Modular Battery Management System

(Technical Paper)

The Impact of Battery Systems on Society and the Environment

(STS Paper)

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On my honor as a University Student, I have neither given nor received
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Introduction

With the rise in technology available for consumer use, many more people are constantly exposed to interacting with electronic equipment than ever before. In every person's pocket is a battery-powered mobile device, in every building are several mains-powered lighting systems, in every vehicle is a battery-powered display, every Zoom meeting relies on a laptop running off a battery, all of which, most people would agree, are improvements to living standards (perhaps with the exception of Zoom meetings over in-person ones). The modern world as we know it would not exist without electricity. Of course, all of this progress does not come without its downsides. It is not uncommon to hear about cases of battery-powered devices catching fire or broken power lines shocking bystanders in the news. The increase in such cases is strongly correlated with the fact that it has become much more commonplace for the public to be near or using high-power electronic devices, as they are much more readily available on the market. My technical work will be to design a modular battery management system (BMS) that will not only actively work to prevent battery failures but will also be configurable for a wide range of application sizes, from electric scooters and bicycles (E-bikes) to electric vehicles (EVs). My STS work will cover the social and environmental effects of developing such technology for widespread public use.

Technical Topic

This project is a battery management system (BMS) designed to monitor, protect, and efficiently use battery packs for electric vehicles. This modular system will be a peer-to-peer network of BMS boards that will be usable for battery packs of many sizes. The BMS will have 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. Each BMS module will be small enough to clip onto 18650 cells, rechargeable lithium-ion cells that are commonly used in electric vehicles (*Cylindrical batteries more suitable for electric vehicles*, 2017). This reduces the amount of battery space needed in electric vehicles.

Electric vehicles (EVs) have recently gained popularity as an environmentally friendly alternative to vehicles that need gas (Xu & Cao, 2015). The battery is an essential component of the electric vehicle and its performance determines the driving range of EVs. A BMS is needed to prevent the battery from overcharging or high currents, which can reduce the lifetime of the battery. In addition, a BMS can report important battery information such as the state of charge and extend the battery lifetime via cell balancing (Brandl et al., 2012). Many BMSs can only be used for a certain battery pack with a maximum number of cells (*Introduction to battery-management systems*, n.d.). This project proposes a modular BMS design that can handle many different pack types and sizes while still providing essential BMS services.

There has been BMS research in both academia and industry. One paper from a joint European effort detailed different battery modeling methods and cell balancing methods such as passive heat dissipation and active distributed balancing. The paper also sets standards for battery management such as system inputs, responsibilities, and possible sources of error (Brandl et al., 2012). Shandong University designed and tested a Li-ion BMS using a microcontroller that had charge and discharge protection, single cell voltage and temperature monitoring, and cell balancing. This BMS monitored 16 cells, with each group of 8 cells being monitored by a chip. This chip communicated with the microcontroller via an I^2C bus (Xiao, Liu, Qiao, & Li, 2012).

A popular BMS from industry is the Orion BMS (*Orion li-ion battery management system | affordable & reliable ev li-ion bms*, n.d.). Along with BMSs, Orion offers a user interface that lets users tweak all the parameters of the BMS. Users can monitor temperature, set current limits and device parameters, see live data being gathered and configure CAN communications. One downfall of the Orion BMS is that it is not modular. Orion offers different BMS sizes of up to 168 cells. However, if a user wants to resize their battery pack, they must buy a new BMS instead of buying an addon module to their existing BMS.

The Modular BMS is a battery management system designed to be usable in several applications, from electric skateboards, scooters, and bicycles to electric vehicles. The BMS features a modular architecture, with many individual module nodes connected to one main node in a peer-to-peer network. This network is implemented through a CAN bus. We plan to use small BMS modules in order to clip to the side of an 18650 cell. Smaller modules will lead to less space needed for battery storage in EVs.

Each module node sends all measured and calculated data from the battery module it monitors to the main node. They also control the passive cell balancing of the module they monitor, based on instructions received from the main node. The main node reads the data from the cell nodes and measurements on the entire pack to make decisions about how to protect and balance the entire battery pack. The main node also communicates to an external device to process or visualize the data, and allows the control settings to be programmed (modified) by this external device.

STS Topic

There are many social and environmental implications with the use of a modular BMS in high-powered electric applications. An area of great interest is with the use of these devices in electric vehicles. In my STS research topic, I would like to cover these implications and any other impacts there may be as a result of widespread adoption of modular BMSs.

Though governments worldwide have prioritized the development of EVs in response to the impacts of climate change, it remains unclear who is responsible for properly disposing the waste batteries these EVs generate (Ding, Zhao, & Li, 2020). This is an imminent problem, as the average lifetime of many battery packs used in EVs is 5-8 years, which means a surge in EV waste batteries is expected to occur within the next two years. In China alone, the accumulative amount of decommissioned batteries is already about 25 GWh, or approximately 200,000 tons. However, currently, no recycling system exists for waste batteries, and manufacturers lack an incentive to do so (Ding et al., 2020).

On top of the environmental impacts of using lithium-ion batteries, which have been investigated in numerous studies, there are several social impacts from mass production of these batteries which are often overlooked. Specifically, the supply chain for the raw materials needed to produce these batteries, such as lithium, cobalt, nickel, manganese, and graphite, introduce social risks with respect to child labor, corruption, occupational toxics and hazards, and poverty (Thies, Kieckhäfer, Spengler, & Sodhi, 2019).

The anticipated scope of my research covers the social and environmental impacts of battery-based systems in high-powered consumer applications, most notably in EVs. This will include an analysis on the entire life cycle of the batteries used, from the supply chain of the raw materials used to their degradation and eventual disposal. A focus of my research will be the impact BMSs have on this entire process, and what can be done in the production and use of BMSs to alleviate some of these issues.

Research Question and Methods

My STS research question is what the implications of designing a modular BMS are not only on the environment but also on society as a whole. The environmental impacts will be evaluated by collecting and analyzing data from past research on how high-powered consumer applications such as EVs affect the environment. The social impacts will be accessed by analyzing a Social Life Cycle Assessment (S-LCA) of current battery systems to determine the parts of the batteries' lifetime that present high social risk.

The impacts EVs have on the environment have already been thoroughly researched, so there are already large amounts of data on this topic. Thus, it makes sense to utilize this vast amount of data to determine how a modular BMS would affect the environment. There is not as much data on the social impacts of EVs and battery systems, so a thorough case study of one specific EV will provide insight on common problems in the life cycle of the batteries used. This study will cover the entire lifetime of the batteries, from the sourcing of raw materials, to the manufacturing process, then finally the disposal of the batteries.

Conclusion

The modern world has become, and will only continue to grow, dependent on “clean” energy storage devices such as the battery. These energy solutions are not always as optimal as they may seem. The disposal of batteries continues to be an easily overlooked problem globally, and battery failure continues to prevail as an obstacle to widespread acceptance of these “green” electrical systems. The supply chain of the raw materials used in the production of these batteries introduces many social risks, which are often overlooked in the mass production of battery packs for EVs and other high-power applications. The proposed project will create a modular BMS that will be usable in various applications, from the smallest battery powered consumer electronics to full-scale EVs. The small size and low cost of this project will ensure that it can be used even in the smallest applications, and will take less space for EV battery packs. More research needs to be done to discover the potential societal and environmental implications this modular BMS can have.

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