Retrofitting a Three-Wheeler into a Solar-Assisted Electric Vehicle: A Sustainable Solution for Urban Mobility

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ABSTRACT

This research investigates the feasibility of converting a traditional three-wheeler into a fully electric vehicle equipped with an on-board solar charging system. The project aimed to address environmental concerns associated with internal combustion engines and promote sustainable transportation. The conversion process involved replacing the existing engine and fuel-related components with an electric motor, batteries, and associated components. A comprehensive evaluation of the prototype's performance was conducted, encompassing maximum speed (30 km/h), grading capacity (1 degree), acceleration (0.106 m/s^2), and driving range (34 km). The electric three-wheeler incorporated four solar panels on the roof and four 12V/26Ah batteries beneath the driver's seat. A DC motor provided the necessary torque and power through a chain-sprocket mechanism. A mechanical reverse system enabled backward movement without altering the motor's rotational direction. The on-board solar charging system extended the driving range by 17 km. The findings demonstrate the potential of converting traditional three-wheelers into electric vehicles, offering a sustainable and eco-friendly transportation solution. The proposed system provides a promising alternative for urban mobility, contributing to reduced emissions and improved energy efficiency.

Keywords - electric three-wheeler, conversion, solar charging, performance evaluation, sustainable transportation, environmental impact.

INTRODUCTION

The urgent need to address climate change and reduce greenhouse gas emissions has intensified the search for sustainable transportation solutions. The transportation sector, particularly road vehicles, is a major contributor to carbon dioxide (CO_2) emissions. To mitigate these environmental impacts, the automotive industry has shifted its focus towards electric vehicles (EVs). EVs offer significant advantages over traditional internal combustion engine (ICE) vehicles, including zero tailpipe emissions, reduced noise pollution, and improved energy efficiency. However, the transition to EVs requires substantial investments in infrastructure, battery technology, and manufacturing processes. One approach to accelerating the adoption of EVs is to convert existing vehicles into electric powertrains. This strategy can leverage existing infrastructure, reduce the environmental impact of new vehicle production, and provide a more affordable option for consumers [1,9].

This research investigates the feasibility of converting a conventional three-wheeler into a solar-assisted electric vehicle [2,10]. The project aims to demonstrate the potential of electric vehicle conversion and the benefits of integrating renewable energy sources.

The primary objectives of this study are:

Vehicle Conversion: To successfully modify a three-wheeler to accommodate an electric powertrain, including the installation of an electric motor, batteries, and associated components [3,4,11].

Solar Integration: To design and implement a solar panel-based charging system that can supplement the battery capacity and extend the vehicle's range [5,12].

Performance Evaluation: To comprehensively assess the performance of the converted electric three-wheeler under various driving conditions, including maximum speed, acceleration, grading capacity, and driving range [6,13].

The following sections delve into the methodology, results, and discussion of this research, providing valuable insights into the technical challenges, environmental benefits, and economic implications of electric vehicle conversion.

In India, the majority of three-wheelers continue to be powered by petrol, with a limited number of electric three-wheelers, primarily imported from China, being introduced since 2020. However, the adoption of electric three-wheelers for commercial transport remains low due to the lack of adequate charging infrastructure. The restricted driving range, caused by the limited capacity of the battery packs, and the extended charging time compared to the quick refuelling of internal combustion engine (ICE) vehicles, further limit their commercial viability [7,14]. This scenario underscores the need for significant research to develop faster charging technologies that can match the short refuelling times of ICE vehicles. Commercial three-wheeler owners in India typically need to operate their vehicles for an entire day to meet their daily income requirements [8,15]. This is challenging with electric three-wheelers due to their lower range and longer downtime for charging. One approach being explored to extend the range is the installation of solar panels on the vehicle roof, which has shown potential for improving the vehicle's performance by enabling on-board solar charging.

The development of electric vehicles in India can either be done by retrofitting existing petrol or diesel-powered vehicles or designing new electric vehicles from scratch. Converting outdated petrol-powered three-wheelers, especially those with a structurally sound chassis but failed engines, to electric models by replacing ICE components with electric motors, battery packs, and controllers is a cost-effective method [9,16]. This retrofitting trend, also gaining popularity in countries like Germany, provides a sustainable alternative to purchasing new electric vehicles. Governments around the world, including India, are pushing for the replacement of fossil fuel-based energy with renewable sources such as solar power, which can be integrated into electric vehicle technology to improve its efficiency and reduce environmental impact. Recent studies have demonstrated that, compared to petrol-powered vehicles, electric vehicles (EVs) have lower environmental impacts and operating costs, though their initial capital investment is higher. As production scales up, EV prices are expected to decrease, and savings from reduced fuel costs will offset the initial investment. In countries like Thailand, the conversion of conventional Tuk Tuks into electric ones has been shown to reduce production costs, depending on the condition of the vehicle and battery selection. Similarly, integrating renewable energy sources like solar power into EVs in India could further reduce emissions and operational costs [17,31].

However, public perception remains a challenge for the widespread adoption of converted electric vehicles in India. A survey conducted in Indonesia revealed that public scepticism towards EV conversions could deter manufacturers from pursuing this transition. Fast-charging infrastructure development, as recommended by several studies, is crucial to support the adoption of EVs in India. Researchers in India have also proposed dual-energy mode systems, allowing the vehicle to switch between fuel and electric modes depending on speed and battery charge, providing a more versatile solution [18,32]. Dynamic simulations of three-wheeler performance, such as those conducted in MATLAB/Simulink, have shown that torque demand increases with gradient, a factor that needs to be considered in Indian cities with varied terrain. Solar-powered electric three-wheelers, despite challenges like inconsistent solar irradiance and temperature fluctuations, have shown promise in improving the range and sustainability of electric vehicles. Therefore, continued research and development in solar-assisted charging systems, combined with government support for EV infrastructure, will be essential for the successful integration of electric three-wheelers in India's transportation system.

METHODOLOGY

System Design

To design an electric three-wheeler, we began by establishing key assumptions to determine the motor capacity. These assumptions were crucial for calculating various vehicle parameters, including load capacity, battery pack size, top speed, and maximum gradability [19,33].

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Our design process started with the following assumptions:

An average person weighs 70 kg (typical for India)

The vehicle can carry up to 400 kg

It can climb slopes of up to 10 degrees

On flat ground, it reaches a top speed of 45 km/h

To calculate the required motor capacity, we analysed different tractive resistance forces. These included aerodynamic resistance, rolling resistance, and gradient resistance. We used specific equations to model these forces accurately. To enhance the motor's torque output, we implemented a chain-sprocket mechanism. This setup consists of a smaller sprocket attached to the DC motor shaft and a larger sprocket on the differential shaft [20,34,35]. This configuration amplifies the motor's torque, thereby improving the vehicle's traction. In our design, the smaller sprocket has 11 teeth, while the larger one has 38 teeth. This gives us a sprocket ratio of 3.45. We calculated this ratio using a specific equation. Furthermore, we incorporated a differential gearbox into the design. Based on the vehicle's specifications, we determined that this gearbox provides a gear ratio of 4.125. By combining these elements - the motor, chain-sprocket mechanism, and differential gearbox - we created an efficient powertrain for our electric three-wheeler [21,36-39]. This system balances power output, torque, and speed to meet our design goals while adhering to our initial assumptions.

The following equations were used in determining the required motor capacity:

$Rs = Ndn / Ndr$ (1)

Where:

Ndn = Number of teeth on the driven sprocket (differential input shaft)

Ndr = Number of teeth on the drive sprocket (DC motor shaft)

Rs = Sprocket ratio

The total tractive resistance on sloped roads, necessary to determine the maximum torque, was calculated using the following formulas:

Aerodynamic Resistance:

$Fair = 0.5 \times \rho air \times A \times Cd \times V2$ (2)

Where:

- ρair = Air density (kg/m³)
- A = Frontal area of the vehicle (m²)
- Cd = Drag coefficient
- V = Vehicle speed (m/s)

Rolling Resistance:

$Frl = \mu rl \times m \times g \times \cos\theta$ (3)

Where:

- μrl = Rolling resistance coefficient

- m = Vehicle mass (kg)
- g = Gravitational acceleration (9.81 m/s²)
- θ = Slope angle (degrees)

Gradient Resistance:

$$F_{gr} = m \times g \times \sin\theta \quad (4)$$

Total Tractive Resistance:

$$F_{tq} = F_{air} + F_{rl} + F_{gr} \quad (5)$$

In designing the electric three-wheeler for Indian conditions, the required motor capacity was determined using various resistance forces, including aerodynamic, rolling, and gradient resistance, along with the necessary torque and power requirements.

The following formulas and parameters were used to calculate the maximum torque, power, and driving range:

Maximum Torque at the Wheel:

$$T_{wmax} = F_{tq} \times r_w \quad (6)$$

Where:

- T_{wmax} = Maximum torque at the wheel
- F_{tq} = Total tractive resistance (calculated using Eq. (5))
- r_w = Radius of the wheel

Motor Torque:

$$T_{mmax} = T_{wmax} R_s \times R_f \times s \times \eta_f \quad (7)$$

Where:

- T_{mmax} = Minimum torque provided by the motor
- R_s = Sprocket ratio
- R_f = Gear ratio of the final drive
- s = Slip factor (assumed to be 1 for ideal conditions)
- η_f = Efficiency of the final drive

Maximum Power at the Wheel:

$$P_{wmax} = F_{tq} \times V_{max} \quad (8)$$

Where:

- P_{wmax} = Maximum power at the wheel
- V_{max} = Maximum speed of the vehicle

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Motor Power:

Pmmax = Pwmax ηs × ηf (9)

Where:

- Pmmax = Minimum power provided by the motor
- ηs = Efficiency of the sprocket system
- ηf = Efficiency of the final drive

From the calculations, the maximum tractive resistance (Ftq) on a sloped road is determined to be 1616 N. Using this value, the maximum torque at the wheel is found to be 327.96 N·m, and the required power at the wheel is 3010.75 W. To meet these conditions, the motor must provide a minimum torque (Tmmax) of 40 N·m and power (Pmmax) of 5500 W.

Driving Range:

The driving range was calculated using a 48 V, 100 Ah battery pack and the following formula:

S = C × Ub × dodPm × Vmax (10)

Where:

- S = Vehicle driving range (km)
- C = Battery capacity (Ah)
- Ub = Battery pack voltage (V)
- dod = Depth of discharge
- Pm = Motor rated power output
- Vmax = Maximum vehicle speed

For a 48 V, 100 Ah battery pack with a depth of discharge (dod) of 80%, the driving range was calculated to be between 50 to 60 km per day under ideal conditions when the battery is fully charged. However, due to market limitations in India, the specified motor with the required capacity (40 N·m, 5500 W) was unavailable. Instead, performance testing was conducted using a locally available DC motor with a rated torque of 3.5 N·m and 1500 W, along with a 48 V, 26 Ah battery pack. With the available motor and battery configuration, the driving range was recalculated using Eq. (10), leading to a reduced range, which highlights the importance of optimizing component availability and performance for Indian market conditions [22-25,41].

Electric System

BLDC Motor and Controller

Motor Specifications:

Voltage: 48V

Speed: 5600 RPM

Power: 1500W

Current: 31.25A

The Brushless DC (BLDC) motor is the heart of our electric propulsion system. We chose this type of motor for several reasons:

High efficiency (typically 85-90%)

Compact design

Higher energy density

Low maintenance due to absence of brushes

Better heat dissipation

Reduced electromagnetic interference

The motor controller serves as the brain of the electric drive system. It performs several crucial functions:

Regulates energy flow from the battery to the motor

Converts DC power from the battery to the appropriate form for the BLDC motor

Implements speed control based on throttle input

Provides regenerative braking capability

Protects the motor from overload conditions

Throttle/Accelerator

The throttle is a crucial interface between the driver and the motor control system [26,28]. It consists of:

A potentiometer that varies resistance based on pedal position

An output voltage that correlates with the desired motor speed

Integrated power switch functionality to turn the entire electric drive system on and off

The throttle signal is fed into the motor controller, which then adjusts the power delivery to the motor accordingly.

Solar Panel System

Panel Specifications:

Quantity: 4

Power Rating: 80Wp each

Configuration: Connected in series

The solar panels are mounted on the vehicle's roof to maximize exposure to sunlight. The series connection brings the total system voltage to match the 48V battery pack [27,29,40].

Battery System

Battery Specifications:

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Type: Lead-acid (rechargeable)

Configuration: 4 batteries, 12V 26Ah each, connected in series

Total Pack Voltage: 48V

Total Capacity: 26Ah (1248Wh)

Lead-acid batteries were chosen for their:

Low cost

Reliability

Wide availability

Good performance in moderate climates

Charge Controller

The charge controller is a critical component that sits between the solar panels and the battery pack. Its primary functions include:

Preventing battery overcharging

Optimizing charging efficiency

Providing battery status information to the driver

Protecting solar panels from reverse current flow during grid or AC charging

Power Flow and Distribution

The electrical energy flows as follows:

Solar panels generate DC electricity

Charge controller manages the charging process

Batteries store the electrical energy

Motor controller draws power from the batteries

BLDC motor converts electrical energy to mechanical energy

Chain-sprocket mechanism transfers power to the differential

Differential distributes power to the wheels

Mechanical System

Chain-Sprocket Mechanism

Smaller sprocket: 11 teeth (attached to motor shaft)

Larger sprocket: 38 teeth (on differential shaft)

Sprocket ratio: 3.45:1

This mechanism amplifies the motor's torque output, improving the vehicle's traction and climbing ability.

Differential

Gear ratio: 4.125:1

The differential serves several important functions:

Further amplifies torque from the motor

Allows wheels to rotate at different speeds during turns

Distributes power equally to both wheels when moving straight

Ensures smooth control on curved roads

Frame and Body

The vehicle's frame and body are designed from the ground up to optimize:

Weight distribution

Center of gravity

Aerodynamics

Integration of electrical components

Suspension System

A custom-designed suspension system ensures:

Comfortable ride quality

Stable handling characteristics

Adaptation to various load conditions

Braking System

An efficient braking system is implemented, potentially including:

Regenerative braking through the electric motor

Mechanical disc or drum brakes for reliable stopping power

Design Philosophy

By opting for a ground-up design approach, we've been able to:

Optimize component placement for ideal weight distribution

Design a frame that integrates battery and motor mounts efficiently

Achieve a lower center of gravity for improved stability

Tailor the suspension system to the unique characteristics of an electric drivetrain

Implement aerodynamic features to maximize energy efficiency

Ensure proper cooling for electrical components

This comprehensive design allows us to create a vehicle that is specifically optimized for electric propulsion, offering superior performance, efficiency, and handling compared to converted ICE vehicles.

RESULTS AND DISCUSSION

Vehicle Performance Analysis

Before conversion, the mass of the auto-rickshaw (three- wheeler) was 295 kg. During the conversion to an electric vehicle, engine components like the internal combustion engine (ICE), transmission gearbox, fuel tank, and related accessories were removed, reducing the mass to 128 kg. The addition of electric vehicle components, including the battery pack, motor, and controller, added a total of 143.6 kg. As a result, the total curb mass of the electric three-wheeler became 311 kg. When combined with the vehicle's load-carrying capacity, the gross vehicle mass of the prototype totalled 381 kg.

Motor Characteristics

The brushless DC (BLDC) motor used in the electric three-wheeler, sourced from the local Indian market, The motor was selected to meet the vehicle's torque-speed and power-speed requirements. BLDC motors are known to deliver high torque at lower speeds and reduced torque at higher speeds.

The specifications of the motor used in this study are:

Maximum Torque (Tmax): 3.5 N-m

Maximum Power (Pmax): 1500 W

Rated Speed (Nrated): 5300 RPM

Maximum Speed (Nmax): 5600 RPM

This type of motor was ideal for the Indian market, given its compactness, efficiency, and performance in urban driving conditions.

Force of Tractive Effort

The vehicle's performance is defined by key parameters such as maximum speed, the slope the vehicle can climb, and its driving range with a fully charged battery pack. These performance characteristics are influenced by the tractive effort and the relationship between motor torque and wheel torque, as well as motor power and wheel power.

The relationship between the motor torque (Tm) and the wheel torque (Tw) is expressed using the following equation:

$$Tw = Tm \times Rs \times Rf \times \eta s \times \eta F \qquad (11)$$

Where:

Tw = Torque at the wheel

Tm = Torque from the motor

Rs = Sprocket ratio

Rf = Final drive ratio

ηs = Sprocket efficiency (assumed 75%)

ηF = Final drive efficiency (assumed 85%)

From the calculations, the maximum torque at the road wheel was determined to be 31.75 N-m. Additionally, the maximum power delivered at the road wheels (Pw-max) was calculated as 956.25 W, based on the motor's maximum power output (Pm-max), sprocket efficiency, and final drive efficiency.

These calculations underscore the vehicle's capability to perform efficiently on urban and sloped roads in India, balancing the need for torque at lower speeds and energy conservation at higher speeds.

Driving (Tractive) Resistance

Driving resistance (Frq)—also referred to as road load—is essential for calculating the required tractive effort for an electric vehicle. It consists of three components: rolling resistance (Frl), aerodynamic resistance (Fad), and gradient resistance (Fgr).

Aerodynamic Resistance (Fair) is directly proportional to the square of the vehicle's speed (υ^2) and is influenced by air density (ρair), the frontal area of the vehicle (A), and the drag coefficient (Cd). It can be calculated using the following equation:

$$Fair = 12 \times \rho air \times A \times Cd \times \nu 2 \quad (12)$$

Rolling Resistance (Frl) is determined by the interaction between the tires and the road surface. This resistance force is given by:

$$Frl = \mu r \times m \times g \quad (13)$$

where:

μr = coefficient of rolling resistance

m = mass of the vehicle

g = acceleration due to gravity (9.81 m/s^2)

Gradient Resistance (Fgr) refers to the resistance encountered by the vehicle while climbing an inclined road. It is dependent on the slope of the road (gradient angle, ϕ) and is calculated as:

$$Fgr = m \times g \times \sin(\phi) \quad (14)$$

As the gradient angle increases, so does the gradient resistance, making it more challenging for the vehicle to ascend slopes. For this study, a gradient range of 0 to 5 degrees was considered, and the results showed that as the slope increases, the gradient resistance rises correspondingly.

Performance Comparison

Vehicle performance was analysed by comparing tractive forces (generated by the motor) and tractive resistances (forces that oppose motion). The tractive power (Pw-max) and torque (Tw) at the wheels were determined to be 956.25 W and 31.75 N-m, respectively. When driving on a level road at 30 km/h, the required power and torque were 939.8 W and 22.8 N-m, respectively. At a 1-degree gradient, the vehicle's maximum speed was recorded at 21.5 km/h, with a corresponding resistance torque of 31.2 N-m. At a 2-degree gradient, the vehicle encountered a higher resistance of 42.04 N-m, exceeding the tractive torque provided by the motor, rendering the vehicle incapable of ascending slopes steeper than 2 degrees with the current motor configuration. The analysis highlights the importance of using a motor with sufficient torque to improve performance on

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sloped roads, especially in India where varying terrains are common. A motor with higher torque and power would increase the vehicle's climbing ability, load-carrying capacity, and overall speed.

Driving Range

The vehicle's driving range is heavily influenced by the battery's capacity. For this project, a 48V lead-acid battery pack was used, consisting of four 12V, 26Ah batteries connected in series. Lead-acid batteries were chosen for their availability and mass-energy density. The driving range can be calculated using the following equation:

$S = V \times CP$ (15)

Where:

S = driving range

V = battery voltage (48 V)

C = battery capacity (26 Ah)

P = power consumption (calculated from motor power and vehicle speed)

For this vehicle, the calculated driving range at maximum speed (30 km/h) is approximately 17 km per full battery charge. If charged using both solar panels and a 2A AC charger, the range can be extended to 34 km per day. The solar panels mounted on the vehicle roof generate up to 4.4A, contributing to battery charging during daylight hours. However, using a larger battery pack would significantly enhance the vehicle's driving range.

Climbing Performance

The climbing performance refers to the vehicle's ability to navigate inclined roads. The forces acting against the vehicle while climbing are mainly due to gradient resistance. For this vehicle, the maximum excess traction force (Fex) was calculated as 82.65 N, using the following equation:

$Fex = Ftr - Frl$ (16)

Where Ftr is the tractive force from the motor, and Frl is the rolling resistance. The maximum gradient angle the vehicle can handle is computed using:

$\tan(\theta) = Fexm \times g$ (17)

Thus, the gradient angle (θ) of the road the vehicle can climb was determined to be 1.26 degrees, corresponding to a gradient percentage of 2.2%. This performance can be improved by using a motor with higher torque output, which would allow the vehicle to climb steeper slopes—a crucial feature for Indian roads, especially in hilly regions.

Maximum Gradient Angle Calculation

The maximum gradient angle (θ) that the developed electric vehicle can overcome is computed using the excess traction force (Fex) and the vehicle's gross weight, which is the product of its mass and gravitational acceleration (mg). The formula for calculating the angle is:

$\tan(\theta) = Fexmg$ (18)

Thus, the angle of the sloped road (θ) is given by:

$\Theta = \tan - 1\ (Fexmg)$ (19)

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For this vehicle, the excess traction force Fexis already determined, leading to a calculated gradient percentage (q′) of 2.2% and a slope angle (θ) of 1.26 degrees, using the formula:

$q' = \tan(\theta) \times 100$ (20)

This indicates that the vehicle can manage road gradients up to 1.26 degrees, which is relatively low and may be a limitation in regions with steeper terrain, such as hilly areas in India.

Acceleration Performance

The acceleration performance of an electric vehicle is typically highest on level roads, where gradient resistance is minimal. In this scenario, the net tractive force (Fex) used to accelerate the vehicle can be calculated by subtracting both rolling resistance (Frl) and aerodynamic resistance (Fair) from the tractive force (Ftr) provided by the motor:

$Fex = Ftr - Frl - Fair$ (21)

For the vehicle under consideration, the calculated excess traction force Fex is 44.3 N. The maximum acceleration (αmax) of the vehicle is then computed using the formula:

$\alpha max = Fexm \times \lambda$ (22)

where:

m = gross vehicle mass,

λ = rotational inertia effect, equal to 1.1.

Given the mass of the vehicle and using the previously calculated excess traction force, the maximum acceleration is determined to be 0.106 m/s^2. This corresponds to the vehicle reaching a top speed of 30 km/h on a level road.

The time required to accelerate from 0 to 30 km/h can be calculated using the following kinematic equation:

$\alpha = dvdt$ (23)

Where:

dv = change in velocity (from 0 to 30 km/h),

dt = time taken to reach the maximum speed.

By substituting the values into this equation, the time required for the vehicle to accelerate to its maximum speed is found to be 78 seconds. For Indian road conditions, particularly with varied terrain and frequent traffic stops, improving acceleration would be critical for enhancing overall vehicle performance. This could be achieved by using a motor with higher torque or by optimizing the battery and motor controller systems to deliver more power during acceleration phases. Additionally, a lighter and more energy-dense battery pack—such as a lithium-ion system—would further reduce the vehicle’s weight and improve both acceleration and driving range, addressing the limitations presented by lead-acid batteries used in the initial design. Incorporating regenerative braking systems could also aid in energy recovery, enhancing the vehicle's overall efficiency during frequent stops and starts in city driving conditions. This would not only improve acceleration but also extend the driving range and battery lifespan.

CONCLUSION

This research outlines the development and performance analysis of an electric vehicle equipped with an on-board solar charging system, converted from a traditional Indian-made three-wheeler auto-rickshaw. The vehicle, based on an old model, was retrofitted with a differential gearbox and a mechanical reverse system, incorporating a chain-sprocket mechanism. Performance testing demonstrated that the maximum speed achievable by the vehicle is 30 km/h on flat terrain. The vehicle's load-carrying capacity is limited to one passenger weighing approximately 80 kg, in addition to the driver, due to the lower power rating of the DC motor used. The vehicle's gradient-climbing ability is restricted, with a maximum climb angle of 1 degree at a top speed of 21.5 km/h on sloped roads, indicating limitations in its torque capacity. The driving range, powered by a fully charged lead-acid battery pack, is 17 km, but with the integration of a 320 W peak solar panel installed on the roof, an additional 17 km range can be achieved under optimal sunny conditions. The solar panel, operating at 48 V and 4.4 A, fully charges the battery in approximately 6 hours under favourable conditions. However, the varying intensity of solar radiation and atmospheric temperature can affect the efficiency of the photovoltaic (PV) system. By combining AC charging with solar power, the vehicle can extend its range up to 34 km per day. In terms of acceleration, the vehicle's maximum acceleration rate was found to be 0.106 m/s^2, requiring 78 seconds to reach the top speed of 30 km/h. This performance is deemed sufficient for short-distance urban commutes but highlights the need for motor and battery improvements for enhanced capability. The vehicle's performance could be significantly enhanced by employing a higher-rated motor with greater torque and power, though this would inevitably raise the cost of the vehicle. Additionally, the driving range could be improved by increasing the battery pack's capacity, though doing so would increase the vehicle's overall weight, thereby burdening the motor and impacting efficiency. In India, the vehicle’s adoption would benefit from the establishment of widespread charging infrastructure, a key concern when considering solar electric vehicles in emerging markets. One of the primary challenges encountered in this vehicle conversion project is the increased weight of the vehicle due to the retention of the original chassis, which is the heaviest component. Replacing the internal combustion engine and associated components with batteries, motors, and electrical systems further alters the vehicle’s weight distribution, making it difficult to achieve an optimal centre of gravity. This could negatively affect the vehicle’s stability and overall performance. Going forward, adopting lighter chassis materials and improved design techniques would be essential for optimizing the electric vehicle’s balance, performance, and efficiency.

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