IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Simulation of Interleaved converter for BLDC applications using a SEPIC DC-DC converter in Discontinuous conduction mode

Budala. Surya Teja[1], B.V.V.L Kalabharathi[2], K.Rambabu[3]
M.Tech student[1], Associate Professor[2], Associate Professors[3]
Department of Electrical and Electronics Engineering,
[1]Aditya Engineering College, Surampalem, Andhra Pradesh, India

Abstract: This paper presents a strategy for using SEPIC in BLDC motor in Discontinuous Conduction Mode (DCM), which is often advised for low-power applications. Using three interleaved SEPIC converters, this is possible. Because the power is distributed among the interleaved modules, the proposed design reduces stress on the semiconductor components. By considering both capacitance and inductor current, the design handles DCM functioning (DCVM and DICM, respectively). In this study, the proposed converter's analysis examined. In addition, the effectiveness of the converter is measured. Component count is lowered by using coupled inductors, which minimize input ripple current, lower switching losses, less total harmonic distortion (THD), and greater resistance to duty cycle mismatches. High torque/inertia ratio, efficiency, robustness, and low EMI (electro-magnetic interference) are some of the advantages of BLDC motors. Matlab/Simulink software is used to implement the proposed approach.

Key words: Electro-magnetic interference (EMI), total harmonic distortion (THD), BLDC Motor, Electric Vehicle (EV), Discontinuous Conduction Mode (DCM).

I. INTRODUCTION

In the past ten years, there has been a notable increase in the electrification of transportation systems, especially given their favourable effects on the environment because they assist reduce greenhouse emissions, pollution, and global warming. Almutairi and others [1]. However, to supply the energy requirements of the cars, battery energy storage devices are needed in the electric transportation sector. Additionally, a key factor in regulating charging speed and addressing the issue of the driving range is the charging infrastructure. Cano and co. [2]. Chargers for electric vehicles (EVs) can generally be divided into three levels: level 1, level 2, and level 3. Each level has ratings that determine the charger's position, delivery window, and amount of power. [3] Khaligh et al.An AC-DC conversion unit rectifies the grid's power in a conventional EV charger layout, while a Power Factor Correction (PFC) DC-DC conversion unit controls the output voltage or current.

There are many Power Electronic Unit (PEU) variants for each stage of the charger. Uncontrolled rectifiers (sometimes referred to as diode-bridges) introduce severely distorted input current, leading to significant Total Harmonic Distortion (THD) and poor input Power Factor (PF). To rectify the PF, a number of methods were suggested, including the use of active and passive PFC. Active PFC is often utilised with DC-DC converters that have a constant input current. Mohammed and others[4]. To offer fast or ultra-fast charging, or Extreme-Fast Charging (UFC), a three-phase supply is required; however, a single-switch DC-DC converter cannot be used because it is unable to unfold the three line-currents. [5] Kolar et al. Consequently, it is advised to use numerous modules.The UFC concept necessitates cutting-edge power electronics technologies, hence it is heavily researched and examined. UFC stations are groups of EV chargers that share upstream equipment to charge multiple vehicles at once, according to reports in the literature. H. Tu and others [6].

But if not properly managed, this puts a significant strain on the grid and causes issues including overloading transformers and feeders, rising power losses, and deteriorating power quality. Wu, Q., and others [7]. Due to the UFC station's high power ratings, it is also necessary to link to the Medium Voltage (MV) grid. The use of battery energy storage devices and non conventional sources in UFC stations has been suggested by Meyer et al. [8] as a solution to the aforementioned issues. Shao et al.'s[9] discussion of coordinated planning for distribution networks and UFC stations with on-site storage includes a presentation of an optimal UFC design. in general UFC stations can either be DC connected or AC connected (with distributed AC-DC conversion stages).

However, their dependability is compromised, and they encounter issues with the metering and protection systems. In systems with bidirectional charging, this becomes more challenging. Tu, H., and others [6]. Dual Active-Bridge (DAB) converter modular units are used in ElMenshawy et al[10] .'s and [11] DC-DC conversion stage to accomplish UFC and guarantee equal distribution of power throughout the modules. Units for processing power in part for UFC are suggested by Iyer et al. [12]. Only a small percentage of the total power can be used under this approach; the rest is delivered directly to the load. The power ratings are decreased by partial power processing. As a result, the charging units' size and price are decreased.Additionally, it doesn't offer any separation between EVs and the DC bus. In Vasiladiotis et al[13] .'s modular design based on cascaded H-bridge and isolated DC-DC converters, a split storage stage is incorporated.

The proposed design has many different parts. The system needs big output capacitors or filters to decrease the 2nd order harmonic component because the energy storage is also built into the design. In Justino et al[14] .'s proposal, between the MV grid and the converter units, a 3-winding transformer is used to feed an ultra-capacitor bank of e-buses with an AC-connected charger. In the literature, various power converter topologies for EV chargers have been published. A single-stage single-switch topology with step-up/down capabilities is offered by Zeta, Cuk, SEPIC, and buck-boost converters and behave as excellent PFC regulators while running in Discontinuous Conduction Mode, according to Singh et al (DCM). Since there are no low-order harmonics in the input current, a large input filter is not necessary. Gangavarapu and others [16] decreased inrush current, constant input and output currents are features of cuk-based PFC converters. Lin, X., and others [17]. Zeta-based converters offer positive output voltage, low output ripple, and good voltage regulation, although they are subject to high voltage constraints in DCM. A gentle switching is used to lessen the strains, however it comes at the expense of more parts. Kushwaha and others [18].

Additionally, compared to Cuk-based converters, Zeta and SEPIC converters offer lower size capacitors and higher power densities. [19] Khodabandeh et al. An example of a three-phase rectifier using There has only ever been one Continuous Conduction Mode (CCM) SEPIC converter shown. The system's design not only calls for a large input inductor, but also yields a 26% THD. This is a result of the three-phase system's single switch being used. Additionally, the system is not modular, which has a negative impact on reliability. One SEPIC module is used in every phase of the 3-ϕ PFC rectifier modular design by Ayyanar et al. [21], which operates in CCM. Two control loops are required in the system for the PFC to be acceptable.

II. PROPOSED SYSTEM

The recommended method employs a unidirectional converter with a full diode-bridge at its initial degree. SEPIC's fundamental DC-DC converter istransformed into a remoted and in interleaved model for the second level, as shown in Figure 2. DCVM and DICM are both used in DCM operations. The DICM is seen as operating with a constant current at the battery sideto be in the output inductance so that the next step to capacitor. (the HFT's magnetising inductance). The intermediate capacitor of the SEPIC takes into account DCVM functioning. A comparison of the DCVM and DICM modes in the SEPIC-based converter is presented in [34] and [35] came to the conclusion that the high-power systems place more voltage stress on the switch, DCVM operation is not advised.Interleaving is used to enable DCM operation for low power modules that can be integrated and connected in parallel to address better electricity according to segment.As seen in Figure 2, the proposed system has a SEPIC DC-DC converter. Examples of converters include a fundamental SEPIC PFC converter, an isolated SEPIC PFC converter, and an interleaved and isolated SEPIC PFC converter.

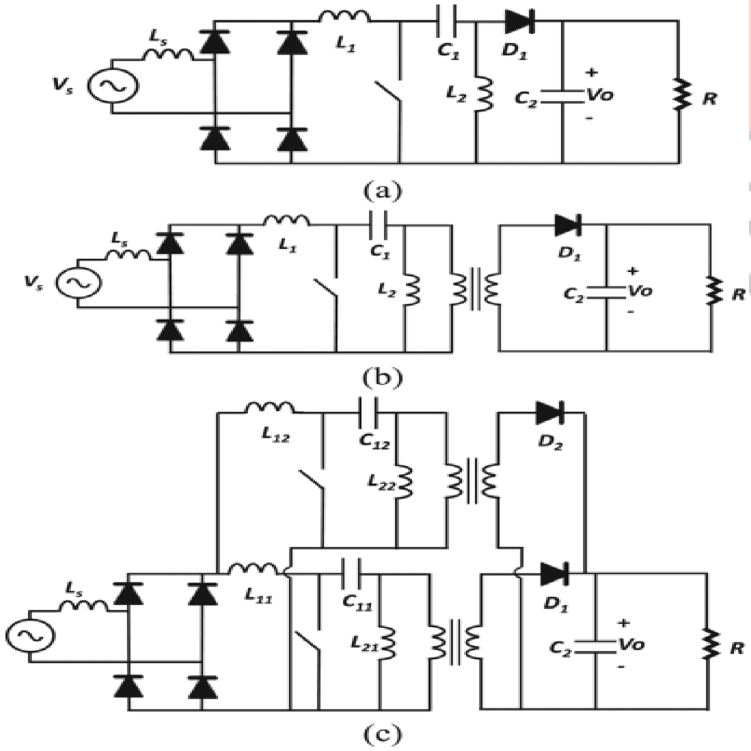


Figure 4. Flow diagram of the proposed control algorithm.

Each phase's separate SEPIC DC–DC converter output is linked in parallel using converter interleaved SEPIC converters, as shown in Figure 1.c. Separation of the input and the output may be accomplished using HFTs inorder to make the parallel connection work.

II.I DCM operation

In region 4, stages B and C basically operate in DCM if section A operates in DCM. To ensure DCM operation, the subsequent conditions must maintain

$$t_{N,ON} + t_{DaN_{ON}} < T_s \quad (1)$$

$$D\left(1 + \frac{V_p \sin(\omega t)}{v_o} n\right) < 1 \quad (2)$$

$$D < \frac{X}{X+Y} \quad (3)$$

The average output current is given by

$$I_0 = \frac{v_0}{R} \quad (4)$$

$$D = X\sqrt{\frac{2}{3}k_{aN}} \quad (5)$$

where the conduction parameter k_a is given by

$$k_{aN} = \frac{2l_{eq}N}{RT_s} \quad (6)$$

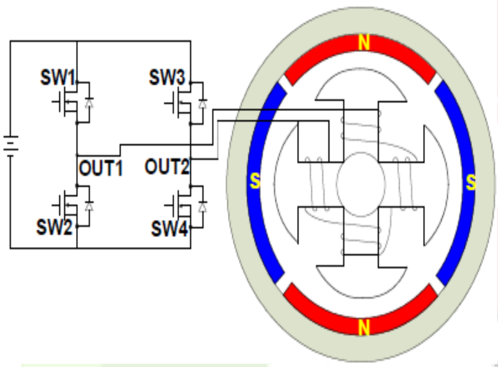
the essential price of phase A to ensure DCM

$$k_{a,Ncrt} = \frac{3}{2}\frac{1}{(M+n)^2} \quad (7)$$

III. BLDC MOTOR

It is becoming increasingly popular for industrial and electric vehicle (EV) applications because of its high efficiency, high power density, and minimum maintenance. Instead of mechanically regulated brushes, a brushless DC motor (BLDC) includes an electronically controlled commutation system that is driven by direct current energy (DC). Electronic commutation eliminates the problems of DC drives while preserving all of their benefits. Because current and torque are directly proportional to rpm, voltage and volts in this motor are also directly proportional. In most cases, the commutation signal comes from the Hall Effect sensor. When space is at a premium, a BLDC motor will not be able to satisfy the same requirements as other motors, such as brushless DC (BLDC).

BLDC motors may be found in a wide range of products, from household appliances to automobiles. We must focus on reducing costs and increasing productivity since the market is too competitive. Driven by the topological technique and the second control approach, BLDC motor drives may be made more affordable. The number of switches, sensors, and related circuitry in the power converter is decreased by using the topological method. A six-switch inverter configuration is the most common for BLDC motor drives. The cost decrease can be accomplished by minimizing the number of switches. Additional advantages include lower switching and conduction losses.



IV. SIMULATION RESULTS:

The energy needed by the load is occasionally insufficient. In this instance, a portion of the period sees the current flowing through the inductor drop to zero. The inductor is fully discharged at the conclusion of the commutation cycle, which is the only difference between the above-described principle and this one. But this has some impact on the earlier equations.

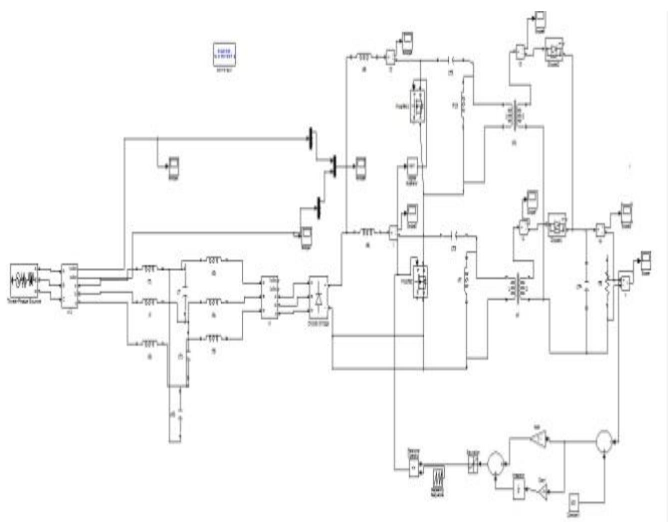


Fig 4.1 Simulink Diagram of Discontinuous Capacitor Voltage Mode (DCVM) SEPIC Converter

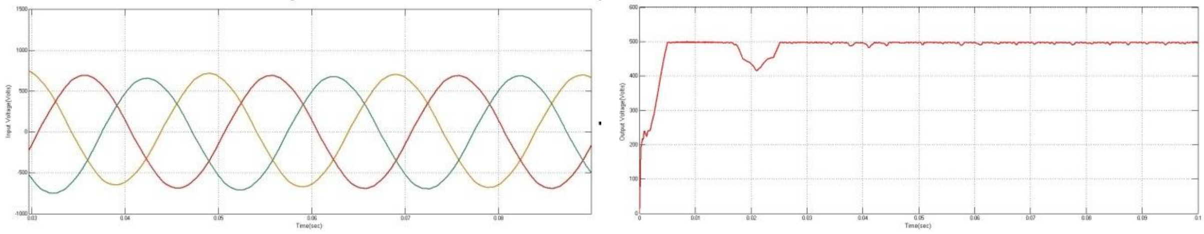


Fig 4.2(a) Simulation Input Voltage waveform of Discontinuous Capacitor Voltage Mode (DCVM) SEPIC Converter (b) Simulation output Voltage waveform of Discontinuous Capacitor Voltage Mode (DCVM) SEPIC Converter

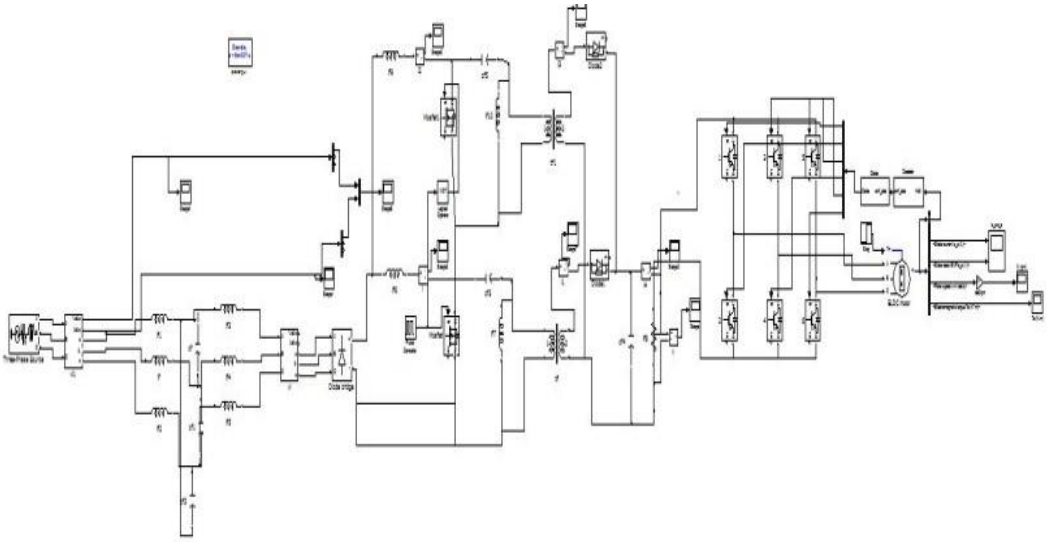


Fig 4.3 Simulink Diagram of BLDC Motor Drive Fed SEPIC Converter

Current and commutation torque ripple can both be reduced by adding an additional voltage source during the non-commutating period. The proposed BLDCM drive can be created to operate with a broad speed range control, improved AC mains power quality, and little torque ripple. As we can see that stator current and electromotive force of SEPIC fed BLDC Motor converter graph for both in the below Figure 4.3. And rotor speed(rpm) and Torque waveforms are shown below in figure 4.4 and 4.5 as per observation we can see that a rise in the speed at initial time so later on the a steady and maintained speed for the motor. Coming to the torque a quick rise in before interval of time with a sudden change of torque and then get down to required result with some peaks in the figure 4.6.

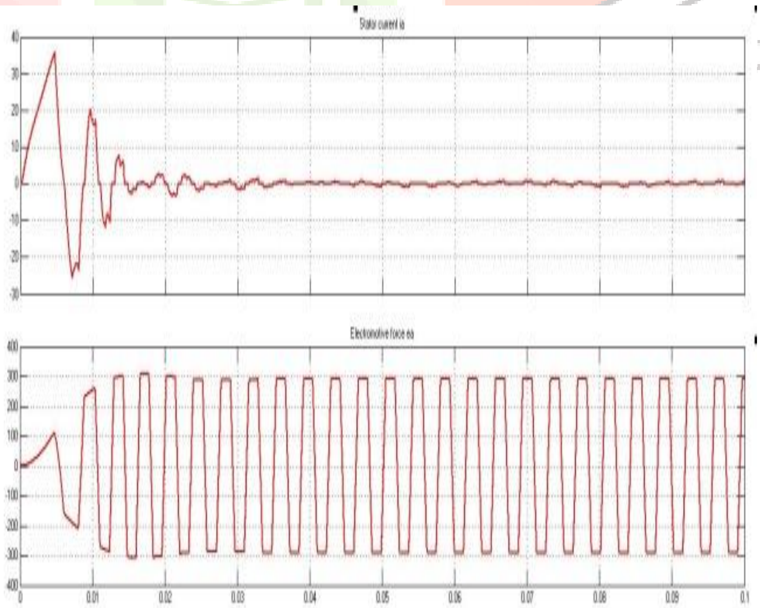


Fig 4.4 Simulation Stator Current and Electromotive Force waveform of BLDC Motor Drive Fed SEPIC Converter

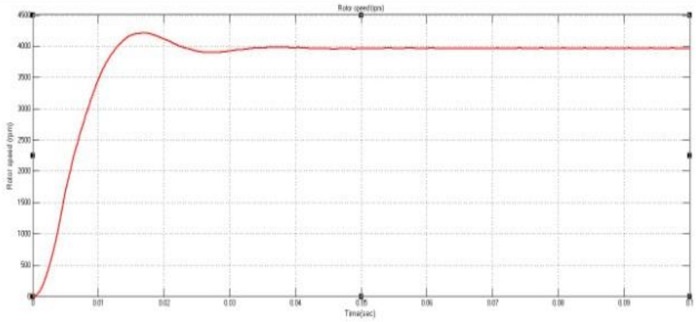


Fig 4.5 Simulation Rotor Speed waveform of BLDC Motor Drive Fed SEPIC Converter

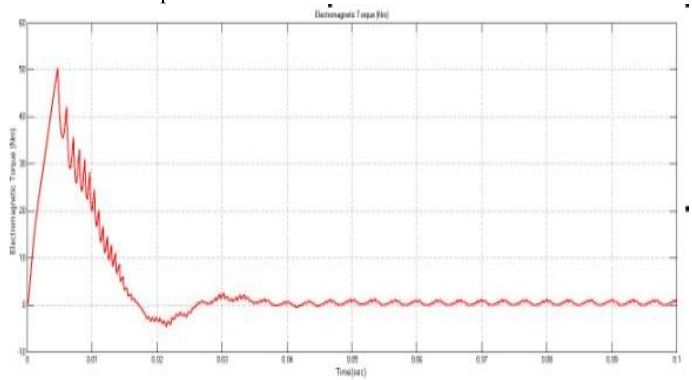


Fig 4.6 Simulation Torque waveform of BLDC Motor Drive Fed SEPIC Converter

Figure 4.1shows the MATLAB simulation circuit of the Discontinuous Output Inductor Current Mode (DOICM) SEPIC Converter. The proposed interleaved phase modular simulation results are shown in above Figures 4.2 and 4.3. For DOICM and DCVM operations, respectively. Simulation diagram of BLDC Motor Drive Fed SEPIC Converter and its wave forms are shown from 4.4 to 4.6. In figure 4.8 shows stator output current and voltage to the BLDC motor. Here THD for discontinuous voltage mode is 0.5% and in discontinuous current conduction mode it gives 1.5%. Power is divided between the inner modules and the phases, which lessens the current strains in the switches. This SEPIC converter reduces the switching losses compare to the conventional Buck- Boost converters.

V. CONCLUSION

In this article, a high-voltage gain SEPIC DC-DC converter is used to further describe the BLDC-driven pumping system. On the basis of solid operational data in a constant speed condition, the critical appraisal of planned work has been promoted Each of the three isolated SEPIC-based converters is linked in parallel to the outputs of the other two. Modularity, fault-ride-through capabilities, and redundancy are three key elements of this architecture that all help to increase the system's reliability. MATLAB/Simulink was used to simulate a two-module interleaved system. The Matlab/Simulink environment is used to test the torque ripples, speed error, stability index, and power-quality attributes under a variety of speed conditions. As a result, pumping applications will benefit greatly from this combination of benefits. It is possible to achieve increased power quality characteristics like reducing harmonics and tightening control of DC output voltage with greater dependability at a cost that is not prohibitive.

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