Electric Vehicle Cooling System

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Abstract: *Accurate simulation of complex lithium-ion batteries used in powertrain electrification is becoming more important, necessitating fast and exact modeling methodologies. Temperature also has a huge impact in the kinetic and transport phenomena of electrochemical systems; hence it is crucial that models of batteries account for it. In this study, we provide a practical method for developing a thermally dependent simulation model of a lithium cell that can be used across a range of temperatures. A comparable circuit model consisting of a single voltage source, a single resistor linked in series, and a single RC block described the discharge dynamics seen in the experiment. The state of charge, average current, and temperature dependencies of the equivalent circuit components were determined by conducting pulse current discharge experiments on high power lithium LiNi-CoMnO cathode and graphite-based anode cells under various operating circumstances. Pulse current discharge testing, part of a numerical approach for parameter estimation, led to this finding. The process aids in the development of a detailed model that can predict electrical current and voltage performance and evaluate the state of charge during operation. Using a dedicated driving cycle for a lithium battery, the model's accuracy in predicting battery voltage was found to be within 6%. For a condition involving a constant current discharge, the model was also used to simulate heat buildup.*

Keyword: *Electric vehicles, Lithium-ion batteries, Cooling , Non Cooling,* LiNi-CoMnO$_2$.

I. INTRODUCTION

Lithium-ion batteries are the preferred energy storage option for EVs due to their superior technical qualities (EVs). The current li-ion batteries are more expensive, have a slower discharge rate, last longer, and have less energy density. The result is a limited maximum efficiency with which they can solve these problems [1]. Electric vehicle performance is very sensitive to battery capacity, and battery core temperature is a major determinant in battery performance.

1.1 Understanding the value of a cooling system

While advancements in battery technology have allowed electric cars to offer more power and need less frequent charging, designing an effective cooling system remains one of the greatest obstacles to ensuring the safety of batteries. The rate at which an electric vehicle's battery is emptied affects how much heat is generated during operation. Electricity storage in batteries is achieved by the use of a voltage difference. Increasing the battery's temperature causes the electrons within to get excited, lowering the potential gap between the positive and negative terminals. [2] Batteries can only perform properly within a certain temperature range, thus without a cooling system to keep them within this range, they will stop working. In the event that there is a significant temperature disparity between the various battery cells, the whole pack's performance might be negatively affected. This may result in irregular charging and discharging of the batteries.[3]

1.2 How efficient is each kind of electric vehicle cooling system?

As engineers rethink car engines, they'll investigate battery heat management options. At certain temperatures, phase transition substances become liquid. The substance may absorb heat without altering temperature due to the phase change. Phase change material cooling solutions for battery packs are limited by volume shift. Phase change materials can only absorb their own heat, hence they can't reduce the temperature. [4] Phase change materials may boost a building's thermal efficiency by reducing temperature fluctuations and off-peak cooling needs. Poor performance prevents using certain car components. Adding cooling fins to a gadget speeds heat dissipation. The fin may condense and convert battery heat. High thermal conductivity makes fins beneficial for cooling, but their weight is undesirable. [5] Fins cool internal combustion engines and electronics. Adding fins to an electric vehicle's undercarriage to cool the batteries was formerly proposed, however the increased weight negated any cooling benefits. Air conditioning converts battery heat. Radiant heat dissipates with airflow. Air cooling is easier to install and run, but less effective and more maintenance intensive. The electric Nissan Leaf is air-cooled. Air-cooled battery packs are being questioned as EVs gain popularity, particularly in warmer climates. Tesla believes liquid cooling is safer than AC.

Liquids are better than air in removing heat. Liquids may store heat in their bonds and are small and easy to install. Liquid coolants maintain battery temperature and uniformity better. Incorrectly handled glycol in poorly maintained liquid cooling systems may harm personnel and the environment. Leaks and improper disposal create problems. Tesla, Jaguar, and BMW use these innovations. Li-ion pouch cells cooled by air, indirect liquid, direct liquid, and fins. U.S. and Chinese academics investigated. Air cooling uses twice as much energy as other ways to maintain the same temperature, while fin cooling adds 40% to the cell's weight. Indirect liquid cooling is inefficient. (Cooling lithium-ion batteries)

Temperature range, homogeneity, energy efficiency, size, weight, and operating simplicity distinguish EV battery cooling systems (i.e., implementation, maintenance). [6] Each setting is temperature balanced. Energy efficiency is tougher to accomplish since cooling benefits must exceed cooling system heat. Heavy cars may have lower power. Liquid cooling: inefficient, small, light. Easy-peasy. Ineffective cooling methods include phase transition materials, fans, and air. Liquid cooling is the only viable choice for battery packs since it's fast, small, and requires minimal parasitic power. These solutions will help manufacturers regulate heat. [7]

Direct and indirect liquid cooling varies dependent on whether the cells are dipped or pushed via pipelines. Direct cooling immerses battery cells in liquid. No automobiles yet have thermal management systems. Direct and indirect cooling use different liquids. Nonconductive coolant is needed as the battery will be submerged. [8] Pipes transport coolant and condensers in ICE and indirect cooling systems. Electric vehicle cooling systems will change when done. Build your cooling system to maintain battery pack temperatures. Manufacturers' cooling systems differ.

II. BACKGROUND STUDY

A cost-to-go controller may beat one that looks at state variations for optimum control. Cost-to-go is estimated using MPCs. Cost-effective. The suggested controller uses less energy than a predictive model but needs the same computer power. [8] MPC improves automobiles and powertrains. Cars that communicate can estimate traffic and energy demands. Thermoregulation requires traction. Real-time computation is possible by separating vehicle and battery dynamics. Helpful toggle. Compared to standard controllers, our battery utilization exhibits highway and urban performance. Our technique is energy efficient. [9]

Case study demonstrates hybrid powertrain power sharing mechanism. The suggested approach's capacity to produce high-quality solutions is tested utilizing EM and traditional thermostat and PI cooling systems with varying adjustments. The suggestion might enhance fuel efficiency by 0.7% to 2.4%. [10] A lumped parameter model and updated cooling approaches are provided. When an electric motor's rotor has a hub, shaft cooling is pointless. Temperatures permitted this. Rotor jet cooling cooled permanent magnets. [11] Transient driving causes cooling case oscillations. Liquid cooling causes variations. Several system redesigns exist. These designs improve cabin comfort, heat recovery, and battery thermal management. [12] Direct oil cooling cools torus-type axial-flux permanent magnets. Tested, simulated, and finite element analyzed lumped thermal equivalent circuits. We compare the machine's oil-cooling and water-cooling efficiencies. [13]

External cooling and rapid charging decreased maximum temperature from 58 to 49 degrees Celsius. Charge rate, coolant temperature, flow rate, and plate configuration are examined. Simulated 5C charging. It's 20% more efficient. [14] Several thermocouples are buried for this reading. Convection coefficient is determined experimentally and computationally. Within 20 times the nozzle's distance, calculate the coefficient. Around the impact location, power reached 7,550 W/m 2. [15] Four equal-capacity cooling slot designs are being examined. Simulating motors and cooling systems. Loss analysis dictates channel layout's EM performance. Evaluate electromagnetic pathways. After determining the most effective cooling strategy for each machine, the key behavioral differences and advantages of automobile hairpin winding machine cooling system design will be emphasized. [16]

Gaseous Comparing Stirling machines, air refrigeration, and throttle cooling computationally. Spacecraft cooling system characteristics were predicted. Safer coproducts. [17] Three heat sinks' fin shapes are compared for cooling efficiency. Case fans. Fins reduce wind speeds by 15%. Studies show CFD improves electric motor cooling. Experiments validate CFD. [18] This study discusses reversible EV charging. AC-to-DC converter (direct current). Thermal management, power stage design, start, operation, and control are covered. Data show DC-AC high-power operation and system starting. [19]

IGBT module maximum operating temperature restricts motor controller radiator size, helping air-cooled motors. The thermal resistance network model describes these concepts. Improve air-cooled motor efficiency. The approach was tested on a two-seat electric aircraft prototype. Electric airplane motor controllers might be 5% lighter with air-cooled radiators. [20] Electric motor 14.7 kVA/57,000 rpm. Silicone tubes vs. oil-immersed stators for cooling. These tubes cool end windings, stator slots, and phase coils. Electric machine designers, engineers, and manufacturers may profit. Electricians may be interested. [21]

III. PROPOSED MODEL

3.1 EV Battery Cooling System

It is required to choose an appropriate cooling method for the Li-ion battery module of an electric vehicle (EV), as well as to identify a supercooling control method, in order to maintain the temperature at a level between five and zero degrees Celsius. It is essential to keep the temperature at its optimal level since doing so will improve the battery's service life, minimize the amount of maintenance that is required, and boost the level of safety it provides. When deciding on a method of cooling, numerous trade-offs between various characteristics such as weight, cooling effect, temperature uniformity, and value must be considered.

3.2 Electric Vehicle Cooling System

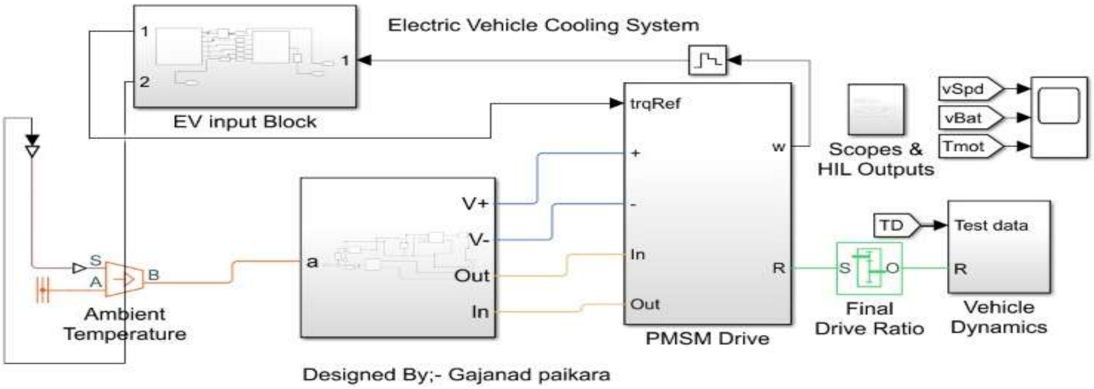

Figure 1: Proposed model

3.3 EV Input Block

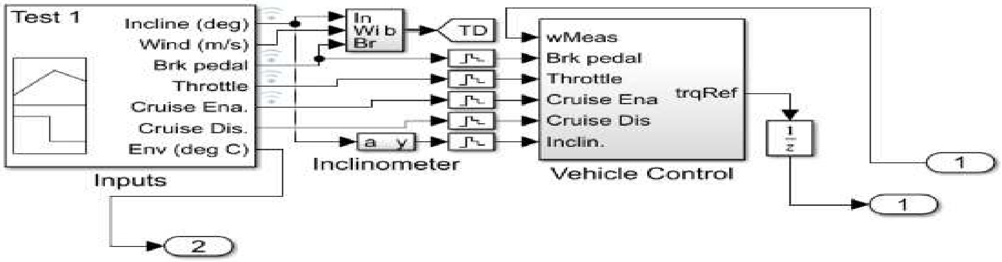

Figure 2: Proposed ev input block

3.4 Subsystem

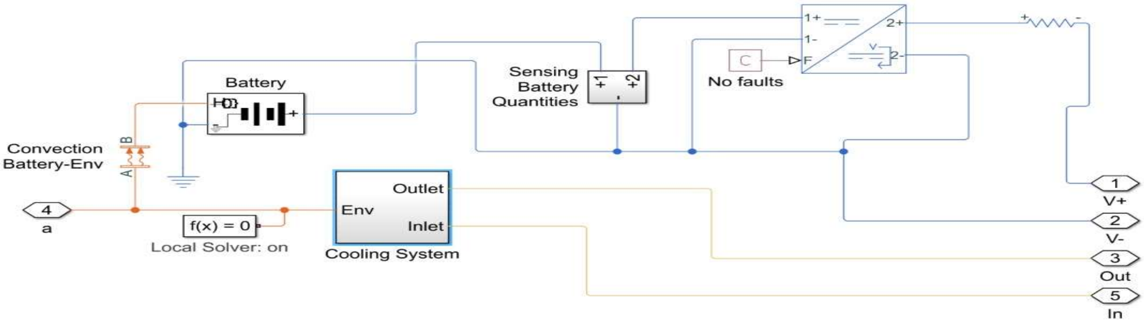

Figure 3: Proposed battery subsystem

3.5 Cooling System

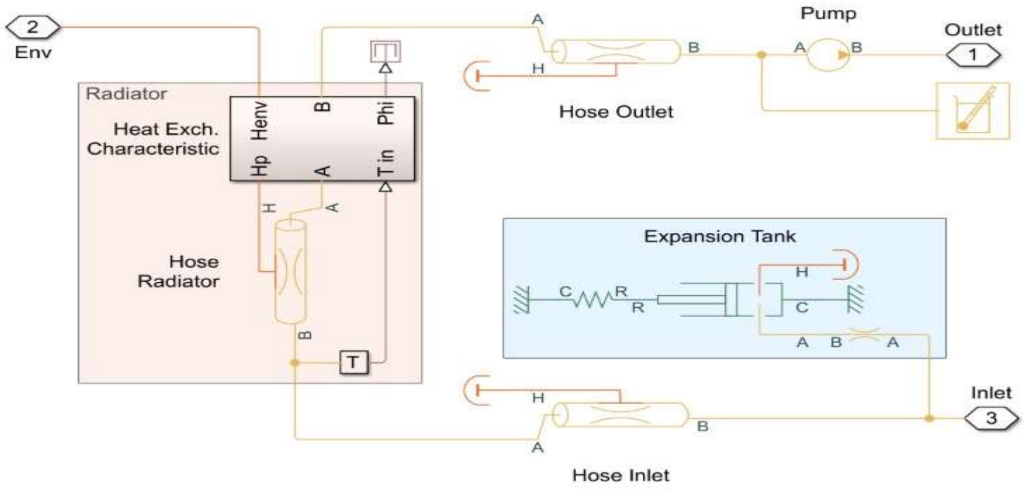

Figure 4: Cooling system unit

3.6 Pmsm Drive

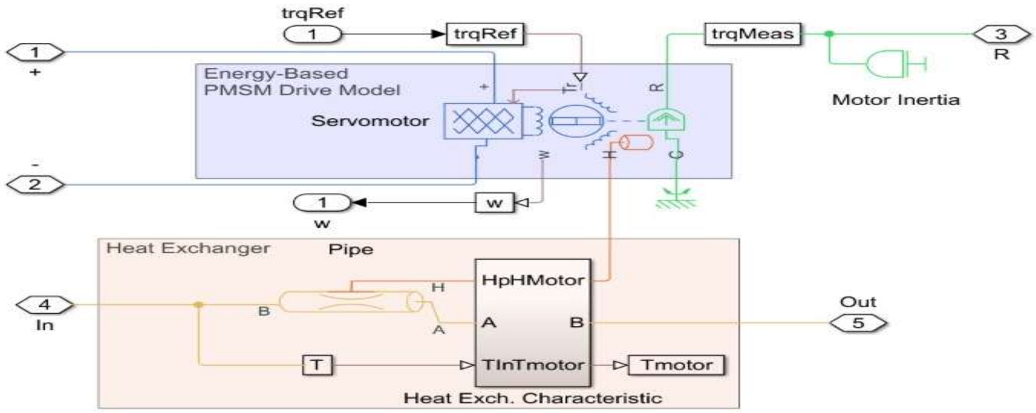

Figure 5: PMSM drive system

3.7 Vehicle Dynamics

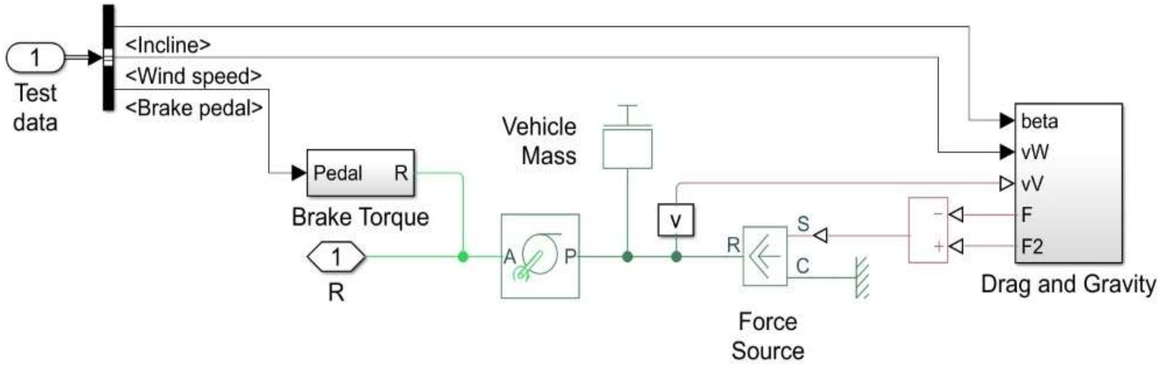

Figure 6: Vehicle dynamic unit

3.8 Scopes & Hil Output

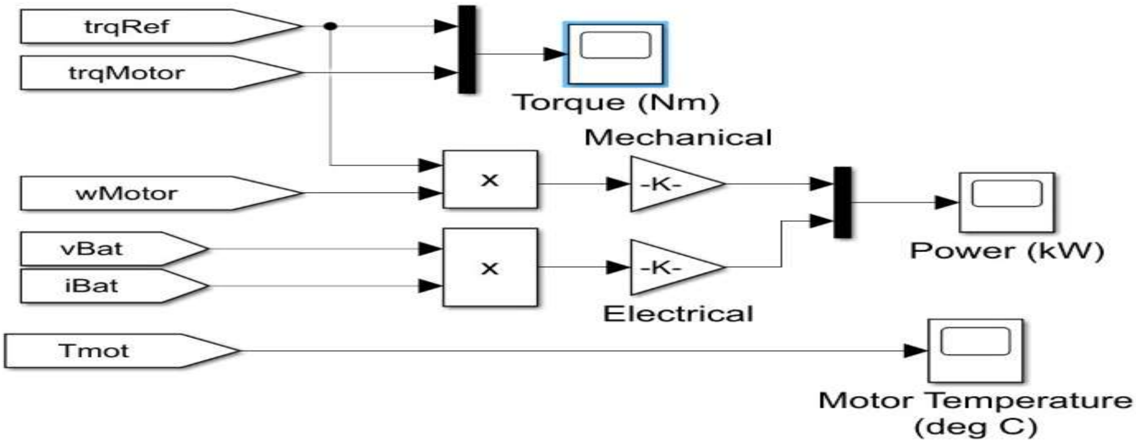

Figure 7: Scopes and output

3.9 Drag and Gravity

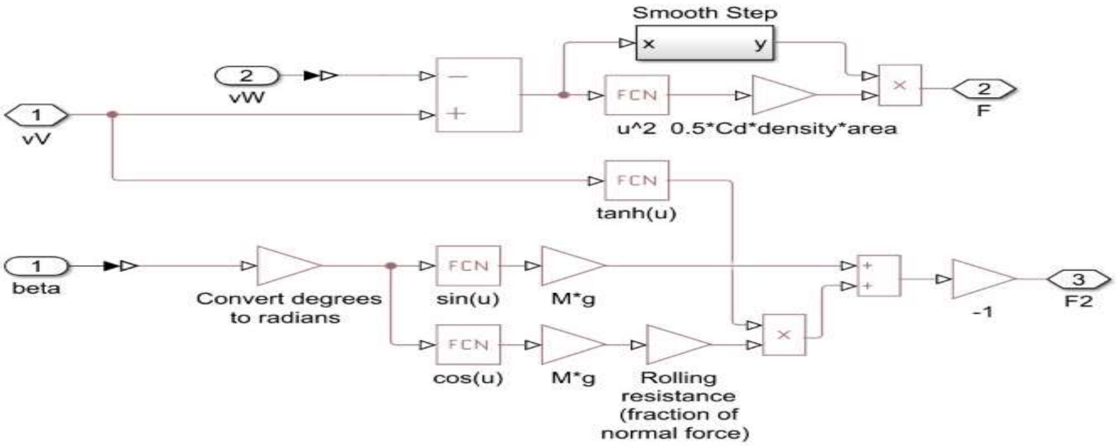

Figure 8: Drag and gravity unit

IV. PROPOSED RESULT ANALYSIS

4.1 Simulation Results from graph between power and time

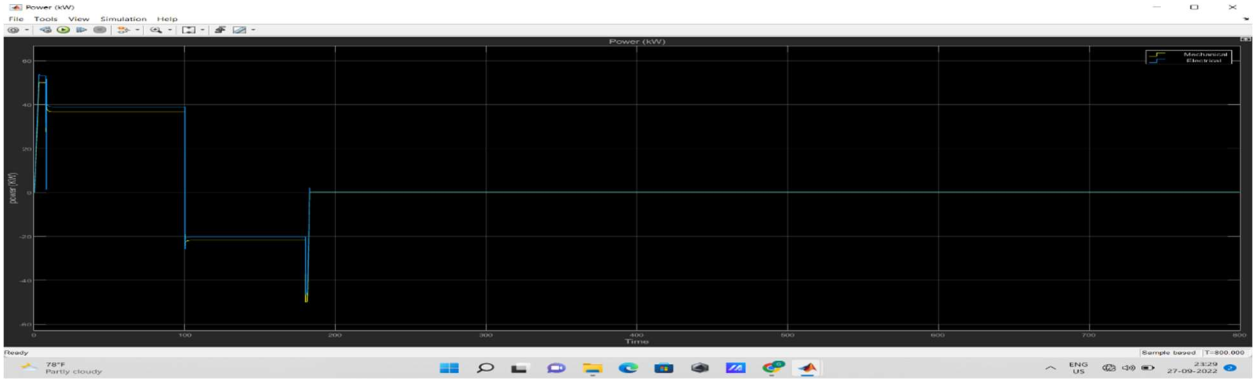

Figure 9: Simulation Results from graph between power and time

4.2 Simulation Results from graph between motor temp (deg c) and time

This figure 10 shows the performance of graph between motor temp (deg c) and time.

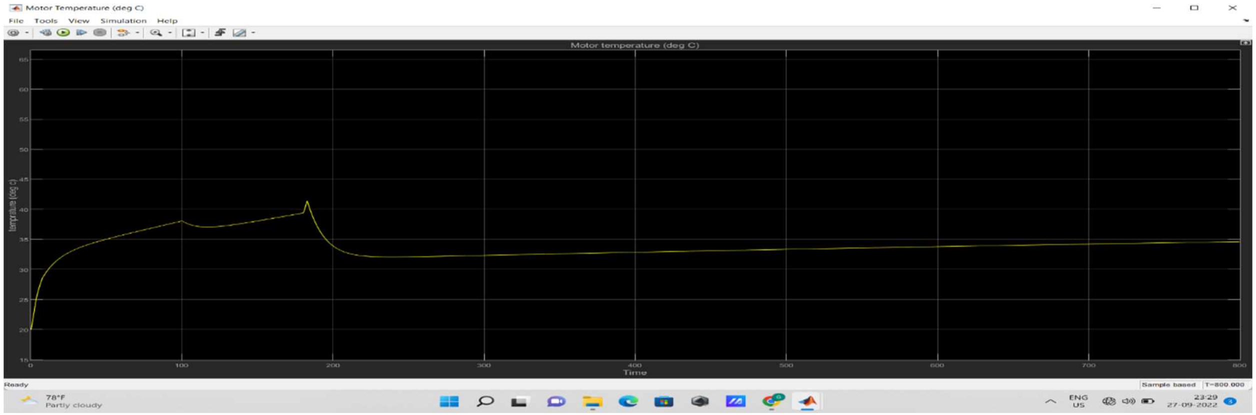

Figure 10: Simulation Results from graph between motor temp (deg c) and time

This figure 11 shows Graph between Demand and achived torque and time.

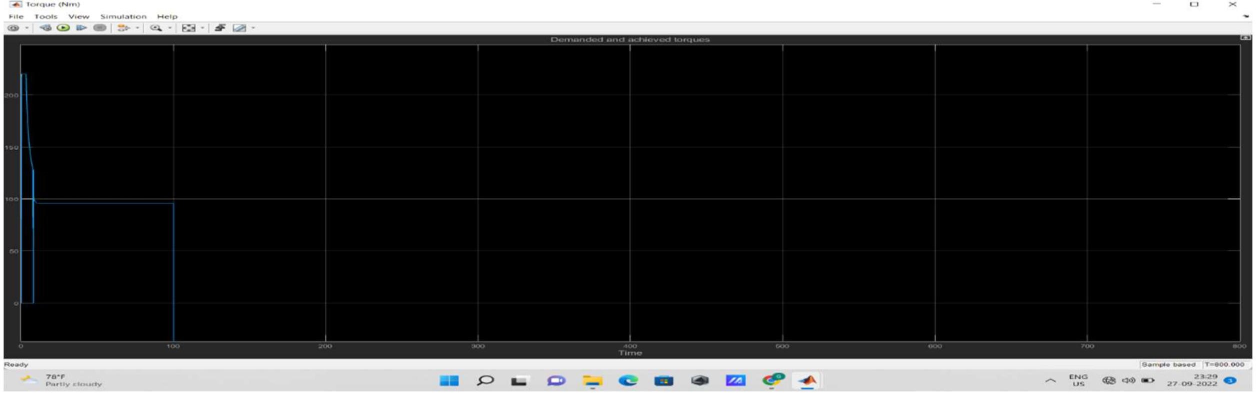

Figure 11: Graph between Demand and achived torque and time

This figure 12 shows the Simulation results from scope for the cooling system.

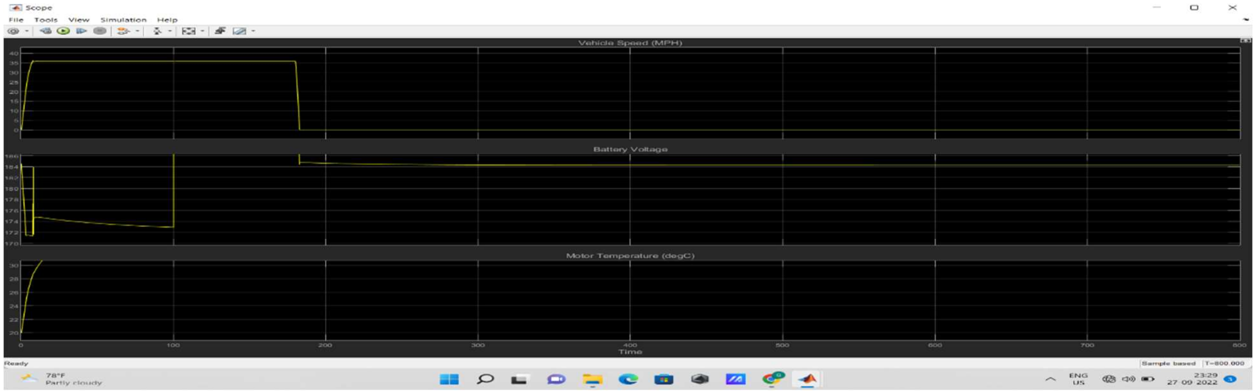

Figure 12: The Simulation results from scope

4.3 Result Analysis in term of cooling system

4.3.1 Vehicle Speed

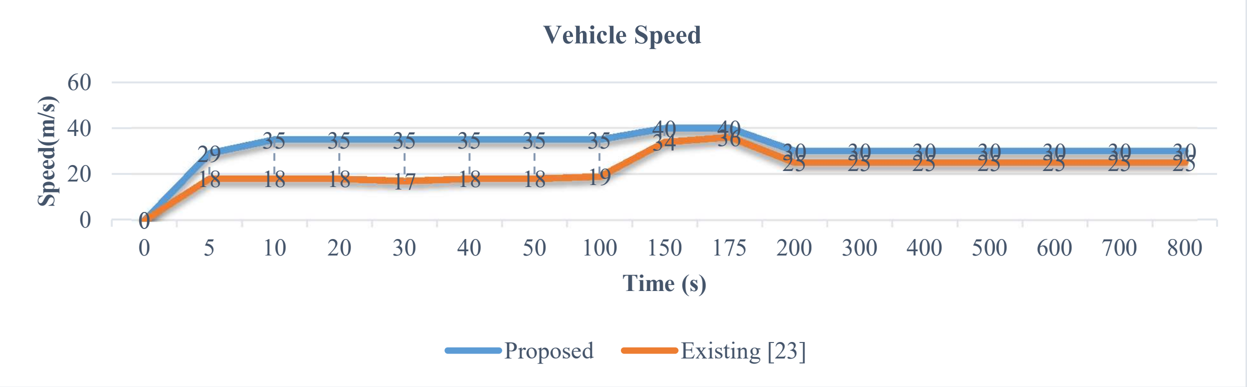

Figure 13 : Vehicle speed in term of cooling system

4.3.2 Motor Torque

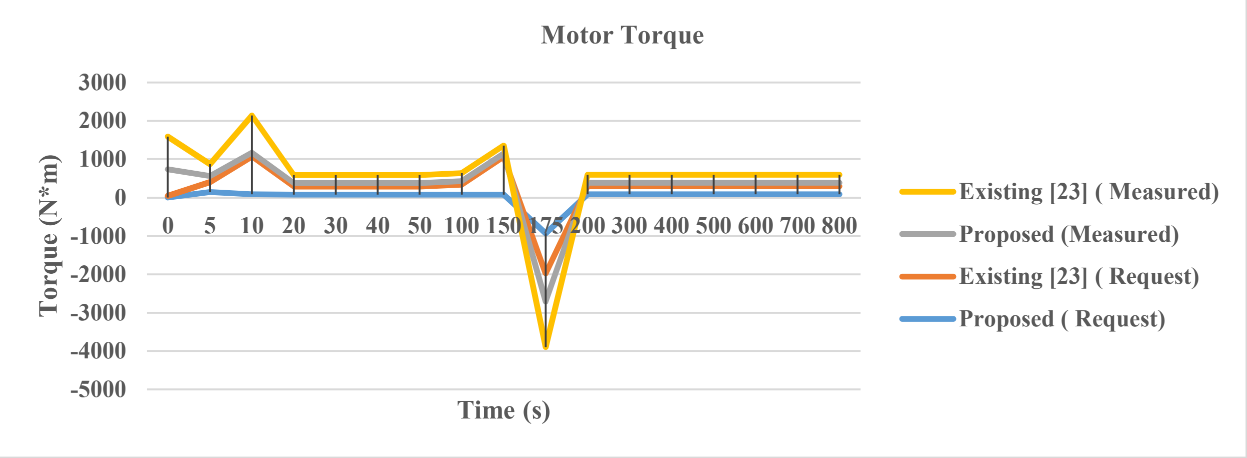

Figure 14 : Motor torque in term of cooling system

4.3.3 Motor Temperature

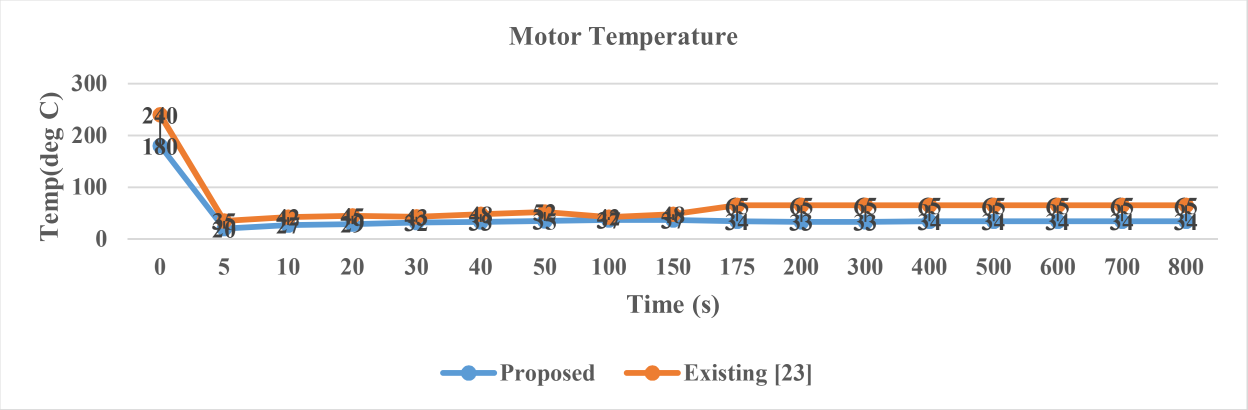

Figure 15 : Motor temperature in term of cooling system

4.4 Result Analysis in term of no cooling system

4.4.1 Vehicle Speed

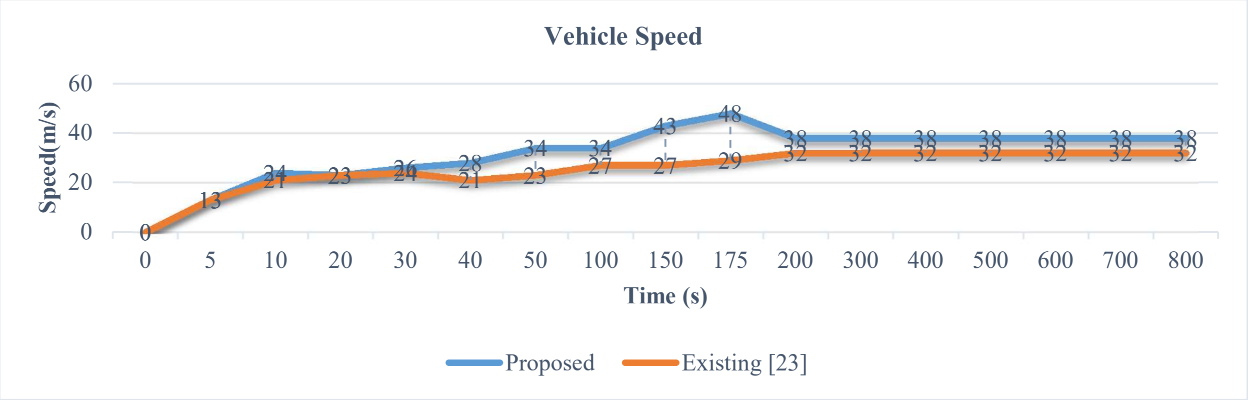

Figure 16 : Vehicle speed in term of no cooling system

4.4.2 Motor Torque

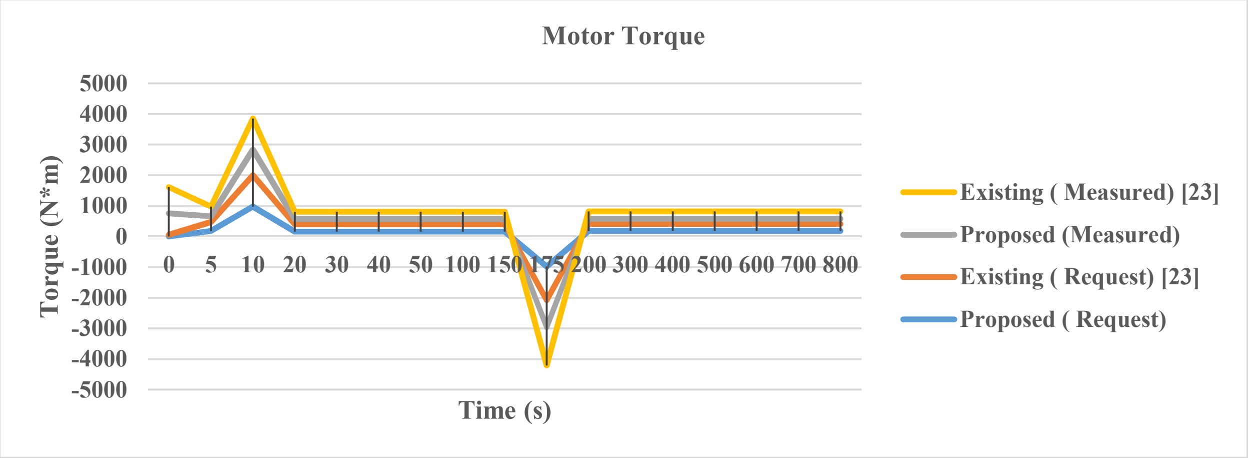

Figure 17 : Motor torque in term of no cooling system

4.3 Motor Temperature

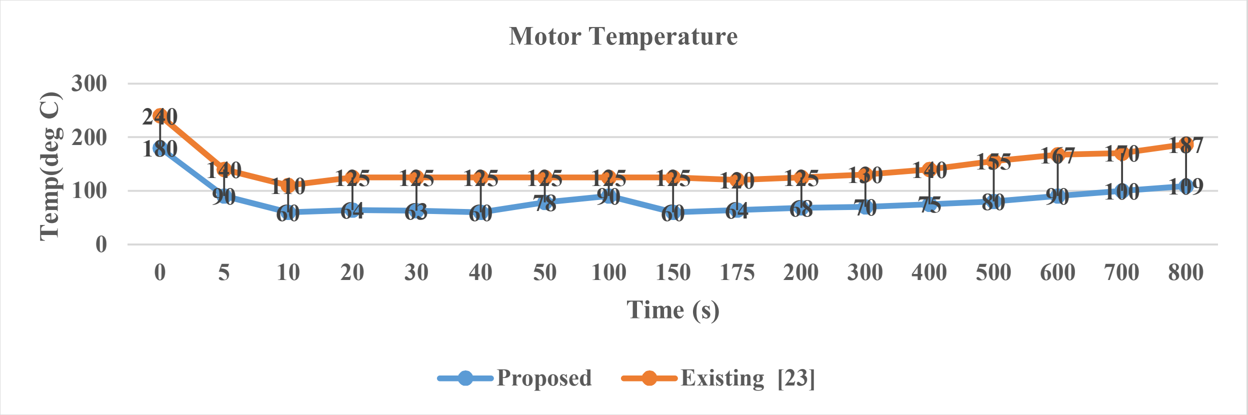

Figure 18 : Motor temperature in term of no cooling system

IV. CONCLUSION

This report details many methods for cooling the batteries in electric vehicles. The electric vehicle's battery heat management system is its most vital component (BTMS). One of the most crucial aspects of electric vehicle maintenance is ensuring that the batteries are never heated over their optimal working temperature and that the maximum temperature and temperature difference experienced while charging and discharging are maintained to a minimum. Adequate and effective cooling solutions will significantly reduce the negative effects of high battery mobile floor temperatures while also improving the battery's thermal efficiency. These adjustments will be made to enhance battery life. In addition, it increases the car's safety and makes it last longer. Liquid cooling is one of the most dependable and potentially useful techniques of battery cooling in the future. A more space-efficient and cost-effective design should be considered in light of the tactics mentioned here, which will be of great aid in boosting the battery's overall performance even when exposed to intense charging and discharging conditions.

When applied to the chemistry of the LiNixMnyCozO2 (NMC) cell under study, a similar circuit consisting of a voltage source, a series resistor, and a single RC element was adequate to capture the dynamics of the system. For a better fit to experimental data, the same techniques used to evaluate the parameters might be used to the design of a more complicated analog circuit model with similar functionality.

When evaluated with a single 20-minute New European Drive Cycle, the model was shown to be accurate within 6% of the real world. The model accounts for both endothermic production of heat and endothermic accumulation of heat inside the cell. Also, the model can estimate the cell voltage and SOC for any given current profile.

We will investigate how changing the equivalent circuit model's parameters affects the current's magnitude in future work.

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