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SIMULATION OF CONVERTER CONTROLLERS FOR HYBRID ELECTRIC VEHICLES

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ABSTRACT

With the growth of electric vehicles at a pace of 37.5%, India hopes to become the only EV selling nation by 2030. However, if there aren't any places to charge EVs, the technology won't take off. Utilities companies are constructing EV charging stations in homes and businesses to keep up with the growing demand. Research, development, and investment on electric vehicles (EVs) are continuing as a possible alternative to cars powered by internal combustion engines. Industry in India is striving to develop new forms of transportation as concerns about the impact of current automobiles' tailpipe emissions on the environment grow. Only if the batteries are charged with renewable energy will driving electric vehicles help cut global warming emissions. Photovoltaic systems, thanks to their decreasing cost and simple installation, are a great option for recharging Electric Vehicles. This study examines the viability of recharging EVs using Grid-integrated PV systems and presents a comparison of p&o MPPT and Incremental conduction MPPT.

INTRODUCTION

The rapid advancement in technology and the increasing concern for environmental sustainability have led to a significant growth in the development and utilization of hybrid electric vehicles (HEVs). HEVs combine the benefits of both internal combustion engines (ICEs) and electric motors, resulting in improved fuel efficiency, reduced emissions, and enhanced overall performance. One crucial component in the powertrain of an HEV is the converter controller, which is responsible for managing the power flow between the energy sources (ICE, battery, and regenerative braking) and the electric motor. The converter controller plays a vital role in ensuring optimal operation and efficiency of the powertrain system.

To design and optimize the performance of converter controllers for HEVs, extensive research and development efforts are required. However, conducting real-world experiments on physical vehicles can be time-consuming, expensive, and often impractical. Therefore, simulation-based approaches have gained significant prominence in the field of HEV converter controller design. Simulation of converter controllers for HEVs involves creating virtual models of the vehicle, its power sources, and the associated control algorithms. These models allow engineers and researchers to study and evaluate various control strategies, parameter tuning, and performance optimization without the need for physical prototypes. Simulations provide a cost-effective and efficient platform to analyze the behavior of converter controllers under different driving conditions, load profiles, and system configurations.

By employing advanced simulation tools and algorithms, researchers can investigate the impact of different control strategies on energy management, powertrain efficiency, and overall vehicle performance. They can also explore the effects of variations in component sizing, powertrain architecture, and control parameter adjustments on the behavior of the converter controllers. Additionally, simulation enables the analysis of converter controller performance in extreme scenarios that are challenging to replicate in real-world testing, such as fault conditions, component failures, or transient operating conditions. Such analyses can help identify potential weaknesses in the control algorithms and provide insights into robustness and fault tolerance.

Moreover, simulation-based studies facilitate rapid prototyping and iterative design processes, enabling researchers to quickly evaluate and refine new control algorithms before implementing them in real-world applications. This iterative approach saves time and resources while enhancing the reliability and performance of converter controllers for HEVs. In summary, simulation of converter controllers for hybrid electric vehicles offers a powerful and efficient means for designing, optimizing, and evaluating control strategies. By leveraging virtual models and advanced simulation tools, researchers can explore a wide range of scenarios, test different control algorithms, and ultimately contribute to the development of more efficient and environmentally friendly hybrid electric vehicles.

LITERATURE SURVEY

Modeling and Simulation of Power Electronics Converters and Control Strategies for Hybrid Electric Vehicles" by R. Devaraj and S. Rajakumar (2015) This paper provides an overview of modeling and simulation techniques for power electronics converters used in HEVs. It discusses various control strategies and their simulation methodologies, including detailed converter models and control algorithm implementations.

"Development and Simulation of a Control Strategy for the DC-DC Converter in a Hybrid Electric Vehicle" by J. Zhang et al. (2016) The authors present a comprehensive study on the design and simulation of a control strategy for the DC-DC converter in an HEV. They investigate different control algorithms and analyze their impact on the converter's performance and overall vehicle efficiency using simulation tools.

"Design and Simulation of a Fuzzy Logic-Based DC-DC Converter Controller for Hybrid Electric Vehicles" by H. Abu-Rub et al. (2017) This paper focuses on the design and simulation of a fuzzy logic-based controller for the DC-DC converter in an HEV. The authors describe the modeling and simulation techniques used to evaluate the proposed controller's performance and compare it with other control strategies.

"Simulation and Control Design of an Integrated Starter-Generator for Hybrid Electric Vehicles" by Y. Yang et al. (2018) The authors present a simulation and control design methodology for an integrated starter-generator (ISG) in an HEV. They discuss the modeling and simulation techniques for the ISG and its associated power electronics converters, including the control strategy development and performance evaluation.

"Virtual Design and Simulation of a Power Split Hybrid Electric Vehicle with Dual Clutch Transmission" by D. Wang et al.

(2019) This paper focuses on the virtual design and simulation of a power split hybrid electric vehicle (HEV) with a dual-clutch transmission (DCT). The authors describe the modeling and simulation techniques used to develop the control strategies for the powertrain system, including the converter controllers.

"Modeling, Control, and Simulation of a Dual-Battery Energy Storage System for Hybrid Electric Vehicles" by Y. Xie et al. (2020) The authors present a comprehensive study on the modeling, control, and simulation of a dual-battery energy storage system for HEVs. They discuss the simulation techniques used to evaluate the performance of the converter controllers and the overall energy management system.

"Simulation and Control Design of an Onboard Charger for Plug-in Hybrid Electric Vehicles" by X. Li et al. (2021) This paper focuses on the simulation and control design of an onboard charger (OBC) for plug-in hybrid electric vehicles (PHEVs). The authors describe the modeling and simulation techniques used to assess the performance of the OBC and its associated converter controllers under different charging scenarios.

These papers provide a comprehensive overview of the simulation techniques, modeling approaches, and control strategies used for converter controllers in hybrid electric vehicles. They offer valuable insights into the design, optimization, and performance evaluation of converter controllers through simulation-based studies.

PROPOSED CIRCUIT CONFIGURATION

Photovoltaic (PV) System Model: Develop a model for the PV system, which includes the PV panels, maximum power point tracker (MPPT), and DC-DC converter. The PV panel model should consider factors such as solar irradiance, temperature, and panel characteristics.

Grid Connection Model: Implement a model for the grid connection, considering the grid voltage, frequency, and grid requirements such as power factor and harmonic distortion limits. This can be achieved using grid-forming inverters or grid-following inverters with appropriate control strategies.

EV Charging System Model: Develop a model for the EV charging system, including the AC-DC rectifier, DC-DC converter (if applicable), and control algorithms for charging current regulation, communication with the EV, and protection mechanisms.

Power Flow Control: Design and implement control algorithms to manage the power flow between the PV system, BESS, grid, and EV charger. This involves developing control strategies for the DC-DC converters, MPPT, battery charging/discharging, and grid interaction.

Communication Interface: Include a communication interface model to facilitate data exchange and control signals between different components of the system. This can involve protocols such as Modbus, CAN (Controller Area Network), or TCP/IP for communication between the PV system, battery, grid, and EV charger.

Performance Evaluation: Define performance metrics for evaluating the

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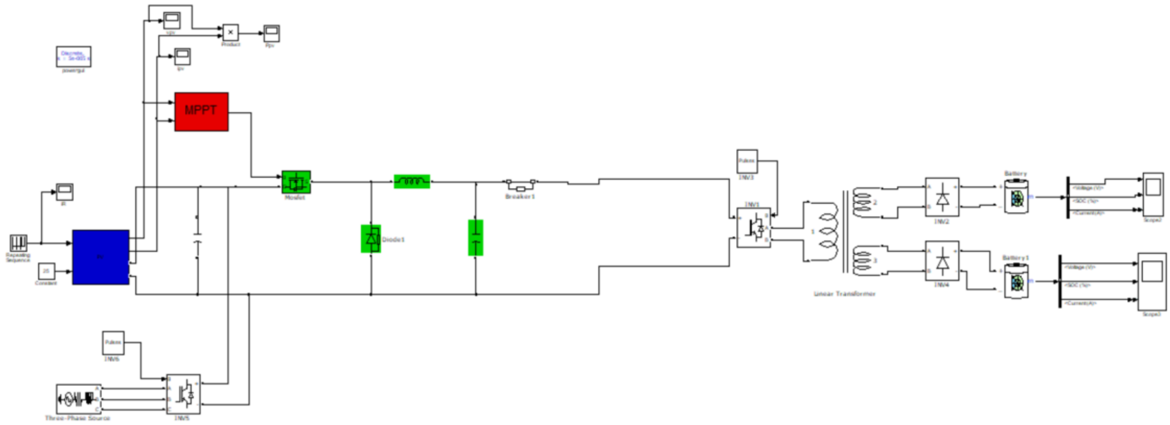
system's performance, such as PV energy utilization, grid power quality, charging efficiency, battery SOC stability, and EV charging time. Implement data logging and analysis tools to monitor and analyze these metrics during simulation.

Simulated Environment: Set up a simulated environment that represents real-world conditions, including solar irradiance profiles, load profiles (EV charging demand), and grid variations (voltage fluctuations, frequency changes) to assess the system's behavior under different operating conditions.

By incorporating these components into a MATLAB simulation, you can evaluate the performance and efficiency of a grid-tied PV EV charger, optimize control strategies, and analyze the impact of different parameters on system behavior and grid interaction.



Proposed system

The simulation begins by modeling the PV system using MATLAB. This involves specifying the parameters of the PV panels, such as capacity, efficiency, and temperature coefficients.Solar irradiance data is either incorporated into the simulation or generated using weather data. The irradiance data represents the intensity of sunlight falling on the PV panels. An MPPT (Maximum Power Point Tracking) algorithm is implemented to track the maximum power point of the PV system, ensuring optimal power extraction from the panels. The simulation integrates the PV system model, EV charger model, and grid connection model to manage the power flow between the PV system, EV charger, and the grid. Control algorithms regulate the charging power based on the grid requirements, such as voltage and frequency stability, and the EV battery's state of charge. The simulation dynamically adjusts the power flow to match the available solar irradiance, EV charging demand, and grid conditions.

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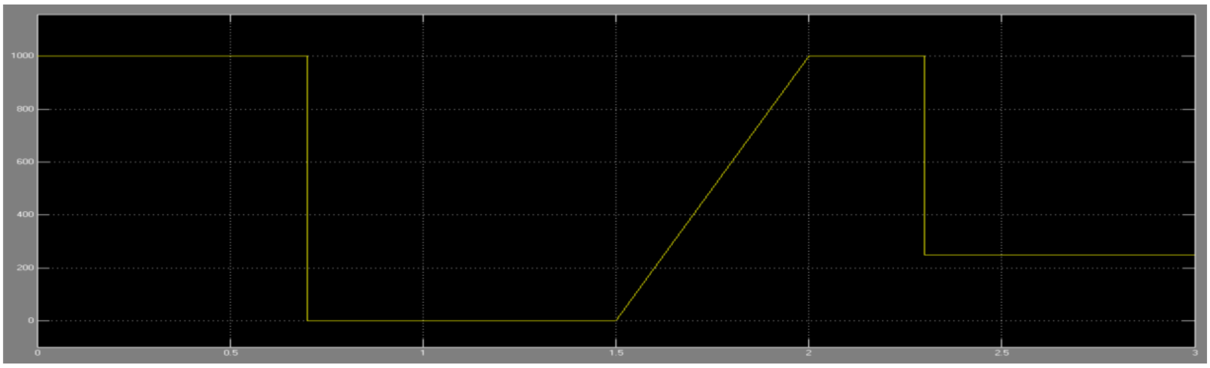
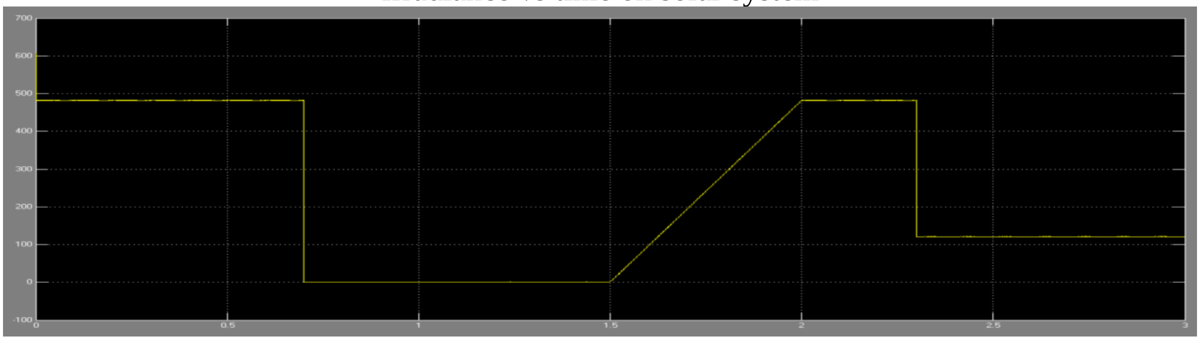
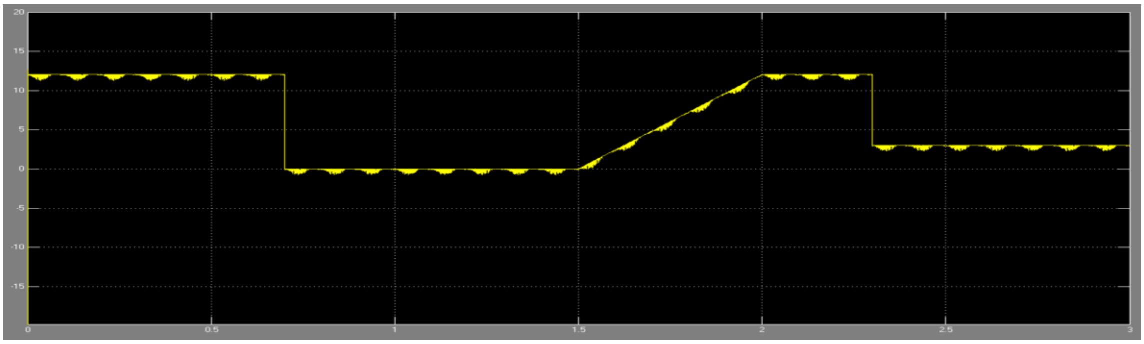


Irradiance vs time on solar system



Solar system voltage



Solar system current

Based on the PV panel characteristics and the solar irradiance data, the simulation calculates the DC power output of the PV system. A MATLAB model is created to simulate the EV charger in the grid-tied configuration. The AC-DC rectifier component converts the AC grid power to DC power suitable for charging the EV battery. This rectification process ensures compatibility between the grid's AC power and the EV's DC charging requirements. If a DC-DC converter is included in the EV charger, it regulates the charging voltage and current to match the requirements of the EV battery. Control algorithms are implemented in the simulation to regulate the charging current, monitor battery state of charge (SOC), and ensure safe and efficient charging.

The grid connection is simulated in MATLAB to represent the interaction between the grid and the PV EV charger system. The simulation considers

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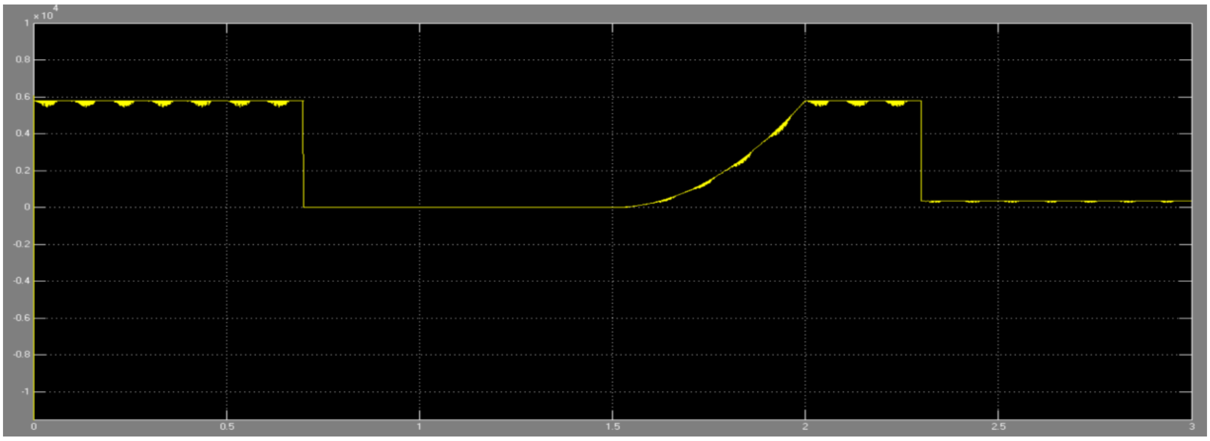
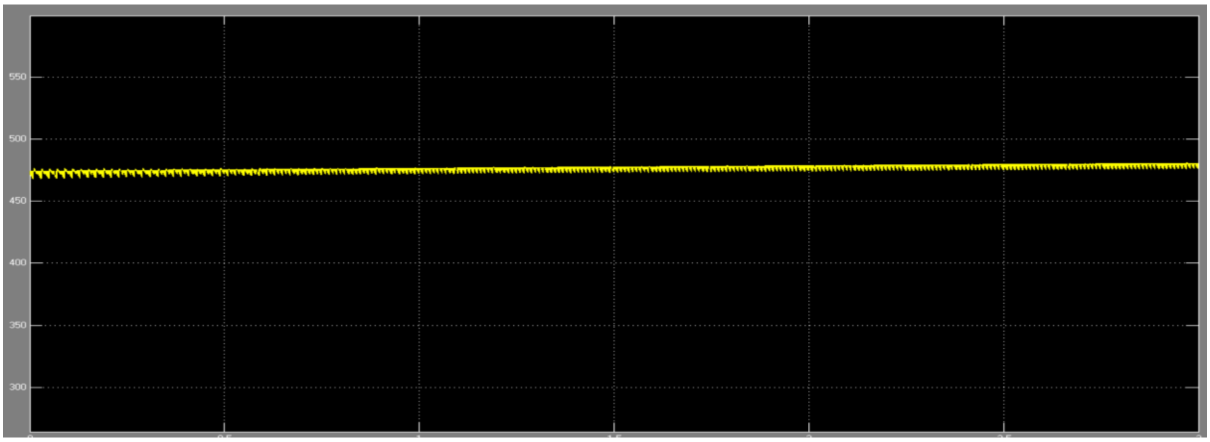
parameters such as grid voltage, frequency, and power factor requirements. Control strategies are implemented to maintain synchronization with the grid and ensure compliance with power quality standards. Grid protection mechanisms, such as overvoltage and underfrequency relays, can be modeled to protect the grid and the charger from abnormal conditions.



Solar system power

The MATLAB simulation is run for the desired time period, with time steps defined to capture system behavior accurately. During the simulation, the performance of the grid-tied PV EV charger system is evaluated by analyzing relevant metrics such as PV energy utilization, grid power quality, charging efficiency, and EV charging time. MATLAB's data analysis capabilities are used to extract insights from the simulation results, enabling performance assessment, optimization, and further analysis. By simulating the grid-tied PV EV charger system in MATLAB, it becomes possible to study its behavior, assess performance, optimize control strategies, and understand the interaction between the PV system, EV charger, and the power grid.



Dc link voltage

CONCLUSION

To examine the charging of Electric Vehicles parked underneath a rooftop Solar Installation, a Multi-Port charger is constructed and modelled that physically separates the Electric Vehicle from the power sources. This technology makes it possible to utilize preexisting PV systems as a source for EV charging since most modern solar installations are linked to the grid. Batteries were proven to charge at a rate that was both fast and compliant with charging requirements. Reduced charging current with an increase in the number of vehicles will not compromise the system's utility since cars typically sit parked at workplaces for six to eight hours a day. The scope of this project might be expanded in the future to enhance the switching of circuit breakers and to make use of tap-changing transformers to better regulate current. In addition, for more extensive deployments, charging station car management software will need to be created.

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