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MACHINE LEARNING BASED INTEGRATION OF ELCTRIC VEHICLE BATTERY CHARGING AND BATTERY CELL EQUALISATION IN ONE CIRCUIT

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ABSTRACT

The increasing use of electric vehicles demands optimized charging methods and optimized battery management systems to enhance performance, safety and life. This paper presents a Machine learning based approach that integrates EV charging and battery cell equalisation to achieve maximum energy distribution and optimize overall efficiency. Our system employs machine learning algorithms to adjust the equalization method automatically in real-time. The equalization and charging integration maximizes battery life by reducing overcharging and underuse of the individual cells, yields improved energy density. Simulation results confirm that the machine learning approach possesses faster equalization, less charging time, and more evenly distributed SOC compared to conventional methods. The circuit here described works as a charger for the battery when the EV is plugged into the grid and as a voltage balancer when EV is in motion. The proposed circuit works on the flyback converter mode and provides power factor correction while charging the battery [3].

This research contributes to the development of smart BMS solutions that can lead to greener and more efficient EV usage. The proposed framework focuses on the potential for artificial intelligence to revolutionize EV energy management, promoting longer-lasting battery life and more efficient charging technologies.

Keywords: Convolutional Neural Network, Electric Vehicle, Matlab Simulink, Isolated Converter, Battery Pack**.**

I. Introduction

The shift to electric transport is an unstoppable worldwide trend, driven by the increasing pressure to adopt low-carbon vehicles to mitigate the greenhouse effect. It's estimated that in most cases, the traditional internal combustion engine (ICE) will increasingly be replaced by hybrid and pure electric cars as the overall mode of transport to help curb CO2 emissions [1, 2]. Most of today's hybrid electric vehicles (HEVs) and electric vehicles (EVs) are powered by lithium-ion battery packs, which provide higher power density and longer lifetimes compared to other battery types [3–5]. The purpose of this paper is towards the Machine Learning based integration of electric vehicle battery charging and battery cell equalization. Utilizing Artificial Intelligence (AI) technology, the system is to provide an effective battery management techniques. Machine Learning in EV technology is its integration into charging battery equalization systems. Battery charging and cell equalization have traditionally been executed as standalone processes, each executed by standalone parts. With the progress that has been achieved in Machine Learning, these processes are now capable of being intelligently combined, and their cost-effectiveness and efficiency. In this application, CNN(Convolutional Neural Network) method is employed to execute the battery equalization systems. CNNs are trained with a supervised learning technique. This involves that the CNN is provided with a collection of labeled training images. The most advantageous feature of CNNs is minimizing the parameters in ANN (Artificial Neural Network) [4].

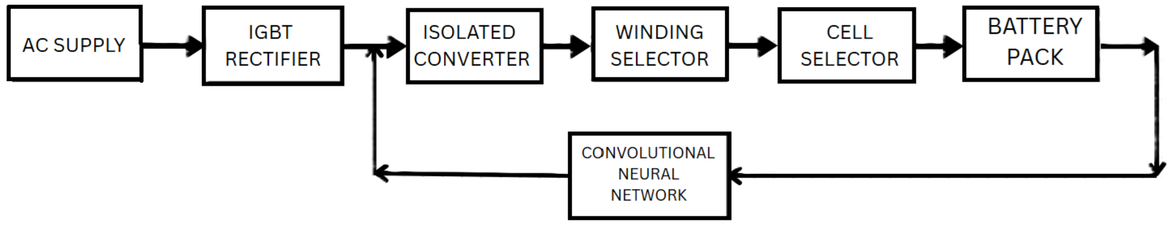

Fig- 1: Block Diagram of ML based integration of electric vehicle battery charging and battery cell equalization in single circuit.

A smart battery charging and equalization system for electric vehicles is depicted as shown in the figure 1. An AC supply is first fed into an IGBT rectifier, which transforms AC into DC. To direct energy to the proper battery cell in the battery pack, an isolated converter powered by the DC output is connected to a winding selector and a cell selector. For optimum performance and cell balancing, a Convolutional Neural Network (CNN) keeps an eye on the battery pack, evaluates the condition of the cells, and provides feedback to regulate the converter and charging path.

1.1 Enhanced Battery State Estimation:

A significant focus is on improving the accuracy of State of Charge (SOC) and State of Health (SOH) estimation. Machine learning algorithms, including neural networks, recurrent neural networks (RNNs), and support vector machines (SVMs), are being employed to analyze complex battery data. These techniques aim to overcome the limitations of traditional methods, which often struggle with the nonlinear and dynamic behaviour of lithium-ion batteries [6-7].

1.2 Adaptive Equalization Strategies:

Researchers are developing machine learning-based control algorithms to optimize cell equalization. This involves adapting equalization strategies in real-time based on factors such as temperature, SOC, and aging. Reinforcement learning is emerging as a promising approach for creating adaptive equalization controllers that can learn optimal strategies through interaction with the battery system [8].

Integrated Charging and Equalization Circuits: There's a growing interest in designing integrated circuits that combine charging and equalization functionalities. This aims to reduce the complexity, cost, and size of EV battery systems. Studies explore the use of advanced power electronics and control techniques to enable simultaneous charging and equalization.

1.3 Fault Diagnosis and Prognosis:

Machine learning is being used to detect and diagnose battery faults, such as cell imbalances and degradation. This enables early intervention and improves the safety and reliability of EV batteries. Anomaly detection algorithms are employed to identify deviations from normal battery behaviour, which can indicate potential faults.

Data-Driven Approaches: Machine learning-based battery management relies heavily on data. Researchers are focusing on collecting and analyzing large datasets of battery data to train accurate models.

Real-Time Optimization: There's a trend towards developing real-time optimization algorithms that can adapt to changing battery conditions. This is crucial for maximizing battery performance and lifespan.

1.4 Emphasis on Safety:

Safety is a paramount concern in EV battery management. Machine learning is being used to enhance safety by improving fault detection and preventing overcharging/over-discharging.

Data Availability and Quality: Obtaining high-quality battery data is a major challenge. More research is needed to develop standardized datasets and data acquisition techniques.

Computational Complexity: Some machine learning algorithms can be computationally intensive, which can be a limitation for real-time applications. Research is needed to develop efficient algorithms that can be implemented on embedded systems.

Model Generalization: Machine learning models must be able to generalize to a wide range of operating conditions and battery types. More research is needed to improve the robustness and generalizability of these models. In essence, the ongoing research is heavily focused on the intelligent control of EV battery systems, and machine learning plays a vital role in enabling that intelligent control [8].

II. Literature review

The convergence of machine learning (ML) and electric vehicle (EV) battery management, specifically the integration of charging and cell equalization, has garnered significant research attention. Studies consistently demonstrate the potential of ML algorithms to enhance battery performance and longevity. Researchers are exploring novel power electronic topologies and control strategies to combine charging and equalization functions into unified systems, thereby reducing hardware complexity and cost. A prominent trend involves the utilization of ML for accurate State of Charge (SOC) and State of Health (SOH) estimation, crucial for optimizing charging profiles and predicting battery degradation. Neural network architectures, including LSTM and CNNs, are increasingly employed to capture the temporal dependencies and complex relationships within battery data. Moreover, ML-driven adaptive cell balancing strategies are being developed to minimize energy loss and accelerate balancing speed, addressing the inherent variations in cell capacities and resistances. The application of ML extends to optimizing charging profiles based on real-time battery conditions and user preferences, ensuring safe and efficient charging. Beyond individual battery management, ML is also being investigated for broader e-mobility applications, such as charging infrastructure optimization and vehicle-to-grid (V2G) integration. Overall, the literature underscores the transformative potential of ML in advancing EV battery technology, facilitating the development of more efficient, reliable, and sustainable electric transportation systems [9]
The integration of machine learning into electric vehicle (EV) battery management systems, particularly for combined charging and equalization, is a rapidly evolving field.

- Huaxia Zhan, Haimeng Wu, Musbahu Muhammad, Simon Lambert [3] offer a unique method that combines cell equalization and electric vehicle battery charging into a single circuit. This combined system guarantees balanced charging across all cells, reduces hardware complexity, and increases overall efficiency. The technique improves battery performance, increases lifespan, and streamlines battery management system design by utilizing intelligent control strategies.
- Priya S, Vinoth Kumar P, Sridevi V, M Batumalay, Gunapriya D [11] suggest a model for tracking battery systems and determining the State of Charge (SOC) of electric vehicles that is based on Convolutional Neural Networks (CNNs). By providing real-time, data-driven insights into battery health and performance for EV applications, their method improves prediction accuracy, encourages sustainable energy use, and strengthens battery management.
- Feng-Ming Zhao, De-Xin Gao, Yuan-Ming Cheng, Qing Yang [12] present a cutting-edge technique for estimating the State of Health (SOH) and forecasting the Remaining Useful Life (RUL) of lithium-ion batteries that combines AT-CNN and BiLSTM. In applications involving electric vehicles, their model increases prediction accuracy, facilitates proactive maintenance, and extends the lifespan and dependability of battery systems.
- Flynn and Giannetti [13] investigate the application of Convolutional Neural Networks (CNNs) to determine which residential properties are appropriate for home charging of electric vehicles. Their study maps features like garages and driveways using machine learning and satellite imagery. This strategy promotes sustainable transportation, helps plan EV infrastructure, and makes it easier to implement home charging stations in specific urban locations.
- Athari Alnatsheh and Tuqa AL Makkawi [14] Examine EV charging trends and energy usage in "Optimizing Electric Vehicle Charging Infrastructure through Machine Learning." They suggest intelligent infrastructure planning using machine learning to improve grid stress, boost sustainable energy integration in urban transportation systems, and increase efficiency.

2.1 Machine Learning in EV battery management system

❖ Peng Li [15] has significantly contributed to the field of machine learning in electric vehicle (EV) battery management. Peng Li work focuses on utilizing ML techniques for accurate battery health monitoring, state-of-charge estimation, and optimization of battery management systems, enhancing efficiency, longevity, and performance of EV batteries in real-world applications.

❖ Hui Liu [16] has made contributions to the machine learning-based predictive modelling of electric vehicle (EV) battery behaviour. In order to improve the overall effectiveness and dependability of EV battery management systems, his research focuses on using machine learning (ML) to forecast battery performance, optimize charging cycles, and extend battery life.

❖ Xiaoyang Li [17] advances the application of data-driven machine learning techniques in battery management systems. In order to improve the sustainability and dependability of EV battery systems, his research focuses on predictive maintenance and energy efficiency. It does this by using machine learning techniques to improve battery performance, predict failures, and optimize energy use in electric vehicles.

III. Conclusion

Machine learning application in EV battery charging and cell equalization is a potential solution for next-generation BMS. The proposed circuit increases efficiency, extends battery life, and reduces energy losses. Future work will focus on real-time hardware implementation and further optimizing ML algorithms to enhance adaptive control. Application of machine learning to combine electric vehicle charging and battery cell equalization is a giant step towards the development of battery management systems. With the application of data-driven intelligence, these systems are able to optimize charging rates, improve cell balancing, and ultimately extend battery life. Such integration not only renders electric vehicles efficient and reliable but also contributes to the overall cause of sustainable transportation by maximizing the performance and lifespan of major battery components. Machine learning ability to learn with shifting driving conditions and battery degradation trends ensures a stronger and smarter EV battery management system.

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14. Athari Alnatsheh and Tuqa AL Makkawi (The Hashemite University): Authors of "Optimizing Electric Vehicle Charging Infrastructure through Machine Learning: A Study of Charging Patterns and Energy Consumption."
15. Peng Li: Visiting Professor at The University of Texas at El Paso (UTEP), research focuses on optimizing electric vehicle (EV) battery management through ML techniques.
16. Dr. **Hui Liu**, a researcher at the **Harbin Institute of Technology**, specializing in the application of machine learning (ML) techniques to electric vehicle (EV) battery management systems.
17. Dr. **Xiaoyang Li**, a researcher specializing in the application of machine learning (ML) techniques to electric vehicle (EV) battery management systems.