A Novel Design and Tracking for Kick Scooter based on Solar Flower

Mr. G. OM SURAJ
Dept. of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore, INDIA
omsuraj.g.eee@kct.ac.in

SOWMINI G A
Dept. of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore, INDIA
sowmini.21ee@kct.ac.in

VIJAY DANIEL E
Dept. of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore, INDIA
vijaydaniel.21ee@kct.ac.in

KAVITHA K
Dept. of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore, INDIA
kavitha.21ee@kct.ac.in

Abstract **This article introduces a novel topology and design methodology for a solar kick scooter equipped with a solar sunflower panel. The proposed topology introduces a sunflower-shaped solar panel to increase the effective panel area by employing dynamic expansion mechanism. The panel remains folded while the scooter is in use and expands like a sunflower when at rest, allowing efficient solar energy harvesting. This approach improves the scooter's energy efficiency by maximizing solar exposure while reducing power losses associated with conventional fixed panels. The mathematical analysis highlights the significance of dynamic panel expansion and its impact on energy harvesting throughout the day. Furthermore, the role of real-time sunlight intensity detection in optimizing panel positioning is emphasized. A systematic methodology for integrating the solar panel expansion mechanism with the scooter's power management unit is proposed. To verify the proposed topology, MATLAB/Simulink simulations are conducted, followed by experimental validation using a prototype. The proposed system achieves a solar tracking efficiency improvement of 23%, a power output gain of 18%, and a reduction in battery charging time compared to conventional fixed-panel configurations.**

Keywords: Battery charging, dynamic panel expansion, energy efficiency, solar-powered kick scooter, sunflower-shaped solar panel.

I. INTRODUCTION

In recent years, the emphasis on environmentally friendly transportation has driven significant interest in integrating renewable energy sources into mobility solutions, particularly electric scooters [1]. These vehicles have emerged as viable alternatives to fossil-fuel-based transportation due to their clean and efficient operation. However, conventional electric scooters heavily rely on grid-based charging infrastructure, limiting their range and increasing energy consumption from non-renewable sources [2]. To address these limitations, there is a growing need for solar-powered electric kick scooters equipped with advanced solar tracking systems to enhance energy efficiency and self-sustainability [3].

Several researchers' efforts have explored the integration of solar power into electric scooters. A solar charging dock for personal electric vehicles was proposed, demonstrating the feasibility of off-grid charging [4]. However, it suffers from a fixed positioning, making it inefficient during non-charging periods and limiting energy harvesting to stationary use only. To overcome the energy management some researchers are explored using an IoT-based smart charger dock utilizing solar panels allowing remote energy management [5]. Despites these advancements, stationary solar panel charging which cannot maximize energy absorption throughout the day.

A broader perspective on solar-powered electric vehicles was discussed in [6], emphasizing the benefits of integrating renewable energy. However, the study lacks a dedicated solar tracking mechanism, leading to suboptimal power generation.

On other hand some researchers have explored the design and implementation of solar-powered scooters [7] and [8]. Still these methods faced major challenges in energy inefficiency due to fixed solar panels that cannot dynamically track sunlight. Some researchers introduced a dual-axis solar tracking system for small-scale applications [9]. However, the system relied on complex mechanical linkages, making it bulky and expensive. To address this a single axis tracking mechanism was proposed to improve energy harvesting [10]. While this approach increased efficiency, but it failed to account for latitudinal variations and provided limited improvement in total energy capture. To overcome the latitudinal variations researchers explored automatic solar trackers using stepper motors and microcontrollers [11] and [12]. Although these systems offered improved tracking, they required high power consumption, reducing the net gain in energy efficiency. Additionally, calibration complexity and maintenance challenges made these systems less practical for lightweight vehicles like kick scooters. To overcome this some researchers had investigated a sensor-based tracking system that relied on photo sensors to align panels with the sun [13]. However, the performance of this approach was highly sensitive to

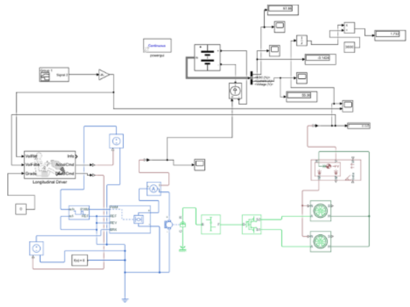
environmental factors, such as cloud cover and sensor degradation, which affected tracking accuracy.
To overcome the above limitations, this paper proposes a novel solar-powered electric kick scooter featuring an advanced dynamic solar tracking mechanism along with its methodology. The proposed topology having a merit stated below:

1. Enhanced energy efficiency by utilizing the proposed tracking mechanism.
2. Dynamic panel expansion mechanism and effective area utilization achieved by the solar flower panel.
3. Sunflower shaped solar tracking system integration with the kick scooter.
4. Dual axis mechanism gives a provision for dynamic tracking of sun light.
5. High power density by eliminating the traditional sensor based tracking system.

This paper discusses in a format of design methodology of the proposed topology in Section III, Simulation analysis in Section IV, Experimental analysis in Section V followed by the conclusion.

II. DESIGN METHODOLOGY AND ITS OPERATION

Solar Kick Scooter is a cutting-edge eco-friendly electric two-wheeler that possesses an active solar tracker system to maximize the energy input. The solar panel installed on the roof dynamically alters its slope by real-time movement via LDR sensors and servo motors in such a manner that the vehicle receives maximum solar radiation at any time of the day. An extendable sunflower-shaped solar panel, which is automatically extended during parking of the vehicle, provides extra surface area to output maximum power when extended. Such a power is stored in a vast lithium-ion battery that is controlled by a Battery Management System (BMS) so that it avoids overcharging, overheating, and deep discharge so that power is ensured for long-term reliability and performance.
Propulsion is ensured through a high-performance Brushless DC (BLDC) hub motor, minimizing mechanical losses in transmission and optimizing performance. Acceleration and braking are regulated by the Electronic Speed Controller (ESC) precisely and optimize energy consumption. The scooter additionally features regenerative braking system, where kinetic energy at braking is converted to electric energy and charged to the battery, optimizing overall efficiency and maximizing battery life.
For facilitating intelligent energy management, the scooter is equipped with an IoT-enabled monitoring system in the form of NodeMCU microcontroller and Blynk App, which allows real-time tracking of battery status, solar power, and motor energy consumption. Low battery, high power consumption, or system malfunction notifies the users, allowing them to undertake proactive



maintenance and ensuring safety. These safety components involve an emergency brake system, overcurrent protection, speed limiter, and LED lights to enhance night visibility.
Regarding convenience, the scooter features a foldable light structure to facilitate convenience in carrying and aerodynamics. The mechanical system features shock mounts to remove vibration in the tracking system. Model simulation, modelled through MATLAB/Simulink, computes the system's performance in solar panel tracking, battery charging, motor driving, and IoT monitoring.
The charging system comprises Schottky diodes for reverse current prevention and a microcontroller-controlled microswitch MOSFET to control current in response to sunlight intensity and battery charge. These are used to achieve maximum charging efficiency with energy loss prevention.
By adding real-time solar tracking, regenerative braking, and intelligent monitoring, the Solar Kick Scooter reduces reliance on traditional charging, giving clean and efficient urban transportation

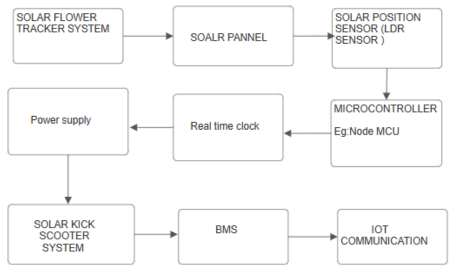


FIG 1.2(a)SOLAR FLOWER WITH KICK SCOOTER

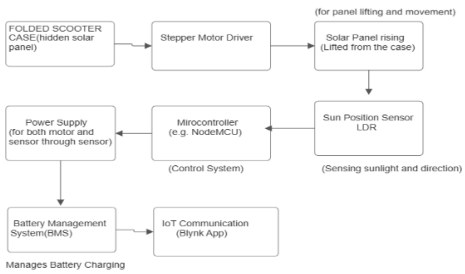


FIG. 1.21(b) DUAL AXIS SOLAR TRACKER
Solar flower system is designed in a way that its surface area would be most extended to generate energy but be in idle state in the scooter. Heliotropy in nature acquaints us with a concept which utilizes servo motors and hinge

joints such that the solar flower may be able to have petal-like solar panels stretching as much as possible towards receiving a large portion of the sun's light. The solar flower system is also coupled with the EMS of the scooter to allow dynamic power supply adjustment. These solar panels utilized here are monocrystalline photovoltaic (PV) panels with high efficiency and a long life span. NodeMCU microcontroller is employed for monitoring and controlling in real time with the help of IoT. Wireless communication NodeMCU sends and receives crucial parameters like solar power generation, battery charging, and energy usage to the Blynk App for remote observation of scooter efficiency and energy readout. The synchronization of the real-time clock (RTC) is utilized for giving precise monitoring of energy, regulating the supply of power as per usage patterns. It is controlled by a Maximum Power Point Tracking (MPPT) charge controller, which dynamically controls the voltage and current to deliver maximum power supply to the lithium-ion battery. Battery Management System (BMS) charges the battery efficiently and safely, keeping it from being overcharged, deeply discharged, and overheating. For further augmenting the energy harvesting, the dual-axis tracking system follows the location of the solar flower based on the sun's movement during the day. Two Light Dependent Resistors (LDRs) placed at both ends of the solar panel are employed within the system in an effort to gauge the change of the sunlight intensity. Real-time sensor readings are read by the NodeMCU microcontroller and used for rotating the panel's tilt angle accordingly.

1. Primary Axis (Latitude Adjustment): Moving the north-south tilt of the panel because of the change in sun position with the seasons.
2. Secondary Axis (Longitude Adjustment): Minor tilting of the east-west direction of the panel to follow the sun path throughout the day.

Because the scooter is moving, the solar panel is attached in a manner that avoids unnecessary adjustment for stability of the ride. EMS supplies energy dynamically with more emphasis on real-time power demand and storing surplus energy for future use. IoT-based implementation of EMS makes it efficient to monitor real-time

1. Battery status and charge condition
2. Solar power generation and consumption
3. Motor power consumption and regenerative braking recovery

The Blynk App dashboard provides users with alerts for low battery levels, high energy consumption, or system malfunctions, ensuring proactive maintenance and optimal performance

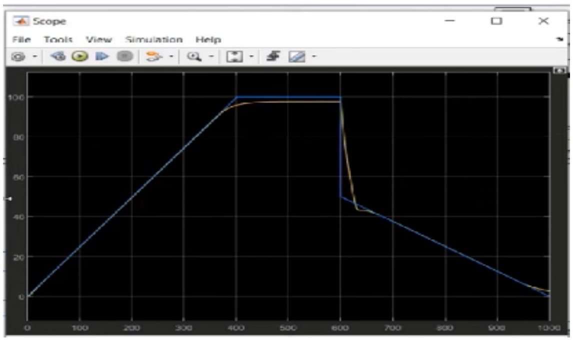


Fig 1.23(a): Fig 1.1 Model of solar kick scooter

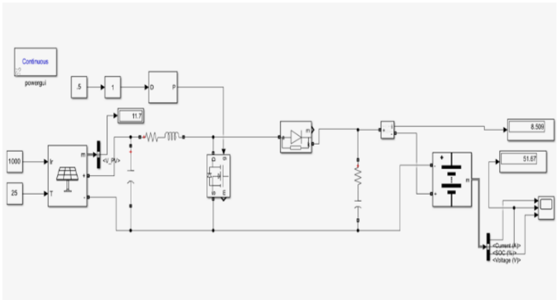


Fig 1.23(b): model of battery charging using panel

The Solar Kick Scooter MATLAB model is intended for the observation of its performance during operation and efficiency with energy consumption in actual practical applications. It combines key components like the vehicle body, gear motor, lithium-ion battery, H-bridge motor driver, and solar panel recharging system linked to a boost converter. Test cases are made by the use of Signal Builder software to model such variables as variation in speed, resistance from the terrain, and variation in solar intensity. H-bridge motor-driven gear addresses acceleration, regenerative energy recovery, and braking. Solar panel MPPT-based boost converter also finds usage for the purposes of power harvesting maximization for effectively charging the battery. This simulation allows the system performance with respect to energy consumption, charging of batteries, and performance in real-time to be gauged, thereby an ideal tool for designing and optimizing the performance of the scooter prior to its usage. The MATLAB simulated result relies on signals developed through the Signal Builder tool simulating the parameters of the vehicle, including speed, load, and road terrainWith these parameters, the simulation determines the scooter's performance in different conditions. The solar panel and the boost converter are instrumental in the maximum power transfer through monitoring the Maximum Power Point (MPPT). It controls the voltage and current output for battery charging efficiently. The outputs are important parameters like the State of Charge (SoC), the voltage of the battery, and the current drawn through, illustrating the energy efficiency and power management of the scooter. The outputs are utilized to investigate the efficiency of the solar charging system for maximizing energy consumption for long periods of operation

Fig 1.24(a) The speed variation using signal builder

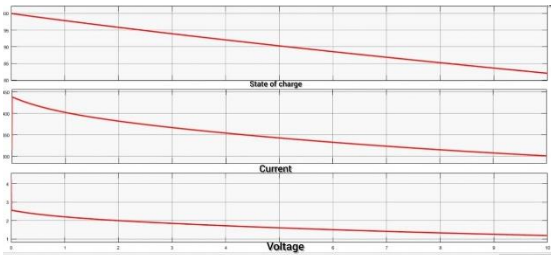


Fig 1.24(b) The soc, current and voltage outputs of battery

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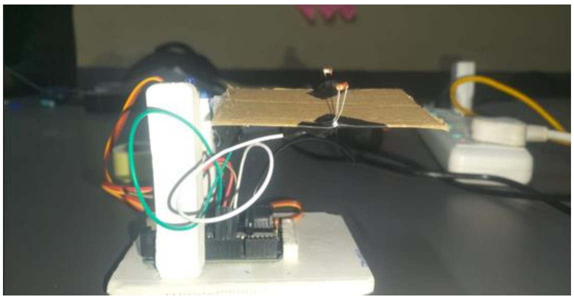
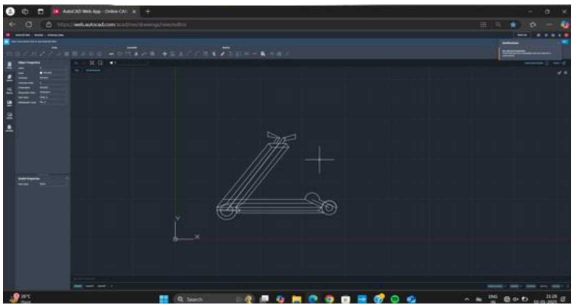
III. PROTOTYPE AND AUTOCAD MODEL OF SOLAR TRACKER

A solar flower tracking system is an emerging device that simulates the movement of a flower, adjusting the angle of solar panels throughout the day to maximize sunlight collection. Compared to fixed solar panels, the system adjusts its position relative to the sun constantly, enhancing power output. It can be applied to solar kick scooters or other solar renewable energy systems to enhance efficiency. The prototype also contains the bulky hardware components consisting of a solar panel, a source to convert sun energy into electrical energy, and LDR sensors, sensing the position of the sun from varying intensities of lights. A microcontroller in an Arduino Uno regulates sensor outputs and is used to control movements of servo motors, which are accountable for spinning the panel along horizontal (east-west) and vertical (tilt) directions. The system is operated by a 6V or 12V Li-Ion battery, storing the stored energy, and is charged efficiently using an MOSFET and diode combination. The entire build is housed within an aluminum or 3D-printed housing, and wiring is established by jumper cables and wires. Arduino IDE is used as the control program, with the ability to interface with Blynk App for IoT monitoring. The system is employing LDR sensors on either side of the panel to detect variations in sunlight. The Arduino senses the light intensity disparity and provides instructions to the servo motors, facing the panel towards the sun. The panel's horizontal movement varies from east to west during the day and the tilt adjusts for sun position changes in seasons. The energy obtained from the solar panel is accumulated in a battery with the assistance of the MOSFET and diode circuit to reduce energy loss. In the process of developing the prototype, the mechanical system is first constructed by attaching the solar panel on servo motors with the support structure made of 3D-printed parts or aluminum brackets. Lastly, the circuit wiring is completed, wherein LDR sensors are wired to Arduino, servo motors to PWM pins, and the MOSFET and diode charging circuit. Lastly, programming of the Arduino is performed, wherein a minimalist code reads sensor values, adjusts the servo angles as needed, and contains a threshold logic to prevent unnecessary movement. Upon assembly, the solar flower is put to test where it is exposed to direct sunlight and observed how it adjusts its angle automatically in tracking the sun. The efficiency of battery charging after and before the facility for tracking is enabled is compared as the system performance indicator. The enhanced solar energy usage makes this solar tracking system of widespread application for renewable energy installations.

(a)
(b)

Fig 1.5 (a) PROTOTYPE OF TRACKING SYSTEM (b) Designing in AUTOCAD





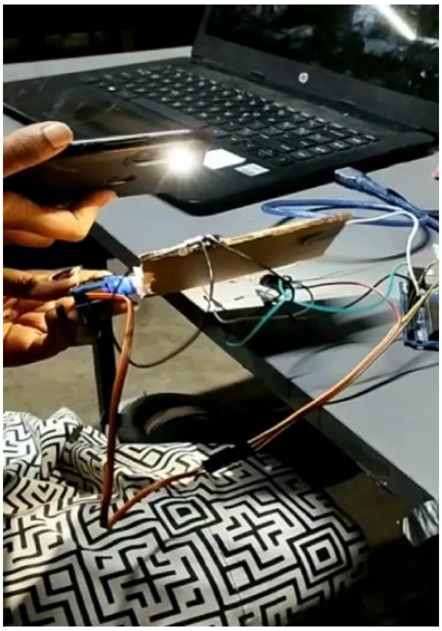
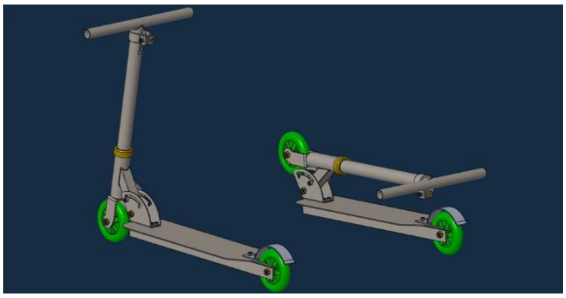


Fig 1.5(c): Mechanism of the prototype



(a)
(b)

Fig 1.6 (a) The complete design of the kick scooter
(b) AutoCAD model of solar tracker & kick scooter

IV. CONCLUSION

The solar-powered kick scooter is an eco-friendly and futuristic urban mobility solution by harnessing the energy of solar energy harvesting, online monitoring, and intelligent energy management systems. The energy efficiency in design is maximized by a dual-axis solar tracking system, which makes a constant alteration of the angle of the solar panel based on the position of the sun with the assistance of LDR sensors, servo motors, and an IoT-based control system on NodeMCU. Additionally, an extendable sunflower-design solar panel has the largest energy-harvesting surface area when docked to enable the scooter to provide maximum power delivery and battery capacity. The system uses a high-efficiency BLDC hub motor driven by a Lithium-ion battery supplied by a Battery Management System (BMS) to prevent overcharging and increase the lifespan of the battery. Efficiency is optimized via regenerative braking by converting kinetic energy into stored electric energy. Smart monitoring through IoT integration with the Blynk App enables users to track battery condition, power usage, and solar energy capture remotely. MATLAB simulation ensures stability of the scooter by vehicle dynamic analysis, motor performance, and charging of battery from a boost converter. The result verifies efficient energy consumption with stable State of Charge (SOC), voltage, and current rates, thereby ensuring the system to operate stably. Generally, the solar kick scooter is a self-sustaining, clean alternative to traditional electric vehicles as far as reduced grid-dependency in charging and facilitating the use of clean power is concerned. Equipped with built-in solar tracking technology, regenerative braking, and IoT-enabled monitoring, this product provides additional sustainability, efficiency, and ease of use apart from being an excellent innovation for modern city mobility.

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