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# REVOLUTIONIZING ELECTRIC MOBILITY: LITHIUM BATTERY DESIGN AND SIMULATION WITH MATLAB SIMSCAPE

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## *ABSTRACT*

*This paper gives a thorough analysis that uses MATLAB Simscape for lithium battery design and simulation to maximize the performance of electric vehicles (EVs). Finding the best pack configuration and cell design to achieve particular performance goals for EV operation is the goal. Battery capacity, voltage, and energy requirements are estimated through meticulous simulations based on vehicle parameters. After that, MATLAB Simscape is used to model and analyze the battery system to determine its performance under different driving scenarios and thermal management techniques. Important discoveries show how well the improved battery system works to increase the efficiency and range of EVs. This study advances electric vehicle (EV) technology, which may have favorable effects on sustainability and energy efficiency.*

## *KEYWORDS*

*Electric Vehicles(EVs), Battery technology, EV range, Sustainability, Energy Efficiency.*

## 1. INTRODUCTION

To alleviate environmental issues and lessen the transportation industry's reliance on fossil fuels, electric cars, or EVs, have gained traction. Since lithium batteries are the main form of energy storage in contemporary electric vehicles, optimizing battery systems is essential to the development of EV technology. Achieving the appropriate performance metrics for electric vehicles (EVs) necessitates a meticulous evaluation of battery design factors and modeling approaches[1].

This study offers a comprehensive review of how to use MATLAB Simscape for lithium battery design and simulation to optimize the performance of electric vehicles. Finding the best pack configuration and cell design to meet the specified performance targets for EV operation is the aim. Comprehensive calculations are utilized to approximate battery capacity, voltage, and energy requirements according to vehicle specs, guaranteeing efficiency and compatibility. The battery system is then modeled and evaluated under various driving situations and thermal management strategies using MATLAB Simscape. These simulations' outcomes offer insightful information on how well the updated battery technology works to extend the range and efficiency of EVs. The conclusions further the advancement of electric vehicle (EV) technology, which may have favorable effects on energy conservation and sustainability. The objective of this project is to increase the change towards a transportation ecosystem that is more efficient and sustainable by strengthening battery design and simulation procedures[2].

## 2. BACKGROUND

The urgent need to reduce greenhouse gas emissions and decrease global warming has made electric cars (EVs) a more viable alternative to traditional internal combustion engine automobiles. The core element of electric vehicle propulsion systems is the lithium-ion battery, which is renowned for its high energy density, long cycle life, and relatively low self-discharge rate[3]. Lithium-ion batteries offer an appealing alternative for EV energy storage when compared to other battery chemistries, enabling longer driving ranges and faster charging times. Performance, efficiency, and overall driving experience are all directly impacted by the design and choice of batteries in electric vehicles. The energy density, power density, cost, weight, and safety are factors that affect battery choices. Cell placement, pack structure, heat management, and integration with the vehicle's drive train are all taken into account during the design process.

When it comes to electric vehicle battery system optimization, simulation tools are essential. Engineers can use MATLAB Simscape, a multi domain physical modeling platform, to simulate and analyze complicated electrochemical and thermodynamics of lithium-ion batteries[4]. With MATLAB Simscape, researchers can assess different battery designs, forecast performance in a range of operating environments, and fine-tune design parameters to achieve desired performance goals. By incorporating simulation tools such as MATLAB Simscape into the battery design process, engineers may reduce the number of expensive prototyping rounds, accelerate development cycles, and optimize battery systems for improved safety, efficiency, and dependability in electric vehicles.

## 3. METHODOLOGY

This section outlines the methodology for figuring out how many cells an electric vehicle (EV) needs, and the simulation setup used to assess the battery system.

### 3.1. Calculating the Number of Cells Needed for the Electric Car

The number of cells required for the electric automobile was determined methodically, taking into account the specifications and performance objectives of the vehicle. The vehicle weight, the specifications of the engine, the greatest speed that could be reached, and the distance that could be traveled at full charge were all taken into account when estimating the battery capacity, voltage, and energy requirements[5].

### 3.2. Simulation Setup in MATLAB Simscape

Utilizing MATLAB Simscape, a potent simulation framework for multidomain physical modeling, the battery system was modeled and assessed. Simulations were created to evaluate the battery system's performance under various driving scenarios and heat control strategies. Among the crucial elements of the simulation system were:

- Modeling the battery pack and individual cells to mimic the behavior observed in the actual world.
- Evaluation of the charging and discharging characteristics, level of charge, and temperature analysis of batteries.
- Battery balancing strategies to guarantee consistent cell usage and lifespan.
- Assessment of the effects of thermal control techniques and cooling systems on battery longevity and performance.

### 3.3. Simulation Scenarios

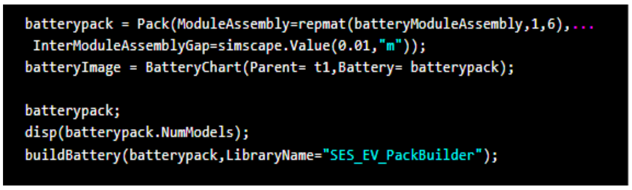
Simulation scenarios were designed to test the battery system under realistic operating conditions, including different driving profiles, environmental factors, and load demands[6]. These scenarios allowed for a comprehensive analysis of the battery's performance and enabled optimization of design parameters to meet the specified performance targets for the electric vehicle.

## 4. LITHIUM BATTERY DESIGN AND SIMULATION

This section contains the battery design process results and a discussion of the MATLAB Simscape simulation results. The chosen cell configuration, pack arrangement, and thermal management plan are highlighted, along with the battery system's performance under various driving scenarios.

### 4.1. Battery Design Process

The battery design process involved determining the optimal cell configuration and pack layout to meet the performance targets for electric vehicle (EV) operation. This was accomplished by using a methodical process that included computations based on variables like vehicle weight, maximum speed, and reachable distance at full charge.



```
batterypack = Pack(ModuleAssembly=repmat(batteryModuleAssembly,1,6),...
 InterModuleAssemblyGap=simscape.Value(0.01,"m"));
batteryImage = BatteryChart(Parent= t1,Battery= batterypack);

batterypack;
disp(batterypack.NumModels);
buildBattery(batterypack,LibraryName="SES_EV_PackBuilder");
```

Figure 1: Code Snippet.

This sample of code, in Figure 1, controls how an electric vehicle's battery pack is created and displayed. A predefined battery module assembly is replicated six times horizontally in an iterative manner, with a predetermined inter-module assembly gap, to create the initial battery pack. A Battery Chart function is then used to provide a visual depiction of the battery pack, which makes its structure easier to understand. In addition, the code shows relevant details about the battery pack, such as how many versions it has. Lastly, a build Battery function is used to construct the battery pack by using the assembled pack and providing the library where the pack builder is located. This summarizes the process of designing, developing, and completing the battery pack for integration into an electric vehicle in a concise manner.

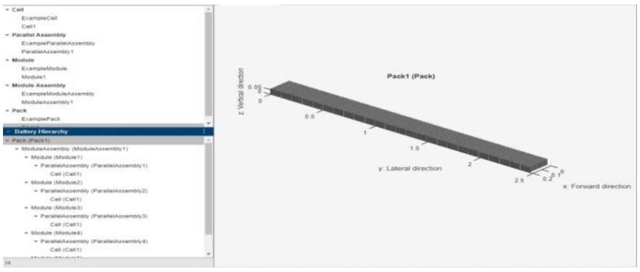


Figure 2: Battery Builder Snippet.

## 4.2. Simulation Results

The battery system was thoroughly modeled and simulated using MATLAB Simscape to evaluate its performance in a range of operational scenarios and thermal management techniques. The results of the simulations shed light on several aspects of battery behavior, including temperature, state of charge (SoC), and charging/discharging patterns.

### 4.2.1. Cell Level Analysis

A thorough analysis of each cell's performance, including variables like voltage, current, and state of charge (SoC), was made possible by the simulation analysis. For optimum performance and endurance, this study made it easier to spot possible problems or anomalies at the cell level.

### 4.2.2. Module Level Monitoring

Moreover, the battery modules were observed, as in Figure 3, through the simulation to guarantee consistency and effectiveness throughout usage. Through the examination of variables like voltage and temperature between modules, any imbalances or disparities were quickly identified and fixed, resulting in an improvement in the dependability of the system[7].

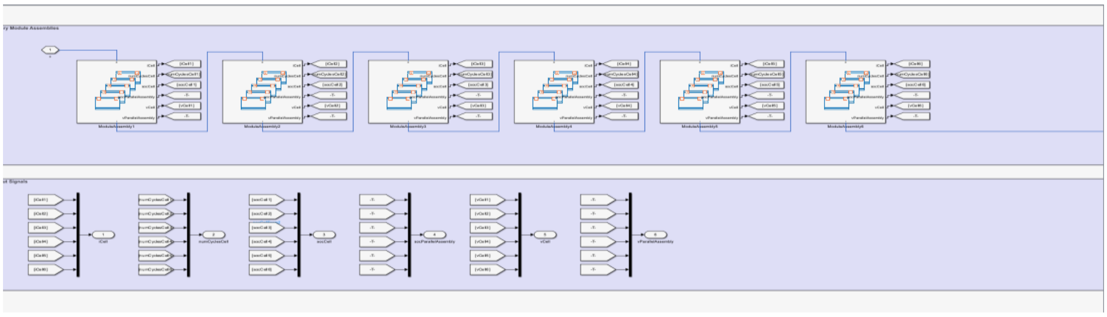


Figure 3: Monitoring

### 4.2.3. Thermal Management and Aging Assessment

An extensive analysis of thermal management techniques and their effects on battery aging was also done by the simulation. Thermal management techniques that effectively offset aging effects and assure extended battery lifespan were identified through simulation of cooling processes and assessment of temperature distribution within the battery pack[8].

### 4.2.4. Balancing and Optimization

The simulation also looked at balancing strategies to maximize battery longevity and performance. The energy distribution within the battery pack was modified by using balancing algorithms and tracking the voltages of individual cells, which enhanced the system's overall reliability and efficiency[9].

## 4.3. Discussion of the Results

The results of the research provide insight into the many approaches used to improve the longevity and performance of lithium battery systems in electric vehicles (EVs). The employment of complex techniques such as the Kalman filter for state of charge (SoC) assessment, constant current constant voltage (CCCV) charging for efficient energy replenishment, and active balancing for minimizing cell imbalances is significantly responsible for the optimization of battery performance.

### 4.3.1. Kalman Filter for Soc Estimation

A complex method of tracking battery health and performance in real-time is demonstrated via the use of the Kalman filter for SoC estimate[10]. The Kalman filter provides a strong framework for precisely estimating the level of charge, enabling precise management of battery operation, and improving overall system reliability by combining readings from various sensors with predictive algorithms.

### 4.3.2. CCCV Charging Strategy

Using the CCCV charging method is a critical first step in streamlining the charging procedure and extending battery life[11]. By ensuring a regulated charging profile, this method reduces the possibility of overcharging or undercharging, which can result in cycle life reduction and capacity deterioration. Rapid charging and maintaining battery health are both efficiently balanced by CCCV charging, which maintains a constant current phase followed by a constant voltage phase.

### 4.3.3. Cooling Techniques

The analysis of novel cooling methods, such as parallel and U-shaped channels, emphasizes how important thermal management is to maintaining battery safety and performance[12]. By dissipating heat produced during operation, these tactics hope to reduce the possibility of thermal runaway and guarantee a consistent temperature throughout the battery pack. In particular, the use of parallel channels results in improved cooling efficiency, as shown, in Figure 4, by MATLAB simulations. In comparison to conventional cooling techniques, this image demonstrates the improved heat dissipation capabilities of parallel channels, which lower temperatures throughout the pack. EV producers may contribute to the sustainability and efficiency of electric transportation by extending the operating lifespan and improving battery dependability through the utilization of novel technology.

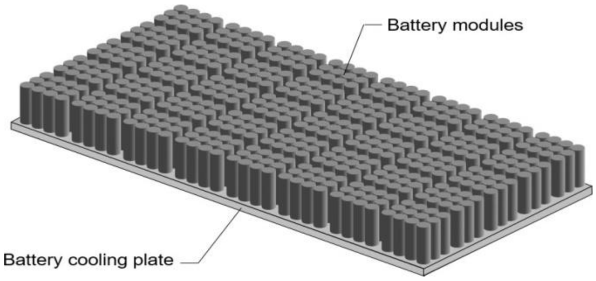


Figure 4: Cooling Plate

### 4.3.4. Active Balancing for Aging Mitigation

One proactive method for resolving cell imbalances and reducing the impacts of aging within the battery pack is active balancing. Active balancing eliminates voltage differentials and encourages uniform energy use across the pack by dispersing charge among individual cells[13]. This improves system performance and energy economy in addition to extending battery life[14].

## 5. FUTURE PROSPECTS

Subsequent investigations will focus on advancing battery technology and optimizing methodologies to continuously push the boundaries of electric vehicle capabilities. Some examples of this may include new materials researched for enhanced durability and heat conductivity, machine learning algorithms incorporated for predictive maintenance and optimization, and alternative battery chemistries[15]. Furthermore, developments like the integration of wireless battery management systems (BMS) [16] and the creation of client dashboards or real-time monitoring applications could improve the convenience and efficiency of electric vehicles even more. Research efforts will also be directed toward developing holistic strategies that consider the entire electric vehicle ecosystem, such as grid integration, charging infrastructure, and lifespan assessments, to provide a more sustainable and efficient transportation paradigm [17]. By addressing these problems and leveraging cutting-edge technologies, we can accelerate the adoption of electric vehicles and have a beneficial impact on a future that is more environmentally friendly and sustainable.

## 6. CONCLUSION

In this work, MATLAB Simscape is used to simulate and develop lithium batteries as part of an extensive examination into the optimization of electric vehicle (EV) performance. The research determined the best pack arrangement, cell design, and thermal management techniques to achieve the given performance goals for EV operation through painstaking calculations and simulations. The results demonstrate how crucial sophisticated modeling methods are for determining battery size, voltage, and energy needs to guarantee compliance with vehicle regulations and improve overall performance. Furthermore, the investigation into novel cooling methods and active balancing approaches has highlighted the vital function that thermal management plays in preserving battery safety, extending lifespan, and enhancing performance.

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## Appendix: Calculations

Battery Parameters and Battery Build. Calculations parameters set:
Maximum speed = 180 km/hr.

The achievable distance at full charge = 405 km.

Vehicle weight = 2149 kg (accounting for 5 passengers each at 70 kg).

Motor RPM:

Max speed, v =180 km/hr; 180*(5/18)=50m/s. Tyre diameter, d= 18 inches
Tyre circumference, c=2*pi*r = 2*3.142*0.2286 = 1.4365m

Wheel RPM, N= v(m/m)*c(m)

v= 180 km/hr = 180*1000 = 180,000m/hr = 180000/60 = 3000m/m

N = 3000/1.4365 = 2088.41RPM.

Motor RPM:

Required motor RPM, Nr= Gear Ratio(GR) * N

Gear ratio = 7.94

Nr = 7.94 * 2088.41 = 16581.9754 RPM.

Vehicle Parameters. Rolling Resistance, Fr:
Fr = coefficient of friction * Mass * gravitational force.

Fr= 0.011*2149*9.8 = 231.6622N.

Drag Force, Fd:

Fd = 0.5 * air density * Coefficient of drag(Cd) * Frontal Area(Af) * v^2

Fd = 0.5 * 1.225*0.23*2.22*50^2 = 781.8562N.

Gradient Force, Fg:

Fg = mass*gravitational force * sin theta Fg = 2149*9.8*sin 45 = 14891.81N
Traction Force, F = Fr+Fd+Fg = 15905.33N Motor Power:
Motor power = Traction Force * Velocity

Motor power = 15905.33 * 50 = 7952664.4342w = 795.27kW.
Rated motor power (2.5) = 318.108kW Battery Selection.
Battery energy, E = (Traction force * Range)/3600

= (1013.53* 405)/3600 = 114.02kWh

Power required = F*v
= 1013.53*50 = 50.617kW

Cell parameters.

Considering 18650 lithium cells at nominal voltage 3.7V and current at 3A:

Battery voltage, Vb= 350V.

Battery capacity = E/Vb = 114.02k/350 = 325.77Ah. Cells Required:
Total Number of cells, Ct:

Ct = Cells in series(Sc) * Cells in parallel(Pc). Sc= 350/3.7 = 95 cells.
Pc = 325.77/3 = 109 cells.

Ct= Sc*Pc= 95*109 = 10,355cells.

Testing and simulation on 95s109p configuration.

## AUTHOR

**Sally Kinya Kimathi** is an undergraduate student at Dedan Kimathi University of Technology(DeKUT), Kenya, specializing in the automotive sector with a keen focus on electric automobiles and green energy. Driven by a strong desire to fight climate change and minimize carbon emissions, Sally regularly advocates for electric vehicle awareness events in Kenya and participates in conversations about environmentally friendly transportation options. She is committed to expanding her knowledge in the areas of renewable energy and electric vehicles as an enthusiastic volunteer and member of IEEE.
Sally's research interests center around renewable energy systems, exploring their performance and potential applications in the automotive industry. She has authored articles and papers, showcasing her dedication to innovation in the EV sector. In addition, Sally served as the CASS Chair of the IEEE DeKUT SB chapter in 2023 and represented the chapter as a Mentorship Program Representative in 2024.
Committed to empowering others, she engages in mentorship and STEM programs, educating young students on the future of electric automobiles and delivering presentations on renewable energy technologies.