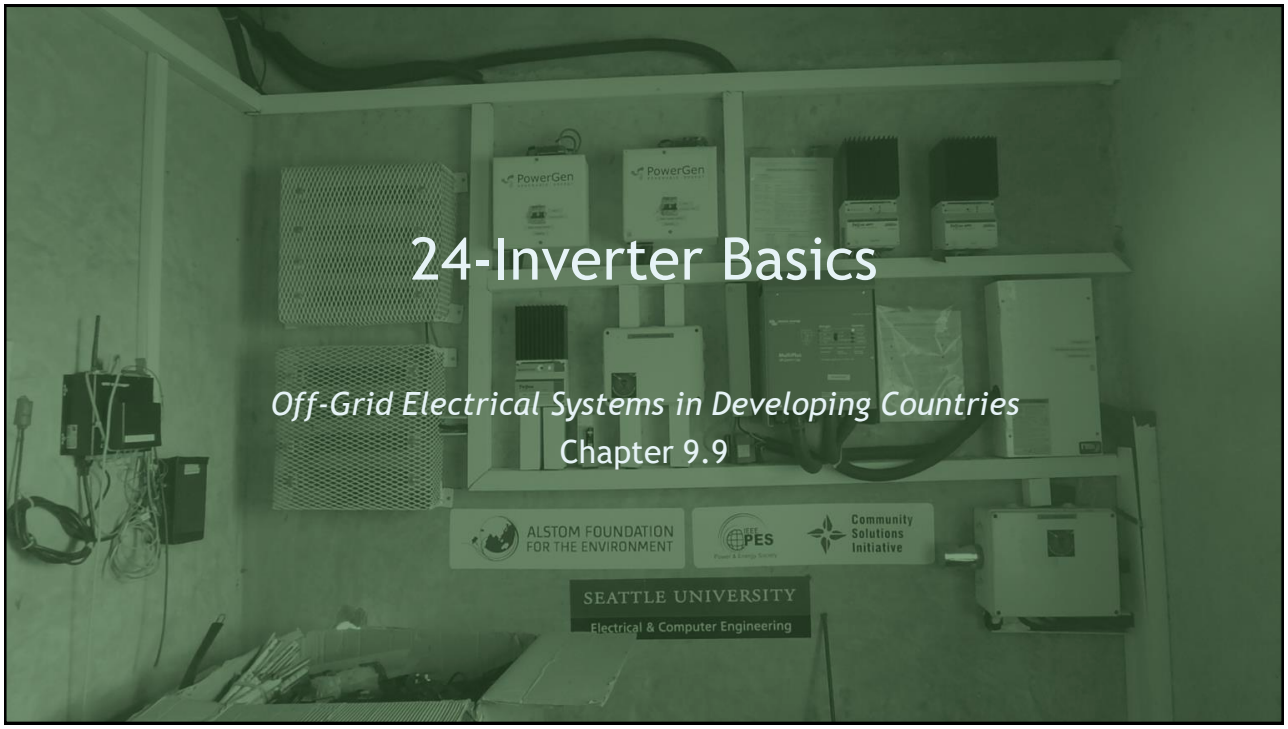


24-Inverter Basics

Off-Grid Electrical Systems in Developing Countries

Chapter 9.9

1

Learning Outcomes

At the end of this lecture, you will be able to:

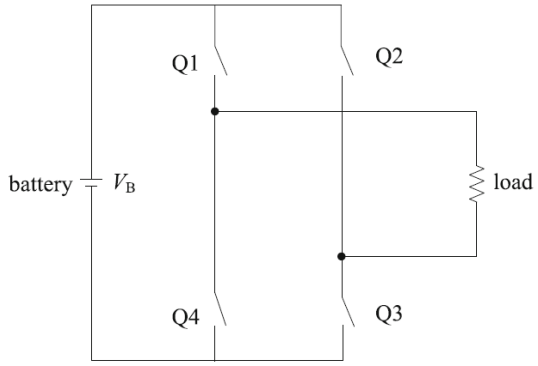
- ✓draw and understand the basic operational principles of inverters
- ✓describe the differences in squarewave and sinusoidal inverters
- ✓determine the power output supplied by an inverter

2

2

Inverters: Basic Circuit

- Use solid-state switching to alternate polarity of voltage applied to a load
- Switch in pairs
  - Q1, Q3 open and close at same time
  - Q2, Q4 open and close at the same time
- Voltage output can be increased via DC—DC converter at the input or transformer at the output (or both)



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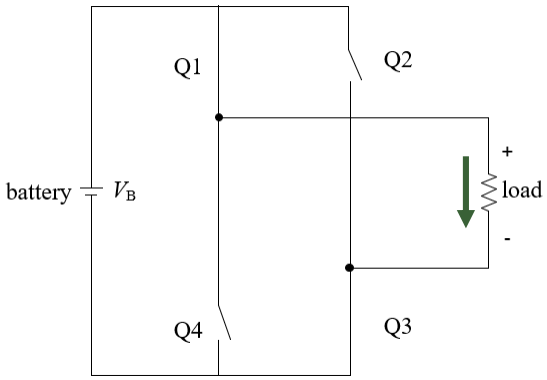
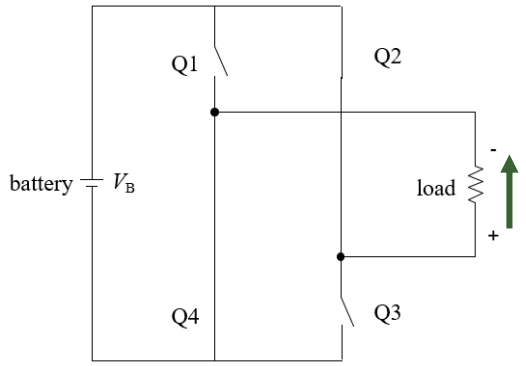
Inverters: Basic Circuit





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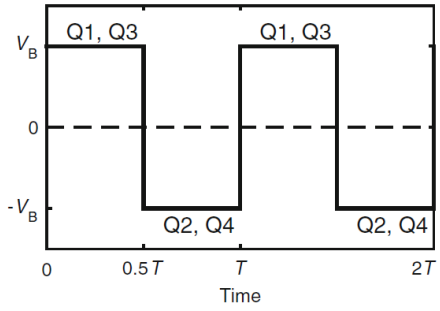
Output Signal

- Waveform is square
- Centered at zero



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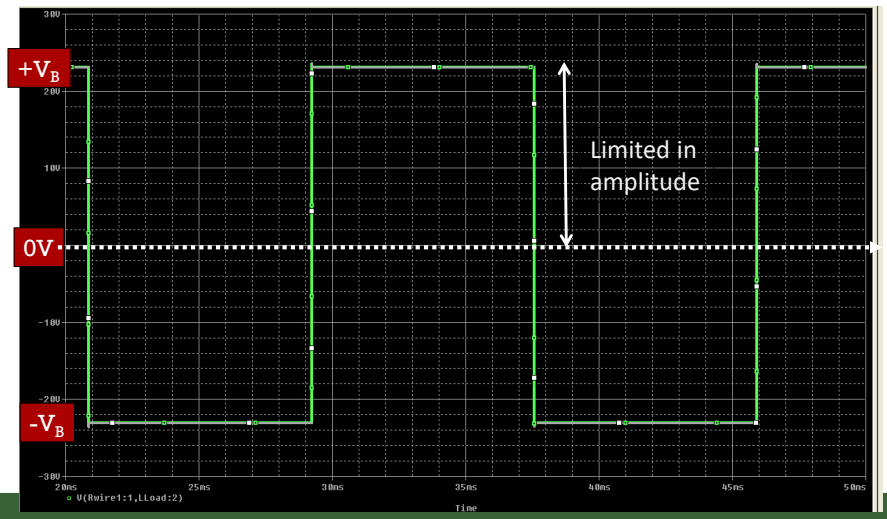

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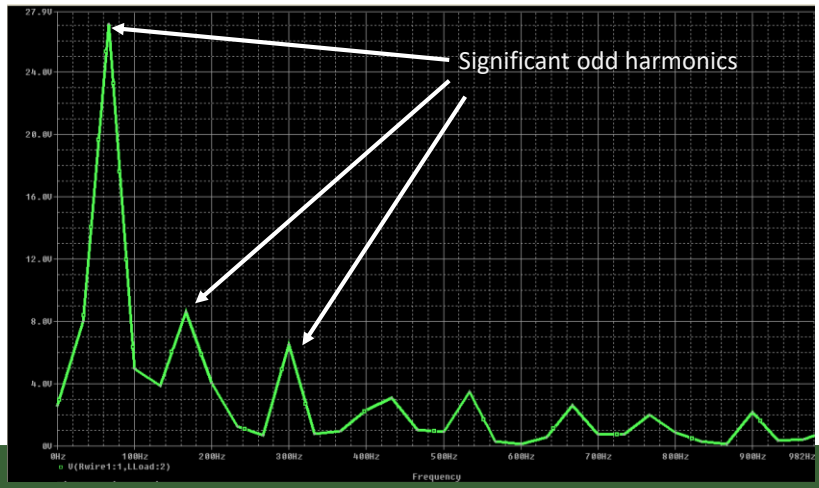
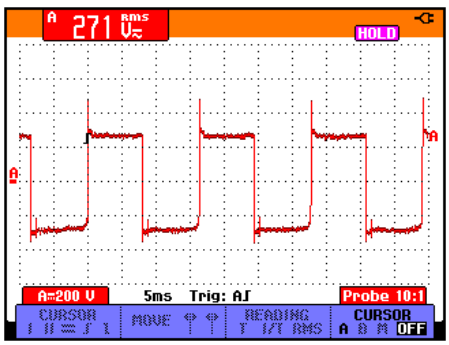
Inverter

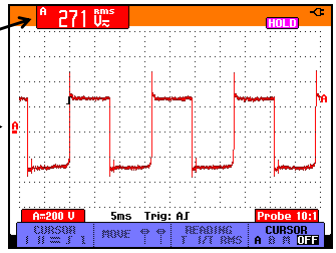


Squarewave Inverter

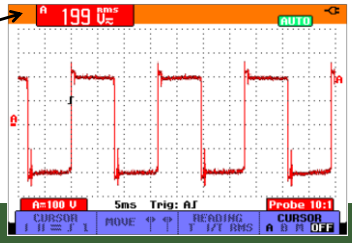


Squarewave Inverter

V_B = 12.4 V



V_B = 9 V



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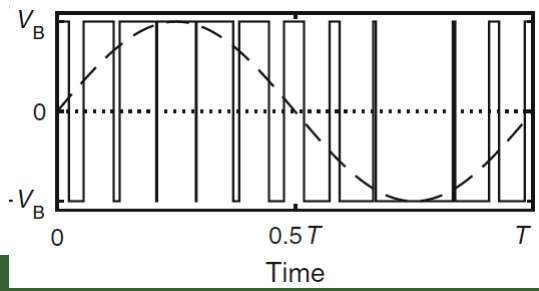
PWM Inverters

- Distortion in output can be reduced using PWM
- Vary duty cycle over the course of the output



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PWM Inverter

- Switching frequency should be much greater (4kHz - 10kHz) than fundamental frequency (60 Hz or 50 Hz)
- Basic idea: vary the duty ratios within each switching period to replicate a sine wave

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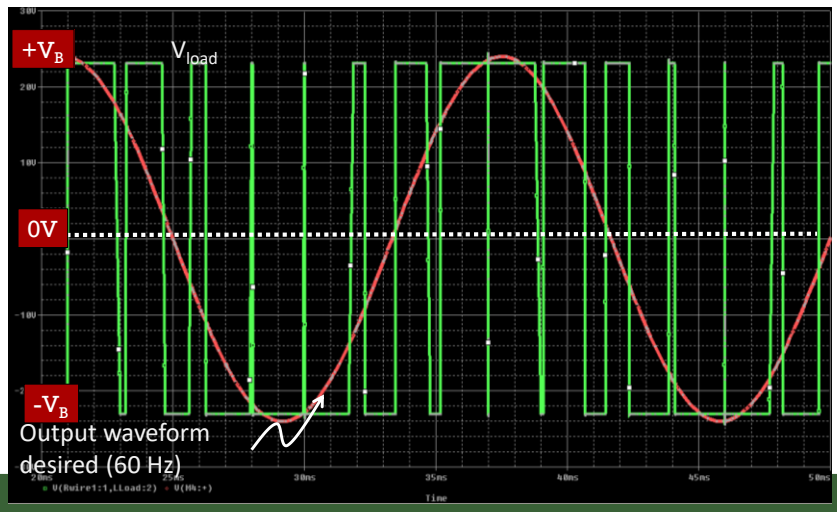

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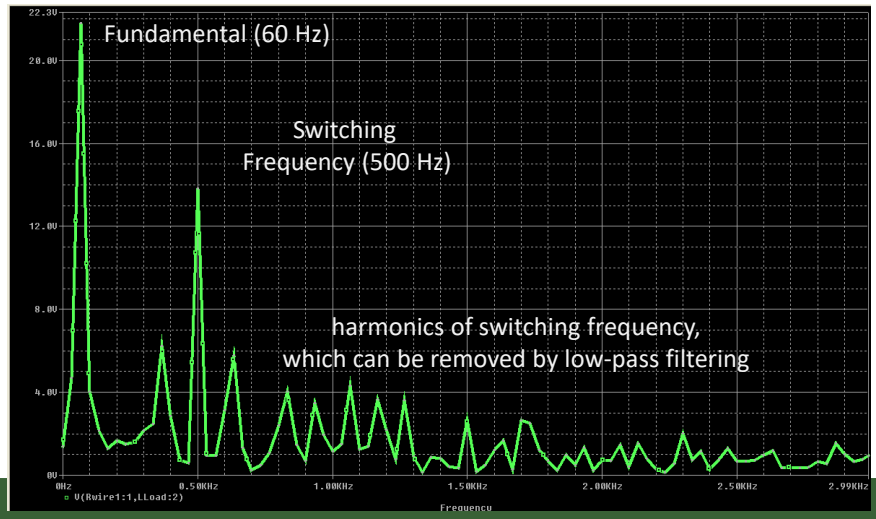

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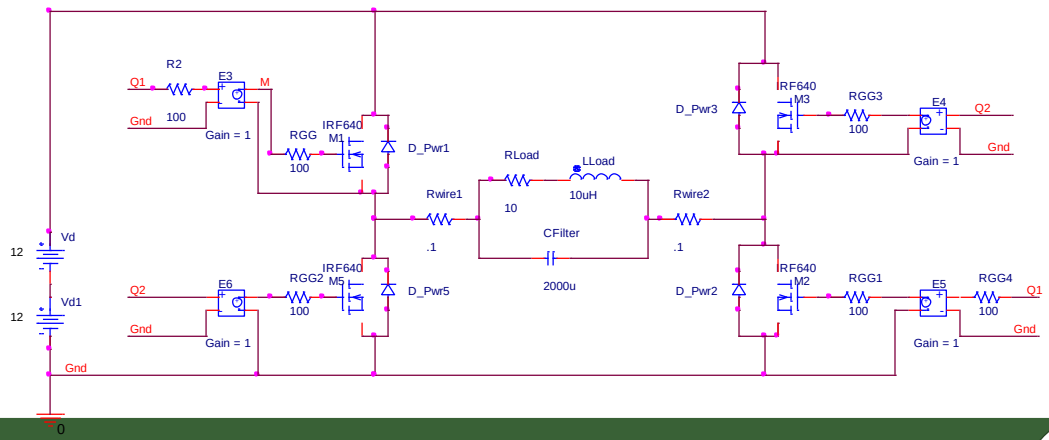
PWM Inverter



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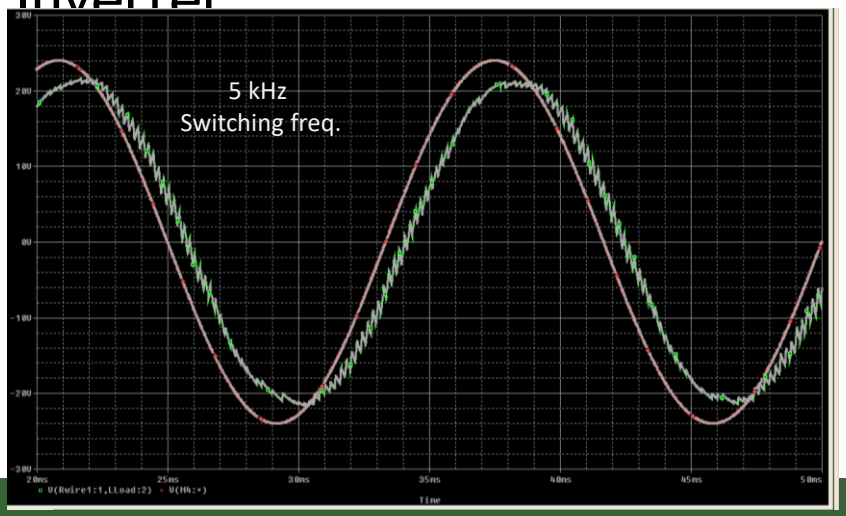
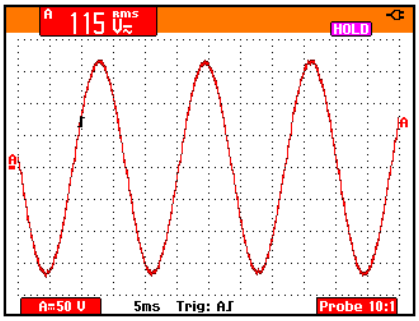
PWM Inverter



PWM Inverter

PWM Inverter



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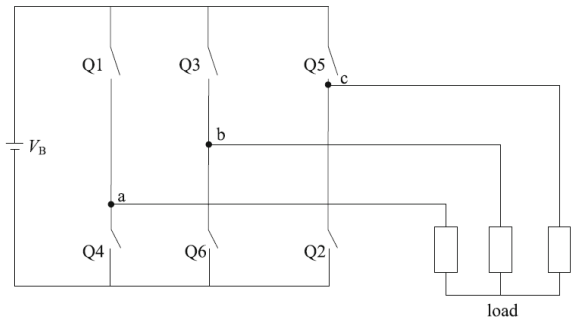
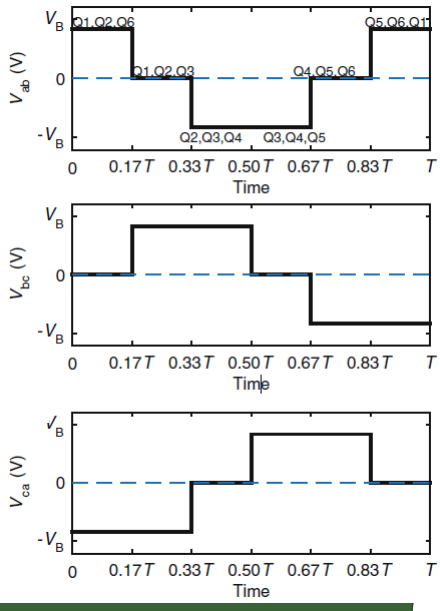
Three-Phase Inverters





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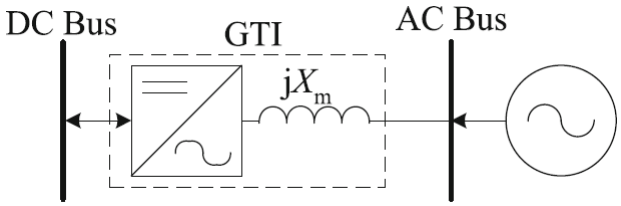
Grid Tied Inverters (GTI)

- Certain inverters can be coupled to AC Bus's with other AC coupled sources

Note that "grid tied" does not necessarily mean the national grid is on site



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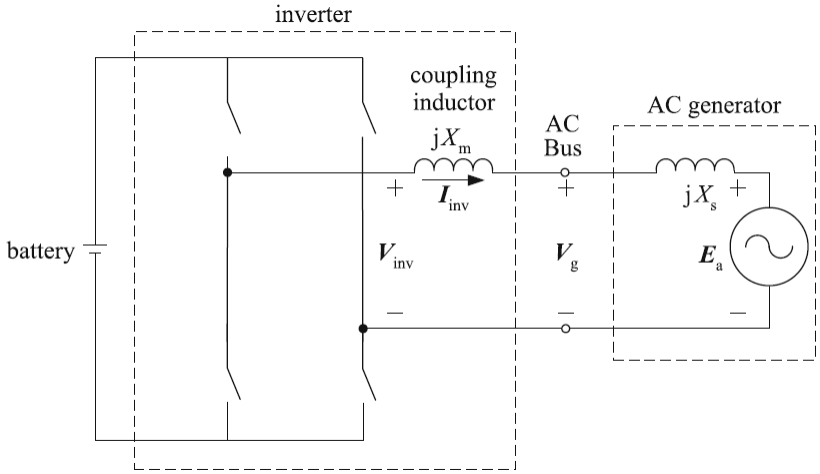
GTI

- Inverters have large coupling inductors
- Inverter current:

$$I_{inv} = \frac{V_{inv} - V_g}{jX_m}$$



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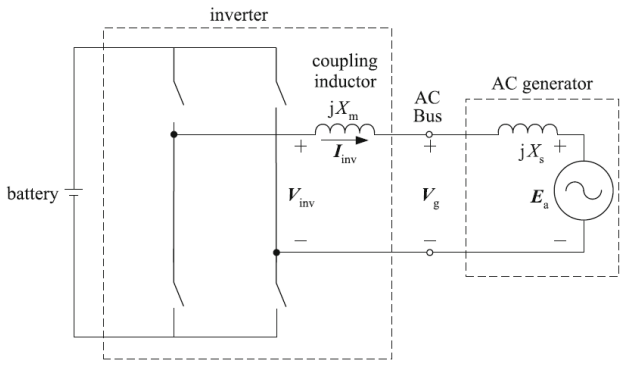
Inverter Power

$$P_{inv} = \mathrm{Re}\left\{\boldsymbol{V}_{inv}\boldsymbol{I}_m^*\right\} = \mathrm{Re}\left\{\boldsymbol{V}_{inv}\left(\frac{\boldsymbol{V}_{inv}-\boldsymbol{V}_g}{\mathrm{j}X_m}\right)^*\right\}$$

$$P_{inv} = \mathrm{Re}\left\{\frac{|\boldsymbol{V}_{inv}|^2}{-jX_m} - \frac{\boldsymbol{V}_m\boldsymbol{V}_g}{-\mathrm{j}X_m}\right\}$$

$$P_{inv} = \mathrm{Re}\left\{\frac{|\boldsymbol{V}_{inv}|^2}{-\mathrm{j}X_m} - \frac{|\boldsymbol{V}_{inv}||\boldsymbol{V}_g|\cos(\delta)+\mathrm{j}|\boldsymbol{V}_m||\boldsymbol{V}_g|\sin(\delta)}{-\mathrm{j}X_m}\right\}$$

$$P_{inv} = \frac{|\boldsymbol{V}_{inv}||\boldsymbol{V}_g|\sin(\delta)}{X_m}$$

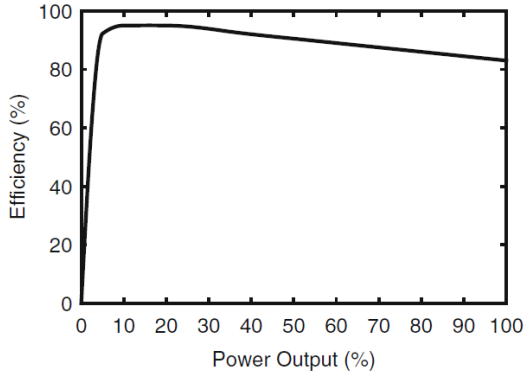


Power supplied by the inverter can be controlled by adjusting the inverter's voltage magnitude and phase

Inverter Efficiency

- Inverter efficiency is not constant, and is non-linear
- Low efficiency at low-loading
- Inverter efficiency is sometimes reported as the "European" efficiency, which considers different operating points

$$\eta_{inv} = 0.03\eta_{inv}(0.05) + 0.06\eta_{inv}(0.10) + 0.13\eta_{inv}(0.20) + 0.10\eta_{inv}(0.30) + 0.48\eta_{inv}(0.50) + 0.20\eta_{inv}(1.00)$$



Practical Considerations

- Higher-quality inverters feature:
  - output sinusoidal voltage with little distortion and constant frequency and magnitude;
  - good voltage regulation;
  - high efficiency at low loading;
  - insensitivity to changes in input voltage;
  - short-term increased surge capacity;
  - low-voltage disconnect capability;
  - can be configured in the field;
  - include data logging and diagnostic features

Contact Information

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