GRID-CONNECTED PHOTOVOLTAIC AND BATTERY ENERGY STORAGE INTEGRATED ELECTRIC VEHICLE CHARGING STATION WITH ENHANCED POWER QUALITY

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ABSTRACT

This paper presents an electric vehicle (EV) charging station with improved grid power quality that is coupled with battery energy storage (BES). The unit templates (UTs) and reference grid currents are estimated using the positive sequence components (PSCs) of the three phase grid voltages. A bidirectional buck-boost converter is used to connect the EV and BES at a DC-link. EVs are powered by the solar array during daytime and by the utility grid during low solar generation periods Furthermore, the point of common connection voltages synchronize with grid voltages when the system is connected to the grid.

I INTRODUCTION

The rapid growth of electric vehicles (EVs) has significantly increased the demand for reliable and efficient charging infrastructure. Conventional EV charging stations mainly depend on the utility grid, which increases grid stress during peak demand hours. To address this issue, renewable energy sources such as photovoltaic (PV) systems are increasingly integrated into EV charging stations.

However, PV generation is intermittent and depends on solar irradiance. Therefore, incorporating a Battery Energy Storage (BES) system enhances reliability by compensating for fluctuations in solar generation. An integrated PV–BES–grid system ensures uninterrupted EV charging while maintaining improved power quality.

This paper presents a grid-connected EV charging station integrated with a PV array and BES. The system ensures:

- Efficient power sharing among PV, BES, EV, and grid

- Bidirectional power flow capability

- Improved grid power quality

- Seamless transition between grid-connected and standalone modes

II LITERATURE SURVEY

The development of electric vehicle charging infrastructure has attracted significant research attention due to the rapid growth of EV adoption. Advanced traffic coordination and hierarchical control strategies for connected automated vehicles have been discussed in [1], highlighting the importance of intelligent system-level optimization. With increasing EV penetration, the integration of renewable energy sources into charging stations has become essential. The utilization of rooftop solar photovoltaic systems for supporting EV charging loads has been explored in [2], demonstrating the feasibility of combining solar generation with transportation electrification.

Power electronic converter design plays a critical role in EV charging applications. A reconfigurable phase-shift full-bridge converter suitable for wide voltage range EV charging has been presented in [3], while improved dual-active-bridge converter modulation strategies ensuring zero-voltage switching and reduced current stress have been investigated in [4]. Motor performance evaluation and drive characteristics, relevant to EV operation, have also been analyzed in [5]. Furthermore, load management strategies for DC fast-charging stations have been proposed in [6] to mitigate peak demand and improve system efficiency.

Vehicle-to-grid (V2G) capability has emerged as a promising approach to enhance grid flexibility. The demonstration of microgrid resiliency through V2G operation has been reported in [7], and smart cross-system frameworks for joint allocation and scheduling of V2G services have been developed in [8]. Energy management strategies for smart homes integrated with EVs have been investigated in [9], while game-theory-based and computationally efficient predictive energy management approaches for hybrid vehicles have been discussed in [10] and [11]. In addition, EV charging stations operating as flexible power reserves have been studied in [12], and advanced deep reinforcement learning-based energy management strategies for hybrid electric vehicles have been presented in [13].

The integration of battery energy storage systems with EV charging stations has gained importance for peak shaving and renewable intermittency management. Optimal control and modular design approaches for battery energy storage systems based on partial power conversion have been proposed in [14]. Fast-charging stations combined with battery storage using optimal control of semi-dual active bridge converters have been introduced in [15]. Smart modular storage solutions providing grid services have been discussed in [16], and a comprehensive review of quick-charging station topologies has been provided in [17].

On-board charger topologies have also been widely researched. Dual-active-bridge converters using SiC devices for EV onboard charging have been analyzed in [18], while integrated magnetic-based isolated onboard battery chargers have been developed in [19]. High-efficiency single-stage onboard chargers have been presented in [20], focusing on reduced component count and improved performance. For off-board charging stations integrated with photovoltaic systems, power quality improvement techniques have been demonstrated in [21]. Further advancements combining PV generation with battery energy storage and grid connection have been reported in [22], highlighting the importance of improved power quality and coordinated control.

Grid synchronization and harmonic mitigation are crucial for maintaining stable grid interaction. Advanced

synchronization schemes based on dual enhanced second-order generalized integrator frequency-locked loops have been proposed in [23] to enhance grid-feeding converter performance under distorted conditions. Additionally, adaptive filtering techniques for signal processing applications have been investigated in [24], contributing to improved disturbance rejection capability.

Although extensive research has addressed converter design, renewable integration, battery storage, energy management, and grid synchronization, limitations remain in achieving independent control of EV and stationary storage systems, seamless transition between operating modes, and enhanced power quality under dynamic conditions. These research gaps motivate the development of an improved grid-connected EV charging station architecture integrating photovoltaic arrays and battery energy storage with advanced control strategies

III EXISTING SYSTEM

In conventional electric vehicle charging infrastructure, the majority of charging stations are primarily dependent on the utility grid for supplying power to electric vehicles. In such systems, the three-phase AC supply from the grid is converted into DC through rectification and power electronic converters to charge the EV battery. Although this method ensures reliable energy availability, it places a significant burden on the utility grid, particularly during peak demand periods. As the number of electric vehicles increases rapidly, the cumulative charging demand results in higher stress on distribution networks, leading to voltage regulation problems, increased losses, and deterioration in overall power quality.

To reduce the dependence on conventional energy sources, photovoltaic (PV) based EV charging stations have been introduced in recent years. In these systems, the PV array generates DC power which is processed through a DC–DC converter equipped with maximum power point tracking control to extract maximum available solar energy. The generated power is then used to charge the EV battery or is supplied to the grid. However, PV-based systems suffer from inherent intermittency due to variations in solar irradiance. During cloudy conditions, low sunlight hours, or nighttime, the PV output decreases significantly or becomes unavailable, necessity for an improved architecture that can efficiently integrate PV generation and battery energy storage with enhanced control strategies to ensure stable, reliable, and high-quality EV charging operation.

IV PROPOSED SYSTEM

Shown above is a portable power supply that has a dual-active-bridge converter for power factor correction (PFC). A grid-connected onboard charger for battery charging has been introduced. A very effective on-board charger has been introduced. Because it only requires one step of charging, this charger is both simpler and more efficient than its dual- stage counterpart. Only low-power apps utilize the on-board charger. An electric vehicle charging station has been produced by Singh et al and Jain et al. All electric vehicles are charged in utilizing solar panels and the grid.

Voltage Source Converter (VSC)

When converting between alternating current (AC) and direct current (DC), voltage source converters play an essential role. It receives power from the DC solar array. It is then transformed into three-phase alternating current (AC) and sent to the three-phase gridvia a statictransfer switch (STS). In order for electrons, or electric

current, to flow across a two-terminal circuit, a voltage source must be coupled to the circuit and maintained at a constant pressure. Common examples of realistic voltage sources are cells, batteries, and generators, among others. Some more recent FACTS Fast programmable shunt and series voltage injections into the ac network are provided by controllers based on voltage-sourced converters (VSC). This allows for further increase of controllability and power transfer capabilities. A Voltage Source Converter (VSC) uses power semiconductor switches such as IGBTs or MOSFETs to convert DC power into controlled AC power and vice versa. It enables bidirectional power flow between the DC-link and the grid As a general rule, the principle asserts that different wavelengths of light are emitted when light touches a surface due to various interactions between the light and the item.

Electric vehicles (EVs) use voltage source inverters, which convert direct current (DC) from the battery to alternating current (AC), to power electric motors. In order for the motor to run at a speed that allows the vehicle to accelerate and decelerate, this conversion is essential.
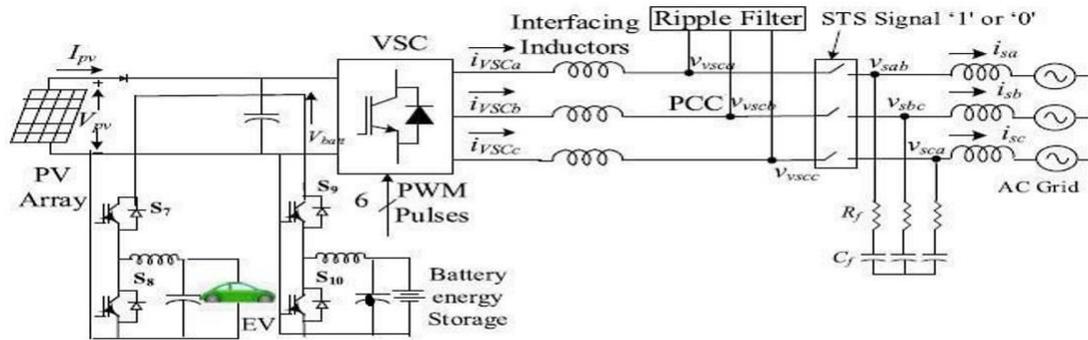
System topology

However, electric vehicle batteries will not be charged in the event that the grid and PV arrays aren't available. This limit is cured in [22], which likewise consolidates a BES. A typical dc converter incorporates the EV battery and BES, notwithstanding. Contrasted with BES, the voltage level of an EV battery is reliably lower. Thusly, the dc connect incorporation of the BES and the EV battery ought to each utilization their own committed dc converter. Subsequently, this study presents an answer: an off-board EV accusing station coupled of a BES that charges EVs utilizing PV power and the BES. It manages the progression of power among the PV exhibit, the BES, the EV, and the framework, and it additionally expands the power that the PV array can deliver. When everything is running great, the PV array drives the electric vehicle's charging while likewise taking care of overabundance power once again into the grid. The BES stores the abundance power on the off chance that the matrix goes down. In the event that PV array isn't accessible, the BES might in any case work with electric vehicle charging.

The key features of the present work are as follows:-

o Electric vehicle (EV) battery charging is done using the PV array, with any excess electricity being sent to the grid and BES.

o When there is no PV source available, the BES charges the EV battery. This ensures that the grid is not overloaded and that as little electricity is traded as possible.

o The PV array is directly linked at the dc connection in this architecture. This leads to an increase in the system's overall efficiency. Fourthly, since the regulation of voltage source converters (VSCs) handles EV charging and discharging, nonlinearities are injected into the grid.

o The system's capacity to automatically and smoothly transition between grid disconnection and reconnection modes of operation.

As displayed in Figure 1, the BES-prepared EV charging station is currently a work in progress. The VSC works with the two-way progression of power among the PV array, BES, EV, and grid. It changes over direct current (DC) to rotating current (AC) so it could be traded with the network. At the common dc association, the EV and BES are connected by free bidirectional dc converters. This converter controls the charging and releasing of the BES and EV. To diminish harmonic current, the VSC is associated with the PCC by means of point of interaction inductors. The framework is connected to the grid and brought into synchronization utilizing a static exchange switch (STS).

Nowadays, top shaving is extremely popular on the grounds that to the far and wide utilization of battery energy capacity (BES) in electric vehicle charging. However, the absolute expense of the incorporated halfway power handling converter goes up since additional batteries are utilized. By controlling the BES's power stream to the EV battery, the converter mitigates misfortunes in this arrangement.

V SIMULATION RESULTS
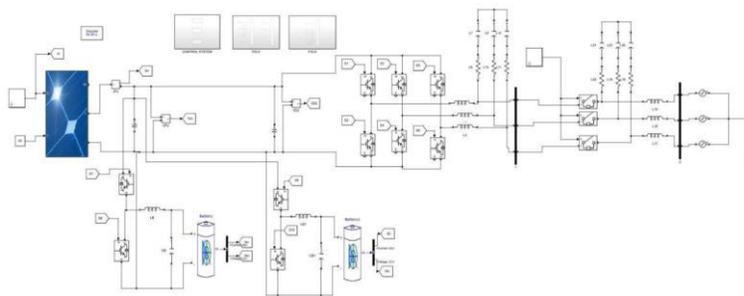
MATLAB/SIMULINK Grid-Connected Photovoltaic and Battery Energy Storage Integrated Electric Vehicle Charging Station With Enhanced Power Quality

Performance Under Variation of Solar Insolation

During rise in PV array irradiation from 600 to 1000 W/m2 , PV array generation increases, since EV and battery are in floating mode, as shown in Fig.
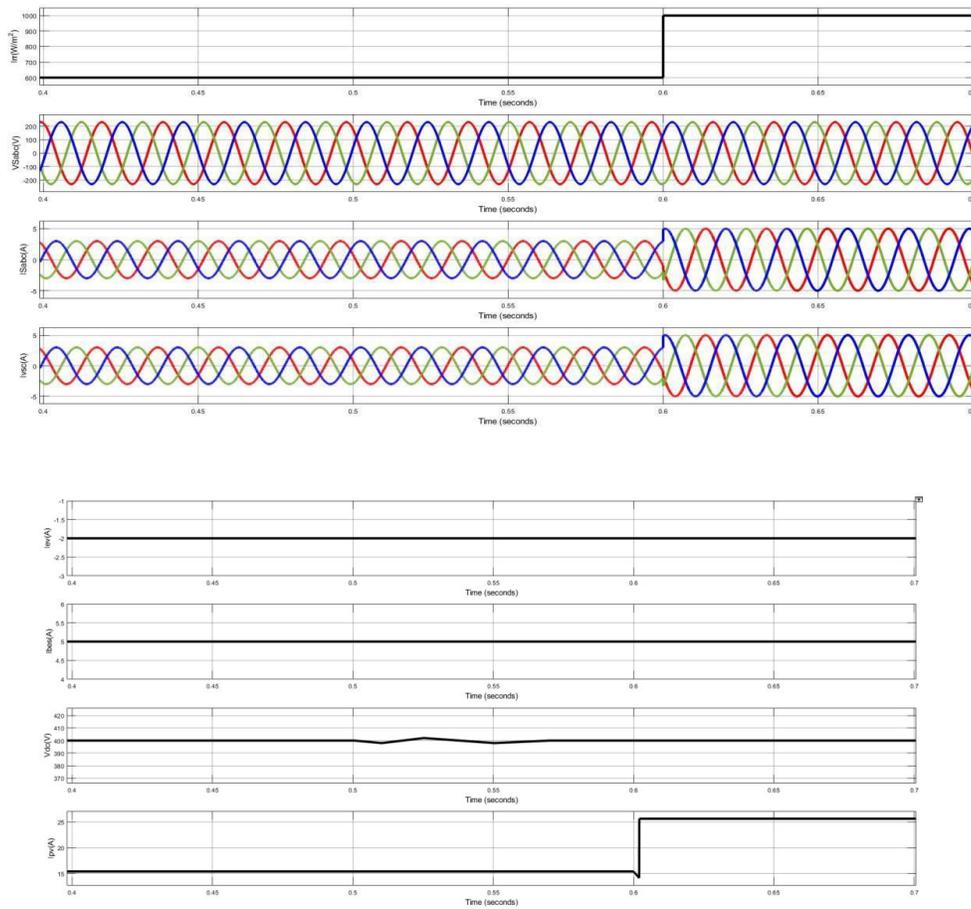

Simulated response of EV charging station under variation of PV insolation

Performance of System at Outage of Grid

Simulated performance at grid outage is shown in Fig. 8.3 (a). When grid outage is observed, charging station operates in SM. Therefore, grid currents and voltages immediately become zero. The BES compensates for surplus power and starts charging. EV charging remains unchanged.
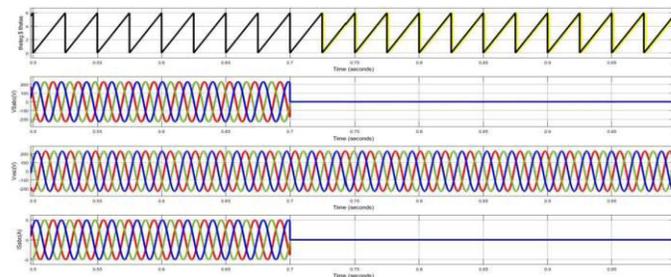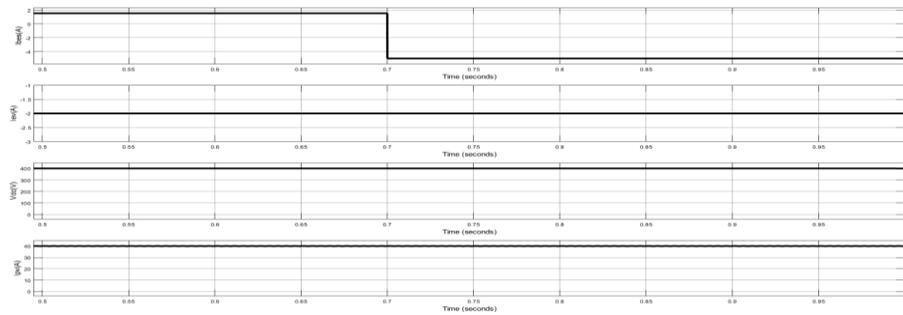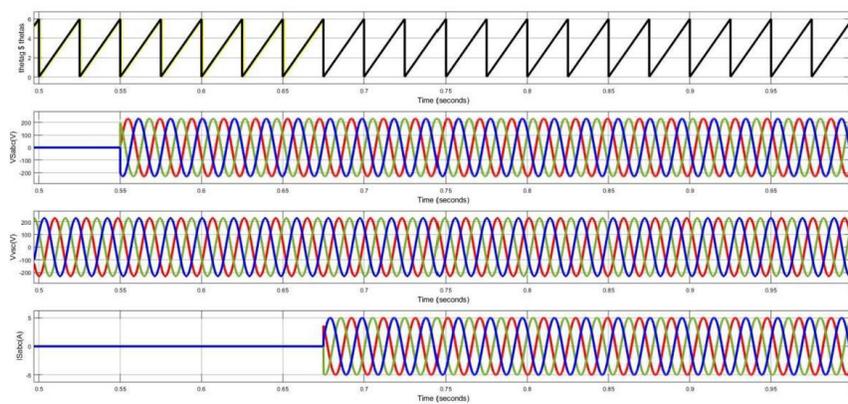
(a)

Performance of System at Grid Reconnection

The simulated response of system at grid recovery is presented in Fig. 8.3 (b). During grid restoration, the VSC synchronizes to the grid, and the grid voltages and the currents are appeared. The BES starts discharging without affecting the EV charging.

(b)

Simulated performance at (a) grid disconnection and (b) grid reconnection
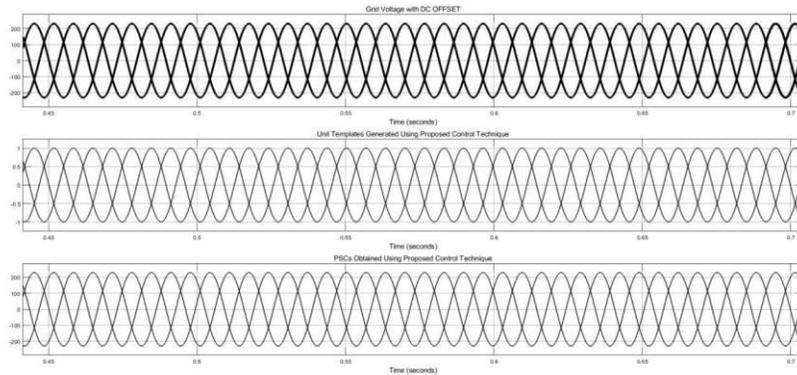
Comparative of the proposed control with fractional order correntropy adaptive filtering algorithm at dc offset

VI CONCLUSION

The integration of a Battery Energy Storage System (BES) with an Electric Vehicle (EV) charging station provides an efficient, reliable, and sustainable solution for modern transportation and power systems. By incorporating battery storage, the charging station can effectively manage peak load demand, reduce stress on the utility grid, and ensure uninterrupted charging even during grid fluctuations or outages.

The battery energy storage system enables energy buffering by storing electricity during off-peak periods or from renewable energy sources and supplying it during high-demand conditions. This improves overall system efficiency, enhances power quality, and minimizes charging delays for electric vehicles. Additionally, the integrated system supports fast charging, stabilizes voltage and frequency, and reduces operational costs for both users and grid operators.

Overall, an EV charging station integrated with battery energy storage plays a vital role in promoting large-scale EV adoption, improving grid stability, and supporting clean and sustainable energy utilization. This approach represents a key step toward the development of smart charging infrastructure and future-ready electric mobility systems.

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