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Design of SEPIC Converter with Inverter fed AC Motor

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Abstract

Now, a day, converter topology plays a vital role in power electronics application. The switching stress and voltage gain can be improved to a great extent. The proposed converter employs a SEPIC converter and a coupled inductor, with low duty ratios and high turns ratios generally needed for the coupled inductor to achieve high step-up voltage conversion. The basic inductor has been replaced by a coupled inductor increases the voltage gain and secondary winding of the coupled inductor in a series with a switched capacitor for further increasing the voltage. The input voltage is 24V and the output voltage is equal to 200V. Steady-state operation and design procedure is presented. This paper is focusing on implementing PI controller to control the speed of the AC motor.

***Index Terms*— Single - Ended Primary Inductance converter (SEPIC), DC-DC power conversion, Ripple Reduction.**

1. INTRODUCTION

The reduction of voltages, high range of currents, and fast load transients are fast growing in power delivery for high-performance digital electronics. Power converters used for these applications need to have a fast response, high efficiency, and a small size. They are designed with the intent to pass the electromagnetic compatibility (EMC), which is mandatory and vital for some applications like telecommunication products. The input and output filter capacitors in the power converter play a central role in determining the performance of each of these aspects.The basic converter topologies such as the Buck, Boost, Fly back, SEPIC, Cuk, Zeta and others, have long been attractive and are often chosen for implementing simple, cost effective, and low power converters. The use of a single active switch with relatively simple control circuitry is a strong reason for this choice. For applications which require low ripple current at the input and output port of the converter, the Cuk converter are appear to be a potential candidate in the basic converter topologies. The fly back converter requires an additional input and output L–C filter to reduce the switching ripple and noise level at both terminals.

The major disadvantage of the Cuk topology besides its inverting output polarity is that both the power switch and the output diode must carry significantly higher currents compared than other topologies. The buck and the boost converters with an input or output filter results in a more bulk converter when compared to the Cuk converter. This is because the input and output inductor cannot be coupled into a single magnetic core as in the Cuk converter; hence, it increases the cost and board area required, which is an undesirable for many applications. The SEPIC converter has been developed primarily to have step up/down capability without inverting the polarity of the regulated output voltage. On the other hand, the output capacitor in the SEPIC is subjected to a large peak current due to the presence of the output diode. Thus, larger output capacitance with low ESR should be used to maintain low ripple voltage on the output.

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2. BLOCK DIAGRAM

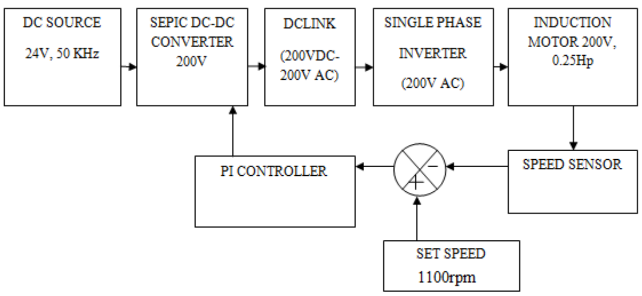

Fig. 1: Block diagram of the proposed system

Fig. 1 gives the block diagram of the SEPIC converter. The input voltage of 24V fixed DC supply is given to the SEPIC converter. The SEPIC converter is used to step up the voltage gain of 200V.The DC link is used to maintain the voltage between the converter and the inverter. The single phase inverter is used to convert the DC voltage into AC voltage. The AC voltage is fed into the induction motor. The speed of the induction motor is compared with the set speed by the comparator and the error is given to the PI controller.

3. CIRCUIT DIAGRAM AND OPERATION OF THE SEPIC CONVERTER

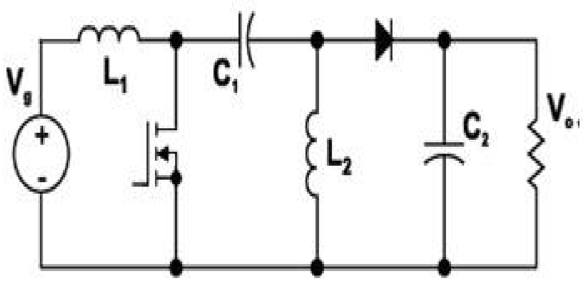

Fig. 2: SEPIC converter

A SEPIC (Single Ended Primary Inductor Converter) DC-DC converter is a fourth-order nonlinear system which is capable of operating in either step-up or step-down. It has several characteristics

1) The same polarity between input voltage and output voltage;

2) Small input ripple current;

3) It can be easily extended to multiple-output.

The elementary circuit of the SEPIC converter shown in figure 2 consists of a power MOSFET switch S and a diode D. The energy storage elements are inductors L_1, L_2 and capacitors C_1, C_2, R is the load resistance. V_g and V_0 are the input and output voltages respectively. The circuit diagram of the SEPIC converter is given in fig. 2

4. MODES OF OPERATION

There are two possible modes of operation in the SEPIC converter. Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM). The modeling of a SEPIC converter operating in CCM is presented. There are two cases in CCM mode.

CASE (i)

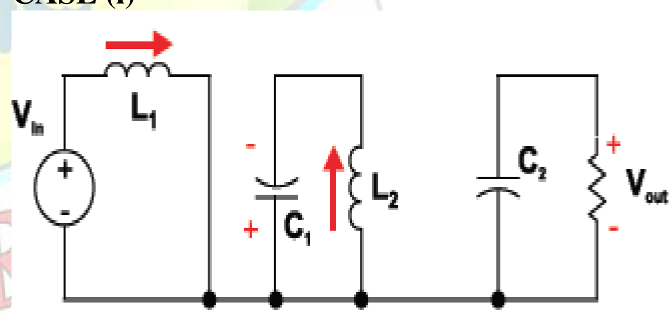

Fig. 3: Mode 1: when Switch is ON

Fig. 3 shows the circuit when the power switch is turned on. The inductor, L_1 gets the charge from the input dc voltage source during the ON condition. The second inductor also gets energy from the first capacitor C_1. No energy is supplied to the load capacitor during this ON condition. Current passing through the inductor and the capacitor voltage polarities are marked in this figure.

CASE (ii)

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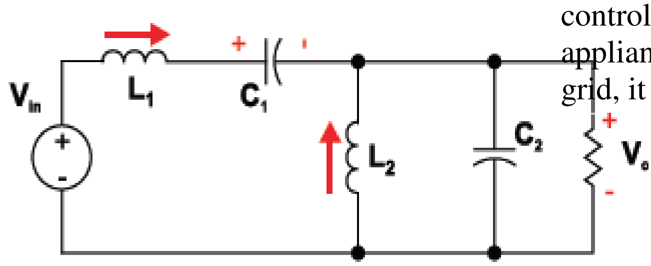

Fig. 4: Mode 2: when Switch is OFF

When the power switch is turned off, the inductor gets the charges from the capacitor C_1 and also provides current to the load, as shown in Fig. 4. The load side inductor is also connected to the load during this time.

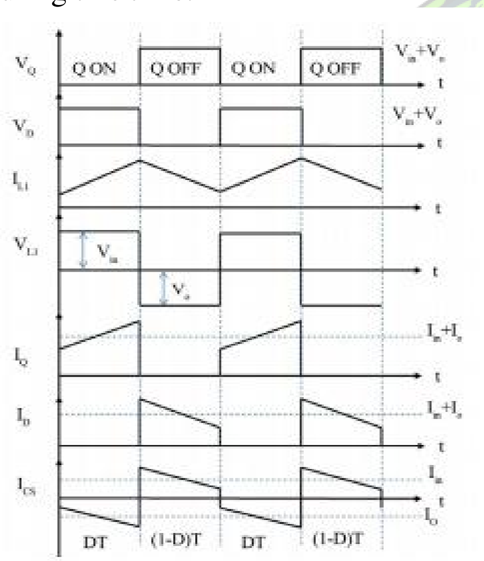

Fig. 5: Voltage and Current waveform of each component of the SEPIC in CCM.

SINGLE PHASE INVERTER

In this type, Single phase Full bridge converter is used to convert DC to AC. An AC output is obtained from a DC input by closing and opening switches in an appropriate sequence. Two switches are turned ON at a same time S_1 and S_2 are triggered and then $V_0= V_{dc}$ and S_3 and S_4 are triggered and $V_0= -V_{dc}$ thus we get an alternating output voltage. The duty cycle and the frequency of the gate pulses can be controlled. Thus by varying this frequency the output AC voltage can be controlled .For our domestic and industrial AC appliances as well as for feeding the PV power to grid, it is desirable to get an AC voltage of 50Hz.

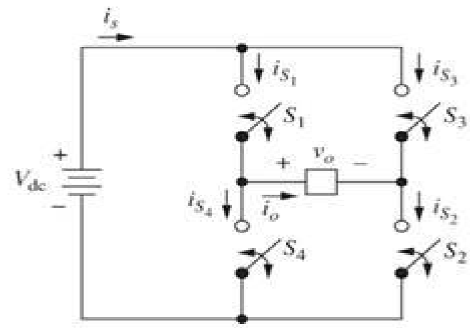

Fig. 6: Single phase full bridge inverter

INDUCTION MOTOR

An induction is an AC electric motor in which the electric current in the rotor needed to produce torque is induced by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and synchronous motors .An induction motor rotor can be either single phase or three phases based upon the supply.

Advantage of Induction Motor

- Induction motor has ability to connect directly to AC source.
- This is an important cost saver in industrial uses.
- Induction motor is easy to program for its various uses.
- Low maintenance cost and durability of the product.

5. DESIGN SPECIFICATIONS OF THE PROPOSED CONVERTER

A proposed converter had the following specifications:

1. Input DC voltage = 24V
2. Output DC Voltage = 200V
3. Switching Frequency = 50KHZ

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4. Resistance, R=150Ω

CALCULATION OF LC FILTER

Assume, resonance will occur at frequency f=50 KHz (apply switching frequency)
Filter capacitance and inductance can be calculated from the following equation

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Assume inductance, L = 10mH, which gives capacitance value as,

$$C = \left(\frac{1}{2\pi f}\right)^2 \times \frac{1}{L}$$

$$C = \left(\frac{1}{2\times3.14\times50\times10^3}\right)^2 \times \frac{1}{10\times10^{-3}}$$

C = 1000μH

6. SIMULATION AND RESULT ANALYSIS

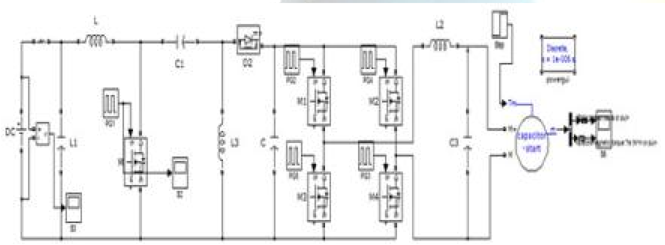

Fig. 7: Simulation circuit of SEPIC converter with inverter for Motor load

Thus, the Fig. 7 shows the SEPIC converter with single phase converter with inverter which is connected to capacitor-start induction motor.

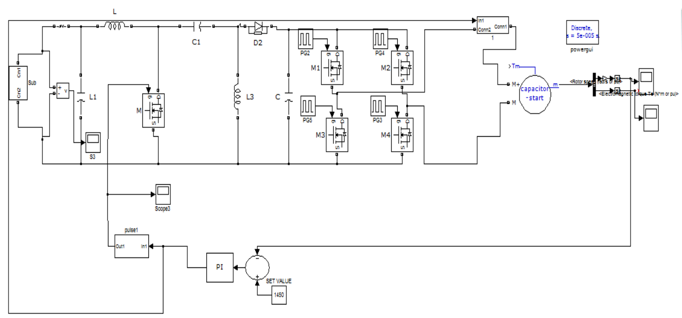

Fig. 8: Simulation circuit of SEPIC converter with inverter for closed loop system

The proposed closed loop system of the SEPIC converter with motor load is shown in the Fig. 8.

SIMULATION WAVEFORMS

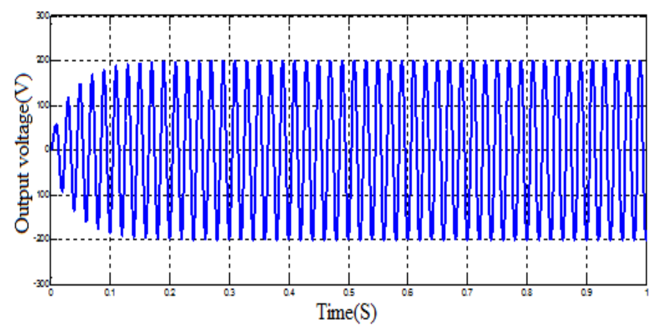

Fig. 9: Output voltage of the SEPIC converter with inverter for R load

Thus, the characteristics of the output voltage of SEPIC converter with single phase inverter connected to the R load are shown in the fig. 9.

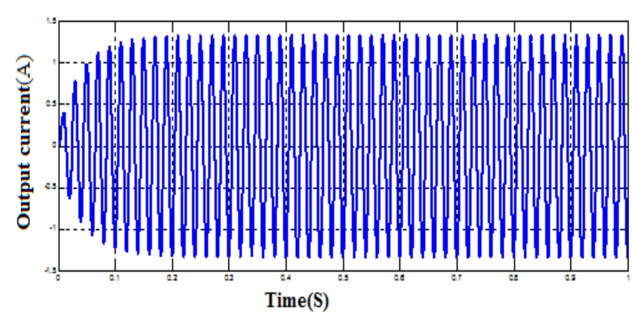

Fig. 10: Output current of the SEPIC converter with inverter for R load

Thus, the characteristics of the output current of SEPIC converter with single phase inverter connected to the R load are shown in the fig. 10.

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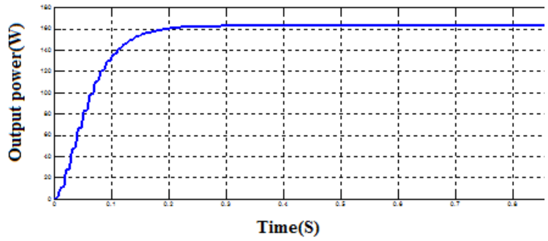

Fig. 11: Output power of the SEPIC converter with inverter for R load

Thus, the characteristics of the output power of SEPIC converter with single phase inverter connected to the R load are shown in the fig. 11.

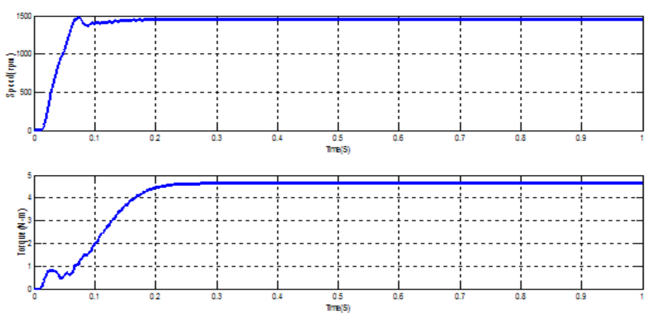

Fig. 12: Motor Speed and Motor Torque (open loop)

Thus, the characteristics of the speed and the torque of the SEPIC with inverter for motor load is shown in the fig. 12.

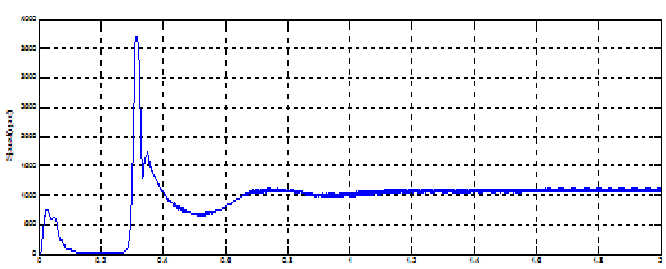

Fig. 13: Motor speed of the closed loop system

Thus, the speed characteristics waveform for the SEPIC converter with inverter for motor load with the closed loop system is shown in the fig. 13.

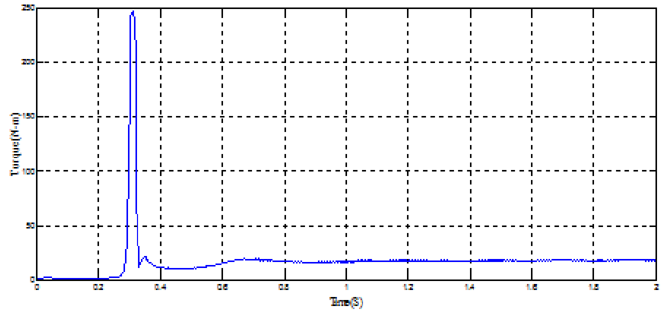

Fig. 14: Motor Torque of the closed loop system

Thus, the torque characteristics waveform of the SEPIC converter with inverter for motor load with the closed loop system is shown in the fig. 14.

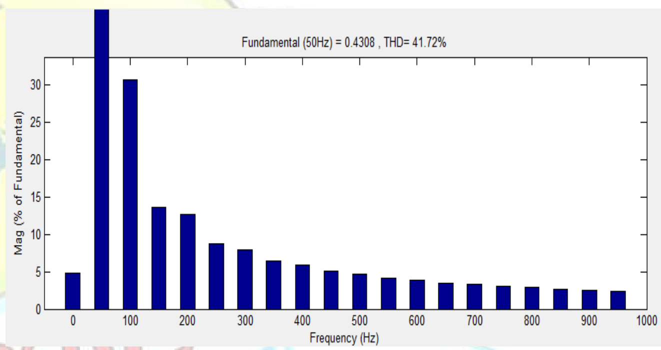

Fig. 15: THD results of the proposed system

Thus, the THD results of the proposed system are shown in the fig. 15.

TABLE 1 SIMULATION RESULTS

PARAMETERS	PROPOSED SEPIC CONVERTER
Input voltage Vin	24V
Inductance L_1,L_2	100µH
Capacitance C_1,C_2	30µF
Output voltage V_0	200V
Output current I_0	1.4A
Output power	163W
Speed	1100rpm
THD (%)	41.72%

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7. CONCLUSION

This paper has proposed the SEPIC converter with inverter for R load and Motor load. The design values of the SEPIC converter also included in the proposed system. This proposed converter is used for high power applications. The voltage gain has been raised in the proposed system with reduced duty cycle. The voltage gain of 200V AC output voltage has been obtained in the proposed system. The ripple present in the voltage has been reduced considerably. Simulation circuit and waveforms also included in this paper. The experimental based prototype will be included for validation.

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