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Design and simulation of a novel AC to DC Bridgeless SEPIC Converter

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Abstract

In real world there is a need of high voltage dc supply in electric traction, HVDC transmission etc. To convert ac to dc normally bridge rectifiers are used. There are some problems created due to the use of more number of power electronic components like high switching voltage stress, complexity of circuit control and poor power factor. In conventional bridge rectifiers the total harmonic distortion (THD), electromagnetic interferences also in considerable level. The required number of electronic devices also high in bridge type rectifiers. To compensate these drawbacks a bridgeless SEPIC PFC rectifier is proposed. This proposed converter will converts ac into dc without using any bridge type rectifiers. At the same time power quality also maintained in a considerable level. To demonstrate the probability of the proposed technique simulation results are presented here.

Key Words**:** single ended primary inductance converter (SEPIC), total harmonic distortion (THD), power factor correction (PFC), discontinuous current mode (DCM).

1 Introduction

Now a day the power quality improvement of the ac system has become a great distress due to the increase in electronic equipments. As a result of electronic components the harmonic contamination in the power lines are enhanced. So to improve the transmission efficiency and the power factor there is a requirement of PFC converter circuits [1].

Active PFC is preferred here since it has negligible harmonics in the input line current, the load behaves like a pure resistor and it leads to near-unity loadpower factor. Most switched mode power supplies as well as active PFC circuits in the market today consist of dcdc convertersuch as a buck, a boost, a buckboost, a Cuk, a zeta, a single-ended primaryinductance converter (SEPIC) converter [2].

This method of approach is suitable for only a low-to-medium power range. For high power ranges, the high conduction loss caused by thehigh forward voltage drop of the diode bridge begins to degrade the overall system efficiency, and the heat generated within the bridge rectifier may destroy the individual diodes [3].

Hence, it becomes necessary to utilize a bridge rectifier with higher current-handling capability or heat-dissipating characteristics. This increases the size and cost of the power supply, which is unacceptable for an efficient design. In each switching cycle there are always three power semiconductors in the flowing-current path in conventional active PFC circuits. It is the main reason for high conduction losses [4].

To avoid the drawbacks caused by the conventional bridge type ac to dc rectifiers in this paper a new method is proposed namely bridgeless SEPIC converter. In this without the help of diode bridge the ac supply is converted into dc by using very few passive elements. The proposed bridgeless rectifier and its operation are briefly given in this paper.

2 BLOCK DIAGRAM

The block diagram for the proposed bridgeless SEPIC rectifier is shown in figure1.Here the ac supply is given to an auto transformer. Because the essential input voltage may not be as same as the supply voltage. By using an auto transformer the input ac supply is converted into the required voltage level.

Then the supply is given to the SEPIC rectifier through the source inductance. The source inductor is used for the input power factor controlling purpose. By controlling the input power factor the output voltage fluctuations is also able to be controlled. Then it is given to the proposed bridgeless SEPIC rectifier.

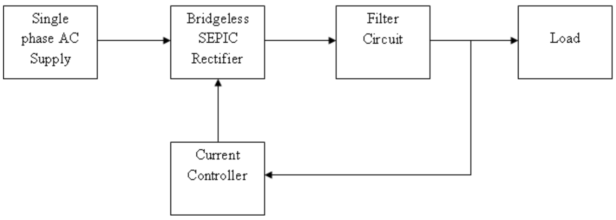

Fig 1. Block diagram

In this bridgeless SEPIC rectifier the input ac supply voltage is first converted into the variable dc voltage by using the inductors. Then it is filtered by using the filtering circuit. In this bridgeless SEPIC rectifier normal capacitors are used for reducing the output ripples and for the filtering purpose.

The output voltage to the load will be in the form of pure dc voltage. This will be able to use in any type of dc loads. There will be a possibility of change in output voltage by simply controlling the few components of this circuit. In this method the circuit complexity is very much reduced due to the simple circuit operation.

By using the current controller the closed loop control is formed. The current controller is a device to sense the output current and voltage for the purpose of maintaining the output at a constant level. In open loop control there may be a chance to occur some fluctuations in the output. To avoid this there is a need of closed loop control. The brief explanation of proposed circuit is given in the following chapters.

3 PROPOSED BRIDGELESS SEPIC RECTIFIER

Normally a rectifier can be operated in two different operating modes namely Continuous Conduction Mode (CCM)

Discontinuous Conduction Mode (DCM)

CCM is mainly used for high power applications. For low power application the SEPIC converter is operated in DCM mode. In DCM the SEPIC converter shows good performance even with simple control and also nearly unity power factor can be achieved naturally.

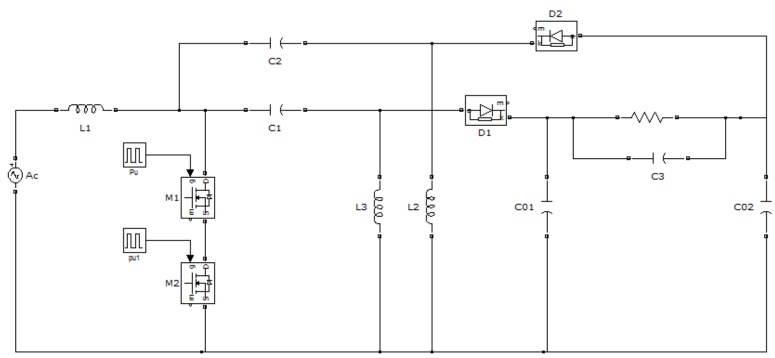

Fig 2. Proposed Bridgeless SEPIC Rectifier

In this converter by using three inductors and few capacitors the ac supply is converted into pure dc voltage with less than 1% voltage ripple.Assume that here the three inductors denoted in this SEPIC rectifier are working in DCM. If it is operated in DCM near-unity power factor can be achieved even though the input line current having more harmonics .In DCM, both diodes Do1 and Do2 are turned off at zero current, and both switches are turned on at zero current. Thus, the reverse recovery of the rectifier and the switching losses are considerably reduced.

4

The theoretical analysis of the proposed rectifier is performed during one switching period in a positive half-period of the input voltage. Similar to the conventional SEPIC the DCM for the proposed rectifier occurs when the current through diode Do1 drops to zero before the end of the switch-off time. Thus, the circuit operation in one switching cycle, Ts, can be divided into three stages. To simplify the analysis, it is assumed that the rectifier is operating in steady state condition.

4 DESIGNING OF CONVERTER CIRCUIT

The voltage conversion ratio of the proposed bridgeless SEPIC rectifier is given by the following formula

$$M = \frac{V_0}{V_m} \tag{1}$$

To operate the converter in DCM mode the sum of duty cycle should be less than one

$$D_2 < (1 - D_1) \tag{2}$$

M is the voltage conversion ratio. The value of M should be greater than or equal to 2.

$$Vo/2Vac0 = M2. \tag{3}$$

Above equation shows that the step-down property is lost (comparedto the conventional SEPIC), which may be considered asa disadvantage in some applications. However, the constraintin above equation can be removed by implementing inputoutput galvanic isolation. On the other hand, similar to the conventional SEPIC, galvanic isolation can be obtained easily by employing twowinding inductors for both L2 and L3 instead of two separateones.

The dimensionless parameter Ke given by the following equations

$$K_e = \frac{2L_e}{R_l T_s} \tag{4}$$

$$K_e = \frac{1}{2(m+2)^2} \tag{5}$$

The emulated resistance is calculated by the formula which is given here

$$R_e = \frac{2L_e}{D_l^2 T_s} \tag{6}$$

The equivalent circuit inductance of the converter is given by the following equation because the three inductors are connected in parallel.

$$\frac{1}{L_e} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \tag{7}$$

The value of the source inductance or input inductance L1 must be equal to

$$\frac{1}{L_1} = \frac{V_m D_1}{f_s \Delta_{il1}} \tag{8}$$

For simplicity the inductor values L2 and L3 will be taken as equal and their values are estimated by the following equation

$$L_2 = L_3 = \frac{2L_1 L_e}{[L_1 - L_e]} \tag{9}$$

By using the above equations the values of the three inductors are calculated. The inductor values are designed as per the design.

The peak-to-peak inductor input current ripple in both proposed and the conventional SEPIC converters are proportional to the operating duty cycle. When both of the rectifiers are operating at the same ratio of Ke/Ke-crit, then the ratio between the input current ripples is given by

$$\frac{\Delta i_{L1}, BL}{\Delta i_{L1}, conv} = \frac{L_1, conv}{L_1, BL} * \frac{1+M}{2+M} \tag{10}$$

It is clear that if both converters are designed to have the same input current ripple, then the amount of input inductance required by the bridgeless SEPIC is always less than that of the conventional SEPIC. The low-frequency peakpeak output voltage ripple is given by

$$\Delta V_0 = \frac{1}{C_0}\int_{\frac{T_L}{8}}^{\frac{3T_L}{8}} [i_{D01} - i_0]dt \tag{11}$$

$$= \frac{T_L V_0}{2C_0}[\frac{1}{R_e M^2}(\frac{1}{\pi} + \frac{1}{2}) - \frac{1}{R_L}] \tag{12}$$

Where Co1 = Co2 = Co. The output voltage ripple in the proposed converter topology is twice than the conventional SEPIC. However, connecting an additional capacitor across the load terminals with a capacitance of (C3 = Co/2) produces the same output voltage ripple as that of the conventional SEPIC.

The capacitors are used to reduce the output voltage ripple. The higher capacitor value improves the purity of output voltage. However the capacitor designing will reduce the circuit size and complexity.

5 SIMULATION OF CLOSED LOOP CONTROL

The following diagram shows the simulation diagram of bridgeless SEPIC converter in closed loop control. Normally in closed loop control the output is feedback to the input to control the output voltage at constant level. In this converter the output voltage is taken as a sample and it is given to the PI controller.

By using PI controller the output voltage from the simulation is compared with the reference voltage (the required output voltage). The difference between these voltage levels are used to produce the pulsating output and it is then given to the switching device. This method is commonly known as Pulse-width modulation (PWM).

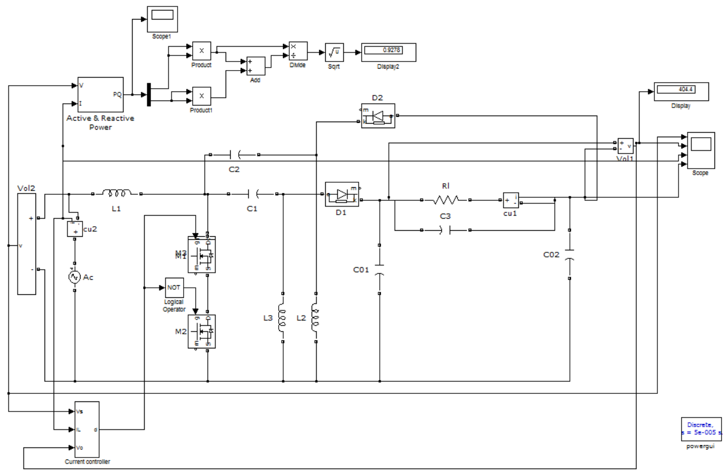

Fig 3. Simulation diagram for closed loop control

The diagram for current controller is shown in figure4. In current controller three parameters from the SEPIC converter are taken as sample namely input voltage, input current, output voltage. First the output voltage is compared with our required output. The difference between the output voltage and the required output is given to a PI controller. The input voltage given to the converter is multiplied with the output of PI controller.

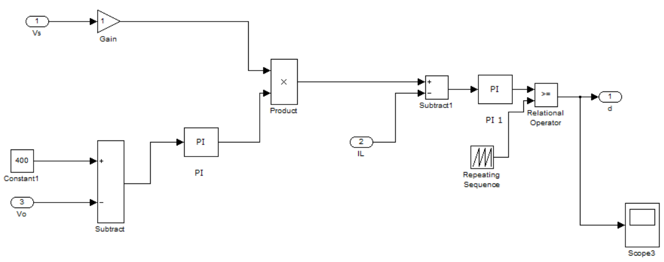

Fig 4. Current controller subsystem

This product value given to the subtractor block. The input current sample of the converter is subtracted from this product value and the result is given to a PI controller. The output of this PI controller is compared with a repeating sequence by using a relational operator. Thus the output pulses are generated by using a current controller and given to the switches of the converter.

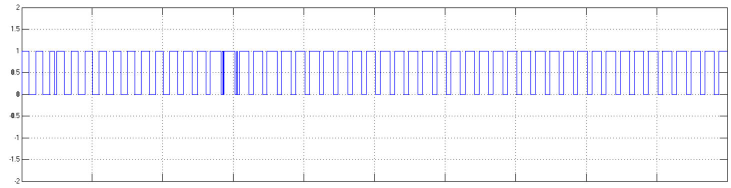

Fig 5.Pulse generated by current controller

The above diagram shows that the pulses generated by the current controller. According to the fluctuations occurred in the output of the controller the pulse width is varied. This can be note it down from the waveform generated by the current controller block. The input and output voltage waveforms and the output current waveform of the closed loop control of SEPIC converter is shown in the figure 6.

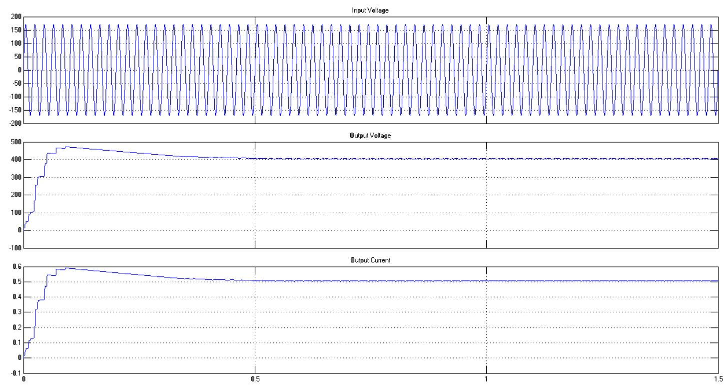

Fig 6. Input & output waveforms of closed loop control

The value of THD measured in closed loop control is shown in figure 7.here the THD value is reduced to 4.35%. The power factor is 0.9205. For simplicity in the circuit 100 resistive load is used as a load. The level of THD is reduced from the existing SEPIC converter circuit

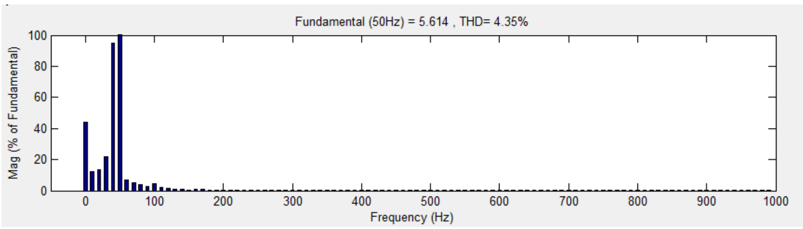

Fig 7. Input current THD

6 CONCLUSION

Here a new single-phase bridgeless rectifier with low conduction losses and low input current distortion has been presented, analyzed and verified experimentally. From the conventional SEPIC rectifier the proposed new bridgeless rectifier is derived. Comparing with conventional SEPICPFC circuit, due to the lower conduction loss and switching loss, the proposed topologies can further improve the conversion efficiency. The main features of the proposed converter include high efficiency, low voltage stress on the semiconductor devices, and simplicity of design. These advantages are desirable features for high-power and high-voltage applications. The proposed bridgeless PFC configuration, as described in this paper, has been implemented to verify the performance of the system. Namely, to maintain same efficiency, the proposed circuits could operate with higher switching frequency. Thus, additional reduction in the size of PFC inductor could be achieved. Besides improving circuit topology and performance, a further reduction in rectifier size could be realized by integratingthe three inductors into single magnetic core. The proposed concept can be extended easily to other power conversion systems to satisfy the requirement of high-voltage demands.

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