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Electric Vehicle Battery Pack Charging Time Prediction

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Abstract

The electric vehicle's most crucial component is its battery, which provides the vehicle with power. A key element of electric vehicles (EVs) is the battery management system (BMS), which ensures the safe and efficient functioning of the battery pack. Previous research on electric vehicles has identified some drawbacks, such as lengthy charging times and the need for different charging methods depending on battery capacity and temperature. In the proposed work, the battery's state of charge and remaining capacity will be estimated by measuring the voltage and current with the use of a current sensor and temperature monitor. The novelty of the work lies in its ability to increase the range of electric vehicles. This is achieved through higher energy densities in high-voltage batteries, which allow for longer driving distances between charges. Additionally, faster charging systems can handle higher charging power levels, resulting in quicker charging times. These improvements in performance are made possible by the use of high-voltage batteries, which provide the necessary power for greater peak speeds and improved acceleration. As electric mobility becomes more widespread, the ability to accurately predict charging times based on layout becomes crucial in building user confidence, optimizing energy grid management, and promoting the widespread adoption of electric vehicles.

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1. Introduction

Over the past two decades, India has made significant progress in the development of electric vehicles. However, with this progress comes the need for accurate predictions of EV charging load in order to optimize grid scheduling and ensure safety. The study focuses on regional EV charging load and suggests a forecast approach based on nonlinear programming and EV charging behavior features. Encouraging orderly EV charging and accurately predicting the area EV charging load are the objectives. The charging requirements distribution is predicted using the Monte Carlo approach. Since the purpose of this prediction procedure is to estimate the charging requirements during EV usage, it bears similarities to traditional power load forecasting. Precise forecasting is essential for formulating systematic charging plans and offering charging station and pile solutions. EVs, as greener substitutes for conventional internal combustion engine vehicles, are gaining popularity. However, their battery packs' lengthy charge times pose a significant obstacle to their wider implementation.

A high voltage battery pack, commonly found in hybrid and electric cars, is composed of multiple modules and cells arranged in a series and parallel configuration. Each cell typically has a voltage range of one to six volts and is the smallest compact form of a battery. Modules are created by connecting multiple cells in either a series or parallel arrangement. However, it should be noted that even batteries with the same chemical composition may not be identical in terms of performance.

The evolution of batteries is primarily driven by the trade-off between power and energy, as it is not possible for a battery to have both high power and high energy simultaneously. Manufacturers often use classification systems to categorize batteries based on these factors. Another common classification is durability, which indicates that the battery's chemistry has been altered to provide a longer lifespan at the expense of power and energy. Constant power voltage is the level at which a battery can charge itself. It is a simple charging technique that can be used for all types of batteries. However, the current may fluctuate during the charging process.

The main drawback of this method is that it requires a high amount of power initially, which may not be available in most residential and parking complexes. Another approach is continuous current, which involves applying varying voltage to the battery while maintaining a steady flow of current. In this case, the state of charge (SOC) decreases linearly over time with a constant voltage. The temperature rise, voltage increase, negative potential evolution, and charging time can be used to calculate the shutdown. To store and convert the electrical, a battery capacity and a motor are attached. To break and alter the speed, user control is normally mounted to the handle. A battery-operated Vehicle (Two-Wheeler) refers to a vehicle designed for road use and powered solely by an electric motor whose movement energy is supplied solely by the vehicle's battery system.

An electric vehicle (EV) is a mode of transportation primarily powered by electricity, including electric bicycles and low-speed scooters styled similarly to traditional scooters but powered by electricity. Because of the strong demand for fossil fuels on international markets, as well as the smother ride of environmental concerns caused by an increase in the number of internal combustion engine vehicles, there is a growing interest in battery research and development for electric and hybrid vehicles.

These cars represent a viable future solution in the sector of road transportation, considering the desire to cut carbon emissions as well as air and noise pollution. Unlike internal combustion engines, which use liquid fuel to power their motors, e-bikes use a brushless DC electric motor (Switched reluctance) that is powered by a rechargeable battery, chargers, and control. The key benefit of these cars is that they do not require any fossil fuel to operate. Because they have fewer moving parts, they require less maintenance. When compared to traditional gas bikes, these e-bikes are more dependable, energy-efficient, and environmentally beneficial. Electric motorcycles in India are free from gas taxes and other laws and do not require an operating license because they travel at a speed of only a few kilometers an hour.

2. Literature Review

One of the most crucial tools for addressing global environmental issues is the electric vehicle (EV). The impact of climate change, along with advancements in renewable energy, battery chemistry, fast construction, data collection and analysis, and energy security, has led to the incorporation of Electric Vehicles (EVs) into policies in both developed and emerging nations. This is seen as a means of reducing carbon emissions and providing affordable, emission-free transportation [1]. The Battery Electric Vehicle (BEV), which is powered solely by a battery and recharged by plugging in, is a comprehensive solution to this issue. Li-ion batteries are the most advantageous type of battery available on the market for electric vehicle applications due to their high energy density, low maintenance, and extended lifespan [2].

A method for predicting the charging time of battery electric vehicles based on regression and time series analysis has been developed using actual data collected from operating vehicles. Additionally, a method for estimating the remaining charging time of electric vehicle batteries has been proposed and implemented in a production electric vehicle control system for performance validation [3]. A predictive model for electric vehicle charging time has also been developed, taking into account both geographic and temporal variability. This model integrates weather data, traffic patterns, and charging station availability to provide accurate predictions tailored to specific locations and time periods [4].

Multiple methods of estimation are used, but currently, model-specific methods are considered the most effective. Therefore, the first step is to create a battery model, as the accuracy of the model directly affects the state estimate. In order to accurately estimate a battery's state of charge, a well-trained battery model and an appropriate SOC estimation approach are necessary [5]. When designing a BMS, it is crucial to carefully select the battery type and SOC estimation method, as they are interdependent. A battery model is essential for tracking and analyzing battery performance, identifying defects, and preventing thermal runaway.

Standard models and their corresponding characteristics are evaluated and explained in order to demonstrate the capabilities of the batteries [6]. The BMS plays a critical role in protecting the battery pack from deep discharge, overcharging, undercharging, temperature monitoring, and short circuits. It ensures that each battery cell is charged to the maximum SOC level [7]. The BMS also facilitates communication between various devices and collects data for analysis and user communication. It monitors the temperature of the battery pack to ensure it stays within safe operating limits. Additionally, the BMS oversees the overall operations of the battery pack for evaluation purposes [8].

In the field of battery energy storage systems (BESS), the battery management system (BMS) is a rapidly developing area with significant applications in business, industrial, and electric vehicle settings. Specifically for electric vehicle (EV) applications, the BMS is an internal component of a lithium-ion battery pack [9]. The key to charging storage batteries is achieving proper regulation procedures that allow for quick charging while preventing unsafe overcharging. To address this, a two-level control technique has been proposed for series strings of batteries, utilizing the recirculating charge adjustment method and an outer loop supervision system [10].

Slow-charging lithium-ion batteries (LIBs) is necessary to preserve their full capacity (stored energy) and promote longer battery cycle life. This can be achieved through low electrode loadings of nanostructured materials or tailored active partial phasic mechanisms, which enable fast D-C switching [11]. However, these methods result in limited volumetric energy densities (the amount of stored energy per volume of material) in the battery pack. To overcome these challenges and improve battery longevity and fast charging capabilities, a new paradigm in battery technology is necessary, particularly for batteries used exclusively in electric vehicles [12].

Data acquisition gauges measure operational factors such as temperature, current, and battery voltage, among others. State estimation keeps an eye on power capabilities, health (SOH), and stored charge (SOC). Safety protection refers to keeping the battery operating within its limitations in order to extend its service life [13]. This includes guarding against out-of-tolerance circumstances such as overcharging, overloading, thermal stress, and thermal runaway using both passive and active balancing techniques. Cells may be balanced [14]. The battery pack has a BMS, which monitors various factors during charging and discharging to ensure safe operation. The primary metrics tracked by the BMS are the State of Charge (SOC) and State of Health (SOH).

The off-board or on-board control system receives information about these monitored parameters. Additionally, the BMS is responsible for safely and efficiently operating the EV [15]. Batteries are typically assembled in series and parallel configurations to create packs. Differences in cell properties are determined by chemical processes and internal resistance. Cell balancing is necessary during charging and discharging for a longer lifespan. There are two available balancing techniques: passive and active. Active cell balancing involves continuously monitoring each cell's voltage and current [16].

The detection of battery characteristics include temperature, impedance, smoke detection, and the voltage and current of each individual cell. Estimating the battery's state of function (SOF), SOC, and SOH are all included [17]. Sensor and actuator failures are included in the fault detection method referred to as On-Board Diagnosis (OBD). Furthermore, it identifies insulation flaws, overcharge, and over discharge. Charge management determined by the charger's power level, battery, and charging current [18].

2.1 Problem Statement

Electric and hybrid electric vehicles rely on high-voltage battery packs to power their electric motors. These packs are crucial as they store the energy required to run the vehicle. To ensure optimal functioning, a battery management system (BMS) is used. The BMS has multiple roles, including prolonging the battery's lifespan and increasing the vehicle's driving range. It achieves this by regulating the charging and discharging of the battery packs. However, if not properly managed, these processes can cause the battery's practical specific charge to decrease quickly and the electrodes to age faster than usual

2.2 Objective

To accurately calculate weather data and determine the charging time for an electric vehicle, a temperature monitor must be used. A module should also be created to predict the charging time of the battery pack based on the vehicle's location. Charging an electric vehicle can be done at home or at a public charging station, with the time to fully charge varying from 30 minutes to half a day. The main objective of electric vehicles is to surpass traditional fuel-powered bikes on Indian roads, with a significantly lower total cost of ownership. However, it is important to consider the drawbacks before purchasing these vehicles. E-bikes in India have limited fuel capacity and range, making them unsuitable for long-distance travel. Due to their limited battery capacity, these vehicles struggle to cover large distances. Owners must charge their batteries for at least eight hours per day, which can reduce the battery's lifespan. Additionally, replacing the battery every two years can be costly. Most e-bikes require 3-8 hours to fully charge the battery.

3. Proposed System

The block diagram in Figure 1 represents the proposed system, which aims to develop an advanced and adaptive model for predicting electric vehicle (EV) battery pack charging times based on geographical factors. The primary objective is to enhance user convenience, optimize energy grid management, and contribute to the widespread adoption of electric vehicles.

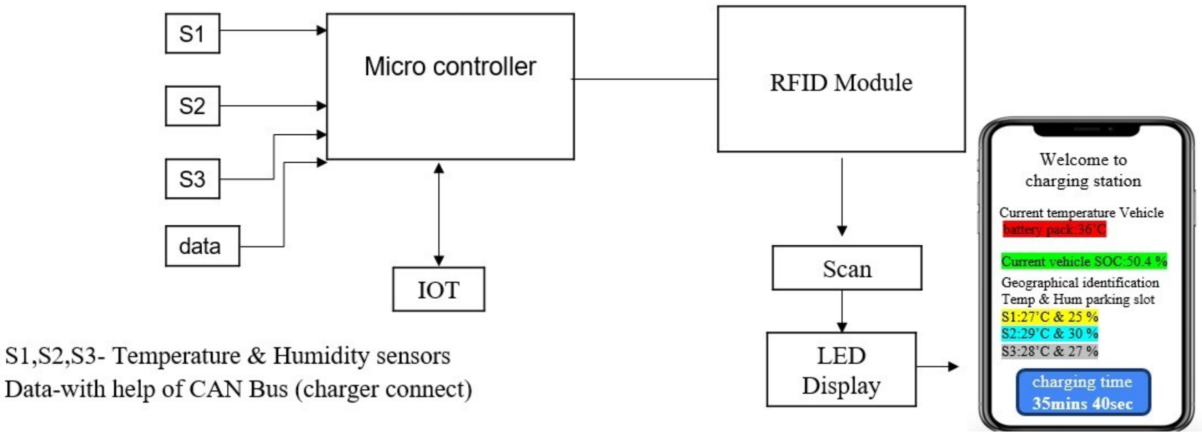

Figure 1. Block Diagram

Figure 2. illustrates the charging station. Implementation of EV smart charging systems, vehicles will have the ability to communicate with local utilities to ensure that their batteries are charged at the most cost-effective time and with minimal impact on the grid. To optimize the charging rate and extend the lifespan of the battery, it is necessary to use automated charging stations that continuously monitor the EV charging process.

Some cars also have the option to use off-board chargers in addition to their on-board systems. An on-board charger is installed within the vehicle and can only be accessed through the charging system's interface. This type of charger, known as "slow charging," is used to gradually charge the battery by connecting it to the AC electrical grid. In contrast, an off-board battery charging system is installed externally and is used to quickly recharge the battery by accessing the DC voltage of the device. This process is referred to as fast charging. The type of batteries used in the battery pack depends on the desired power output for the electric vehicle.

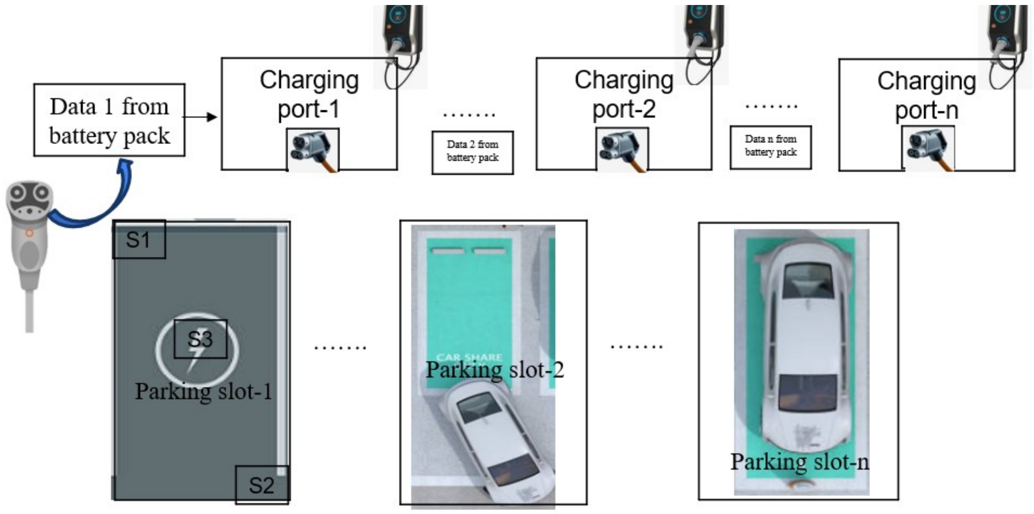

Figure 2. Charging Station

The maximum discharge current of the batteries is determined by the peak power required by the motor, while the continuous discharge current is determined by the motor's power consumption during EV travel. The maximum discharge output of the battery pack provides information on the motor's peak power output and current consumption. The continuous current of the batteries is dependent on the EV's ongoing electricity needs. If the designer chooses to connect all batteries in a single serial string with a parallel battery system, a thermal management system (HVAC) is necessary to maintain the batteries at specific temperature.

Additionally, the power converting system for the EV charging station includes an inverter and its enclosure applications are a crucial component of the infrastructure for EV charging, specifically electric vehicle charging software. Additionally, EV charging software enables vehicle-to-grid (V2G) and grid-to-vehicle (G2V) interactions. This allows for a bidirectional flow of electricity, allowing EVs to act as backup generators and provide energy back to the grid during outages, peak load demands, or other unexpected conditions. This technology can greatly increase the overall dependability of the electricity distribution system. Similar to other energy storage systems, V2G allows EV batteries to be used as a backup resource, reducing distribution network operating costs, improving power quality, and regulating the grid. In the long term, V2G has the potential to decrease the need for electrical generating investments.

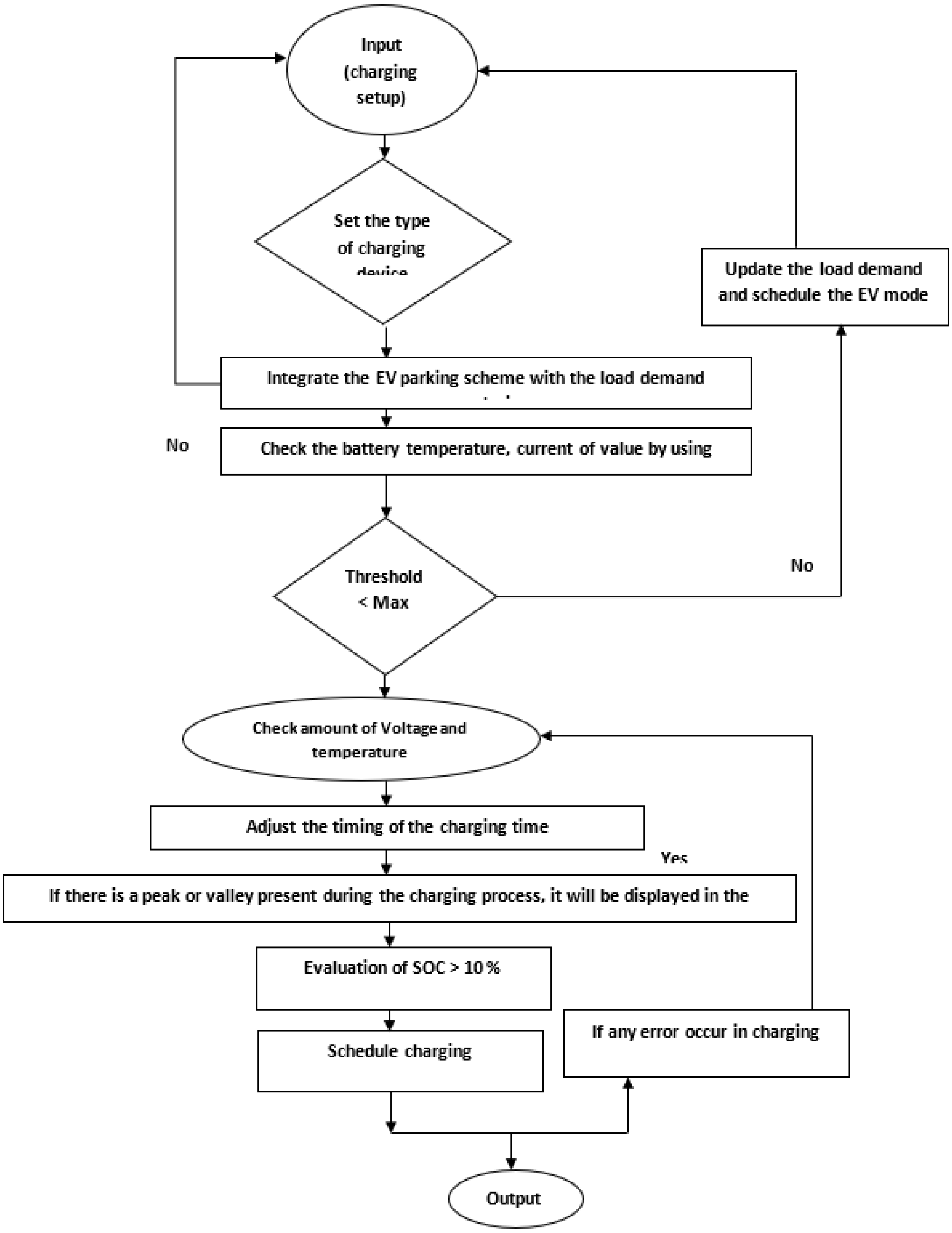

Figure 3. Flow Chart of Charging an Electric Vehicle's Battery Pack

Components of the Project

- Lithium-ion Battery (Hardware)
- L298 Motor Drive
- RIFD Module
- I2C Module

- SIM Card
- Arduino uno Controller
- Volt, Temp, Current Sensor

4. Result

Figure 4 and 5 shows the hardware set up of EV Battery Pack Charging Time Prediction. It was developed by Arduino; the Arduino Uno is a microcontroller board based on the Microchip ATmega328P microprocessor. It features a set of digital and analog input/output (I/O) pins that can be connected to other expansion boards (shields) and devices. This open-source board is produced by Arduino and is designed for easy interfacing with other components.

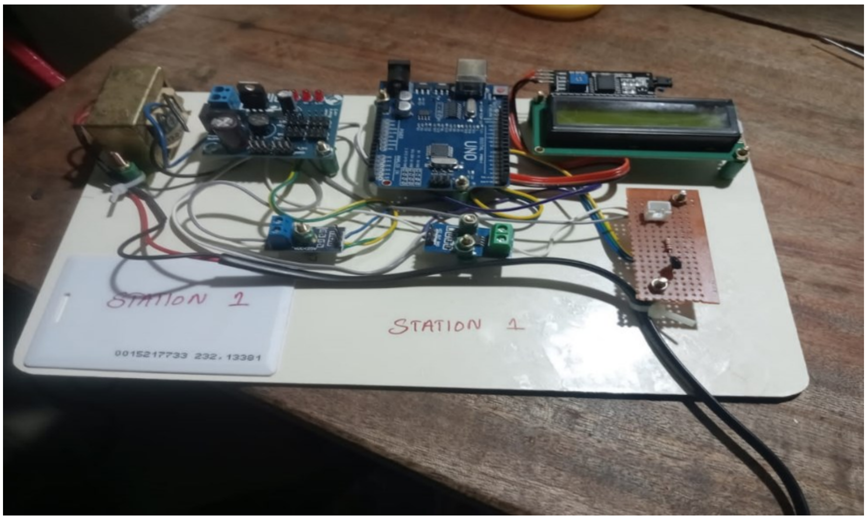

Figure 4. Prototype Model 1 Charging Station

When cables are linked between the charging station and the fetched wires, charging wires retrieve the voltage from the battery. The charger monitors the entire battery's power and voltage by drawing power for a brief period of time, leaving drops of opposition caused by the system's internal wiring and power from the battery. Usually, after a battery has recently been charged, this type of current imposing will make sure that the voltage of the power source improves to the voltage that is established by the battery's qualities. In this case, the voltage will rise to volts with a reasonably consistent current circulation.

Charging wires retrieve the voltage from the battery when connected to the charging station. The internal wiring of the network and power from the battery can cause resistance, but the charging device is able to monitor and regulate the electrical power and pressure of the entire pack. This type of current control ensures that the power output voltage increases to the appropriate level based on the battery's characteristics once it is fully charged. As a result, a consistent current flow will cause the voltage to rise to the desired level

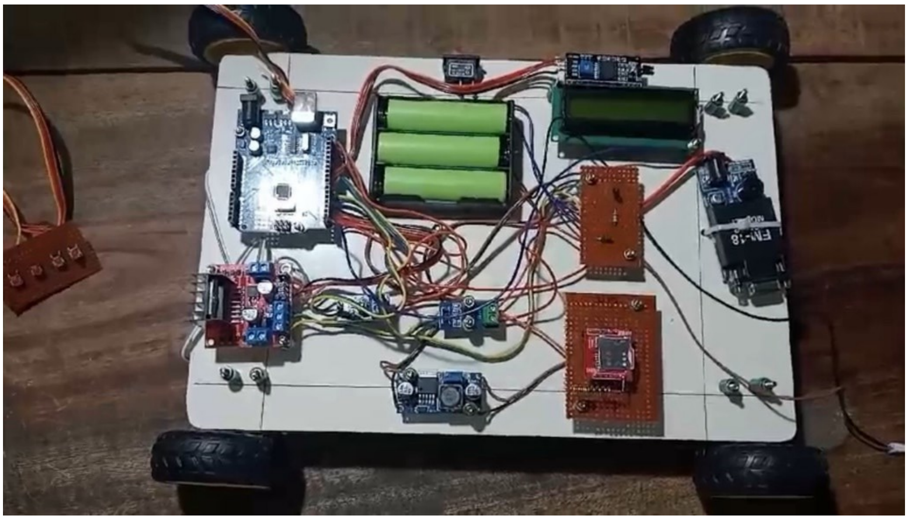

Figure 5. Prototype Model 2 EV

The charging based on an electric car construction process or the Arduino microcontroller. While the battery is being charged, charging stations will require less waiting time than after the discharge is completed at the station. The authorizing cars at charging stations is through the use of IoT-based mesh networks. These networks allow for the monitoring and control of the charging and discharging processes of electric vehicle (EV) batteries. Sensors are utilized to track important battery properties such as voltage, current, and temperature. The data collected by these sensors is then transmitted to the cloud through the Internet of Things (IoT) for processing and storage. It is important to note that EVs rely on these batteries as their primary power source, which are composed of multiple small cells rather than a single large battery.

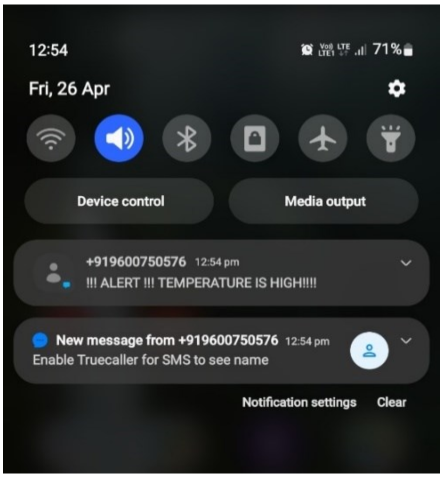

Figure 6. Sending Message to Mobile Phone

Set up the sensor inputs. Take input from the sensors of voltage, current, and temperature. Convert the sensor from analogue to digital and monitor its value. Display the values obtained. Check whether the battery's temperature exceeds the threshold value. If the threshold value is smaller, repeat the steps above. If the threshold value is high, the vehicle should come to a stop and alert message send as shown in Figure 6.

Factors such as short circuiting, denting, overcharging, and overheating can all lead to damage to the battery. Therefore, electric bikes must have systems in place to regulate the DC battery charging process and provide users with diagnostic information. This is especially important as most electric vehicles use lithium-ion batteries, which are susceptible to "thermal runaway" a phenomenon where the battery's thermodynamic properties increase at a faster rate than they can be dissipated, making them more prone to issues**.** When charging infrastructure is limited, home charging has been proven to be a practical and effective option, particularly for early adopters of electric vehicles.

However, regulators should not assume that public charging stations are unnecessary for increasing uptake, as home charging may not be accessible for all consumers in the existing market. In fact, solely focusing on the percentage of charging activities that occur at each type of location may underestimate the significance of workplace and public charging in the early stages of the market. Instead, the frequency of charging occurrences (rather than the volume) can demonstrate that even vehicles that primarily charge at home may still occasionally utilize public charging infrastructure. There are two types of charging stations available for public use: Level 2 and DC fast chargers. Enhancing usage and suitably coordinating charging networks with driver requirements, level 2 public charging stations are a valuable addition to the network of recharging alternatives available to them. For example, charging while working or shopping falls under this category. However, fast charging is more useful for drivers who plan to travel longer distances and may need to refuel more frequently. This depends on the charging duration and its correlation with the driver's current choices and habits. In addition to providing EV drivers with uninterrupted driving for up to an hour, fast charging is also beneficial for those who need to quickly recharge their vehicle during a busy day.

5. Conclusion

As the future of EV technology in India is full of promise. With battery technology advancements, charging infrastructure expansion, solutions for range anxiety, and the development of autonomous driving capabilities, EVs are set to revolutionize the way we commute. EV wireless charging using RFID is a promising technology that can potentially revolutionize the EV charging industry. It offers numerous benefits, including increased convenience, efficiency, and safety, and has the potential to significantly reduce the environmental impact of transportation.

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