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A STUDY ON HARMONIC ANALYSIS OF SEPIC POWER CONVERTER

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ABSTRACT

In the recent years development in power electronics has led to advancement in power converter topologies. DC-AC power converters have very wide applications in field of renewable energy sources, battery storing networks, excitation circuits etc. Literature suggests that the power converting circuits in the process adds harmonics in the output voltage and current. Hence there is a requirement of power converting topology which adds less or no harmonics in the output voltage. As completely eliminating the harmonics is a complex task hence minimizing the effect of it is always taken care. The proposed concept delivers a novel concept for DC-DC power converter which produces less amount of harmonics in the output voltage and current. The circuit is simulated on MATLAB/Simulink platform and it is found that the efficiency of the converter is increased and its value is found to be 95%.

INDEX TERMS:*DC-DC power conversion, switched circuits, voltage multipliers.*

I. INTRODUCTION

Power factor is the ratio of true power to apparent power or power factor is the cosine of angle between voltage and current in a circuit. When the current and voltage are in phase, then the power factor is unity. Most of the loads in a domestic household circuit are inductive in nature and hence have low lagging power factor. With low power factor loads, the current flowing through electrical system components is higher. The excessive currents results in heating, which can damage or shorten the life of equipment. The low power factor is highly undesirable as it causes an increase in current, resulting in additional losses due to I^2R power loss in all the elements of power system from power station generator down to the utilization devices. Power factor is a measure of how effectively the current is being converted into useful work output and more particularly is a good indicator of the effect of the load current on the efficiency of the supply system.

A distorted current waveform can be the result of a rectifier, variable speed drive, switched mode power supply, discharge lighting or other electronic load. Power factor correction attempts to adjust the power factor of an AC load or an AC power transmission system to unity (1.00) through various methods. Both active and passive power factor correction circuits can be used to improve the power factor. In this paper an active power factor correction circuit is used. Using active power factor correction reduces the cost and bulkiness of the circuit.

The usual solution is a boost converter pre-regulator operating in DCM. It is a simple and cost effective method because in DCM it works as a voltage follower. The operation in DCM reduces the commutation losses. This solution is limited for low-power applications due to an increased converter conduction losses operating in DCM. Since the input inductor of the boost converter operates in DCM, a high-frequency filter composed by an inductor and capacitor must be used in the pre-regulator input in order to reduce the current ripple at the input and the problem presented by the boost pre-regulator operating in DCM is the input current distortion.

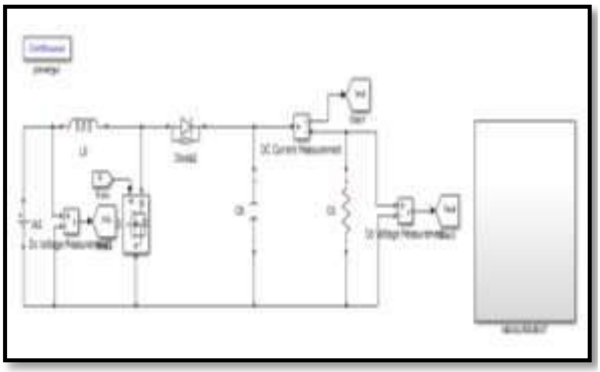


Fig. 1. Boost converter

The voltage applied across the input inductor during its demagnetization is equal to the difference of the output voltage and the input voltage; hence, the current distortion increases when the difference between the output voltage and the peak input voltage is reduced. Therefore, the output voltage must be increased for reducing the third-harmonic input current distortion and improving the power factor. The boost converter can operate with power factor as unity independently of the difference between the output and input voltage operating at the boundary of the DCM and continuous conduction mode (CCM) with a variable switching frequency modulation. The classical SEPIC converter, shown in figure 2, presents a step-up/step-down static gain and usually issued as a high power factor pre-regulator in applications where the output voltage is lower than the peak of the ac input voltage.

The pre-regulator using the classical SEPIC converter in DCM presents two additional operation characteristics. Firstly, the converter operates as a voltage follower (DCM) with a low value for the inductor L2 and using a high value for the inductor L1, but the input current presents a low current ripple just as a boost power factor rectifier operating in CCM with current-control loop.

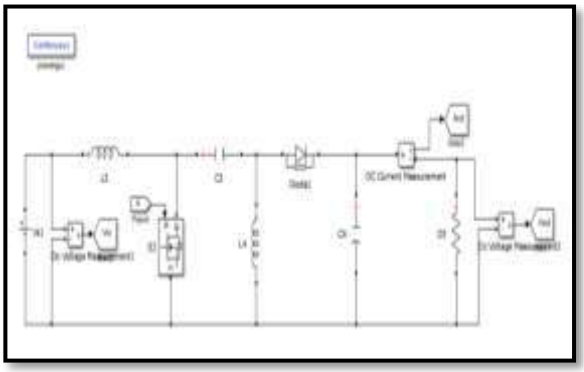


Fig. 2. Classical SEPIC Converter

Consequently, the Lf–Cf filter used in the boost converter in DCM is not required in the SEPIC converter operating in DCM. Therefore, the number of components for both converters operating in DCM is equal. But, in a practical application, an electromagnetic interference (EMI) filter is necessary as in any rectifier circuits. The second important characteristic using the SEPIC converter in DCM is that it acts as a voltage follower. The third-harmonic distortion is not presented because the inductor L2 is demagnetized with the output voltage.

The modified SEPIC dc–dc has an additional diode DM and capacitor (CM) at the classical SEPIC converter, the inclusion of the diode and the capacitor reduces the switch voltage and provides additional advantages. The modified SEPIC converter operates as a voltage follower and the input current presents low current ripple such as a classical SEPIC converter, designing the converter in DCM and using a low value for the inductor L2 and a high value for the inductor L1.

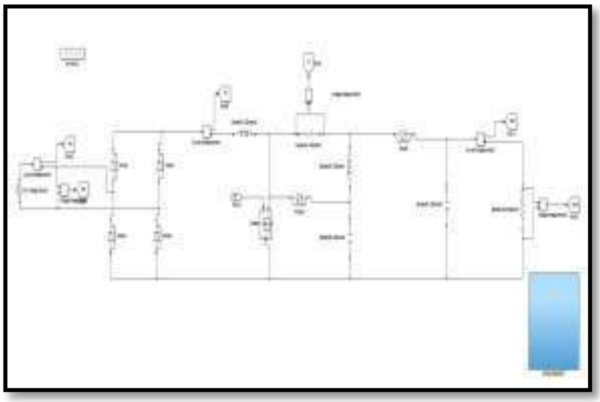


Fig. 3. Modified SEPIC Converter.

The modified SEPIC converter operating in Discontinuous Conduction Mode (DCM) presents three operational stages. For analysis the steady state operation is considered and all the components are assumed to be ideal. The voltages across all the capacitors are considered constant during a switching period. In DCM operation when the power switch is turned off the currents in all diodes of the circuit are equal to zero. Therefore, the DCM operation occurs when DO and DM diodes are not conducting before the switch is turn-on. It has a diode bridge and an ac source at the input side. High value of the input inductor L1 is chosen to reduce the input current ripple. Inductor L2 is kept low so as to operate it as a voltage follower. At steady state the voltage across both the inductors are zero and the sum of the input voltage Vin and capacitor CS voltage is equal to the capacitor CM voltage.

II. THEORITICAL ANALYSIS

The three operation stages of Modified SEPIC in DCM are presented as follows:

1) First Stage [t0 −t1]:

When the power switch S is turned ON, the input inductor L1 stores energy and full voltage comes across the inductor (VL1). The voltage across the inductor L2 (VL2) is equal to the voltage across the capacitor CM minus the voltage across the capacitor CS. This difference in voltage is equal to the input voltage as presented in equation (1). The currents through inductors L1 and L2 are increasing, but since L2 is lower than L1, the current variation in L2 is higher than in L1. The diodes DM and DO does not conducts during this period.

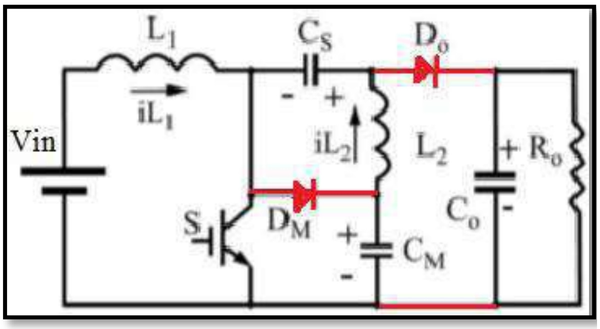


Fig. 4. First operating stage.

2) Second operating Stage [t1 −t2]:

At t1, the power switch S is turned OFF and the stored energy in the input inductor L1 is transferred to the output through the CS capacitor and output diode Do. The energy is also transferred to the CM capacitor through diode DM and the maximum switch voltage is equal to the CM capacitor voltage. The energy stored in inductor L2 is also transferred to the output and the capacitor CS through the diodes DO and DM. The voltage across L1 is equal to CM capacitor voltage minus the input voltage and this difference is equal to the CS capacitor voltage as calculated by (1). As the inductor dissipates energy the voltage across the inductor L2 is equal to the negative of the capacitor voltage CS. Thus, the voltage across the inductor L1 and L2 are equal to the negative capacitor CS voltage during this stage. The time interval (t2–t1) is defined as td and is equal to the transference period of the energy stored in inductors L1 and L2 through diodes Do and DM . When current through L1 and L2 are equal with the same direction, the currents through the diodes Do and DM becomes zero, thus finishing this operation stage. Therefore, td is the conduction time of diodes DM and Do, where the energy stored in the inductors L1 and L2 is transferred.

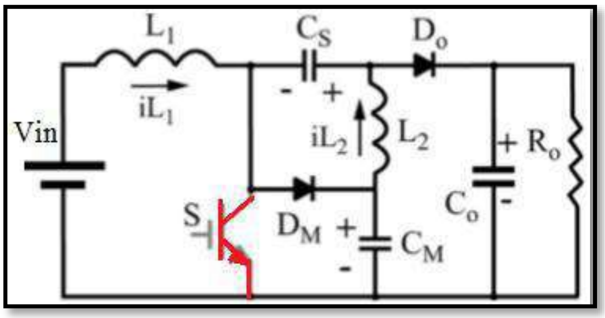


Fig. 5. Second operating stage.

3) Third Stage [t3 −t4]:

The diodes Do and DM are blocked during the instant t3 and the voltage across the inductors L1 and L2 are zero, maintaining the current through them as constant. The currents through the inductors L1 and L2 are same. The third stage is finished when the power switch S is turned ON at the instant where t = t4, thus returning to the first operating stage.

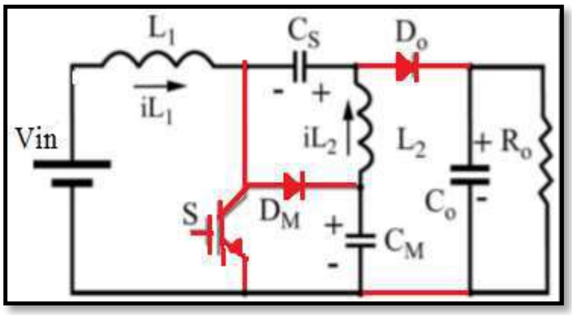
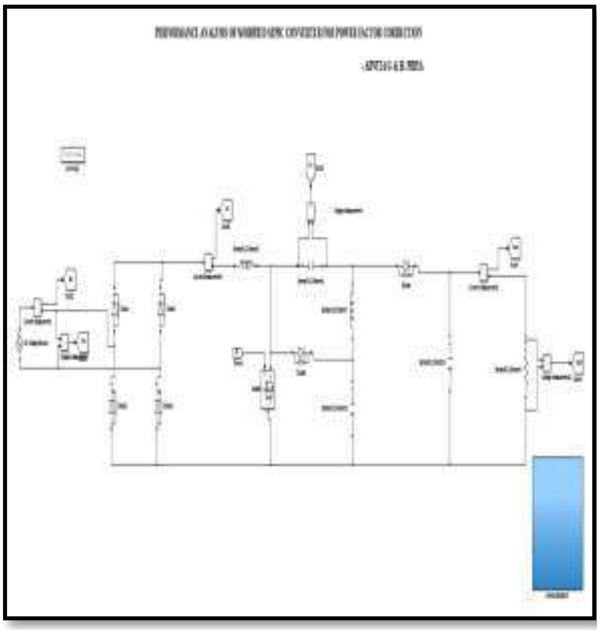


Fig. 6. Third operating stage.

The maximum switch voltage is equal to the capacitor CM voltage, and this voltage is very much lower than the output voltage. The average current through the L1 inductor is equal to the input current and the average current through the L2 inductor is equal to the output current. The average current in the capacitors CS and CM are zero under steady state; thus, the average current of diodes DM and Do are equal to the output current.

III. MATLAB SIMULATION

The Power factor correction converter known as the Modified SEPIC converter were simulated using MATLAB software and the following results were obtained. The converter performance with (third harmonic distortion technique) and without were compared and the following conclusion were obtained. The FFT analysis was done to calculate the harmonic distortions. In the Modified SEPIC converter the harmonic distortion was about 9% and by the inclusion of a third harmonic reduction block the harmonic distortion in the input current was reduced to a value less than 5%, which is in the acceptable range.



IV. CONCLUSION

The power factor correction shapes the input current of off-line power supplies to maximize the real power available from the mains. Ideally, the electrical appliance should present a load that includes a pure resistor, so that the reactive power drawn by the device is zero. The input current harmonics are absent, the input current is a perfect replica of input voltage (sine wave). The current drawn from the mains is at a minimum for the real power required to perform the needed work, and this minimises losses and cost associated. The freedom from harmonics also minimizes interference with other devices being powered from the same source.

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