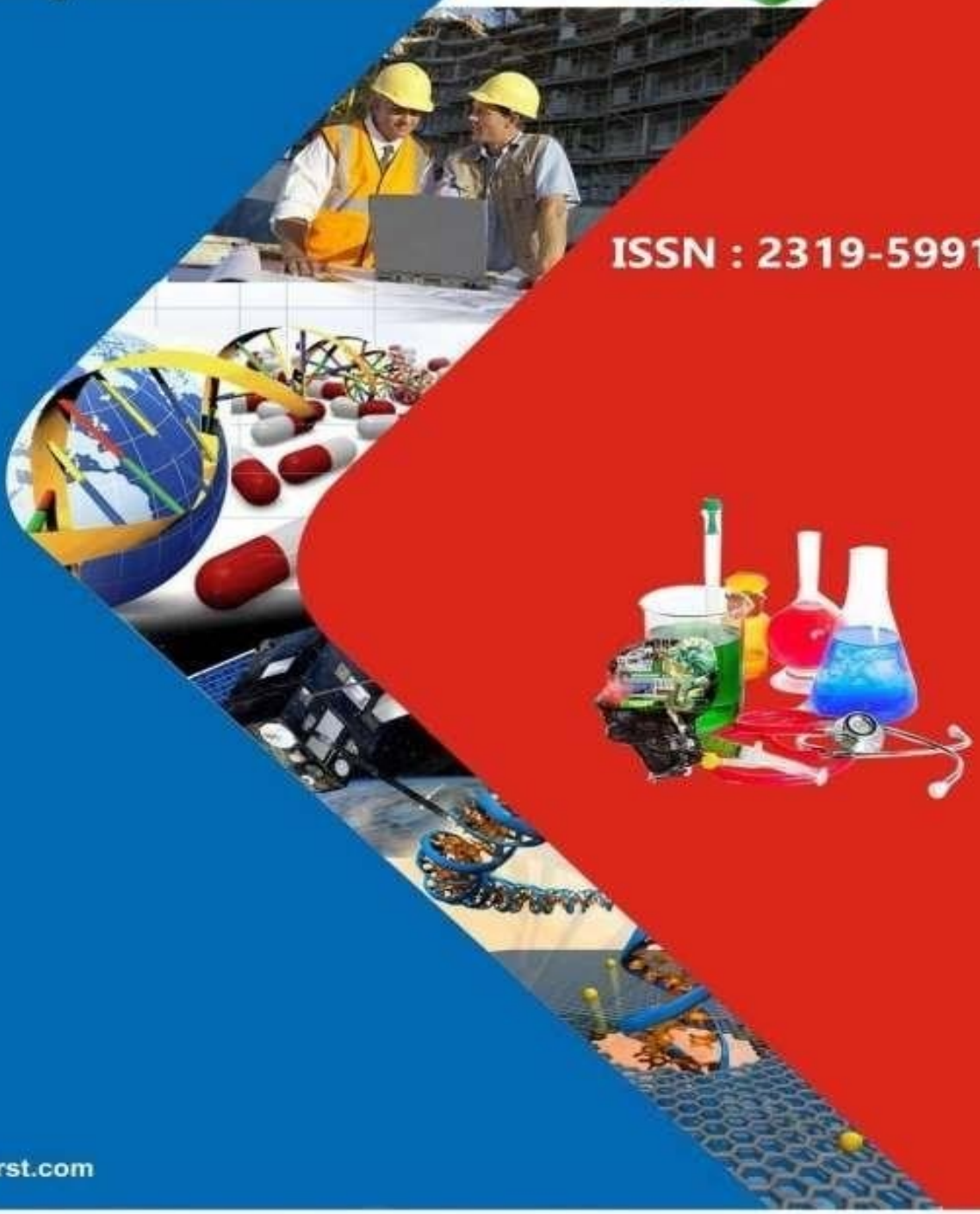
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Enhancing Fuel Efficiency and Performance in Two-Wheelers via Hybrid Retrofitting

[1]A. Rohith Ramachandra Gowdu, [2]B. Vara Prasad, [3]G. Polinaidu, [4]K. Likhitha, [5]S. Yeshwanth [6]B. Sravani,[7]Lakkidapu Advila, [8]Dr.R.S.R. Krioshnam Naidu

1,2,3,4,5. B.Tech Students, Dept. of EEE, NSRIT, Visakhapatnam, AP

6,7Assistant Professor, Dept. of EEE, NSRIT, Visakhapatnam, AP

8 Professor & HOD, Dept. of EEE, NSRIT, Visakhapatnam, AP

NSRIT-Nadimpalli Satyanarayana Raju Institute of Technology

ABSTRACT

In India, two-wheelers are a common mode of transportation, resulting in significant petrol consumption. This growing demand for fuel contributes heavily to the country's expenditure, with 80–90% of spending allocated to petroleum imports. This dependency not only strains the economy but also drives up petrol prices, rising inflation concerns are closely linked to environmental challenges, with India being the fourth-largest emitter of greenhouse gases. The transport sector alone accounts for 13% of the country's CO_2 emissions, particularly in densely congested areas. Although there is a growing push for (EVs), widespread adoption remains challenging. A practical alternative is to retrofit existing petrol-powered scooters into hybrid electric models rather than discarding them. This strategy aligns with the National Electric Mobility Mission Plan 2020 (NEMMP 2020), promoting cleaner mobility while reducing carbon emissions. Our project focuses on improving urban transportation by converting conventional scooters into hybrid electric vehicles. The proposed system involves modifying a petrol scooter equipped with an 80cc internal combustion engine by replacing the back wheel with an electric hub motor. This transformation creates a two-wheel drive system, where the hub motor powers the back wheel and the traditional engine drives the front wheel.

Keywords: *FRID, Rear wheel, CVT.*

1. INTRODUCTION

To overcome the limitations of conventional vehicles, the proposed system introduces a Front and Rear Wheel Independent Drivetrain (FRID) designed to improve vehicle efficiency and performance. This drivetrain setup integrates key aspects such as engine power, electric traction motor, energy sources, and drivetrain control strategies. By carefully combining these elements, the system achieves optimal gradeability, acceleration, and top speed, resulting in a highly efficient hybrid electric vehicle. The FRID system features essential components like an engine controller, motor controller, and electric motor, each playing a vital role in managing the vehicle's propulsion. The parallel FRID design is specifically developed to meet the following objectives:

- Achieving desired gradeability, acceleration, and maximum speed
- Delivering an overall efficient hybrid electric vehicle

In the case of FRID type vehicles like engine controller, motor controller and electric motor are the main components present in this drivetrain arrangement. By controlling the propulsion of sources present in this drivetrain configuration, ICE, electric motor, the torque has to be controlled independently [1]. Working on the parallel hybrid drive train for a scooter with simulation data

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[2] by controlling the torque delivery of both the internal combustion engine (ICE) and the electric motor independently, the system effectively balances power output for improved performance. Simulations conducted on a parallel hybrid drivetrain for a scooter demonstrate that hybrid electric vehicles outperform conventional ICE-powered vehicles due to optimized engine operation, resulting in improved energy efficiency. Additionally, fluctuating global oil prices have accelerated interest in electric vehicles; however, widespread EV adoption continues to face various challenges. As a viable alternative, hybrid electric vehicles offer a practical solution by combining ICE reliability with electric efficiency. In the proposed design, replacing the front wheel of a two-wheeler with an electric hub motor while retaining the original Continuously Variable Transmission (CVT) system on the rear wheel ensures both wheels can provide propulsion torque independently. This design enhances flexibility and adaptability in diverse driving conditions. The hybrid electric scooter's control strategy differs from renewable scooter as it employs a dedicated motor controller integrated with an step unit to regulate the electric motor's performance. Furthermore, an essential energy management system is included to optimize power distribution between the ICE and electric motor, ensuring the vehicle meets performance expectations while enhancing overall efficiency. By leveraging these features, the proposed FRID system offers an effective solution for improving the performance, efficiency, and environmental impact of two-wheelers.

This strategic transition protects the battery from the high starting current required by the motor, ultimately enhancing battery life and performance. Furthermore, hybrid scooters demonstrate improved efficiency due to a greater reliance on electric mode, which optimizes energy consumption. During emergency situations, the scooter can still operate using the engine mode, ensuring reliability when battery power is unavailable.

The system offers three distinct driving modes for optimal performance and efficiency:

1. **Economy Mode:** Uses the electric motor exclusively for propulsion, ensuring energy efficiency.
2. **Power Drive Mode:** Operates solely on the internal combustion engine for higher power demands.
3. **Hybrid Mode:** Combines both power sources for enhanced performance and flexibility.

By adopting this retrofitting approach, we aim to improve vehicle efficiency, reduce environmental impact, and contribute to achieving the goals outlined in NEMMP 2020.

1. LITERATURE REVIEW

The literature surrounding Hybrid Electric Vehicles (HEVs) underscores the growing significance of alternative vehicle technologies in addressing the challenges of fuel consumption, environmental impact, and energy efficiency in the transportation sector. Researchers and experts have delved into various aspects of HEVs, ranging from design considerations to performance evaluations, highlighting the potential of hybrid technology to revolutionize the automotive industry. Nataraj (2014) [9] emphasized the importance of reducing fuel consumption and exhaust emissions in the automotive sector, citing Hybrid Electric Vehicles as a significant innovation in achieving higher efficiency and lower emissions. The study analysed the combined propulsion efforts of internal combustion engines and electric motors, particularly in urban settings, showcasing the benefits of hybridization for enhancing overall vehicle performance. Malik and Kumar (2017) [10] conducted a comprehensive review of Hybrid Electric Vehicles, focusing on their ability to deliver comparable performance to conventional vehicles while significantly improving fuel efficiency and reducing emissions. The study explored different hybrid drive train configurations, such as series, parallel, and series-parallel, and

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highlighted the role of advanced battery technologies in optimizing the performance of HEVs. Hazarathaiah et al. (2019) [11] contributed to the field by designing and fabricating a hybrid electric bike, showcasing the practical application of hybrid technology in two-wheeled vehicles. The study underscored the advantages of hybrid electric vehicles, which leverage both batteries and internal combustion engines for propulsion, offering enhanced efficiency and reduced environmental impact compared to traditional vehicles. The studies highlight how Hybrid Electric Vehicles (HEVs) can reduce environmental impact, lower fuel consumption, and improve energy efficiency in transportation. Researchers are advancing HEVs' design, performance, and practical applications, paving the way for a greener automotive industry

2. PROPOSED WORK METHODOLOGY

The proposed system presents a method to enhance the efficiency of conventional scooters by converting them into hybrid electric vehicles that incorporate both an internal combustion engine (ICE) and an electric motor. This design focuses on improving mobility and optimizing performance efficiency and reduce environmental impact it shows in Fig1.

3.1 Vehicle Configuration and System Design

The proposed hybrid scooter is based on a conventional two-wheeler with an **80cc petrol internal combustion engine**. To transform this vehicle into a hybrid model:

- The **rear wheel** continues to be powered by the petrol engine.
- The **front wheel** is replaced with an **electric hub motor**, enabling two-wheel drive functionality.
- This configuration allows the scooter to operate using different propulsion modes based on driving conditions and power requirements.

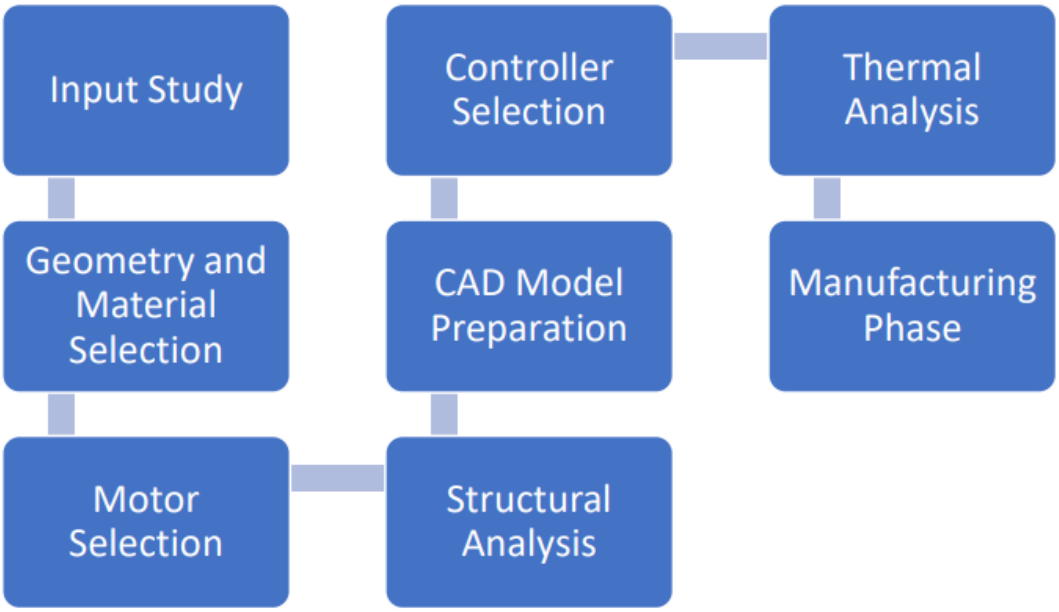


Figure 1: *Methodology chart*

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3.2 Mode Selection and Operation: The proposed system features **three distinct driving modes** designed to optimize performance, energy efficiency, and reliability.

3.2.1. Economy Mode (Electric Motor Only)

- In this mode, the scooter starts and operates using only the front-wheel electric hub motor.
- This mode is ideal for low-speed conditions such as **start-stop traffic** or **crawling traffic**, where conventional engines are highly inefficient and consume excessive fuels. EV Motors are inherently more efficient in such conditions as they consume no power while idling. This feature enhances mileage and conserves fuel during frequent stops it shows in Fig1.

3.2.2. Power Drive Mode (Internal Combustion Engine Only)

- In this mode, the scooter starts and runs solely on the petrol engine, which powers the rear wheel.
- This move is intended for **emergency situations**, such as when the battery is fully discharged or if there is a malfunction in the electric motor it shows in Fig2.
- Power Drive Mode ensures the scooter remains functional even if the hybrid system encounters an issue.

3.3.3. Hybrid Mode (Combined Power Sources)

- In Hybrid Mode, the scooter combines the capabilities of both the internal combustion engine and the electric motor to optimize efficiency and performance.
- During start-up, the scooter initially relies on the ICE to provide sufficient torque to overcome inertia.
- After a **12-second delay**, the front-wheel electric hub motor takes over, maintaining propulsion at optimal energy efficiency.
- If the battery's charge level is low, the system seamlessly combines the power of both the ICE and the electric motor to maximize mileage.
- By avoiding battery usage during initial acceleration, the system helps improve battery life and performance.

3.3 Key Components and System Integration: To implement this hybrid drivetrain system, several essential components are integrated:

3.3.1 BLDC Motor (Brushless DC Motor):

- A **1500-watt** BLDC motor is employed to power the front wheel.
- BLDC motors are known for their high efficiency, reliability, and low maintenance requirements.

3.3.2 Lithium-ion Battery Pack:

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The system includes **four lithium-ion batteries** connected in series. Each battery has a capacity of **60 volts** and **32Ah**, providing sufficient energy for the electric motor. Lithium-ion batteries are preferred for their superior energy density, longer life cycle, and consistent performance it shows in fig2.

3.3.3 Control Units:
The system employs two key control units to manage propulsion sources and optimize performance: BLDC Motor Controller: Serves as an interface connecting the electric motor, accelerator, braking system, and battery.

3.3.4 Primary Control Unit: This unit coordinates interactions between the BLDC motor controller, the internal combustion engine, and the battery pack.

3.3.5 Miniature Circuit Breaker (MCB): An **MCB** is incorporated for protection, ensuring the system remains safe from electrical faults or overload conditions it shows in Fig2.

3.3.6 Performance Optimization: To achieve optimal performance, the proposed system follows these design strategies: **Efficient Energy Use:** The hybrid system prioritizes electric motor usage in traffic conditions to minimize fuel consumption. **Enhanced Torque and Speed:** The combination of a **high-wattage BLDC motor** and **optimized ICE control** ensures improved acceleration, climbing ability, and top speed. **Battery Longevity:** Since the battery is not utilized during the initial start-up phase in Hybrid Mode, its overall lifespan and efficiency are improved.

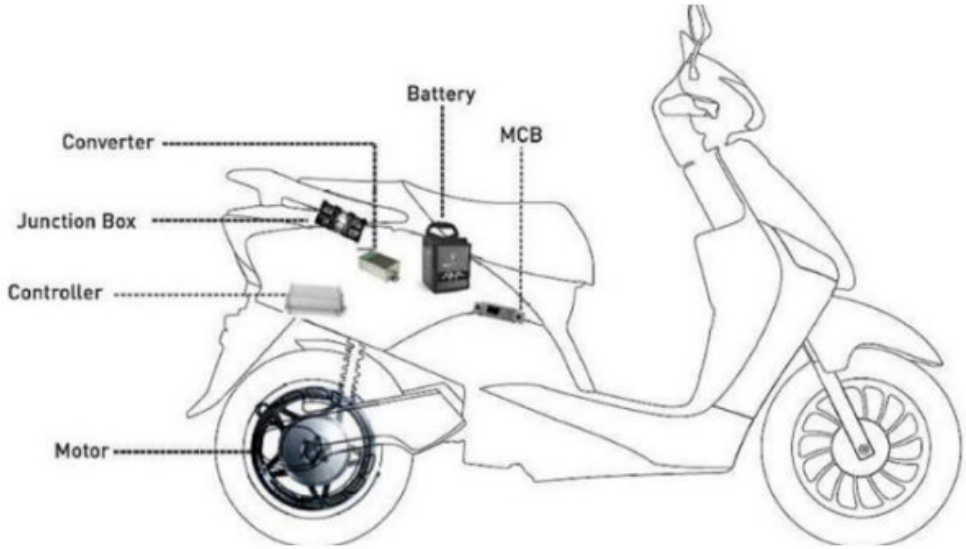


Figure 2: *Retrofitting*

The proposed hybrid system effectively combines the strengths of both ICE and electric motors, providing a cost-effective solution for improving urban mobility. By integrating the three operational modes — **Economy Mode**, **Power Drive Mode**, and **Hybrid Mode** — the system aims to achieve an overall efficiency of up to **90%**, ensuring improved mileage, reduced emissions, and enhanced scooter performance.

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This retrofitting approach aligns with the goal of enhancing energy efficiency in transportation while making sustainable mobility solutions more accessible.

The above Fig. 3 shows the block diagram of FRID type vehicles. This hybrid powertrain uses 746W driven front wheel and the rear wheel is driven by a conventional engine. Four Li-ion battery having a rating of 12V, 9Amph each are connected in series to deliver power to the motor. The batteries can be charged through an external electric source. The control strategy is developed such as both the wheels The scooter be powered either independently or simultaneously by the motor and engine, depending on its operational needs. It offers three distinct driving modes:

1. **Economy Mode:** Propelled solely by the motor.
2. **Power Drive Mode:** Propelled exclusively by the engine.
3. **Hybrid Mode:** Utilizes both the motor and engine together for propulsion.

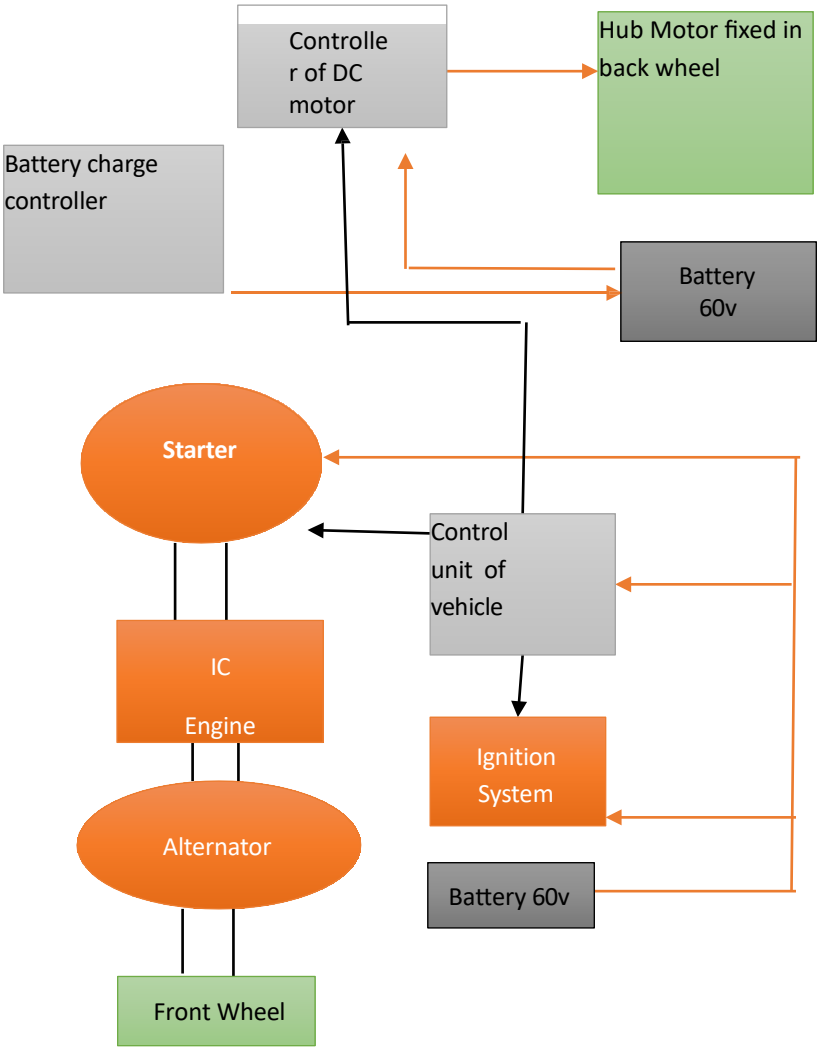


Figure 3: *Block diagram*

4. Simulation results:

The 3rd mode of operation is hybrid mode. It's shown by simulated data for the given mode

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operation. For simulation purpose, followings are main components:

- BLDC Motor
- Lamp (Indicates supply to ignition system)
- 555 delayed timers off circuit
- Resistors- 10K, 100K, 2.2K
- Capacitors- 0.1µF, 100 µF
- Transistor (BC547)

Now off delay time of timer can be set as: Time Period (T) =1.1×R1×C1

T= 1.1×100k ×0.1µF
T=12 seconds

As a result, when the push button is pressed, there will be a 10-second delay before the lamp, indicating power to the ignition system, lights up. After 12 seconds, the ignition system's power supply will be disconnected, and the BLDC motor will be powered instead.

5. IMPLEMENTAION:

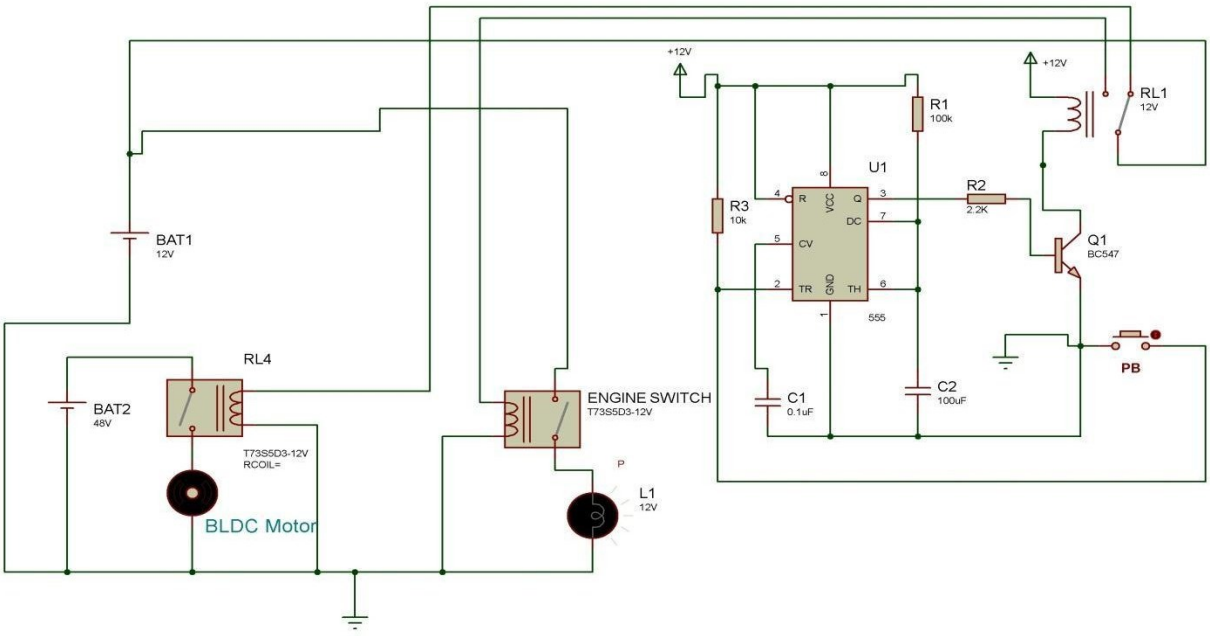


Figure 4: *Circuit of before simulation.*

This circuit indicates that both the lamp and the Brushless dc motor are in the off state. Since the push button is not turned and the relay is default stage.

In hybrid electric vehicles (HEVs), the ignition system plays a vital role in initiating combustion in the internal combustion engine (ICE). Common ignition systems include conventional, electronic, and capacitor discharge ignition (CDI) systems, with CDI being widely used in hybrid scooters for its fast and efficient spark generation. The ignition system ensures smooth engine startup, particularly in Power Drive Mode and during initial phases of Hybrid Mode.

The Brushless DC Motor (BLDC) is an essential component in hybrid scooters, known for its high efficiency, precise torque control, and low maintenance. It operates without brushes, reducing wear and enhancing performance. In hybrid scooters, the BLDC motor typically drives the front wheel, improving efficiency in Economy Mode and assisting the ICE in Hybrid Mode. The BLDC motor's ability to provide instant torque makes it ideal for urban traffic, while its support for regenerative braking further enhances energy efficiency.

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By combining an efficient ignition system with a BLDC motor, it shows in Fig 5 hybrid scooters achieve Enhanced fuel efficiency, lower emissions, and improved performance make them a viable solution for promoting sustainable urban mobility.

BLDC Hub Motor: A high efficiency electric motor is essential for providing propulsion to the scooter. The motor should be selected based on power output, torque, size, and compatibility with the scooter's existing systems it shows in Fig 5.

Throttle: The throttle plays a crucial role in regulating the airflow into the engine of a vehicle, thereby controlling its speed and power output. alongside the throttle's control over the internal combustion engine, it also communicates with the electric motor(s). Depending on the hybrid system ' s design (series, parallel, or series parallel).



Figure 5: *Circuit of supply to ignition system and supply given to Brush less dc Motor*

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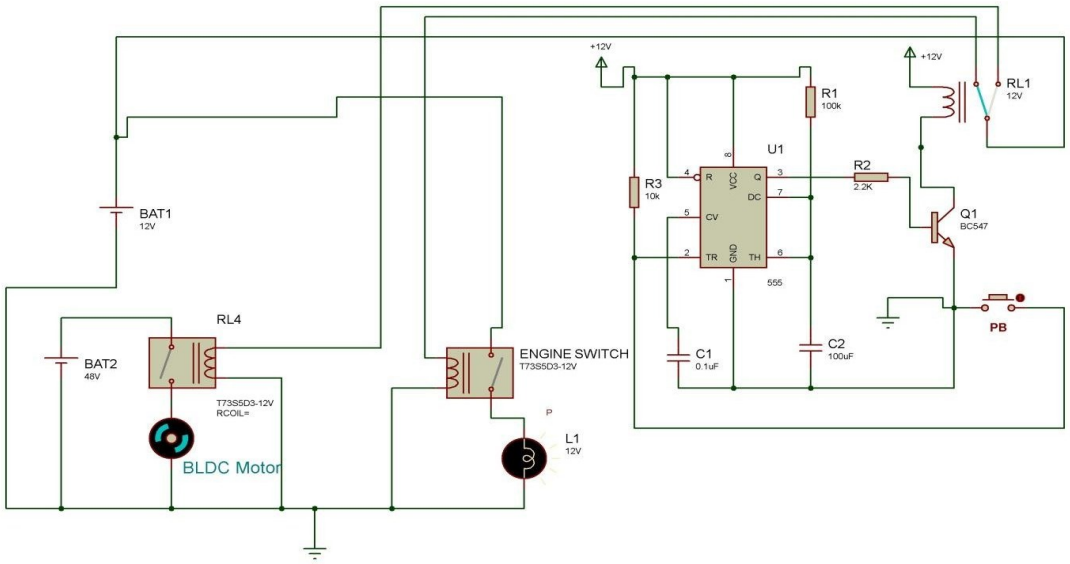


Figure 6: *supply to ignition system.*

As push button is pressed, the relay is switched from its normal position. These circuit shows that lamp is in the on state hence, there is supply to ignition system and scooter will start on the engine.

Battery Pack: An electronic controller manages the power delivery from the battery pack to the electric motor. It regulates the motor's speed, torque, and efficiency, ensuring smooth operation and optimal performance it shows in Fig 8.

Charger: A charger unit is necessary for recharging the battery pack when the scooter is not in use. The charger should be compatible with the battery pack's specifications and provide efficient and safe charging

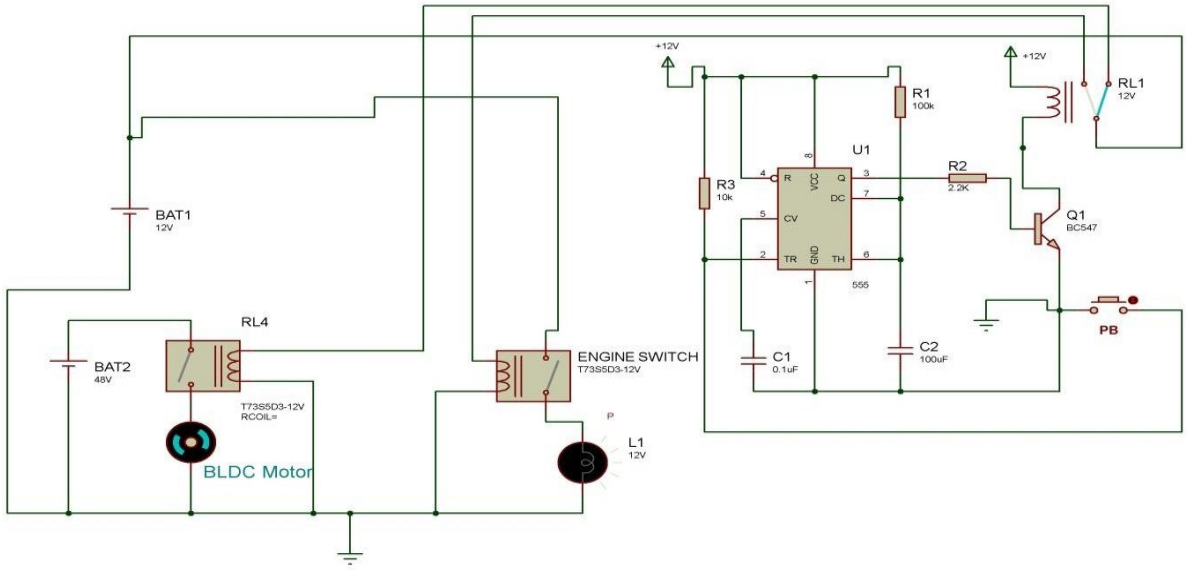


Figure 7: *supply given to Brush less dc Motor*

After a delay of 12 seconds, the main relay will return to its initial position. As a result, the ignition system's power supply will be disconnected, and the BLDC motor will be powered instead. This transition effectively switches the system to electric mode operation.

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6. CALCULATIONS:

For BLDC Motor:

$Torque = \frac{(Power \times 60)}{(2 \times v \times speed)}$

$Torque = \frac{(1500 \times 60)}{(2 \times 3.14 \times 1440)} = 9.95Nm$

$Efficiency = \ = \frac{(output\ Power)}{(input\ power)} \times 100$

$Efficiency = 48 \times 13.20 \times \frac{100}{48} \times 15.54 = 85\%$

Speed in kmph = $D \times RPM \times 0.001883$

Speed in kmph = $30 \times 1440 \times 0.001883$

Speed in kmph =$81.34\ Km/hur$

Battery Calculations:

Battery rating : $60V, 30Ah$

No of batteries used:1

Let average current drawn: $6A$

$In\ one\ charge\ it\ can\ complete = 81.34 \times \frac{30}{6} = 406$

7. ASSUMPTIONS:

Petrol price in liters=100Rs.

Electricity price in units = 6Rs.

Energy / charge = 0.532 Kilo watt/hur

Distance covered by 1 Year = 15000Km

Years used = 1years

Battery pack price = 8000Rs.

One year driving distance= 2000Km

Table 1: *components Ratings*

Make – TVS
Model: HONDA AVAITOR
Max Power: 3.5BHP
Displacement: 87.8cc
MaximumTorque:5.8Nm@4000rpm
Number of gears: Automatic
Net Weight: 104KG
Fuel Tank Capacity: 3.5liters

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Motor Ratings:
Motor Type: Brushless DC motor
Power: 1500 Watts
Voltage: 60Volts
Rated Current: 15.54A
Wheel Motor diameter-12inches=12*2.5=30cm
Controller Ratings:
Voltage: 48V
Current: 5-10 Amps
Battery Ratings:
Battery Type: Lithium ion
Voltage: 60V
Ampere hour rating: 30
Tested Parameters:
Speed (RPM) = 1440Ampere
No load current=3Ampere
Full load current=15.20Ampere

Table 2: *Cost calculations for electric and engine scooter*

For Electric Scooter:
Cost of Vehicle= 60,000Rs.
Range of Charge= 85 Km/Charge
Maintenance cost= 2000Rs.
Battery Cost= 10000Rs.
Units of power consumed considering 612 charges=
612×0.432×5=1321.92Rs.
Total Cost= 60,000+3000+10000+1321.92
=74321.92Rs ~ 74,330Rs.
For Engine operated Scooter:
Cost of Vehicle= 60,000Rs.
Mileage/Km/liter = 50 Km/Charge
Maintenance cost= 10,000Rs.
Liters of petrol consumed= 720
Cost of petrol consumed= 720×78
=56,160Rs.
Total Cost= 60,000+10,000+56,160
=1, 26,160Rs

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8. Working Models:



Figure 8- *Student working analysis*

CONCLUSION

This project demonstrates that hybrid scooters offer several advantages over both fully electric and fully engine-operated scooters. Key benefits include the flexibility to operate in either engine mode or electric mode independently, allowing the hybrid scooter to harness the strengths of both systems. Hybrid scooters consume less fuel compared to traditional engine-operated models, reducing running costs while also minimizing pollutant emissions, contributing to a more environmentally friendly solution. In hybrid mode, the scooter starts using the internal combustion engine (ICE) and, after a predetermined delay, switches to electric mode.

However, it is important to note that the maintenance cost of hybrid scooters is greater than of conventional engine-scooters. Despite this, hybrid scooters excel in delivering higher torque, addressing one of the common limitations of fully electric scooters. Given these benefits, hybrid scooters emerge as a more versatile and practical alternative to both fully engine-operated and electric

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scooters. In light of rising crude oil prices, transitioning to electric vehicles is becoming increasingly crucial. However, this shift may be challenging for the general public to adopt immediately. An efficient and economical approach to advancing sustainable mobility is to convert existing petrol-powered scooters into hybrid electric models instead of discarding them. This strategy not only extends the lifespan of these vehicles but also makes eco-friendly transportation more accessible. Given India's substantial two-wheeler market — with approximately 2 crore units sold in 2017-18, of which 40% were scooters — this project highlights retrofitting as a practical and impactful solution. By adapting current systems, the project effectively tackles common challenges faced by electric scooters, such as limited speeds and inadequate charging infrastructure. Furthermore, this initiative contributes to lowering CO_2 emissions and reducing dependence on crude oil imports, offering both environmental and economic benefits. Ultimately, this innovation supports sustainable mobility while remaining affordable for consumers.

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