Modular Battery Management System

(Technical Paper)

Environmental Impact of Alternative Energy Sources, Batteries, and BMSs

(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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Introduction

In an increasingly mobile and environmentally-aware time, batteries have become much more widely used than ever before. From electric bikes – or E-bikes – and scooters to electric vehicles – or EVs – and even our homes, batteries have started to dominate as our main source of energy (Stevens, 2017). With all the benefits that batteries provide as energy storage devices ("Benefits of energy storage," n.d.), it can be easy to overlook some of the potential risks they bring. For example, Lithium-ion – or Li-ion – cells are very high performance but can also present great danger to the user if not handled correctly (*Different types of batteries*, 2019). Without proper protection, they may even explode, which has led to many car fires in EVs. Thus, the Battery Management System – or BMS – was developed (*Bu-908: Battery management system*, 2019). Its main goal is to provide safety for users of battery cells, typically for more volatile batteries such as Li-ion cells, but has expanded to provide more features such as measuring state-of-charge – or SOC – and state-of-health – or SOH – of battery packs.

Technical Topic

This project is a Modular 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," 2017). This reduces the amount of battery space needed in electric vehicles.

Electric vehicles 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 I2C bus (Xiao, Liu, Qiao, & Li, 2012).

A popular BMS from industry is the Orion BMS (*Orion li-ion battery management system*, 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

As stated before, the use of batteries has become much more widespread as new technologies such as E-bikes and EVs have become more popular. In fact, EV sales are expected to grow 500% within the next decade (Balasingam, Ahmed, & Pattipati, 2020). Batteries are not just used for EVs: they are also used in storing the energy gained from renewable sources such as wind and solar. With so many more batteries being used, the environmental impacts of using batteries cannot be ignored. While the most obvious environmental impacts come from the disposal of used batteries, many impacts arise throughout a battery's lifecycle: from manufacturing, usage, and storage to treatment, disposal, and recycling (Dehghani-Sanij, Tharumalingam, Dusseault, & Fraser, 2019).

Many stakeholders are involved in this discussion. First, there are the consumers of any products that use batteries, including EVs, E-bikes, electric scooters, wireless devices, flashlights, phones, laptops, etc. This group expands to include almost everyone in modern society. Second, there are the producers of products that use batteries. Most people in this group also fall into the consumer group, so they have an idea of what makes a product usable and efficient. In high-power products such as EVs, producers typically use a BMS developed by a third group: developers of BMSs. The people in this group also typically fall into the first consumer group, but may also fit into the second group and thus have knowledge on the challenges producers face as they relate to battery management. Many other stakeholders are also involved, such as the battery manufacturers, transportation services, disposal services, and the government (for regulations related to battery manufacture, use, and disposal). All of these groups play important roles and each of them has the capacity to either help or hinder the environmental sustainability of battery use.

This research is significant for numerous reasons; one is that there is a tremendous amount of expected growth in the usage of batteries in the next few years, which will exacerbate any environmental impacts batteries have. Another reason is that many consumers purchase these new battery-powered technologies, such as EVs, with the expectation that they are helping the environment by switching to renewable sources of energy. In reality, the harm caused by using batteries in these alternative technologies may outweigh the benefits of using renewable sources of energy, something many consumers may easily overlook. This is especially important as many consumers do consider environmental impacts when purchasing electric vehicles, even if it comes after cost and performance (Ouyang, Ou, Zhang, & Dong).

While there are many different types of batteries, the primary focus of the research will be on the product lifecycle of Li-ion batteries, from manufacturing to disposal, due to their high usage in the global energy storage system (Dehghani-Sanij et al., 2019). The possible uses of BMSs to aid in reducing batteries' environmental impact will also be researched, but as it is still in the early stages of research, there may not be much accurate information available.

Research Question and Methods

The research question I hope to answer is two-fold: first, should batteries be used as our primary energy storage devices in the first place? Many new technologies allow energy storage with less negative consequences than batteries, although they are typically more expensive or harder to use. And second, if we continue to use batteries at the current rate, what can BMSs do to reduce the environmental impact of battery usage? Most BMSs today only accurately model the cell's charge levels for first-time use since most batteries are replaced by the time they reach 80% of their original capacity anyway (Balasingam et al., 2020). However, there is some ongoing research into the reuse of cells from EVs as renewable energy storage systems, in which case a new BMS would be required to ensure the safety of those systems.

The methods that will be employed to purse these research questions can be split into three main steps: gathering, analyzing and concluding. In the first step, data as well as various views and commentaries that have been made in past articles are gathered from many sources. In the second step, the gathered data and commentaries are analyzed for trends that are common among many sources, or for certain points that vary among the different sources. All of these similarities and differences are taken into account and summed up in the third step, making conclusions from the information gained from the various sources.

These methods will prove beneficial in making concrete and well-supported conclusions rather than cherry-picking data that supports an initial claim. They can easily be used to compare and contrast various energy storage technologies to answer the first research question. These methods can also be used to discover many different ways BMSs can be used to reduce the environmental impacts of battery usage, thus answering the second research question.

Conclusion

Batteries have become a widely used technology that we constantly rely on in everyday life. With each new piece of technology that is released for consumer use comes a set of batteries for powering it. We are surrounded by batteries of all sizes. We have larger and larger battery packs capable of delivering more power in an instant – and of failing catastrophically. That is why BMSs are needed now more than ever to ensure safety while using these high-performance cells. The Modular BMS I described is better suited for handling this increasing size of battery packs: it can theoretically handle any number of cells, from an E-bike or scooter to a full EV made up of hundreds of cells. However, in this entire process of using batteries and BMSs to provide safe and efficient forms of energy, it is important to keep in mind the environmental impacts of batteries, from manufacturing and using them to disposing and recycling them.

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