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 discusses 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-de converter [9]. Non-isolated bidirectional dc-de 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-de converter.

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-de 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-de 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-de 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-de converter is shown in fig.3(c). This circuit reduce the ripple content.
in the output voltage. In non isolated bidirectional C-filter with dc-dc converter is shown in fig.3 (d).
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 $\delta$. The average output current is less than the average inductor current by a factor $1 - \delta$, 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 $\delta = 0.7$ as shown in fig 4(b). Fig 4(c) shows the triggering pulses for Mosfet M1 & M2. Fig 4(d) shows the pulse and voltage across boost switch M1. Boost output voltage is shown in Fig 4(e).

**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, $\delta = 0.7$ as shown in fig 5(b). Fig 5(c) shows the triggering pulses for Mosfet M3 & M2. Fig 5(d) shows the pulse and voltage across boost switch M3. Fig 5(e) shows the 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.

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.
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. Fig 8 (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 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.

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. Fig 9 (d) shows the transformer output voltage. Fig 9(e) shows the 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.

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 isolated bidirectional dc-dc converter.

Table: 1 – Boost Mode

<table>
<thead>
<tr>
<th>Input Voltage</th>
<th>Half bridge Efficiency</th>
<th>Non-isolated Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>82.22 %</td>
<td>83.82 %</td>
</tr>
<tr>
<td>16</td>
<td>83.81 %</td>
<td>84.20 %</td>
</tr>
<tr>
<td>20</td>
<td>84.71 %</td>
<td>87.3 %</td>
</tr>
<tr>
<td>24</td>
<td>87.1 %</td>
<td>86.58 %</td>
</tr>
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</table>

Table: 2 – Buck Mode

<table>
<thead>
<tr>
<th>Input Voltage</th>
<th>Half bridge Efficiency</th>
<th>Non-isolated Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>834.4 %</td>
<td>86.22 %</td>
</tr>
<tr>
<td>44</td>
<td>810.7 %</td>
<td>86.92 %</td>
</tr>
<tr>
<td>48</td>
<td>86.81 %</td>
<td>87.35 %</td>
</tr>
<tr>
<td>52</td>
<td>86.96 %</td>
<td>88.71 %</td>
</tr>
</tbody>
</table>

Table: 3 – Closed Simulation Parameters

<table>
<thead>
<tr>
<th>V_i (V)</th>
<th>L (µH)</th>
<th>C (µf)</th>
<th>F_s (kHz)</th>
<th>V_o (V)</th>
<th>R (Ω)</th>
<th>C (µf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-15</td>
<td>12.8</td>
<td>5.5</td>
<td>50</td>
<td>24</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
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, 
\[\eta = \frac{Output \times 100}{Input}\]

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 = \((12/15) \times 100 = 80\%\).

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 43.7V and 37.4V (R & Motor Load arrangement). and the buck mode output voltage is 7V is R Load arrangement.
Conclusion

The Non-isolated bidirectional dc-dc converter is quite good and more sophisticated compared to the isolated bidirectional dc-dc converter. In this paper to perform the non-isolated bidirectional dc-dc converter 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 converter 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.

References

Biographical notes.

S.A. Elankurisil has obtained B.E degree from Madras university and M.E Degree from Sathyabama university in the years 1998 and 2006 respectively. He has twelve years of teaching experience. He is presently a research scholar at sathyabama university. He is a life member of I.S.T.E.

S.S. Dash is working as a Professor in SRM University, Chennai, India. He has 16 years of teaching and research experience. He has received ME Degree in power system Engineering from University College of Engineering, Burla, India, in the year of 1996. He obtained PhD degree in Electrical Engineering from Anna University in the year of 2006. His current research interests concern FACTS, Drives, AI techniques, Power System Operation and power electronics converters.

