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A New Topology on Bridgeless AC-DC Conventional Converter for Power Factor Correction

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Abstract

This paper introduces power conversion principles and defines the terminology. The concepts of sources and switches are defined and classified. From the basic laws of source interconnections, a generic method of power converter synthesis is presented. Reduction of power loss is also presented. Finally, the notions of commutation cell and soft commutation are introduced and discussed.

Keywords: Bridgeless converter, power semiconductors, electronic switches.

1. Introduction

The task of a power converter is to process and control the flow of electric energy by supplying

Voltages and currents in a form that is optimally suited for the user loads. Energy was initially converted in electromechanical converters (mostly rotating machines).Today, with the development and the mass production of power semiconductors static power converters find applications in numerous domains and especially in particle accelerators. They are smaller and lighter and their static and dynamic performances are better. A static converter is a meshed network of electrical components that acts as a linking, adapting or transforming stage between two sources, generally between a generator and a load

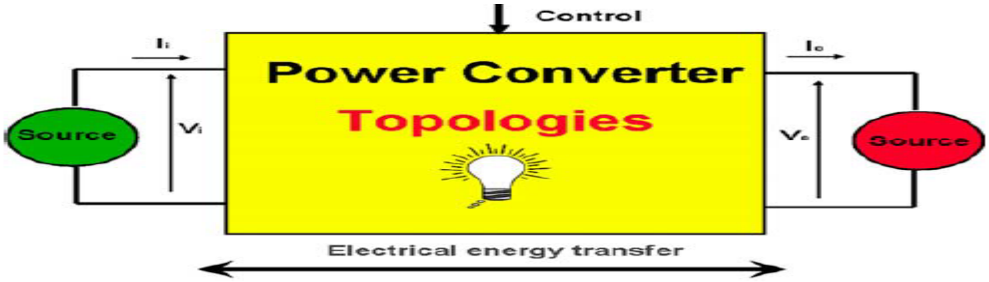

Figure 1: Power converter definition

An ideal static converter controls the flow of power between the two sources with 100%efficiency. Power converter design aims at improving the efficiency. But in a first approach and to define basic topologies, it is interesting to assume that no loss occurs in the converter process of a power converter. With this hypothesis, the basic elements are of two types: – non-linear elements, mainly electronic switches: semiconductors used in commutation mode, linear reactive elements: capacitors, inductances and mutual inductances or transformers. These reactive components are used for intermediate energy storage but also for voltage and current filtering. They generally represent an important part of the size, weight, and cost of the equipment [2].This introductory paper reviews and gives a precise definition of basic concepts essential for the understanding and the design of power converter topologies. First of all the sources and the switches are defined. Then, the fundamental connection rules between these basic elements are reviewed. From there, converter topologies are derived. Some examples of topology synthesis are given.

Finally, the concept of hard and soft commutation is introduced.

2. Sources

As mentioned in the introduction, a power converter processes the flow of energy between two sources. To synthesize a power converter topology, the first step is to characterize these sources. We shall see later that the converter structure can be directly deduced as soon as the sources are defined: voltage or current sources and their reversibilities.In the energy conversion process, a source is mainly a generator (called often input source) or a load (called output source). However, in the case of a change of direction of the energy flow, i.e., a change in the sign of the power, the sources (generators and loads) can exchange their functions (i.e., restitution of energy of a magnet towards the grid).

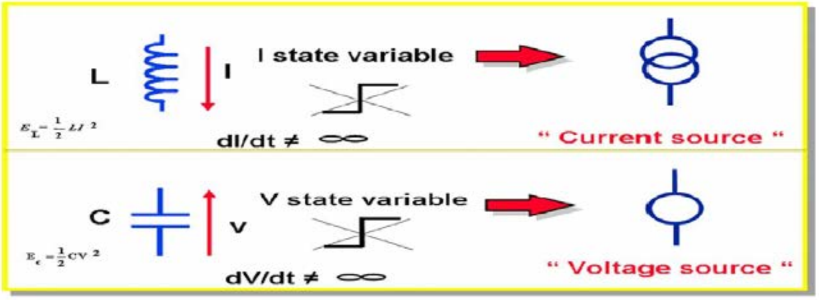

Figure 2: Inductance and capacitor versus current and voltage source

The input/output of a converter can be characterized as voltage or current sources (generator or loads), either DC or AC, current-reversible and/or voltage-reversible. There are only eight possibilities

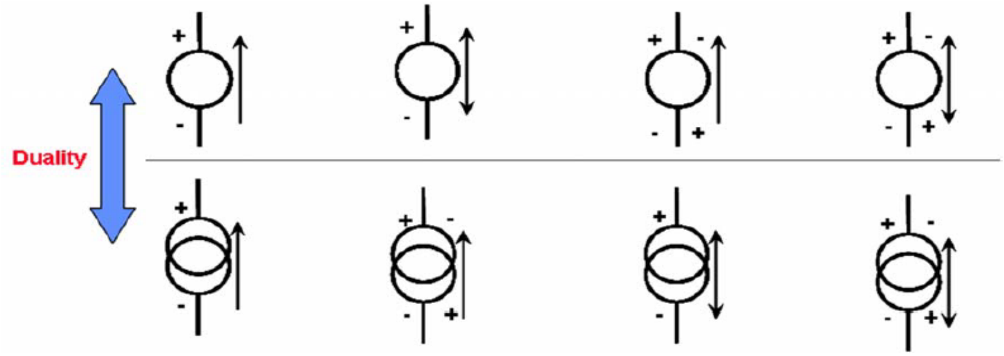

Figure 3: Voltage and current sources with their reversibility

3. Source nature modification

Connecting in series an inductance with an appropriate value to a voltage source (that is dipole with zero instantaneous impedance) turns the voltage source into a current source. In the same way, connecting in parallel a capacitor of appropriate value to a current source (dipole with infinite instantaneous impedance) turns the current source into a voltage source these inductive or capacitive elements connected in parallel or in series with the source can temporarily store energy. Consequently, if an inductance connected to a voltage source turns it into a current source, it is important to determine the current reversibility of this source. In practice, the identification of a real generator or of a real load with a voltage or current source is not obvious. This is why the nature of the source is often reinforced by the addition of a parallel capacitor in the case of voltage sources and by the addition of a series inductor in the case of current sources. Obviously, the current source obtained by connecting an inductance in series with a voltage source keeps the same current reversibility as the voltage source. The inductance acts as a buffer absorbing the voltage differences. Consequently, the current source obtained by connecting a series inductance to a voltage source is reversible in voltage. When the voltage source itself is reversible in voltage there is no particular problem. But, if the voltage source is not reversible in voltage, the current source obtained by connecting a series inductance to the voltage source is only instantaneously reversible with respect to voltage. The former result can easily be transposed to the voltage source obtained by connecting a capacitor in parallel with a current source. The voltage source thus obtained keeps the same voltage reversibility as the current source and is reversible in current. However, this reversibility is only instantaneous if the current source is not reversible in current

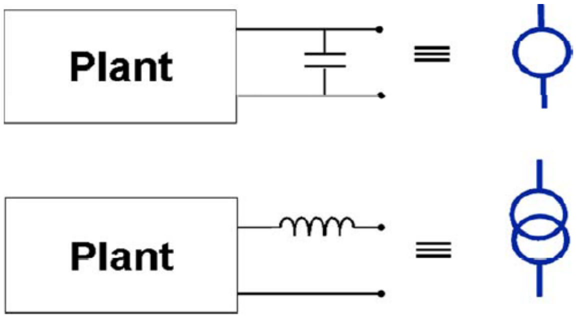

Figure 4: Source nature confirmation or modification

4. Interconnection of sources: commutation rules

To control the power flow between two sources, the principle of operation of a static power converter is based on the control of switches (turn-ON and turn-OFF) with particular cycles creating periodic modifications of the interconnection between these two sources.

The source interconnection laws can be expressed in a very simple way:

– A voltage source should never be short-circuited but it can be open-circuited;

– A current source should never be open-circuited but it can be short-circuited.

From these two general laws, it can be deduced that a direct connection between two voltage sources or between two current sources cannot be established by means of switches

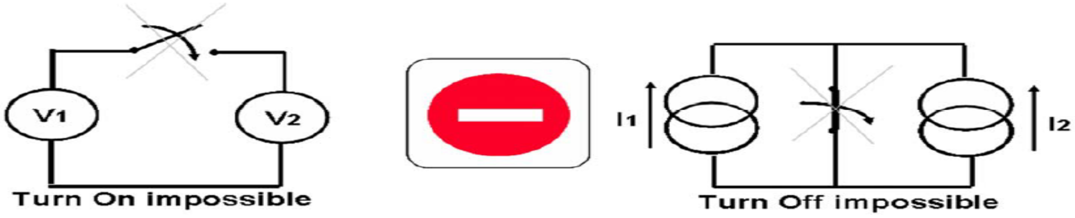

Figure 5: Basic interdictions of source interconnection

In the case of two voltage sources, the switch turn-ON can only happen when the two sources. Have the same values that are to say at the zero crossing of the voltage across the switch. The turn-ON must then be spontaneous (since it depends on the external circuit) and the turn-OFF can be controlled at any time. In the case of two current sources, the switch turn-

OFF can only happen when the two current sources reach the same value, that is to say when the current in the switch reaches zero. In this case, the turn-OFF is spontaneous and the turn-ON can be controlled at any time. Thus it is obvious that capacitors can be connected in parallel and inductances in series but with zero voltage, respectively, zero current, as is routinely done. The previous laws forbid the commutation of switches between two sources of the same nature.

5. Structure of power converters

A power converter can be designed with different topologies and with one or several intermediate conversion stages. When this conversion is achieved without an intermediate energy storage stage, the conversion is called direct conversion and is achieved by a direct converter. On the other hand, when this conversion makes use of one or more stages storing energy temporarily, the conversion is called indirect and is achieved by an indirect converter.

The prohibition on connecting two sources of the same nature gives relevance to the following

Two classes of basic conversion topologies: – direct link topology: when the two sources have different natures; – indirect link topology: when the two sources have the same nature

5.1. Direct link topology converters

A direct converter is an electrical network composed of switches only and is unable to store energy. In such a converter, the energy is directly transferred from the input to the output (assuming the losses can be neglected); the input power is equal to the output power at any time

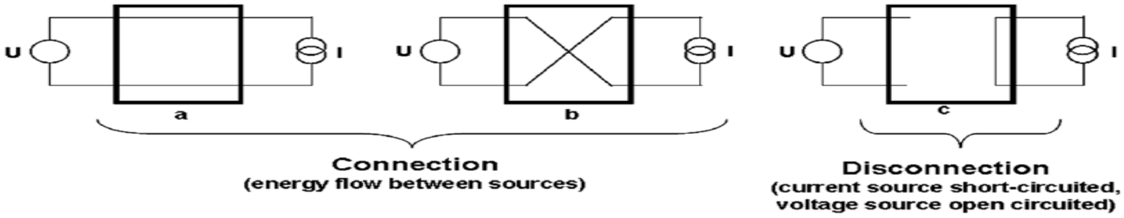

Figure 6: Direct link topology converters

Taking into account the interconnection rules recalled above, the possible connections between a voltage source and a current source are. The simplest structure allowing all these connections is the four-switches bridge .With K1 and K3 closed,– with K2 and K4 closed,– with K1 and K2 closed (or with K3 and K4 closed When some of these connections are not necessary, it is possible to replace the bridge structure by simpler structures using fewer switches (i.e. buck converter).

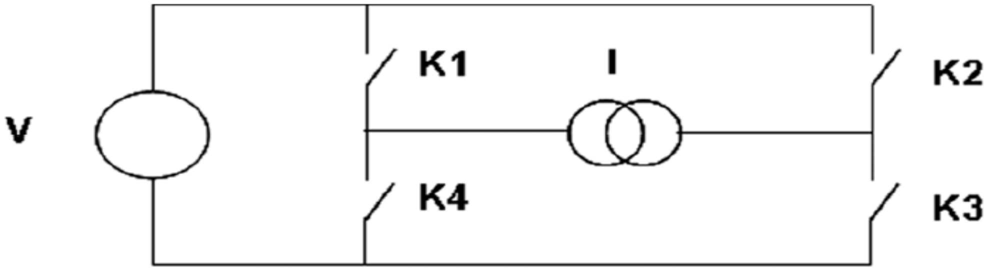

Figure 7: Basic configuration of voltage–current direct converter

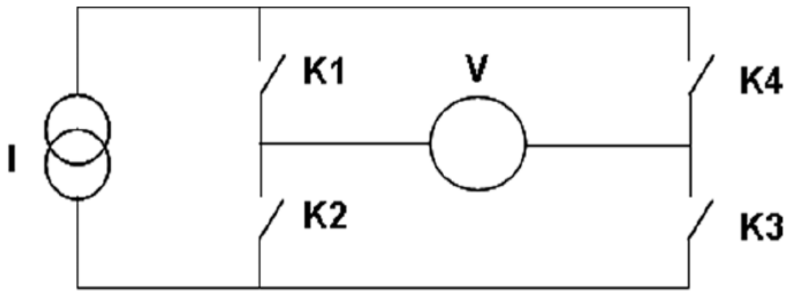

Figure 8: Basic configuration of current–voltage direct converter

5.2. Indirect converters

It is not possible to directly interconnect two sources of the same nature with switches. It is necessary to add components to generate an intermediate buffer stage of a different type without active energy consumption (capacitor or inductance). This buffer stage is a voltage source (capacitor) if the energy transfer is between two current sources, and it is a current source (inductance) if the energy transfer is between two voltage sources

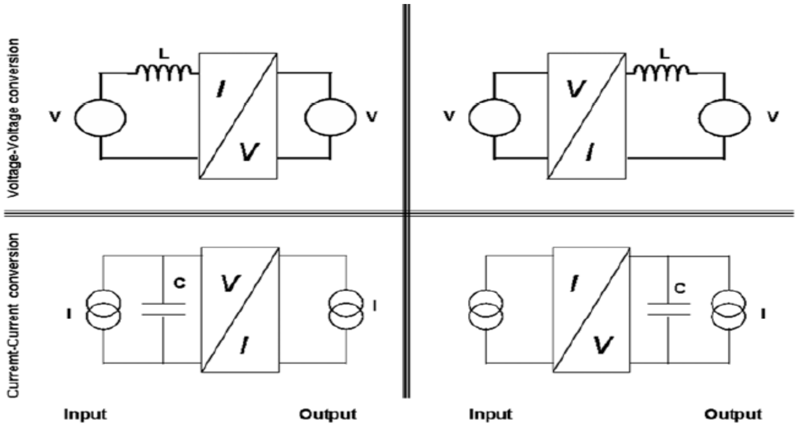

Figure 9: Indirect converters

6. Single Phase Bridgeless SEPIC Converter with High Power Factor

Power factor is defined as the ratio of real power to apparent power and its value ranges from 0 to 1. When the voltage and current waveforms are in phase, the power factor is said to be unity. A non-corrected power supply with a typical power factor equal to 0.65 will draw approximately 1.5 times greater input current than a power factor corrected supply (pf = 0.99) for the same output loading. When voltage and current are in phase with each other in an AC circuit, the electrical energy drawn from the mains is fully converted into another form of energy in the loads and the power factor is unity. As the power factor drops, the system becomes less efficient. When the power factor is not equal to 1, the current waveform does not follow the voltage waveform. These results not only in power losses, but May also cause harmonics that travel down the neutral line and disrupt other devices connected to the line. The closer the power factor is to unity, lesser the current harmonics, since all the power is contained in the fundamental frequency. The equipment connected to an electricity distribution network usually needs some kind of power conditioning, typically rectification, which produces a non-sinusoidal line current due to the non-linear input characteristic. Diode rectifiers convert AC input voltage into DC output voltage in an uncontrolled manner and are widely used in relatively low power equipment, such as electronic equipment and household appliances. In both single and three-phase rectifiers, a large filtering capacitor is connected across the rectifier output to reduce the ripple in the DC. As a consequence, the line current is non sinusoidal. In most of these cases, the amplitude of odd harmonics of the line current is considerable with respect to the fundamental. Line current harmonics have a number of undesirable effects on both the distribution network and consumers. The presence of nonlinear loads leads to high harmonics and results in poor power factor at the input side and also poor power quality. In order to ensure good quality power supply various international agencies have proposed different standards such as IEC 1000-3-2, EN 61000-3-2, IEEE 519-1992 etc. recommended practices and requirements for harmonic control in electrical power system for both individual consumers and utilities. So to comply with the recommended standards it is necessary to use suitable power factor correction technique to reduce the harmonic distortion and improve the power factor. Power factor Correctors (PFC) are broadly classified as Passive PFC and Active PFC. Passive PFC uses only passive elements such as inductor and capacitor. Even though passive PFC’s are simple and robust, the circuit is bulky and expensive. Also it suffers from poor dynamic response; shape of input current depends on the load and is less efficient. Power supplies with active power factor correction (PFC) techniques are becoming increasingly popular for many types of electronic equipment to meet harmonic regulations and standards. In active PFC active switches are used in conjunction with reactive elements and provide more efficient solution for power factor correction. Also the output voltage is controllable. In active power factor correction techniques the switching takes place at high frequency and shapes the input current as close as possible to a sinusoidal waveform which is in phase with input voltage

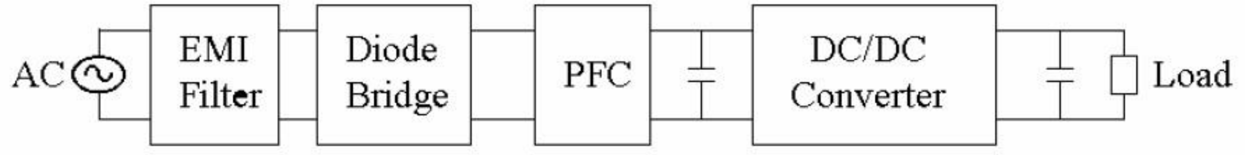

Figure 10: SEPIC Converter with High Power Factor

The active power factor correction (PFC) [1] circuits are widely used to effectively draw the energy from the mains via an AC to DC converter. Conventional Power Factor Correction circuits utilize a diode bridge rectifier and a DC-DC converter at the front end [2]. Any DC-DC converters can be used for this purpose depending on the requirement. Commonly used converter for Power Factor Correction circuits are boost converters because of its low cost, high performance and simplicity. a conventional Power Factor Correction circuit based on a boost DC-DC converter is shown. However in conventional Power Factor Correction circuit’s significant conduction loss are generated due the forward voltage drop across the diode bridge rectifier. The conduction losses across the bridge rectifier degrade the converter efficiency especially at low line input and high power applications. The converter efficiency can be improved by using a new topology called bridgeless circuits in which the diode bridge rectifier at the input side is eliminated. In bridgeless topology the lower part diode rectifier is replaced by two MOSFETs. In Figure 2(b) a bridgeless PFC circuit based on boost converter is shown. By comparing it with the conventional topology it is clear that the number of components in bridgeless topology is less and thereby lesser conduction losses and improved efficiency. Comparing the conduction path of conventional and bridgeless topology, at every moment, inductor current goes through two semiconductor devices in bridgeless topology, whereas in bridge topology it goes through three semiconductor devices. The PFC circuits with boost converter at the DC-DC converter stage suffers from many drawbacks. The dc output voltage is always higher than the peak input voltage, size of EMI filter is larger, input–output isolation cannot be implemented easily, larger PFC inductance, the startup inrush current is high, and there is a lack of current limiting during overload conditions [3]-[4]. To overcome the problems associated with boost type PFC converters, especially in universal applications where the output voltage is lower than the input voltage the step up/down converters such as buck-boost, cuk, Single Ended Primary Inductance Converter (SEPIC) can be used. Among them a SEPIC converter offers several advantages as it can be used for both step up and step down operation. Also unlike the buck-boost a topology, polarity of the output voltage is not reversed and thereby the control and

7. Results And Discussions

A Bridgeless SEPIC PFC circuit is simulated for closed loop operation using MATLAB/SIMULINK closed loop SIMULINK Model of the circuit is shown. The simulation results for input voltage & input current and output voltage and output current are shown in Figure 8 & 9 respectively. Input current and input voltages are almost sinusoidal. The output voltage is a constant DC with value 50V.

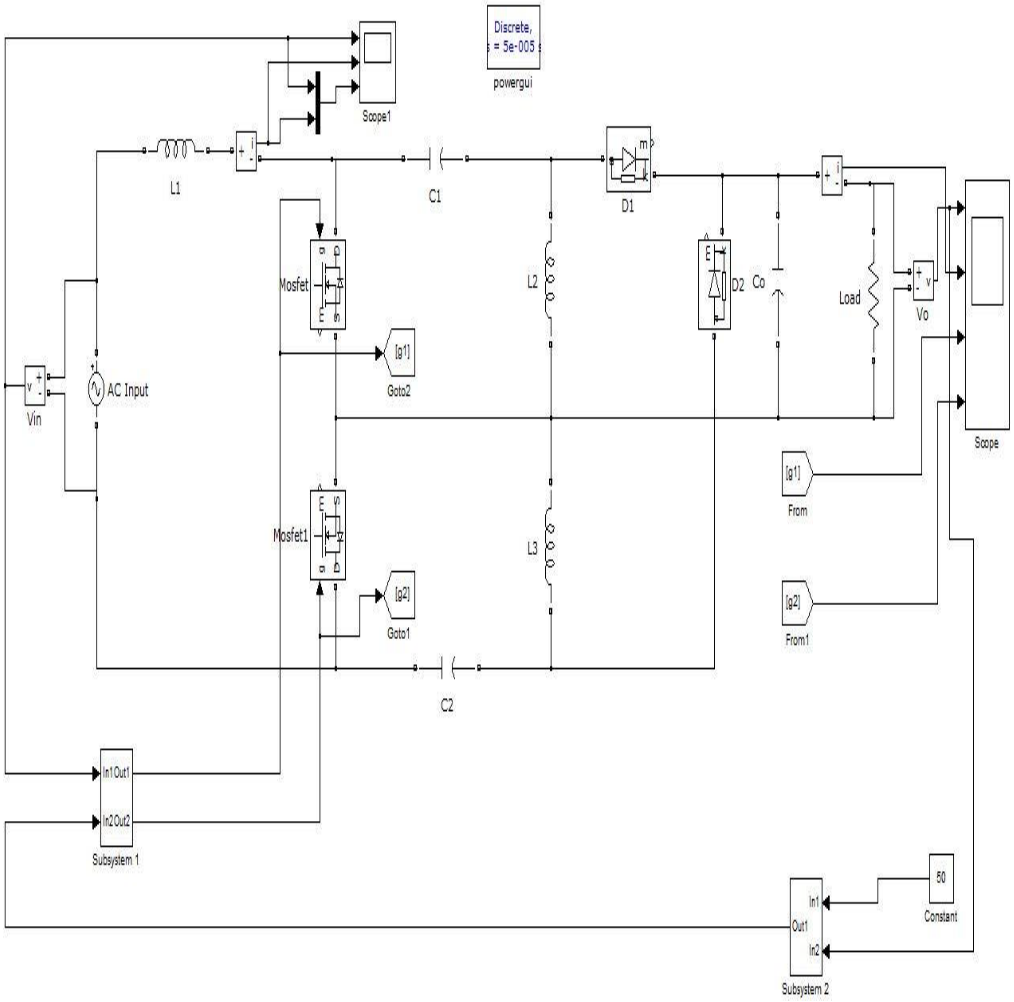

Figure 11: Closed Loop SIMULINK Model of Bridgeless SEPIC PFC

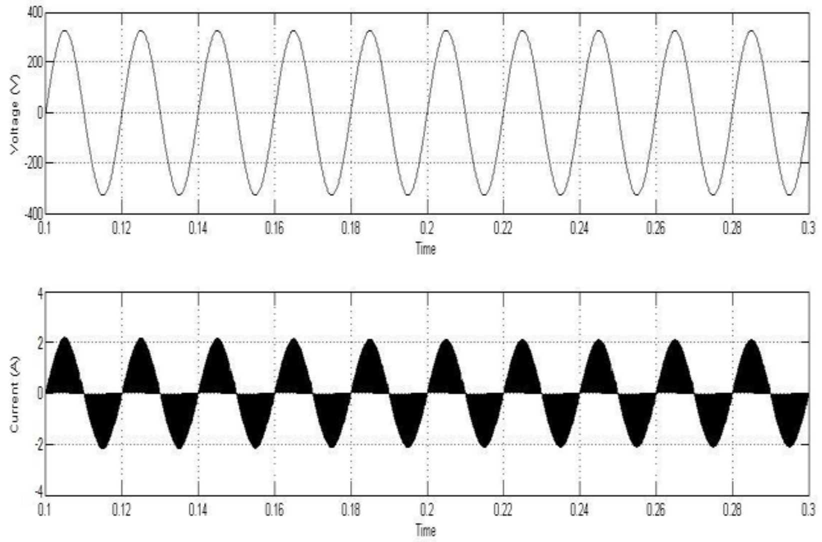

Figure 12: Simulation results for input voltage & input current for closed loop operation

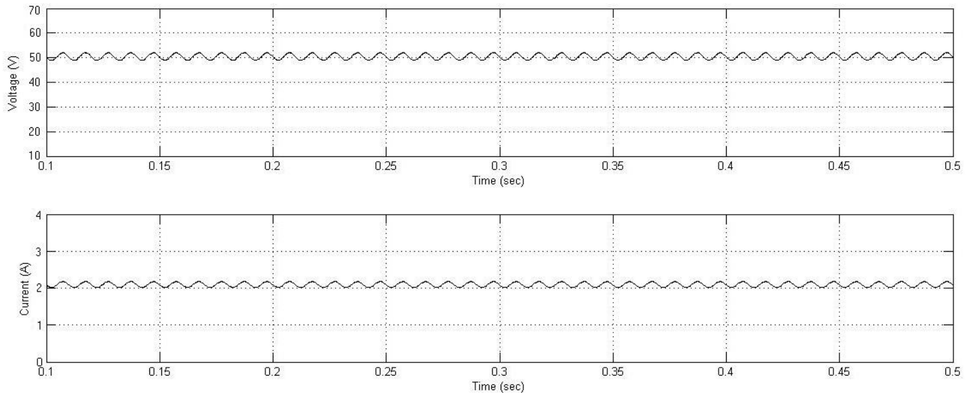

Figure 13: Simulation results for output voltage and output current

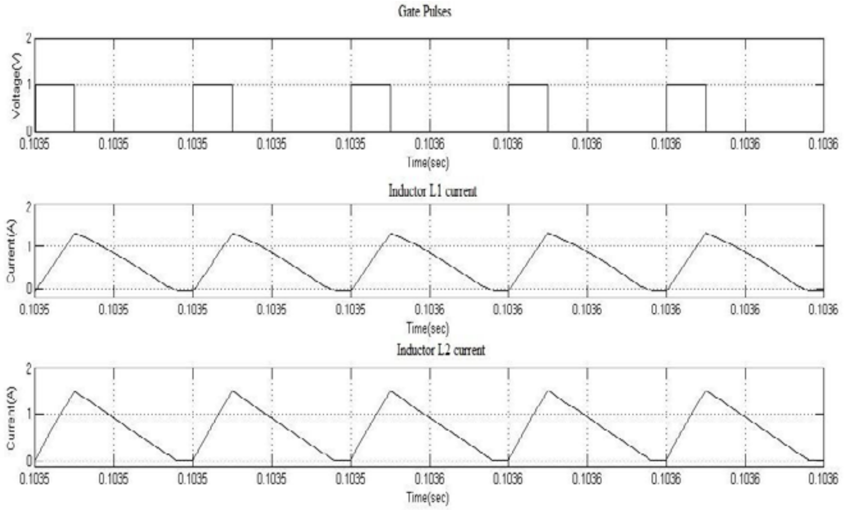

Figure 14: Gate Pulses for Switch and Current through Inductors L1 and L2

During positive half cycle of operation when switch S1 is turned ON the current through both the inductors increases linearly, which corresponds to mode 1 operation. When the switch S1 is turned OFF, the inductor current decreases linearly to zero from its peak value and corresponds to mode 2 operations. The region where the inductor current remains zero represents mode 3 operation. In Figure 11 the current through diode Do1 is shown. During Mode 1 the diode does not conduct and in Mode 2 it is forward biased and conducts. In Mode 3 it remains OFF

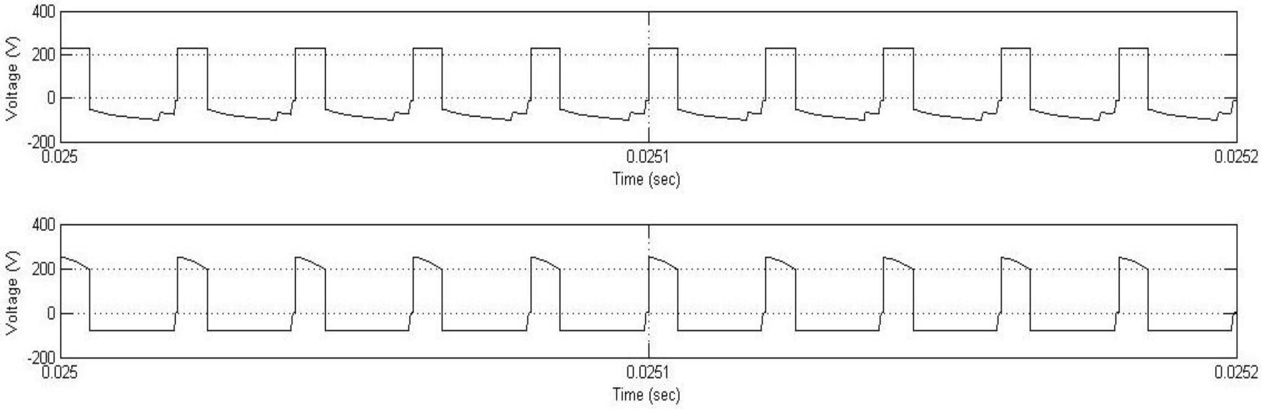

Figure 15: Voltage across inductors L1 and L2

The harmonic spectrum for closed loop operation is shown in Figure 13. THD is obtained as 11.42% and the power factor calculated is 0.9934. So the designed converter shapes the input current to be in phase with the input voltage and considerably reduces the THD

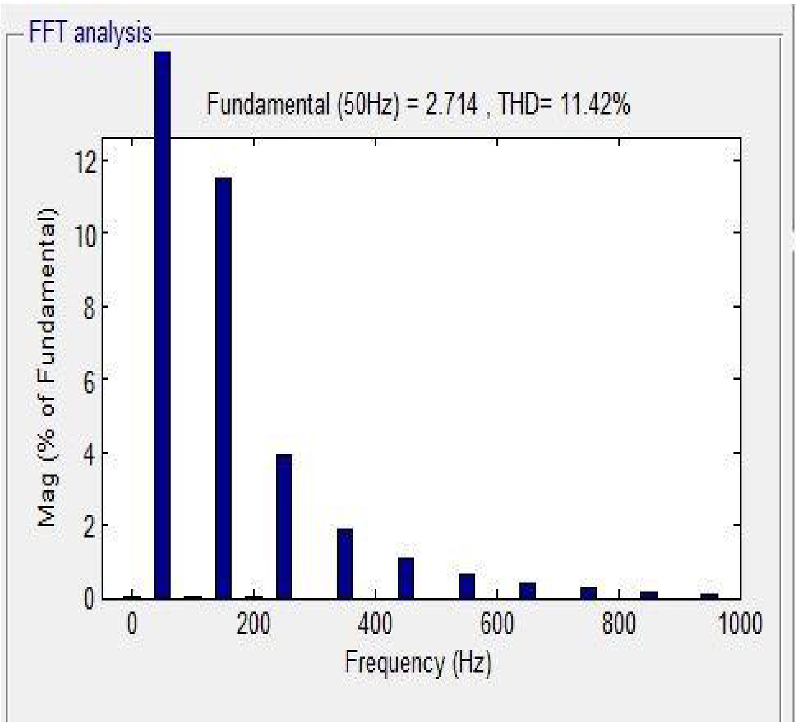

Figure 16 : Harmonic Spectrum for closed loop operation

Figure 17: Hardware setup of Bridgeless SEPIC PFC

8. Conclusion

This paper has introduced and classified the basic power converter components: sources and switches. The direct and indirect power converter topologies were derived from the interconnection rules of the sources. A general and systematic method of synthesis was described and illustrated by someexamples.With the fast development of turn-off controllable power semiconductors; the commutation mechanism becomes more and more important. To improve the performance of the converters, the frequencies are increased with a reduction of the losses and EMI perturbations. The local treatment of the commutation is no longer possible and it is thus essential to design a suitable topology for the commutation of high-frequency and high-power semiconductors. The right turn-on and turn-off conditions for the switches have to be enabled by the circuit topology. Soft commutation is certainly the most appropriate way to reach these goals. A bridgeless SEPIC Power Factor Correction circuit has been presented in which the input diode bridge rectifier is eliminated and thereby the number of conducting components is reduced. During each half cycle a maximum of eight components conduct. Thus the conduction losses are considerably reduced when compared to conventional PFC circuits. The circuit operation of the converter is discussed in detail and closed loop simulation of the circuit is done. From the simulation results, it is clear that the input voltage and input current are almost in phase and the power factor is high. This circuit would be most suitable to be used as a switch mode power supply application for low power equipments, especially those requiring high quality input power.

9. References

[1] Nedmohan, Power Electronics Converters, Applications and Design, Third Edition, Wiley-India Edition, 2012.

[2] J. Wang, W. G. Dunford, and K. Mauch, “Analysis of a ripple-free input current boost converter with discontinuous conduction characteristics,” IEEE Transactions on Power Electronics, vol. 12, no. 4, pp. 684–694, July 1997.

[3] Jian Sun, “On the Zero-Crossing Distortion in Single-Phase PFC Converters, IEEE Transactions on Power Electronics, vol. 19, no. 3,pp 685-692, May 2004.

[4] R. Martinez and P. N. Enjeti, “A high performance single phase rectifier with input power factor correction,” IEEE Transactions on Power Electronics, vol. 11, no. 2, pp. 311–317, March 1996.

[5] M. Mahdavi and H. Farzanehfard, “Bridgeless SEPIC PFC rectifier with reduced components and conduction losses,” IEEE Transactions on Industrial Electronics, vol. 58, no. 9, pp. 4153–4160, Sep. 2011.

[6] Esam H. Ismail, “Bridgeless SEPIC Rectifier with Unity Power Factor and Reduced Conduction Losses”, IEEE Transactions on Industrial Electronics, vol. 56, no. 4, April 2009.

[7] Mohd Rodhi Sahid, Abdul Halim Mohd Yatim, “Modeling and simulation of a new Bridgeless SEPIC power factor correction circuit”, IEEE Conference on Industrial Electronics, vol. 57, no. 6, pp 599-611, April 2011.

[8] Jae-Won Yang and Hyun-Lark Do, “Bridgeless SEPIC Converter with a Ripple-Free Input Current”, IEEE Transactions on Power Electronics, vol. 28, no. 7, July 2013