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Design of EV for Goods Carrying Application

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Abstract: The rising demand for sustainable transportation solutions has spurred a notable upsurge in Electric Vehicle (EV) development. This paper delves into the design considerations and challenges specific to crafting an EV tailored for goods-carrying applications.The design process encompasses several facets, ranging from selecting suitable battery technology and motor specifications to refining chassis design and energy management systems. Achieving optimal space utilization and weight distribution is paramount for designing an electric vehicle for goods transportation, all while ensuring sufficient payload capacity and range. Moreover, factors like charging infrastructure, operational necessities, and regulatory compliance are integral considerations in the design phase. Incorporating advanced technologies such as regenerative braking and telematics can significantly enhance the vehicle's performance, efficiency, and safety. The paper emphasizes the significance of a comprehensive design approach that not only prioritizes performance but also considers the vehicle's environmental footprint and economic feasibility. By addressing these aspects, the design of Electric Vehicles for goods-carrying applications can play a pivotal role in advancing sustainable and efficient transportation systems.

I. INTRODUCTION

India holds a prominent position in the global automotive industry, boasting an annual production of approximately 30.92 million vehicles across various segments, from two-wheelers to four-wheelers catering to both commercial and private needs. However, this expansive road network heavily reliant on Internal Combustion Engine (ICE) technology significantly contributes to CO2 emissions, accounting for 18% of the total emissions generated by ICE engines worldwide. The prevalent use of fossil fuels such as oil, gas, and biofuels to power vehicles in Indian cities exacerbates this environmental challenge.

Projections indicate a steep rise in transportation energy demands, estimated to be four times higher in 2047 compared to 2017, exacerbating the energy supply crisis. Recognizing the urgency of addressing these issues, the Indian government has launched initiatives like the National Electric Mobility Mission Plan (NEMMP-2020) and the National E-mobility Program to promote the adoption of Electric Vehicles (EVs). EVs present a promising avenue for decarbonizing transportation, on leveraging three-wheeler EVs in congested urban areas. These compact vehicles, exemplified by electric rickshaws, offer practical and economical solutions, accommodating one to four passengers' luggage, and operating at an average speed of 25 km/hour. Embracing EVs, especially in densely populated urban centers, holds immense potential for reducing emissions and enhancing sustainability in India's transportation landscape.

A. Retro fitment:

Retrofitment refers to converting a combustion engine vehicle into an electric vehicle by replacing conventional powertrain components with electric powertrain counterparts [3], [4]. While designing a retrofitment kit...

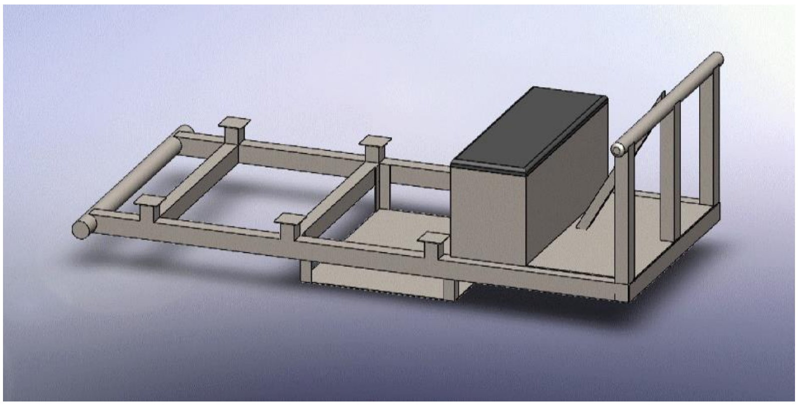

Figure1: Chassis of EV

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B. Structure of Proposed Hess

Mechanical Structure:
The mechanical structure of three-wheeler electric vehicles (EVs) is meticulously engineered to optimize performance, efficiency, and safety. It comprises a sturdy frame and chassis designed to uphold the vehicle's weight and ensure structural integrity. Unlike traditional internal combustion engine (ICE) models, electric three-wheelers seamlessly integrate an electric motor, controller, and battery pack into their powertrain.

This integration demands careful attention to weight distribution and space utilization. Additionally, the suspension system plays a vital role in absorbing shocks and vibrations from uneven road surfaces, thereby enhancing passenger comfort and vehicle stability. Steering and handling mechanisms are precisely engineered for accurate control and maneuverability, particularly in congested urban settings.

Safety features such as seat belts and robust crash-worthy designs are incorporated to safeguard occupants in case of collisions. Overall, the mechanical structure of three-wheeler electric vehicles represents a harmonious blend of innovation and practicality, aimed at revolutionizing urban transportation with sustainable and efficient mobility solutions.

Despite numerous technical and mechanical constraints, retro fitment proves to be a cost-effective alternative to designing a new electric vehicle from scratch, consequently reducing maintenance costs. However, the installation of a retrofitment kit may alter the vehicle's designed dynamics, and not all required components may be readily available domestically.

Electrical Structure:

I. Battery (48V, 60Ah)
Batteries are fundamental components within Electric Vehicles (EVs), exerting influence over factors such as weight, cost, range, and performance. Diverse battery chemistries are employed based on considerations such as vehicle type, weight, and structural requirements. The selection process for batteries and their chemistries entails the consideration of multiple factors to achieve optimal performance.

Figure2: Lithium-ion battery Model

II. Motor (2.5kW, 48V, 52A)
The electric motor functions as the primary propulsion mechanism in an EV, converting stored energy from the battery pack into mechanical motion. It necessitates high starting torque for rapid acceleration. The motor's power output is transmitted to the wheels either directly or via a transaxle.

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Figure3: BLDC Motor used in this model

III. Controller (6kW, 24/72V, 180A)

Responsible for regulating power flow from the battery pack to the motor in response to accelerator input, the motor controller plays a critical role. Computer-controlled controllers ensure precise speed control and efficient energy utilization during both acceleration and braking phases, enabling bidirectional energy transfer. The controller's power rating is contingent upon voltage and current requirements.

Figure 4: Controller

IV. DC-DC Converter (48V/12V)

The DC-DC converter transforms higher-voltage DC power from the traction battery pack into lower-voltage DC power essential for operating vehicle accessories and recharging auxiliary batteries. These converters temporarily store electrical energy, serving as crucial intermediaries for voltage level conversion within automotive systems.

Figure 5: DC*DC convertor.

V. Charger (48V, 6A)
Chargers are pivotal in replenishing the electric vehicle's battery. On-board chargers perform the task of converting AC supply to the appropriate DC voltage. These computer-controlled "smart chargers" ensure efficient charging, with direct connection to the battery pack.

Figure 6: Charger

II. MODES OF OPERATION

Motor sizing and selection.
The different resistances acting on vehicles are :

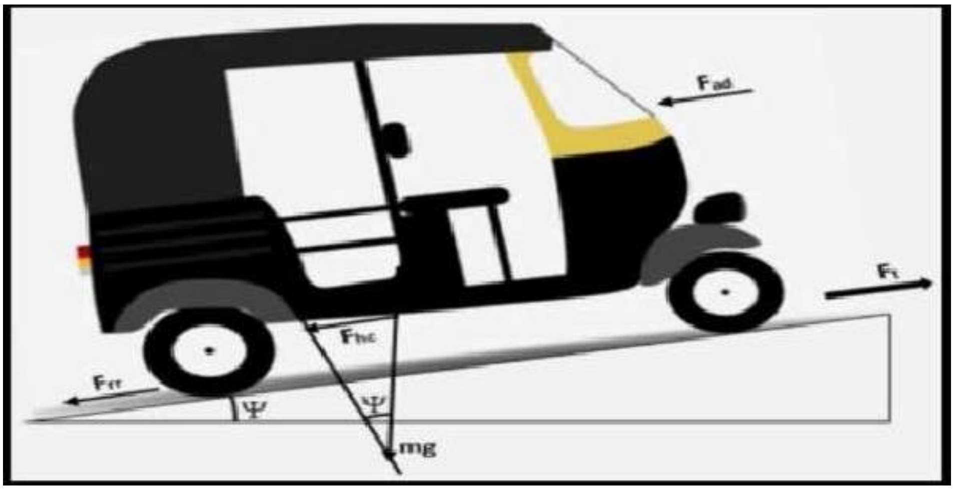

Figure 7: EV Vehicle Dynamics.

1. Rolling Resistance:
Rolling resistance refers to the resistance that a vehicle must overcome due to the rolling motion between its wheels and the surface it travels on. Mathematically, it is expressed as:

Fr = Fr*m*g
Where, fr = rolling resistance coefficient of tire, or = Coefficient of R.R
m = Mass of Car
g = Gravitational force

2. Gradient Resistance:
Gradient resistance is a form of gravitational force. It is the force that tends to pull the vehicle back when it is climbing an inclined surface. It is given by
Fg= m*g*sinα

3. Aerodynamic Resistance:
The resistance offered by air in the atmosphere while vehicle travelling through it is known as aerodynamic drag resistance.

It is given by,
Fd= 1ρCdAfv2 2 Where,
ρ= density of air (kg/m3),
Cd =Aerodynamic drag coefficient, Af = Frontal area (m2),
v = vehicle speed (m/s).

Table 2: Calculation Parameters

Cd	0.25	
ρ	1.225	Kg/m3
µr	0.02	
Af	1.614	M2
Vmax	40	kmph
V	11.11	m/s
α	10	

POWER CALCULATION:
Calculations are conducted under various conditions such as maximum speed, maximum grade ability, and Indian Drive Cycle (IDC). Among these, determining the maximum power required for the maximum grade ability condition involves power calculations.

Table 3: Power Calculation

Aerodynamic Resistance	30.45	N
Rolling Resistance	92.21	N
Gradient Resistance	800	N
Torque	4.15	NM
Pmotor	2.5	KW

SELECTING THE MOTOR

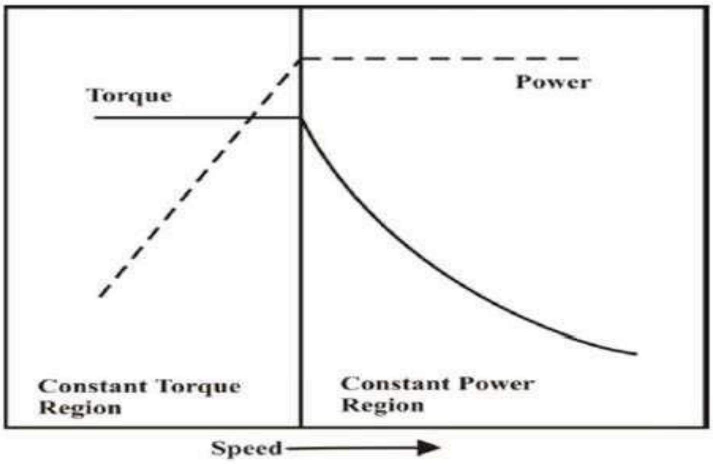

Figure 8: Ideal Torque-Power Curve for EV

The motor selection process involves comparing various parameters of different types of EV motors. Commonly used motors include the Permanent Magnet Synchronous Motor (PMSM), Switched Reluctance Motor (SRM), Brushless DC Motor (BLDC), and Induction Motor [7]. These motors are evaluated based on different criteria such as efficiency, cost, ease of control, starting torque, power output, lifespan, maintenance, noise, and size [8]. Following the comparison, the specifications of the chosen motor are as follows:

Table 4: Motor Specification

Motor type	BLDC
Voltage Level	48V
Max Torque	19 Nm

BATTERY SIZING AND SELECTION

A. Considering vehicle running for IDC cycle, the total resistance force on vehicle Ftotal is 210N.
B. IDC cycle runs for 3.948km and 648 seconds. The average power consumed by vehicle is given by, Pavg = Ftotal
C. *Vavg.
D. Total energy required can be calculated by integration power consumed over IDC time cycle, Etotal = Pavg
E. *(tcycle/3600).
F. Average energy required per km (IDC) is given by, Eav
G. g
H. = Etotal (2-ηd).
I. For designing vehicle for 105 km range, battery capacity of 7.257 kWhr (144 Ah) is required.

BATTERY TECHNOLOGY

The predominant battery chemistries utilized in electric vehicles globally are Nickel Metal Hydride (NiMH) and Lithium-ion (Li-ion). NiMH technology, while mature, is considered older. However, due to Li-ion batteries' capability for higher specific energy and power, their demand is experiencing rapid growth. Li-ion batteries offer advantages such as low self-discharge rates, compact size, faster charging times, and higher energy density. In the context of 3-W applications, where space availability is limited and weight constraints are crucial, Li-ion batteries are preferred over NiMH batteries.

Table 5: Selected Battery Specifications

Particular	**Specification**
Nominal Energy	3.5 Ah
Pack Voltage	50.8 V
Pack Capacity	144 Ah
Cell Nominal Voltage	3.63 V
Cell Constant Voltage	4.2 V
Cell Cutoff Voltage	2.5 V
Constant Current	1C
Operating Temperature	-20 to 45 ◦C
Peak current	!30 A
Max Speed	rpm

III. RESULTS AND DISSCUSION

Table 5: Result

Sr .no	Maximum speed	Travel time
1.	30km/h	2hr
2.	20km/h	2.5hr
4.	18km/h	3 hr

- Vehicle Performance Metrics: In the design process, essential performance metrics such as maximum speed, maximum gradeability, payload capacity, and range were determined. These metrics underwent thorough simulation and testing to ensure optimization for goods carrying applications while maintaining efficient energy utilization.

- Battery Technology Selection: Various battery chemistries underwent evaluation based on criteria such as energy density, power output, charging efficiency, and weight. Lithium-ion batteries emerged as the preferred choice due to their high energy density, rapid charging capabilities, and suitability for compact spaces in goods carrying vehicles.

- Motor Selection and Powertrain Configuration: Different electric motor types, including Permanent Magnet Synchronous Motor (PMSM), Switched Reluctance Motor (SRM), and Induction Motor, underwent comparison based on factors such as efficiency, torque output, and ease of control. The selected motor, along with the appropriate powertrain configuration, was chosen to optimize performance and efficiency for goods carrying applications.

- Chassis Design and Structural Integrity: The mechanical structure of the electric vehicle was meticulously engineered to ensure robustness, stability, and safety while accommodating payload requirements. Finite Element Analysis (FEA) and prototype testing were conducted to validate the chassis design and ensure compliance with regulatory standards.

- Energy Management System (EMS) Optimization: An efficient energy management system was implemented to regulate power flow between the battery pack, motor, and other vehicle components. Advanced control algorithms and real-time monitoring were employed to optimize energy usage, enhance vehicle performance, and prolong battery life.

- Integration of Advanced Technologies:
- Advanced features such as regenerative braking, telematics, and smart charging systems were integrated into the design to further enhance vehicle efficiency, safety, and user experience. These technologies bolster the overall functionality and competitiveness of the electric vehicle in the goods carrying market.

- Environmental and Economic Impact: The adoption of electric vehicles for goods carrying applications offers significant environmental benefits by reducing carbon emissions and dependency on fossil fuels. Additionally, the lower operational costs associated with electric vehicles contribute to economic sustainability for businesses and fleet operators.

IV. CONCLUSION

In summary, the integration of three-wheeled Electric Vehicles (EVs) presents a solution to contemporary transportation challenges. These vehicles offer an eco-friendly alternative to combustion engine counterparts, thereby aiding in the reduction of carbon emissions and contributing to environmental preservation. Their compact design makes them well-suited for areas grappling with significant traffic congestion.

Furthermore, adopting electric powertrains can notably improve energy efficiency and lower operational costs, rendering three-wheeler EVs a viable option for both individuals and businesses.

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