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SMART SOLAR INTEGRATED V2G ENERGY MANAGEMENT SYSTEM

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ABSTRACT - A Smart solar-integrated V2G energy management system is a smart solution to optimize energy generation, storage, and consumption in modern homes. By integrating renewable energy sources such as solar panels, battery storage, and Vehicle-to-Grid (V2G) technology, SSIEMS ensures efficient energy utilization and saves money. The system manages the power flow between household appliances, electric vehicles, and the grid, ensuring an optimal balance between energy demand and supply. It emphasizes renewable energy, avoids reliance on the grid as much as possible, and balances loads for stability in the grid, along with controlling frequency. SSIEMS offers a path toward sustainable use, lower carbon footprints, and smart, resilient, and environmentally friendly energy management in the future.

Keywords:
vehicle to grid(V2G), photovoltaic (PV), smart solar integrated V2G energy management system (SSIEMS), Social and Environmental Management Unit (SEMU).

I.INTRODUCTION

Accelerated demand for clean and sustainable energy around the world has made the adoption of renewable energy technologies, such as solar power, and electric vehicles (EVs), grow faster. Residential energy systems are at the forefront of this transformation, using innovations to enhance energy efficiency and reduce carbon footprints. Challenges of integrating renewable energy and EVs into the grid include energy storage limitations, peak load management, and grid stability. An integrated SSIEMS combining solar power and V2G technology is a promising solution to these challenges.[1] Solar photovoltaic panels can produce clean energy for household energy needs, while EVs with V2G capabilities offer flexible energy storage and dynamic interaction with the grid. The SSIEMS coordinates energy flows, optimizing the use of solar energy, cost-effective energy storage, and efficient grid support. The system balances supply and demand in real-time by reducing energy costs for homeowners but also supports the grid because it mitigates peak load stress and improves overall reliability.[1] This project explores SSIEMS design and implementation toward optimizing energy utilization, increasing grid stability, and rendering cost-effective energy solutions for residential setups. The study addresses the following key aspects: energy flow management, bidirectional energy transfer, and real-time decision-making, which places SSIEMS as a model for future energy systems.[2]

II. SYSTEM ARCHITECTURE

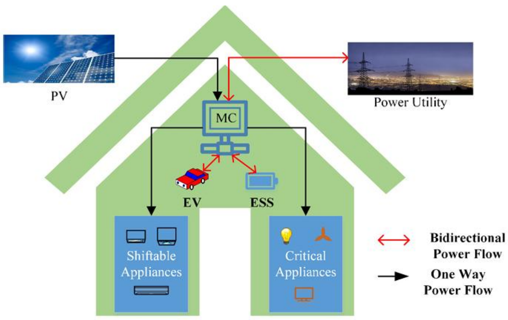

Fig.2.1. System Architecture of SSIEMS

The Fig 2.1 represents the system architecture of SSIEMS. Solar panels are installed to convert sunbeams into clean electricity. The output is transmitted for household power supply needs or fed into a battery for storing energy. A solar inverter is used to ensure the DC power from the photovoltaic panels can feed home appliances and even get connected to the main power grid.[3]

The EV provides a flexible energy storage capability. The EV may draw extra solar energy or take advantage of off-peak grid hours to get charged; it can also give its stored energy back to the home or grid during peak times, thereby stabilizing the grid and reducing dependence upon the grid for the home.[4]

The core of the architecture comprises the SEMU, designed with advanced control algorithms and equipped with real-time sensors, which monitor energy flows in the solar PV system, the battery, the EV, household appliances, and the grid. The SEMU optimizes energy usage through parameters such as energy demand, solar generation, tariffs for electricity, and the conditions of the grid.

III.IMPLEMENTATION OF PROPOSED SYSTEM

The implementation of home energy management through Vehicle-to-Grid technology is a transformative energy utilization method that enhances the sustainability of energy and, at the same time, achieves grid stability.

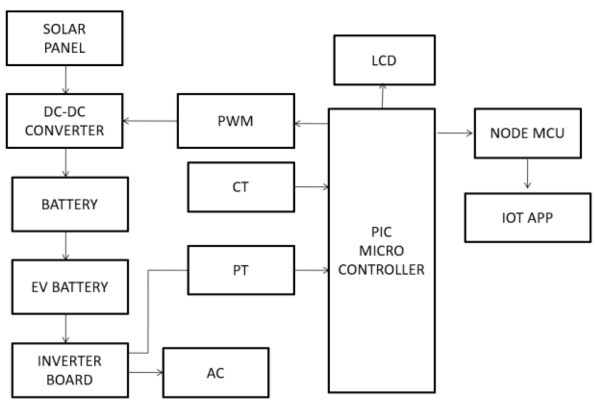

Fig.3.1.Block Diagram

The Fig3.1 represents the block diagram of a solar-powered energy management system integrated with V2G technology. The process begins with a solar panel that generates DC electricity, which is regulated by a DC-DC converter to ensure a stable voltage.[5] The converted power is stored in a battery, which then supplies energy to an EV battery for electric vehicle charging. The EV battery output is connected to an inverter board, which converts the stored DC energy into AC power for external use. A PIC microcontroller serves as the central control unit, managing power flow and system monitoring. It receives inputs from current (CT) and potential (PT) transformers, which measure electrical parameters and send data to the microcontroller for processing.[6] A PWM (Pulse Width Modulation) module is used to regulate the DC-DC converter, ensuring efficient power delivery. The system also includes an LCD display for real-time monitoring. Additionally, a NodeMCU module enables IoT connectivity, sending data to an IoT application for remote monitoring and control.[7] This setup ensures efficient energy utilization, real-time monitoring, and remote accessibility, making it suitable for smart energy management in renewable energy-based EV charging systems.

IV. RESULT AND DISCUSSION

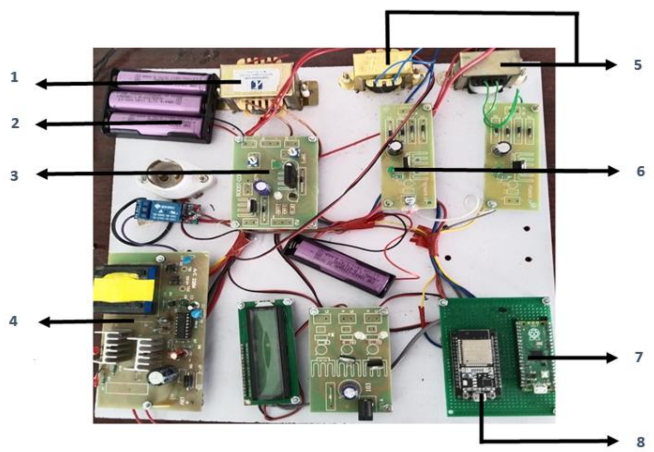

Fig.4.1. Hardware configuration

Figure Out:

1. Step-up transformer
2. Lithium ion batteries
3. DC-DC converters
4. Inverter
5. Step down transformers
6. DC power supply circuit
7. PIC Microcontroller
8. Node MCU (Esp3266)

The Fig4.1 represents the hardware configuration of Smart Solar Integrated V2G Energy Management System, which is an advanced renewable energy solution designed to optimize solar power for EV charging, household applications, and grid integration. The system begins with solar panels that generate DC electricity from sunlight. This power is regulated using a DC-DC converter, which ensures stable voltage before storing it in high-efficiency lithium-ion batteries. These batteries act as the primary energy storage unit, providing power when needed. A DC power supply circuit distributes stable power to the PIC microcontroller, the core control unit responsible for managing energy flow and ensuring system stability.

When AC power is required, the stored DC power is fed into an inverter, which converts it into AC electricity suitable for household appliances or grid supply. Depending on the application, a step-up transformer increases the voltage for grid integration, while a step-down transformer reduces it for low-voltage loads. One of the key features of this system is its Vehicle-to-Grid (V2G) integration, which allows bidirectional power flow. The EV battery, when fully charged, can discharge excess energy back to the grid or supply power to home loads, enhancing overall energy efficiency.

To ensure real-time monitoring and efficient power management, the PIC microcontroller processes data from current transformers (CT) and potential transformers (PT), which measure electrical parameters like voltage and current. A pulse-width modulation (PWM) controller regulates the DC-DC converter, ensuring optimal battery charging and energy distribution. The system also includes an LCD display to provide real-time operational data, making it easy for users to monitor system performance.

For remote accessibility, the NodeMCU (ESP8266) enables IoT-based monitoring and control. It connects to a cloud-based IoT application, allowing users to track power generation, battery levels, and grid interactions from anywhere. This smart monitoring system enhances user convenience and ensures energy efficiency.

Overall, this project integrates renewable energy, smart grid technology, and IoT for an efficient energy management solution. It optimizes solar power utilization, enables EV charging, supports V2G functionality, and ensures intelligent energy distribution with real-time monitoring. By incorporating step-up and step-down transformers, lithium-ion batteries, inverters, and microcontroller-based automation, the system maximizes energy efficiency and reliability. This innovative approach reduces dependency on traditional power sources, promotes sustainability, and provides a scalable solution for modern energy management.

Fig.4.2.Output

The Fig4.2 represents the output of the Smart Solar Integrated V2G Energy Management System, where the voltage produced by solar panels is 5-6V and the DC voltage is converted to 11-12V which charges the electric vehicle battery. Then the voltage is stepped up and inverted to 240V AC, which is used to drive the home appliances

V. CONCLUSION

The Smart Solar Integrated V2G Energy Management System demonstrates a sustainable and efficient approach to energy utilization by integrating solar power with vehicle-to-grid (V2G) technology. This system optimizes energy flow between solar panels, electric vehicles (EVs), and the power grid, enhancing energy efficiency, reducing grid dependency, and promoting renewable energy adoption. The research and development of this system contribute to advancing green energy solutions, supporting the global transition towards sustainable energy. Overall, this project highlights the potential of integrating renewable energy with smart grid technology, paving the way for a cleaner and more sustainable energy ecosystem.

VI. REFERENCES

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