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SIMULATION OF BRIDGELESS SEPIC CONVERTER WITH POWER FACTOR CORRECTION FED DC MOTOR

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Abstract: In this project, the Single Ended Primary Inductor converter (sepic) is used to achieve high power factor with reduce input ripple current. The power factor correction is suffered from high conduction loss due to input bridge diode. The bridgeless sepic converter is used to avoid conduction loss. The input current ripple is reduced by using an additional winding and an auxiliary capacitor. In switching period, the input current is proportional to the input voltage and achieved near unity power.

Keywords: Power Factor Correction, DC-DC Converter, Sepic Converter, Bridgeless Sepic Converter.

I.INTRODUCTION

The power factor of an AC electric power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power. In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor. Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment. Electronic switch-mode DC to DC converters are available to convert one DC voltage level to another.

These circuits, very similar to a switched-mode power supply, generally perform the conversion by applying a DC voltage across an inductor or transformer for a period of time (usually in the 100 kHz to 5 MHz range) which causes current to flow through it and store energy magnetically, then switching this voltage off and causing the stored energy to be transferred to the voltage output in a controlled manner. By adjusting the ratio of on/off time, the output voltage can be regulated even as the current demand changes. This conversion method is more power efficient (often 80% to 95%) than linear voltage conversion which must dissipate unwanted power. This efficiency is beneficial to increasing the running time of battery operated devices. A drawback to switching converters is the electronic noise they generate at high frequencies, which must sometimes be filtered. In order to restrain harmonic pollution and improve power system quality, power factor correction (PFC) circuit is applied in pre-stage of power supply. Conventionally PFC topology is constituted by BOOST circuit, whose control is complexity, output voltage is higher than input voltage and electrical isolation is difficult to achieve between input and output. PFC topology is constituted by FLYBACK circuit must work in discontinuous mode (DCM) and required large electromagnetic interference (EMI) filter in [5]. And power consumption of rectifier will increase gradually with increase power. Base on advantage of SEPIC circuit, such as isolation easy, EMI small and input current is continuous, the working principle of the different modes of the traditional SEPIC-PFC are analyzed in details in this paper firstly. It is note that there are several problems in traditional circuit, such as the great loss of rectifier bridge structure, the reverse current recovery under continuous mode and so on in [8],[9]. To solve the above mentioned problem, A new bridgeless SEPIC PFC circuit is presented. Based on traditional SEPIC power factor correction, these new circuits utilize the bridgeless technique instead of the pre-rectifier in the corrector. In the process of turning on the switch, the input current only flow one diode, and it can effectively reduced energy consumption in the conduction process.

The circuit works in the current DCM, the input current cannot only automatically follow input voltage, and reduced EMI of input current, but also make the

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switch turn on low-current state, the diode turn off in zero-current, which reduce the conduction losses of the switch and the reverse recovery losses of the diode[1]-[7],[10],[11]. In this paper, the working principle of the circuit and derivation of key parameters are presented. And then small-signal mode of the bridgeless SEPIC-PFC circuit is derived, the control mode of the system is established. Finally, the simulation is carried out under the PSIM simulation software. According to the theoretical analysis above, the prototype of the bridgeless SEPIC PFC circuit is made, and the design method and experimental results are given[12]-[24]. Experimental results verify that theoretical analysis and simulation results are correct.

II. DC-DC CONVERTER

Isolated DC-DC converters convert a DC input power source to a DC output power while maintaining isolation between the input and the output, generally allowing differences in the input-output ground potentials in the range of hundreds or thousands of volts. They can be an exception to the definition of DC-DC converters in that their output voltage is often (but not always) the same as the input voltage. A current-output DC-DC converter accepts a DC power input, and produces as its output constant current, while the output voltage depends on the impedance of the load. The various topologies of the DC to DC converter can generate voltages higher, lower, higher and lower or negative of the input voltage; their names are:

- Buck
- Boost
- Buck boost
- Cuk
- Sepic

The output voltage is less than input voltage when buck converter operation. The output voltage is greater than input voltage when boost converter operation. The output voltage is less or greater than input voltage when buck-boost converter. The cuk converter is similar to buck-boost converter. But the advantage of the CUK converter is that the input and output inductors create a smooth current at both sides of the converter while the buck, boost and buck-boost have at least one side with pulsed current. 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 is controlled by the duty cycle of the control transistor. The conventional Sepic Rectifier is shown in figure1[9],[11]. This topology is similar to the bridgeless boost PFC rectifier. Despite the mentioned advantage, in comparison to the conventional SEPIC rectifier, this converter has three extra passive elements which contribute to the volume and weight of the converter. Another major problem with this converter is that it doubles the output voltage which considerably increases the size of output filter. To overcome these limitations, a new bridgeless SEPIC PFC is introduced in this paper. This converter has no extra (passive or active) elements in comparison to conventional SEPIC PFC.

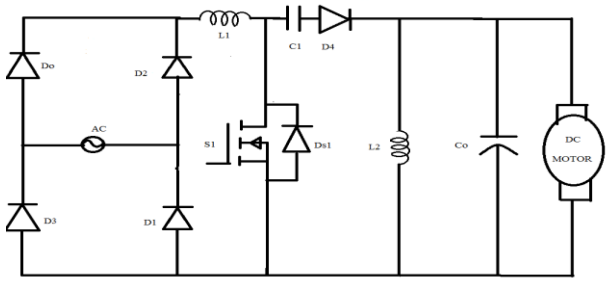

Fig. 1. Conventional Sepic PFC Rectifier

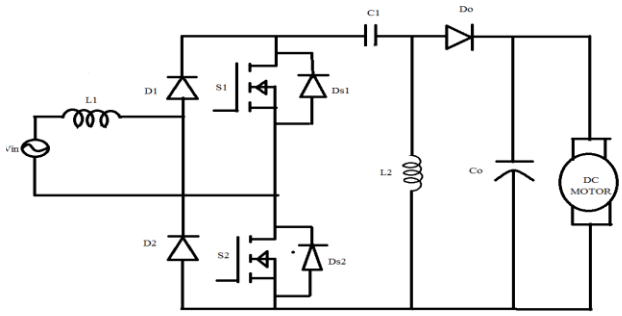

Fig. 2. Bridgeless sepic Converter

Also, in this converter, the conduction losses (number of active elements in the current path) are reduced in comparison to the conventional SEPIC PFC. The bridgeless Sepic Rectifier is shown in figure 2 [1],[11]. In this converter, The component count is reduced and it shows high efficiency due to the absence of the full-bridge diode. However, in this converter, an input inductor with large inductance should be used in order to reduce the input current ripple. In addition, the conduction losses on intrinsic body diodes of the switches are caused by using single pulse width modulation (PWM) gate signal. In order to overcome these problems, a bridgeless SEPIC converter is changed in proposed. It is shown in figure 3. An auxiliary circuit, which consists of an additional winding of the input inductor, an auxiliary small inductor, and a capacitor, is utilized to reduce the input current ripple. Coupled inductors are often used to reduce current ripple. The operation of the proposed converter is symmetrical in two half-line cycles of input voltage. Therefore, the converter operation is analyzed during one switching period in the positive half-line cycle of the input voltage. It is assumed that the converter operates in discontinuous conduction mode (DCM), so the output diode Do is turned OFF before the main switch is turned ON.

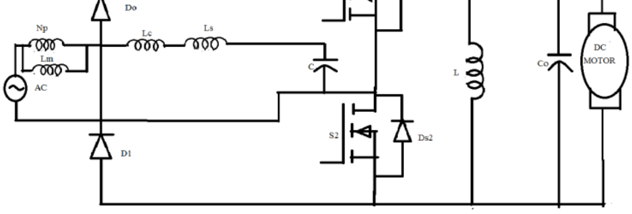

Fig. 3. Proposed Bridgeless sepic Converter

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The capacitance of the output capacitor Co is assumed sufficiently large enough to consider the output voltage Vo as constant. For a half period of the input voltage, one switch is continuously turned ON and the current via an intrinsic body diode is forced to flow through the channel of the switch. It can reduce the conduction loss on the switch further and the efficiency can be improved. The main difference is existing input ripple current more harmonics should be presented then the proposed system to eliminate the input ripples. And the existing system coupled inductor is not connected.

III. ANALYSIS OF PROPOSED RECTIFIER

The auxiliary circuit includes additional winding Ns of the input inductor *Lc*, an auxiliary inductor *Ls*, and a capacitor *C*. The coupled inductor *Lc*. is modelled as a magnetizing inductance *Lm* and an ideal transformer which has a turn ratio of 1: n (*n*=*Ns* /*Np)*. The leakage inductance of the coupled inductor L*c* is included in the auxiliary inductor *Ls*.The other components *C*1, *L*1, *Do*, and *Co* are similar to those of the conventional SEPIC PFC converter.

Diodes *D*1 and *D*2 are the input rectifiers and operate like a conventional SEPIC PFC converter. *D*S1 and*D*S2 are the intrinsic body diodes of the switches S1 and S2. The switches S1 and S2 are operated with the proposed gate signals.

Mode 1 [t0, t1]:
At *t*0 , the switch S1 is turned ON and the switch S2 is still conducting. Since the voltage *vp* across *Lm* is *V*in , the magnetizing current *im* increases from its minimum value *Im*2 linearly with a slope of *V*in */Lm*. It is shown in figure 4

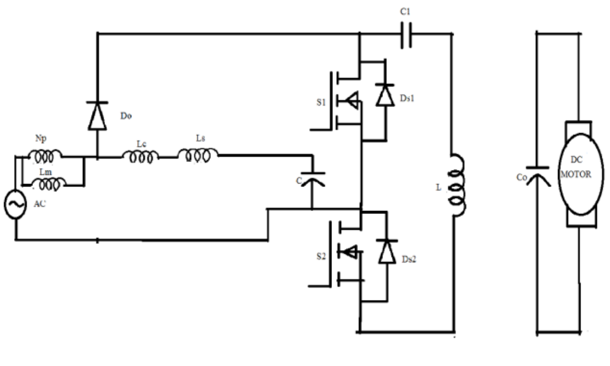

Fig. 4. Mode 1 operation

Mode 2 [t1, t2]:

At *t*1 , the switch S1 is turned OFF and the switch S2 is still conducting. Since the voltage *vp* across *Lm* is −*Vo* , the magnetizing current *im* decreases from its maximum value *Im*1 linearly with a slope of −*Vo* /L*m*. It is shown in figure 5.

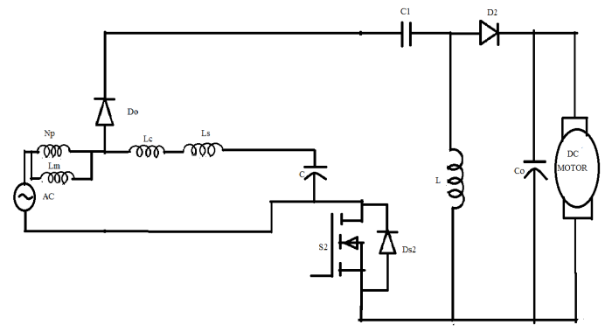

Fig . 5. Mode 2 operation

Mode 3 [t2, t_0]:

At *t*2 , the current *iDo* becomes zero, and the diode *Do* is turned OFF. Since *i*in = *im* − *nis* = −*is* – *i*L1 in this mode, the input current *i*in is the sum of freewheeling Currents Is2 and *IL*2. It is shown in figure 6.

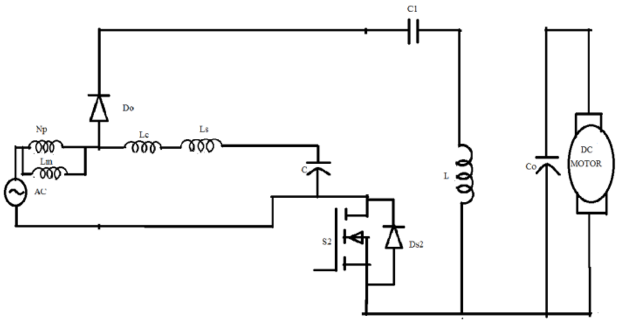

Fig. 6. Mode 3 operation

IV. SIMULATION RESULT

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering and science. In industry, MATLAB is the tool of choice for high productivity research, development, and analysis. MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neutral networks, fuzzy logic, wavelets, simulation, and many others.

Sim Power Systems libraries contain models of typical power equipment such as transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, and their validity is based on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Québec, a large North American utility located in Canada, and also on the experience of École de Technologie Supérieure and Université Level. The capabilities of SimPowerSystems software for modeling a typical electrical system are illustrated in

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demonstration files. And for users who want to refresh their knowledge of power system theory, there are also self-learning case studies.The Sim Power Systems main library, powerlib, organizes its blocks into libraries according to their behavior. To open this library, type powerlib in the MATLAB Command Window. The power lib library window displays the block library icons and names. Double-click a library icon to open the library and access the blocks. The main powerlib library window also contains the Powergui block that opens a graphical user interface for the steady-state analysis of electrical circuits.The simulation circuit diagram is shown in figure 7.

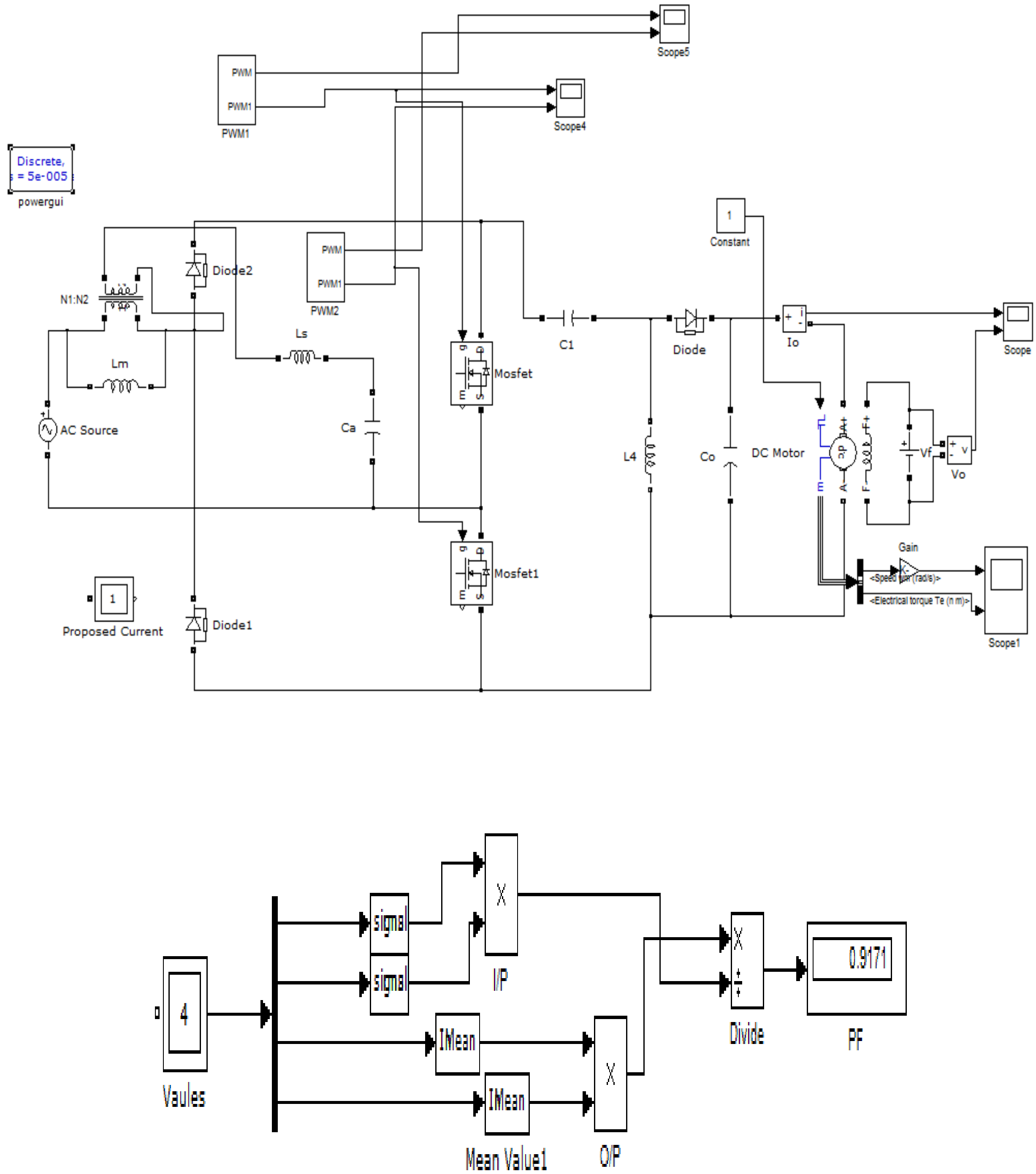

Fig.7. simulation circuit diagram

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The carrier PWM output waveform is shown in figure 8.

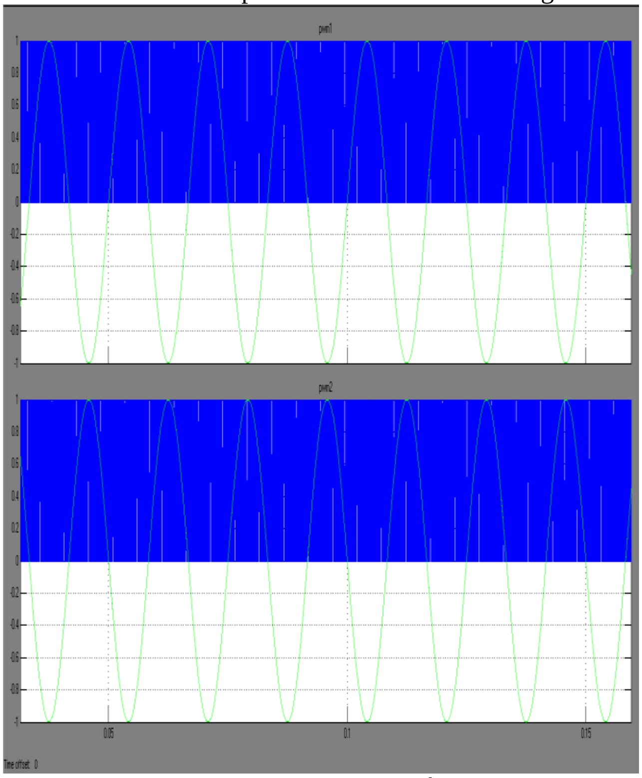

Fig 8 carrier pwm output waveform

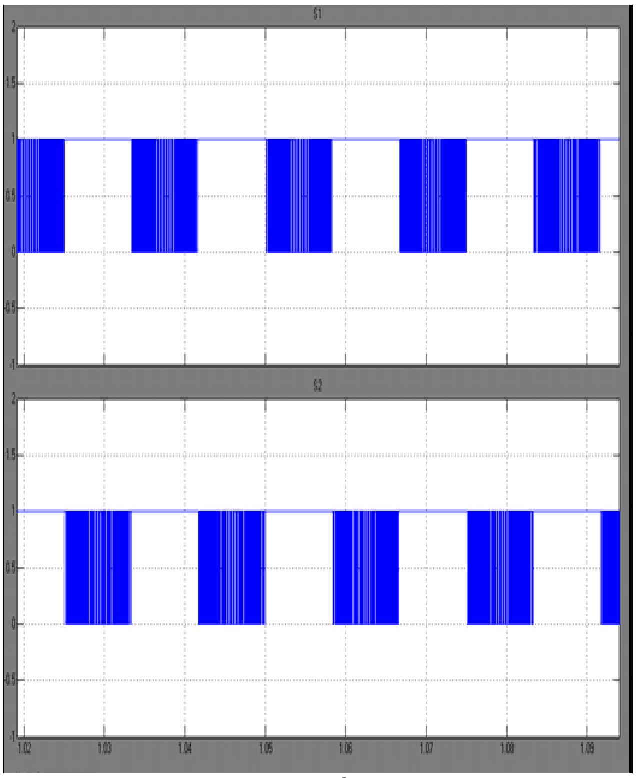

Fig .9.pwm pulse output

The PWM pulse output waveform is shown in figure 9.

The current ripple waveform is shown in figure 10.

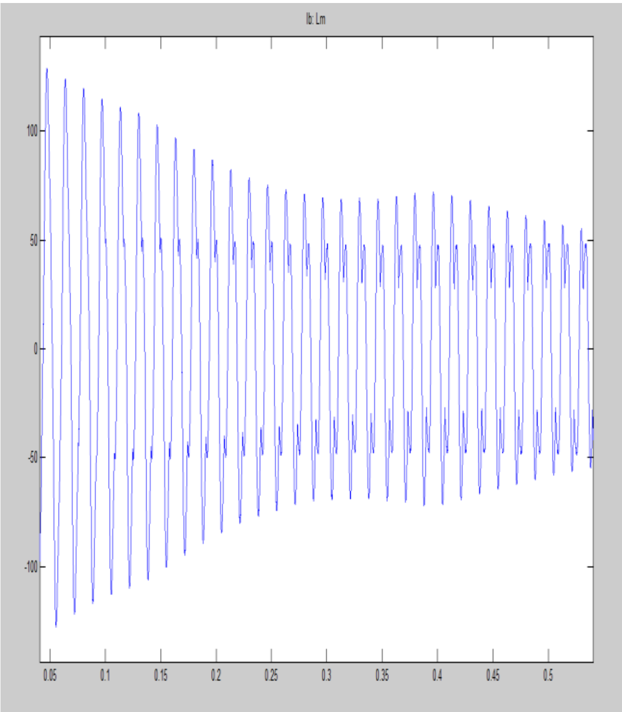

Fig .10.current ripple

The output current and output voltage waveform of dc motor is shown in fig 11

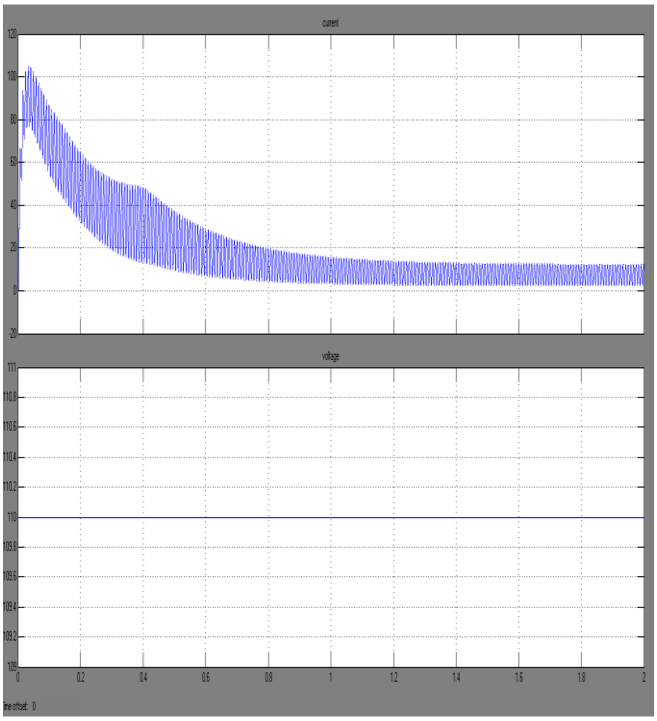

Fig.11 output current and voltage waveform of dc motor

The speed and torque waveform of dc motor is shown in figure 12

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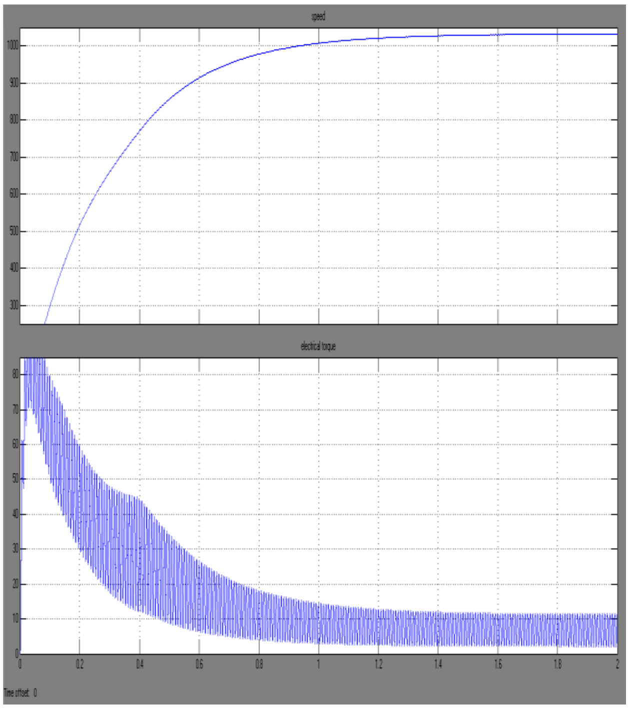


Fig.12 speed and torque waveform of dc motor

The harmonic of sepic converter with power factor correction fed dc motor is shown in fig 13

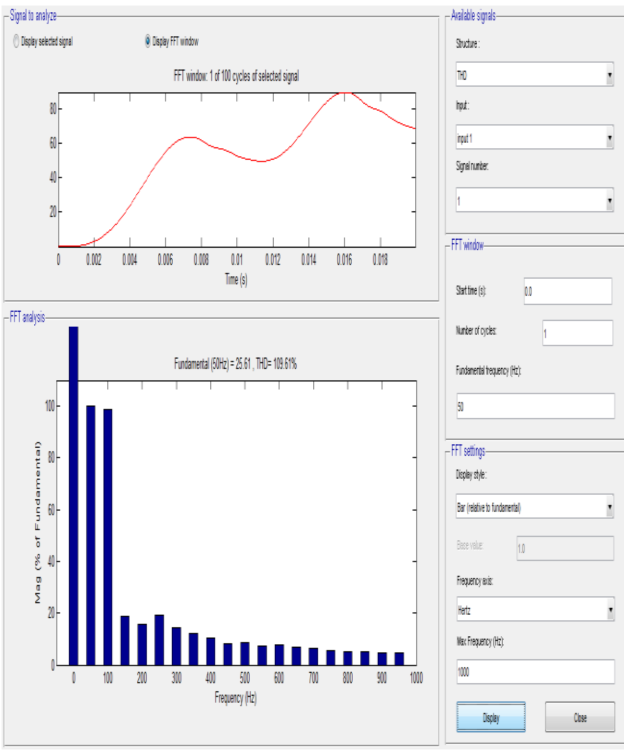
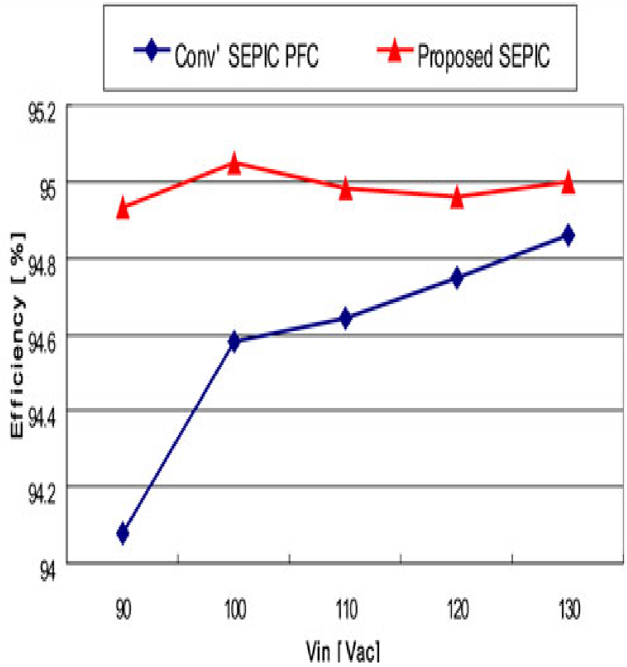
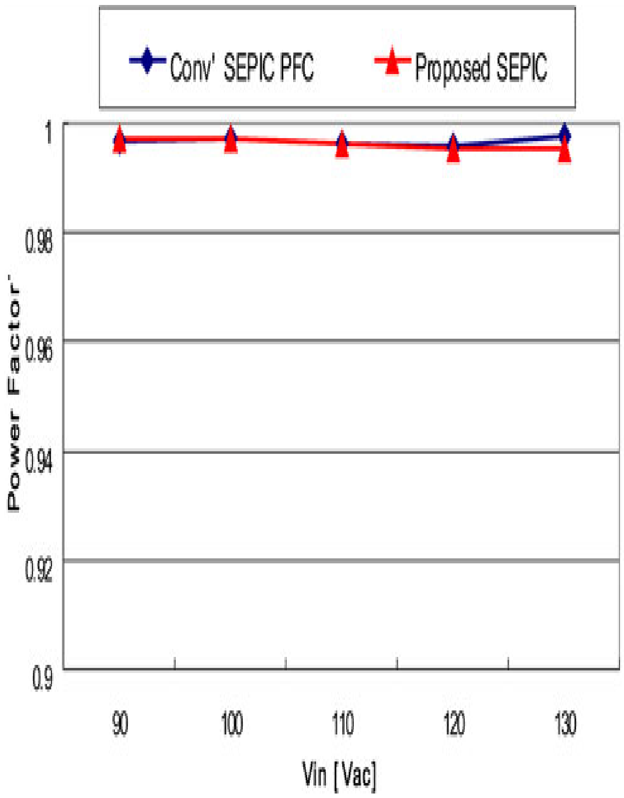


Fig.13 Hormonic of sepic converter with power factor correction

In this proposed system, we get 0.91 power factor. The efficiency and power factor between conventional Sepic Converter and proposed sepic converter is shown in figure 14



(a)



(b)

Fig.14. Efficiency and power factor

V.CONCLUSION

A bridgeless SEPIC converter with ripple-free input current has been proposed. In order to improve the efficiency, the input full-bridge diode is eliminated. The input current ripple of the proposed converter is significantly reduced by utilizing an auxiliary circuit consisting of an additional winding of the input inductor, an auxiliary small inductor, and a capacitor. The theoretical analysis, simulation results, and experimental results were provided.

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BIOGRAPHY

Dr.Govindaraj Thangavel born in Tiruppur , India , in 1964. He received the B.E. degree from Coimbatore Institute of Technology, M.E. degree from PSG College of Technology and Ph.D. from Jadavpur University, Kolkatta, India in 1987, 1993 and 2010 respectively. His Biography is included in Who's Who in Science and Engineering 2011-2012 (11th Edition). Scientific Award of Excellence 2011 from American Biographical Institute (ABI). Outstanding Scientist of The 21st century by International Biographical centre of Cambridge, England 2011.

Since July 2009 he has been Professor and Head of the Department of Electrical and Electronics Engineering, Muthayammal Engineering College affiliated to Anna University, Chennai, India. His Current research interests includes Permanent magnet machines, Axial flux Linear oscillating Motor, Advanced Embedded power electronics controllers,finite element analysis of special electrical machines,Power system Engineering and Intelligent controllers.He is a Fellow of Institution of Engineers India(FIE) and Chartered Engineer (India).Senior Member of International Association of Computer Science and Information. Technology (IACSIT). Member of International Association of Engineers(IAENG), Life Member of Indian Society for Technical Education(MISTE). Ph.D. Recognized Research Supervisor for Anna University and Satyabama University Chennai Editorial Board Member for journals like International Journal of Computer and Electrical Engineering,International Journal of Engineering and Technology,International Journal of Engineering and Advanced Technology (IJEAT).International Journal Peer

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Reviewer for Taylor &Francis International Journal “Electrical Power Components & System”United Kingdom,Journal of Electrical and Electronics Engineering Research,Journal of Engineering and Technology Research (JETR),International Journal of the Physical Sciences,Association for the Advancement of Modelling and Simulation Techniques in Enterprises,International Journal of Engineering & Computer Science (IJECS),Scientific Research and Essays,Journal of Engineering and Computer Innovation,E3 Journal of Energy Oil and Gas Research,World Academy of Science, Engineering and Technology,Journal of Electrical and Control Engineering （ JECE),Applied Computational Electromagnetics Society etc.. He has published 132 research papers in International/National Conferences and Journals. Organized 40 National / International Conferences/Seminars/Workshops. Received Best paper award for ICEESPEEE 09 conference paper. Coordinator for AICTE Sponsored SDP on Soft Computing Techniques In Advanced Special Electric Drives, 2011. Coordinator for AICTE Sponsored National Seminar on Computational Intelligence Techniques in Green Energy, 2011.Chief Coordinator and Investigator for AICTE sponsored MODROBS - Modernization of Electrical Machines Laboratory. Coordinator for AICTE Sponsored International Seminar on “Power Quality Issues in Renewable Energy Sources and Hybrid Generating System”, July 2013.