This is vital to understand!!!

$$P = \underbrace{V_{RMS} I_{RMS}}\ \underbrace{\cos\theta}$$

True Power = Apparent Power · Power Factor ($0 \le PF \le 1$)

$$P = AP \cdot PF$$

This is important because we pay for energy, not power, and energy is $W = \int_0^T P\,dt$ as long now as T is a long time, like seconds or minutes or hours, or even longer. This Energy is what the Electric Meter on a house or building records, in units of Watt hours, or Wh. (W·s is Joules, but they are too small and require too many conversions.)

Time average power

In 2012 the average US residential utility customer consumed 903 kWh / month

La - highest - 15,046 kWh
Me - lowest - 6,367 kWh

In 2012, the total US consumption of electricity

was 3,694,650 MWh !

or 3.69465 TWh

37% went to residential
36% commercial
26% industrial
2% transportation

~~Average~~ The world consumed (in ~2012)

$19{,}320{,}360{,}620$ MWh/yr $\cdot$ (365.25)(24)

$= 16{,}936{,}228{,}120{,}000$ MWh

Millions
Billions
Trillion
Quadrillion
Quintillion $\Longrightarrow$ 17 Quintillion Wh !!

$\underline{17 \times 10^{15}\ Wh} \times 3600 \frac{J}{Wh}$

$= 61{,}200 \times 10^{15}$ J
$= 61.2 \times 10^{18}$ J

Per Capita Consumption:

Afghanistan, Chad, Sierra Leone $\rightarrow$ ~ 8,700 Wh
US (6th) $\longrightarrow$ 14.75×10^{6} Wh
Iceland (1st) $\longrightarrow$ 51.17×10^{6} Wh

Go back to:

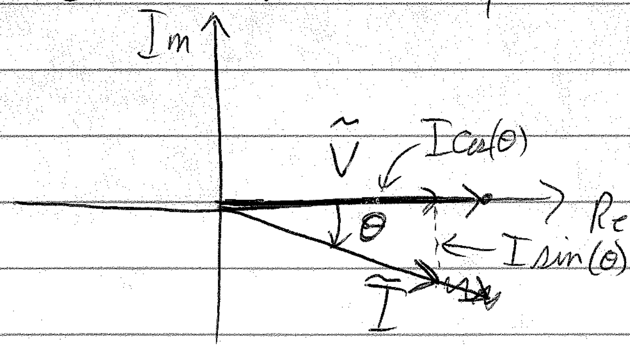
$$P = P_{APP} \cos(\theta) = V_{RMS} I_{RMS} \cos(\theta)$$

In our power system, we keep V_{RMS} constant, and each house, office, factory, etc takes whatever I it needs to get the power it requires, so

$$I_{RMS} = \frac{P}{V_{RMS} \cos(\theta)}$$

If the Power factor is less than 1, then I_{RMS} must be larger to provide the same P (time Average Power)

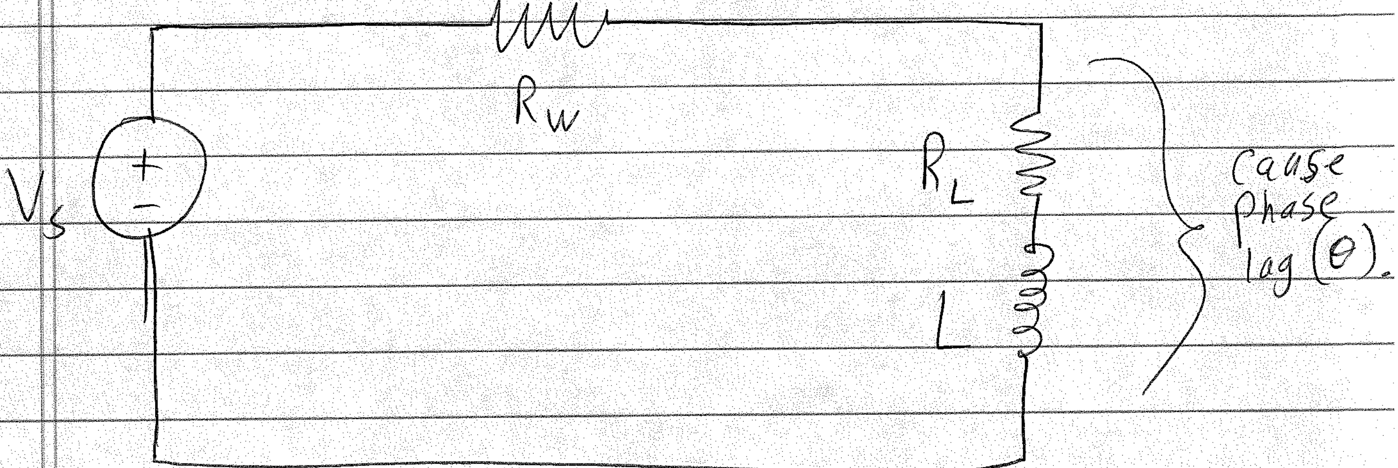
Think of it this way:



$$P = V_{RMS} \underbrace{I_{RMS} \cos(\theta)}_{\text{Projection of } \tilde{I} \text{ onto Re axis}}$$

To get the same P as $|\theta|$ increases I_{RMS} must increase.

But this is real current that the power company must provide, ~~and which leads to increased~~



Most commercial and industrial loads, and increasingly most residential loads, are <u>inductive</u> (motors) which cause I to <u>lag</u> V (ELI)

So If you need a power P in the load,

$$I = \frac{P}{V \cos(\theta)}$$

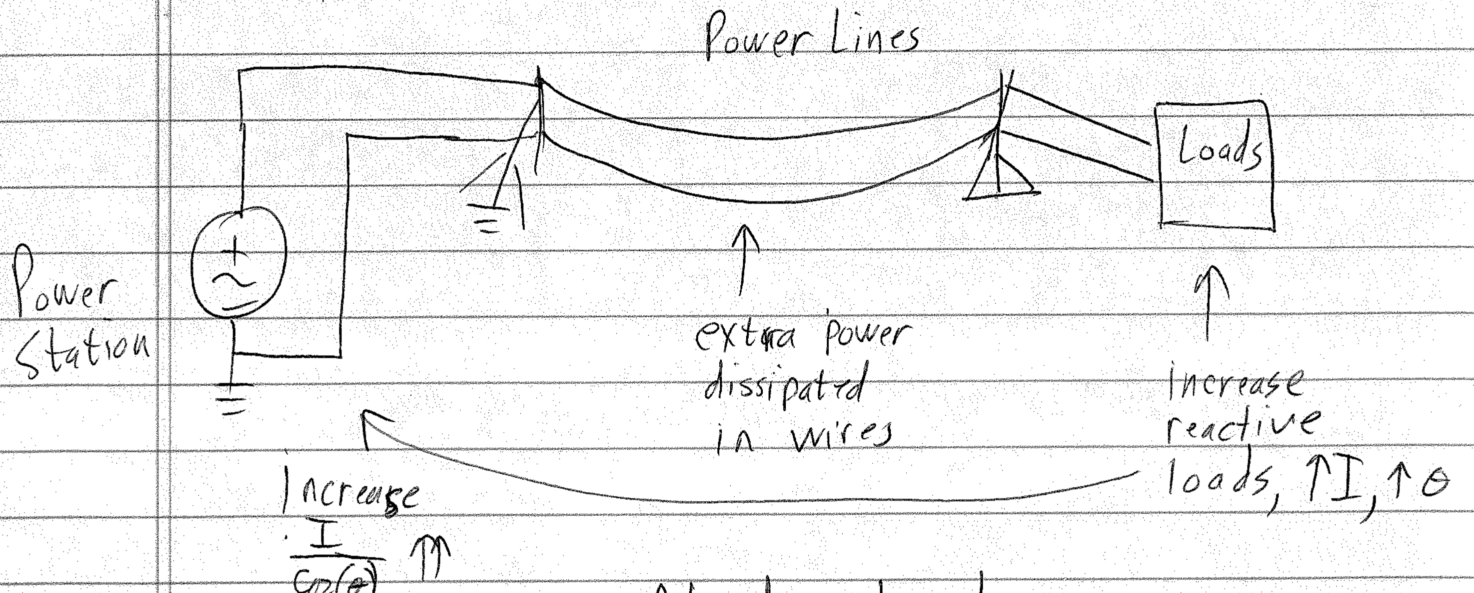
$$P_W = R_W I = \frac{R_W P}{V \cos(\theta)}$$

As $\theta \uparrow$, $\cos(\theta) \downarrow$, $P_W \uparrow$ (energy loss in wires that Power Company cannot charge for.)

Power Companies therefore measure the PF at a companies connections to the grid, and charge extra if the PF < 0.85 or about that.

This corresponds to $\theta = \cos^{-1}(0.85) \approx 32°$.

The quantity $P_{APP}\sin(\theta)$ is called the "Reactive Power". ~~and corresponds to the amount of energy~~ Having to supply this Reactive Power is what costs extra for the power company. It can have real effects besides price:



Already a hot day, more power dissipated,

Wires heat → get longer → sag.