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Simple Phase Shift Controlled DC-DC Converters for High Voltage Applications

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ABSTRACT: With rapid development of renewable energy there is a rise in utilization of isolated DC-DC converters for applications like smart grid and electric vehicles. High efficiency, high gain and high power density are the parameters expected from a normal DC-DC converter, but when it comes to the output voltage, it will be of poor quality. The use of a transformer in the above system can correct this fault. This transformer isolates the Active Boost Rectifier (ABRs) which is composed of a traditional diode rectifier and a switch along with a Voltage Doubler(VD). Replacing inverter with an interleaved DC-AC converter on the primary side helps to generate a voltage from equal or lower input supply. This system can be useful anywhere where one does not have access to mains outlet for example a car, trailer or cottage. It can power appliances like radios, tape recorders, televisions, electric shavers, fluorescent lamps or cell phone charger. A voltage multiplier if implemented instead of the ABR-VD produces high voltage gain and can be used for high voltage applications , this is realized using fast switching diodes with addition of a phase shift control which provides gate pulses for switches on the inverter side by shifting phase angle and producing delay in pulses. This technique if utilized gives better performance parameters for DC-DC converter such as voltage gain, low voltage stress and soft switching behaviour. Various control strategies to suit high voltage low current application is considered giving more importance to phase shift control scheme and implementing it with a suitable closed loop controller for complete control is done and this work is studied alongside an interleaved configuration which can be used for same application with similar results.

KEYWORDS: Interleaved Converter, Voltage Doubler, Soft Switching, High Voltage.

I.INTRODUCTION

DC-DC converters are important in most of the portable electronic devices and are employed in variety of applications including supply for personal computers, office equipment, spacecraft power systems, laptops, telecommunication equipments as well as DC motor drives which are very much useful to people . The input to a basic DC-DC converter is a DC voltage say V_{in} and the converter produces a regulated output voltage say V_{out} which is having a magnitude and sometimes polarity that differs from that of the input . The ideal DC-DC converter exhibits 100% efficiency but in practice efficiencies of 70% to 95% are obtained as maximum , this is achieved using switched mode or chopper circuits whose elements dissipate negligible power. Different techniques allows control and regulation of the total output voltage. This controlling approach is employed in applications involving alternating current, including high efficiency DC-AC inverters, AC-AC power converters and some AC-DC power converters (low harmonic rectifiers). In most of applications it is desired to incorporate a transformer into the switching converter, to obtain dc isolation between the input and output. In off-line power supply applications, isolation is usually required by regulatory agencies. This isolation can be attained by simply connecting a 50 Hz or 60 Hz transformer at the power supply AC input terminals. However, since transformer size and weight vary with regards to the value of frequency, incorporation of the transformer into the converter can make significant improvement.

When large conversion ratio is required, the use of a transformer can allow great converter optimization. By making a proper choice of the transformer turns ratio the voltage or current stresses imposed on the transistors and diodes can be reduced, leading to improved efficiency and lower cost. The ratio of turns on primary side to secondary side of a transformer is same as the ratio of voltage at primary to that of secondary but inverse of current value of primary to secondary.

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II.FULL BRIDGE DC-DC CONVERTER

DC-DC converters are used to convert DC voltages from one voltage level to another voltage level. They can be of two types step up or step down. Most of the power electronic converters consist of semiconductor switches like MOSFETs and IGBTs. DC-DC converters are classified into two non isolated and isolated converters. A transformer is present in the isolated topology which provides isolation between the input and the output. The non-isolated converters are buck (step down) converter, boost converter (step up) converter, buck boost converter and cuk converter. The various isolated converters are forward converter, flyback converter, push pull converter, half bridge converter and full bridge converters. In recent times the high power isolated DC-DC converters has developed in the market due to its requirement in the applications like fuel cell applications, battery based storage systems and telecommunications systems etc. In most of the applications the transformer is incorporated due to the circuit to provide isolation. The advantages of using isolation is that the transformer present in the isolated topology can provide large step up or step down conversion ratio, multiple DC outputs can be obtained by providing multiple secondary windings, voltage and current stress in the transistors can be reduced by proper design of turns ratio. The basic requirement of a converter is small size and high efficiency. To achieve small size high switching frequency operation is necessary but the switching losses increases with increase in switching frequency. The solution for this problem is using soft switching techniques such as Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS) these techniques provide zero voltage or current during switching transitions and thus reduce switching losses.

Full bridge converters are mostly used in medium to high power applications. The output voltage can be controlled by two methods Pulse Width Modulation (PWM) control and phase shift control. The full bridge configuration used for high input voltage and high power applications is the phase shifted full bridge DC-DC converter. Phase Shifted Full Bridge DC-DC converter (PSFB) is similar to the conventional full bridge DC-DC converter but with a phase shifting control. In phase shifted full bridge DC-DC converter, the switches attain zero voltage switching which reduces the switching losses and the converter can attain high efficiency at high switching frequencies. It has benefits such as low switching noise and it doesn't require additional snubber circuits to reduce losses. PSFB converters are used to step up or step down dc voltages and to provide isolation in medium to high power applications such as renewable energy systems, telecom rectifiers, battery charging systems, server power supplies

III.CONVERTERS AT SIDES OF FBC

The input voltage depends on the design and purpose of the inverter. An inverter converts the DC from sources such as batteries or fuel cells to AC form. An inverter can produce a square wave, modified sine wave, pulsed sine wave, Pulse Width Modulated (PWM) wave or sine wave depending on circuit design. The two dominant commercialized waveform types of inverters as of now is modified sine wave and sine wave. There are two basic designs for producing household plug-in voltage from a lower voltage DC source, the first of which uses a switching boost converter to produce a higher voltage DC and then converts to AC. The second method converts DC to AC at battery level and uses a line-frequency transformer to create the output voltage. The AC output frequency of a power inverter device is usually the same as standard power line frequency, 50 hertz. The AC output voltage of a power inverter is often regulated to be the same as the grid line voltage, typically 230 V even when there are changes in the load that the inverter is driving. This allows the inverter to power numerous devices designed for standard line power. Some inverters also allow selectable or continuously variable output voltages. A power inverter will often have an overall power rating expressed in watts or kilowatts. This describes the power that will be available to the device the inverter is driving and indirectly the power that will be needed from the DC source.

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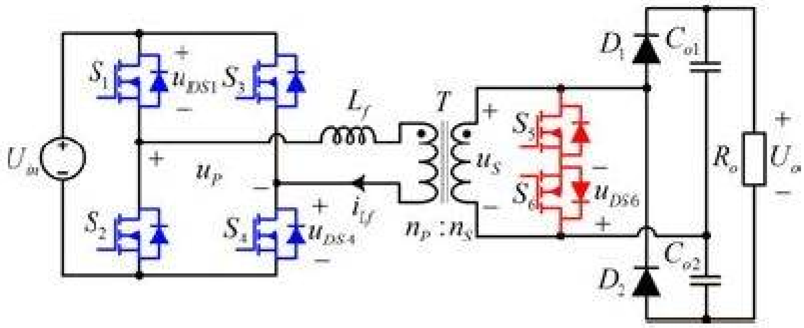

Fig. 1 A FBC with ABR at Secondary Side

A full wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. Full wave rectification converts both polarities of the input waveform to pulsating DC, and yields a higher average output voltage. Similar to the half wave circuit a full wave circuit as used in the FBC-ABR VD produces an output voltage or current which is purely DC or has some specified DC component. Full wave rectifiers have some fundamental advantages over their half wave rectifier counterparts one such converter is shown in fig.1. The average DC output voltage is higher than that of half wave, the output of the full wave rectifier has much less ripple than of the half wave rectifier producing a smoother output waveform. In a full wave rectifier circuit two diodes are used, one for each half of the cycle. A multiple winding transformer is used whose secondary winding is split equally into two halves with a common centre tapped connection. This configuration results in each diode conducting in turn when its anode terminal is positive with respect to the transformer centre point producing an output during both half cycles and produces an output which is twice that of a half wave rectifier. Cascaded diode and capacitor stages can is added to make a voltage multiplier (Cockroft-Walton Circuit). These circuits are capable of producing a DC output voltage potential tens of times that of the peak ac input voltage, but are limited in current capacity and regulation. Diode voltage multipliers frequently used as a trailing boost stage or primary High Voltage (HV) source are used in HV laser power supplies, powering devices such as Cathode Ray Tubes (CRT) (like those used in CRT based television, radar and sonar displays), photon amplifying devices found in image intensifying and Photo Multiplier Tubes (PMT) and magnetron based Radio Frequency (RF) devices used in radar transmitters and microwave ovens. Before the introduction of semiconductor electronics transformer less powered vacuum tube receivers powered directly from AC power sometimes used voltage doublers to generate DC high voltages.

IV.FBC AND AN INTERLEAVED TWO SWITCH CONVERTER

Studies are going on the field of interleaved converter with the goal of improving the power converter performance and other factors such as size and efficiency. The benefits on interleaving includes high power capability and improved reliability one such configuration is as shown in fig .2 which is a basic conventional converter.

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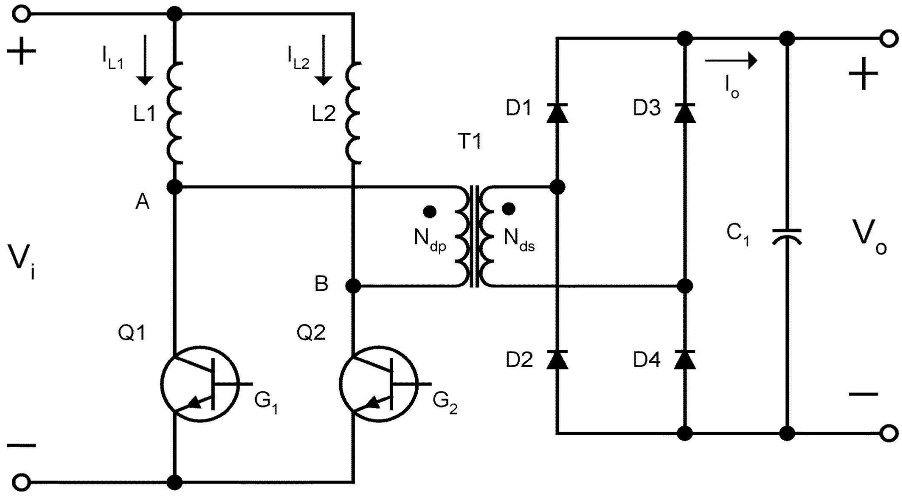

Fig. 2 A Conventional Converter

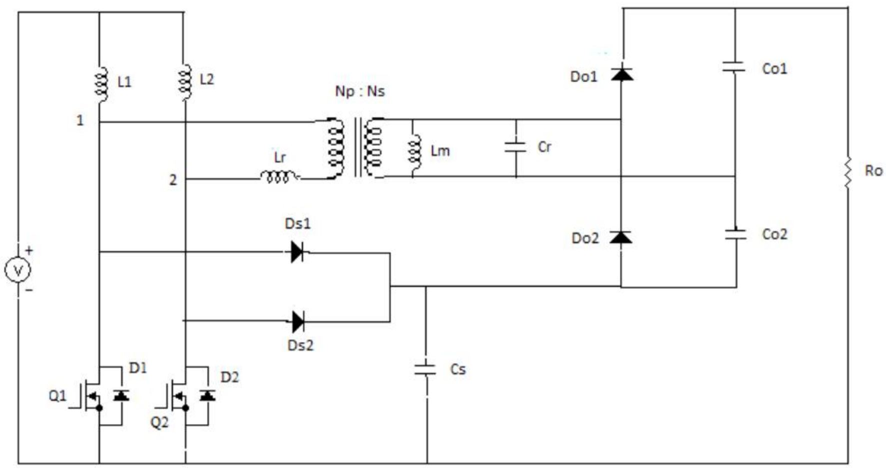

Fig. 3 The Circuit of an interleaved Converter

V.CONTROLLING OF THE CONVERTER

Phase Shifted Full Bridge DC-DC converters are used mostly to step down high DC voltages and provide isolation in different power applications like server power supplies, battery charging systems and renewable energy systems. Mostly micro controllers have been restricted to only performing supervisory or communications tasks. With the availability of micro-controller devices, it is now possible to use micro controllers for closing control loops, in addition to handling the micro controller functions. The transition to digital power control means there is a transition from hardware to software. In addition to the flexibility this simplifies the system considerably. These systems can implement advanced control strategies to optimally control the power stage under different conditions. A PSFB converter consists of power electronic switches that form a full bridge on the primary side of the isolation transformer and diode rectifiers or MOSFET switches for Synchronous Rectification (SR) on the secondary side. This topology allows all the switching devices to switch with Zero Voltage Switching (ZVS) resulting in lower switching losses and an efficient converter. Here ZVS for switches in the one leg of the full bridge and zero or low voltage or low voltage switching for switches in the other leg is achieved across the complete load range, by changing dead times for primary side switches based on load conditions. For such an isolated topology, signal rectification is required on the secondary side. For systems with low output voltage and/or high output current ratings, implementing synchronous rectification instead of diode rectification which achieves the best possible performance by avoiding diode rectification losses. In

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this work, voltage doubler active boost rectification is implemented on the secondary side with different switching schemes to achieve optimum performance under varying load conditions. A DC-DC converter system can be controlled in various modes like Voltage Mode Control (VMC), Average Current Mode Control (ACMC) or Peak Current Mode Control (PCMC). Implementing these different control modes for controlling the same power stage typically requires redesigning the control circuit along with some changes to the power stage sensing circuit. With a microcontroller based system, all these modes can be experimented with on the same design with minimal or no additional changes. A system is implemented here using VMC and PCMC control schemes. PCMC is a highly desired control scheme for power converters because of its inherent voltage feed forward, automatic cycle by cycle current limiting, flux balancing and other advantages. Implementing PCMC for a PSFB system requires complex PWM waveform generation with precise timing control for PCMC implementation with a microcontroller, the regulated output voltage is dependent on the amount of output voltage ripple. Peak efficiency greater than 95% and efficiency greater than 90% down to 10% load is achieved for almost all converters.

VI. RESULT AND DISCUSSION

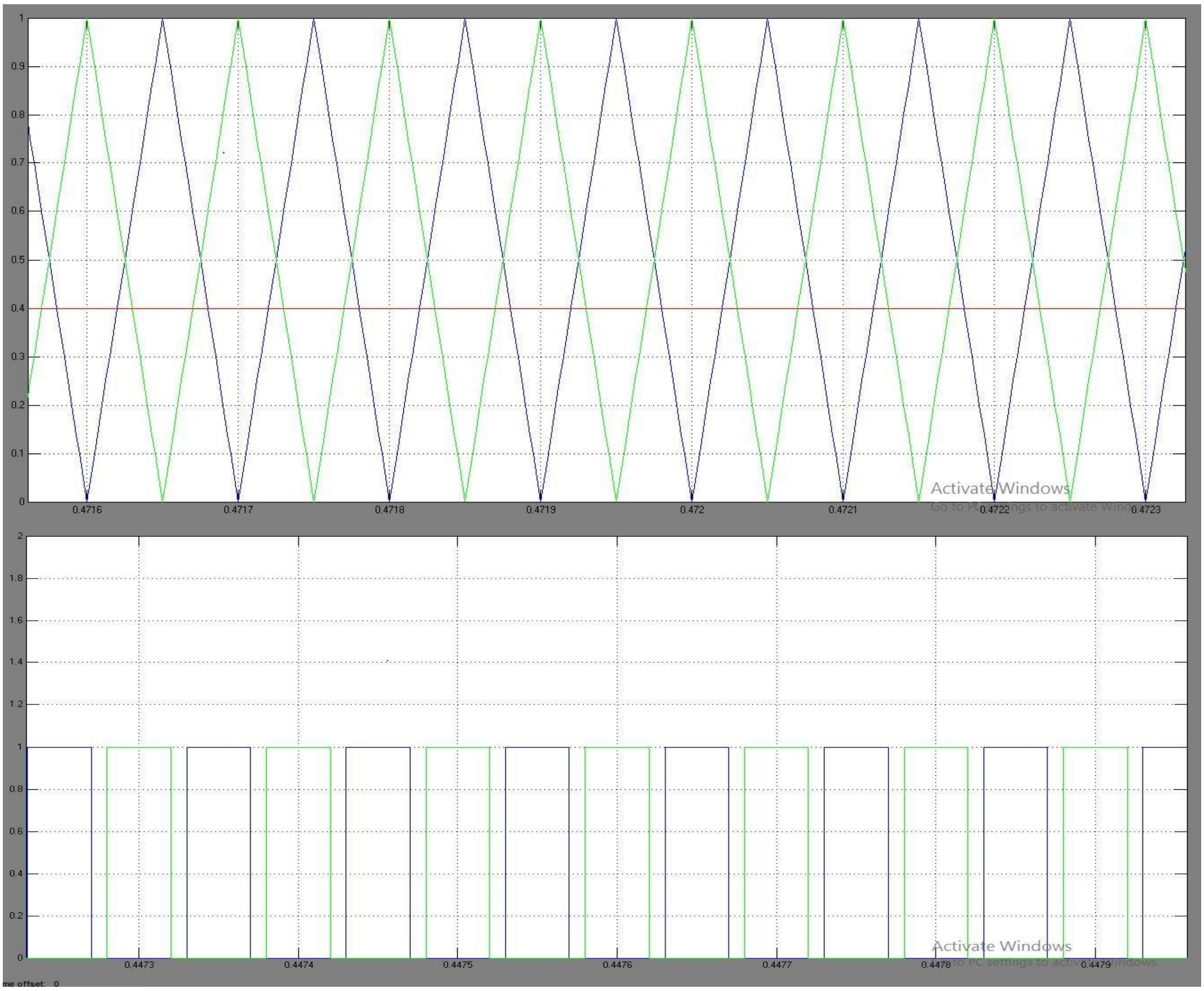

Fig. 4 The Pulses for the Existing System

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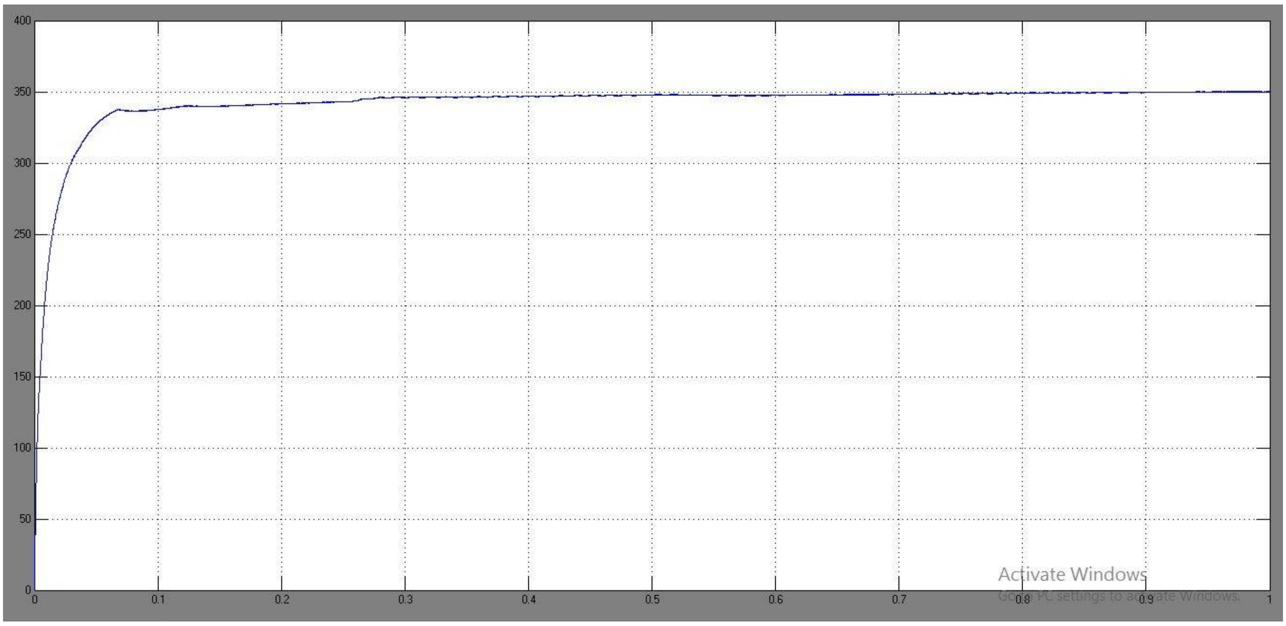

Fig. 5 The Output Voltage of the Existing System

The simulation results of the FBC-ABR configuration for a voltage value of 110-120 V as input gives an output voltage around 350V which is as shown in the fig.5 . The frequency of the pulses is here taken as 80KHz and depending on which a new pulse is generated for three points to be given to the gates of converters which is as shown in the fig.4 .

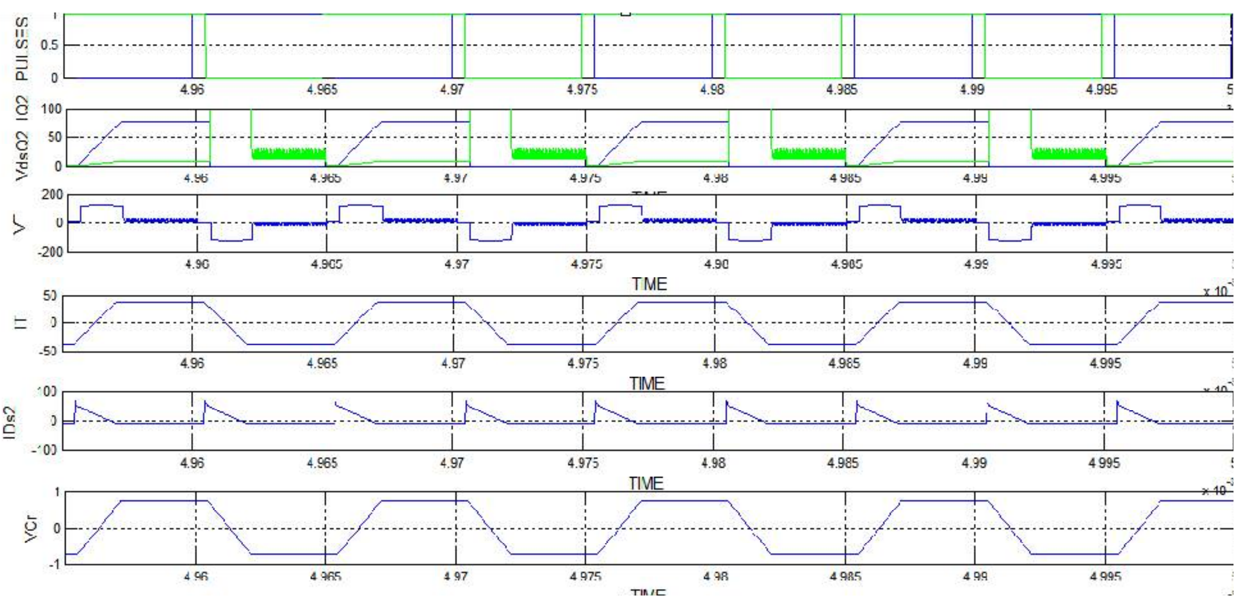

Fig. 6 The Converter Side Simulation Results of the Converter in Making

The second converter here is having an interleaved converter on the primary side and a normal rectifier on the secondary side this kind of configuration can be used for water pumping applications. The input value here is comparatively low but it produces a output voltage of almost 400V as shown in the fig.7 .The voltage and current parameters of the converters from simulation work is given in fig. 6. Bothe the converters are isolated by a transformer

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the main aim is for reducing the step up value that is the turns ratio of transformer and for that changes in circuits are done like the changes in inverter side as an interleaved configuration and the normal rectifier in to a ABR the validation is done with MATLAB 2013a and it is evident that both converters are highly applicable for high voltage DC applications ranging from 350-400 V . A combination of both that is the primary side of an interleaved inverter and the secondary side which is a ABR is taken in to consideration for producing a better output which is considered as a future work from the study conducted .

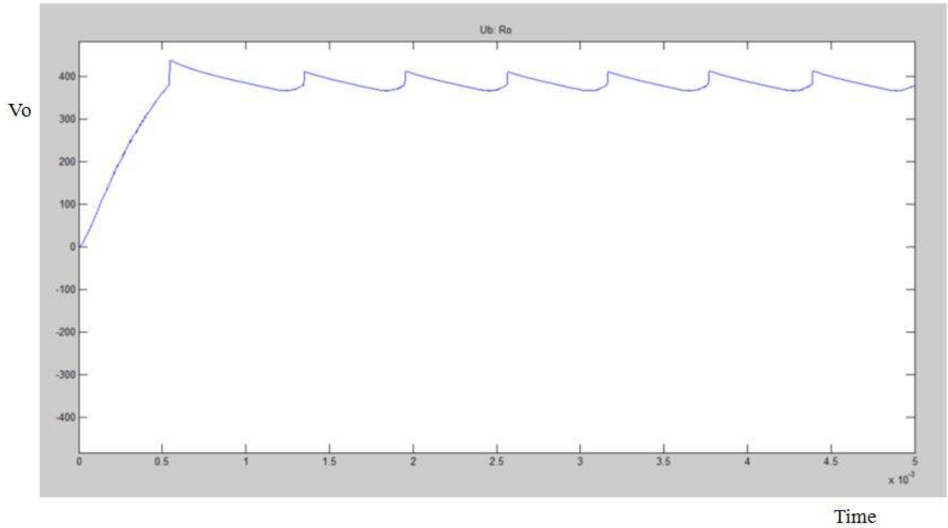

Fig. 7 Output Voltage of the Proposed Converter

VI.CONCLUSION

In the ABR-VD converters all the power switches are operated at fixed 50% duty cycle, and the output voltage regulation is achieved by adopting phase shift control between the primary and secondary side switches. ZVS performance has been achieved for both the primary and secondary side switches in a wide voltage and load range. Furthermore, the reverse recovery problems associated with the rectifier diodes. From the survey conducted to know the developments in the field of isolated DC-DC converter it is understood that if an interleaved converter on primary side is used for high voltage applications the topology will be having smaller voltage drop, faster dynamic response, lesser component count and lesser complexity and also the phase shifted DC-DC converter which can solve the problems of full bridge DC-DC converter such as high switching losses, conduction losses and lower efficiency. A possible modification of the SVM to a hybrid form is under consideration.

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