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Improved Power Management Control of a Multiport Converter Based EV Charging Station with PV and Battery

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Abstract:** With the expected rise in popularity of EVs and PHEVs, quick charging speeds have become a need. Increasing the charging rate requires more energy, which the grid can't supply. As a result, there has been a surge in research into alternative methods of charging electric vehicles (EVs) that don't need the traditional power infrastructure. In this study, a photovoltaic (PV) source is employed to facilitate high power EV charging. PV output power, though, is intermittent since it is subject to the vagaries of the weather. As a result, a renewable energy based rapid charging station combines battery storage with the PV in a grid-tied system to provide a constant supply for charging electric vehicles on-site. In order to support the high charging rates required when a large number of EVs are linked to the electrical grid, fast charging stations powered by renewable energy should be cost effective, efficient, and dependable. However, the power infrastructure might be strained by fast charging stations, especially super-fast charging stations, due to the possibility for overload during peak hours, abrupt power gaps, and voltage dips. An electric vehicle (EV) charging station that utilises a multiport converter and is connected to a photovoltaic (PV) power generator and a BESS is the subject of this project's in-depth modelling. Power gap balancing, peak shaving, valley filling, and voltage sag correction are just a few of the stabilisation benefits that this development's control system and combination of PV power generation, EV charging station, and battery energy storage (BES) provides. When daily charging demand is matched with sufficient daytime PV output, the impact on the power system is minimised. The advantages of the proposed multiport EV charging circuits with the PV-BES design are confirmed in various modes through MATLAB/Simulink simulation results.

***Keywords:** PV, BES, EV Charging Station, Multiport Converter.*

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1. INTRODUCTION

Intensive research of EV systems is motivated by the potential scarcity of fossil fuels and the present environmental issues of lowering greenhouse emissions. Consumers' openness to replacing their gas-powered automobiles with electric ones has a substantial effect on EV research. This openness is the most important feature in forecasting EV demand. The authors of come to the conclusion that the length of time required to charge an electric vehicle is one of the most significant obstacles facing the EV market today. This dissertation is dedicated to finding new ways to speed up the charging process for electric vehicles. One of the possible solutions is to use, on a large scale, EV as shown in figure 1.

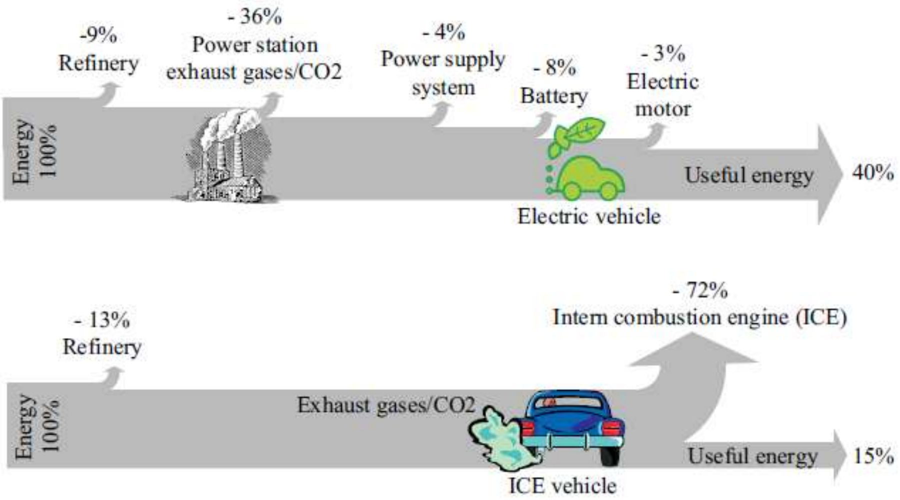

Fig.1: EV versus internal combustion engine vehicles.

EVs have developed as a practical another to traditional gas-engine cars in response to the increased interest in reducing fossil fuel use and pollution. Due to the partial EV battery capacity, extensively spread charging stations are necessary for the growth and increasing use of EVs. However, the constancy and dependability of the power grid is put to the test by the proliferation of fast and superfast charging stations that are openly linked to the grid, resulting in problems such peak demand overload, voltage sag, and power gap. The integration of PV generating with EV charging infrastructure has been explored by some academics, although it is currently seen as contributing only a negligible amount of electricity to EV charging stations. Due to the increased need for quick charging during the day, PV generation has been rapidly expanding, allowing for optimal power usage during peak hours. To deal with the intermittent nature of solar electricity, a BES can be used to control the DC bus or load voltage, equalise the power gap, & smooth out the PV output.

In this work, rather than employing three individual DC/DC converters, a multiport DC/DC converter is utilised for the EV charging station due to the multiport power converter's high power density & efficiency. In light of this literature review, we may categorise the designs of charging stations into two topologies: those that employ an alternating current bus and those that employ a direct current bus. To maximise solar energy consumption while minimising the

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expense and losses associated with converters, a DC bus charging station was selected in this work since both PV output and BES may be seen of as DC current source. Nonisolated multiport converters, which are often descended from buck or boost converters, may offer improved portability, power density, and efficiency over their isolated counterparts. This project uses a DC bus nonisolated construction with SiC switches to reduce power losses and maximise efficiency.

Electric Vehicle Technology

Existing EV equipment is required for load coordination. Chen et al. gives a thorough overview of the vehicles' actual structures. All proposed designs for "plug-in" vehicles have the idea that the grid may be used to replenish the battery to a full charge. Several types of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) are depicted in Figure 2.The following provides a basic summary for the four shown classes:
BEV – Batteries are the sole source of energy for a BEV, which is an electric vehicle; Figure 2. A BEV is a vehicle that does not have an internal combustion engine and is instead charged by an electrical outlet or, on a small number of models, through the removal and replacement of the battery pack. An electric motor & motor inverter are used to achieve the driving system in BEVs. Typically, a transmission shaft and a mechanical coupler (MC) are used to achieve the connecting to the wheels (TR). Regenerative braking allows for the recovery of some of the power consumed from the battery while driving. The sole power source is a battery pack with a specific capacity.

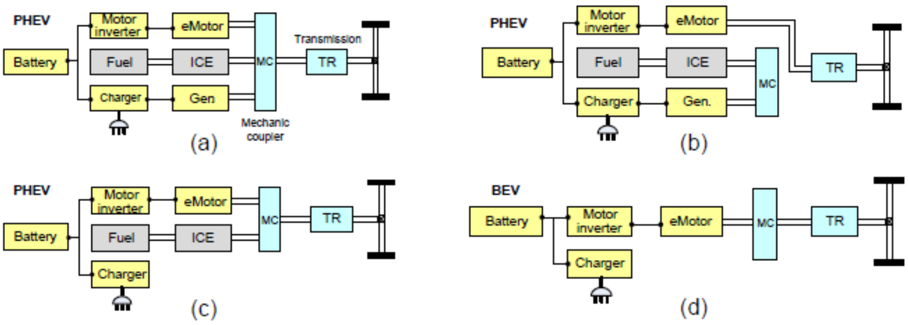

Figure 2: Plug-in vehicle architectures.

PHEV – A PHEV is a vehicle that combines an electric motor with an internal combustion engine (ICE) that can be charged from the grid, driven for short distances on electric power alone, and equipped with regenerative braking. A PHEV's normal engine and gasoline tank are used to increase its range because its battery is less than that of a BEV. Figure 2 (a), (b), and (c) illustrate the three types of PHEVs: series-parallel, serried, & parallel hybrids. A BEV has greater energy density than a PHEV does, on average. Both categories, however, share the need for a link to the low-voltage (LV) grid system in order to accomplish their charging goals. Both these groups shall be referred to collectively as "EV" for the duration of this work. In order to reduce environmental impacts, comply with government incentives, and meet customer needs, conventional electric power networks are undergoing constant and fast transformation. The term "smart grid" refers to the emerging concept of an intelligent electrical grid. Distribution-

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level smart grid has the potential to improve dependability and sustainability. Microgrids, which allow for the seamless connection of decentralised power sources, are largely responsible for the realisation of these qualities (DG). Microgrids can function either in conjunction with the main power grid or independently. Microgrid stability and cost-effectiveness depend on accurate and reliable control. Voltage and frequency regulation are the primary functions of the microgrid control system in both modes of operation,

- Controlling power flows to and from the main grid,
- balancing microgrid loads, resynchronizing with the main grid,
- Minimising operational costs are all essential to maximising the efficiency of a microgrid.

System Modelling

Figure 3a depicts a typical DC bus charging station's layout, which uses three distinct converters to link the station's three power sources (the AC grid, the EV charger's unidirectional source, and the PV array itself, which provides both input and output power). A second bidirectional power source BES is included in the suggested DC bus charging station (Fig. 3b). The BES is used to regulate the DC link voltage and compensate for PV over- and under-production of electricity (Fig. 3). This setup allows for a detailed discussion of functionality and operational modes.

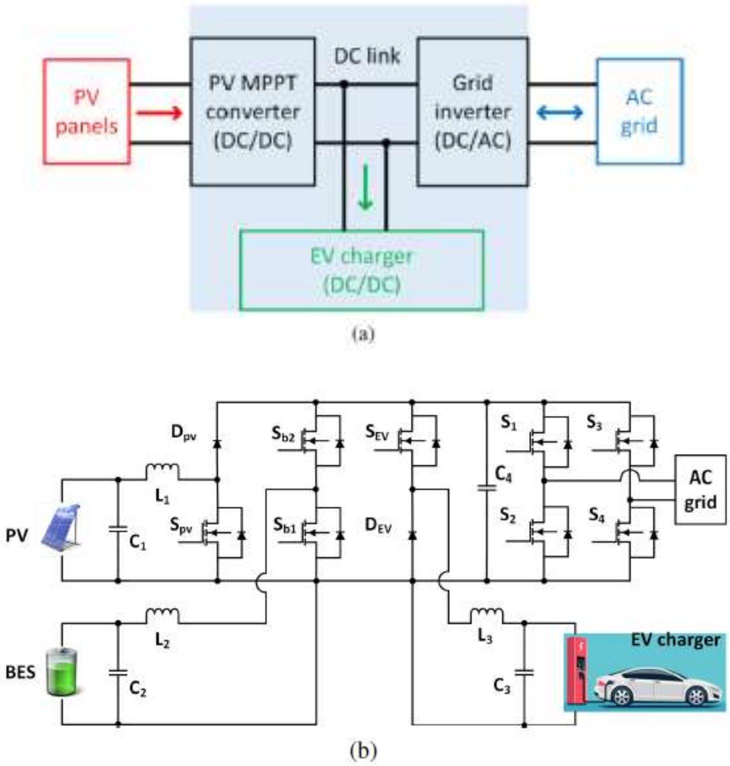

Fig.3: (a) the conventional architecture b) the proposed multiport converter.

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The extent of reality is utilised in fuzzy logic, which is a computational method. The quantity of validity and linguistic components utilised by a fuzzy logic system are used to create a certain result. The kind of the output is decided by the state of this input.

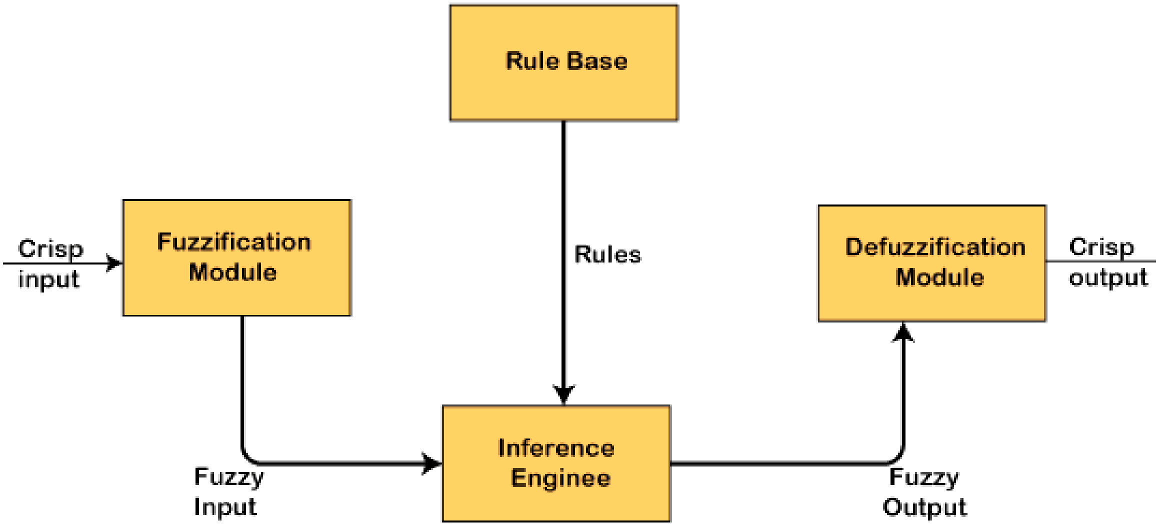

Fig.4: Fuzzy logic system.

In fuzzy logic, problems are defined and addressed by the application of rules that connect an expert's inputs with the intended results. An important influence on fuzzy logic comes from fuzzy sets, membership functions, linguistic variables, and fuzzy rules. A value of an input element is estimated or computed as a percentage of its membership in a fuzzy set, or other abstract set, using this function. As the x-axis represents the cosmos at large, the y-axis represents the various levels of involvement with that cosmos. The figure below is an example of a membership function.

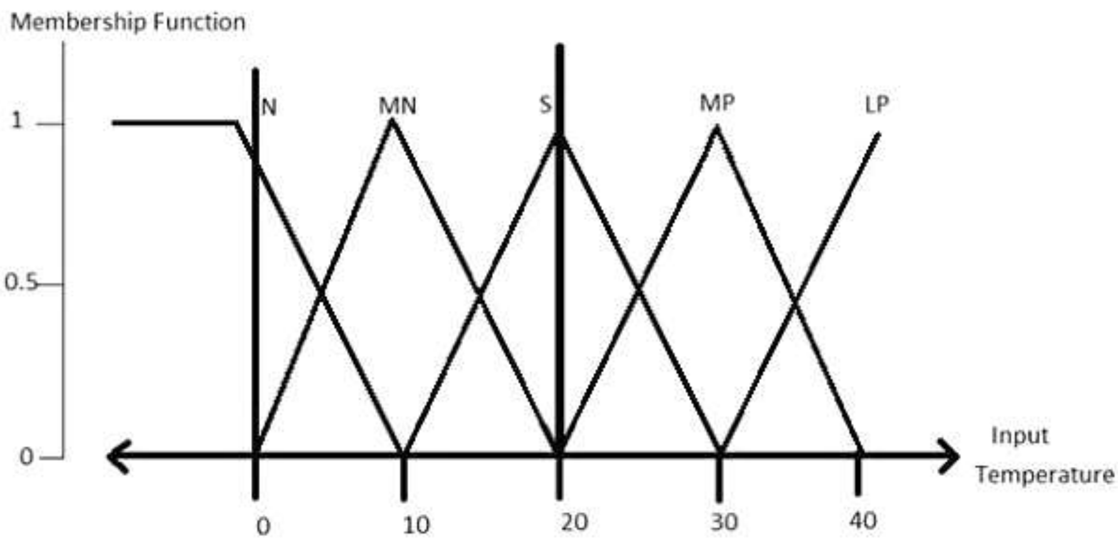

Fig.5: Membership rules.

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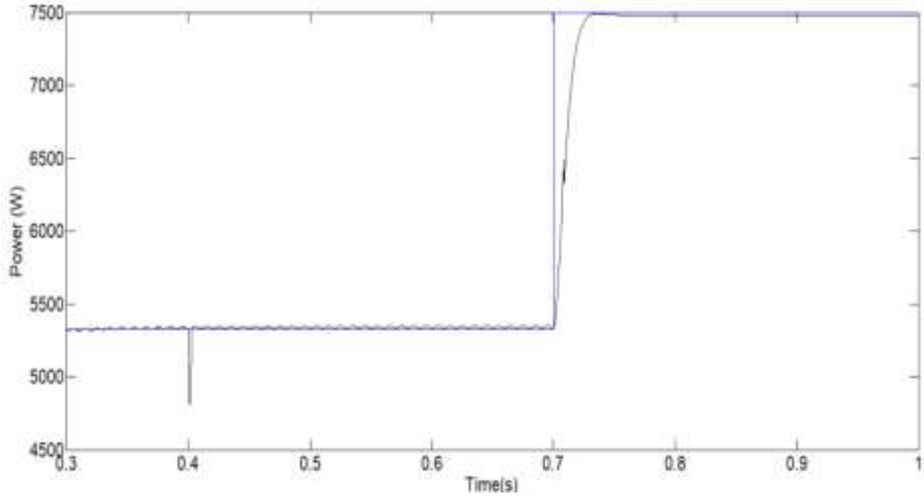
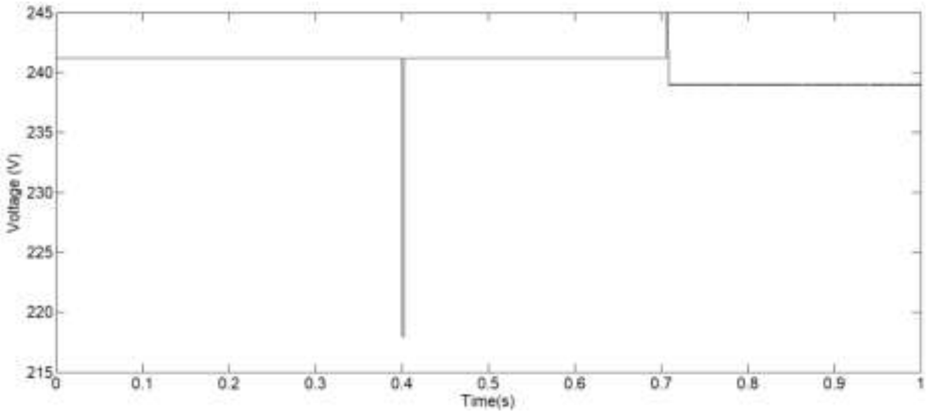
3. SIMULATION RESULTS

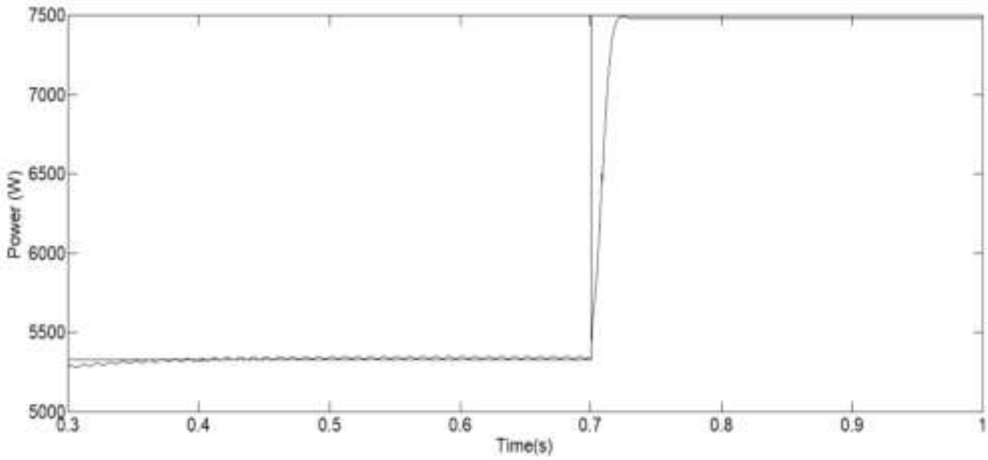
Case-1: Ev Charging:



(a) Existing waveform of Demand and consumed power of EV charging.



(b) Existing waveform of Terminal voltage of the EV charger.



(a) Proposed waveform of Demand and consumed power of EV charging.

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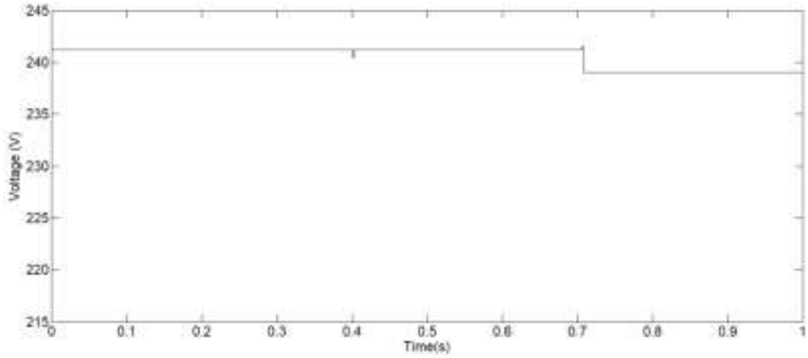
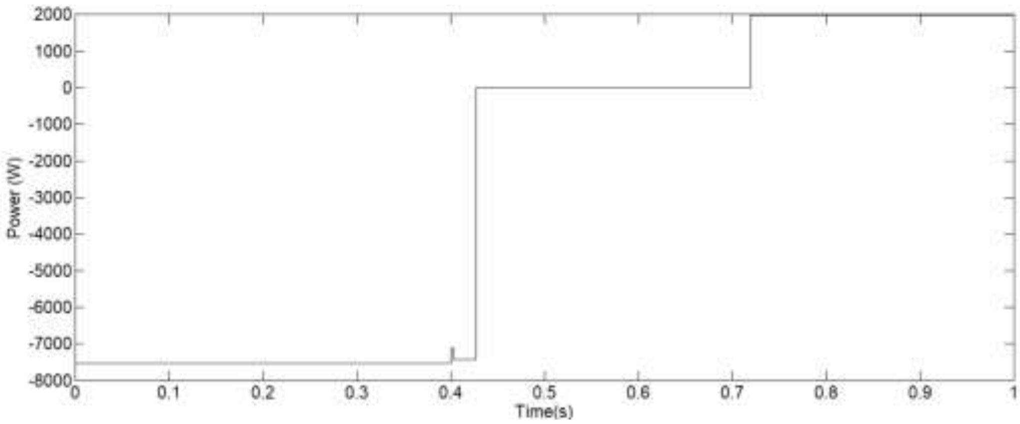


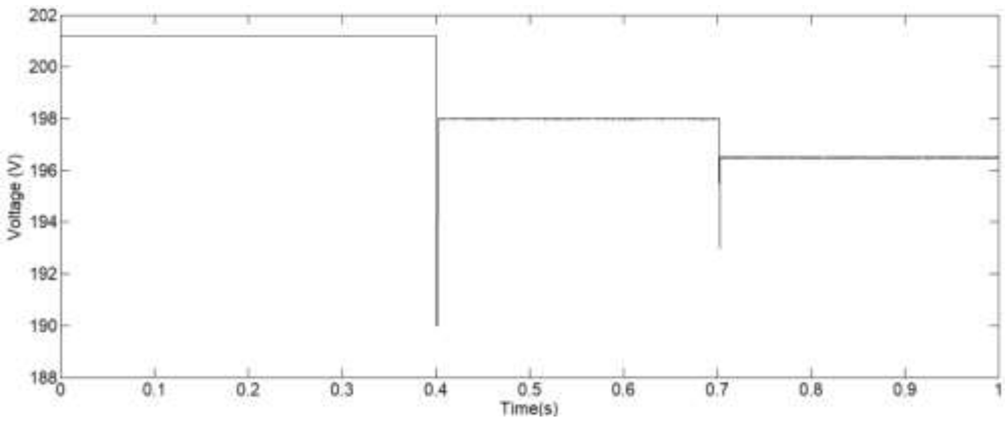
(b) Proposed waveform of Terminal voltage of the EV charger.
Fig: 6- EV charging waveforms.

MATLAB/Simulink is used to model the control strategy. When the simulation duration reaches 0.4ms, the irradiance should be reduced from 700k/W^2 to 600k/W^2, and when the simulation time reaches 0.7ms, the load should be adjusted. Figure 6 shows that about 700ms into the simulation, the demand for charging electric vehicles spikes from 5.7kW to 7.7kW.

Case: 2- Battery Energy Storage:



(a) Existing waveform of Output power from BES.



(b) Existing waveform of Terminal voltage of the BES.

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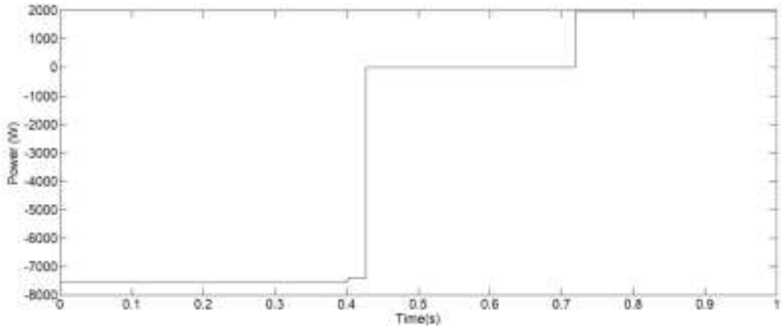
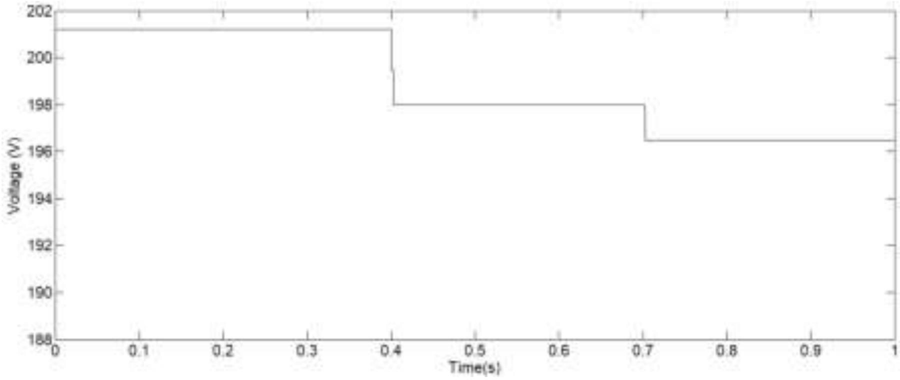


(a) Proposed waveform of Output power from BES.



(b) Proposed waveform of Terminal voltage of the BES.
Fig: 7- The simulation results of the BES.

Here, the simulation duration is between 0 and 0.4ms, during which the demand for EV charging is minimal and PV generation is enough. The excessive PV generation then charges the BES, and the PV-to-EV mode is initiated. When the simulation time is between 0.4ms and 0.7ms, the PV panels can generate 5.7kW, which is sufficient for charging an electric vehicle. Therefore, the system is run in PV-to-EV mode without the need for BES charging or discharging. Under the situation of 400k/W2 irradiance, the PV panels are unable to offer all of the needed 7.7kW charging power once the charging demand increases at 0.7ms. As seen in Fig. 7, the BES then begins to discharge, supplying 2kW of power for EV charging while also providing voltage support.

4. CONCLUSION

This result recommends a PV and BES-based multiport converter for EV charging stations. In order to prevent the voltage drop and provide a steady power supply for recharging electric vehicles, a BES controller is designed. With the suggested method, the BES will begin discharging when PV is inadequate for local EV charging and will begin charging when PV output is surplus or the power grid is in a valley of low demand, such as at night. Therefore, the grid's dependability and stability are improved when EV charging is combined with PV production and BES. Simulation models of the multiport converter based EV charging stations and the suggested SiC equivalent are produced in ANSYS TwinBuilder after exploring the various operating modes and their advantages. Simulation findings demonstrate that compared

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to Si based EV charging stations under the same operating circumstances, the efficiency can be enhanced by 5.67 percent in the PV-to-EV mode, 4.46 percent in the PV-to-BES mode, and 6.00 percent in the BES-to-EV mode.

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