Power System Fundamentals

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

Types of System Loads

- General Types of System Loads
  - Non-Motor
    - Lighting
      - Incandescent, fluorescent, etc.
    - Heating
      - Water heating, resistance heating. etc.
  - Motors
    - Induction
      - Most popular type
      - Air Conditioners, freezers, washers, fans, pumps, etc.
    - Synchronous

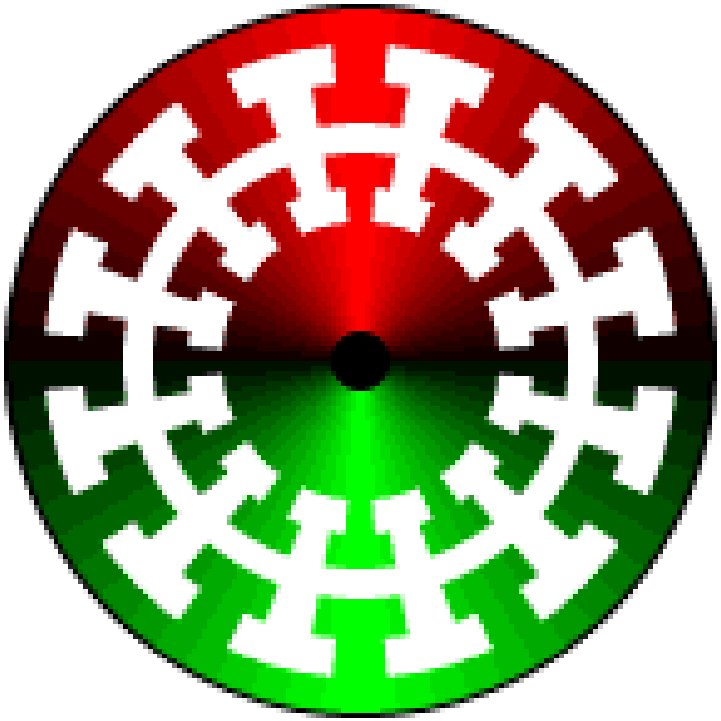
Non-motor Load

- Load magnitude varies with voltage magnitude
- Two general classifications
  - **Constant Current Load**
    - Varies directly with the voltage
  - **Constant Resistance/Impedance Load**
    - Varies with the square of the voltage

Motor Load

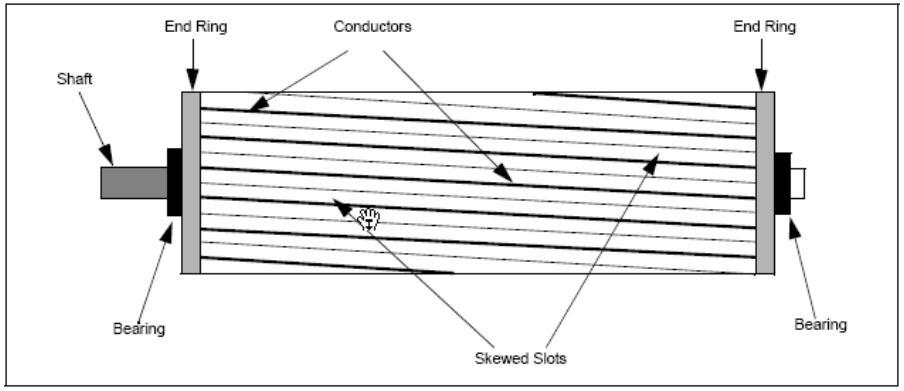
- Motor Load – makes up a large portion of total load (typically 40% to 60%)
  - Classified as **Constant Power Load**
  - Often motors are of the induction type
  - Favored due to simplicity and ruggedness
  - Requires large amount of reactive power to start

Motors



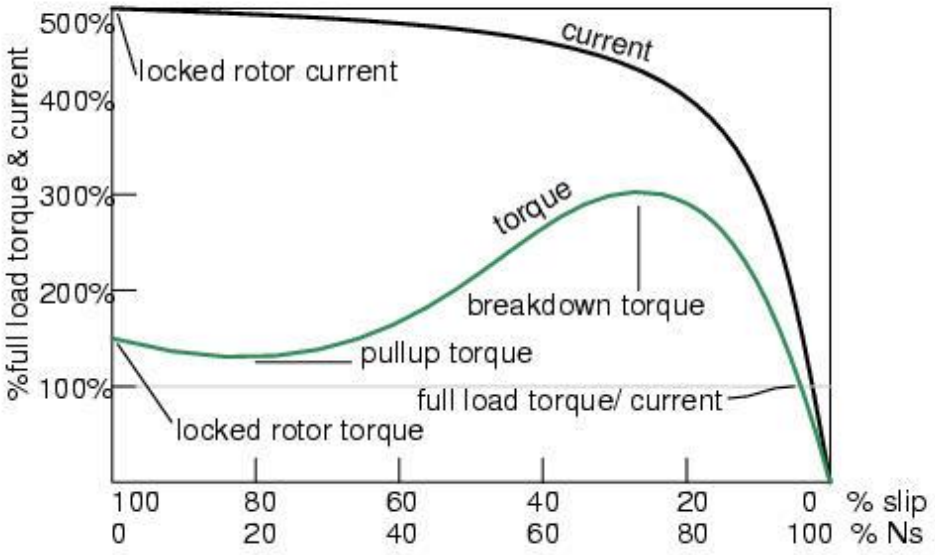
- Stator windings are distributed around the stator
- Three-phase AC voltages are applied to the stator windings
- An electric current is induced in the rotor bars
- Magnetic field of the stator drags the rotor around
- Rotor falls behind or “slips” as the field rotates

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



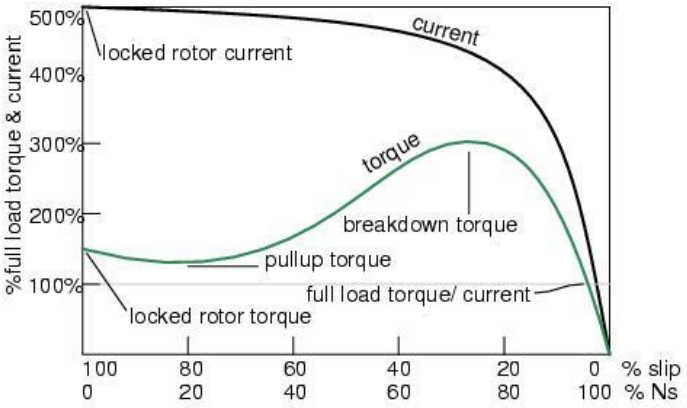
- Induction motors at rest appear just like a short circuited transformer
- Draws a very high current called “Locked Rotor Current” (LRC) when started
- The LRC of a motor can be as high as 500% of full load current (FLC)

Characteristics of Motors

- The current drawn by a motor has two components:
  - Reactive (magnetizing current) – dependent on stator voltage. Can vary from as low as 20% of FLC to as high as 60% of FLC
  - Active (working current) – directly proportional to the load

Characteristics of Motors

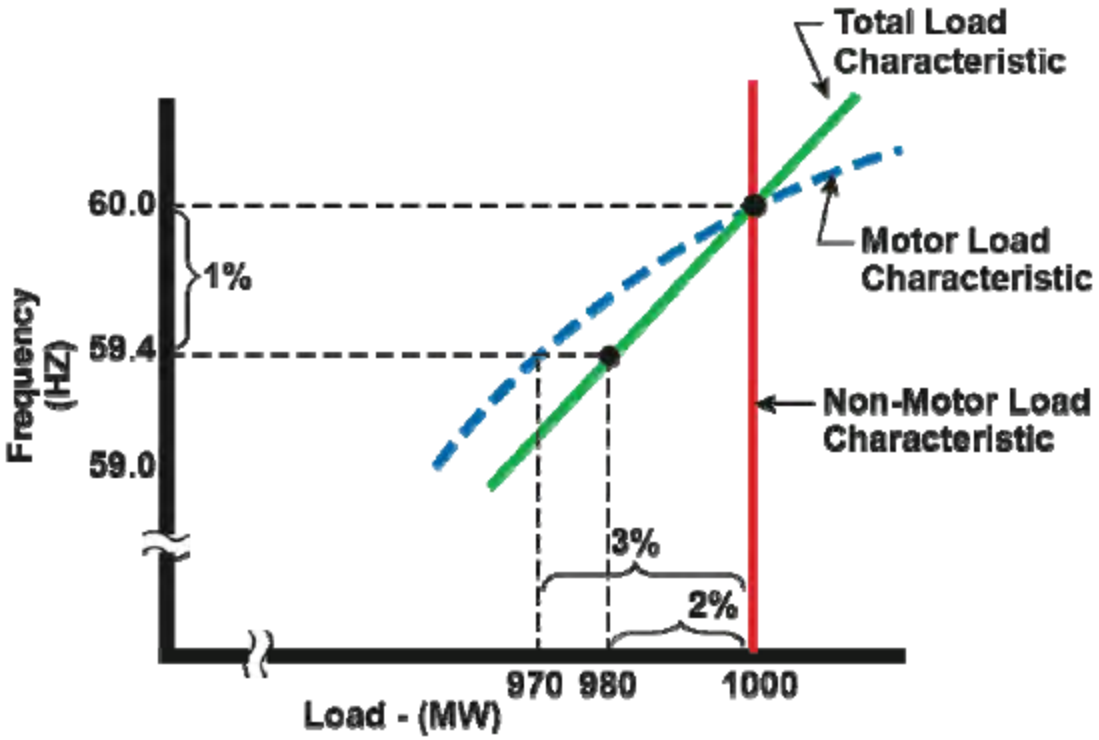
- Motor load does not significantly vary with voltage magnitude
  - Tries to maintain the same power output as voltage drops
- If voltage drops to 80% or less of rated there is a chance motors will slow down or “stall”
- Combined reactive power draw of numerous stalled motors could prevent system voltage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



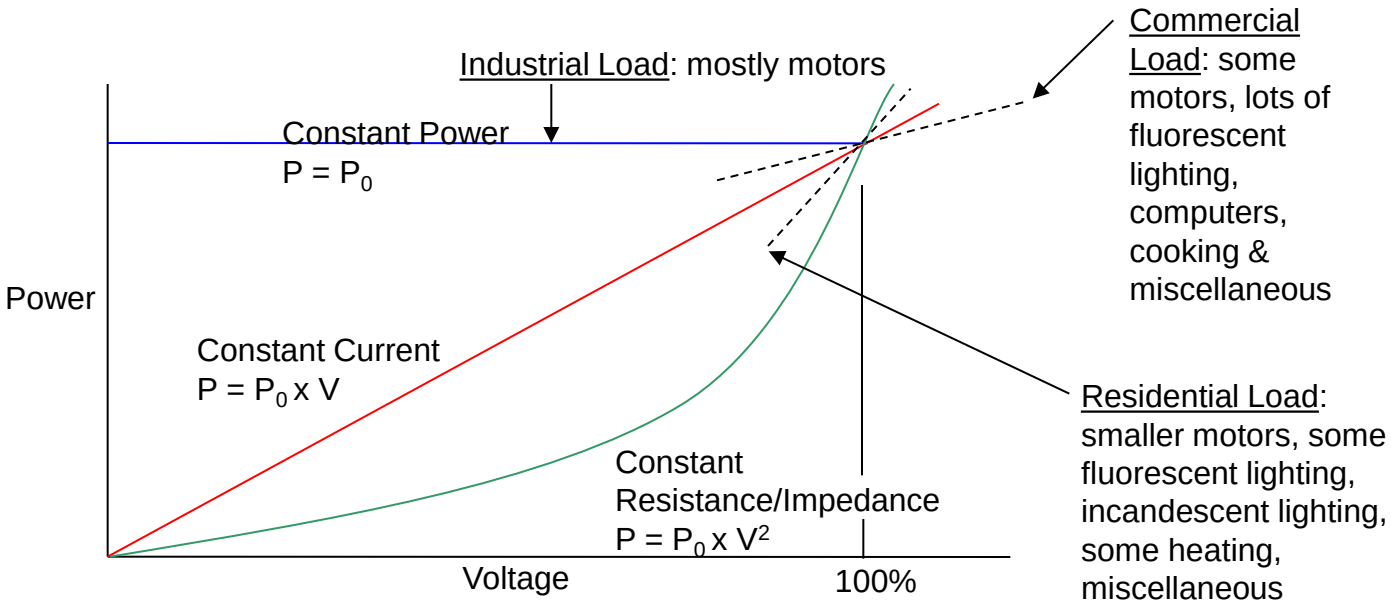
Effect of frequency on load

- 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



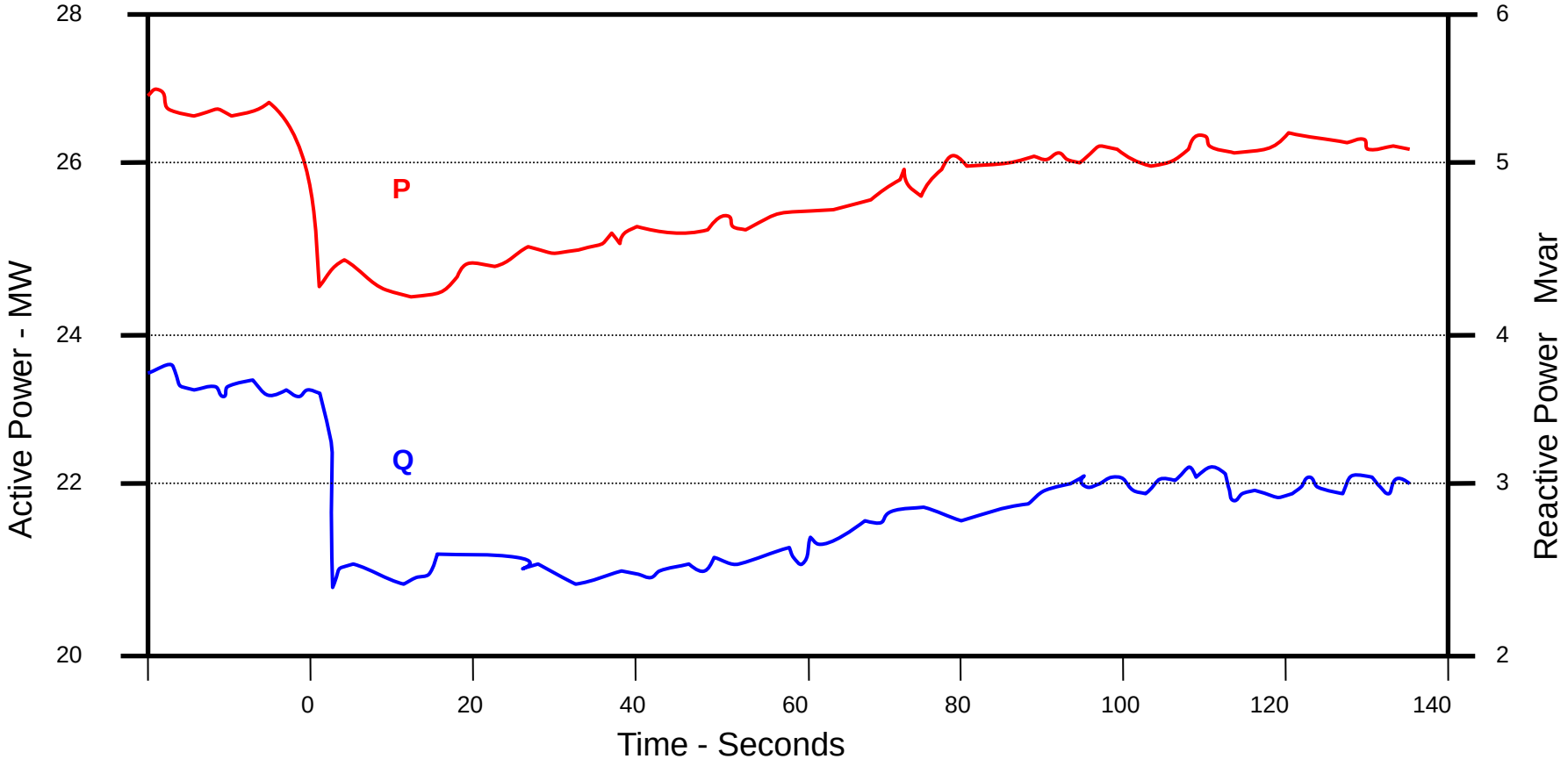
Effect of Voltage on Loads



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?

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For additional detailed information on any of the topics discussed, please refer to the appropriate PJM manual which can be found by accessing: http://www.pjm.com/documents/manuals.aspx

Resources and References

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