I-NPC Module Switching Pattern (Single Phase)

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What is the “three level”?

Three level outputs!

(+E, 0, -E)
NPC & T-type 3-level Configuration

(1) $V_{out} = +E$

(3) $V_{out} = -E$
Switching Pattern

(2)

\[ V_{out} = 0 \]
Generate PWM Pulse

Carrier wave 1

Reference wave

Carrier wave 2

T1

T3

T4

T2
Switching Pattern (Phase Voltage)

Carrier wave 1
Reference wave
Carrier wave 2

T1
T2
T3
T4
Switching Pattern (Phase Voltage)

Output voltage (Phase voltage)

After filtering

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If an inductive load is connected, the current waveform is lagging behind the voltage waveform.

Current delay: $\alpha$

Power factor: $\cos \alpha$
Switching Pattern

T1
T2
T3
T4

(1) (2) (3) (4)

Inductive load

D1
D2
D5
D6
D3
D4

$\text{I}_{\text{out}}$
Loss Matrix

<table>
<thead>
<tr>
<th>Current</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>+I_o</td>
<td>+E</td>
</tr>
<tr>
<td>Psat: T1</td>
<td>Psat: T2</td>
</tr>
<tr>
<td>Psat: T2</td>
<td>Pf: D5</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>-I_o</td>
<td>Pf: D1</td>
</tr>
<tr>
<td>Pf: D2</td>
<td>Pf: D6</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

※ There is no Err on D2 and D3
Switching Pattern (1) SW mode B

T2: ON
T3: Turn on (Free wheeling)
D6: Free wheeling
Switching Pattern (1) SW mode B

T1
T2
T3
T4

V_{out}
I_{out}

D1: Free wheeling
D2: Free wheeling
T3: Turn OFF

D5
D6

T1 ON
T2 ON
T3 OFF
T4 OFF

I_{out}
Switching Pattern (1) SW mode B

Switching pattern for T1, T2, T3, T4

- T1: OFF
- T2: ON
- T3: Reverse recovery
- T4: OFF

Diagram showing:
- Vout and Iout graphs
- Transistors T1 and T2 in SW mode B
- Diodes D5 and D6

Diagram notes:
- D1: Reverse recovery
- T3: Turn ON

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Switching Pattern (1) SW mode B

D1: Free wheeling
D2: Free wheeling
T3: Turn OFF
Switching Pattern (2) SW mode A

T1

T2

T3

T4

V_{out}

I_{out}

I_{out}

T1: ON
T2: ON
Switching Pattern (2) SW mode A

T1: Turn OFF  
T2: ON  
D5: Turn ON

V_{out}  
I_{out}

T1  
T2  
T3  
T4

(2)
Switching Pattern (2) SW mode A

- **T1**: Turn ON
- **T2**: ON
- **D5**: Reverse recovery
Switching Pattern (2) SW mode A

T1: Turn OFF
T2: ON
D5: Free wheeling

V_{out}  I_{out}
Switching Pattern (2) SW mode A

T1: Turn ON
T2: ON
D5: Reverse recovery
Switching Pattern (2) SW mode A

T1: Turn OFF
T2: ON
D5: Free wheeling
Switching Pattern (2) SW mode A

- T1: Turn ON
- T2: ON
- D5: Reverse recovery
Switching Pattern (2) SW mode A

T1: Turn OFF
T2: ON
D5: Free wheeling
Switching Pattern (3) SW mode B’

T1

T2

T3

T4

V_{out}

I_{out}

T2: ON

D5: Free wheeling
Switching Pattern (3) SW mode B’

T1: Turn OFF
D3: Free wheeling
D4: Free wheeling
Switching Pattern (3) SW mode B’

T1

T2

T3

T4

T2: Turn ON
D4: Reverse recovery
D5: Free wheeling

V_{out} \quad I_{out} \quad (3)
Switching Pattern (3) SW mode B'

T1

T2

T3

T4

V_{out}

I_{out}

(3)

T2: Turn OFF
D3: Free wheeling
D4: Free wheeling
Switching Pattern (4) SW mode A’

T1

T2

T3

T4

\[ V_{out} \]

\[ I_{out} \]

T3: ON

T4: ON

D5

D6

T1 OFF

T2 OFF

T3 ON

T4 ON
Switching Pattern (4) SW mode A’

T3: ON
T4: Turn OFF
T6: Free wheeling
Switching Pattern (4) SW mode A’

T1
T2
T3
T4

(4)

T3: ON
T4: Turn ON
D6: Reverse recovery
Switching Pattern (4) SW mode A’

T1

T2

T3

T4

T3: ON
T4: Turn OFF
T6: Free wheeling

V_{out}

I_{out}
Switching Pattern (4) SW mode A’

T1

T2

T3

T4

V_{out}

I_{out}

T3: ON

T4: Turn ON

D6: Reverse recovery
Switching Pattern (4) SW mode A’

T1

T2

T3

T4

Switching Pattern (4) SW mode A’

V_{out}

I_{out}

T3: ON

T4: Turn OFF

T6: Free wheeling
Switching Pattern (4) SW mode A’

T1

T2

T3

T4

V_{out}

I_{out}

(4)

T3: ON
T4: Turn ON
D6: Reverse recovery
Switching Pattern (4) SW mode A’

T1

T2

T3

T4

V_{\text{out}}

I_{\text{out}}

T3: ON
T4: Turn OFF
T6: Free wheeling

(4)