IJARIIT
INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 10, Issue 6 - V10I6-1378)
Available online at: https://www.ijariit.com

Smart EV Charging Station with Grid Green Power and Wireless Charging

Vivek Makane
vivek.balwant.makne@gmail.com
RMD Sinhgad School of Engineering, Pune

Aditi Prashant Ozardekar
aditiozardekar@gmail.com
RMD Sinhgad School of Engineering, Pune

Varsha V. Nanavare
varshananavare.rmdssoe@sinhgad.edu
RMD Sinhagd School of Engineering Pune

ABSTRACT

The demand for green charging has increased with the rapid growth of electric vehicles (EVs). This paper reviews a smart EV charging station integrating solar and wind power with on-grid electricity to support multiple charging modes: DC fast charging, AC charging, wireless charging, and grid-powered AC charging. An RFID-based system secures access to wireless charging, enhancing usability. This review looks into the design, benefits, and challenges of integrating renewable energy into EV charging, highlighting the system's potential for environmental and operation advantages in sustainable infrastructures.

KEYWORDS: *EV Charging Station, Renewable Energy Source, Energy Management*

INTRODUCTION

The emergence of EVs is the most sweeping change toward sustainable transportation, enabling independence from fossil fuels, thereby curtailing greenhouse gas emissions. However, larger adoption of EVs relies upon an easily reachable and efficient charging infrastructure. Notably, traditional charging stations use electrical energy obtained from electricity grids that is sourced mainly from non-renewable resources, which inhibits the advancement of sustainability. This has raised the interest in a newer innovation, the integration of renewable energy sources, which includes the ever-expanding domains of solar and wind power, into EV charging systems. Alongside this are newer developments in wireless charging technologies that offer exciting prospects in user convenience and automation.

This paper explores the approach for the incorporation of solar and wind-based green power for smart EV charging stations which is supported by various advanced charging techniques, including wireless charging. This research focuses on developing a sustainable yet user-friendly solution powered by renewable and conventional power sources. This study examined the design, methodology, and effectiveness of a prototype that combines solar and wind energy with other charging mechanisms, such as DC fast charging, AC charging, wireless charging, and grid-AC charging.

RELATED WORK

"Overview of Electric Vehicles Charging Stations in Smart Grids" by M. Wadi, W. Elmasry, M. Jouda, H. Shahinzadeh, and G. B. Gharehpetian. This paper presents an incoherent insight into the technological make of EV charging stations within the smart grid, with emphasis on their inevitable role in facilitating the transition towards sustainable transportation. The paper deals with all the charging technologies such as Level 1, Level 2, DC Fast Charging, and wireless charging while addressing issues concerning the scalability of infrastructure, its integration with the grid, and interoperability. Then, the paper investigates how optimal placements for on-grid and off-grid charging stations can be found using a DC-DC converter, which would enhance charging efficiency. Finally, future trends for charging infrastructure are analyzed in the paper.

"Dynamic Wireless Charging for Inductive Power Transfer Systems in Electric Vehicles" by Ponmani Raja M., Karthik Chandran, and Jeyakannan. The authors have studied DWC for EVs, which is the idea of charging vehicles while in motion. This technique tries to eliminate the shortcomings of conventional charging, such as longer recharging times and shorter driving distances. The principle of the proposed system is the installation of many inductive pads under roadways, enabling power transfer as moving vehicles drive on top.

Initial results with a small-scale model using enamelled copper wire and a toy car suggest that the potential of DWC to improve convenience and efficiency in the charging process can be huge, with the authors suggesting further work to scale up and optimize this technology.

"Recent Advances in Smart Grid Architecture and Grid-Electric Vehicle-Charging Station Interaction" by Dongning Zhang. This paper reviews smart grid technologies that are useful for optimal EV charging and for keeping energy distribution stable. Smart grids with features like smart metering and demand response alleviate grid stress and foster EV infrastructure. The study points out the contributions of EVs to the reduction of emissions and increasing the use of renewable energy. Case studies demonstrate that smart grid technologies improve EV charging efficiency, lower energy waste, and promote sustainable transportation. The paper forecasts that future developments will focus on advanced grid-EV integration, such as vehicle-to-grid (V2G) systems, to enhance grid stability and energy efficiency.

"Solar-Based Wireless Charging System for Electric Vehicles" by Aravind Kumar, Yashaswini N., and Rudresh S. J. This paper discusses the integration of solar energy and wireless power transfer (WPT) for EV charging. Wireless charging through inductive coupling, an efficient and contactless energy transfer, is a promising aspect. Citing studies by Choi et al. (2014) and Rakhman et al. (2013), this paper illustrates the viability of these systems, while Uthaya Banu et al. (2018) highlight the environmental benefits of combining solar energy with WPT. Challenges like extended charging times and infrastructure limitations are discussed, alongside dynamic charging solutions as proposed by Magudeswaran et al. (2019). The paper suggests further research into the standardization of wireless charging of EVs, and its integration with smart grids, towards expanded infrastructure.

Konstantina Dimitriadou, Nick Rigogiannis, Symeon Fountoukidis, Faidra Kotarela, Anastasios Kyritsis, and Nick Papanikolaou have authored "Current Trends in Electric Vehicle Charging Infrastructure; Opportunities and Challenges in Wireless Charging Integration". This paper reviews EV charging infrastructure, examining conductive and wireless (inductive) charging advancements. This paper discusses wireless charging standards such as magnetic couplers and compensation networks and emerging power system architectures, including the Internet of Energy (IoE). Innovations such as dynamic and quasi-dynamic charging are analyzed, pointing out the role of smart control and communication in improving EV charging solutions.

"Challenges and Barriers of Wireless Charging Technologies for Electric Vehicles" by Geetha Palani, Usha Sengamalai, Pradeep Vishnuram, and Bened. This paper reviews the theoretical framework and challenges of wireless EV charging, particularly using magnetic resonance coupling. This paper covers the impact of power pad positioning in efficiency and, in other works, safety concerns by interruption of foreign objects. The optimization of software-in-the-loop models is developed to improve system performance and answer concerns over safety, thus realizing effective wireless charging solutions.

"Smart Environment: The Base for Energy Management Strategy-Based Scenario of a Solar Charging Station for Electric Vehicles" by Morteza Azimi Nasab, Mohammad Zand, P. Sanjeevikumar, Atif Iqbal and Baseem Khan. The presented article concerns a solar charging station for EVs with Smart Energy Management in order to optimize costs and to be efficient. This paper shows how predictive analytics combined with automatic management strategies could be optimized using deep learning for forecasting the level of EV charging and Social Network Analysis used for EV behavior assessment. Tested on the IEEE 33-bus network, this proposed system will decrease energy consumption and emit a useful model for urban smart environments.

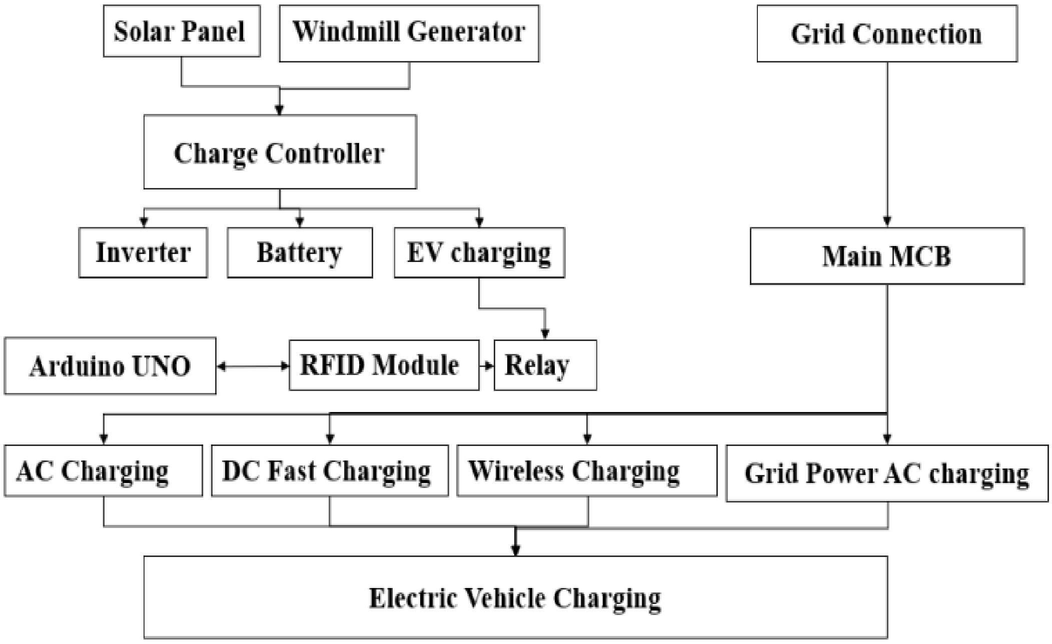
“Renewable Energy Power Assimilation to the Smart Grid and Electric Vehicles via Wireless Power Transfer Technology” by Hamid Allamehzadeh, Sarbagya Shakya.This paper explores advancements in smart grid technologies and their role in integrating renewable energy sources, particularly wind and solar, for efficient electric power transfer. Wireless Power Transfer (WPT), especially Inductive Power Transfer (IPT), has emerged as a promising solution for charging electric vehicles (EVs) without physical connections, enhancing energy efficiency through magnetic resonance. As EV adoption grows, smart grid-connected and standalone wireless charging stations powered by renewables could support widespread EV usage and sustainable transportation. This review examines the opportunities and challenges of WPT in EV charging infrastructure, highlighting the potential for smart grids to revolutionize clean energy-driven mobility.

“A Comprehensive Analysis: Integrating Renewable Energy Sources with Wire/Wireless EV Charging System for Green Mobility” by ,Ahmed Shahin, Almoataz Y. Abdelaziz, Azeddine Houari, Babak Nahid-Mobarakeh, Serge Pierrfederici, Fujin Deng, Sayed Abulanwar. Integrating renewable energy sources with existing power grids can help manage the increased demand from EV charging, even if most charging occurs during off-peak hours. This paper reviews various EV charging methods, emphasizing grid-based charging with renewables. The most practical approach is large-scale renewable energy stations connected to the grid. The study also highlights challenges, particularly for wireless charging systems, like energy loss, coil alignment, and safe, efficient power transfer. It explores different wireless charger setups, especially a series-series configuration with photovoltaic integration, achieving around 98% efficiency and reliable operation despite grid fluctuations.

“Principal Challenges for Designing an Efficient Wireless Power Transfer for Electric Vehicles” by Yosra Ben Fadhel, Kamal Al-Haddad.The rising need for safe and convenient battery charging methods has turned attention to wireless power transfer (WPT) technology.

As electric vehicles become a key solution for lowering CO2 emissions, they rely on efficient Li-ion battery charging. WPT offers a user-friendly and dependable way to charge these batteries, easing customer concerns about charging accessibility. Inductive power transfer has been pivotal in advancing electric cars, buses, and trains, opening doors for wireless charging applications. However, challenges like power loss and low transfer efficiency remain, requiring further research. This paper explores the core design of a resonant inductive WPT system and addresses essential hurdles in developing an efficient wireless charging solution for electric vehicles, supporting progress in driverless EV technology.

METHODOLOGY



This section outlines the system design and functionality of a sustainable EV charging station powered by renewable energy sources with a grid backup. The station is designed to deliver multiple charging options, managed through a central control unit to optimize efficiency and ease of use for EV owners.

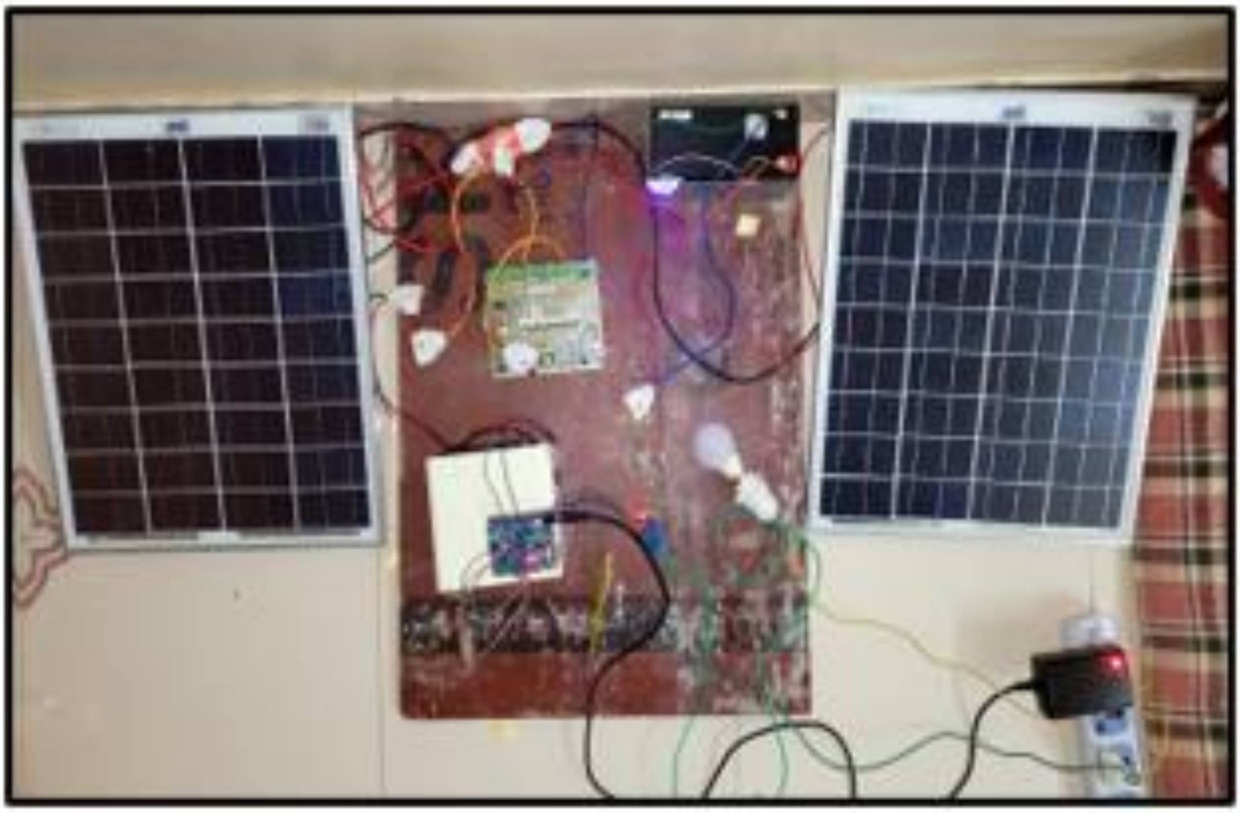
Renewable Energy Sources
The charging station draws power from two primary renewable sources: solar panels and windmill generators. Solar panels capture sunlight and convert it into electrical energy, while wind turbines harness wind energy. Both power sources are connected to a charge controller, which regulates their output, stabilizing voltage levels and protecting the system from overcharging. This dual-source setup ensures a consistent energy supply.

Energy Management and Storage
The charge controller directs the incoming power in three possible paths:
Battery Storage: Surplus energy generated by solar panels and wind turbines is stored in a battery. This allows the station to have a backup power supply for EV charging during periods with low renewable generation, like cloudy or windless days.
Inverter: The inverter converts stored DC power from the battery to AC power, making it compatible with grid-based charging systems. This AC output can be used to supplement grid power or provide standard AC charging directly.
Direct EV Charging: When renewable energy is available, the charge controller can direct power straight to the EV charging circuit, minimizing reliance on stored energy or the grid.
Grid Backup System: A grid connection is integrated into the station through the Main Circuit Breaker (MCB), allowing for additional power when renewable sources are insufficient. The grid backup is primarily utilized for AC charging, ensuring that the station remains fully operational regardless of weather conditions or energy storage levels.
Control System and Access Management
An Arduino UNO microcontroller acts as the central controller for the charging station, managing all operations and providing secure access through an RFID module. Only users with authorized RFID cards can initiate charging. When a valid RFID is detected, the Arduino activates a relay that opens the charging circuit, allowing energy to flow. This system enhances both security and user control, ensuring that only verified users can access the station.

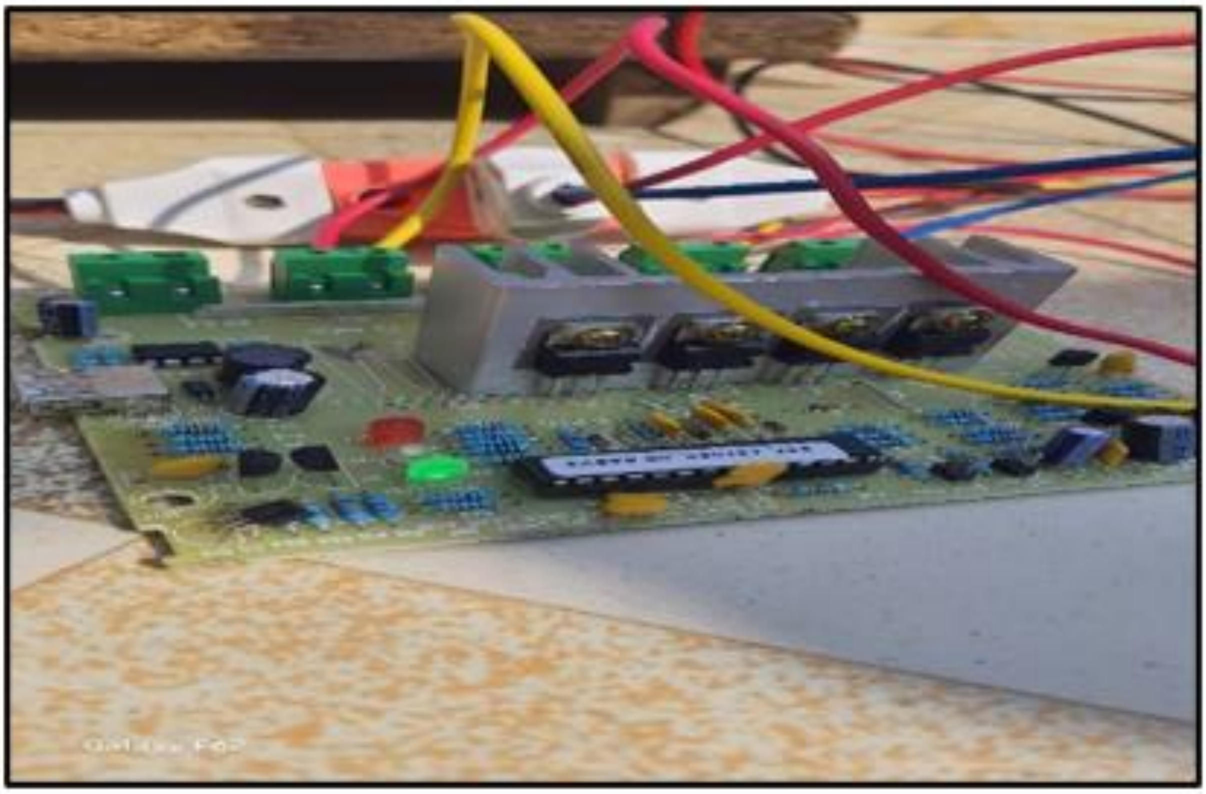
Charging Options
The station provides four charging modes to suit different user needs:
AC Charging: Standard AC charging is available through either the inverter or the grid, offering compatibility with most EVs.
DC Fast Charging: Direct DC power is provided for faster charging, which is ideal for users who need a quick recharge.
Wireless Charging: Wireless charging, enabled through inductive coupling, offers a contactless option, allowing users to charge without connecting physical cables.
Grid-Powered AC Charging: This mode uses grid power directly for AC charging, providing a reliable option when renewable or stored energy is not available.

EV Charging Output
The different charging options converge at the Electric Vehicle Charging unit, where users can select the charging mode that best suits their vehicle's requirements and available power sources. This approach offers a flexible, user-centered experience, accommodating various EV types and charging needs.

RESULTS

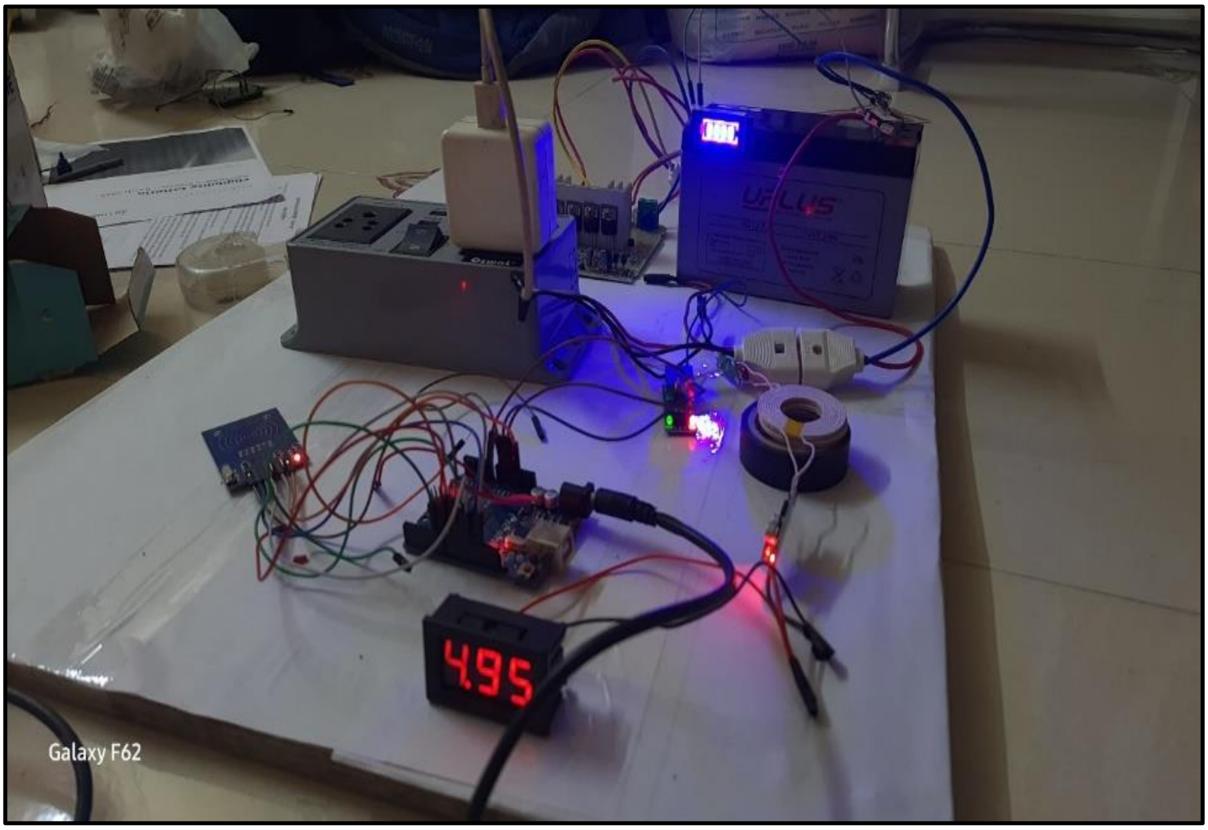


Assembling and Testing of Components



Charge Controller working on Solar

Setup Testing in Sunlight on Solar Power



Wireless transmitter and receiver testing

CONCLUSION

The results of this project indicate that by utilizing a solar-powered wireless EV charging station, integrated with renewable energy sources like solar and wind power, it is feasible to achieve reliable and efficient vehicle charging comparable to conventional grid-dependent systems. With the addition of a wireless charging feature, activated through an RFID-based authentication system, this solution offers a streamlined, hands-free charging experience that underscores the convenience of emerging technologies in EV infrastructure.

Compared to traditional plug-in methods and fossil fuel-reliant charging stations, this sustainable setup demonstrates a promising alternative that not only supports environmental goals but also shows potential for reducing operational costs over time. Integrating green power with versatile charging options establishes this approach as a viable solution for the future of electric mobility.

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