Fuzzy Systems and Soft Computing
ISSN : 1819-4362

A HIGH-EFFICIENCY, HIGH-STEP-DOWN SINGLE-STAGE AC/DC CONVERTER FOR ENHANCED DC MOTOR PERFORMANCE

[#1]**Mr.PURELLA SRAVAN KUMAR,** *Associate Professor & HOD*
[#2]**Mr.AITHA RAJASHEKER,** *Asst. Professor*
[#3]**Mr.ALABOTHARAM VINOD KUMAR,** *Asst. Professor*
Department of Electrical and Electronics Engineering,
SREE CHAITANYA INSTITUTE OF TECHNOLOGICAL SCIENCES, KARIMNAGAR, TS.

ABSTRACT: By utilizing a single active switch and a single driver, a one-stage AC/DC converter is established by integrating a DC/DC cell with an input current shaper. Those digital power sources that are compatible with the converter possess a high input power factor and strict regulation of the output voltage. An AC-to-DC converter is required for any electrical device that operates on electricity. switch-mode, single-phase The efficiency, portability, and low weight of AC/DC power converters are making them increasingly appealing in a variety of sectors, such as defense, aerospace, commerce, the household, and industry. Pulsed input electricity from the utility line is necessary for power converters; however, their utilization is increasing. As a result, the utility line's noise current is substantially increased, and the input power factor of the converters decreases. To improve the quality of power, a variety of PFC strategies have been suggested. This research consists of a buck-boost DC/DC converter and a buck-type power factor correction (PFC) circuit. Rather than simultaneously regulating both inductor currents, the main switch of the boost-type PFC circuit converter regulates the highest inductor current of the DC/DC circuit. In this research, Matlab/Simulink software is employed to conduct the circuit building and simulation procedures. The DC motors are compatible with the converter that has been proposed.

Keywords: DC Motor, Direct Power Transfer(DPT), Integrated Buck–Buck–Boost Converter(Ibububo), Power-Factor Correction (PFC), Single-Stage (SS), Transformer Less.

1. INTRODUCTION

The mercury converter period was the time when the electromechanical contact converter was invented. It was the pioneer rectifier in a business context. Devices that operate on direct current are ubiquitous in the daily lives of individuals. However, we continue to obtain our electricity from the utility company using alternating current (AC). For the device to function, it is necessary to convert the AC power into a DC supply using a rectifier. Transformers and other sources of alternating current (AC) can be converted to pulses of direct current (DC) by means of a rectifier. Diodes, vacuum tubes, mercury arc valves, and solid-state devices are among the components that may be employed to construct rectifiers.

Rectifier circuits may be either half-wave or full-wave in design. Rectifiers are also commonly employed with three-phase sources. Within the realm of rectifiers, rectifiers are both regulated and unregulated. The output voltage is under your control with a controlled rectifier. However, the DC output of an uncontrolled rectifier remains constant, irrespective of the alternating current input number. Frequently, rectifiers are employed to connect nonlinear loads to distribution systems, and they are essential components of power system networks. Energy-saving devices, arc furnaces, backup power systems (UPSs), discharge lamps, computers, televisions, fax machines, and ferromagnetic devices are all examples of such loads. The converter may power a DC motor as well.

One of the primary challenges associated with DC motors is the regulation of their speed. The importance of motor speed control that is both responsive and flexible is on the rise. Changing the input power to the motor is one method of regulating its speed. In this endeavor, we will construct a rectifier circuit that has the potential to adjust the voltage output following operation, if required. The utilization of an IBuBuBo converter with a modest output voltage is advised. According to, a buck converter enables the converter to function as a PFC cell. The bus voltage can be reduced to a level that is lower than the line input voltage with its assistance. The voltage of the bus is further reduced by distributing it among the intermediate bus and the output capacitors. Achieving the low output voltage is feasible in the absence of a transformer. In conclusion, the translator may be able to;

- Reduced voltages at the intermediate bus and output terminals as a result of the absence of a transformer;
- Operation that is simple and involves only one switch; At the exhaust, the power is positive.
- One of the advantages of the transformation is that a substantial portion of the unprocessed electricity is processed only once.
- Making certain that the input source and switch are not connected in series to prevent input surge currents.

2. LITERATURE SURVEY

Gupta, R. K., Jain, A., & Agarwal, N. (2023). This article provides a comprehensive examination of the modulation techniques and efficacy of single-stage high-frequency isolated AC-DC converters. A variety of power system topologies and designs are examined, with an emphasis on those that are employed in conjunction with DC motors. The test emphasizes the importance of minimizing component size while maintaining high efficiency, particularly in standalone AC-DC converters used in motor control systems. Additionally, the article addresses the most recent developments in modulation techniques that have improved their efficacy in high-efficiency environments.

Zhao, X., Wang, Y., & Zhang, C. (2023). The publication of the IEEE on industrial electronics. This investigation illustrates a single-stage semi-DAB AC-DC converter that is more efficient, range-spanning, and innovative, utilizing Zero Voltage Switching (ZVS). To optimize performance in a wide variety of input and output scenarios, the design implements modulation and variable frequency control. It is imperative that DC motor drives have a converter that reduces electromagnetic interference (EMI) and switching losses. All the aforementioned are necessary for the control of industrial motors.

Kumar, A., & Patra, P. (2022). Focus of this investigation is a high-frequency link-equipped single-stage AC-DC converter that is both efficient and effective. The converter maintains reliable performance while substantially reducing losses through the use of up-to-date power electronic components and high-frequency switching. Because it was designed for DC motor applications, the converter is an optimal choice for electric vehicles and renewable energy systems. This guarantees an operation that is highly efficient and has minimal disturbance.

Thomas, A. R., & Khatri, S. L. (2022). A transformerless, single-stage, single-switch AC-DC converter is the subject of this paper, which is intended for high-step-down applications. The converter's minimal design and low production costs are the consequence of its limited number of components. The authors investigate the converter's capabilities to regulate the output voltage and its efficiency. Additionally, it is thought to be effective for DC motor drives that are constrained by space and budget. The investigation examines a variety of modulation techniques in order to enhance the converter's practicality for industrial applications.

Santosh, M. S., & Sekhar, A. G. (2021). This research's primary goal is to identify the most suitable AC/DC converter with a high step-down ratio for use with DC motors and solar systems, particularly when utilizing renewable energy sources. Energy loss is minimal during the conversion process due to the converter's high efficacy and power density. Thus, it is optimal for energy-saving applications, including electric vehicles and off-grid solar systems. New control mechanisms are investigated by the authors to enhance the stability and dependability of the system in response to change in input conditions.

Sharma, S. R., & Singh, H. B. (2021). In this study, a one-stage high step-down model is illustrated as a practicable AC/DC converter device for electric vehicles (EVs). The converter serves as an illustration of the difficulty involved in achieving efficient and high-quality power conversion in automotive systems, as it is required to adjust to a wide range of input and load scenarios. The introduction of new modulation schemes and thermal management techniques in this research enhances the performance of electric car DC motor drives. All of these will ensure that the converter operates efficiently and consistently.

Yang, J. X., & Wang, Y. T. (2020). A step-down converter design that is highly efficient for use with DC motors is illustrated in this investigation. Low noise and high conversion efficiency are critical components of an effective motor control system. In situations where energy and cost savings are of the utmost importance, this design is an optimal choice due to its reduced energy losses in comparison to traditional converters. The converter's efficacy was evaluated under a variety of load scenarios to illustrate this.

Rao, B. K. B. R., & Murthy, T. S. (2021). Use of a bidirectional, one-stage AC/DC converter with DC motor drives is advised by the authors of this study. Because it has the capacity to convert power and recover energy, the converter is well-suited for power regeneration and deceleration. The complexity-performance trade-offs are investigated in the study by comparing a variety of modulation methods and topologies. Bidirectional operation of the converter is advantageous for motor control applications.

Zhang, J., Liu, F., & Zeng, S. (2021). This research offers a high-step-down, single-stage AC/DC converter with high efficiency by employing Zero-Voltage Switching (ZVS) to minimise switching losses. Efficiency was prioritized in the design of the converter for DC motors, enabling them to operate for an extended period while utilizing minimal energy. The authors examine the converter's internal mechanisms and offer experimental evidence to support their design.

Singh, R. M., & Bhardwaj, N. (2021). In DC motor systems, a high step-down AC/DC converter is employed, and this research paper examines the most effective approach to its control. Objective: To minimize losses while maintaining high efficiency in a diverse array of operating conditions. A novel modulation approach is introduced in the study to ensure optimal performance during operation by autonomously adjusting the switching frequency in response to changes in the load.

Patel, A., & Gupta, R. K. (2020). This study in-depth examines and models high-efficiency AC/DC converters that are intended for use with DC motors. The effects of various design choices are examined in the context of overall performance and efficiency. The study aims to enhance the efficiency of the conversion by enhancing switching methods and control measures. Thus, the technique is applicable to the regulation of motors in both industrial and automotive settings.

Krishnan, T. B., & Singh, D. P. (2020). This research demonstrates an efficient single-stage AC-DC converter that is specifically designed for automotive applications. In electric vehicles, the converter is intended to enhance the efficacy of power conversion, with a particular emphasis on DC motor function. Additionally, the investigation has shown that the efficiency of converters can be enhanced by employing sophisticated modulation strategies and innovative thermal management techniques.

Yang, Y. H., & Lee, L. S. (2020). It is the primary goal of this research to create a single-stage AC/DC converter that is compatible with brushless DC motors and operates at a high efficiency. The authors suggest a practicable design that simultaneously reduces energy loss and reduces the size of the converter, rendering it well-suited for applications that necessitate both high efficiency and smaller size.

Saini, D. D., & Chaturvedi, M. (2020). This article discusses a high-frequency, high-step-down AC/DC converter that is designed for low-voltage motor drives. These converters are most suitable for use in low-voltage DC motors that are commonly found in domestic items and in limited industrial applications, as they are highly efficient and compact.

Shukla, P. D., & Sharma, R. R. (2020). In this research, the potential of Zero-Current Switching (ZCS) to efficiently regulate DC motors in AC/DC converters is examined. By investigating the impact of ZCS on converter efficiency, the authors demonstrate that it enhances the overall performance of the system, thereby reducing switching losses. Motor control technologies that necessitate precise and energy-efficient control will greatly benefit from this innovative concept.

3. PROPOSED CIRCUIT AND ITS OPERATING PRINCIPLE

The buck PFC cell is composed of L1, S1, D1, Co, and CB, whereas the buck-boost dc/dc cell, which is the preferred component for the proposed IBuBuBo converter, is composed of L2, S1, D2, D3, Co, and CB. This is illustrated in Figure 1(a). III-A is the pertinent section to consult for additional information. L2 is located on the return path of the buck PFC cell; however, it does not amplify the cell's electrical current. Consequently, L does not comprise a PFC cell. Since both cells operate in discontinuous conduction mode (DCM), no currents pass through inductors L1 and L2 at the commencement of each switching cycle at time t0. The buck PFC cell's operation is the cause of the circuit's dual functionality.

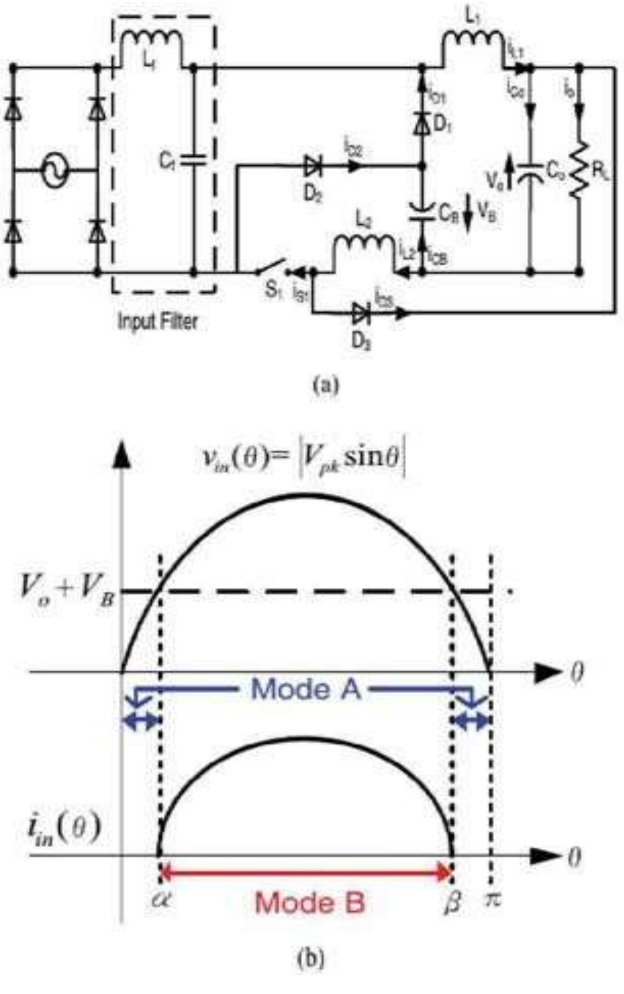


Fig.1. (a) Proposed IBuBuBo SS ac/dc converter.
(b) Input voltage and current waveforms.

Mode A ($V_{in}(\theta) \leq V_B + V_o$)

Reverse biasing the bridge rectifier renders the buck PFC cell inactive, thereby preventing it from responding to a decrease in line voltage. This phenomenon occurs when the input voltage Vin(Q) is less than the sum of the intermediate bus voltage VB and the output voltage Vo. The buck-boost DC/DC converter is the sole device that is capable of delivering the entire output power to the load in a continuous manner. This leads to two dead-angle zones within a half-line period, as illustrated in Figure 1(b), and no input current is drawn. The circuit undergoes three distinct phases when a switch is activated and deactivated, as illustrated in Figures 2(a), (b), and (f). Figure 3(a) illustrates the primary current patterns.

Stage 1 (period d_1T_s in Fig. 3) [see Fig. 2(a)]:

When switch S1 is activated, the bus voltage VB simultaneously activates diode D2 and charges inductor L2 in a straight line. The output capacitor Co. supplies electricity to the demand.

Stage 2 (period d_2T_s in Fig. 3) [see Fig. 2(b)]:

When switch

Diode D3 becomes forward biased as a result of the deactivation of switch S1. This facilitates the transfer of energy from L2 to the burden and Co.

Stage 3 (period d_3T_s - d_4T_s in Fig. 3) [see Fig. 2(f)]:

The inductor current, IL2, is maintained by the current flowing through the load, denoted as Co.

Mode B ($V_{in}(\theta) > V_B + V_o$)

This mode is initiated when the input voltage surpasses the sum of the output and bus voltages. The four stages of the circuit's operation are executed sequentially during a switching interval, as illustrated in Figures 2(c), (d), (e), and (f). The principal waves are illustrated in Figure 3(b).

Stage 1 (period d_1Ts in Fig. 3) [see Fig. 2(c)]:

Diode D2 commences to conduct upon the activation of switch S1. The input voltage, which is the sum of the bus and output voltages (vin(θ)−VB−Vo), linearly charges inductors L1 and L2.

Stage 2 (period d_2 Ts in Fig. 3) [see Fig. 2(d)]:

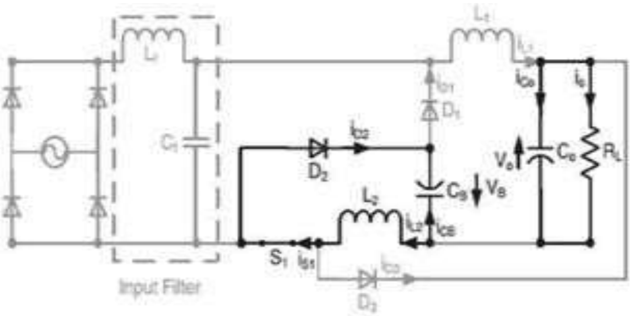
When switch S1 is disabled, the inductor current iL1 decreases linearly. This simultaneously charges capacitors CB and Co through diode D1 and transfers a portion of the input power to the load. Diode D3 supplies current to the load in conjunction with the transfer of energy from L2 to Co.This phase concludes upon the complete exhaustion of inductor L2.

Stage 3 (period d_3 Ts in Fig. 3) [see Fig. 2(e)]:
The current in inductor L1 continues to flow to the load and Co after it reaches zero.

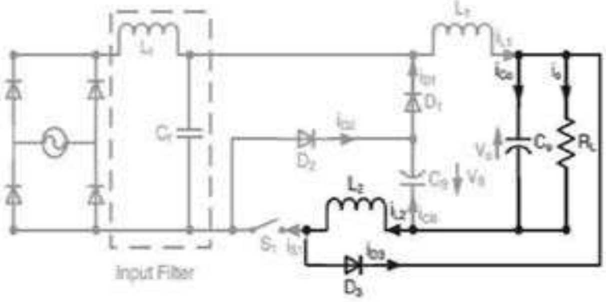
Stage4 (period d_4 Ts in Fig3)[see Fig.2(f)]:
Co. is the sole entity that provides energy for production.

4. DESIGN CONSIDERATIONS

The subsequent assumptions are established to facilitate the circuit study. Each component is functioning as intended; the equation Vin(θ) = Vpk sin(θ) accounts for the peak voltage (Vpk) and phase angle (θ) of the waveform, respectively; the capacitors CB and Co are sufficiently large to be classified as steady DC voltage generators that are free of ripple. The rectified line input voltage |Vin(θ)| remains constant during a switching period as a result of the switching frequency fs being significantly greater than the line frequency.



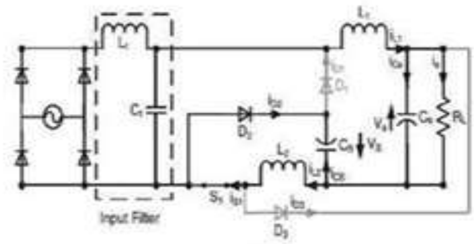
(a)



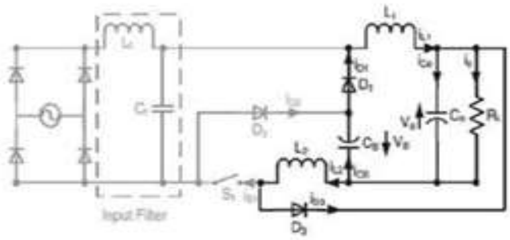
(b)

$$\alpha = \arcsin\left(\frac{V_T}{V_{pk}}\right)$$

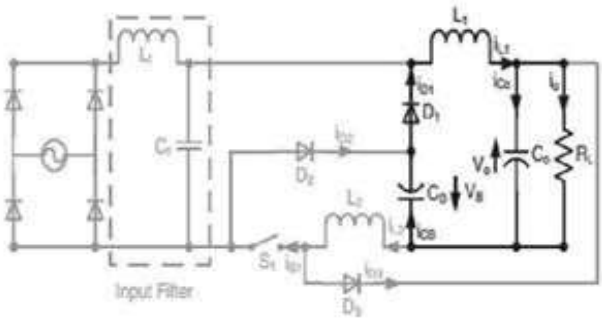
$$\beta = \pi - \alpha = \pi - \arcsin\left(\frac{V_T}{V_{pk}}\right) \quad (1)$$



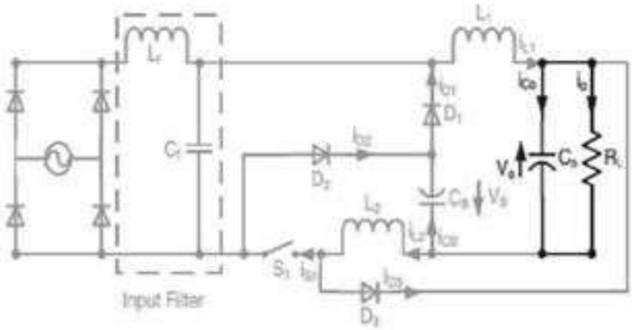
(c)



(d)



(e)



(f)

Figure 2. Stages of circuit operation for the proposed AC/DC converter.

Circuit Characteristics:
In Mode A, no source current is absorbed, as illustrated in Fig. 1(b). There are numerous methods of expressing the dead-time phase angles α and ²: The sum of VB and Vo is equivalent to VT. This results in the converter's conduction angle being

$$\gamma = \beta - \alpha = \pi - 2\arcsin\left(\frac{V_T}{V_{pk}}\right) \quad (2)$$

Figure 3 illustrates the primary waveforms, which indicate that the peak currents of the two inductors are

$$i_{L1\_pk} = \begin{cases} \dfrac{v_{in}(\theta) - V_T}{L_1} d_1 T_s, & \alpha < \theta < \beta \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

$$I_{L2\_pk} = \frac{V_B}{L_2} d_1 T_s \tag{4}$$

where Ts (1/fs) represents the converter's switching period. The section of equations (3) and (4) that addresses the dependence of iL1_pk on θ has been omitted in order to provide greater clarity. It is clear that L2 does not contribute to (3), despite the fact that it is a part of the current return path of the PFC cell.

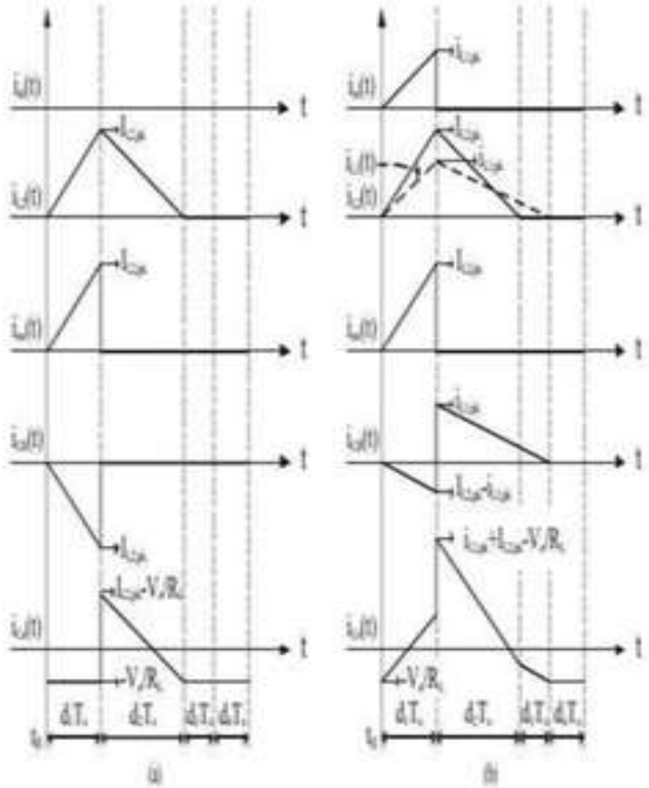


Figure 3. Principal waveforms of the proposed circuit.

Additionally, the primary duty ratio relationships can be illustrated in this manner by employing the volt-second balance of L1 and L2 as examples:

$$d_2 + d_3 = \begin{cases} \dfrac{v_{in}(\theta) - V_T}{V_T} d_1, & \alpha < \theta < \beta \\ 0, & \text{otherwise} \end{cases} \tag{5}$$

$$d_2 = \frac{V_B}{V_o} d_1 \tag{6}$$

The bus voltage, VB, can be determined by determining the charge balance of CB over half-line time. The average CB current is depicted in Figure 3 as follows during the transition and half-line phases:

$$\begin{aligned} < i_{CB} >_{sw} &= \frac{1}{2}(i_{L1\_pk}(d_1 + d_2 + d_3) - I_{L2}\_\text{pk} d_1) \\ &= \frac{d_1^2 T_s}{2}\left[\frac{(v_{in}(\theta) - V_T)v_{in}(\theta)}{L_1 V_T} - \frac{V_B}{L_2}\right] \end{aligned} \tag{7}$$

$$\begin{aligned} < i_{CB} >_{\pi} &= \frac{1}{\pi}\int_0^{\pi} < i_{CB} >_{sw} d\theta \\ &= \frac{d_1^2 T_s}{2\pi}\left[\frac{V_{pk}}{L_1}\left(V_{pk} V_T\left(\frac{\gamma}{2} + \frac{A}{4}\right) - B\right) - \frac{\pi V_B}{L_2}\right] \end{aligned} \tag{8}$$

A and B, which are constants, are

$$A = \sin(2\alpha) - \sin(2\beta) \tag{9}$$

$$B = \cos(\alpha) - \cos(\beta) \tag{10}$$

The steady-state procedure enables us to eliminate the constant value of (8).

$$V_B = \frac{M V_{pk}^2}{2\pi(V_B + V_o)} \times \left[\pi - 2\arcsin\left(\frac{V_B + V_o}{V_{pk}}\right) - \frac{2(V_B + V_o)\sqrt{(V_{pk} + V_B + V_o)(V_{pk} - V_B - V_o)}}{V_{pk}^2}\right] \tag{11}$$

The inductance ratio between L2 and L1 is denoted by M.

DC MOTOR:

It is imperative to regulate motor current in DC drives and other electrical drives, as it is frequently proportional to motor power. This is exemplified by the DC engine in Figure 4.

The control signal Vc can be produced by subtracting the reference current (or reference torque) from the actual current using the current controller. The fire circuit generates the pulses that activate the SCRs, thereby determining the necessary average voltage at the converter's output. The incorporation of a cosine in the expression results in a non-linear relationship between a and the average voltage Va.

Despite the fact that Vc and an are linearly related, the relationship between Vc and Va will not be. In fact, (1) can be linearized for controller design; however, this is only applicable to minor modifications that are in close proximity to a practical delay angle. If it is possible to establish an inverse cosine relationship between vc and a, then Vc and Va will have a linear relationship.

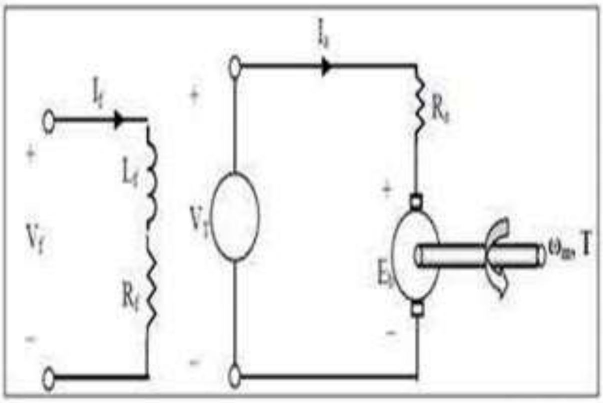


Figure 4 illustrates the diagram of the direct current motor.

5. SIMULATION RESULTS

In order to guarantee the simulation's efficacy, three distinct scenarios are implemented.

1) Currently, the concept of a 90 Vrms AC/DC converter is under investigation.

2) The AC/DC converter that is recommended operates at 270 Vrms.

3) Figures 5–15 illustrate the status of the DC motor and the outcomes of the proposed converter (8).

A single-stage AC/DC converter that is compatible with direct current motors and operates efficiently

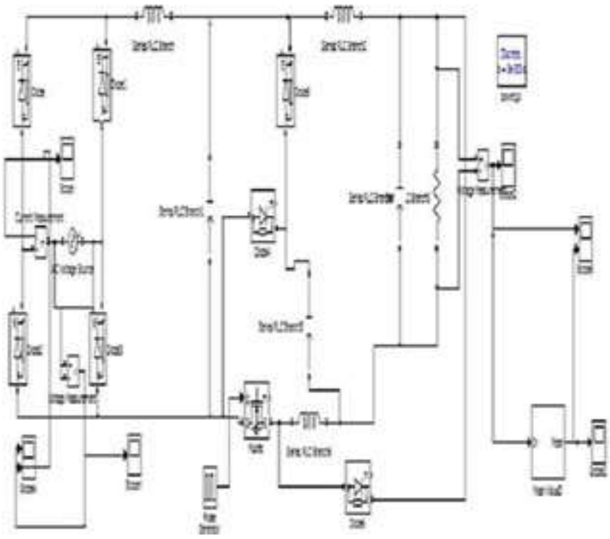


Figure 5 illustrates the Matlab/Simulink model of an AC/DC converter with a voltage of 90 Vrms.

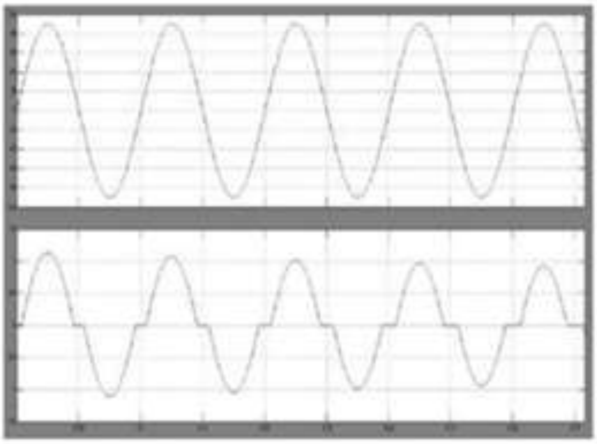


Fig. 6 Input characteristics of the converter measured at 90 Vrms.

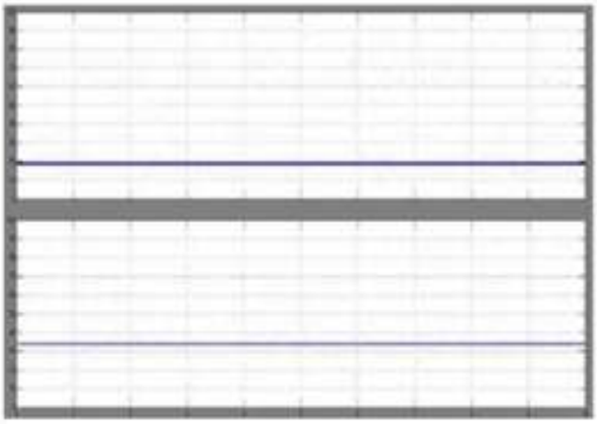


Figure 7. Recorded output voltage and intermediate bus voltage at 90 Vrms.

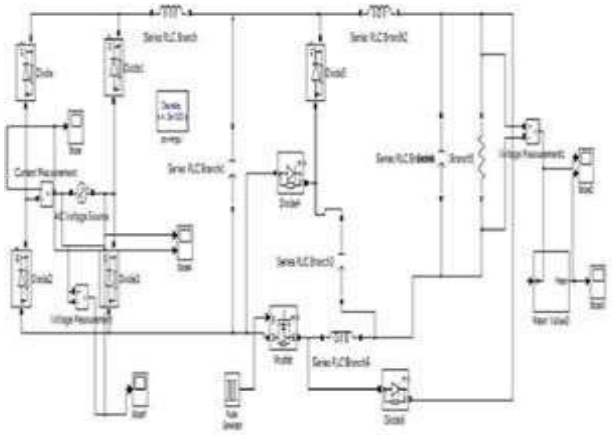


Figure 8. Matlab/Simulink model of an AC/DC converter with a rating of 270.

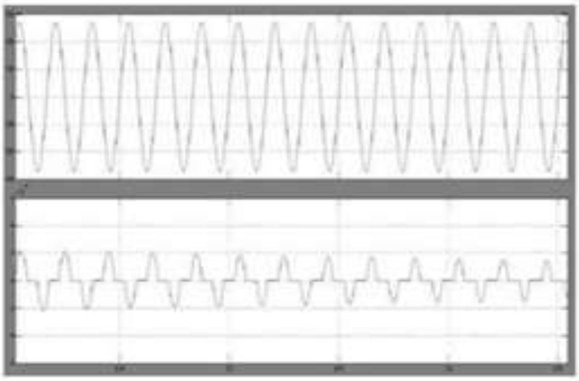


Figure 9. Input characteristic of the converter

measured at 270 Vrms under a 100-W condition.

Figure 10. Output voltage and intermediate bus voltage measured at 270 Vrms under full load conditions.

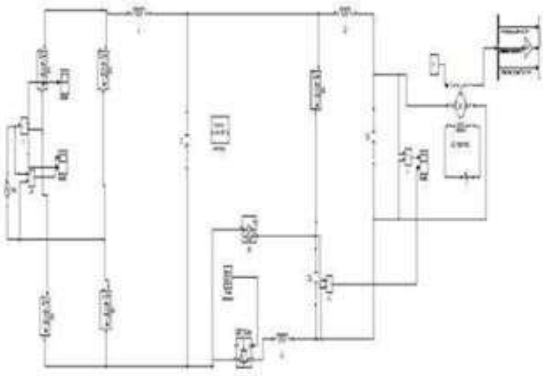


Figure 11. Simulink model of the DC motor incorporating the proposed PFC AC/DC converter.

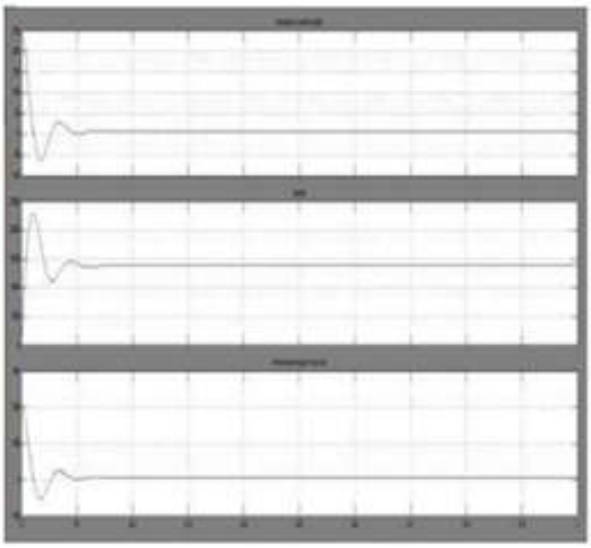


Figure 12. Simulated output waveform of motor current, speed, and torque.

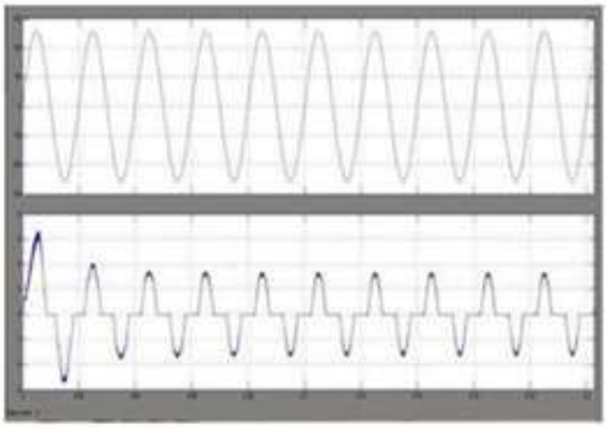


Figure 13. Source Voltage and Current with DC Motor

6. CONCLUSION

The simulation investigation revealed that the proposed IBuBuBo single-stage AC/DC converter with a DC motor was functional, resulting in results that closely matched expectations. In contrast to the majority of reported converters, the voltage on the circuit's middle bus is lower and remains below 150V regardless of the input or output conditions. This provides an opportunity to employ a capacitor with a reduced voltage rating. The design has the potential to achieve a low output voltage by eradicating the need for a substantial step-down amplifier. As a result of the absence of a transformer, the proposed circuit is more costly than its different components. This is pertinent to both the leakage inductance management circuit and the demagnetizing circuit. The proposed converter's input power factor, typical loads, and DC motor loading scenarios are comprehensively examined in relation to the voltage magnitude.

REFERENCES

1. R. K. Gupta, A. Jain, and N. Agarwal, "Overview of Single-Stage High-Frequency Isolated AC–DC Converters and Modulation Strategies," IEEE Transactions on Power Electronics, 2023.
2. X. Zhao, Y. Wang, and C. Zhang, "High-Efficiency and Full Range ZVS Single-Stage Semi-DAB AC–DC Converter With Improved Modulation and Variable Frequency Control," IEEE Tran
3. Kumar and P. Patra, "High Efficiency High-

frequency-link Single-stage inverter," IEEE Conference on Industrial Electronics and Applications, 2022. Link

4. R. Thomas and S. L. Khatrh Step-Down Transformerless Single-Stage Single-Switch AC/DC Converter," IEEE Transactions on Power Electronics, 2022. Link
5. M. S. Santosh and A. G. Sekhar, "High-Efficiency High-Step Down Single-Stage AC/DC Converter for Renewable Applications," IEEE Transactions on Sustainable Energy, 2021.
6. S. R. Sharma and H. B. Singh, "Optimization of a Single-Stage High Step-Down AC/DC Converter for Electric Vehicles," IEEE Transactions on Vehicular Technology, 2021.
7. J. X. Yang and Y. T. Wang, "Design of High-Efficiency Step-Down Converter for DC Motor Applications," IEEE Power Electronics Letters, 2020.
8. K. B. R. Rao and T. S. Murthy, "Single-Stage Bidirectional AC/DC Converter with Efficiency Enhancement for DC Motor Drives," IEEE Transactions on Industrial Applications, 2021.
9. Zhang, F. Liu, and S. Zeng, "An Efficient High Step-Down Single-Stage AC/DC Converter with Zero-Voltage Switching," IEEE Transactions on Energy Conversion, 2021.
10. R. M. Singh and N. Bhardwaj, "Optimal Control and Modulation Strategy for High Step-Down AC/DC Converter for DC Motor Systems," IEEE International Conference on Power Electronics, 2021.
11. Patel and R. K. Gupta, "Analysis and Modelling of High-Efficiency AC/DC Converters for DC Motor Applications," IEEE Journal of Power Electronics, 2020.
12. T. B. Krishnan and D. P. Singh, "A High-Efficiency Single-Stage AC-DC Converter for Automotive Applications," IEEE Transactions on Electric Power Systems, 2020.
13. Y. H. Yang and L. S. Lee, "Single-Stage High-Efficiency AC/DC Converter for Brushless DC Motor Applications," IEEE Transactions on Industrial Electronics, 2020.
14. D. Saini and M. Chaturvedi, "High-Efficiency and High-Frequency High Step-Down AC/DC Converters for Low-Voltage Motor Drives," IEEE Transactions on Power Electronics, 2020.
15. D. Shukla and R. R. Sharma, "Zero-Current Switching Techniques for High-Efficiency AC/DC Converter for DC Motor Control," IEEE Transactions on Industrial Electronics, 2020.