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INTEGRATED BATTERY COOLING**

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# DEVELOPMENT OF AN ENERGY REGENERATIVE SYSTEM FOR EV BATTERY CHARGING USING A BELT-DRIVEN MOTOR AND INTEGRATED BATTERY COOLING

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**ABSTRACT:** *The Energy Regenerative system represents a groundbreaking solution to the prevalent challenges confronting electric vehicles (EVs), including issues of limited range, reliance on external charging infrastructure, and concerns regarding battery overheating. With a focus on revolutionizing the electric vehicle industry, this research project introduces a pioneering approach that centres on optimizing energy management and extending the operational range of EVs. The core principle of this research involves the integration of two batteries, denoted as Battery A and Battery B, in conjunction with a dynamo to harness kinetic energy during motion. While Battery A undergoes discharge, Battery B is concurrently charged through the dynamo, and vice versa. The dynamos generate DC-current, which is subsequently stabilized to facilitate the charging of the batteries. To address challenges related to overheating and thermal management in electric vehicles, an intricately designed cooling system utilizing copper pipes is incorporated, ensuring optimal operating temperatures for the batteries across diverse riding conditions. A distinctive feature of this research project is the inclusion of dynamos for energy harvesting during the vehicle's motion. These mechanisms will be visually presented to enhance user comprehension. This innovative approach is poised to reshape electric vehicle design, providing a more convenient and environmentally sustainable transportation option for the future.*

**KEYWORDS:** *Energy Regenerative, Dual-Battery System, Energy Management, Energy Efficiency, Battery Cooling, Battery Temperature Maintenance, Battery Longevity, Range Extension.*

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## 1. INTRODUCTION

The burgeoning prominence of electric vehicles (EVs) as eco-friendly alternatives to traditional gasoline-powered vehicles is accompanied by several advantages, including reduced emissions, lower operating costs, and quieter operations. However, the evolving electric vehicle industry faces persistent challenges that necessitate continuous research and development efforts. A pivotal challenge revolves around the performance and temperature management of lithium-ion batteries that power electric vehicles. While these batteries boast high energy density and environmental benefits, their sensitivity to temperature variations poses a significant hurdle. Operation outside the optimal temperature range leads to performance degradation, impacting the vehicle's range, power output, and safety. Therefore, effective thermal management becomes a paramount concern in the design and operation of electric vehicles. Simultaneously, the availability and convenience of charging infrastructure remain critical issues, contributing to the phenomenon known as "range anxiety." This research project proposes an innovative solution to these challenges by introducing a self-charging electric vehicle concept. In this approach, the vehicle's motion serves as a source of energy regeneration by harnessing kinetic energy during acceleration and braking, capturing energy that would otherwise dissipate as heat. The project incorporates alternators and a dual-battery system to create a vehicle capable of continuous operation while reducing dependence on external charging infrastructure and extending its range. To ensure effective management of the energy regeneration system, the project integrates a sophisticated copper pipe-based liquid cooling system. This system utilizes ethylene glycol as a proven coolant with excellent heat transfer properties, circulating through the copper pipes to regulate battery temperature. This cooling mechanism safeguards the batteries against overheating during energy regeneration, promoting efficient charging and discharging cycles. The project represents a significant advancement towards sustainable, efficient, and reliable electric vehicles. Through the fusion

of energy harvesting, dual-battery technology, and advanced cooling systems, the research aims to overcome barriers hindering widespread electric vehicle adoption. The innovative approach strives to provide enhanced performance, extended range, and increased convenience for riders, contributing to the broader goal of environmentally responsible transportation. The main objectives of the paper are:

- To develop a conceptual design of a prototype for an Electric Two-Wheeler.
- To generate electric charges from a belt-driven mechanism.
- To prevent the battery from overheating by adding a cooling liquid agent allowing it to flow through the copper pipe.
- To display the regenerative mechanism through voltage fluctuation in the resistor, the temperature of the battery, and also the charge percentage of the batteries.
- To assemble the belt-driven motor which will be connected through a dynamo (for regeneration purposes) through a belt to charge a battery efficiently while driving a two-wheeler.

## **2. LITERATURE SURVEY**

**Kinetic Energy Harvesting Technologies for Applications Inland Transportation: A Comprehensive Review (2021):** This paper presents a thorough review of energy harvesting technologies applicable across various aspects of land transportation. Firstly, it provided a summary of the commonly utilized energy harvesting technologies in this context. Secondly, it delved into different energy harvesting systems, offering insights into their designs, simulations, and experimental implementations. Thirdly, the paper conducted a comprehensive analysis of these energy harvesting technologies, involving calculations and simulations to

evaluate their performance. Additionally, a comparative examination of the various energy harvesting systems was carried out using diverse methodologies.[1]

**Battery Cooling in Electric Two-Wheeler - A Review (2023):** This paper reviewed the drawbacks of E-bikes, which employ heat-absorbing materials to decrease the heat produced by the battery. It was feasible not only to implement but also to design a dedicated battery chamber. While the battery underwent charging and prolonged transportation, an alternative cooling approach involved monitoring its temperature. Allowing the vehicle to take breaks intermittently served as a practical strategy to reduce the battery temperature. Therefore, having a thorough grasp of temperature dynamics became essential, facilitating diverse processes for cooling the battery. [2]

**Thermal Management Systems for Batteries in Electric Vehicles: A Recent Review (2023):** The project provided a comprehensive review of the energy source for modern-day Electric Vehicles (EVs), with a focus on the prevalent use of lithium-ion battery packs. Recognizing temperature sensitivity as a significant constraint on lithium-ion battery performance, the study emphasized reviewing existing Battery Thermal Management Systems (BTMS) and their practical implications. The analysis unfolded in two key aspects. Firstly, it delved into design considerations, evaluating the intrinsic value of thermal safety and exploring international market potential. Secondly, the study conducted a thermal stability analysis, encompassing scenarios such as thermal runaway situations, extreme weather conditions, and aging phenomena. The impact of sub-zero temperatures, charging/discharging rates, failures arising from short-circuiting, the absence of temperature uniformity, and mechanical deformation was systematically evaluated. Furthermore, the project compared various theoretical and experimental models of battery thermal management strategies proposed by different authors. This comparative analysis aimed to assess the effectiveness of these strategies in both hybrid and electric vehicles. By addressing these aspects, the study contributed valuable

insights into enhancing the performance and safety of lithium-ion batteries in the context of electric and hybrid vehicle technologies. [3]

Design and Fabrication of Cooling System in Electric Vehicle (2019): The project focused on developing a cooling system designed to mitigate heat dissipation from batteries, ultimately enhancing the lifespan of the battery pack. Both electric and hybrid cars played a crucial role in reducing reliance on fossil fuels, sharing the common feature of utilizing batteries to store electrical energy. In the context of electric vehicles (EVs), ensuring optimal performance, prolonged battery life, and high safety standards necessitated meticulous temperature control of the battery cells. Therefore, the implementation of an effective and well-designed cooling system became paramount. This system aimed to maintain the battery cells within the recommended temperature range during the vehicle's operation, thereby contributing to sustained performance, extended longevity and heightened safety in electric vehicles. [4]

Magnetorheological and wedge mechanism-based brake-by-wire system with self-energizing and self-powered capability by brake energy harvesting (2016): This described a braking system that utilized special fluids influenced by magnets and incorporated a wedge-shaped mechanism, enabling electronic operation without physical connections. The design aimed to both generate its power from braking energy and enhance its braking force without requiring external power sources. [5]

A State-Of-The-Art Review of car suspension-based piezoelectric energy harvesting systems (2020): This explains a detailed analysis or overview of the latest advancements and the current status of systems that use car suspensions to collect or harvest energy through piezoelectric technology. These systems essentially converted the movement or vibrations from the car's suspension into electrical energy that could be used for various purposes. [6]

A review of energy sources and energy management systems in electric vehicles (2012): This paper provides a comprehensive overview of the current state-of-the-art in various aspects of Electric Vehicles (EVs). It covered a spectrum of topics, including energy sources, storage devices, power converters, low-level control energy management strategies, and high supervisor control algorithms implemented in EVs. The paper emphasized a comparative analysis of the advantages and disadvantages associated with different vehicle technologies. Moreover, the standards and patterns of drive cycles for EVs were outlined, shedding light on the benchmarks and norms in this field. The discussion extended to the advancements in power electronics and power processors, facilitating the implementation of sophisticated controls, both at low levels and through high supervisory algorithms, in EVs. This implementation aimed to achieve optimum performance, including the realization of fast-charging stations. The paper acknowledged the rapid growth of EVs and their integration with alternative resources into the utility grid. In this context, it highlighted the pivotal role of smart grid control in managing the energy demand, underlining the increasing significance of intelligent grid systems with the expanding adoption of electric vehicles.[7]

Overview of energy harvesting and emission reduction technologies in hybrid electric vehicles (2021): This explains a broad view or summary of technologies designed to capture energy from various sources and reduce emissions specifically in hybrid electric vehicles. It likely covered methods for gathering energy that would otherwise be wasted and technologies aimed at decreasing the environmental impact of these vehicles. [8]

Energy Harvesting Solutions for railway transportation: A Comprehensive Review (2022): This paper suggests a detailed assessment or thorough examination of various methods used to capture and utilize energy in the context of railway transportation. It likely covered different technologies or approaches focused on gathering energy from the railway

environment to power various systems or reduce energy consumption within the railway sector.

[9]

Vibration energy harvesting in automotive suspension systems: A detailed review (2018): The paper constituted a thorough review of energy harvesting systems centered around vehicle suspensions. In particular, it undertook an analytical and statistical examination of regenerative suspensions in vehicles, encompassing a review of concepts, designs, simulations, test rig experiments, and on-road vehicle trials. The most prevalent energy harvesting systems employed in vehicle suspensions were systematically compared, highlighting their respective advantages and limitations. Furthermore, the paper delved into the complex challenges and unresolved research gaps within this domain. It not only identified these issues but also offered recommendations to address and overcome these challenges, providing a valuable roadmap for future research endeavors in the field of energy harvesting from vehicle suspensions. [10]

A review of barriers and challenges of electric vehicles in India and vehicle to grid optimization (2020): The paper provided a comprehensive overview of studies on the market penetration rates of Electric Vehicles (EVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Battery Electric Vehicles (BEVs). It delved into various modeling approaches and optimization techniques applied to these vehicle types. Notably, the study uniquely focused on a developing country like India, addressing critical research on essential barriers and inadequate charging facilities. A distinctive aspect of the paper was its exploration of the new concept of Vehicle-to-Grid, which served as an additional power source in situations where renewable energy sources were unavailable. This development added an innovative dimension to the research, expanding the discussion beyond vehicle penetration rates to include emerging technologies with potential implications for energy management and sustainability. [11]

#### A Review of Lithium-Ion Battery for Electric Vehicle Applications and Beyond (2019):

This paper provides a comprehensive overview of recent research and advancements in lithium-ion batteries employed in electric vehicles (EVs). It covered commonly utilized methods for battery sorting. Additionally, the paper critically examined the characteristics and challenges associated with estimating a battery's remaining useful life (RUL) and state-of-charge (SOC). The discussion included an exploration of strategies aimed at addressing these challenges. Furthermore, the paper introduced a novel approach for sorting retired lithium-ion batteries and estimating both the RUL and SOC of these retired batteries. [12]

Lithium-ion battery fast charging: A Review (2019): This research indicated a comprehensive evaluation or summary of the process and technology behind quickly charging lithium-ion batteries. It likely delved into various methods, advancements, and considerations related to rapidly charging these types of batteries, offering an overview of the existing research and developments up until 2019. [13]

Design and Implementation of the Electric Motor Controller for Two-Wheeler Hybrid Vehicle (2019): This paper describes the creation and application of the control system responsible for managing the electric motor in a hybrid two-wheeled vehicle. It likely covered the planning, development, and practical use of the technology that regulated how the electric motor operated within the context of a hybrid vehicle. [14]

Design and Development of Energy Regenerating Electric Two-Wheeler (2020): The paper examined how the economies of developing countries, such as India, were closely tied to the cost of fuel, given its substantial daily consumption. A significant portion of transportation in these countries relied on conventional fuels like petrol and diesel. While electric bikes were introduced in India in the 1990s, they did not gain much popularity initially due to the limited performance of batteries and lower mileage per charge. However,

advancements in charging and battery technologies led to improved performance of electric vehicles. In response to these developments, the authors of the paper proposed the implementation of an energy-regenerating electric bike. The paper further detailed the design, development, and presentation of a prototype supporting this concept. [15]

**A Comprehensive Review on The Integration of Electric Vehicles for Sustainable Development (2022):** This paper suggested a thorough examination or overview of how electric vehicles were being incorporated into various aspects of society to promote sustainability and long-term development. It likely covered a wide range of topics, such as the environmental impact, policies, infrastructure, and socio-economic aspects related to the integration of electric vehicles, aiming to understand their role in fostering sustainable practices and growth. [16]

**A Review on Passive Cooling Techniques for Lithium-ion Battery Thermal Management System of Electric Vehicles (2021):** This research referred to an in-depth evaluation or summary of different methods used to cool lithium-ion batteries without actively consuming additional energy. Specifically focusing on electric vehicles, it likely explored various passive cooling techniques employed to manage the temperature of these batteries, which is crucial for their performance, safety, and longevity. [17]

**ESP32-based embedded system for level I vehicular automation using IOT (2022):** This research suggested the creation of an embedded system using ESP32, a microcontroller, for implementing basic vehicular automation at the first level. It likely involved leveraging IoT (Internet of Things) technologies to enable communication and control within vehicles for functionalities like data sensing, processing, and possibly basic automation, all managed through the ESP32 microcontroller. [18]

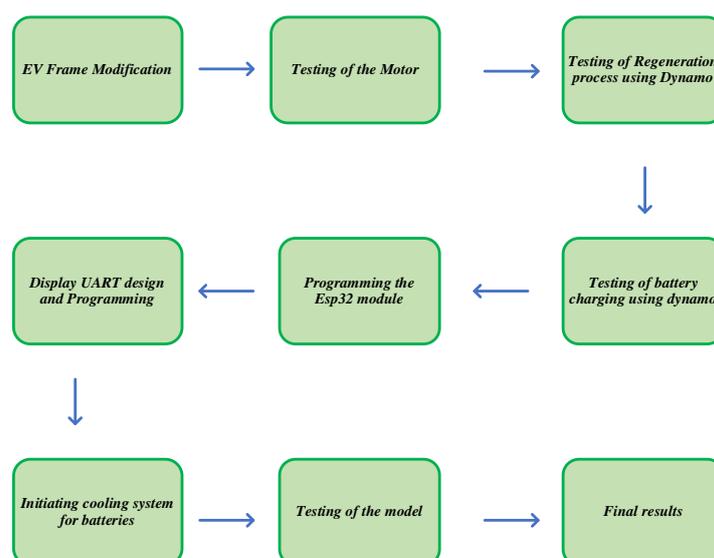
**Global Insights on Future Trends of Hybrid/EV Driveline Lubrication and Thermal Management (2020):** This paper implied a comprehensive exploration or analysis of anticipated

future directions in lubrication and thermal management systems specifically tailored for hybrid and electric vehicle drivelines. It likely covered emerging trends, technologies, and strategies related to maintaining optimal performance, efficiency, and durability of drivetrain components in these types of vehicles. [19]

**Understanding Charging Behaviour of Electric Vehicle Users (2013):** This paper delved into the psychological dynamics influencing the charging habits of electric vehicle (EV) users, drawing on data from a 6-month field study involving 79 participants. The findings revealed that, on average, users charged their EVs three times weekly, covered approximately 38 km per day, and typically had surplus energy upon recharge. A central hypothesis explored in the paper revolved around the concept of user–battery interaction style (UBIS) as a key variable in understanding EV users' charging behavior. UBIS was measured as a relatively stable trait with some consistency across different devices. The study's outcomes aligned with the conceptual model, highlighting the significance of UBIS and its comfortable range in explaining the typical charge levels chosen by individuals. The research indicated that UBIS is linked to users' confidence in their mental model of range dynamics, their utilization of range, and the incorporation of excess energy from renewable sources. These findings suggested that users' psychological attitudes and perceptions played a pivotal role in shaping their charging behavior. Consequently, the study had broader implications for optimizing the sustainability of electric mobility systems. In essence, the paper underscored the importance of psychological factors, particularly UBIS, in comprehending how EV users approach and engage with the charging process. These insights could contribute to the development of strategies and interventions aimed at fostering more sustainable and efficient electric mobility systems. [20]

### 3. METHODOLOGY

The study involved developing the regenerative energy of an electric vehicle using a dynamo. Firstly, the electric vehicle frame was modified to position the materials correctly. After this modification, the motor for propelling the vehicle was tested for pulling capacity, RPM check, and torque. Following the motor testing, the evaluation of the regeneration process using the dynamo commenced. This process aimed to check the output current generated by the dynamo while the vehicle was in motion. Another crucial step involved testing battery charging through the dynamo, confirming efficient charging while the rider operated the vehicle. For collecting information on battery charging, the regeneration process, etc., the ESP32 Microcontroller played a vital role in storing and displaying the data. The ESP module was programmed, and a display UART design was created, enabling riders to access all vehicle information and plan their journeys accordingly. Considering that extended battery use can cause overheating, a cooling system using a liquid cooling agent was implemented and tested to standardize battery temperature. Following this procedure, the vehicle components were assembled, and the vehicle was tested with a test drive. The workflow of the project is showed in Figure 1.



**Figure 1:** Methodology

- **EV Frame Modification:** The EV Frame is made up of iron metal which is used to set-up the basic materials. Vehicle parts such as Motor, Dynamo, Wheel, Battery, Shock absorber, Controller and others (as shown in Figure 2). We have designed the frame with respect to the placement and position of the components by measuring their dimensions of each material. We modified the frame so that the motor and the dynamo can be placed accurately to run the vehicle without any disturbance.

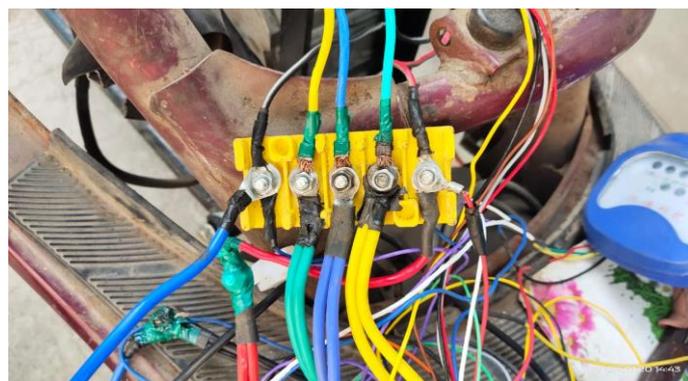


**Figure 2:** EV Frame

- **Testing of Motor:** We used 48v 1kw motor which consist of 3000rpm (revolution per minute) for our vehicle and also, we have tested that the pulling capacity of the motor is up to the weight of carrying 2 persons (Approx. 200kg) (as shown in Figure 3). We used chain drive system for the motor so that it can have enough grip and no energy losses whereas while using belt drive system there will be mild slip between the motor and the wheel due to this there will be a small amount of energy loss.



**Figure 3:** Testing of the Motor



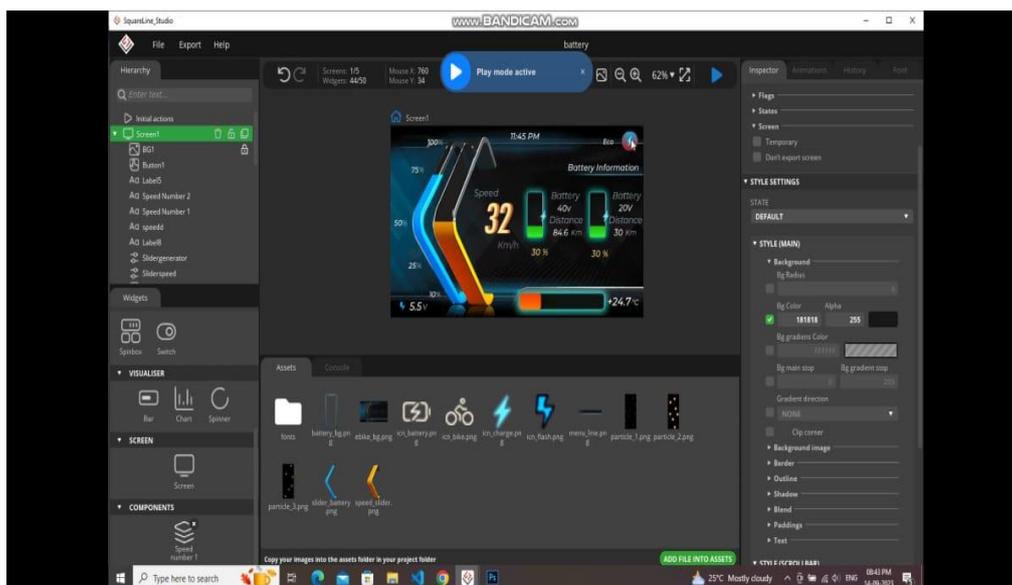
**Figure 4:** Connections of hall sensor and phase wires

Whenever we changed the connections in different probabilities, we got different results we attempted multiple tries and also, we tested hall sensor wires position and we got different feedback same like the phase wire connections finally we skimmed the result which we required and connected the final wire connections with respect to it (as shown in Figure 4).

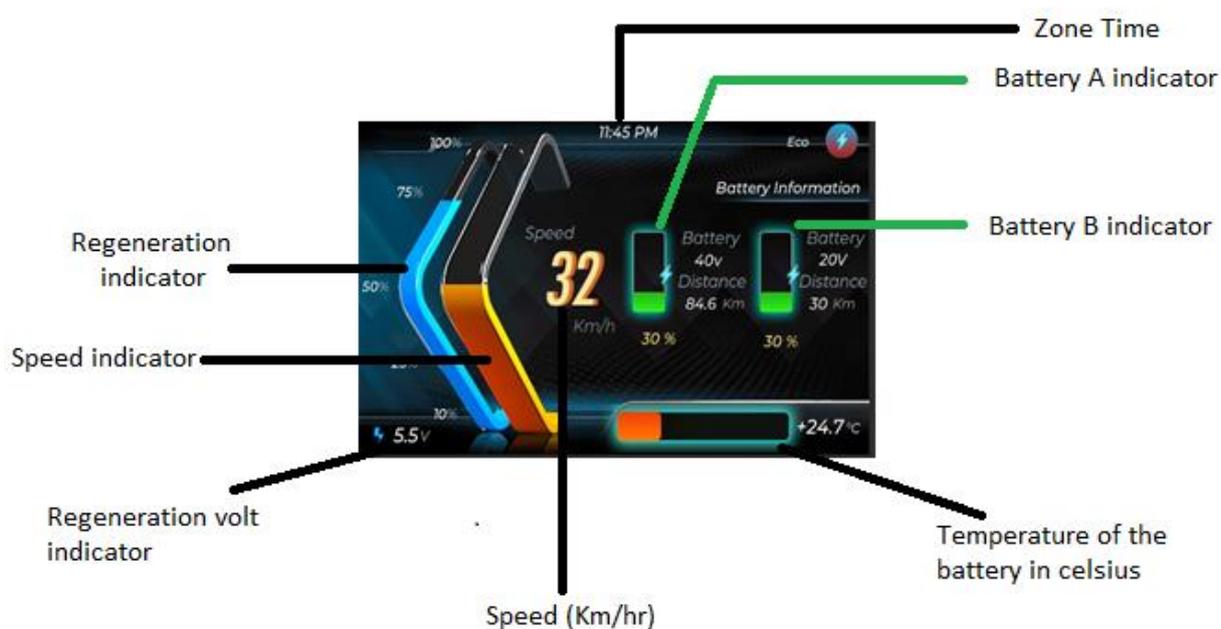
**Table 1:** Testing of Motors Rotation

SL. NO.	TEST	COMBINATION			FEEDBACK
		POSITION 1	POSITION 2	POSITION 3	
1	Test 1	Yellow	Blue	Green	Front Speed No Pickup
2	Test 2	Green	Yellow	Blue	Failed
3	Test 3	Blue	Yellow	Green	Failed
4	Test 4	Green	Blue	Yellow	Failed
5	Test 5	Blue	Green	Yellow	No Smoothness Good Pickup Front Speed
6	Test 6	Green	Yellow	Blue	Reverse Speed Smoothness Front Speed

- ***Testing of Regeneration process using Dynamo:*** We are using a belt-drive to connect the motor to the dynamo and connecting the motor to the battery in which the motor starts to run, due to the connection of motor to the dynamo with the belt, now when the motor is been rotated the dynamo is automatically rotated with the belt now when the dynamo is rotated the rpm of dynamo is partially decreased in which the output voltage of the dynamo is calculated with the help of multi-meter (as shown in Table 1).
- ***Testing of battery charging using Dynamo:*** The charges produced in dynamo cannot be directly transferred to the battery due to fluctuation so, we are using a mini stabilizer in between the circuit of dynamo to battery so that the power is been stabilized and charge a constant power to the battery. Let assume the two batteries named A and B, when the Battery A is in use, automatically Battery B gets charged using dynamo, this process is initiated throughout in vice versa.
- ***Programming the ESP32 Module:*** We need a Microcontroller which can distribute a power to all the modules and sensors in this situation we are using a ESP32 Microcontroller which can also use to control the data transfer within the system. To programming ESP32 Module we are using Micro-python language.
- ***Display UART design and Programming:*** We are using display so that the user can easily identify the status of the vehicle and plan his journey accordingly, so that we need a display in which the user can understand the vehicle status in better way so we built a good user-friendly UART design using SquareLine software (as shown in Figure 5 and 6) which contains its own assets.



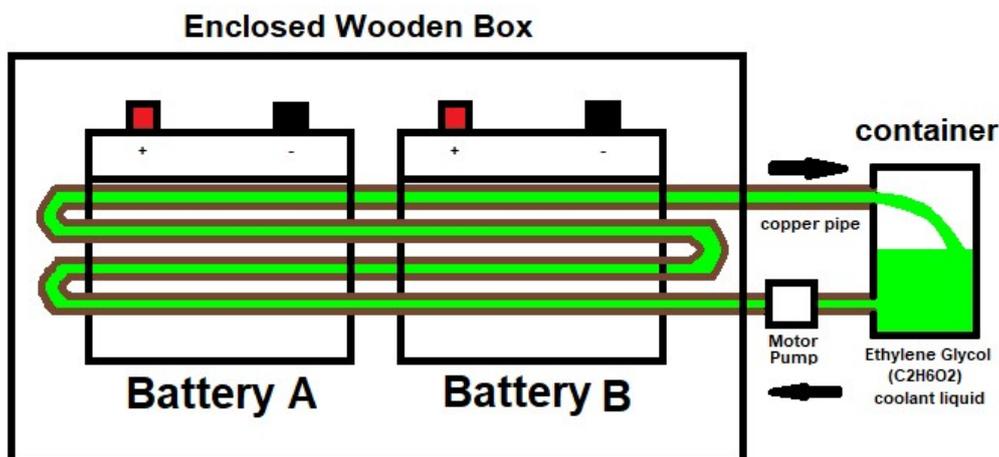
**Figure 5:** UART Design using Square Line Software



**Figure 6:** UART Design of the Display

The display is featured by battery temperature in Celsius, percentage of regeneration, regeneration Voltage, battery capacity in both the batteries, etc.,

- **Speed (Kmph):** kilometres per hour is a unit of speed commonly used to measure the velocity of the electric vehicles. The benefits of measuring and optimizing speed in km/hr for electric vehicles are Range optimization and energy efficiency.
- **Regenerative voltage indicator:** The voltage indicator indicates the amount of voltage generated by the dynamo to charge the battery, this can be helpful to the user to know the battery status and the percentage increased by the charging battery.
- **Zone time:** zone time refers to the time zone setting option available within the ev onboard computer. this feature allows drivers to view the current time in their local time zone. The time zone feature ensures that the displayed time remains accurate.
- **Battery Temperature in Celsius:** The temperature of the Ev's is very crucial for maintaining the performance and longevity. The temperature sensor is equipped in an electric vehicle within the battery pack to monitor temperature variations, the sensor provides real-time data and maintain the battery within the optimal temperature range.
- **Dual battery indicator:** The Dual battery indicator is typically refers to the feature that shows the status of the battery like Percentage of the battery, Charging status in form of regeneration, Interchanging details, charge and discharge status.
- ***Initiating Cooling System for Batteries:*** In Electric Vehicles we are using cooling system to standardize the battery temperature. We are using a Liquid cooling agent named Ethylene Glycol (C<sub>2</sub>H<sub>6</sub>O<sub>2</sub>) to pass through the Copper pipe which is winded around the batteries. When this process is happens, the batteries get maintained in a standard temperature (Between 10o to 40oC) (as shown in Figure 7).



**Figure 7:** Battery Cooling System

- **Testing of the Model:** After assembling process of the vehicle is done, we Test-drive the vehicle and assumed that vehicle is running with good efficiency with the maximum speed of 60 kmph and all the processes is working successfully.
- **Final Result:** Finally, after all the process completion, the vehicle is ready to drive whenever we needed it.

### **Problem identification:**

In India the electric vehicle has a limited range that can be covered in a single charge for example: for 100% charge of the battery, it gives 90km range and also driver can cover only limited range, drivers cannot able to travel long distance due to the charging issue, it takes long time to charge a battery in electric vehicle (around 4-5 hours) and also there are only limited number of charging stations and also in India the individual houses can only prefer charging port to their electric vehicle, peoples who live in apartment and complex areas does not have proper facilities for the charging their electric vehicle.

According to our Indian climatic condition summer and winter seasons are experiences in high temperature, so in summer seasons the battery get heated and also while driving the

batteries gets more heated, hence by combining both the situations the battery gets overheated and sometimes it has the possibilities to explode. Also India has experiences more cases of exploding batteries in electric vehicle. Rapid charging is also one of the cause for overheating batteries and also electric vehicle companies are not initiating a good cooling system for the batteries, as we all know overheating of batteries has chances for damage, due to this reason the customers face issues in batteries and changing the new batteries every 6 to 12 months.

### 3.1 Existing Technology of Electric Two-Wheelers

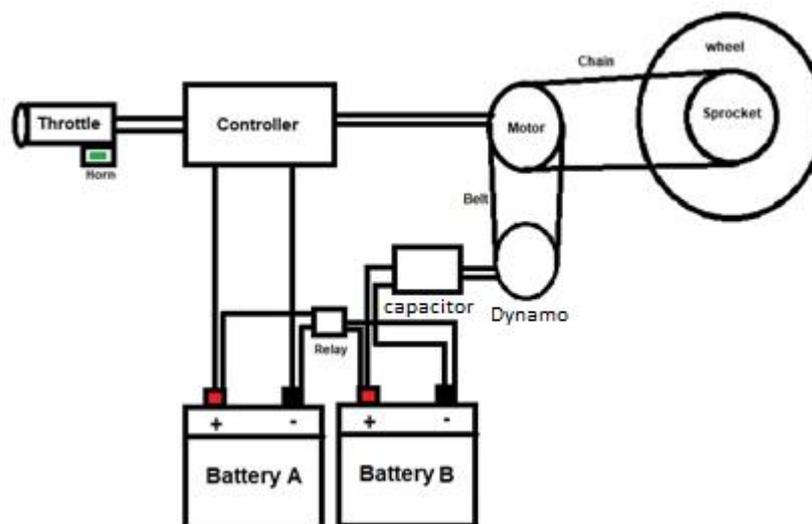
India's electric two-wheeler segment has been rapidly evolving, driven by increasing environmental concerns, government incentives, and technological advancements. Here are some key aspects of electric two-wheeler technology in India:

- **Battery Technology:** Lithium-ion batteries dominate the electric two-wheeler market due to their high energy density, lighter weight, and longer lifespan compared to traditional lead-acid batteries. Advancements in battery technology aim to improve range and charging times.
- **Range and Charging Infrastructure:** Manufacturers are working on increasing the range of electric scooters and motorcycles per charge. Simultaneously, efforts are being made to expand the charging infrastructure by setting up charging stations in cities and along highways.
- **Motor Efficiency:** Electric motors used in two-wheelers are becoming more efficient and powerful, offering better acceleration and performance while maintaining energy efficiency.
- **Charging Infrastructure:** The availability of charging stations varies significantly across regions. Urban areas and certain developed regions tend to have a better-developed charging infrastructure compared to rural and remote areas.

- ***Start-ups and Innovation:*** India's start-up ecosystem is contributing to electric two-wheeler technology. Several homegrown companies are emerging, introducing innovative designs, improved battery technology, and affordable electric vehicles.
- ***Performance Enhancement:*** Electric vehicles are no longer just about eco-friendliness; there's a growing focus on enhancing the performance aspect of electric two-wheelers, such as faster charging, increased speed, and better handling.
- ***Battery Cooling:*** Many electric scooters and motorcycles use air cooling as a passive method to dissipate heat from the battery pack. These systems rely on the natural flow of air around the battery to regulate temperature. Vents and strategically placed openings in the chassis allow air to circulate, carrying away heat from the battery cells.
- ***Regenerative Braking:*** When the rider applies brakes, regenerative braking systems capture the kinetic energy generated during deceleration. Instead of dissipating this energy as heat (as in traditional braking systems), it converts it back into electrical energy. This energy is then stored in the vehicle's battery, effectively recharging it while slowing down the vehicle.

### 3.2 Proposed Technologies in Electric Two-Wheeler

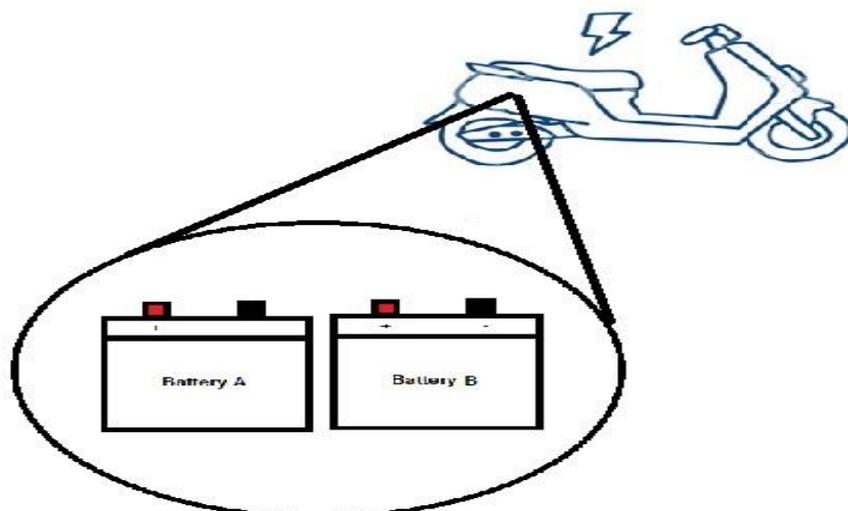
- ***Regeneration through Dynamic State:*** When the vehicle is in movement the dynamo which is connected to the motor will produce DC Current which is then transferred into another battery (as shown in Figure 8). So, in this case, when the vehicle is accelerated, the dynamo generates charges and transferred to the Battery whereas in existing technology the regeneration takes place only when we apply brake or during deceleration.



**Figure 8:** Regeneration Mechanism using Dynamo

The dynamo generates the voltage by the rpm (revolutions per minute) and the capacitor (50wv 15000 $\mu$ F) is used to keep the constant flow to the battery, the capacitor can carry up to 50 volts to charge 48v 20amps battery. The controller is used to supply proper voltage to the components such as throttle, motor, ignition etc..., this controller consists of the sensor, power and phase wires to all the components the rotation of the motor is directed by the controller. The relay is used to interchange the two batteries for example: if the battery A is in use the battery B gets charged by the controller at that time with the battery A comes less than 20% then the relay changes to battery B in use this process goes vice versa.

- **Dual Battery System:** In this technology the dual battery system is been used for the regeneration purpose. As we all know the battery cannot charge and discharge at the same time so, in this case when one battery gives power to the motor to run the vehicle, at the same time the dynamo charges the other battery. This process continues whenever the vehicle is in running state (as shown in Figure 9).



**Figure 9:** Dual Battery System

- **Battery Cooling System:** The Battery Cooling System plays a major role to keep the battery from overheat. We all know that the battery gets heated while riding the vehicle over a long period of time, due to this reason the lifespan of the battery will be decreased and sometimes the battery has chance to explode. So, we are intimating a liquid cooling system in which the batteries are winded around the copper pipe and a coolant named Ethylene Glycol ( $C_2H_6O_2$ ) is allowed to pass through the pipe by which the batteries temperature gets normalized.
- **Display for the vehicle:** The displays in electric vehicles are used for showing the percentage of the battery, speed of the vehicle, range of the vehicle, date and time etc..., these information's are for the user-understanding so that he can plan his journey accordingly, in our vehicle the information such as temperature of the batteries, switching of the batteries and regeneration process is added so that the user can know all the information of the vehicle and maintain the health of the vehicle (as shown in Figure 10).



**Figure 10:** Front-View of the display

### 3.3 VEHICLE PARTS PLACEMENT

*Battery:* underneath the seat of the two-wheeler.

*48v 1Kw Motor:* front facing of the rear wheel.

*Dynamo 48v 15Ah:* placed top of the motor

*Controller:* Backside of the seat

*Copper pipe winded box for the cooling system:* surrounding of the batteries A & B

*Container 50ml for storage of liquid coolant:* below the dashboard

*Transparent Pipe:* From the container to the Box.

*Display:* Top of the dashboard.

*Chain:* Connected from wheel to motor.

*Belt:* connected from motor to dynamo.

**Calculations:**

The range calculation for the battery, based on the motor specifications (48v 1000w BLDC motor), is detailed below:

**Current Calculation**

$$\text{Power} = \text{voltage} \times \text{current}$$

*(Note: 1Kw = 1000 Watt)*

$$1000\text{w} = 48\text{v} \times \text{current}$$

$$\text{Current} = 1000/48$$

$$\text{Current} = 20.83 \text{ amps}$$

**Power Calculation**

The power required to run 1000w motor for 1 hour.

$$1000 * 1 = 1000 \text{ watt hour}$$

Efficiency for 80%

$$(1000/0.8) = 1250\text{-Watt Hour (wh)}$$

$$\text{Power} = 1250\text{-Watt Hour}$$

**Battery Calculation**

It is the conversion of Watt Hour of battery into ampere of battery

$$\text{Power} = \text{voltage} * \text{current}$$

$$\text{Watt hour} = \text{voltage} * \text{ampere hour}$$

$$1250 = 48 * \text{Ampere Hour (AH)}$$

$$\text{Ah} = 1250/48$$

$$\text{Ah} = 26.041$$

### **Ampere hour = 26 Ah**

The calculated range for the electric two-wheeler equipped with a 48v 26Ah battery is determined to be 52 kilometers. This estimation is based on the assumption that each 1Ah of battery capacity can cover up to 2 kilometers in distance. Therefore, the determined 26Ah battery is expected to provide the necessary power for the 1000w motor to run for 1 hour, resulting in an efficient solution for the electric vehicle's energy requirements. In summary, the proposed setup of a 48v 26Ah battery aligns with the objective of achieving a range suitable for practical use, ensuring a reliable and sustainable operation of the electric two-wheeler.

## **4. RESULTS AND DISCUSSION**

- **Extended of the Electric Vehicle range:** The increase in Electric vehicle's range achieved through the implementation of Dual battery setup and self -charging capabilities. The extended range enhances the practicality and versatility of the Electric vehicles for various usage scenarios, such as long-distance travel and daily use. The electric vehicle extends up to 10 -15 kms range according to the running time.

[In normal electric vehicle there is no dynamo used to charge the battery they simply used a BLDC Motor to run the vehicle and when the vehicle is deaccelerated then the regen power charges the current battery and also the power generates by the BLDC motor is low].

- **Dual battery setup:** Implementing a dual battery setup with an automatic switching in an Electric vehicle. When Battery A is in use then the Battery B keeps charging by the regeneration process. When Battery A drops below 20 percentage the mechanism automatically switches to Battery B and vice versa.

[In day today electric vehicle the dual battery is used for extending the range and also for the backup. They normally use dual battery as a stepney for electric vehicle for long distance travel. But in our case, we use dual battery to charge battery when the vehicle is in motion].

## 5. CONCLUSION

The development of the Integrated Energy Regenerative System for Electric Two-wheeler Charging using a Belt-driven Motor with a Cooling System represents a significant stride towards sustainable transportation and heightened energy efficiency. This research endeavour has successfully engineered a system capable of powering electric two-wheelers while concurrently generating energy during dynamic states, thereby reducing overall energy consumption. A distinctive feature of this project lies in the regeneration process occurring even during throttle acceleration, differentiating it from conventional electric vehicles where regeneration typically happens during deceleration or free motion. Furthermore, the integration of a cooling system has been strategically implemented to ensure the efficient operation of the system, thereby augmenting its longevity and reliability. This research paper delves into the technical intricacies of the developed system, exploring its unique capabilities, performance metrics, and potential implications for the broader landscape of sustainable transportation. Considerations for real-world implementation, cost-effectiveness, and scalability are also scrutinized to ascertain the practicality and impact of the proposed system. In essence, this paper aims to contribute valuable insights to the field of sustainable transportation and energy-efficient electric vehicle technologies.

## 5.1 Findings of the study

The findings of our research project, encompassing a dual-battery configuration and a liquid cooling system, present a substantial potential impact on the electric vehicle (EV) industry and the broader realm of sustainable transportation. The following implications underscore the significance of our outcomes:

- **Extended Electric Vehicle Range:** The incorporation of a dual-battery setup with self-charging capabilities holds the promise of significantly extending the range of electric vehicles. This enhancement addresses a critical constraint by making EVs more viable for extended trips and daily commuting.
- **Enhanced Energy Efficiency:** The research project's targeted focus on energy harvesting and advanced battery management has the potential to yield improved energy efficiency. This optimization allows electric vehicles to utilize available energy more effectively, aligning with sustainability goals.
- **Improved Battery Performance:** The integration of a dual-battery setup along with a cooling system is engineered to enhance overall battery performance. This improvement encompasses the extension of battery lifespan, the maintenance of stable temperature conditions, and the optimization of charging and discharging cycles. These advancements contribute to the reliability and durability of EVs.
- **Innovation in EV Technology:** The innovative elements of our research, particularly in the domains of energy harvesting, battery management, and cooling systems, represent a noteworthy contribution to the evolution of electric vehicle technology. This innovation has the potential to stimulate further research and development, fostering continuous improvement within the EV industry.

By addressing critical challenges in electric vehicle technology, our research project strives to shape a more sustainable and efficient future in transportation. These research outcomes collectively contribute to the ongoing refinement of EVs, rendering them more accessible, dependable, and environmentally conscious. This research paper aims to comprehensively elucidate these findings and their implications for the broader field of electric vehicle technology and sustainable transportation.

### **CONFLICTS OF INTEREST**

The authors declare no conflicts of interest.

### **DATA AVAILABILITY STATEMENT**

Not Applicable

### **REFERENCES**

- [1] Hongye Pan, Lingfei Qi, Zutao Zhang and Jinyue Yan 2021, Kinetic energy harvesting technologies for applications in land transportation, *Applied Energy*. <https://doi.org/10.1016/j.apenergy.2021.116518>.
- [2] Dr. M.K. Murthi, A. Kishor, M. Ansar Mubeen, A. Balaji, 2023, Battery Cooling in Electric Two-Wheeler - A Review. <https://www.doi.org/10.56726/IRJMETS38833>.
- [3] Hafiz Muhammad Ali, 2023, Thermal management systems for batteries in electric vehicles: A recent review, *Energy Reports* <https://doi.org/10.1016/j.egy.2023.04.359>.
- [4] Darshan V. Naik, Karan R. Parab, Sushrut S. Parab, Omkar S. Patade, Joshi Guruprasad R, 2019, Design and Fabrication of Cooling System in Electric Vehicle.
- [5] Liangyao Yu, Member, IEEE, Liangxu Ma, Jian Song, and Xuhui Liu, 2016, Magnetorheological and Wedge Mechanism-Based Brake-by-Wire System with Self-Energizing and Self-Powered Capability by Brake Energy Harvesting.

- [6] Doaa Al-Yafeai, Tariq Darabseh, y and Abdel-Hamid I. Mourad 2020, A State-Of-The-Art Review of Car Suspension-Based Piezoelectric Energy Harvesting Systems.
- [7] Siang Fui Tie, Chee Wei Tan, 2012, A review of energy sources and energy management system in electric vehicles <http://dx.doi.org/10.1016/j.rser.2012.11.077>.
- [8] Shengxi Bai, Chunhua Liu, 2021, Overview of energy harvesting and emission reduction technologies in hybrid electric vehicles. <https://doi.org/10.1016/j.rser.2021.111188>.
- [9] JianyongZuo, LiweiDong, FaYang, ZihengGuo, TianpengWang, LiZuo, 2023, Energy harvesting solutions for railway transportation: A comprehensive review. <https://doi.org/10.1016/j.renene.2022.11.008>.
- [10] Mohamed A.A. Abdelkareema, Lin Xua, Mohamed Kamal Ahmed Alia, Ahmed Elagouza, Jia Mia, Sijing Guoa, Yilun Liuc, Lei Zuoc, 2018, Vibration energy harvesting in automotive suspension system: A detailed review <https://doi.org/10.1016/j.apenergy.2018.08.030>.
- [11] Sonali Goel, Renu Sharma, Akshay Kumar Rathore, 2021, A review on barrier and challenges of electric vehicle in India and vehicle to grid optimization. <https://doi.org/10.1016/j.treng.2021.100057>.
- [12] Weidong Chen, Jun Liang, Zhaohua Yang, Gen Li, 2019, A Review of Lithium-Ion Battery for Electric Vehicle Applications and Beyond.
- [13] Anna Tomaszewska a, Zhengyu Chu b, Xuning Feng b, Simon O'Kane c, Xinhua Liu a, Jingyi Chen a, Chenzhen Ji a, Elizabeth Endler e, Ruihe Li b, Lishuo Liu b, Yalun Li b, Siqi Zheng b, Sebastian Vetterlein f, Ming Gao g, Jiuyu Du b, Michael Parkes f, Minggao Ouyang b, Monica Marinescu c, Gregory Offer c, Billy Wu a, d, 2019, Lithium-ion battery fast charging: A review <https://doi.org/10.1016/j.etrans.2019.100011>.

- [14] Gerard Francesco Apolinario, Chrisean Adolfo, Christine Joy Arce, Zyra May dela Rosa, 2019, Design and Implementation of Electric Motor Controller for Two-wheeler Hybrid Vehicle.
- [15] Pratik jaywant ahire, ninad Jeevan Deshpande, Abhishek trimbakrao khiste, yashvardhan Ravindra sapkale, Prof. M.N. Pohare, 2020, Design and Development of Energy Regenerating Electric Two-Wheeler.
- [16] S. Hossain, Laveet Kumar, M. M. Islam, and Jeyraj Selvaraj, 2022, A Comprehensive Review on the Integration of Electric Vehicles for Sustainable Development. <https://doi.org/10.1155/2022/3868388>.
- [17] S S Mallick, S Neog, D K Mahanta<sup>1</sup> and M Rafi, 2021, A review on passive cooling techniques for lithium-ion battery thermal management system of electric vehicle <https://doi.org/10.1088/1757-899X/1145/1/012046>.
- [18] A. Meghana, M. R. Bharath, Saurabh Kumar, et al, 2022, ESP32 based embedded system for level I vehicular automation using IOT <https://doi.org/10.1063/5.0076784>.
- [19] Simon C. Tung, Mathias Woydt and Raj Shah, 2020, Global Insights on Future Trends of Hybrid/EV Driveline Lubrication and Thermal Management <https://doi.org/10.3389/fmech.2020.571786>.
- [20] Thomas Franke, Josef F. Krems, 2013, Understanding charging behavior of electric vehicle users <http://dx.doi.org/10.1016/j.trf.2013.09.002>.