A ZVS-PWM Three Phase Current Fed Push Pull DC-DC Converter with Reduced Harmonics

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Abstract- In this paper, a ZVS-PWM three-phase current fed push–pull dc–dc converter with reduced harmonics is proposed. When compared to single-phase topologies, the three-phase dc–dc conversion increases the power density, uses the magnetic core of the transformer more efficiently, reduces the stress on switches, and requires smaller filters since the frequency for its design is higher. The proposed converter employs an active clamping technique by connecting the primary side of the transformer to a multi level inverter and a clamping capacitor and secondary side with three-phase full wave rectifier. This circuit allows the energy from the leakage inductances to be reused, increasing the efficiency of the converter. If appropriate parameters are chosen, soft-commutation of the switches (ZVS) can also be achieved. The soft-commutation improves the efficiency even further, allows higher switching frequencies to be used, and reduces the electromagnetic interference significantly. Applications such as fuel cell systems, transportation, and uninterruptable power supplies are some examples that can benefit from the advantages presented by this converter.

Index Terms—Active clamping, dc–dc power conversion, multiphase, soft-commutation, matlab.

I.INTRODUCTION

Three-phase systems are well known by their use in electric power generation transmission and distribution. The cost saving that they provide by employing less material than single-phase systems assured success in these areas and led to three-phase rectifiers, inverters, and also dc–dc converters.

After this, other three-phase dc–dc converter topologies were developed and compared, and techniques to increase the efficiency even more using soft-commutation [2]–[4] and reducing the number of semiconductors in the output rectifier bridge were studied. Most studies conclude that the three-phase structures perform better than their single-phase counterparts [5]. Depending on the topology, the voltage across the switches is not naturally clamped, requiring passive voltage clamps that dissipate energy stored in the leakage inductances [6]–[8] to prevent overvoltage which reduces efficiency. In order to avoid this problem, active clamping techniques have already been presented for single-phase converters and have successfully reused the energy that would be dissipated both in nonisolated [9] and isolated topologies [10].

The introduction of high-frequency three-phase transformers on dc–dc converters brought the possibility of increasing power density, using the magnetic cores more efficiently and reducing the current stress on power switches. In addition, the increase in the high-frequency component seen by the filters allowed the use of much smaller inductors and capacitors. The voltage across the switches is not naturally clamped, requiring passive voltage clamps that dissipate energy stored in the leakage inductances to prevent overvoltage.

In this topology, a full three-phase bridge and a clamping capacitor on the primary side of the transformer are responsible for the active clamping without the need for an extra switch [11]. Compared to single phase inverter multilevel inverter reduces harmonics and enhances the efficiency compared to the converter in [1]. In the future, the proposed converter could be applied as a high-efficiency alternative to many applications such as the energy processing of photovoltaic arrays and fuel cell systems [12][13] or automotive devices and fuel cell powered vehicles [14], where the three-phase dc–dc conversion is already showing its benefits.

II.PROPOSED ZVS PWM THREE PHASE DC-DC CONVERTER
A. Circuit Description

The circuit for the proposed ZVS-PWM three phase current fed push pull dc-dc converter is shown in Fig. 1. Switches S1’-S12’ and capacitor Cg1-Cg6 is added to the converter presented in [8] for active clamping. Inductance Ld1, Ld2, Ld3 are responsible for maintaining current during the commutation level. They represent the sum of the leakage inductance of the transformer and an external inductance, which is added to each phase if needed.

B. Modulation

The gate signals are generated by the comparison of the modulating signal VM and ten triangular carriers 36° of phase from each other. VG1, VG2, VG3, VG4, VG5, VG6, VG7, VG8, Vg9, Vg10, VG11, and Vg12 are the gate signals of S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11 and S12 respectively, and V’G1, V’G2, V’G3, V’G4, V’G5, V’G6, V’G7, V’G8, V’G9, V’G10, V’G11 and V’G12 are the gate signals of S1’, S2’, S3’, S4’, S5’, S6’, S7’, S8’, S9’, S10’, S11’ and S12’ switches respectively. The converter proposed in this paper can work in all the twelve regions simultaneously as defined TABLE I which is different from [1][8]. Thus decreasing the switching losses.

<table>
<thead>
<tr>
<th>Region</th>
<th>Duty cycle</th>
<th>Switches simultaneously on</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>0 &lt; D &lt; 1/12</td>
<td>None</td>
</tr>
<tr>
<td>R2</td>
<td>1/12 &lt; D &lt; 1/6</td>
<td>Up to two</td>
</tr>
<tr>
<td>R3</td>
<td>1/6 &lt; D &lt; 1/4</td>
<td>Up to three</td>
</tr>
<tr>
<td>R4</td>
<td>1/4 &lt; D &lt; 1/2</td>
<td>Up to four</td>
</tr>
<tr>
<td>R5</td>
<td>1/3 &lt; D &lt; 5/12</td>
<td>Up to five</td>
</tr>
<tr>
<td>R6</td>
<td>5/12 &lt; D &lt; 1/2</td>
<td>Up to six</td>
</tr>
</tbody>
</table>

In this paper, this converter will be analyzed for operation in region R12. Operating in region R12 proves the principle of the active clamping in this topology for the worst case as, higher the duty cycle is, the higher is the voltage across the switches. A good design for the other regions could achieve an even better result.

C. Working

At the beginning all the switches are kept open. In this stage no current will flow through the transformer. So the sine wave will have zero carriers and zero step will be produced. Now in the next step switch S1 and S2 are switched ON, keeping all the other switches OFF. In this stage current from VG1 will pass through the switch S1 and S2 then to inductor Ld1 and finally to the rectifier bridge. Thus producing the positive step one output from the inverter. Now switch S3 and S4 are switched ON keeping switch S1 and S2 ON and all other switches OFF. This will produce a current output from the equivalent voltage of bridge 1 and 2. Bridge 1 and 2 are interconnected and thus the current from them is the voltage equivalent. To get third positive step we will switch ON the combination of 1-2 and 2-3 bridges and thus increasing the number of bridges raising the positive step.

To obtain the negative part of the 11 step output the voltage from V’G1 is applied to the opposite leg of the bridge1 that is to the switch S1’ and S2’. Thus the first negative output is obtained. To obtain the second negative step output switch S3’ and S4’ is switched ON keeping the switch S1’ and S2’ ON and keeping all other switches OFF.

Thus the bridges will be operated in the order of 1-2, 1-3, 1-4, 1-5, 1-6, 2-4, 2-6, 3-4, 3-5, 4-5, 4-6, 5-6

III. SIMULATION

Simulation circuit for the project is shown in Fig 2. The output from the 11 level inverter is shown in Fig. 3. The output voltage produced for the input of 36V is produced in the Fig. 4.
IV. PROTOTYPE DESCRIPTION
A prototype implementing the proposed converter was built in order to validate the simulation results. The prototype is made for single phase and the output with respect to three phases is validated. The main specifications and components used are shown in TABLE II. A photograph of the prototype can be seen in Fig. 5.

V. CONCLUSION
In this paper, a ZVS-PWM three-phase current-fed push–pull dc–dc converter with reduced harmonics has been proposed. The operation stages were described, and the main waveforms were plotted. A prototype was built for a rated...
power of 4 kW based on the parameters calculated in the design example. This prototype was able to operate with active clamping and soft-commutation (ZVS) of the MOSFETs. The waveforms acquired through the matlab validate the output, and the measured efficiency for full load was 93.2%, remaining above 94% for most of the load range. As an isolated topology, this converter presents competitive efficiency and can be applied with good performance as an energy processing stage for many renewable sources. The most suitable applications include distributed generation, uninterruptable power supplies, and transportation.

REFERENCES


