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Optimizing Hybrid Solar EV Charging Station with On-board EV Battery Management System

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Abstract: *Adoption of electric vehicles (EVs) is crucial for reducing dependency on fossil fuels and greenhouse gas emissions. Nevertheless, there are disadvantages to EVs' growing popularity, including as increased energy usage, problems with storage efficiency, and pressure on the infrastructure required for charging. A hybrid charging station that integrates a battery management system (BMS) with renewable energy is a workable solution. Solar photovoltaic panels generate clean energy for EV charging, and surplus electricity is stored in a backup battery system to ensure availability even during periods of poor solar output. The inbuilt BMS optimizes battery performance and extends battery longevity by managing energy flow, charging, and discharging. The charging station also enables bidirectional power flow, which enables power to be given back into the grid, helping balance the energy supply during times of heavy demand. By addressing issues like range anxiety, energy inefficiency, and high costs, this approach combines renewable energy, sound management, and grid support for sustainable, cost-effective EV charging.*

Keywords – *Battery Management System, Electric Vehicles, Energy Storage, Grid Integration, Smart Grid.*

I. INTRODUCTION

Effective charging infrastructure is urgently needed because to the growing demand for electric cars (EVs) worldwide, which is being driven by the need to battle climate change and cut carbon emissions. While the intermittent nature of solar electricity creates reliability difficulties, reliance on grid power rises energy bills and strains infrastructure. These issues can be resolved with a hybrid EV charging station that uses both solar and grid power. Hybrid stations save operating costs and rely less on the grid by using solar energy when it is available. Grid power guarantees dependability when solar power is insufficient. Grid-tie inverter (GTI) technology allows surplus solar energy to be re-fed into the grid, improving energy efficiency and reducing expenses. As EV use increases, this strategy also reduces grid stress. By replacing heavy transformers with high-gain DC-DC converters, integrating photovoltaic (PV) systems with grid electricity optimizes system size and cost while ensuring a steady energy supply. Maximum power point tracking (MPPT) in conjunction with advanced charging methods enhances grid stability, load forecasting, and storage. India's aim to switch to electric vehicles by 2030 is supported by this scalable solution. India's heavy reliance on petroleum imports makes the transition to clean energy a solution to both its economic and environmental problems. Battery longevity, performance, and safety are guaranteed by integrating BMS technologies. For EV infrastructure, hybrid systems that combine solar and wind energy provide sustainable energy options. The goal of efficient designs with improved BMS and renewable energy sources is to develop carbon neutrality and sustainable electric mobility globally.

II. METHODOLOGY

Hybrid EV Charging Station for 3-Phase and 1-Phase Supply

For effective EV charging, the suggested simulation model for a three-phase hybrid EV charging station combines grid and solar power. In order to remove harmonics, 10 kW of power is sent via an LCL filter made consisting of a 30 µF capacitor and a 5 mH inductor from the grid's 415 V RMS at 50 Hz. A rectifier circuit employing IGBTs switching at 10 kHz transforms the AC output to DC, and a 5600 µF capacitor stores the DC power. For the best battery charging, a Buck-Boost converter with a 20 mH inductor and 0.625 µF capacitor modifies voltage. While the converter is managed by Pulse Width Modulation (PWM) and feedback is handled through transformations and a Proportional-Integral (PI) controller, a Battery Management System (BMS) keeps an eye on charge and health. Using an inverter and LCL filter, 18 strings of 25 cells each from complementary solar panels produce DC power for smooth grid integration.

The grid supplies 230 V RMS at 50 Hz for single-phase systems, which then pass 4 kW through an LCL filter that has a 6.23 µF capacitor and 4.36 mH and 4.06 mH inductors. A bridge rectifier circuit employing IGBTs transforms AC power into DC, which is then stored in a 5600 µF capacitor. A Buck-Boost converter uses a 100 µF capacitor and a 20 mH inductor to control voltage changes. By using PWM control, which is managed by feedback processed by a Proportional-Resonant (PR) block, the BMS guarantees safe charging. Active and reactive power are measured via a Phase-Locked Loop (PLL) block. An inverter and LCL filter integrate the DC power produced by solar panels with 11 cells per string into the grid, improving energy use and operational efficiency.

Battery BMS Simulation and Performance Management

A simulation model of a lithium-ion battery with a nominal voltage of 360V and a capacity of 300Ah, starting at a 50% State of Charge (SoC), is part of the hybrid station. Blocks for measuring voltage and current keep an eye on the battery while it charges and discharges. To avoid overcharging, charging ends at 90% SoC, while discharge stops at 40% SoC to preserve battery health. The State of Health (SoH) uses MATLAB routines to assess battery longevity based on charge cycles, while the SoC is determined using Coulomb counting. Using thermal blocks to simulate heat generation and I2R losses, electrical parameters are used to predict temperature. For effective and sustainable EV charging solutions, this integrated hybrid system offers thorough insights into battery performance and management.

FIGURES AND TABLES

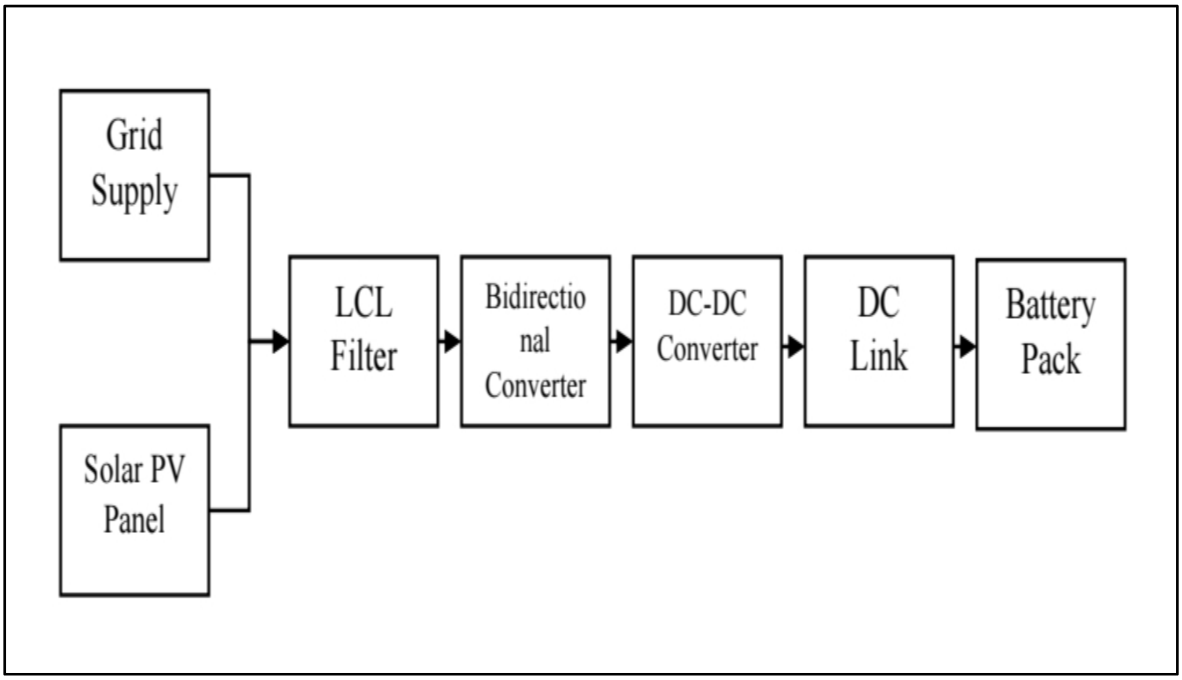

Fig 1 Block Diagram of Hybrid Charging Station

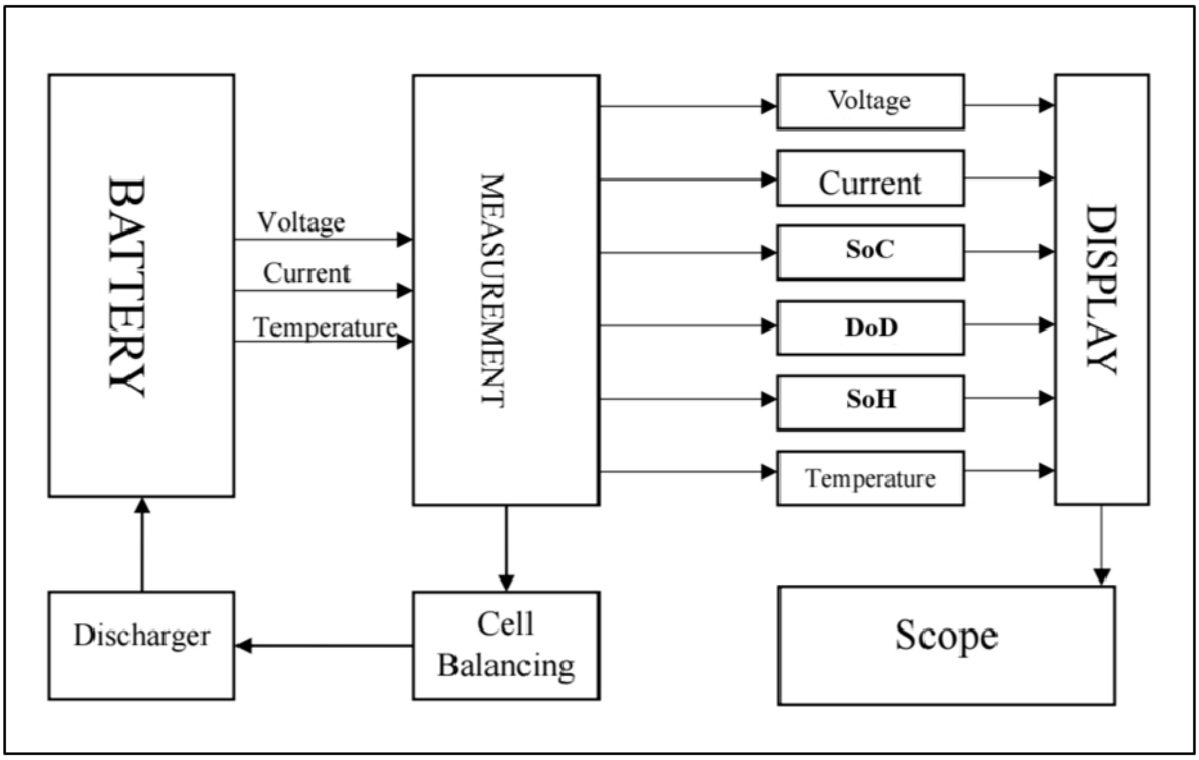

Fig 2 Block Diagram og Battery Management System (BMS)

III. CONCLUSION

For successful and sustainable car charging, the hybrid EV charging station simulation model skillfully combines grid and solar electricity. Utilizing rectifier circuits, Buck-Boost converters, and LCL filters, the system guarantees clean and adaptable power delivery to battery requirements. By providing real-time charge, health, and performance monitoring, onboard Battery Management Systems (BMS) improve battery safety. With the use of MPPT and smooth grid connectivity, solar panel integration maximizes energy use while lowering reliance on the grid. The stability and effectiveness of the system are maintained by sophisticated control methods that use PI and PR controllers. Long-term dependability is guaranteed by the battery model's accurate SoC and SoH tracking and temperature estimation. This all-inclusive hybrid solution promotes the use of clean energy and aids in the shift to environmentally friendly transportation systems by providing a scalable and sustainable approach to EV infrastructure.

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