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A NEW SEPIC VOLTAGE-DOUBLER CONVERTER FOR DC DRIVES

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ABSTRACT: In this paper, Single-Ended Primary Inductor Converter (SEPIC) as voltage-doubler converter fed DC motor is proposed. Soft-switching technique such as Zero-Voltage-Switching (ZVS) and Zero-Current-Switching (ZCS) operation plays a vital role in high voltage applications. The model has been simulated through MATLAB/SIMULINK using Diode Bridge, SEPIC topology and closed loop DC motor load. The prototype is modeled with input side Diode Bridge Rectifier, SEPIC Topology and Microcontroller ATMEL 89S52. The soft switching scheme for the proposed topology is developed with DC motor load. The converter achieves high efficiency due to soft-switching and output voltage is achieved twice the input voltage. The presented analysis is verified by a prototype of 33 kHz and 55W converter. Also, the comparative results of simulated and prototype are generated and are shown**.**

KEYWORDS : Optocoupler, Power amplifier, SEPIC topology, Zero-Voltage-Switching (ZVS).

I. INTRODUCTION

SEPIC converter are mainly used for their non-inverting output voltage polarity, non-pulsating input current and for their efficiency. P-MOSFET is high voltage rated power semiconductor device because of their on-state Drain-Source Resistance. So, it causes higher conduction loss. Therefore, the overall efficiency can be improved if the voltage stress is reduced with decrease in current. To reduce the voltage stress and increase the voltage gain, voltage multiplier technique is proposed. In order to reduce the volume and weight of the converter, soft-switching techniques such as zero-voltage-switching (ZVS) and zero-current-switching (ZCS) are necessary. However, switching losses and electromagnetic interference noises are significant in high-frequency operation. Therefore, various soft-switching techniques have been introduced. Among them, the active clamp technique is often used to limit the voltage spike effectively, achieve soft-switching operation and to increase the system efficiency.

SEPIC converter has low input current ripple but bulk inductor is used in order to minimize the current ripple. It is one of important requirement due to the wide use of low voltage sources such as batteries, super capacitors, and fuel cells. Two switches can operate with soft switching. However, three power diodes and three separate inductors are utilized. The voltage stress of the power switches is the sum of the input voltage and the output voltage. Soft-switching operation is achieved by two power switches and two magnetic components. It has a pulsating input current and an additional filter is required in the input stage to suppress the input current ripple. Hence, magnetic component can be increased in number.

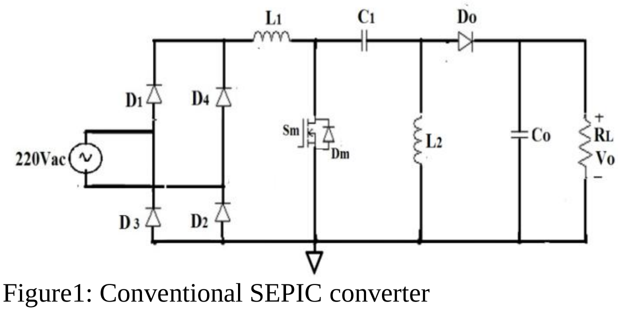


Figure1: Conventional SEPIC converter

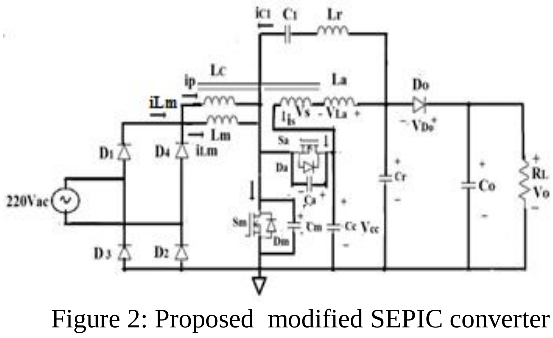


Figure 2: Proposed modified SEPIC converter

The switch consists of two power MOSFET's. The voltage stress of the switches in the conventional can be found in proposed SEPIC converter. Parasitic voltage across the switch is minimized by using a snubber circuit.

II. ANALYSIS AND CIRCUIT CONFIGURATION OF PROPOSED CONVERTER

The conventional SEPIC converter is shown in Fig. 1. The circuit diagram of the proposed ripple-free modified SEPIC converter is shown in Fig. 2. In the proposed converter, the resonant inductor Lr and the active clamp cell consisting of the auxiliary switch Sa and the clamp capacitor Cc are added to the conventional SEPIC converter. The coupled inductor Lc is modeled as the magnetizing inductance Lm and a transformer is high-frequency and made up of Ferrite-core with a turn ratio of 1: 2, 40V and 2A. The diodes Da and Dm are the intrinsic body diodes of the auxiliary switch Sa and the main switch Sm. The capacitors Ca and Cm are their parasitic output capacitances. The duty ratio D is based on the main switch Sm and the switches Sa and Sm are operated asymmetrically. To simplify the steady-state analysis, it is assumed that those capacitors C1, Cc, and Co have large values and the voltage ripples across them can be ignored. The magnetizing inductance current iLm is approaching to its minimum value and the auxiliary inductor current iLa is approaching to its maximum value. And the output diode is not conducting.

1. Soft-Switching Operation

The auxiliary switch Sa is turned OFF. Then, the energy stored in the magnetic components such as Lm, Lr and La starts to charge Ca and discharge Cm. Therefore, the voltage Vsa across the auxiliary switch Sa starts to rise from zero and the voltage vSm across the main switch Sm starts to fall from Vcc. Then, the body diode Dm is turned ON. After that, the gate signal is applied to the switch Sm and the channel of Sm takes over the current flowing through Dm. Since the voltage Vsm is clamped as zero with turn-on of Dm before the switch Sm is turned ON, zero-voltage turn-on of Sm is achieved.

The input voltage is applied to Lm and the current iLm increases linearly from its minimum value. The main switch Sm is turned OFF. Then, the voltage Vsm increases and the voltage decreases from Vcc at the same time due to the energy stored in the magnetic components Then, the body diode Da turned ON. After that, the gate signal is applied to the switch Sa and the channel of Sa takes over the current flowing through Da. Since the voltage Vsa clamped as zero before the switch Sa turned ON, zero-voltage turn-on of Sa achieved. With the turn-on Sa, the output diode Da starts to conduct. Then the resonance occurs between the resonant inductor Lr and the capacitor C1.

The output diode current decreases and the zero-current turn OFF of the diode Do are achieved. Since the current changing rate of Do is controlled by a resonant manner, its reverse-recovery problem is reduced.

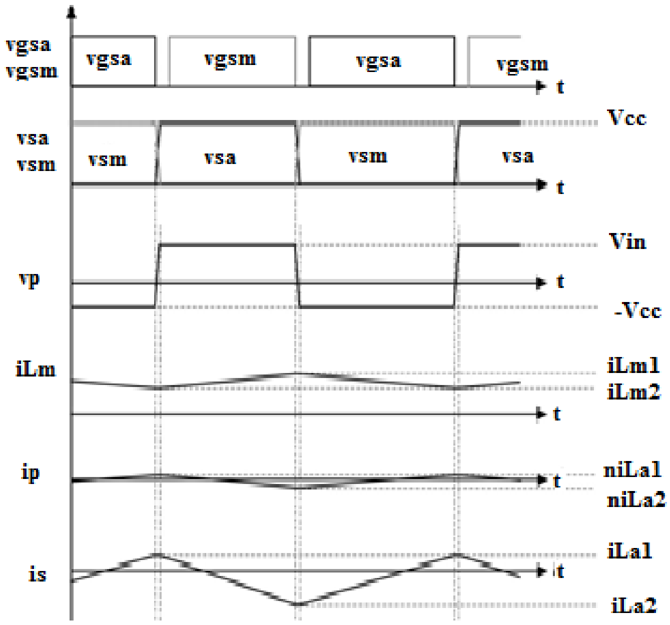


Figure 3: Waveforms of Soft-Switching Proposed SEPIC.

III. DESIGN PARAMETER

1. Input Current Ripple

The input current i_{in} given by

$$i_{in}(t) = i_{Lm}(t) + i_v(t) \quad (1)$$

The ripple component of i_{in} can be removed by satisfying the following condition:

$$L_a + L_r = n(1-n) L_m \tag{2}$$

Where, n is turns ratio. Under the condition of (2), the input current i_{in} is constant.

2. ZVS Condition

The ZVS condition for Sa is given by

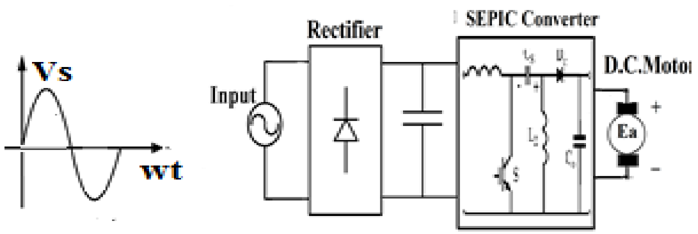
$$I_{Lm1} - (1-n) I_{La2} > 0 \tag{3}$$

Since I_{Lm1} is always positive and I_{La2} is always negative for *n* <1, the condition of (3) is always satisfied for *n > 1*. Therefore, the ZVS of Sa is always achieved.

Similarly, for the ZVS condition for Sm , the following condition should be satisfied

$$-I_{Lm2} - (1-n) I_{La1} > 0 \tag{4}$$

IV. DESCRIPTION OF A PROPOSED CONVERTER



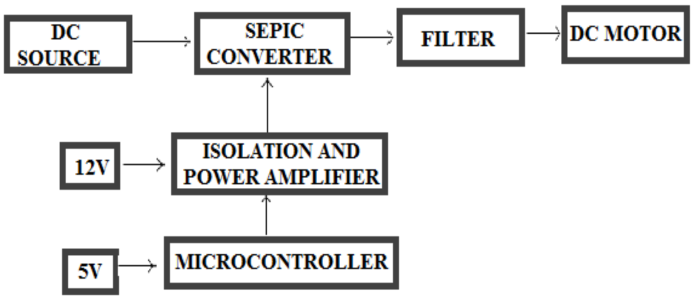


Figure 4: Simulated Block Diagram of SEPIC with Motor load. Figure 5: Hardware Block Diagram of SEPIC with Motor load

The switch used in proposed converter is Power MOSFET has lower switching losses but its on-resistance and conduction losses are more. MOSFET is a voltage-controlled device. MOSFET has positive temperature coefficient for resistance. This makes parallel operation of MOSFET easy. In MOSFET secondary break down does not occur, because it has positive temperature co-efficient. Powers MOSFET in higher voltage rating has more conduction losses. The chosen MOSFET is IRF 840 and voltage and current rating is 500V and 8A. All the power MOSFETs are designed for application such as switching regulators, switching converters, motor drives. The IRF-840 provides fast switching, ruggedized device design, low on-resistance and cost effectiveness, dynamic dv/dt rating, repetitive avalanche rated and ease of paralleling. The hardware implementation includes Power circuit and Control circuit.

The input supply is AC then it is given to bridge rectifier the function of rectifier is used to convert ac into DC as in Fig.5. The DC source may be Battery or fuel cell. SEPIC Converter is used to convert low voltage dc to high voltage dc and vice versa. Moreover presence of coupled inductor produce significant reduction in converter volume and attaining soft switching method to reduce the switching losses and voltage stress and also improve the efficiency. The output has DC output voltage. It is used to run the motor, battery charging, and telecommunication applications. Microcontroller is used to generate triggering pulse for MOSFET's. It is used to control the outputs. Micro controller have more advantage compare then analog circuits and microprocessor such as fast response, low cost, small size and etc. Driver amplifier is also called as power amplifier because it is used to amplify the pulse output from micro controller. It is also called as optocoupler IC. It provides isolation between microcontroller and power circuits.RPS gives 5V supply for micro controller and 12V supply for driver. It is converted from AC supply. AC supply is step down using step down transformer. A capacitive filter circuit is used where a capacitor is connected at the rectifier output and dc is obtained across it. The filtered waveform is essentially a dc voltage with negligible ripple and it is ultimately fed to the motor load.

1. Power circuit

The 230/12V AC input is rectified into 16V pulsating DC with the help of full bridge rectifier circuit.

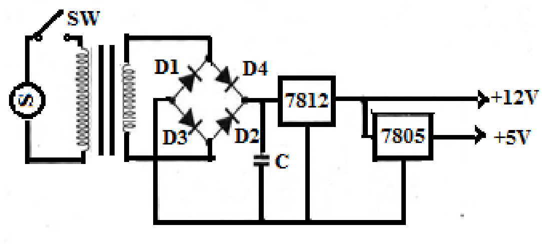


Figure 6: Circuit Diagram of Power Circuit

The ripples in the pulsating DC are removed and pure DC is obtained by using a capacitor filter. The positive terminal of the capacitor is connected to the input pin of the 7812 regulator for voltage regulation. An output voltage of 12V obtained from the output pin of 7812 is fed as the supply to the pulse amplifier. An output voltage of 5V obtained from the output pin of 7805 is fed as the supply to the microprocessor .From the same output pin of the 7805, a LED is connected in series with the resistor to indicate that the power is ON.

2. Control circuit

The control circuit controls the power circuit by using gate pulses generated by controller**.** The control circuit has the following Power supply, Microcontroller, Driver circuit (Isolation circuit).

The driver unit consists of optocoupler and isolation circuit**.** There are many situations where signals and data need to be transferred from one subsystem to another within a piece of electronics equipment, or from one piece of equipment to another, without making a direct ohmic electrical connection. Often this is because the source and destination are (or may be at times) at very different voltage levels, like a microprocessor which is operating from 5V DC but being used to control a MOSFET which is switching 240VAC. In such situations the link between the two must be an isolated one, to protect the microcontroller from over voltage damage.

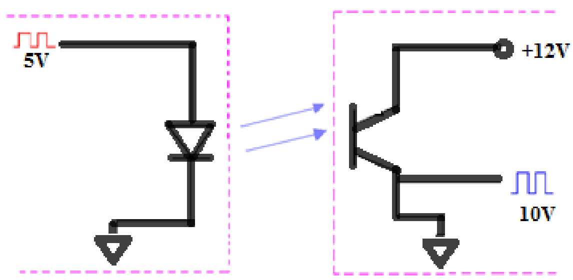


Figure 7: Optocoupler operation

Optocoupler is an electronic device designed to transfer electrical signals by utilizing light waves to provide coupling with electrical isolation between its input and output. The main purpose is to prevent high voltages from damaging components or distorting transmissions on the other side. An opto-isolator contains a source (emitter) of light, almost a LED that converts electrical input signal into light, and a photo sensor, which detects incoming light and either, generates electric energy directly.

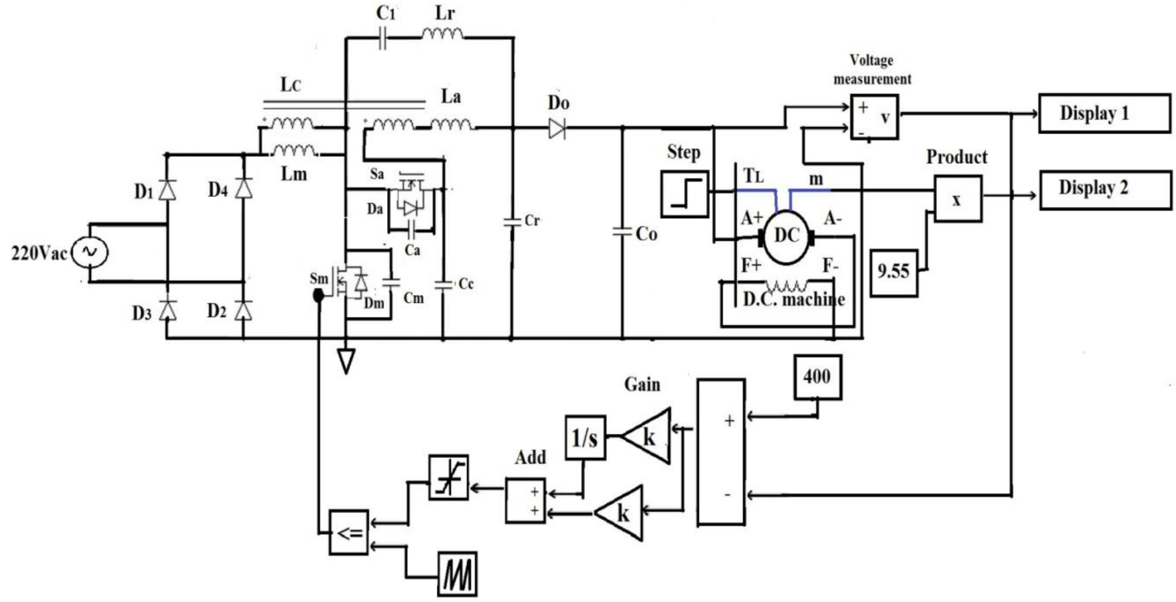


Figure 8: Circuit Diagram of Proposed system

The figure 8 shows the circuit configuration of Diode Bridge rectifier, Capacitor, SEPIC converter, PI Controller with closed loop DC Motor load. The given input is ac and it is rectified into dc by rectifier for sepic converter to drive the dc shunt motor.

V. SIMULATION RESULT AND DISCUSSION

The SEPIC and the D.C. Motor are connected in the Simulink with Proportional Integral (PI) Controller which acts as bridge between them. The system interfaced with the MATLAB takes a larger time for providing the output. The SEPIC topology is controlled using the PI Controller as explained. The controller is carried out between 0 and 1 for a closed loop system.

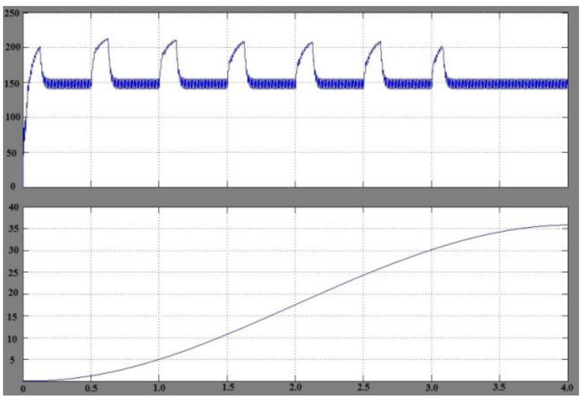


Figure 9: Input and Output Voltage Waveform

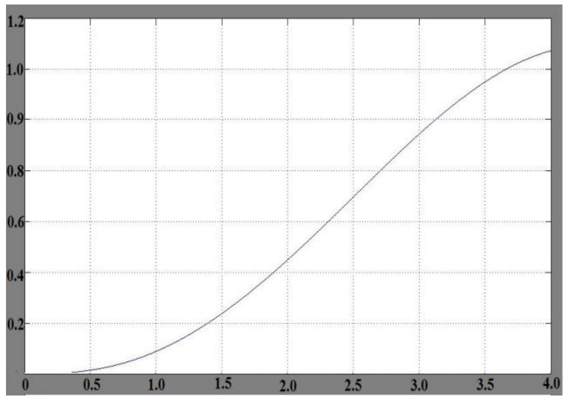


Figure 10: Output current Waveforms

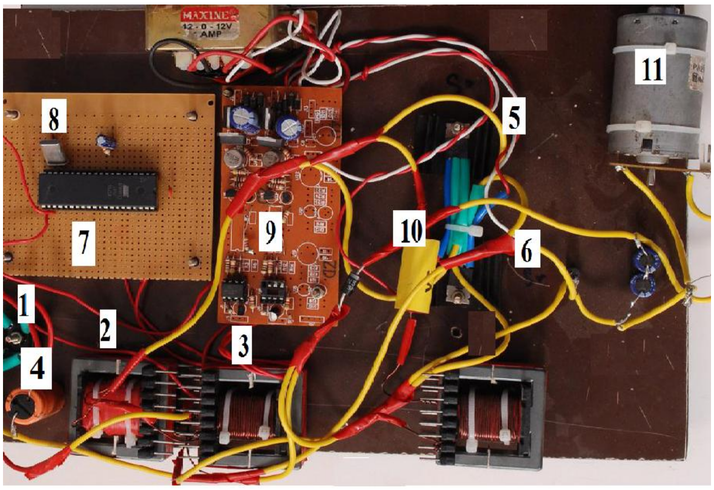
The converter with motor Load is simulated at various load conditions in order to obtain maximum voltage. The main objective to drive a D.C. Motor to attain twice that of an input voltage of the system. The current is predicated at all the loaded conditions. The results obtained in the form of waveform are with respect to the time. The figure 9 shows the output voltage. The output voltage is observed to be 35V. The figure10 shows the output current of D.C. Motor and it is 1.1A for the given input voltage is 17Vdc.

VI. EXPERIMENTAL RESULT

To verify performance and analysis of the proposed SEPIC converter, a prototype is implemented and tested with the following specification.

1) Input voltage Vin = 17V.
2) Output voltage Vo = 35V.
3) Switching frequency fs = 33 kHz.
4) Output power Po = 55W.

The control circuit was implemented with a Microcontroller AT89S52 from Atmel's family. The turn ratio n of the coupled inductor is selected as 0.25. Then, the conditionfor inductor rating is 100 µH. The value of Capacitor is selected as 4.7 µF, 124V. The input pulse given to the driver circuit and the voltage is approximately 5V. The driver amplifier amplifies the input voltage. The amplified output pulse voltage nearly 12V from the circuit. This amplified driving pulse is used to drive the MOSFET switches.



1. Diode Bridge Rectifier

2. Transformer1:2,40V, 2A, Ferrite core

3. Inductor 100µH

4. Diode MIC 5408

5. MOSFET (Sa) IRF840 500V, 8A, Ferrite core

6. MOSFET (Sm) IRF840 500V, 8A, Ferrite core

7. Microcontroller AT89S52

8. Optocoupler

9. Driver circuit

10. Capacitor 4.7µF, 250V

11. DC Motor (Shunt) 48V, 1500RPM

Figure 11: Overall view of Hardware Kit

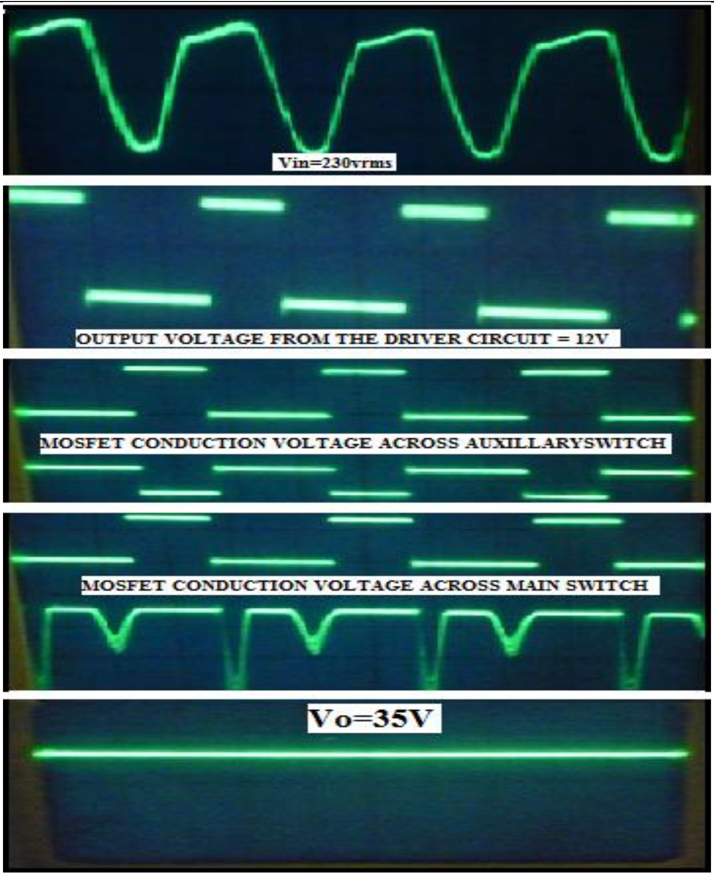


Figure 12: Hardware Output Waveforms

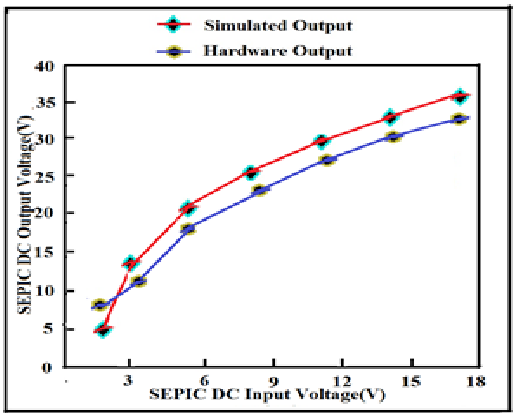


Figure 13: Comparison of simulated and hardware Voltage

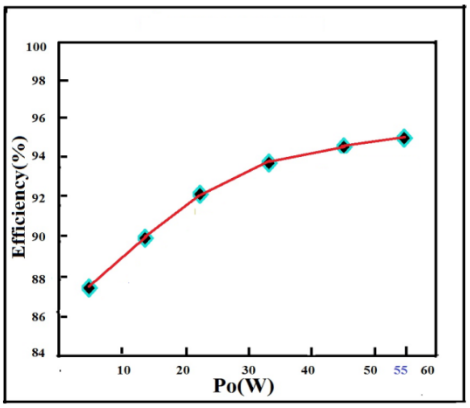


Figure 14.Efficiency vs Output Power of motor load for motor load

The variations are very small which relates the characteristics of the converter more close between the simulation and the hardware results. The proposed converter shows better characteristics due to its soft-switching of power switches and the output diode.

The SEPIC converter fed DC Motor attains an efficiency of 94.5% at full load condition. The proposed converter exhibit higher efficiency due to its soft-switching characteristics of power switches and the output diode. The converter shows lower efficiency under light load. This is due to MOSFET's secondary current. It increases the conduction loss and also the power loss at light load.

VII. CONCLUSION

The operating principle, analysis, and the implementation of a SEPIC converter with soft-switching are presented in this paper. In the proposed converter,the coupled inductor and power switchesaremainly used for ripple-free input current and to achieve ZVS operation. The advantages of the proposed converter are low voltage stresses, low switching losses, reverse-recovery problem of theoutput diode, and high-voltage applications. The design consideration ofthe proposed converter is included. The experimental results based on a prototype are presented for validation.

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