modularity. Orion offers different BMS sizes of up to 168 cells, but each is distinct. In contrast, the modular BMS is designed to be usable in several applications, from electric skateboards, scooters, and bicycles to cars. The BMS features a modular architecture, with many individual module nodes connected to one main node on a controller-area-network (CAN) bus. Each module node sends all measured and calculated data from the battery module it monitors to the main node and also controls the passive cell balancing of the module they monitor, based on commands from the main node. The main node reads the data from the cell nodes and measurements across the battery pack to make decisions about how to best protect and balance the entire system. The main node will also provide a user interface to process or visualize the data and allow settings to be modified. The final design of the modular BMS will be made to perform the basic functionality of monitoring battery status and health, while being as modular and scalable as possible in order to be used in a variety of applications, such as cars and e-bikes.

STS Topic

The spate of Bolt battery fires, while catastrophically bad for GM's image, is not the only recent instance of battery-electric vehicle-related problems. Hyundai also needed to recall about 90,000 of its Kona EV models for the same issue after 15 fires; Ford recalled 20,500 of its Kuga plug-in hybrid vehicles in Europe for battery overheating issues that had caused a handful of fires (Wayland & Kolodny, 2021). These examples show that GM is not alone in the issues it faces in the industry transition to battery-electric vehicles.

According to Wayland and Kolodny (2021), two of the largest problem areas that traditional "legacy" manufacturers face are in software and batteries, two areas where they typically lack expertise, compared to younger rivals such as Tesla. In the case of both the Bolt and Kona EV recalls, the issues stemmed from manufacturing defects with the LG-sourced battery cells. In an individual battery cell, the anode tab connects the negative terminal of the battery to the other battery cells in the module, while the cathode tab serves the same purpose for the positive terminal. A separator is also typically present, separating the anode and cathode of the battery cell. The specific defects were that the anode tab on an individual cell could be torn and the separator could be folded (Voelcker, 2021). In the rare instance that both defects were present in the same cell, a fire could result when the battery was charged too fully.

While battery-electric vehicles generally have a much lower incidence of catching on fire than comparable gasoline vehicles, when an electric vehicle fire does occur, the relative novelty of the technology contributes to additional media scrutiny and widespread interest (Eisenstein, 2021). The negative media attention that the fires themselves attracted was exacerbated by the fact that GM had to issue three recalls that continued to increase in scope over nearly an entire year, starting in November 13th, 2020 and the most recent on August 20th, 2021 that expanded the recall to include all Bolts that had not yet been considered affected (Voelcker, 2021).

Adding to the situation, according to Lehto (2021), was the confusing and unclear messaging to owners about what to do. In the initial November 2020 recall, GM instructed owners to avoid charging their Bolts over 90 percent while engineers investigated the root cause (Lambert, 2020). After nearly two months without any updates to owners, a software fix was finally rolled out on April 21st, 2021, which turned out not to solve the underlying issue--additional vehicles with the software fix were reported to have still caught on fire (Graham, 2021b). Additional fires in early July then led to the second expanded recall by GM, with the additional guidance to owners to include instructions to avoid running the battery down to below 70 miles of range. Then, out of an “abundance of caution,” GM expanded the recall to include all Bolts in August (Blanco, 2021). The official recall notice now instructs owners of these vehicles to avoid charging over 90%, discharging below 70 miles of remaining range, charging indoors unattended, and parking too close to other vehicles or structures, significantly limiting the capability of the vehicle and causing inconvenience for owners (Voelcker, 2021). How has GM's approach to both handling the battery fires and even electrification as a whole contributed to the consumer perceptions in the wake of the recalls, and do these incidents only impact GM's reputation with consumers as a brand, or do they also impact the perception of the battery-electric vehicle technology itself?

In the context of STS, the concept of paradigm shift is relevant to the discussion of the Bolt fires. According to Kuhn (2012), paradigms are " universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners," while a paradigm shift is a situation "in which an older paradigm is replaced in whole or in part by an incompatible new one." In this instance, the technology of internal combustion engine vehicles has largely been the solution to personal mobility for much of modern society. However, with the new paradigm of electrified vehicles, not only has the technology itself changed, but the industry and technology associated with the necessary infrastructure for electric vehicles requires a transformation. This fits the idea of a paradigm shift in that one paradigm is partly or fully replacing the old paradigm, the way that something had previously been thought about or done.

The major paradigm shift occurring is the automobile industry's change in focus from producing fossil fuel-powered vehicles to battery-electric vehicles, spurred by both governmental pressure and consumer demand. The Bolt fires are arguably a byproduct of this paradigm shift, since any major paradigm shift in technology comes with inherent risks. In addition, the exposure to risk has increased dramatically due to the scale at which the industry is transitioning to electric vehicles. At 17 million vehicles purchased in the US each year, with a quarter of new sales being electric by 2035 (Plumer et al., 2021), the scale at which the technology is being adopted makes issues almost inevitable. The paradigm shift concept can help with analyzing the process that GM and the automobile industry is undergoing with electrification. The concept of a paradigm shift is not without its criticisms, as some believe it is too generalized and can be applied across too many disciplines and is not conclusive. However, in context with the electrification of the automotive industry, the concept of a paradigm shift fits well and provides an opportunity to perform deeper and more structured analysis.