Research Article

Hybrid Renewable Power Generation for Modeling and Controlling the Battery Storage Photovoltaic System

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A major portion of the global energy demand was likely to be fulfilled by an extensive supply of renewable power. Renewable energy outputs, on the other hand, are changeable due to the dynamic nature of their sources. The integration of these variable sources of power into current power grids is proving difficult for electrical power system operators all around the world. The fundamental issue with renewable energy systems is that, due to the stochastic nature of renewable power, electricity production varies from period to period. Recent research and development on renewable technologies can ensure the islands’ long-term electricity supply. Renewable energy sources, on the other hand, are limited by their unpredictable nature and significant reliance on weather conditions. To offset this disadvantage, several renewable energy sources and converters must be joined. To balance the power generation and load power, a hybrid renewable power generation for standalone application is proposed. The solar plant model is made up of a 170 W photovoltaic (PV) panel connected in series, and conversion of energy is done using the maximum power point tracking (MPPT) algorithm, which regulates a buck-boost converter modulation. The MPPT method used in the converter’s control step is based on perturb and observe (P&O) and enhanced with a PI controller.

The bidirectional buck-boost DC-DC converters (BBDC) are utilized to preserve a DC-link voltage stable. This is also storing additional hybrid energy in a large battery and is distributed to the system load; then there is a shortage of hybrid power. The load current power is regulated in terms of the frequency and enables it to be achieved using three vector control technique voltage source inverters (VSI). The results were offered to demonstrate a hybrid performance of this organization.

1. Introduction

Hybrid renewable power generation is becoming increasingly versatile and appealing to meet load in both standalone and grid-connected modes. The predictable power generation resources were finite and will be consumed in the next years [1]. In the current context of increased power generation needs, leading to the advancements of sophisticated digital technology and a much more pleasant lifestyle, it is critical to produce more energy to close a significant gap between generation and transmission requirements. When the system has a power shortage, embedded production in distribution systems compensates for it. Fossil fuels presently account for the majority of the world’s energy sources.
One of the benefits of fossil fuels is the ability to generate hydroelectric power from a single source. However, as fossil fuels are not renewable and therefore will eventually run out, they pose a threat to energy stability [2]. Even while the costs of energy generated from fossil fuels are inexpensive in comparison to other possibilities, the transformation of such materials into electricity causes substantial pollution issues, such as the release of greenhouse gases into the atmosphere, which contributes to present global warming.

For decades, hybrid systems combining wind and PV energy sources have consumed a lot of attention. A hybrid organization may additionally incorporate a DC or AC converter, a packing area, filters, and a load management process control in addition to the energy sources [3]. All of these elements can be linked in a variety of ways. In renewable energy source applications, data-acquisition systems are commonly utilized to gather data on the deployed system’s routine and estimation purposes. The information is initially conditioned with precise electronic circuits before being interfaced with a computer via a data achievement card. Solar energy is the most ecofriendly and speediest green energy source among some of the renewable energy sources [4]. However, the PV system’s biggest disadvantage is that even the power it generates is greatly dependent on climatic circumstances. A PV system, for example, may not be able to generate any electricity at night or even during overcast times. As a result, the PV system generates power periodically, which implies that it may not be able to fully supply
the power at any one time [5]. In an appropriate hybrid framework, this challenge is fixed by a PV integrating systems by some other energy storage technologies.

The ability to combine renewable sources of energy to form a hybrid system, on either side, is an ideal alternative for distributed energy-producing systems. As a result, alternative energy sources may be extra to the energy system to assure a long-term supply of electricity to the demand whenever the wind is inadequate. Solar energy, in addition to wind, is a frequently used renewable energy source [6]. It is also a reliant energy source, comparable to wind because the amount of energy created is based on numerous seasonal factors like irradiation angle, panel temperatures, and irradiance levels. As a result, the extra energy can be stored and used to charge equipment. The research can be carried out after simulating three distinct solar farms with such a rated output of 15 kW that are believed to be located in remote locations. The DC-DC converter system uses buck conversions with the perturb and observe (P&O) MPPT control algorithm, which ensures that the power produced for each solar plant is stable [1]. Between the storage battery as well as the DC-link, a BBDC is used to construct controller parameters, and a switching power inverter is used at the load-side end. To reduce the undesirable high-frequency vibrations caused by a load current of VSI depending on an inverter operating frequency, a humble passive L-C filter is put after the inverter at the load-side end [7]. The numerical solution can be used not only to evaluate the performance of the battery storage generated in PV-wave hybrid
systems, but also to generate the amount of network hybrid renewable power output that meets the consumer load requirements in any situation. In this research, the proposed standalone PV-wave hybrid system model design was modeled and developed. The results are provided to demonstrate that the proposed system is effective.

2. Related Works

Grid extension to remote areas is fraught with technical and financial challenges. It has promoted the exploration and usage of renewable energy sources (RES) for decentralized power generation. The usage of renewable energy sources necessitates the use of a power source that is not always available. This difficulty has been mitigated to some extent by the installation of an energy storage unit (ESU) integration. The procedural review of a hybrid wind and PV production in a standalone method is presented in this study. The entire generation is influenced by associated components such as converters, storage units, controllers, and optimization strategies. Wind and solar energy are widely available, ubiquitous, and likely to show a significant role in a future energy market. To solve the problem of global warming caused by emissions from fossil-fuel-based thermal power stations, the analysis of the advancement of standalone renewable power units based upon PV and wind microgrids is included in this article [8].

A multi-input converter (MIC) is suggested, constructed, evaluated, simulated, and implemented to develop wind-PV power. The MIC is capable of processing both solar and wind energy, with its construction developed from the forward DC/DC conversion to a step-down/up power for a charger device, DC circulation uses. The MIC consists of a DSP-based control system, a higher adapted double-ended forward, a mutual output inductance, a lower altered double-ended forward, and an above altered double-ended forward. The two redesigned double-ended converters can work independently or in tandem to handle the hybrid renewable energy’s variance under diverse air conditions. Improved results and lower volume can be obtained when the MIC is integrating the operation. The suggested MIC can recycle the energy held in the leaking inductance while achieving a high step-up voltage output. To attain a MPPT, the perturb and observe technique is used to pull a maximum output from wind turbines and solar panels. The MIC is built, examined, simulated, and put to the test. The possibility and

![Figure 6: Yuasa NP18-12 battery, 0.2 pulse discharge.](image)

**Table 2: Modified P&O algorithm’s different control operations.**

| Case | $(\Delta V)$ | $(\Delta P)$ | $(\Delta I)$ | TD   | $G$    | $d$           |
|------|-------------|-------------|-------------|------|-------|---------------|
| 1    | Positive    | Positive    | Positive    | Correct | High  | $d = d + \Delta d$ |
| 2    | Positive    | Positive    | Negative    | Correct | Constant | $d = d - \Delta d$ |
| 3    | Positive    | Negative    | Positive    | Incorrect | High  | $d = d - 2\Delta d$ |
| 4    | Positive    | Negative    | Negative    | Incorrect | Constant | $d = d + 2\Delta d$ |
| 5    | Negative    | Positive    | Positive    | Correct | Constant | $d = d + \Delta d$ |
| 6    | Negative    | Positive    | Negative    | Correct | Low    | $d = d - \Delta d$ |
| 7    | Negative    | Negative    | Positive    | Incorrect | Constant | $d = d - 2\Delta d$ |
| 8    | Negative    | Negative    | Negative    | Incorrect | Low    | $d = d - 2\Delta d$ |
hold appliances can run on DC, this article proposes an
of the solar PV production in a DC and maximum house-
due to an increase in demand for renewable energy. Because
national grid. Solar PV use has increased in recent years
efficient and cost-effective. The additional advantage is that renewable energy supplies can be more e
supply for both big and minor consumers. The additional
for a voltage of DC bus variance. In this method, the
power system. The orphanage was given in this work. The National Aeronautics and Space Administration (NASA) surface meteorological and particularly a solar website provided solar sources for
software architecture at a location of 6° 51' N latitude and 7° 35' E longitude, with a yearly average of solar radiation of 4.92 kWh/m²/d. This research is centred on the
modeling, simulations, and improvement of the orphanage’s power system. The orphanage’s consumption of load habits is investigated and appropriately modeled for improvement. The suggested standalone solar power system analysis was performed and designed using the Hybrid Optimization Model for Electric Renewables (HOMER) software. The design was created to give the best configuration settings depending on hour-by-hour energy requirements and market data. This report included a full design, specification, and anticipated effectiveness of the software [12].

3. Materials and Methods

This study briefly explains the basic schematic plan of a hybrid PV-wave renewable power technology. Figure 1 depicts an entire block figure of a standalone PV-wave HRES. The proposed system involves of a PV system, a pulse width modulation (PWM), an OWC scheme, a BBDC with even a proportional-integral-derivative (PI) ratio of control duty, a storage battery, and insulated-gate bipolar transistor (IGBT) VSI located on the demand side [13]. A solar PV system consists of a PV grid as well as a DC-DC transmitter with the MPPT technique. In a photovoltaic panel, MPPT is utilized to raise system performance by controlling the DC-DC converter. The Darrieus turbine-driven permanent-magnet oscillator is bidirectional [14], and an AC-DC three-phase converter was used to build the OWC technology.

To satisfy the load need, the HRES uses a renewable photovoltaic and a wave-energy system as a major power generating source, with a battery bank serving as a backup energy storage device. As a result, if the HRES-generated power is insufficient to change the system load requirements, the battery storage will provide energy to equalize the system power requirement. The DC-link voltage has to be constant to connect a PV-wave, and the battery bank in hybrid architecture

Figure 7: The DC-DC converter controller’s diagram.
To retain a voltage DC-link constantly, the HRES uses a BBDC with a PI controller. To manage the voltage demand side in terms of an occurrence and breadth, a three-phase VSI with a very composite vector control method is employed at the demand side. The next sections provide a detailed summary of each aspect of organizational HRES and controllers.

### 3.1. PV Module Modeling

A PV-cell is made up of a p-n junctional semiconducting material; then its equivalent circuit is revealed in Figure 2. This paper [16] refers to the mathematical analysis of PV systems. When solar energy falls upon that PV panel’s surface, the PV process utilizes MPPT to get the most electricity. The formulas from the study referenced [17, 18] were used to create the PV system. Table 1 shows the PV array characteristics. The power of the solar SRP-305-WHT panel is simulated in a suggested hybrid renewable power generation using Matlab-2019 SIMULINK. I-V parameters of a photovoltaic panel are not linear. The experimental solution for the current would be as follows.

\[
I = I_{PV} - I_o \left[ \exp \left( \frac{V + R_s I}{V_T} \right) - 1 \right] - \frac{V + R_p I}{R_p},
\]

(1)

where \( V_T = k T N_s / q \).

### 3.2. Oscillating Wave Column (OWC)

This segment contains measured formulae that demonstrate the energy produced by the OWC scheme. The power produced at a wave turbine is made up of two terms: \( P_t \) (pressure of air) and \( P_v \) (velocity of air) [19]. As a result, the total energy of the chambers will be expressed to use the calculation.

As a result of the incident light, the current created is as follows:

\[
I_{PV} = (I_{PV,n} + K_f \Delta T) \frac{G}{G_m},
\]

(2)

where \( \Delta T = T - T_n \) and \( I_{PV,n} = (R_p + R_s) / R_p I_{sc,n} \).

The diode leakage current is stated as

\[
I_o = I_{sc,n} + K_f \Delta T \frac{1}{\exp \left( \frac{(V_{oc} + K_f \Delta T) / n V_T}{n} \right) - 1},
\]

(3)

A perfect photovoltaic cell’s current is given as

\[
I = I_{PV} N_{par} - I_o N_{par} \left[ \exp \left( \frac{V + R_s (N_{ser} / N_{par}) I}{V_T N_{ser}} \right) - 1 \right] - \frac{V + R_s (N_{ser} / N_{par}) I}{R_p (N_{ser} / N_{par})}.
\]

(4)

Table 3: OWC parameter.

| Length of chamber OWC | 1.6 m |
|-----------------------|-------|
| Area of water surface inside a chamber | 1.5 m² |
| Area of inlet turbine | 0.013 m² |
| Height of wave (m) | Period of wave (s) | Depth (m) |
| 0.97 | 4.8 | 16.48 |
| 0.97 | 4.78 | 15.76 |
| 0.87 | 4.76 | 15.74 |

Figure 8: (a) An illumination profile of MPPT. (b) Matching results.
below. 

\[
\text{Power of Chamber } \equiv P_c = P_V + P_r, \quad (5)
\]

where due to atmospheric velocity term, the power \( P_V \) operating on the turbine is 

\[
P_V = \rho A_2 \left( \frac{V_2}{2} \right)^3. \quad (6)
\]

And, because of the air pressure condition, the power \( P_r \)
the primary storage technique. In PV systems, batteries are also attainable to the turbine is

$$ P_t = \left( \frac{X_2}{X_1} \right)^2 \frac{W^2}{\theta^2} \left( 2 \cos (\omega t)^2 - 1 \right) \times \sin^2 \left( \frac{\theta}{2} \right) + \frac{Q \phi}{A_z} (V_z - V_z) \right) \times Q_e \times \rho. \quad (7) $$

Because the OWC’s independent power is the product of a generator coefficient power $C_{OC}$, the overall power output is produced by an OWC that equals

$$ P_{total} = (P_e + P_r) \times C_{OC}. \quad (8) $$

3.3. Battery Storage System. In PV systems, batteries are also the primary storage technique. The model of battery is utilized to investigate the impacts of a different rate of charge, as well as the battery’s state of charge (SOC) and state of health (SOH) [20]. Various test scenarios can be used to determine the best battery size for a specific application. Without any need for costly staging areas, simulations are utilized to compare alternative storage methods.

Figure 3 depicts a simple transmission line battery concept. The model of battery considers the battery’s state of charge (SOC) and depth of charge (DOC). With a rising current discharge, the battery’s serviceable capacity decreases; the DOC of the battery monitors the segment of the battery’s capacity to a functioning capacity [21]. An open-circuit battery voltage $E_{oc}$, internal resistance $R_{in}$ and two RC-parallel branching are included in the model. The formulas for the system are displayed on the following equations.

$$ E_{oc} = E_0 - K_0 (1 - \text{SOC}), $$

$$ R_1 = R_{10} e^{(-K_0 (1 - \text{SOC}))}, $$

$$ R_2 = \frac{R_{20}}{\text{DOC}}, $$

$$ \text{SOC} = 1 - \frac{1}{C_{n}} \int i_{\text{bat}} d\tau, $$

$$ \text{DOC} = 1 - \frac{1}{C_{\text{n}(i_{\text{avg})}}} \int i_{\text{bat}} d\tau, \quad (9) $$

where SOC is the battery’s condition of state charge, DOC is the battery’s condition of deep charge, $C_{n}$ is the capacity of a battery, $C(I_{\text{avg}})$ is the current-dependent capacity of a battery, $E_{0}$, when the batteries are fully charged, is the open-circuit voltage, $K_0$ is a constant, $K_1$ is constant, $R_{10}$ is a 1st constant RC branch in $\Omega$, $R_{20}$ is a 2nd constant RC branch in $\Omega$, $\tau_1$ is the 1st the time constant RC branch in $\Omega$, and $\tau_2$ is the 2nd the time constant RC branch in $\Omega$.

For various C-rates, Figure 4 displays the modeled characteristics of discharge curves for the Yuasa Np18-12 lead-acid batteries. $E_0 = 12.84$, $K_0 = 1.7$, $R_0 = 0.12 \Omega$ for charge and 0.057 for discharge, $R_{10} = 0.16 \Omega$ for charge and 0.02 for discharge, $K_1 = 7$, and $R_{20} = 0.0055 \Omega$ in both charging and discharging, according to testing on the Yuasa Np18-12 battery. The battery’s 0.2C pulse charging and discharging is shown in Figures 5 and 6, correspondingly.

A solar panel, conversion, loads, and battery bank are the most frequent components of freestanding photovoltaic systems. When there are differences between accessible and necessary energy, the energy formed by a photovoltaic module is retained in a rechargeable battery to satisfy the requirements of demand [22]. Charge-discharge devices have wider sheets than vehicle batteries and are designed to be continually drained to that more at 80% depth of discharge (DOD), providing them a good alternative for PV storage. The unit is normally designed to power a capacity for 2-3 days, resulting in a great rechargeable battery which will have to be changed every several decades.

The energy transfer from a PV module to the battery and a demand is controlled by a battery management system (BMS). Measuring the battery SOC, adjusting the DC-DC
converter pulse width, and applying the charging method are all tasks performed by the BMS. The BMS is based on an estimate of the SOC. The battery charge and discharge are affected by the current battery SOC [23]. The DC-DC inverter is utilized to convert MPPT tracking to charge the battery and power the demand. Sensors and measuring circuits measure the photovoltaic panel, battery, load voltage, and current, as well as the solar panel and battery condition [24]. The control algorithm uses these analytics to enhance the system’s activity to make the effective use of existing energy to keep a battery at such a maximum SOC while also guaranteeing the demand requirements are fulfilled throughout all times.

3.4. Modified P&O MPPT. The standard P&O is not ideal for tracking changeable radiation levels since it also oscillates frequently about the MPP whenever the PV system’s peak power is generated at a specific operational point and deviates from MPP if solar irradiation changes [25]. The divergence is caused by a shift in the level of irradiation. As a result, both of the aforementioned factors result in energy losses in the PV module, as well as limitations in typical P&O solutions. To circumvent these limitations, a modified P&O approach is assigned. By changing the current (I) variable in the algorithm, the improved P&O improves the network efficiency.

The proposed MPPT algorithm behaves like classic P&O under constant irradiance. When the irradiance changes, the MPPT algorithm behaves differently than the conventional P&O algorithm. The number of iterations is increased for velocity tracking during poor tracking periods [26]. This MPPT algorithm can distinguish between power fluctuations caused by solar illumination and measured voltage disruptions. As a result, according to the cited article, MPP deviation can be ignored. Table 2 details the different control measures of the improved P&O algorithm, and it may cover up to eight different scenarios. The tracking motion and controlling success are determined by the power differential (P). There are two types of cases that can be explored.

Case 1. The PV panel is in continuous irradiation if the changes in voltage (ΔV) and current (ΔI) have opposite signs.

Case 2. If the (ΔV) and (ΔI) take almost the same sign, the PV array gets irradiated differently.

3.5. DC-Link Voltage Control. A planned PV-wave hybrid standalone system’s circuit layout is presented in this section. A neutral device is connected among the capacitors attached even before VSI enabling supplying single-phase and three-phase applications to the present scheme. The DC-link portion of a BBDC is linked to the battery bank in this research; the major goal of the BBDC’s management is to keep a continual voltage DC-link as a standard value, as well as discharge or charge power from or to the batteries reserve according to with an essential load power [27]. Figure 7 shows a schematic representation of the battery system BBDC controller. By employing BBDC, the value of a large battery can indeed be considered lower than the standard DC-link voltage (Vdc), resulting in fewer batteries needing to be synchronized. The battery capacity voltage is maintained around 300 V in the planned standalone systems, while Vdc = 650 V.

The battery’s bank of depletion is assumed to be 60% in this work, and it is created on the idea it should deliver an electric power of up to 2.5 kW, and demand is around an hour whenever the produced energy wave is zero.

The value of the inductance in a BBDC is critical for it to operate in the charging process. In addition, the presence of an inductor on the battery bank side leads to decreased ripple current, resulting in a longer lifetime and improved efficiency [28]. The operation of the charging process is also influenced by the incoming and outgoing currents, the value of the capacitors, and the switching speed. The inductance and capacitor values are as follows:

\[
L_2 = \frac{V_{\text{Battery}} \times (V_{\text{DClink}} - V_{\text{Battery}})}{I_{\text{Battery}} \times V_{\text{DClink}} \times f_w},
\]

Buck mode capacitance
\[
C_2 = \frac{I_{\text{Battery}} \times K_L}{f_w \times 8 \times V_{\text{Battery(ripple)}}},
\]

Boost mode capacitance
\[
C_3 = \frac{I_{\text{DClink}} \times D_{\text{Boost}}}{V_{\text{DClink(ripple)}} \times f_w},
\]

where \(V_{\text{Battery}}\) is the energy of battery voltage, \(V_{\text{DClink}}\) is the voltage DC-link, \(I_{\text{DClink}}\) is the current DC-link, \(I_{\text{Battery}}\) is the current of battery storage, \(V_{\text{Battery(ripple)}}\) is the output of buck side preferred a ripple voltage, \(V_{\text{DClink(ripple)}}\) is the boost-side output preferred a ripple voltage, \(K_L\) is the approximate coefficient of measurement current ripple at the backside, and \(f_w\) is a scaling factor.

3.6. VSI Monitoring on the Load Side. A three-phase control technique VSI has utilized an interface device among a user load as well as the DC link voltage at a load end. The speed and amplitude only at the user load end are controlled by the load-side VSI controller. Since there is no electricity generation that developed a sense in the suggested HRES technology, its maximum output voltages should be managed in terms of primary frequency magnitude [29]. The output voltage is regulated using the state space modulation technique as the necessary hybrid or loading power varies.

The vector control method is adopted in this study, which depends on the simultaneously rotating scheme presented. Using the selected maximum output voltages electrical frequencies, the three-phase \(V_x, V_y,\) and \(V_z \) voltages and \(I_x, I_y,\) and \(I_z \) currents should be translated and monitored from a standard stationary frame \(a - b - c \) to a comparison by a rotating frame of \(d - q \). 220 V and 50 HZ are the defined root mean square (RMS) values for the output voltage waveform and load voltage rate in this research.
The following are the voltage formulas by using references rotating \(d - q\) frame transition:

\[
V_d = V_{d0} - H_f \frac{d i_d}{dt} + H_f \omega i_q,
\]

\[
V_q = V_{q0} - H_f \frac{d i_q}{dt} - H_f \omega i_d. \tag{11}
\]

The active and reactive power is calculated using the \(d - q\) reference rotational frame conversion.

Active power \(P\) = \(\frac{3}{2} (i_d v_d + i_q v_q)\),

Reactive power \(Q\) = \(\frac{3}{2} (i_q v_d - i_d v_q)\). \tag{12}

If the standard rotational frame is \(v_q = 0\) and \(v_d = |V|\), the power of active and reactive formulas is as follows:

\[
P = \frac{3}{2} i_d v_d = \frac{3}{2} |V| i_d,
\]

\[
Q = \frac{3}{2} i_q v_d = \frac{3}{2} |V| i_q. \tag{13}
\]

As a result, regulating direct and quadrature current components can regulate real and reactive power, correspondingly. Case \(V^*_d\) could also be controlled by it for resistors.

\[
V^*_d = \sqrt{2} V^*_{\text{RMS}} \tag{14}
\]

The model is then run using a combination of ocean wave and PV systems, as well as a battery-energy storage system. Finally, the whole modeling of a hybrid power system, which would be founded on grid connectivity, has been completed. The simulation parameters are listed in Tables 3.

A strict profile for fluctuating solar radiation is utilized to demonstrate the usefulness of the suggested method. As suggested by the efficiency test, EN 50530, this profile includes several geometries such as step-up, step-down, ramp-up, and ramp-down. Two different slopes are chosen, with values of 1875 W/m²/s and 2500 W/m²/s, respectively, as shown in Figure 8(a). The suggested tracker may be thoroughly tested under intermittent and stable situations using this profile. The time of a test was prolonged by 4 seconds, while the temperature remained constant at 25 degrees Celsius. For both the P&O method and its version, the switching frequency step size is \(\Delta f = 0.0002\).

To begin, the suggested P&O sensor was tested under a certain irradiance profile, with the simulated results shown in Figure 8(b). PV grandeurs including voltage \((V)\), current \((I)\), load voltage \((V_{in})\), and power \((P)\) have their waveforms shown. The various grandeurs have acquired the same levels as the photovoltaic curve, as may be observed. It may be proven that the conversion utilized is a voltage step by comparing the behaviors of \(V\) and \(V_{in}\). Moreover, the development of irradiance has a greater impact on the morphologies of \(I\) and \(P\) than on \(V\), which will only be marginally influenced.

4. Result and Discussion

In the OWC system, battery storage, PV system, and BBDC with a PI control duty cycle, a voltage regulator is positioned at a lateral loading that makes up the proposed hybrid model. PV array and DC-DC converters with an MPPT algorithm make up a PV-solar system. The bidirectional turbine was powered by an asynchronous generator (SG) and an AC-DC three-phase rectification in OWC systems. The PV-renewable and wave-energy systems are employed as the major power generating source to satisfy systems demand requirement in hybrid renewable energy source (HRES), while stored energy is being used as a standby energy storage system. The DC-link voltage should be constant to interface PV-wave and a battery system in hybrid architecture. To keep a DC-link voltage steady, the HRES uses a BBDC with a PI controller.

The simulations were divided into four sections. The model of an ocean wave power converter was completed first, followed either by simulation of a photovoltaic system. Finally, the DC-link is linked to a three-phase VSI. Figures 12–14 illustrate the results achieved after attaching...
a hybrid approach to a three-phase grid. The load voltage depicted in Figure 14 is completely sinusoidal in a waveform.

5. Conclusion

Renewable energy resources are inconsistent, and designing a solar PV power producing system is difficult. An innovative freestanding PV-wave control scheme is conceived and modeled, complete with appropriate energy flow controllers. In this difficult situation, this study is aimed at constructing a hybrid power production system consisting of energy battery storage PV-wave renewables and an effective power control method to fulfill the load requirements. The results show that a controller can keep the voltage DC-link steady despite variations in produced hybrid power and necessary load power. Moreover, the controller is designed in such a way that battery storage can collect surplus energy produced by the combination organization and send it to the load demand throughout a hybrid network outage by managing the BBDC. The suggested hybrid system performs effectively in steady-state energy and also intermittent load power, solar, and wave circumstances. This study can be viewed as a first step in developing a standalone PV-wave hybrid model.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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