Micro Controller based Current Fed Dual Bridge DC-DC Converter

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Abstract—Here emphasis is to realize a new isolated current –fed pulse width modulation dc-dc converter –current fed dual- bridge dc –dc converter – with small inductance and no dead time operation. Previously current fed full bridge dc-dc converter were used for few applications. There are few draw backs in current fed full bridge converter. The output of the dc choppers with resistive load is discontinue and contains harmonics. The ripple content is normally reduced by an LC filters. But concentrating now current fed dual bridge. The new topology has more than 3 x smaller inductance than that of current –fed full-bridge converter, thus having faster transient response speed. Compared with the conventional Full bridge Converter, the dc to dc converter with the new topologies have lower input current ripple, less stress on power switching components and smaller output filter inductor.

Index Terms—Current-fed, dc-dc converter, deadtime, dual-bridge,

1.1 INTRODUCTION

The main reason why AC electricity was accepted as the form of choice for the modern electric power system is the magnetic transformer. The inability to conveniently change voltage levels became one of the major drawbacks of Edison’s early DC system concept. The DC transformer can be a device that, like its AC counterpart, provides lossless transfer of energy between circuits at different voltage or current levels which become useful to adopt DC system in place of existing AC systems. In power electronics, the DC – transformer is realized as a DC – DC converter. Energy is transferred between two DC circuits at different voltage and current levels.

Importance of DC – DC Conversion

DC to DC conversion is significant in electronic circuit applications and is becoming increasingly important. Modern fixed- output DC power Supplies find their way into products ranging from home appliances to industrial controllers. A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. This is a summary of some of the popular DC-to-DC converter topologies: Today most supplies are built with DC to DC converters. The incoming AC is rectified directly with a simple diode circuit and then the high level DC is converted to desired levels. Modern power supplies of this type range from 2V output for special logic up to 500V or more for industrial applications. Others are intended to handle the 12V level used in many telephone networks. Converters for 12V to 24V support analog power supply applications and are also used in many commercial designs for automobiles. The output of the oscillator is fed to main output transformer through the MOSFETS driving stage. This is a step-up transformer, which generates 30V AC from a DC source of 12V. Contemporary research in DC-DC power conversion is strongly motivated by the need to increase performance while reducing size and maintaining or improving efficiency.
To combat these difficulties, new circuit topologies and system architectures can be used. Replacing hard-switched square-wave topologies with resonant, soft-switched converters allows high frequency converter designs that take advantage of techniques employed in tuned radio frequency power amplifiers. To solve the problem of controlling this high-frequency DC-DC converters, a new architectural approach will be employed which partially decouples the problems of efficient power conversion and controlled power delivery. In this project work, the PWM oscillator is designed to produce 20 KHz approximately, because the transformer core (Ferrite core) used in this project work can withstand up to 20 KHz only.

Problems with High-Frequency Power Conversion
Whereas at low frequencies conduction losses are generally dominant, at high frequencies two other loss mechanisms, switching loss and gating loss, must also be considered. In addition, traditional control strategies for low frequency converters are impractical at high frequencies. Finally, implementing passive components compatible with efficient power processing at high frequency is often difficult; inductors are of particular concern, as there exist few permeable materials whose performance is acceptable for application in high frequency power conversion.

Switching Loss
Switching loss arises from the fact that no practical active element can turn on or off instantaneously: there is some interval during which the device must traverse the region between the on and off states. During this time, the device both conducts current and drops voltage, dissipating power. To ameliorate switching losses, zero-voltage switching topologies are often employed. In these topologies, a continuous resonating action is used to ensure that switches only change state when supporting little or no voltage. While ZVS can be advantageous when applied to DC-DC conversion at full load, it becomes a problem at light load: since the losses accompanying resonant operation are present at all load conditions, efficiency when delivering only a fraction of full power is severely reduced.

Gating Loss
Gating loss is a result of the fact that turning any active device on or off involves a transfer of energy. In a MOSFET, for example, the gate capacitance must be charged to turn the device on and discharged to turn it off. In a switching scheme where the gate terminal is charged from the supply and discharged into ground, power loss proportional to frequency results. By employing resonant structures in driving the gate, energy can be recovered and reused in subsequent cycles. In the simplest of such circuits, the energy transferred onto the gate capacitor is transferred off and stored on an external inductor until the next switching cycle; in this way, energy is only lost in conduction. In effect, a resonant gate driver is itself an RF amplifier; thus, the benefits of resonant gate drive can often be most fully developed by using a cascade of resonant converters, one driving the next.

Control Strategies
Control strategies employed at low frequencies are not easily adapted to efficient high frequency topologies. Since such strategies often required direct manipulation of the harmonic content of operating waveforms, they are generally incompatible with ZVS and resonant gate drive topologies. Regulation can be achieved by other techniques, such as frequency control; even so, realizing regulation over a wide load range becomes increasingly difficult as frequencies increase, as do considerations of converter dynamics and the complexity of implementing control circuitry. The purpose of this project work is to demonstrate the operation of DC – DC converter. The main advantage of this converter is, the output
voltage of this converter can be programmed, so that the required voltage can be obtained. The basic oscillator of the converter is designed with PWM (Pulse Width Modulation) IC, for this purpose 3524 IC is an internal oscillator; with the help of two external components i.e., Resistor and capacitor connected to Pin No. 6 and 7 of the IC; frequency can be varied from 1Hz to 50KHZ. The required frequency is 20 KHz approximately.

The oscillator frequency can be easily set by an external resistor. The output of the oscillator is fed to main output transformer through the MOSFETs driving stage. This is a step-up transformer, which generates 30V AC from a DC source of 12V. The selection of inverter transistors or power MOSFETs and the design of the inverter transformer depend on the specific requirement of the inverter. If the accuracy of the specification is more or the tolerances are higher, it is more difficult to design and the cost also increases considerably. DC-to-DC converters are usually designed for the highest possible efficiency but if the output and frequency stability are higher, it is simplicity. Some of the specific requirements of an inverter or converter may be listed as follows:

- Input Voltage and its variation
- Nominal output voltage and its regulation
- Output frequency and its stability
- Output power
- Type of load and power factor
- Overall efficiency at various loads
- Size and weight

The controller used in this project is ATMEG 89C51, and this is 40pin IC having 32I/O lines. The ATMEG AT89C51 is a low power, higher performance CMOS 8-bit microcomputer with 4K bytes of flash programmable and erasable read only memory (PEROM). Its high-density non-volatile memory compatible with standard MCS-51 instruction set makes it a powerful controller that provides highly flexible and cost effective solution to control applications. Micro-controller works according to the program written in it. The program is written in such a way, so that the Microcontroller can read and it can store the information received from the keyboard. According to the received information from the keyboard, the Microcontroller energizes the corresponding relay. These relay contacts are used to control the reference voltage of variable regulator. Micro-controllers are "Embedded" inside some other device so that they can control the features or actions of the product.

2. FULL BRIDGE DC-DC CONVERTER.

The novel soft-switching topology for DC–DC converters for Regulated- Output applications and for Constant–Input, Variable Output applications is discussed by (Ayyanar R. et al, 2001). The features here are Zero voltage switching down to no–load without serious conduction loss penalty, constant frequency operation and near-ideal filter waveforms. The converter operation is analysed for typical Switched–mode power supply applications i.e., fixed and well–regulated output voltage and for battery chargers with a PFC pre-regulator, i.e., for fixed–input, variable output applications.

Isolated converter topologies:

Isolated converter topologies provide advantages in applications requiring large voltage conversion ratios. Transformer isolation can reduce switch and diode device stresses and allows multiple windings or taps to be used to for multiple converter outputs. The full bridge is a popular design for both buck and boost applications and has become a basis for numerous resonant zero voltage and zero current switching (ZVS, ZCS) schemes. Often in high power applications a phase shift modulation (PSM) switching
scheme is used to achieve ZVS and/or ZCS transitions through the interaction of converter parasitic energy storage elements. Another advantage for using the full bridge converter is the fact that when power application are requested the full bridge converter can act as a modular block and that it is possible to stack up. For this purpose the chosen topology for the converter to be used in this application is a Full bridge phase shifted PWM converter. Higher power application are requested the full bridge converter can act as a modular block and that it is possible to stack up. For this purpose the chosen topology for the converter to be used in this application is a Full bridge phase shifted PWM converter.

**FB-Converter Model in DCM & CCM**

In order to reduce the size and the weight of magnetic components it is desirable to increase the switching frequency for DC-DC converters. When conventional PWM converters are operated at high frequencies, the circuit parasitic has negative effects on the converter performance. Switching losses increase in high power applications and snubbers or other means of protection are required, which introduce significant losses and lower the efficiency. In the case of the conventional full bridge converter, the diagonally opposite switches (Q1 and Q2, or Q3 and Q4) are turned on and off simultaneously.

**Operation:**

In the FB-PWM converter, when all four switches are turned off, the load current freewheels through the rectifier diodes. In this case the energy stored in the leakage inductance of the power transformer causes severe ringing with MOSFET junction capacitances. This creates the need for using snubbers that increase the overall losses bringing down the efficiency. If snubbers are not used, the selection of the devices becomes more difficult as the voltage rating for these switches has to be much higher. As the voltage rating goes up, so do the conduction losses and as a result the overall losses increase. At the same time the cost increases as well. In order to minimize the parasitic ringing, the gatesignals of Q2 and Q4 are delayed (phase-shifted) with respect to those of Q1 and Q3, so that the primary of the transformer is either connected to the input voltage or shorted. The leakage inductance current is never interrupted, thus solving the problem of parasitic ringing associated with the conventional full-bridge PWM converter.
Besides preventing switches A and B (or C and D) from conducting simultaneously, this dead time is essential for conventional dual-end (half- and full-bridge) converters to obtain a regulated output voltage when the input voltage changes. During the dead time, the input current becomes zero; this discontinuity causes a large input ripple current. Thus, large input filters must be used to satisfy the conducted EMC requirements. This dead time also needs a large output inductor to smooth the output voltage and limit the ripple current through it. The large output inductor slows the output response time.

Lower output inductance value improves the output transient speed and reduces the output filter size, thus improving power density (power-to-volume ratio) of the DC-DC converter. Several methods, for example, magnetic transformer tapping and implementation with two transformers can be used to realize no dead time topologies. Figure 2.3 shows their typical waveforms of input current and the voltage Vp across the primary winding of the transformer. This research presents two topologies of no dead time DC-DC converters. They are the Dual-Bridge DC-DC converter and the Dual-Bridge converter with ZVS. The new topologies are characterized by no dead time property and have significantly reduced output filter inductors.

**CCM and DCM Operation**

DCM occurs with large inductor current ripple in a converter operating at light load and containing current-unidirectional switches. Since it is usually required that converters operate at no load, DCM is
frequently encountered. The properties of the converter change radically in the discontinuous conduction mode. The conversion ratio \( M \) becomes load-dependent and the output impedance is increased.

The ripple magnitude depends on the applied voltage, the inductance value, and on the transistor conduction time \( D T_s \). However, the ripple does not depend on the load resistance \( R \). The inductor current ripple magnitude varies with the applied voltages rather than the applied currents. If the load resistance is increased so that the DC load current is decreased, the ripple magnitude \( L_i \) will remain unchanged. If the load resistance increases there will be a point when \( L_i I = \) is reached. As the load is decreased, the diode current cannot be negative therefore the diode must become reverse biased before the end of the switching period. This is what is known as discontinuous conduction mode (DCM).

![Waveforms of CCM & DCM FB converter](image)

### 3. DUAL BRIDGE DC-DC CONVERTER AND BLOCKDIAGRAM AND ITS BRIEF DESCRIPTION

**Dual Bridge DC-DC Converter**

With the widespread use of low voltage microprocessors as well as various low-voltage ICs, research on DC – DC converters with low voltage and high current output has become increasingly important. There has been a recent trend in industry to use the bridge topologies in lower conversion power ranges of 100W to 300W and lower input voltage in the tens of volts. This chapter deals with the circuit description and operation of the two topologies of Dual bridge DC to DC converter. Also, the comparison of the circuit with conventional full bridge is done and the Fourier spectra of both the circuits are presented.

**Topologies to Prevent Dead Time**

The topologies used to prevent dead time are the two transformer implementation with two diode output rectifier and the tapped primary full bridge circuit.
Advantages of No Dead Time Operation
The topologies with no dead time during the operation result in energy being continuously transmitted from DC source to the output load in the whole switching period. Because of the lower input ripple current in a no dead time DC – DC converter, the conducted EMI filter is relatively smaller. Lower output inductance value improves the output transient speed and reduces the output filter size, thus improving power density (power to volume ratio) of the DC – DC converter.

Circuit Description:
The switches S1, S2, S3 and S4 form a Full bridge converter. The switches S1, S2 and capacitors C1, C2 form a Half bridge converter. Dual - bridge shown in Figure 3.3 is the combination of the two bridges. The two bridges are connected by S5 for bidirectional control of current. Suppose the converter works in steady state and its output inductor current is under continuous conduction mode. The high frequency transformer is modelled by the following: the transformer has the turn’s ratio n, its total stray inductance Lσ is the sum of the primary stray inductance and the secondary stray inductance reflected across the transformer to the primary. The magnetizing inductance Lm is much bigger than the leakage inductance. Figure 3.3 Dual bridge DC-DC converters.

Circuit:
Circuit Operation
In mode 1 as in Figure 3.4(a) the switches S1 and S4 are turned on. The load current flows through S1, load and S4. The voltage across the primary side of transformer, $V_p = V_{in}$ and voltage across the secondary side of transformer, $V_s = nV_{in}$. Input current $i_{in}$ increases and equals the primary winding current $i_p$.

In mode 2 as in Figure 3.4(b) The switches S4 is off and S5 is on. The current $i_p$ flowsthrough S1, load and S5 charging C2 while the capacitor C1 discharges. The voltages, $V_p = V_{in}/2$ and $V_s = nV_p = nV_{in}/2$. At $t_2$, S1 and S5 turn off and S2 and S3 turn on.
The mode 3 operation as in Figure 3.4(c) is in symmetry with time interval $t_0 < t < t_1$ and the voltage, $V_s = nV_p = -nV_{in}$. The operation of mode 4 as in Figure 3.4(d) is in symmetry with time interval $t_1 < t < t_2$ and now the voltage, $V_s = nV_p = -nV_{in}/2$.

**Idealized Waveforms**

The ideal waveforms of the Dual Bridge converter are shown in Figure 3.5.

The control signals of the switches S1 to S5 are as shown. VS1 and VS2 are two 50% duty ratio complementary control signals of S1 and S2. VS3 and VS4 are control signals of switches S3 and S4 with duty ratio, D and switching frequency, f. VS5 operates at $f_0 = 2f$ ($T_0 = T/2$). The values of D and $(1-D)$ are obtained from the equations 4.1 and 4.2.

\[ D = \frac{(t_1 - t_0)}{T_0} = \frac{(t_3 - t_2)}{T_0} \quad (3.1) \]

\[ 1 - D = \frac{(t_2 - t_1)}{T_0} = \frac{(t_4 - t_3)}{T_0} \quad (3.2) \]
Advantages of Dual bridge topology over Conventional Methods
The following are the advantages of Dual bridge topology over the conventional methods.

- No dead time.
- One power transformer and no magnetic tapping on the primary winding.
- Significantly reduced input current ripple.
- Significantly reduced output filter inductance value, thus inductor size.
- Less stress on switching components.
- Self-Driven synchronous rectifiers can be used as output rectifiers to increase the Power efficiency of the converter.
- The ZVS dual bridge DC – DC converter is implemented by fixed frequency PWM Control without using phase – modulated control.

4. BLOCK DIAGRAM AND ITS BRIEF DESCRIPTION
The block diagram and its brief description of the project work “MICROCONTROLLER BASED PROGRAMMABLE DC - DC CONVERTER” is explained in this chapter. The main block diagram, which is shown at the end of this chapter, consists following blocks.

Fig: 4.1 block diagram for micro controller based programmable dc - dc converter

DC - DC Converters – An Overview
Many Industrial drives and processes take power from DC voltage sources. In most cases, conversion of DC source voltage to different levels is required. For example, Bus, Train, Ship, Flight, etc; Generally these kind of huge traveling bodies are equipped with huge batteries, and with the help of this DC – DC Converter, different DC levels are generated to energize various electronics equipment’s. There
is a need to energize electrical devices like tube light, cooler, etc.; for which AC voltage is required and with the help of an inverter connected to a fixed DC source as input source, the required AC voltage can be generated. Whether it is an Inverter or Converter, the input source is DC, and generates different DC levels or from DC to AC source to energize various Electrical and Electronic devices belonging to these traveling bodies.

Many Industries (manufacturers of DC – DC converters) offering high power converters up to 1000W. Using high switching frequency, hybrid circuit, chip-on-board and surface mounting technologies, these DC-DC converters provide high power density, a low profile and high efficiency. Accurate current sharing and fixed frequency synchronization of DC-DC converters allows reliable parallel operation for easy expansion. The product line covers commercial, industrial and military grade applications.

SIMULATION RESULTS

5. Simulation of Current Fed Full bridge DC-DC converter
Simulation circuit for current fed full bridge DC-DC converter is shown in fig: 5.1
The simulation was done for conventional half bridge and Full bridge DC-DC converter and Dual Bridge Converter systems. The simulation results are presented. Fourier spectrum was obtained for Conventional circuit and Dual Bridge circuit. From the frequency spectrum it is observed that the Dual bridge DC-DC converter produces lesser harmonics compared to the conventional converter. Significantly reduced input current ripple.

6. Simulation of Current Fed Dual bridge DC-DC converter
Fig: 6.1 Current-Fed Dual-Bridge DC-DC Converter

Fig: 6.2 Switching Pulses for M1, M2, M3, M4, M5, M6

Fig: 6.3 Transformer Primary & Secondary Waveforms
7. CONCLUSION

The topologies Dual Bridge DC – DC Converter have been described with modes of operation and ideal waveforms. The circuits have been analyzed. The simulation was done for conventional Full bridge DC-DC converter and Dual Bridge Converter systems. The simulation results are presented. Fourier spectrum was obtained for Conventional circuit and Dual Bridge circuit. From the frequency spectrum it is observed that the Dual Bridge DC-DC Converter produces lesser harmonics compared to the conventional converter. The timing sequence of control signals, transformer primary voltage with no deadtime operation and simulation results are given by IEEE transactions on Power Electronics, Vol. 19, No. 1, January 2004 by Wei Song and Brad Lehman. The Dual Bridge DC-DCConverter for R load was implemented. The various stages of the control and main circuits are presented with all specifications. The output waveforms obtained at different stages are presented. The experimental results coincide with the simulation results. This project work “MICRO CONTROLLER BASED PROGRAMMABLE DC-DCCONVERTER” is successfully designed, developed, tested and a prototype Module is fabricated for the demonstration purpose. Since it is a prototype module, the converter output current is limited to 500 milli-amps, but for the various practical applications this current can be increased. The converter is designed to operate at 12V DC for this purpose 12V lead acid battery can be used as input source and solar energy can be utilized for charging the battery. For the demonstration purpose 6 different DC levels are designed, in case if required more outputs can be derived from the same converter. Similarly the output voltages also can be programmed according to the one’s requirement. This type of designs is very well suited for field applications where the domestic power is not available.

The advantage of PWM IC based converters is compact in design, easy for maintenance and troubleshooting. To increase the power handling capacity, higher rating MOSFETS can be used with a suitable main output transformer. In this project work, for programming the desired output microcontroller chip is used for selecting the channel as well as for displaying the channel voltage. The same controller also can be used for displaying the channel current. For this purpose, current transformer can be used and its primary can be connected in series with the load. The current flowing through CT primary can be measured and displayed with little modifications in the hardware and software.

8. REFERENCES


[104]. Victor Yakushev, Valery Meleshin and Simon Fraidlin“Full-Bridge Isolated Current Fed Converter with Active clamp,” 0-7803-5160-6/99/$10.00@1999 IEEE.


9. APPENDIX

HARDWARE DETAILS

The IC’s and other important components used in this project work, procured from theHyderabad Electronics Market. The details or data sheets of the IC’s are down loaded from theInternet. The following are the web sites that can be browsed for collecting the data sheets._

www. Texas Instruments.com_
www. National semiconductors.com
www. Fairchild semiconductors.com
The following are the IC’s and other important components used in this project work

(1) 89C51 Microcontroller Chip
(2) 74LS573 Latch
(3) SGS 3524 PWM IC
(4) LM 317 3-Terminal Adjustable Regulator
(5) Voltage Regulator
(6) Z44 Power MOSFETS
(7) Relay
(8) BC 547

The required PCB’S (Printed Circuit boards) for the project work fabricated by SUNRISE CIRCUITS, Kusaginuda Industrial Estate, Hyderabad. Kusaginuda Industrial Estate isvery famous for fabricating the Industrial grade PCB’s.