Generalized Single Phase Z-Source Matrix Converter

S. H. Hosseini
J. Nabati
A. Mirlou

Faculty of Electrical and Computer Engineering
University of Tabriz, Tabriz, Iran
Outline

✓ INTRODUCTION
✓ PROPOSED TOPOLOGY
✓ SWITCHING PATTERN
✓ SIMULATION RESULTS
✓ CONCLUSION
INTRODUCTION

Ac–Ac matrix converter can directly convert ac voltage to variable frequency and amplitude ac voltage without significant energy storage device.

Applications of single-phase matrix converters:

- Induction motor drives
- Radio-frequency induction heating
- Audio power amplification
- Compensation of voltage sags and swells
INTRODUCTION

In primary converter model topology, amplitude of output voltage can’t be greater than amplitude of input voltage.

**Z-source converters** is introduced to solve this problem.

**Z-source network structure’s advantages:**
- Ability of providing buck - boost mode
- Reducing inrush current
- Reducing current harmonics
INTRODUCTION

By using Z-source network, buck-boost mode operations is obtained.

Z-source network’s location

Basic block diagram
INTRODUCTION

Single phase ac–ac converter’s problems:

- Frequency restriction
  
  In literature, just step up and step down frequency is generated. i.e. kf or f/k with (k=1,2,3,...)

- Low frequency harmonic and amplitude problem

  Previous researcher just tried to solve harmonics or amplitude problems.

Here we introduced a novel topology to solve above mentioned problems together.
PROPOSED TOPOLOGY

An LC input filter and diode rectifier that is connected in series to a Z-source network and RL load.

In previous topologies bidirectional switches is used but in this topology because of using diode rectifier, bidirectional switches is not necessary.
PROPOSED TOPOLOGY

• This topology has 3 different states:
  ➢ Active mode
  ➢ Freewheeling mode
  ➢ Shoot through mode
PROPOSED TOPOLOGY

Active mode

Current path in active mode
PROPOSED TOPOLOGY

Freewheeling mode

Current path in freewheeling mode
PROPOSED TOPOLOGY

Shoot through mode

Current path in shoot through mode
PROPOSED TOPOLOGY

To eliminate low frequency harmonics, special switching pattern is used. Both PWM and PAM are combined.

If PWM method is assumed, pulse amplitude is constant and by varying pulse width, converter generates required voltage.

If PAM is assumed, pulse width is constant and by varying pulse amplitude, converter generates required voltage.

For varying pulse amplitude, varying input voltage amplitude is required. Z-source network
SWITCHING PATTERN

- In one switching period we have:

\[ \int_{0}^{T} v_L(t) dt = 0 \]

- Where \( v_L \) is inductor voltage, \( T \) is switching period and \( D \) is shoot through time, so capacitor voltage can be shown as follow:

\[ v_{c_{in}}(t) = \frac{D(t)}{12(Dt)} \]
by defining gain of Z-source network (K) as ratio of output voltage to input voltage:

\[ K_t(t) = \frac{V_o}{V_{in}t} \frac{1}{12(t)} \quad \Rightarrow \quad D_t(t) = \frac{K_t(t)1+2\phi t}{2\phi t} \]
SWITCHING PATTERN

Z-source converter

$V_{\text{in}} \rightarrow D \rightarrow V_{\text{in}} \rightarrow V_{\text{ref}} \rightarrow V_{\text{in}} \rightarrow D(t) = \frac{K(t)1 + 2\theta t}{2\theta t}$

$V_{\text{in}} \rightarrow D \rightarrow V_{\text{in}} \rightarrow V_{\text{ref}} \rightarrow V_{\text{o}}$
SWITCHING PATTERN

$V_{\text{ref}}$ shows the voltage that should be generated in output.

<table>
<thead>
<tr>
<th>Stage</th>
<th>State 1 (Active)</th>
<th>State 2 (Free-wheeling)</th>
<th>State 3 (Shoot through)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{ref}} &gt; 0$</td>
<td>$S_{1a}, S_{2b}$</td>
<td>$S_{1a}$</td>
<td>$S_{1a}, S_{1b}$</td>
</tr>
<tr>
<td>$V_{\text{ref}} &lt; 0$</td>
<td>$S_{2a}, S_{1b}$</td>
<td>$S_{2a}$</td>
<td>$S_{2a}, S_{2b}$</td>
</tr>
<tr>
<td>$(</td>
<td>V_{\text{ref}}</td>
<td>&gt;</td>
<td>V_{\text{in}}</td>
</tr>
<tr>
<td>$(</td>
<td>V_{\text{ref}}</td>
<td>&lt;</td>
<td>V_{\text{in}}</td>
</tr>
</tbody>
</table>
In boost mode changing in shoot through time (D) is used (i.e. PAM) and in buck mode PWM method is employed (D=0). This means when reference voltage amplitude is greater than input voltage PAM method is used and in the other status PWM method is used.
SIMULATION RESULTS

Simulation parameters

LC input filter: $L_1 = 0.1 \text{ mH}, C_i = 6.8 \mu\text{F}$

Z-source network: $L_1 = L_2 = 1 \text{ mH}, C_1 = C_2 = 1 \mu\text{F}$

Load: $R = 100 \Omega$, and $L = 3 \text{ mH}$.

The switching frequency: 20 kHz,

Input voltage: $40 \text{ V}_{\text{rms}} / 60 \text{ Hz}$.

Output voltages are presented for different frequency.
Output voltages are presented for different waveforms and frequencies to show good performance of the introduced topology. Triangular waveform is generated from sinusoidal input with 40 V rms and 60 Hz. And sinusoidal waveforms are generated with different frequencies. The generated frequencies are 120Hz, 40Hz and 0Hz (DC waveform).
SIMULATION RESULTS

Introduced converter has ability of generating all waveforms. Simulation results for triangular waveform output voltage is presented as a sample.
SIMULATION RESULTS

Simulation results for 120 Hz output voltage:
Output frequency is increased from 60Hz to 120Hz. Voltage Amplitude is also increased from 57V to 150V.
Harmonic spectrum of 120Hz output voltage shows that low frequency harmonic problem is solved.
SIMULATION RESULTS

Previous converters couldn’t generate 40Hz frequency from 60Hz. Figure below shows the simulation results for 40Hz output voltage.

- Output voltage
- Input voltage and $V_{\text{ref}}$
SIMULATION RESULTS

Low frequency harmonic spectrum of 40Hz output voltage
As 40Hz frequency previous converters couldn’t generate DC waveform from 60Hz. Figure below shows the simulation results for DC output voltage.
CONCLUSION

✓ In this paper a novel topology and switching pattern for a single phase Z-source matrix converter is presented.

✓ The proposed topology has improved significantly in performance of single phase matrix converters.

✓ The main characteristics of generalized single phase Z-source matrix converter are as follow:

- Providing wide range frequency in output
- Good harmonic spectrum
- Working both in buck and boost mode
Thanks

S. H. Hosseini, J. Nabati, A. Mirlou
Faculty of Electrical and Computer Engineering
University of Tabriz
Tabriz, Iran