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College of Engineering

ECE 528 – Understanding Power Quality

http://www.ece.uidaho.edu/ee/power/ECE528/

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Lecture 4

Today…

- Power electronics review
- Common devices and topologies
- The Power Quality perspective on power electronics

What are Power Electronics?

- Power electronics refers to devices employing semiconductors to convert and control electrical energy
- Types of conversions:
  - magnitude
  - Frequency
  - Number of phases

Why are power electronics important to PQ?

- They cause harmonic distortion
- The presence of harmonic distortion from power electronics can affect the power system and other loads
- Power electronic devices have particular vulnerabilities when it comes to PQ
- The use of power electronic devices is increasing

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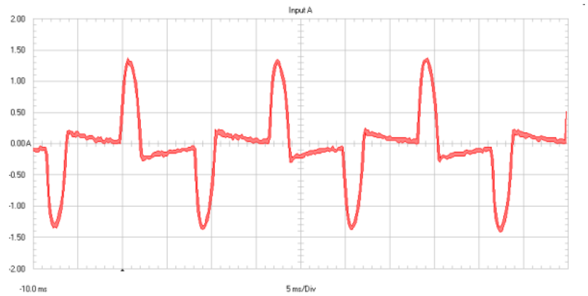
How power electronics create harmonics

Generally, a power electronic device draws current in "pulses" from the power system.

Current waveform for a desktop computer.



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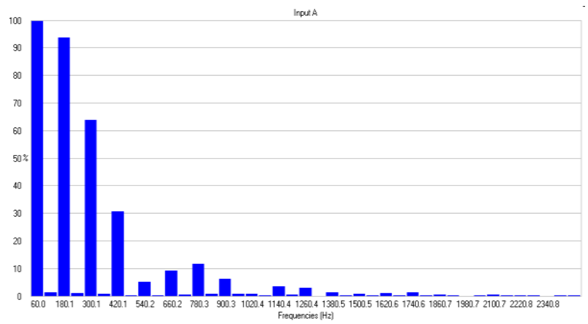
Non-linear current – harmonics

As we learned with the Fourier Series, the non-linear current can be "assembled" from sinusoids.

Harmonic spectrum of the computer current. High 3rd, 5th, and 7th harmonics.



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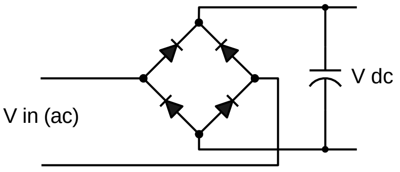
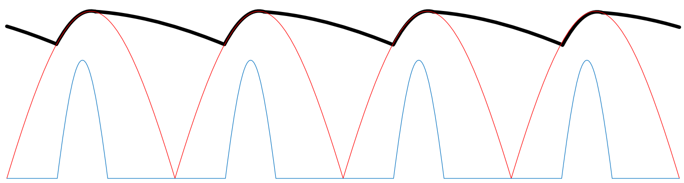
Why is the current drawn in "pulses"?

The basic rectifier, filter-capacitor combination





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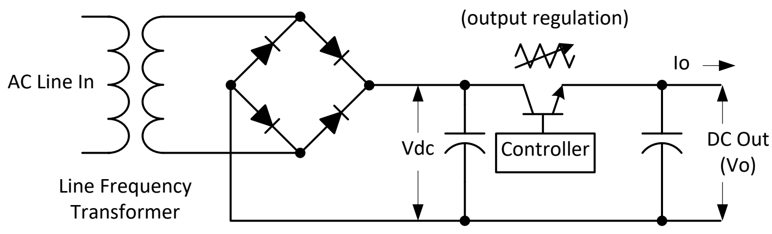
Controlling the output: A regulated, linear DC power supply

We want the dc output voltage to be nearly constant despite load variations and supply voltage variations.

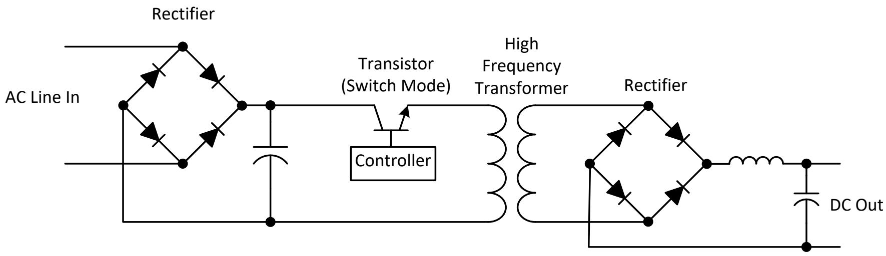


Transistor operated in active region as a variable resistor – varies voltage drop to regulate output voltage.

Losses in the linear dc supply

- Vo < Vdc (output voltage < capacitor voltage)
- The power dissipated in the load is: Vo*Io
- The power dissipated in the transistor is: Pswitch=(Vdc-Vo)Io
- If Vo = ½ Vdc, then Pswitch=½(Vdc)Io
- The "switch mode" supply reduces losses significantly.

Controlling the output:
Switch mode power supplies



Transistor is operated as a **switch**; either on, or off.

Advantages:

Reduced losses and weight

More tolerant of input voltage variations

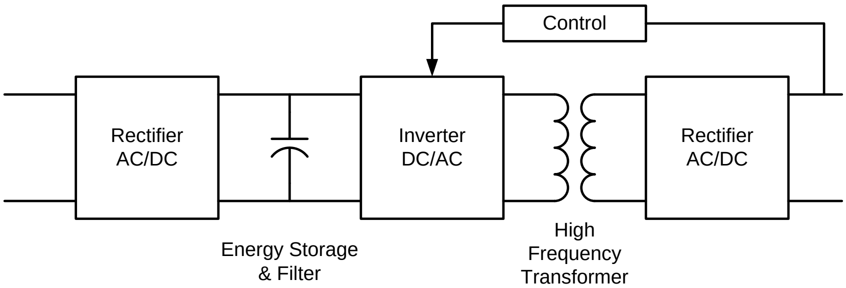
Disadvantages

High switching frequency – interference

Increased complexity

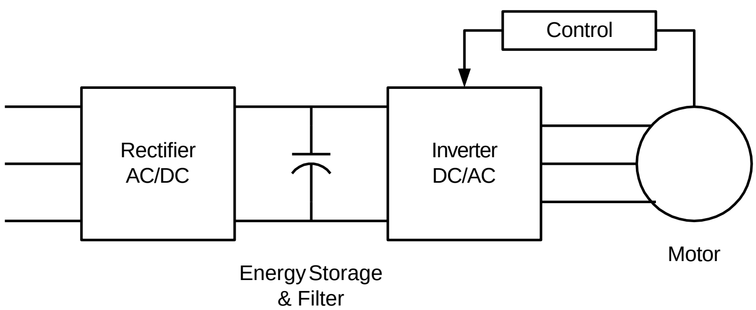
Topologies of converters

- The general switch mode power supply



Topologies of converters

- The variable frequency drive (VFD, ASD, VSD)

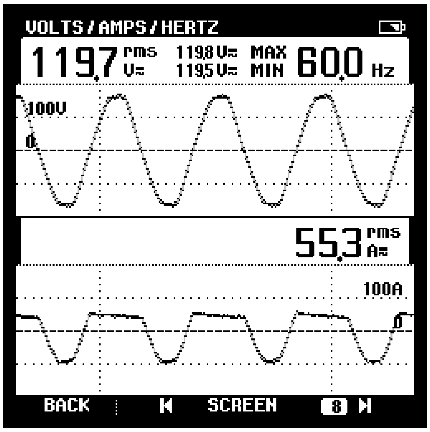


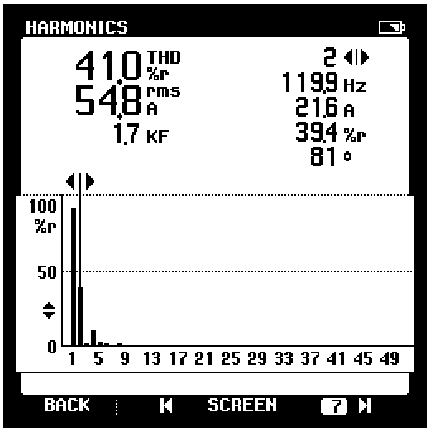
- See PSQ pages 214-223 or FPQ pages 201-205

Where are power electronics?

- Almost everywhere…
  - Industrial systems
    - Motors (Drives)
    - Control systems
  - Lighting
    - Electronic ballasts in fluorescent lights
    - Dimming systems
  - Generation
    - Convert DC from solar, or AC from Wind to 60Hz AC.

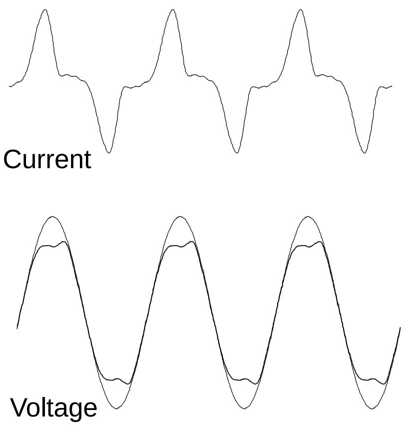
Where are power electronics?





Some PQ issues with power electronics

- Impact on line voltage
  - “flat-topping” reduces ride through time of electronic loads during voltage sags
  - Distorted voltage results in distorted current, even in linear loads.



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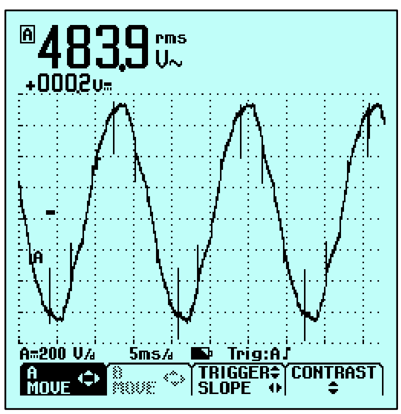
Some PQ issues with power electronics

- Other line-side issues
  - Higher frequencies associated with harmonics and high switching frequencies can increase capacitive coupling.
  - Line voltage notching if rectifier uses thyristors



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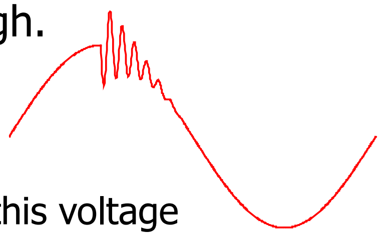
Power electronics vulnerabilities

- Flat-topped voltage – reduces dc bus voltage, reducing stored energy for voltage sag ride-through.
- Capacitor switching.



What will happen when this voltage waveform passes through the rectifier and into the dc bus capacitor?

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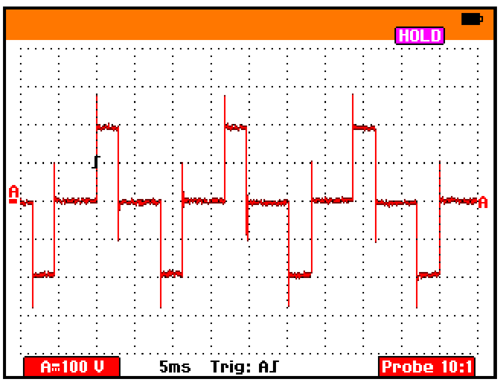
Load-side issues

- Primary issue is the fact that the "ac" output from a converter contains high frequency components.
- Voltage output of a small UPS.



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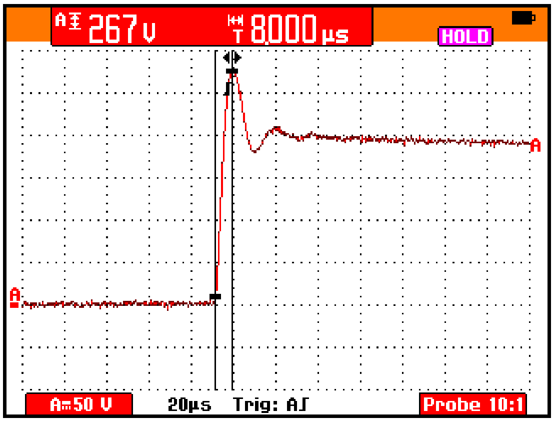
Load side issues

Short rise time may affect load the same way a transient would.

If the rise time here represents ¼ cycle, what would the frequency be?



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Special problem with PWM drives

- A Pulse Width Modulated VFD can effectively vary both the voltage and frequency of its output signal.
- This is done by varying the width of output voltage pulses.
- Rise time can be 0.1 micro second.
- If the motor leads are “long,” voltage reflections can lead to increased voltages at the motor terminals.

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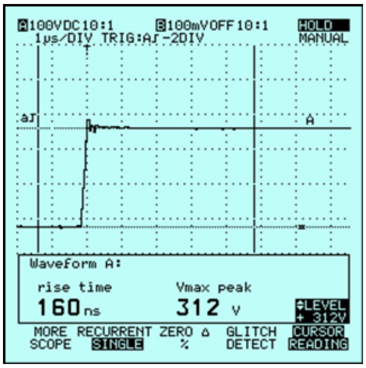
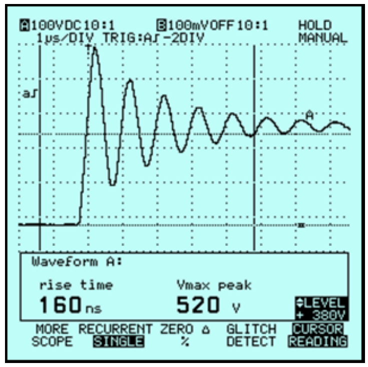
Voltage reflections in PWM drives



Normal leading edge of PWM voltage pulse



Leading edge of PWM voltage pulse with reflected voltage

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Problems for the investigator

- In some cases, handheld meters may give misleading readings.
- Average responding meters may read values significantly higher or lower than the True-RMS values of voltage and current, depending on the wave shape.
- Some problems, such as high frequency voltage reflections may require oscilloscopes or other more specialized monitoring equipment.

Next time…

- Terminology
  - Read chapters 1 and 2 in FPQ and PSQ if you haven't
  - Skim both texts to familiarize yourself with them
- Investigation planning