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Department of Electrical and Electronics Engineering

16EE267-PROJECT WORK
FIRST REVIEW

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PROPOSED TITLE

Design and development of modified SEPIC converter for BLDC drive

Overview of the Presentation

- ***Abstract***
- ***Introduction***
- ***Literature Survey***
- ***Block Diagram***
- ***Circuit diagram***
- ***Existing converter***
- ***Comparison Between Existing Converter And Proposed Converter***
- ***ZETA Converter***
- ***Cuk Converter***
- ***Quasi Z-source Converter***
- ***Conclusion***
- ***References***

Abstract

- For the system to work properly, it needs a suitable DC-DC converter. High output voltage and power, low harmonic distortion, low ripple content at both current and voltage, and high efficiency gain with fewer component requirements are just a few of the parameters for a good converter.
- A lot of the converters are made to meet some of the aforementioned requirements. With increased potential for BLDC drive based Electric Vehicle (EV) applications, the converter chosen in this article is one that will be suitable for those applications.
- Before recommending a converter for a certain usage, its performance must be evaluated. Various converter topologies are considered.
- The validation process goes into great detail for the design topology, components used, equations created, loss calculations, and output performances.
- The majority of converters perform better than expected when choosing the right component values. Applications that work well are provided together with the findings of the converters and the related values.

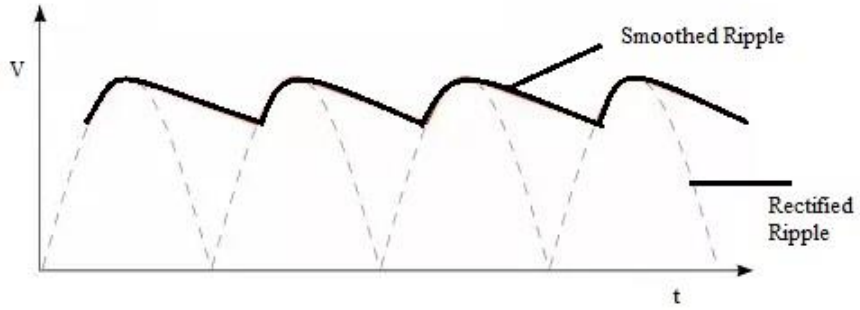
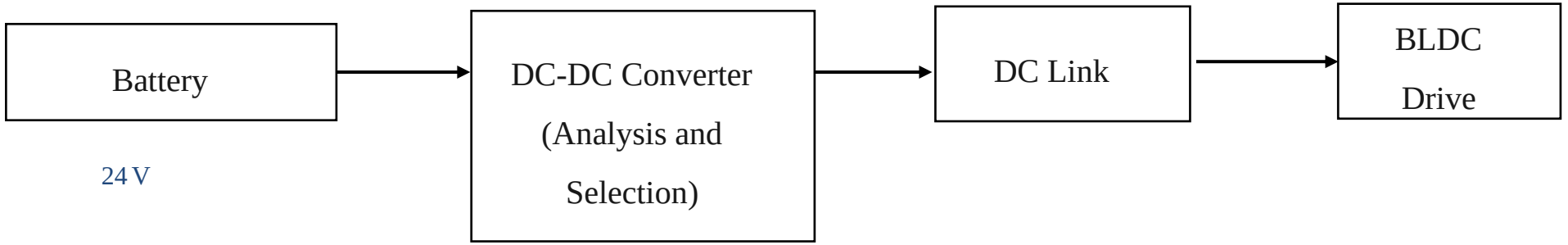


Figure: Ripple factor

Literature Survey

- A. Anand and B. Singh, **"Power Factor Correction in Cuk–SEPIC-Based Dual-Output-Converter-Fed SRM Drive**," IEEE Trans. Industrial Electronics, vol. 65, no. 2, pp. 1117-1127, Feb. 2018. https://doi.org/10.1109/TIE.2017.2733482.
  - In this paper, a **PFC based switched reluctance motor (SRM) drive** is proposed.
  - Generally, the SRM drive is fed with a simple **diode bridge rectifier** followed by a **bulky capacitor**, which draws peaky current at low power factor and high-input-current total harmonic distortion (THD).
  - **Dual Converter** is a combination of **Cuk** and **SEPIC** converters.
  - Drawback: **Acoustic Noise** & **Complex**.
- Bhim Singh, Vashit Bist, Chandra A, and Al-Haddad K **"Power Factor Correction in Bridgeless-Luo Converter fed BLDC Motor Drive"**, *IEEE Transactions of Industry Applications*, Vol. 51,No.2,pp.1179-1188,2015. https://doi.org/10.1109/TIA.2014.2344502.
  - This paper presents a power factor correction (PFC)-based bridgeless Luo (BL-Luo) **converter-fed brushless dc (BLDC) motor drive**.
  - The speed of the BLDC motor is controlled by an approach of **variable dc-link voltage**, which allows a low-frequency switching of the voltage source inverter for reduced **switching losses**.
  - The proposed BLDC motor drive is designed to operate over a wide range of speed control with an **improved power quality at AC mains**.
- N. Kumarasabapathy & M. Ramasamy, **"Modified isolated power factor correction Cuk-converter fed BLDC motor drive with Fuzzy Logic Controller for pumping applications"** *Journal of the Chinese Institute of Engineers*, Vol. 43, no. 6, pp. 553-565,July2020. https://doi.org/10.1080/02533839.2020.1777204.
  - This paper presents a **Fuzzy Logic Controller (FLC)** based **modified Power Factor Correction Cuk Converter (PFCCC**) operated Voltage Source Inverter (VSI) fed Brushless DC (BLDC) motor drive for agricultural water pumping applications.
  - To decrease the effect of **poor PF**, **Power Factor Correction (PFC)** circuits are added to the AC input side of the water pumping system to **enhance the efficiency and PF of the system.**
  - MATLAB/Simulink simulation results and experimental prototype model results are presented to **validate the performance of the designed system**.

Block diagram



1.Modified SEPIC Converter
2.Zeta Converter
3.Quasi Z-source Converter
4.Cuk Converter

Figure: Block diagram

Circuit Diagram-Modified SEPIC Converter

Modified SEPIC converter

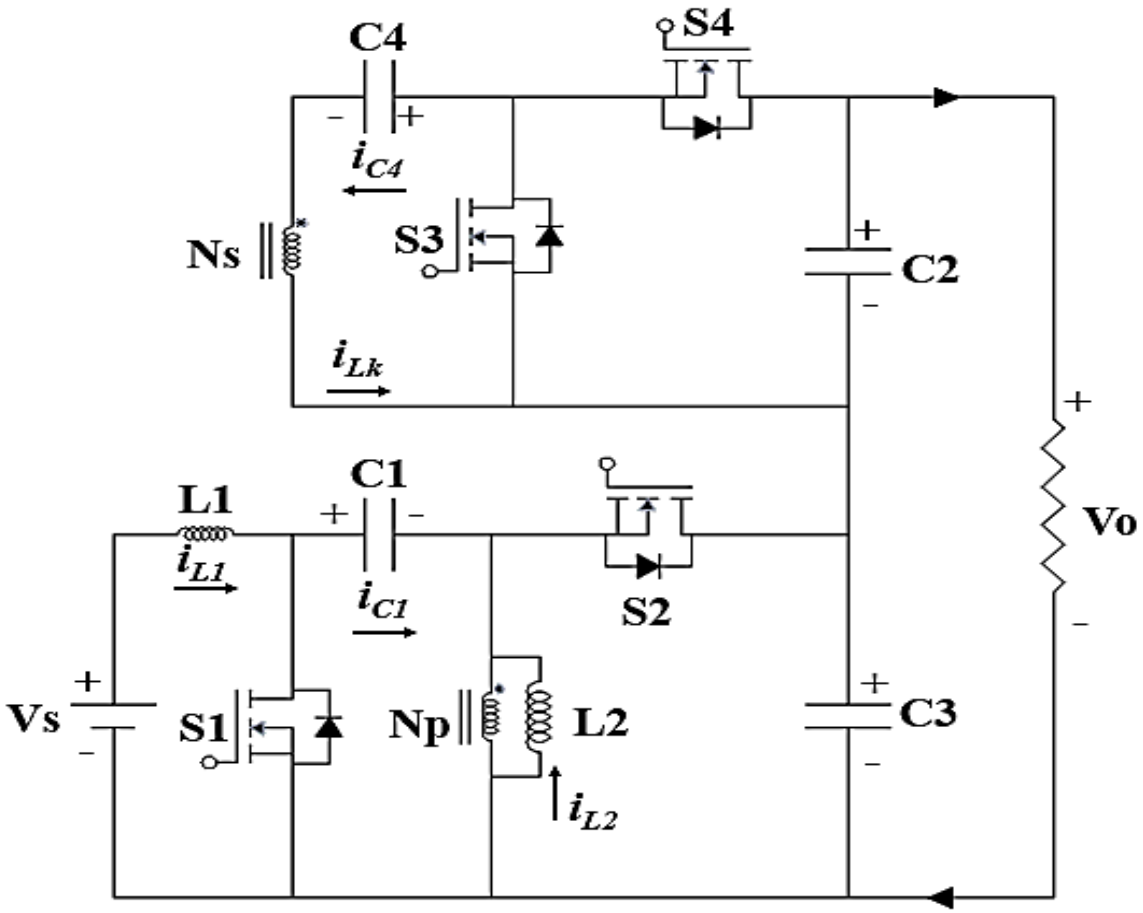


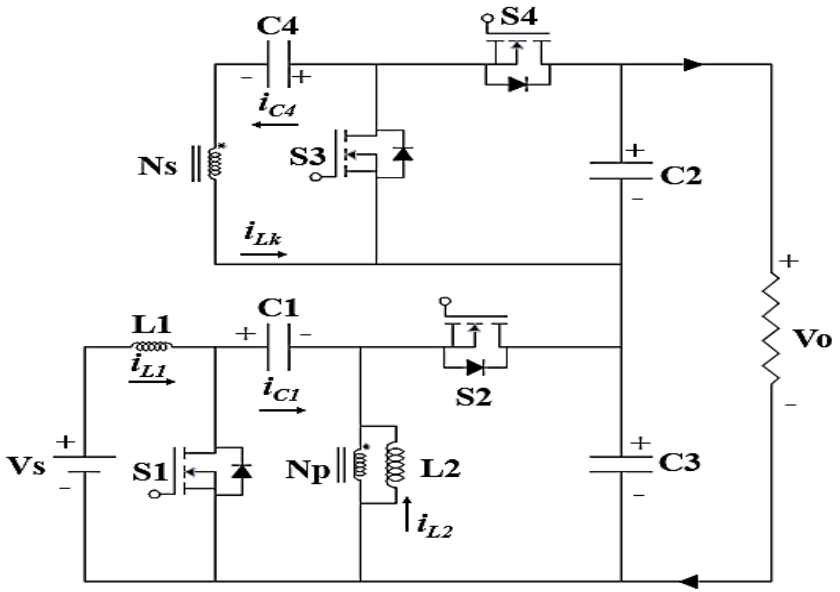
Figure: Modified SEPIC converter

The Modified SEPIC applications are high power, high current and static gain applications .

The Modified SEPIC consists of

- Coupled inductor,
- Leakage inductor L1,
- Magnetizing inductor L2,
- Four MOSFET switch S1-S4,
- Two intermediate capacitors C1 and C4,
- Output capacitor C2 and C3
- Load resistor R.

Modified SEPIC Converter-Proposed Converter Topology



S.NO	Components	Values
1	Leakage Inductor, L1	10 mH
2	Intermediate Capacitor, C1 & C4	1000 µF
3	Magnetizing Inductor, L2	10 mH
4	Output Capacitor, C2 & C3	1200 µF
5	Switch x 4	MOSFET
6	Resistive Load, R	100 Ω
7	Switching frequency, fs	33 kHz

Design Equations of Modified SEPIC

The Leakage and Magnetizing Inductance, L1 & L2 can be expressed as,

$$L = \frac{V_S D}{f_S * \Delta I_L} \quad (1)$$

For ΔIL, assuming for design calculation as 4.8% of **ILoad.**

$$L_1 = L_2 = \frac{24 * 0.67}{33.3 * 0.048} = 10\ mH$$

Where, Vs - Source voltage (v), D - duty cycle, fs - switching frequency (kHz), ΔIL – change in load currents. The Intermediate capacitors, C1 & C4 can be calculated from the following equation.

$$C = \frac{V_o D}{R * fs * \Delta I_C}$$

For ΔVC, assuming for design calculation as 2% of **Vo**.

$$C_1 = C_4 = \frac{48 * 0.67}{1 * 33.3 * 0.96} = 1000\ \mu F$$

Where, Vo - output voltage (v), D - duty cycle, fs - switching frequency (kHz), ΔVC - change in capacitive voltage. The Output filter capacitors, **C2 & C3 are large enough to filter the output ripples**.

$$C_2 = C_3 = 1200\ \mu F \text{ (Kept as constant)}$$

Existing Converter

SEPIC CONVERTER

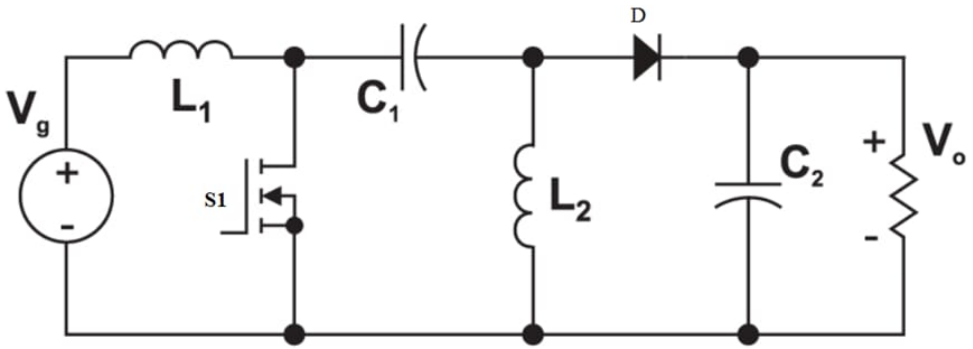


Figure: Existing system for SEPIC converter

- The single-ended primary-inductor converter (SEPIC) is a type of DC/DC converter that allows the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input.
- The ***output of the SEPIC is controlled by the duty cycle of the control switch.***
- The voltage value of the SEPIC converter rises or falls depending on the duty cycle of switches and active components in the circuits.
- Diode is employed to manage the reverse voltage and peak current.

Comparison Between Existing Converter And Proposed Converter

Proposed system-Modified SEPIC Converter

- Same input and output voltage polarity
- Low input current ripple
- Possibility of having multiple output
- Good power factor
- Good efficiency
- Stable operation

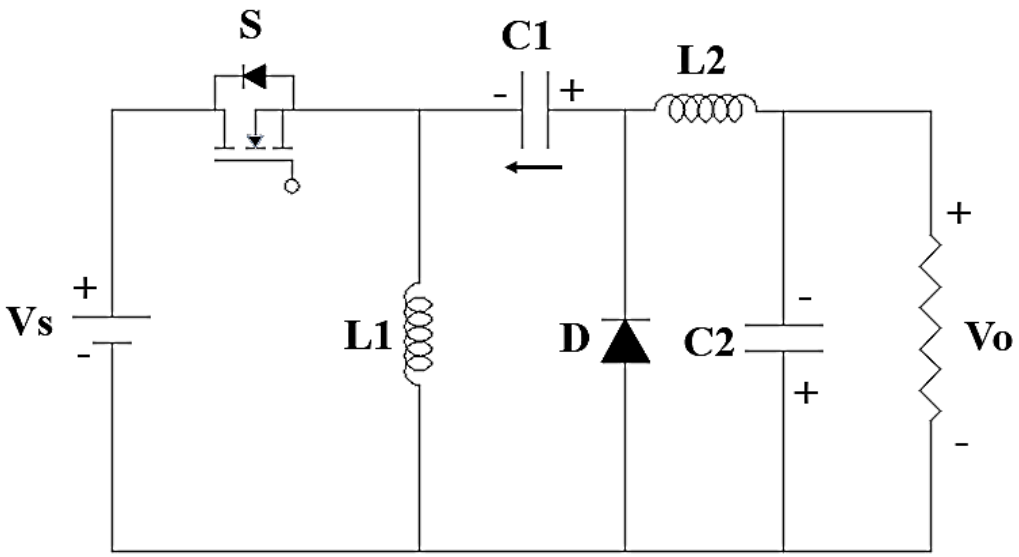
➢ **It is suggested for BLDC-based EV applications.**

Existing Converter

- SEPIC has a tiny pulsating output current.
- SEPIC converter transfers all its energy via the series capacitor, a capacitor with high capacitance and current handling capability is required.
- The fourth-order nature of the converter also makes the SEPIC converter difficult to control, making it only suitable for very slow varying applications.

ZETA Converter

ZETA Converter



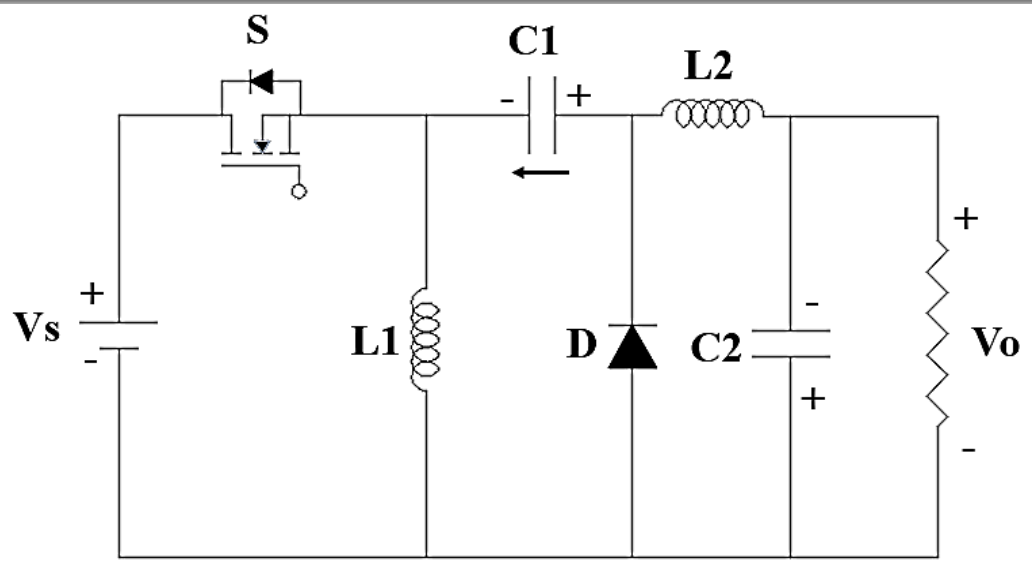
Zeta converter is a fourth-order DC-DC converter made up of two inductors and two capacitors and capable of operating in either step-up or step-down mode. It is a buck-boost type converter. It means you can step up the voltage and step down as well.

- The output voltage is positive in reference to the ground which makes the sensing circuit simple.
- The main drawback is input current is discontinuous, which is not desired for some applications. The passive element requirement is more. It is a fourth order converter, which makes the control difficult.

APPLICATION

- Automotive battery recharge from solar PV cells

ZETA Converter



S.No	Components	Values
1	Inductors, L1 & L2	1.6 mH
2	Capacitor, C1	150 µF
3	Output Capacitor, C2	720 µF
4	Resistive Load, R	100 Ω
5	Switching frequency, fs	25 kHz

Design Equations of ZETA converter

A straightforward Zeta converter design example is provided in the following section. The converter's input voltage is Vs = 24v, and its output must remain at 72v. The load resistance may be between 50 and 100Ω. The duty cycle D can be calculated by,

$$D = \frac{V_o}{V_d + V_o} \qquad (4)$$

The inductors L1 and L2 can be obtained from the equation (13) and (14).

$$L_1 \geq \frac{(1-D)^2 * R_o}{2Df_s} \qquad (5)$$

$$L_2 \geq \frac{(1-D) * R_o}{2f_s} \qquad (6)$$

The sizing of capacitor C1 can be expressed as,

$$C_1 \geq \frac{D * I_o}{\Delta V_{C1} * f_s}$$

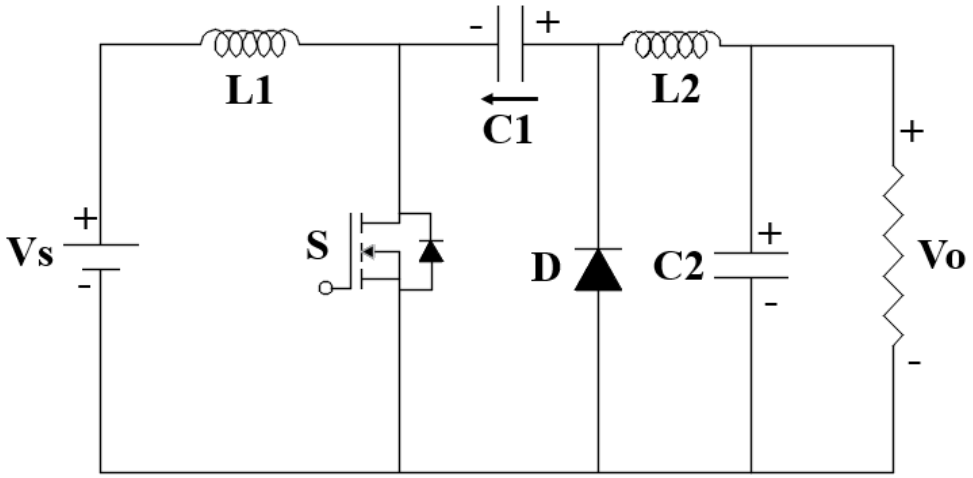
Similarly, the sizing of capacitor C2 can be expressed as,

$$C_2 \geq \frac{(1-D) * V_o}{8 * \Delta V_{C1} * L_2 * {f_s}^2}$$

Based on the above equations, component values are calculated and used in the simulation of ZETA converter

Cuk Converter

Cuk Converter



- It is a type of buck-boost converter with low ripple current.A cuk converter can be seen as a combination of boost converter and buck converter, having one switching device and a mutual capacitor, to couple the energy.

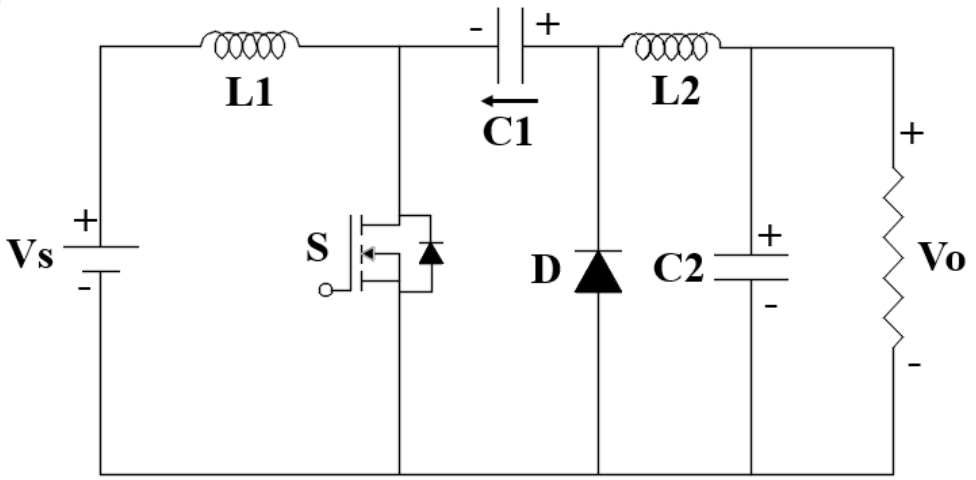
- The cuk converter consists of single MOSFET switch, inductors L1 and L2, intermediate storage capacitor C1, output capacitor, C2 and load resistor R.

APPLICATION

- voltage regulation for the Dc application systems.
- hybrid solar-wind energy system as a regulator

The main difference between SEPIC Converter and Cuk converters is the ***non- reversal voltage polarity on the output side of the converter****. In the results of previous studies, the SEPIC Converter has a performance with efficiency, not less than 88 %*

Cuk Converter



S.NO	COMPONENT	VALUE
1	Inductors, L1 & L2	18 mH
2	Capacitor, C1	200 µF
3	Output Capacitor, C2	720 µF
4	Resistive Load, R	100 Ω

Design Equations of CUK converter

The average value of input voltage is expressed as,

$$V_{in} = \frac{2\sqrt{2}V_s}{\pi} \quad (8)$$

The duty cycle ratio, D can be given as,

$$\frac{V_o}{V_s} = \frac{D}{1-D} \quad (9)$$

The input inductance, L1 is calculated from, 5

$$L_1 = \frac{DV_{in}}{\Delta I L_1 f_s} \quad (10)$$

The output inductance, L2 is calculated from,

$$L_2 = \frac{(1-D)DV_{dc}}{\Delta I L_2 f_s} \quad (11)$$

The intermediate capacitor, C1 can be expressed as,

$$C_1 = \frac{DI_{dc}}{\Delta V_{C_1} f_s} \quad (12)$$

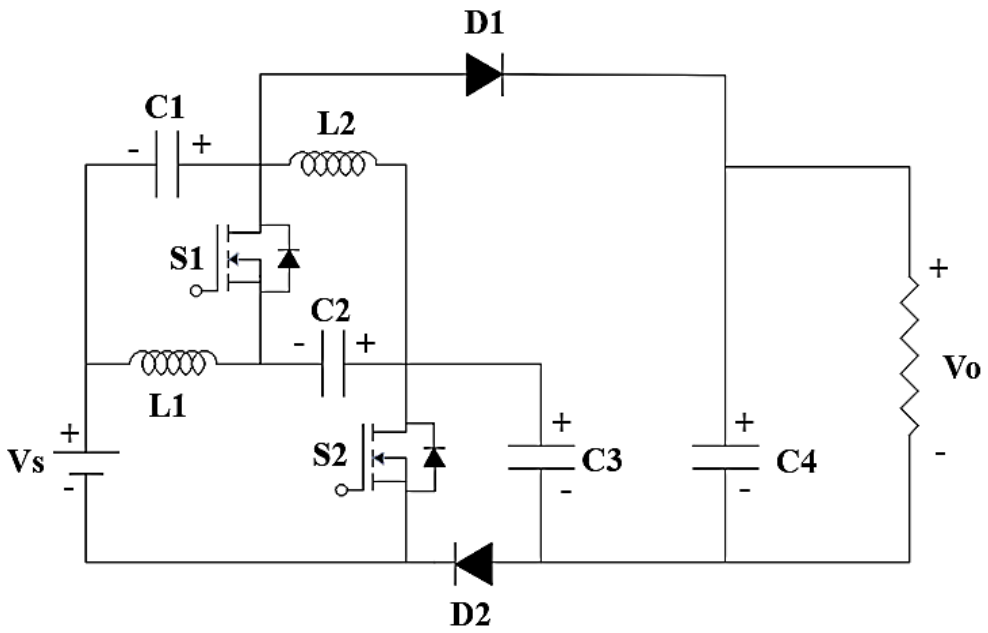
The output capacitor, C2 can be expressed as,

$$C_2 = \frac{I_{dc}}{\omega * \Delta V_{C_2}} \quad (13)$$

Based on the above equations, component values are calculated and used in the simulation of Cuk converter, which is presented in Table 3.

Quasi Z-source Converter

Quasi Z-source Converter



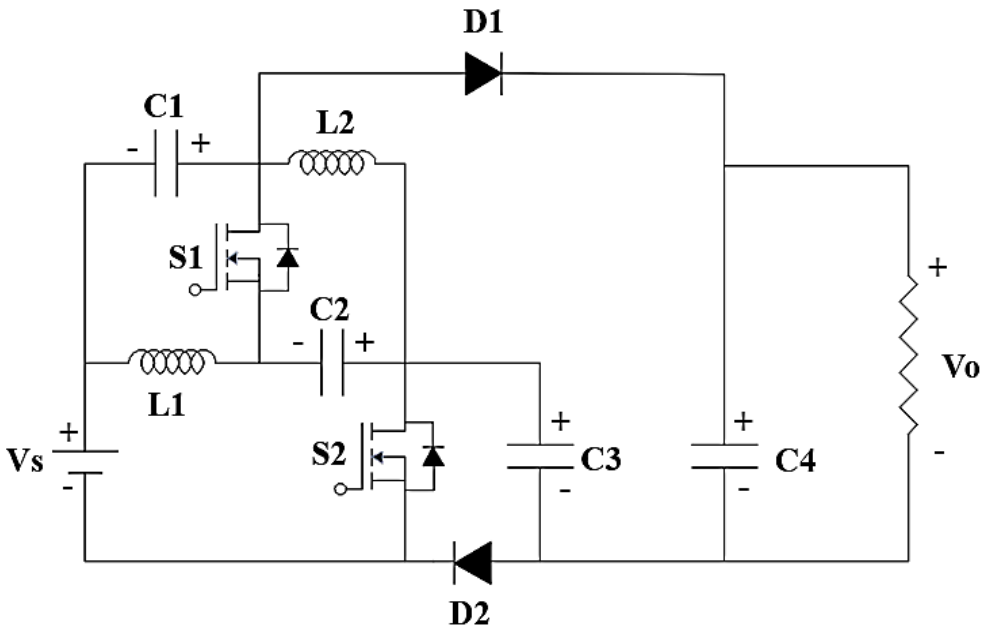
The Quasi Z-source converter is compact, less expensive, and has a high efficiency ,Moreover both the input source current and output load current of the proposed converter are continuous, which provides advantage for input and output filtering.

- It is used in wide range for high power with medium voltage applications.
- It consists of two MOSFET switches, inductors L1 and L2, diodes D1 and D2, intermediate storage capacitor C1, C2, C3 and C4 and load resistor R

APPLICATION

- Wide range for high power with medium voltage

Quasi Z-source Converter



S.NO	Components	Values
1	Input Inductor, L1	20 mH
2	Input Filter Capacitor, C1	200 µF
3	Magnetizing inductor, L2	20 mH
4	Storage Capacitors, C2 & C3	650 µF
5	Output Capacitor, C4	1000 µF
6	Resistive Load, R	100 Ω

Design Equations of Quasi Z-source converter

The input inductor L1 can be determined by,

$$L_1 \geq \frac{D(1-D)V_s}{\Delta i_{L1} f_s (1-2D)} \qquad (14)$$

Similarly, inductor L2 can be determined by,

$$L_2 \geq \frac{D(1-D)V_s}{\Delta i_{L2} f_s (1-2D)} \qquad (15)$$

The Capacitors C1-4 value can be determined by,

$$C_1 \geq \frac{I_{L2}(1-D)}{\Delta V_{C1} f_s} \qquad (16)$$

$$C_2 \geq \frac{I_{L2}(1-D)}{\Delta V_{C2} f_s} \qquad (17)$$

$$C_3 \geq \frac{I_o}{\Delta V_{C3} f_s} \qquad (18)$$

$$C_4 \geq \frac{I_o(1-D)}{\Delta V_{C4} f_s} \qquad (19)$$

REFERENCES

YEAR	AUTHOR	ARTICLES	LINK
Feb 2018	A. Anand and B. Singh	"Power Factor Correction in Cuk– SEPIC-Based Dual-Output-Converter-Fed SRM Drive", IEEE Transactions of Industrial Electronics, vol. 65, no. 2, pp. 1117- 1127	https://doi.org/10.1109/TIE.2017.2733482.
2015	Bhim Singh, Vashit Bist, Chandra A, and Al-Haddad K	"Power Factor Correction in Bridgeless-Luo Converter fed BLDC Motor Drive", IEEE Transactions of Industry Applications, Vol. 51, No. 2, pp. 1179 – 1188	https://doi.org/10.1109/TIA.2014.2344502.
July 2020	N. Kumarasabapathy & M. Ramasamy,	"Modified isolated power factor correction Cuk-converter fed BLDC motor drive with Fuzzy Logic Controller for pumping applications" *Journal of the Chinese Institute of Engineers*, Vol. 43, no. 6, pp. 553 - 565	https://doi.org/10.1080/02533839.2020.1777204

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May 2020	Rodnei Regis de Melo, Fernando Lessa Tofoli, Sergio Daher and Fernando Luiz Marcelo Antunes	"Interleaved bidirectional DC - DC converter for electric vehicle applications based on multiple energy storage devices", *Electrical Engineering*, Springer Publications	https://doi.org/10.1007/s00202-020-01009-3.
2017	Vaiyapuri Viswanathan & Seenithangom Jeevananthan	"Hybrid converter topology for reducing torque ripple of BLDC motor", *IET Power Electronics*, Vol. 10, No. 12, pp. 1572-1587	https://doi.org/10.1049/iet-pel.2015.0905.

THANK YOU