ECE 528 – Understanding Power Quality

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

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Lecture 3

Today…

- Power electronics review
- Common devices and topologies
- Some PQ issues with power electronics
- PQ Terminology

We're in PSQ ch. 2 and 5, FPQ ch 2 and 6

What are Power Electronics?

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

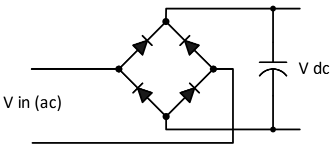
Why are power electronics important to PQ?

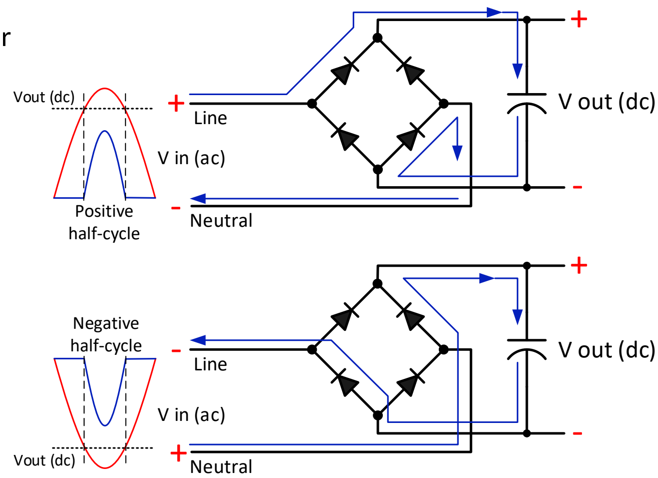
- The use of power electronic devices continues to increase
- They cause harmonic distortion
- The presence of harmonic distortion from power electronics can affect the power system and other loads
- Power electronic devices have particular vulnerabilities when it comes to PQ

Harmonics – from AC to DC conversion (Rectification)

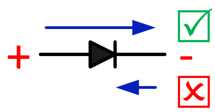
Where the current pulses come from…

The basic rectifier with capacitor





Diodes: like one-way valves for current



Current flows on source side when Vin > Vout

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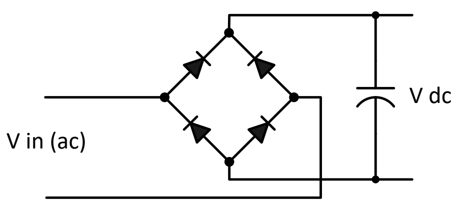
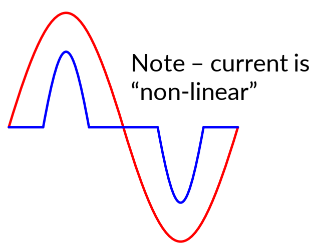
Harmonics – from AC to DC conversion (Rectification)

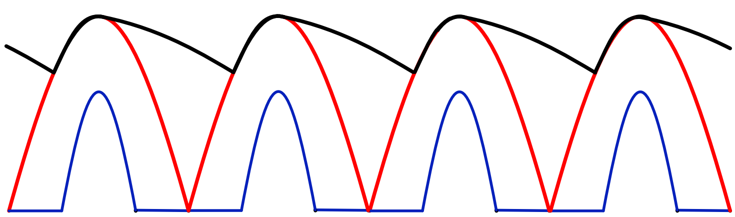
The basic rectifier with capacitor



Input AC Voltage

Input AC Current





DC Voltage

Rectified Voltage

Current between rectifier and capacitor

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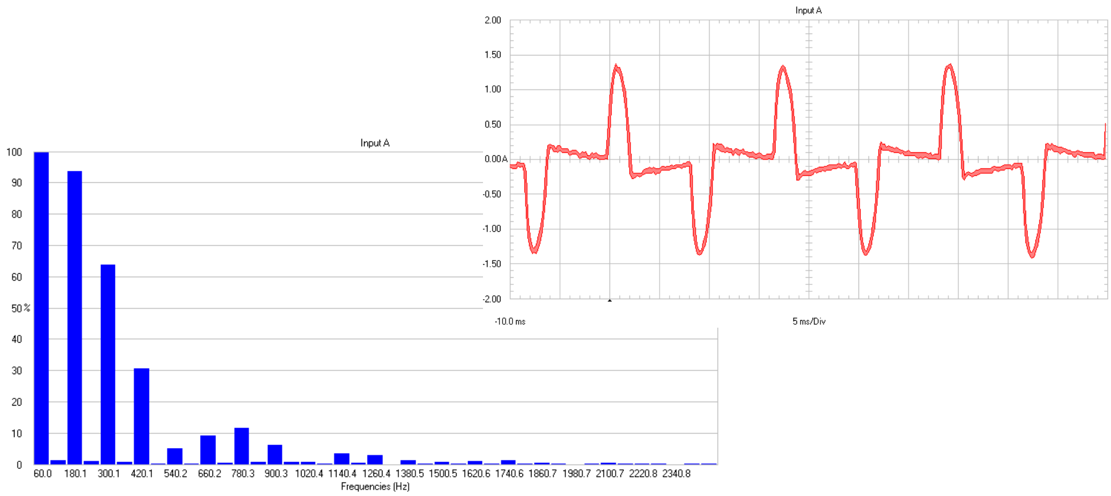
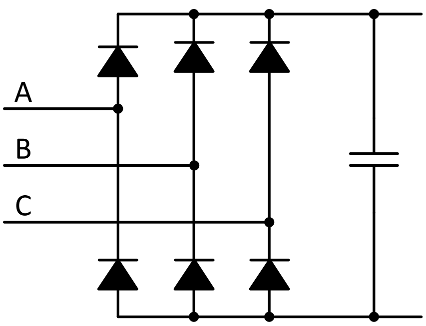
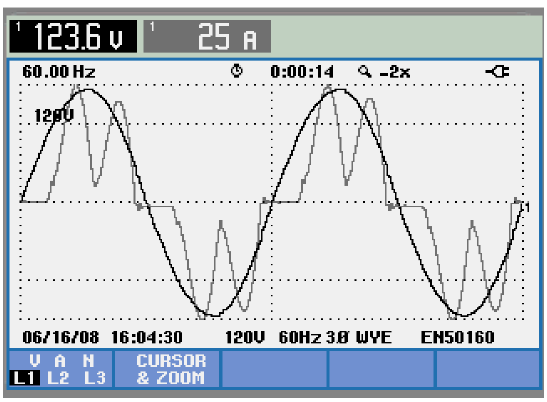
Current for a desktop computer and its spectrum



Harmonics - 3-Phase Rectification

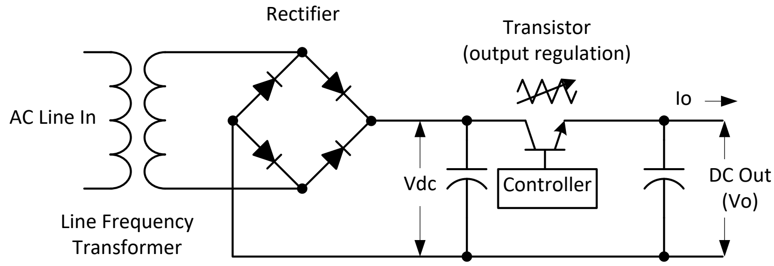
Basic 3-Phase Rectifier





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.

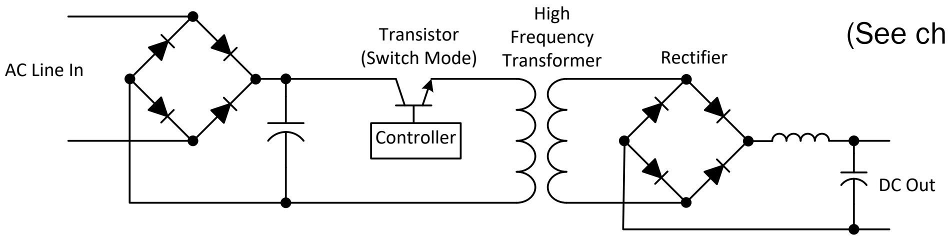


Transistor operated in active region as a variable resistor – varies voltage drop to regulate output voltage.

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



(See ch. 6 in FPQ)

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

Advantages:

Reduced losses and weight

More tolerant of input voltage variations

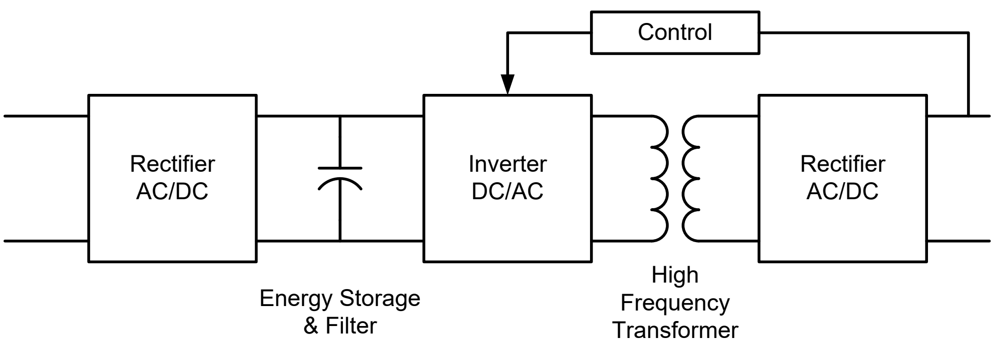
Disadvantages

High switching frequency –interference

Increased complexity

Topologies of converters

- The general switch mode power supply



Topologies of converters

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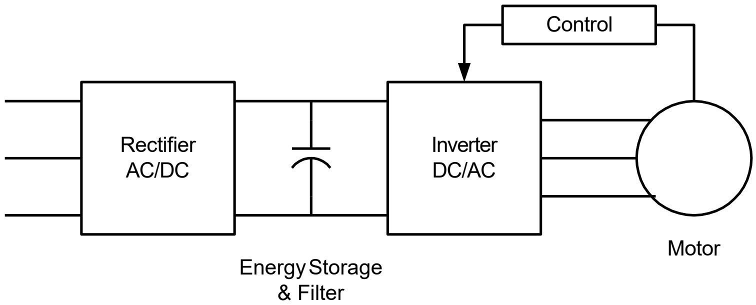
- The variable frequency drive (VFD, ASD, VSD)



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

Some PQ issues with power electronics

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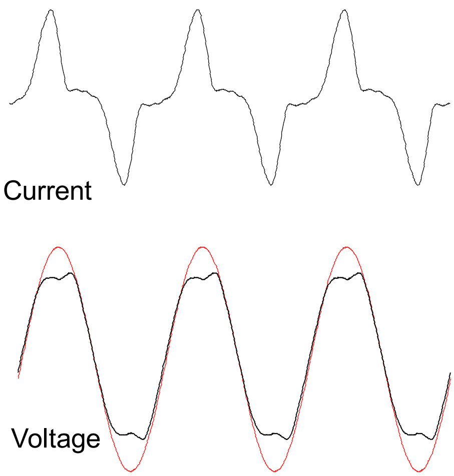
Impact on line voltage

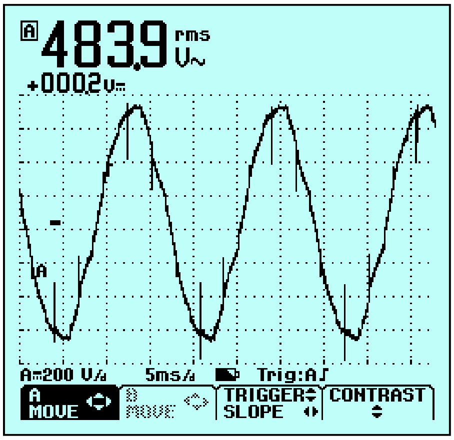
Distorted voltage results in distorted current, even in linear loads.

“Flat-topping” reduces DC bus voltage in power supplies, reducing ride-through time of electronic loads during voltage sags.



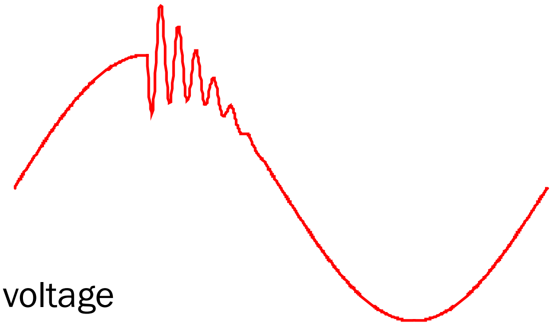
Some PQ issues with power electronics

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



Power electronics vulnerabilities

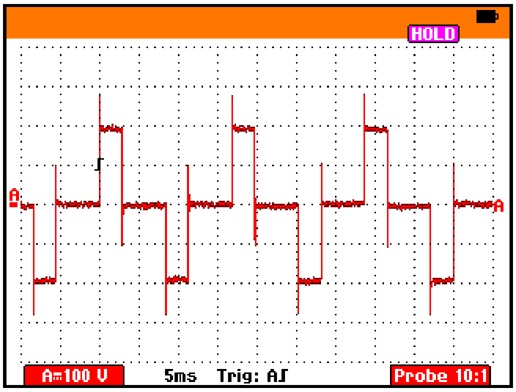
- Capacitor switching.



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

Load-side issues

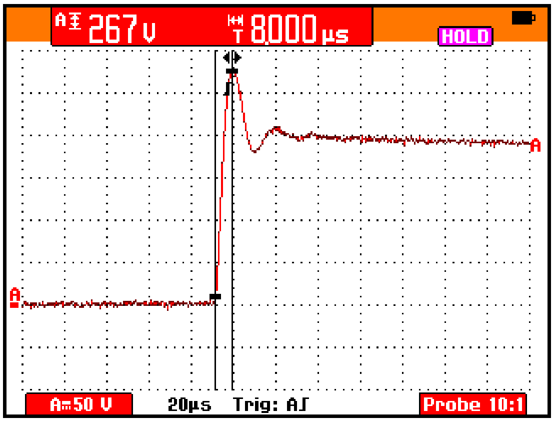
- Primary issue is the fact that the “ac” output from a converter contains high frequency components.
- Voltage output of a small UPS.



Load-side issues

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

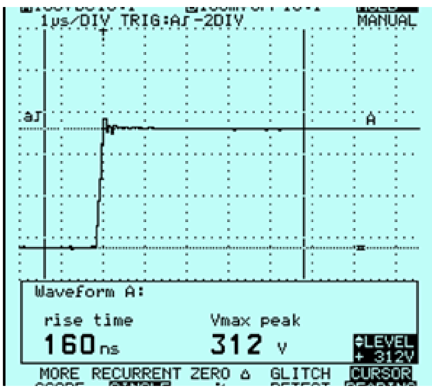
If the rise time here represents ¼ cycle, what would the frequency be?



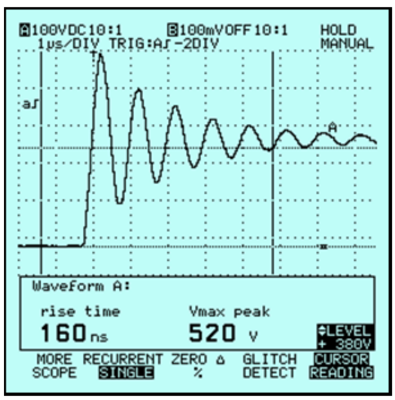
Special problem with PWM drives

- 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 microsecond.
- If the motor leads are “long,” voltage reflections can lead to increased voltages at the motor terminals.

Voltage reflections in PWM drives



Normal leading edge of PWM voltage pulse



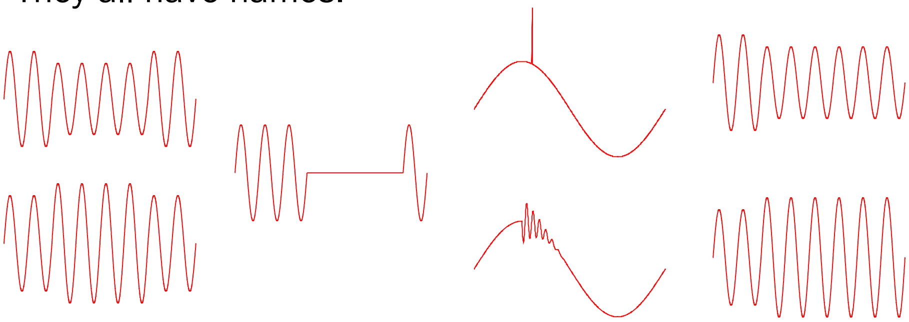
Leading edge of PWM voltage pulse with reflected voltage

Problems for the investigator

- Some handheld meters may give misleading readings for distorted waveforms.
- 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.

Terms and definitions

- Allow engineers to discuss issues, search for information, etc.
- Problem - Most of the public including engineers outside of power quality are not familiar with power quality terms and their definitions.
- They all have names:



Ambiguous terms

Brownout

Dirty Power

Glitch

Clean Ground

Spike

Clean Power

Surge

Blip

Power Bump

Four general types of disturbances (IEC)

- Conducted low freq.
  Harmonics
  Sags/swells/interruptions
  Imbalance
  DC offset
- Conducted High freq.
  Transients
  Induced high frequency signals
- Radiated low freq.
  Electric and magnetic fields
- Radiated High freq.
  Electric and magnetic fields

See FPQ p. 17 or PSQ p. 16

Categories based on duration (IEEE)

- Transients — nanoseconds to 3 cycles
- Short duration
  - Instantaneous — 0.5 – 30 cycles
  - Momentary — 30 cycles – 3 seconds
  - Temporary — 3 s – 1 minute
- Long duration — > 1 minute
- Steady State

See Table 2.2 in either text

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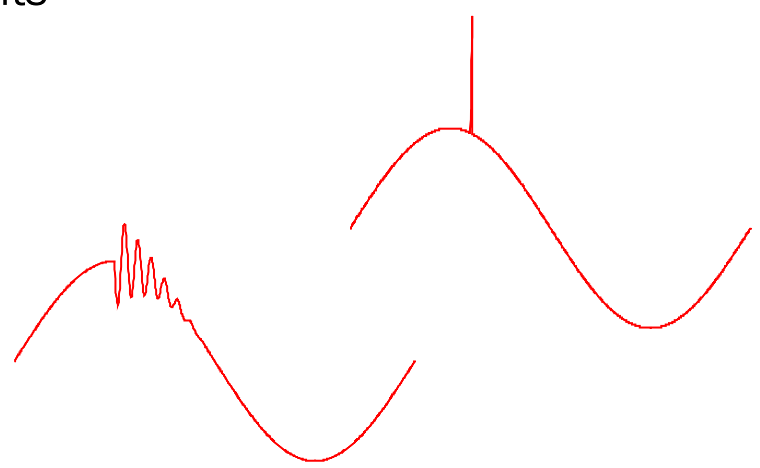
Transients



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Describing transients:

- Impulsive
  - Peak magnitude
  - Time to rise/time to return to 50% of peak
  - *A 1.2kV, 1.2/50ns impulsive transient*
- Oscillatory
  - Frequency
  - Duration
  - Maximum absolute value
  - *A 720Hz, quarter-cycle, 1.3pu oscillatory transient*

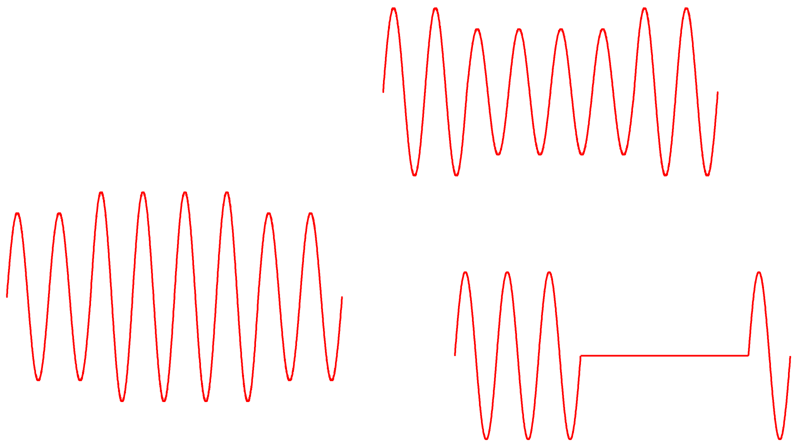
Events tend to have "signature" transients

Same device switching

(All scales are the same)

Different devices switching

Short duration variations



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Clearly describing sags, undervoltage, swells, and overvoltage

- What is “a 40% voltage sag”? Is it more or less severe than a 60% voltage sag of the same duration?
- We’ll use a remaining-voltage convention and describe sags, swells, undervoltage, and overvoltage carefully to avoid confusion.

A sag to 40% of nominal voltage.

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Describing short-duration disturbances

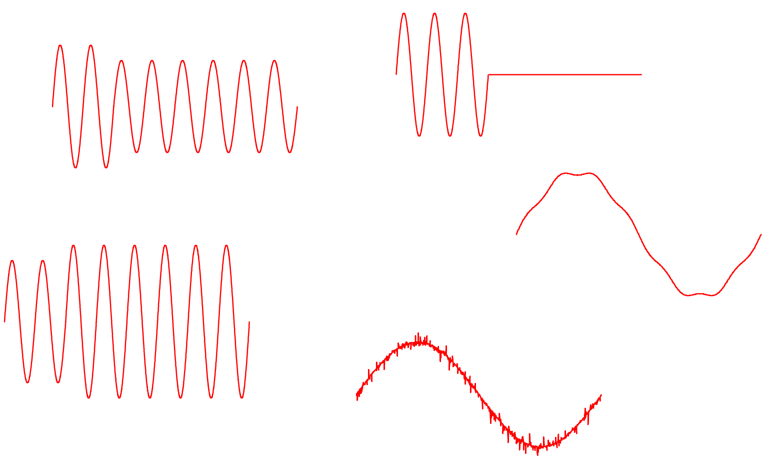
(Include descriptors from all four columns)

Duration	**phases**	**Disturbance**	**Magnitude** *(for sags and swells)*
• Instantaneous • Momentary • Temporary • Cycles	• Single • Two • Three	• Sag • Swell • Interruption	• Percentage • Per-unit

A momentary single-phase sag to 70% of nominal.

A 4-cycle, three-phase sag to 50% of nominal.

Long duration variations and steady-state conditions



Describing long-duration disturbances

(Include descriptors from all four columns)

Duration	phases	Disturbance	Magnitude
• Minutes and seconds	• Single • Two • Three	• Undervoltage • Overvoltage • Interruption	• Percentage • Per-unit

A three-minute, single-phase interruption.

A 2-minute, three-phase overvoltage of 1.2 per-unit.

Next time…

- Read chapters 1 and 2 in FPQ and PSQ if you haven't
  - Skim both texts to familiarize yourself with them
    - Information around pages 150, 153, and 197 in FPQ may help with HW1
- Investigation planning

Note: FPQ ch. 1 is a good review of distribution systems and apparatus.