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Designing a Solar/Wind Hybrid Power System for Charging Electric Vehicles

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Abstract –

The prospective spread of electric vehicles (EV) and plug-in hybrid electric vehicles leads to the need for fast charging rates. Higher charging rates lead to high power demands, which cannot be supported by the electrical grid. Thus, the use of on-site sources alongside the electrical grid for EV charging is a rising area of interest. In this dissertation, a photovoltaic (PV) source is used to support high power EV charging. However, the PV output power has an intermittent nature that is dependent on the weather conditions. Thus, battery storage is combined with the PV in a grid-tied system, providing a steady source for on-site EV charging in a renewable energy based fast charging station. Renewable energy based fast charging stations should be cost effective, efficient, and reliable to support the high charging rates demanded when a large number of EVs are connected to the electrical grid. However, fast charging stations, especially super-fast charging stations may stress power grid with potential overload at peaking time, sudden power gap and voltage sag.

This project discusses the detailed modeling of a multiport converter based EV charging station integrated with PV power generation and battery energy storage system. This study introduced the concept of charging electric vehicles using a local hybrid solar/wind power system. The PV and wind farms are linked to EV stations using power converters. Furthermore, in the time of peak demand, the proposed system can be connected to the grid to balance the load demand. In this project, the control scheme and combination of PV power generation, EV charging station and battery energy storage (BES) provides improved stabilization including power gap balancing, peak shaving and valley filling, and voltage sag compensation. As a result, the influence on power grid is reduced due to the matching between daily charging demand and adequate daytime PV generation. MATLAB/Simulink Simulation results are presented to confirm the benefits at different modes of this proposed multiport EV charging circuits with the PV-BES configuration.

Keywords – Electric Vehicle, PV system, BES, WECS, Multiport converter.

I. INTRODUCTION

Renewable energy resources like wind and solar energy are getting popularity for these reasons. Two or more renewable energy resources can be utilized in a hybrid renewable energy system (HRES) which can work as a standalone or grid connected system. A hybrid renewable energy system offers better quality in terms of reliability compared to single source based system. This is due to the fact that one power source can supply power to the load when other sources are either generating low or no power. The selection of renewable resources in HRES depends on the particular location. In this research work a wind-solar HRES is considered. Wind and solar combination is most promising source of generating energy primarily due to their complementary nature advantage. Wind power generation could be low in time when solar power generation is in its peak. On the other hand, the wind is often stronger in seasons when there is less solar irradiance. Wind and solar energy are unpredictable in nature, as they depend on climate condition. To improve the reliability of a wind-solar hybrid system other sources like battery storage, fuel cell, diesel generator can also be integrated.

With the growing interest in decreasing the fossil fuel utilization and pollution, electric vehicles (EVs) have emerged as an applicable alternative to conventional gas engine vehicles. The development and increasing utilization of EVs requires widely distributed charging stations due to the limited EV battery capacity. However, large scale of directly grid-connected charging stations, especially fast and superfast charging stations, stress power grid stability and reliability with peak demand overload, voltage sag, and power gap issues. Some researchers have been integrating photovoltaic (PV) generation with EV charging infrastructure; however, the PV integration is still considered as a minor portion of power source for EV charging stations in researches. As for the higher demand of fast-speed charging during daytime, the rapid development of PV generation optimizes power consumption at peak hours with its adequate daytime generations. With respect to the intermittency of solar energy, a battery energy storage (BES) can be employed to regulate the DC bus or load voltage, balance power gap, and smooth PV power. Furthermore, the energy from various input sources had to be transferred via power converters, including isolated and nonisolated types. Isolated converters are more sophisticated than non-isolated converters due to the use of transformers. As a result, transformers are not required in the circuits of the majority of applications, which instead require a multiport dc-dc converter. In addition, in order to extract maximum power from the solar part of the system, there is a need for a tracking technique.

Considering the high power density and high efficiency merits of the multiport power converters, a multiport DC/DC converter is employed in this project for the EV charging station instead of using three separate DC/DC converters. Among the aforementioned research, the charging station architectures can be classified into two topologies: using AC bus or DC bus. As PV output and BES can both be regarded as

DC current source, DC bus charging station is chosen here to improve the utilization efficiency of solar energy and decrease the cost and losses of converters. Compared with isolated multiport converters, nonisolated multiport converters that are usually derived from buck or boost converters may feature a more compact design, higher power density, and higher efficiency compared with isolated multiport converters. Accordingly, a DC bus nonisolated structure with SiC switches is leveraged in this project, to improve efficiency and minimize the power losses.

II. EV CHARGING SYSTEM

The function of charging devices in the widespread adoption of EVs is crucial. Features of charging devices are directly related to battery performance & overall charging system. Low size and weight, maximum dependability & efficiency, maximum power efficiency, & least cost are all desirable qualities in a battery charger. There are a variety of charging methods, parts, and management links that must all work together for a battery charger to function. EV chargers necessitate utility current with low losses and a greater power factor to mitigate the effects of poor power quality & boost effective output.

Simply said, there are three types of chargers: those installed on the vehicle, those located off the vehicle, and those that use wireless technology. One-phase or three-phase electricity may power any charging system, and each charging system can be either unidirectional or bidirectional. Off-board charging solutions often require three-phase electricity due to their greater power ratings.

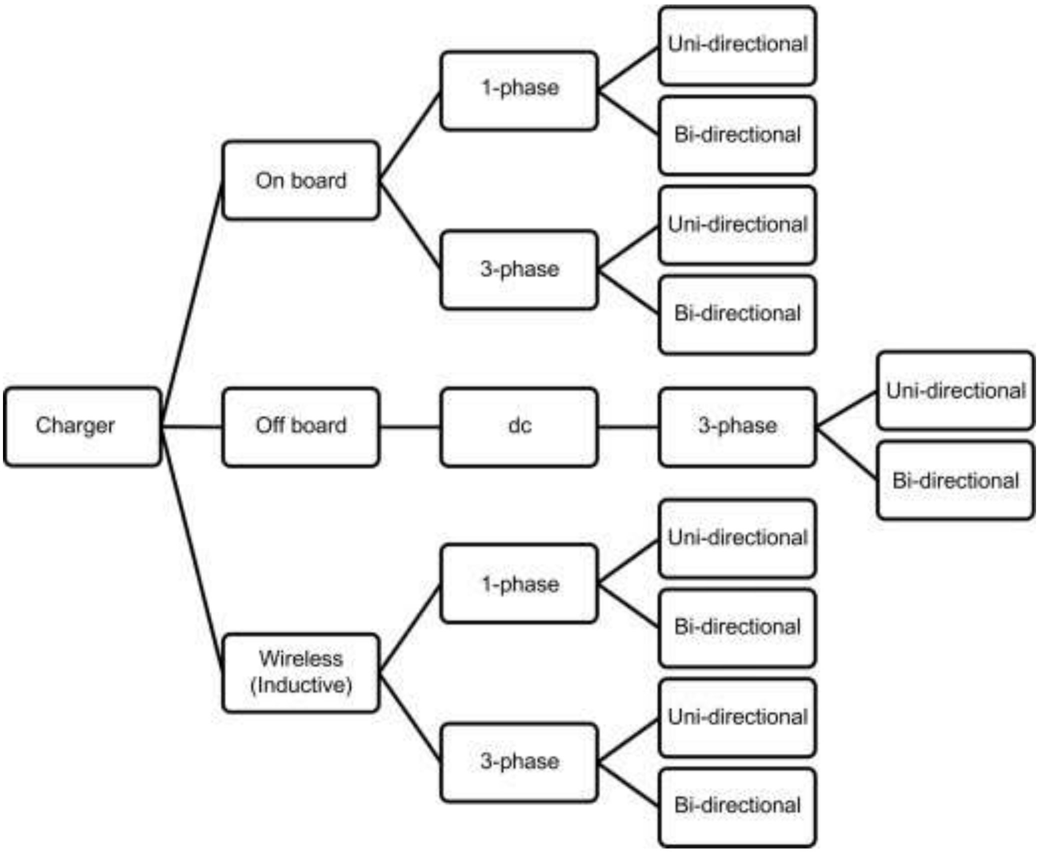

Fig.1: Types of chargers.

An efficient power conservation system that reduces the overall number of plug-in hybrid electric vehicles (PHEVs) charging in the quickest infrastructure possible by making use of an additional super capacitor and flywheel. In addition, employed two batteries ranging in capacity from 10 kwh to 15 kwh to demonstrate that the new framework of the computational methods requires only around 15 minutes to charge from a minimal state of charge of 20 percent to an optimal level of 95 kwh.

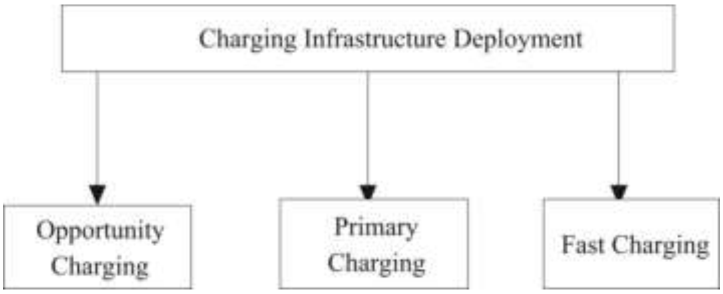

Fig.2: Charging system structure.

There are a number of different battery charging configuration options available, including a standalone PV-EV battery charging system and a universal battery charging system.

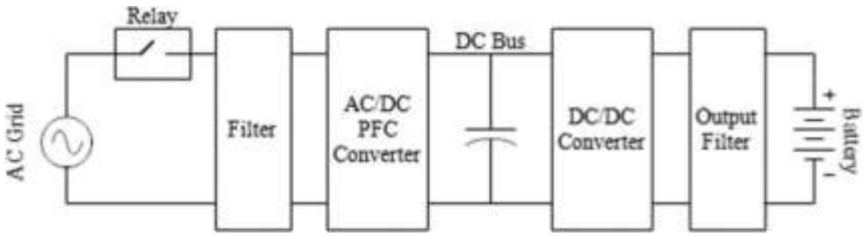

Fig.3: Conventional charging system

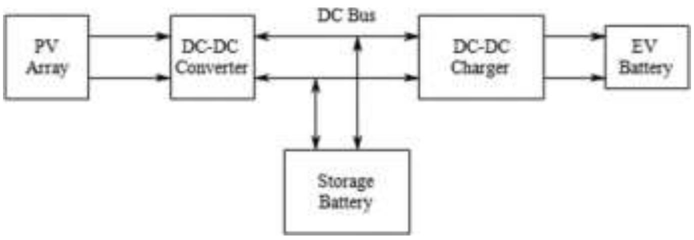

Fig.4: PV-EV charging system.

Using the electricity from the grid system is the standard method of charging batteries, as seen in Fig. 3. Instead to using grid power, RES can be used to charge the EV's battery. One of the off-board chargers used to charge the battery without tapping into the grid is the PV stand-alone system seen in Fig. 4. The sun's rays aren't always strong enough to power the system, thus a backup battery bank is required. When there is a lack of sunlight, the EV's battery may be charged using the surplus electricity stored in the backup battery. If you exclude the secondary battery, this setup can function as an on-board charger.

III. PROPOSED SYSTEM

In order to explain and build the hybrid system presented in this paper, solar PV panels and wind turbines combine to create a highly reliable hybrid energy system that can harvest renewable energy under various weather situations. When the sun is shining and the wind isn't too strong, solar panels will generate energy; nevertheless, when severe weather strikes and the sky is cloudy, wind turbines become crucial. To maximize the utilization of renewable energy resources, the suggested solar/wind hybrid power systems combine both sources of electricity with a bank of batteries to store the energy. In the case of extra energy, by using an inverter, the extra energy from the solar part can feed the power grid. In addition, to design a power plant, a machine learning model is required to predict future energy.

1) Solar PV subsystem

Solar PV systems use the photovoltaic effect to turn sun radiation into power. Semiconductor materials with P-N junctions employ this method to generate energy when exposed to light. Fig 5 shows a solar cell's equivalent circuit.

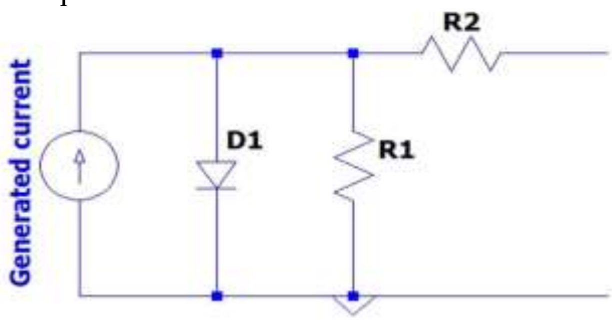

Fig. 5. solar cell's equivalent circuit

Characteristics of Solar Cells I-V Curves are essentially a visual summary of a module's operation that shows how current, and voltage relate to each other under the different irradiance and temperature circumstances. Fig. 6 depicts the I-V, P-V curves of the proposed solar module.

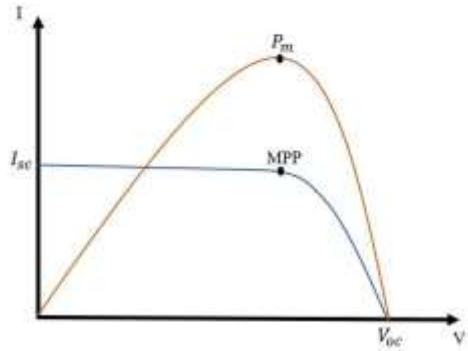

Fig. 6. Solar module I-V and P-V characteristic

The proposed charging station block diagram is seen in Fig. 7.

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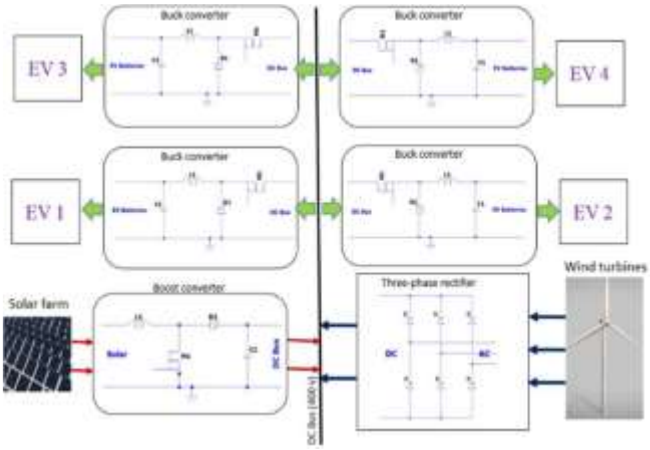

Fig. 7. Charging station block diagram (proposed system)

During the day, solar and wind energy are used to recharge the battery. By stepping up the voltage to 400V using a boost converter, the solar panel's output is managed. Since wind is present at night, it partially charges the DC bus. Then the EVs are charged by battery via utilizing a buck converter. Solar energy is widely available and cost-free, but power stability is challenging. However, it may be effectively made up for by fusing with another energy source. As a result, in this study, solar and wind energy are combined. When there is wind, the battery is charged. When it is hot, a PV module may be used to charge the battery. This research proposes a hybrid system that is unusual in that it generates power from two separate renewable sources. When the hybrid solar/wind system is unable to absorb enough energy, the extra energy stored in the battery is utilized to charge EVs.

In the conventional architecture of DC bus charging station with PV integration, all the three power sources, including PV and EV charger unidirectional sources, and AC grid bi-directional source, are all connected through three separate converters. The proposed DC bus charging station (Fig. 8), consists of one more bi-directional power source BES sharing the same DC bus. The BES is utilized to maintain the DC link voltage and balance power surplus/insufficiency from the PV. With this configuration, the function and operating modes can be discussed as follows in detail.

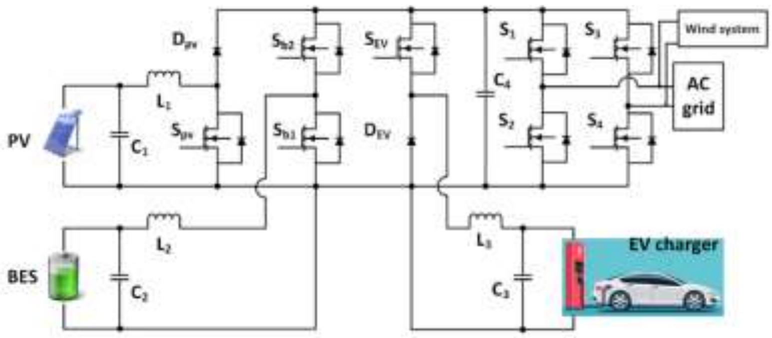

Fig:8 multiport converter architecture (extension system)

IV. SIMULATION RESULTS
A. PROPOSED SYSTEM:-

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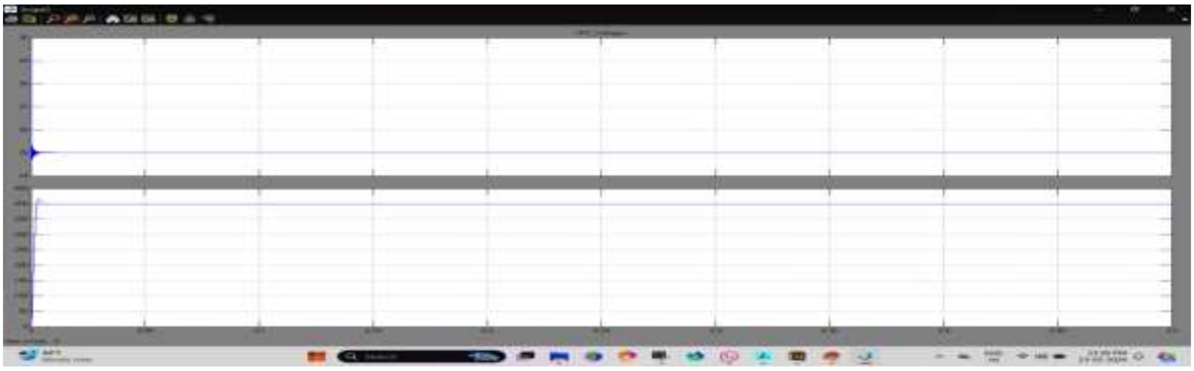


(a)

(b)

Fig:9 simulation waveforms of output voltage of utilized buck & boost converter.

Based on Fig. 9, the employed boost converter step up the voltage from 25V to 400V in the proposed DC fast charging station. No need to state that in order to charge the EV batteries a buck converter is required to step down the voltage for the batteries. Fig. 9 shows the output voltage of the buck converter which should be equal to the needed voltage of the EV batteries. According to the figure above, by using a buck converter, the voltage of the DC bus will be changed to the desirable voltage for the EV bank of batteries.

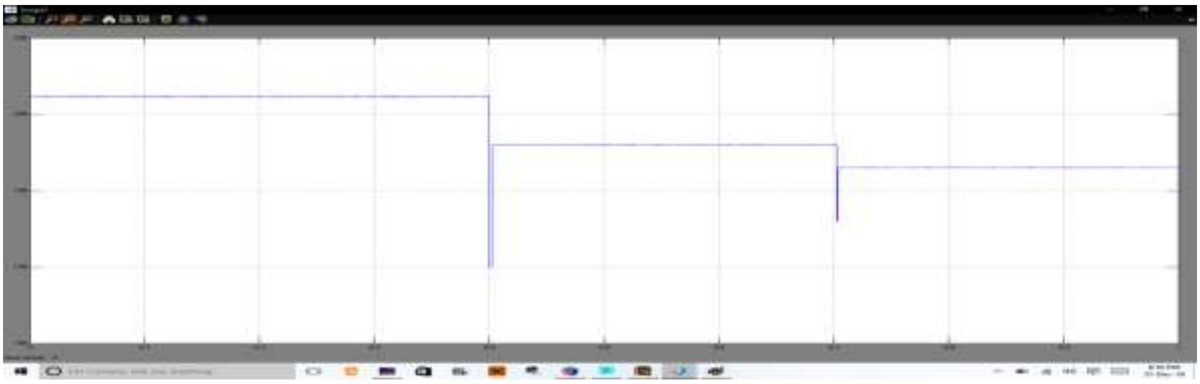
(a)

(b)

Fig:10 The simulation results of EV charging, (a) the demand and consumed power of EV charging, (b) the terminal voltage of the EV charger.

The control scheme is simulated with MATLAB/Simulink. At 0.4ms of the simulation time, the irradiance drops from 700k/W^2 to 600k/W^2, and at 0.7ms of the simulation time, the load should be varied. At 700ms of the simulation time, EV charging demand suddenly goes up from 5.7kW to 7.7kW; it can be seen in Fig. 10.

(a) Output power from BES.



(b) Terminal voltage of the BES.

Fig:11- The simulation results of the BES.

In this case, between the simulation time of 0 to 0.4ms, the EV charging demand is low while the PV generation is sufficient. Therefore, both PV-to-EV and PV-to-BES modes are triggered, and the surplus PV generation charges the BES. Between the simulation time of 0.4ms to 0.7ms, the PV panels can provide 5.7kW which meets the EV charging amount. As a result, the system is operated in PV-to-EV mode and no BES charging/discharging is required. After the charging demand increase at 0.7ms, the PV panels are not able to supply all the required 7.7kW charging power under the condition of $400k/W^2$ irradiance. Therefore, the BES starts to discharge and supply EV charging with 2kW and provides voltage support, as shown in Fig. 11.

V. CONCLUSION

The rise in EV utilization creates a demand for energy that the infrastructure of the present power system cannot provide. In this work, a hybrid renewable energy charging station that requires no external electrical source and has no maintenance costs is presented. The storage batteries are charged by the use of renewable energy sources, and from them, the cars are charged. In these charging stations, the cost of power is lower, and simple to use power is obtained. In this project, a multiport converter based EV charging station with PV and BES is proposed. A BES controller is developed to regulate the voltage sag, and balance the power gap between PV generation and EV charging demand. With the proposed control design, BES starts to discharge when PV is insufficient for local EV charging, and starts to charge when PV generation is surplus or power grid is at valley demand, such as during nighttime. As a result, the combination of EV charging, PV generation, and BES enhances the stability and reliability of the power grid.

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