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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 9

Today…

- Finish motor starting sags and mitigation
- Impacts of voltage sags and short interruptions on equipment:
  - Rectifier-based loads
    - Electronics
    - AC Drives
  - Motors
  - Relays, contactors

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Motor starting mitigation

- Wye-delta starters reduce starting current to 33% of the full-voltage value.
- What happens if we apply a wye-delta starter to the example in lecture 8?

$$Vmin := \frac{kVAst_{sc}}{kVAst_{sc} + 0.33 \cdot kVA_{LR}} = 0.932 \qquad Vmin = 93.231\,\%$$

The previous value was 81.97%

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Impact of "soft starting" the motor

- In our example, a voltage sag to 82% of nominal voltage is reduced to a "voltage fluctuation" or flicker of about 6.8%.
- How much flicker is acceptable?
  - Energy providers usually limit the maximum system fluctuation, or how much one can flicker the neighbor's voltage.
  - Providers usually also consider flicker when sizing service transformers and conductors.

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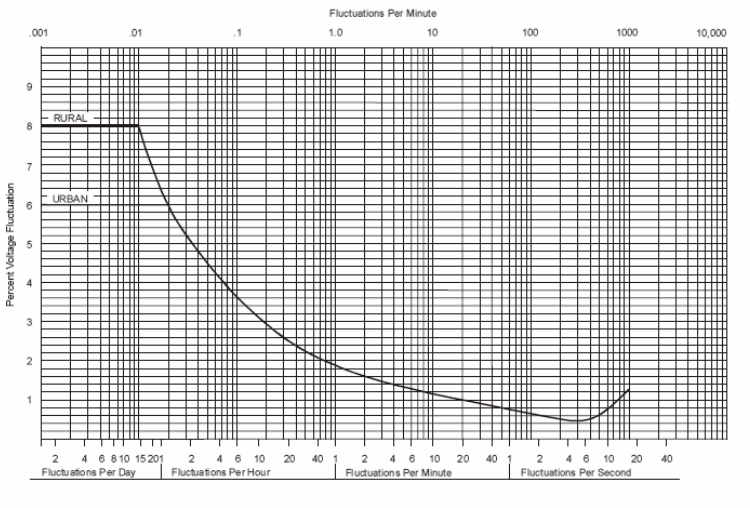
Allowable flicker – see PSQ p. 347-348, 512-519



Voltage Sag impacts: The switch-mode power supply - again

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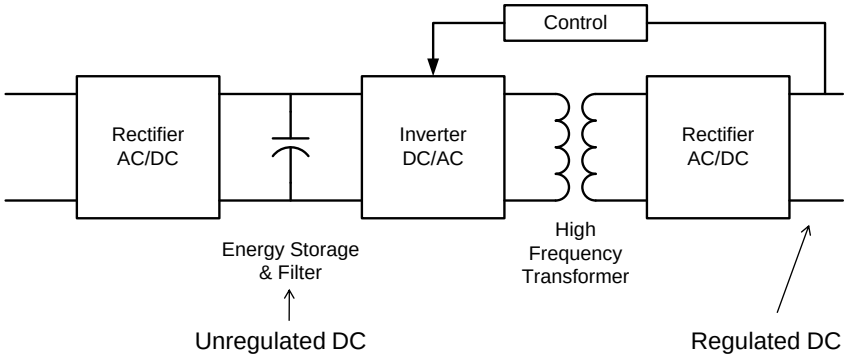

The issue is how low the unregulated DC bus voltage can get before the regulated DC bus voltage can no longer be maintained at an acceptable level

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Energy storage in capacitors

$$energy(J) = \frac{1}{2}CV^2$$

Energy (Joules) stored in a capacitor is a function of the size of the capacitor and the voltage across the capacitor.

$$V(t) = \sqrt{V_o^2 - \frac{2Pt}{C}}$$

Voltage at some time after discharging begins depends on the initial voltage, the power or load, the size of the capacitor, and the elapsed time (P=Watts, t=seconds)

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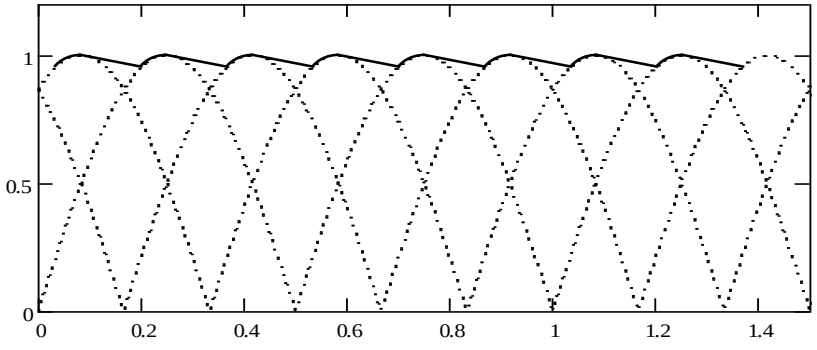
How voltage sags impact loads

- Rectifier-based loads: Normal



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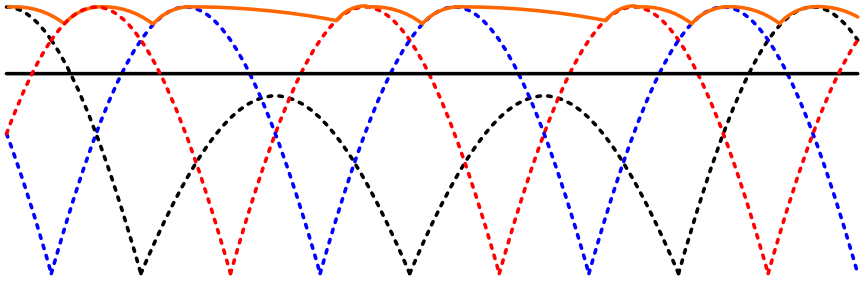
How voltage sags impact loads

- Rectifier-based loads: single-phase sag
  - Light load compared to capacitor size



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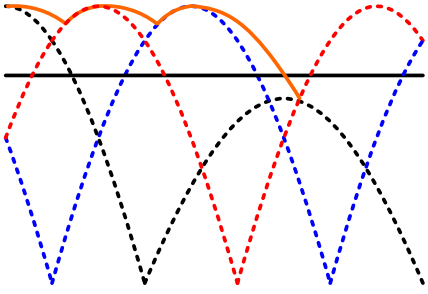
How voltage sags impact loads

- Rectifier-based loads: single-phase sag
  - More load, or smaller capacitor



Voltage on the unregulated DC bus drops below the minimum level necessary

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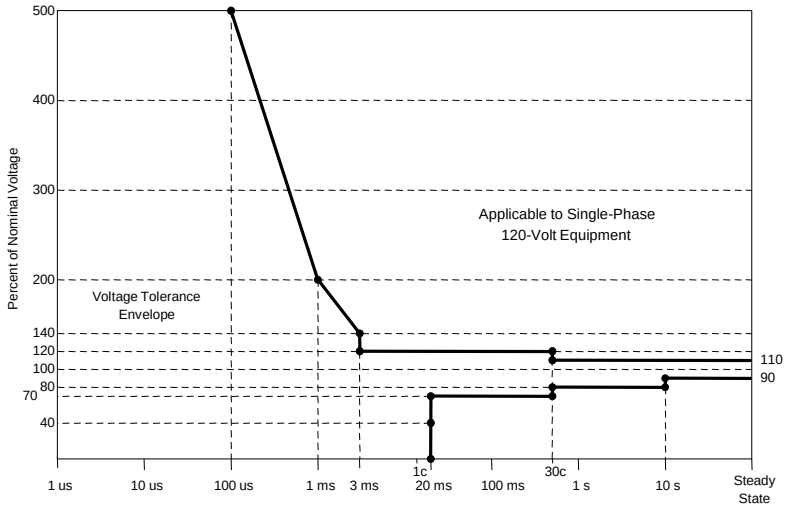
ITI Curve: Equipment "ride-through"



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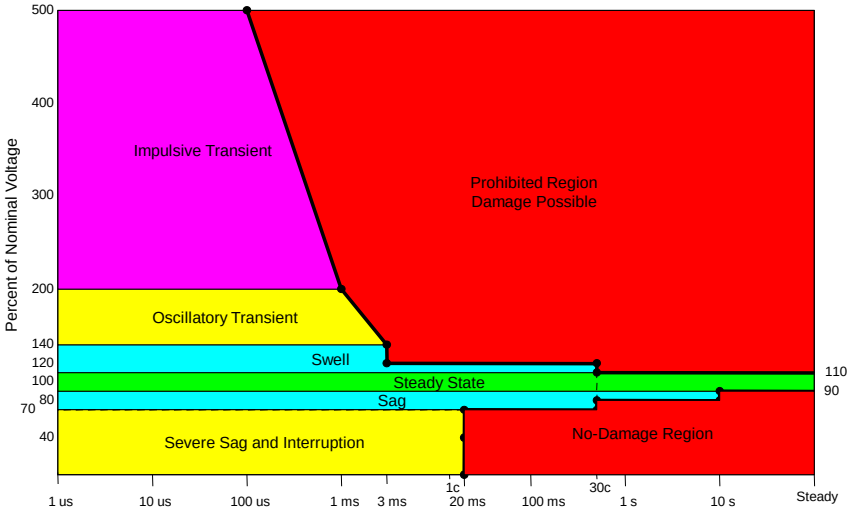
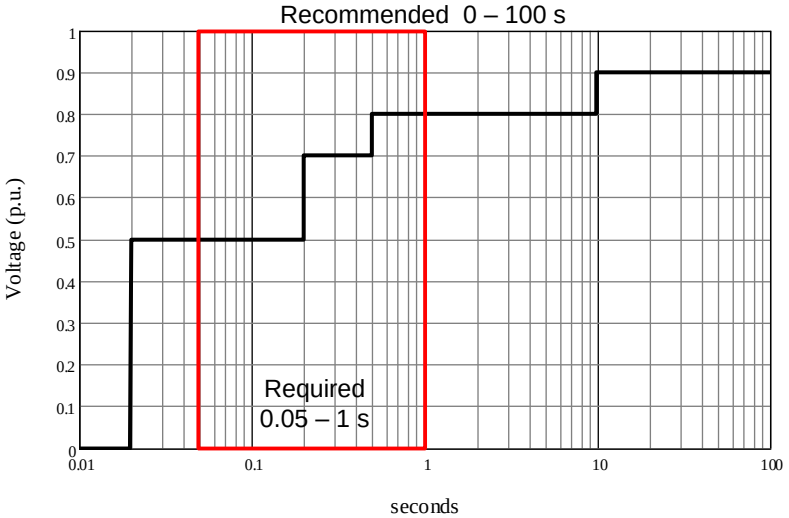
ITI Curve (Information Technology Industry Council)



SEMI F47 standard: equipment "ride-through"



Variable speed AC drives

- Issues associated with rectifier based loads apply
- Drive's control system may trip the drive:
  - Low DC bus voltage
  - Overcurrent – reduced voltage will increase current drawn by drive for same power output
  - Voltage imbalance
  - Current imbalance
- Post-sag inrush current may damage rectifier

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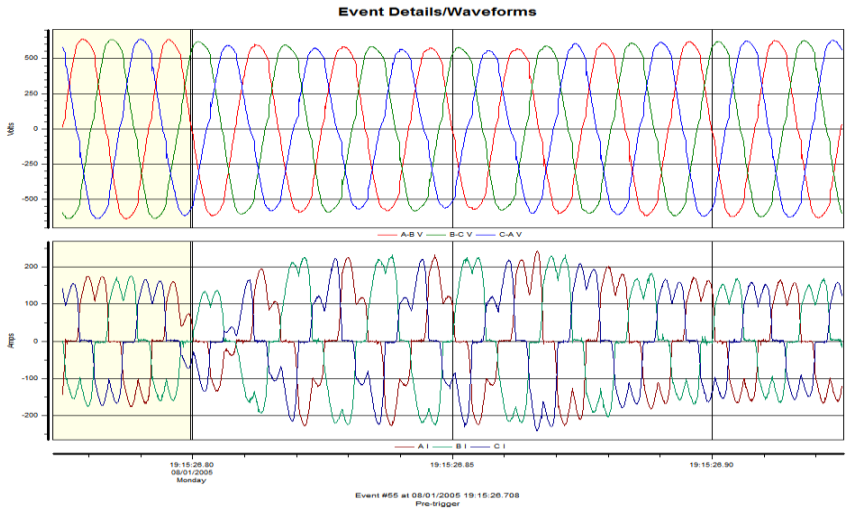
AC drive responding to a voltage sag



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Line-connected motors

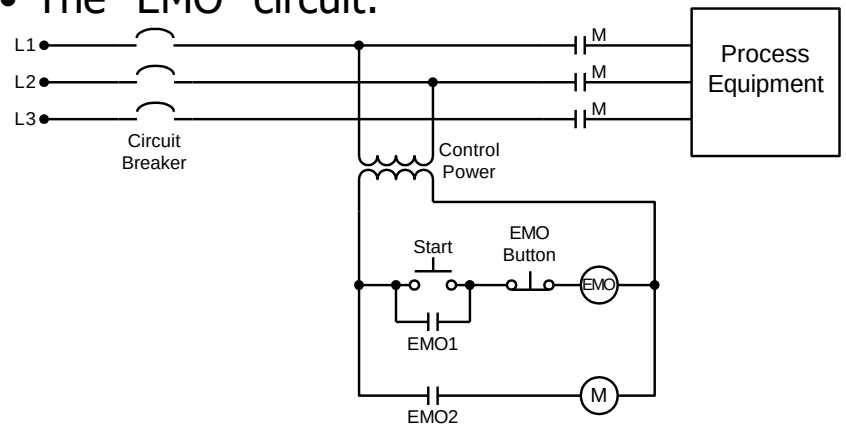
- Motors on the system will slow down during a voltage sag and need to re-accelerate.
- Re-accelerating motors increases the sag recovery time.

Typical voltage sag tolerance – IEEE 1346

Equipment	Upper Range	Average	Lower Range
PLC	20ms, 75%	260ms,60%	620ms, 45%
PLC I/O card	20ms, 80%	40ms, 55%	40ms, 30%
5hp AC drive	30ms, 80%	50ms, 75%	80ms, 60%
ac control relay	10ms, 75%	20ms, 65%	30ms, 60%
Motor starter	20ms, 60%	50ms, 50%	80ms, 40%
PC	30ms, 80%	50ms, 60%	70ms, 50%

How a voltage sag turns into an "outage"

- The "EMO" circuit:



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How a voltage sag turns into an outage

- "EMO" (Emergency Off) circuits may respond to a voltage sag as if someone pressed the emergency stop button.
- Emergency shutdowns are typically not orderly or controlled.
- Other equipment may keep running making it difficult to determine why some equipment tripped

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Economic Impacts

- Process outages
- Damaged products
- Lost time for restarting

Next time…

- More on the issue of post-sag damage to rectifiers
- Characterizing sags and sag performance
  - Standards and indices
- To do:
  - Read PSQ Chapter 3
  - Read FPQ Chapter 3 and 4
  - Work on homework 2