Comparison of isolated and non-isolated bi-directional dc - dc converter for DC motor

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Abstract:

This paper presents a comparison of non-isolated and isolated bidirectional dc-dc converter. The isolated boost bidirectional converter size is large more component is presented in the circuit, core saturation problem, more switching losses, less efficiency as compared to the non isolated bidirectional dc-dc converter. Conventional Non-isolated bidirectional converter without filter, this paper proposed the pi filter of non-isolated bidirectional dc-dc converter to improve the efficiency as compared to the performance of isolated bidirectional dc-dc converter is discussed in detail. Hardware results are compared with the matlab 7.3 Version with the simulation results.

Index term: Bidirectional power flow, zero voltage switching, Micro controller, half bridge, isolated boost converter and non- isolated boost converter.

1. Introduction:

Power electronics converter system for application such as telecom, automobile and space craft. The conventional half bridge increases the conduction losses and current stress level is high on the device as compared to the non isolated bidirectional dc-dc converter.

Battery powered systems often stack batteries in series to achieve high voltage it is used in hybrid electrical vehicles, lighting systems, speed control of dc motor and computer application. A dual active full bridge dc-dc converter was proposed for bidirectional dc-dc converter [1]. The full bridge bidirectional dc-dc converter for high power and voltage levels [2]. The dual half bridge topology as compared to the dual full bridge topologies, it has the least component less size for the same power rating with no total devices [3]. The main supply fails, battery supplies the load. This mode of operation is boost mode power flows in opposite direction is buckmode [4]. ZVS is transition the transformer leakage inductance are store energy to charge and discharge the internal capacitance of MOSFET switch. This ensures the voltage across the switch V_{DS}, decreases to zero before the switch is turned ON [5]. Low stress on the switches, galvanic isolation low ripple in the battery charging current fast switch over on failure [6].

The output side capacitor is large they free from distortion output and maintain constant dc output voltage [7]. ZVS is achieved for the power switch and converter operates at a constant switching frequency [8]. It is significant advantages in efficiency over isolated half bridge bidirectional dc-dc converter [9]. Non-isolated bidirectional dc-dc converters to increase the voltage ratio [10-13]

This non-isolated converter operates with the continuous inductor current fixed switching frequency and improving efficiency [14]. This paper deals with the comparison of isolated and non-isolated dc-dc converter.
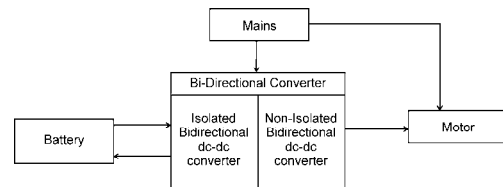

Fig.1 Block Diagram comparison of isolated and non isolated dc-dc converter with dc motor

2. Operating Principle:

Fig. 2 shows the isolated bi-directional half bridge dc-dc converter. In the circuit transformer is step up the voltage to create the more leakage losses due to the inductance in the winding.

The transformer in the each side is placed on the half bridge circuit. In non isolated bidirectional conventional dc-dc converter is shown in fig.3(a) Non-isolated bidirectional dc-dc converter is produced the step up voltage without transformer. This circuit is simple quality and reduce the switching losses and reduce the number of switches S_1 is turned ON the power flow from low voltage side to high voltage side is said to be boost mode. Switch S_2 is turned ON the power flow from high voltage side to low voltage side is said to be buck mode. In the circuit only one switch is turned ON at a time. To save the switching losses, space and switches. But in the half bridge dc-dc converter there are two switches can be turned ON at a time. Switching frequency is remaining constant in the entire circuit.In non isolated bidirectional Pi filter with dc-dc converter is shown in fig.3(b).This circuit help to reduce the ripple content . peak to peak Voltage and current are low as compared to the C-filter and LC filter .In non isolated bidirectional LC- filter with dc-dc converter is shown in fig.3(c).This circuit reduce the ripple content
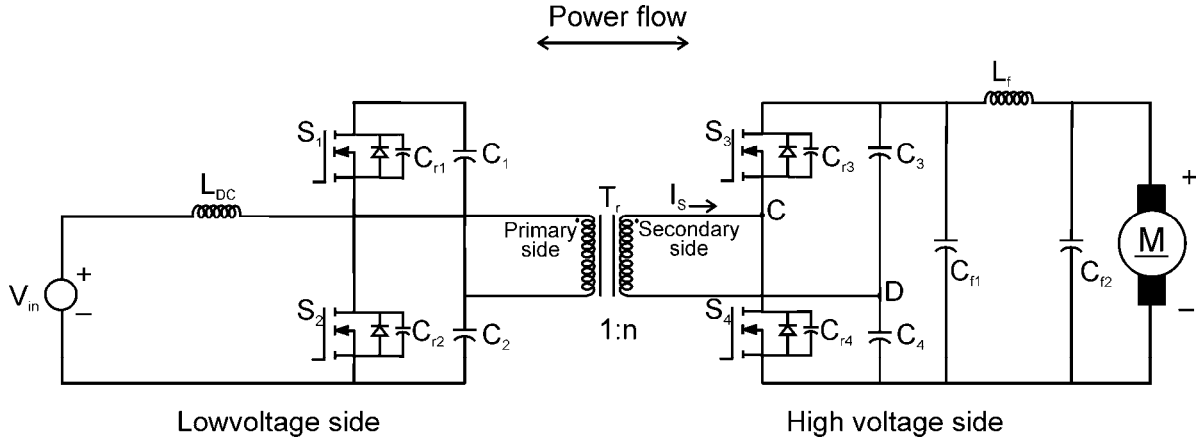
Fig 2- Bidirectional half-bridge pi filter with DC motor

in the output voltage. In non isolated bidirectional C - filter with dc-dc converter is shown in fig.3 (d).
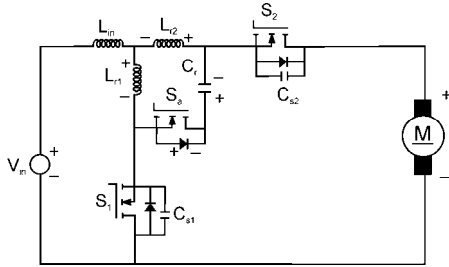

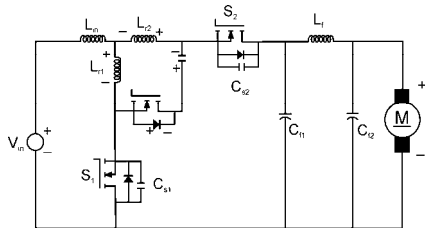Fig 3a - Conventional bidirectional non isolated dc-dc motor

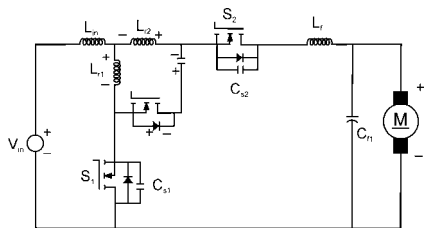Fig 3b - Proposed non isolated Bidirectional pi filter with DC motor

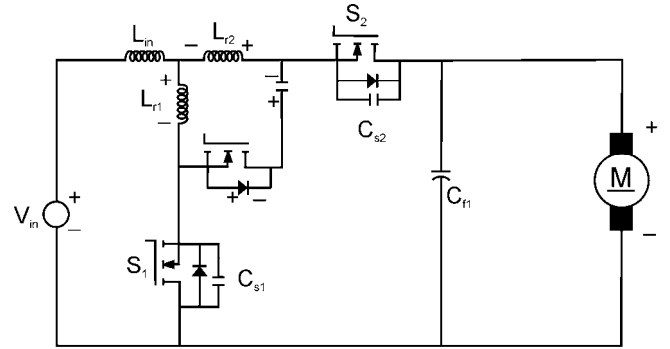Fig 3c - Proposed non isolated Bidirectional LC filter with DC motor

Fig 3d - Proposed non isolated Bidirectional C filter with DC motor

3. Design Guide lines

1. $L = V_o \delta / f \Delta I$ -------(1)
2. $I_o = V_o / R$ -------(2)
3. $P_o = V_o^2 / R$ -------(3)
4. $E_1 = 4.44 \, N_1 \, \Phi f$ -------(4)
5. $E_2 = 4.44 \, N_2 \, \Phi f$ -------(5)
6. $C = \delta / 2 \, f \, R$ -------(6)
7. $V_o = V_{in} \delta$ -------(7)
8. $V_o = \dfrac{V_{in}}{(1-\delta)}$ -------(8)

4.Simulation results

The converter is simulated in a manner similar to the proposed converter, which is also an active clamp converter but one that can operate in one direction only. The converter is operated with a low-side voltage of 100 V, a high-side voltage of 200 V, maximum power of 500 W, and a switching frequency of 100 KHz.

The analytical and operating principle of the proposed dc-dc converter is first verified with the simulation. The simulation parameters are as follows:
Input voltage(V_{in}): 100 V
a) Duty cycle (δ): 0.7
b) $L_{in} = L_{r2} = 8mH$, $L_{r1} = 5mH$
c) $Cr = 9 \, \mu F$, $Cs2 = 1000 \, \mu F$
d) R- Load & Motor Load.

Non-isolated bi-directional dc-dc converter is simulated using Mat lab Simulation. It has two modes of operation such as,

i) Boost mode or Forward mode.

ii) Buck mode or Reverse mode.

The Proposed circuit is simulated using different loads such as R-load & Motor load.

BOOST MODE WITH R-LOAD:

Boost converters can step-up the output voltage without a transformer. Due to a single switch, it has a high efficiency. The input current is continuous. However a high peak current has to flow through the power Mosfet. The output voltage is very sensitive to changes in duty cycle δ. The average output current is less than the average inductor current by a factor 1- δ, and a much higher rms current would flow through the filter capacitance, resulting in the use of a larger filter capacitor than those of buck regulator.

The circuit diagram for boost mode is shown in fig 4(a).The input voltage is given as 100V, which is boosted to 200V at duty cycle, δ = 0.7 as shown in fig.4(b).Fig 4(c) shows the triggering pulses for Mosfet M1& M2.Fig 4(d) shows the pulse Vgs & Vds across boost switch M1. Boost Output voltage is shown in Fig 4(e).
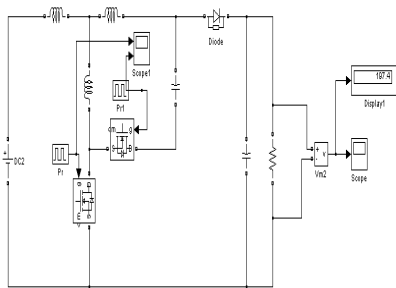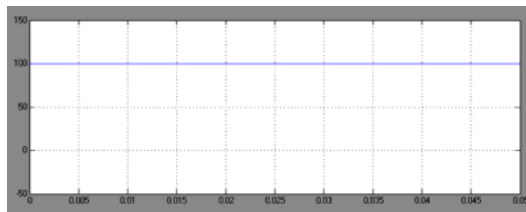

Fig 4(a): Circuit Diagram
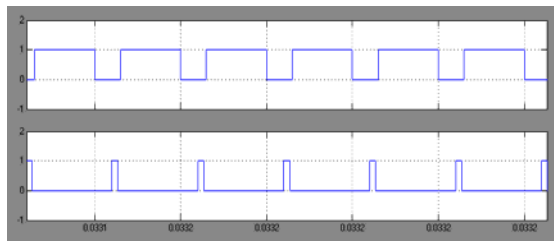

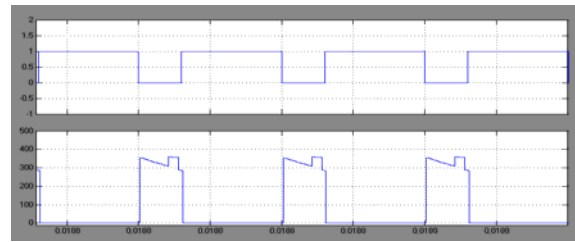Fig 4(b): Input DC Voltage

Fig 4c): Driving Pulses for Switches

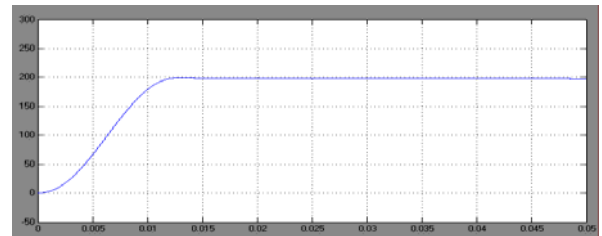Fig 4(d): Pulse And Voltage Across Boost Switch

Fig 4(e): Output Voltage

5.BUCK MODE WITH R-LOAD:

The buck converter requires only one switch which is simple and has high efficiency greater than 88.7%.The di/dt of the load current is limited by inductor L. However, the input current is discontinuous and a smoothing input filter is normally required. It provides one polarity of output voltage and unidirectional output current. Fig 5(a) shows the reverse or buck mode of operation. In this case, the high voltage of 200V is step down to low voltage of 100V, at duty cycle, δ = 0.7 as shown in fig.5 (b). Fig 5(c) shows the triggering pulses for Mosfet M3 & M2. Fig 5(d) shows the pulse Vgs & Vds across boost switch M3. Fig 5(e) shows the Output Voltage
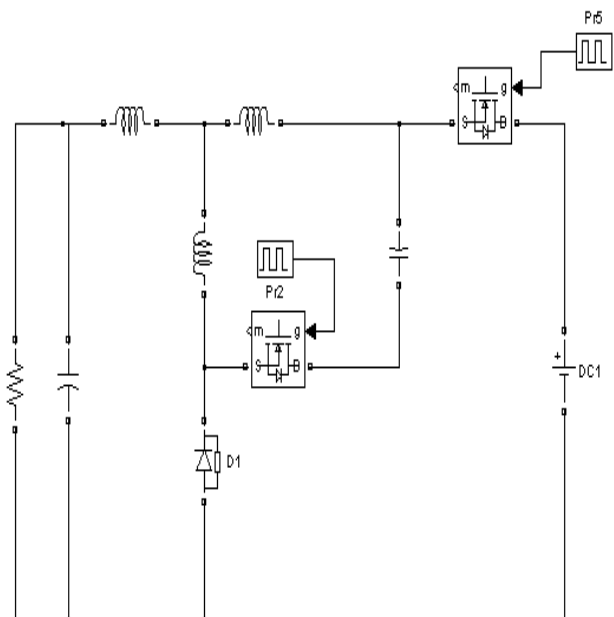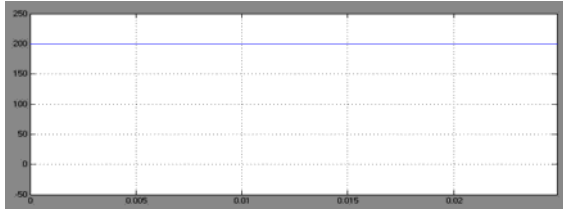

Fig 5(a): Circuit Diagram
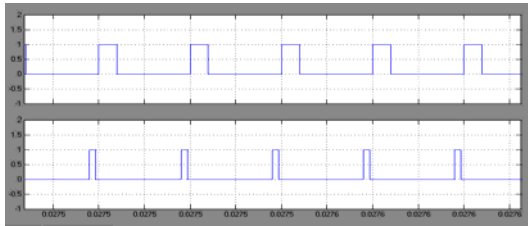
Fig 5(b): Input DC Voltage
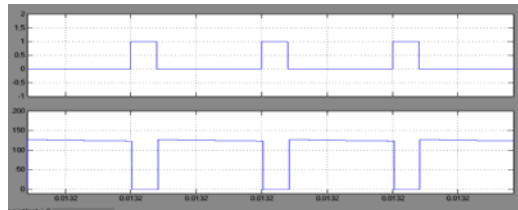

Fig 5(c): Driving Pulses for Switches

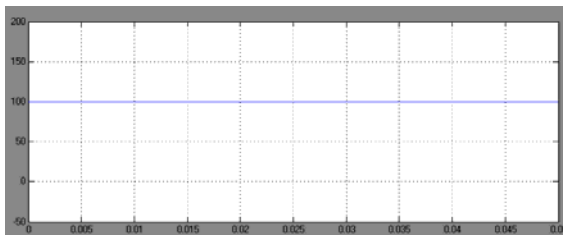Fig 5(d): Pulse And Voltage Across Buck Switch

Fig 5(e): Output Voltage

6.BOOST MODE WITH MOTOR LOAD:

Fig 6(a) represents boost converter fed dc drive. Boost converter is used to control the speed of the dc motor. Fig 6(b) shows the dc input voltage. Fig 6(c) shows the triggering pulses for Mosfet M1& M2. Fig 6(d) shows the armature speed of the motor.
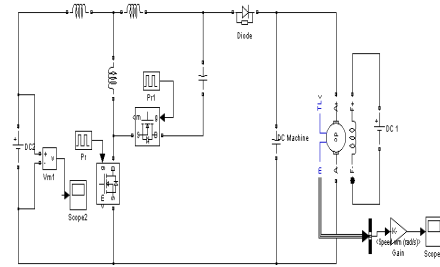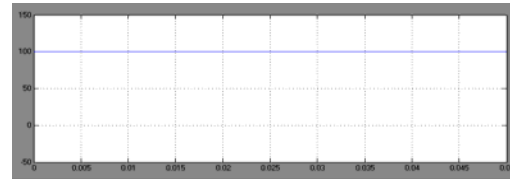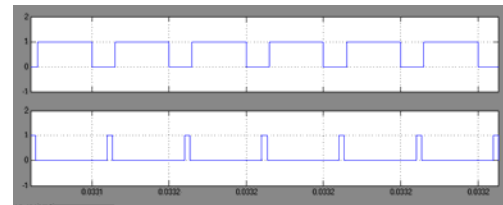

Fig 6(a): Circuit Diagram

Fig 6(b): Input DC Voltage

Fig 6(c): Driving Pulses for Switches
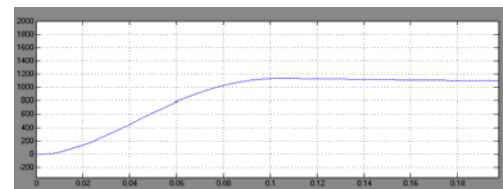
Fig 6 (d): Armature Speed in RPM

7. OPEN LOOP SYSTEM

In open loop control system the performance of the electric drive for a particular setting of its parameters cannot be maintained constant when disturbing factors, such as applied voltage, change in load, temperature of the motor etc. Thus the manual open loop control system can be used only in processes which are slow and of elementary nature. Fig 7 (a) shows the open loop circuit diagram or input disturbance circuit diagram. In this circuit, the input supply is varied from 100V to 110V at t = 1sec, the corresponding variations in the output side is noted in fig 7(b).The input disturbance is given through switch combination. In this case, the output voltage gets increased due to the disturbance.
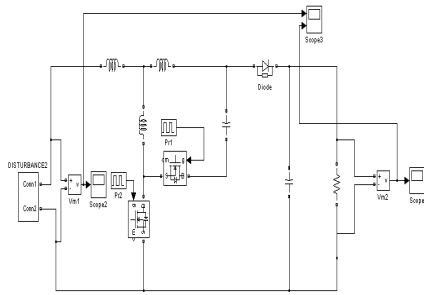
Fig 7(a): Open loop diagram

Fig 8(a): Closed loop System

Fig 7(b): Input and Output Voltage with disturbance

Fig 8(b): Input and Output Voltage with disturbance

8. CLOSED LOOP SYSTEM

The open loop system shown above can be converted as a closed - loop system by the provision of a feedback signal and an amplifier shown in fig.8 (a). Feedback loops in an electrical drive developed for the requirement of

1. Protection to the drive system
2. To improve the steady state accuracy.
3. To improve the speed response of the drive.

The closed loop systems are performed over open loop system for maintaining the operating conditions at desired values in presence of normal disturbances.Fig8 (a) shows the closed loop circuit diagram. The output value is compared with reference or set value. This difference is called as an error. This error value is given to PI Controller. This controller is used to regulate the output voltage. This adjusts the Ki, Kp value which depends upon the error. The PI Controller output is given to the controlled voltage source. This CVS is used to regulate the input voltage with the help of feedback system. Thus, the output voltage is regulated with the help of feedback system. The input and output voltage with input disturbance. Thus regulated output voltage is obtained.
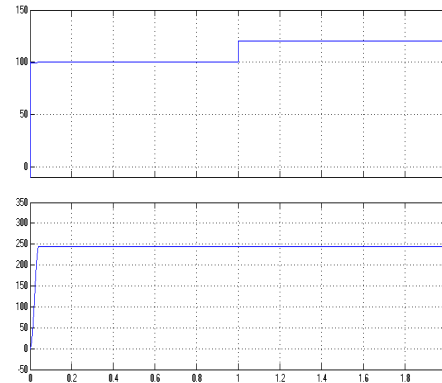
In this circuit, the input supply is varied from 100V to 110V at t = 1sec, the corresponding variations in the output side is noted in fig 8(b).The input disturbance is given through switch combination. From the above closed loop curve, it is noted that the output remains constant even though the input disturbance has occurred. Thus, the regulated output voltage is obtained from the closed loop system with respect to the set value, V=240V.

Thus the proposed converter operates with continuous inductor current and provides soft switching regardless of the direction of power flow. Therefore, ZVS-PWM converters are especially suited for constant load applications.

9. CONVENTIONAL CIRCUIT

Fig 9(a) shows the conventional dc-dc converter. This converter consists of inverter, transformer & rectifier. Thus this converter is used to convert low voltage dc of 100V to high voltage dc of 200V and duty cycle = 0.5. Using mat lab simulation, the input is given as 100V and the measured output after rectification is 193.8V. Fig 9 (b) shows the input voltage of the converter. Fig 9 (c) shows the triggering pulse for MOSFET's M1 & M2. Each MOSFET conducts at 180.Fig9 (d) shows the transformer output voltage. Fig 9(e) shows the dc output voltage.

Fig 9 (a): Conventional Circuit

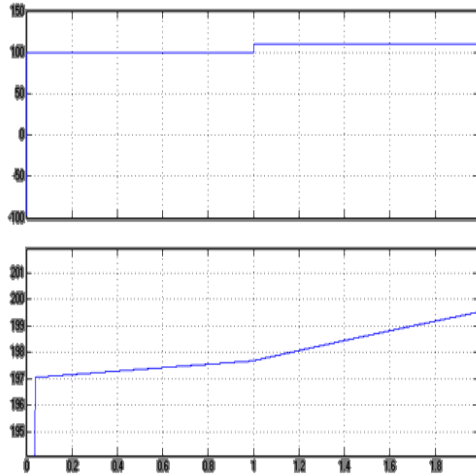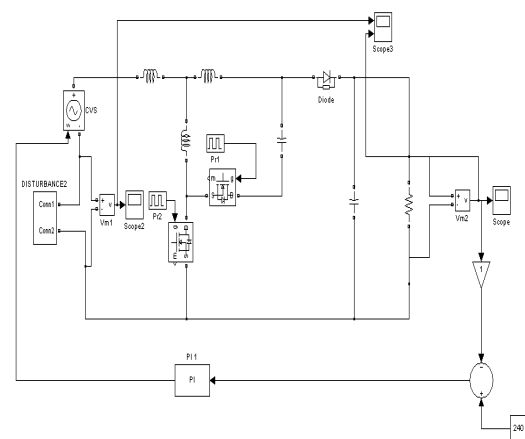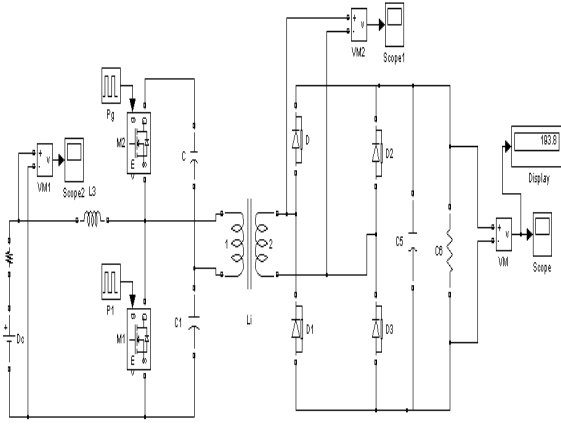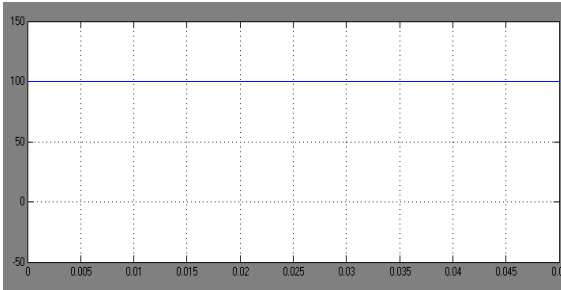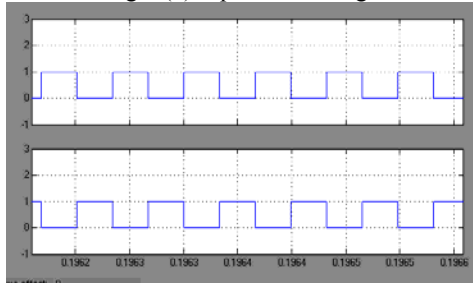Fig 9 (b):Input DC Voltage

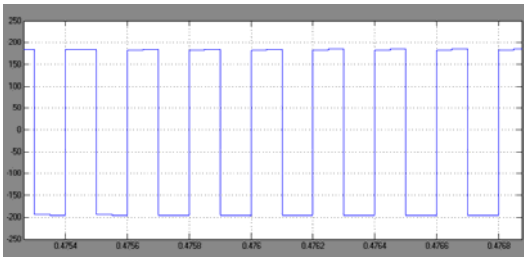Fig 9 (c): Driving pulses for M1 and M2
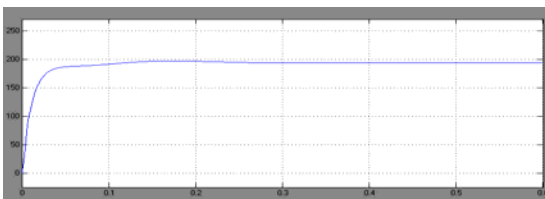

Fig 9 (d): Transformer Output voltage

Fig 9 (e): Dc Output Voltage

10.COMPARISON BETWEEN CONVENTIONAL CIRCUIT & PROPOSED CIRCUIT

The comparison simulation results between Conventional dc-dc converter and proposed non-isolated bidirectional ZVS-PWM active clamped dc-dc converter have been discussed. Fig.10 shows the performance of the converters. From the curve, it is noted that the non-isolated bidirectional dc-dc converter has better performance than conventional dc-dc converter.

1. Need of Transformer.

2. No. of stages are more.

3. Losses are also more.

4. Cost and Size are high.
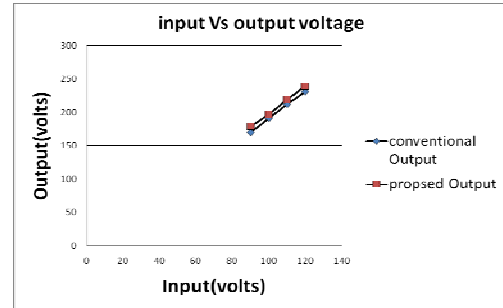
Fig 10: Converter Performance

Thus, the simulation results are consistent with the theoretical analysis, which verifies the previous analysis and the operating modes concept. The proposed non isolated bidirectional dc-dc converter with pi filter is giving the high efficiency as compared to the isolatedbidirectional dc-dc converter.

Table: 1 – Boost Mode

Input Voltage	Efficiency Half bridge	Efficiency Non-isolated
12	82.22 %	83.82 %
16	83.81 %	84.20 %
20	84.71 %	873 %
24	871 %	86.58 %

Table: 2 – Buck Mode

Input Voltage	Efficiency Half bridge	Efficiency Non-isolated
40	854 %	86.22 %
44	8107 %	86.92 %
48	86.81 %	87.53 %
52	86.96 %	88.71 %

Table: 3 – Closed Simulation Parameters

V_i	L	C_r	F_s	V_0	R	C
12-15V	12.5µH	5µf	50 KHz	24V	100Ω	100 µf

Table: 4 – Open Loop Ripple in Passive Filter

	π	LC	C
V_0	24.01V	21.459V	23.87V
Ripple Voltage	0.016	0.12	0.16
η%	89%	87%	86%

Table : 5 Performance Evaluation of Controllers for Non-Isolated dc-dc convertor with resistive load

Controller	Startup transient						Line Disturbance		Load Disturbance	
	Deadtime	Risetime	Peak time	Peak over shoot	Settling time	Steady state ripple	Settling time	Steady state ripple	Settling time	Steady state ripple
PI	4 µs	1.37 msec	1.76 msec	1.2 %	8 msec	0.016 Volts	3 msec	0.016 Volts	3 msec	0.016 Volts

with increased component losses and therefore the efficiency decreases. In addition, there is no isolation between the input and output voltage, which is a highly desirable criterion in high power applications.

Efficiency = (12 / 15) * 100 = 80%.

Thus, the efficiency of the converter using motor-load at full load 0.5 A was 80%, which was an 88.5% drop off from the R-load at full load 2A at an efficiency of 88.5%.This proposed converter with R-load can be used in DC transmission of low power applications (about 20/40V rating). Thus, the operation of the proposed converter was analyzed;

Experimental results further demonstrated the feasibility of the proposed ideas. The boost mode output voltage is

HARDWARE RESULTS

The AT89C2051 is a low-voltage, high performance CMOS 8-bit microcomputer with 2K Bytes of Flash programmable and erasable read only memory. The device is manufactured using ATMEL high-density nonvolatile memory technology and is compatible with the industry standard MCS-51 instruction set. By combining a versatile 8-bit CPU with flash on a monolithic chip, the Atmel AT89C2051 is a powerful microcomputer, which provides a highly flexible and cost effective solution to many embedded control applications.When R-load is simulated to this non-isolated bidirectional dc-dc converter, the efficiency is 88.5%.When the load is changed to motor load in hardware implementation ,the efficiency is reduced to 80%.The difference in efficiency is 8.5%.This has been decreased due to losses in the motor. The rating of the dc motor is 220V, 1A at a maximum power of 19W. The input power to the motor is calculated as, 15W. Since the output of the converter in boost mode using motor load is 30V. The output power given is 12W.Hence the efficiency at full load can be calculated as,

$$\% \eta = \frac{Output}{Input} * 100$$

The efficiency dropped off significantly as the current gets increased. This drop is expected since conduction losses - which are proportional to current – and are the dominant losses in the soft-switching converter. Port 3 pins P3.0 to P3.5, P3.7 are seven bidirectional I/O pins with internal pull-ups. P3.6 is hard-wired as an input to the output of the on-chip comparator and is not accessible as a general purpose I/O pin.

Due to the current – handling limitation of single switch, the output power of the converters are small typically tens of watts. At a higher current, the size of these components increases

43.7V and 37.4V

(R & Motor Load arrangement).and the buck mode output voltage is 7V is R Load arrangement
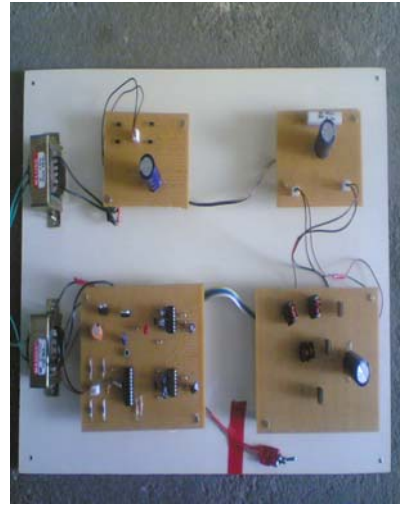

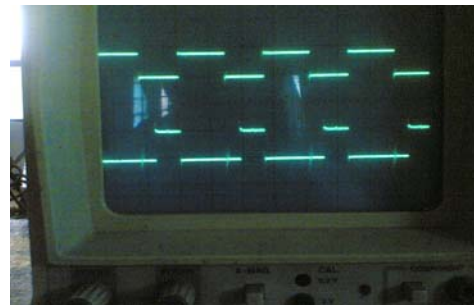Fig10.1 - Photograph of Proposed Converter Kit using with R-load

Fig10.2 - Photograph of Boost mode Output Diagram using R-load
Boost Mode - Output Pulse

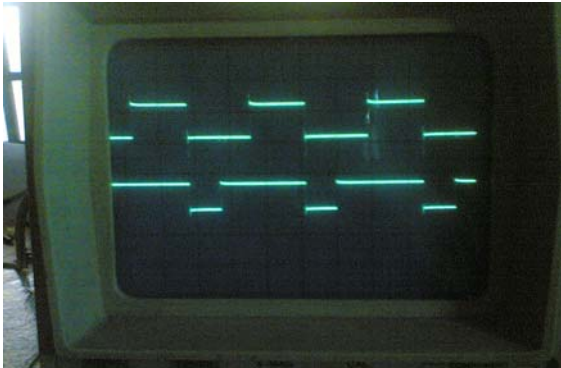| L_{DC} – 27 µH	D – 0.5
C1- C4-70 µH	L1- 5 mH, L2- 8 mH,
Transformer High frequency Ferrite core	R - 100Ω
R - 100Ω	C_f - 14.7 µf
C_f - 14.7 µf	L_f - 15 µH
L_f - 15 µH	
Minature motor 1A Model 842 V=220V	power 19W

Fig 10.3 - Photograph of Buck Mode Output Diagram using R-Load Buck Mode - output pulses
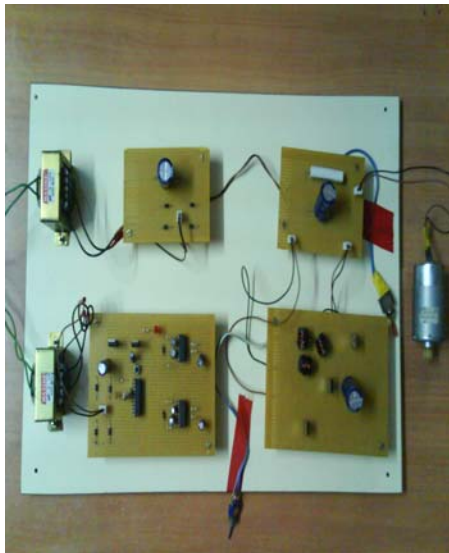
Fig10.4 - Photograph of Proposed Converter kit using m Motor Load

Fig10.5 Boost Mode Output Wave

Conclusion

The Non-isolated bidirectional dc-dc converter is quite good and more sphosticated compare to the isolated bidirectional dc-dc converter. In this paper to perform the non-isolated bidirectional dc-dc conveter with pi filter to produce more efficiency compared to the c filter in the output side less size, less space less weight, reduce the switching losses, reduce the conduction losses, reduce the harmonic with out the transformer are presented. It is operated the efficiency is 89% and switching frequency is 100 Khz. The hardware and simulation results are presented on both the circuit.

Closed loop simulation is presented for both isolated and non isolated dc-dc conveter to improve the steady state accuracy and speed response of the drive. The closedloop system are performed over open loop system for maintaining the operating conditions at desired value in presence of normal disturbance.

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Biographical notes.

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