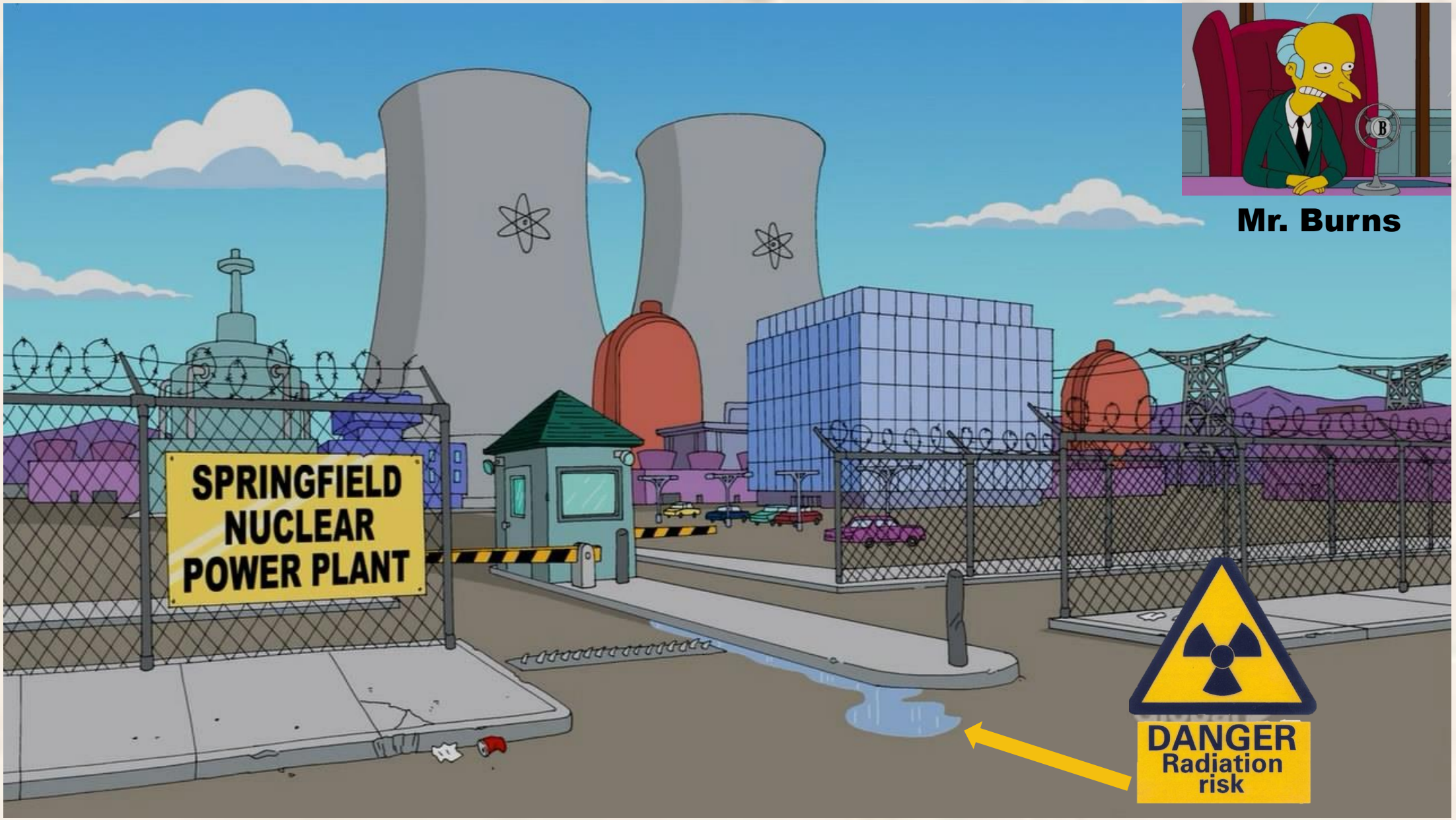


Mr. Burns

Electrical Power Formulae & Power Factor

Fachgesprach 17

☺ WTF Institute of Higher Learning ☺

By Mat Ansari

8-10-2017

Courier New

8:00pm

Energy (Work) & Power

Energy (Work)

(Force x Distance)

- IP Units
  - $ft.lb_f$
  - Btu (1 Btu = 778 $ft.lb_f$)
- SI Units
  - Joule = Newton x Meter
  - 1J = 1N.m

Power

(Rate of doing Work)

- IP Units
  - $Ft.lb_f$ per min (1 hp = 33,000 $ft.lb_f$/min)
  - $Ft.lb_f$ per sec (1 hp = 550 $ft.lb_f$/sec)
  - Btu per hour (1 Btuh = 0.2931 Watt)
- SI Units
  - 1 Joule per sec = 1 Watt

Energy (Work) & Power

Hydronics

- Head = Energy per pound
  = $ft.lb_f/lb_f$
  = ft

- Power = Head x Flow

$$\text{Water HP} = \frac{\text{Head x GPM}}{3960}$$

Electrical

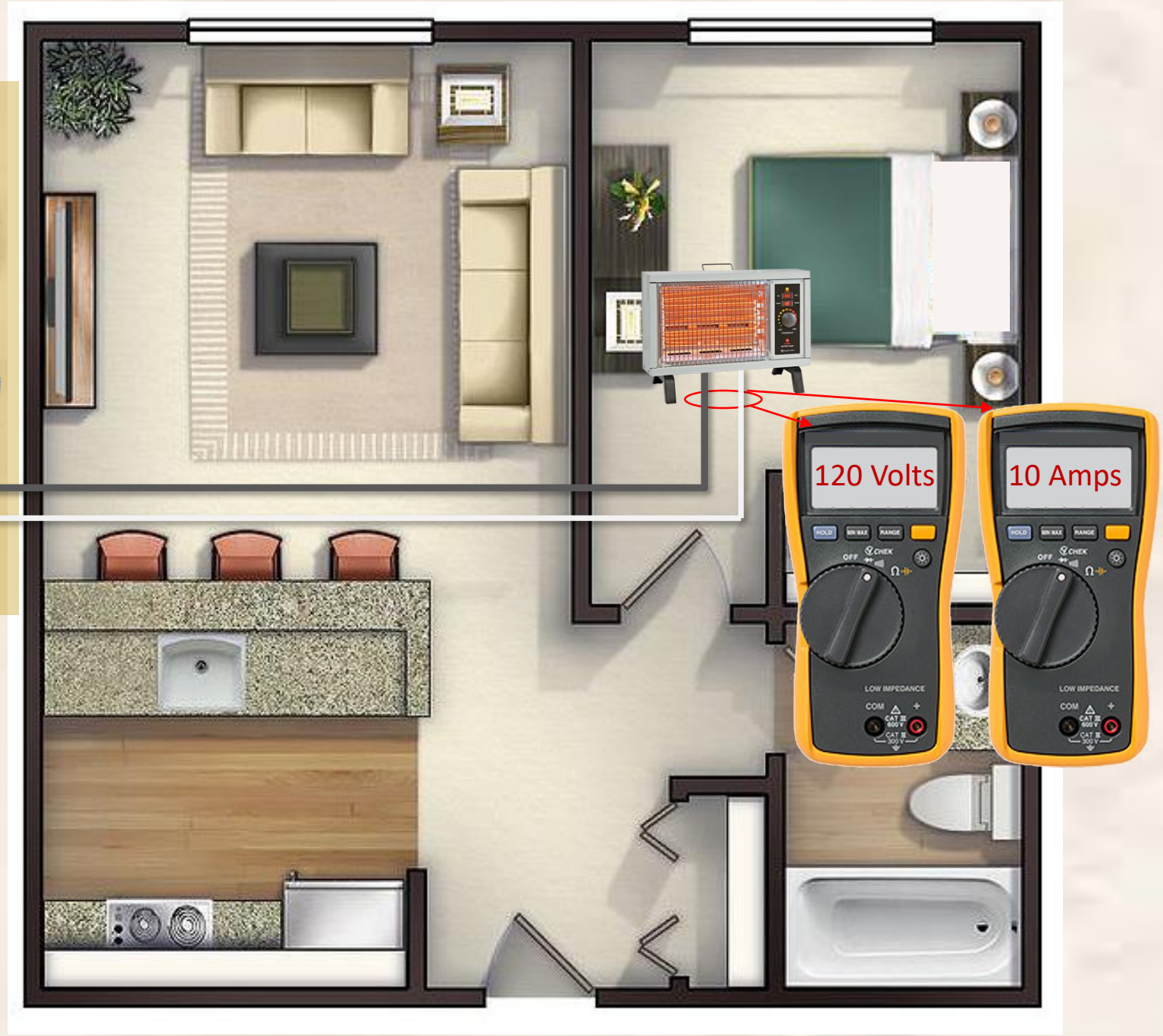
- Voltage = Energy per unit charge

- Ampere = Flow of charge per second

- Power = Voltage x Amperes (Watts)

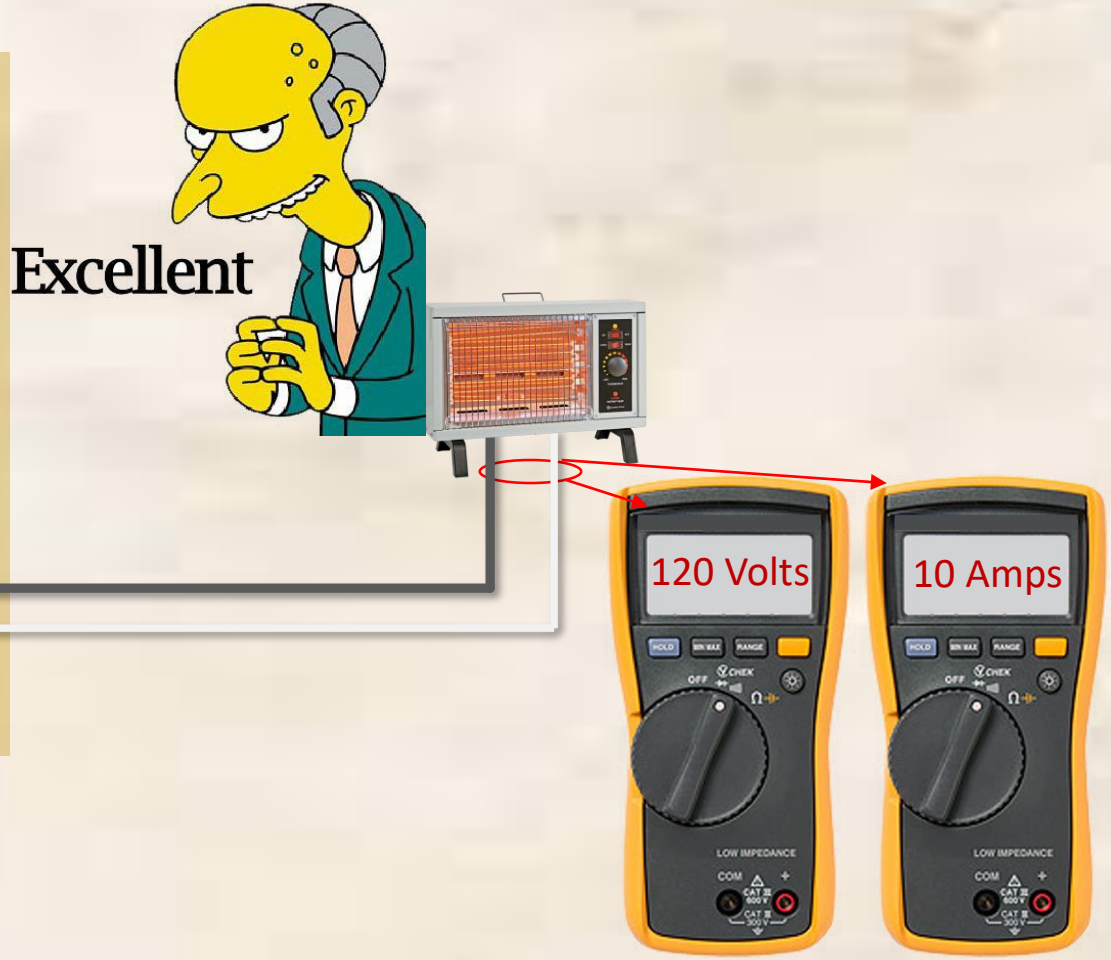
Watt-hour Meter

Watts = (3600 x Kh) ÷ t



Watt-hour Meter

Watts = (3600 x Kh) ÷ t



PURE RESISTIVE LOAD

Power VA = Volts x Amps

Power VA = 120 x 10 = 1200

Watt-hour meter reads a RATE of 1200 Watts.
(It is a Watt-hour meter but you can compute Watts.)

Watts = VA = 1200

Line readings match Watt-hour meter power readings.

You are using 1200 and paying for 1200.

Mr. Burns is happy.

Watt-hour Meter

WTF? You are ripping me off!

1 HP 115V 1Φ 1750 RPM

100% Loaded

VA = Volts x Amps = 115 x 13 = 1495 VA

Wattmeter Reads = 1061 Watts

Ratio of Watts to VA = 1061/1495 = 0.71

In other words – the Wattmeter is reading 71% of the system VA

You are paying for 71% of the energy Mr. Burns has to produce for you

50% Loaded

Watt-hour Meter

Real Power
Active Power
Watts or kW

We will call this "W" or "kW"

1 HP 115V 1Φ 1750 RPM

50% Loaded

Apparent Power
VA or kVA

We will call this "VA" or "kVA"

VA = Volts x Amps = 115 x 10.6 = 1219 VA

Wattmeter Reads = 622 Watts

Ratio of Watts to VA = 622/1219 = 0.51

This is the
POWER FACTOR
PF = Watts/VA
PF = kW/kVA

In other words – the Wattmeter is reading 51% of the system VA

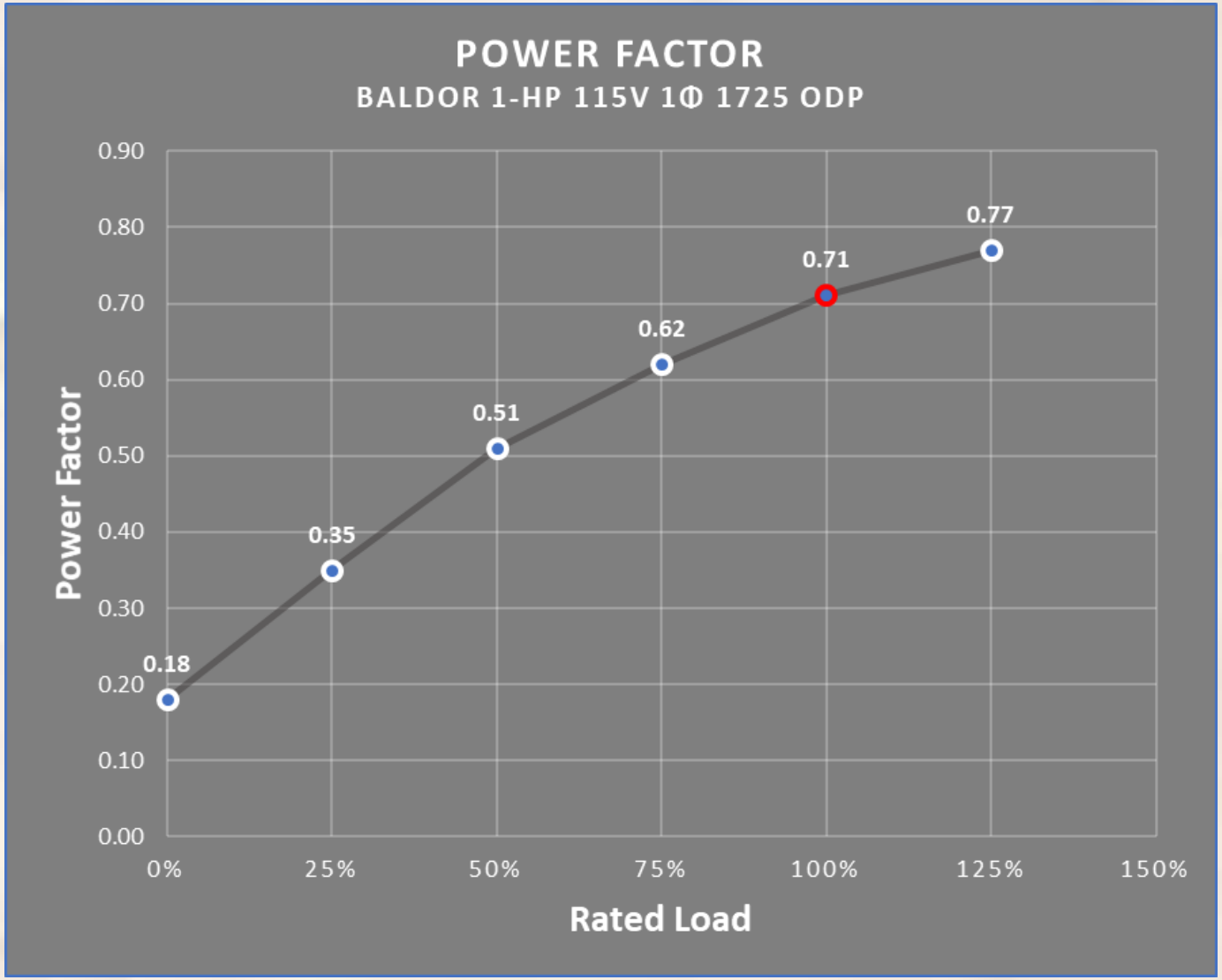
You are paying for 51% of the energy Mr. Burns has to produce for you – and now he is really pissed!

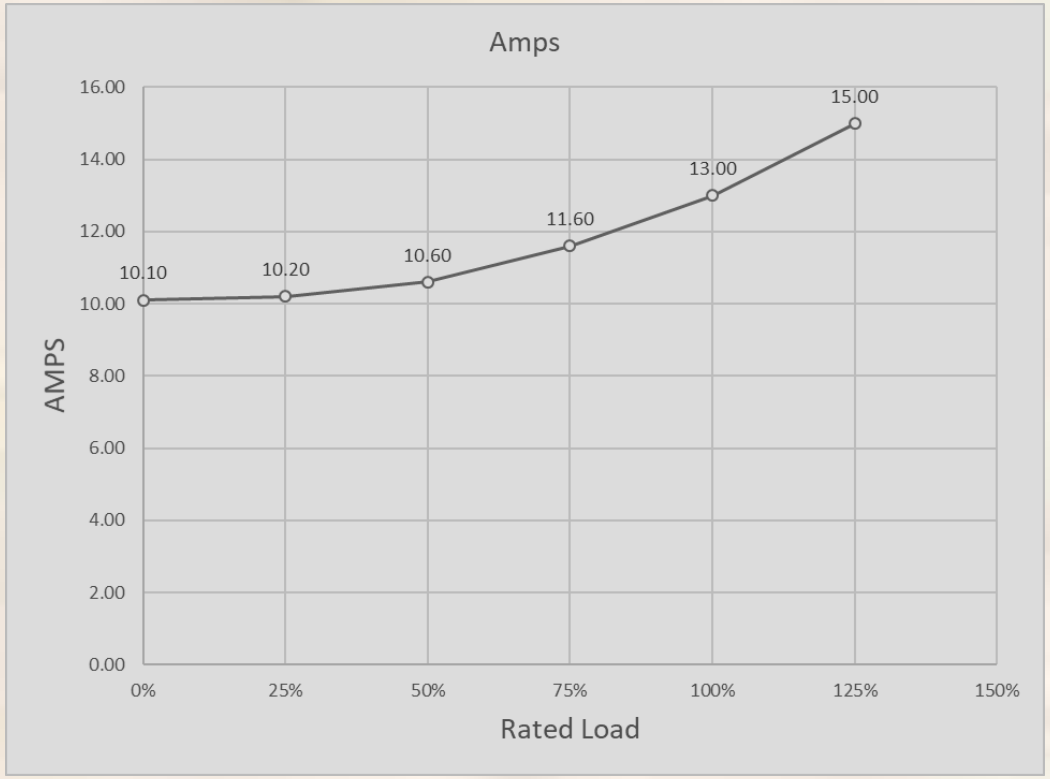
Watt-hour Meter

1 HP 115V 1Φ 1750 RPM

50% Loaded

Capacitor Bank


POWER FACTOR
BALDOR 1-HP 115V 1Φ 1725 ODP
Power Factor
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.18
0.35
0.51
0.62
0.71
0.77
0%
25%
50%
75%
100%
125%
150%
Rated Load


Amps
AMPS
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
10.10
10.20
10.60
11.60
13.00
15.00
0%
25%
50%
75%
100%
125%
150%
Rated Load

Some Useful Formulas

$$\text{Power Factor (PF)} = \frac{\text{Watts}}{\text{Volt x Amperes}}$$

$$\text{Power Factor (PF)} = \frac{\text{kW}}{\text{kVA}}$$

AC 1-Phase $\quad \text{Watts} = \text{Volts x Amps x PF}$

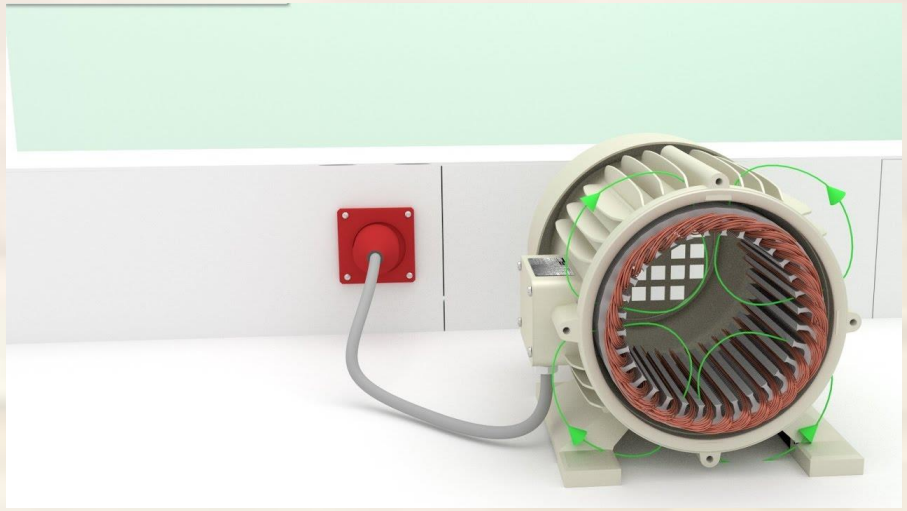
AC 1-Phase $\quad \text{kW} = \frac{\text{V x A x PF}}{1000}$ x 1.732 for 3-Phase

AC 1-Phase $\quad \text{Amps} = \frac{\text{kW x 1000}}{\text{Volts x PF}}$ x 1.732 for 3-Phase

AC 1-Phase $\quad \text{Amps} = \frac{\text{VA}}{\text{Volts}}$

When VA is known

Note:
PF is in the denominator

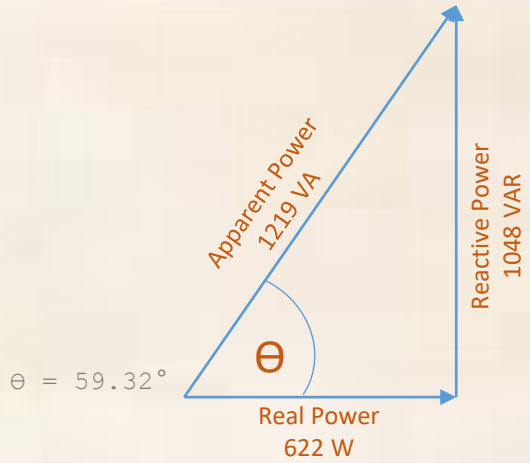


Motor magnetizing power (Reactive Power)

$$VAR = \sqrt{VA^2 - W^2}$$

$$VAR = \sqrt{1219^2 - 622^2}$$

$$VAR = 1048 \text{ VAR}$$



$$PF = \cos\theta = W/VA$$

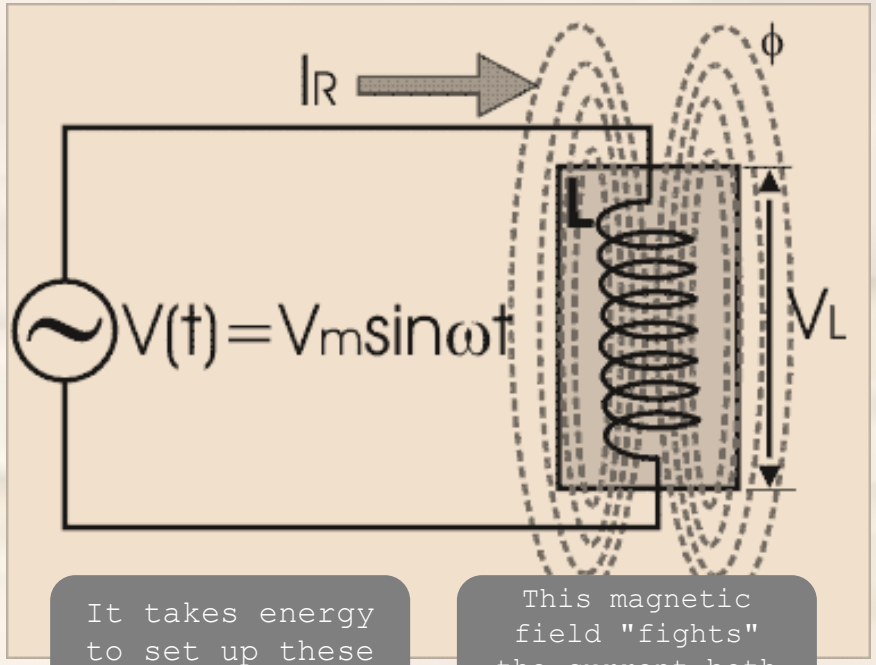
Notes:

1. Some Utilities use this "VAR" for assessing PF penalty.

2. Old electro-mechanical Power Meters can only read Watts (or kW). Separate kVAR meters were installed. Newer digital Meters "know" all 3.

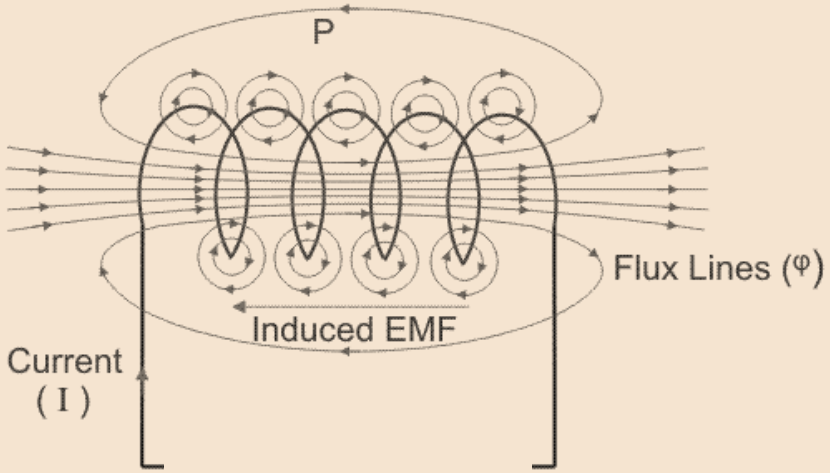
3. In the near future they will start basing energy charges on VA-hr usage and then the PF will become the Customer's problem not the Utility's.

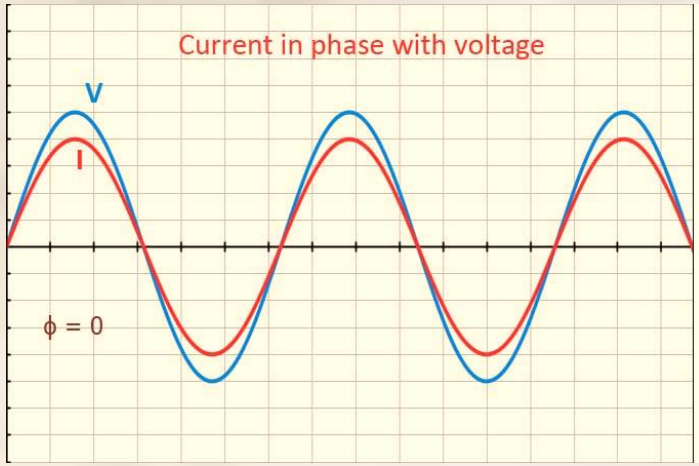
Current LAGS the Voltage in Inductors



It takes energy to set up these magnetic fields

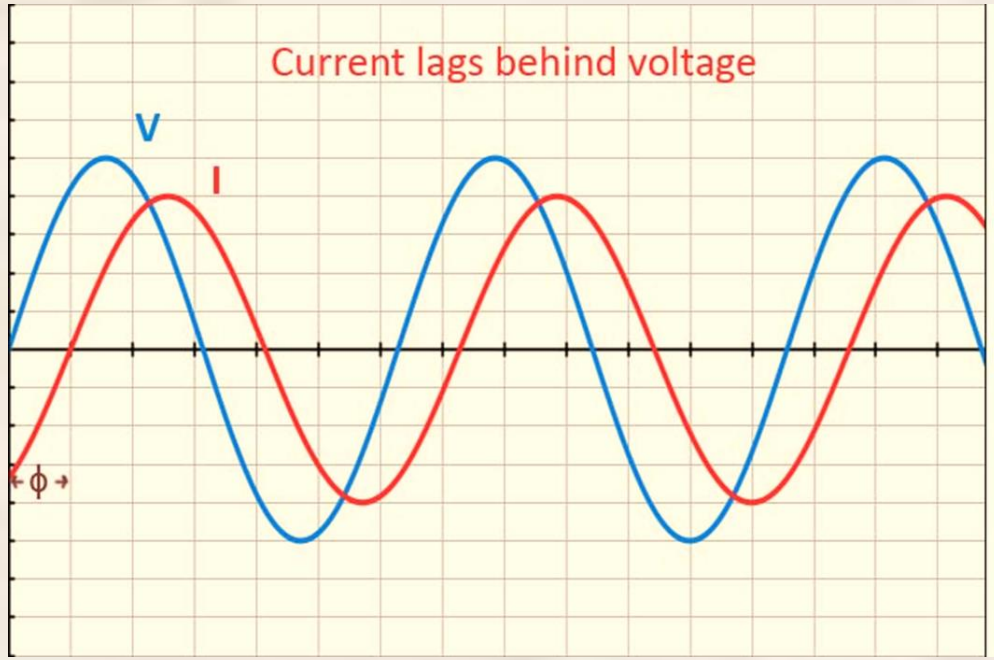
This magnetic field "fights" the current both ways

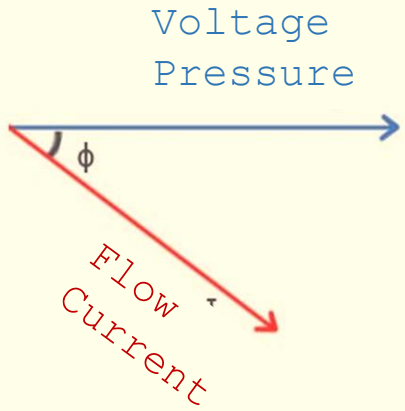


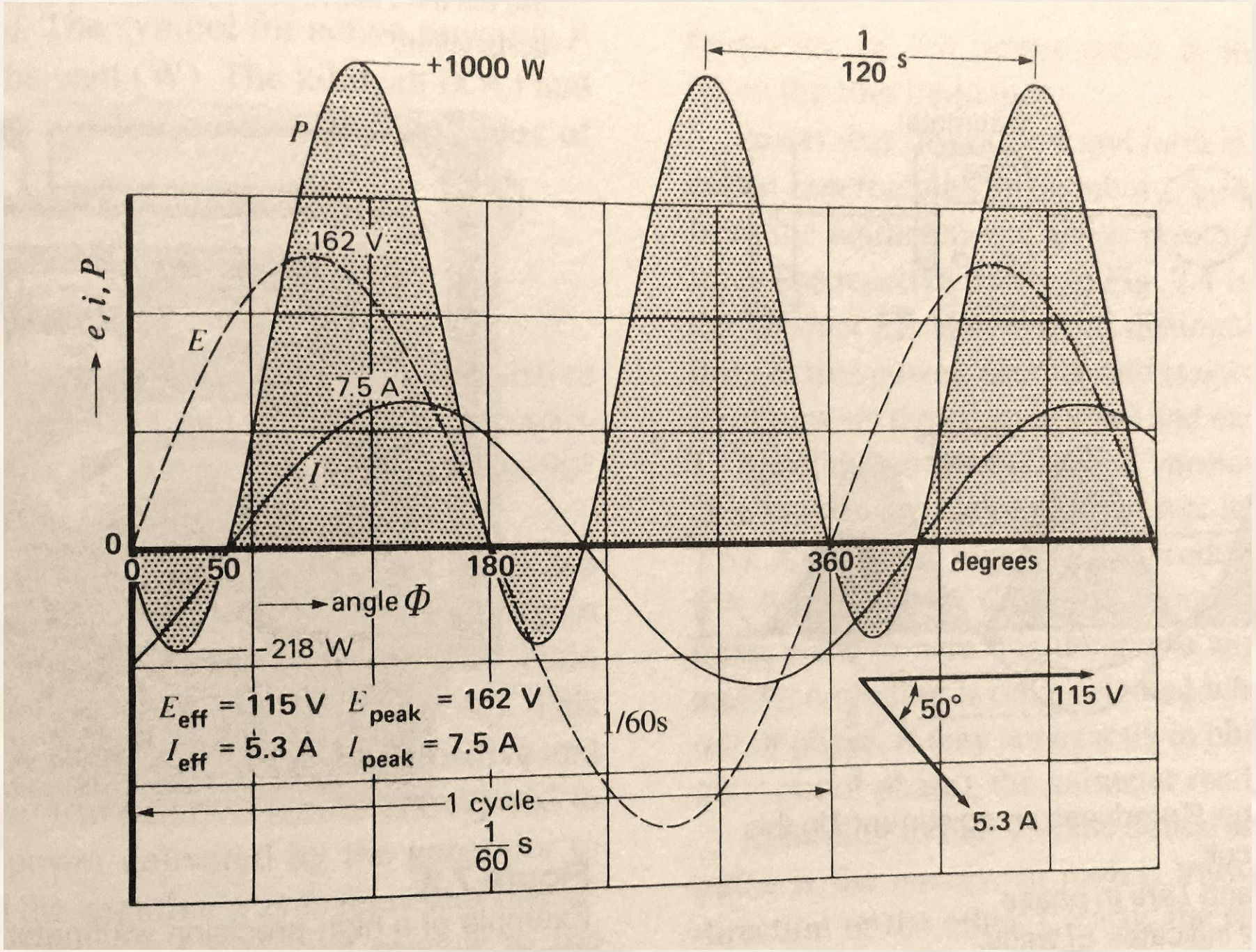


Pure Resistance
V & I in Phase

"Pressure" and "Flow" are lined up





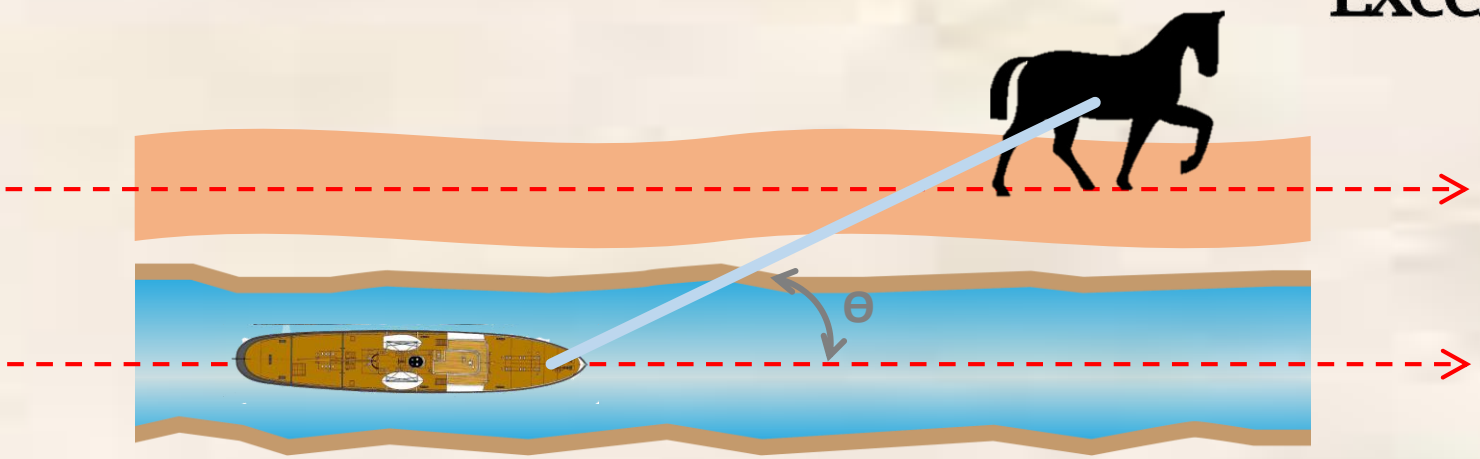

+1000 W
P
1/120 s
162 V
E
7.5 A
I
e, i, P
0
0
50
180
360
degrees
angle Φ
-218 W
E_{eff} = 115 V E_{peak} = 162 V
I_{eff} = 5.3 A I_{peak} = 7.5 A
1/60s
1 cycle
1/60 s
50°
115 V
5.3 A

Before Mr. Burns was in nuclear Energy, he rented out horses to pull canal boats

He got paid by keeping a record of how many miles his horse pulled the boat

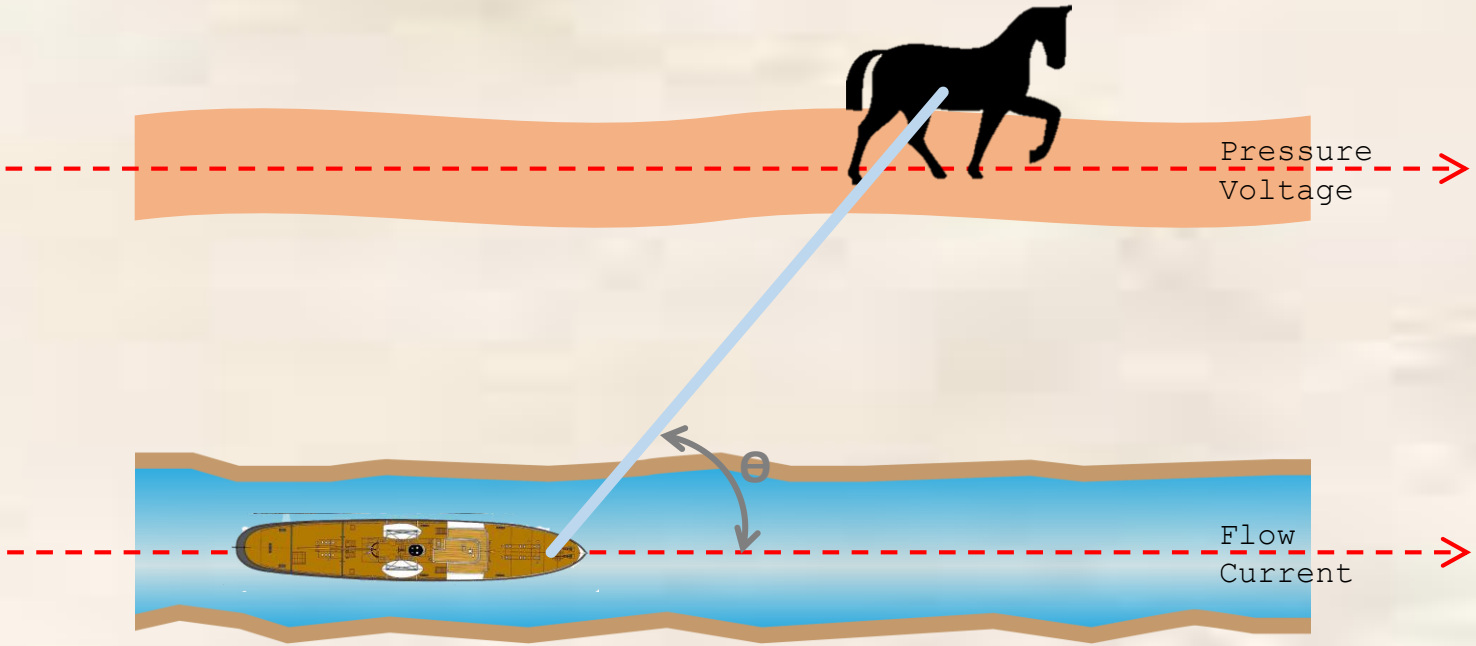
A bad analogy – Don't carry it too far!

Small angle θ = Large (near 1) Power Factor = Good



A bad analogy – Don't carry it too far!

Large angle Θ = Small (near 0) Power Factor = Bad



The End

LIFE IS LIKE A MONKEY... IT THROWS SHIT AT YOU