Power System Elements

System Loads

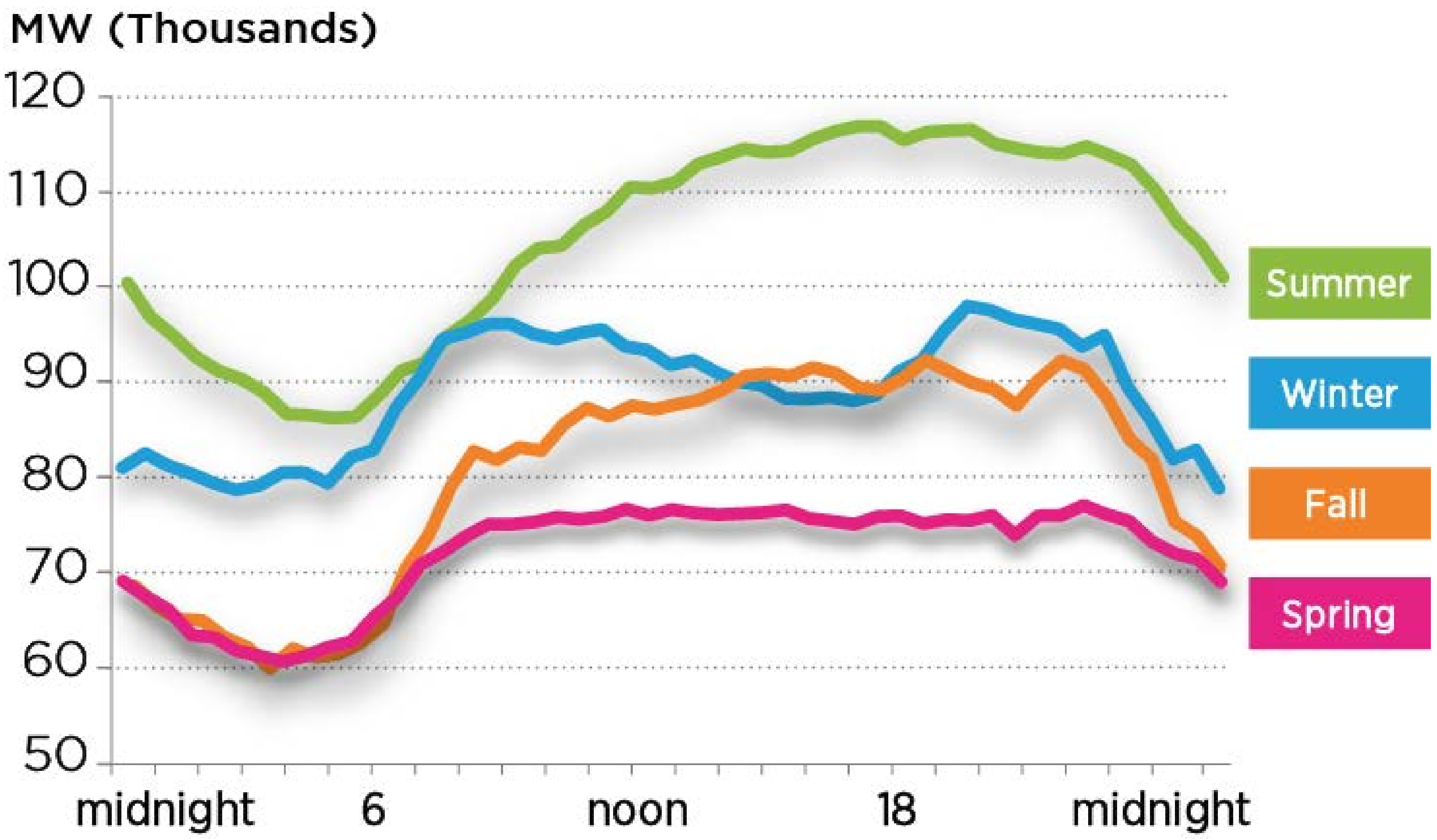
PJM State & Member Training Dept.

Objectives

Identify the different types of general load on the power system

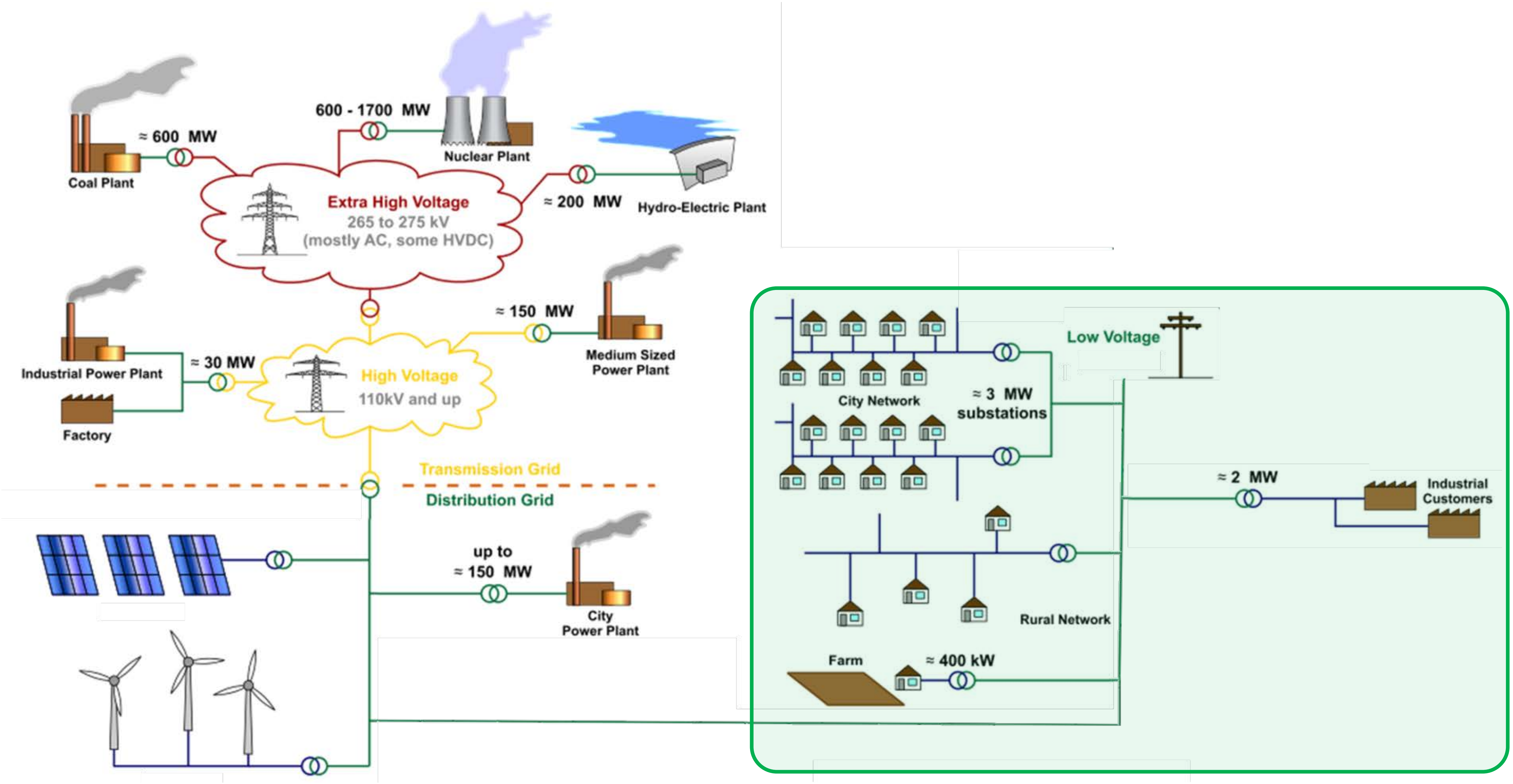
- Describe the characteristics of non-motor load on the power system
- Describe the characteristics of the motor loads on the power system
- Describe the effects of changing voltage has on the different load types

Load Curves

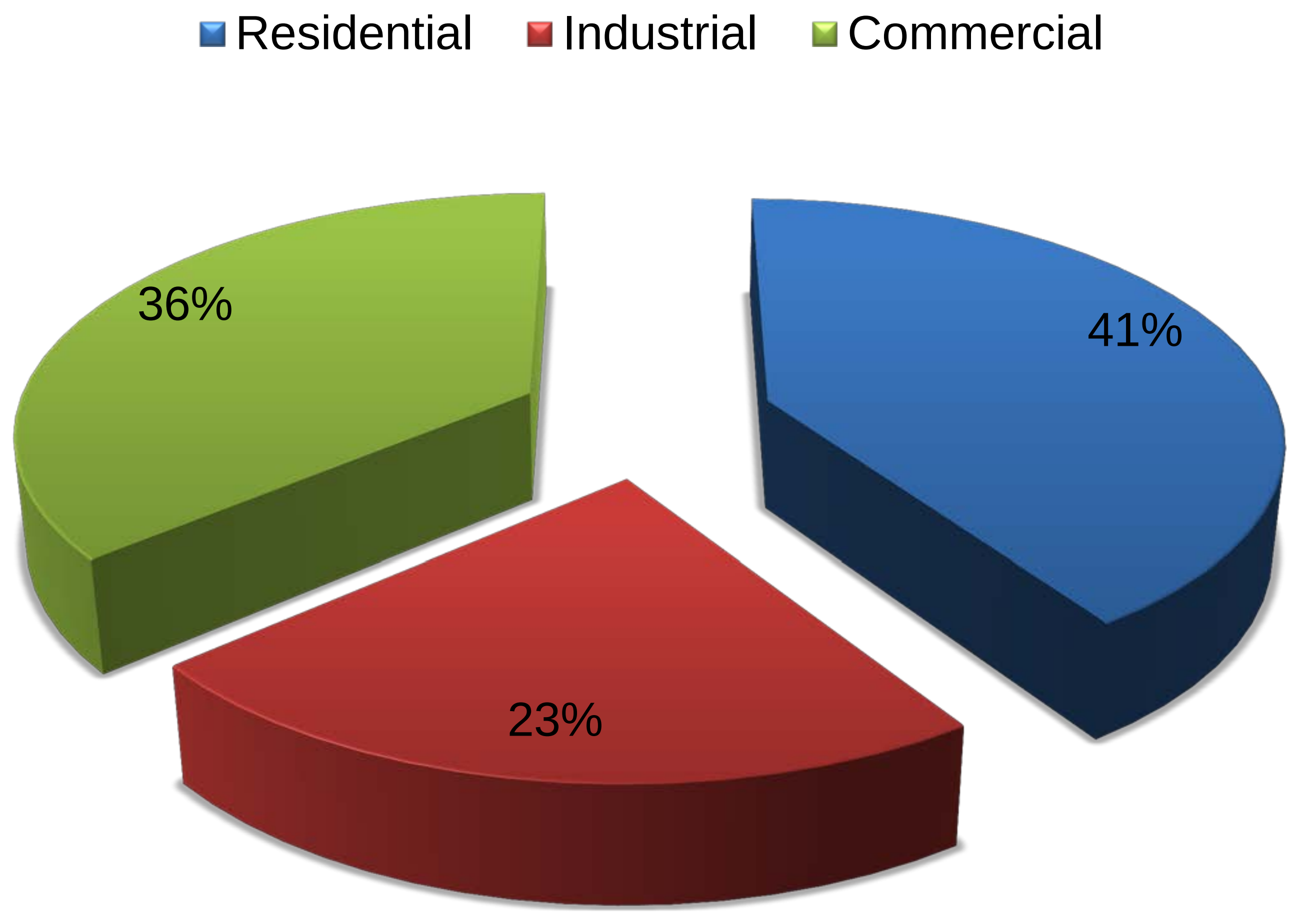


MW (Thousands)
120
110
100
90
80
70
60
50
midnight
6
noon
18
midnight
Summer
Winter
Fall
Spring

System Configuration



PJM's Load Profile*



*load profile is the average across the RTO as of 2014

General Types of System Loads

- **Non-Motor**
  - Lighting
    - Incandescent, fluorescent, etc.
  - Heating
    - Water heating, resistance heating. etc.

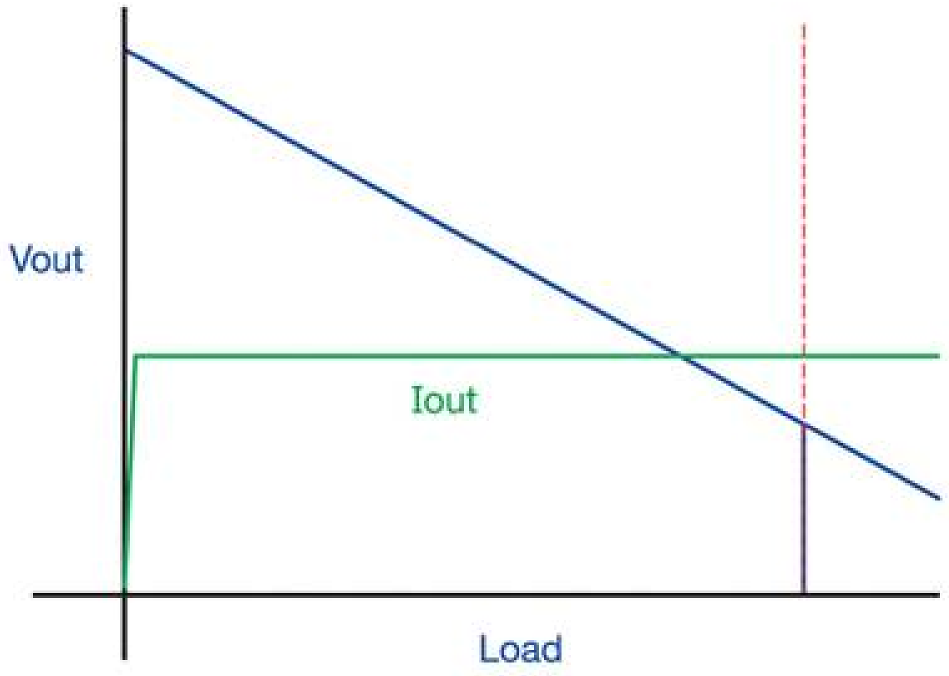
Non-Motor Load

Load magnitude varies with voltage magnitude

- Two general classifications
  1. **Constant Current Load**
     - Varies directly with the voltage
  2. **Constant Resistance/Impedance Load**
     - Varies with the square of the voltage

Non-Motor Load – Constant Current Load

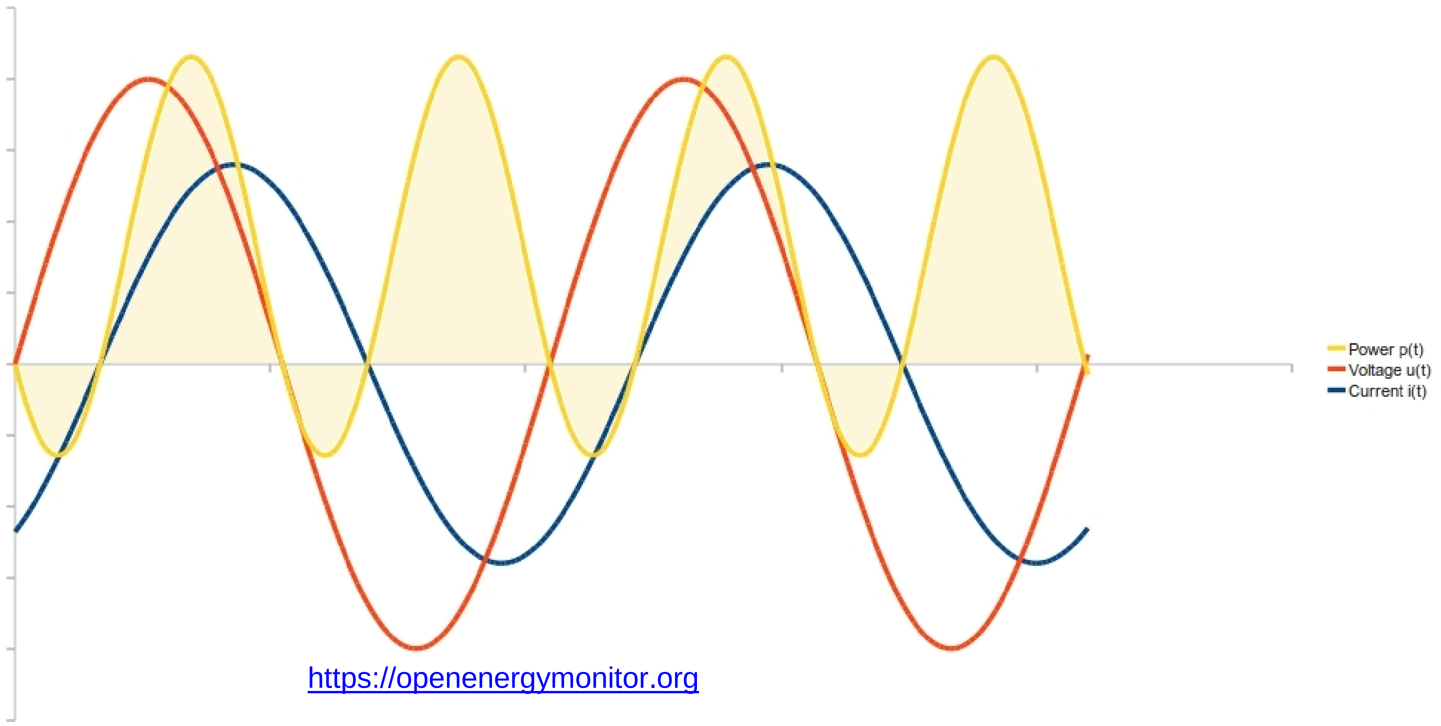
- Current remains constant with fluctuations in voltage so Power is variable
- This is a very rare load on the system
  - Custom designed circuitry for loads that require a constant current



http://www.digikey.com/

Non-Motor Load – Constant Resistance/Impedance Load

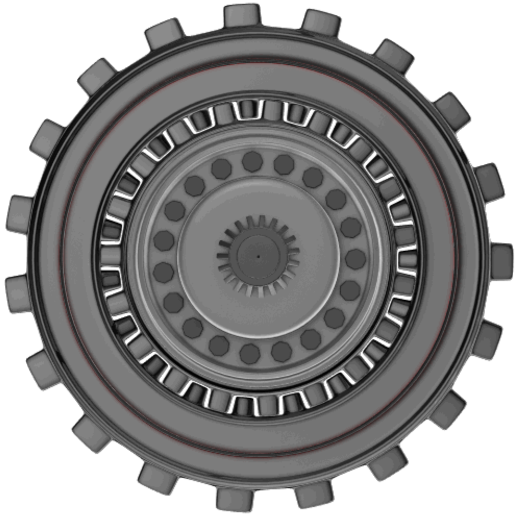
- Impedance remains constant as current or voltage changes
- Most non-motor loads on the system appear as constant impedance
  - However every load has slightly different characteristics



https://openenergymonitor.org

General Types of System Loads

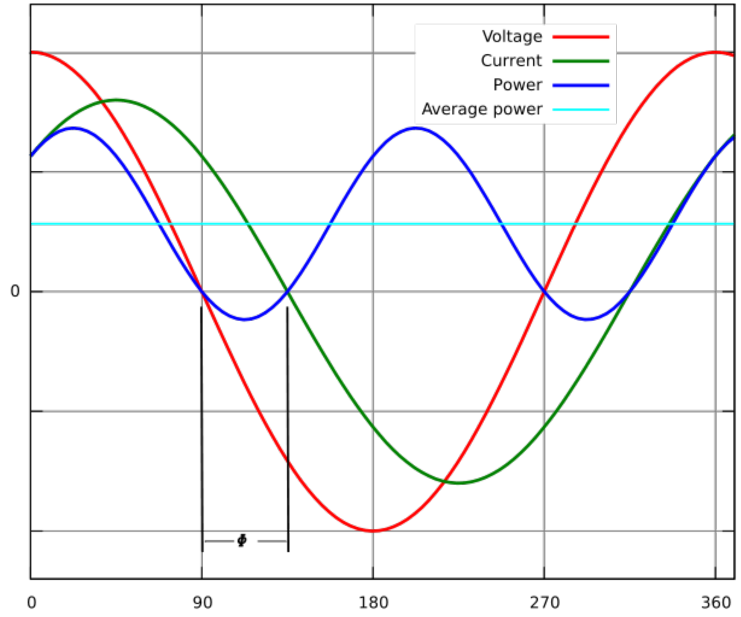
- **Motors**
  - Induction
    - Most popular type
    - Air Conditioners, freezers, washers, fans, pumps, etc.
  - Synchronous



Motor Load

Motor Load – makes up a large portion of total load **(typically 40% to 60%)**

- Classified as **Constant Power Load**
- Often motors are of the induction type
- Favored due to simplicity and ruggedness
- Requires large amount of reactive power to start



http://www.overunityresearch.com

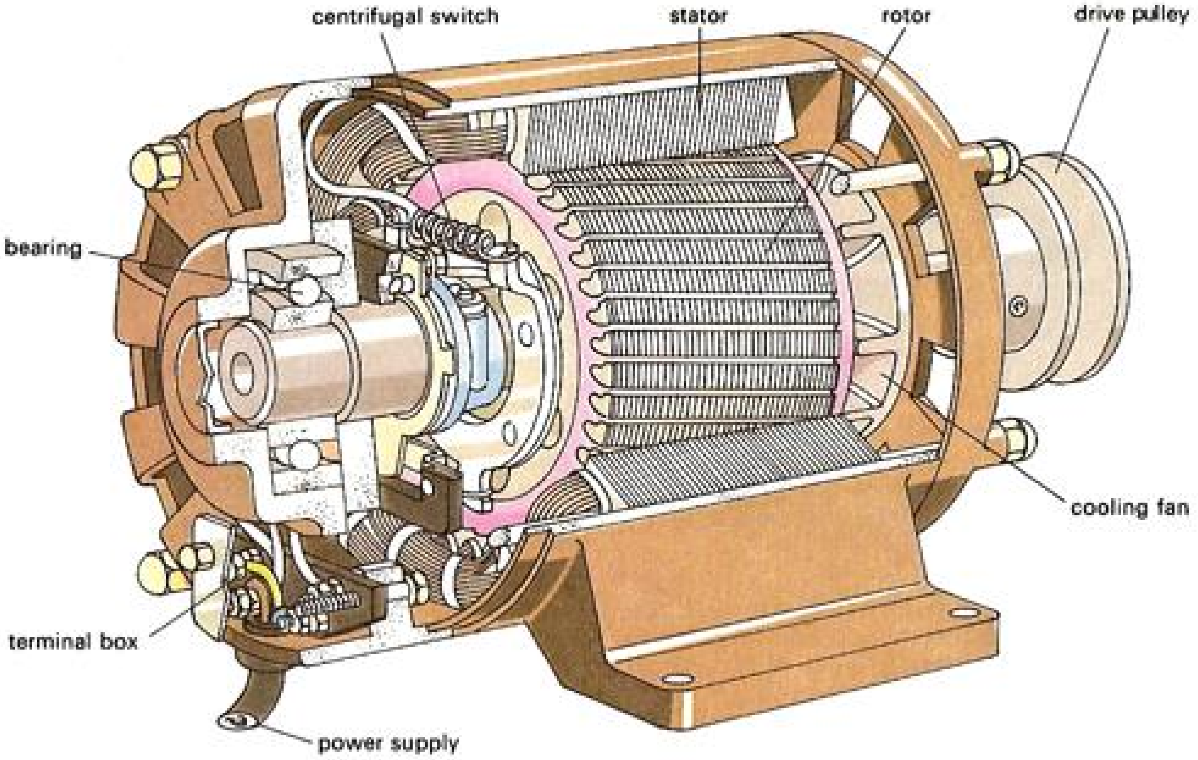
Motors

- Stator windings are distributed around the stator
- Three-phase AC voltages are applied to the stator windings
- An electric current is induced in the rotor bars
- Magnetic field of the stator drags the rotor around
- Rotor falls behind or “slips” as the field rotates

Induction Motor Video

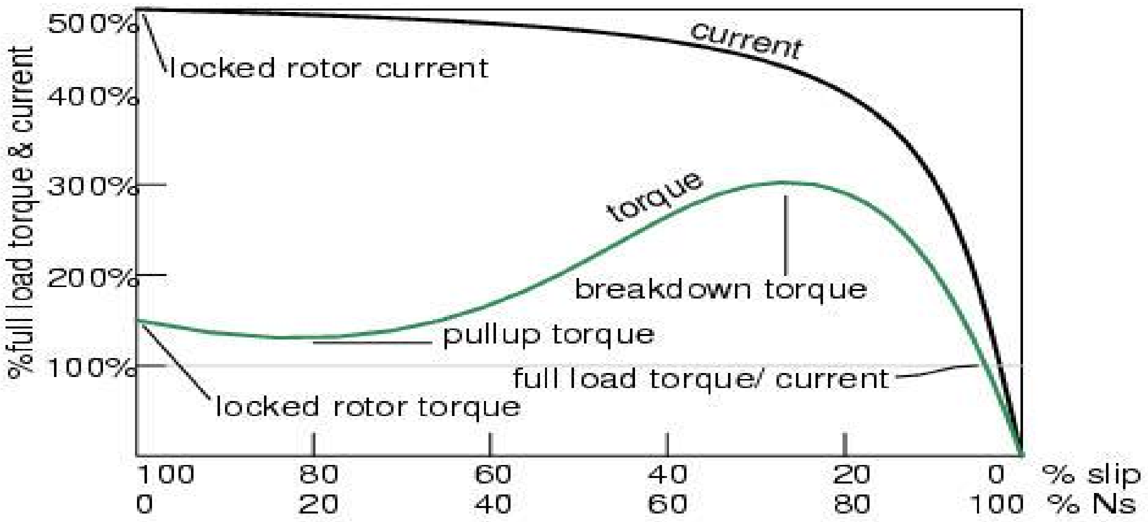
Motors

- The rotor slots on a squirrel cage rotor are not exactly parallel to the shaft. They are skewed for two main reasons:
  - To make the motor run quietly by reducing magnetic hum
  - To help reduce the locking tendency of the rotor
- Almost 90% of three-phase AC induction motors are of the squirrel cage rotor type



Characteristics of Motors

- Induction motors at rest appear just like a short circuited transformer
- Draws a very high current called **"Locked Rotor Current" (LRC)** when started
- The LRC of a motor can be as high as 500% of full load current (FLC)



Characteristics of Motors

The current drawn by a motor has two components:

1. **Reactive (magnetizing current)** – dependent on stator voltage
   - Can vary from as low as 20% of FLC to as high as 60% of FLC
2. **Active (working current)** – directly proportional to the load

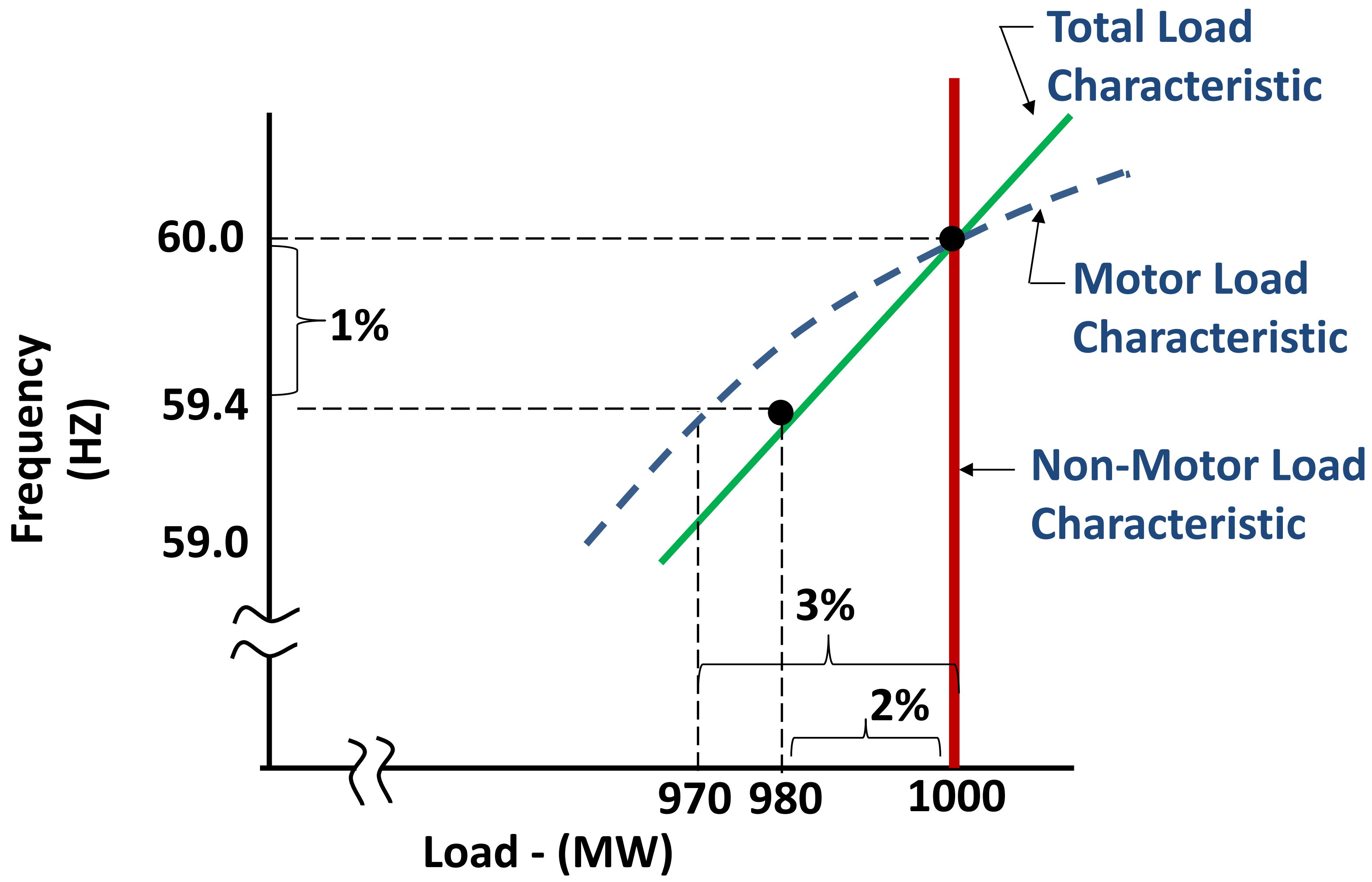
Characteristics of Motors

- Motor load does not significantly vary with voltage magnitude
  - Tries to maintain the same power output as voltage drops
- If voltage drops to 80% or less of rated there is a chance motors will slow down or “stall”
- Combined reactive power draw of numerous stalled motors could prevent system voltage from recovering

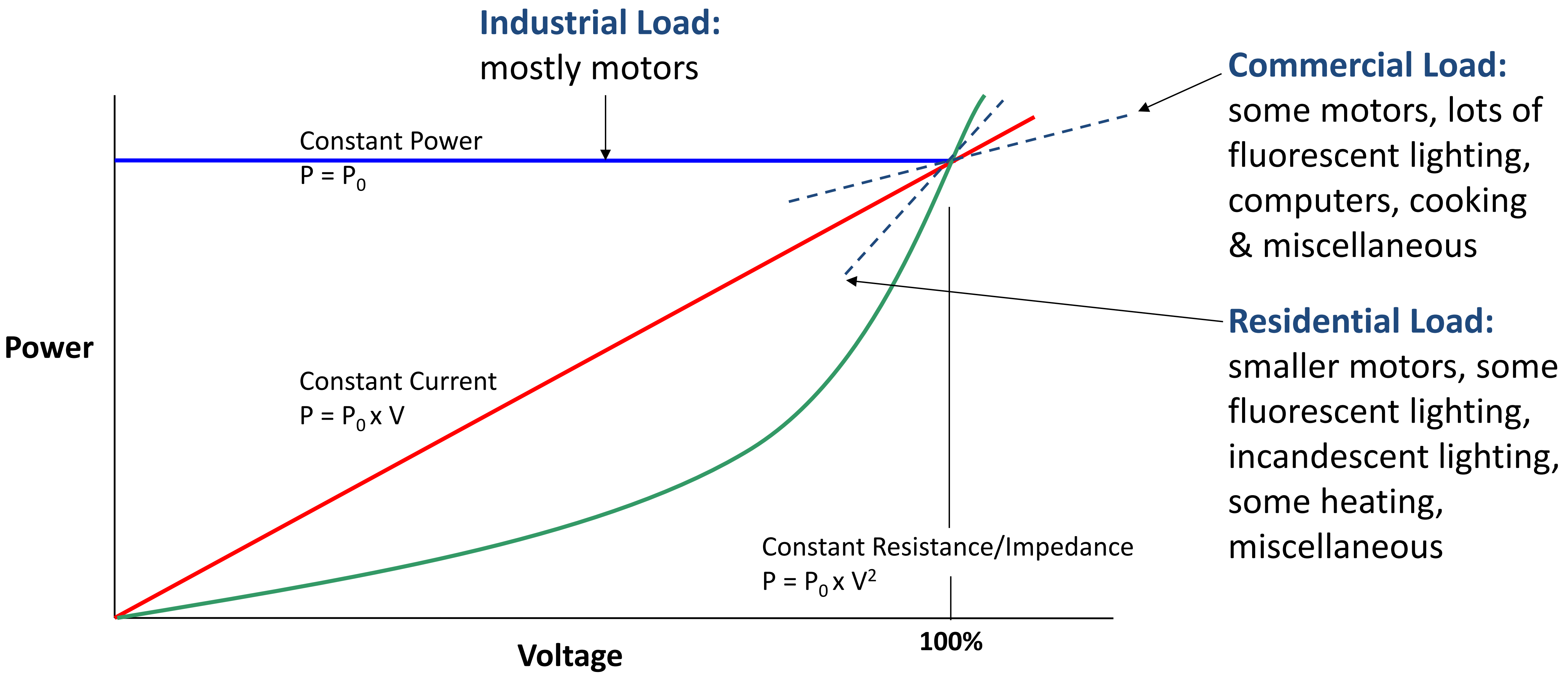
Effect of Frequency on Load

- **Non-Motor Load**
  - More dependent on voltage than frequency
  - For all intensive purposes we could say that non-motor load does not vary with frequency
- **Motor Load**
  - More dependent on frequency than voltage
  - Rule of thumb is for a 1% drop in frequency, motor load will decrease by 3%

Effect of Frequency on Load



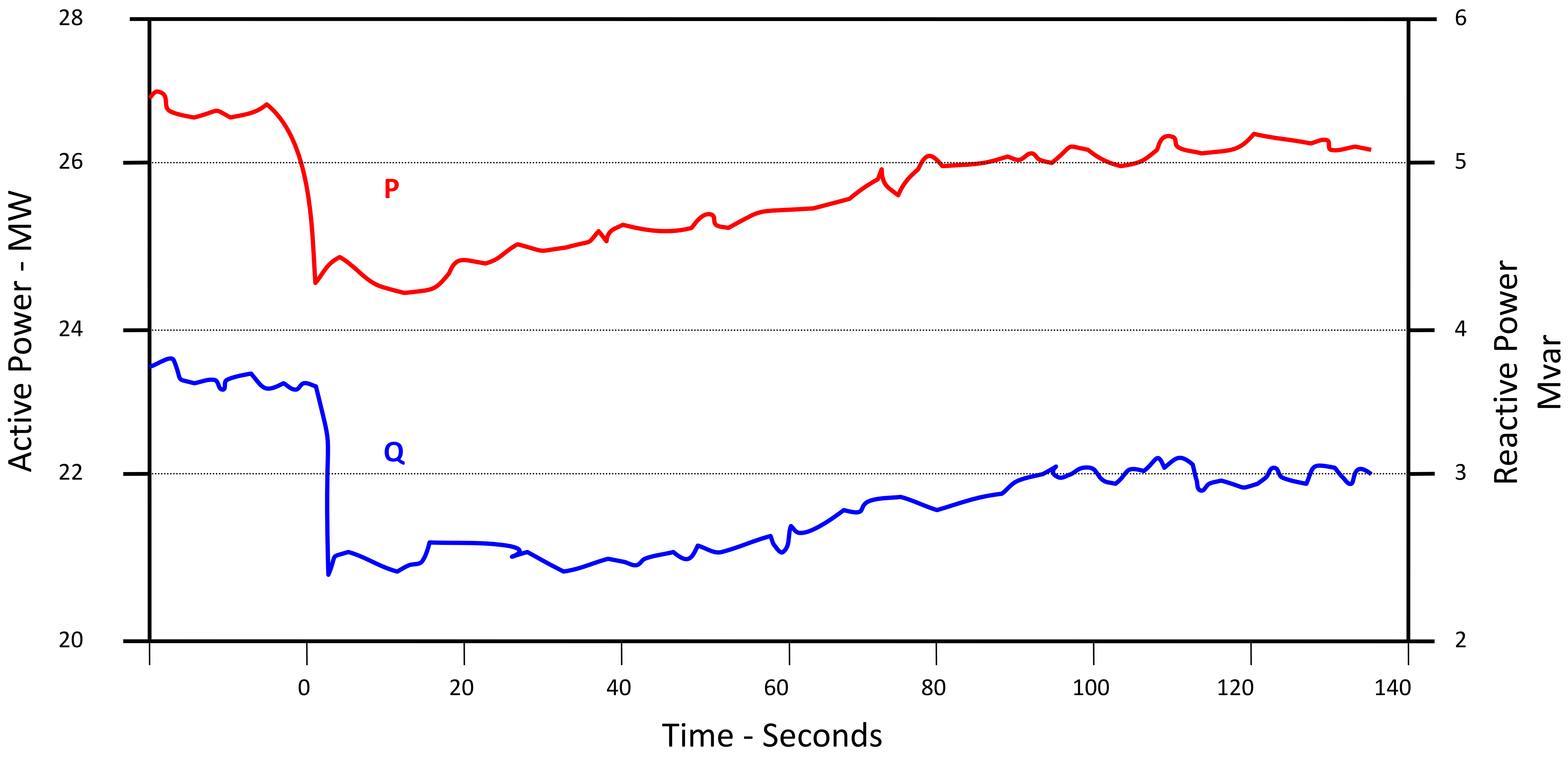
Effect of Voltage on Loads



Effect of Voltage on Loads

- Total System Load reduction due to a decrease in voltage
  - A rule of thumb is that for a **5% percent reduction in voltage** you will see approximately a **3% reduction in system load**

Effect of Time on Load Magnitude



Load Diversity

- Prolonged periods of low voltage will lead to loss of load diversity
  - During low voltage the output of a heater will reduce
  - This causes more heating units to be on or stay on longer to maintain the same temperature
  - More heaters operating and for longer periods will eventually cause an increase in total system load

Summary - Load

- Two types of system load are Motor and Non-motor
- Non-motor load has two classifications: Constant current and constant resistance/impedance
- Non-motor load tends to vary with voltage
- Motor load tends to remain constant (Constant Power)
- At start up or when recovering from a stall, motors can draw 5 to 8 times their normal MVARs

Summary - Load

- Motor load attempting to return from a stalled condition can prevent system voltages from recovering

- Extended periods of low voltage can lead to loss of load diversity

- Loss of load diversity results in an increase of system load

- For a mix of motor and non-motor load, the total customer load on the system will decrease by 3% for a 5% drop in voltage

Questions?

PJM Client Management & Services

Telephone: (610) 666-8980

Toll Free Telephone: (866) 400-8980

Website: www.pjm.com

The Member Community is PJM's self-service portal for members to search for answers to their questions or to track and/or open cases with Client Management & Services

Resources and References

- Clark, H. (2004). *Voltage and Reactive Power for Planning and Operation*.
- Freescale. (2004-2013). *Motor Control Tutorial*. Retrieved from http://www.freescale.com/webapp/sps/site/training_information.jsp?code=WBT_MOTORCONTROL_TUT#