



# Power Factor Correction

Save Money and Energy

Presented by:

Alan L. O'Quinn, P.E.

Team Power Solutions, LLC

[aoquinn@teampowersolutions.com](mailto:aoquinn@teampowersolutions.com)

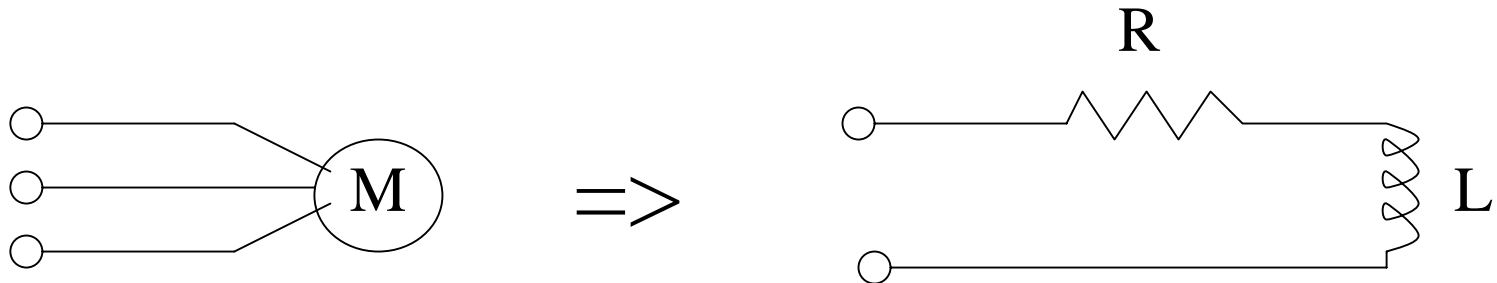
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# What is Power Factor Correction?

- Usually adding capacitance to Power System.
- Ideal power factor is 1.0
- Typical industrial complex is 0.65 – 0.8 pf.

# How Do You Get Low PF?

- Motor loads are inductive and need VARs.



# What's Wrong With Low PF?

- Wastes Power
- Overloads Equipment
- Costs Money
- Uses Up Natural Resources

# Complex Power

$$\text{Apparent Power} = S = P + jQ \quad \text{VA}$$

$$\text{Real Power} = P = |V| |I| \cos(\theta) \quad \text{W}$$

$$\text{Reactive Power} = Q = |V| |I| \sin(\theta) \quad \text{VAR}$$

$$\text{Power Factor} = \text{PF} = \cos(\theta)$$

# Single Phase Power

$$I = \text{kVA} / \text{kV} = \text{kW} / (\text{kV} \times \text{PF})$$

$$\text{kVA} = \text{kV} \times I$$

$$\text{kW} = \text{kVA} \times \text{PF}$$

# Three Phase Power

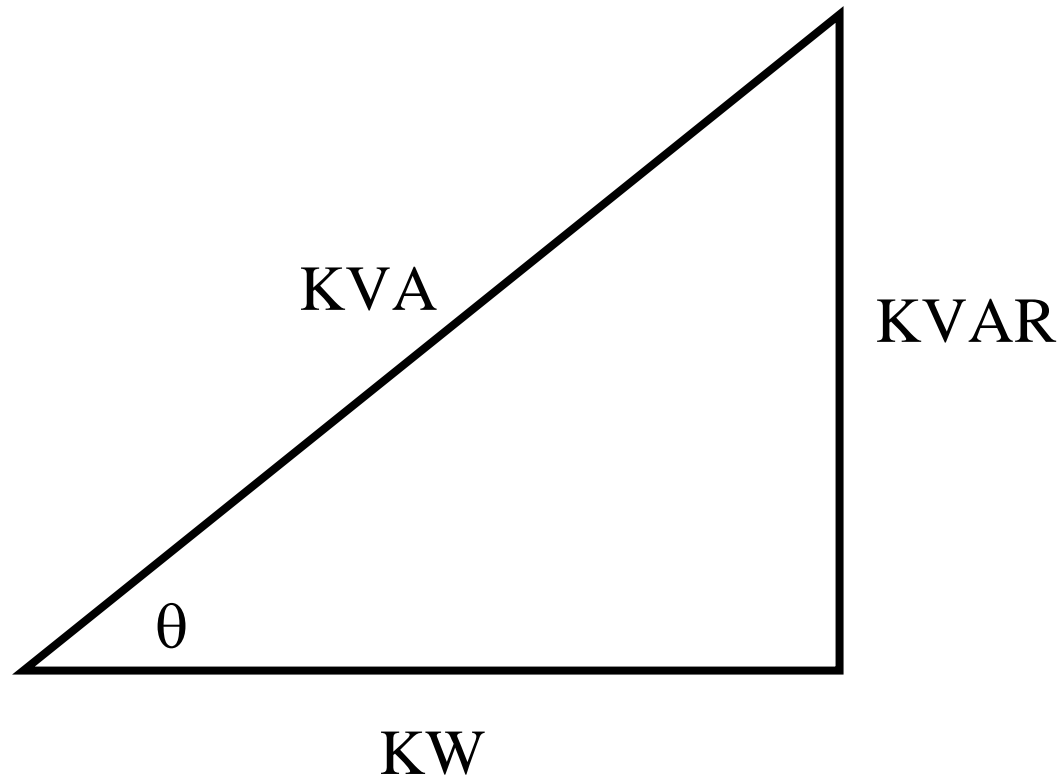
$$I = \text{kVA} / (\text{kV} \times 1.732) = \text{kW} / (\text{kV} \times 1.732 \times \text{PF})$$

$$\text{kVA} = \text{kV} \times 1.732 \times I$$

$$\text{kW} = \text{kVA} \times \text{PF}$$

Note: kV is the phase-to-phase voltage

# Power Triangle

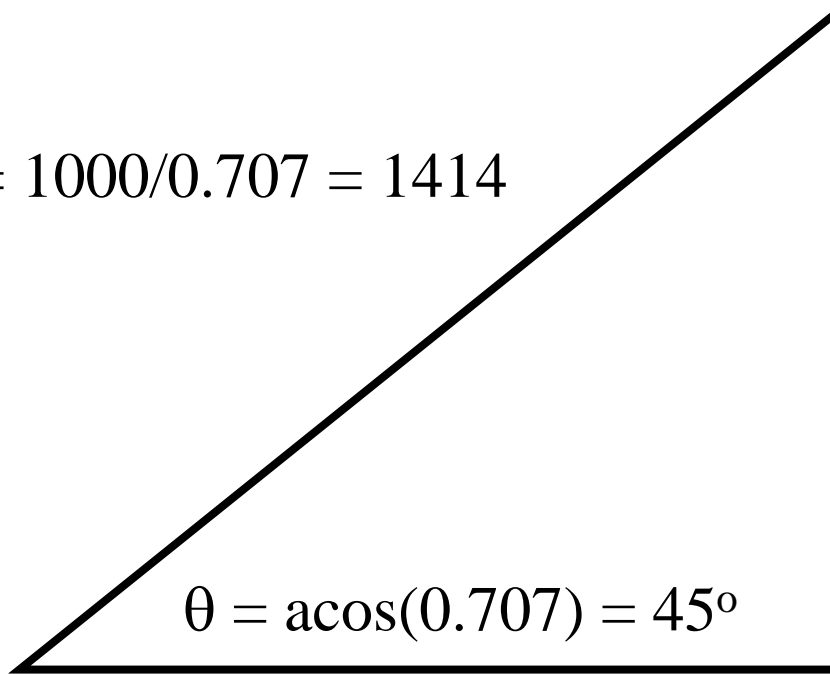


# Classic PF Example

- Facility has peak demand of 1000 kW Load
- Power Factor is 0.707 lagging
- Calculate kVAR.
- Calculate amount of capacitance in kVAR needed to correct to a 0.9 PF
- How much is capacitance in microfarads?

# Draw Power Triangle

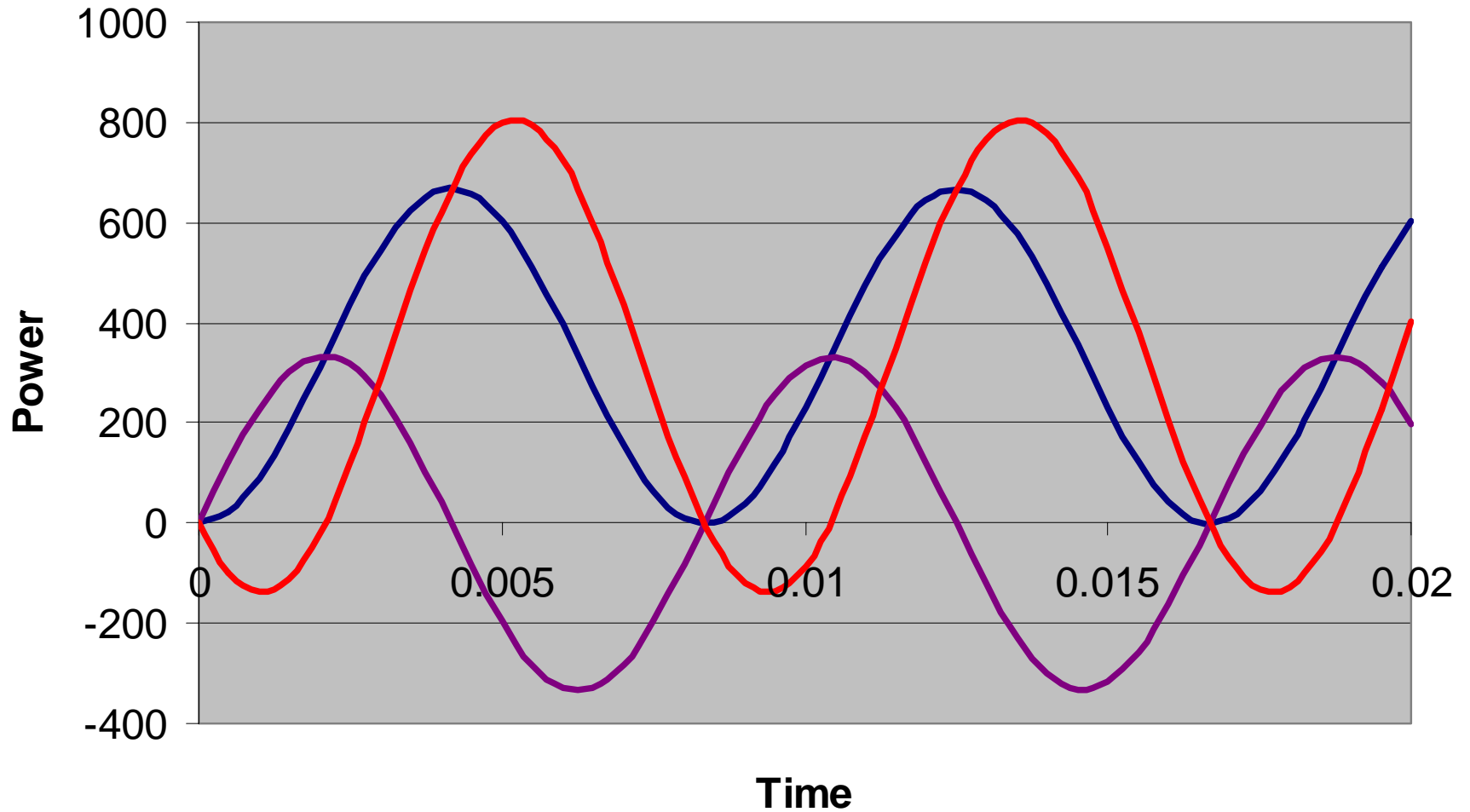
$$\text{KVA} = 1000 / 0.707 = 1414$$



$$\begin{aligned} \text{KVAR} &= \\ &= \sqrt{1414^2 - 1000^2} \\ &= 1000 \end{aligned}$$

# Graphical Representation of Power

PF = 0.707

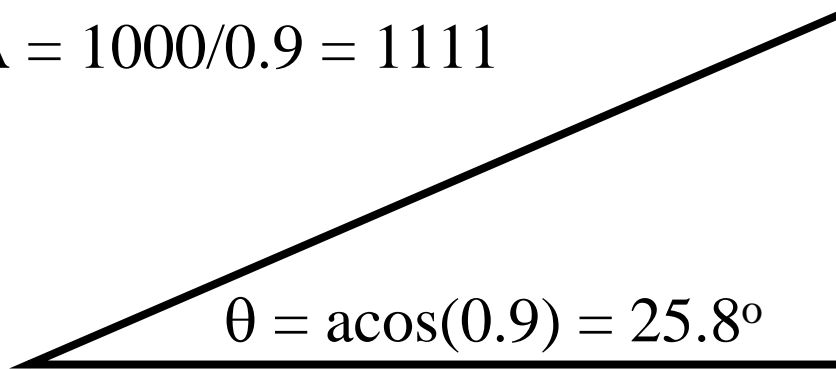


— Real — Reactive — Apparent

# PF Example Continued

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$$\text{KVA} = 1000/0.9 = 1111$$

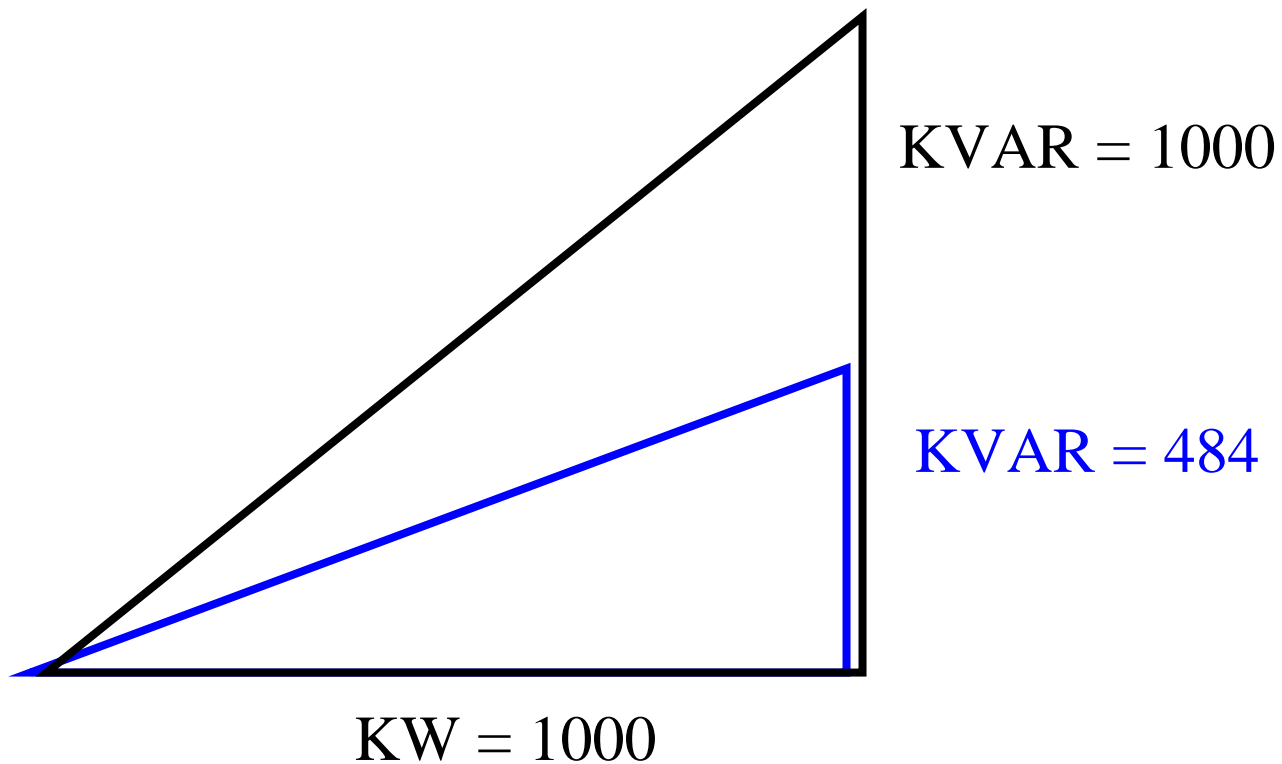


$$\begin{aligned}\text{KVAR} &= \\ &= \text{sqrt}(1111^2 - 1000^2) \\ &= 484\end{aligned}$$

$$\text{KW} = 1000$$

$$\text{Added kVAR} = 1000 - 484 = 516$$

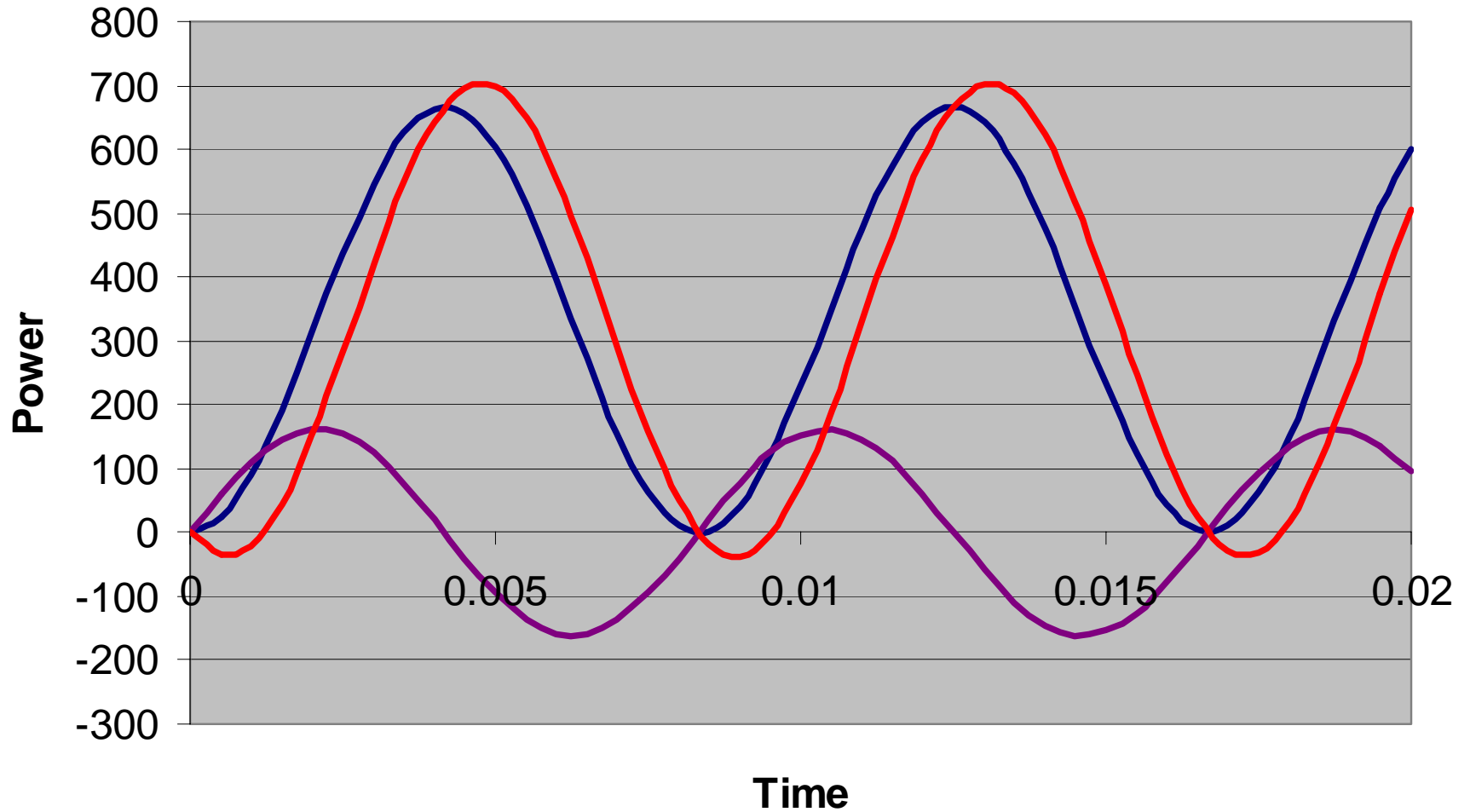
# Comparison



$$\text{Added kVAR} = 1000 - 484 = 516$$

# Graphical Representation of Power

PF = 0.9



— Real — Reactive — Apparent

# PF Example Continued

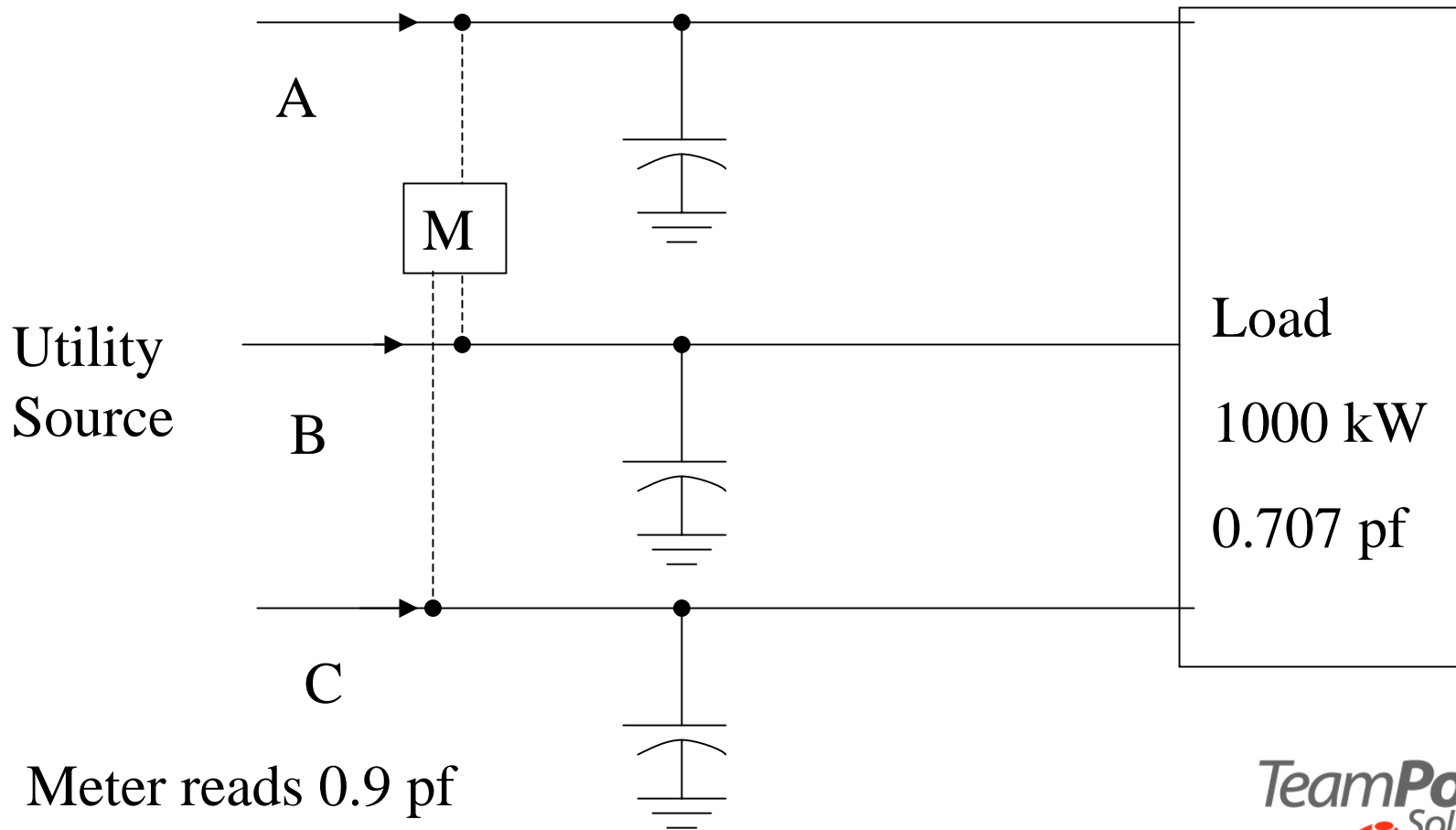
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$$\begin{aligned} C &= ( \text{kVAR} \times 10^3 ) / ( 2 \pi f ) (\text{kV})^2 \\ &= ( 500 \times 10^3 ) / ( 2 \pi 60 ) (0.480)^2 \\ &= 5,759 \text{ microfarads} \end{aligned}$$

Note: 480 volts was the assumed voltage.

# PF Example Continued

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# PF Example Continued Slide 4 of 4

What is the reduction in amps supplied by the utility?

kVA before was 1414

kVA after pf correction is 1111

Reduced kVA is 303 kVA

Reduced amps is  $303 / ( 0.480 \times 1.732 ) = 364$  amps

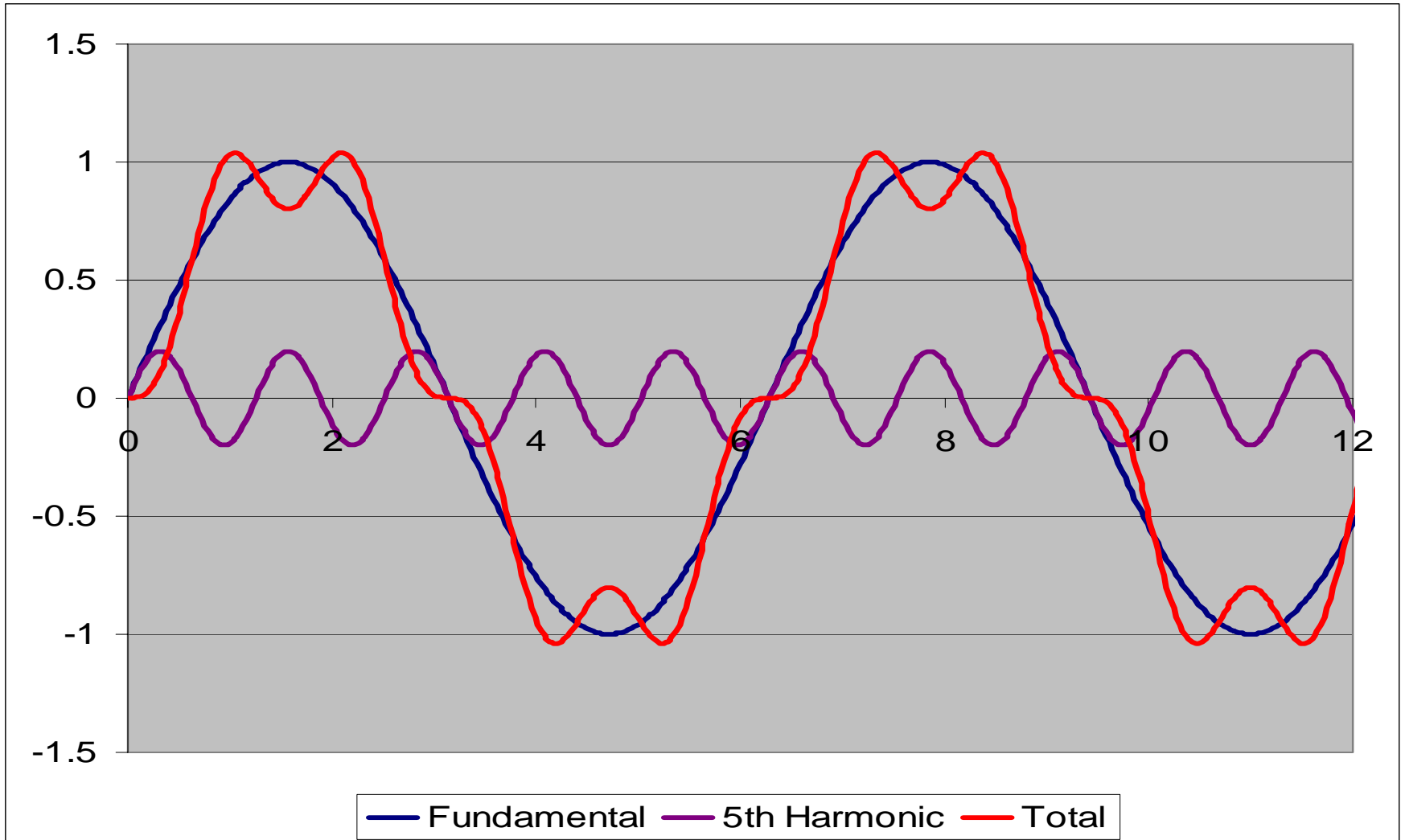
# Benefits

- Reduced  $I^2R$  losses
- Less voltage drop.  $V_{LN} = I Z_{eq}$
- Reduced conductor size.
- Possible reduce substation transformer size.
- Provides Voltage support

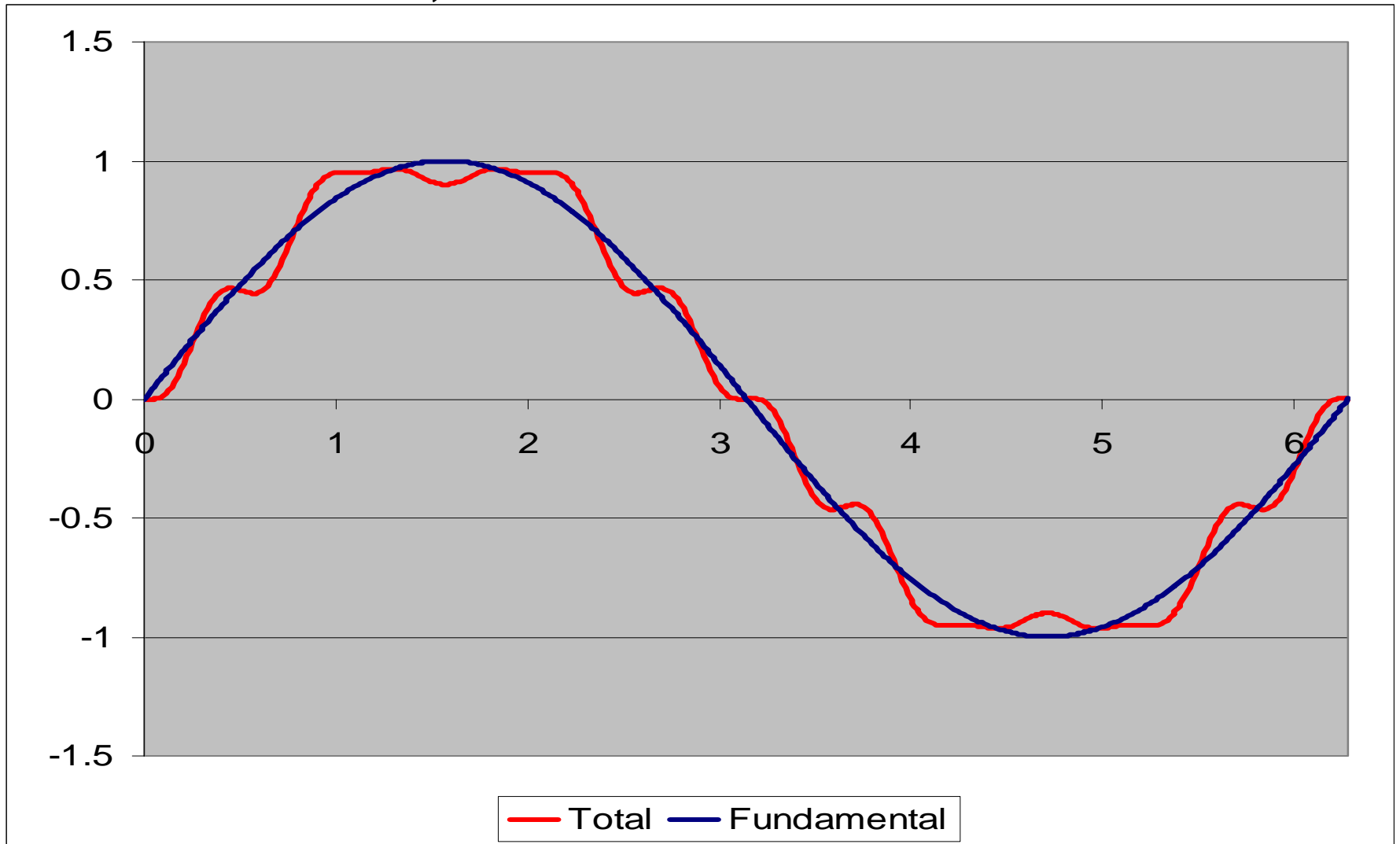
# Harmonics

- Multiple of the fundamental frequency distortions. 5<sup>th</sup> = 300 Hz, 7<sup>th</sup> = 420 Hz
- Created by non-linear devices such as UPS systems, rectifiers, VFDs, welders, fluorescent ballasts, personal computers
- IEEE 519-1992

# 5<sup>th</sup> Harmonic Distortion



# 5<sup>th</sup>, 7<sup>th</sup>, 11<sup>th</sup> 13<sup>th</sup> Harmonics



# Harmonic Resonance

- Occurs when capacitance reactance and system reactance are equal.
- Large currents circulate between transformer and capacitor.
- Higher voltages may occur across equipment.
- Usually 5<sup>th</sup>, 7<sup>th</sup>, 11<sup>th</sup>, and 13<sup>th</sup> are the frequencies of most concern

# System's Harmonic Resonance

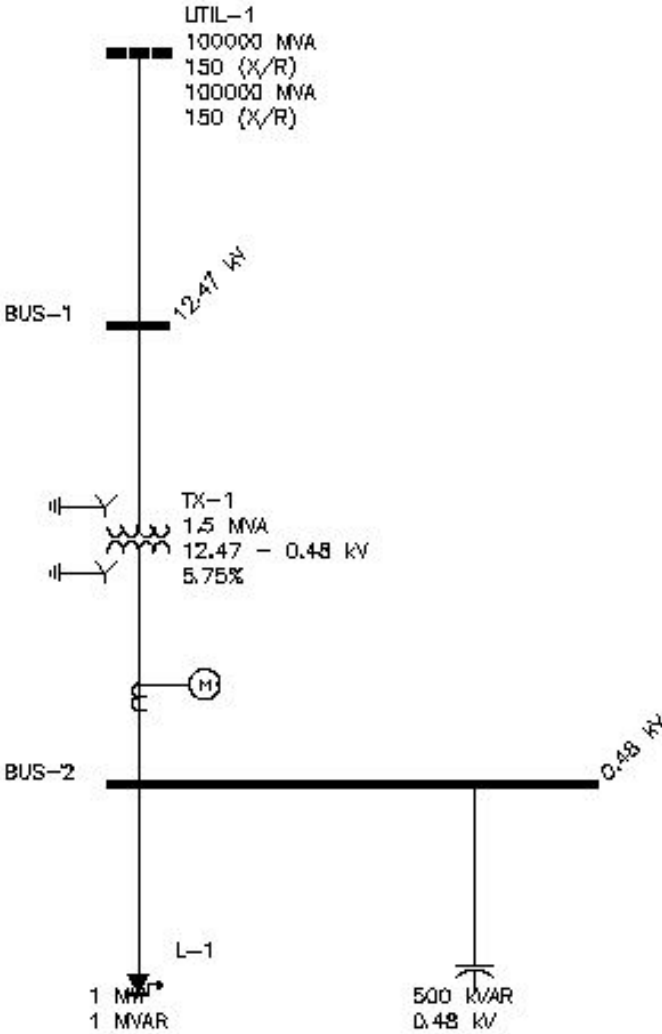
Previous Example: 1500 kVA Transformer, %Z = 5.75  
500 kVAR of Capacitance

Harmonic Order =  $h = \sqrt{\text{kVA}_{\text{SC}} / \text{kVAR}}$

$\text{kVA}_{\text{SC}} = \text{kVA} / (\%Z/100) = 1500 = 1500/0.0575 = 26,087$

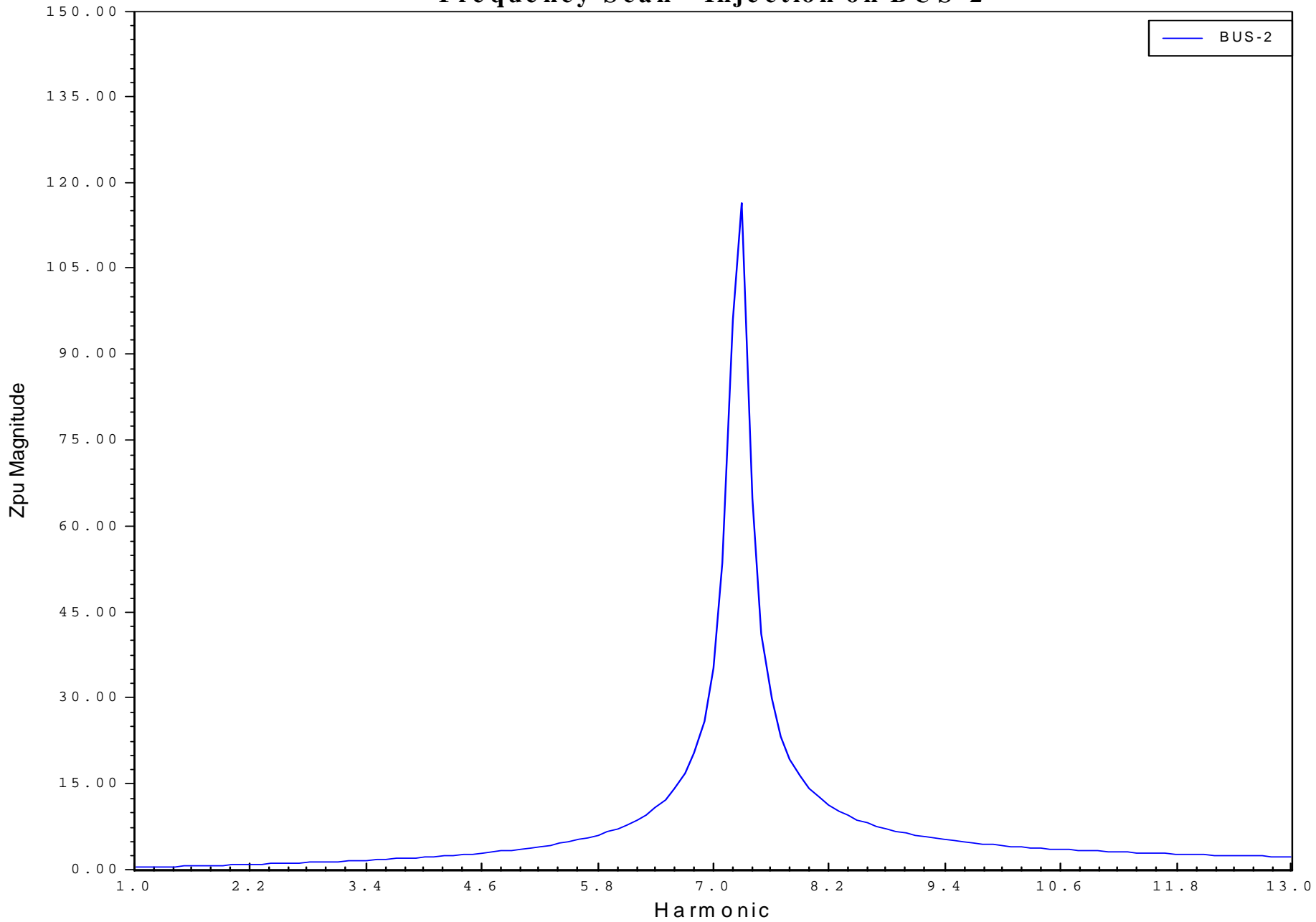
$h = \sqrt{26,087 / 500} = 7.22$

# Easy Power Model



Load has 5<sup>th</sup>, 7<sup>th</sup>, 11<sup>th</sup> and 13<sup>th</sup> Harmonics each with 10% Current Distortion

# Frequency Scan - Injection on BUS-2



# Documented Sources

- GE Corporation, GE Low Voltage Power Factor Correction Capacitors GEP-974-G, 2003
- Su, Kendall L. Fundamentals of Circuit Analysis, Waveland Press, 1993
- Matthes, John H. Introduction to the Design and Analysis of Building Electrical Systems. Van Nostrand Reinhold, 1993