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Electric Vehicle Charging Technique for Enhanced Battery Longevity

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Abstract - *The lithium-ion battery represents the most significant expense in electric vehicles (EVs). Enhancing battery performance is crucial for advancing the EV market because it extends battery life, lowers ownership costs, and builds consumer confidence in the product. This paper explores a strategy for improving battery performance that not only prolongs its lifespan but also boosts its storage capacity. We focus on identifying the optimal charging profile for an EV battery by determining when the battery is most receptive to charging and devising a profile that minimizes the impact on its longevity. The analysis reveals that incorporating rest periods during the charging process can effectively reduce battery degradation in two key ways. Firstly, it mitigates the rate of change in the internal resistance of the battery. Secondly, it decelerates the capacity fade over time. Additionally, this approach helps maintain a lower average temperature during charging, further contributing to battery health.*

Key Words: Battery internal resistance, Battery charger, capacity fade, electric vehicle, lithium-ion battery.

1. INTRODUCTION

Technology has evolved rapidly over the past century, leading to profound changes on our planet. One of the main concerns has been the rise in pollution and climate change. Traditional vehicles rely heavily on fossil fuels, contributing significantly to environmental degradation and climate issues. As a result, there's a growing interest in transitioning to electric vehicles (EVs) . However, this shift faces challenges, mainly due to the higher costs associated with EVs, which are largely influenced by battery technology and their overall lifespan . To address these challenges, extensive research is underway further, Lawson found that introducing rest periods during battery discharge could enhance battery longevity. Additionally, implementing rest periods during charging could extend the cycle life of alkaline batteries by lessening plating effects , although this strategy has not yet been applied to lithium batteries.

The newly proposed method outlines an enhanced charging profile for electric vehicle (EV) batteries, which achieves charging with less battery degradation while minimizing heat effects that can harm battery health.

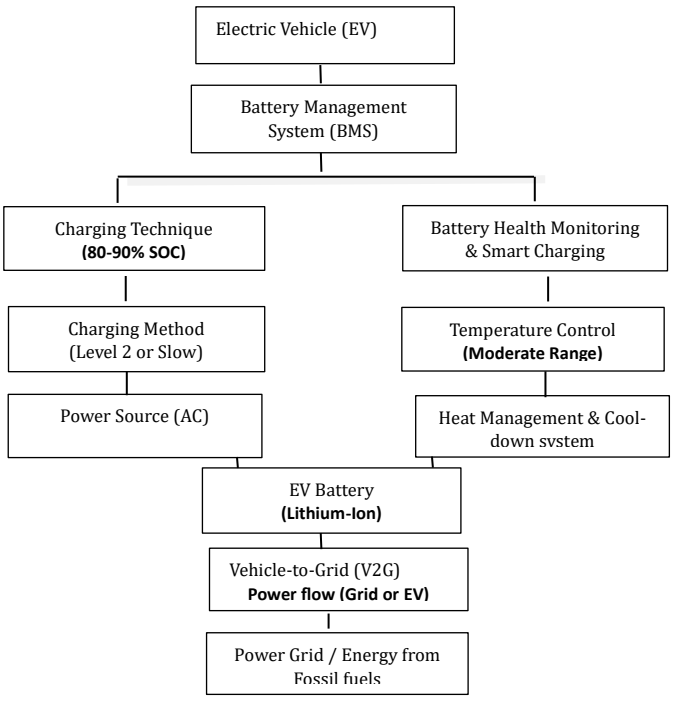

Fig 1: Block Diagram

2. SOLID ELECTROLYTE INTERFACE

Battery internal resistance plays a crucial role in influencing overall battery performance. It constrains how much current the battery can handle and affects the speed of charge and discharge cycles. One key contributor to increased internal resistance is the formation of the solid electrolyte interface(SEI). This phenomenon occurs through a chemical reaction between the electrolyte and anode, resulting in the deposition of a thin protective layer, as illustrated in Fig. 2.

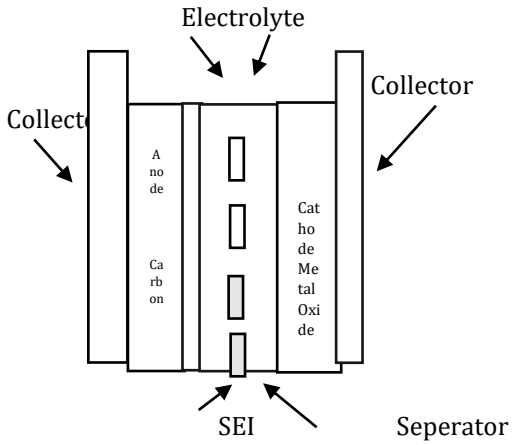

Fig 2: Representation of Battery Cell

2.1 During First Charge:

- When the battery is first charged, some electrolyte decomposes and forms a thin SEI layer on the anode
- This layer acts as a barrier, preventing further decomposition of the electrolyte.
- During Charging (Energy storage):
- Lithium ions move back from the anode to the cathode, generating electrical power.
- The SEI remains stable, ensuring smooth lithium-ion transport.

3. Battery charging (chemical reaction)

The battery cell operates through a series of chemical reactions during the charging process, which can be divided into three key stages: charge transfer, mass transport, and the intercalation process . The third stage involves the intercalation process, during which lithium ions begin to penetrate the electrode material as charging occurs.This method also requires a significant amount of time.

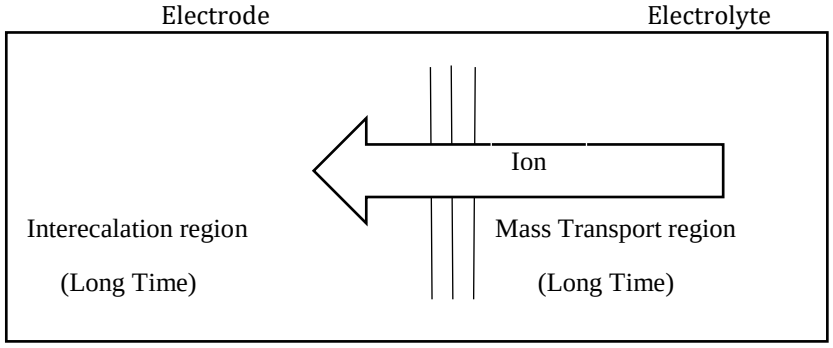

Fig:3 Cell Chemical Reaction

3.1. Charge Transfer (Electron Flow)

What happens: During charging, electrons are supplied by the charger and move through the external circuit to the anode (negative side) of the battery.

Key point: The anode receives electrons from the external circuit. At the same time, lithium ions (Li*)

move through the electrolyte from the cathode to the anode.

Reaction for charger transfer at the Anode (charging):

$$Li_xC_6 + xe^- \rightarrow Li_1C_6$$

This represents the lithium ions (Li*) being stored in the graphite structure of the anode, as electrons flow into the anode.

3.2. Mass Transport (Lithium-ion Movement)

- **What happens:** The lithium ions (Li*) move from the cathode to the anode through the electrolyte.
- **Key point:** The electrolyte allows the transport of lithium ions(Li*), and this movement is vital for charging the battery. As ions are transported from the cathode to the anode, they create a chemical potential that stores energy.
  Lithium-ion Movement (Mass Transport):

$$LiCoO_2 \rightarrow Li_xCoO_2 + xLi^+$$

- Here, lithium ions (Li*) leave the cathode material (usually lithium cobalt oxide) and move towards the anode (usually graphite).

3..3. Intercalation (insertion of Lithium ions)

- **What happens**: The lithium ions (Li*) that have moved to the anode intercalate (insert) into the graphite structure of the anode. This is how the battery stores energy during charging.
- **Key point:** The process of intercalation is reversable. When the battery is discharging, lithium ions move back from the anode to the cathode, releasing energy.
  Anode Reaction During Intercalation (charging):

$$Li_xC_6 \rightarrow Li_1C_6 + xLi^+ + xe^-$$

- Lithium ions (Li*) are inserted between the layers of the graphite anode, storing the energy that will later power the EV when needed.

4. METHODOLOGY

4.1 STANDARD CHARGING PROFILE:

The conventional method of charging a lithium-ion battery, commonly referred to as constant current constant voltage (CCCV) charging .

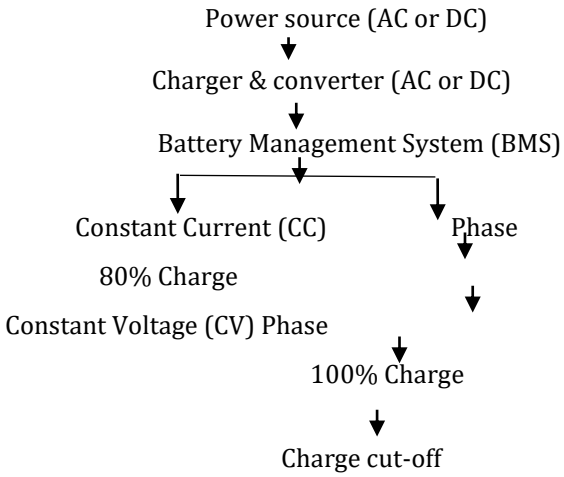

Fig 4: Block diagram of Standard profile

4.2 Explanation of this Standard profile:

1. Power source (AC/DC) & Charger

- Converts AC power to DC for battery charging.
- Supplies power to the Battery Management System (BMS)

2. BMS

- Controls the charging process to prevent overcharging or overheating.

3. Constant Current (CC)

- The charger supplies a steady current, and battery voltage gradually rises.

4. Constant Voltage (CV)

- Charging current gradually decreases as the battery fills up.

5. Charge cut-off:

- Prevents overcharging and improves battery lifespan.

Existing:

There is widely accepted and defined pattern of voltage and current changes that should be followed when charging the battery, typically involving a constant current (CC)phase followed by a constant voltage (CV)phase to ensure optimal charging efficiency and battery longevity.

4.3 Modified charging profile:

A modified profile refers to a type of pulse profile with a variable pattern that adapts to the limitations set by the battery m anufacturer.
Charging with designated rest intervals, wherecharging (ON) occurs for a specific duration, followed by(OFF) for another s et duration, in a repeated cyclical manner during the charging period.
On the other hand, incorporating restperiods during charging will extend the overall charging duration.

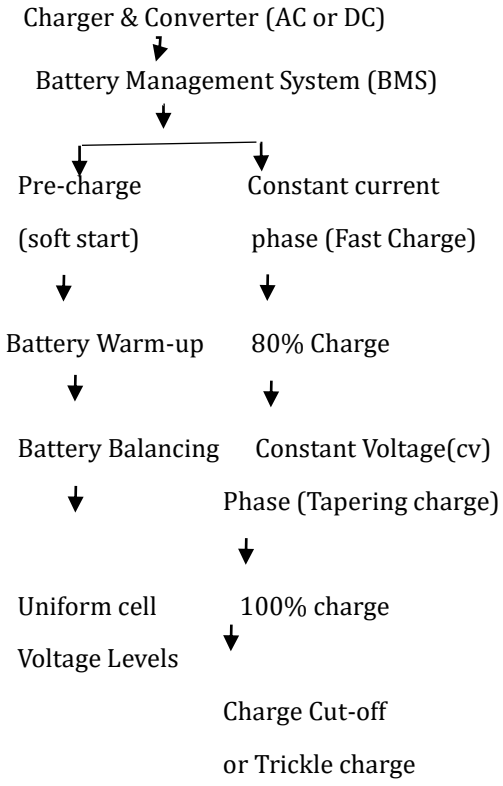

Fig 4.1: Block diagram of Modified Profile

4.4 Explanation of this profile:

1. Pre-Charge

- Used for deep-discharged batteries (very low voltage)
- Prevent sudden stress on battery cells.

2. Constant Current (CC)

- Delivers a steady high current for quick charging.
- Voltage gradually increases.
- Charges up to 80% capacity efficicently.

3. Battery Balancing

- Ensures all battery cells in the pack have uniform voltage.
- Improves battery health and prevents weak cells from overcharging.

4. Constant Voltage (CV)

- Charging current gradually decreases.
- Prevents overcharging while ensuring full charge.

5. Charge Cut-off

- Charging stops when the current drops below a threshold.
- Some systems use trickle charging to maintain full charge without overload.

4.5 Existing:

Modified charging profiles are designed to enhance battery performance, extend lifespan, and improve energy efficiency. These profiles optimize charging by adjusting power delivery based on factors like battery temperature, state of charge (SoC), grid demand, and user preferences. In this profile Energy efficiency is higher through real-time adjustments.

Modified Charging profiles are shaping the future of EV charging by making it faster, safer, and smarter. These technologies help extend battery life, reduce energy costs, and integrate with renewable energy sources. Faster charging without overheating, Longer battery life by preventing damage.

5. RESULTS AND DISCUSSION

The experimental tests were conducted under identical conditions for both profiles. The battery type utilized is lithium iron phosphate (LiFePO4). The charging parameters are a 0.8C raeand avoltage of 3.65. The discharge limits are defined by a 0.8C discharge rate voltage of 2.0. The Arbin machine functions as a programmable charger and an environmental chamber maintaining an ambient temperature of 25°C.

It is evident that the temperature during,charging was adjusted based on variations in the charge profile,leading to a reduction in battery temperature.From a capacity perspective, charging the battery with modified profileincreases its ability to hold more capaciyby 0.15%, as illustrated in Fig. 6. Furthermore, theraeofbattery capacity declinehas improved, decreasing from 0.014% to 0.012% per cycle,representing a 1% reduction in degradation. Consequently, thebattery life will increase by 17% (assuming the end of life is reached at 80%).

6. CONCLUSIONS

An analysis of two charging profiles has been conducted to demonstrate the impact of incorporating a rest period into the charging process. The standard charging processis initially introduced, showcasing the typical battery capacity degadation caused by cycling. Furthermore, thereduction inbattery capacity degradation has significantly increased the battery's lifespan. Efforts are underway to discover methods for minimizing the loss of battery capacity. Additional tests are being carried out by altering the rest.

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