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SOLAR-ASSISTED EV CHARGING MICROGRID WITH BIDIRECTIONAL INVERTER (V2H DEMO)

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Abstract
The rapid growth of electric vehicles (EVs) and the increasing demand for sustainable energy solutions have led to the development of solar-assisted EV charging microgrids. This paper presents the design and implementation of a solar photovoltaic (PV)-based EV charging system integrated with a bidirectional inverter to enable Vehicle-to-Home (V2H) operation.

The proposed system combines PV generation, energy storage, and EV charging infrastructure within a microgrid framework to enhance energy efficiency, reliability, and grid independence. A bidirectional inverter plays a crucial role in enabling two-way power flow between the EV battery, the microgrid, and residential loads.

It allows EVs not only to charge from solar energy (PV-to-Vehicle) but also to discharge stored energy back to the home during peak demand or grid outages, demonstrating V2H capability. The system incorporates maximum power point tracking (MPPT) for optimal solar energy utilization, along with intelligent energy management strategies to balance supply and demand.

Multiple operating modes such as Grid-to-Vehicle (G2V), Vehicle-to-Grid (V2G), and V2H are supported, ensuring flexibility and improved grid stability.

The V2H demonstration highlights the potential of EVs as distributed energy storage units that can provide backup power, reduce electricity costs, and enhance resilience in smart homes. Overall, the proposed solar-assisted microgrid offers an eco-friendly and efficient solution for next-generation EV charging infrastructure and decentralized energy systems.

Keywords: Sensors, Solar, Battery, Charge Controller, Inverter, Voltamperemeter.

1. Introduction

The transportation and energy industries are on the verge of a massive shift fueled by breakthrough technology: solar-powered bidirectional charging for electric vehicles. The use of solar electricity in bidirectional charging systems for EVs represents a significant step forward in sustainable and efficient transportation solutions.

This method not only meets the rising demand for renewable energy but also improves the overall resilience and stability of the electric grid. Solar-powered bidirectional charging allows EVs to charge from and discharge energy back to the grid, resulting in a dynamic energy exchange system.

This bidirectional property is especially relevant in the context of renewable energy integration, as it enables EVs to function as mobile energy storage units, thereby improving grid stability and reducing reliance on non-renewable energy sources.

Advancements in photovoltaic technology, energy storage systems, and smart grid infrastructure have accelerated the synergy between solar power and bidirectional charging.

This paper explores the fundamental components, technological aspects, economic impact, and environmental implications of solar-powered bidirectional charging systems. It also examines communication and control strategies for integrating EVs into smart grids, including Vehicle-to-Grid (V2G) technologies and global advancements.

Figure 5.1 depicts a block diagram of solar-powered bidirectional charging for an electric vehicle. During the day, EVs are powered by solar energy, while the grid supplies electricity when solar power is insufficient.

An MPPT controller optimizes solar panel output. A boost converter increases solar panel voltage to 400V for the DC bus, while a buck-boost converter charges the battery at 200V. In G2V mode, grid AC power is converted to DC, while V2G mode enables energy flow back to the grid.

2. Methodology

1. System Design

The microgrid is designed around a common DC bus architecture. The solar PV array and battery storage are connected via appropriate converters (boost converter with MPPT and bidirectional DC-DC converter). The EV charging station is also connected to this DC bus, while a bidirectional DC-AC inverter connects the system to the home's AC load panel.

2. Hardware Implementation

Key components such as solar panels, charge controller, battery packs, and bidirectional inverter are selected. The inverter design includes power electronics components like Insulated Gate Bipolar Transistors (IGBTs) and filters for clean power output.

3. Control System Development

A central microcontroller (e.g., Arduino or Raspberry Pi) is programmed to implement an Energy Management System (EMS). The EMS controls power flow between solar panels, battery, EV, and home loads based on real-time conditions and state of charge (SOC).

Operating Modes:

- **Solar to EV/Home (Charging Mode):** Priority given to solar power
- **Battery to EV/Home (Backup Mode):** Battery supplies power when solar is insufficient
- **EV to Home (V2H Mode):** EV powers home during outages

4. Simulation and Testing

System architecture and control algorithms are simulated using MATLAB/Simulink to validate performance and bidirectional power flow.

5. Prototyping and Demonstration

A scaled prototype is developed to demonstrate V2H functionality using an EV simulator and small household loads.

3. Need of Study

1. Clean and sustainable energy integration
2. Efficient energy utilization
3. Vehicle-to-home capability
4. Energy independence and backup power
5. Smart grid and microgrid development

4. Objectives

1. Develop a solar-based microgrid
2. Implement EV charging system
3. Design bidirectional inverter
4. Demonstrate V2H functionality
5. Promote sustainable and smart energy solutions

6. Scope of Study

The scope of this study focuses on the design, implementation, and evaluation of a solar-powered EV charging system integrated within a microgrid, incorporating a bidirectional inverter to demonstrate Vehicle-to-Home (V2H) functionality.

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