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A Comprehensive Review on Life Cycle Assessment of Batteries used in Electric Vehicles

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ABSTRACT: One of the most important issues in battery research is battery aging, which reduces the battery's capability for power and energy over time. Therefore, a thorough understanding of aging behaviour is necessary to optimize battery system design. Empirical and semi empirical models (EMs) are widely employed in cost analysis, smart charging, and feasibility studies, among other applications, because it will be easy to use. The design has boosted the energy density by over 50%. When the available capacity is restricted, an acceptable cycle life can be expected, even under fast charging. This method lowers a battery system's useful energy density, however for car applications where traditional overnight charging isn't an option, this compromise might still be acceptable.

In electric vehicles, the tested cell. Unfortunately, without proper understanding of their intrinsic limitations and the connection between stress components, these models are vulnerable to large estimation mistakes. This article reviews aging research and empirical and semi empirical modeling approaches, emphasizing the shortcomings and difficulties of the various models while concentrating on the trends seen throughout studies. We start by providing an overview of the primary aging mechanisms in lithium-ion batteries. The examination of empirical modeling methodologies comes next, then issues of the present and future and a conclusion. Our findings show that stress factors' effects are easily oversimplified and that their relationships are frequently ignored. The information in this article can be utilized to assess the shortcomings of aging models and enhance their precision for a range.

KEYWORDS: battery chemistry, battery retention, thermal management, state of charge, life cycle

I.INTRODUCTION

Lithium-ion batteries are prime candidates for Electric Vehicle (EV) and grid storage applications[1], because of their high power density and higher cycle life compare battery Lithium-ion batteries (LIBshave the advantages of high energy density, no memory effect, and long lifetimes compared with lead-acid or nickel-metal hydride batteries; therefore, they are extensively used in mobile phones, computers, and electric vehicles. [3]. Casualties may occur when a LIBs SOH drops to a certain level. [4] Lithium-ion batteries are the energy storage of choice in many applications including transportation (cars, buses, trains, air craft, etc.), portable electronics and back-up power systems. This is mainly due to their high energy and power densities, high efficiency as well as low self-discharge compared to their counterparts (NiCd, NiMH and Lead Acid.[5] Like other battery types, the energy and power densities of lithium-ion batteries diminish with aging. This is due to change in battery capacity and internal resistance as the battery ages.[6] The empirical or semi-empirical models are based on large amount of experimental data and semi-empirical equation.[7] since they were first commercialized by Sony in 1991 [1], lithium-ion battery (LIB) technology has been widely adopted due to its relatively high energy and power density, high efficiency, and rather a long lifetime [8]. Today, LIBs play a vital role in the energy transition; they help integrate renewable energy sources (RESs), provide ancillary services, and reduce transportation emissions. In addition, LIBs are also widely used in the mobile device industry, aerospace and aviation industry, and defense industry [9]. All of these contribute to a rapidly increasing LIB mark.[10] electrified vehicles, such as hybrid electric vehicles (HEVs), plug-in HEVs (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs), are now established on the market. The powertrain

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technology has been proven for both passenger cars and commercial vehicles such as buses and trucks, despite relatively high component Manuscript received 15 September 2021; revised 3 December 2021 and 15 February 2022; accepted 2 March 2022. [11] ELECTRIFIED vehicles, such as hybrid electric vehicles (HEVs), plug-in HEVs (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs), are now established on the market. Various cell comparisons is shown in table no. 1 as follows.

Cell type	Material introduction	Voltage range	Charge
A	2014	3-4.10	1c
B	2012	2.80-4.15	1c
C	2016	3.00-4.20	1c
D	2018	3.00-4.20	1.5c

Table 1: material introduction

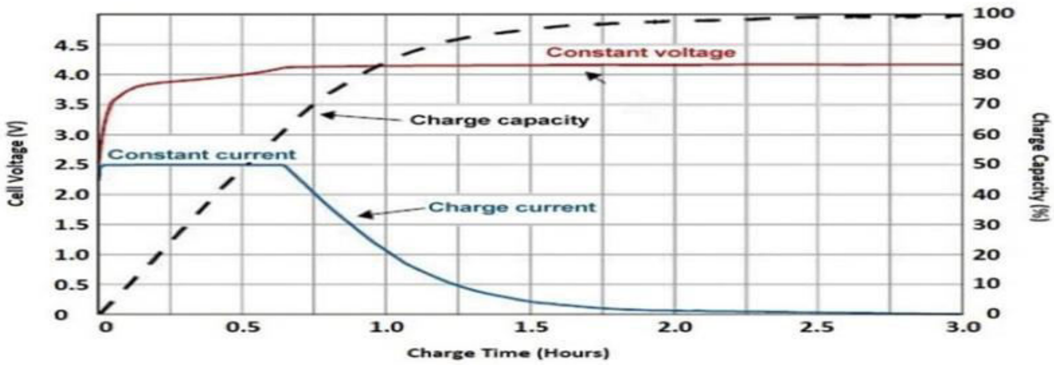

Figure 1.Graph charging and discharging graph

As shown in figure 01 the Graph of charging discharging: This charge curve of lithium ion battery plots various parameters such as voltage, current etc.

1. When the cell assemble battery pack form they must be charge using constant current, constant voltage, cc-cv charger highly recommended for battery
2. The cc-cv method starts with constant charging while the battery pack voltage rises.
3. When the battery reaches full charge cut-off voltage, constant voltage mode take over and drop in charging current
4. The charging current keep down until reaches 0.05C
5. The battery reaching full charge voltage at stage does not mean that the battery is 100 % charged. Trickle charging mode kicks immediately after the current starts reducing and the cell gets balanced. When every cell balanced and has a reaches its full charge voltage then we said battery fully charge

II. SIMULATION ASSESMENT THEORY

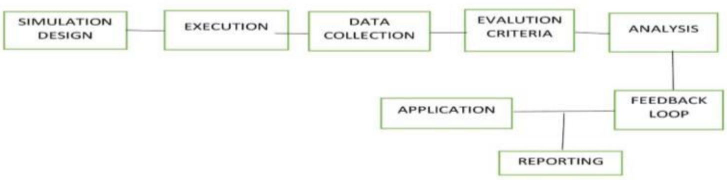

Figure no.2. Simulation process of battery

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As shown in figure no. 2 the Simulation Assessment Theory is a method used to evaluate and improve systems or processes through the use of simulations. It's commonly applied in various fields like engineering, education, business, and healthcare to predict the behaviour of complex systems, test scenarios, and make informed decisions. Here's a step-by-step explanation of the process:

1. Define Objectives
- Identify Goals: Clearly outline what you want to achieve with the simulation. This could include understanding system behaviour, evaluating different strategies, or predicting outcomes.
- Specify Metrics: Determine the criteria for success and how you will measure the effectiveness of the simulation.

2. Develop the Model
- Create a Conceptual Model: Develop a theoretical framework that describes the system or process you want to simulate. This includes identifying key components, interactions, and variables.
- Build the Simulation Model: Translate the conceptual model into a mathematical or computational model. This involves coding and using software tools to create a virtual representation of the system.

3. Validate the Model
- Test Accuracy: Ensure the model accurately represents the real system. This involves comparing the model's outputs with actual data or results from real-world scenarios.
- Refine the Model: Make adjustments based on validation results to improve the model's accuracy and reliability.

4. Run Simulations
- Design Experiments: Set up different scenarios and parameters to test various conditions within the simulation.
- Execute Runs: Perform the simulations according to the designed experiments to collect data on system behaviour under different conditions.

5. Analyse Results
- Interpret Data: Review the data collected from the simulations to identify patterns, trends, and insights.
- Evaluate Outcomes: Compare the results against the predefined objectives and metrics to assess the performance and effectiveness of different scenarios.

6. Make Decisions
- Draw Conclusions: Use the insights gained from the simulation to make informed decisions or recommendations.
- Implement Changes: Apply the findings to improve the real-world system or process, based on the outcomes of the simulation.

7. Review and Refine
- Assess Impact: Evaluate how well the implemented changes perform in real-world conditions.
- Iterate: Refine the simulation model and repeat the process as necessary to address new questions or improve accuracy.

8. Document and Communicate
- Report Findings: Document the results, methodology, and conclusions of the simulation study.
- Share Insights: Communicate the findings with stakeholders and decision-makers to ensure that the knowledge gained is effectively utilized.
- Assumptions: Be aware of the assumptions made during the modeling process, as they can impact the accuracy of the simulation.
- Complexity: The complexity of the model should match the complexity of the real system being simulated.
- Software Tools: Choose appropriate simulation software and tools that align with the goals and requirements of the study.

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By following these steps, Simulation Assessment Theory helps in understanding complex systems, predicting outcomes, and making better-informed decisions through a structured and iterative approach.

Aging of battery:
Another popular method for estimating the state-of-charge (SoC) and state-of-health (SoH) is machine learning (ML), using techniques like neural networks and support vector machines. Not the same There are various ML techniques; some train the algorithm to extraction model characteristics, including polarization and ohmic resistance Polarization capacitance, resistance, and [17], [18], or com combine regression models with empirical modeling methodological. For SoH prediction [19]. Accuracy levels can be high. However, massive datasets are required for training with ML techniques. algorithm [12], algorithm [20]. The term "aging" of lithium-ion batteries describes the slow deterioration of their capacity and performance over time.

Several variables influence this process:
Cycle Life: The battery degrades with each charge and discharge cycle. The capacity and overall longevity of the battery are decreased by frequent cycling.

Temperature: High temperatures cause chemical reactions in batteries that can result in increased internal resistance and capacity loss, which speeds up the aging process. Very low temperatures can also affect battery performance, albeit not as much.

Charge Levels: A battery may get strained if it is continuously charged to full capacity or discharged to extremely low levels. Keeping it charged between 20 and 80 percent of the way can help extend its life.

III. METHODS OF BATTERY RECYCLING

Battery recycling is an essential procedure for handling spent batteries, recovering precious materials, and lessening the impact on the environment. Depending on the kind of battery and the materials it includes, different techniques are applied. These are the primary techniques for recycling batteries:

1. Utilizing mechanical methods
Crushing and Shredding: In order to reduce the size of the batteries, they are first crushed and then shredded. This procedure aids in the separation of the battery's various parts.

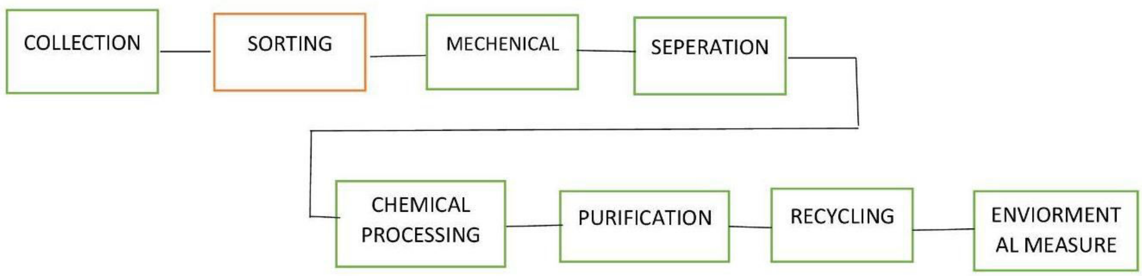

Figure no.3 - Process of battery recycling

Screening and Sorting: To separate various materials, including metals, polymers, and other components, the crushed material is screened and sorted as shown in figure 3.

2. The Processing of Pyro metallurgy
High-Temperature Smelting: In this technique, the battery components are heated in a furnace to extremely high temperatures. The battery components melt due to the intense heat, a

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3. Processing Hydrometallurgical

Leaching: To dissolve the valuable metals, the battery ingredients are treated with acid or other chemicals. Nickel, cobalt, and lithium can be extracted selectively using this method.

Precipitation and Separation: The solution is treated to precipitate and separate the various metals so that they can be collected and purified after leaching.

4. Utilizing Biotechnology in Processing

Bioleaching: This new technique pulls metals from battery trash by use of microorganisms. Certain bacteria have the ability to decompose battery components and liberate metals into a solution for additional recovery.

Bio mining: Using living organisms to extract valuable metals from ores or waste materials is a technique similar to bioleaching

5. Considering the Environment and Safety

Correct Handling: In order to prevent environmental pollution, battery recycling procedures need to handle dangerous elements like lead and cadmium with caution.

Rules & Guidelines: Battery recycling procedures are safe and environmentally responsible when they follow rules and guidelines.

Research on battery recycling is always changing with the goals of maximizing environmental effect, cutting costs, and increasing efficiency.

Model update for lithium ion battery:

Specification	LPF	NMC	LCD	LTO
Nominal voltage	32v	3.7v	3.7v	3.7v
Temperature range	-20degree to 60 degree	-20degree to 60 degree	0 Degree to 45 degree	20 degree to 60 degree

Table No.2. – Various battery comparison

As shown in table no. 2, Lithium-ion battery technology is constantly evolving in order to maximize sustainability, safety, and performance. An outline of several noteworthy and current advancements in battery models and technology is provided below:

1. Solid-State Batteries: Unlike conventional lithium-ion batteries, which use liquid or gel electrolytes, solid-state batteries employ a solid electrolyte.

Improvements include increased safety (lower chance of leaks or fires), more energy density, and possibly longer lifespans.

Problems: Exorbitant production expenses and intricate manufacturing procedures.

2. Silicon Anode Batteries: Unlike traditional graphite anodes, these batteries employ silicon as the anode material.

Improvements: Compared to graphite, silicon has a far larger capacity for storing lithium ions, which can greatly boost energy density.

Challenges: During charge-discharge cycles, silicon grows and contracts dramatically.

3. Lithium-Sulphur (Li-S) Batteries: Sulphur serves as the cathode ingredient in lithium-sulphur batteries.

Improvements: Because sulphur is abundant, they are lighter and less expensive, and they offer a higher potential energy density.

Challenges: Although research is ongoing to overcome them, they have problems with conductivity and cycle life.

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4. High-Nickel Cathodes: Compared to conventional cathodes, these batteries employ cathodes with a greater nickel concentration.

5. Cobalt-Free Batteries: These batteries drastically cut down on the amount of cobalt present in the cathode materials.

Specification of lithium ion battery:

Specification	Description
Cell Chemistry	Type of Li-ion chemistry (e.g., LFP, NMC, LCO, LTO)
Nominal Voltage	Average voltage during discharge (e.g., 3.2V, 3.7V, 3.8V)
Capacity	Amount of charge the battery can hold (e.g., 1000mAh, 3000mAh)
Energy Density	Amount of energy stored per unit weight or volume (e.g., 150 Wh/kg)
Cycle Life	Number of charge-discharge cycles before significant capacity loss (e.g., 2000 cycles)

Table 3.specification of lithium ion battery

As shown in table no.3, Lithium-ion battery's specification contains a number of technical parameters that outline its capacity, safety features, and overall performance.

The following are some essential characteristics of lithium-ion batteries that are often mentioned: A measurement of the battery's capacity expressed in milliampere-hours (mAh) or ampere-hours (Ah). A larger capacity battery allows a device to run on it for longer before needing to be recharged the voltage.

(1) Nominal Voltage: For the majority of lithium-ion cells, this is typically 3.7V. This represents the mean voltage upon discharge.
(2) Minimum Voltage: Typically 3.0V per cell, this is the lowest voltage that a battery can safely discharge to.
(3)Maximum Voltage: Typically approximately 4.2V per cell, this is the greatest voltage a battery can safely attain while being charged. Charge Current: Usually expressed in amps (A), this is the highest current that a battery may be safely charged.
(4)Discharge Current: Also expressed in amps (A), this is the highest current that a battery can securely provide to a load. Peak and continuous discharge currents are examples of this.

The gravity metric energy density is expressed in watt-hours per kilogram, or Wh/kg. It shows how much energy is held in each battery mass unit. The volumetric energy density is expressed in watt-hours per liter, or Wh/L. It shows how

IV. CONCLUSION

Because of their vital significance in the transportation industry's electrification Lithium-ion batteries are acknowledged as a crucial technology in accomplishing the objectives specified in the climate deal in Paris. Knowing how batteries age is One of the primary scientific issues concerning LIBs and essential in order to better comprehend the trade-offs between attributes, such as lifespan, cost, and performance. An analysis of the behavior and empirical modality of LIB I was discussed, with an emphasis on the impact of interdependence of stresses associated with operations. The displayed review finds that generalizing about aging is extremely challenging. Behavior in relation to how operating condition affect causes of stress as opposed to attribution. n conclusion, studies on lithium-ion (Li-ion) batteries highlight both their promise for future development and their critical role in enabling contemporary technologies. Li-ion batteries suffer a number of major obstacles while being widely used in a wide range of applications, including consumer electronics, electric cars, and renewable energy storage. Our investigation demonstrates the impressive

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strides achieved in enhancing battery performance with the introduction of solid-state batteries, silicon anodes, and high-nickel cathodes. These developments should improve battery longevity overall, safety, and energy density.

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