MJSAT 1 (2) 62-67

MJSAT

Malaysian Journal of Science
and
Advanced Technology

journal homepage: https://mjsat.com.my/


# Modelling and Simulation of DC-DC Boost Converter and Inverter for PV System

Mohamed Aqeel Shafeek*[1], Hariprasad Yogaraju[1], Jasspeed Singh[1] and Lingeswarran Thanaventhran[1]

[1]*Manipal International University, MIU Boulevard, Putra Nilai, 71800, Negeri Sembilan, Malaysia.*

**KEYWORDS**

*Photovoltaic generation*
*DC-DC Converter*
*Simulation*

**ARTICLE HISTORY**

*Received 14 June 2021*
*Received in revised form 20 June 2021*
*Accepted 21 June 2021*
*Available online 22 June 2021*

**ABSTRACT**

Research in renewable energy sources has seen an incremental trend for its various advantages over conventional energy sources. Photovoltaic generation system acquires the maximum market share in the energy systems employing the renewable energies. The low efficiency in terms of the output voltage is a prime disadvantage of the photovoltaic generation system. On the other hand, the industries in the majority make use of equipment requiring high voltage input. Considering the requirement of high voltage input for industrial application and the low-voltage constraint of the Photovoltaic (PV) generation system, this paper proposes a modelling and simulation of DC-DC boost converter and three-phase inverter in MATLAB SIMULINK. The circuit is designed based on the traditional standard circuits of the converter and inverter. The investigation resulted the development of an accurate model but also compact compared to other designs. Additionally, this will allow the power electronics circuit simulated beforehand in any experiment-based work.



## 1. INTRODUCTION

Renewable energy has been gaining the attention oof researchers in recent times. The reasons for the excessive focus in this area is the rapid reduction in conventional energy sources, an increase in the greenhouse effect, and the need for controlling environmental pollution. Also, the usage of renewable energy sources is economical (nearly zero maintenance cost and zero fuel cost) and reliable [1]. The photovoltaic (PV) system is an essential phenomenon in the overall development towards the alternative energy sources and acquires a significant share in the 'renewable energy system market.' Considering the significance of the PV system, several researchers all over the globe are making efforts to explore the potential of its usage in the industrial and domestic applications [1], [2]. Though the PV generation system finds a wide range of applications, the usage is hindered because of its low efficiency. In simple words, the output voltage received is low, which further decreases with the operating temperature. The reason for the efficiency reduction is the working principle of PV modules, as it is designed to only convert the visible light intensity to electrical energy and not the complete spectrum [3]. Considering a drastic growth in the last few decades, with close to $330 billion investment in the year 2017, several researchers are working in the field of PV generation system concerning the requirement of increasing the efficiency and effectiveness of utilization of solar energy through improvisation or proposition of converter topologies [4].

For example, Fathabadi [5] proposed the utilization of DC-DC boost converter to be used in the PV system to provide higher efficiency. The developed system comprised only one 'metal oxide semiconductor field effect transistor' (MOSFET) switch and two diodes. Pires et al. [6] proposed a new non-isolated DC-DC converter for the PV generation system by integrating the classical boost and Cuk DC-DC converters. Kaouane et al. [7] designed a buck-boost DC-DC converter having two power switches and capable of regulating constant voltage regardless of the input. The developed system integrated buck-boost with the 'single-ended primary inductance converter' (SEPIC). Prabaharan et al. [8] proposed a new approach in improving the efficiency of the PV generation system by developing a converter topology having the combination of the boost converter and switched capacitor.

*Corresponding author:
E-mail address: Mohamed Aqeel Shafeek <aqeel.sh@outlook.com>.
2785-8901/ © 2021 The Authors. Published by Penteract Technology.

Pires et al. [9] proposed a triple inverter topology with multilevel operations to improve the maximum voltage applied to the isolation transformer. The topology adapted the multilevel 'pulse width modulation' (PWM) schemes. The ongoing research shows the significance of the improvement required in the PV generation systems in the industrial scenario [10]. Apart from the converter topologies, some rigorous research has also taken place in improving the inverter topologies, evident from the detailed review presented by Jana et al. [11]. Considering the requirement of improving the effectiveness in the utilization of PV generated energy, technical issues, and challenges faced in the PV based energy generation system along with the technical requirement and technical advancements. This work proposes a converter-inverter topology with MOSFET switches. The boost converter and the 3-phase inverter are interfaced in the present work. The simulations are carried out using MATLAB, and results are validated using the PV system prototype.

## 2. THEORY

Solar energy is believed to be the largest source of untapped energy, which is appropriate to be used for electric energy generation using the photovoltaic cell [12]. Given the current electricity usage and world population, enough solar radiation falls on the earth's surface at any instant of time to provide an average of twenty gigawatts of power to every person [13]. In simple words, solar energy is the only renewable energy source having vast potential compared with any possible energy consumption level [14]. There are several ways of harvesting solar energy, photovoltaics being the most important one. A solar panel array working with photovoltaics principle is shown in Figure 1.

**Fig. 1.** A solar panel array using the photovoltaic principle [14]

PV is a method of generating electrical energy by transforming the solar radiation into direct current, employing the semiconductors capable of exhibiting the photovoltaic effect [15]. It is a process wherein, two dissimilar materials in close contact generate an electrical voltage when struck by the light or any other radiant energy. The operating principle of the PV solar cell is explained schematically by representing a single photoelectric cell [16].

The PV has excellent potential for society as it offers the way to generate electricity with a negligible amount of pollution from an energy source [17]. The PV industry is undergoing rapid growth due to the continuing rise of global energy and the depletion of fossil fuels. As discussed in the previous section, the efficiency of the PV generation needs to be improved. It is also clear from the literature reviewed that various topology have been proposed for the same purpose. The present work deals with interfacing boost converter (BC) with the inverter. The boost converters are used when the minimum voltage generated is at least 1.5 times the input voltage [18].

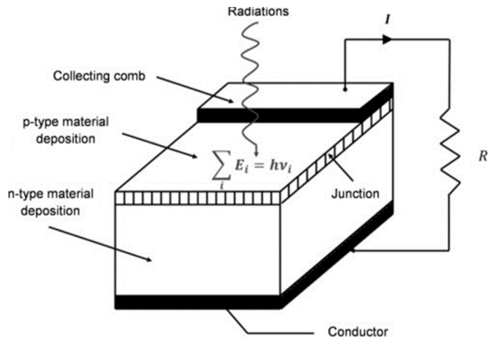


**Fig. 2.** Schematic representation of a single photoelectric cell [18].

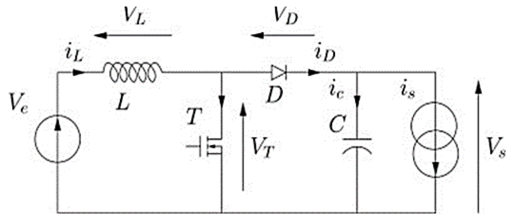


**Fig. 3**. A simple boost converter circuit capable of generating 3A of output current [19].

BCs are regularly employed in the automotive and industrial applications to generate the required level of higher output voltages from lower input voltages. A simple boost converter circuit capable of generating 3A of output current is shown in Figure 3 [18]. The boost converter can be obtained using a parallel chopper, replacing the machine by a constant voltage source in series with an inductance, and replacing the voltage source by a parallel R-C type load as shown in Figure 4 [19].

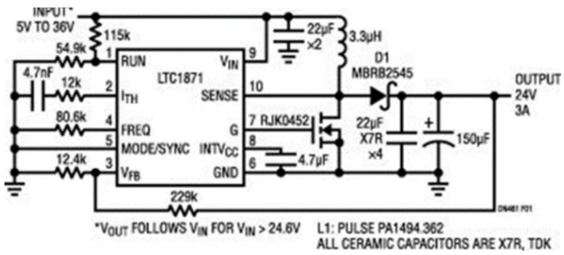


**Fig. 4.** Schematic representation of boost converter using a parallel chopper [19].

An inverter refers to a converter which facilitates the utilization of continuous voltage to power a load. The structure of simple three-phase inverter resembles the extension of the full-bridge chopper using three half bridges, as shown in Figure 5 [20]. With a brief introduction to PV, boost converter and inverter, the present work is based on the theoretical hypothesis that the efficiency of the photovoltaic generation system can be increased by interfacing the boost converter and three-phase inverter. The function of the boost converter shall be to raise the low output voltage received from the PV systems installed in the solar array. The three-phase array shall then convert the input DC voltage to required AC voltage by the industrial equipment.

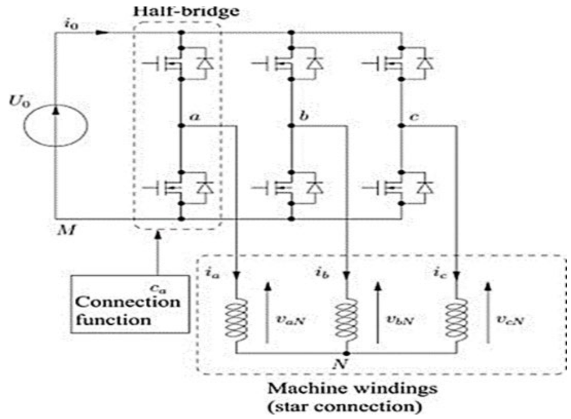


**Fig. 5.** Circuit diagram of a simple three-phase inverter [20].

## 3. Calculations

Initially, the duty cycle (D) is calculated using Equation (1).

$$D = 1 - (V_s/V_0) = 0.856 \quad (1)$$

The switching frequency is set to 25 kHz as a standard. Minimum inductance (Lmin) required for the Circuit is calculated using Equation (2).

$$L\_min = [D(1-D)^2 R]/2f = 36.3H \quad (2)$$

To ensure continuous current inductance value is set to 120 µH. The output ripple voltage is maintained at 1% to maintain a stable output. Using this information, the minimum capacity to be used is determined using Equation (3).

$$C \geq D/Rf((\Delta V_0)/V_0) = 34.2\ F \quad (3)$$

The pulse width modulation percentage is found using the duty ratio, as shown in Equation (4).

$$PWM = D \times 100 = 85.6\% \quad (4)$$

**Table 1.** Design Specifications

| No | Components | Specifications |
|---|---|---|
| 1 | **PV System** | |
| | **[Canadian Solar CS6P-260\|265P]** | |
| | Nominal Max. Power (Pmax) (W) | 265 |
| | Opt. Operating Voltage (Vmp) | 30.6 |
| | Open Circuit Voltage (Voc) | 37.7 |
| | Short Circuit Current (Isc) | 9.23 |
| | Lifetime (Years) | 30 |
| 2 | **DC-DC Boost Converter** | |
| | **[34V – 240V]** | |
| | Inductance Min (H) | 36.3 |
| | Capacitance (F) | 34.2 |
| | Duty Cycle | 0.856 |
| | PWM (%) | 85.6 |
| | Lifetime (Years) | 25 |
| 3 | **Inverter LC Filter** | |
| | Inductance Min (H) | 0.08 |
| | Capacitance (µF) | 120 |

## 4. Experimental Procedure

A DC-DC boost converter is used in this project to ensure the amplification of the generated DC voltage at the PV system. The principle behind the boost converter is to amplify the input voltage and provide a higher voltage than the input. In this project, the solar panel produces a maximum of 35 V DC. This voltage is to be amplified to at least 240V DC in order to use this system as the feeder to the three-phase inverter. The three-phase inverter is fed with DC voltage by the DC-DC converter. The design of a three-phase inverter contains three single-phase inverter switches with each connected to one of the three load terminals of the three phases. The operations of the three switches are present in an orderly manner so that each switch operates at 180-degree point of the fundamental output waveform producing three-phase voltages at the end of the process. The control block diagram of the designed system is, as shown in Figure 6.

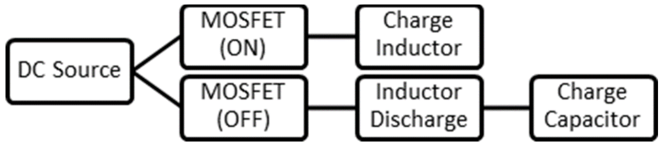


**Fig. 6.** Control block diagram of the design used in the present work.

Initially, the circuit of a DC-DC boost converter and a three-Phase inverter is simulated on MATLAB Simulink to ensure the design functions expectedly. The circuit shown in Figures 7 and 8 is used.

The two individually functioning circuits are integrated, as shown in Figure 9 to test the final product represents the same design using Proteus software. Moreover, the successful simulation work of the two circuits is then implemented in Proteus software to ensure the availability of the design components in the market. To control the switching of the MOSFET, the PWM signal is used. This is achieved with the use of an Arduino Uno. The waveform in Figure 11 is achieved using an Arduino at a frequency of 25kHz.

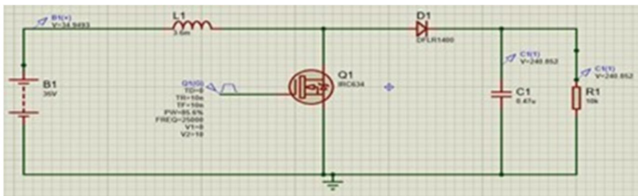


**Fig. 7.** Proteus simulation of the DC-DC boost converter design

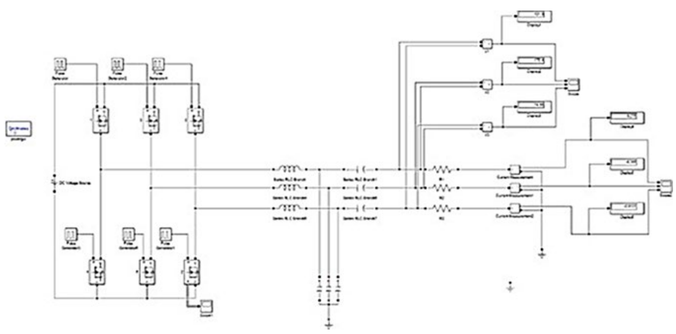

**Fig. 8.** MATLAB simulation of three-phase inverter circuit.

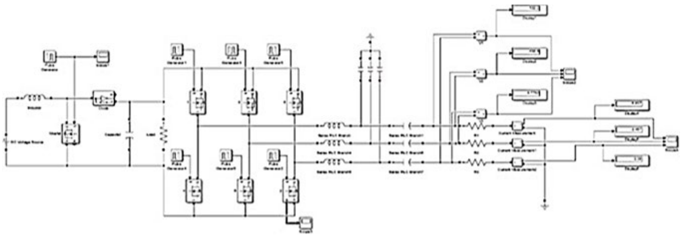

**Fig. 9**. MATLAB simulation of integration of DC-DC boost converter and a three-phase inverter circuit.

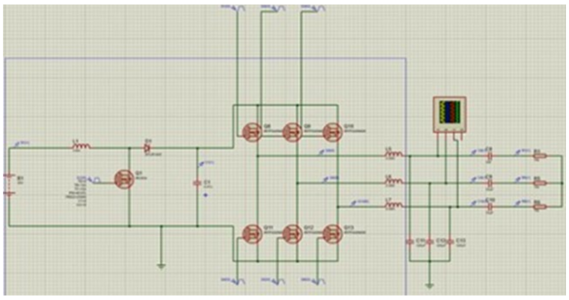

**Fig. 10.** Schematic diagram of the integrated DC-DC boost converter and three-phase inverter using Proteus software.

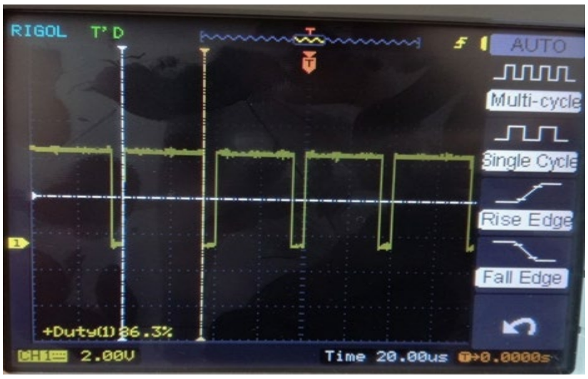


**Fig. 11.** Pulse width modulation signal generated by ARDUINO UNO

The coding used for the generation of pulse width modulation using the Arduino Uno is given as code snippet 1

```
#include <PWM.h>int32_t frequency = 25000; //frequency st to 25
   KHzvoid setup(){  InitTimersSafe(); bool success =
   PinFrequencySafe(9, frequency);}void loop(){  int sensorread =
   analogRead(A0);  pwmWrite(9, sensorread/4);  delay(30);  }
```

Code Snippet 1: Coding for Arduino PWM

## 5. Results and Analysis

The waveforms are obtained using MATLAB/Simulink for the calculated values in the previous discussed section. Figure 12 represents the waveform for the DC-DC boost converter. As seen in the waveform in Figure 12, the input DC voltage of 35V has been amplified to a steady state voltage of 239.8V, which is just 0.2V lesser than the theoretically calculated value of voltage. A transient voltage has been seen across the load, just as the circuit is switched ON due to the inductance effect which goes to the maximum amplitude of 430V. Figures 13 and 14 represents the simulated waveform of three-phase inverter voltage/time and current/time, respectively. Figures 15 and 16 represents the simulated waveform of integrated voltage/time and current/time, respectively.

The simulation of the DC-DC boost converter and three-phase inverter is done in Proteus software successfully and expected output has been achieved. For DC-DC boost converter simulation in proteus software, the expected boosted output is achieved (which is 240 V), but waveform could not be displayed. However, for, three-phase inverter, the expected waveform is achieved but at very low efficiency. In the simulation of the DC-DC boost converter, another issue is faced regarding the load resistance used. The initial design is only supposed to use the resistance of 100Ω, but the simulation did not produce the expected result. This is because of the power rating of the resistor since a high voltage is seen across the resistor the power of it had to be considered.

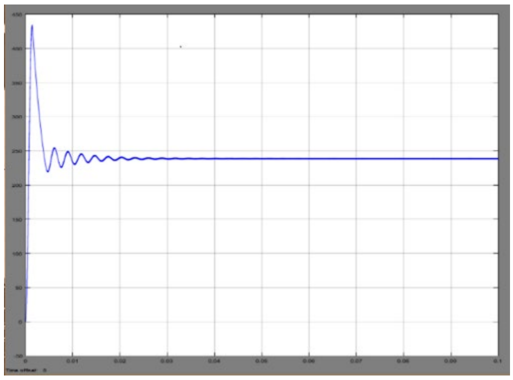

**Fig. 12.** DC-DC boost converter output waveform

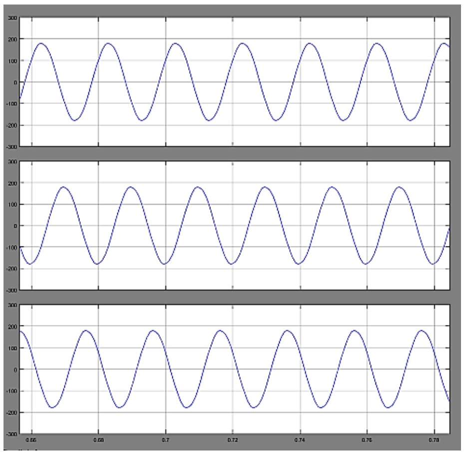

**Fig. 13.** MATLAB simulation of three-phase inverter voltage/time waveform

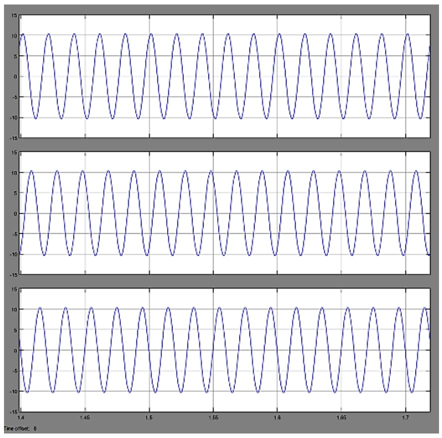

**Fig. 14.** MATLAB simulation of three-phase inverter current/time waveform

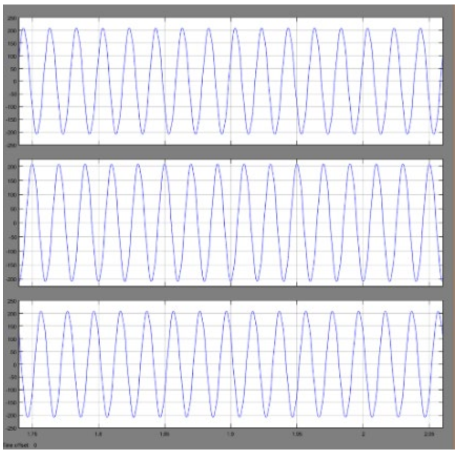

**Fig. 15.** MATLAB simulation of integrated circuit voltage/time waveform

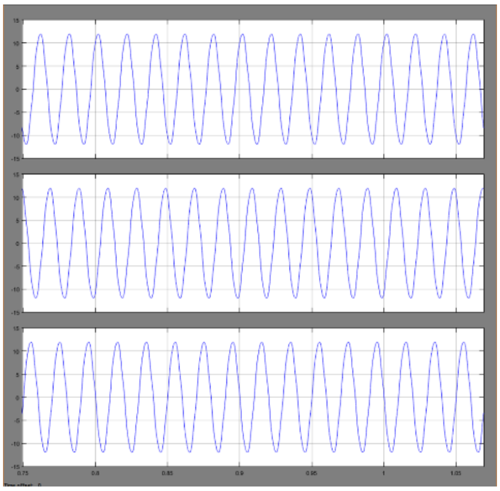

**Fig. 16.** MATLAB simulation of integrated circuit current/time waveform

On Proteus, the only option of resistors available is for 0.5W, 7W and 10W. For this purpose, the load resistance had to be changed to a value that can withstand the output. By using the formula given in Equation (5), the power to withstand is calculated.

$$P = V^2/R \quad (5)$$

Since power resistors are hard to be found in the market, the value of resistance is increased, resulting in a lower current flowing through the resistor protecting the circuit. In the present work, some of the limitations faced include the use of the function generator in the lab. Even though pulses can be generated to feed the MOSFET for the switching function, the expected output could not be satisfied.

The reason for this is that the required duty ratio of the pulse is 85.6% whereas the maximum achievable duty ratio on a signal generator is limited to 80%. By using a duty ratio of 80%, the maximum achievable voltage is limited to 175V. For this reason, an alternative method of pulse generation is used. Arduino can be used for this case, but again the drawback to this issue is the maximum amplitude of the pulse since the Arduino board is limited to an output of 5V maximum. The required voltage of the MOSFET is 10V. The solution to this lies in whether the 5V output can be amplified or not. Regardless, the expected output is achieved using 5V, solving this issue.

## 6. Conclusions

The present work proposes interfacing of a DC-DC boost converter with a three-phase inverter using MATLAB/Simulink, which could be fed by a PV system. The DC-DC converter plays a significant role in solar energy, especially in the solar PV system. The DC input to the three-phase inverter system must be sufficient to make sure the inverter circuit works efficiently. An accurate model of the DC-DC boost converter and an inverter has been simulated in MATLAB/Simulink for the PV system. The proposed design is simple and much easier, and compact compared to the other existing designs.

## References


[1] P.-C. Chen, P.-Y. Chen, Y.-H. Liu, J.-H. Chen, and Y.-F. Luo, “A comparative study on maximum power point tracking techniques for photovoltaic generation systems operating under fast changing environments,” *Solar Energy*, vol. 119, Sep. 2015, doi: 10.1016/j.solener.2015.07.006.

[2] K. Srikumar and Ch. Saibabu, “A system and novel methodology to track maximum power from photo voltaic system: A comparative and experimental analysis,” *Journal of King Saud University - Engineering Sciences*, vol. 32, no. 7, Nov. 2020, doi: 10.1016/j.jksues.2018.02.006.

[3] S. Koundinya, N. Vigneshkumar, and A. S. Krishnan, “Experimental Study and Comparison with the Computational Study on Cooling of PV Solar Panel Using Finned Heat Pipe Technology,” *Materials Today: Proceedings*, vol. 4, no. 2, 2017, doi: 10.1016/j.matpr.2017.02.145.

[4] R. Reshma Gopi and S. Sreejith, “Converter topologies in photovoltaic applications – A review,” *Renewable and Sustainable Energy Reviews*, vol. 94, Oct. 2018, doi: 10.1016/j.rser.2018.05.047.

[5] H. Fathabadi, “Novel high efficiency DC/DC boost converter for using in photovoltaic systems,” *Solar Energy*, vol. 125, Feb. 2016, doi: 10.1016/j.solener.2015.11.047.

[6] V. Fernão Pires, D. Foito, F. R. B. Baptista, and J. Fernando Silva, “A photovoltaic generator system with a DC/DC converter based on an integrated Boost-Ćuk topology,” *Solar Energy*, vol. 136, Oct. 2016, doi: 10.1016/j.solener.2016.06.063.

[7] M. Kaouane, A. Boukhelifa, and A. Cheriti, “Regulated output voltage double switch Buck-Boost converter for photovoltaic energy application,” *International Journal of Hydrogen Energy*, vol. 41, no. 45, Dec. 2016, doi: 10.1016/j.ijhydene.2016.06.140.

[8] N. Prabaharan, P. E. Campana, A. R. ann Jerin, and K. Palanisamy, “A new approach for grid integration of solar photovoltaic system with maximum power point tracking using multi-output converter,” *Energy Procedia*, vol. 159, Feb. 2019, doi: 10.1016/j.egypro.2018.12.005.

[9] V. Fernão Pires, A. Cordeiro, D. Foito, and J. Fernando Silva, “Three-phase multilevel inverter for grid-connected distributed photovoltaic systems based in three three-phase two-level inverters,” *Solar Energy*, vol. 174, Nov. 2018, doi: 10.1016/j.solener.2018.09.083.

[10] P. K, U. Govindarajan, V. K. Ramachandaramurthy, S. O. S. T, and B. Jeevarathinam, “Integrating solar photovoltaic energy conversion systems into industrial and commercial electrical energy utilization—A survey,” *Journal of Industrial Information Integration*, vol. 10, Jun. 2018, doi: 10.1016/j.jii.2018.01.003.

[11] J. Jana, H. Saha, and K. das Bhattacharya, “A review of inverter topologies for single-phase grid-connected photovoltaic systems,” *Renewable and Sustainable Energy Reviews*, vol. 72, May 2017, doi: 10.1016/j.rser.2016.10.049.

[12] V. Ribé, “Environmental Issues Associated with Energy Technologies and Natural Resource Utilization,” in *Encyclopedia of the Anthropocene*, Elsevier, 2018. doi: 10.1016/B978-0-12-809665-9.09103-5.

[13] A. E. Brooks, "Future Energy 3rd Edition Improved, Sustainable and Clean Options for Our Planet," pp. 383–404, 2014.

[14] P. Moriarty and D. Honnery, *Managing Global Warming: An Interface of Technology and Human Issues*. 2019.

[15] S. C. Bhatia, *Advanced Renewable Energy Systems.* 2014.

[16] M. Feidt, *Finite Physical Dimensions Optimal Thermodynamics 2: Complex Systems*. 2018.

[17] C. J. Cleveland and C. Morris, *Handbook of Energy: Chronologies, Top Ten Lists, and Word Clouds*. 2014.

[18] S. Winder, *View on ScienceDirect Power Supplies for LED Driving*. 2017.

[19] N. Patin, *Power Electronics Applied to Industrial Systems and Transports*, vol. 3. 2015.

[20] N. Patin, *Patin, N. (2015). Power Electronics Applied to Industrial Systems and Transports. ISTE Press - Elsevier. vol. 2. 35–100*, vol. 2. 2015.