OVER TECHNOLOGIES
The smart spaces makers

Energy management in Smart Environment

Adriano Cerocchi, Ph.D.
cerocchi@dis.uniroma1.it

@ACerocchi #smartspaces

in collaborazione con:

CIS SAPIENZA
Cyber Intelligence and Information Security

DOMOTICA.it
il portale italiano dell'automazione domestica

Introduction > Course agenda

Introduction > Course agenda

Lecture 1:

- Forewords: power or energy?
- Electric energy: an italian story
- Energy distribution:
    - Thomas Edison Vs Nikola Tesla
    - A.C. production and distribution
    - A.C. - D.C. converter
    - Green energies
    - Smart Grids
- Power: Apparent, Active and Reactive
- Measuring the electric energy: how to
- A smart approach to activity recognition
- A smart approach to in-house energy management

Lecture 2:

- introduction to smart houses: example and definition
- general architecture of a smart house
- actuators: relay and dimmer technologies
- BUS comparison: I2C, CAN, Ethernet, KNX, EDS
- interfaces
- **final projects**

Forewords > Power or Energy?

Forewords: power or energy?

We talk about...

Power

↓

when we talk about
an instantaneous value

Power = P(t)

↓

Watt

Energy

↓

when we talk about
a value in the time

$$\textbf{Energy} = \int_a^b \textbf{P(t) dt}$$

↓

Watt-hour

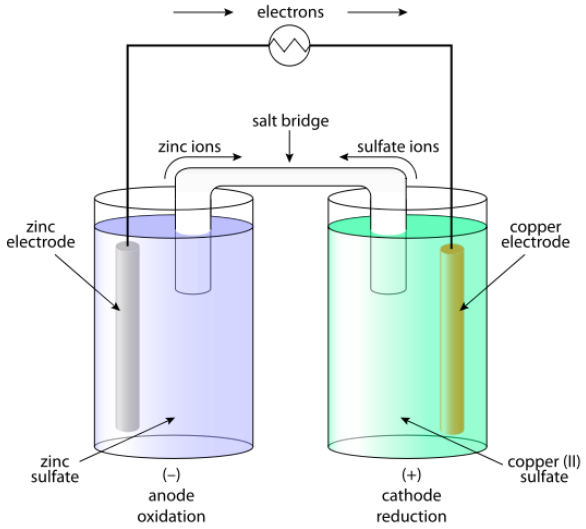
Electric Energy > An italian story

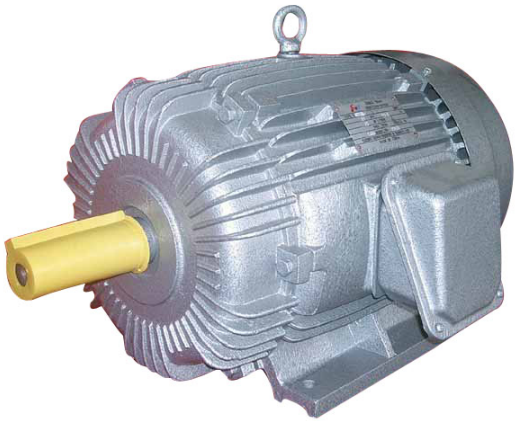
Electric Energy > An italian story

Alessandro Volta

Luigi Galvani

Galileo Ferraris

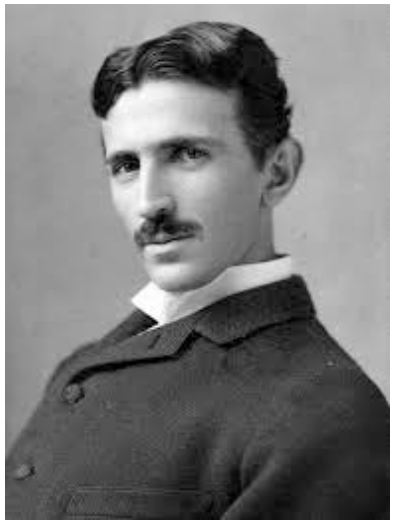




Energy distribution > Thomas Edison Vs Nikola Tesla

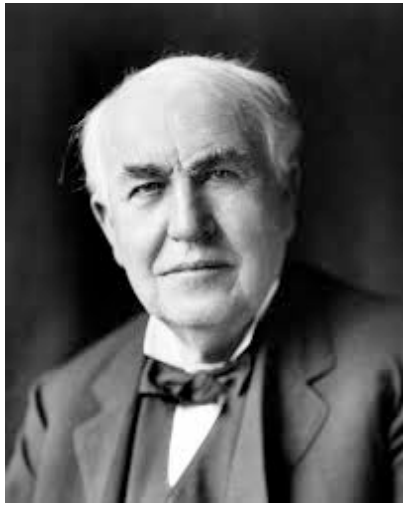
Energy distribution > Thomas Edison Vs Nikola Tesla

Nikola Tesla: "alternating current is the best solution"



Edison and Tesla were the main actors of the currents-war...

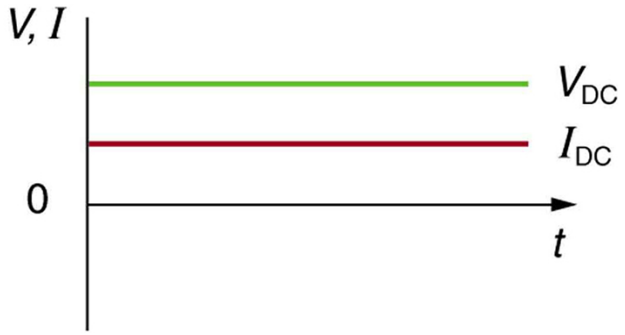
...Edison was able to burn an elephant with the aim of defame Tesla idea



Thomas Edison: "direct current is the best solution"

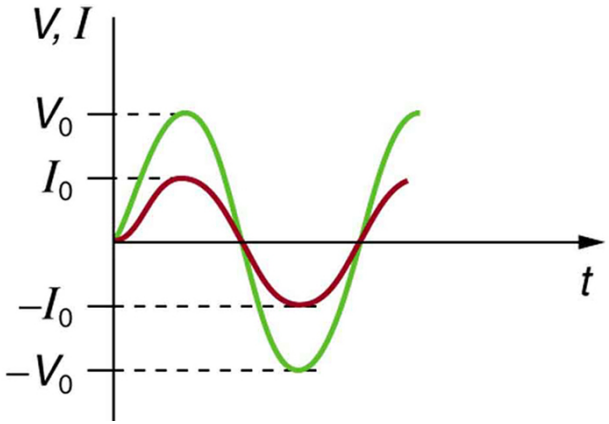
Energy distribution > Thomas Edison Vs Nikola Tesla

direct current



- constant current and voltage amplitude and direction (polarity)
- devices work with DC
- produced by dinamos
- easy to store in batteries

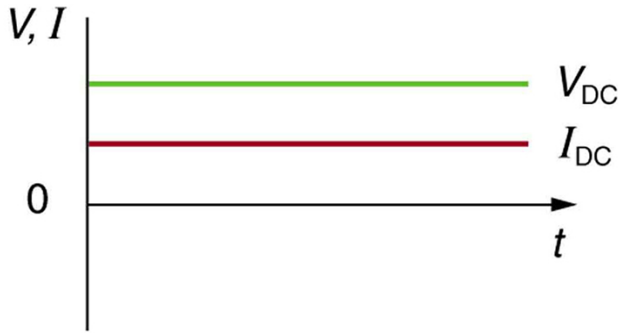
alternating current



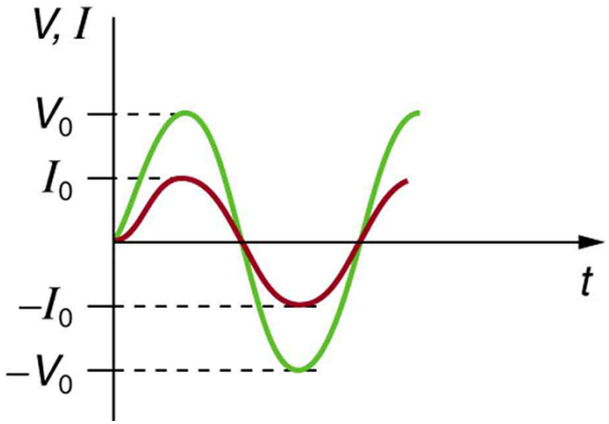
- current and voltage are sine waves at constant frequency
- easy to be produced
- Voltage is easy to be increased/decreased
- easy to transform to DC (using rectifiers)

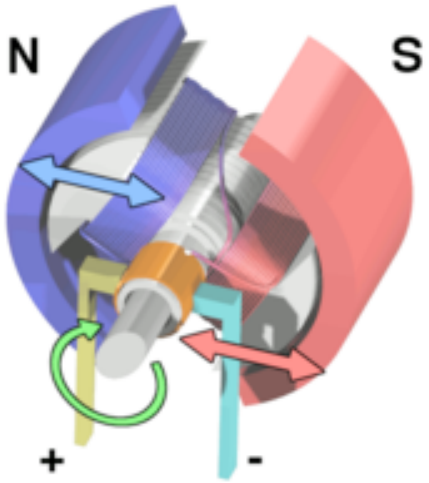
Energy distribution > Thomas Edison Vs Nikola Tesla

direct current



alternating current





dinamo

(induction motor with brush)

induction motor

(brushless)

The (first) Joule law: the heat amount released by a conductor is proportional to the square of the current:

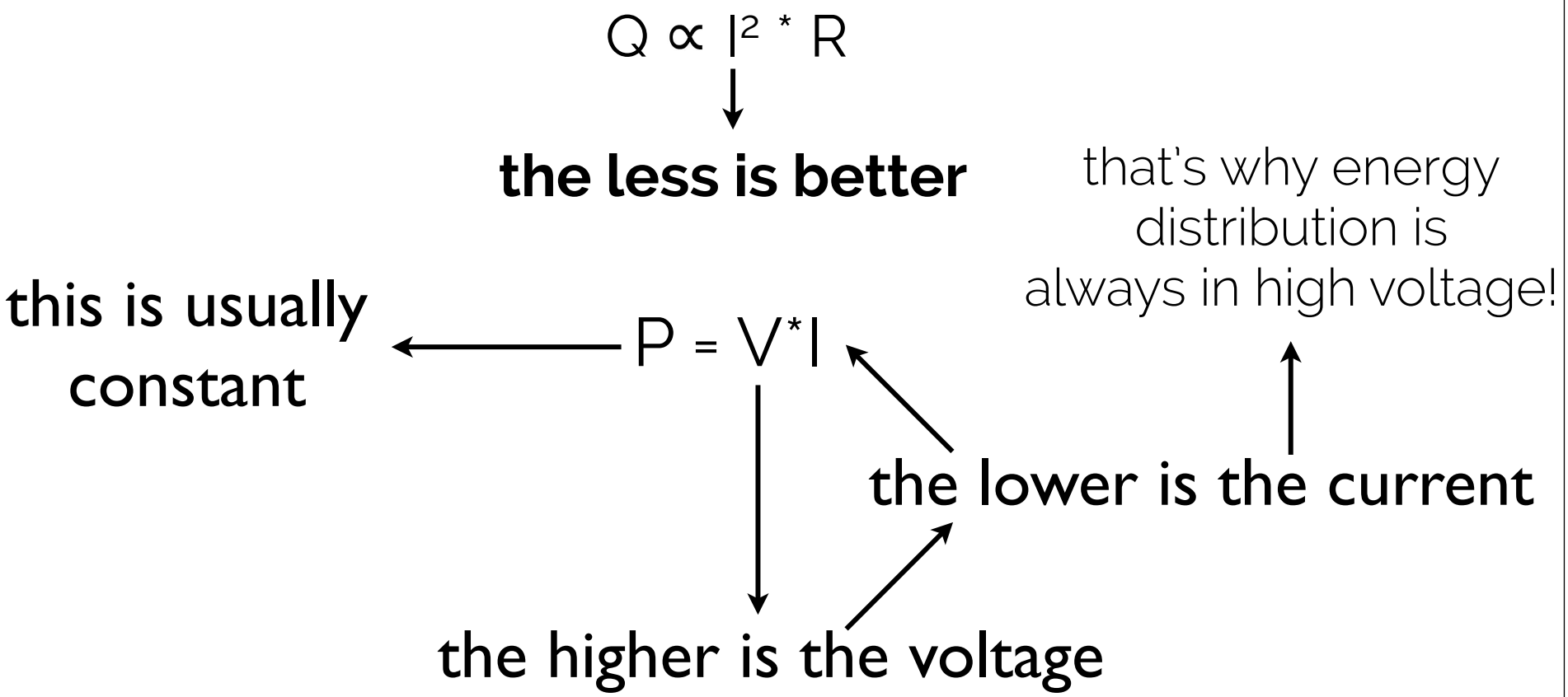
$$Q \propto I^2 * R$$

in general it consist in energy waste

the less is better

Every conductor has $R \neq 0$ **the longer is the wire, the higher is R**

The (first) Joule law: the heat amount released by a conductor is proportional to the square of the current:



The (first) Joule law: the heat amount released by a conductor is proportional to the square of the current:

$$Q \propto I^2 * R$$

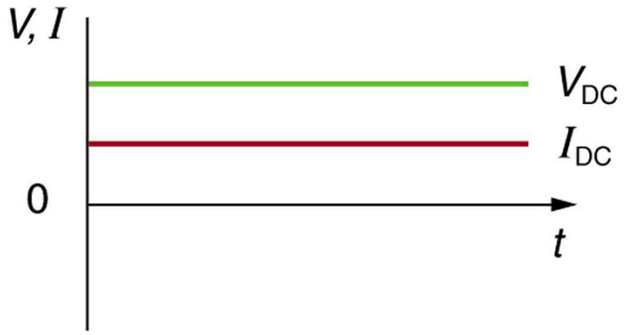
↓

the less is better → that's why energy distribution is always in high voltage!

We need a strategy to efficiently change (increase and decrease) the voltage

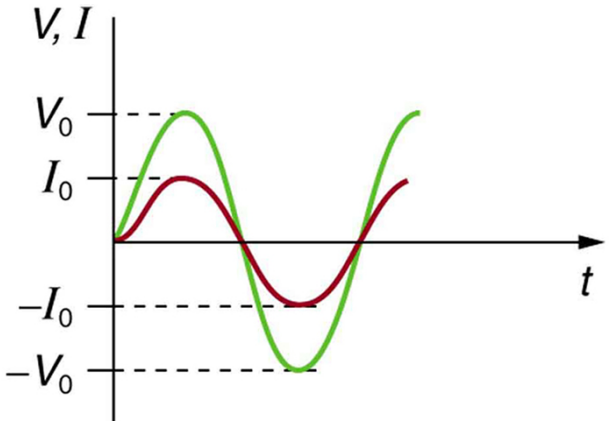
Energy distribution > Thomas Edison Vs Nikola Tesla

direct current



- constant current and voltage amplitude and direction (polarity)
- devices work with DC
- produced by dinamos
- easy to store in batteries

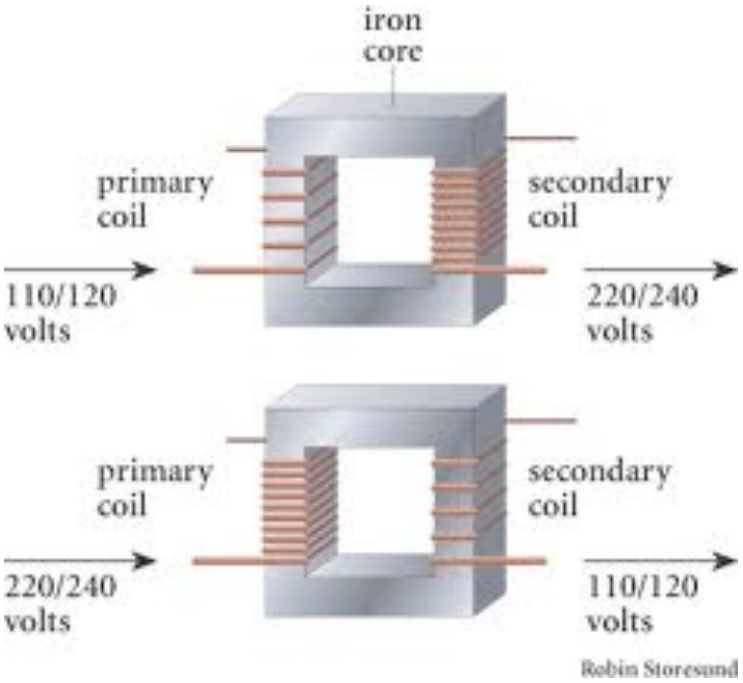
alternating current



- current and voltage are sine waves at constant frequency
- easy to be produced
- **Voltage is easy to be increased/decreased**
- easy to transform to DC (using rectifiers)

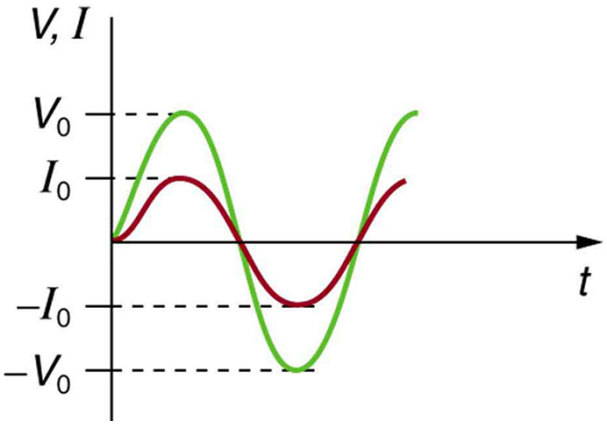
Energy distribution > Thomas Edison Vs Nikola Tesla

step-up trasformer



step-down trasformer

alternating current



- current and voltage are sine waves at constant frequency
- easy to be produced
- **Voltage is easy to be increased/decreased**
- easy to transform to DC (using rectifiers)

Energy distribution > Thomas Edison Vs Nikola Tesla

Nikola Tesla: "alternating current is the best solution"

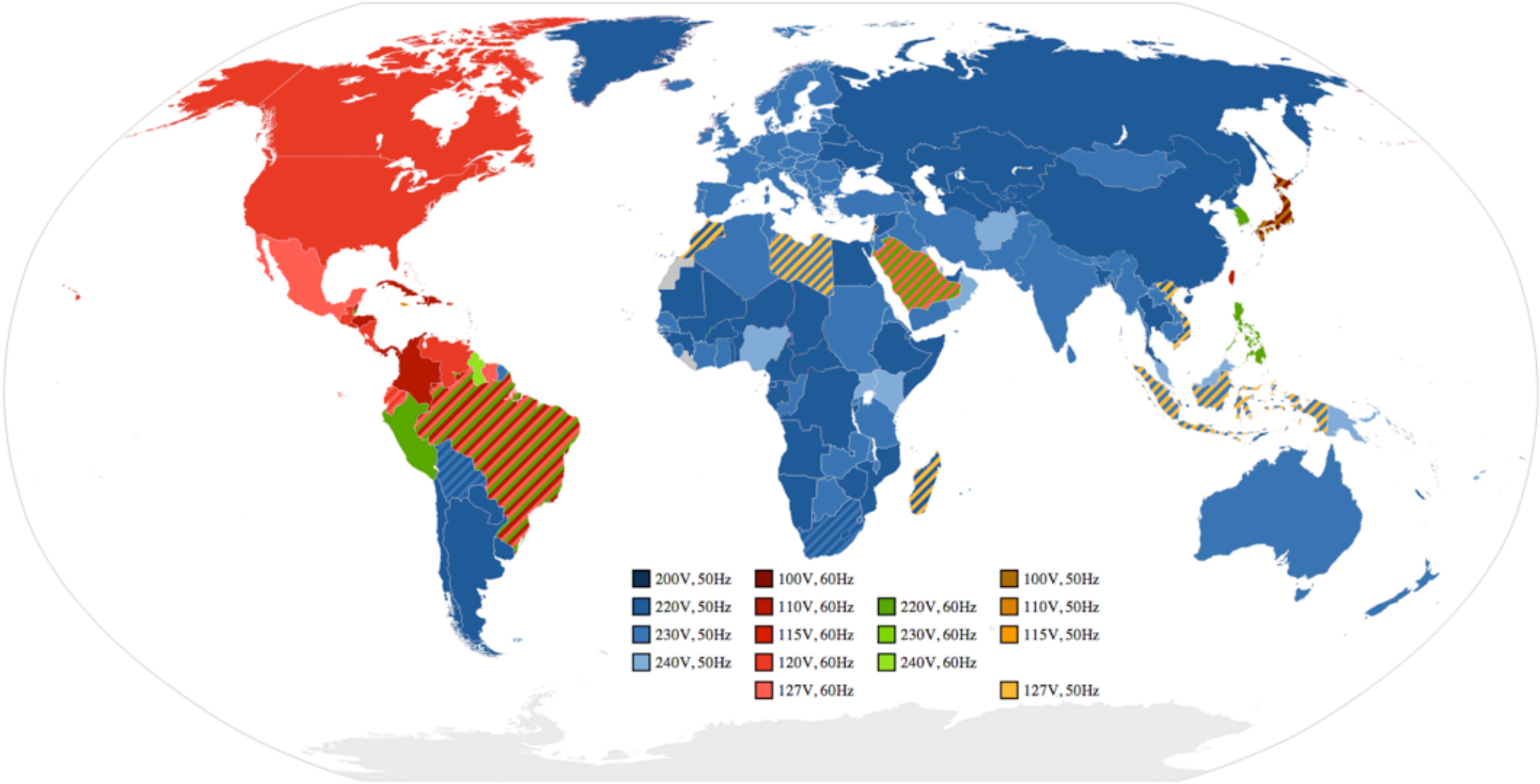
Edison and Tesla were the main actors of the currents-war...

...Edison was able to burn an elephant with the aim of defame Tesla idea

Thomas Edison: "direct current is the best solution"

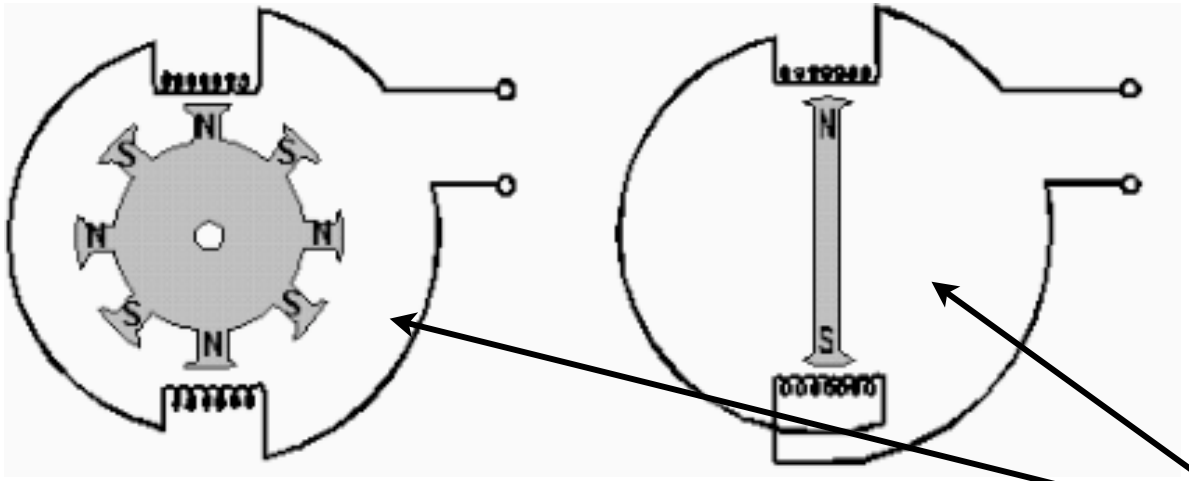
Energy distribution > Thomas Edison Vs Nikola Tesla

Nikola Tesla: "alternating current is the best solution"



Energy distribution > A.C. production and distribution

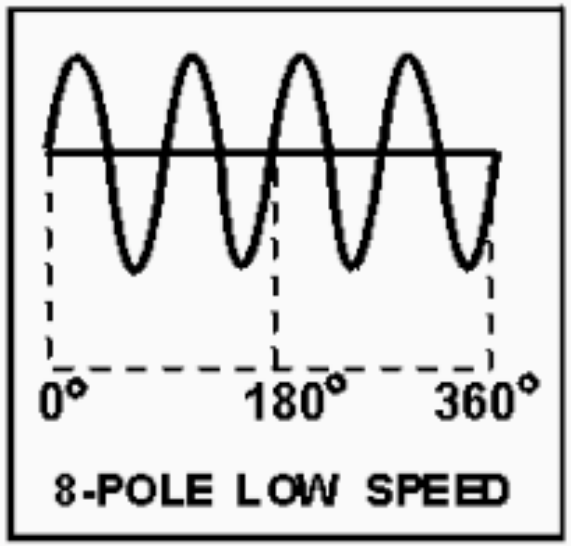
Energy distribution > A.C. production and distribution

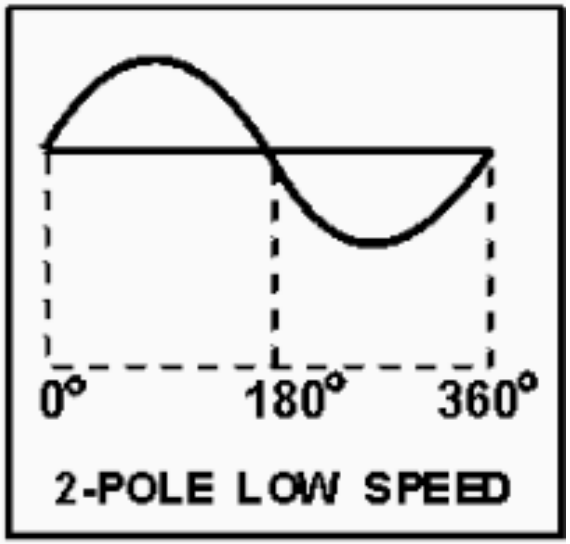


very easy implementation

...

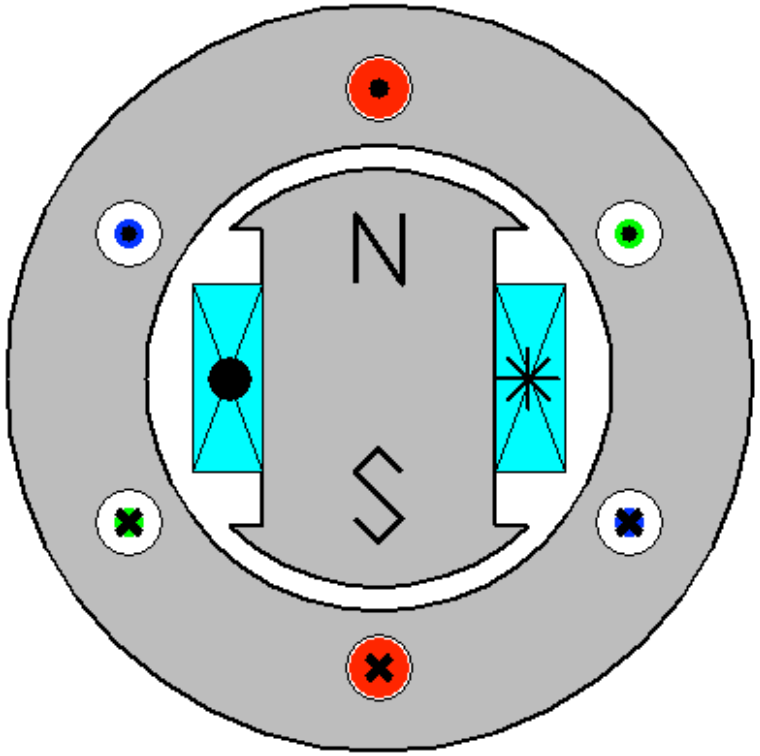
but low efficiency...



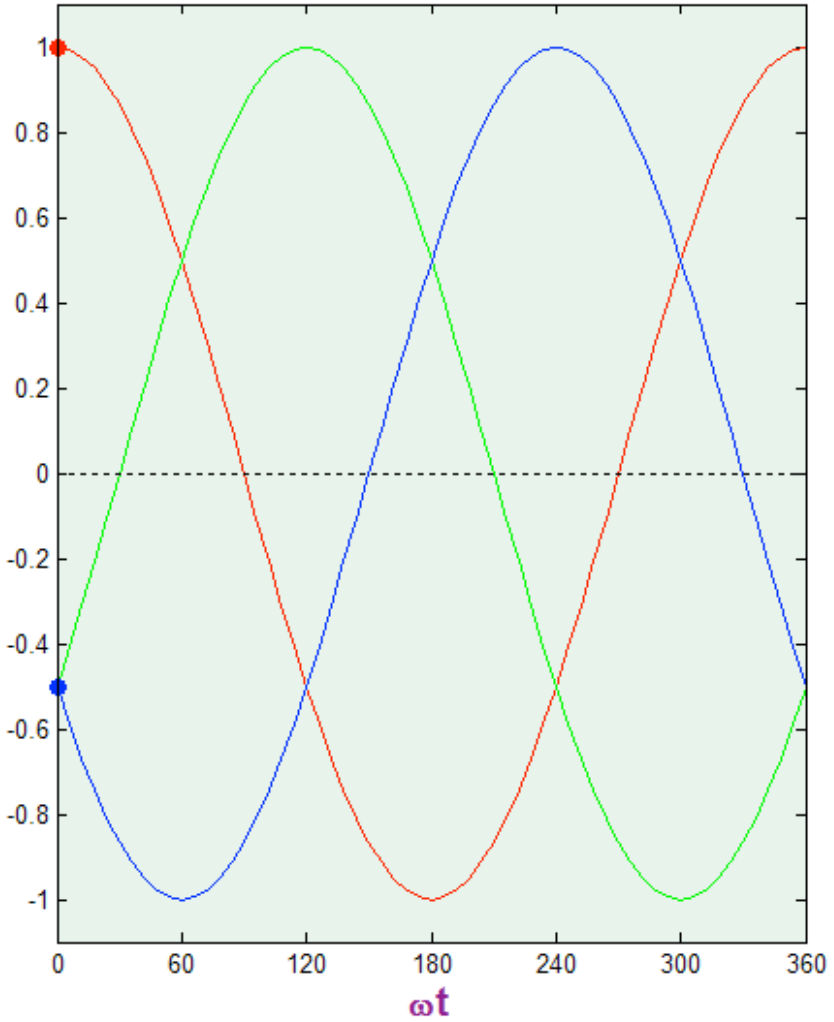


Energy distribution > A.C. production and distribution

Better efficiency: 3-phase system

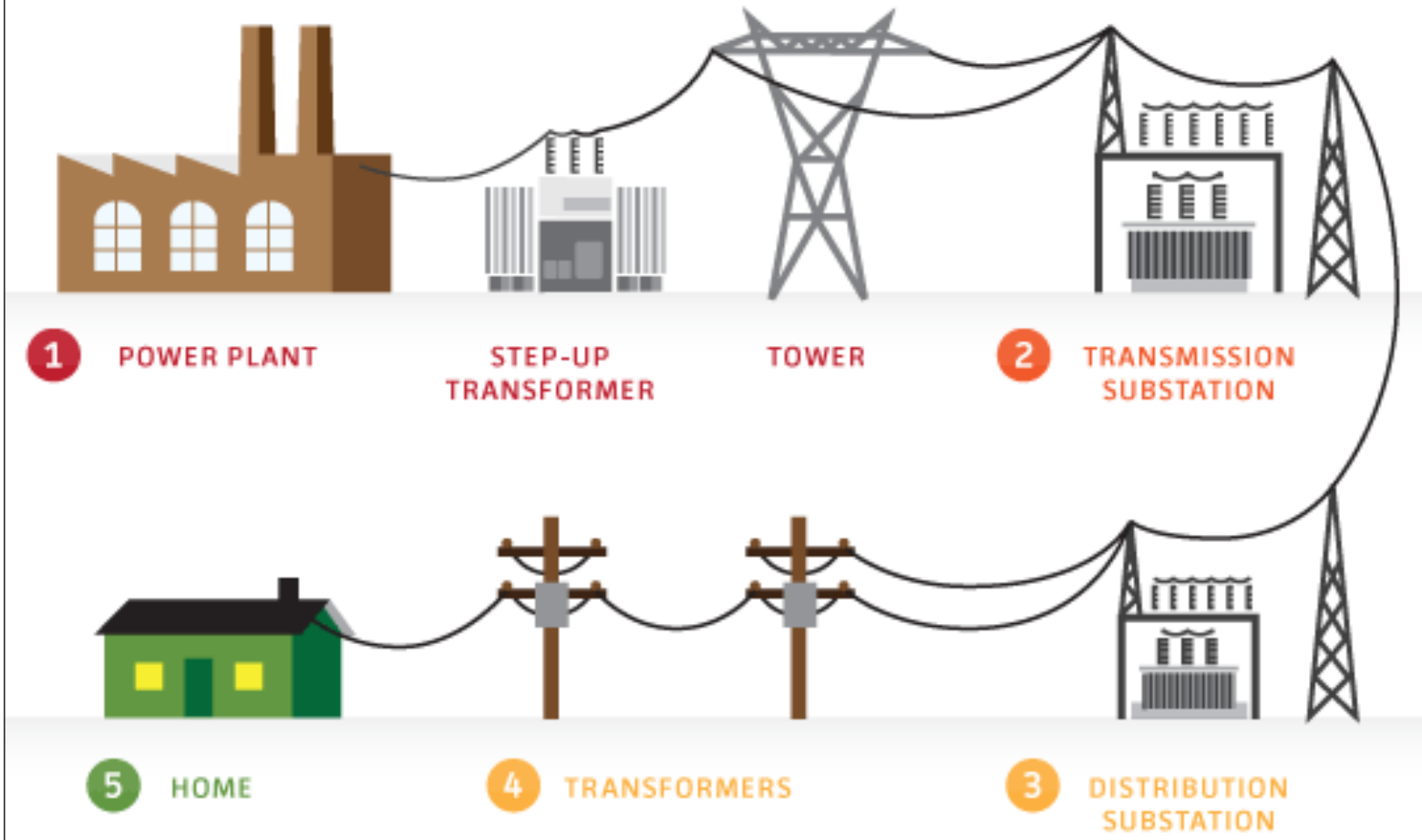


Phase A Phase B Phase C



animation: http://www.ece.umn.edu/users/riaz/animations/alternator.gif

Energy distribution > A.C. production and distribution

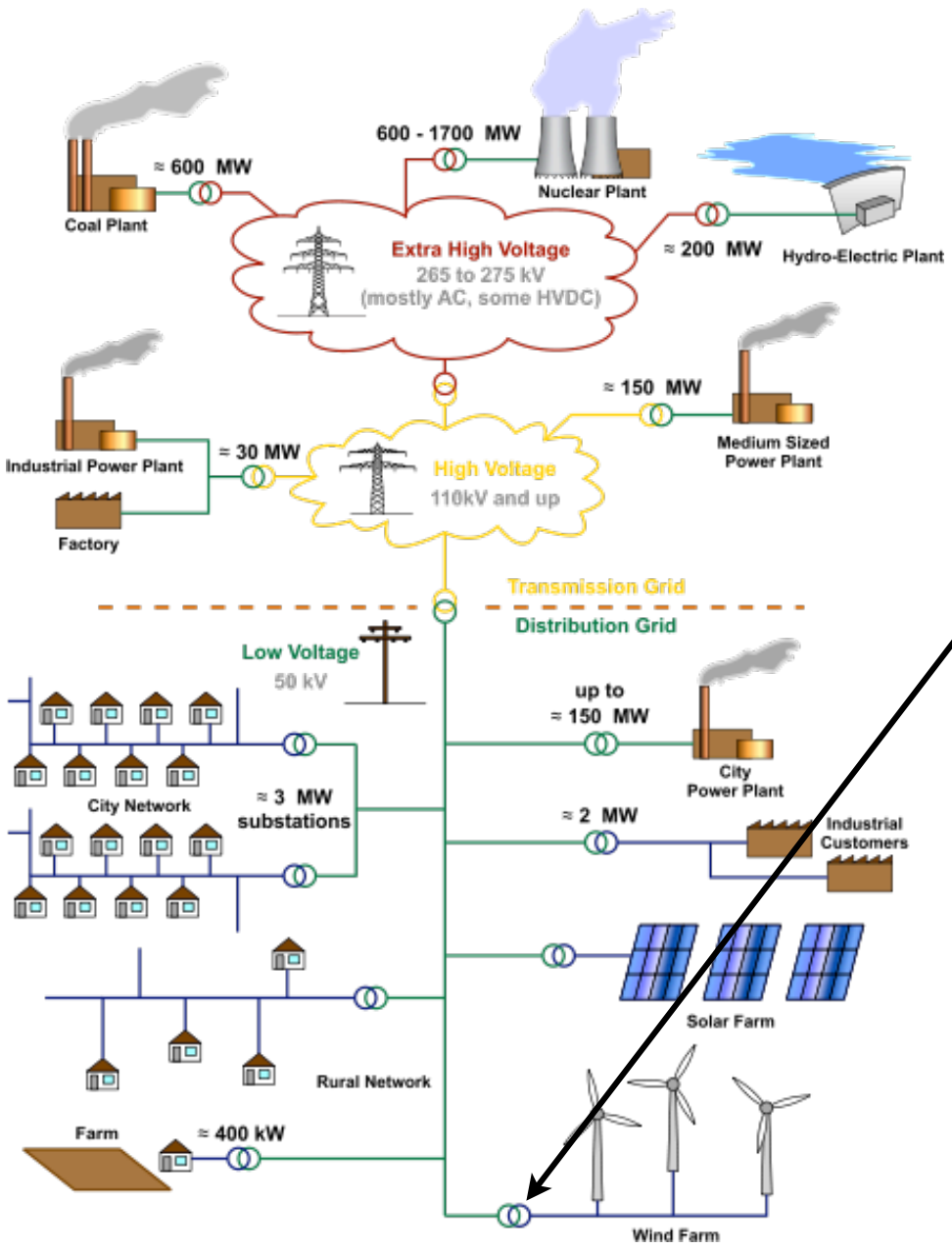


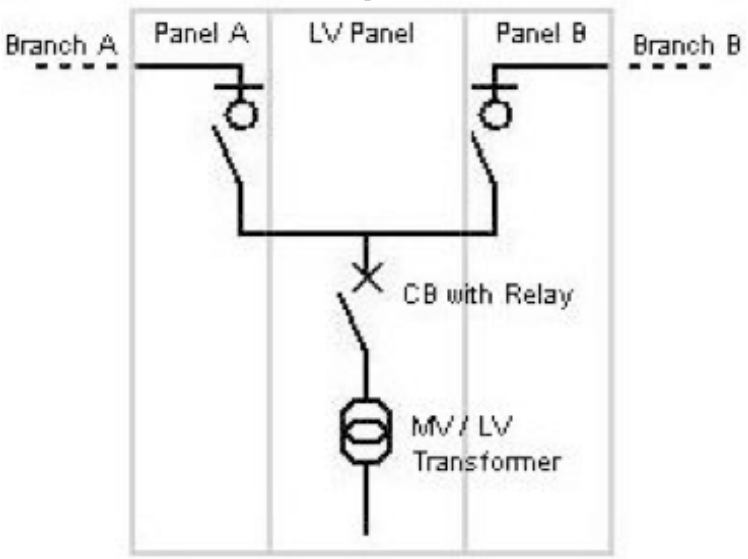
HV = 60kV - 150kV

MV = 1kV - 30kV

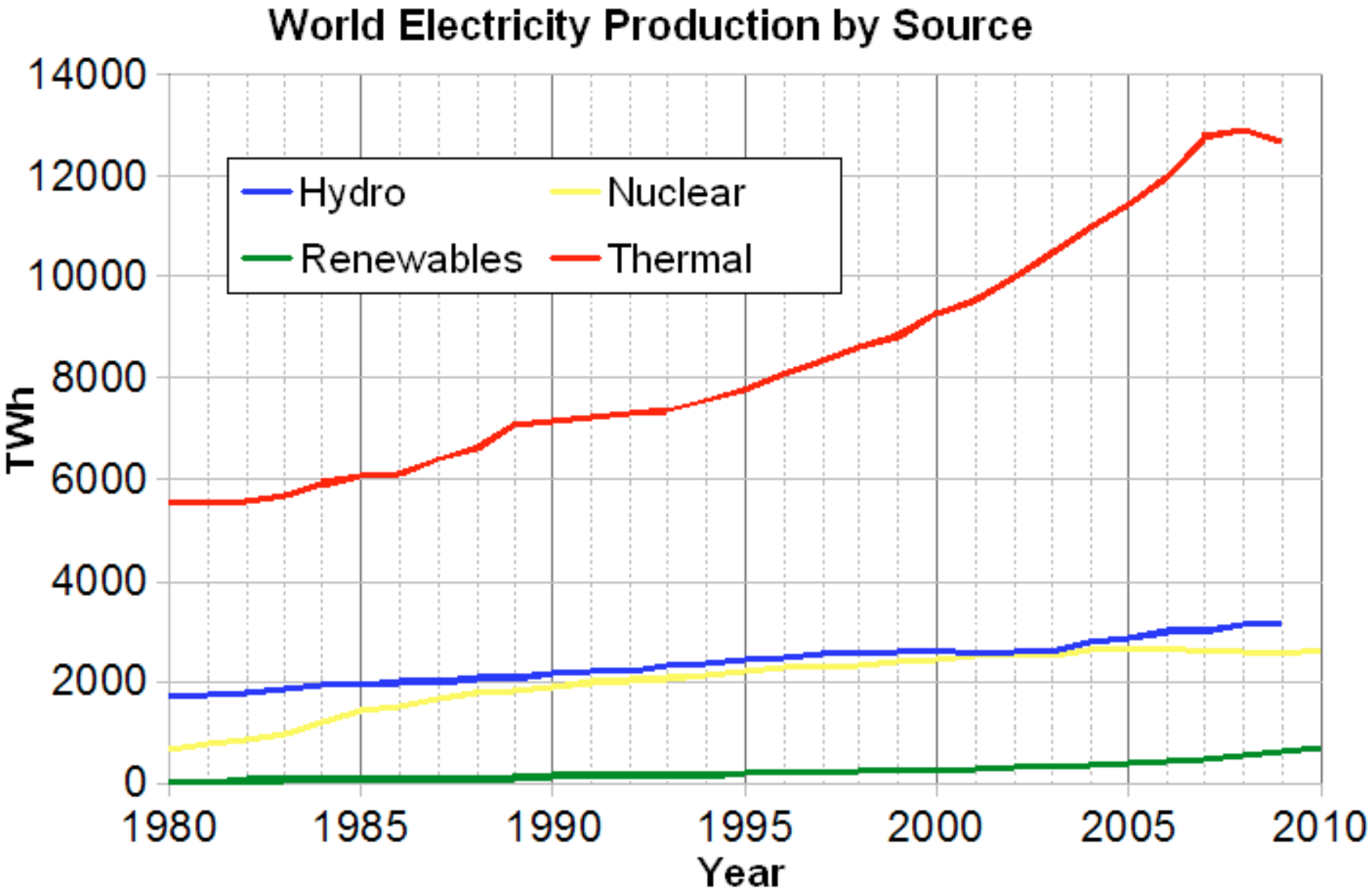
LV = 50V - 1kV

Energy distribution > A.C. production and distribution



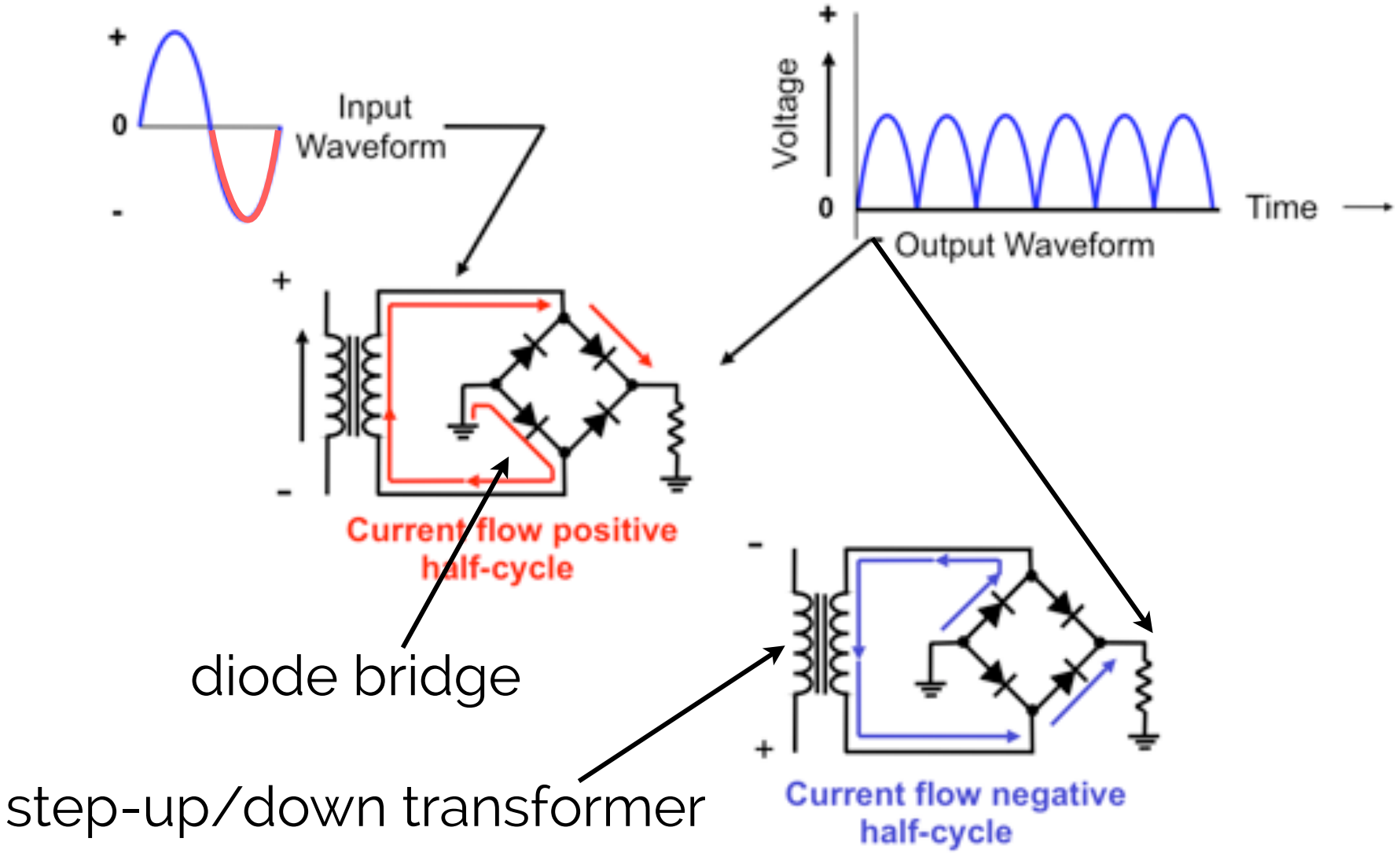


Energy distribution > A.C. production and distribution



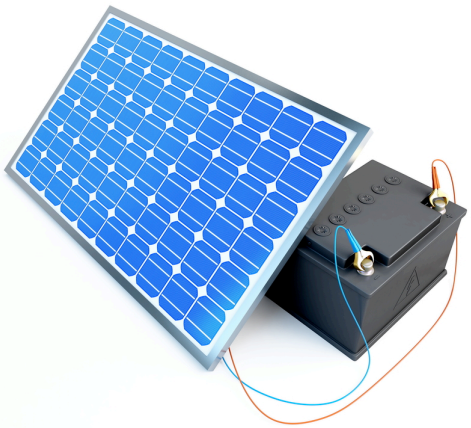
Energy distribution > A.C. - D.C. converter

Energy distribution > A.C. - D.C. converter



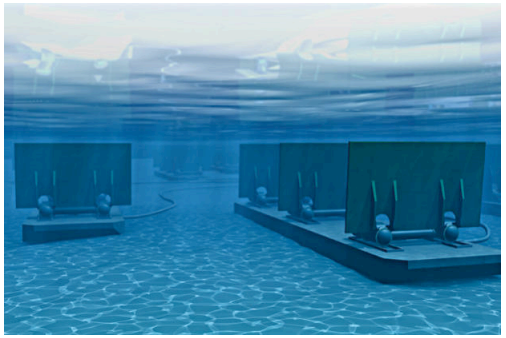
Energy distribution > Green Energies

Energy distribution > Green Energies



Solar Energy

Wind Energy

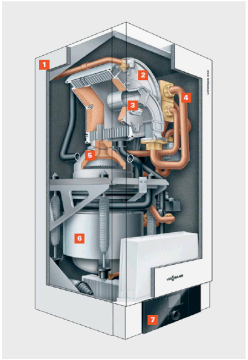


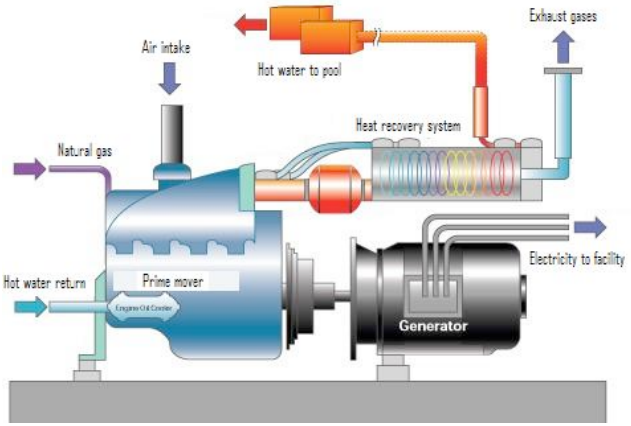
Wave Energy

...

Discussion: which is the most durable technology?

But also:

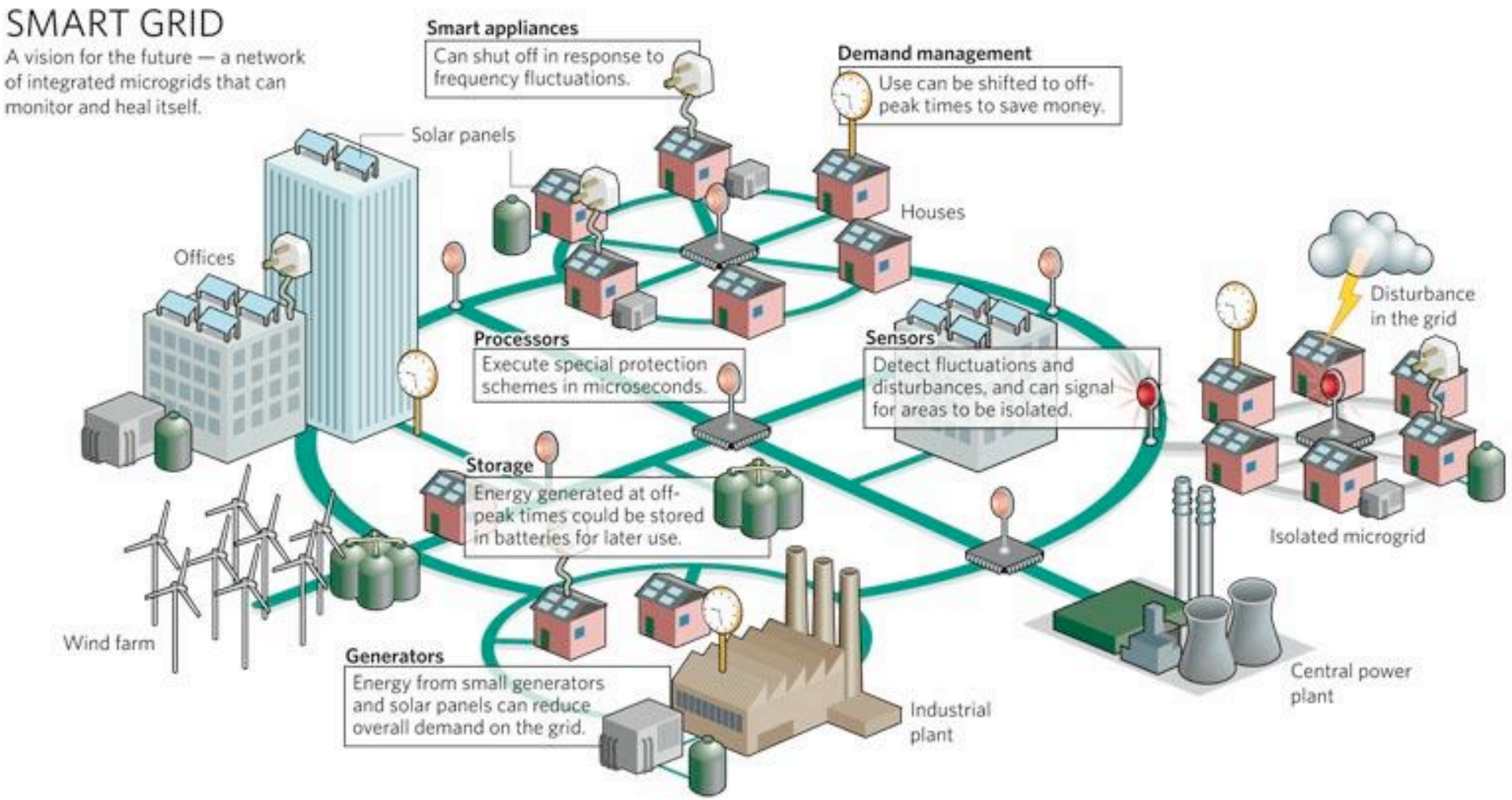




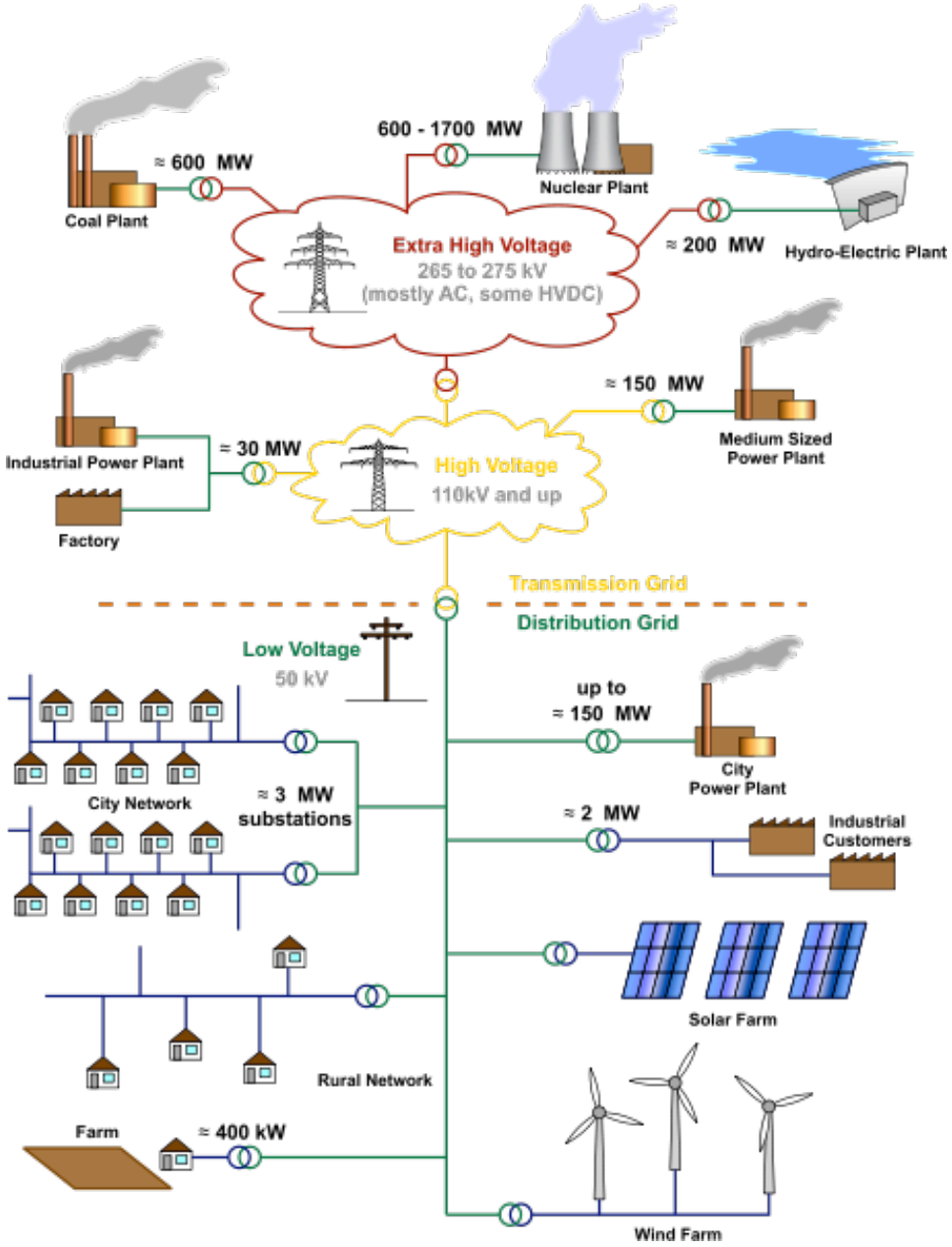
Co-generation solutions...

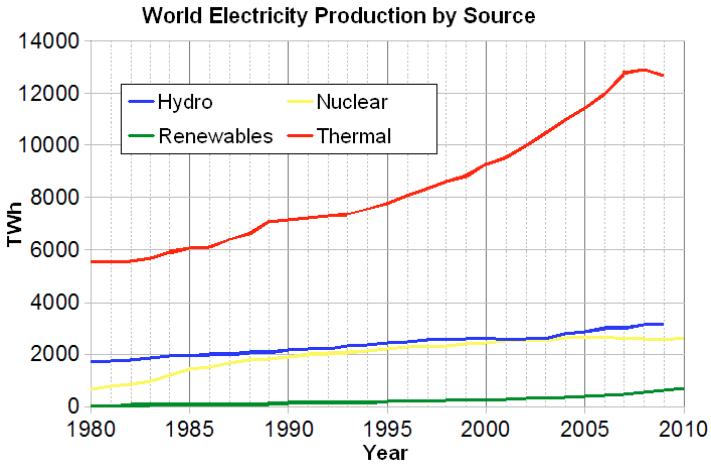
Energy distribution > Smart Grids

Energy distribution > Smart Grids



Energy distribution > Smart Grids

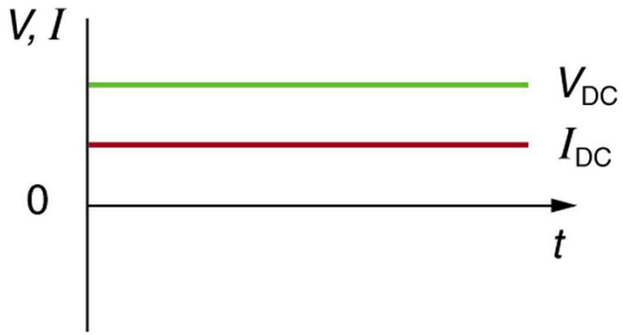




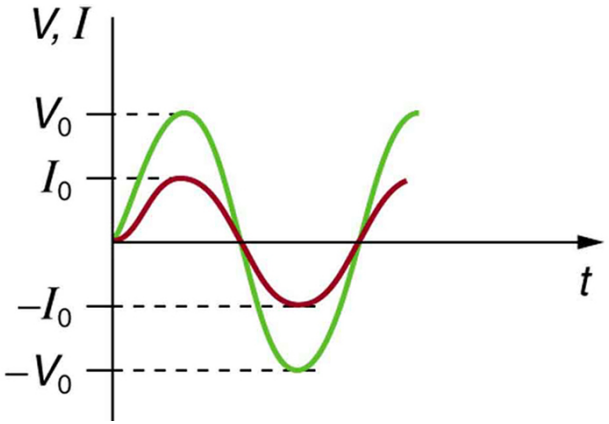
Power > Apparent, Active and Reactive

Power > Apparent, Active and Reactive

direct current



alternating current

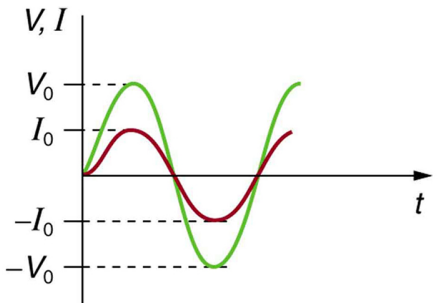


$P = V^*I$

$P(t) = V(t)^*I(t)$

Power > Apparent, Active and Reactive

alternating current



rms = root mean square

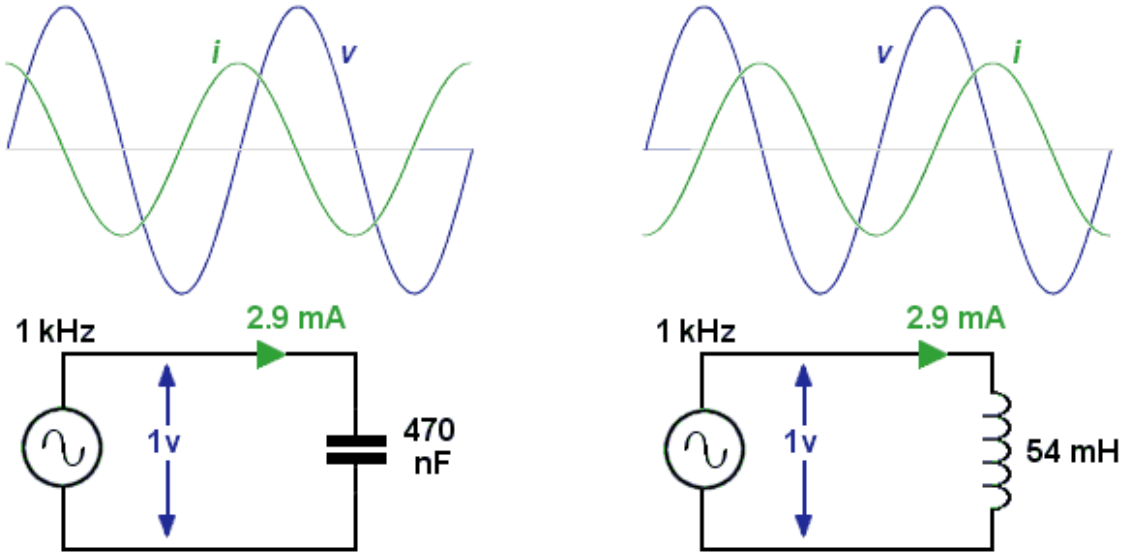
$$P_{avg} = V_{rms} * I_{rms}$$

$$V_{rms} = V_p / \sqrt{2}$$

$$I_{rms} = I_p / \sqrt{2}$$

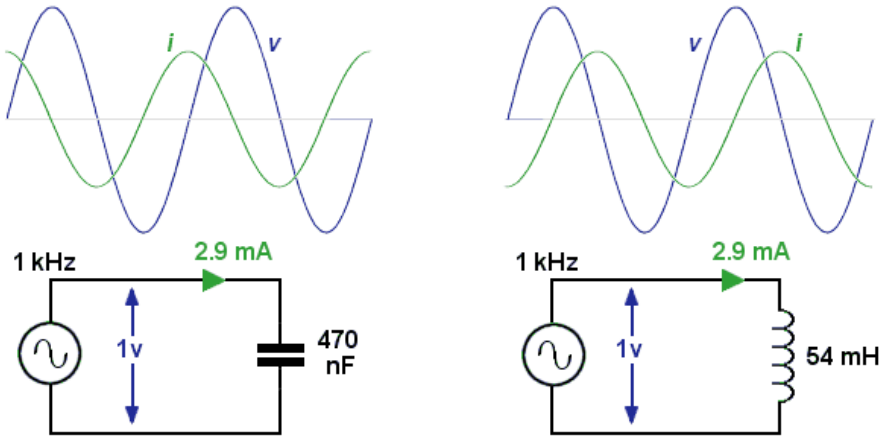
$$P(t) = V(t) * I(t)$$

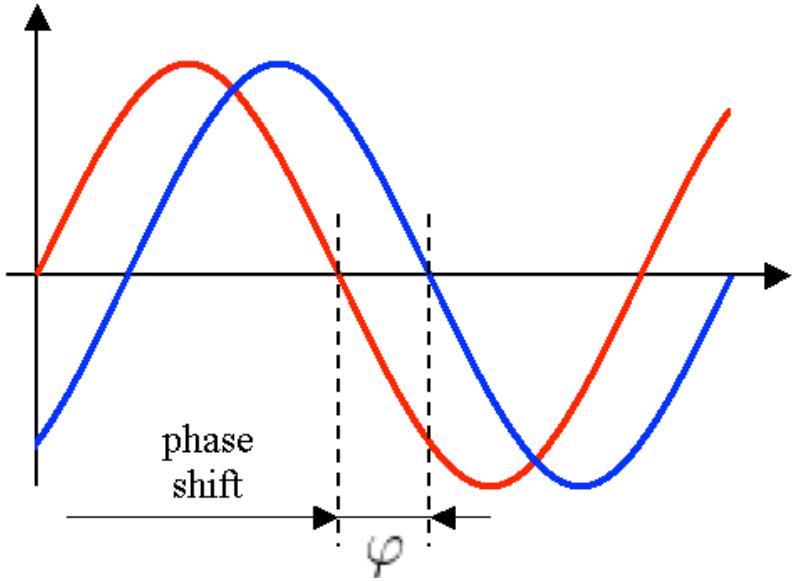
what if we have delays?



Power > Apparent, Active and Reactive

what if we have delays?

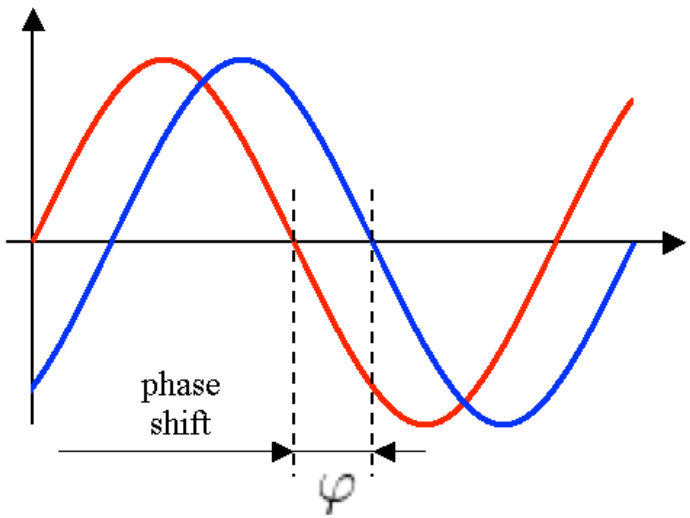




$P_{avg} = V_{rms} * I_{rms} * \cos\varphi \longrightarrow$ Active (or Real) Power

$Q_{avg} = V_{rms} * I_{rms} * \sin\varphi \longrightarrow$ Reactive Power

Power > Apparent, Active and Reactive



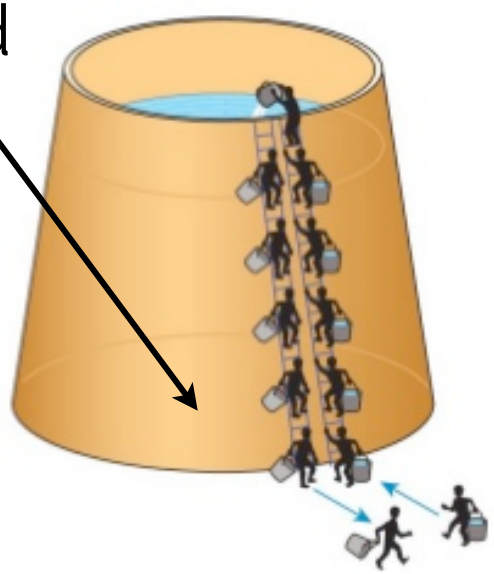
Active (or Real) Power

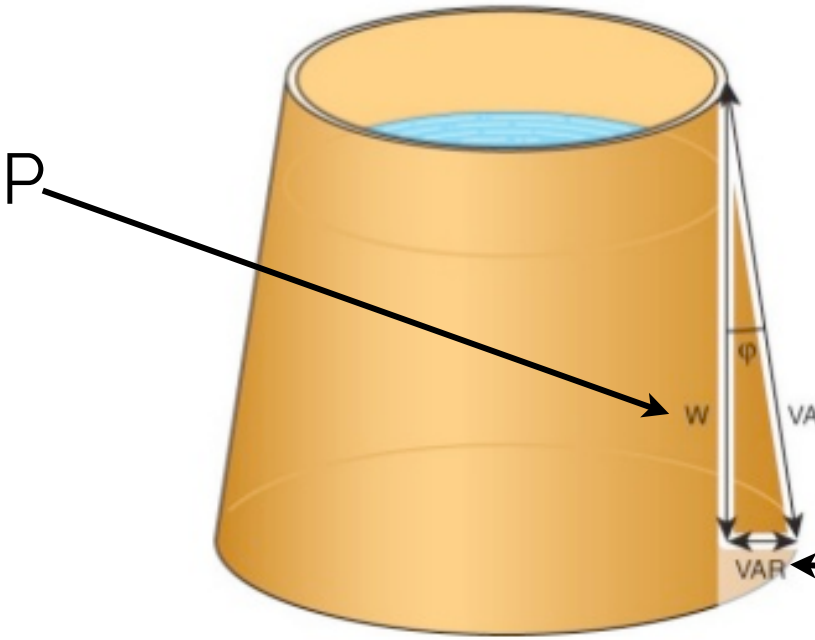
$$P_{avg} = V_{rms} * I_{rms} * \cos\varphi$$

Reactive (or Real) Power

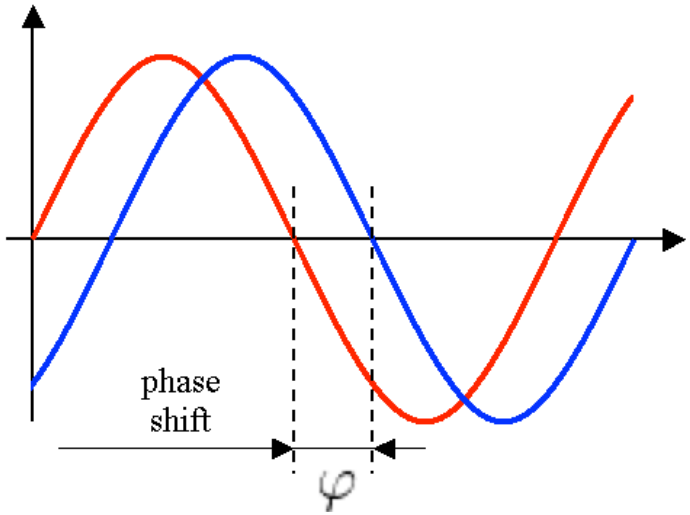
$$Q_{avg} = V_{rms} * I_{rms} * \sin\varphi$$

constant fill
speed





Power > Apparent, Active and Reactive

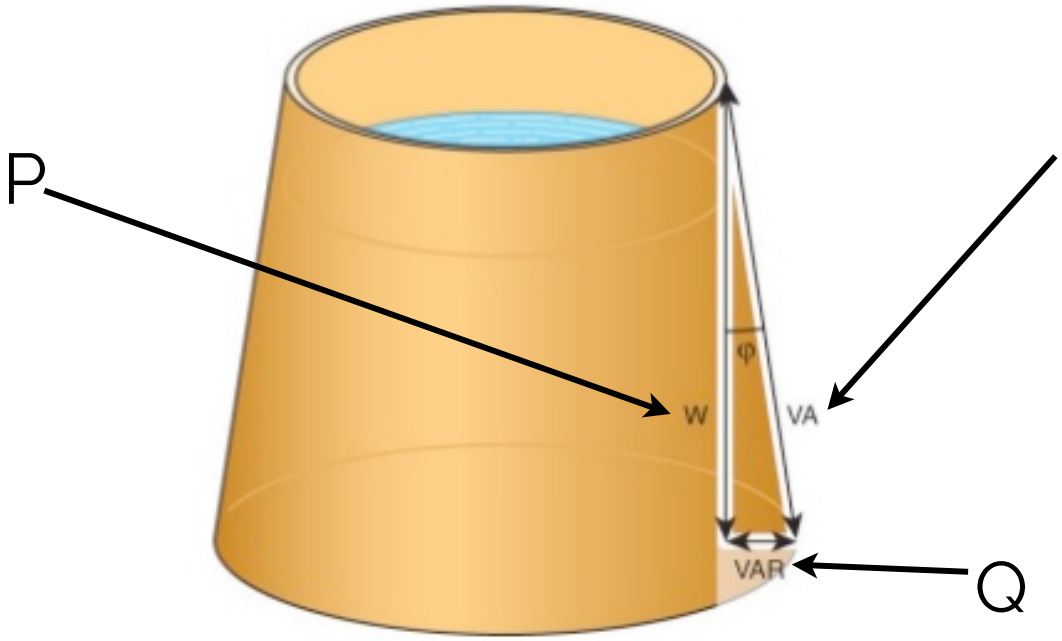


Active (or Real) Power

$$P_{avg} = V_{rms} * I_{rms} * \cos\varphi$$

Reactive (or Real) Power

$$Q_{avg} = V_{rms} * I_{rms} * \sin\varphi$$



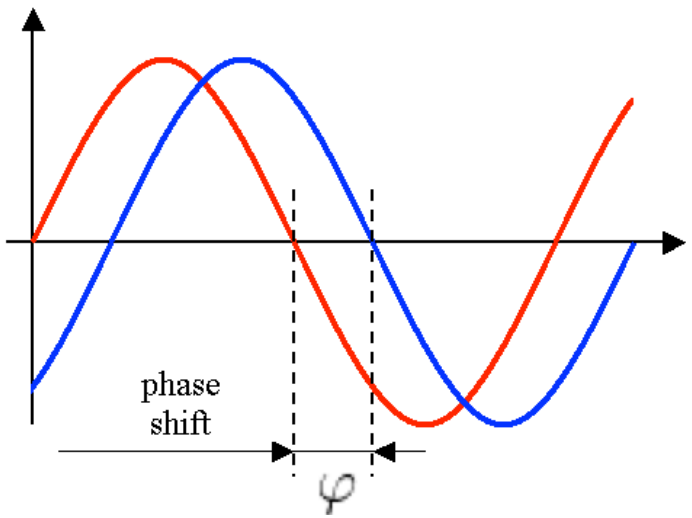
Apparent Power:

$$S_{avg} = \sqrt{(P_{avg}^2 + Q_{avg}^2)}$$

↓

i.e. an higher current requirement for energy transmission! --> Joule Effect!

Power > Apparent, Active and Reactive



Active (or Real) Power

$$P_{avg} = V_{rms} * I_{rms} * \cos\varphi$$

Reactive (or Real) Power

$$Q_{avg} = V_{rms} * I_{rms} * \sin\varphi$$

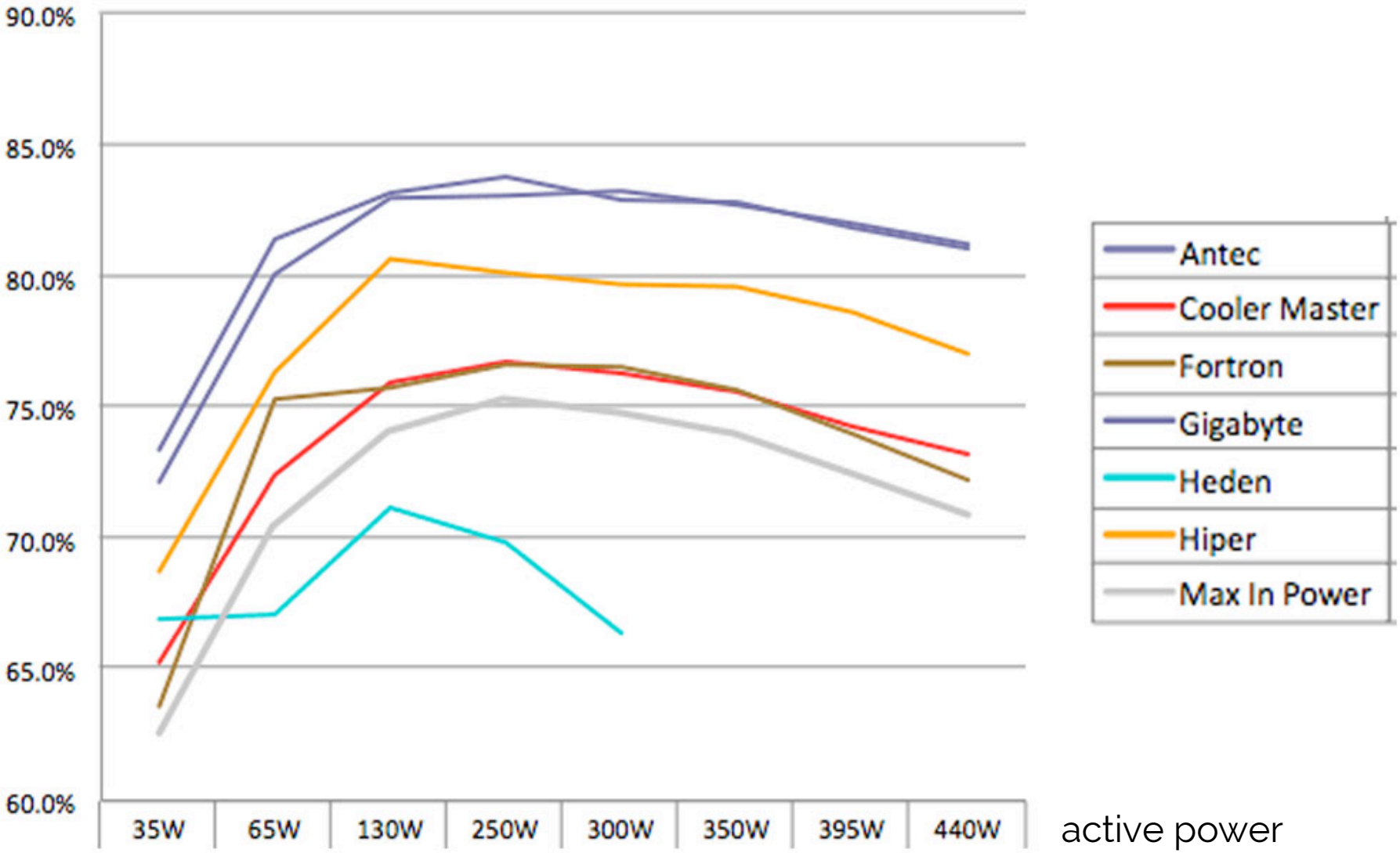
Apparent Power

$$S_{avg} = \sqrt{(P_{avg}^2 + Q_{avg}^2)}$$

P_{avg} --> Watt Q_{avg} --> VAR S_{avg} --> VA

Power Factor = $P_{avg} / S_{avg} = \cos\varphi$

Power Supply Efficiency



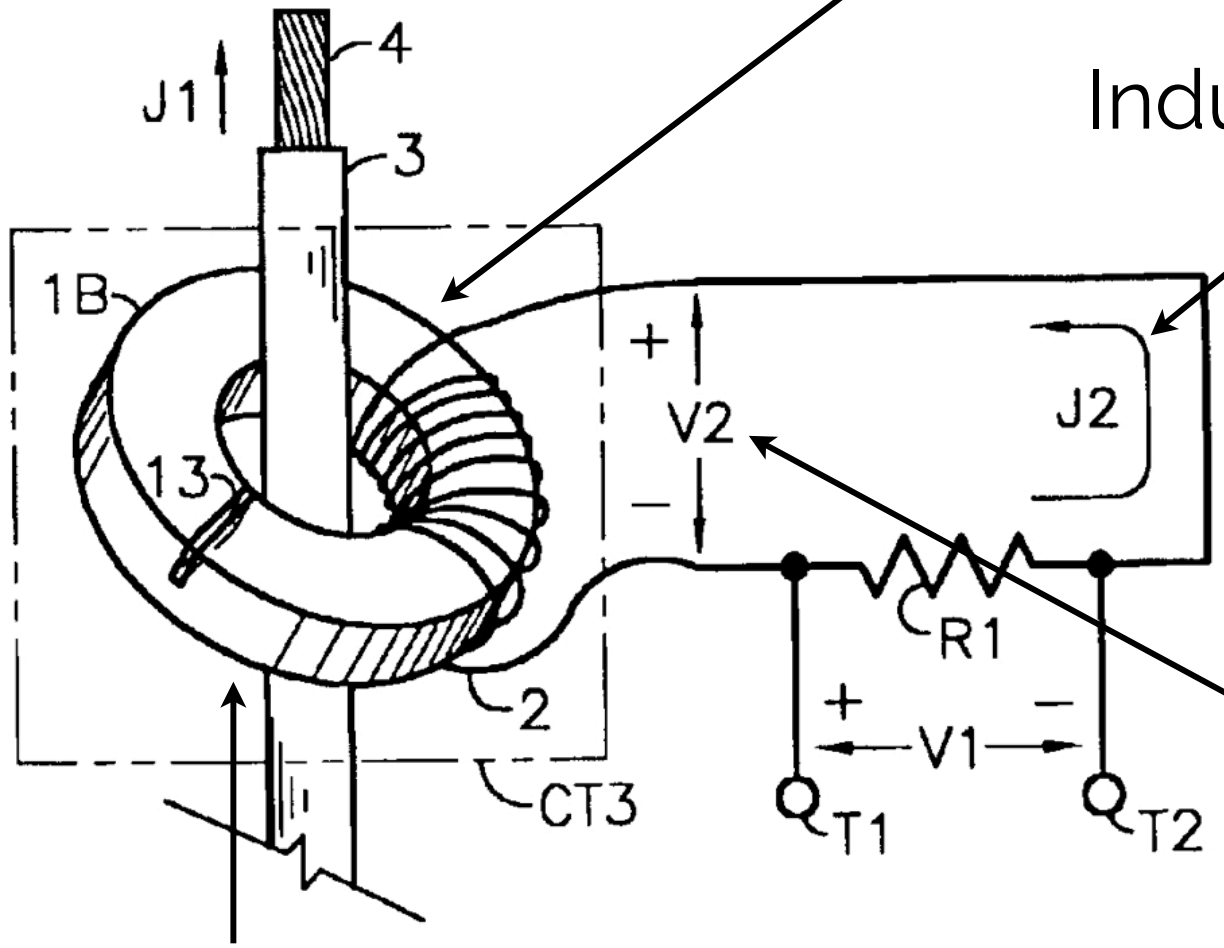
active power

http://www.behardware.com/articles/734-10/product-survey-7-power-supplies-for-less-than-45-euros.html

Measuring the electric energy > How to

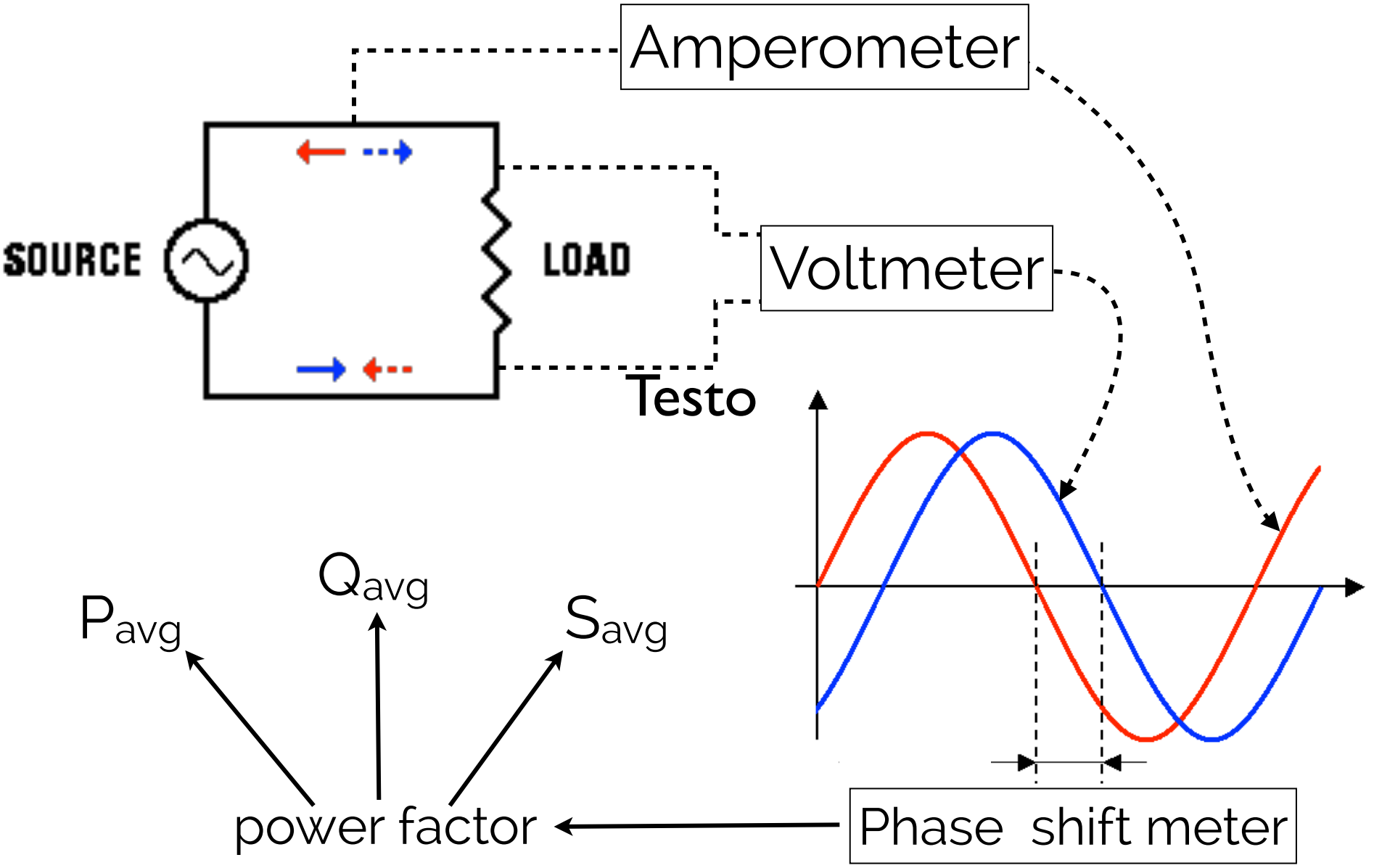
Current Transformer

Induction current



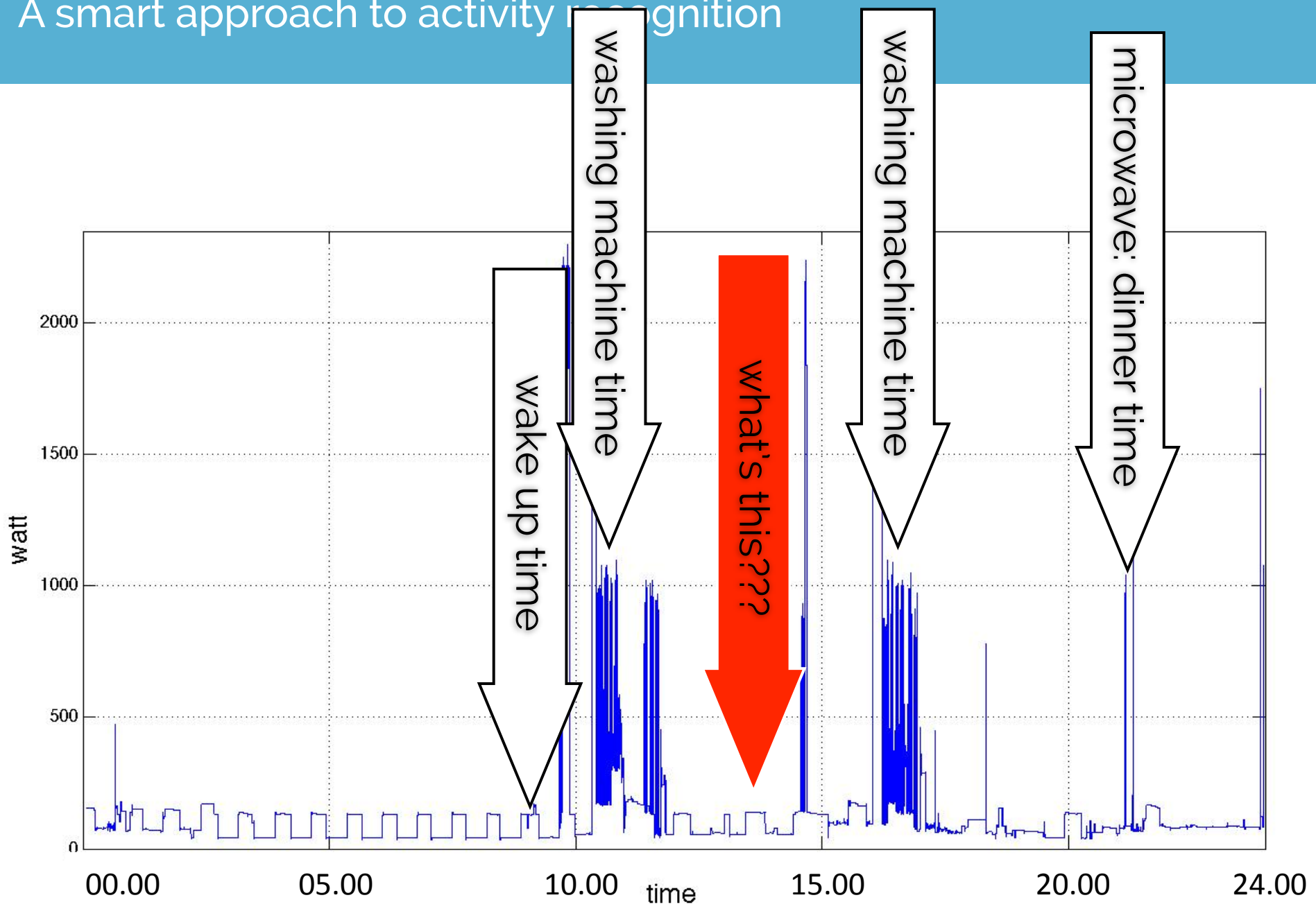
Proportional Voltage

It measures the current flow, i.e. **active power**

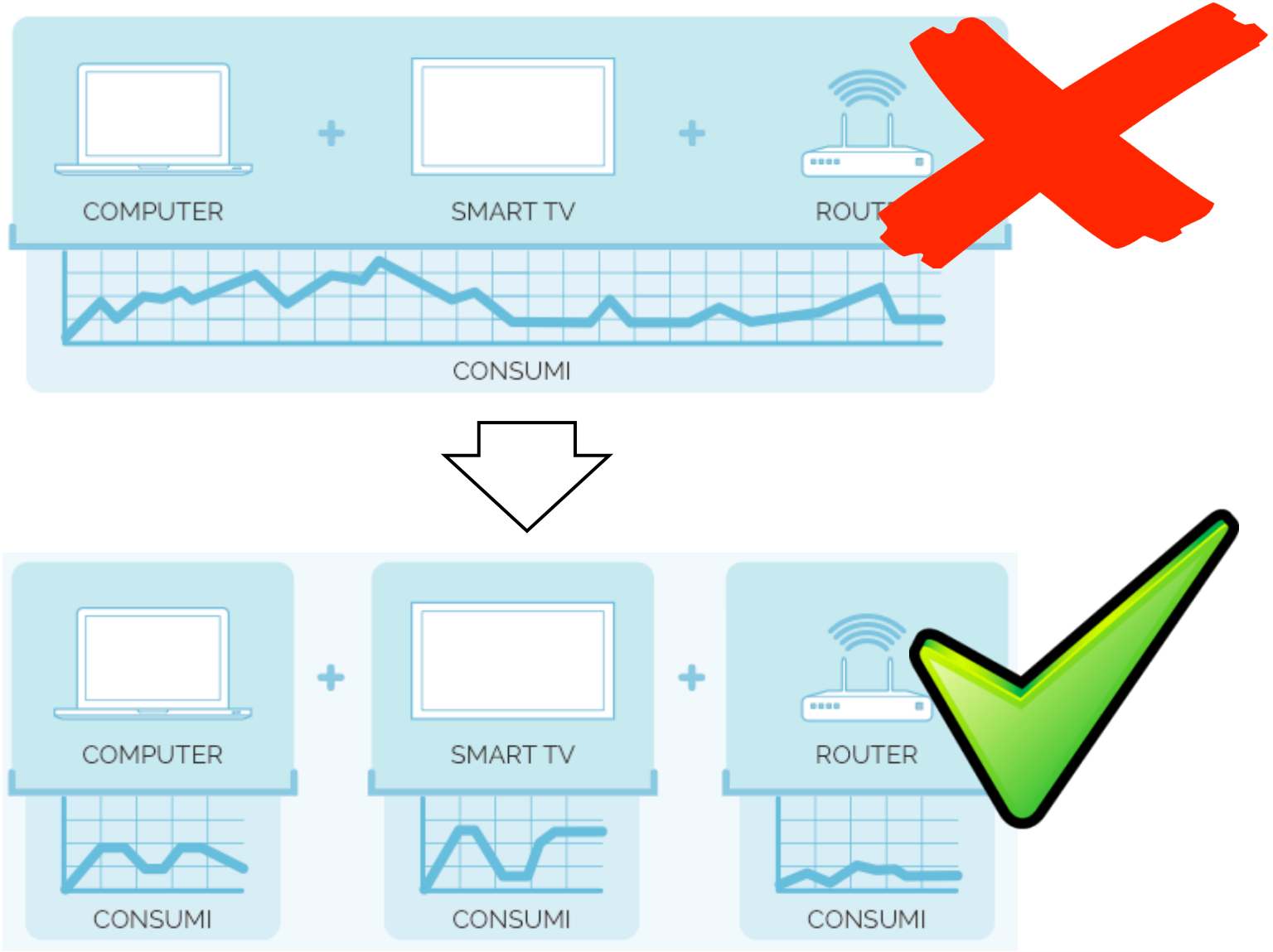

Amperometer
SOURCE
LOAD
Voltmeter
Testo
Qavg
Pavg
Savg
power factor
Phase shift meter

A smart approach to activity recognition

A smart approach to activity recognition



A smart approach to activity recognition



A smart approach to activity recognition

Consumption waveshapes tell us a lot of things:

- household week schedule:
  - wake-up time
  - sleep time

- household life-style:
  - how many times (and at which time) he watch the TV
  - how many times he buy food
  - in which room he prefer to live
  - how many times he use the hoven
  - ...

- ...

A smart approach to activity recognition

Consumption waveshapes tell us a lot of things:

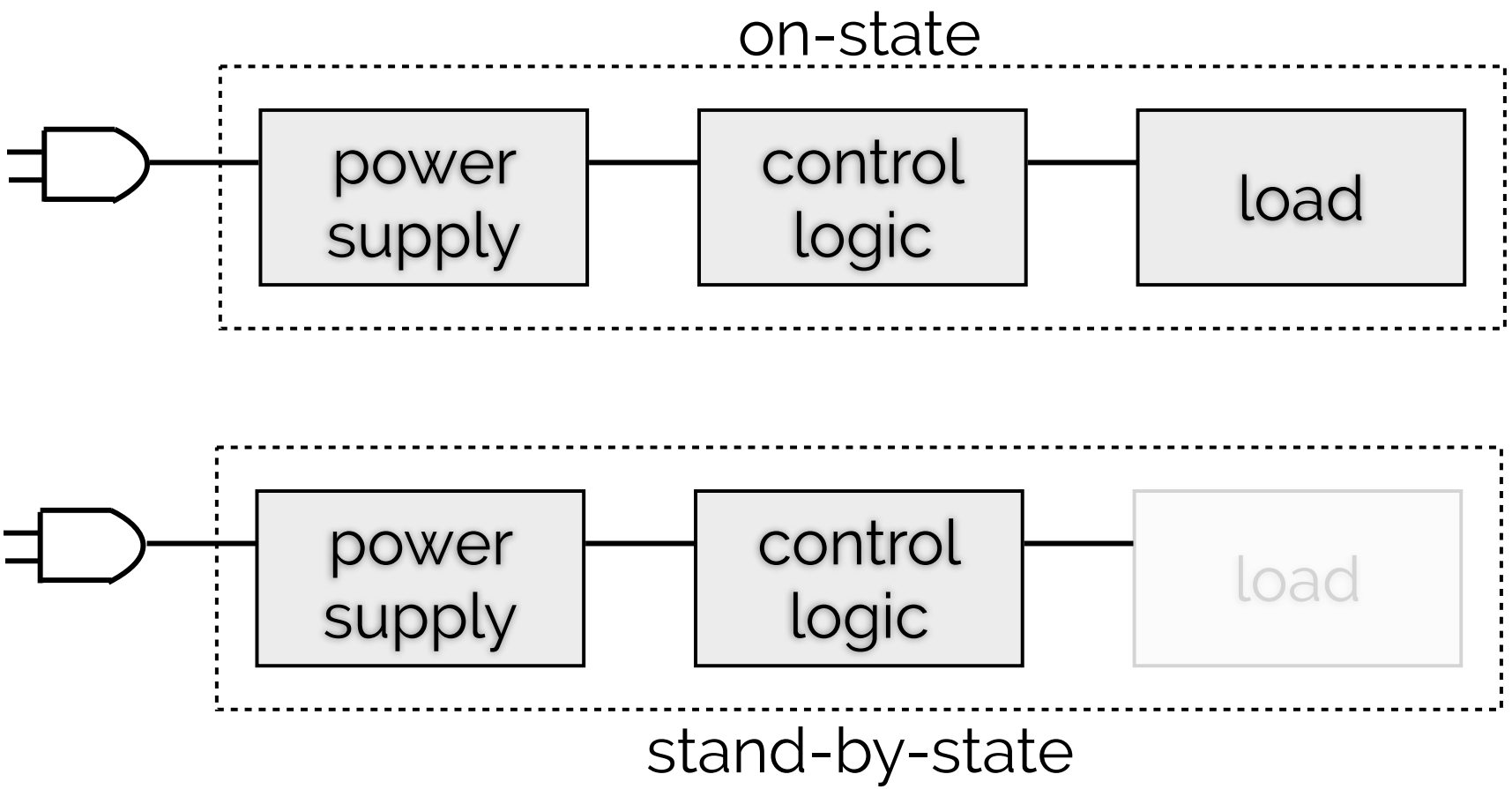
- household week schedule:
  - wake-up time
  - sleep time

- household life-style:
  - how many times (and at which time) he watch the TV
  - how many times he buy food
  - in which room he prefer to live
  - how many times he use the hoven
  - ...

- many other with **complex event processing**

A smart approach to activity recognition

Stand-by recognition example:



A smart approach to activity recognition

Stand-by recognition example:

on-state --> Q/P ~=0

stand-by-state --> Q/P ~= ∞

Just looking at single consumption (active/reactive) it is possible to guess the stand-by-state devices

[- PATENT PENDING -]

A smart approach to in-house energy management

- live demo -

Exam > Available projects

Exam > Available projects

Project 1: a smart SMS gateway

the project has the aim to implement a multi-provider sms gateway able to send and receive sms via REST/COMET interface selecting for every message the most convenient (€) provider

Project 2: 3-lines LCD display java driver

the project has the aim to implement a Java driver for a simple 3-line LCD display (Arduino style) for Cubieboard 2 board

Project 3 (thesis oriented): voice interface for smart spaces

the project has the aim to implement a smart device able to deal with the house inhabitants providing information, storing plans and programming the environment. The project must be based on Android voice recognition API