Understanding Power Factor

Presented by
Scott Peele PE

Progress Energy

Understanding Power Factor

- Definitions
  - kVA, kVAR, kW, **Apparent Power vs. True Power**
- Calculations Measurements
- Power Factor Correction
  - Capacitors
- System Impacts
  - I^2 R losses, Chapter 9 NEC
  - Equipment sizing
- Power Factor Charges
- Problems with adding Caps
  - Harmonic resonance
  - Volt rise
- Power Factor vs Load Factor

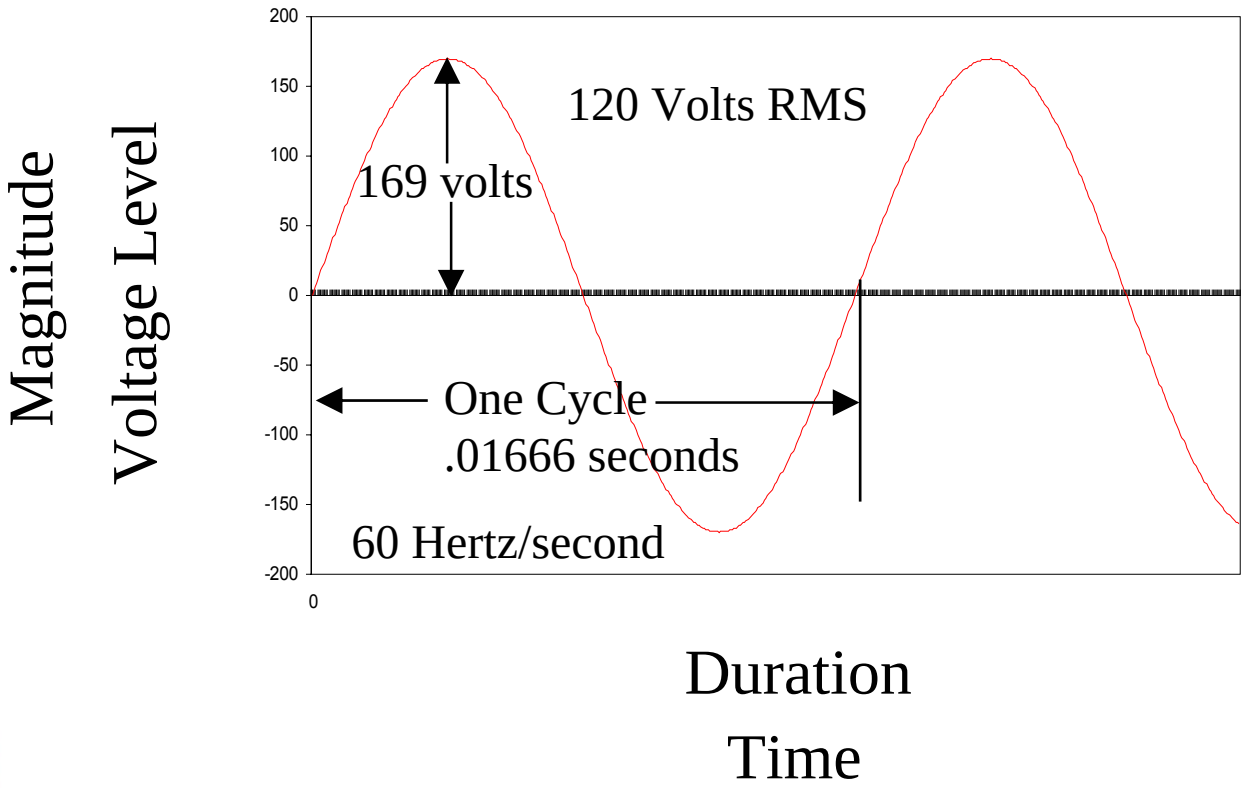
Progress Energy

What is Power Factor

Power Factor is the cosine of the phase angle between current and voltage.

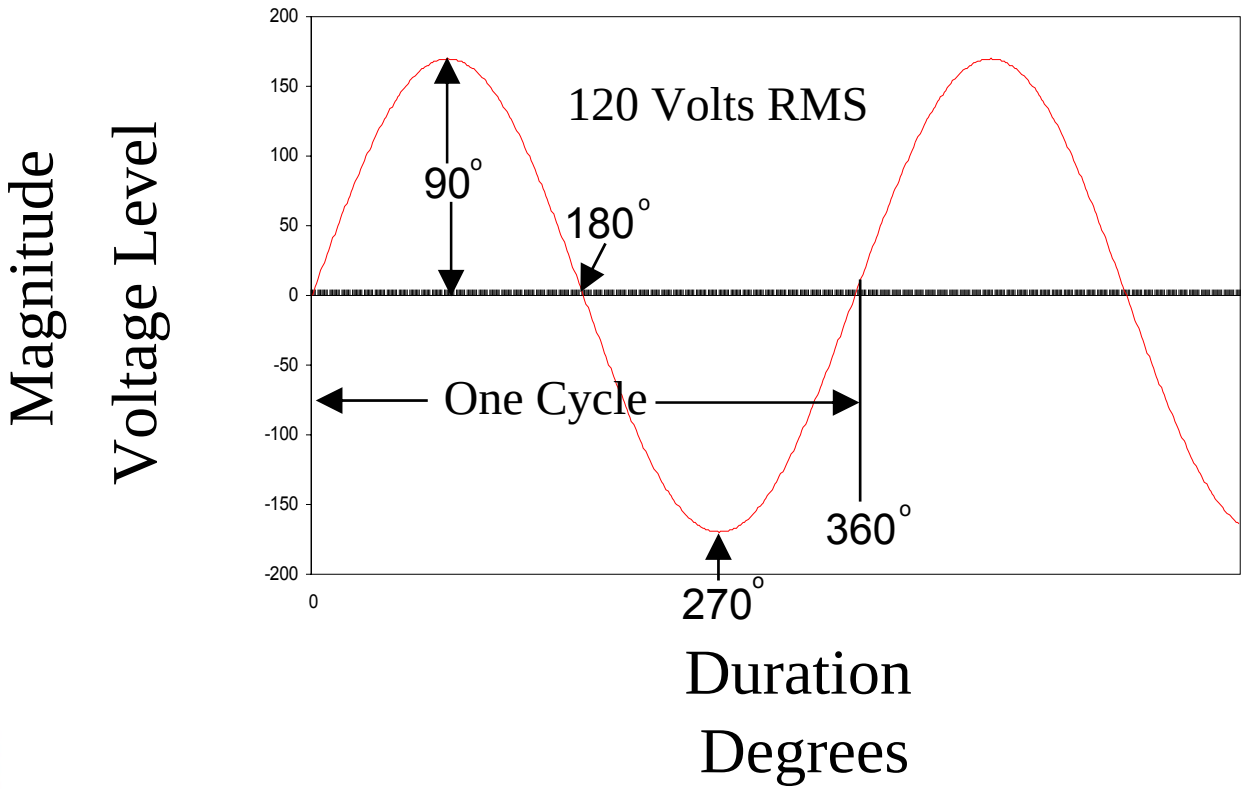
Power Factor is the ratio of true power to apparent power.

Understanding Alternating Current AC



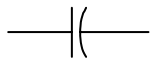
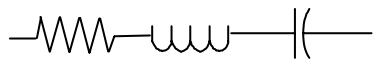
Progress Energy

Phase Angle



Progress Energy

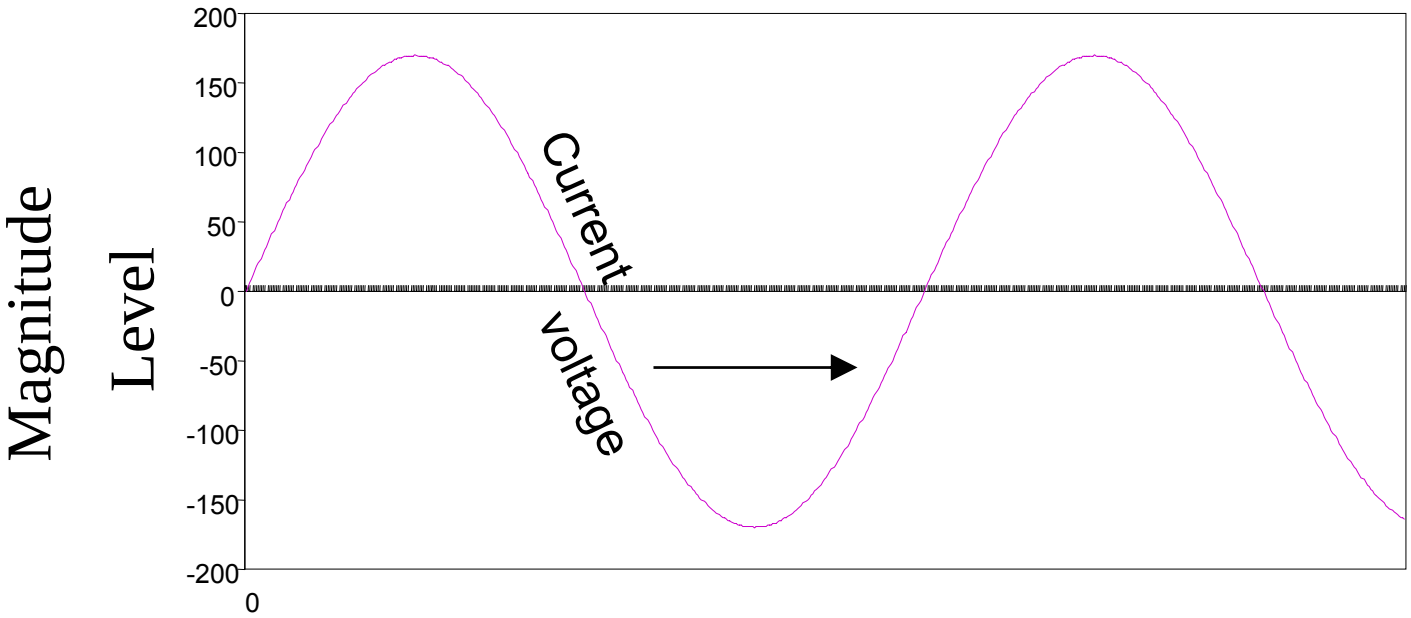
Three Basic Circuits or Loads

- Resistive 
- Inductive 
- Capacitive 
- Or any combination
  - Resistive Inductive
  - Inductive Capacitive 
  - Resistive Capacitive
  - Resistive Inductive Capacitive

Types of Loads

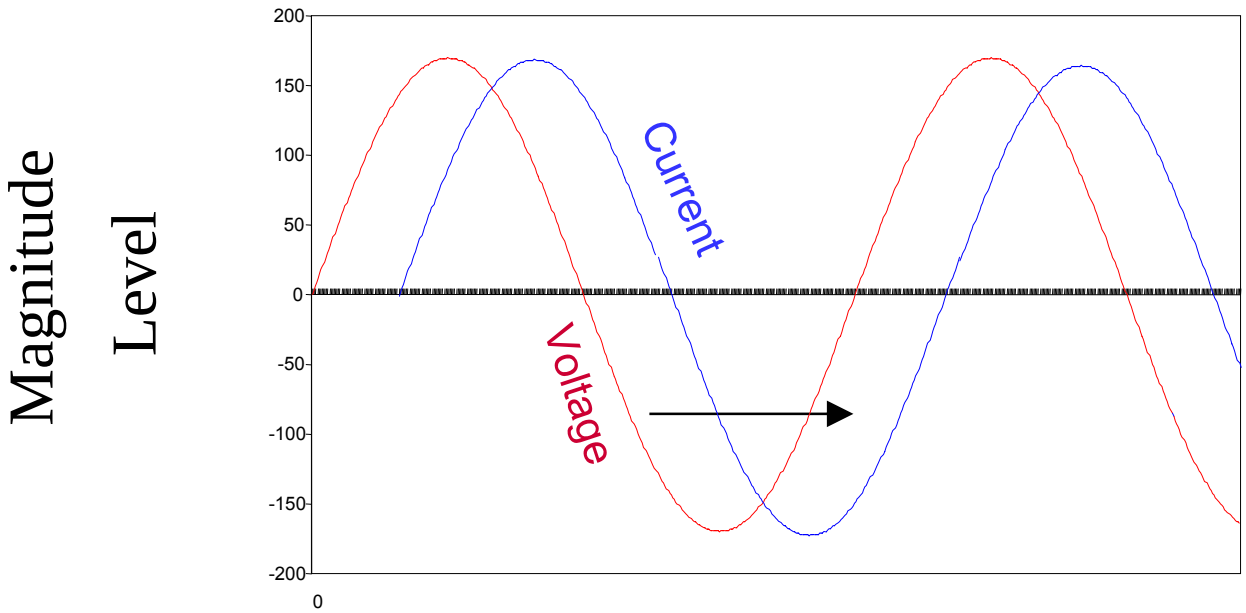
- Resistive – Incandescent Lamp Resistance heat
- Inductive – Motors – Contactor Coils – Relays (coils)
- Capacitive – Capacitors – Start Capacitors – Run Capacitors – Power Factor Correction Capacitors

Resistive Loads
In Phase



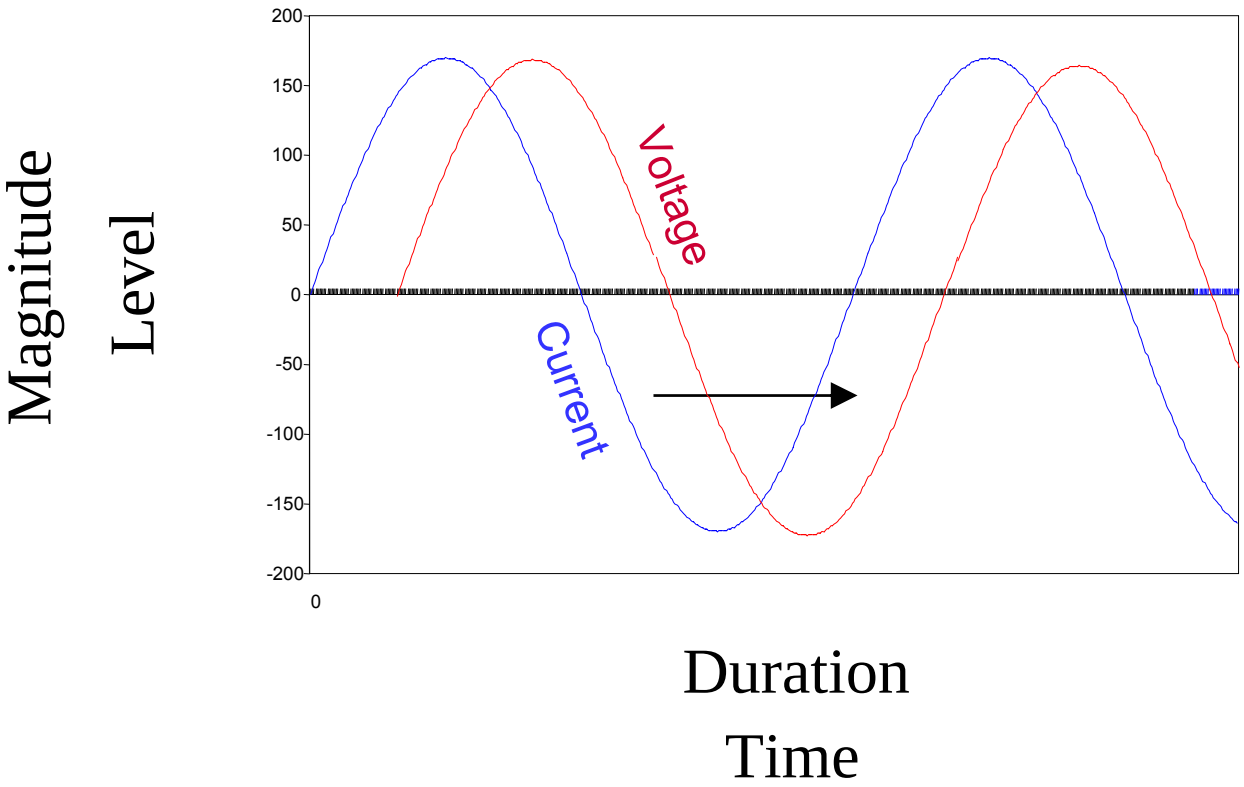
Progress Energy

Inductive Loads
Lagging



Progress Energy

Capacitive Loads
Leading

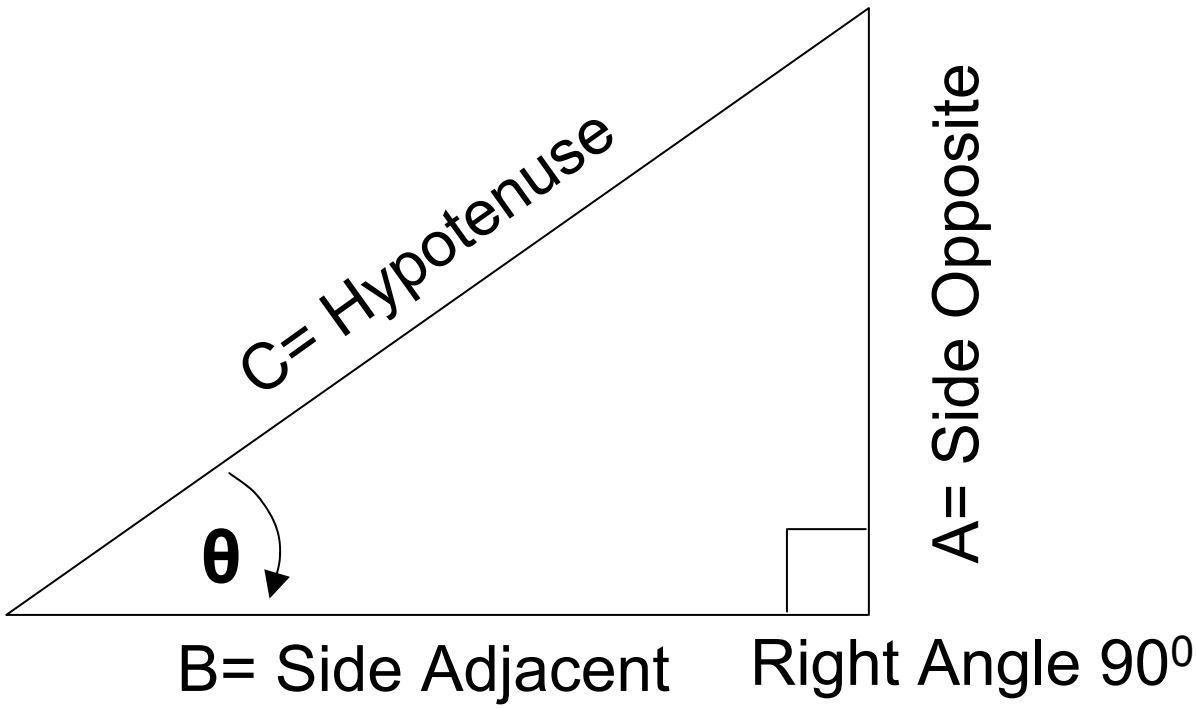


Progress Energy

What is Power

- Power is measured in Watts.
- Volts X Amps X Power Factor = Watts
- Watts only equals Volts X Amps when the Power Factor is 1 or unity.
- Most of the time the Power Factor is less than 1.
- Power = Watts : True Power
- Volts X Amps = VA : Apparent Power

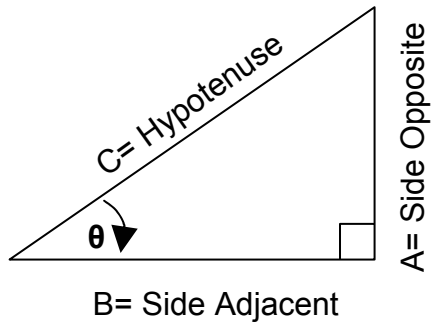
Understanding Right Triangles



Power Triangle

$$\text{Power Factor} = \frac{\text{True power}}{\text{Apparent power}}$$

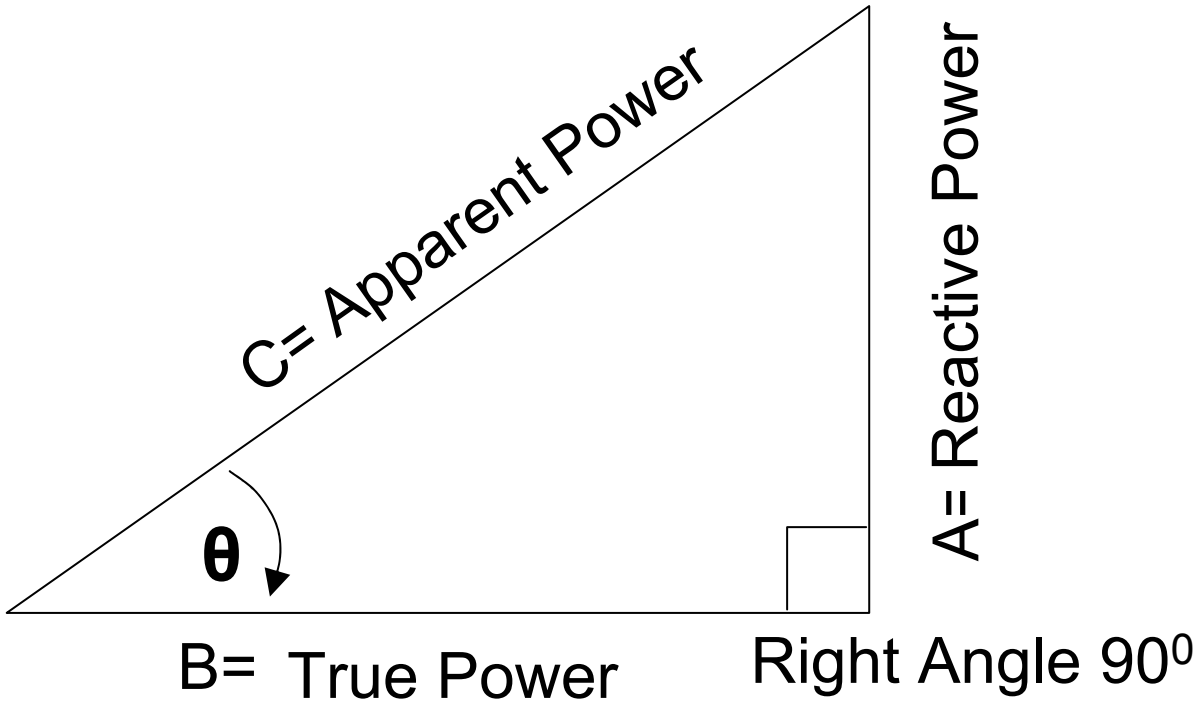
$$\text{Cos } \theta = \frac{\text{Adjacent side}}{\text{Hypotenuse}}$$



$$\text{Power Factor} = \text{Cos } \theta$$

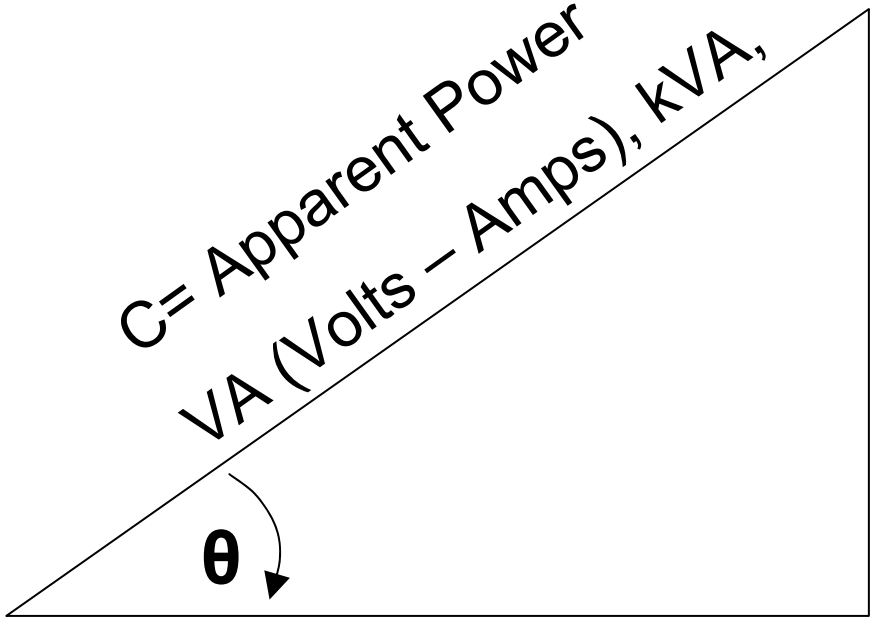
Progress Energy

$$\text{Power Factor} = \frac{\text{True power}}{\text{Apparent power}}$$



Progress Energy

Understanding Power Triangle



A= Reactive Power

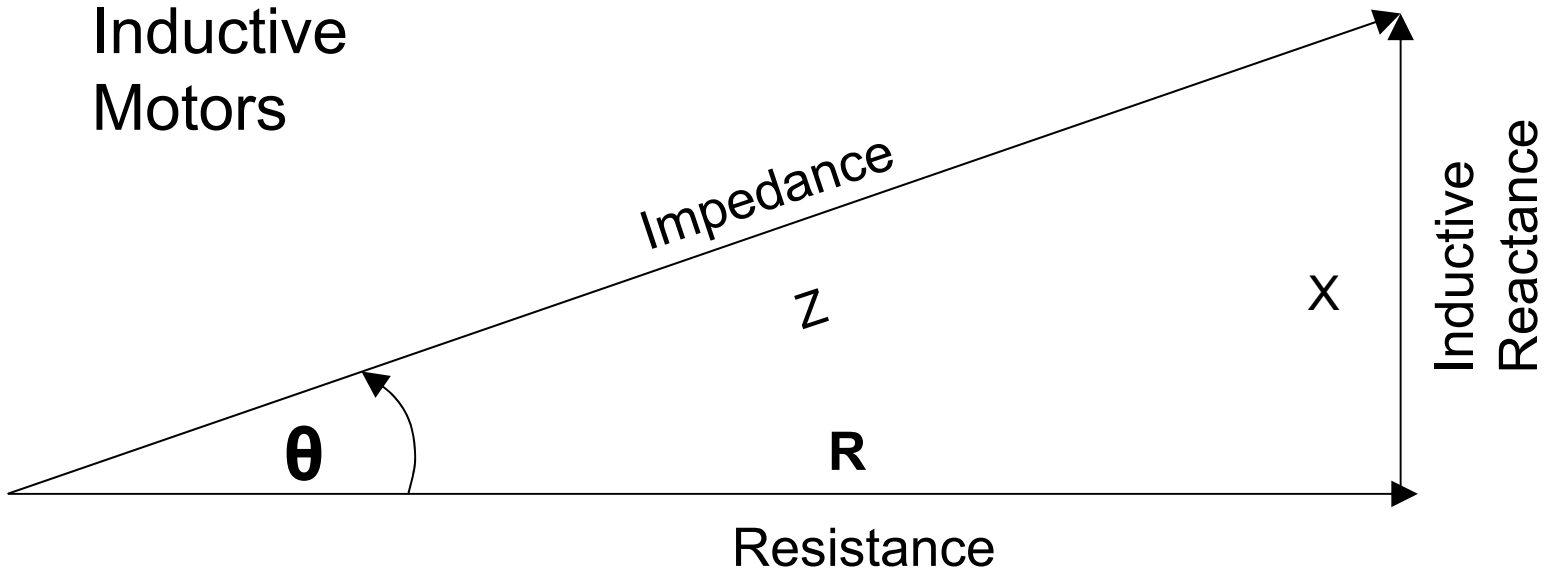
VAR, kVAR Reactance

B= True Power

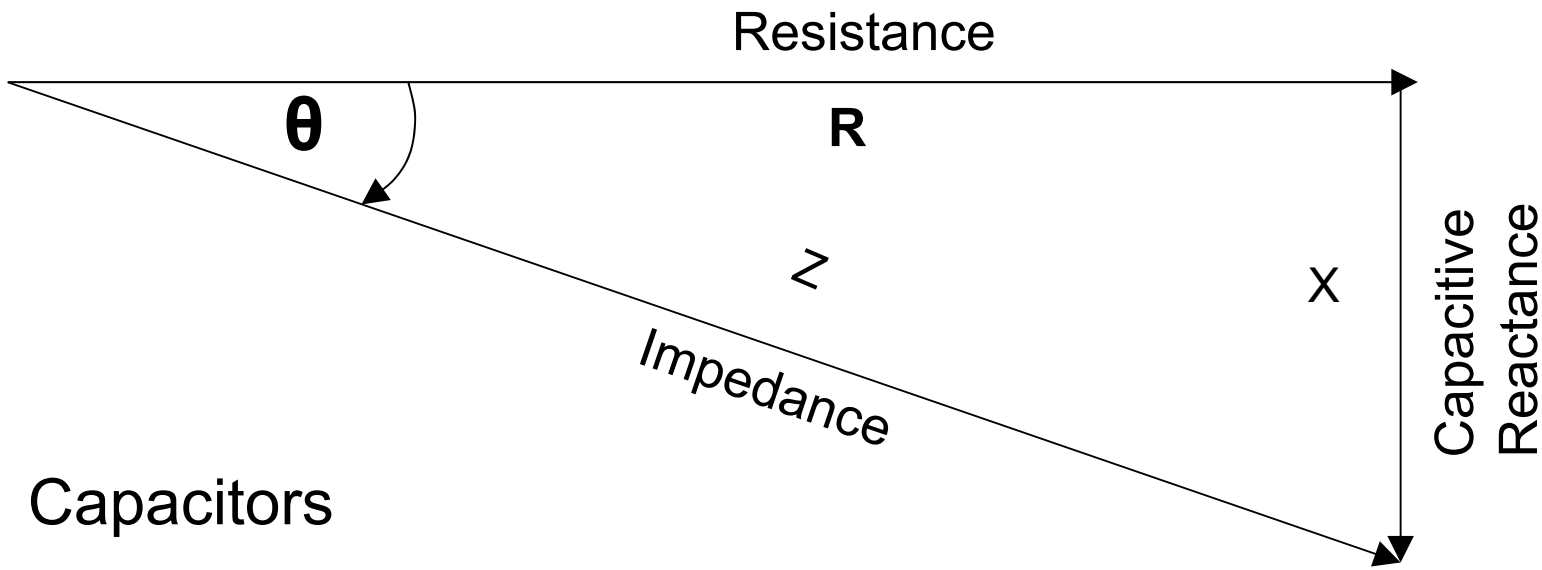
Watts, KW, Power

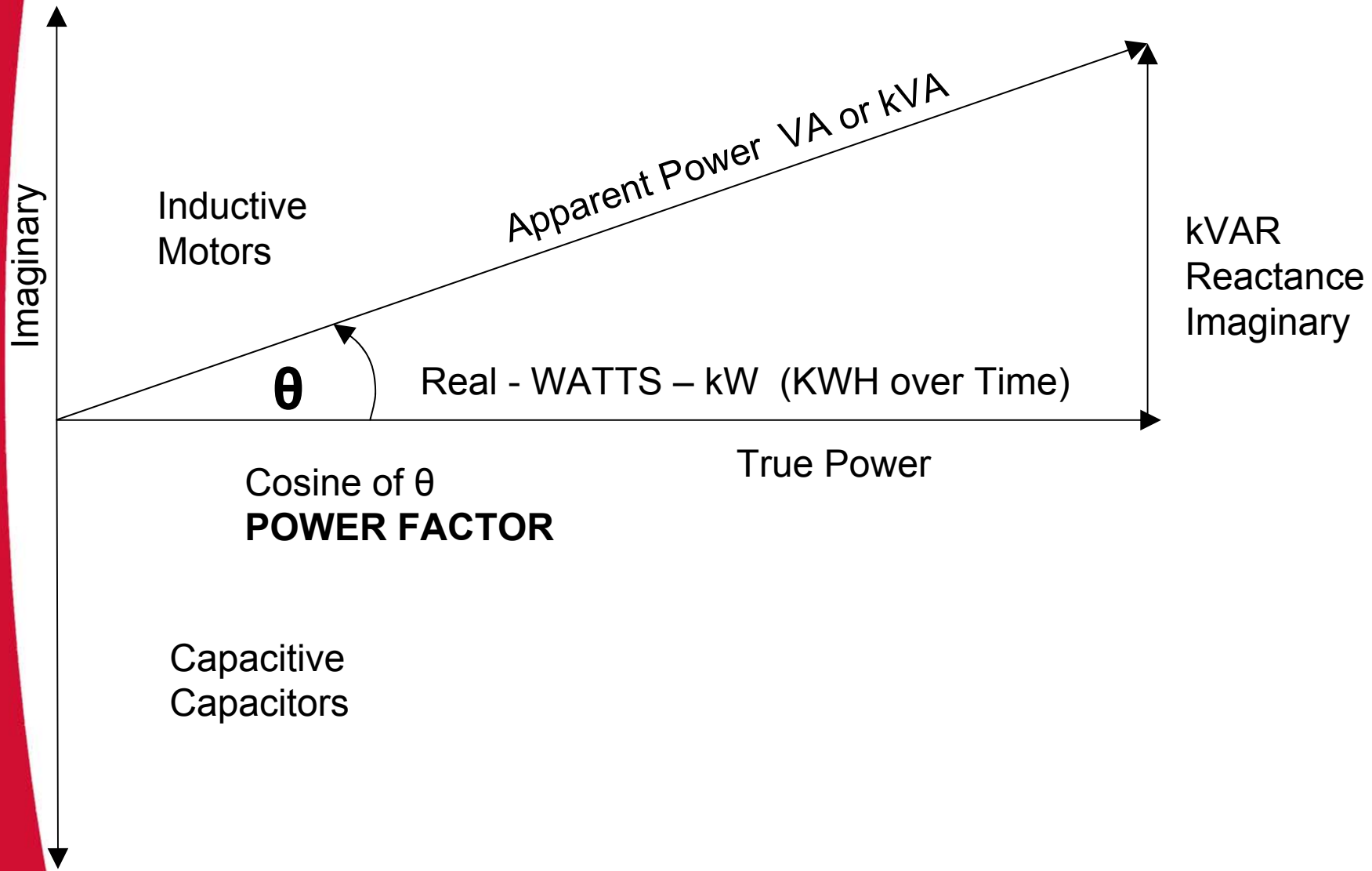
Progress Energy

Graphical representation of resistance, reactance, and impedance



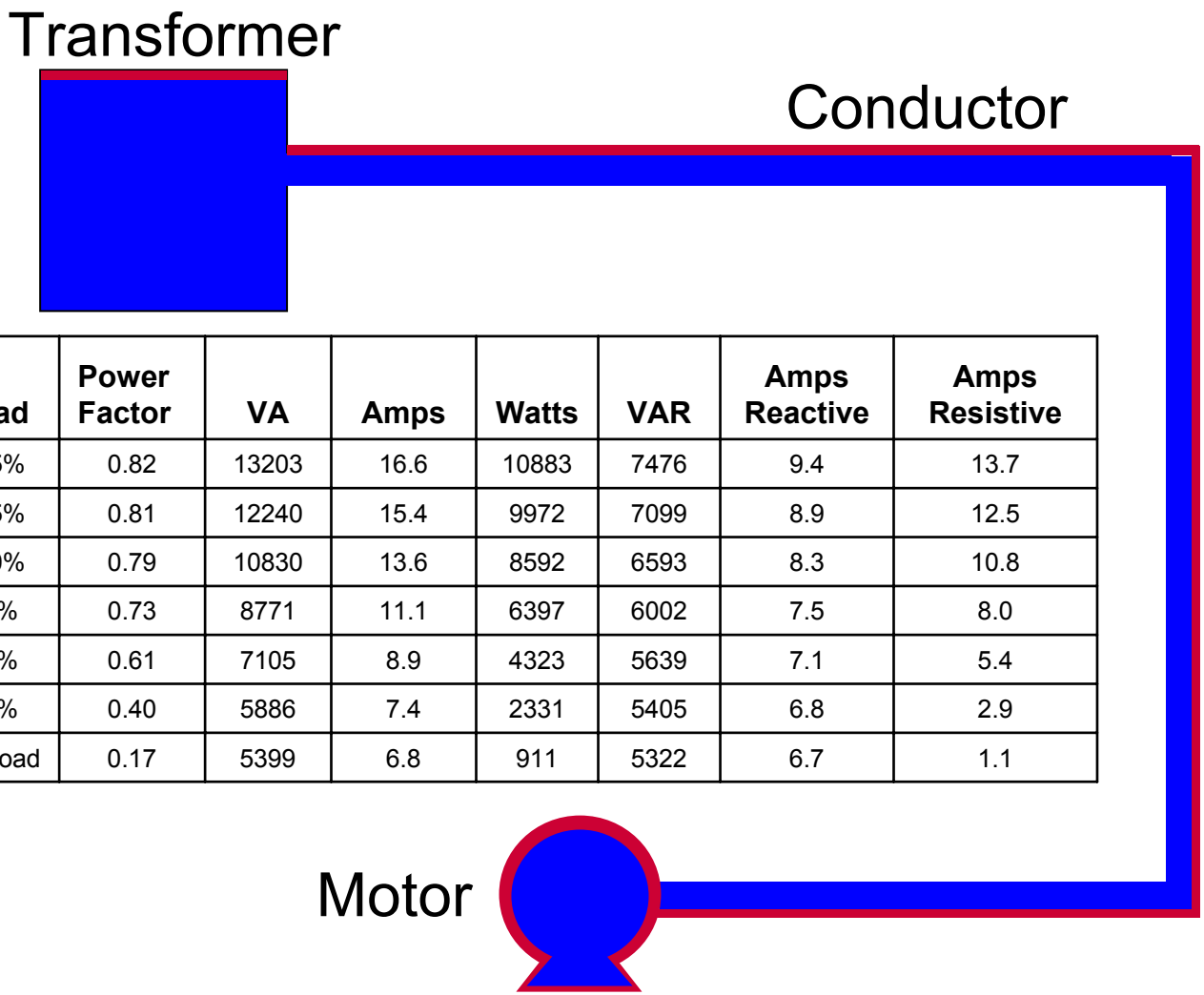
Graphical representation of resistance, reactance, and impedance





Progress Energy

10 HP 460 Volt 4 Pole Motor



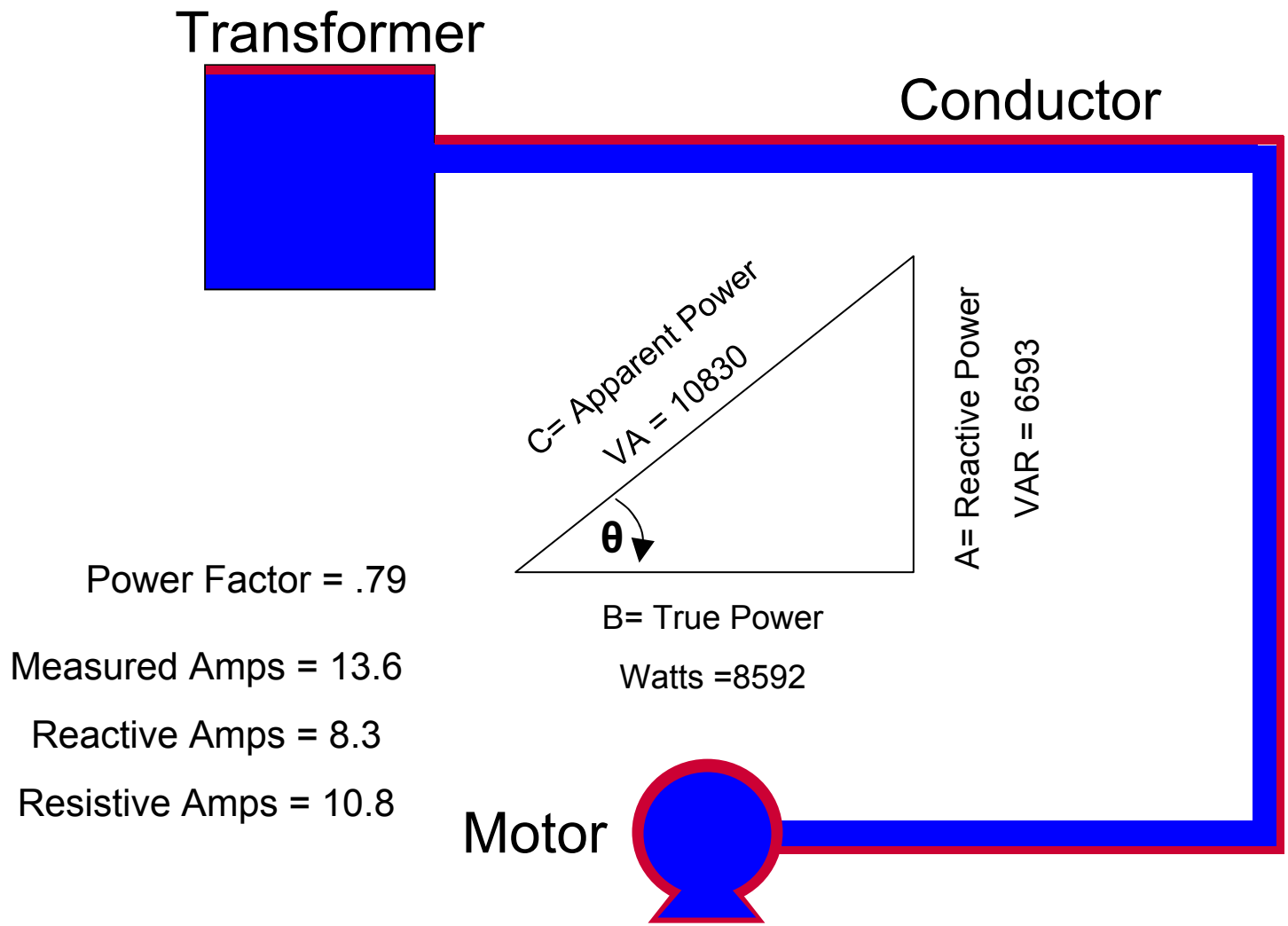
Load	Power Factor	VA	Amps	Watts	VAR	Amps Reactive	Amps Resistive
125%	0.82	13203	16.6	10883	7476	9.4	13.7
115%	0.81	12240	15.4	9972	7099	8.9	12.5
100%	0.79	10830	13.6	8592	6593	8.3	10.8
75%	0.73	8771	11.1	6397	6002	7.5	8.0
50%	0.61	7105	8.9	4323	5639	7.1	5.4
25%	0.40	5886	7.4	2331	5405	6.8	2.9
min load	0.17	5399	6.8	911	5322	6.7	1.1

= KW Load (resistive)

= KVAR Load (reactive)

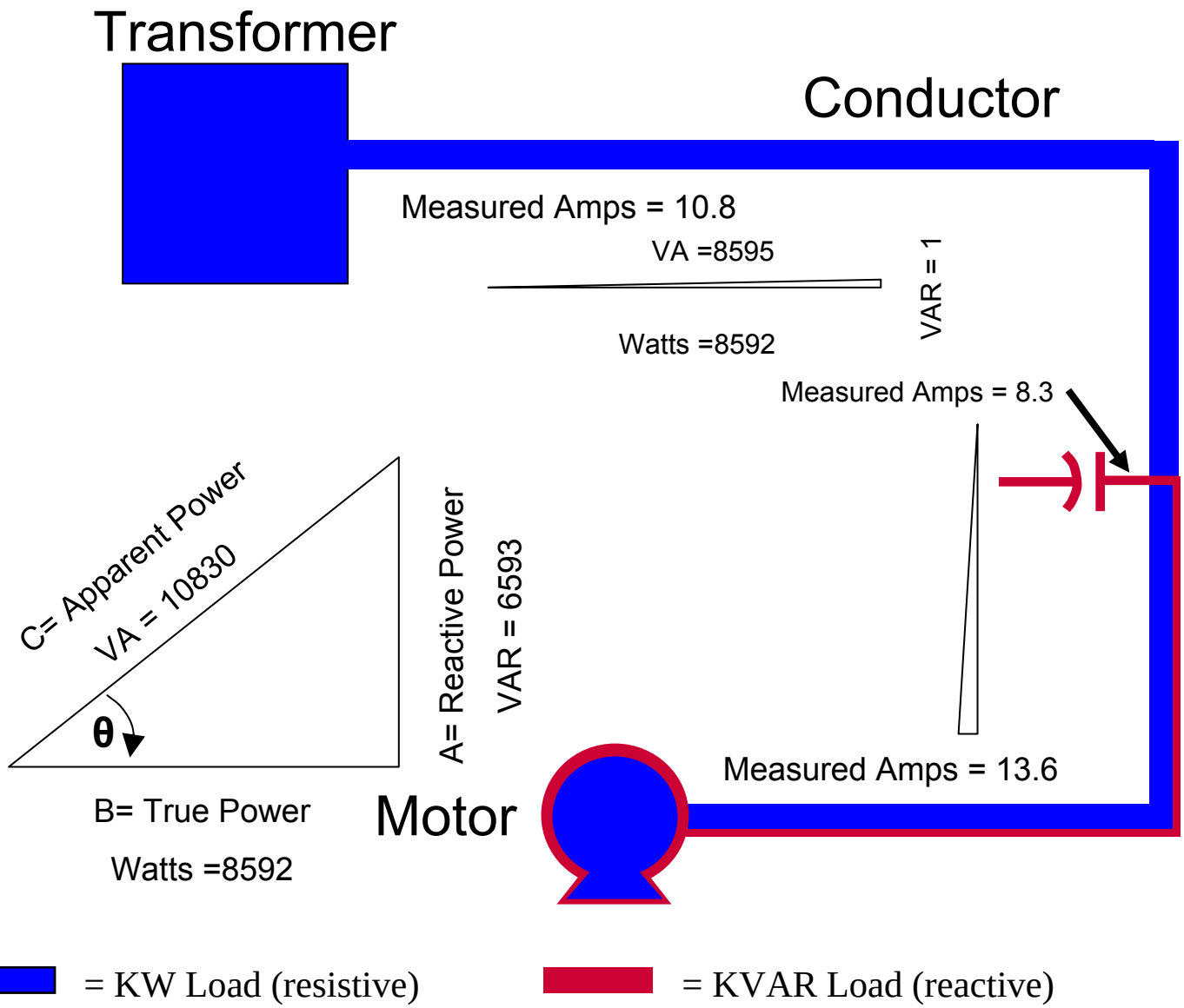
Progress Energy

10 HP Energy Flow



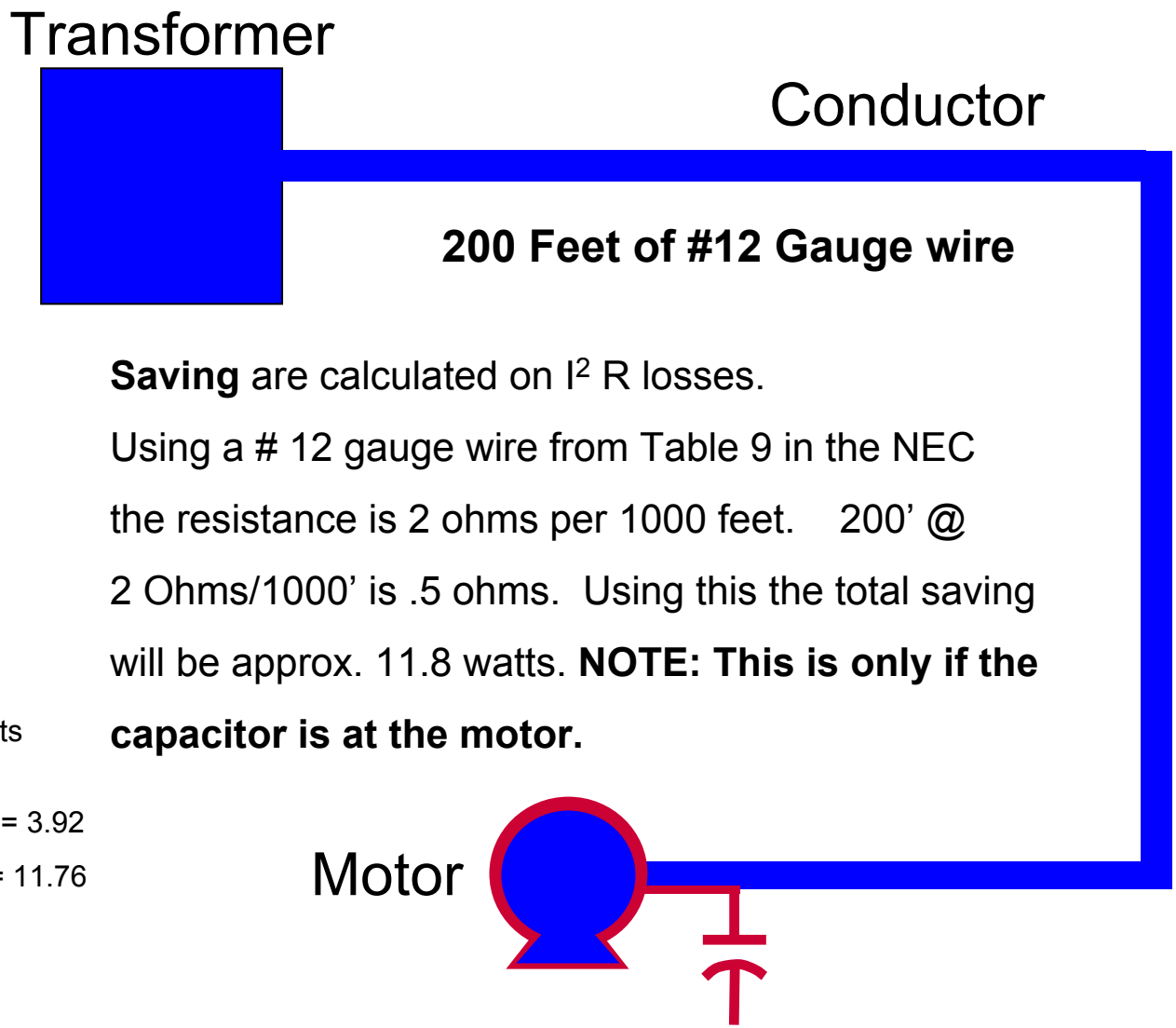
Progress Energy

10 HP Adding Capacitance



Progress Energy

10 HP Energy Savings



Saving are calculated on I^2 R losses.

Using a # 12 gauge wire from Table 9 in the NEC the resistance is 2 ohms per 1000 feet. 200' @ 2 Ohms/1000' is .5 ohms. Using this the total saving will be approx. 11.8 watts. **NOTE: This is only if the capacitor is at the motor.**

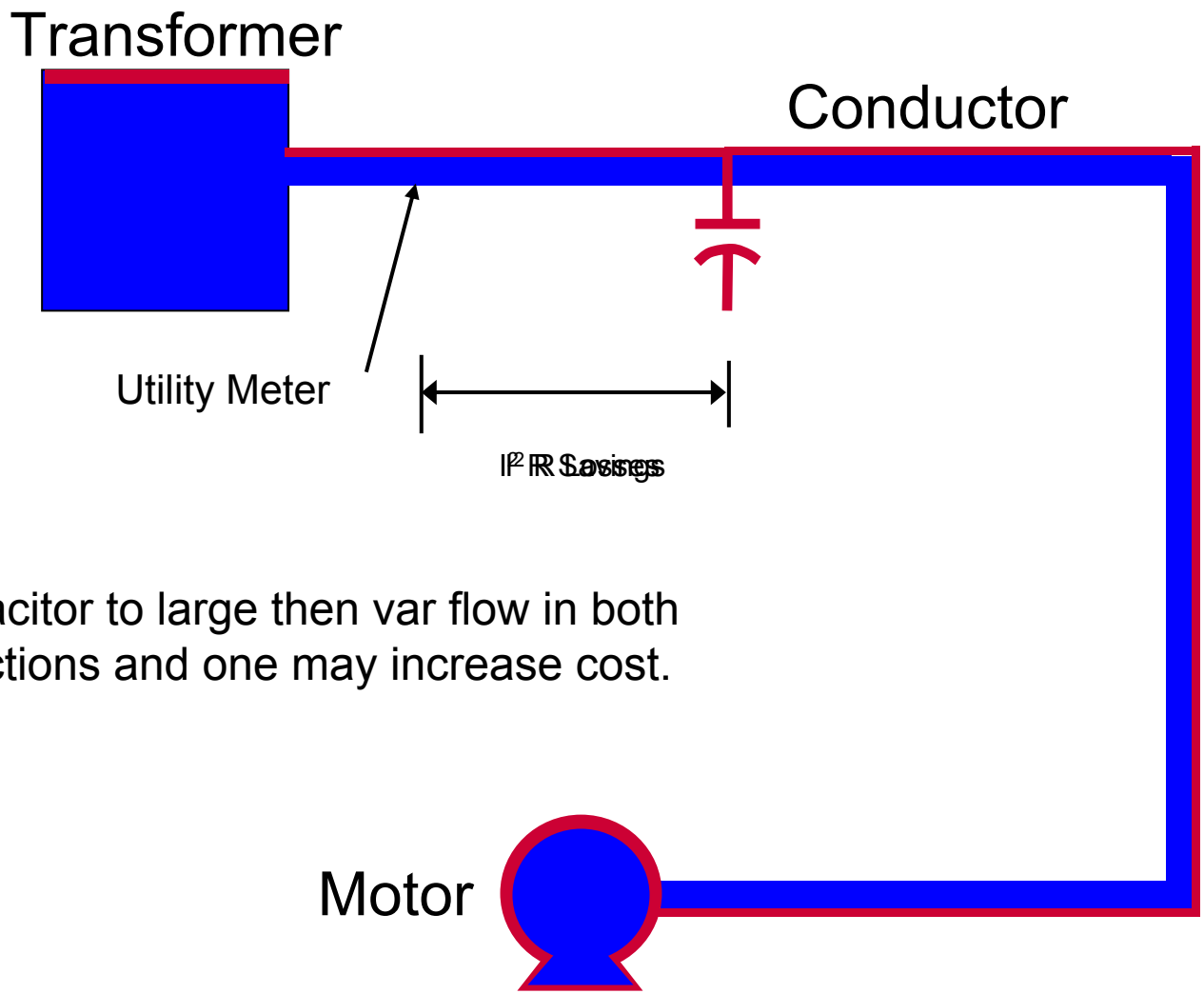
I^2 X R = Watts

2.8^2 X .5 = 3.92

3 X 3.92 = 11.76

Progress Energy

10 HP Capacitor Sizing



Capacitor to large then var flow in both directions and one may increase cost.

= KW Load (resistive)

= KVAR Load (reactive)

Progress Energy

Power Factor Penalty

Based on one month operation at 8 hours a day

Example of Power Factor Charge

PF Charge Factor

NC Charge		$0.40		kW Charge	$10.25
Max Billing kW		8.592		kWh Charge	$0.03854
Power Factor		0.79			
Calc	kVA	10.8759		kW	8.6
Calc	kVAR	6.6681		kWh	2064

Less than .85 then a $0.40 charge

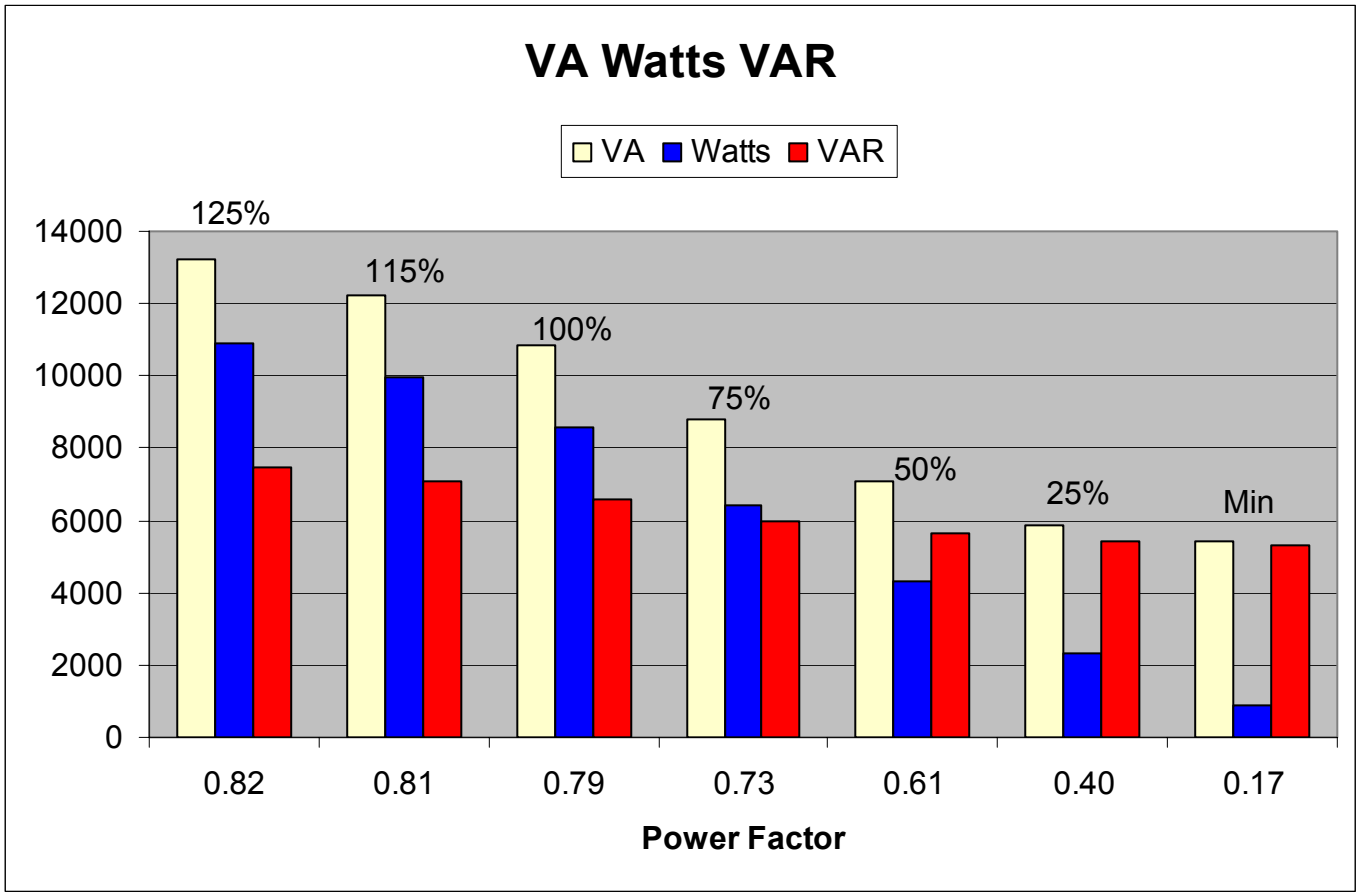
For kVar – (kW X.62)

In this Case $0.54

PF Charge		$0.54
kW Charge		$88.15
kWh Charge		$79.55
Total Charge		$168.23

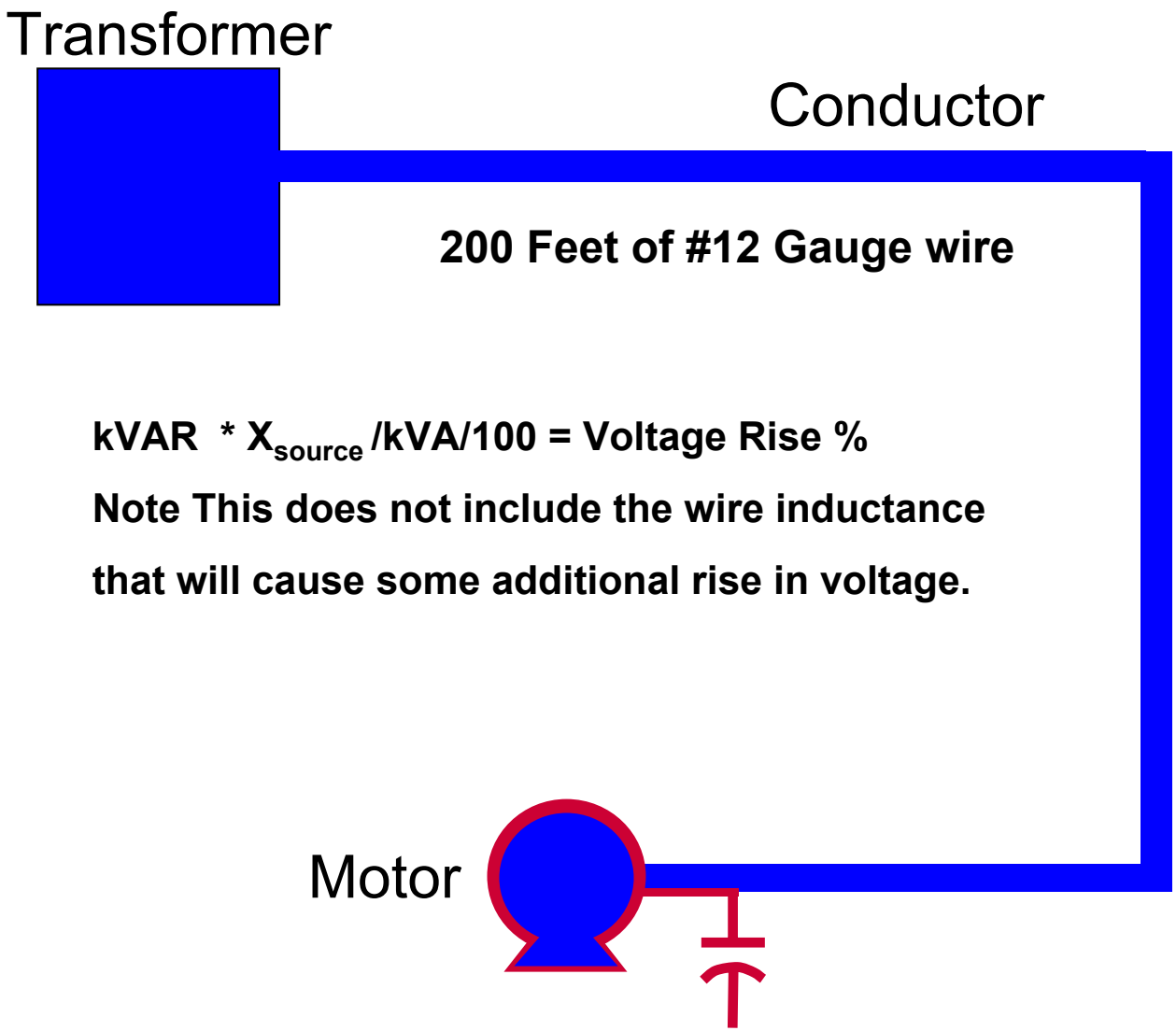
Progress Energy

10 Horse Power Motor



Progress Energy

10 HP Voltage Rise



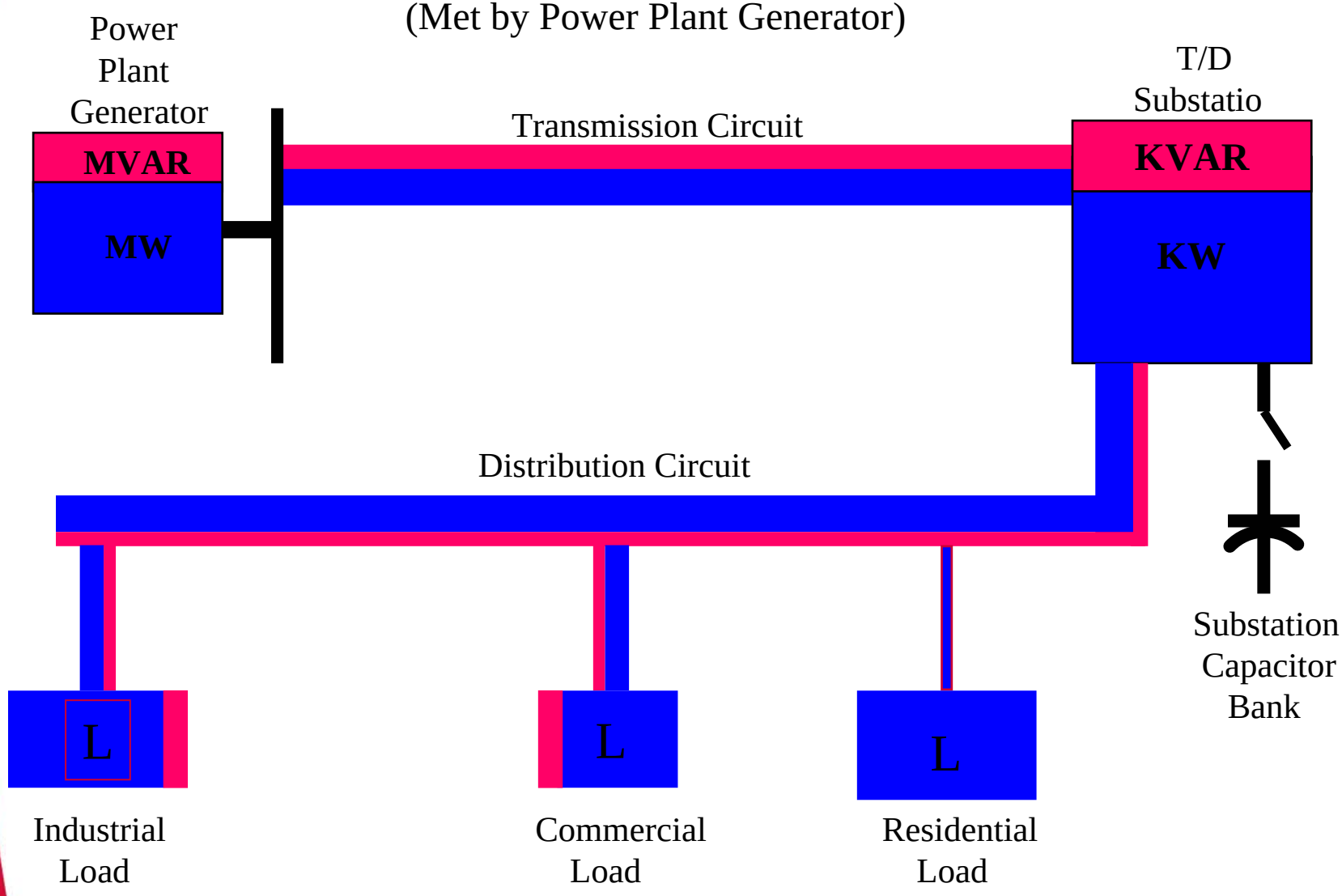
kVAR * X_{source} /kVA/100 = Voltage Rise %

Note This does not include the wire inductance that will cause some additional rise in voltage.

Progress Energy

System VAR Requirements

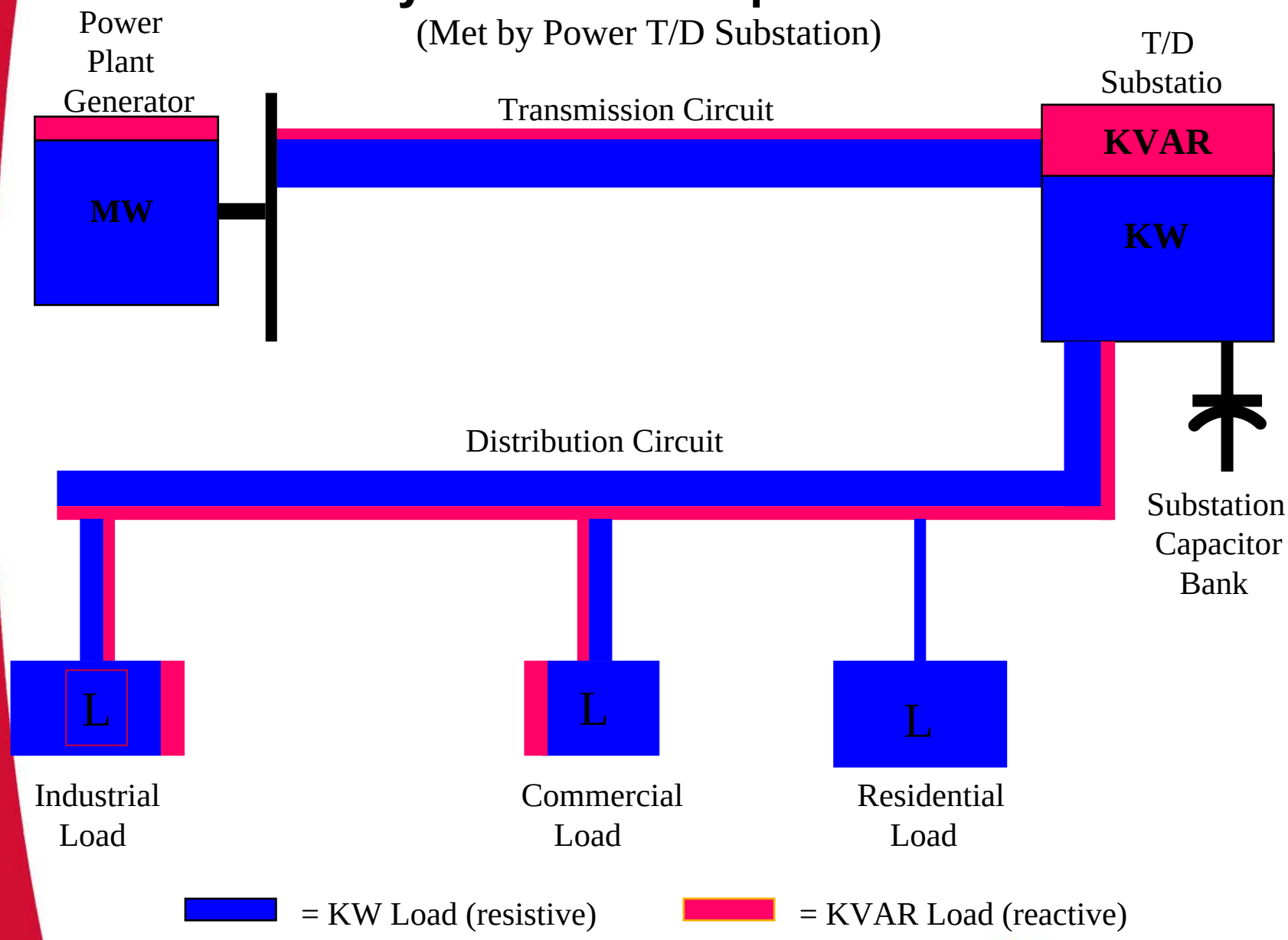
(Met by Power Plant Generator)



Progress Energy

System VAR Requirements

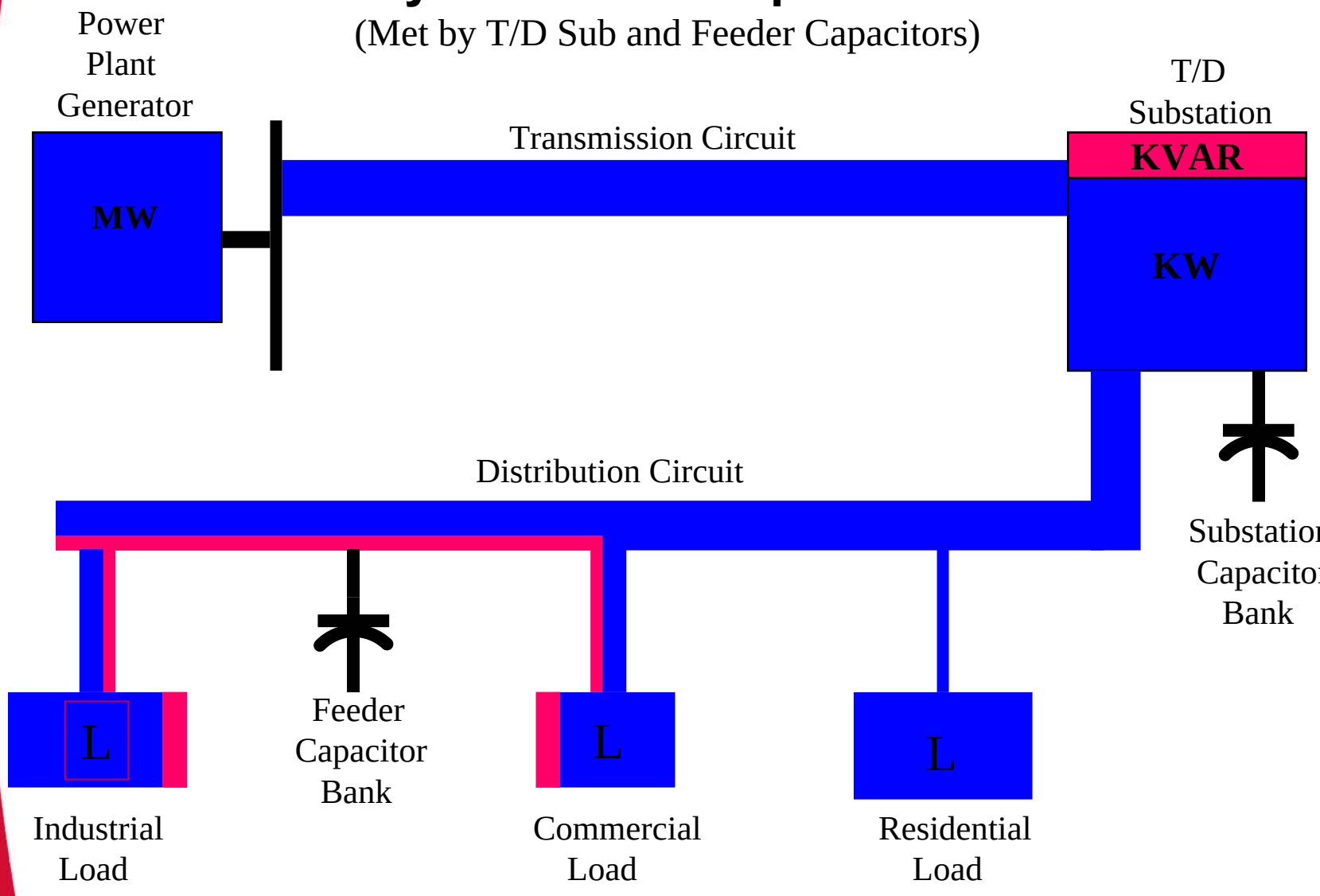
(Met by Power T/D Substation)



Progress Energy

System VAR Requirements

(Met by T/D Sub and Feeder Capacitors)



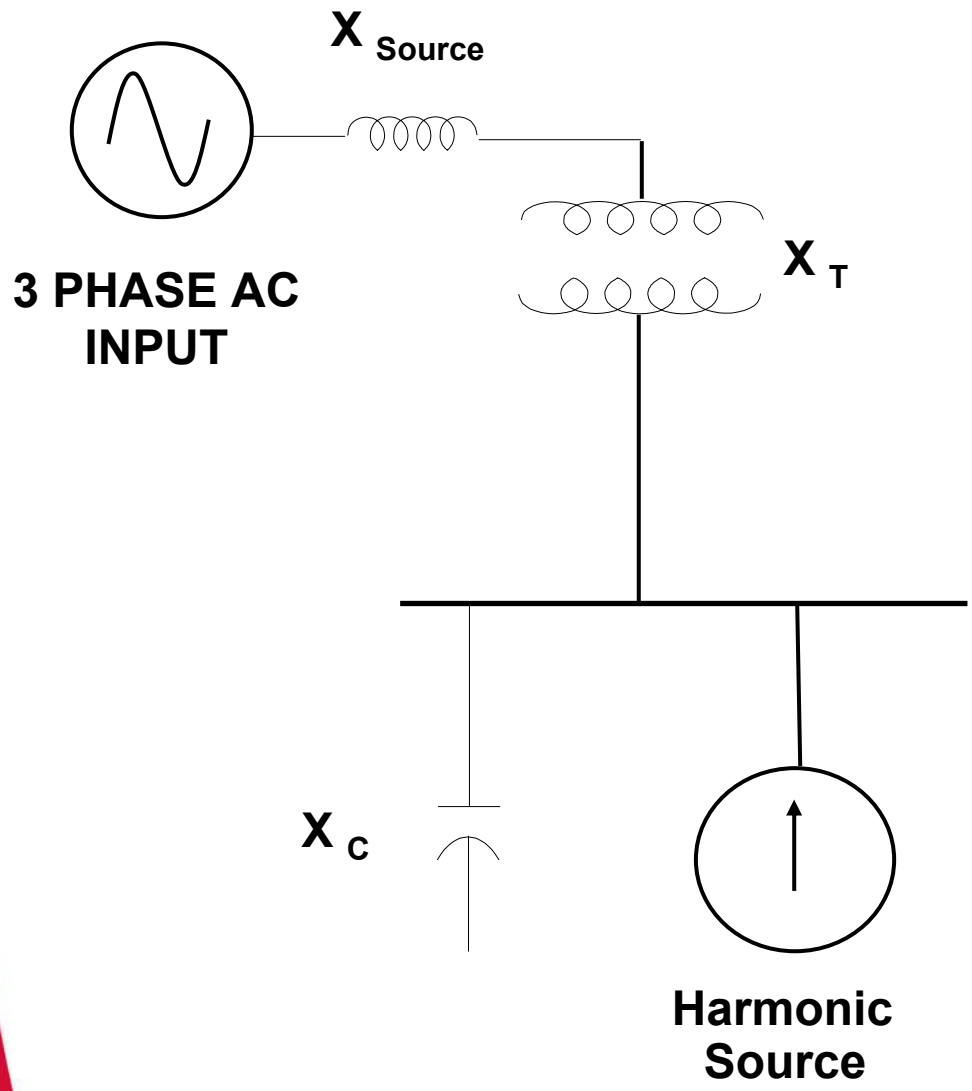
Progress Energy

Things We have Talked About And Other Things to Talk About

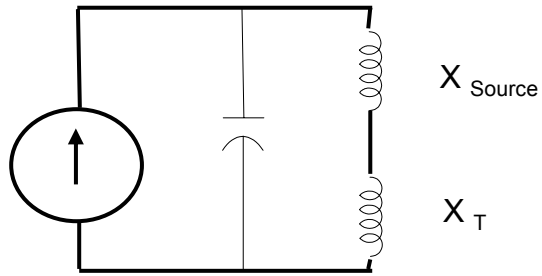
- Phase Angle
- Power Factor
- I^2R Loss
- Power Factor Penalty
- Voltage Rise
- Harmonic resonance
- Load Factor --- Power Factor

Progress Energy

Harmonic Resonance

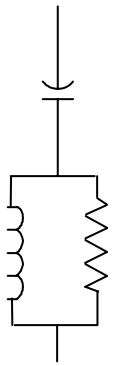


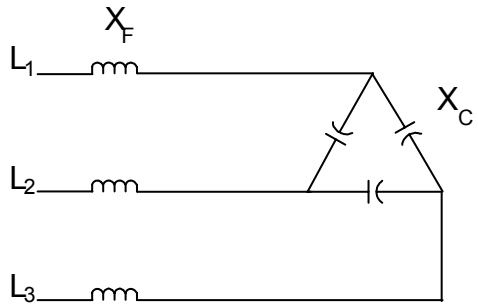
Equivalent Circuit

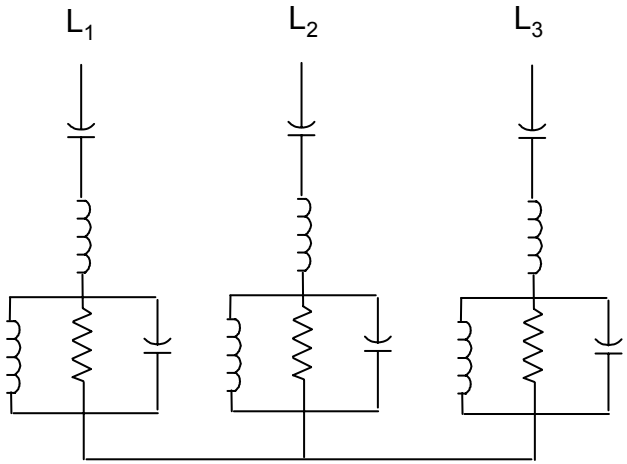


Progress Energy

Harmonic Filters







Progress Energy

Power Factor Vs Load Factor

- They have no relation
- Load Factor is kW at 100% operation

Yielding so many kWh vs. Actual kWh

Example

Hours in a Month = 30 X 24 = 720 Hours

Load is at 8 kW

8 X 720 = 5760 kWh

Actual kWh by load is 3240

Load Factor then is 3240/5760

Load Factor = .56

Progress Energy

Understanding Power Factor

- Definitions
  - kVA, kVAR, kW, **Apparent Power vs. True Power**
- Calculations Measurements
- Power Factor Correction
  - Capacitors
- System Impacts
  - I^2 R losses, Chapter 9 NEC
  - Equipment sizing
- Power Factor Charges
- Problems with adding Caps
  - Harmonic resonance
  - Volt rise
- Power Factor vs Load Factor

Progress Energy

Questions