

OVERVIEW OF MULTIPOINT EV FAST CHARGING STATIONS WITH FLOATING SOLAR PV USING MODIFIED Z-SOURCE INVERTER TECHNOLOGY

Mukul Banerjee^{1,*}, Sukanta Roy^{1,2}, and Sourav Saha¹

Received: June 02, 2025; Revised: September 29, 2025; Accepted: October 08, 2025

Abstract

Electric cars (EVs) are growing in popularity; thus, infrastructure for charging them must be sufficient to make refueling them as pleasurable as driving a conventional car. In this regard, advancements in Multipoint Fast-charging (MFC) offer promising alternatives. MFC systems can use floating solar PV (FPV) and innovative modified Z-source inverters (MZSI) to adjust to the evolving demands of EV recharging. MZSI is better for EV charging stations because of the recent increase in EV usage. For the design of the charging station to integrate multiple sources and offer a multipoint charging alternative, an efficient inverter was required. This article describes how MZSI is designed for stations that use the grid and FPV to charge several electric vehicles. To raise the voltage in response to the demands of the battery side, the recommended MZSI is placed between the input and output sections. This converter architecture has five operational modes: grid-battery, battery-grid, FPV-grid, FPV-battery, and FPV-to-grid-and-battery. Some studies use two connections for charging, producing 1 kW at each charger. According to calculations, the MZSI's efficiency is 90.18% when FPV runs in both grid and battery conditions. The proposed MZSI has several advantages over the conventional ZSI, such as higher efficiency, a simple control system, affordability, and simplicity of construction. Our analysis focuses on integrating multipoint converters with FPV energy and offers details on a distinct MFC topology design for electric vehicle charging stations that employs MZSI. For FPV-based multipoint EVFCs, we note that an MZSI offers greater effectiveness and flexibility, a cheap cost, a regulatory system, and straight forward construction.

Keywords: EV Fast charging; Floating Solar PV; MZSI Technology; Renewable Energy; Solar PV System

¹ Department of Mechanical Engineering, National Institute of Technology Mizoram, India. E-mail: banerjeeindia.10@gmail.com*; sukanta.me@nitmz.ac.in; sourav.saha36@gmail.com

² Department of Mechanical Engineering, Curtin University Malaysia, CDT 250, Miri, Sarawak, Malaysia.

* Corresponding author

DOI: <https://doi.org/10.55766/sujst10097>

Suranaree J. Sci. Technol. 33(2):010411(1-11)

Introduction

According to the information provided by the World Health Organization (WHO), air pollution causes over 3.6 million deaths worldwide and accounts for 18% of premature births (Khan *et al.*, 2018).

EVs are becoming more and more popular as a solution to these environmental and health issues. Comprehensive data comparing electric vehicles (EVs) and traditional automobiles across a number of parameters is included in Table 1 below. EVs are a more environmentally friendly choice since they are capable of being recharged with electricity from alternative sources after being connected to the grid. EVs are powered by power storage technologies, and rechargeable Li-ion batteries are popular due to their high energy density and also high range compared to other batteries. Driving ranges that are competitive remain achievable with electric vehicles. However, there are several obstacles in the way of accepting electric vehicles (Manzetti & Mariasiu, 2015). The main benefits of EVs are increased wheel-to-wheel efficiency and reduced or eliminated local pollution. Energy storage is currently the primary focus (Asna *et al.*, 2021).

Despite the COVID-19 pandemic, the EV market increased by 42.90% worldwide in 2019 and 2020 (International Energy Agency, 2021). The infrastructure for charging electric cars must also develop accordingly, as sales are anticipated to rise to 13.8 million in 2024 from 3.1 million in 2020 (Safayatullah *et al.*, 2022). Sales of new EVs over the last two years are shown in Figure 1.

EVs face significant challenges because of insufficient charging infrastructure, particularly FCS, which has the ability to rapidly recharge car batteries, increasing the driving range and making electric vehicles more effective for protracted excursions. Renewable energy sources, particularly solar FPV, are becoming more and more popular to incorporate into EV charging infrastructures since they may reduce greenhouse gas emissions, charging expenses, and the strain on the electrical grid (Ashique *et al.*, 2017). A battery energy storage system is included to enhance EV-FCS performance and mitigate environmental intermittency (Saxena *et al.*, 2017). A stable grid connection is necessary to counteract the sporadic nature of alternative energy sources. It encourages the return of excess energy to the grid, provides a consistent power source, and integrates FPV systems incorporating particular converter designs alongside the grid (Ahmed *et al.*, 2023). These converters ensure the stability of the electrical grid and ensure efficient energy conversion (Jang *et al.*, 2021). For this, multiport charging stations for smartphones are required. For FPV grid integration, electronic inverters were crucial for harnessing floating solar energy to generate usable electrical power (Kougioulis *et al.*, 2023). Each of the different inverter technologies has advantages and disadvantages of its own. ZSI, one of the many

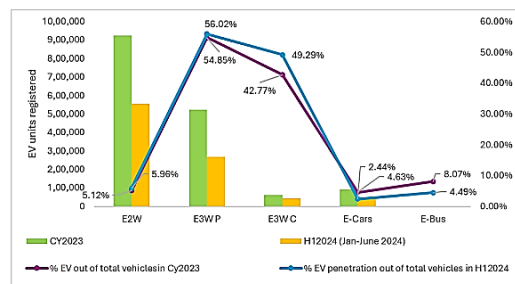


Figure 1. Comparison of new electric vehicle sales during the past two years (Banerjee and Das, 2023)

Table 1. Compares electric vehicles (EVs) with Traditional Automobiles (CVs) in-depth using a number of parameters (Peng, 2003)

Classification	Traditional Automobiles (CV)	Electrical Vehicles (EV)
Impact on the Environment	None	It has reduced emissions (zero tailpipe emissions) and may be charged with RES.
Effectiveness	Insufficient energy efficiency (20.1–30.1% conversion efficiency) and no regenerative braking	Exceptional energy efficiency (above 84.90 % conversion effectiveness)
Operational Costs	More fuel costs (gasoline and diesel are frequently costlier than energy) and upkeep	Lower maintenance (fewer moving parts) and fuel expenses (electricity is less expensive than gasoline)
The performance	A rise in noise pollution	Instant torque allows for quick acceleration and silent operation.
First Expenses	None	Long-term savings in operational costs
The Infrastructure for Charging nBattery Limitations	None	Possibility of charging at home
Safety and Health	Critical health threats linked to emissions (allergies, respiratory conditions, etc.)	Reduced health risks and noise pollution threats resulting from emissions

inverter technologies, is a popular option for FPV-grid integration because of its exceptional efficiency and capacity to control voltage fluctuations (Peng, 2003). Peng started developing ZSI in 2003 to tackle the short comings of voltage supply and current source inverters. Even though they could manage elevated currents, they faced constraints due to issues such as irregular capacitors being impacted by elevated input current and voltage, significantly reducing their grid integration efficiency. Because it offers a special remedy for some of the most pressing problems in energy accumulation and other energy management, grid reliability, and the integration of alternative resources, vehicle-to-grid (V2G) technology is growing in importance in the current system with loads from electric vehicles. Traditional G2V and V2G should be supported by the inverter topology in EV charging stations. To provide multiport charging options, the converter requires a large number of output terminals. Among the three restrictions are (a) the capability of multiport charging (Assadi *et al.*, 2023; Somefun & Longe, 2025), (b) power flow in both G2V and V2G directions (Tashakor *et al.*, 2016), and (c) FC, which is found in the investigations. In this proposed study, the ZSI has been modified to accommodate these constraints. The need for multiport charging solutions can now be satisfied by dividing the Z-network's capacitors to produce multiple charging outputs. A detailed analysis shows that it performs better than the modified and regular ZSIs in relation to their effectiveness and the ability to charge multiple devices. The upgraded ZSI offers a number of benefits over conventional technology, including improved stability, efficiency, and the ability to handle the growing demands of EV charging infrastructure.

This study identified some research gaps: Multiport Architecture Scalability: There are also insufficient evaluations of the environmental effects of floating PV on aquatic ecosystems, increased fault tolerance when there are several ports loaded, and further research is required in the areas of islanding detection, reactive power compensation, and harmonics.

Electric Vehicles quick charging station framework

Plug-in hybrid and electric vehicles can now be charged with balanced conductive power thanks to the J1772 guideline, the norms defined by the Society of Automotive Engineers (SAE) (Feng *et al.*, 2016).

It is recommended that clients charge their electric vehicles using home networks, as there is no existing infrastructure for curtailment charging. (Williamson *et al.*, 2015). Figure 2, Integrated AC level-1 chargers, which make use of 120-volt AC power inputs, and AC level-2 chargers, which reply on 240-volt AC power inputs, provide a categorization of the framework for fast charging and have respective peak power outputs of 1.9 and 19.2 kilowatts. Onboard chargers with low power outputs, usually 50 kW, can incorporate DC quick chargers. At this point, the power levels are 475 kW. These chargers can receive DC voltage for EV battery charging and offer high-speed charging through independent power electronics converters. In the production of EVTECH, devices can be built and charged for up to 150 kW of direct current and 65 kW of alternating current. In order to satisfy the requirements for quick charging, it can tolerate an electrical voltage of up to 1 KV. This method, recognized as "dynamic DC-power splitting," intelligently regulates the output power during simultaneous charging, enabling linked electric vehicles to be accommodated in the best possible way for a short time. Features of an espresso & charge include remote access, less grid impact, and the capacity to charge four automobiles in tandem. ABB's HP Terra electric vehicle chargers are FCS devices rated at 350 kW, capable of enduring 500 A of output current and 920 V DC of output voltage. Convenient charging stations increase the demand for EVs since they are more flexible and cost-effective to build. Energy management is made possible by highly intelligent charging that makes use of the Protocol for Open Charge Points. Multiple charging connector standards, including GB/T, CCS, and CHAdeMO protocols, are available with the Phihong DO series. It has a 360

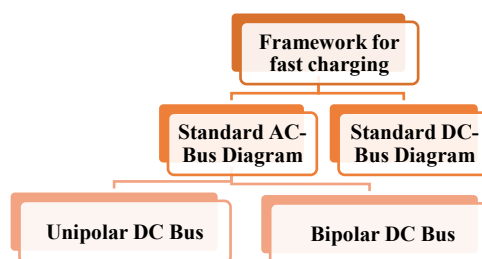


Figure 2. Demonstrates how to categorize the quick charging framework

Table 2. Displays manufacturers that are now making DC fast charger SOA (Khaligh & D'Antonio, 2019)

Manufacturing companies	Tritium	PHIHONG	EVTEC	Tesla	ABB
Type of model	Veefil PK	DO Series	Espresso Charge	Supercharger	Terra HP
Voltage of input (V/AC)	480	415	400	480	480
Voltage of output (V/DC)	920	500	500	50-410	920
Current of output(A)	500	150	300	330	500
Power(kW)	475	360	150	140	350
Efficiency (%)	>98.5	>94	93	91	95
Cooling System	Liquid	Fan	Less Ventilation	Liquid	Liquid
Supported charging connector	CHAdemo	CHAdemo V1.2	CHAdemo JEVS	V3 Superchargers	CHAdemo CCS-1
Time to Charge (minutes)	10	15	24	30	10

kW output power, a 500-volt DC voltage, and a 150-amp current output. It may be charged concurrently at four DC charging ports. Both load balancing and pantograph charging are supported. Among the main applications are EV bus stops and highway fueling stations. To learn more about commercially available chargers, electrical range, battery capacity, engine type, rating, and the cost of energy per kilometer, the different EV model types are described in Table 2. (Williamson *et al.*, 2015). Supplementary research has been performed to contribute to decreasing the financial burden of EVs while offering approximately 200 kilometers of power coverage. Using the grid, electric car batteries can be recharged using AC or DC chargers. Worldwide, a large number of connectors have been used to make extremely rapid charging speeds possible. Connectors of today have a special strength rating. (Khaligh & D'Antonio, 2019). These methods are described in the ensuing sub-chapters.

1. FCS (AC) for EVs

The distribution network is connected to a 3-Ø AC bus system via a step-down transformer, so it indicates a line-to-line voltage of 250-480 V can be used to operate AC-connected equipment. This AC bus supplies all of the chargers at the stations, and every charger is displayed as a distinct AC-DC stage. The AC-connected device with more transformation stages performs worse and is more complicated and expensive. The availability of cutting-edge technology for rectifiers and inverters is one advantage of using an AC bus. The feasibility of utilizing AC switchgear to secure devices, and the existence of existing AC power delivery system standards. Furthermore, guidelines for EV charging stations are created (Yilmaz and Krein, 2012). As shown in Figure 3, A significant number of current EFC stations are linked to AC networks. Even though it is equipped with a universal AC plug, allowing for unrestricted EV charging. It comes in a range of sizes, volumes, and pin-outs and is

primarily created with the company's electric vehicle manufacturer, taking into account the nation, power, and frequency levels.

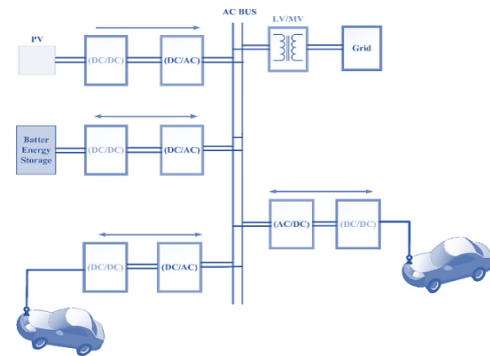


Figure 3. Shows an AC interface charging station. (Rojas *et al.*, 2017)

Currently, various kinds of AC charging connectors are in use worldwide. Five pins make up the Type-1 connector standard SAEJ1772 for single-phase charging: two designated for AC lines, two for a single line, and one for ground protection. Current and maximum voltage specifications are 80A, 240V, and 120V, respectively. The IEC 62192-type-2 connector standard, formulated by the International Electrotechnical Commission (IEC), is applicable for charging using both AC and DC. The electric systems are suitable for 3-phase AC systems since their current (I) and voltage (V) ratings are arranged properly: 3-phase 400 volts, 63 A, 80 A, and 1-phase 230 volts. The GB/T 20234 type-3 connector standard allows for the AC and DC charging of a three-phase system with 379 V of voltage and 34.9 A of current. Type-4 is a Tesla US connector that is only used in the US that facilitates both AC and DC charging. The maximum voltage and power ratings are 17.2 kW charging and 240-volt AC. conventional ground-based system, The components of the inverter are situated on the shore of the system (Gorjian *et al.*, 2021). The construction of FPV platforms should minimize any

negative effects on the environment and avoid obstructing the natural flow patterns of the water. Incorporate functionalities such as platform gaps to reduce the impact of shade and allow water to get through (Singh *et al.*, 2019).

2. FCS (DC) for Electric vehicles

The DC bus design for the DC-linked network necessitates a central AC-DC front-end converter, which provides a highly energy-saving way to link DC storage and FPV. At these voltage levels, the DC bus EFC stations' architecture ought to adhere to the same requirements as the EFC stations for the AC bus. There is no need for separate AC/DC converters because every charger has a DC bus and a DC-DC converter attached to it. The system works better than AC-connected devices with fewer converter levels. The front center end offers a single link to the utility, which is one possible benefit of the "DC distribution" method. Because DC systems don't have reactive power, complex control algorithms can be easily simplified (Acharige *et al.*, 2023). Depending on the car's electrical supply, partial power converters reduce the system's price, improve efficiency of conversion, and reduce the ratings of converters. It is advised that, depending on specific needs, Figure 4 illustrates how power DC-DC converters function with an EFC station's standard DC bus (Rojas *et al.*, 2017). Level one and level two chargers are intended to be replaced by these.

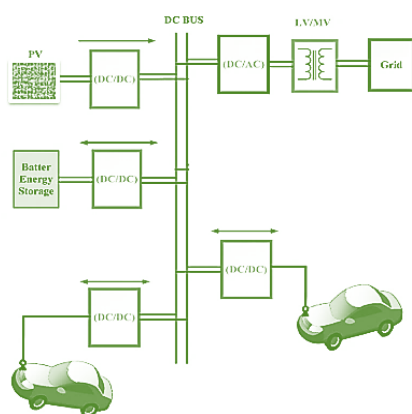


Figure 4. The DC interface of the charging station (Rojas *et al.*, 2017)

Depending on the manufacturer, these have ratings ranging from 50 kilowatts to 500 kilowatts. The control stage and conversion of power get bigger and more costly as the power volume rises. One of the primary arguments in favor of off-board DC quick chargers is this. The second reason to use DC chargers is protection. Larger power handling equipment and massive power converters have raised serious concern about passenger security.

Solar FPV Structure

An FPV system's main parts are inverters, underwater cables, energy interactions, PV modules, pontoons or separate floats, and mooring systems. Among the many important features of building FPV systems is how FPV modules are connected to one another. Partial shadowing conditions (PSC) require this. Partial shadowing conditions (PSC) require this. Numerous scholars have put forth various link arrangements in this context. It works well with FPV arrays (Liao, 2013). A pontoon is a mechanical device that can automatically add a substantial amount of buoyancy. Parallel wiring and the right number of PVMs are used to build this series, depending on the space available and the platform's characteristics (Exley *et al.*, 2021).

Increase the number of holes in weight-efficient polyethylene to create a greater float. Figure 5 describes different positions of FPV parts, and Figure 6 describes large-scale FPV. High-density polyethylene, which is well known for its accuracy, long-term durability, Flotation devices are usually made with materials that are resistant to corrosion and UV light. Glass fiber-reinforced plastic (GRP) can also be used to create platforms for floating objects. HDPE, which is recyclable, is commonly utilized to construct gasoline tanks, water supply lines, and bottles. The majority of floating systems are made of HDPE, which comes in a variety of shapes and floats (Ramanan *et al.*, 2024). The floating framework is firmly supported by a sturdy base. This prevents the structure that floats on water from moving freely. Cables and anchors are used in the mooring system to keep the floating equipment stable (Yousuf *et al.*, 2020). Special wires must be constructed in order to be used in water. Despite their higher cost, waterproof IP67 junction panels are advised even if no electrical components are submerged (Kim *et al.*, 2014). These wires could be utilized as floating cables. Since it links the solar panel to the grid, this is crucial. Underwater wires have to be resistant to leaks and shacks because of their purpose.

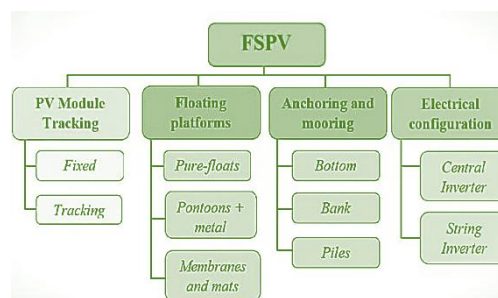


Figure 5. Different position of FPV parts (Banerjee and Das, 2023)

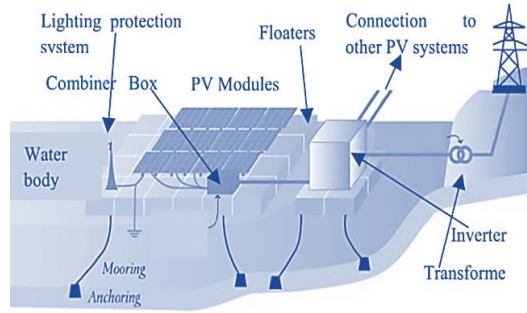


Figure 6. Large-scale Floating Solar PV (Liao and Yi-Hung, 2013)

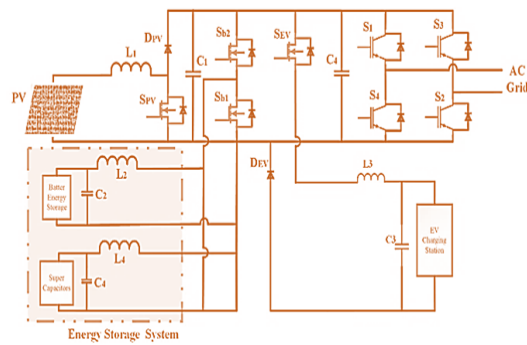


Figure 7. Shows Multiport FPV integrated converter for an EVCS (Da Câmara *et al.*, 2019)

Three-phase, bidirectional AC-DC converter with Multiport connection to FPV-based EVFCs

This converter is suitable for complex energy control scenarios because, as a power electronic device, it can control many power sources and loads. The primary advantage of using this EVCS microgrid's multi-port converter is its ability to integrate many loads and power sources into a single power conversion phase. Compared to other systems, this integration requires fewer components and power conversion steps.

The microgrid system might become simpler and more effective as a result. Solar panels in a floating photovoltaic (FPV) system use sunlight to generate power. Figure 7 visually describes the FPV-integrated multiport converter for an EV charging station. Energy management and storage are accomplished using the Battery Energy Storage System (BESS). Local grid: Most likely, the electrical distribution system in the area (Huang *et al.*, 2023). The viability of employing this converter in microgrid applications for electric vehicle charging stations is confirmed by the control

scheme's efficacy, particularly during transients (brief variations in power or voltage). This strategy seeks to increase system efficiency and simplify it while maintaining dependable control and functioning with a variety of power source circumstances.

Modified Z-Source Inverter (MZSI) Integrated to FPV Based EVCSs

The ZSI contains two capacitors, two inductors, and four switches for the operation. This inverter may provide a boost or buck output, depending on the cycle of duty. Furthermore, both non-shoot-through and shoot-through functions are possible with this inverter architecture. Figure 8 shows a diagram of the functional blocks for the suggested system. A multiport EV charger is made by modifying a traditional Z-source inverter. In a typical design, there are two capacitors in the inverter. To split the voltage, these capacitors are separated into one or more capacitors with identical ratings. The station for charging is powered by two sources: grid integration and a solar photovoltaic system. The solar FPV system meets the charging station's necessary demand.

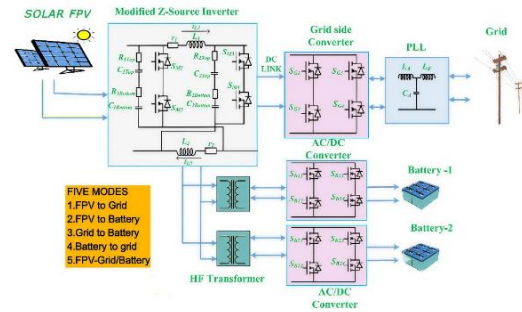


Figure 8. Displays the functional blocks of the topology in a diagram combined with FPV-Based EVSCs (Ramanathan *et al.*, 2024; Alahmad *et al.*, 2025)

When power use is minimal and the FPV is unable to provide the charging station's requirement, the charger uses the grid to make up the deficit. When demand surpasses the FPV's capacity, the excess power it generates will be fed into the grid system. In a separate scenario, the grid must supply all of the charging station's demand when there is no sunshine. Figure 9 visually describes operational switching between modes. This power state is completely erratic due to the FPV generation and the uncertain load. This problem can be handled by a typical ZSI.

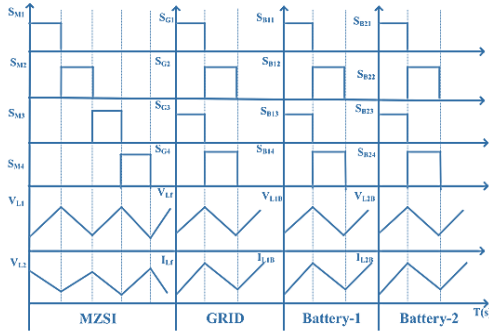


Figure 9. The demonstration of operational mode switching

Tapping multiple ports is not feasible, though. This unpredictable power flow may be managed by the modified inverter design utilized in this project, which also maintains a steady voltage at the terminals of the charger. To alter the voltage differential between MZSI and the grid, three high-frequency transformers were used (Da Câmara *et al.*, 2019). These modes of operation are PV to grid, PV to battery, PV to grid/battery, grid to battery, and battery to grid. The MZSI functioned with a 25% duty ratio, while the switches in HBCs operated with a 50% duty ratio. All the mode diagrams shown Figure 10 to Figure 14.

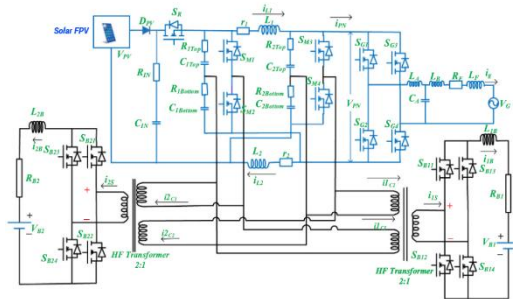


Figure 10. Mode of operation FPV-Grid (Ramanathan *et al.*, 2024; Alahmad *et al.*, 2025)

Solar FPV to Grid: Mode –I

In this mode, the FPV system components supply electricity to the grid while the MZSI operates a standard inverter. Power will be delivered to the grid via HBC-1 and MZSI. During this mode, the SM1, SM2, SM3, and SM4 switches, together with the diodes in HBC, are required to be switched ON and OFF for a 50% duty cycle. The switches SM1 and SM4 are engaged for the positive half cycle, in contrast to the SM2 and SM3 switches, which are engaged for the negative half cycle. Each switch has a 0.5 duty cycle. The duty cycle of each switch is 0.5. To bring the FPV system's operation of switches SG1, SG2, SG3, and SG4 is conducted at a duty cycle of 25% to facilitate the conversion from DC to AC. The blue lines indicate the active zones, and the black lines indicate the non-active zones.

Solar FPV to Battery: Mode –II

In mode two, the MZSI operates a standard inverter, and the battery is powered by the FPV system. The battery will be powered by HBC-2, HBC-3, and MZSI. In this mode, SB11, SB12, SB13, and SB14 switches located in HBC-2, along with SB21, SB22, SB23, and SB24 switches in HBC-2 are required to be turned ON and OFF with a 50% duty cycle. Both HBC 1 and HBC 2 are off

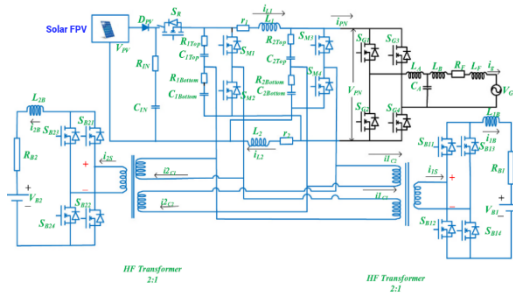


Figure 11. Mode of operation FPV-Battery (Ramanathan *et al.*, 2024; Alahmad *et al.*, 2025)

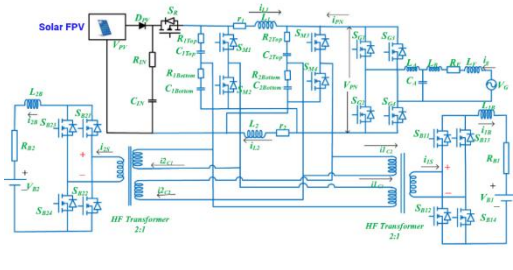


Figure 12. Mode of operation Grid-Battery (Ramanathan *et al.*, 2024; Alahmad *et al.*, 2025)

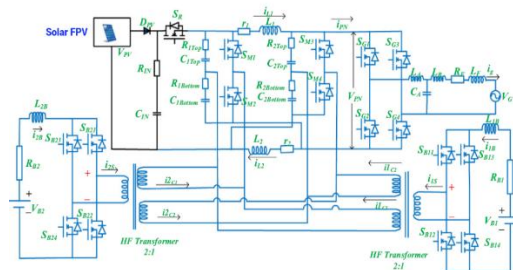


Figure 13. Mode of operation Battery-Grid (Ramanathan *et al.*, 2024; Alahmad *et al.*, 2025)

throughout the negative half cycle. For the HBC converter to convert AC to DC, the AC output is provided by the MZSI. After transformation, a battery can be used to store the DC supply or utilized to recharge the EV's batteries via the charging connector. The blue lines indicate the active zones, and the black lines indicate the non-active zones.

Grid to Battery: Mode –III

This link between battery and grid is established via Mode III. When FPV is not available, to charge the batteries, EVCS requires power. In this configuration, the charging station's entire power supply will come from the grid. The source Communication between battery and grid is controlled by the MZSI. To satisfy the requirements, the duty cycle has been modified. In this mode, the three H-bridge converters operate at a 50% duty cycle. The blue lines indicate the active zones, and the black lines indicate the non-active zones.

Battery to Grid: Mode –IV

The battery's grid connection is handled via Mode IV. In this mode, the battery can provide electricity to the grid. The supply of electricity between the power grid and the battery pack is controlled by the MZSI. The duty cycle has been modified based on the grid's demand. In this condition, each of the three H-bridge conversions operates at a 50% duty cycle. The blue lines indicate the active zones, and the black lines indicate the non-active zones.

Solar FPV to Grid/Battery: Mode –V

In this mode of operation, MZSI is linked to all three sources. To supply electricity to the grid and battery in V mode, in addition to generating the rated power, the FPV system controls the load on the grid and charge sides. The generation of FPV power fluctuates during the day, making it impossible to supply the grid and batteries with energy continually. According to modes III and IV, electricity will flow either from the grid to the battery or, after the FPV is completely off, from the battery to the grid. Other possibilities include the FPV generating less power than what is required by the grid or battery side. This mode may have two sub-modes; for instance, when FPV is unable to provide the battery-side market, the grid uses it to regulate it. In order to maintain the grid, the MZSI may regulate battery power under various conditions. Various losses of MZSI systems are depicted in Figure 15. When the load requirement cannot be met and sustained by FPV generation alone, the grid is under additional strain to handle it. To validate this alternative scenario, the FPV generation rate has been adjusted (Da Câmara *et al.*,

2019). During a full cycle, the average current within the transformer is zero. In contrast, the average current that flows into the switch constitutes 25% of the ILB. The mean current was reduced to zero because of the distribution of current on all primary sides and the duty cycle. Consequently, the voltage measured across each transformer equated to 50% of the capacitor voltage (VC). In H-bridge converters, there exist four switches, and these switches remain ON for 50% of the overall time and OFF for 50% of the overall time. In these operating conditions, the inductance value is designated as L_B , while the capacitance value is C_{HB} .

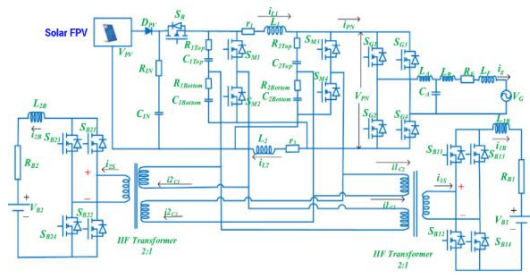


Figure 14. Mode of operation FPV-Grid/Battery (Ramanathan *et al.*, 2024; Alahmad *et al.*, 2025)

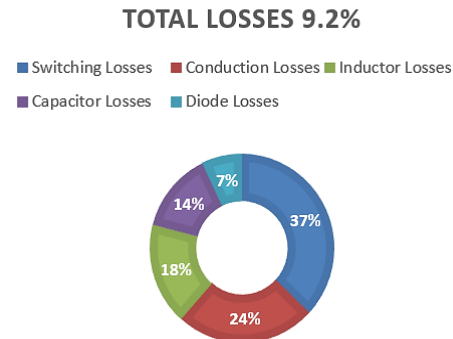


Figure 15. Shows various losses of MZSI Systems

Implementing MZSI in a real-time setting presents challenges

When installing, several practical issues with integrating FPV systems with EV charging infrastructure need to be taken into account. Space and site selection are crucial things to think about. Finding FPV panel In urban areas with a restricted amount of room, spots with adequate space and sun exposure are crucial. The MZSI's comparison evaluation is shown in Table 3. For stability and compatibility, FPV systems are meticulously linked with the electrical grid.

Table 3. Shows Evaluation of the MZSI in comparison (Ramanathan *et al.*, 2024)

Parameter	MZSI	ZSI	Semi ZSI
Efficiency	90.18%	85%	88%
Option for multiport charging	Yes	No	Yes
Expense	Moderate	Low	Moderate
Complexity of control	Simple	Moderate	Moderate
Ability to Increase Voltage	Higher	Moderate	High
Integration of the Grid	Excellent	Good	Excellent

Modern inverter technologies, like the MZSI, can address grid capacity problems and voltage swings. Issues with voltage fluctuations and grid capacity can be mitigated by modern inverter technologies such as the MZSI. Resulting in increased panel efficiency from water's natural cooling, three charging ports, and the ability to charge many EVs simultaneously with a single power supply, all of which contribute to an efficiency of 90.18%.

Conclusion

This article describes the design and construction of an MZSI for FPV-based EV multiport charging. The FPV system serves as the input source, and the grid and batteries serve as the output. The FPV grid and FPV batteries are linked to the MZSI. Two capacitors make up the capacitor used in the traditional ZSI to provide the multiport option. Two HFT capacitors have been connected for two charging ports. The MZSI has been validated in an array of operating modes, such as grid to battery, battery to grid, FPV to the arrangement, FPV to the battery, and FPV to the battery and grid. Plots of waveforms showing the MZSI's performance in different modes have been observed. Based on computations, when FPV operates in both grid and battery circumstances, the MZSI's efficiency is 90.18%. Compared to the traditional ZSI, the suggested MZSI offers a number of benefits, including increased efficiency, a straightforward control system, cost, and ease of building. In this study some limitations or challenges are follows: Sophisticated control algorithms are needed for modified ZSI topologies in order to manage shoot-through states and guarantee stable operation across many ports. Although multiport systems show promise, problems with synchronization, thermal management, and voltage regulation may arise when scaling up to accommodate huge fleets. Even though three ports have produced efficiencies of up to 90.18%, performance may suffer with additional ports, especially in the presence of variable solar conditions. However, MZSI costs 1.5 times as much as the typical ZSI, though. Given the current surge

in EV usage, this suggested It would be better to use MZSI for FPV-based EVCS.

Future Scope

The following advantages are offered by multi-port FPV charging stations for electric vehicles integrated with MZSI technology. **Increased productivity:** By enabling more efficient utilization of renewable energy sources, the MZSI reduces dependence on the conventional power grid. **Sustainability:** Floating photovoltaic systems support environmental protection by providing a clean and sustainable energy source. **Scalability:** Multiport charging stations can be expanded to accommodate a larger number of electric vehicles, thereby meeting the growing demand in the EV market. This innovative approach to EV charging infrastructure shows significant potential for enhancing both operational efficiency and the long-term sustainability of electric vehicle systems.

Nomenclature

F_{SW}	Switching Frequency
D_O	Duty cycle
I_L	Inductor current
V_C	Capacitor Voltage
V_{PN}	dc-link voltage
I_{PN}	dc-link current
V_{PV}	FPV Voltage
V_G	Grid Voltage
V_B	Battery Voltage
V_C	Capacitor Voltage
D_{omax}	Maximum ST duty ratio
L_1	Inductor 1
L_2	Inductor 2
C_1	Capacitor 1
C_2	Capacitor 2
r_1	Resistor 1
r_2	Resistor 2
M	Modulation index
C_{1Top}	First half of C1 capacitor
$C_{1Bottom}$	Second half of C1 capacitor
C_{2Top}	First half of C2 capacitor

C _{2Bottom}	Second half of C2 capacitor
R _{1Top}	First half of R1 resistor
R _{1Bottom}	Second half of R1 resistor
R _{2Top}	First half of R2 resistor
R _{2Bottom}	Second half of R2 resistor
C _{IN}	Input Capacitor
R _{IN}	Input Resistor
i _{PV}	FPV Current
D _{PV}	FPV Diode
i _{L1}	Inductor 1 Current
i _{L2}	Inductor 2 Current
R _F	Filter Resistor
L _F	Filter Inductor
L _{1B}	Filter Battery 1 Inductor
R _{1B}	Filter Battery 1 Resistor
L _{2B}	Filter Battery 2 Inductor
R _{2B}	Filter Battery 2 Resistor
V _{B1}	Battery Voltage 1
V _{B2}	Battery Voltage 2
r _d	resistance of diode
PL	Power loss
PC	Conduction loss
PS	Switching loss
PD	Diode loss
PL	Inductor loss
PC	Capacitor loss
P _{in}	Input power
P _{out}	Output power
η	Efficiency

Abbreviation

WHO	World Health Organization
FPV	Floating Solar Photovoltaic
EVCS	Electric Vehicle charging systems
ZSI	Z-Source Inverter
V2G	Vehicle to grid
G2V	Grid to vehicle
MZSI	Modified Z-Source Inverter
AC	Alternative Current
DC	Dirrect Current
CCS	Charging connector standards
FC	Fast Charging
IEC	International Electrotechnical Commission
PSC	Partial shadowing conditions
PVMs	Photovoltaic monitoring systems
BESS	Battery Energy Storage System
HFT	High-Temp Reflow capacitors
HBC	H-bridge converter

References

Acharige, S. S., Haque, M. E., Arif, M. T., Hosseinzadeh, N., Hasan, K. N., & Oo, A. M. T. (2023). Review of electric vehicle charging technologies, standards, architectures, and converter configurations. *IEEE Access*, 11, 41218-41255. <https://doi.org/10.1109/ACCESS.2023.3267164>

Ahmed, M. R., Das, B. K., & Tushar, M. S. H. K. (2023). Investigation of a grid-integrated hybrid energy system for residential and electric vehicle (3-wheeler) loads under schedule grid outage. *Alexandria Engineering Journal*, 80, 241-258. <https://doi.org/10.1016/j.aej.2023.08.057>

Alahmad, A. K., Verayiah, R., Shareef, H., Ramasamy, A., & Baswaimi, S. (2025). Enhancing renewable energy integration through strategic stochastic optimization planning of distributed energy resources (Wind/PV/SBESS/MBESS) in distribution systems. *Energy Strategy Reviews*, 59, 101683. <https://doi.org/10.1016/j.esr.2025.101683>

Ashique, R. H., Salam, Z., Aziz, M. J. B. A., & Bhatti, A. R. (2017). Integrated photovoltaic-grid DC fast charging system for electric vehicle: A review of the architecture and control. *Renewable and Sustainable Energy Reviews*, 69, 1243-1257. <https://doi.org/10.1016/j.rser.2016.11.245>

Asna, M., Shareef, H., Achikkulath, P., Mokhlis, H., Errouissi, R., & Wahyudie, A. (2021). Analysis of an optimal planning model for electric vehicle fast-charging stations in Al Ain City, United Arab Emirates. *IEEE Access*, 9, 73678-73694. <https://doi.org/10.1109/ACCESS.2021.3081020>

Assadi, S. A., Gong, Z., Coelho, N., Zaman, M. S., & Trescases, O. (2023). Modular multiport electric-vehicle DC fast-charge station assisted by a dynamically reconfigurable stationary battery. *IEEE Transactions on Power Electronics*, 38(5), 6212-6223. <https://doi.org/10.1109/TPEL.2023.3237622>

Banerjee, M., & Das, P. (2023). A review on barrier and interoperability challenges of electric vehicle for sustainable development. *International Journal of Research and Analytical Reviews*, 10(4).

Da Câmara, R. A., Fernández-Ramírez, L. M., Praça, P. P., Oliveira, D. D. S., García-Triviño, P., & Sarrias-Mena, R. (2019). An application of the multi-port bidirectional three-phase AC-DC converter in electric vehicle charging station microgrid. In *2019 IEEE 15th Brazilian Power Electronics Conference and 5th IEEE Southern Power Electronics Conference (COBEP/SPEC)* (pp. 1-6). IEEE. <https://doi.org/10.1109/COBEP/SPEC44138.2019.9065752>

Exley, G., Armstrong, A., Page, T., & Jones, I. D. (2021). Floating photovoltaics could mitigate climate change impacts on water body temperature and stratification. *Solar Energy*, 219, 24-33. <https://doi.org/10.1016/j.solener.2021.01.076>

Feng, H., Cai, T., Duan, S., Zhao, J., Zhang, X., & Chen, C. (2016). An LCC-compensated resonant converter optimized for robust reaction to large coupling variation in dynamic wireless power transfer. *IEEE Transactions on Industrial Electronics*, 63(10), 6591-6601. <https://doi.org/10.1109/TIE.2016.2589922>

Gorjian, S., Sharon, H., Ebadi, H., Kant, K., Scavo, F. B., & Tina, G. M. (2021). Recent technical advancements, economics and environmental impacts of floating photovoltaic solar energy conversion systems. *Journal of Cleaner Production*, 278, 124285. <https://doi.org/10.1016/j.jclepro.2020.124285>

Huang, G., Tang, Y., Chen, X., Chen, M., & Jiang, Y. (2023). A comprehensive review of floating solar plants and potentials for offshore applications. *Journal of Marine Science and Engineering*, 11(11), 2064. <https://doi.org/10.3390/jmse11112064>

International Energy Agency. (2021). *World energy outlook 2021*. Paris, France.

Jang, Y., Sun, Z., Ji, S., Lee, C., Jeong, D., Choung, S., & Bae, S. (2021). Grid-connected inverter for a PV-powered electric vehicle charging station to enhance the stability of a microgrid. *Sustainability*, 13(24), 14022. <https://doi.org/10.3390/su132414022>

- Khaligh, A., & D'Antonio, M. (2019). Global trends in high-power on-board chargers for electric vehicles. *IEEE Transactions on Vehicular Technology*, 68(4), 3306-3324. <https://doi.org/10.1109/TVT.2019.2897050>
- Khan, S., Ahmad, A., Ahmad, F., Shafaati Shemami, M., Saad Alam, M., & Khateeb, S. (2018). A comprehensive review on solar powered electric vehicle charging system. *Smart Science*, 6(1), 54-79. <https://doi.org/10.1080/23080477.2017.1419054>
- Kim, S. H., Lee, Y. G., Seo, S. H., Joo, H. J., & Yoon, S. J. (2014). Structural design and installation of tracking-type floating PV generation system. *Composites Research*, 27(2), 59-65. <https://doi.org/10.7234/composres.2014.27.2.059>
- Kougioulis, I., Pal, A., Wheeler, P., & Ahmed, M. R. (2023). An isolated multiport DC-DC converter for integrated electric vehicle on-board charger. *IEEE Journal of Emerging and Selected Topics in Power Electronics*, 11(4), 4178-4198. <https://doi.org/10.1109/JESTPE.2023.3276048>
- Liao, Y. H. (2013). A novel reduced switching loss bidirectional AC/DC converter PWM strategy with feedforward control for grid-tied microgrid systems. *IEEE Transactions on Power Electronics*, 29(3), 1500-1513. <https://doi.org/10.1109/TPEL.2013.2260872>
- Manzetti, S., & Mariasiu, F. (2015). Electric vehicle battery technologies: From present state to future systems. *Renewable and Sustainable Energy Reviews*, 51, 1004-1012. <https://doi.org/10.1016/j.rser.2015.07.010>
- Peng, F. Z. (2003). Z-source inverter. *IEEE Transactions on Industry Applications*, 39(2), 504-510. <https://doi.org/10.1109/TIA.2003.808920>
- Ramanan, C. J., Lim, K. H., Kurnia, J. C., Roy, S., Bora, B. J., & Medhi, B. J. (2024). Towards sustainable power generation: Recent advancements in floating photovoltaic technologies. *Renewable and Sustainable Energy Reviews*, 194, 114322. <https://doi.org/10.1016/j.rser.2024.114322>
- Ramanathan, G., Bharatiraja, C., Kotb, H., & Emara, A. (2024). PV-assisted modified Z-source inverter for multiport EV charging infrastructure: Access with PV2V. *Energy Reports*, 11, 5716-5732. <https://doi.org/10.1016/j.egyr.2024.05.036>
- Rojas, J., Renaudineau, H., Kouro, S., & Rivera, S. (2017). Partial power DC-DC converter for electric vehicle fast charging stations. In *IECON 2017 – 43rd Annual Conference of the IEEE Industrial Electronics Society* (pp. 5274-5279). IEEE. <https://doi.org/10.1109/IECON.2017.8216913>
- Safayatullah, M., Elrais, M. T., Ghosh, S., Rezaei, R., & Batarseh, I. (2022). A comprehensive review of power converter topologies and control methods for electric vehicle fast charging applications. *IEEE Access*, 10, 40753-40793. <https://doi.org/10.1109/ACCESS.2022.3166935>
- Saxena, N., Hussain, I., Singh, B., & Vyas, A. L. (2017). Implementation of a grid-integrated PV-battery system for residential and electrical vehicle applications. *IEEE Transactions on Industrial Electronics*, 65(8), 6592-6601. <https://doi.org/10.1109/TIE.2017.2739712>
- Singh, A. K., Boruah, D., Sehgal, L., & Ramaswamy, A. P. (2019). Feasibility study of a grid-tied 2 MW floating solar PV power station and e-transportation facility using SketchUp Pro for the proposed smart city of Pondicherry in India. *Journal of Smart Cities*, 2(2), 49-59. <https://doi.org/10.26789/JSC.2016.02.004>
- Somefun, T. E., & Longe, O. M. (2025). Optimising the reliability of electric vehicle charging stations with vehicle-to-vehicle charging capabilities. *Energy Reports*, 13, 4331-4344. <https://doi.org/10.1016/j.egyr.2025.04.014>
- Tashakor, N., Farjah, E., & Ghanbari, T. (2016). A bidirectional battery charger with modular integrated charge equalization circuit. *IEEE Transactions on Power Electronics*, 32(3), 2133-2145. <https://doi.org/10.1109/TPEL.2016.2569541>
- Williamson, S. S., Rathore, A. K., & Musavi, F. (2015). Industrial electronics for electric transportation: Current state-of-the-art and future challenges. *IEEE Transactions on Industrial Electronics*, 62(5), 3021-3032. <https://doi.org/10.1109/TIE.2015.2409052>
- Yilmaz, M., & Krein, P. T. (2012). Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles. *IEEE Transactions on Power Electronics*, 28(5), 2151-2169. <https://doi.org/10.1109/TPEL.2012.2212917>
- Yousuf, H., Khokhar, M. Q., Zahid, M. A., Kim, J., Kim, Y., Cho, E. C., & Yi, J. (2020). A review on floating photovoltaic technology (FPVT). *Current Photovoltaic Research*, 8(3), 67-78.