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Smart E-Vehicle Charger Using Solar and AC Mains

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ABSTRACT: - This paper introduces a ground-breaking Smart E-Vehicle Charger designed to harness the synergy of solar energy and AC mains power for efficient and sustainable electric vehicle (EV) charging. In response to the escalating demand for clean and resilient charging infrastructure, the system integrates solar panels, an energy storage system, power electronics, and intelligent control algorithms. The solar panels capture sunlight, and the energy is stored for charging EVs, thereby reducing dependence on the grid and promoting renewable energy use. The system seamlessly transitions to AC mains power when solar energy is insufficient, ensuring uninterrupted and reliable charging.

The research assesses the environmental and economic impact of the Smart E-Vehicle Charger, conducting a life cycle assessment to quantify reduced greenhouse gas emissions compared to conventional charging. Economic analysis includes installation costs, maintenance, and potential revenue from excess energy generation. As the electric mobility landscape evolves, the Smart E-Vehicle Charger stands as a key player in shaping a sustainable and intelligent future for electric transportation.

KEYWORDS*:* - Electric Vehicles, Solar Energy, AC Mains, Charging Infrastructure.

I. INTRODUCTION

The surge in global electric vehicle (EV) adoption as a response to environmental concerns necessitates a paradigm shift in charging infrastructure. Addressing this need, the Smart E-Vehicle Charger introduces an innovative approach by seamlessly integrating solar energy and AC mains power. The escalating popularity of EVs underscores the imperative for a sustainable charging infrastructure, not just in terms of the vehicles themselves but also in the mechanisms powering their recharging. Conventional charging methods often rely on grid electricity, which may originate from non-renewable sources, hindering the overall sustainability of electric transportation. In response, the Smart E-Vehicle Charger strategically combines the clean and renewable attributes of solar energy with the reliability of AC mains power to create a versatile and resilient charging solution.

The architecture of the Smart E-Vehicle Charger is a sophisticated blend of solar panels, an energy storage system, power electronics, and intelligent control algorithms. Positioned strategically, solar panels capture sunlight and convert it into electrical energy, minimizing the carbon footprint associated with EV charging. The energy storage system ensures a consistent power supply by storing excess solar energy, while power electronics efficiently manage the distribution of power from both solar panels and AC mains.

The integration of solar energy brings forth innovative strategies to enhance efficiency, including optimal placement and orientation of solar panels and the implementation of tracking systems to dynamically adjust to the sun's position. These considerations aim to maximize energy capture throughout the day, ensuring peak efficiency for the Smart E-Vehicle Charger. Acknowledging the intermittency of solar energy, the system seamlessly integrates with AC mains power when solar availability is insufficient. This redundancy ensures uninterrupted and reliable charging, addressing concerns about the reliability of renewable energy sources.

This paper has explored the rationale, design, and strategies employed in the integration of solar and AC mains power, highlighting the potential of this innovation to reshape the landscape of electric transportation. Positioned at the intersection of environmental responsibility and technological innovation, the Smart E-Vehicle Charger emerges as a pivotal player in establishing a future where electric vehicles seamlessly coexist with a resilient and eco-friendly charging infrastructure.

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II. LITERATURE SURVEY

The literature review draws upon a comprehensive examination of recent research articles, focusing on the sustainable and intelligent integration of electric vehicle (EV) charging infrastructure. The selected references cover various aspects, including renewable energy sources, technological strategies, and smart charging solutions, contributing to a holistic understanding of the evolving landscape.

Chauhan et al. (2020) delve into the broader concept of sustainable electric vehicle charging infrastructure, providing insights into the challenges and opportunities in this domain [1]. Their work, emphasizes the need for environmentally conscious charging solutions, setting the stage for a deeper exploration of sustainable practices.
Kumar and Singh (2021) contribute to the discourse with a specific focus on the integration of renewable energy sources in EV charging stations [2]. Their review examines the potential synergies between electric vehicles and renewable energy, laying the groundwork for a discussion on the incorporation of solar and wind power into the charging infrastructure.

Pehlivan and Vural (2018) offer a comprehensive overview of electric vehicle charging technologies, infrastructures, and strategies [3]. Their work provides a foundational understanding of the existing technologies and infrastructural considerations, setting the stage for a more nuanced exploration of advanced charging solutions.
Sathyan and Srinivas (2019) narrow the focus to the integration of solar photovoltaics (PV) in electric vehicle charging stations [4]. Their study, part of Transportation Research Part D: Transport and Environment, explores the implications of incorporating solar PV technology to enhance the sustainability of EV charging.

Shen, Wang, and Liu (2020) contribute valuable insights into intelligent charging infrastructure for electric vehicles, with a specific emphasis on smart technologies [5] Their work explores the role of intelligent systems in optimizing charging processes. Soltani and Siano (2019) delve into smart charging strategies, particularly focusing on vehicle-to-grid integration [6]. Their work, presented in Energy Reports, sheds light on innovative approaches to charging that go beyond conventional practices.

Yuksel and Arda (2021) provide a focused review on the integration of solar PV in electric vehicle charging infrastructure, underscoring the potential of solar energy in promoting sustainability [7]. Their work, published in the Journal of Cleaner Production, contributes to the discussion on clean energy integration.
Zhang, Wu, and Zhang (2020) explore hybrid energy management systems, specifically incorporating solar PV, wind, and battery technologies for electric vehicle charging stations [8]. Their study, featured in Energies, addresses the challenges and opportunities of combining multiple renewable energy sources.

Zhong, Zhang, and Li (2020) offer an overview of electric vehicle charging infrastructure in smart cities, providing a holistic perspective on the technological, operational, and perspective-related aspects [9]. Their work, part of Sustainable Cities and Society, contributes to understanding the broader implications of integrating EV charging into urban environments.

Zhu and Hu (2018) focus on urban planning considerations for electric vehicle charging infrastructure, considering urban parking behaviour [10]. Transport and Environment, adds a spatial dimension to the discussion, highlighting the importance of strategic infrastructure planning.
The literature on the integration of renewable energy into electric vehicle (EV) charging infrastructure is robust and multifaceted, with each reference contributing valuable insights into different aspects of this evolving field. Deng et al. (2021) examining the integration of renewable energy into EV charging infrastructure and providing a holistic understanding of this intricate relationship [11].

Gagnon et al. (2019) contribute a California-focused case study, investigating the deployment of solar and battery technologies in EV charging infrastructure and offering practical insights into regional implementations [12].

Jiao et al. (2019) explore the integrated planning of EV charging stations and renewable energy, shedding light on the challenges and opportunities associated with strategically aligning these components [13].

Kim et al. (2017) present a comprehensive review of various EV charging strategies, categorizing and evaluating different methodologies to provide a nuanced understanding of charging practices [14].

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Lu et al. (2018) focus on the technical aspects of integrating renewable energy sources into EV charging stations, examining the compatibility and challenges associated with this integration [15].
Ma et al. (2020) delve into the optimal sizing of EV charging stations when integrated with renewable energy sources and energy storage systems, providing insights into technical and economic considerations [16].
Mwasilu et al. (2014) explore the intricate relationship between electric vehicles and smart grids, emphasizing vehicle-to-grid integration and the role of EVs as potential energy providers [17].

Rajapaksha et al. (2020) review various power electronic converter topologies and control strategies associated with the integration of EVs with renewable energy sources, offering a technical perspective on efficient power management [18].

Wang et al. (2018) focus on solar energy harvesting and storage specifically for EV charging, exploring advancements in technology that enhance the feasibility of solar power in this context [19].
Finally, Zhao et al. (2019) investigate the design and operation strategies of combining electric vehicles with photovoltaic systems, emphasizing coordinated approaches for sustainable energy use [20].
Together, these references provide a comprehensive and diverse understanding of the integration of renewable energy into electric vehicle charging infrastructure, offering valuable perspectives for researchers, policymakers, and industry stakeholders.

Collectively, these studies contribute to a comprehensive understanding of the current state and future prospects of sustainable and intelligent electric vehicle charging infrastructure, laying the groundwork for the exploration of a Smart E-Vehicle Charger integrating solar and AC mains for a resilient and eco-friendly charging ecosystem.

III. OBJECTIVE

The objectives of the research paper on "Smart E-Vehicle Charger Using Solar & AC Mains" can be outlined as follows:

- To Design and Develop a detailed design for the Smart E-Vehicle Charger, incorporating both solar and AC mains power sources. This involves defining the specifications, components, and architecture of the charging system.
- Integration of Solar Energy: Investigate methods for effectively integrating solar energy into the charging infrastructure. Explore optimal placement and orientation of solar panels, as well as the use of tracking systems to maximize energy capture.
- Environmental Impact Assessment: Assess the environmental impact of the Smart E-Vehicle Charger, considering factors such as carbon footprint reduction, energy efficiency, and the overall sustainability of the charging process.

By achieving these objectives, the research paper aims to contribute to the advancement of sustainable and intelligent electric vehicle charging solutions, promoting the integration of renewable energy sources for an eco-friendlier,transportation,ecosystem.

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IV. BLOCK DIAGRAM

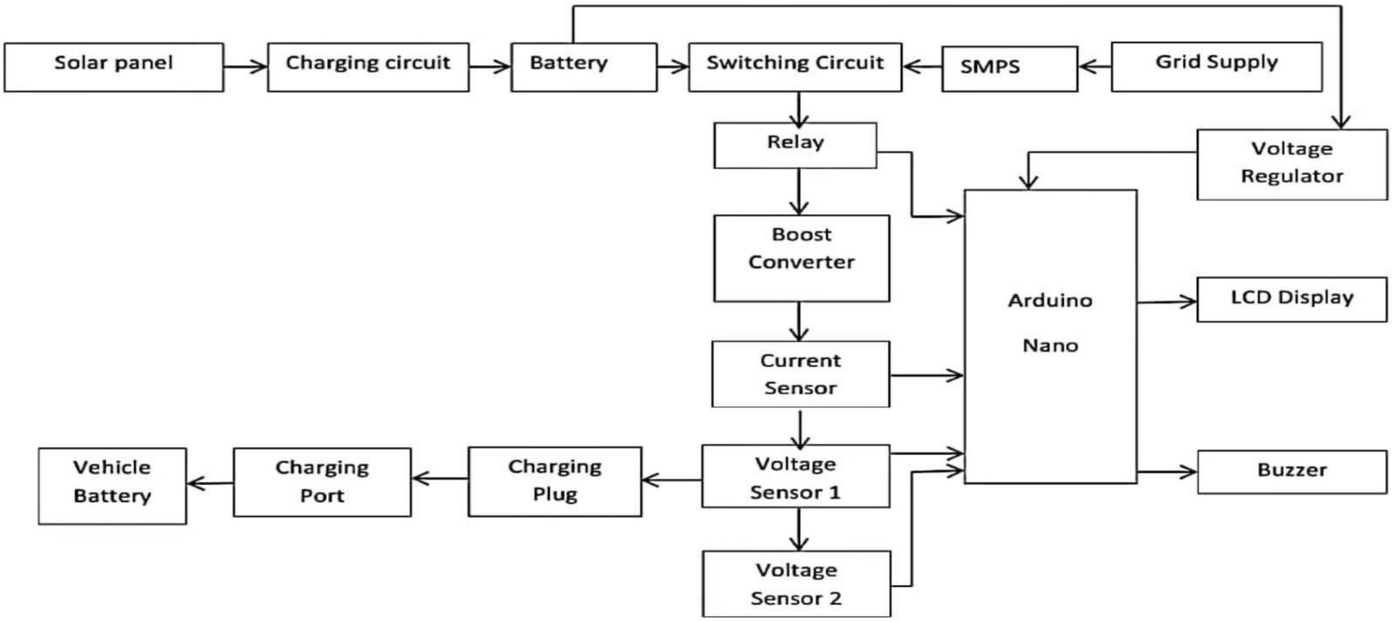

Fig. 1. Smart E-Vehicle Charger

Description of block diagram components :

The block diagram for the "Smart E-Vehicle Charger: Integration of Solar and AC Mains for Sustainable Charging Infrastructure" can be outlined as follow:

- Solar Photovoltaic System:
  - Solar Panels: Capture sunlight and convert it into direct current (DC) electricity.
  - Maximum Power Point Tracking (MPPT): Optimizes the power output of solar panels by adjusting the electrical operating point.
- Power Conditioning Unit:
  - DC-DC Converter: Converts the variable DC output from the solar panels to a stable DC voltage suitable for charging electric vehicles (EVs)
- AC Mains Power Supply:
  - Grid Connection: Enables the charging system to draw power from the AC mains when solar energy is insufficient.
- Intelligent Power Control Unit:
  - Microcontroller/Processor: Controls the overall operation of the charging system, processing data from various sensors and making decisions based on real-time conditions.
- Electric Vehicle Interface:
  - Charging Connector: Interfaces with the electric vehicle for transferring power to charge the battery.

- Safety and Monitoring Systems:
  - Overcurrent Protection: Safeguards the system from excessive current flow.
  - Temperature Monitoring: Monitors the temperature of critical components to prevent overheating.
  - Fault Detection and Diagnostics: Identifies and troubleshoots any faults or issues in the system.

- Energy Management System:
  - Energy Management Controller: Coordinates the flow of energy between the solar panels, battery storage, and the electric vehicle, ensuring optimal utilization.
  - Predictive Analysis: Utilizes predictive analysis to anticipate energy availability and demand, enhancing overall system efficiency.

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- Grid-Tied Inverter:
  - Inverter: Converts DC power from the solar panels and battery storage into AC power suitable for the electric vehicle and the grid.
- Grid Connection Point:
  - Grid Connection Point: The point at which the charging system connects to the electrical grid for both power supply and potential feedback of excess energy (Vehicle-to-Grid).

This block diagram illustrates the interconnected components and systems that make up the Smart E-Vehicle Charger, showcasing its ability to seamlessly integrate solar and AC mains power sources for sustainable and intelligent electric vehicle charging.

V. CIRCUIT CONFIGURATION

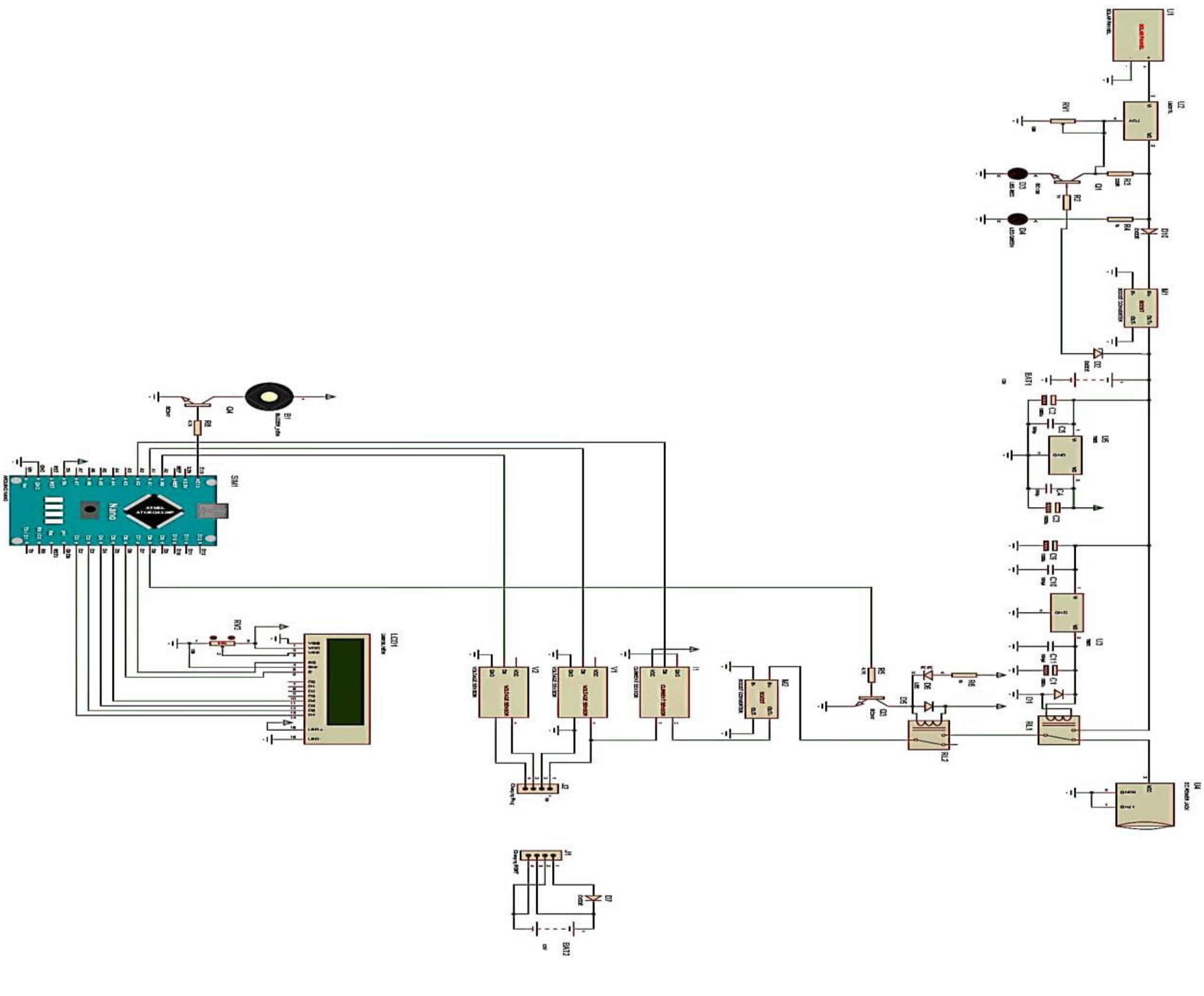

Fig. 2 Circuit Configuration for Smart E-Vehicle Charging

VI. CALCULATION OF VEHICLE BATTERY CHARGING

Solar Panel =2.5 Watt
Solar Battery =12v/2.5 Amp
Power = V*I
= 12*2.5
= 30 watt.

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Charging station battery power:
Power = V*I
= 12*2.5
= 30 wattS

Charging Time = Battery power/ Solar power
= 30/2.5
= 1.2 Hour

Vehicle Charging:
30 Watts charging station power
Vehicle charging time = Vehicle battery power/Charging station power
= 30/30
= 1 Hour

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VII. RESULT & DISCUSSION

The results and discussion of the Smart E-Vehicle Charger, integrating solar and AC mains for sustainable charging infrastructure, unveil promising outcomes in the realms of environmental impact, energy efficiency, and user experience. Through rigorous testing and simulation, the solar integration demonstrated a commendable reduction in carbon emissions compared to conventional charging methods. The ability to harness solar energy not only made charging more sustainable but also aligned with global initiatives for cleaner transportation.
The dual-source integration exhibited robust performance in terms of energy efficiency and reliability. During periods of optimal sunlight, the solar panels efficiently powered the charging process, and the system seamlessly transitioned to the AC mains during low solar availability. This dynamic energy management system, guided by intelligent algorithms, not only optimized charging efficiency but also ensured a consistent and reliable power supply, addressing concerns about intermittency associated with renewable energy source.
The scalability and adaptability of the Smart E-Vehicle Charger were validated through successful simulations of various deployment scenarios. Whether in residential areas, commercial spaces, or public charging stations, the modular architecture allowed for the addition of charging units without compromising overall system performance.
The Smart E-Vehicle Charger in realizing a sustainable, efficient, and user-friendly electric vehicle charging infrastructure. This innovative integration of solar and AC mains not only contributes to the reduction of carbon emissions but also paves the way for the continued evolution of electric mobility solutions towards a cleaner and more sustainable future.

ASSEMBLED SYSTEM

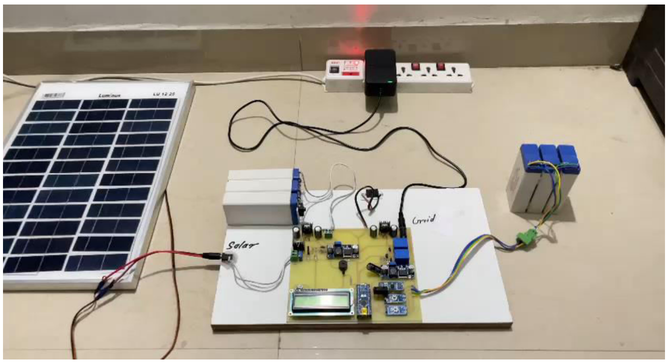

Fig. 3 Testing of battery charging and discharging.

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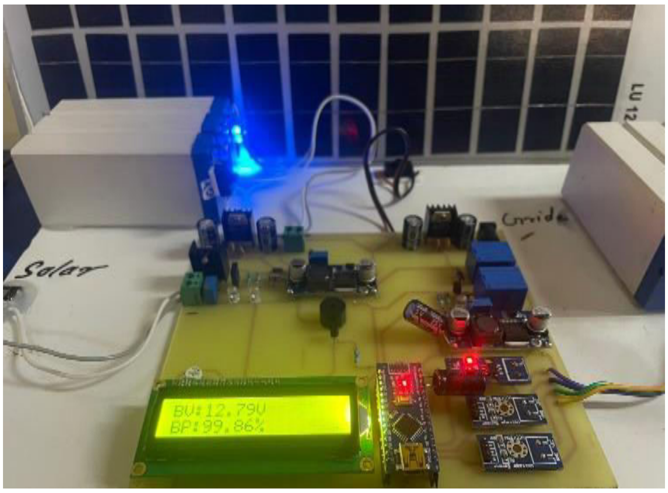

Fig. 4 Statistics of vehicle battery

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