COMPARATIVE STUDY OF POWER FACTOR CORRECTION TECHNIQUES FOR AC/DC CONVERTER

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ABSTRACT: In this paper, three generalized topologies of single stage circuits such as Boost converter, Buck converter & Quasi active power factor correction (PFC) converter circuits are designed and their performance comparison is presented. Converters connected to the mains have the potential of injecting current harmonics that may cause voltage distortion. These harmonics can be significantly reduced if the input power factor is corrected by shaping the input current so that it is sinusoidal and in phase with the supply voltage. In the proposed quasi active PFC system, the power factor is drastically improved by using an auxiliary winding coupled to the transformer of a cascade dc/dc fly back converter. The proposed converter is presented and compared with boost, buck converter for different loads and inputs.

Keywords: AC/DC converters, power factor correction (PFC), single stage, Fly back converter, total harmonic distortion (THD)

II. POWER FACTOR CORRECTION TECHNIQUE

2.1 Buck converter for power factor correction

It requires only one transistor and is simple load current. But, the input current is discontinuous and a smoothing input filter is required. Buck converter provides one polarity of output voltage and unidirectional output current. In systems such as universal line AC-DC converters it is very difficult to improve power factor where high efficiency is required throughout the entire line. A Power Factor Correction circuit using Boost Converter possesses 1% to 3% lower efficiency at 100 Volts than that at 230 Volts. This is due to increased input current that produces higher losses in semiconductors and input filters. Also the high output voltage of Boost Converter in 380-400 Volts range has a detrimental effect on its switching losses and on the size and efficiency of the isolation transformer. The above drawbacks of Boost Converter in Power Factor Correction circuit can be overcome by using Buck Converter with output voltage in 135 Volts range which has higher efficiency throughout the line. Also the lower input voltage to the DC-DC output stage can now be operated with lower voltage rated semiconductors, optimized loss and size of isolation transformer and better performance.
2.2 Boost converter for power factor correction

The input current is \((t) i_s\) controlled by changing the conduction state of transistor. By switching the transistor with appropriate firing pulse sequence, the waveform of the input current can be controlled to follow a sinusoidal reference, as can be observed in the positive half wave in Fig.5(a,b). This figure shows the reference inductor current \(i_{L \text{ref}}\), the inductor current \(i_L\), and the gate drive signal \(x\) for transistor. Transistor is ON when \(x = 1\) and it is OFF when \(x = 0\). The ON and OFF state of the transistor produces an increase and decrease in the inductor current \(i_L\).

![Boost converter](image)

Fig. 4. Boost converter

III. PROPOSED QUASI ACTIVE TECHNIQUE

Quasi-active PFC cell is formed by connecting the energy buffer (LB) and an auxiliary winding (LA) coupled to the transformer of the dc/dc cell, between the input rectifier and the low-frequency filter capacitor used in conventional power converter. The input inductor operates in DCM such that a lower THD of the input current can be achieved [1].

Stage 1 (to − t1):

When the switch (SW) is turned on at \(t = t_0\), diodes D1 and D0 are OFF, therefore, the dc-bus voltage \(V_{CB}\) is applied to the magnetizing inductor \(L_m\), which causes the magnetizing current to linearly increases. This current can be expressed as

\[
i_m = \frac{V_{CB}}{L_m} (t_0 - t_1)\]  

And since diode D1 is OFF, the input inductor \(L_B\) is charged by input voltage, therefore, the inductor current \(i_{LB}\) is linearly increased from zero since it is assumed that the PFC cell operates in DCM.

This current can be expressed as

\[
i_{LB} = \frac{[V_{in} + \frac{N_a}{N_b}](V_{CB} - V_{Ca})}{L_a} (t_0 - t_1)\]  

Where, \(V_{in} = V_m|\sin \theta|\) is the rectified input voltage, \((to - t1) = dTS\) is the ON-time of the switch (SW), \(LB\) is the boost inductor and \(N1, N3\) are the primary and auxiliary turns ratio, respectively.

At this stage, \(i_{LB} = -i_3\) and the capacitor \(C_a\) is in the charging mode. On the other hand, \(D0\) is reversed biased and there is no current flow through the
secondary winding. Since the transformer is assumed ideal, based on Ampere’s law, it has
\[ N_1i_1 + N_2i_2 − N_3i_{LB} = 0 \]
Where \( i_2 = 0 \) at this stage therefore,
\[ i_1 = \frac{N_2}{N_1}i_{LB} \] (3)
\[ i_m = i_{CB} - i_i = i_{CB} - \frac{N_2}{N_1}i_3 \] (4)
Therefore, from (4) it can be seen that the magnetizing current \( i_m \) is supplied by the discharging current from the dc bus capacitor \( CB \) and the current \( i_3 \) which is equal to input current \( i_{LB} \) at this stage. The current through the main switch (SW) is given by
\[ i_{SW} = i_{CB} = i_m - \frac{N_2}{N_1}i_3 = i_m + \frac{N_3}{N_4}i_{LB} \]
Therefore, the current stress of the switch can be reduced by selecting the turn’s ratio \( (N_3/N_1) \), which is designed to be less than 1 to ensure proper operation of the transformer. Compared to the single-stage BIFRED converter, the switch current is given by
\[ i_{SW} = i_m + i_{LB} \] (6)
Obviously, the proposed circuit has less switch current stress, therefore, the conduction loss and switching losses are reduced, and the efficiency is improved correspondingly. This stage ends when the switch is turned off at \( t = t_1 \).

IV. COMPARATIVE ANALYSIS

<table>
<thead>
<tr>
<th></th>
<th>Buck converter</th>
<th>Boost converter</th>
<th>Proposed technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power factor</td>
<td>Less improved</td>
<td>Moderately improved</td>
<td>Highly improved</td>
</tr>
<tr>
<td>Efficiency</td>
<td>70%</td>
<td>70-75%</td>
<td>90%</td>
</tr>
<tr>
<td>THD of input current</td>
<td>25-30%</td>
<td>&gt;20%</td>
<td>&lt;20%</td>
</tr>
<tr>
<td>Semiconductor</td>
<td>1 transistor</td>
<td>3 diode</td>
<td>2 diode</td>
</tr>
<tr>
<td></td>
<td>1 diode</td>
<td>1 bridge</td>
<td>Switch</td>
</tr>
<tr>
<td></td>
<td>1 inductor</td>
<td>1 switch</td>
<td>bridge</td>
</tr>
</tbody>
</table>

V. ACKNOWLEDGEMENT

This paper studies the comparative analysis of the three converters. And help us to understand that quasi active technique is the excellent technique to improve the power factor, efficiency, THD of input current can be controlled more as compare to the buck and boot converter.

REFERENCES


