A GRID CONNECTED PV ARRAY AND BATTERY ENERGY STORAGE INTERFACED EV CHARGING STATION

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Abstract:

In this Paper, a charging station for electric vehicles (EVs) integrated with a battery energy storage (BES) system is presented. The system enhances grid power quality by evaluating the positive sequence components of the three-phase grid voltages for estimation of unit templates and reference grid currents. The EV and BES are connected to a DC link using a bidirectional buck-boost converter. During the day, the EV takes power from the solar array, while at night, it consumes power from the grid. Tests on a hardware prototype validate the system's satisfactory response under various dynamic conditions

Index Terms: Battery Energy Storage (BES), Electric Vehicle Charging Station, Photovoltaic (PV), Power Quality, Synchronization.

1. INTRODUCTION

The demand for electric vehicles (evs) is rapidly growing, leading to an increased need for ev charging stations. While many existing charging stations rely solely on grid power, this approach can be inefficient and costly. To address these challenges, integrating renewable energy sources like photovoltaic (pv) arrays and battery energy storage (bes) systems into ev charging stations can provide a more sustainable and efficient solution. This work presents an advanced ev charging station that incorporates a grid-connected pv array and bes, enabling the charging station to utilize solar energy during the day and grid power when solar energy is unavailable. The system ensures seamless synchronization and power quality improvement, making it a robust solution for ev charging. The present time, the demand of electrical vehi cle (ev) is propagating in the world, and thus, the ev charging station installation is also required. A hierar chical architecture is presented for making decisions on ev merging, regulation of ev trajectories, and operation controller. The fallow space utilization for the building of ev charging station and use of the parking roof for solar photovoltaic (pv) array installation have been presented. We have reviewed the ev charging station consuming power from the grid only. Another converter with zero voltage switchingand discontinuous pwm for the charging of ev using the grid powerhas been demonstrated. However, it does not demonstrate the bidirectional flow of active power. We have presented bidirectional flow of active power. Charging of the ev using grid consumes a huge amount of power. An alternate source of energy should be available in abundance with low running cost. Varghese et al We have demonstrated the ev charging station powered with renewables. However, this charging station suffers from several reservations from load side as well as grid side. When pv generation is not enough, thenev is discharged to deliver the power required by the grid. This type of function is termed as vehicle to grid (v2g) as presented experimentally in .scheduling and allocation of v2g using a smart system framework have been presented the energy management in case of v2g and vehicle to home (v2h) mode has been demonstrated .

FAn online energy management for fuel cellbased hybrid multistack vehicle using the game theory has been presented in [10]. Delprat and riad boukhari [11] have demonstrated energy management for hybrid vehicle by reduction of the computation effort. Another strategy of the energy management for ev charging by setting reference power levels for ev has been demonstrated in [12]. A deep reinforcement learning technique for hybrid electric vehicles energy management on fuelcell/battery/ultracapacitor with action trimming has been discussed in [13].

2. PROBLEM FORMULATION

With the increasing adoption of electric vehicles (EVs), there is a growing demand for efficient and reliable charging stations. A major challenge in EV charging infrastructure is integrating renewable energy sources, such as solar power, with grid connectivity and battery energy storage systems (BES) to ensure continuous power supply. The variability of solar energy, combined with the need for grid stability, creates difficulties in maintaining consistent power quality and managing energy flow to EVsFurthermore, during the day, when solar power is available, it is important to prioritize its use for charging EVs, while at night, the charging station must rely on grid power. Managing this energy transition effectively is crucial to optimize resource use and minimize the reliance on grid power. Additionally, ensuring that the system can respond dynamically to fluctuations in energy supply and demand is essential toavoid interruptions and maintain grid quality.leads to the need for a charging station that integrates solar energy, battery storage, and grid power seamlessly, ensuring reliable, uninterrupted EV charging while improving grid power quality.

2.1.SOLUTION TO THE PROBLEM

The solution involves an EV charging station integrated with a Battery Energy Storage (BES) system, utilizing a bidirectional buck-boost converter to connect both the EV and BES to a common DC link. The system operates in two modes: during the day, the EV charges using power generated by a photovoltaic (PV) array, while at night, it draws power from the grid. To improve grid power quality, the system evaluates the positive sequence components of the three-phase grid voltages, estimating unit templates and reference grid currents.This approach ensures optimal energy usage from solar power while maintaining the stability of the grid. The BES stores excess solar energy generated during the day for later use, providing a reliable power supply for EVs during nighttime or low-sunlight conditions. The system dynamically adapts to fluctuating energy demands and environmental conditions, ensuring uninterrupted charging and minimal reliance on grid power.Testing on a hardware prototype has validated the system’s performance, confirming its ability to maintain satisfactory response under various dynamic conditions, thus providing a reliable, efficient, and sustainable charging solution.

3. METHODOLOGY

•Voltage source converter (vsc) transforms dc power to ac and vice versa.

•The ev and bes are connected via separate bidirectional dc-dc converters at a common dc link.

3.1.System configuration: the ev charging station is designed with a pv array, bes, and grid connection. The system uses bidirectional converters to manage the power flow between these components.

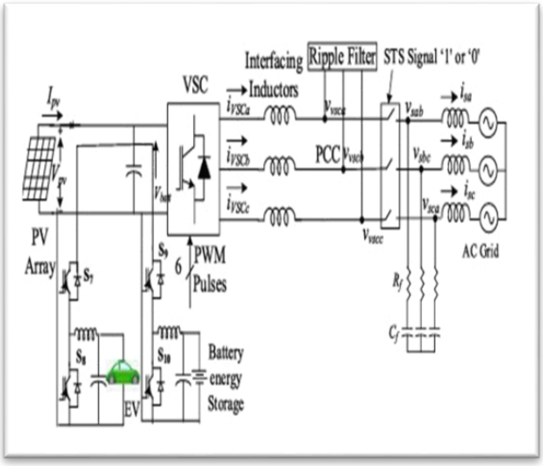

Fig. 1. System topology

3.2.Control Approach:

- MPPT Control: Ensures maximum power extraction from the PV array.
- Grid-Connected Mode Control (GC): Manages the grid connection and ensures power quality by computing unit templates (UTs) and reference grid currents.
- Synchronization and Standalone Mode Control: Manages the transition between grid-connected and standalone modes.
- BES Control: Manages the charging and discharging of the BES.
- EV Control: Regulates the EV charging process.

The methodology ensures that the system operates efficiently under various dynamic conditions, maintains power quality, and seamlessly transitions between different operational modes.GC(Grid control) in the context of a grid connected PV array and battery energy storage system refers to the control mechanisms that regulate the flow of energy between the grid, the PV array, and the battery storage system.

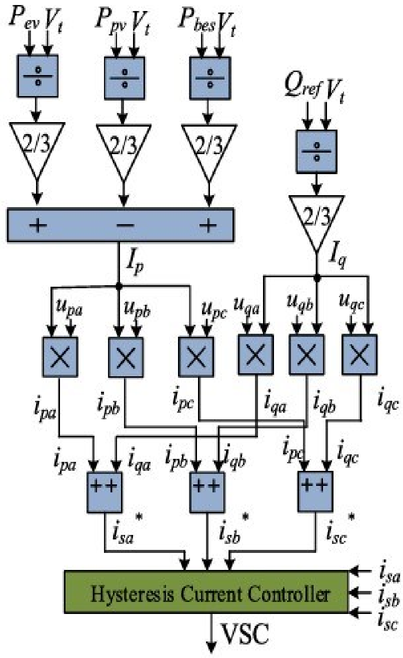

Fig. 2. GC Control

- MPPT Controcol: Ensures maximum power extraction from the PV array.
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- BES Control: Manages the charging and discharging of the BES.
- EV Control: Regulates the EV charging process.
- Experimental Setup:
- Hardware Prototype: Tests conducted on a hardware prototype developed in the laboratory.
- ExperimentalParameters: If such as PV array generation, grid voltage, BES, and EV characteristics are defined.

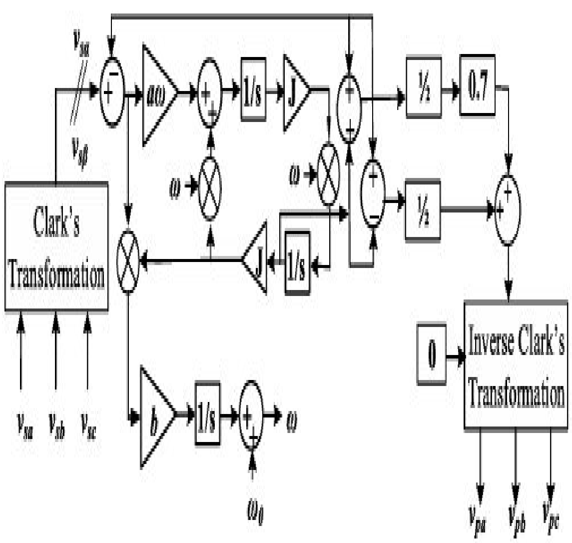


Fig. 3. PSCs estimation

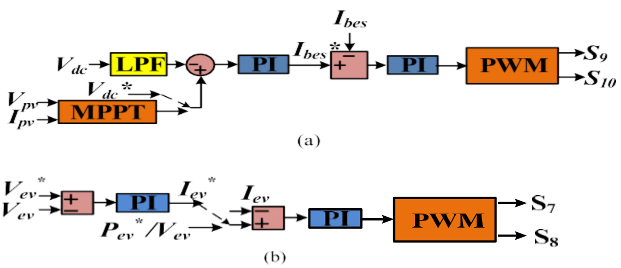


Fig. 4. Control approach. (a) BES control.

(b) EV battery charging/discharging control algorithm.

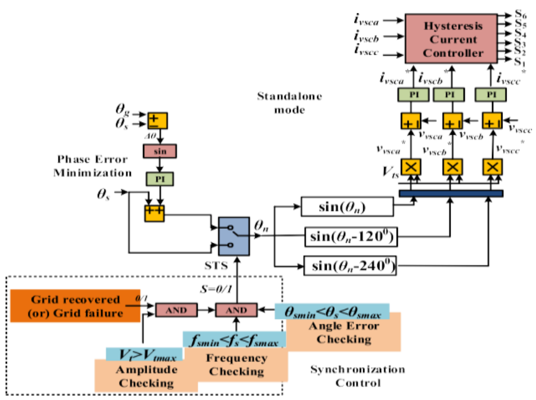


Fig. 5. Synchronization and Standalone control

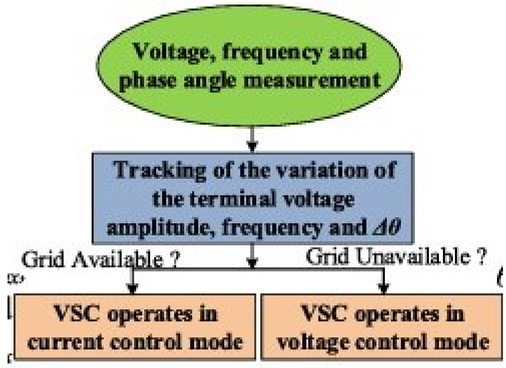


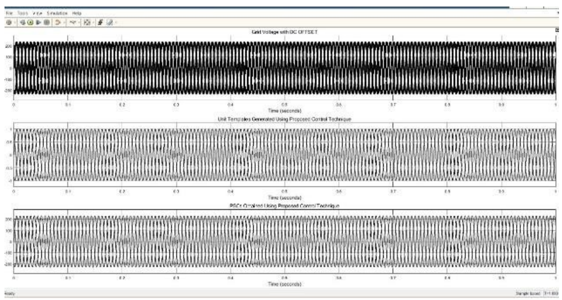
Fig. 6. System-level coordination control for transition between the GC mode and SM.

3.3. Testing and Validation:

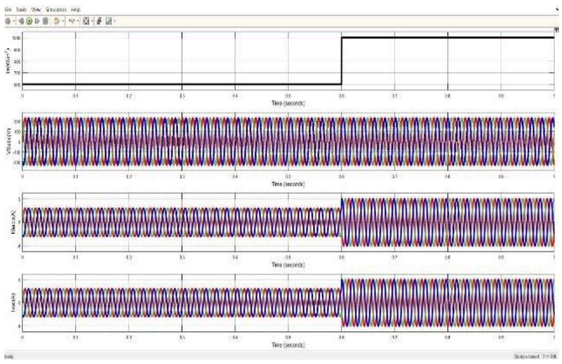
- Dynamic Conditions: System performance is tested under various dynamic conditions, including PV intermittency and grid outage.
- Performance Metrics: Metrics such as power quality, grid synchronization, and seamless transition between modes are evsluated.

4. RESULTS:

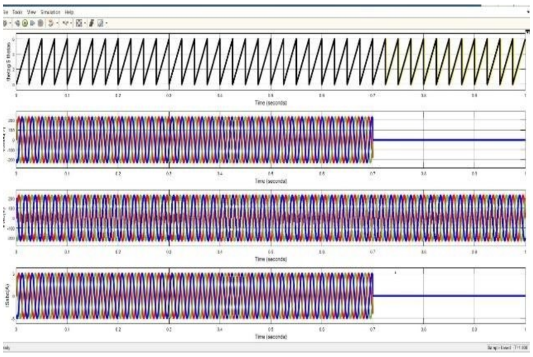
1.Grid voltage with DC off set



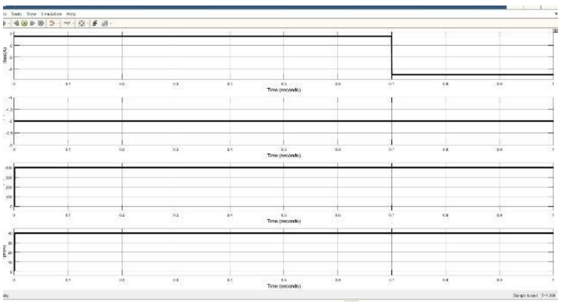
Simulation response on EV charging station under variation of PV insolation.



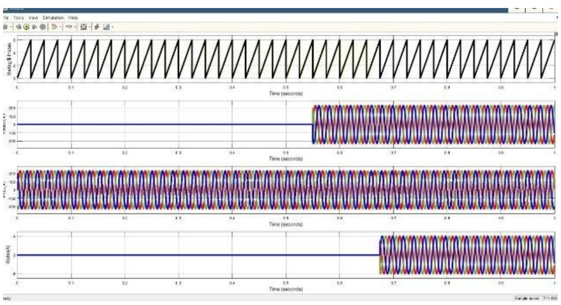
2. Grid disconnected



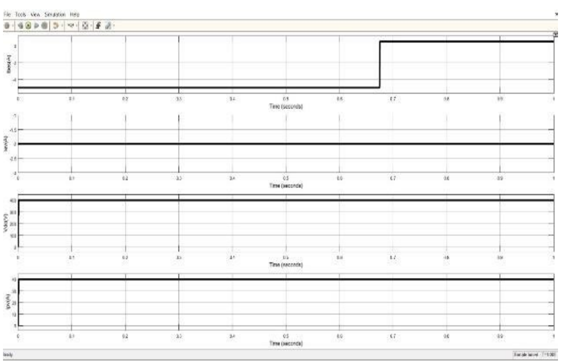
Grid disconnected



3. Grid reconnected



Grid reconnected



5. ADVANTAGES :

- Reduced reliance on the grid during peak demand hours.
- Increased use of renewable energy.
- Improved grid stability by managing power fluctuations.
- Cost savings through net metering.
- More sustainable EV charging infrastructure by minimizing carbon.

5.1.APPLICATIONS:

- Home EV charging: Provides a convenient and sustainable charging solution for homeowners with EVs.
- Backup Power: Offers backup power during grid outages, ensuring continued EV charging and other critical loads.
- Energy Independence: Enable homeowners to reduce reliance on the grid and generate their own clean energy.

6. CONCLUSION:

The research presented a grid-connected PV array and battery energy storage (BES) system interfaced with an EV charging station. The system was demonstrated to improve power quality and efficiently manage energy under various dynamic conditions. The integration of BES allows for seamless transition between grid-connected and standalone modes, ensuring continuous and reliable EV charging. The experimental results validated the system's performance and highlighted its potential for practical applications in enhancing EV charging infrastructure.

7. REFERENCES

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