



## Enhancing Battery Electric Vehicle Performance Through Self-Charging Capability

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**ABSTRACT**–The project focuses on creating a two-passenger battery electric vehicle with a self-charging mechanism, capable of carrying up to 250 kilograms. This innovative vehicle aims to utilize wheel rotation energy for battery charging, thus reducing pollution. The team modified a golf cart-like chassis using Mild Steel C Channel material. Key components, including the alternator, motor, and DC-DC converter, were strategically positioned to harness rotational energy from the wheels, generating 12V to 14V electricity. The DC-DC converter then elevated the voltage to 54V, efficiently charging four connected batteries in series for a 48V power output. Testing verified power supply to batteries and studied travel distances with and without the self-charging system. Results confirmed the system's success in recharging batteries during operation, elevating efficiency and range. Overall, this project successfully fabricates and tests an electric vehicle with self-charging capabilities, offering an eco-friendly solution for sustainable transportation and contributing to a greener automotive future.

**KEYWORDS:** Battery Electric Vehicles, BLDC Motor, Alternator, Battery, DC-DC Converter

### NOMENCLATURE

m= mass of the vehicle kg

V= velocity of the vehicle m/s

a= Acceleration m/s<sup>2</sup>

### 1. INTRODUCTION

Automobiles, commonly known as self-propelled vehicles used for transportation on roads, have undergone significant transformations throughout history based on prevailing means of propulsion. In the early 20th century, electrically powered automobiles emerged but remained



niche until the turn of the 21st century. The quest for more economical, emission-free, and uninterrupted energy sources led to the development of self-charging inverters as an alternative source of electricity [1]. Electric vehicles (EVs) powered by rechargeable batteries have gained momentum, with battery technology being a crucial factor for their success [2]. During the late 19th and early 20th centuries, electric cars were popular due to their comfort and ease of operation compared to gasoline-powered cars of the time. However, recent concerns about environmental impact, rising gasoline prices, and advancements in battery technology have revived interest in electric vehicles, seen as eco-friendly and cost-effective despite higher initial costs [2]. The transportation sector's contribution to carbon dioxide emissions and global warming has heightened the urgency to adopt greener transportation options [3].

Modern electric cars often employ hybrid technology, combining electric and internal combustion engines to optimize efficiency. Kinetic Energy Recovery Systems (KERS) are used to recover and convert the vehicle's kinetic energy during braking [4]. In-wheel motor systems have also been introduced to eliminate the need for internal combustion engines, while innovations like BLDC and PMSM control improve performance [5][6]. One limitation of electric cars is the need for recharging, leading to range constraints. To address this, researchers have explored interchangeable batteries, offering a quick replacement similar to refueling gasoline tanks. Techniques like the multilevel modular capacitor clamped converter have been proposed to generate isolated DC voltage outputs, potentially extending the battery range [7]. In conclusion, the history of automobiles has witnessed various propulsion methods, with recent emphasis on electric vehicles as environmentally-friendly alternatives. Advances in battery technology, hybrid systems, and innovative charging solutions have led to increased adoption of electric cars, contributing to a greener future in transportation. The quest for more efficient and sustainable electric vehicles remains ongoing, with ongoing research and development leading the way towards a cleaner and more sustainable transportation landscape.

## 2. BATTERY ELECTRIC VEHICLES

A Battery Electric Vehicle (BEV) is an electric vehicle that relies on rechargeable battery packs to store chemical energy. Unlike internal combustion engines (ICEs) found in traditional vehicles, BEVs utilize electric motors and motor controllers for propulsion. The efficiency of BEVs surpasses that of other propulsion methods currently in use, and they offer the unique advantage of being able to charge from renewable energy sources. Moreover, when powered by electricity, BEVs produce zero tailpipe emissions, contributing to cleaner air and reduced environmental impact [2,3]. BEVs are not only environmentally friendly but also offer impressive performance, dispelling the misconception that electric vehicles are slow. Their operational mechanism differs significantly from traditional vehicles with internal combustion engines. Instead of relying on an ICE, an all-electric vehicle is equipped with a large rechargeable battery, an electric motor, a motor controller for regulating power, and a charging system. These components replace the traditional fuel tank, fuel line, exhaust system, and IC engine. Charging BEVs is convenient, as they can be plugged into a household electrical outlet or a specialized charging station to recharge their batteries. The major components in existing BEVs include motors, motor controllers, and batteries. The



advantages of driving a battery electric vehicle are numerous[4].It proves cost-effective, with lower maintenance requirements and no need for expensive fossil fuels. BEVs are also safer to drive, emitting no harmful gases or pollutants, and significantly reduce noise pollution compared to traditional engine vehicles.However, despite their advantages, BEVs face certain drawbacks. The driving range on a single charge is relatively shorter compared to traditional vehicles, and their speed may be perceived as lower by some users. Charging times for batteries can also be longer, which might require some planning ahead. Additionally, the availability of recharge points in certain regions may be limited, affecting the overall convenience of owning a BEV.In conclusion, battery electric vehicles offer a promising solution for sustainable transportation, boasting several advantages such as cost-effectiveness, environmental friendliness, and improved performance. While they may have some limitations like driving range and charging infrastructure, ongoing advancements in technology are continuously addressing these concerns, making BEVs an increasingly attractive and viable option for eco-conscious drivers worldwide .

## 2.1. OBJECTIVE

The primary aim of this project is to harness untapped rotational energy from the wheels by implementing a DC synchronous generator. This innovative approach ensures a continuous generation of power, thereby eliminating the need for overnight battery charging. The core objective revolves around creating a compact vehicle capable of accommodating two passengers while maintaining a total weight of 250 kgs.

The design philosophy extends beyond mere passenger transportation. The vehicle's versatility enables its utilization for a range of purposes such as transferring patients within hospital premises, providing convenient transport for the elderly at railway stations, and serving as an alternative to traditional Golf karts. The selection of components for this project is driven by their affordability and widespread availability in the market. This strategic choice guarantees easy servicing, maintenance, and hassle-free replacement of parts in case of damage.In essence, the project centers on the development of a self-charging battery electric vehicle that aligns with the identified objectives. This pursuit is grounded in an extensive review of research papers and expert insights, which have collectively steered the selection of the most promising methodologies for component choice, fabrication techniques, and vehicle testing. Throughout this journey, the emphasis remains on achieving optimal results, while ensuring that the vehicle is designed, constructed, and tested under conditions that faithfully represent its intended usage scenarios. [5]

### 2.1.1. Brushless Dc Motor

DC electric motors, commonly referred to as BLDC motors or electronically commuted motors, derive their power from a DC electric source through an integrated inverter or switching power supply. This inverter facilitates the conversion of the supplied DC electricity into an AC electric signal, which is then employed to drive the motor. It's important to note that the term "alternating current" here doesn't necessarily imply a sinusoidal waveform.To ensure optimal motor performance, the integrated system incorporates supplementary sensors



and electronics. These components play a crucial role in regulating various aspects of the inverter's output. This includes controlling the amplitude and waveform of the AC signal, which in turn determines the percentage of DC bus utilization and overall efficiency. Additionally, the frequency of the AC signal, directly linked to the rotor's rotational speed, is also managed through this intricate control system. This orchestrated interplay of components allows for precise management of the motor's operation, optimizing its efficiency and performance characteristics. [1].



Figure1. DC Motor

The equations for motor are,

1. Kinetic energy,  $E = (1/2) * mv^2$

Where  $m$  = mass of the vehicle  $V$  = velocity of the vehicle

2. Braking distance,  $S$

$$v^2 = u^2 + 2aS$$

3. Vehicle stopping time  $v = u + at$

4. Braking force,  $F$

$$F = m * a$$

$$\text{Brake torque} = \text{brake force} * \text{effective radius of rotor}$$

### 2.1.2. Motor Controller

: A motor controller, comprising one or more devices, plays a crucial role in efficiently managing and controlling the performance of an electric motor according to predetermined parameters. This sophisticated device serves as a versatile tool, offering both manual and automatic functions for initiating and halting motor operations, as well as enabling the selection between forward and reverse rotations. Moreover, it empowers users to regulate and fine-tune the motor's speed, ensuring optimal performance for diverse applications. One of the key capabilities of a motor controller lies in its ability to limit or regulate the motor's torque output, safeguarding it from potential damage due to excessive load conditions. This essential protective feature prevents the motor from operating beyond its designed capacity, thereby enhancing its longevity and reliability. In addition to its performance-oriented aspects, the



motor controller acts as a vigilant guardian against potential faults and overloads. Employing advanced sensing and monitoring mechanisms, it can swiftly detect anomalies in the motor's operation and promptly respond by triggering protective measures. These safeguards shield the motor from potential damage, preventing costly repairs and downtime. In summary, a motor controller is a highly sophisticated and indispensable component in modern electric motor systems. Its comprehensive functionalities encompass everything from precise motor control and speed regulation to protection against adverse conditions, guaranteeing optimal performance, safety, and longevity of electric motors across various industrial and commercial applications.



Figure 2 Controller

## 2.2. Battery

An electric battery represents a marvel of modern engineering, comprising multiple electrochemical cells designed to harness and transform stored chemical energy into a valuable electrical resource. Within these cells lie two vital components: the positive terminal, known as the cathode, and its counterpart, the negative terminal, referred to as the anode. These elements are at the core of the battery's operation, orchestrating the intricate dance of energy conversion. Key to the battery's functionality are the electrolytes, which serve as conductive bridges between the electrodes and terminals. These electrolytes facilitate the movement of ions, allowing them to traverse between the electrodes, ensuring a smooth flow of electric current. Consequently, this well-orchestrated flow of electricity enables the battery to channel its power outward, empowering various devices and systems to perform their intended tasks. In essence, an electric battery is an elegant amalgamation of scientific principles and innovative engineering, enabling us to unlock the vast potential of stored energy and utilize it efficiently for our benefit.



Figure 3 Battery



### 3. Alternator

An alternator is a remarkable electrical generator that efficiently converts mechanical energy into electrical energy in the form of alternating current (AC). To achieve cost-effectiveness and simplicity, the majority of alternators employ a design consisting of a rotating magnetic field and a stationary armature. In some instances, a linear alternator or a rotating armature with a stationary magnetic field may be used. Broadly speaking, any AC electrical generator can be categorized as an alternator, but the term is commonly associated with small rotating machines that are driven by automotive and other internal combustion engines. An alternator that utilizes a permanent magnet for its magnetic field is referred to as a magneto. Additionally, alternators employed in power stations, which are driven by steam turbines, are known as turbo-alternators. It's worth noting that the world's electric power generation largely relies on large 50 or 60 Hz phase alternators in power plants. These high-capacity alternators play a pivotal role in generating the majority of the global electric power supply, which is then efficiently distributed through electric power grids, providing energy to countless homes, industries, and institutions worldwide.

The equations used for calculating the alternator speed and poles are:

1. No. of poles of alternator  $P = \frac{120 \cdot f}{N}$
2. Speed of Alternator  $N = \frac{120 \cdot f}{P}$

### 3. DC – DC CONVERTER

A DC-to-DC converter plays a crucial role in the world of electronic circuits by enabling the transformation of direct current (DC) from one voltage level to another. This ingenious device falls under the class of power converters, making it indispensable in various applications. Notably, it holds immense significance in the realm of portable electronic gadgets like cellular phones and laptops, which heavily rely on battery power. As these electronic marvels encompass multiple sub-circuits, each with its unique voltage level requirements, the DC-to-DC converter comes to the rescue, bridging the gap between the battery's or external supply's voltage and the specific needs of individual circuits. This versatility allows devices to operate seamlessly and efficiently with varying voltage demands. The significance of DC-to-DC converters becomes even more apparent when considering the inevitable decline in battery voltage as its stored energy gets gradually depleted. By adeptly adjusting the voltage levels, these converters ensure a consistent and stable power supply to the device's components, regardless of the battery's diminishing energy. In essence, the ingenuity of DC-to-DC converters lies in their ability to harmonize different voltage levels, making them essential components for the seamless functionality and longevity of countless portable electronic devices we rely on daily.

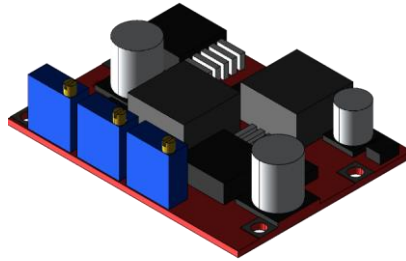


Figure4 Buck Booster

#### 4.Magnetic conversion method

The statement you provided accurately describes the operation of DC-to-DC converters, particularly those that utilize inductors or transformers. Let's break down the key points:

1. **Energy storage and release**: DC-to-DC converters store energy in a magnetic field either in an inductor or a transformer. During the on-time of the switch (when the input voltage is applied), energy is stored in the magnetic field. During the off-time (when the input voltage is disconnected), the energy is released from the magnetic field to the output.
2. **Frequency range**: These converters typically operate at frequencies ranging from 300 kHz to 10 MHz. Higher frequencies allow for smaller passive components (inductors and capacitors), which can result in more compact and efficient designs.
3. **Duty cycle**: The duty cycle of the converter refers to the ratio of the on-time to the total switching period. By adjusting the duty cycle, the amount of power transferred from the input to the output can be controlled. This allows for regulation of the output voltage, output current, or maintenance of constant power.
4. **Output voltage control**: The primary application of adjusting the duty cycle is to control the output voltage. By varying the duty cycle, the average voltage delivered to the output can be controlled, thereby regulating the output voltage level.
5. **Isolation**: Transformer-based DC-to-DC converters provide galvanic isolation between the input and output, which means there is no direct electrical connection between the two. This isolation can be beneficial for safety, noise reduction, and voltage level shifting.
6. **High fluency**: The term "high fluency" seems out of context in this context. It may be a typo or misinterpretation. Transformer-based converters are known for their efficiency and reliability, but it's unclear how "high fluency" would be relevant here.

Overall, DC-to-DC converters are essential in various electronic devices and power systems as they facilitate voltage regulation, power conversion, and isolation in a compact and efficient manner.



## 5. INTERCONNECTIONS AND WORKING

In this operation, the BLDC hub motor is driven by a set of four batteries connected in series. These batteries provide an output voltage of 48V and a current capacity of 28Ah, forming the powertrain of the vehicle. The motor is connected to a pulley through a belt drive system, which propels the vehicle, acting as the drivetrain. As the vehicle starts moving, the pulley keyed to the rear axle connects to the alternator spindle via a belt, causing the alternator pulley to rotate. This rotation disturbs the magnetic flux, leading to the generation of voltage and current. This generated electrical energy is then diverted towards a charging battery with a capacity of 12V and 7Ah. The charging battery is connected to a 12-54V DC-DC converter, which serves the function of stepping up the 12V output from the charging battery to 48V. The converted 48V is then supplied back to the set of four drive batteries, completing the cycle. This continuous process allows the BLDC hub motor to draw power from the set of four drive batteries, while the alternator generates electrical energy that charges the 12V battery. The DC-DC converter efficiently steps up the voltage from the charging battery, ensuring that the set of drive batteries receives the required 48V to keep the motor running smoothly. Overall, this system demonstrates an effective way to power the BLDC hub motor, recycle energy through the alternator, and maintain a sustainable and efficient drive train for the vehicle. Please refer to Figure 5 for a visual representation of the system.

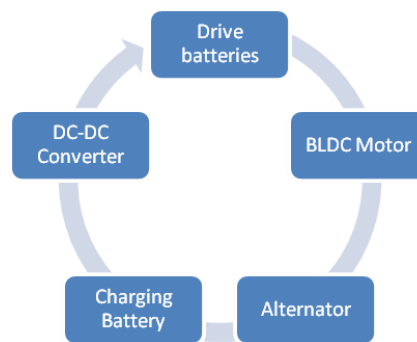


Figure5 Working Cycle

## 6.RESULTS AND DISCUSSION

The battery electric vehicle has been meticulously designed, considering various essential factors to ensure optimal performance. The chassis frame has been skillfully equipped with all necessary connections and supports. The primary objective of this vehicle is to provide a continuous source of power to charge the battery while it moves forward. Through numerous trials, the connections have been successfully established to supply the required power based on the vehicle's demand. A set of 4 Lead acid batteries, each with a voltage rating of 12V and a capacity of 7Ah, has been selected for the project. These batteries have proven to be effective in propelling the vehicle for a distance of approximately 4 km. During the vehicle's operation, rotational energy is harnessed using an alternator and then transmitted to a DC to DC converter, where it undergoes a step-up transformation. Ultimately, this enhanced power



is supplied back to the battery source, creating a closed circuit that ensures continuous recharging. To evaluate the effectiveness of the system, a multimeter is used to measure two critical parameters: voltage source and ampere. These measurements are taken at different points in the closed circuit to gauge the efficiency and reliability of the charging process. Table 1 presents the results obtained from numerous trials in the defined closed circuit. The data collected demonstrates the consistent performance of the system, with stable voltage levels and appropriate ampere readings, reaffirming the success of this well-executed design. In conclusion, the battery electric vehicle has been thoughtfully constructed and thoroughly tested to ensure a reliable and efficient power supply system. The combination of lead acid batteries, the alternator, and the DC to DC converter has proven to be a successful arrangement, effectively powering the vehicle and enabling it to cover substantial distances without compromising on performance.

Table 1 Input and Output Results

Test Trials	Alternator output		Input alternator DC-DC converter		Output from DC-DC Converter to drive batteries	
	V	A	V	A	V	A
	1.	12.9	0.3	12	4	54
2.	13.2	0.3	12	4	54	1
3.	12.8	0.3	12	4	54	1
4.	13.1	0.3	12	4	54	1
5.	13.0	0.3	12	4	54	1

A graph has been constructed to illustrate diverse loading conditions and distinct vehicle speeds. On the horizontal x-axis, the speed of the vehicle is depicted in kilometers per hour (km/hr). Meanwhile, the vertical y-axis portrays the distance covered by the vehicle in kilometers (km).

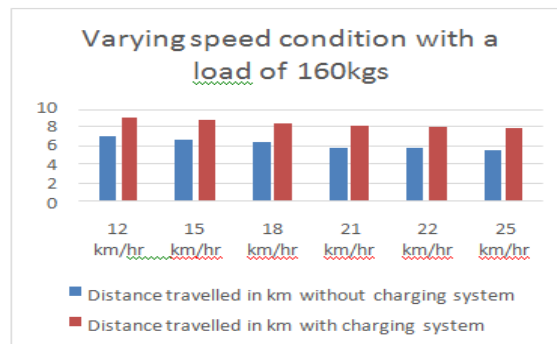


Figure 6 Distance comparison graphs with load of 160kgs

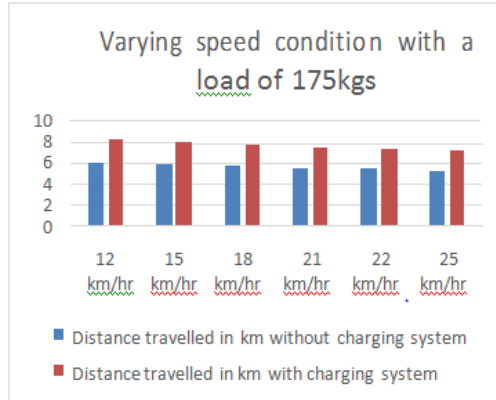


Figure7 Distance comparison graphs with load of 175kgs

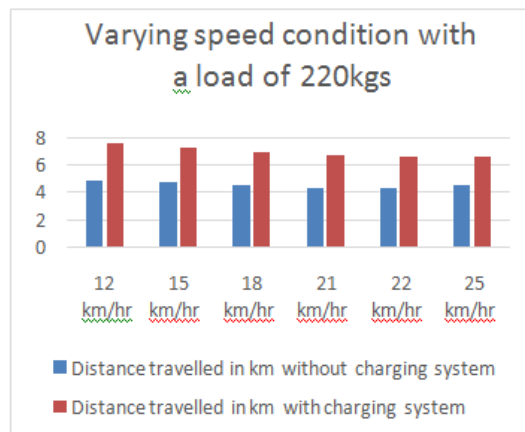


Figure 8 Distance comparison graphs with load of 220kgs

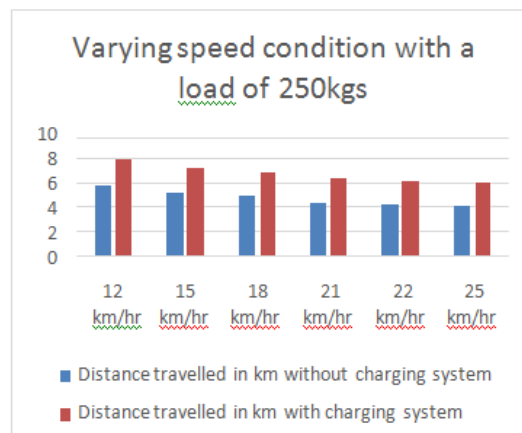


Figure 9 Distance comparison graphs with load of 250kgs



## 7. CONCLUSION

The project aimed to develop a battery electric vehicle for closed circuit areas such as railway station platforms, golf clubs, hospital corridors, and industries. The primary objective was to replace the concept of plug-in charging, commonly found in conventional battery electric vehicles, with a self-charging mechanism. The work involved studying existing technology, components utilization, and the future of battery electric vehicles to frame the outline of the electric vehicle. The vehicle was designed to carry either two passengers or a maximum weight of 250 kg. In the project, several key components were considered, including the alternator system, motor, motor controller, and DC-DC converter, which are widely used in the automotive industry. The use of these components was essential to develop an efficient and practical electric vehicle for the specific use case. Graphs were plotted to analyze the vehicle's performance, and the results indicated that adopting a charging system improved the vehicle's range. This suggests that the self-charging mechanism, powered by the rotational energy from the wheels through an alternator, was successful in charging the series-connected batteries. During testing, the vehicle was connected to the DC-DC converter to supply power to the batteries for multiple trials. The outcome of these tests demonstrated the successful extraction of rotational energy from the wheels, generating 12V - 14V using the alternator under forward motion. The DC-DC converter was then utilized to step up the source voltage from 12V DC to 54V DC, effectively charging the batteries used in the vehicle. Overall, the project showcased promising results, presenting a viable solution for developing a self-charging battery electric vehicle for closed circuit areas. The use of well-established components and the successful implementation of the self-charging mechanism proved the feasibility and effectiveness of the proposed concept. To calculate the self-charging capability of a bike, you'll need to consider various losses and efficiencies. Here are some of the key factors involved.

To calculate the overall efficiency of the self-charging system, you'll need to multiply the efficiencies of each individual component together. For example, if the mechanical efficiency is 90%, the generator efficiency is 80%, the battery charging efficiency is 85%, and the battery storage efficiency is 90%, the overall efficiency would be:

$$0.9 \text{ (mechanical)} * 0.8 \text{ (generator)} * 0.85 \text{ (charging)} * 0.9 \text{ (storage)} = 0.55 \text{ or } 55\%$$

This means that only 55% of the mechanical energy put into pedaling would be effectively stored in the battery. Keep in mind that these numbers are hypothetical and you would need to find or measure the actual efficiencies for the components you are using.

## ACKNOWLEDGEMENT–.

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