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Magnetic Coupled Sepic Rectifier with Voltage Multiplier using PID Conroller for SMPS

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Abstract : This paper presents a new Magnetic coupled sepic rectifier for Switch mode power supply(SMPS).The proposed converter is designed in a bridge less configuration to attain low conduction losses .The use of voltage multiplier reduces the switch voltage stress .The proposed topology is operated in discontinuous conduction mode (DCM),it achieves unity power factor and low total harmonic distortion (THD) of the input current. The DCM operation gives additional advantages such as zero current turn-on in the power switches and simple control circuitry. The magnetic coupled sepic rectifier is simulated in open and closed loop using PID controller. The simulation results are verified experimentally. The proposed converter achieves high efficiency and high power density.
Keywords : Magnetic coupled sepic rectifier (MCSR),Switch mode power supply(SMPS), Total harmonic distortion (THD), Discontinuous conduction mode (DCM), PID controller.

1. Introduction

Switch mode power supply which is widely used as power supply in breakers and it is suitable for Three –phase power metering applications. SMPS have wide array of universal input voltage applications for power factor correction. Most of the power factor correction topologies implement a boost-type circuit configuration at its front end [2]–[9] because of its low cost and its high performance in terms of efficiency, power factor and simplicity. In universal input voltage applications, the boost converter suffers from lower efficiency and higher Total Harmonic Distortion(THD) at low input voltage. In addition, the boost converter has relatively high switch voltage stress which is equal to the output voltage. Also, the boost rectifier has some practical drawbacks, such that the input–output isolation cannot be easily implemented, the startup inrush current is high and there is a lack of current limiting during overload conditions.

The boost converter operating in discontinuous conduction mode (DCM) offers a number of advantages, such as inherent PFC function, very simple control, soft turn-on of the main switch and reduced diode reversed-recovery losses. The DCM operation requires a high-quality boost inductor since it must switch extremely high peak ripple currents and voltages. As a result, a more robust input filter must be employed to suppress the high-frequency components of the pulsating input current, which increases the overall weight and cost of the rectifier. In addition, several PFC topologies based on fly back, buck-boost and Cuk converters have been implemented [10]–[16]. These topologies have an inverting output, circuit complexity, higher conduction losses, low efficiency and low power density. To overcome these drawbacks Magnetic coupled Sepic rectifier is used.

2. Sepicconverter

Single-ended primary-inductor converter (**SEPIC**) is a type of DC-DC converter allowing 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 converter is controlled by the duty cycle of the control transistor.

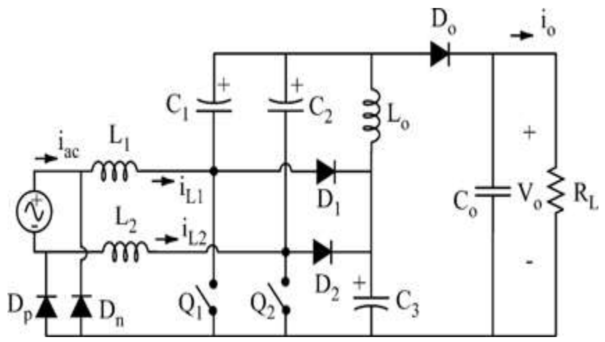

Fig 2.1 Circuit diagram of Sepic converter

SEPIC converter is essentially a boost converter followed by a buck-boost converter, using a series capacitor to couple energy from the input to the output, when the switch is turned off, its output drops to 0 V, following a hefty transient dump of charge.

SEPIC converter has several advantages such as non-inverted output, Step up and step down capabilities in addition to magnetic coupling that will lead to reduction in input current ripple [9]. The SEPIC converter operating in discontinuous conduction mode (DCM) results in reduced switch voltage stress and wide static gain, by inserting a voltage multiplier cell in the SEPIC converter. However, the proposed topology utilizes a full bridge at the input side resulting in lower conduction losses because the current path flows through at least two bridge diodes at any instant of time. In addition, this topology utilizes a Snubber circuit to decrease switching losses. The DCM operation results in soft turn-on switching and relatively low inrush current. The voltage gain can be extended without extreme duty cycle operation which makes the proposed topology suitable for universal line voltage applications. Magnetic coupled SEPIC rectifier with voltage multiplier results in higher overall efficiency and higher power density.

The bridgeless configuration of the Proposed converter will reduce the conduction losses and the multiplier cell (D_1, C_3 and D_2, C_3) will increase the gain and reduce the switch voltage stress. Hence, the proposed topology enhances the overall efficiency. The proposed circuit consists of two symmetrical configurations. Each configuration will operate in a half-line cycle. By implementing two slow diodes $D_p$and D_n, the output ground is always connected to the terminals of the ac mains directly over the whole ac line cycle. As a result, this stabilizes voltage potential of output ground and reduces the common mode EMI generation. Furthermore, the three separate inductors can be magnetically coupled into a single magnetic core to attain an input current having very low current ripples. The generated EMI noise level is greatly minimized as well as the requirement for the input filtering. The proposed converter utilizes two non- floating switches ($Q_1$and Q_2). Switch$Q_1$is turned ON/OFF during the positive half-line cycle and the current flows back to the source through Diode D_p. During the negative half-line cycle, switch Q_2 is switched ON/OFF with the current flowing back through diode D_n . The two power switches $Q_1$and Q_2 can be driven by the same control signal, which significantly simplifies the control circuit. The advantages of the proposed converter with the multiplier cell are the DC output voltage is higher than the peak input voltage, input–output isolation can be easily implemented and high startup inrush current is reduced.

2.1 Principle And Operation Of Sepic Converter

The SEPIC CONVERTER consists of two symmetrical configurations, the circuit is analyzed for the positive half cycle configuration. Assuming that the three inductors are operating in DCM, then the circuit operation during one switching period $T_s$in a positive half-line period can be divided into three distinct operating modes.

First Stage

In this stage, switch $Q_1$is turned-on by the control signal and both diodesD_1 and $D_o$are reversed biased. In this stage, the three-inductor currents increases linearly at a rate proportional to the input voltage v_{ac}

$D_i\, L_n / dt = v_{ac}/ L_n,\ n=1, 2, 0$

Second Stage

In this stage, switch $Q_1$is turned-off and both diodes $D_1$and $D_o$will conduct simultaneously providing a path for the three inductor currents. In this stage, the three inductor currents will decrease linearly at a rate proportional to the capacitor C_1 and voltage V_{C1}. This stage ends when the sum of the currents flowing in the inductors adds up to zero, hence the diodes D_1 and $D_o$are reverse biased

$Di\ L_n / dt = - vc1/ Ln\ ,\ n=1,2,0$

Third Stage

In this stage, switch Q_1remains turned-off while both diodes $D_1$and $D_o$are reverse biased. Diode $D_p$provides a path for iL_o. The three inductors behave as current sources, which keeps the currents constant. Hence, the voltage across the three inductors is zero. This period ends when switch $Q_1$is turned-on initiating the next turn-on of the switching cycle.

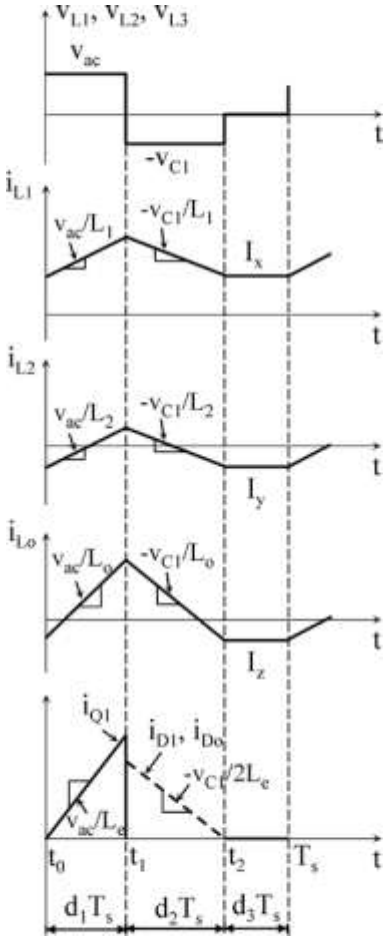

Fig. 2.1 DCM waveforms during the Switching period for the Magnetic coupled SEPIC Converter.

3. Simulation Results

The Magnetic Coupled Sepic Rectifier with voltage multiplier cell is simulated in both open and closed loop system using MATLAB simulink and the results are presented. Scope is connected to display the output voltage.

The following values are found to be a near optimum for the design specifications:

Table 3.1Simulation Parameters

Parameter	Rating
Input voltage	12V
C_1= C_2=C_3	220µF
C_o	1000 µF
L_1=L_2= L_o	500 µH
Switching Frequency	20kHz
Diode (D_1,D_2,D_p,D_n, D_o)	IN 4007
R	200Ω

3.1 Open Loop System

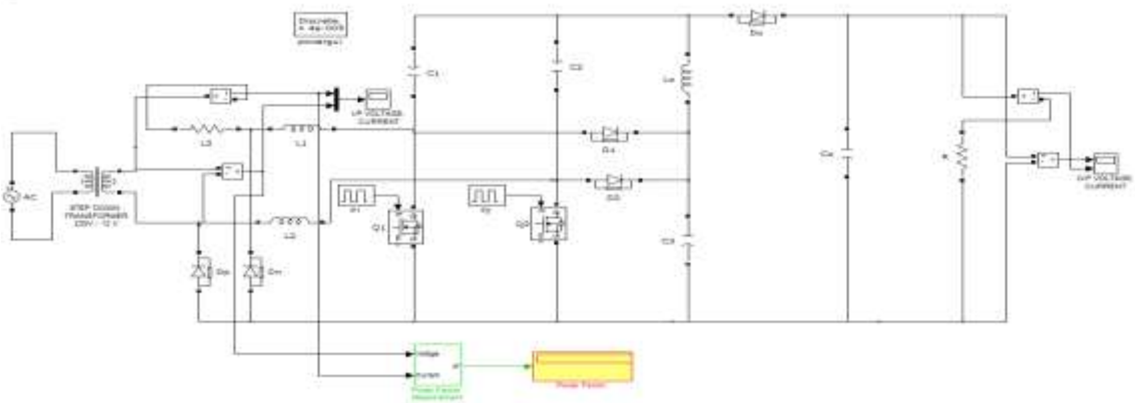

Fig. 3.1 Simulation diagram of open loop SEPIC converter.

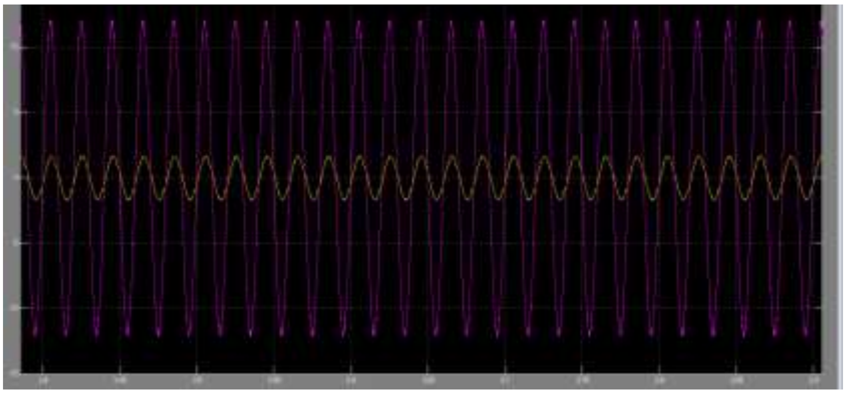

Fig. 3.2 Input Voltage.

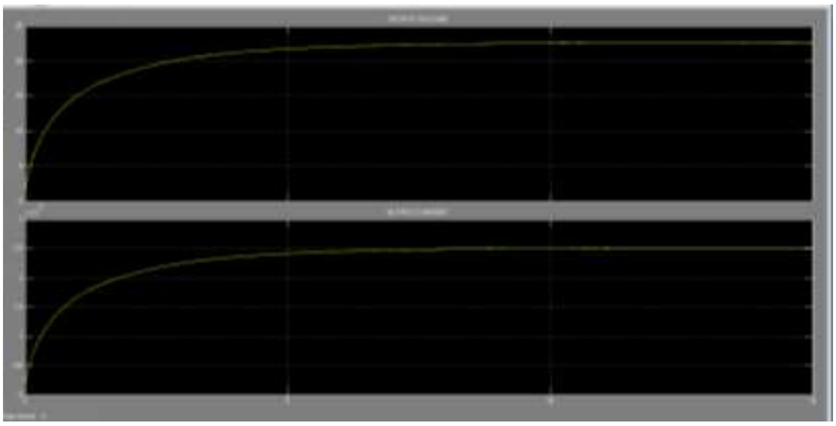

Fig. 3.3 Output Voltage.

3.2 Closed Loop System

The Magnetic coupled SEPIC rectifier is simulated in closed loop system with PID controller using matlabsimulink and the results are presented .scope is connected to display the output voltage.

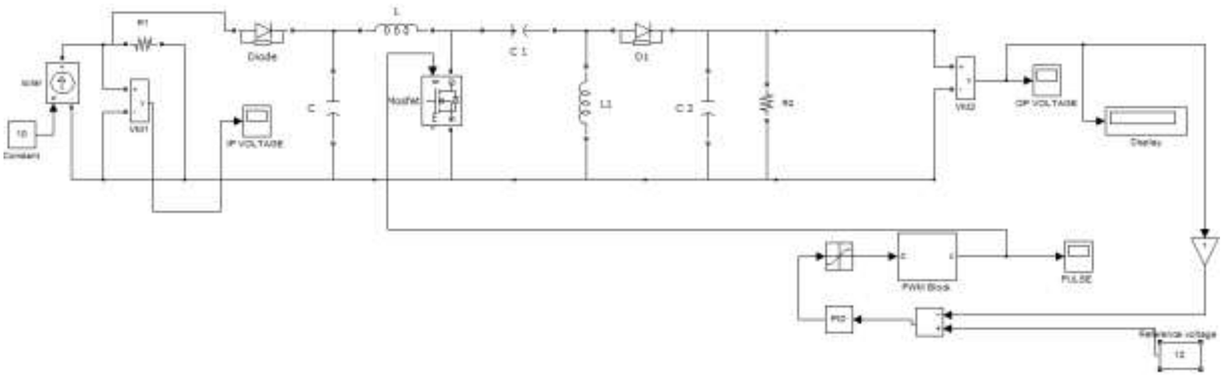

Fig. 3.4 Simulated diagram of closed loop magnetic coupled SEPIC rectifier

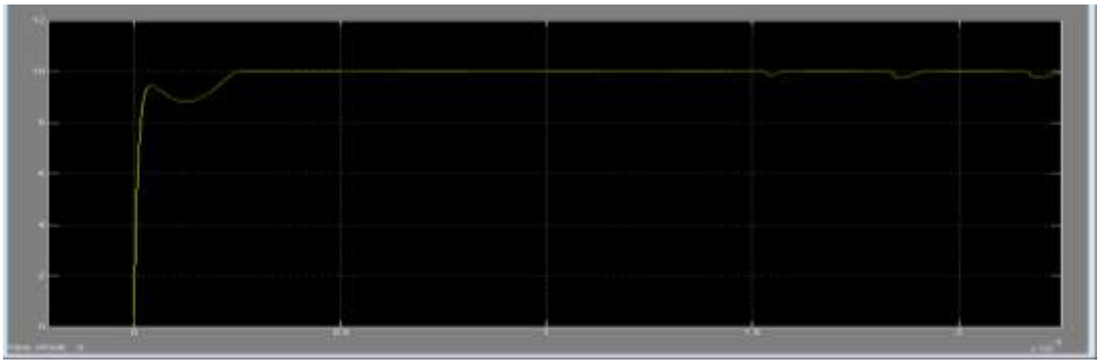

Fig. 3.5 Input Voltage.

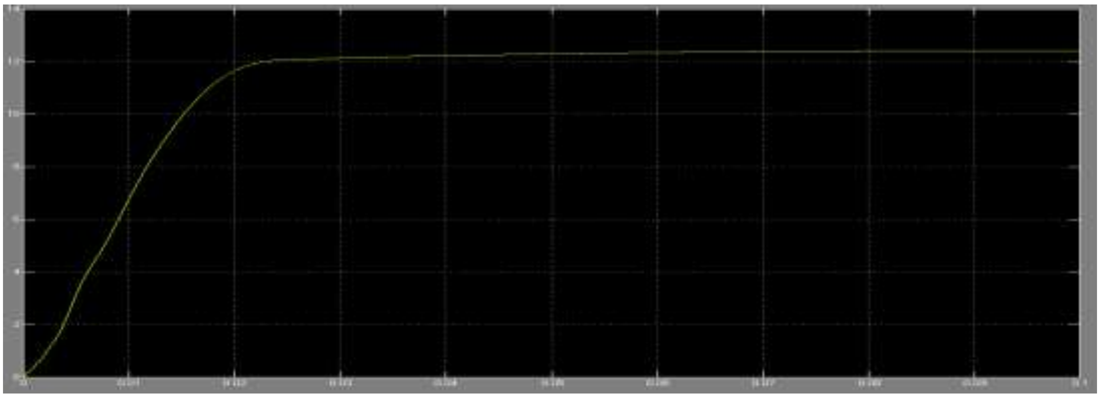

Fig. 3.6 Output Voltage.

4 Hardware Results

The magnetic coupled Sepic rectifier(MCSR) is developed and tested in the laboratory. The proposed converter is the Integration of magnetic coupled Sepic rectifier and Voltage multiplier.It consists of three stages , in the first stage the three- inductor currents increase linearly, in the second stage the three- inductor currents decreases linearly and finally the three- inductors behave as current sources.

The pulses required for the MOSFET are generated by using a ATMEL microcontroller 89C2051.These pulses are amplified by using a driver amplifier. The driver amplifier is connected between the Optocoupler and MOSFET gate. The gate pulses are given to the MOSFET of the magnetic coupled Sepic rectifier. ADC0808 is used for interfacing analog circuit and comparator circuit. To isolate power circuit and control circuit Optocoupler is used.

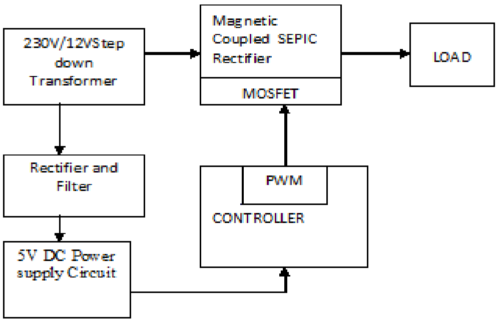

Figure 4.1 Schematic diagram of Magnetic coupled SEPIC Rectifier

Table 4.1 Hardware Parameters

Parameter	Rating
L_0	1mH
$C_1= C_2=C_3$	220µF
C_0	1000 µF
$L_1=L_2$	500 µH
Switching Frequency	50kHz
Diode	IN 4007
MOSFET	IRF840
R	200Ω
Regulator	LM7805,LM7812,5-24V
Driver IC	IR2110,+500V or +600V
Crystal Oscillator	230/15V,500mA,50Hz

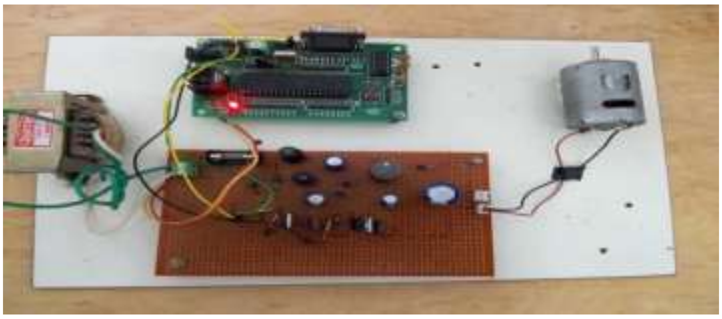

Fig. 4.2 Hardware Layout.

Fig. 4.3 Input Voltage. **Fig. 4.4 Output Voltage.**

5. Conclusion

The closed loop control of Magnetic coupled sepic Rectifier (MCSR) using PID controller is simulated and implemented.The proposed converter is the Integration of magnetic coupled Sepic rectifier and Voltage multiplier, it provides a low voltage stress and low conduction losses .The proposed converter is designed in a bridge less configuration to attain high efficiency. MCSR has improved performance characteristics such as high power capability, modularity, improved efficiency. However MCSR achieves high efficiency and high power density. The closed loop control of PID controller reduces the steady state error

,increases the stability,very less oscillation and fast response. From the simulation results it has been found that the transient performance and steady state performance is improved by using PID controller.The experimental results is found to be more advantages and cost effective with microcontroller. The performance of closed loop PID controller gives satisfactory response, good output voltage regulation and maintain constant voltage. Thus the proposed converter is suitable for Switch mode power supply.

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