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Research Paper

A Grid Connected PV Array and Battery Energy Storage Interfaced EV Charging Station

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Abstract –

This study introduces an improved grid power quality electric vehicle (EV) charging station that incorporates battery energy storage (BES). In order to estimate the unit templates (UTs) and the reference grid currents, the positive sequence components (PSCs) of the three phase grid voltages are considered. A bidirectional buck-boost converter connects the EV and BES over a dc connection. When the sun is shining, an electric vehicle draws juice from its solar array; when the sun isn't shining, the grid supplies the juice. Furthermore, the point of common coupling voltages synchronizes with the grid voltages when the system is linked to the grid. Testing is done using MATLAB/Simulink to ensure the appropriate response holds up in different dynamic scenarios.

Keywords – Electrical Vehicle, BES, PSC, PV System, Power Quality.

1. INTRODUCTION

There has been a recent uptick in interest in researching and developing technologies for renewable energy sources including photovoltaic (PV), fuel cells, wind, etc. As a clean and dependable renewable energy source, PV is an important part of the world's energy portfolio. Power electronics is now seeing a trend toward integrating electronics into either the source (photovoltaics) or the weight (light). This places a demanding, wide-range working condition on the power electronics used in photovoltaic and outdoor lighting applications. Because of this, power electronics converter dependability is of the utmost importance. under order for power electronics to function reliably under such extreme and uncontrolled conditions, they must have a lifespan that is equal to or greater than that of the power source or load. Electric vehicle (EV) grid charging is very electricity intensive. A cheap, readily accessible alternative energy source is ideal. It proved that a renewable energy-powered EV charging station is possible. Nevertheless, there are a number of concerns on both the load and grid sides with this charging station. Discharging electric vehicles meets grid power needs when photovoltaic production falls short. The phrase for this kind of operation is "vehicle to grid" (V2G). We have shown how to allocate and schedule V2G utilizing a smart system architecture. Results for vehicle-to-grid (V2G) and vehicle-to-home (V2H) modes of energy management are in. An automated energy management framework based on game theory has been developed for hybrid multistack vehicles that use fuel cells. Its ability to reduce computational effort demonstrates controlling energy for hybrid vehicles. It has also been shown that establishing standard power levels for EVs is an additional energy management method for EV charging. We have spoken about an action-trimming deep reinforcement learning method for managing the energy of fuel cells, batteries, and ultracapacitors in hybrid electric cars. These days, peak shaving is all the rage because to the widespread use of BES in electric vehicle charging. But the total cost of the installed partial power analyzing converter goes up since more batteries are used. Here, the converter regulates the BES's power flow from the EV battery, cutting down on losses. It offered a quick way to charge electric vehicles and give power back into the grid at busy times. One such objective function is the rate of depreciation of the battery. It has been shown that an additional battery-powered charging station may enhance grid and EV flexibility. For on-board or rental use, the owner may additionally provide the battery that has been charged. The aggregators also install or present the functionality in the smart grid, and they include the batteries into virtual power plants. The idea is explained via numerical modeling, and the management of batteries is handled by professionals. The BES, electric vehicle chargers, and supply equipment have all been thoroughly examined. It demonstrated an on-board charger using power factor correction (PFC) performed using a dual-active-bridge converter, as well as several topologies with varying transformers and power levels. We have introduced an inbuilt charger that charges batteries via the grid. It showcased an on-board charger that was very efficient. The battery is single stage, which means it uses fewer components and is more efficient overall because of that. For low-power applications, only the on-board charger should be utilized. Electric vehicle charging stations were shown. Electric vehicles are only charged using photovoltaic panels and the power grid. But electric vehicle batteries won't be charged if the grid and PV arrays aren't accessible. This disadvantage is mitigated; moreover, a BES is included in this case. A common dc-dc converter integrates the EV battery with the BES. Compared to BES, the voltage content of an EV battery is consistently lower. The dc connection is not the place to integrate the BES; instead, utilize a dedicated dc-dc converter for the EV battery. Consequently, this study presents a solution: an off-board EV charging station coupled with a BES that charges EVs using PV electricity and the BES. In addition to controlling the power flow between the PV array, BES, EV, with the grid, it harvests the most power to the PV array. When everything is running well, the PV array powers the electric vehicle's charging while also feeding excess electricity back into the grid. The BES stores the excess electricity in case the grid goes down. On the other hand, BES enables EV charging in the event that PV generation is not available. Following are some of the most salient aspects of this work.

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

2) BES supplies the EV battery when there is no PV source, reducing grid power exchange and easing grid strain. Thirdly, the PV array is DC-linked directly in this configuration. Consequently, the system's total efficiency is enhanced.

4) Because the regulation of voltage source converters (VSCs) handles EV charging and discharging, nonlinearities are introduced into the grid.

5) The system's capacity to synchronize the grid's disconnection as well as reconnection operating modes in a smooth and seamless manner.

2. GRID-CONNECTED PHOTOVOLTAIC (PV) SYSTEM

The PV system's power inversion step must ensure several requirements for grid-connected applications. Standards such as IEEE 1547, IEC 61727, and NEC 690 control several aspects, including dc-injected currents, total distortion harmonic (TDH), power factor, and detection of islanding operation. Injecting high-quality electricity to the grid is the goal of these guidelines for the MIC. Maximum Peak Power Tracking (MPPT), power decoupling, DC-AC power conversion, boosting the PV dc voltage input, and providing grid-side and PV-side interfacing are all responsibilities of the power inverting stage in a grid-connected PV system.

A. Centralized PV System

Figure 1 shows the centralized multi-string PV system, the first step of a PV system. This setup relies on a single massive inverter. To create a centralized, high-power PV system, individual PV strings are linked in series, and groups of strings are linked in parallel.

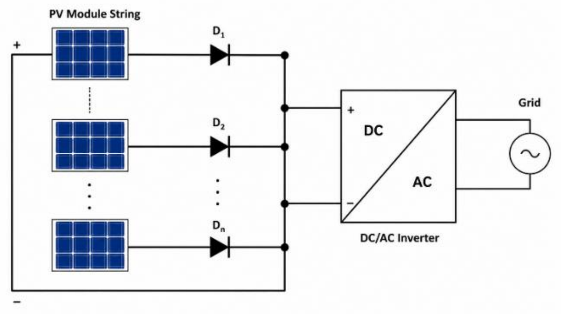

Fig.1: Centralized PV-System.

Even though an amplifier stage isn't required, this type's efficiency is reduced due to losses of energy in string-based diodes and connecting cables. In addition, the quantity of collected power is reduced due to an imbalance between the module's tracking systems, namely MPPT. Hence, novel PV system methodologies were used.

B. String PV System

Both the string as well as multi string methods of PV system design are shown in Figure 2. Each PV string has its own inverter to compensate for the losses caused by the string diodes and the MPPT mismatch. Avoiding the amplification step is possible provided there are sufficient PV panels to produce the necessary DC input voltage, which is around 190V for a US system. By increasing the amount of energy collected, the total efficiency is improved thanks to the MPPT in each PV string. But since the electricity was so low, the inverter ended up costing more in this situation. The multi-string PV design provides an alternative method. Here, a single inverter serves as the source for power from a network of PV strings, each of which has its own DC/DC converter. Here again, you may control each string separately using an MPPT. Here, the inverter is more efficient and has a greater power level, much as in the centralized instance. Still, a little MPPT mismatch between a PV string's modules remains in both methods. Because of this, the existing PV system is unable to collect all of the sun's energy. Therefore, the most effective method that ensures full power harvesting is the AC-Module PV system.

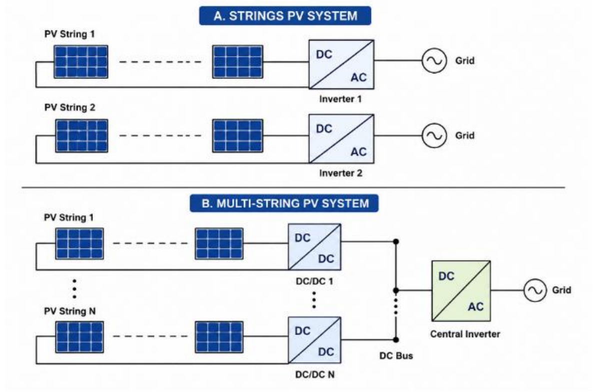

Fig.2: String PV and Multi-String PV Systems.

3. SYSTEM MODELING

As shown in Figure 3, the BES-equipped EV charging station has been created. Through the VSC, power may be transferred in both directions through the PV array, BES, EV, as well as the grid. It converts direct current (DC) to alternating current (AC) so that it may be transferred with the grid. Two independent bidirectional dc-dc converters are attached to the shared dc connection between the EV as well as the BES. This converter controls the charging and draining of the BES as well as EV. To reduce harmonic current, the VSC is connected to the PCC via interface inductors. To link and synchronize the system with the grid, a static transfer switch (STS) is used.

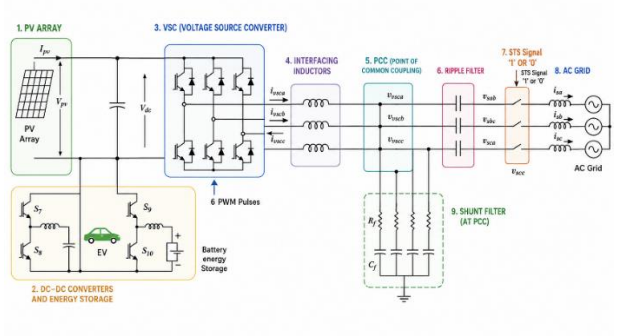

Fig. 3: System topology.

The system's primary function is to charge electric vehicles. The BES is charged using the residual power in the event that the grid goes down. It is possible to discharge either the EV or the BES to the grid, or both, if necessary. There are five different types of control: 1) maximum power point tracking (MPPT), 2) grid connected (GC) mode, 3) synchronization plus standalone (SM) mode, 4) building energy system (BES) control, and 5) electric vehicle (EV) control.

A. GC Mode Control

As seen in Figure 4, the VSC pulses for switching are produced in the GC type by means of the control.

1) Computation of Unit Templates (UTs): As shown in Figure 5, the grid voltages' PSCs are calculated. With the use of Clark's transformation, the three-stage voltages (vsa, vsb, and vsc) are converted to the α-β domain.

$$\begin{pmatrix} v_{s\alpha} \\ v_{s\beta} \end{pmatrix} = \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{pmatrix}$$

The overall transfer function from Fig.4 is attained as

$$v_{p\alpha\beta} = \frac{a\omega}{(s+a\omega)^2+\omega^2} \begin{Bmatrix} (s+a\omega) & -\omega \\ \omega & (s+a\omega) \end{Bmatrix} \begin{Bmatrix} v_{s\alpha} \\ v_{s\beta} \end{Bmatrix}$$

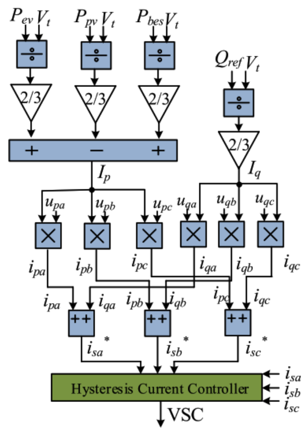

Fig. 4: GC control.

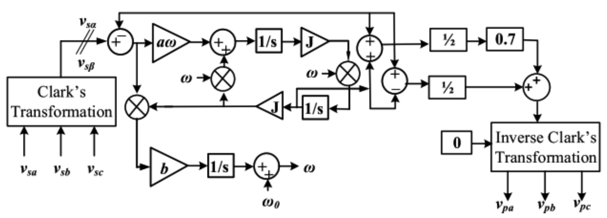

Fig. 5: PSCs estimation.

2) Fundamental Grid Current Active and Reactive Component Computation: Ip, the active component of grid currents, incorporates the dc power circuit. These include feed-forward components for photovoltaics, electric vehicles, and building energy systems. Subtracting the standard grid currents from the actual grid currents is the process. The resulting mistake is sent into the hysteresis current controller, which in turn generates pulses from the VSC gate.

B. BES Control

The BES control system measures the PV source's peak power and uses it to determine the dc link's reference value. When electricity from the PV array is not available, the controller will utilize a constant value of reference. In Fig. 6(a), we can see the schematic of the total control system.

C. EV Control Algorithm

To command the electric vehicle, one must provide certain switching pulses to the dc-dc converter. When the electric vehicle's battery has to be charged, the present standard is calculated by subtracting the difference between the reference and real EV voltages and feeding that result into the PI controller. Figure 6(b) shows that if the grid needs active power from EVs, the current reference for EV batteries is computed by dividing the reference EV power by the EV voltage.

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D. Synchronization and Standalone Control

Figure 7(a) shows that when the grid is down, the STS receives signal S = 0, and the VSC functions in the SM. We compare the grid voltage angle (θg) with the PCC voltage angle (θs), and we estimate the inaccuracy as

$$\theta_e(k) = \theta_g(k) - \theta_s(k).$$

The PI controller uses it to calculate reference PCC voltages. The voltage error is calculated by comparing the actual PCC voltage with these reference PCC values. The PCC reference currents are collected once this mistake is communicated to the PI controller. Subtracting imaginary grid currents from the actual grid currents is the process. The resulting mistake is sent into the hysteresis current controller, which in turn generates pulses from the VSC gate. When the electricity from the PV array and the BES is insufficient or not available to charge the EV battery, an island control transitions to the GC management once the boundary requirements are met via synchronization. As seen in Figure 7(b), the amplitude, frequency, as well as angle are the boundary conditions that are essential for the GC functioning of the system.

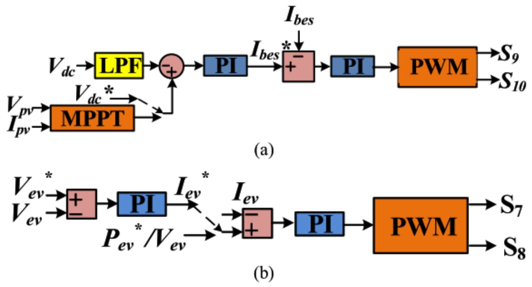


Fig. 6. Control approach. (a) BES control. (b) EV battery charging/discharging control algorithm.

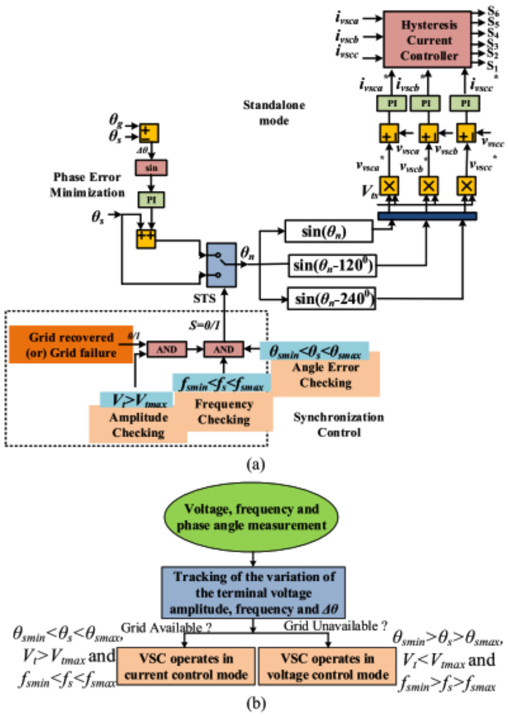


Fig. 7. (a) Synchronization and standalone control. (b) System-level coordination control for transition between the GC mode and SM.

4. SIMULATION RESULTS

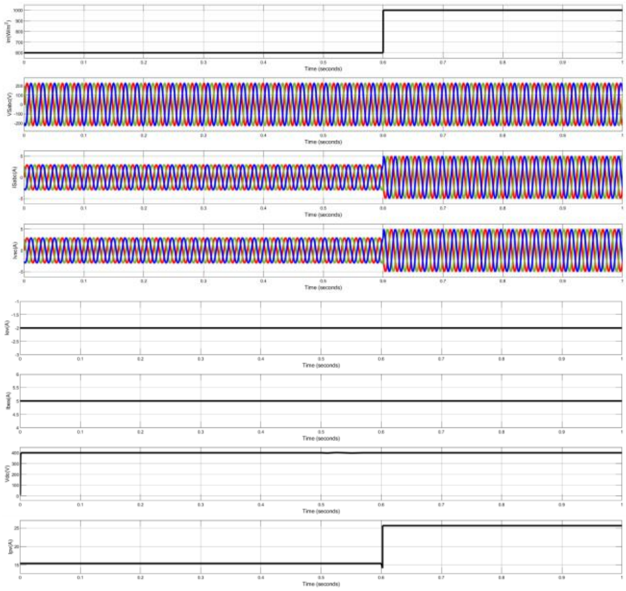
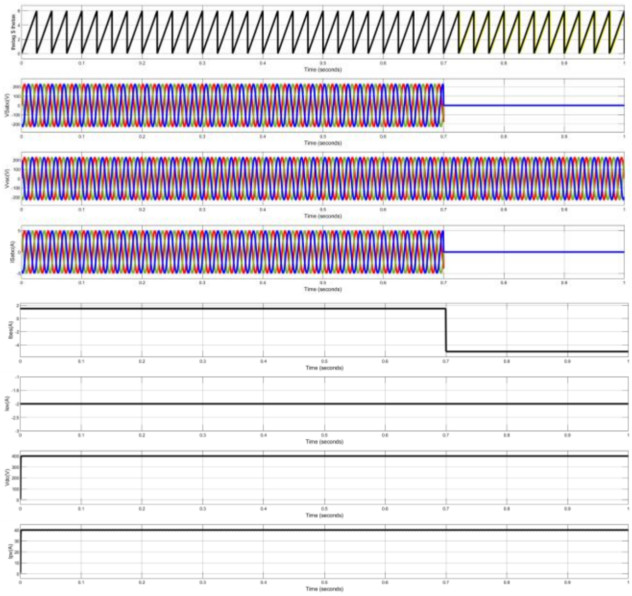
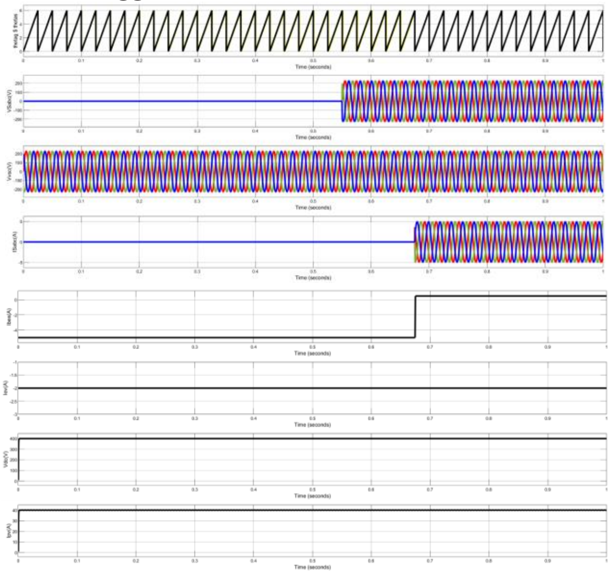


Fig. 8: Simulated response of EV charging station under variation of PV insolation.

Since the EV as well as storage are in floating state, a PV array production increases as the irradiation level rises between 600 to 1000 W/m2, as seen in Figure 8.



(a)



(b)

Fig. 9. Simulated performance at (a) grid disconnection and (b) grid reconnection.

Figure 9(a) displays the simulated performance during a grid outage. Charging stations function in SM mode when a power outage is detected. Hence, voltages and currents on the grid instantly go to zero. The BES begins charging in order to make up for the excess power. Electric vehicle charging rates have not increased. Figure 9(b) shows the simulated system reaction during grid recovery. When the grid is restored, the VSC becomes synchronized with the grid, as well as the voltages and currents of the grid become visible. Without interfering with the EV charging, the BES begins to discharge.

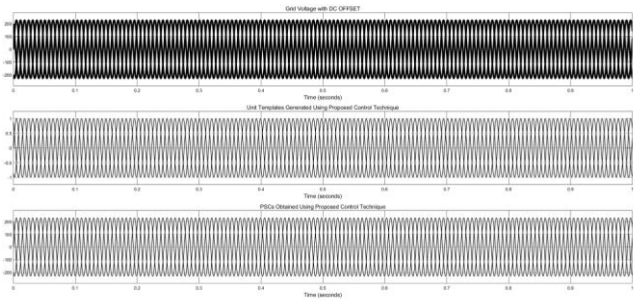


Fig. 10. proposed control with fractional-order correntropy adaptive filtering algorithm at dc offset.

The grid voltages provide a 90-volt direct current offset. The UTs include a dc-offset component after the use of a fractional-order correntropy adaptive filtering algorithm control. Thus, as seen in Figure 10, PSCs that utilize the suggested method experience dc offset, in contrast to UTs and PSCs that employ the suggested control, which experience no such offset.

(a)

(b)

Fig. 11. THD of grid voltage and grid current.

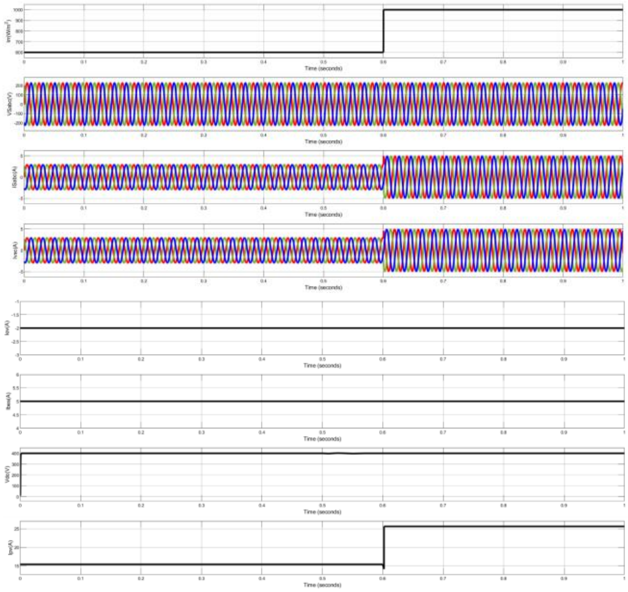
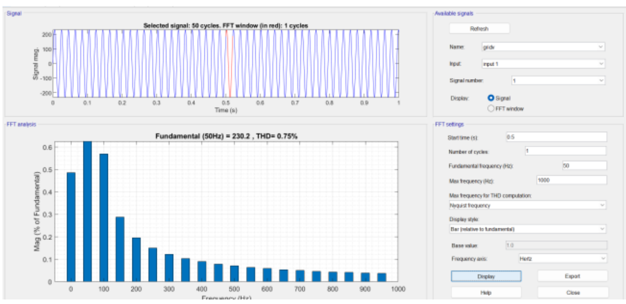


Fig. 12. Simulated response of EV charging station under variation of PV insolation. (proposed system)

Since the electric vehicle and battery are in a floating mode with the ANN controller, as seen in Figure 12, PV array production increases when the irradiation level rises between 600 to 1000 W/m2.



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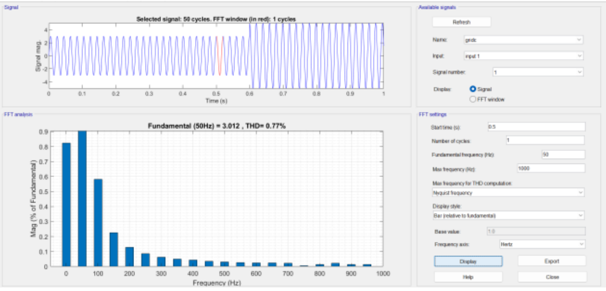
(a)



(b)

Fig. 13. THD of grid voltage and grid current.

CONCLUSION

It is here that the charging station based on PV arrays with BES is introduced. The results of the tests revealed that the electric vehicle charging station's better power quality operation held true over a range of dynamic settings, including fluctuating PV insolation, compensatory mode, including constant power grid mode with a BES. There has also been much research of the system's reaction to BES system changes and discharges.

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