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SOLAR-POWERED AUTO RICKSHAWS: INTEGRATING OPTIMAL MECHANICAL AND ELECTRICAL DESIGN FOR ENHANCED EFFICIENCY AND SUSTAINABILITY

Saran K, Tarun R S, Gowtham Prasanth S
Student
Kumaraguru college of Technology

ABSTRACT

Solar powered electric autorickshaws are an eco-friendly substitute for their fossil fuel-dependent predecessors. In order to improve performance and increase range, this abstract explores the fields of design and technology, emphasizing the value of aerodynamics, lightweight materials, and energy-efficient systems. This study highlights the physical elements and parameters that are essential for the creation of environmentally friendly transportation options. In particular, the motor selection like IP65 with initial torque of 50 Nm and the lithium-ion battery pack with 72v 90 Ah and solar panel of 1.5 KW with dimensions of 1.6 meters of length and 1 meter of width and the controller is the pulse with module space vector PWM. The section on the environmental impact highlights how important these Vehicles are to lowering urban noise pollution and air pollution. Discussions about economic viability carefully examine starting costs, ongoing expenses, and the impact of government incentives, explaining how operators and urban transportation systems can afford it. Benefits to society, such as improved last-mile connection and lower commute costs, are emphasized, suggesting the comprehensive advantages of switching to electric autorickshaws.

Keywords: Solar power, Motor selection, battery selection, Pulse with module, economic viability, Electric vehicles.

INTRODUCTION

Background

The project named "SOLAR POWERED AUTO RICKSHAWS: INTEGRATING OPTIMAL MECHANICAL AND ELECTRICAL DESIGN FOR ENHANCED EFFICIENCY AND SUSTAINABILITY" study focuses on the conversion of manually propelled cycle rickshaws into Permanent Magnet Brushless DC (PM-BLDC) electric motor-driven passenger rickshaws using solar-powered charge batteries. An optional electric charger is included to handle battery charging on cloudy days. The findings show that these converted rickshaws provide a safe, ecologically friendly, energy-efficient, and economically viable transportation option in both rural and urban areas of India.

Scope

The potential uses and opportunities for electric autorickshaws powered by solar energy are numerous. By minimizing reliance on fossil fuels and greenhouse gas emissions, these cars provide a sustainable and eco-friendly form of transportation. The broad adoption of solar-powered autorickshaws in both urban and rural areas is highly potential due to developments in solar technology and battery storage. Incorporating electric propulsion technologies also improves efficiency and lowers running costs in the long run. The potential for electric solar autorickshaws is growing, opening the door for a more sustainable future in urban mobility as governments and businesses throughout the world place a higher priority on sustainability and clean energy efforts.

Project scope & Objectives:

The project aims to demonstrate the feasibility and advantages of utilizing solar-powered electric autorickshaws as a sustainable mode of transportation. By achieving this goal, the project seeks to contribute to the advancement of clean energy technology and promote the adoption of renewable energy in the automotive industry. By showcasing the viability and environmental benefits of solar-powered autorickshaws, the project hopes to inspire broader adoption of clean energy solutions, leading to a reduction in greenhouse gas emissions and a shift towards more sustainable transportation options. Ultimately, the project aims to drive positive change towards a greener and more sustainable future for transportation.

Application

Electric autorickshaws that run on solar power have many uses in a variety of industries and provide effective and environmentally friendly transportation options. These cars work especially effectively in urban and peri-urban regions where short-distance transportation is typical. One of the main uses is in passenger transportation, offering commuters a greener option to conventional fossil fuel-powered cars. Delivering products is another use for solar EV rickshaws, particularly in crowded cities where wider cars can find it difficult to maneuver through congested streets.

Apart from its use in urban transportation, solar electric vehicle (EV) rickshaws are also employed in the tourism and leisure industries. They provide eco-friendly sightseeing tours and shuttle services in popular tourist spots. These cars may also function as portable electronic device chargers, which is a useful feature for outdoor gatherings, festivals, and emergency situations.

LITERATURE REVIEW:

[1] Application of photovoltaic panels in electric vehicles to enhance the range by Illia Diahovchenko

The purpose of this research is to determine whether using readily available, low-cost solar energy technology may increase the range of an electric car. When the electric vehicle is parked, solar panels installed on its roof can be used to recharge it. Photovoltaic modules have the ability to power the vehicle's accessories, including the air conditioner, ventilation system, heated passenger seats, and interior lighting, in addition to helping with propulsion

[2] Solar/battery electric auto rickshaw three-wheeler by Priscilla Mulhall

The goal is to create a cutting-edge electric auto rickshaw powered by solar energy. Research on the traditional auto rickshaw, conceptual infrastructure designs for electric rickshaws in the future, and current design studies and simulations of the next auto rickshaw are all presented in this study.

[3] Solar Based Plugged-in Hybrid Engine Driven rickshaw (Auto-Rickshaw) & its Feasibility Analysis for Bangladesh by Avijit Mallik.

This essay proposes an environmentally friendly auto rickshaw-based transportation system. The current automobiles will be replaced with a micro cross-type system that has been modified to increase the vehicle's economy. Furthermore, a planned infrastructure for recharging is put forth, which will enable the power packs to be charged with partially alternate energy sources like solar power.

[4] Commercial and Technological Feasibility Study of Using Solar E-rickshaw for semi-urban Areas

The main topic of this research paper is transportation mode advancement. As non-renewable energy sources are running out, our attention is being drawn to eliminating gasoline from present vehicles. Renewable energy sources should be used for both the production and consumption of energy.

[5] Study of Solar Energy Driven E-Rickshaw by Diptopal Mukherjee

Thus, the purpose of this project is to examine India's energy situation, the potential effects that these e-rickshaws might have in the present, and how solar energy might be used to power them.

[6] Design of an Electrically Powered Rickshaw, for Use in India

This article's primary goals are to give study findings about the design of an electric rickshaw for usage in Kolkata, India, to highlight the shortcomings of the existing cycle rickshaw, to create a design solution to overcome those shortcomings and to investigate the feasibility of using solar electricity.

[7] Design of E-Rickshaw Using MATLAB or Simulation

This article models an E-rickshaw with mixed-power batteries-UC using MATLAB-Simulink. The two sources' power management was accomplished in a highly sensible and novel way by making effective use of the renewable energy produced while braking.

DESIGN METHODOLOGY

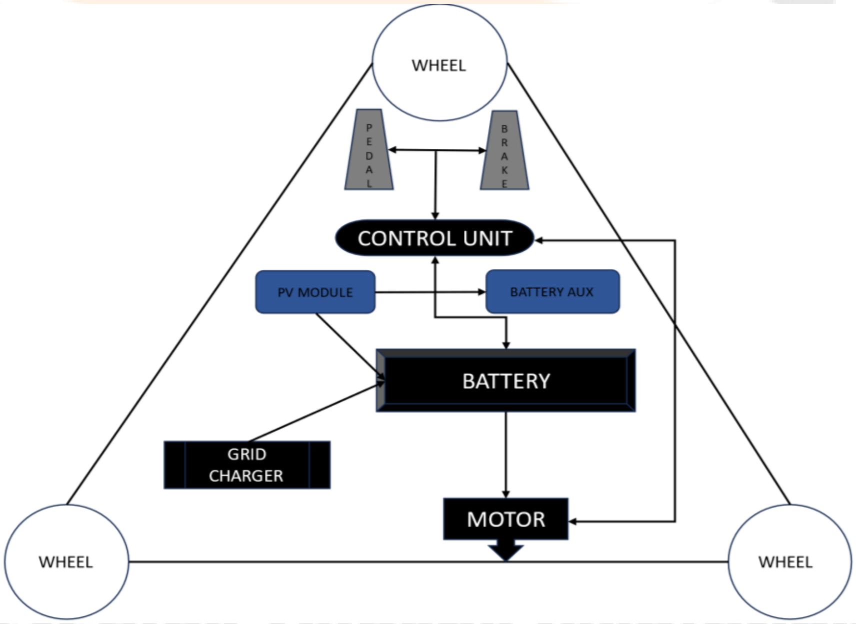


Fig 1 Design methodology flowchart

Electric motor selection

Electric motor used: IP65 BLDC motor.

Fig 2 Motor selected

An electric motor with an IP65 rating for environmental protection is known as a BLDC (Brushless Direct Current) motor. A recognized categorization system called IP (Ingress Protection) rating is used to indicate how well electrical enclosures protect against incursion from moisture and foreign items like dust.

Calculations :

To calculate the energy consumption of the motor per km, we can use the formulae

Energy= 1/ efficiency X Power/ speed + rolling resistance + aerodynamic drag.

Given:

Efficiency of the motor= 90%

Power of the motor= 6Kw

Speed of the vehicle=40km/hr

Rolling resistance= 0.44

Aerodynamic drag= 1.906N

So we substitute the given values

Energy=1/0.9 X 6000/11.11 +0.44+1.906

Energy= 741.32+0.44+1.906

Energy=743.666W

So the motor consumes approximately 743.666W

a medium-sized IP65-rated BLDC motor used in electric vehicles might have an initial torque in the range of 10 Nm to 50 Nm.

Specifications:

Specification	Details
Motor Model	XYZ-123
IP Rating	IP65
Power Output	15 kW
Rated Voltage	72 volts
Rated Current	208 amps
Peak Current	416 amps
Efficiency	95%
Maximum Speed	6000 RPM
Torque	80 Nm
Insulation Class	F
Cooling Method	Forced air cooling
Enclosure Material	Aluminum
Weight	40 kilograms
Dimensions	250 mm x 250 mm x 300 mm
Operating Temperature	-20°C to 50°C
Protection Features	Overload protection, Overheat protection, Short-circuit protection

Table 1. Motor

Solar Panel Selection:

In order to obtain a total power output of 1.5 kW, a 1.5 kW (kilowatt) solar panel system usually comprises of numerous solar panels coupled together. The following are some essential features and details of a 1.5 kW solar panel system: Depending on the manufacturer and model, each solar panel's actual dimensions may change. Conventional household solar panels are typically a few centimeters thick and size 1.6 by 1 meters, or 5.25 feet by 3.25 feet.

Calculation:

selection of solar panel:

Mono-Crystalline: efficiency = 20% - 21%

Hence, performance – is high, and cost also will be high

Standard range of solar panel:

40w – 125w

50w – 150w

75w – 180w

100w – 350w

Normally 12V batteries are used in household

Sample calculations:

9W = 1 Hr (consumes 9W per hour)

Power = P = V x I

The total current needed for charging is = 6250WHr/800 W = 7.18 Hr

The total amount of current used = 800 W per Hr

Battery : Battery Management System used hr equalize the load from high voltage to low voltage

Tubular batteries – 300 cycle

Li-ion

Lithium ferrus phosphate = 200 – 300 cycle

Lithium Titanate = 2000 to 10000 cycle = cost is high

KCT = 250 kW solar panel

= No. of panel chart = 800

= Type of panel = polycrystalline

Load 100 W:

100 Ah – 8 Hrs 24 min

150 Ah – 12 Hrs 36 min

Specification	Details
Solar Panel Model	ABC123
Power Output	1.5 kW
Solar Panel Type	Monocrystalline
Maximum Power Voltage	36 volts
Maximum Power Current	41.67 amps
Open Circuit Voltage	45 volts
Short Circuit Current	45.83 amps
Dimensions	1.6 meters x 1 meter
Weight	20 kilograms

Efficiency	18%
Cell Type	PERC (Passivated Emitter Rear Cell)
Operating Temperature	-40°C to 85°C
Frame Material	Aluminum

Table 2 Solar panel selection

Battery Selection:

A 6.48 kWh lithium ion battery's specs would normally contain the following information. The arrangement and quantity of cells within the battery pack will determine its voltage. Like lithium-ion batteries, sodium-ion batteries normally have a voltage range of 3.2 to 3.7 volts per cell. The number of cells linked in series will determine the battery pack's overall voltage.This is the quantity of charge-discharge cycles that a battery can withstand before seeing a noticeable reduction in capacity. Depending on the chemistry and design, sodium-ion batteries can have a cycle life of several hundred to several thousand cycles, which is comparable to or better than lithium-ion batteries.

Calculations:

How to design a battery pack for Ev for,

Speed=50km

Curb weight and gross weight=600kg

BLDC hub motor = 4Kw,72v

Designing battery pack for 200km travel

Speed of the vehicle= 50kmph

Current taken= 11amp

Acceleration current= 5% extra

Effective current=there will be losses of 1.05%

5 × 1.05=5.250 amp

=1.5 kw power required

Designing battery pack,

Charge-discharge efficiency of li-ion battery=85%=15% losses

Power required =1.5kw

Battery pack capacity=3.8/0.5

Battery pack= 4.4 kw battery needed for moving a vehicle at 50Km/Hrfor 200km

Power required to travel 200km,

Speed of vehicle=50kmph

Current taken=15amp

Acc current=5

Effective current=15 × 1.05

=15.75 amp.

Charging period = t = Bc/CP = 6250/800

T – time to charge

BC – Battery capacity = 6250 WHr @ 72V 90 Ah

CP – capacity power = 800 W from 1 kW solar panel

T = 6250/800 = 7.81 Hrs to full charge

Regenerative braking (concept):

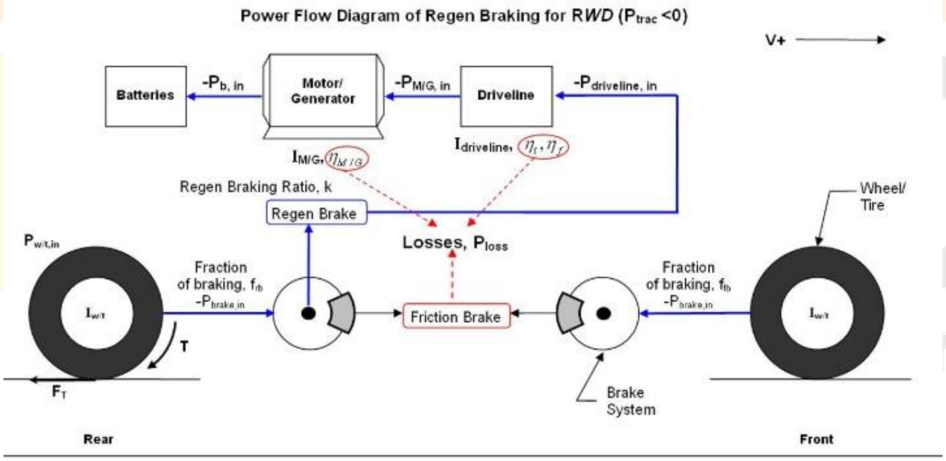


Fig 3 Regenerative braking layout

Electric vehicle (EV) autorickshaws frequently use regenerative braking as a method to increase driving range and energy efficiency. During braking or deceleration, the vehicle's kinetic energy is converted into electrical energy, which is subsequently stored in the battery for later use. The EV autorickshaw's motor runs in reverse and functions as a generator when the driver depresses the brakes or lifts the accelerator pedal. The motor produces electrical energy when the wheels slow down, and this energy is subsequently redirected into the battery. Regenerative braking is the process by which the motor/generator transforms the kinetic energy of the moving vehicle into electrical energy. For storage in the battery, this electrical energy, which is usually in the form of direct current (DC), must be changed to alternating current (AC). Regenerative braking system effectiveness in electric vehicle autorickshaws might differ based on motor/generator efficiency, battery efficiency, and control algorithms. Regenerative braking systems typically have an efficiency of between 60% and 70%. During braking, a considerable amount of the vehicle's kinetic energy can be recovered thanks to regenerative braking. By lowering the reliance on friction brakes, this energy recovery prolongs the life of brake parts and lowers maintenance expenses.

An electric car autorickshaw that has regenerative braking, which can recover up to 70% of the kinetic energy used in the vehicle when it brakes. When the autorickshaw brakes, its kinetic energy of 10,000 joules (J) can be recovered by the regenerative braking system to the tune of 7,000 J

Vehicle Dynamics of an EV-Rickshaw

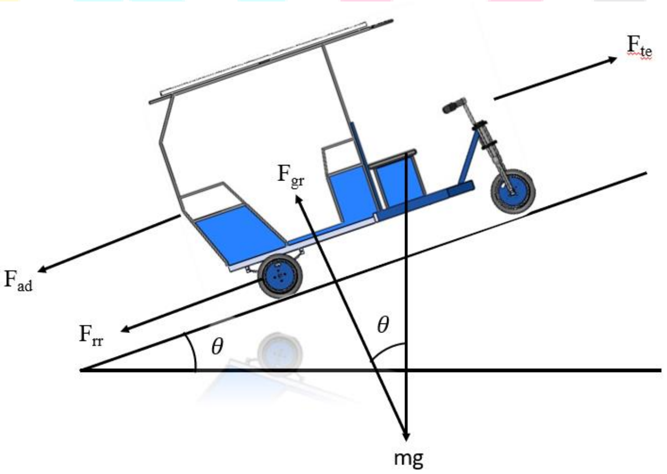


Fig 4 Aerodynamics of the vehicle

Depicts the usual rickshaw structure. Table 1 displays the specifications of the standard rickshaw, whose parameters are used as a guide when creating the power train for an E-rickshaw. The ensuing sections provide a detailed description of the vehicles' flexible modelling. To create a useful model of automotive dynamics, one must comprehend the driving force of an automobile. Figure 2 illustrates the auto-rickshaw's power as it climbs the hill. The rolling resistance, aerodynamic gravity, distance resistance, acceleration capacity, and rolling resistance must all be met .Table 2 displays the maximum force applied to the E-rickshaw along with its meanings. In this case, M is the vehicle's weight in kilograms, g is the gravitational constant (9.81 m = s2), and Cr is the rolling resistance coefficient. For m = s2, let E be a road with a horizontal plain and a speeding car. The force needed to move the car forward by defeating all of the previously listed forces acting on it is equal to the sum of the forces acting on it, including gravity. Equation 1 provides the total operating power of the vehicle, ignoring all extraneous power that is present either directly or indirectly. Frr+ Fad + Fgr+ Faf = Fte.(1)

FORCE	DEFINITION	EXPRESSION
Rolling Resistance force, F.	The force experienced by the vehicle due to friction between the tyres and the running surface.	Cr.M.g
Aerodynamic drag. Fal	The force experienced by the vehicle due to friction with the surrounding air.	$\frac{1}{2}\rho.A.Cr.V.V$
Grade Resistance force, Fgr	The force required to drive the vehicle upward on a slope.	$M.g.sin\theta$
For Acceleration force, Faf	The force which is needed to accelerate the vehicle for different running velocities.	M.a

Vehicle architecture:

Table 3: Forces Acting on an vehicle

E-car charts evaluate every component, including the electric motor, power converters, and power supply, based on the driving habits and characteristics of the automobile. Equation 1 is used to determine the total amount of traction required for the vehicle to drive. Table 1 contains system parameters such vehicle weight, front position, etc. The driving cycle data contains information on vehicle speed and acceleration. The product of total gravity and speed yields the necessary load capacity. Figure 2 depicts the power flow in a typical electric rickshaw. The MATLAB-Simulink domain is used to model the automatic rickshaw's dynamics. By adding solar panels to the planned E-rickshaw's architecture, its energy efficiency can be greatly increased and its dependency on grid charging can be decreased. The car can use solar energy to augment the battery's charge, increasing its driving range and lowering the need for frequent grid charging, by mounting solar panels on its roof. With the potential to go 75 km on a single charge and an average daily driving distance of 150 km, the installation of solar panels can help charge the battery during daylight hours. When the car is in motion, especially in bright light, its solar panels can produce power, which helps to partially recharge the battery without the need for external charging stations.

3 D modal of the New Auto-Rickshaw:

Fig 5 Crossectional view

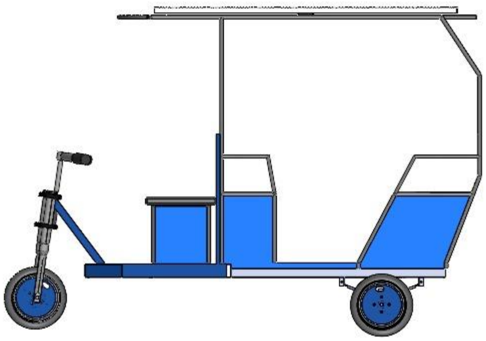
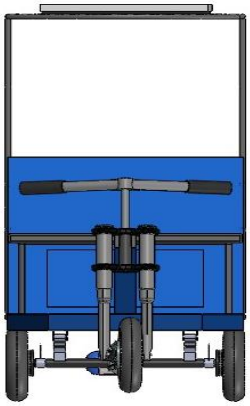


Fig 6 side view of the modal



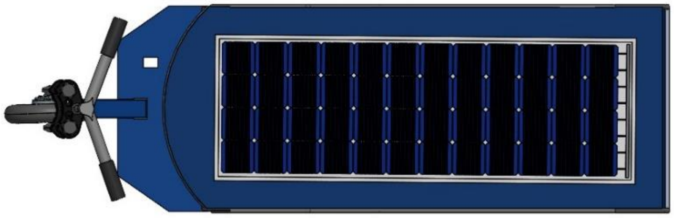


Fig 8 Top view of the modal

Fig 7 Front view of the modal

This is the EV rickshaw's design, which is more practical in terms of size and load capacity. The vehicle body and its load apply static forces to the EV solar vehicle. The vehicle's maximum weight in this variant is 800 kg. The maximum loaded weight is divided by the overall length of the chassis frame to determine the uniform distribution of the load. The model's precise loading configuration is depicted in the attached.

The information supplied describes the features and measurements of our recently created product. These factors function as important markers of the features and functionality of the design. We offer a comprehensive grasp of the product's size, performance capabilities, and general design aspects by providing dimensions and other pertinent parameters. For stakeholders and future consumers to assess if the newly created product is appropriate and effective for their needs, this information is essential.

Table 4 Dimensions and specification of the modal

Fabricated Modal:

S.NO	PARAMETERS	VALUES
1.	DIMENSIONS	2932 X 1462 X 1653 (Without solar panel)
2.	VEHICLE KERB WEIGHT	450 kg
3.	VEHICLE OVERALL WEIGHT	920-950 kg
4.	TOP SPEED	50 Km/hr
5.	BATTERY CAPACITY	6.25 Kwhr @ 72 V 90ah
6.	CHARGING TIME	7.81 hrs in case of solar panel
7.	HYBRID ENERGY	Solar energy
8.	FEATURES	Regenerative braking and solar
9.	BATTERY TYPE	Lithium-ion- battery

OMPONENT	SPECIFICATIONS
Solar panel	10 V

Body frame	Hylem sheet with modified crossection
Battery pack	6 cells of 3 battery pack, 3000 Mah each
Motor	6V DC motor
Controller	L298N Driver controller
Beam	Aluminum rod

TABLE 5 Fabricated modal details

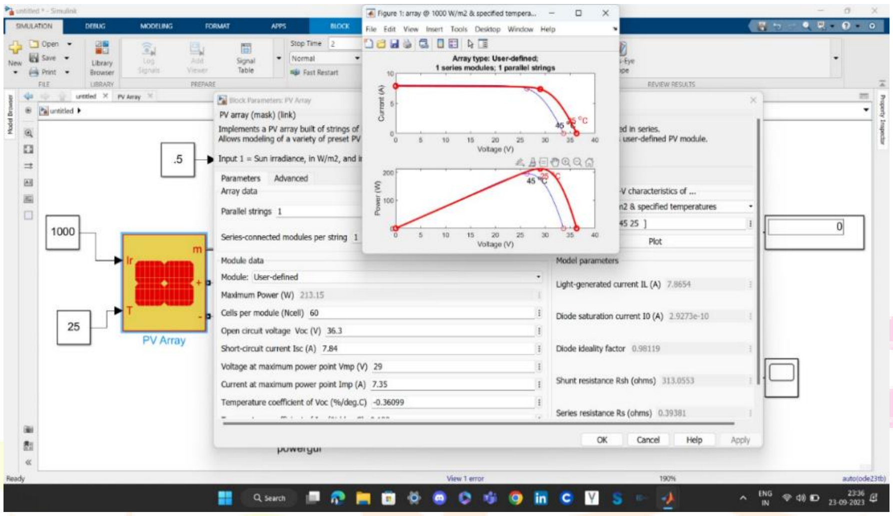
The components for our solar-powered device are carefully selected to meet specific specifications. The solar panel provides a voltage output of 10 volts, ensuring optimal power generation from sunlight. The body frame is constructed using Hylem sheet with a modified cross-section, offering durability and strength while minimizing weight. The battery pack consists of six cells organized into three battery packs, each with a capacity of 3000mAh, providing ample energy storage for extended operation. Powering our device is a 6V DC motor, offering reliable performance and efficiency. To control motor functions, we employ the L298N Driver controller, which ensures precise operation and compatibility with our system. Structural support is provided by an aluminium rod beam, offering strength and stability without adding unnecessary weight.

In addition to meeting these specifications, our design prioritizes cost efficiency. By carefully selecting materials and components, we aim to minimize production costs without compromising quality or performance. Our modular approach allows for easy assembly and customization, further enhancing cost-effectiveness by reducing labor and assembly time.

To showcase the capabilities of our solar-powered device, we offer a demo module that highlights its functionality and features. This demo module provides a hands-on experience, allowing users to interact with the device and understand its operation. Through demonstrations and simulations, we illustrate the potential applications and benefits of our solar-powered solution, emphasizing its efficiency, reliability, and versatility.

SIMULATIONS AND OUTPUTS:

Solar panel Simulation with Solar irradiance:



PV array (mask) (link)

Implements a PV array built of strings of

Allows modeling of a variety of preset PV

Input 1 = Sun irradiance, in W/m2, and i

Parameters Advanced

Array data

Parallel strings 1

Series-connected modules per string 1

Module data

Module: User-defined

Maximum Power (W) 213.15

Cells per module (Ncell) 60

Open circuit voltage Voc (V) 36.3

Short-circuit current Isc (A) 7.84

Voltage at maximum power point Vmp (V) 29

Current at maximum power point Imp (A) 7.35

Temperature coefficient of Voc (%/deg.C) -0.36099

Model parameters

Light-generated current IL (A) 7.8654

Diode saturation current I0 (A) 2.9273e-10

Diode ideality factor 0.98119

Shunt resistance Rsh (ohms) 313.0553

Series resistance Rs (ohms) 0.39381

Fig 9 Output Graph of the Solar panel with irradiance temperature

Current-Voltage Curve:

- Set irradiance temperature to 25°C.
- The red curve represents the given irradiance input.
- The blue curve serves as an assumption input curve for comparing

Power-Voltage Curve:

Similar to the current voltage curve, with adjustments reflecting power values.

Step	Description
1. Assign Parameters	Set operating temperature and irradiance values.
2. Adjust PV Modules	Optimize specifications to achieve optimal voltage and current.
3. Obtain DC Output	DC output voltage obtained from solar power panel.
4. Filter Circuit	Filter circuit comprised of capacitors and inductors.

5. Buck Converter	Transfer energy to the assigned 48 Volt battery.
6. Optimize Values	Adjust voltage, state of charge, and current based on supply.

BLDC Motor Output Graph:

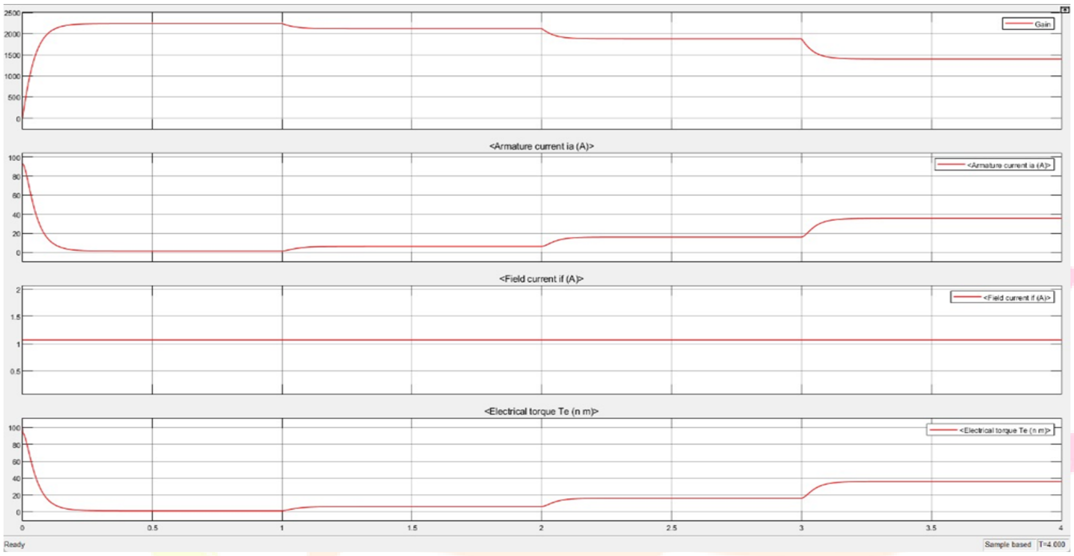


Fig 10 Motor output graph

Step	Description
1. Set Motor Parameters	Apply motor specifications: 70V for armature, 300V for field, load of 1N.
2.Connect DC Source	Connect DC voltage source to armature and field to apply torque value.
3. Insert Constant Block	Include a constant block in the block diagram to set initial values.
4. Display Scope	Add scope on the bus selector to display speed, armature, field current, and electrical torque values.
5. Power Gridlock	Include power gridlock and simulate. Initial graph values will be 0 due to no load.
6. No Load Speed	Add display block and feed values. Simulate and

	connect to bus selector. Obtain no load speed values: 2213 RPM, 2.176 A armature current, 1.066 A field current, 2.2 electrical load.
7. Apply Real Grid Values	Use formula T = P0 / ω to apply values of 4 Newton DC machine source.

Table 7 Motor simulation output step

EV CIRCUIT OVERVIEW:

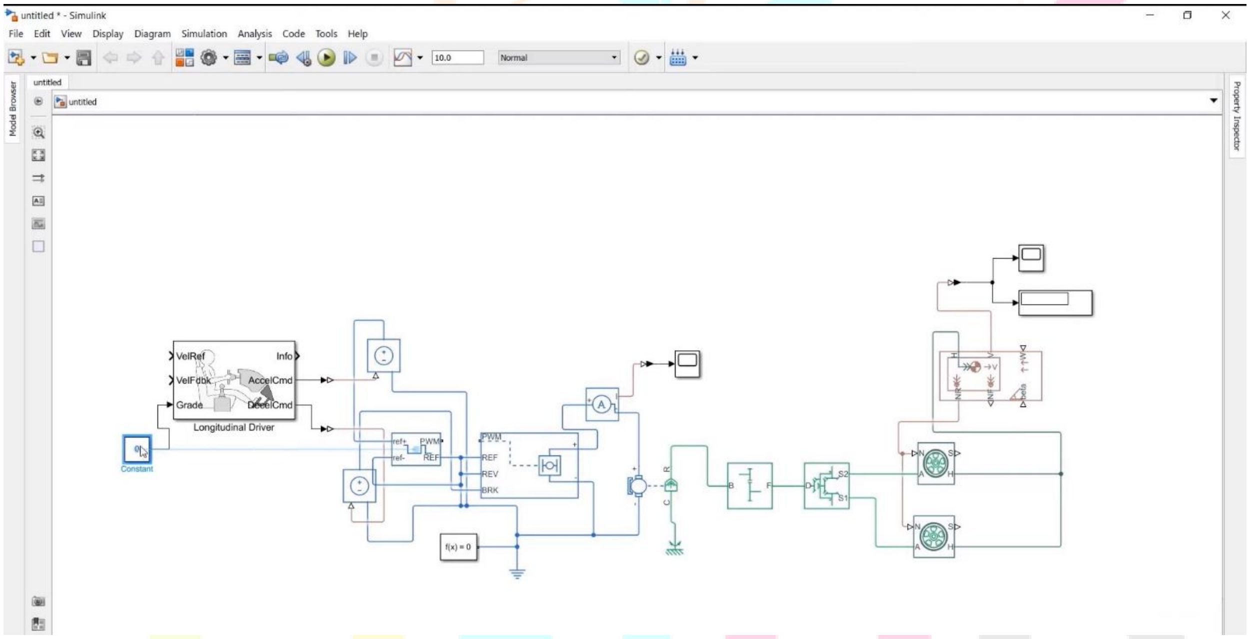


Fig 11 Overall EV circuit

MATLAB can be used to simulate an electric vehicle's (EV) entire circuit in order to study and assess its performance. MATLAB Simulink is used to model every part of the EV circuit, including the motor, battery, motor controller, and other peripherals. To do this, blocks that depict each component's behavior—including its electrical properties, control schemes, and relationships with other components—must be made.

The complete EV system is then represented by a single Simulink model that incorporates the separate component models.To replicate the movement of energy and electrical impulses across the system, connections are made between its constituent parts. MATLAB scripts or Simulink blocks are used to create control algorithms for a variety of operations within the Simulink model, including motor speed control, regenerative braking, and battery management.

Simulation settings, including input signals, initial conditions, and simulation time, are specified after the model is built. The EV system's simulation behavior is set by these parameters. MATLAB Simulink is used to run the simulation, which solves the equations controlling the EV system's behavior over time. Variables including motor speed, battery voltage, current flow, and energy usage are tracked and examined during simulation.
The analysis of the simulation results is done to see how well the EV system performs in various operational scenarios. This entails evaluating elements including power consumption, torque production, energy efficiency, and general system dynamics. To raise the simulation's accuracy and performance, more validation and optimization can be applied to the Simulink model.

CONCLUSION

In conclusion, the integration of solar panels into electric autorickshaws represents a promising solution for sustainable urban mobility. By harnessing solar energy to power these vehicles, we can significantly reduce reliance on fossil fuels and mitigate environmental impact. With that the cost is estimated by,

Component	Price (INR)
Electric Motor	15,000
Controller	10,000
Battery	20,000
Solar Panels	33,000
Chassis	15,000

Wheels and Tires	6,000
Suspension System	36,000
Braking System	8,000
Seating	3,000
Lighting and Electrical	4,000 - 5000
Dashboard and Controls	4,000
Wiring Harness	1,500
Total	Approx. 156000

Table 8 Cost estimation of the modal

The adoption of solar-powered electric autorickshaws offers numerous benefits beyond emissions reduction, lower operating costs, and increased energy independence. Firstly, it helps mitigate the adverse effects of urban air pollution, promoting cleaner and healthier environments for both passengers and pedestrians. Additionally, the use of renewable solar energy reduces reliance on fossil fuels, contributing to energy security and resilience against volatile fuel prices and supply disruptions. Moreover, the widespread adoption of solar-powered electric autorickshaws stimulates economic growth and job creation in the clean energy sector, fostering innovation, entrepreneurship, and investment in green technologies. Furthermore, it enhances public transportation infrastructure, reducing congestion and improving mobility in urban areas. Overall, the transition to solar-powered electric autorickshaws aligns with global efforts to combat climate change, enhance sustainable development, and build resilient, inclusive, and environmentally friendly communities.

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