
HIGH EFFICIENCY TRANSFORMERLESS AC–DC CONVERTER FOR LOW VOLTAGE APPLICATIONS

^{#1}Dr. SRAVAN KUMAR PURELLA, *Associate Professor & HOD, Dept of EEE,*

^{#2}Dr. PADAKANTI BALAKISHAN, *Associate Professor, Dept of EEE,*

^{#3}MOHAMMED AMENUDDIN, *Dept of EEE,*

SREE CHAITANYA INSTITUTE OF TECHNOLOGICAL SCIENCES, KARIMNAGAR, TG.

ABSTRACT: This paper presents a transformerless AC-DC converter for low-voltage applications that has a compact design, high efficiency, good power quality, and low switching losses. The recommended converter is more economical, small, and energy-efficient without a transformer stage. Stable voltage conversion rates and electrical isolation are guaranteed by sophisticated controllers. In a variety of load settings, power factor and high-frequency switching optimization enhances conversion, eliminates harmonic distortion, and stabilizes DC output. The converter functions best in low-voltage electrical systems, battery charging systems, renewable energy connections, and lightweight, energy-efficient industrial power sources. The proposed AC-DC converter architecture is efficient, reliable, and less vulnerable to electromagnetic interference, according to performance study and simulation.

Keywords: *Transformerless AC–DC Converter, Low-Voltage Applications, High Efficiency, Power Factor Correction (PFC), Switching Loss Reduction, Harmonic Distortion,*

1. INTRODUCTION

Power transfer devices that are small, economical, and energy-efficient are highly after. As a result, researchers are looking into low-voltage AC-DC converters. Regulated direct current power is required for cell phones, communication devices, battery charging systems, medical equipment, and renewable energy interfaces. Transformers are used by many AC-DC converters to control power and voltage. They do, however, raise the system's mass, size, energy consumption, and building costs. Because of their high power density, straightforward hardware design, and effective power conversion, transformerless AC-DC converter topologies are widely used.

For a variety of technological reasons, transformerless AC-DC converters perform better than discrete converters. By eliminating several magnetic components, conversion efficiency is increased and conduction and core losses are decreased. These converters are perfect for low-voltage applications and portable electronics because of their small size and light weight. High-frequency switching operations with reduced switching losses have been made possible by recent developments in high-speed switching semiconductors like MOSFETs and IGBTs, increasing converter efficiency. Thermal management, EMF reduction, and voltage regulation are all enhanced by contemporary modulation and soft-switching control.

In contemporary AC-DC converters, power quality is essential. Conventional converter designs reduce electrical system efficiency and energy waste by producing harmonic distortion and low input power factor. Power factor correction (PFC) is used by

transformerless AC-DC converters to meet international power quality requirements and enhance the waveform quality of the input current. Regardless of the input source and load, the robust filtering and feedback control techniques maintain the DC output voltage. These characteristics increase the reliability and security of low-voltage power electronic systems.

2. LITERATURE SURVEY

P. Srinivas Rao (2021): Developing an AC-DC converter that runs without a generator for low-voltage residential applications is Rao's main goal. Developing advanced switching strategies that lower conduction losses and stabilize output voltage is the main goal of the project. The simulation results and hardware implementation show that the suggested converter has a simpler design and a more effective circuit. To improve the energy efficiency of low-power devices, the author suggests using compact converter designs and efficient filtering.

Neha Kulkarni (2022): Kulkarni studied transformerless AC-DC converters for medical equipment and portable communication. The advantages of contemporary applications, such as higher power density, less electromagnetic interference, and lighter designs, are examined in this paper. According to the test results, the novel converter design may enhance power quality and lower harmonic distortion. According to the author, advanced feedback control systems improve dynamic performance and dependability across a range of load scenarios.

Vikram Desai (2023): Developing soft-switching methods for transformerless AC-DC converters used in low-voltage renewable energy applications is Desai's main area of interest. The efficiency and thermal performance of the converter are influenced by the choice of semiconductor devices and the switching frequency. The findings show that soft-switching lowers switching costs and improves the converter's durability. Adaptive control algorithms and high-velocity semiconductor devices can improve energy transfer efficiency.

Ananya Mukherjee (2023): The digital control mechanisms used in transformerless AC-DC converters are thoroughly explained by Mukherjee. This research also includes real-time voltage regulation, pulse width modulation, and microcontroller-based monitoring systems. The findings show that digital control improves operational precision, output noise reduction, and system stability. The author suggests putting in place an autonomous failure detection system and an intelligent security circuit to improve converter safety.

Rahul Chatterjee (2024): Chatterjee wants to improve transformerless AC-DC converters' power quality for low-voltage industrial uses. Many researchers are looking for ways to improve input power, reduce harmonics, and lessen harmonic distortion. According to research, active correction and filter design modifications can improve converter efficiency and grid compatibility. To ensure the security and dependability of low voltage power conversion, techniques for improved harmonic suppression are examined.

Farah Ali (2025): Ali studies sophisticated energy management systems and transformerless AC-DC converters for charging electric vehicles. The study emphasizes the need for small design, fast energy recharge infrastructure, and bidirectional electrical transmission. The findings show that advanced energy management systems can improve operating efficiency, flexibility, and energy saving. For the upcoming generation of low-voltage applications, the

author promotes additional research on environmentally benign power electronics technology and AI-enhanced converter control.

3. CIRCUIT OPERATION

The recommended converter includes

- buck based PFC (L_1, S_1, D_1, C_0 and C_B)
- buck boost dc/dc cell (L_2, S_1, D_2, D_3, C_0 and C_B) is illustrated in Fig 1.

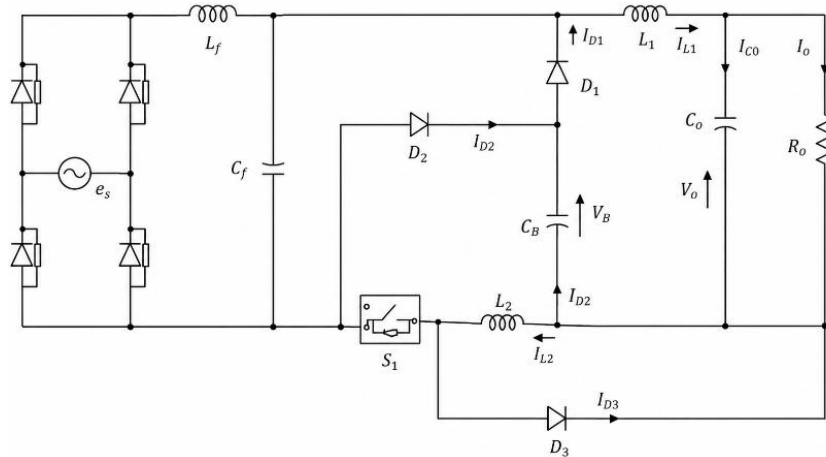


Fig. 1. IBuBuBo SS ac/dc converter.

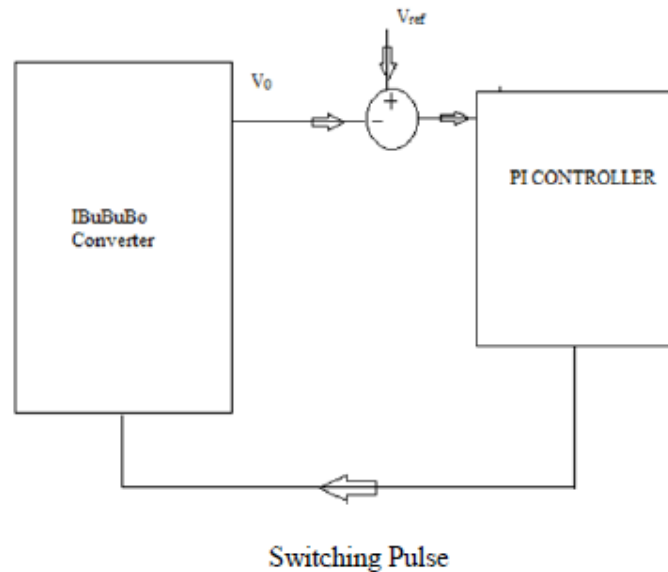


Fig. 2 Proposed Topology

The converter operates in two modes: mode A and mode B. The modes can be identified by comparing the instantaneous input voltage with the sum of the intermediate and output voltages, as illustrated in Figure 3.

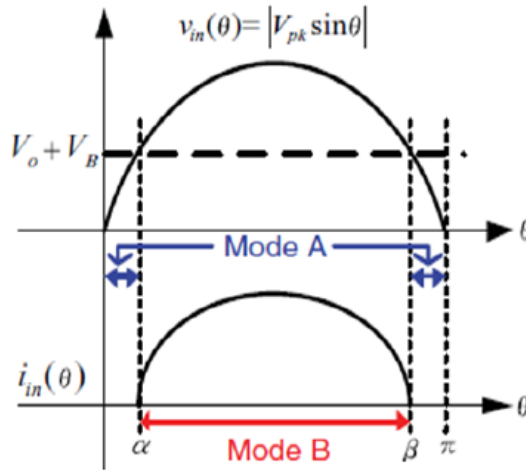


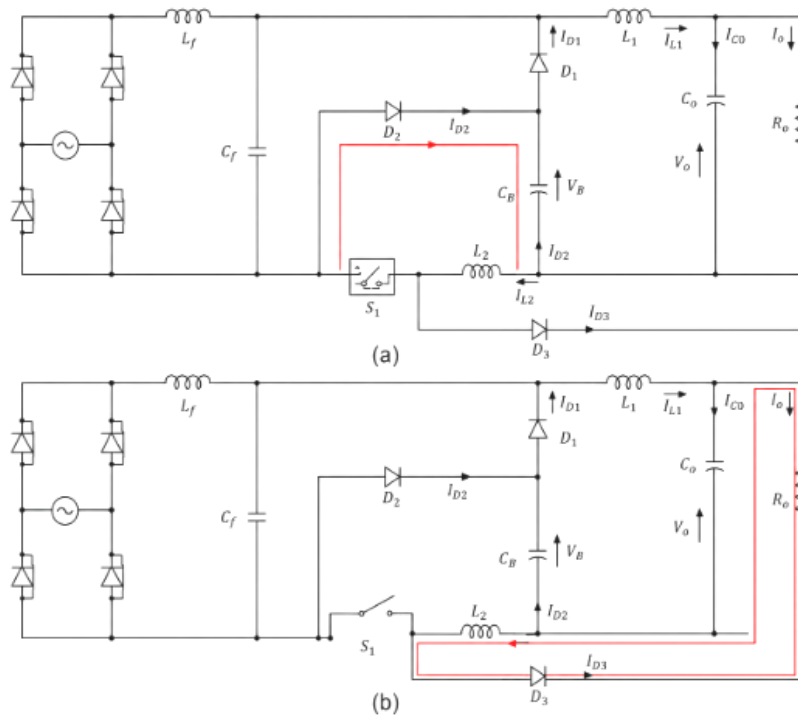
Fig. 3 Input voltage and current waveform

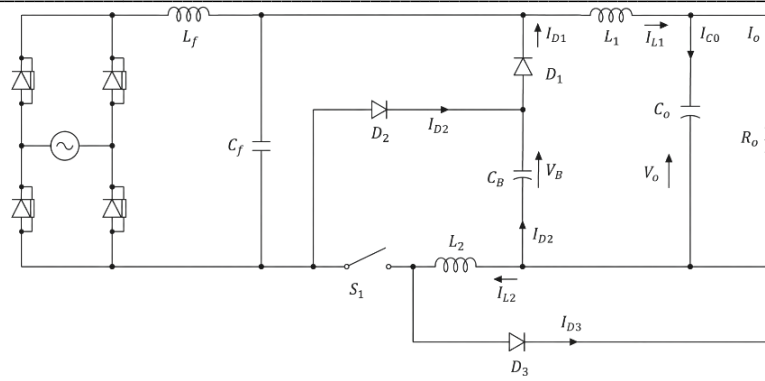
Mode A is initiated when the output and intermediate voltages exceed the instantaneous input voltage. Mode A: Issue with the power factor correction cell. The converter operates in mode B when the instantaneous input voltage exceeds the output and intermediate voltages. Figures 4 (a), (b), and (c) illustrate the three phases of Mode A operation. Figure 5 illustrates the primary waves.

Stage 1: When switch S1 is closed, the capacitor charges L2 through diode D2 [Fig. 4(a)].

Stage 2: S1 opens to release L2 energy to the load, and Co. Diode D3 develops a forward bias (Fig. 4(b)).

Stage 3: The load current is solely supplied by Co when iL2 is entirely depleted, as illustrated in Fig. 4(c).





(c)

Fig. 4 Mode A operation stages

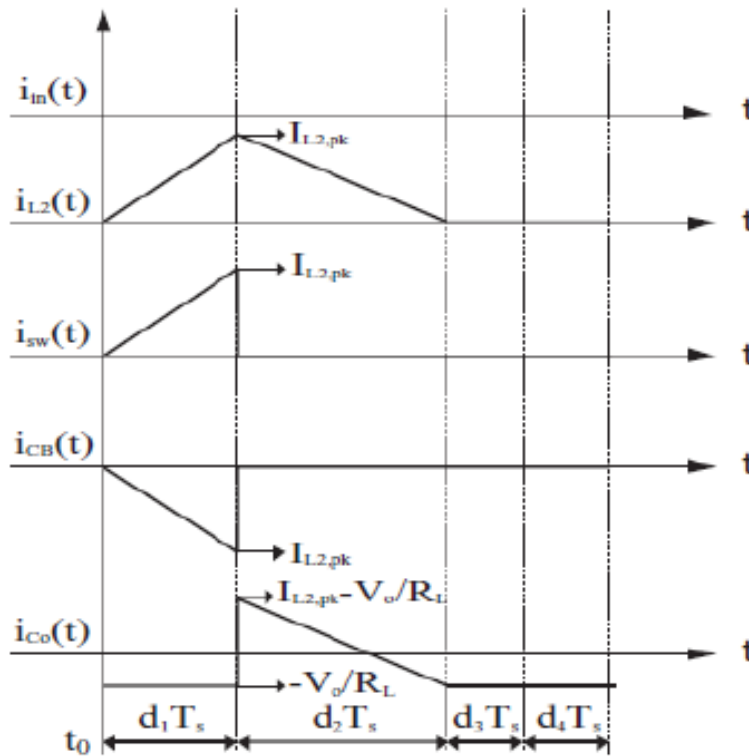


Fig. 5 Mode A key waveforms

The four steps of the mode B function are shown in Images 6 (a), (b), (c), and (d). The most important waves are shown in Figure 7.

Stage 1: When switch S_1 is turned on, the input voltage drops by the total of the output and bus voltages. Consequently, a straight line connects the inductors L_1 and L_2 . The diode D_2 is now working. Look at Picture 6 (a).

Stage 2: When switch S_1 is turned off, the inductor current i_{L1} drops in a straight line, charging capacitors C_B and C_o via diode D_1 . The energy is released right away. At the same time, C_o acquires the energy stored in L_2 . Throughout this phase, the L_2 inductor will continue to operate at full capacity. Look at Picture 6 (b).

Stage 3: As shown in Figure 6(c), the load and the capacitor C_o are powered by the inductor L_1 .

Stage 4: See Fig. 6(d) to understand the role of C_o in sustaining the burden.

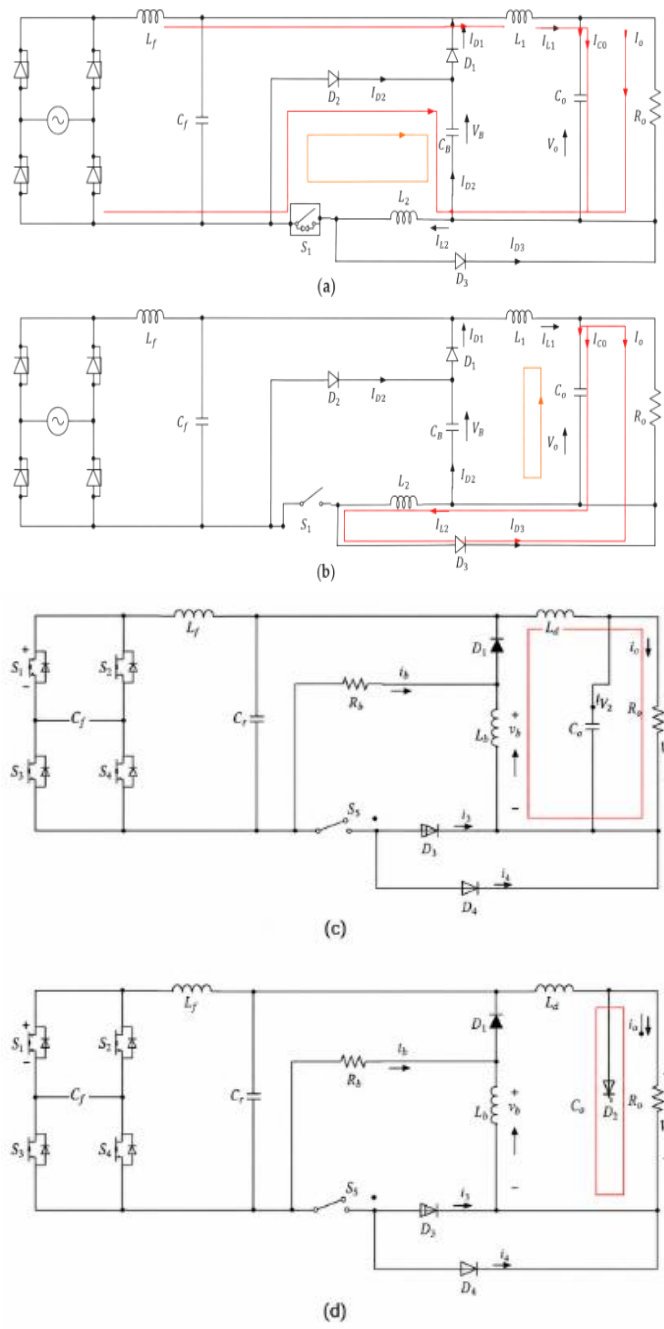


Fig. 6 Mode B operation stages

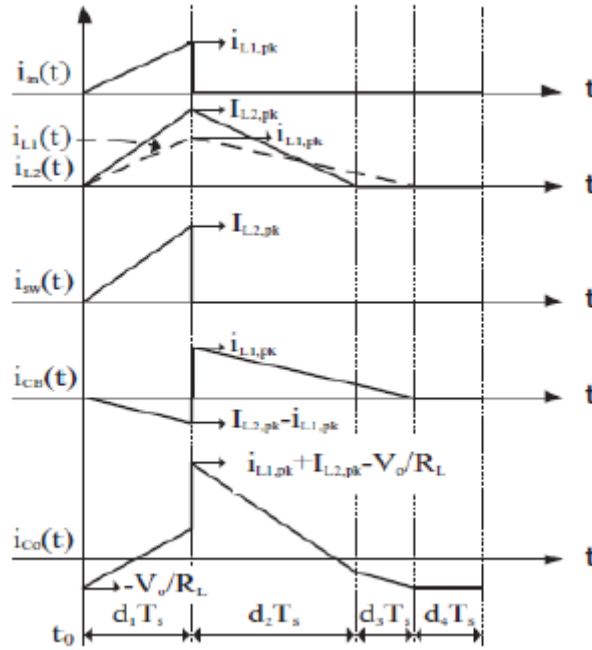


Fig. 7 Mode B key waveforms

The dead times α and β are illustrated in Figure 3.

$$\alpha = \arcsin\left(\frac{V_T}{V_{PK}}\right) \tag{1}$$

$$\beta = \pi - \alpha = \pi - \arcsin\left(\frac{V_T}{V_{PK}}\right) \tag{2}$$

$$\gamma = \beta - \alpha = \pi - 2 \arcsin\left(\frac{V_T}{V_{PK}}\right) \tag{3}$$

Task ratio correlations are demonstrated by volt-second balancing on L1 and L2.

$$d_2 + d_3 = \begin{cases} \frac{v_{in}(\theta) - V_T}{V_T} d_1, & \alpha < \theta < \beta \\ 0, & \text{otherwise} \end{cases} \tag{4}$$

$$d_2 = \frac{V_B}{V_o} d_1 \tag{5}$$

Power factor and intermediate voltage are discussed in Reference [1]:

$$V_B = \frac{M V_{pk}^2}{2\pi(V_B + V_o)} \times \left[\frac{\pi - 2 \arcsin\left(\frac{V_T}{V_{PK}}\right)}{V_{pk}} - \frac{(V_B + V_o) \sqrt{(V_{pk} + V_B + V_o)(V_{pk} - V_B - V_o)}}{2 V_{pk}^2} \right] \tag{6}$$

$$PF = \sqrt{\frac{2}{\pi}} \frac{V_{pk} \left(\frac{\gamma + A}{2} + \frac{A}{4}\right) - V_T B}{\sqrt{V_{pk}^2 \left(\frac{\gamma + A}{2} + \frac{A}{4}\right) - 2 V_{pk} V_T B + \gamma V_T^2}} \tag{7}$$

With A and B values determined by

$$A = \sin 2\alpha - \cos 2\beta \tag{8}$$

$$B = \cos \alpha - \cos \beta \quad (9)$$

The reference voltage closely resembles the converter's output voltage during the adjustment phase. Subsequently, the error signal is transmitted to a PI processor. In order to transmit signals to the switch, the PI processor utilizes a triangular pulse and a control input. The steady-state error is reduced by the controller integrator. The output voltage is regulated by the controller.

4. SIMULATION RESULTS

In order to guarantee that the proposed structure functions as intended, a Simulink model is implemented. The inductance ratio was determined to be $M = 0.4$. The quantity of each chain component is illustrated in Table 1. The following are several critical details regarding the circuit:

- 1) Output power: 100w
- 2) Output voltage: 19Vdc
- 3) Power factor >98%
- 4) Intermediate bus voltage: <100V
- 5) Switching frequency: 20KHz
- 6) Input voltage: 90-270Vrms, 50Hz

Table 1: Circuit Components

Parameters	Values
Input filter inductor Lf	2 mH
Input filter capacitor Cf	2 μF
Inductor L1	106 μH
Inductor L2	46 μH
Diode D1	MUR3040PT
Diode D2	MUR3040PT
Diode D3	MUR3040PT
Capacitor CB	5 mH
Capacitor C0	5 mH

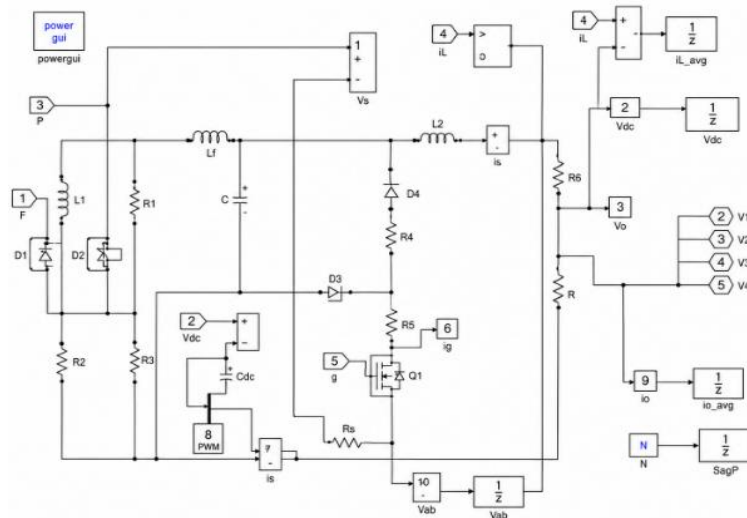


Fig. 8 Simulink model for feedback controlled transformerless single stage ac/dc converter.

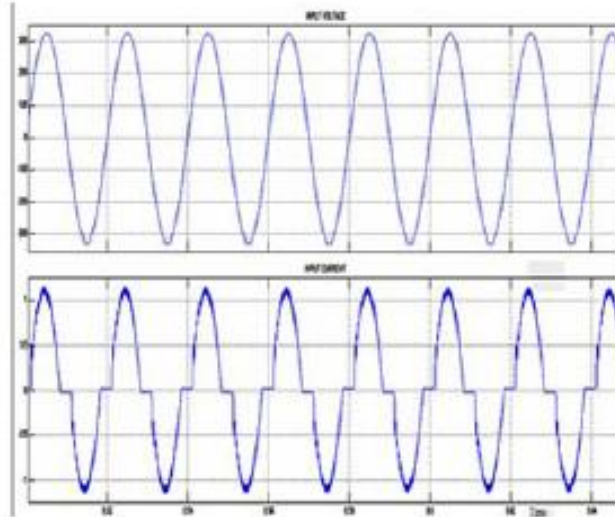


Fig. 9 Input characteristics of the converter

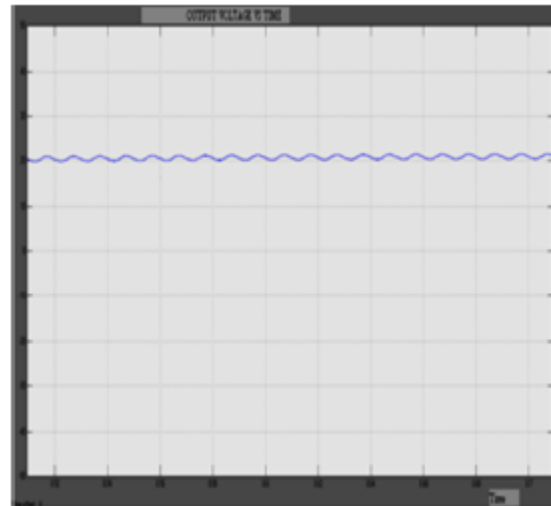


Fig. 10 Output voltage of the converter

The converter's performance and the proposed design were evaluated using a variety of input line conditions. Table 2 illustrates the findings of the investigation.

Table 2: Comparison of Converter Performance

Converter	V_{in}	$V_{\alpha\alpha}$	V_B	Pf
IBuBuBo converter	230	20	99.4	.987
	100	8.84	99.43	.97
Controlled IBuBuBo converter	230	19	95.5	.98
	100	19	39.36	.997

According to a study, the efficacy of power transfer is enhanced by reducing voltage drop, which enables electricity to flow directly from input to output. The proposed design is capable of maintaining a consistent output voltage in the event of fluctuations in the input voltage. As the transmitting angle increases and V_B decreases, the power factor increases.

The output voltage remains constant despite a decrease in the input line voltage due to the controlled converter's optimal power factor and low intermediate bus voltage. The converter's switching and transfer losses are exceedingly low due to its sole switch.

5. CONCLUSION

In conclusion, the transformerless AC-DC converter for low-voltage applications is a highly efficient and advantageous method of producing electricity that is of superior quality, compact, and efficient. The transformer stage is eliminated by the converter, which results in a reduction in weight, a reduction in the system's cost, and the maintenance of consistent voltage and reliable performance in a variety of environments. The recommended configuration is the most suitable for contemporary applications that necessitate energy efficiency and compactness, such as renewable energy interfaces, LED illumination, and consumer electronics. The converter has the potential to significantly improve the safety, efficiency, and durability of low-voltage power transfer systems.

REFERENCES

- [1] Shu-Kong Ki and Dylan Dah-ChuZ, "A High Step-Down Transformerless Single-Stage Single-Switch AC/DC Converter" *IEEE Trans. Power Electron.*, vol. 28, no. 1, January 2013.
- [2] Q. Zhao, F. C. Lee, and F.-s. Tsai, "Voltage and current stress reduction in single-stage power-factor correction AC/DC converters with bulk capacitor voltage feedback," *IEEE Trans. Power Electron.*, vol. 17, no. 4, pp. 477–484, Jul. 2002.
- [3] O. Garcia, J. A. Cobos, R. Prieto, P. Alou, and J. Uceda, "Single phase power factor correction: A survey," *IEEE Trans. Power Electron.*, vol. 18, no. 3, pp. 749–755, May 2003.
- [4] S. Luo, W. Qiu, W. Wu, and I. Batarseh, "Fly boost power factor correction cell and a new family of single-stage AC/DC converters," *IEEE Trans. Power Electron.*, vol. 20, no. 1, pp. 25–34, Jan. 2005.
- [5] D. D. C. Lu, H. H. C. Iu, and V. Pjevalica, "A Single-Stage AC/DC converter With high power factor, regulated bus voltage, and output voltage," *IEEE Trans. Power Electron.*, vol. 23, no. 1, pp. 218–228, Jan. 2008.
- [6] M. K. H. Cheung, M. H. L. Chow, and C. K. Tse, "Practical design and evaluation of a 1 kW PFC power supply based on reduced redundant power processing principle," *IEEE Trans. Ind. Electron.*, vol. 55, no. 2, pp. 665–673, Feb. 2008.
- [7] D. D. C. Lu, H. H. C. Iu, and V. Pjevalica, "Single-Stage AC/DC Boost: Forward converter with high power factor and regulated bus and output voltages," *IEEE Trans. Ind. Electron.*, vol. 56, no. 6, pp. 2128–2132, Jun. 2009.
- [8] H.-Y. Li and H.-C. Chen, "Dynamic modeling and controller design for a single-stage single-switch parallel boost-flyback-flyback converter," *IEEE Trans. Power Electron.*, vol. 27, no. 2, pp. 816–827, Feb. 2012.
- [9] L. Antonio, B. Andrs, S. Marina, S. Vicente, and O. Emilio, "New power factor correction AC-DC converter with reduced storage capacitor voltage," *IEEE Trans. Ind. Electron.*, vol. 54, no. 1, pp. 384–397, Feb. 2007.

-
- [10] E. H. Ismail, A. J. Sabzali, and M. A. Al-Saffar, "Buck–boost-type unity power factor rectifier with extended voltage conversion ratio," *IEEE Trans. Ind. Electron.*, vol. 55, no. 3, pp. 1123–1132, Mar. 2008.
- [11] M. Ryu, J. Baek, J. Kim, S. Park, and H. Kim, "Electrolytic capacitorless, non isolated PFC converter for high-voltage LEDs driving," in *Proc. IEEE Int. Conf. Power Electron. and ECCE Asia*, 2011, pp. 499–506.
- [12] A. A. Badin and I. Barbi, "Unity power factor isolated three-phase rectifier with two single-phase buck rectifiers based on the scott transformer," *IEEE Trans. Power Electron.*, vol. 26, no. 9, pp. 2688– 2696, Sep. 2011.