



Welcome to PEEEB



Lecture 8: DC-AC Converters

Presenter: Dr. Firuz Zare

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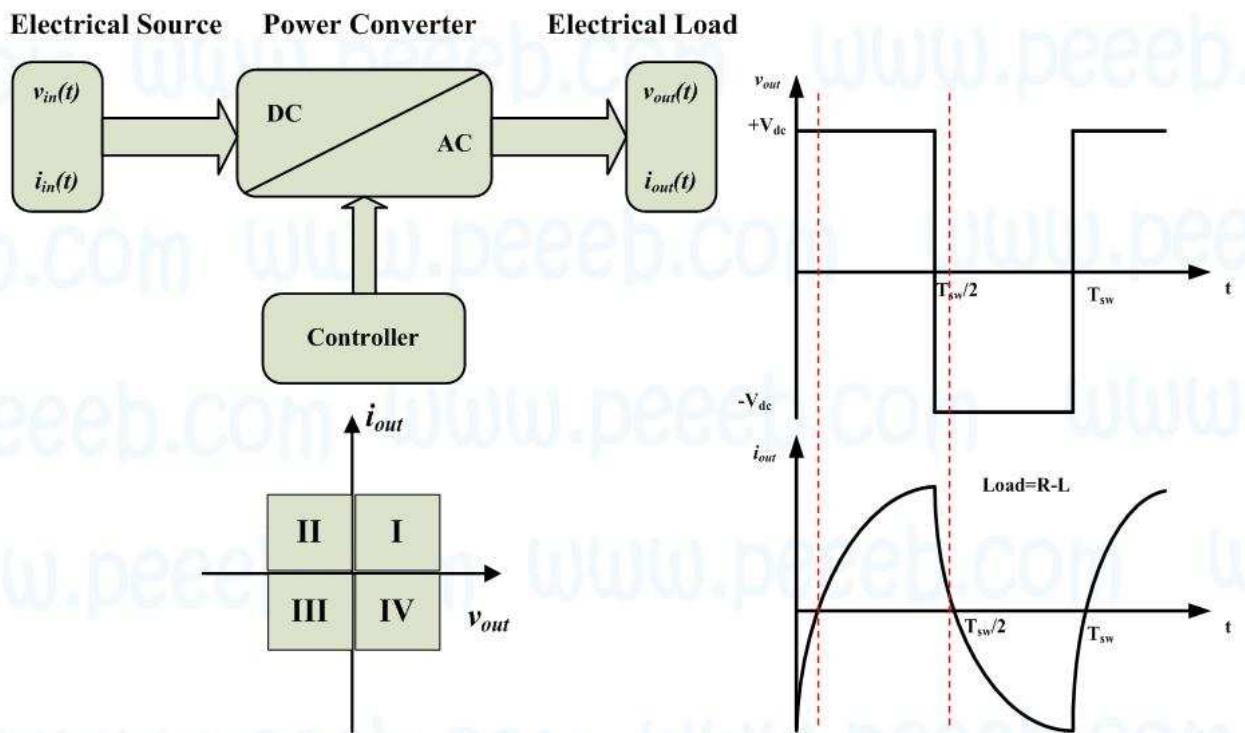
DC-AC Converters

- **Introduction**
 - Current Source or Voltage Source Inverters
 - Single-phase or Three-phase Inverter
 - Modulation Strategies
 - Two-level or Multilevel
 - Close loop or Open loop Control
- **Single-phase Inverter**
 - Bipolar and Unipolar Modulations
- **Three-phase Inverter**
 - Leg, Line and Phase Voltages
 - Active and Zero Switching
 - Common-mode Voltage

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Introduction

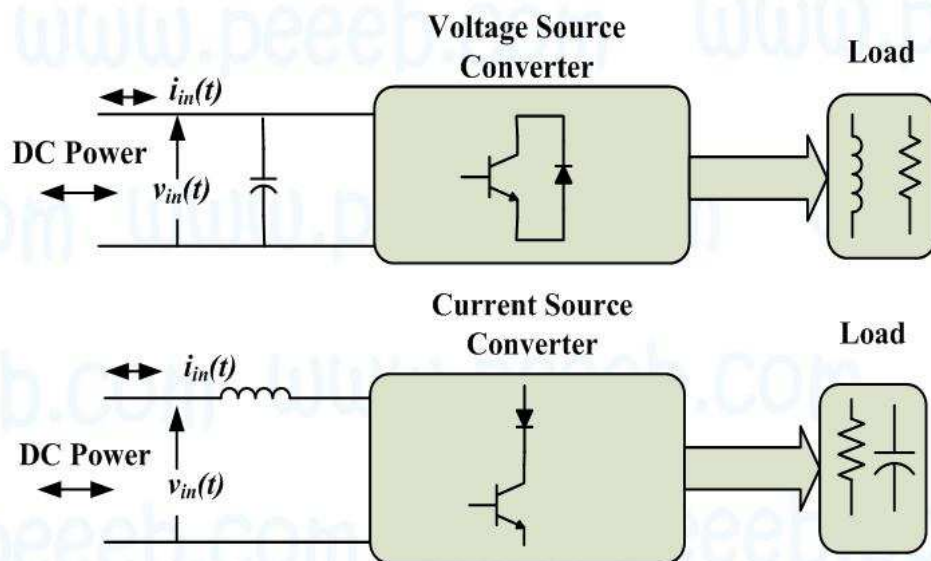


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Introduction

Current Source or Voltage Source



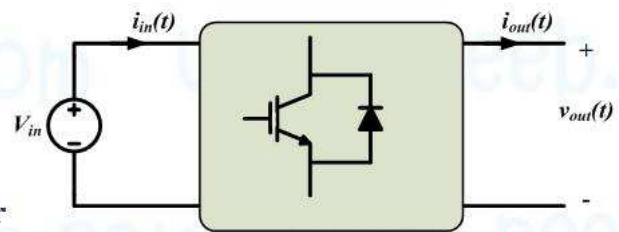
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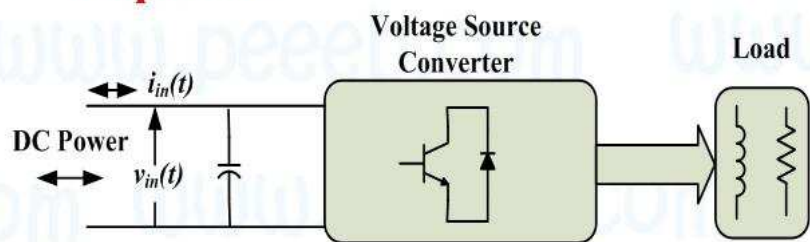
Introduction

Power supplies in DC-AC converters:

- Battery
- PV
- (Grid and Wind Generator) & Rectifier



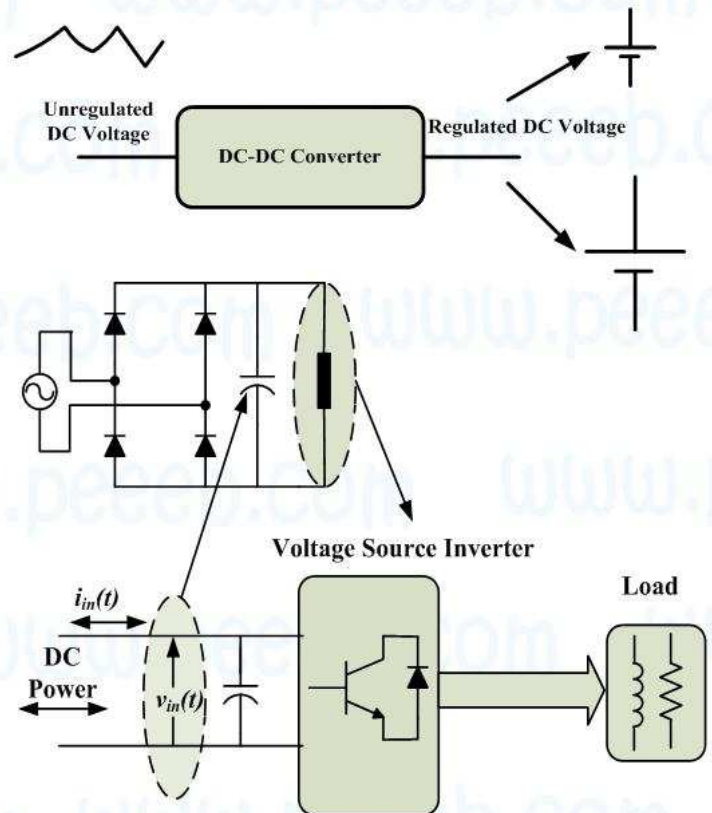
Capacitor



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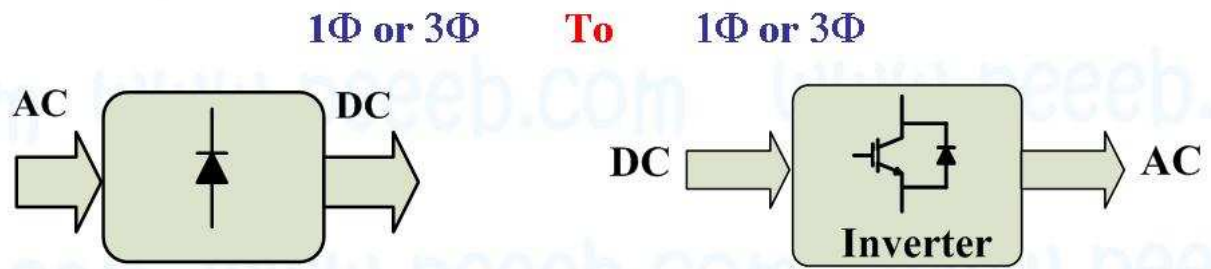
Introduction



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Introduction

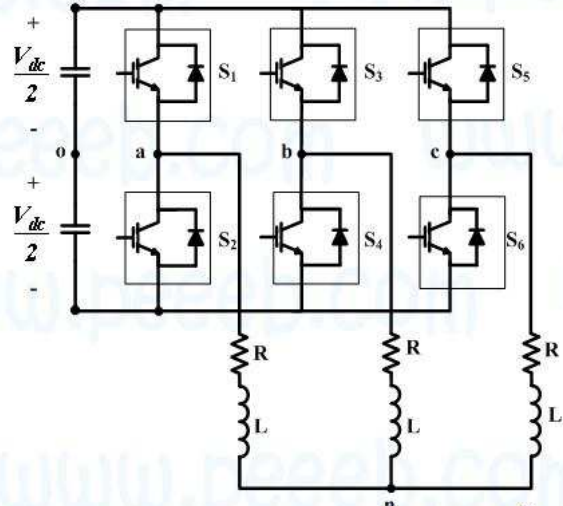
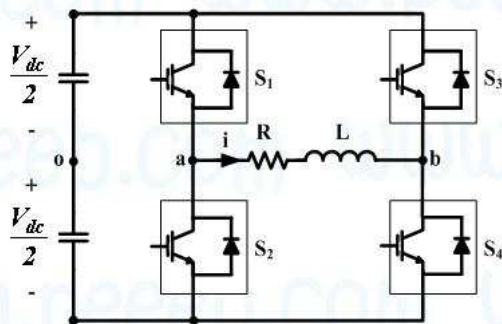
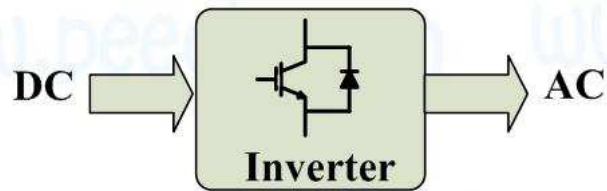


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Introduction

Single-Phase & Three-Phase

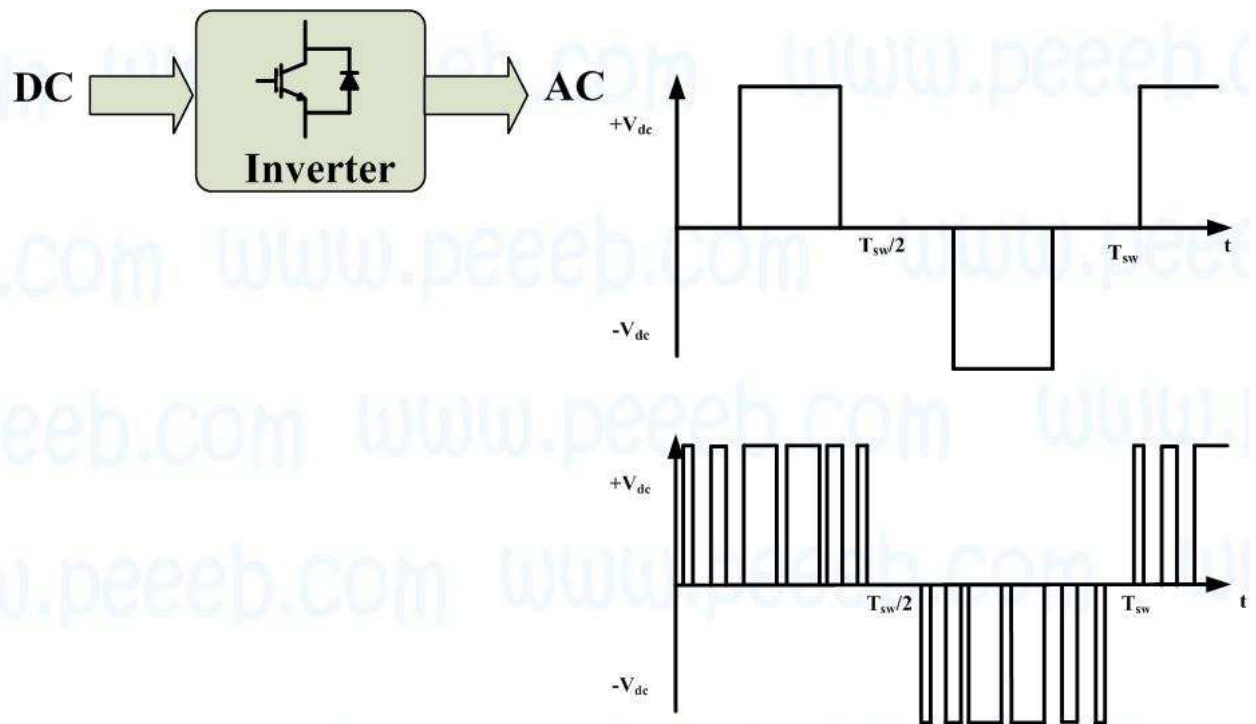


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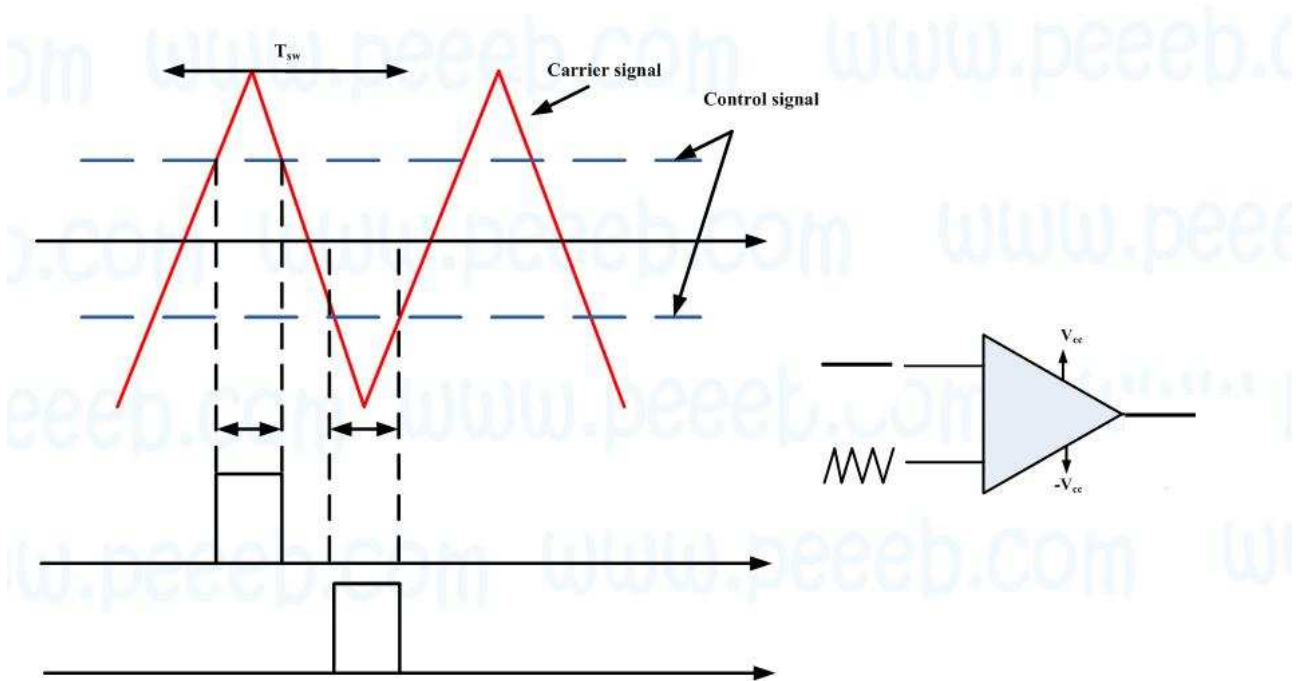
Introduction

Modulation Strategies



Introduction

Modulation Strategies



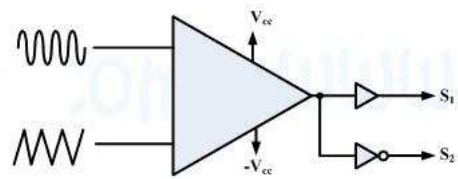
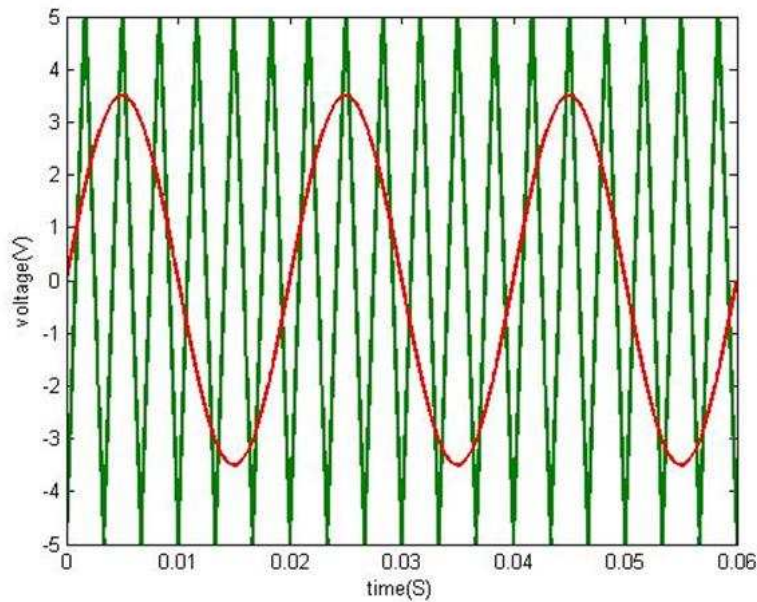
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Introduction

Modulation Strategies

Sinusoidal Pulse Width Modulation



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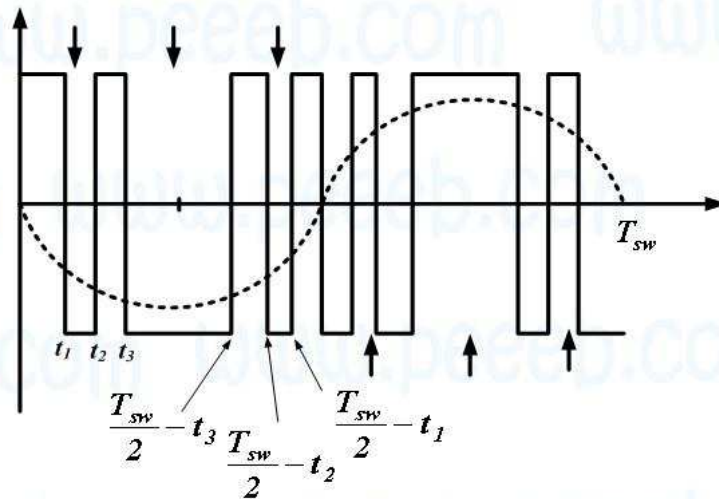
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Introduction

Modulation Strategies

Harmonic Elimination Technique

In this technique, we can switch times, t_1 , t_2 and t_3 to control output voltage and cancel harmonics. This is an off-line switching method in which switching times are stored in a memory.



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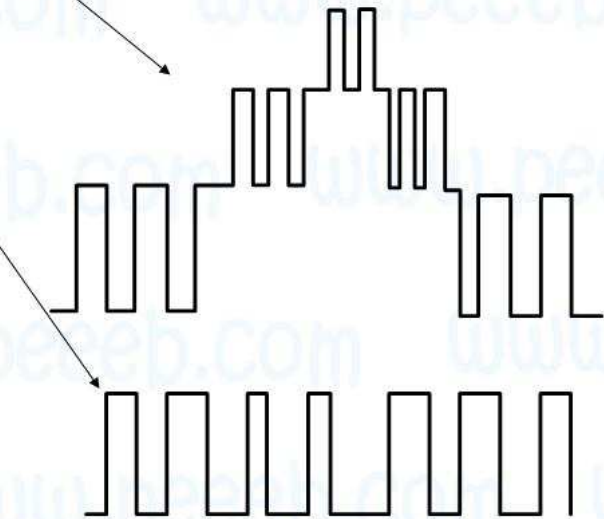
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Introduction

Two-level or Multi-level Inverter

Multi-level Converter

- Less voltage stress
- Better quality and less switching losses
- Suitable for high voltage applications
- Complex circuit and control
- More components



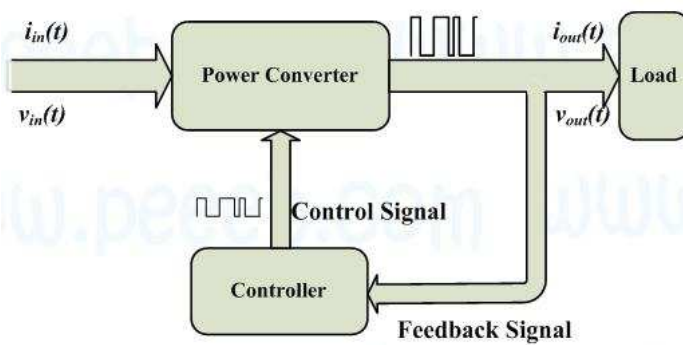
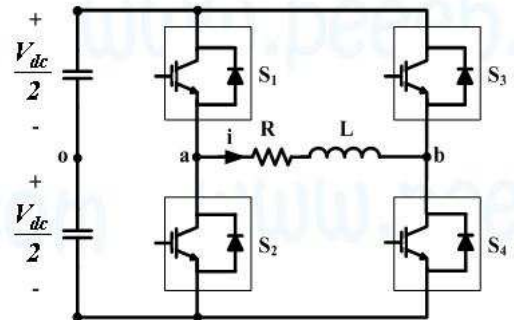
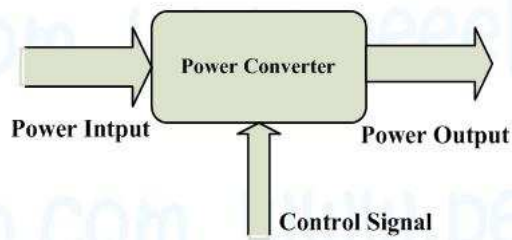
An output voltage generated by an inverter

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Introduction

Close Loop or Open Loop Control

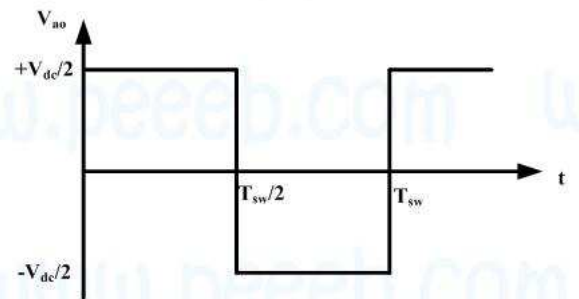
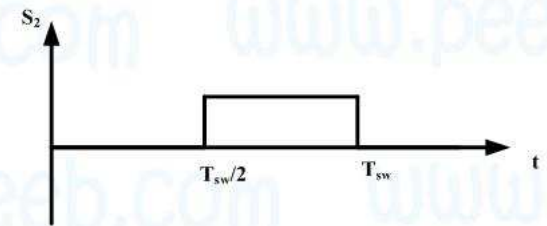
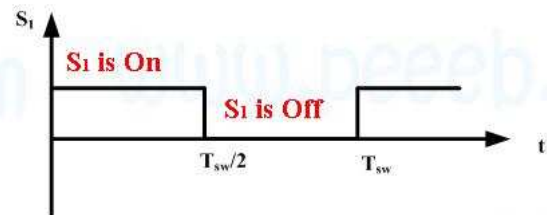
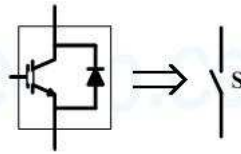
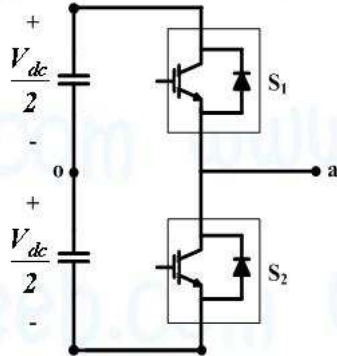


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Single-Phase Inverter

One Leg of Inverter



S1 is on, switching state is 1

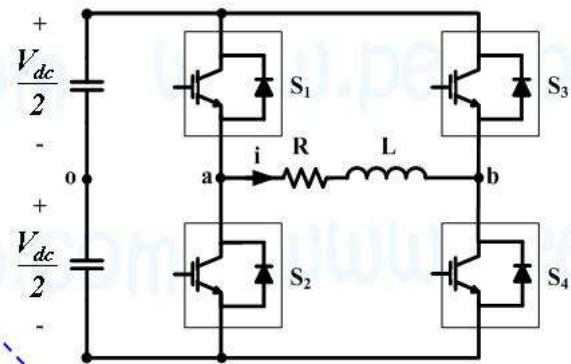
S1 is off, switching state is 0

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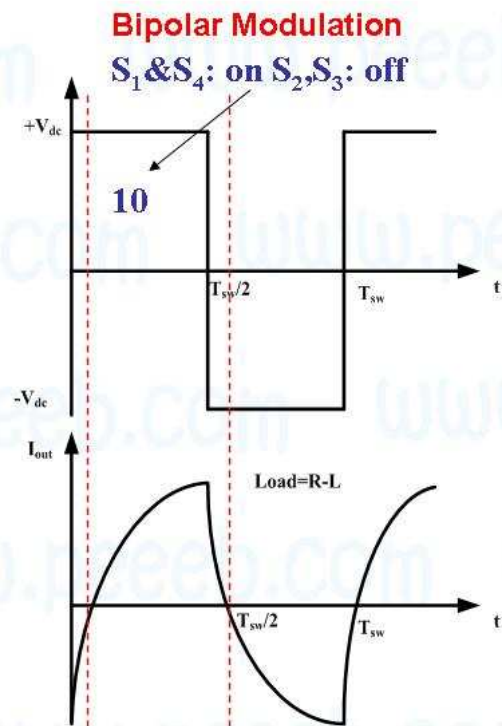
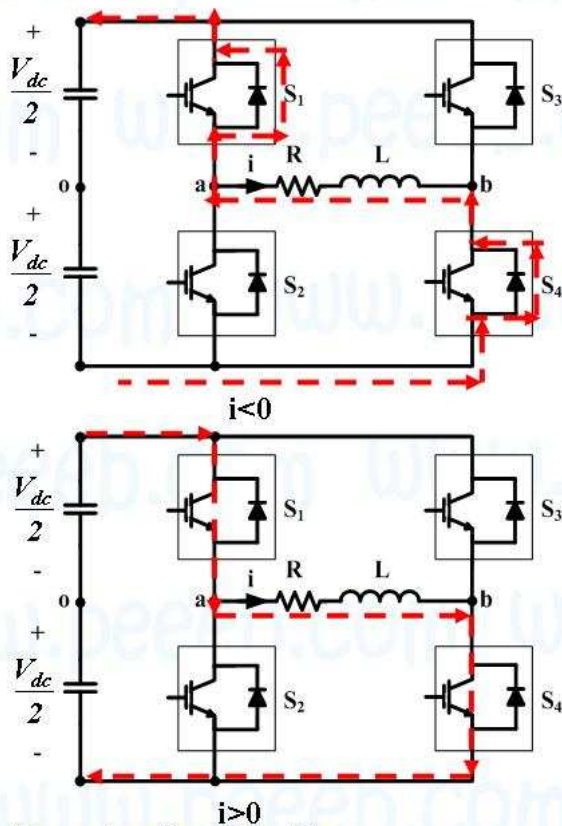
Single-Phase Inverter

S_1	S_3	$v_{ao}(t)$	$v_{bo}(t)$	$v_{ab}(t)$
0	0	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	0
0	1	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$-V_{dc}$
1	0	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	V_{dc}
1	1	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	0



Bipolar and **Unipolar** Modulations

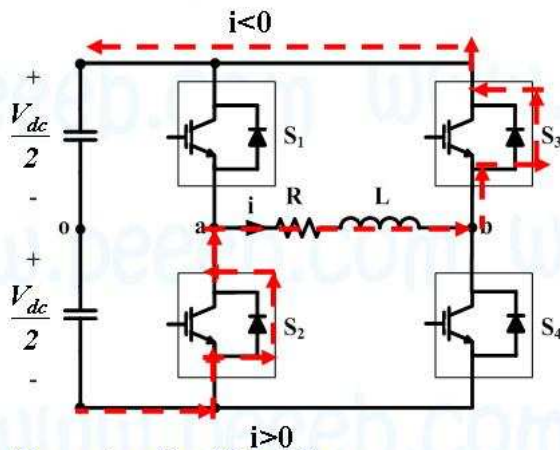
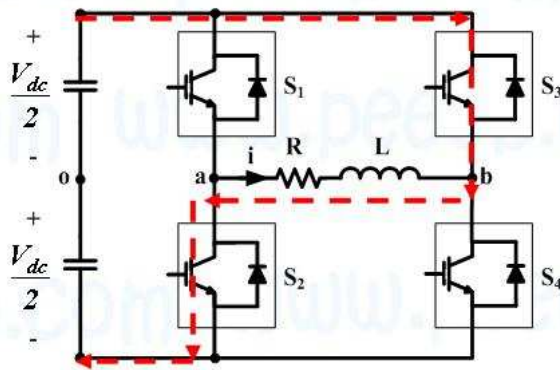
Single-Phase Inverter



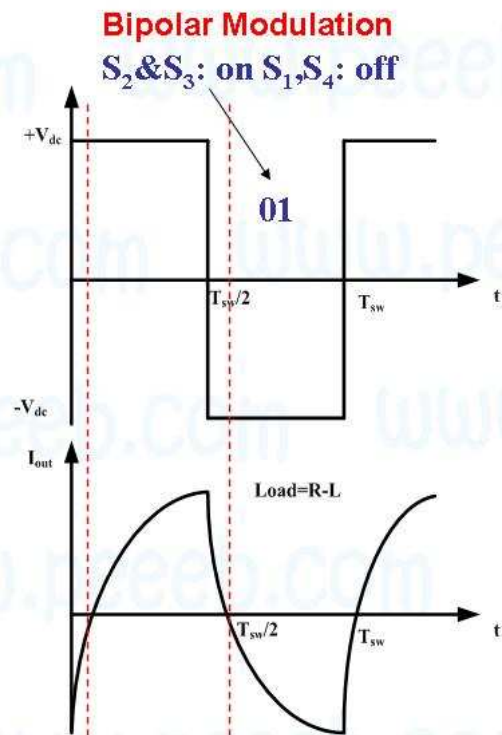
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Single-Phase Inverter



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Single-Phase Inverter

Bipolar Modulation

We can only control the output voltage by changing V_{ac} ! BUT we can control the output frequency.

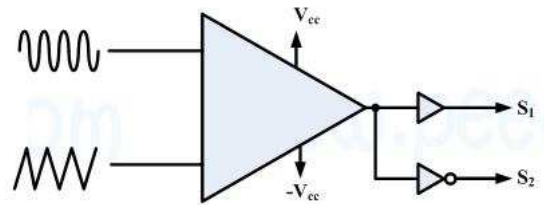
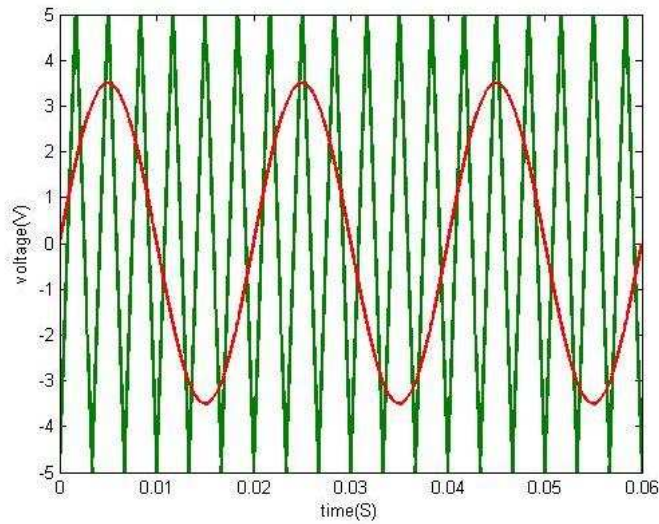
Increasing switching frequency and applying Pulse Width Modulation (PWM) make it possible to change the rms and frequency of output voltage.

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Single-Phase Inverter

Bipolar Modulation

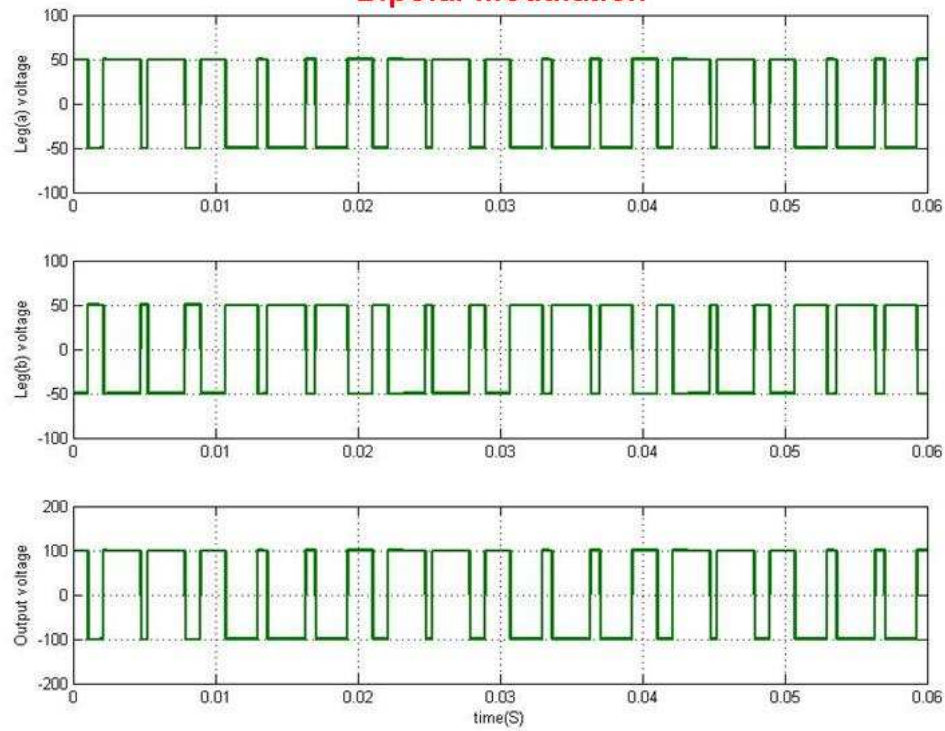


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Single-Phase Inverter

Bipolar Modulation

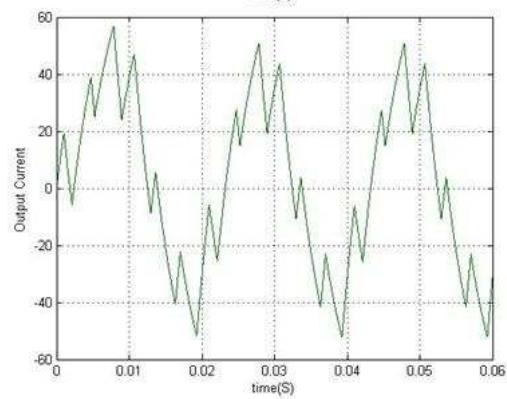
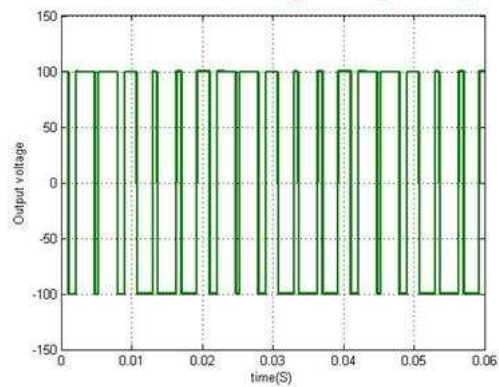


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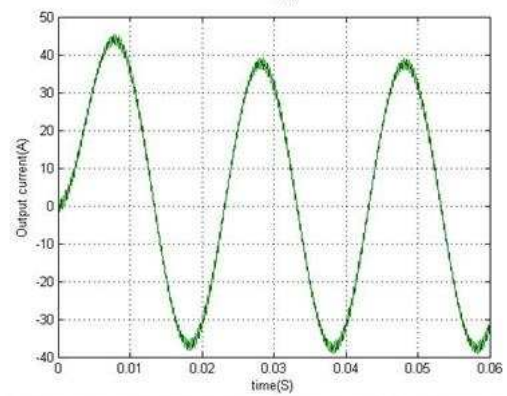
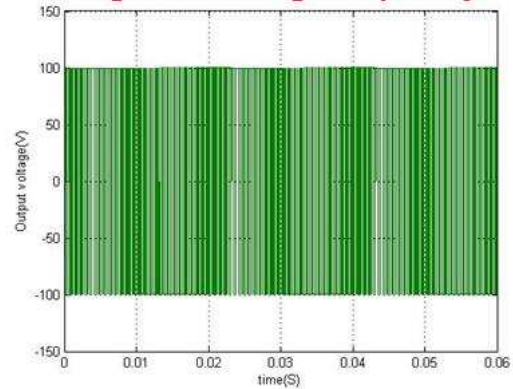
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Single-Phase Inverter

Low Switching Frequency



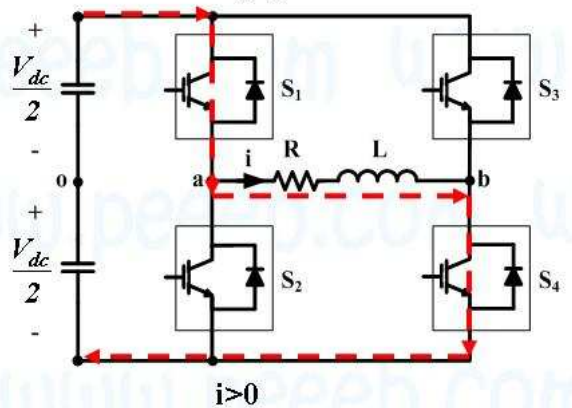
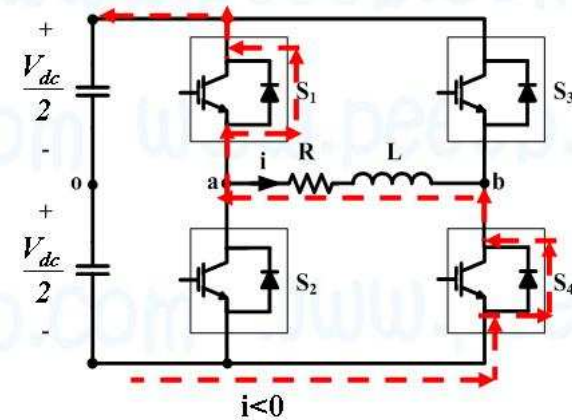
High Switching Frequency



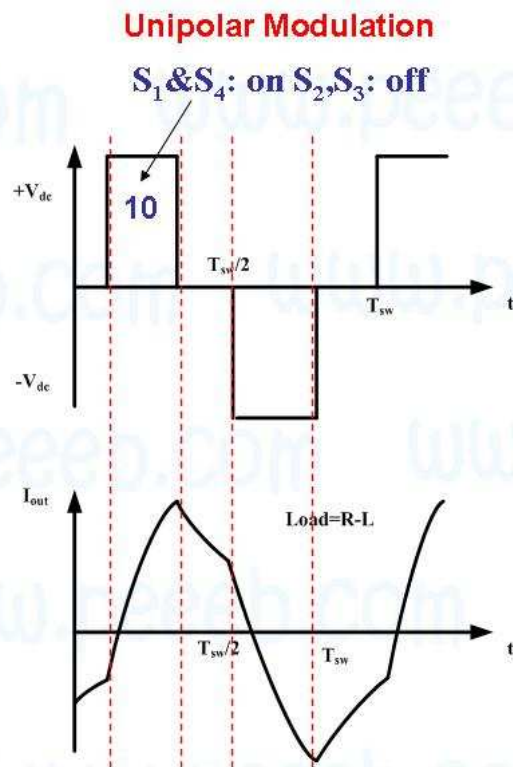
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Single-Phase Inverter

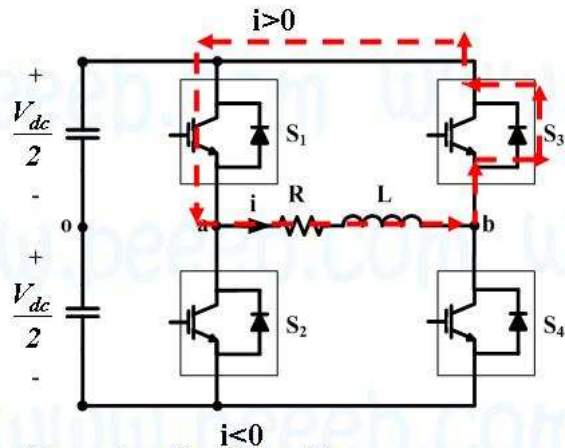
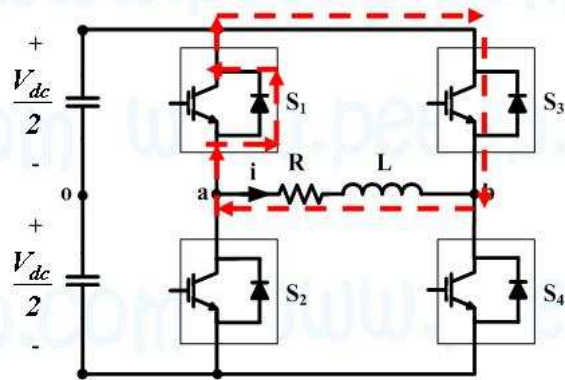


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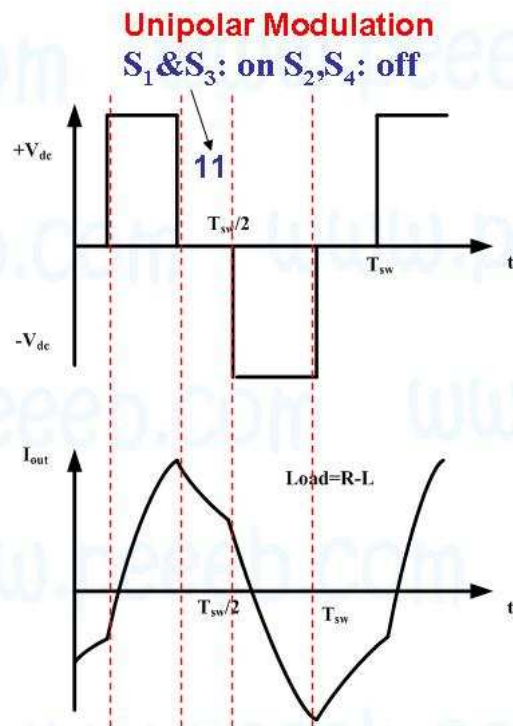


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Single-Phase Inverter

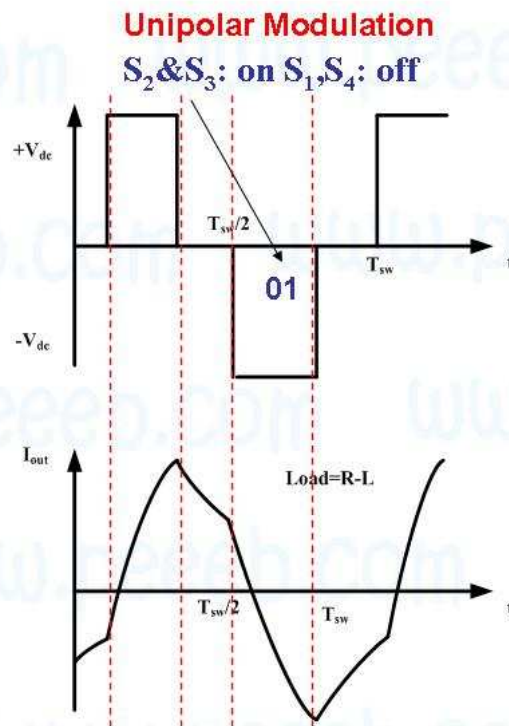
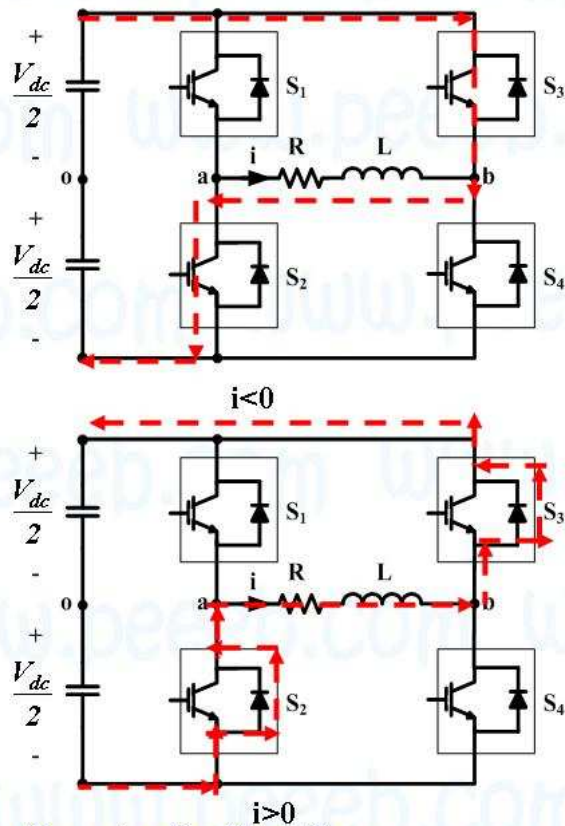


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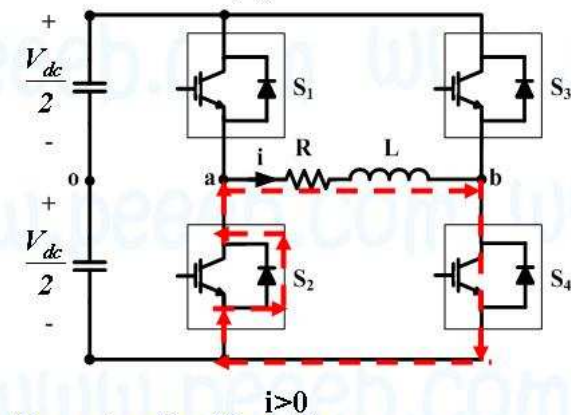
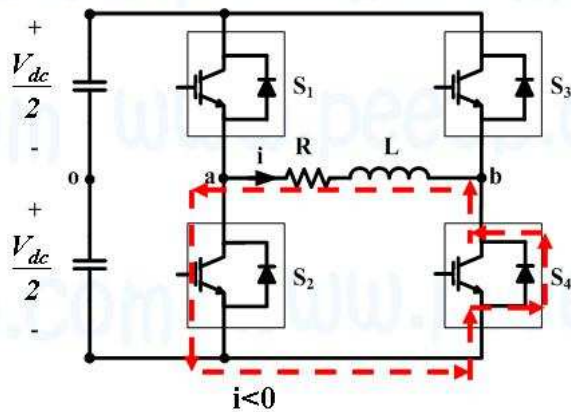
Single-Phase Inverter



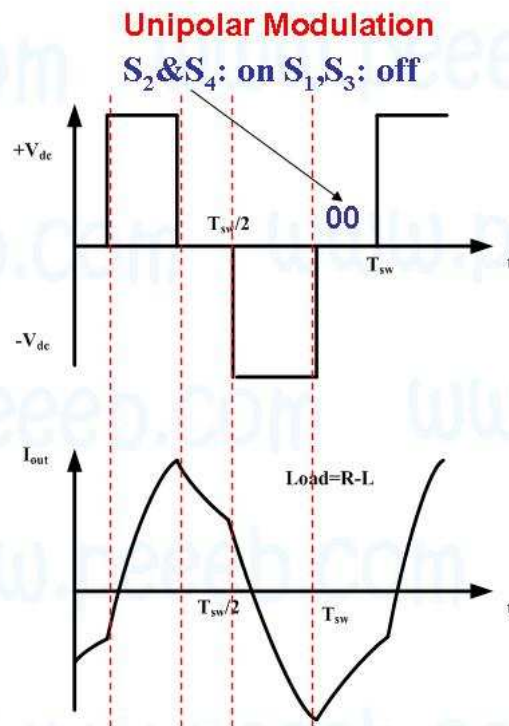
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Single-Phase Inverter



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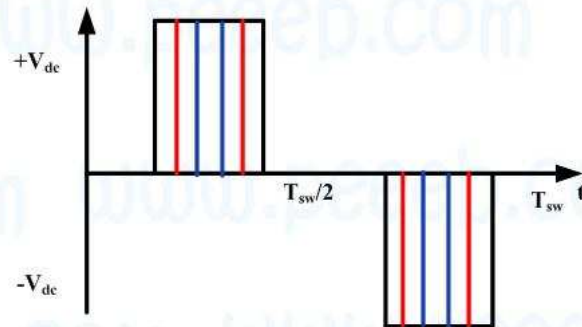


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Single-Phase Inverter

Unipolar Modulation

We can control the output voltage and frequency by changing the pulse width without changing the DC link voltage.

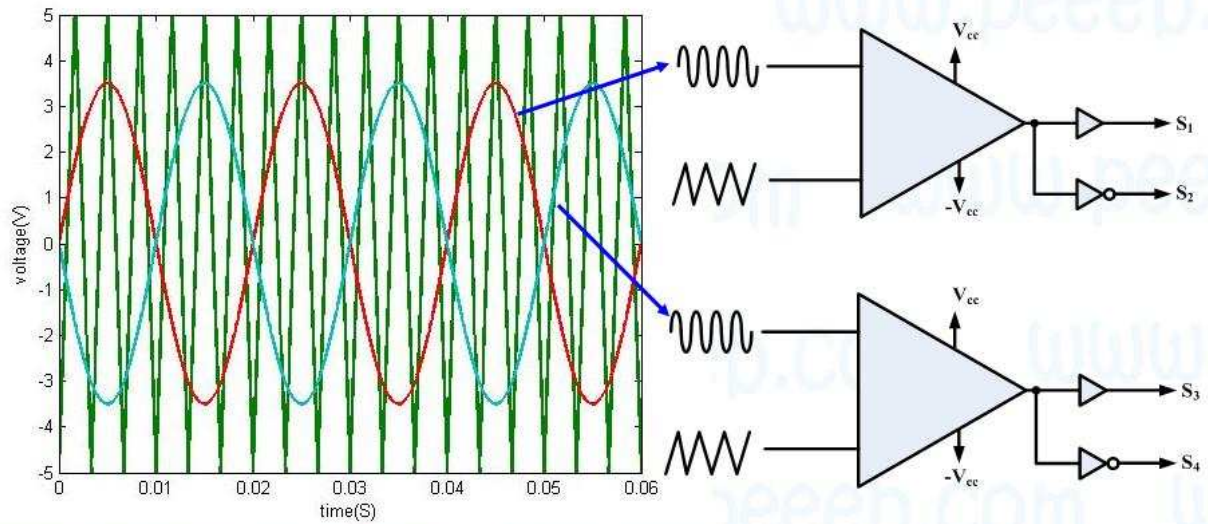


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Single-Phase Inverter

Unipolar Modulation

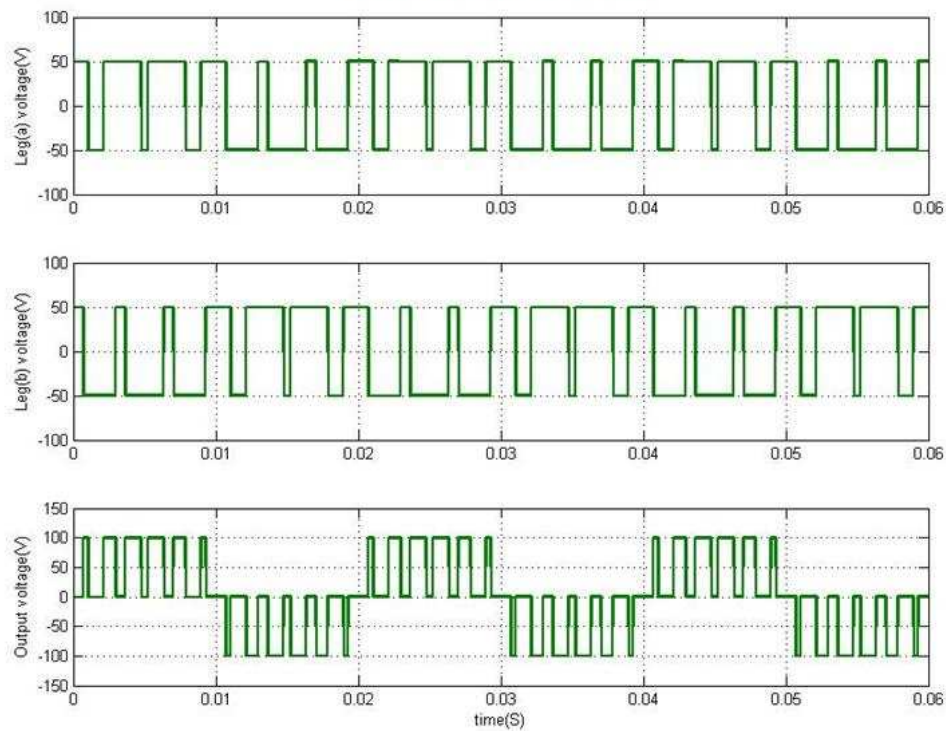


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Single-Phase Inverter

Unipolar Modulation

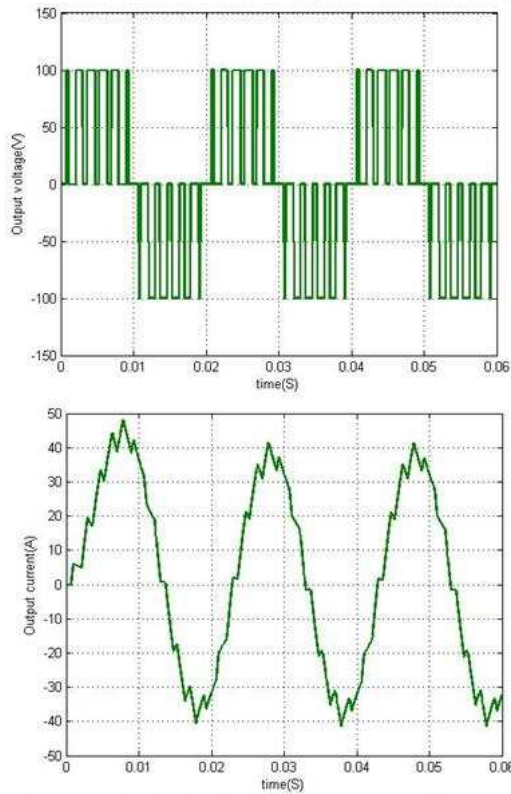


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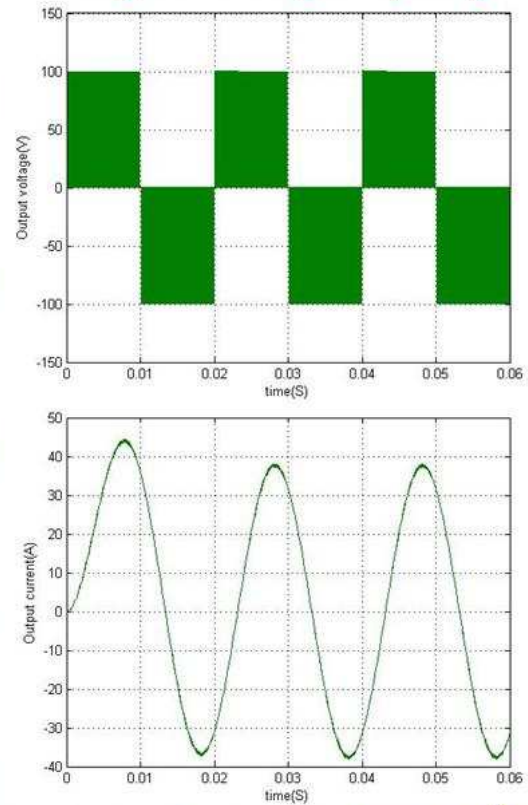
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Single-Phase Inverter

Low Switching Frequency



High Switching Frequency

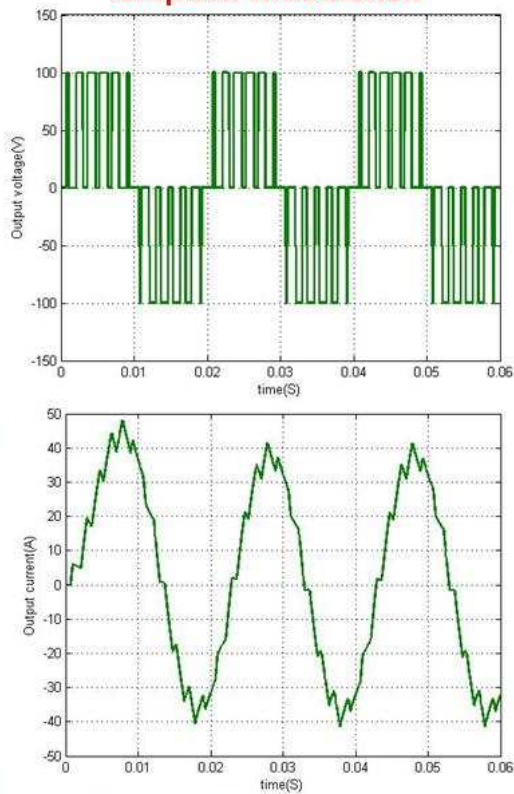


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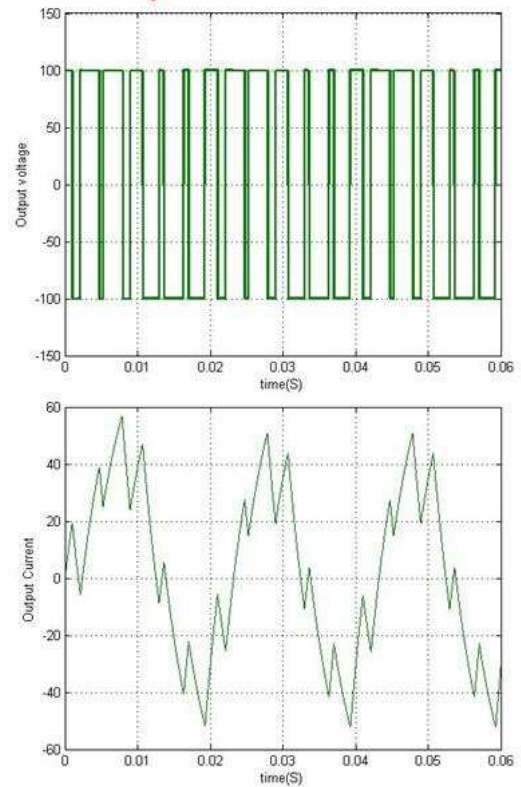
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Single-Phase Inverter

Unipolar Modulation



Bipolar Modulation

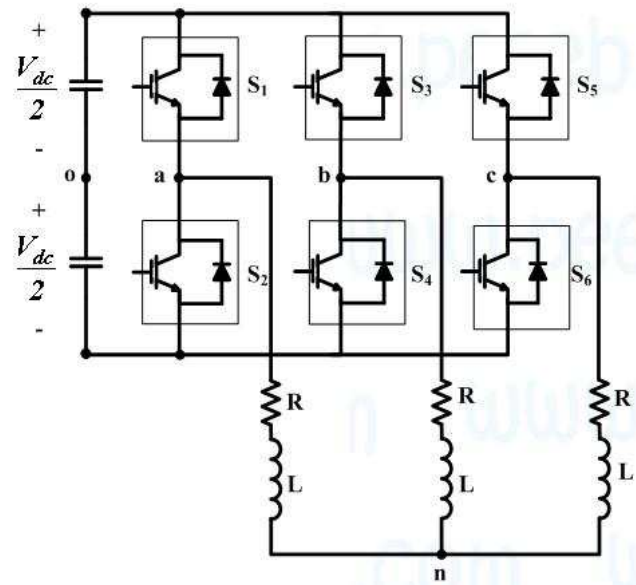


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Three-Phase Inverter

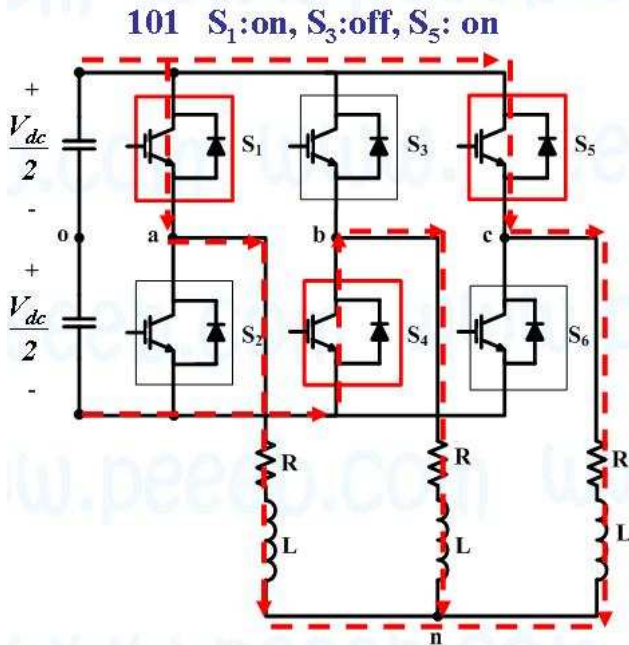
S_1	S_3	S_5	$v_{ao}(t)$	$v_{bo}(t)$	$v_{co}(t)$
0	0	0	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$
0	0	1	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$
0	1	0	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$
0	1	1	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$
1	0	0	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$
1	0	1	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$
1	1	0	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$
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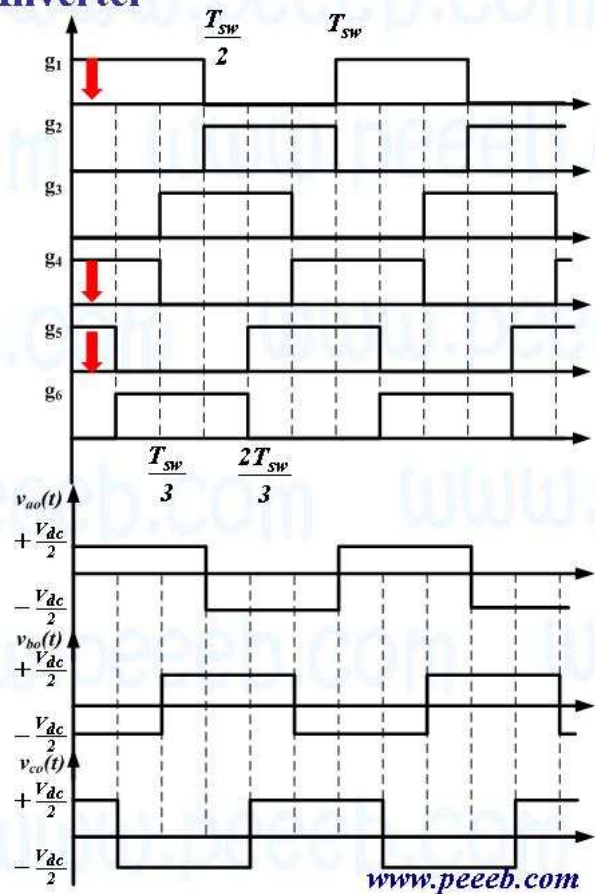
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Three-Phase Inverter

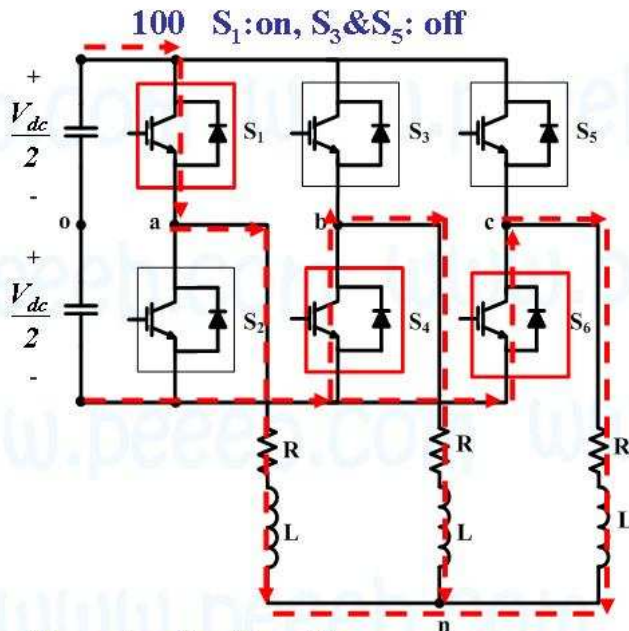


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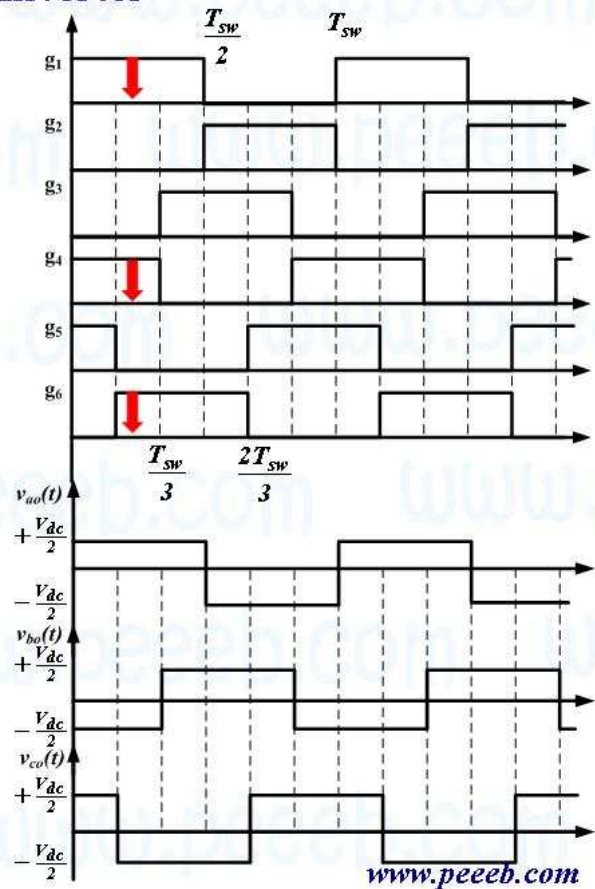


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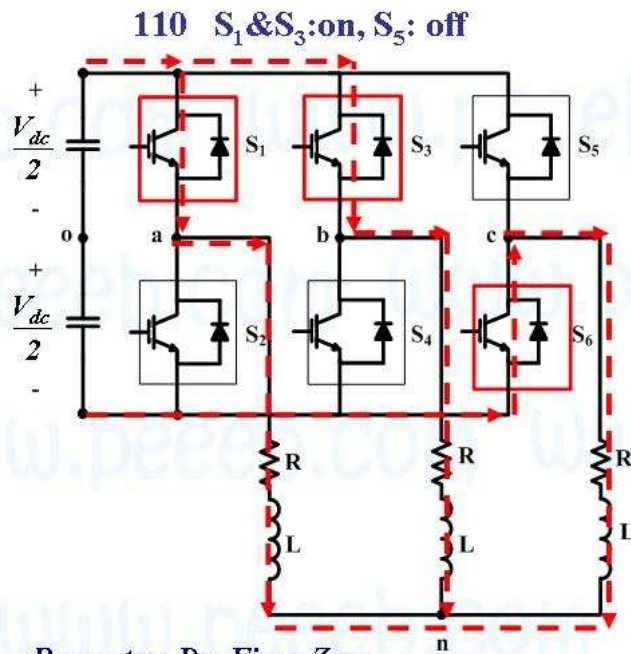


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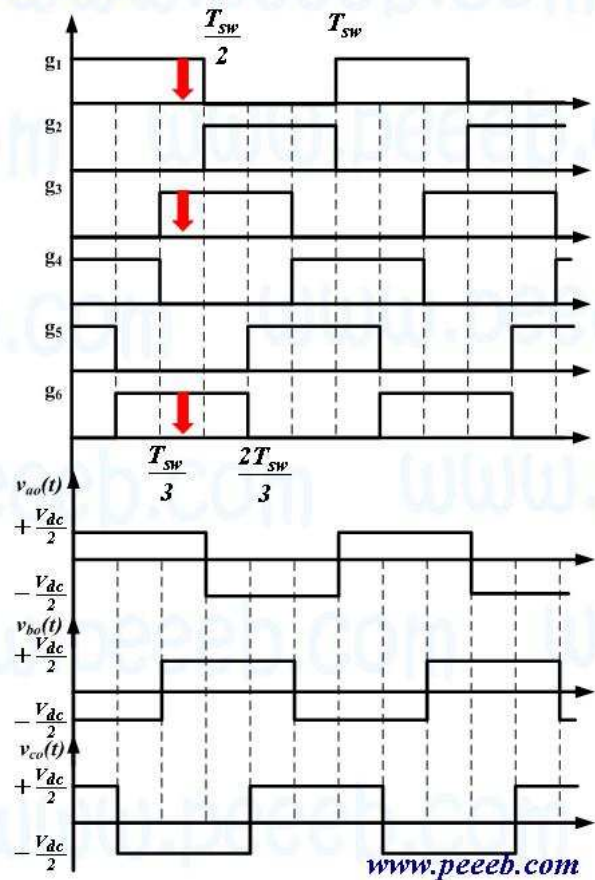


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Three-Phase Inverter

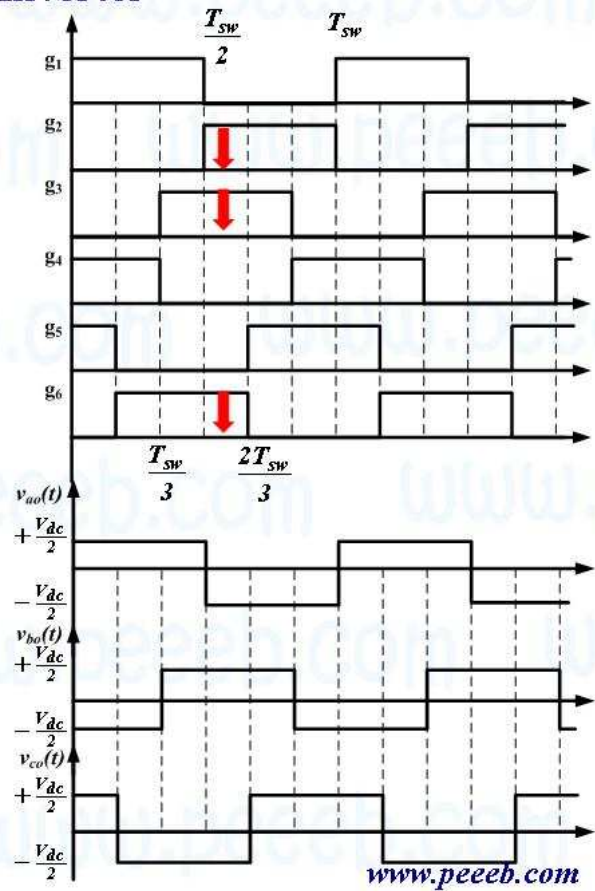
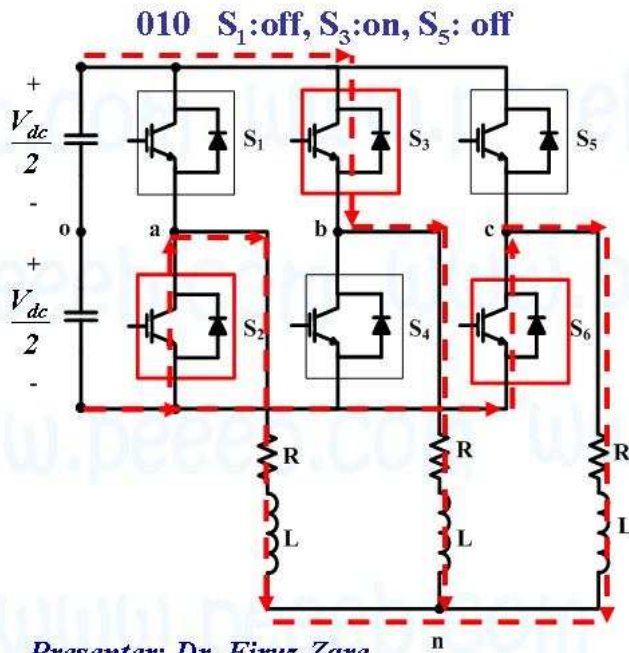


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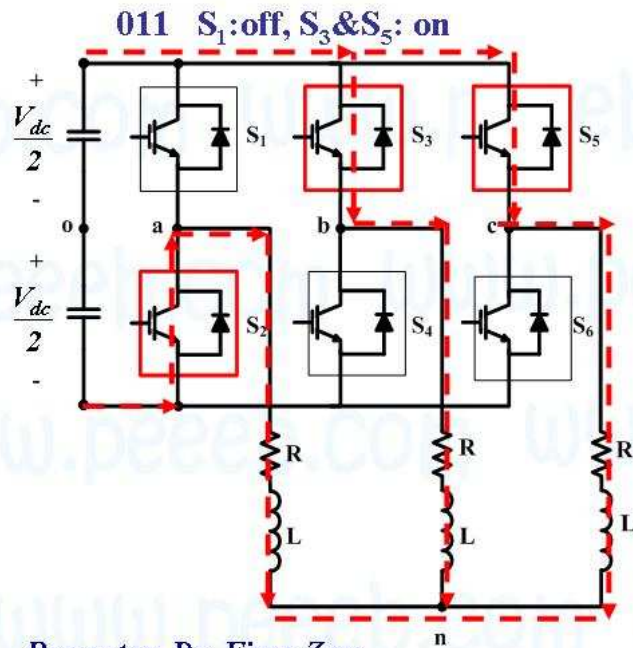


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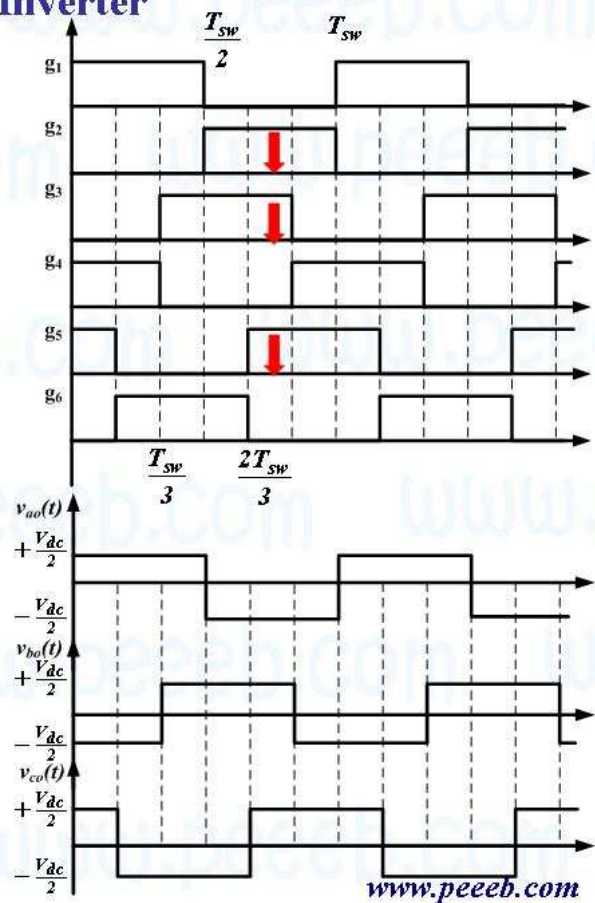
Three-Phase Inverter



Three-Phase Inverter

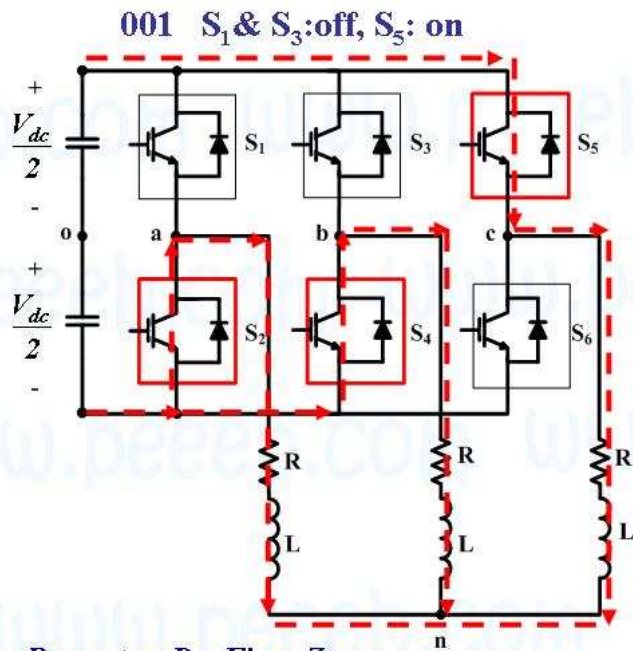


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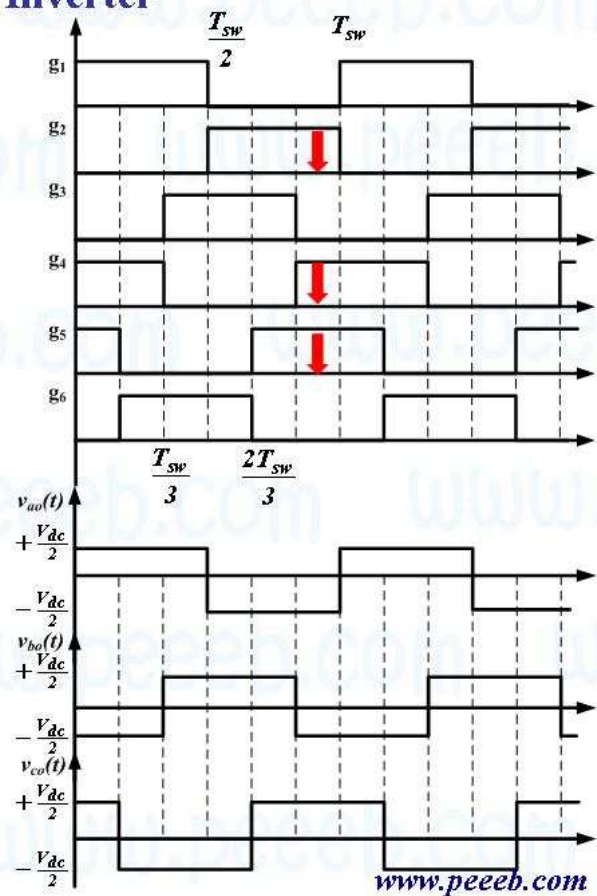


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Three-Phase Inverter

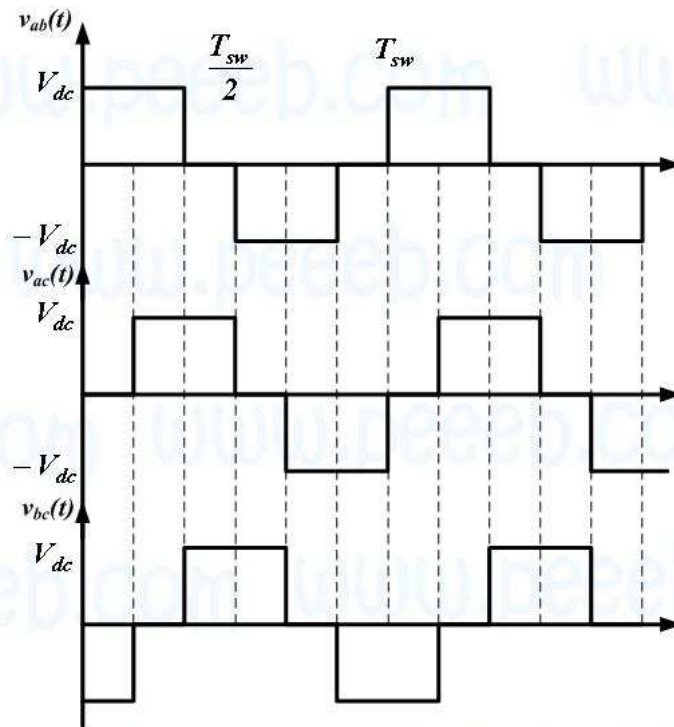


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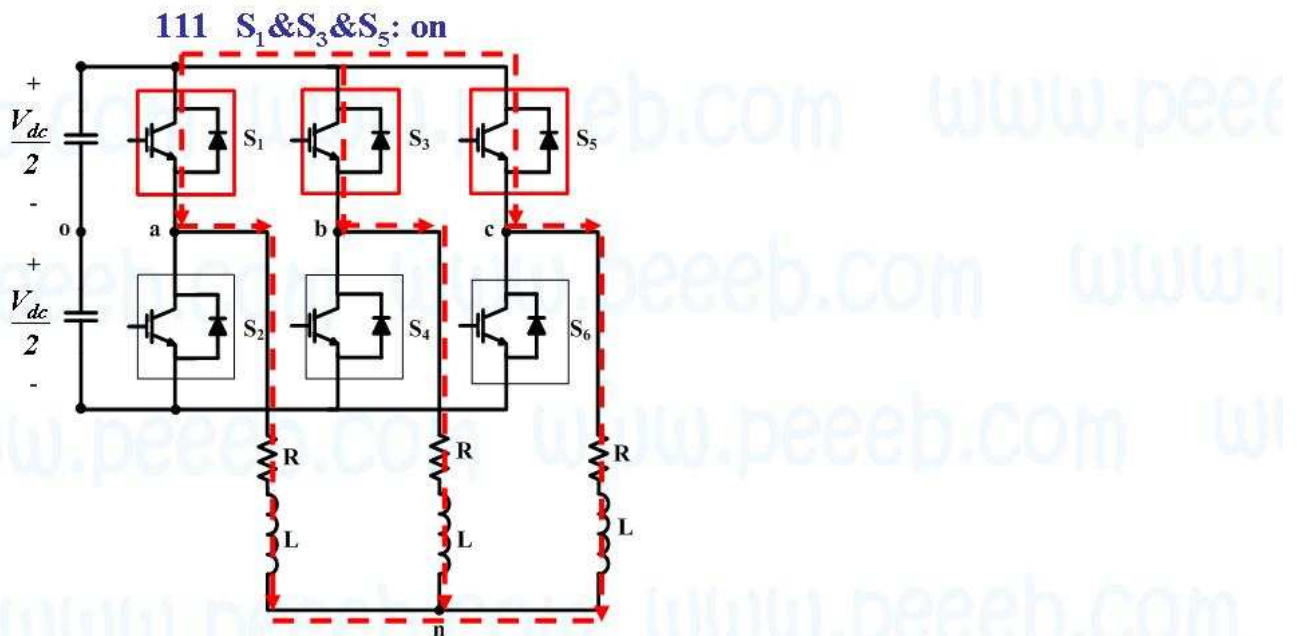
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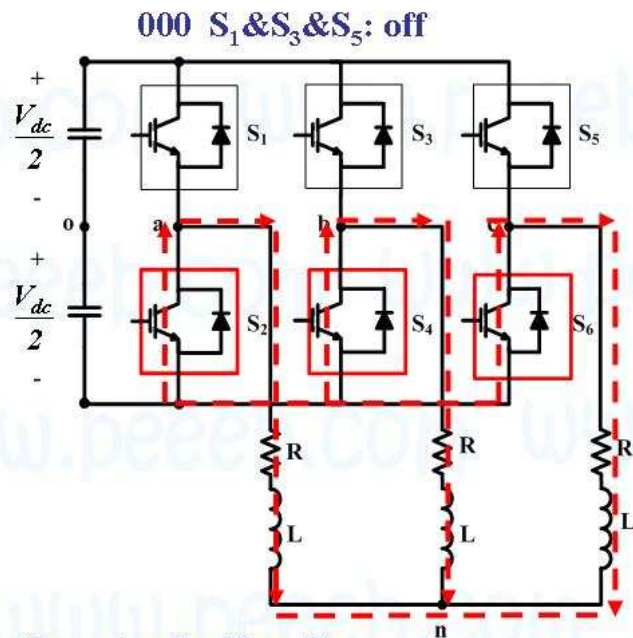
Three-Phase Inverter



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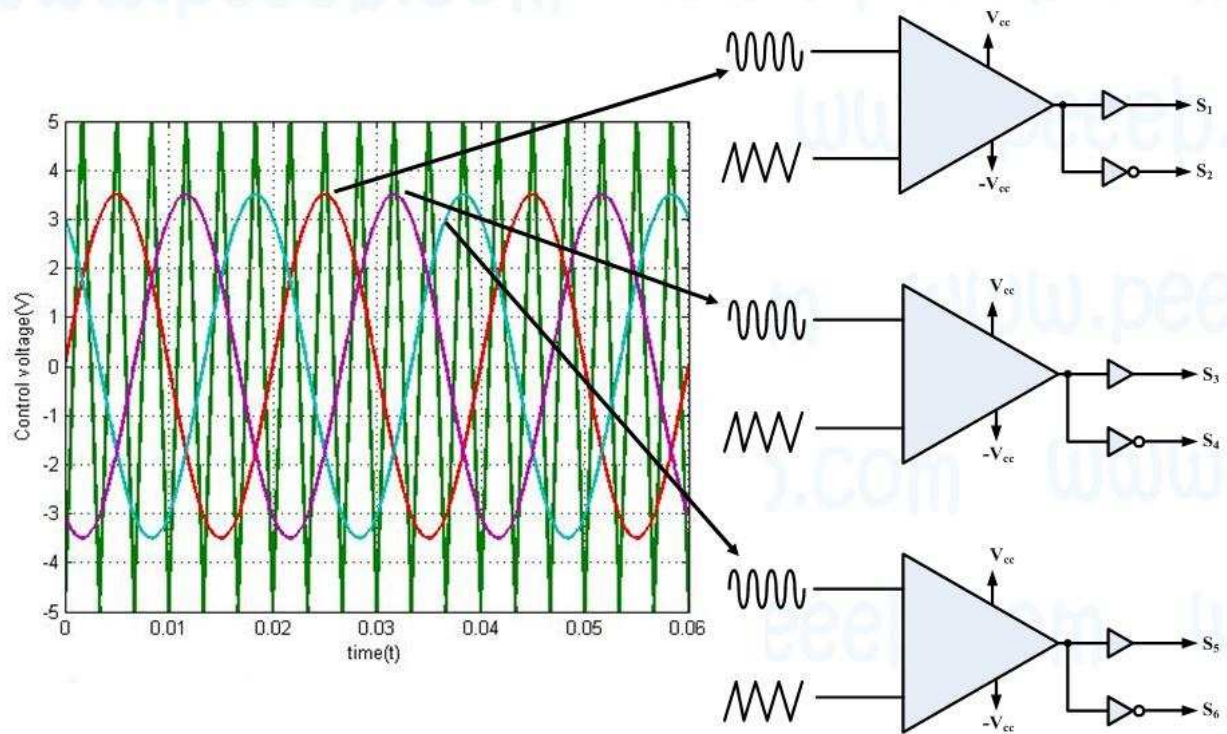
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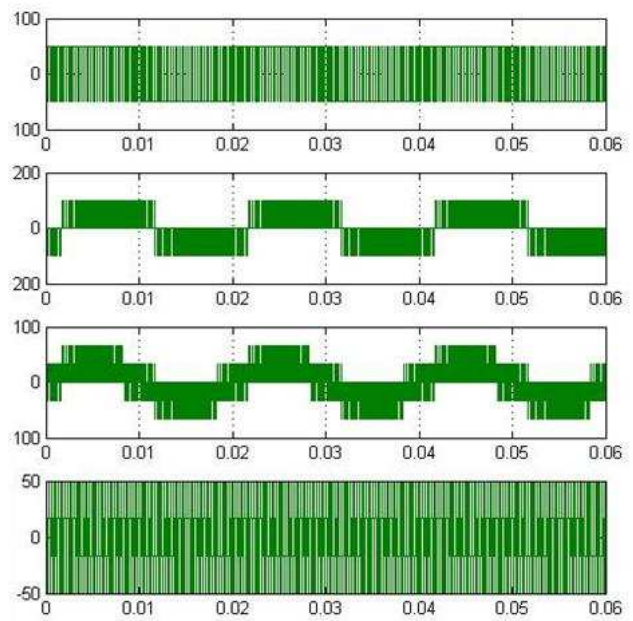
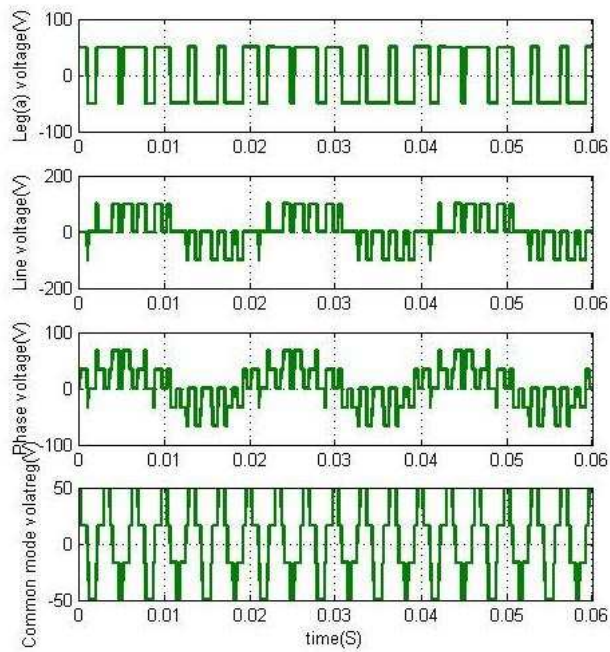
Three-Phase Inverter



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Three-Phase Inverter

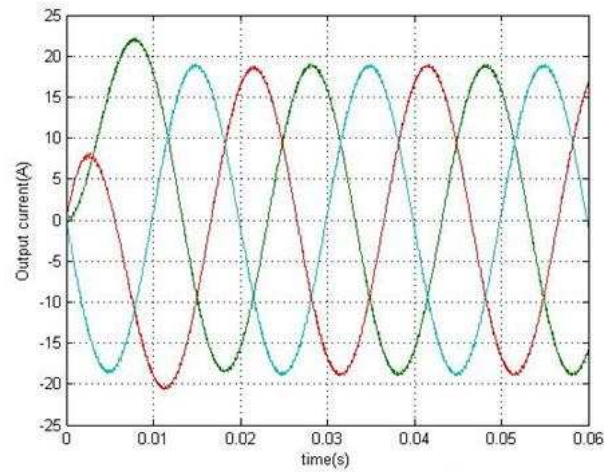
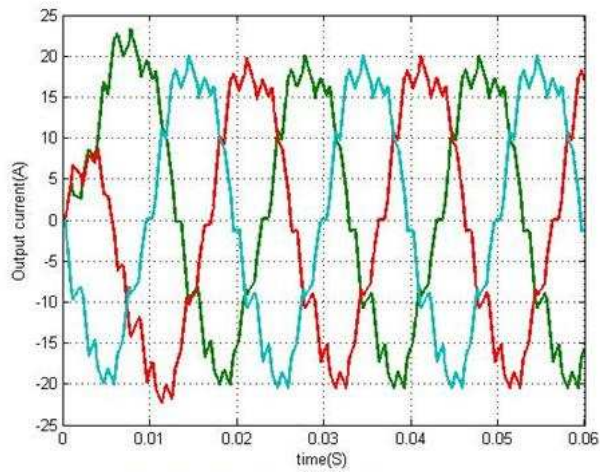


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Three-Phase Inverter

Increasing switching frequency improves load current and decreases harmonics.



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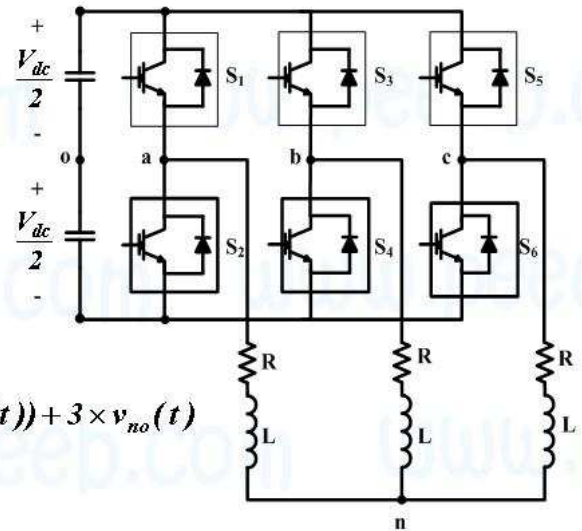
Three-Phase Inverter

$$\begin{cases} v_{ao}(t) = v_{an}(t) + v_{no}(t) \\ v_{bo}(t) = v_{bn}(t) + v_{no}(t) \\ v_{co}(t) = v_{cn}(t) + v_{no}(t) \end{cases}$$

$$v_{ao}(t) + v_{bo}(t) + v_{co}(t) = (v_{an}(t) + v_{bn}(t) + v_{cn}(t)) + 3 \times v_{no}(t)$$

$$v_{an}(t) + v_{bn}(t) + v_{cn}(t) = 0$$

$$v_{no}(t) = \frac{(v_{ao}(t) + v_{bo}(t) + v_{co}(t))}{3}$$



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Three-Phase Inverter

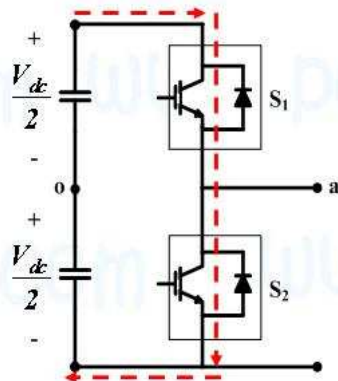
$$v_{no}(t) = \frac{(v_{ao}(t) + v_{bo}(t) + v_{co}(t))}{3}$$

S ₁	S ₃	S ₅	$v_{ao}(t)$	$v_{bo}(t)$	$v_{co}(t)$	$v_{no}(t)$	$v_{an}(t)$	$v_{bn}(t)$	$v_{cn}(t)$
0	0	0	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	0	0	0
0	0	1	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{6}$	$-\frac{V_{dc}}{3}$	$-\frac{V_{dc}}{3}$	$\frac{2V_{dc}}{3}$
0	1	0	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{6}$	$-\frac{V_{dc}}{3}$	$\frac{2V_{dc}}{3}$	$-\frac{V_{dc}}{3}$
0	1	1	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{6}$	$-\frac{2V_{dc}}{3}$	$\frac{V_{dc}}{3}$	$\frac{V_{dc}}{3}$
1	0	0	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{6}$	$\frac{2V_{dc}}{3}$	$-\frac{V_{dc}}{3}$	$-\frac{V_{dc}}{3}$
1	0	1	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{6}$	$\frac{V_{dc}}{3}$	$-\frac{2V_{dc}}{3}$	$\frac{V_{dc}}{3}$
1	1	0	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{6}$	$\frac{V_{dc}}{3}$	$\frac{V_{dc}}{3}$	$-\frac{2V_{dc}}{3}$
1	1	1	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	0	0	0

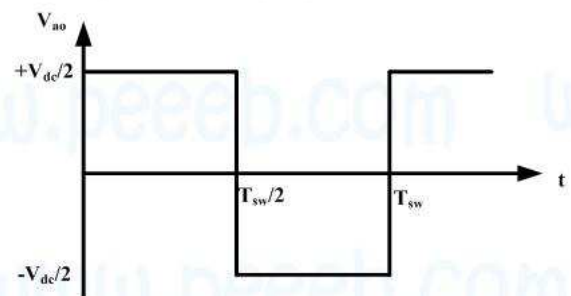
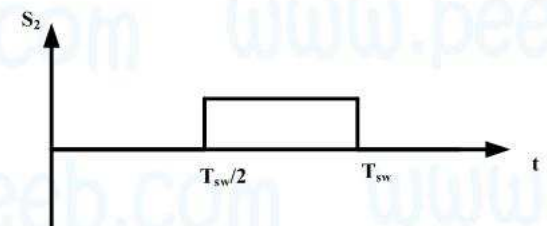
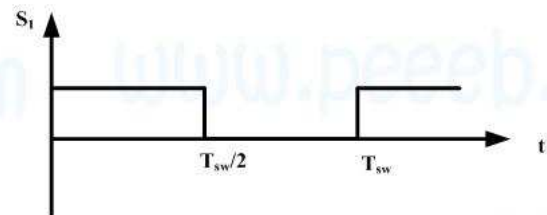
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Dead-time in Inverters



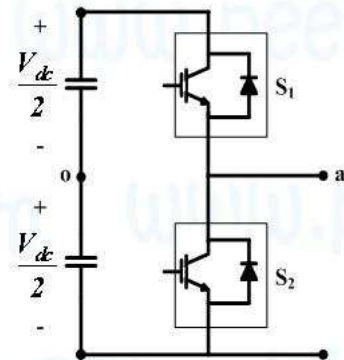
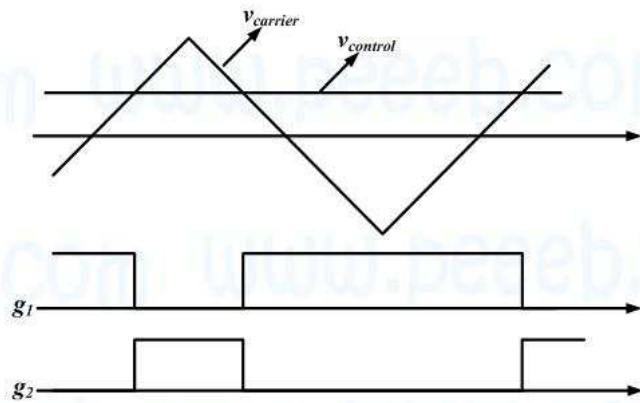
Two switches in each leg **should not be turned on** simultaneously. This case, makes a short circuit across the DC supply and may damage the power converter due to a significant short circuit current through the power switches.



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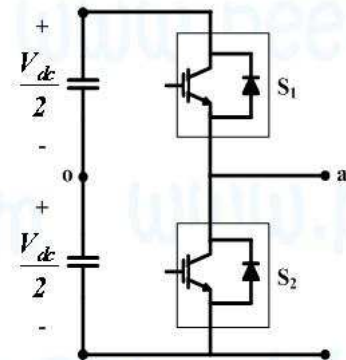
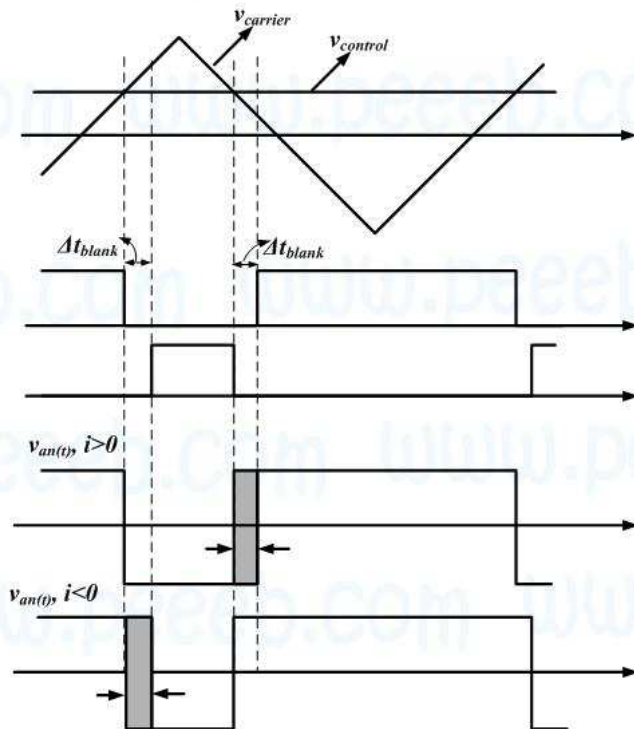
Dead-time in Inverters



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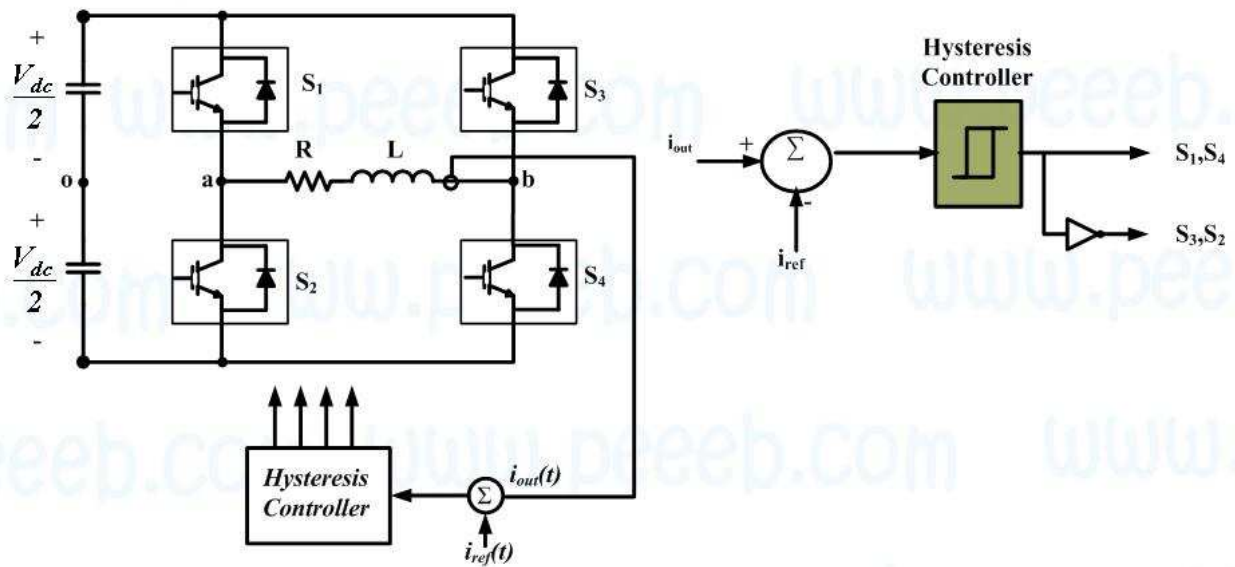
Dead-time in Inverters



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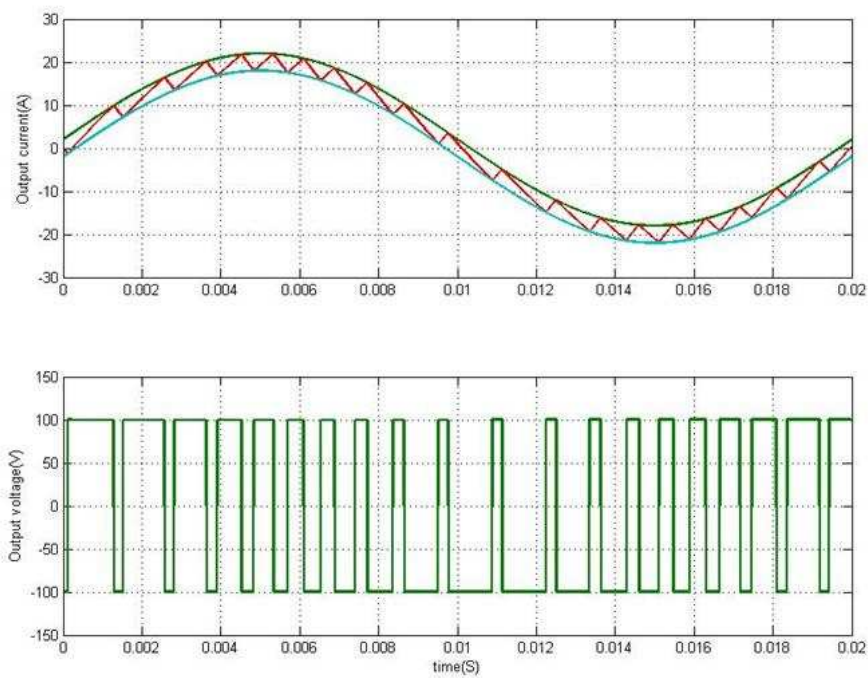
Hysteresis Current Control for a Single-Phase Inverter



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Hysteresis Current Control for a Single-Phase Inverter



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