ISSN (Online): 2583-7052

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 02(11), November 2023, pp. 50-63

Article Title: Hybrid Energy Sources for Innovative Grid-Tied EV Charging Applications

Hybrid Energy Sources for Innovative Grid-Tied EV Charging Applications

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ABSTRACT

Global power consumption is rising, making it vital to look for other sources of energy to solve the impending power crisis. Using grid-synchronized electric vehicles (EVs) is likely to be one way to do this. The whole power system is impacted when several EVs are paired with the grid, leading to imbalances in supply and demand as well as voltage and frequency. We have integrated solar and wind energy in this integration to reduce these concerns. One of the developments in smart grid technology that permits energy exchange between the EV and the grid is vehicle to grid (V2G) technology. The hybrid energy source proposed by this project is used to charge EVs. Here, power from the PV panel, wind turbine, and AC generator is used to charge the EV battery. Any excess energy is then used to fuel the linear and non-linear demands of the subsequent home. A proportional-integral (PI) controller, which is recognized for its dependability and independence from the real system model, is used to maximize the DC voltage extracted from the photovoltaic (PV) panel. The DC voltage is improved overall by the Boost converter's improved DC output. Concurrently, the system incorporates an AC generator to supply extra power to the grid. A three-phase Voltage Source Inverter (VSI) converts an improved output of the Boost conversion process used to convert the electricity from the PV panel into AC power. In order to assure safe current injection into the grid, harmonic components detected in the VSI output are rectified using an LC filter to ensure grid compatibility. In this research, the voltage for the EV battery is adjusted using a bidirectional converter. Electricity from EVs that are not in use may be sent back into the grid for additional purposes. Simulink and MATLAB 2021a are used to simulate and evaluate the proposed method.

Keywords: PV system, DFIG based WECS, boost converter, PI controller, EV battery charging

1 Introduction

Electric vehicles (EVs) are recognized to have a significant impact on energy conservation and emission reduction in the transportation system. EV charging stations allow EVs to communicate with the power grid [1]. Because of the increasing need for energy and the

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depletion of fossil fuels, the electric vehicle (EV) and renewable energy generation have advanced significantly. In addition, when EVs are grouped together at a charging station, they use a tremendous quantity of power, which might have an adverse effect on the grid's ability to function [2]. Given the current rate of depletion of fossil fuels, which are heavily dependent upon to fulfil load demand, the need for alternate energy sources becomes critical. The phenomenon of global warming is also caused by the use of fossil fuels [3]. This is where the incredible rise in distributed generation using photovoltaic (PV) systems and their decreasing cost over time can directly affect. When EVs are used for commuting to work, they are typically left parked at the location for extended periods of time during the day, especially when the sun is shining. Therefore, energy produced by solar carports and PV arrays installed at work may be utilized to charge electric vehicles [4].

To achieve valley filling charging while meeting EVs' energy needs, for example, the power grid can work with them to adjust charging costs throughout the EV charging process. Additionally, EVs can give auxiliary services to the power system, such as reserve supplies [5]. Electric vehicles (EVs) may now serve as distributed energy storage systems that are linked to the grid because to advancements in battery charging technology giving them more flexibility in managing energy or efficiently and economically supplying grid services. The vehicle-to-grid (V2G) idea that utilizes EV batteries as a means of storing energy, provides grid services [6]. When choosing the location of V2G stations with charging/discharging periods based on system loss reduction, grid power flow optimization, and low tariff hours, various researchers have put forward decentralized and centralized smart charging techniques. This is intended to minimize EVs' detrimental implications on distribution networks [7].

To reduce the variations in the dc bus voltage, a hybrid PV-wind power system linked to the grid is recommended. The hybrid use of PV and WT is one of the most promising technologies among renewable energy sources for load demand management because of their complementary energy generation characteristics. In particular, such intermittent power problems may be resolved and power system dependability increased by hybrid renewable energy systems [8]. To combine wind/photovoltaic systems and improve efficiency, lower costs, and boost reliability both under normal operating circumstances and in the event of faults—a great deal of research is still needed. The battery life is shortened by both BESS discharge and battery charging. Furthermore, when weather conditions cause Wind and PV to deliver DC lines with less power, BESS cannot meet the load requirement alone. This method shortens the BESS's lifespan by continuously charging and draining the battery [9]. When compared to fixed speed wind turbines, the DFIG-based WECS also has more power collection, improved power quality, and less mechanical stress on the powertrain [10]. The following list illustrates the framework of the paper: The introduction is described in Section I. Section II provides an analysis of the most recent works. Part III provides an explanation of the proposed

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model and description. Section IV provides the results of the analysis. The conclusion is given in Section V.

2 Recent works

M. N. Gitau *et al* [2021] [11] have proposed to provide a uniform method for synthesizing all two-state DC-DC converters and producing converters that satisfy certain standards. It demonstrates that BBBs are connected in stacked plus cascade, cascade, parallel/interleaved, stacked, or differentially to implement all non-isolated DC-DC converters. In contrast, stacking or stacking in conjunction with cascading generates a minimum of two parallel current channels between the source and the load. The method for achieving the present benefits is less analytically demanding and more straightforward than existing methods. Nevertheless, not all of the extra DC-DC converters come directly from the 14 converter cells.

K. -F. Chu *et al* [2022] [12] proposed a combined V2G coordination and rebalancing solution to maximize AV use. It uses an intelligently controlled fleet of autonomous vehicles (AVs) to fulfil travel requests, figuring out the best routes and times for each one. Once the services are completed without any more appointments, the system uses our planned approach to suggest parking spots for the fleet of AVs. The recommended sites are ideal because they may have significant travel demand in the area, cutting down on potential passengers' needless waiting times, or because these are EV charging stations in case V2G support were required, because of the deterministic approach, incorrect projections might reduce the effectiveness of the system.

T. Shanthi *et al* [2021] [13] have presented a uniquely designed DC-DC converter architecture, namely an n-stage, single switching impedance network (SSIN)-based converter. In the recommended converter, the cross-connected capacitors serve as a voltage doubler as well as aid in achieving the extra voltage increase. The output voltage in the lower duty ratio zone is enhanced by the SSIN's use of the switched capacitor network. However, by placing a tiny capacitor across the input source, the pulsing character of the source current gets rendered continuous with reduced ripple.

M. S. H. Nizami *et al* [2021] [14] have proposed an integrated management system with power grid support features for EVs in low-voltage residential networks towards handle local voltage limitation violations and grid overloading. A local EV aggregator controls the system's EV battery charging and discharging operations. In order to benefit financially during peak tariff periods, EV management techniques, which sell energy to the grid via the vehicle-to-grid (V2G) capabilities or provide a portion of building loads through the vehicle-to-building (V2B) features are being used more and more. However, By midnight, the EVs might have to be discharged to the lowest SoC if extreme grid overloading or under voltages happen often and every day.

H. M. Khalid *et al* [2020] [15] have demonstrated the spread of an internal battery and a car battery for usage in V2G technologies. The hypothesis model and residual vector support a

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prediction structure, improving the study of these fluctuations at the local level. By obtaining a conditional probability-based density function for the measurements, this is achieved. In the event of outliers and a limited sample size, this will ensure the greatest feasible calculation of the underlying system and a improved assessment of central tendency. However, Li-ion battery packs are made up of hundreds of cells and have an intricate structure.

3 Proposed Methodology

The unique grid-tied electric vehicle (EV) charging system uses hybrid energy sources to associate the vehicle towards grid. A PI controller is utilized to extract an ideal DC voltage from the PV panel, which is then pumped into a Boost converter to aid with DC voltage optimization. The required DC power is provided by a (PWM) rectifier in a wind energy conversion system based on a doubly fed induction generator (DFIG). Following proper synchronization, a 3-phase VSI converts the power output from the Boost converter and the improved output from the PWM rectifier into AC, which is then sent into the grid. The power output is kept in a DC link.

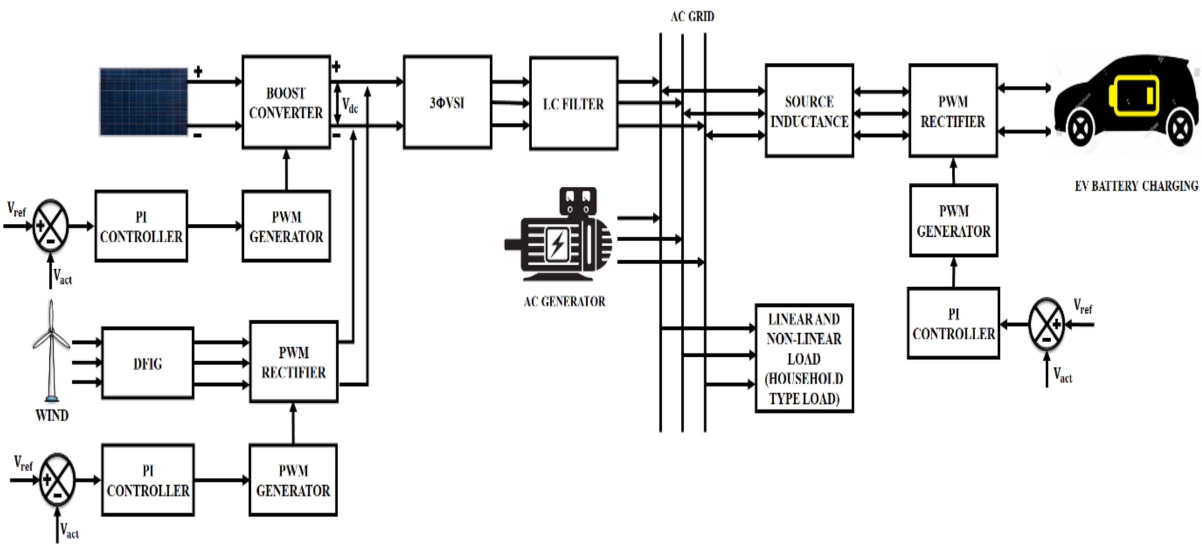

Figure 1: *Proposed Block Diagram*

An LC filter is used to rectify the harmonic present in the VSI, allowing the current to be safely fed into the grid. An electric vehicle's stored energy is effectively recycled back into the grid when it is not in use. The batteries of electric vehicles (EVs) are charged using electricity produced by photovoltaic cells, wind turbines, and AC generators. Implementing the extra energy into the system allows it to be used for more purposes demonstrating two-way power transfer: Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G). MATLAB 2021a/Simulink software is used to simulate and evaluate the suggested approach.

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3.1 PV system

The tracking controller, power converters such as DC-DC converters and inverters, and many parallel and series arrangements of PV modules make up the PV system utilized for power conversion. Therefore, a DC-DC converter may be used to increase the DC voltage produced, and an inverter can be used to change the DC voltage to AC. The PV panel ought to be chosen based on the load rating. The PV cell's electrical equivalent diode model is provided below:

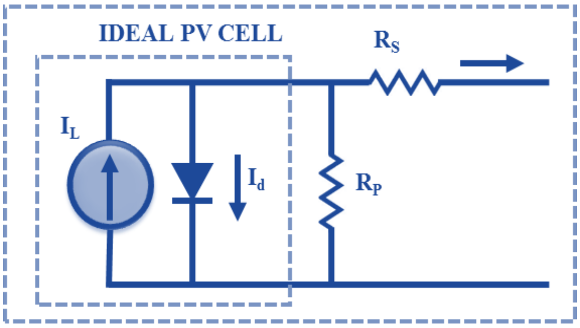

Figure 2: *Equivalent circuit of PV cell*

The PV model is made up of diodes and current sources. Resistance in series R_s and shunt resistance R_{sh}. The cell surface leaking via the edges is represented by the shunt resistance R_{sh}.

3.2 Wind Energy Conversion Systems

Converting wind energy into mechanical power is the aim of wind energy conversion systems (WECS). Wind turbine generators convert this mechanical energy into electrical energy, and it is utilized by windmills to power machines, pump water, and grind grain. Given that wind is an intermittent energy source, varying wind velocities will result in various generator output voltage and frequency variations. The rectifier is used to first convert the generator's variable output ac power into dc. When accessible DC power is supplied into the grid at the necessary constant voltage and frequency, the inverter's modulation index is changed.

3.3 Boost Converter

A boost converter is a DC–DC converter that raises the voltage between its source (input) and load (output). When the available input voltage is less than the target voltage level, it is commonly employed in many different applications. A crucial part of many power supply and energy management systems, the boost converter works on the idea of energy storage and release. Several appropriate control techniques may be used for the creation of a constant voltage. An energy discharge phase and an energy storage phase are used in the converters to transfer energy. When the switch is in mode 1, the inductor, L, begins to store energy from the supply voltage V_{pv} as a magnetic field. This results in an increase in the inductor current.

$$V_{pv} = \mathrm{VL} \tag{1}$$

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Since the diode, D, is reverse biased, no current passes through it and into the output side, isolating the output circuit from the source side.

$$V_O = 0 \tag{2}$$

Current flows across the inductance, switch, and source when the switch is closed, acting in the short circuited mode. Boost converters are basic converters that get their name from their function achieve. The boost converter is made up of the following components: load resistor R, filter capacitor C, diode D, and power switch S. The two modes of operation for the Boost converter are dependent upon the continuity of the input current: Continuous Current Mode (CCM) and Discontinuous Current Mode (DCM). A boost converter operating in continuous conduction mode has two phases, during which Switch S and Diode D alternately operate in the ON and OFF states. In CCM mode, the inductor current is always continuous even when the diode current is either continuous or discontinuous.

In mode 2, the inductor reverses polarity and functions as a source when the switch is in the off position. Lenz law states that an inductor prevents abrupt changes in current, but it does permit a steady flow of current via a diode. Since the diode is forward biased, current passes through it, the load, and the capacitor. The source and any existing inductance are charging the capacitor.

$$V_O = V_c = V_{pv} + V_L \tag{3}$$

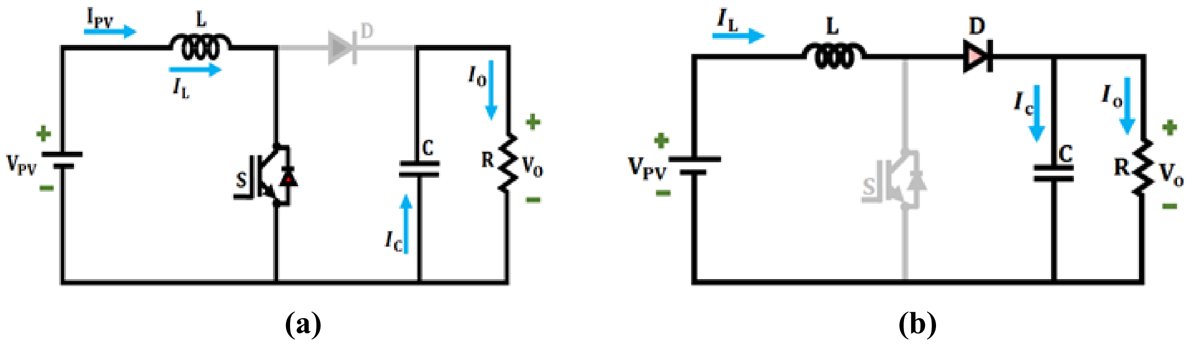

Figure 3: *(a) Mode 1 (b) Mode 2*

Boost converters operate in the modes shown in Figures 3(a) and (b). The total of the stored energy from the source side and the inductor will equal the voltage across the capacitor. There is a difference between the input and output voltages. As a result, the output DC voltage is increased.

$$V_O >> V_{in} \tag{4}$$

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3.4 PWM Generator

The switch in the Sepic converter generates and applies the pulse width modulated signal. The PWM generator effectively divides the average power reduction into discrete parts. An average current and voltage are transferred towards the load side through keeping the switch on aimed at a extensive amount of time than it is off. This extended ON time will result in a greater power delivery. The generation of pulse width modulated gate pulse signals is the primary purpose of the PWM generator and transfer them to the switch of the converter.

3.5 PWM Rectifier

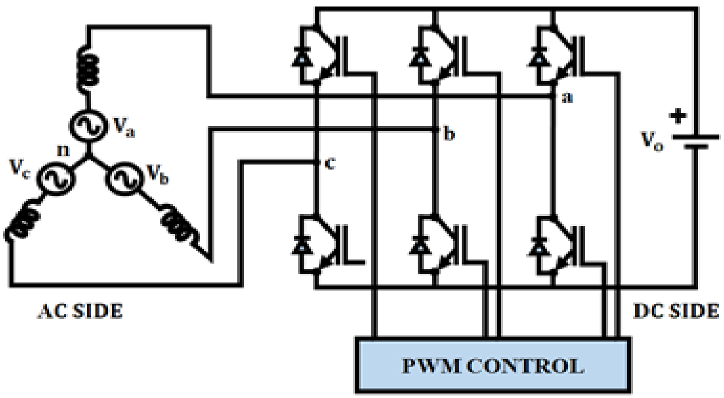

Figure 4: *Three Phase PWM Rectifier*

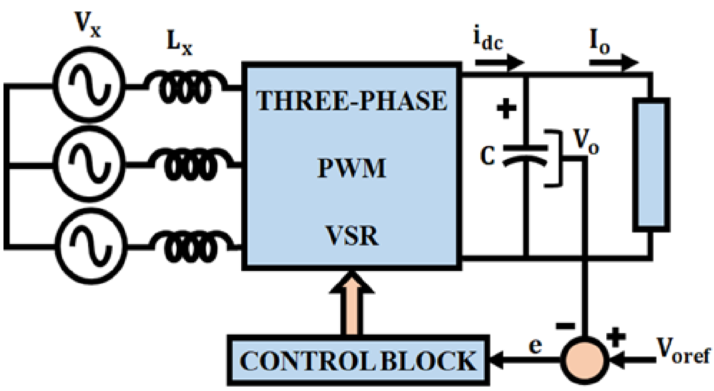

Figure 5: *Operation of PWM Rectifier*

PWM Rectifier is a regenerative converter, it emphasizes force commutation methods theory. The converter's output, in this instance DC voltage, should be constant as DC bus voltage is used in a variety of applications. A control loop and DC capacitor are used to provide the constant DC bus voltage. A fundamental method of effective for a rectifier is towards using the output voltage as feedback to maintain a constant DC voltage across the capacitor. The converter must function in unity power factor mode, a reference voltage applied must be

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capable of preventing diode conduction to the control loop; otherwise the converter will change into a bridge rectifier with three phases. The PWM Rectifier is shown in Figure 4. Figure 5 illustrates the functioning of the PWM rectifier, and the steps involved in its operation are described below.
To determine if the condition has been satisfied, the DC link voltage is compared to the preset reference value. To create the switching pattern of the converter, many control strategies are applied. By using these methods, pulses will be produced based on the error signal that the comparator generates. In order for the current to return to the source side with the DC link voltage's assistance. The comparator operates by comparing the voltage reference and the voltage real value; the capacitor connected to the DC connection is drained, enabling the converter to function as a rectifier, if the comparator's error value is positive. In this instance, the DC current Io will be positive. In this case, the control block will deliver six pulses to each power semiconductor device. Additionally, by delivering the appropriate phase shift, it will enable power to go from the erratic AC to the DC sides, restoring the voltage in the capacitor. When the output current becomes negative, the capacitor will be overloaded and compared to a reference voltage. The AC will then be regulated by the control system by controlling the capacitor's discharge.

3.6 PI Controller

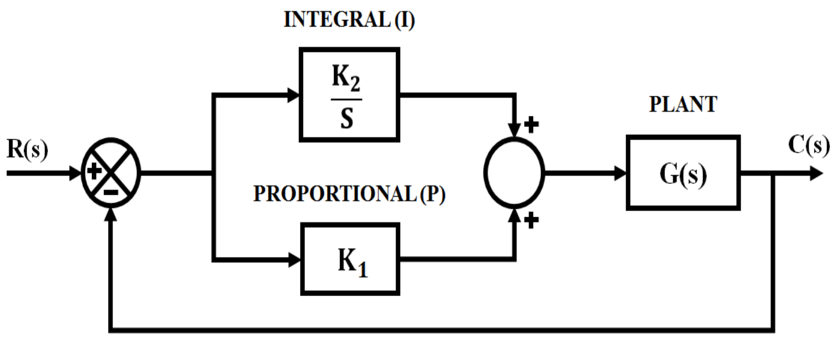

Figure 6: *Basic block of PI Controller*

A feedback controller is the proportional integral controller, or PI controller. The plant is controlled by the integral of that value and the weighted sum of mistakes, which has to be under control. PI-Controllers are currently used to control almost all processes, from slow to fast systems, and from motion control to aerospace. Despite this achievement, study on the issue of PI-controller tuning has continued. Additionally, PI-Controllers should be often returned as a result of variations in system dynamics and operating point swings. This has led to much investigate into the capabilities and promise of the so-called adaptive PI controllers. The PI controller adds one to the system's type and order. Additionally, it causes the steady state error to get to zero, something that generally does not happen with proportional alone control. The

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PI controller lowers the maximum overshoot and enhances damping. Additionally, it shortens the rising time and reduces bandwidth.
In the instance of noisy data, the system may be more stable in the steady state if derivative activity is included. This is because the high frequency components in the inputs cause the derivative action to be more sensitive. In the lack of derivative action, the PI controlled system responds less well to actual (non-noise) signals.

4 Results and Discussion

The proposed work is implemented in MATLAB simulation and the following result is obtained.

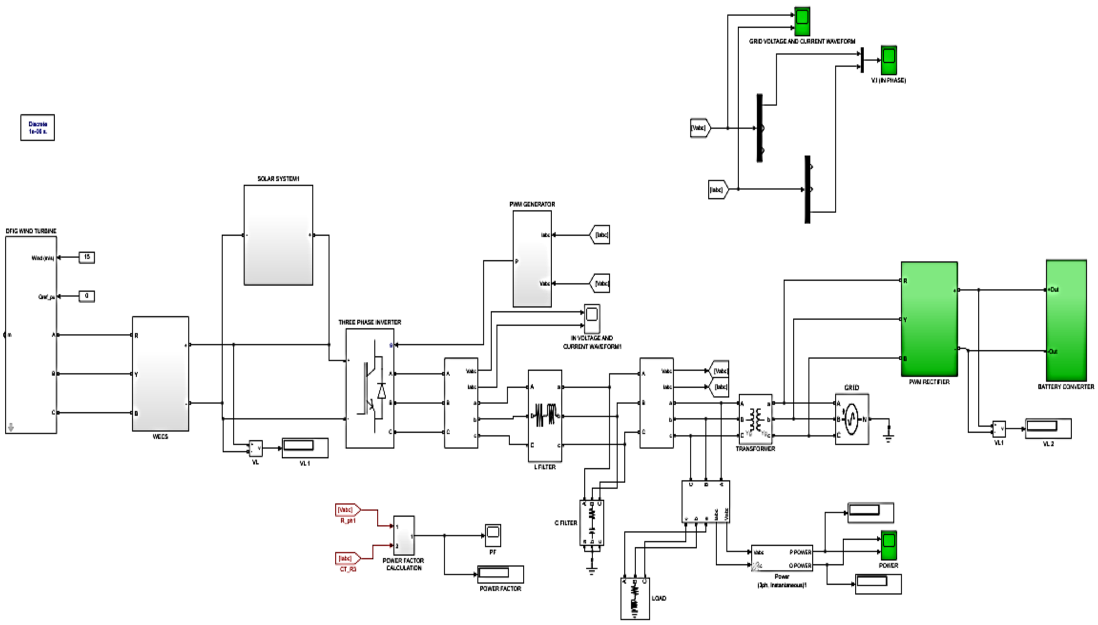

Figure 7: *Simulation Diagram*

The boost converter's voltage, current, temperature, and irradiation waveforms are displayed in Figure 8. This particular capacity is achieved by storing energy in an inductor and transferring it to the load at a greater voltage. The voltage waveform of the solar panel indicates that it maintains a constant value of 175V after 0.2 seconds, whereas the current waveform displays an abrupt surge to 20A and subsequent decline at 0.01s.

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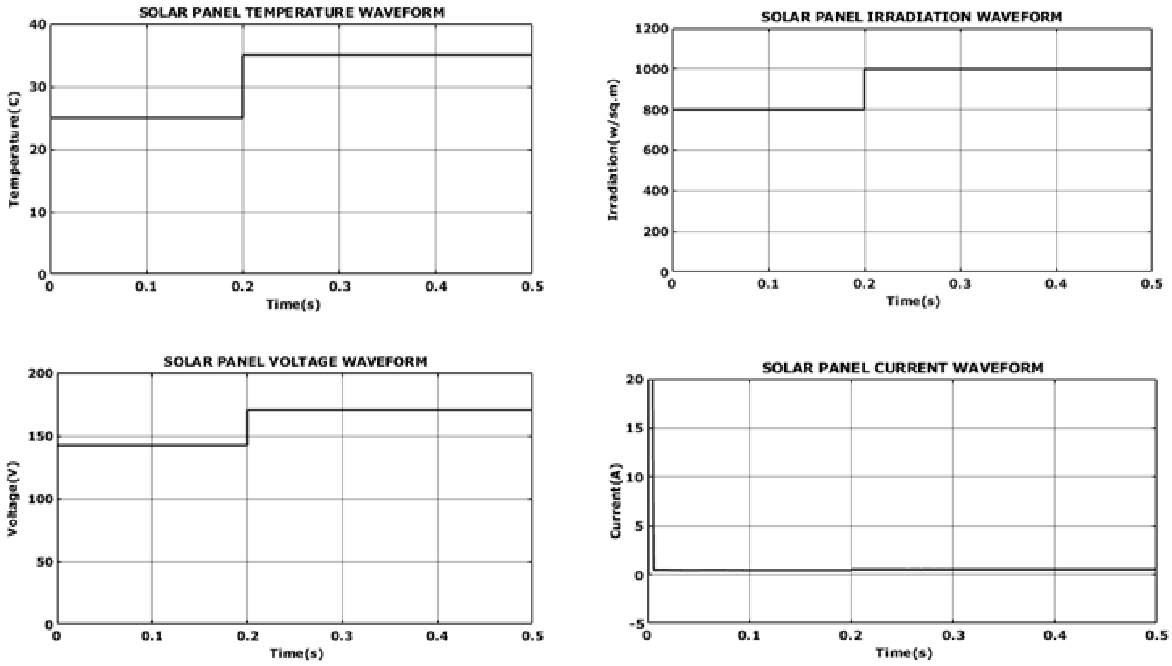

Figure 8: *Solar panel waveforms*

From the waveform of the converter's voltage and current seen in Figure 9. Ultimately, 600 volts is the converter output value that is obtained. It's clear that the current reaches its maximum or peak at the same time as the voltage does.

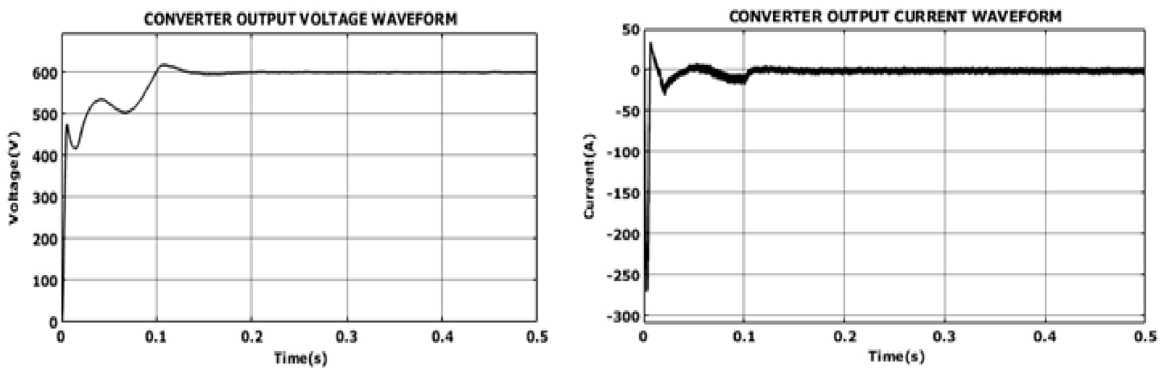

Figure 9: *Converter Output Waveforms*

Figure 10 shows the grid's output voltage and current waveform, which has a constant voltage and frequency and is sinusoidal in nature.

Figure 11 illustrates the voltage and current waveforms of the AC generator. According to Faraday's law of electromagnetic induction, a current-carrying conductor cuts a uniform magnetic field to create electromotive force, also known as voltage that provides the fundamental concept for AC generators.

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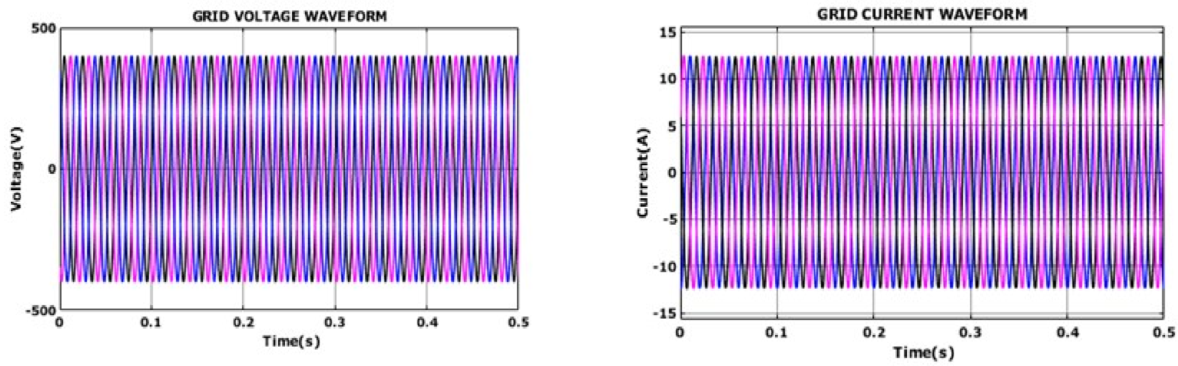

Figure 10: *Grid Output Waveforms*

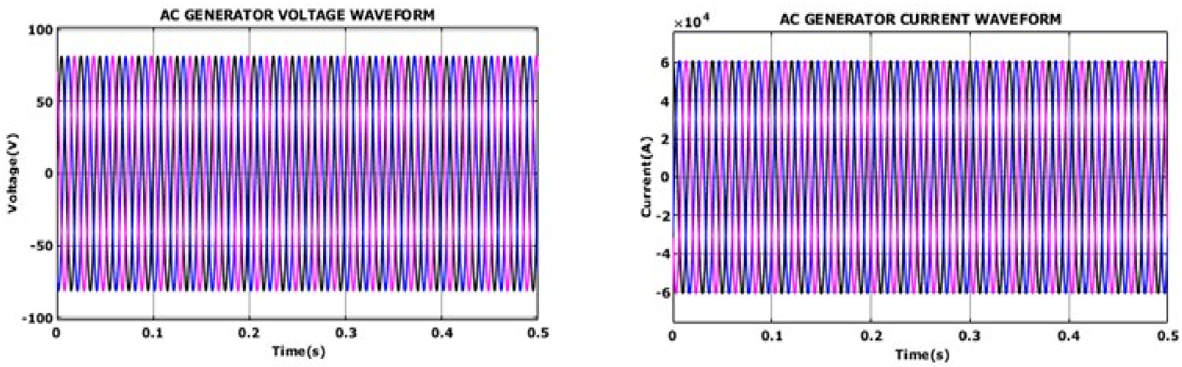

Figure 11: *AC generator waveforms*

The proposed WECS system's DFIG and PWM rectifier-based output voltage is shown in Figure 12; the voltage value is 600(V). The PWM rectifier's output voltage was kept at around 600 volts.

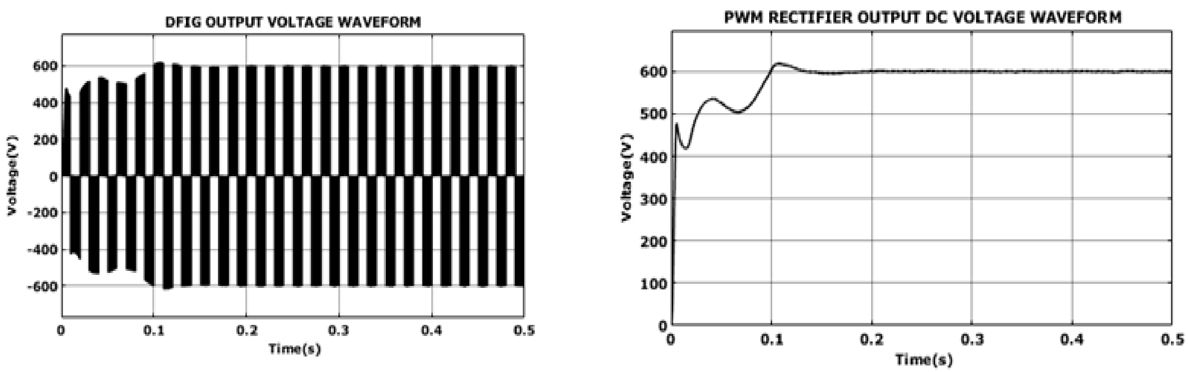

Figure 12: *DFIG and PWM rectifier output voltage waveform*

The voltage, current, and state of charge of the battery are depicted in figure 13. The battery SoC waveform, which yields an approximate SoC of 80%. The waveforms that show the

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battery's voltage and current levels. The voltage and current of the battery are 12V and 1.8A, respectively. An electric vehicle's stored energy is effectively recycled back into the grid when it is not in use.

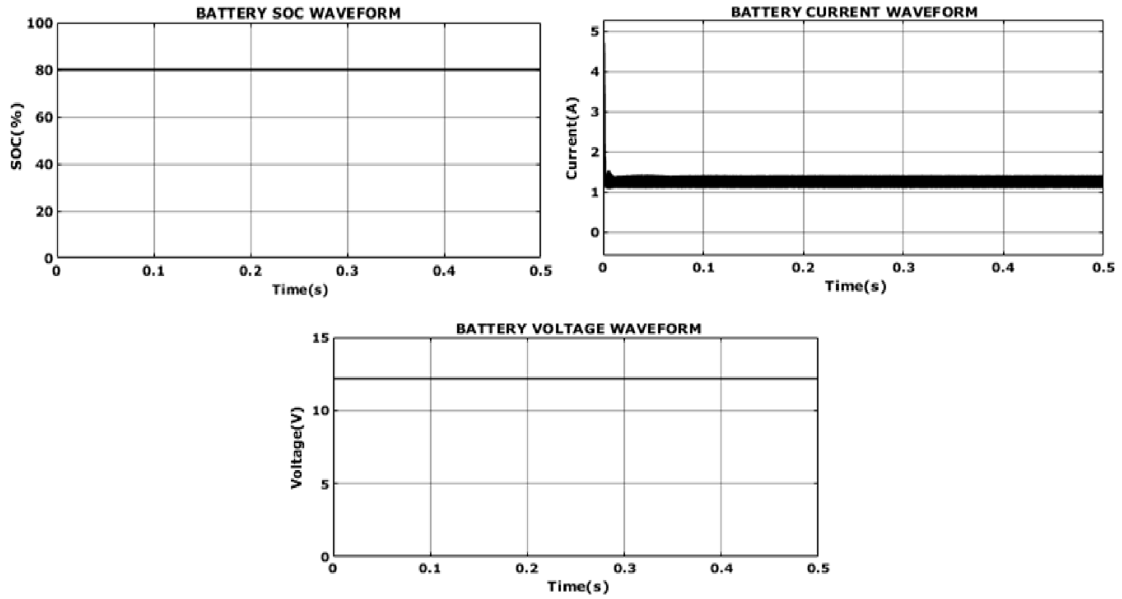

Figure 13: *Battery waveforms*

The work's real and reactive power waveforms are displayed in Figure 14, with the real power attaining 9950(W).

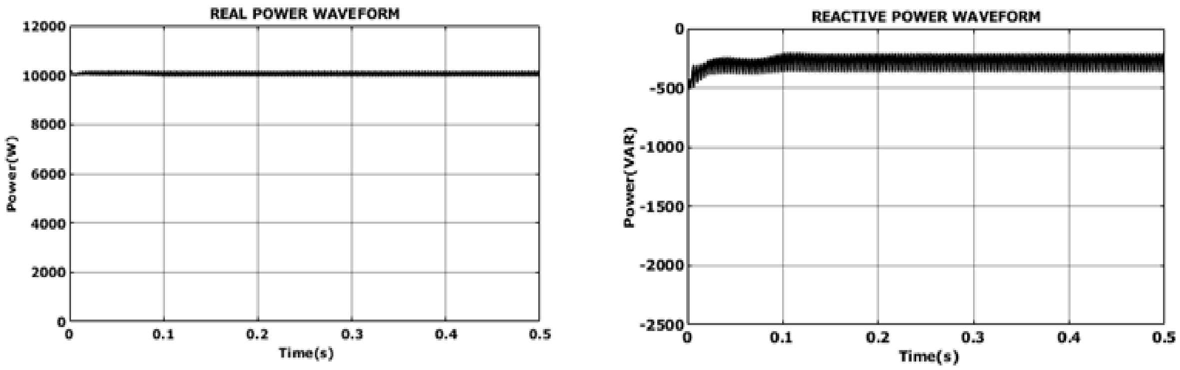

Figure 14: *Real and reactive power waveforms*

5 Conclusion

In this study, a unique hybrid energy source-based method for grid-tied electric vehicle charging is proposed. Communication between a vehicle and the grid is made possible by it. The inverter receives voltage from the solar system using a boost converter. It is suggested to

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control the voltage of the DC bus and the current of the boost converter using an energy management method. A PI controller regulates the PWM rectifier, which enables the WECS with DFIG and AC-DC conversion. The converter's output, which transforms the DC voltage into an AC voltage, is fed into the grid via a three phase VSI. The LC filter is used to decrease harmonics and create sinusoidal waveforms. Here, the PV panel, wind, and AC generator charge the battery of the electric vehicle. Any remaining power is then used to power the linear and non-linear loads in the next household. During times when there is less demand for EVs, the bidirectional power flow makes it easier to recycle excess electricity back into the grid for other purposes and to charge EV batteries effectively. It has been effectively utilized to raise battery charging efficiency through the creation and consideration of hybrid charging systems. Finally, this paper was implemented using MATLAB 2021a/Simulink software.

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