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Comparative Analysis of SEPIC and Buck Converter-Fed PMBLDC Motor Drive for Power Factor Correction and Speed Regulation

[1]Akash Ganesh Bhople, [2]Dr. Vijayalaxmi Biradar, [3]Dr. Anant G. Kulkarni

[1](PhD Research Scholar), Department of Electrical Engineering, Kalinga University, Raipur, India
Email: akashgbhople45@gmail.com

[2](PhD Supervisor), Department of Electrical Engineering, Kalinga University, Raipur, India
Email: iqac@kalingauniversity.ac.in

[3](PhD Co-Supervisor), Principal, Siddhivinayak Technical Campus, Shegaon, India
Email: dranantgkulkarni@gmail.com

Abstract: This paper presents a comparative analysis of SEPIC (Single-Ended Primary-Inductor Converter) and Buck converter-fed Permanent Magnet Brushless DC (PMBLDC) motor drives, focusing on efficiency, voltage regulation, ripple performance, and application suitability. A voltage follower approach in discontinuous conduction mode (DCM) is employed for speed regulation. The Buck converter excels in step-down applications with high efficiency, whereas the SEPIC converter offers bidirectional voltage conversion (step-up/step-down) with continuous input current, enhancing power quality. MATLAB/Simulink simulations validate the performance of both converters under varying load conditions. Results demonstrate that the SEPIC converter provides superior voltage regulation and reduced input current ripple, making it ideal for applications with fluctuating input voltages, such as renewable energy systems and battery-powered devices. In contrast, the Buck converter is more efficient for stable step-down requirements in low-voltage motor drives. The study provides key insights for selecting the optimal converter topology based on design constraints and operational requirements.

Keywords: SEPIC Converter, Buck Converter, PMBLDC Motor, Power Factor Correction (PFC), PWM Control, Voltage Regulation, MATLAB/Simulink.

1. Introduction

DC-DC converters are integral to modern power electronics, enabling efficient voltage regulation in applications such as motor drives, renewable energy systems, and portable electronics. Among these, Buck and SEPIC converters are widely adopted due to their distinct operational advantages. The Buck converter is a preferred choice for step-down voltage conversion due to its simplicity and high efficiency. In contrast, the SEPIC converter provides greater flexibility with both step-up and step-down capabilities while maintaining continuous input current, reducing electromagnetic interference (EMI).

This study evaluates the performance of Buck and SEPIC converters in driving a PMBLDC motor, emphasizing:

- Efficiency: Buck converters exhibit lower conduction losses, whereas SEPIC converters suffer additional losses due to passive components.
- Voltage Regulation: SEPIC converters dynamically adjust output voltage, making them suitable for variable input

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conditions.

- Ripple Performance: SEPIC's continuous input current minimizes ripple, improving electromagnetic compatibility (EMC).
- Application Suitability: Buck converters are optimal for fixed step-down applications (e.g., microcontroller power supplies), while SEPIC converters excel in battery-powered and renewable energy systems.

The paper is structured as follows: Section 2 compares Buck and SEPIC converter topologies, Section 3 discusses control methodologies, Section 4 analyzes design factors, Section 5 presents simulation results, and Section 6 concludes with recommendations.

2. Comparison of Buck and SEPIC PFC Converters

2.1 Buck Converter

The Buck converter is a step-down DC-DC converter that reduces the input voltage to a lower output voltage using a switch, inductor, diode, and capacitor. The output voltage depends on the duty cycle of the switching operation. Its simple design and high efficiency make it suitable for applications requiring a stable lower-voltage supply.

2.2 Control of a Buck Converter Fed BLDC Motor

2.2.1 PWM Control

Pulse Width Modulation (PWM) is used to regulate the output voltage of the Buck converter. By varying the duty cycle of the switching signal, the average voltage supplied to the motor can be adjusted. A higher duty cycle results in a higher output voltage, while a lower duty cycle reduces the voltage, enabling precise speed control of the BLDC motor.

2.2.2 Voltage Control

To maintain a stable voltage supply, a feedback control loop is implemented. The actual DC link voltage is sensed and compared with a reference voltage. A proportional-integral (PI) controller processes the error signal and generates the required PWM control signal to adjust the duty cycle of the Buck converter. This ensures a consistent and regulated power supply to the BLDC motor.

2.2.3 Speed Regulation

The speed of the BLDC motor is directly proportional to the applied voltage. By controlling the output of the Buck converter, the motor speed can be efficiently regulated. A speed controller is implemented by sensing the motor speed using Hall effect sensors and adjusting the PWM signal accordingly to maintain the desired speed under varying load conditions.

2.3 SEPIC Converter

The Single-Ended Primary-Inductor Converter (SEPIC) topology allows both step-up and step-down voltage conversion. It consists of two inductors, a capacitor, a diode, and a switch. Unlike the Buck converter, the SEPIC converter maintains a continuous input current, reducing ripple and enhancing power quality. This makes it suitable for sensitive applications such as LED drivers and battery-powered systems.

2.4 Control of a SEPIC Converter Fed BLDC Motor

2.4.1 Reference Voltage Generation

A reference voltage proportional to the desired motor speed is generated. This voltage (Vdc*) is obtained by multiplying the speed with a constant known as the motor voltage constant (Kb). It is then compared with the actual DC link voltage (Vdc) to regulate the speed.

2.4.2 Voltage Controller

The difference between Vdc* and Vdc is processed through a proportional-integral (PI) controller, which generates a control signal to compensate for voltage fluctuations. The PI controller parameters (Kp and Ki) are fine-tuned using MATLAB Simulink to optimize performance.

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2.4.3 PWM Generation

The output of the PI controller (Vc) is fed into a PWM generator, which modulates the duty cycle of the SEPIC converter. A sawtooth waveform is compared with Vc to generate a switching signal for the MOSFET, controlling the power flow to the motor.

2.4.4 Electronic Commutation

The BLDC motor operates using a Voltage Source Inverter (VSI) and a trapezoidal Permanent Magnet AC (PMAC) motor. The stator windings are sequentially excited based on rotor position, which is detected via Hall effect sensors. The switching sequence for different rotor positions is implemented using a truth table, ensuring optimal commutation for smooth operation.

3. Factors Affecting Design and Development

3.1 Efficiency

The Buck converter is highly efficient due to its simple design and minimal power losses. In contrast, the SEPIC converter contains additional passive components, which contribute to higher conduction losses and affect overall efficiency.

3.2 Voltage Regulation

The Buck converter provides excellent voltage regulation for step-down applications but lacks the flexibility to handle varying input conditions. On the other hand, the SEPIC converter can dynamically adjust the output voltage, making it more suitable for applications with fluctuating input voltage.

3.3 Ripple Performance

The SEPIC converter maintains a continuous input current, reducing ripple and improving electromagnetic compatibility (EMC). In contrast, the Buck converter may exhibit higher input ripple, necessitating additional filtering in noise-sensitive applications.

3.4 Suitability for Applications

The Buck converter is ideal for applications requiring a stable step-down voltage, such as power supplies for low-voltage microcontrollers. Meanwhile, the SEPIC converter is preferred in battery-powered systems and renewable energy applications where input voltage varies significantly.

2. Circuit Description:

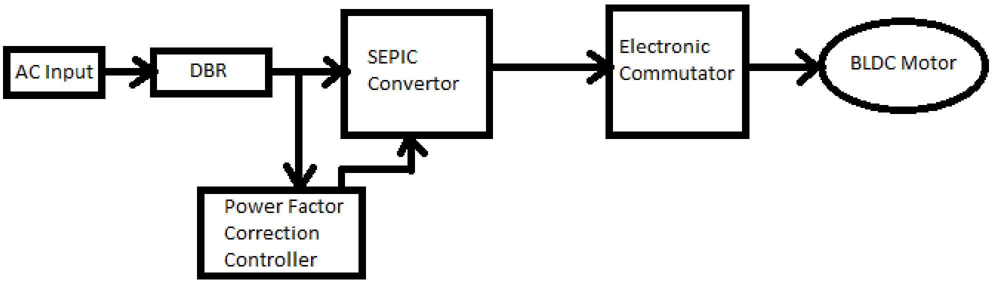

Fig. 1 SEPIC fed BLDC Motor

4.1 Working of a SEPIC Converter Fed BLDC Motor

The single-phase AC supply is first converted into DC using a diode bridge rectifier (DBR). However, the rectified voltage may be unregulated and contain ripples. To address this, a Single-Ended Primary Inductor Converter (SEPIC) is used to regulate the DC voltage by either stepping it up or down, ensuring a stable DC link voltage suitable for Voltage Source Inverter (VSI) operation.

The regulated DC output from the SEPIC converter is then fed into the VSI, which converts it into a three-phase AC supply

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to drive the Brushless DC (BLDC) motor. The BLDC motor operates based on electronic commutation, where Hall effect sensors detect the rotor position and send signals to the inverter. This allows the VSI to control the switching sequence, ensuring smooth rotation and efficient motor performance.

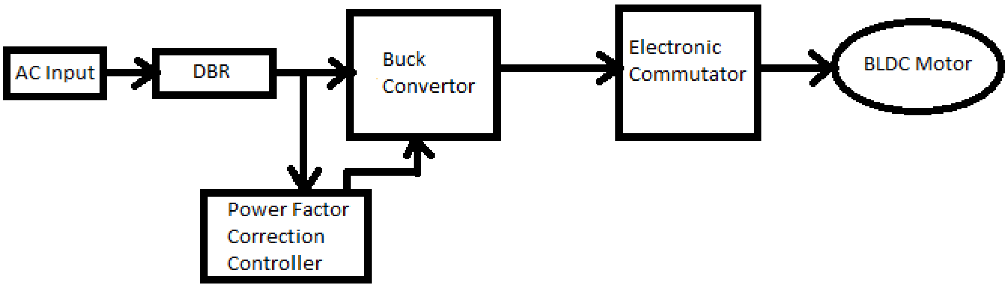

Fig. 2 SEPIC fed BLDC Motor

4.2 Working of a Buck Converter Fed BLDC Motor

A Buck converter steps down the input DC voltage to a desired lower level suitable for driving a Brushless DC (BLDC) motor. It consists of a power switch (MOSFET/IGBT), a freewheeling diode, an inductor, and a capacitor. The operation is controlled by adjusting the duty cycle of the PWM signal applied to the switching device.

The regulated output voltage from the Buck converter ensures efficient operation of the BLDC motor by minimizing losses and enhancing performance. This controlled voltage supply optimizes motor efficiency, improves reliability, and contributes to overall system stability**.**

4.3 Advancements in BLDC Motor Drives and Power Factor Correction Converters

In recent years, Brushless DC (BLDC) motor drives have gained significant attention from manufacturers, designers, and researchers due to their superior performance compared to traditional induction motor drives. The development of high-energy-density permanent magnet materials has enabled the design and production of more compact and efficient BLDC motors.

The integration of advanced software tools such as MagNet, Motor-Solve, and SPEED has further enhanced the accuracy and efficiency of motor design. Additionally, the increased adoption of Digital Signal Processors (DSPs) in power electronics and drive applications has facilitated the implementation of sophisticated control algorithms, leading to improved performance and efficiency.

Recent advancements in sensorless control techniques have eliminated the need for rotor position sensors, making BLDC motors more suitable for operation in hazardous environments while simultaneously reducing system costs. Furthermore, the miniaturization of Power Factor Correction (PFC) converters, enabled by integrated magnetics, has contributed to increased power density. The use of mixed conduction modes and the integration of multiple converter topologies have also opened new research avenues for improving light-load efficiency.

This version corrects grammatical issues, removes redundancy, and enhances readability while keeping the technical content intact. Let me know if you need any more refinements!

Conclusion The SEPIC converter-fed PMBLDC motor drive demonstrates superior voltage regulation and reduced ripple compared to the Buck converter, making it ideal for variable input applications. However, the Buck converter remains preferable for high-efficiency, fixed step-down scenarios. Future work will explore hybrid topologies and advanced softswitching techniques to further improve efficiency.

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