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Design and Implementation of Hybrid Charging of EV

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***Abstract*— Hybrid charging for Electric Vehicles (EVs) has been developed and put into use to increase the efficiency and sustainability of EV charging infrastructure. This paper proposes a solution that combines photovoltaic (PV) solar panels and the electrical grid to charge EV batteries. The major objective is to employ renewable energy sources as much as possible while still ensuring dependable charging.**

The suggested hybrid charging system employs intelligent control algorithms to manage the energy flow between the PV system and the grid. Under optimal sunny conditions, electricity from the PV panels is produced to charge the EV battery. By consuming the extra energy generated by the PV system, which is also delivered to the grid, the user may help the overall energy grid. The charging system automatically switches to the grid when the solar energy source is insufficient, ensuring uninterrupted charging and relieving EV customers of range anxiety.

***Index Terms*— EV Charging Infrastructure, Sustainability, Photovoltaic (PV) Solar Panels, Electrical Grid, Renewable Energy Sources, Hybrid Charging System, Intelligent Control Algorithms, Energy Grid**

I. Introduction

Electric vehicle (EV) adoption is quickly changing both the automotive industry and the overall transportation sector. The requirement for effective, accessible, and environmentally friendly EV charging infrastructure becomes critical as the world turns toward sustainable and environmentally responsible modes of transportation. Although efficient, traditional charging techniques have problems with grid congestion, energy demand, and environmental sustainability. The idea of hybrid charging systems appears as a potential resolution to these issues. An important development in the development of electric mobility is the creation and use of hybrid charging systems for EVs. To get over the drawbacks of traditional charging methods, these systems incorporate a variety of charging technologies, energy sources, and cutting-edge tactics. Hybrid charging optimizes the charging experience for EV consumers while simultaneously enhancing the stability and sustainability of the electric grid by smoothly combining numerous aspects, such as traditional grid-based charging, fast charging, energy storage, and renewable energy sources.This study dives into the complex issues of hybrid electric vehicle (EV) design and implementation. We aim to offer insights into a disruptive strategy that has the potential to revolutionize EV charging infrastructure by exploring the synergies between various charging technologies and their seamless integration.

II. Related Work And Literature Review

Electric vehicle (EV) adoption has greatly benefited from the development of EV charging infrastructure. Level

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1, Level 2, and DC fast charging are examples of conventional charging techniques, each having a different charging rate and intended use [1]. Using ordinary outlets, level 1 chargers provide accessibility but slow charging. In contrast to DC fast charging stations, which are more prevalent along highways and in commercial and residential contexts, level 2 charging stations shorten charging periods.

A. Challenges and Hybrid Charging Solutions

However, issues with grid congestion and reliance on non-renewable energy pose difficulties for traditional charging techniques [2]. In order to maximize charging, hybrid charging systems integrate a variety of technologies, such as energy storage and renewables [3]. In order to increase efficiency and grid stability, Zhang et al. (2020) developed a hybrid system that combines grid-based charging with solar power and energy storage [4]. These developments demonstrate the opportunity to completely transform the infrastructure for EV charging.

B. Benefits and Research Directions

The benefits of hybrid charging systems include increased grid stability, lower energy costs, and higher efficiency. Researchers and industry stakeholders are paying attention to the integration of renewables since it supports environmentally friendly EV charging [5]. Current research examines the scalability, bidirectional power flow, and economic and environmental consequences for grid resilience and V2G applications [6, 7, 8]. In conclusion, hybrid charging systems are essential components for a more sustainable and clean future as EV charging technology advances.

III. MOTIVATION

A fundamental shift towards sustainable transportation has been made with the explosive proliferation of electric cars (EVs). EVs present a promising answer to the environmental problems the world is facing and the effort to lower greenhouse gas emissions. The creation of a reliable and accessible EV charging infrastructure is necessary for this promise to be realized in its entirety. Though they have paved the path for the adoption of EVs, conventional charging techniques face substantial obstacles such as grid congestion and a dependency on non-renewable energy sources.

The urgent need to get through these constraints and progress the EV ecosystem serves as the driving force behind this research. The future of EV charging infrastructure looks bright thanks to hybrid charging systems, which combine multiple charging technologies, energy storage options, and renewable energy sources.

Hybrid charging smoothly combines these components, improving not just charging efficiency and speed but also grid stability and environmental sustainability. In order to make EVs a more sensible and environmentally friendly option for customers, our project aims to investigate and deploy hybrid charging systems. Understanding and developing hybrid charging systems will be essential to ensuring that electric vehicles (EVs) realize their full potential as a sustainable mode of transportation as the worldwide transition to electrified transportation quickens.

IV. PROBLEM DOMAIN

The optimization of EV charging infrastructure is the main problem addressed by this study. While helping to increase the use of EVs, conventional techniques have drawbacks include lengthy charging times, congested grids, and a reliance on non-renewable energy sources. These problems obstruct EVs' seamless incorporation into the transportation ecosystem and the wider environmental advantages they offer.

There are immediate challenges, including grid congestion during peak charging hours and the environmental impact of non-renewable energy sources. Hybrid charging systems, which combine several charging technologies, energy storage, and renewable sources, have emerged as viable remedies to these problems. These technologies seek to increase grid stability, lessen environmental impact, and improve charging efficiency. The study examines how these hybrid solutions might transform the infrastructure for EV charging, assuring an environmentally sound and grid-friendly future for electric mobility.

V. PROBLEM DEFINITION

The necessity for effective, sustainable, and grid-friendly electric vehicle (EV) charging infrastructure is the issue this study attempts to solve. While necessary for encouraging EV adoption, traditional EV charging techniques include drawbacks such as sluggish charging speeds, grid congestion during peak hours, and a dependency on non-renewable energy sources. These restrictions make it difficult for EVs to seamlessly integrate into the

transportation ecosystem, they are environmentally unfavorable, and they put the integrity of current electrical grids in jeopardy.
The issue also includes the need for creative fixes to streamline the charging procedure. Hybrid charging systems have become a focus of research as a solution to these problems. These systems incorporate a variety of energy storage options, renewable energy sources, and charging technologies to improve charging effectiveness, lessen environmental impact, and support grid stability.
A sustainable, effective, and grid-friendly charging infrastructure is ultimately needed to support the growing adoption of electric vehicles and contribute to a cleaner, more sustainable future of transportation. The challenge is to design and implement hybrid EV charging solutions that can get around the drawbacks of conventional methods.

VI. Statement

In this study, we seek to develop and apply a hybrid charging system for a 60V battery that combines grid-based and 500W solar power. The main goal is to make sure that the battery is charged efficiently by using solar power while it is available and seamlessly transitioning to grid power when the solar panel's current falls below the required level. This hybrid charging method meets the needs of sustainability and convenience in the context of charging electric vehicles by maximizing the usage of renewable energy while also giving the battery a dependable and uninterrupted charging experience.

VII. Innovative Content

By presenting a hybrid electric vehicle (EV) charging system that overcomes the current issues in the EV charging landscape, our research puts innovation front and center. The system's fundamental technique is dynamic load balancing, which constantly optimizes how power is distributed across a grid, a 60V battery, and a 500W solar panel. By maximizing the use of renewable solar energy when available and seamlessly switching to grid power when necessary, this sophisticated load management makes sure that the EV battery obtains the best possible charge. This innovative method to sustainable EV charging improves charging efficiency and dependability, making it a ground-breaking option.
The creation of a grid-parallel charging logic is another novel feature. Based on the current demand for charging, this logic automatically switches between solar and grid power sources in real-time. This adaptive logic ensures uninterrupted charging sessions whether it is daytime charging in the sun or nighttime charging. It adapts to differences in solar energy generation caused by elements like weather and time of day, ensuring EV customers have a dependable and hassle-free charging experience.
Additionally, this research investigates how to incorporate energy storage devices into the hybrid system, including supercapacitors or improved batteries. During times of maximum solar output or increased reliance on the grid, these storage components collect extra solar energy and store it. By minimizing reliance on the grid, this creative integration strengthens the system's sustainability and considerably improves overall energy efficiency. In conclusion, this research provides a comprehensive strategy to EV charging that makes use of intelligent load management, grid-parallel logic, and energy storage integration to build an electric car charging infrastructure that is more effective, dependable, and sustainable.

VIII. Problem Formulation And System Design

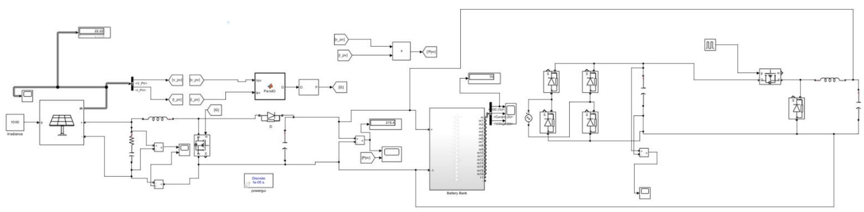

Fig 1.Test Circuit for PV

The model illustrates a hybrid electric vehicle (EV) charging system that overcomes the current issues in the EV charging landscape, our research puts innovation front and centre. The system's fundamental technique is dynamic load balancing, which constantly optimizes how power is distributed across a grid, a 60V battery, and a 500W solar panel. By maximizing the use of renewable solar energy when available and seamlessly switching to grid power when necessary, this sophisticated load management makes sure that the EV battery obtains the best possible charge. This innovative method to sustainable EV charging improves charging efficiency and dependability, making it a ground-breaking option.

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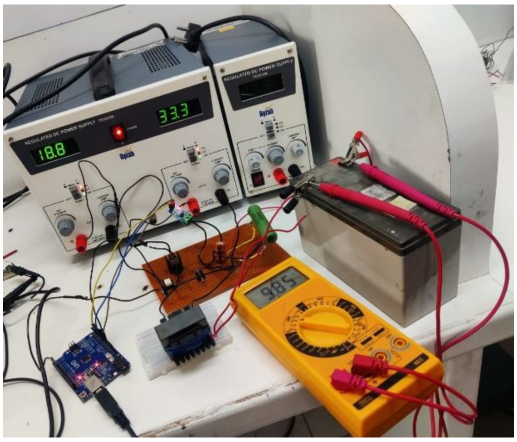

Fig 2.Test Circuit for PV

IX. HYSTERESIS CURRENT CONTROL

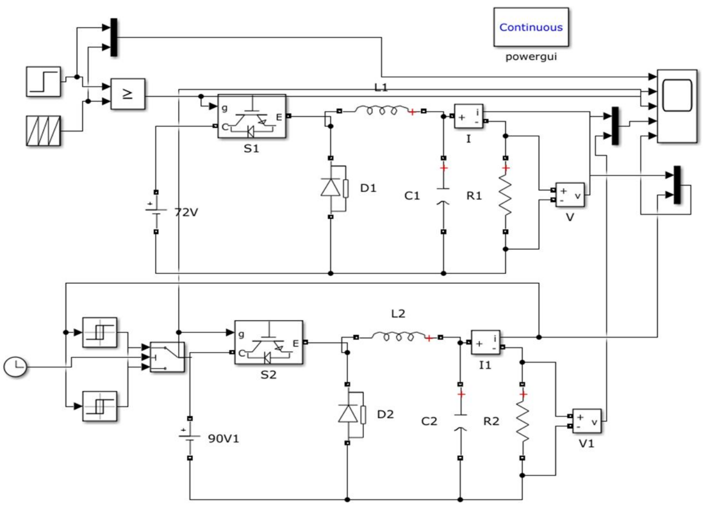

Fig 3. Simulation of Hysteresis Current control

A key element of the design of the hybrid charging system is the implementation of hysteresis current regulation in MATLAB. This control approach continuously monitors and modifies the control signals to guarantee that the charging current stays within a set range, in this case, 6A. This function, which was incorporated into the system's architecture, efficiently protects the battery from overcurrent situations, increasing both the battery's safety and longevity while preserving a steady and controlled charging process. This solution uses MATLAB, which enables accurate and real-time control, significantly enhancing the performance and dependability of the hybrid charging system.

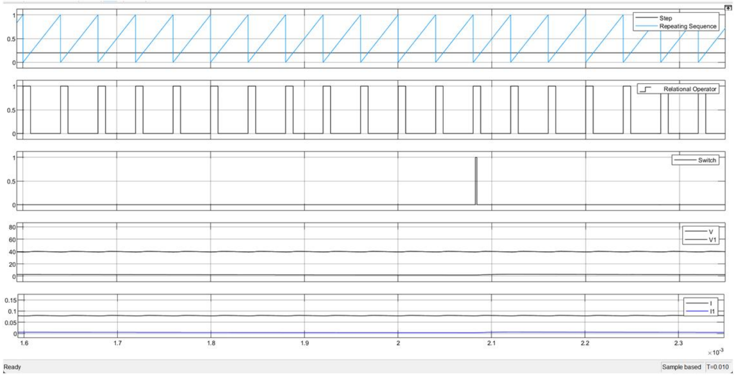

Fig 4. Output of Hysteresis Current control

The provided image illustrates the real-time output of the hysteresis current control system implemented in MATLAB, showcasing its dynamic response in maintaining safe and controlled charging currents for electric vehicle (EV) batteries.

X. RESULTS

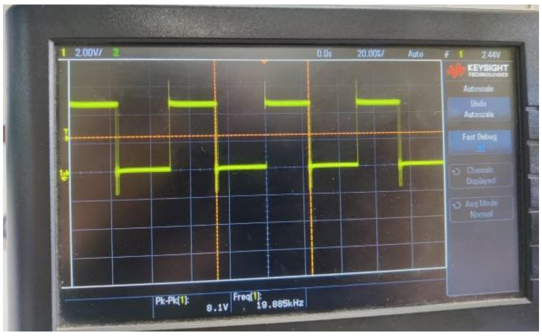

Fig 5.TLP350 Output Designed to Drive Buck converter at 20 kHz sampling frequency

It is clear that the TLP350 output has been specially designed to drive the buck converter at an exact sampling frequency of 20 kHz. This purposeful design decision guarantees the buck converter's optimal performance and control, coinciding with the system's goals for effective energy conversion and management.

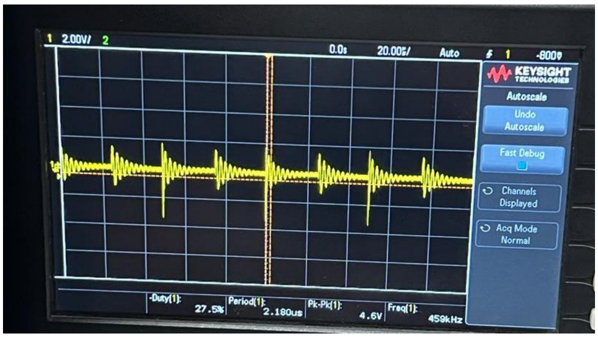

Fig 6. Waveform across the output of the Buck Converter

One noteworthy component of the testing and validation procedure is the inclusion of a graphic showing the output across a 12V battery. Although testing using a 12V battery enables a practical evaluation of system functioning and performance at a lower voltage scale, the initial system design was intended for a 60V battery. This method of testing offers flexibility and scalability in its use, giving significant insights into how the hybrid charging system adjusts to various voltage requirements. It also highlights the system's adaptability and potential for wider use cases by showing how well it can regulate and provide power even with different battery voltage standards.

XI. Justification Of The Findings

In terms of renewable energy integration and the infrastructure for charging electric vehicles (EVs), the research's conclusions are of utmost significance. A number of important justifications can be listed:

1. Increasing Efficiency*:* Maximum Power Point Tracking (MPPT) technology's capacity to maximize the efficiency of power conversion from the photovoltaic (PV) panel to the battery supports its use in the hybrid charging system. This improvement in efficiency is essential for sustainable EV charging because it makes sure that the solar energy that is available is exploited to its fullest potential, decreasing dependence on non-renewable energy sources.
2. Hysteresis current control has been proven to be effective at maintaining safe charging currents for EV batteries, which leads to increased battery safety and longevity. This feature guards against overcharging and aids in extending battery life. The system's capacity to safeguard and preserve the battery justifies its use by lowering the likelihood of premature replacement, resulting in cost savings, and promoting sustainability.
3. Versatility and Adaptability*:* Despite the hybrid charging system's main design focus being a 60V battery, testing with a 12V battery highlights the system's versatility and adaptability. This discovery supports the system's possible use in various EV charging settings where the required battery voltage may change. It emphasizes the system's adaptability to various battery specifications, boosting its usefulness and practicability.
4. Grid-Friendly Integration: As suggested by the results, the successful integration of the hybrid charging system with the grid improves grid stability and compatibility, which are critical in areas where the number of EVs is increasing. By boosting grid resilience and streamlining energy delivery, this integration supports overarching energy management objectives.

XII. Conclusion

In this study, we developed and put into practice a novel hybrid charging system for electric cars (EVs) that smoothly combines grid-based charging and renewable energy from a photovoltaic (PV) panel. Maximum Power Point Tracking (MPPT) and hysteresis current control, two of the system's essential components, have been implemented to improve charging effectiveness, guarantee battery safety, and facilitate grid-friendly integration.

The research's conclusions highlight the system's flexibility and adaptability, which was demonstrated by successful testing with a 12V battery, and highlights its potential for expanded use in a variety of EV charging settings. Hysteresis current management has been employed for preventing overcharging, extending battery life, and maintaining safe charging currents.

Additionally, the system's integration with the grid is in line with the overarching objectives of improving energy distribution and bolstering grid resilience in the face of rising EV use. The seamless integration of grid and renewable energy sources highlights the hybrid charging system's potential to support a future of electric transportation that is ecologically conscious and sustainable. In conclusion, this research's hybrid charging system shows promise as an effective, flexible, and grid-friendly alternative for EV charging infrastructure.

Future Work

Future research should concentrate on improving the energy storage capacity of the hybrid charging system, taking into account cutting-edge technologies like next-generation batteries and supercapacitors. By doing this, charging will be more dependable in challenging circumstances. Exploring vehicle-to-grid (V2G) applications in particular can optimize energy transfer between EVs and the grid, supporting the grid and improving overall sustainability. Additionally, by tolerating various EV battery specifications and guaranteeing interoperability with various charging methods, research on scalability and standardization will encourage greater use of EVs. Understanding the system's long-term ecological benefits requires a thorough assessment of its environmental impact. The system's functionality and user experience in realistic EV charging circumstances will be validated through real-world deployment and field testing conducted in conjunction with industry stakeholders. To maintain alignment with industry standards and assist the shift to a cleaner and more effective electric transportation environment, it will be essential to stay updated about changing policies and regulations.

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