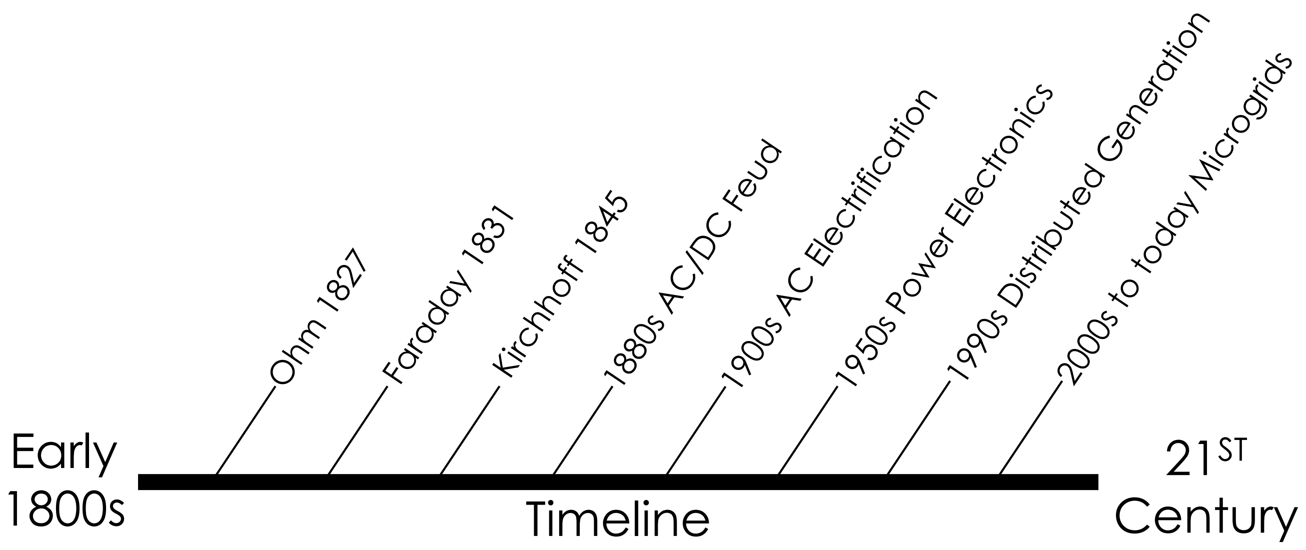
ELECTRICAL FUNDAMENTALS

PLUG – OCTOBER 27, 2016

ARINDERPAL MATHARU – IDEAWORKS – MOHAWK COLLEGE

Introduction

Goal: To provide you with the Electrical Fundamentals



Current

Current – Current is the flow of electrical charge through an electronic circuit. Current is measured in **AMPERES** (AMPS).

2 notations used: Conventional and Electron Flow

$$1\ \mathrm{A} = 1\frac{\mathrm{C}}{\mathrm{s}}$$

$6.24\ x\ 10^{18}$electrons have 1 C of charge

Andre Ampere
1775-1836

Voltage

Voltage – Voltage is the electrical <u>force</u> that causes current to flow in a circuit. It is measured in **VOLTS**.

Alessandro Volta
1745-1827

Named after him because he invented the voltaic pile

Ohm's law

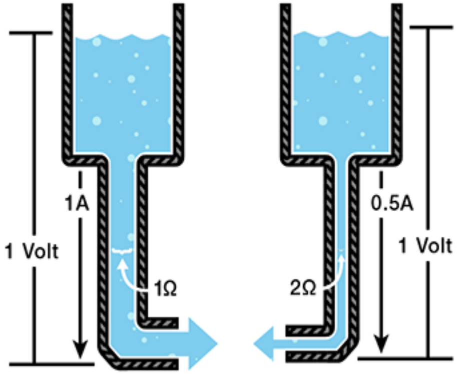
- In 1827, found a proportional relationship between galvanometer reading and thermocouple for a circuit-now known as Ohm's Law
- Its an empirical law

$$V = I * R$$

Georg Simon Ohm
1789-1854

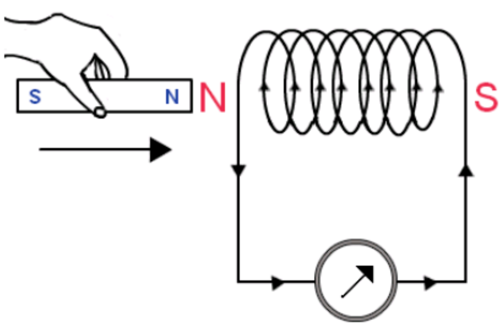
Analogy

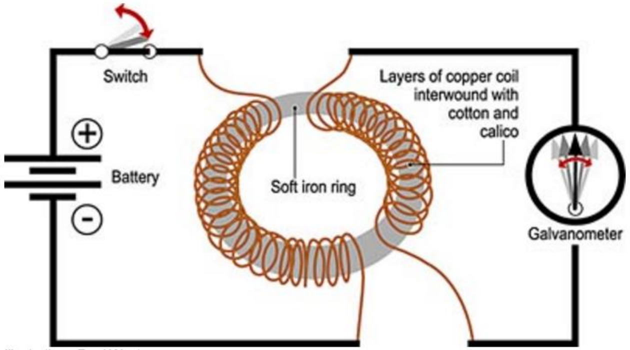
- Water = Charge (measured in Coulombs)
- Pressure = Voltage (measured in Volts)
- Flow = Current (measured in Amperes)
- Hose Width = Resistance



Faraday’s Law

On pressing the key an electric current flows through the primary coil. This builds up a magnetic flux through the iron ring and the secondary coil, and the galvanometer gives a deflection.





$$i = -\frac{N}{R}\frac{d\Phi_B}{dt} \quad \Rightarrow \quad \varepsilon = -N\frac{d\Phi_B}{dt}$$

Circuit Configuration

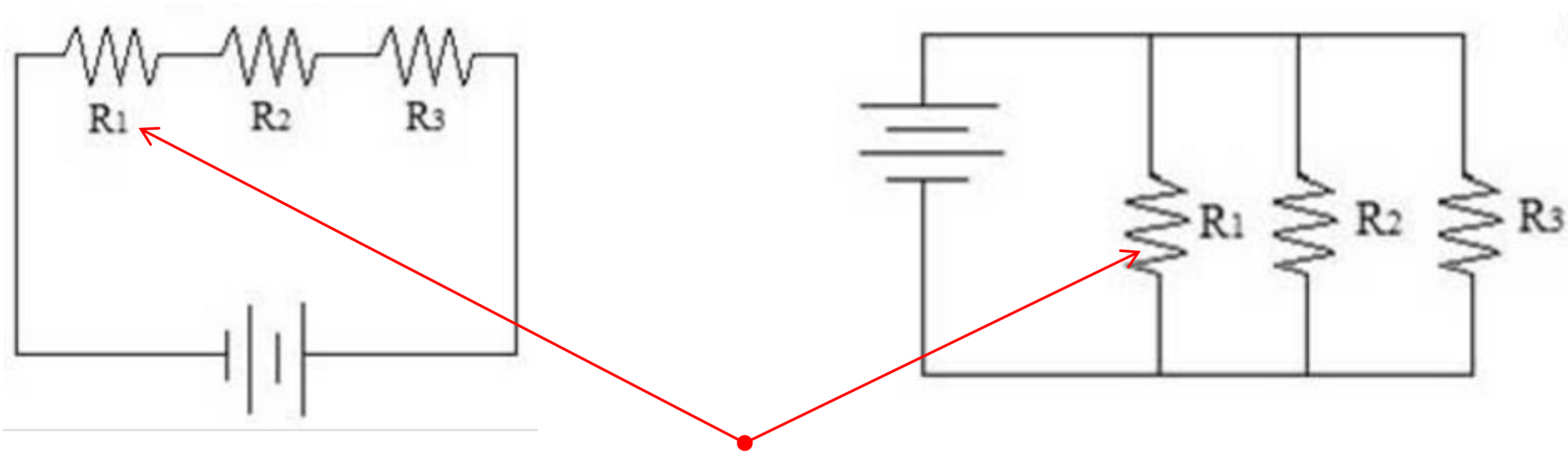
Components in a circuit can be connected in one of two ways.

Series Circuits

- There is only a single path for current to flow.

Parallel Circuits

- There are multiple paths for current to flow.

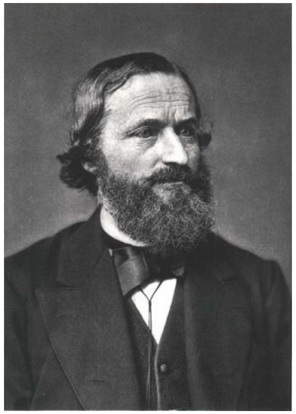


Components

(i.e., resistors, batteries, capacitors, etc.)

Summary of Kirchhoff's Laws

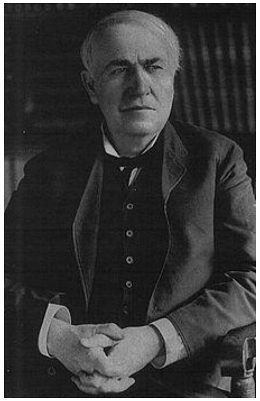
- Kirchhoff's Voltage Law **(KVL)**:
  - The sum of all of the voltage drops in a series circuit equals the total applied voltage.
- Kirchhoff's Current Law **(KCL)**:
  - The total current in a parallel circuit equals the sum of the individual branch currents.



Gustav Kirchhoff
1824-1887

First commercial electric system (US)

- First distribution systems were DC (Thomas Edison)
- Electric load was essentially incandescent lamps
- Other systems (motors) required other voltages which meant different generators
- DC generators had to be within close proximity to users
- DC could be used with storage batteries

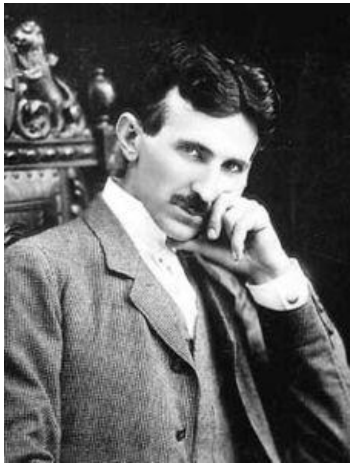


Thomas Edison
1847-1931

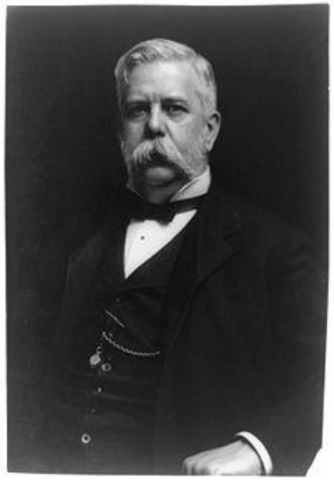
First light bulb

Tesla invents the AC electric system

- AC shows up in 1880s (George Westinghouse)
- AC could be generated with higher efficiencies
- AC could be transmitted over larger distances
- It was easier to increase and decrease voltages (transformation)



Nikola Tesla
1856-1943



George Westinghouse
1846-1914

War of currents

- Edison makes a negative campaign
  AC was more danger
  Edison’s employee, developed the first electric chair (AC)
- Niagara Falls Commission contract (1893)
  Edison + General Electric lost against George Westinghouse + Tesla
  1896 generation started to Buffalo industries
- AC was adopted between time period 1890 to 1917 and onwards

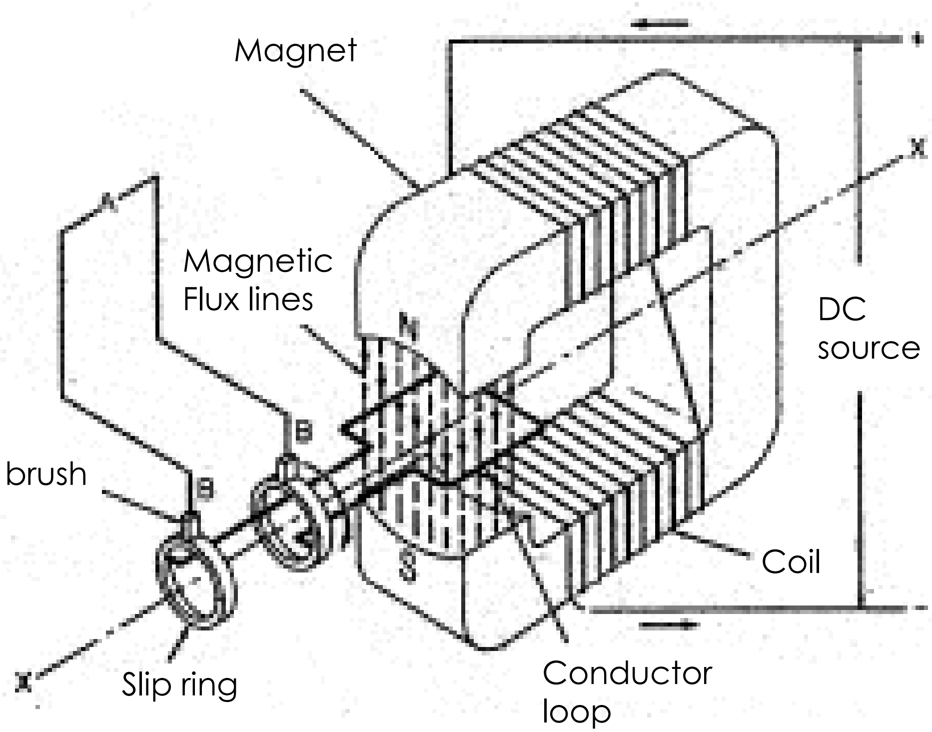
To summarize - Why did we go with AC?

- AC power is easier to generate
- DC power is provided at one voltage only
- AC power could be stepped up or down to provide any voltage required (way of reducing transmission losses)
- DC is very expensive to transmit over large distances compared to AC, so many plants are required
- DC power plants must be close to users
- AC plants can be far outside cities

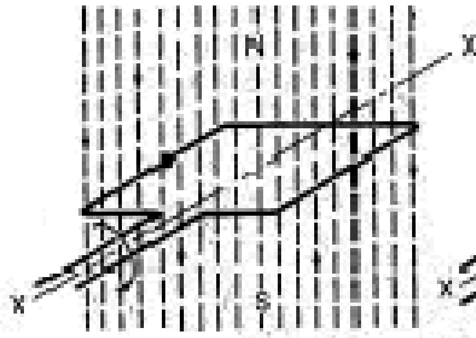
…And by 1895 DC was out and AC was in

The electric generator

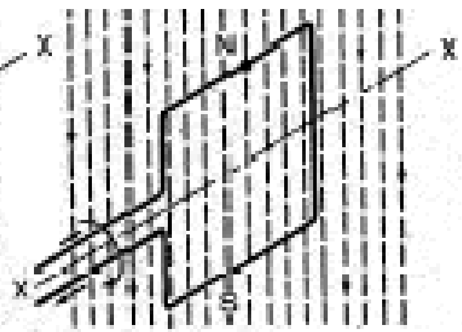
- When a coil of wire is rotated inside a magnet, electricity is produced
- this electricity is AC
- the voltage depends on how much wire the coil has and **how fast it is rotated.**
- Devices called transformers can make the voltage bigger or smaller
- Transformers only work with AC



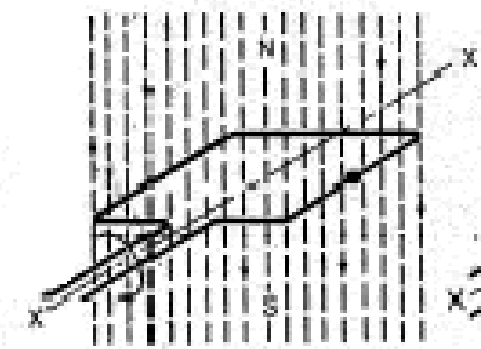
Single phase



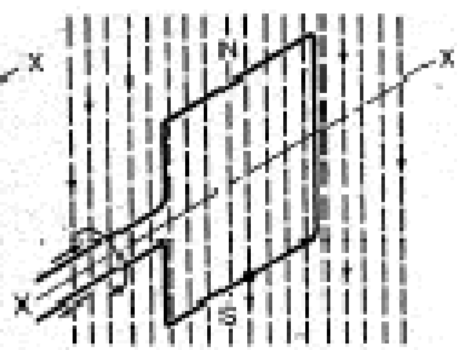
Start



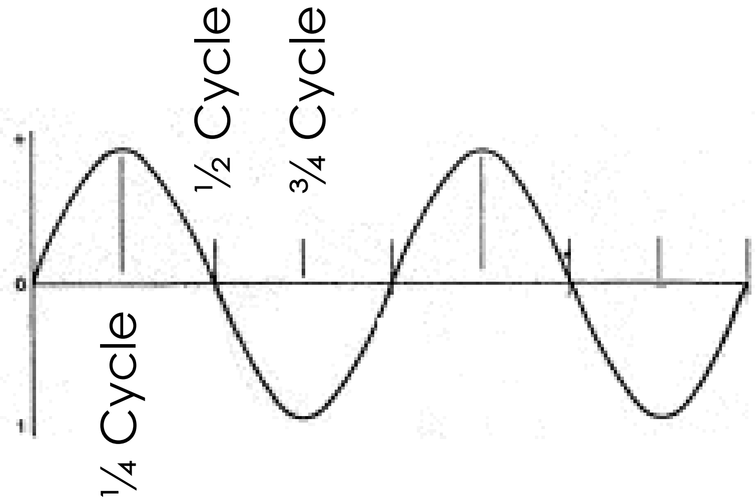
¼ Cycle



½ Cycle



¾ Cycle



Power

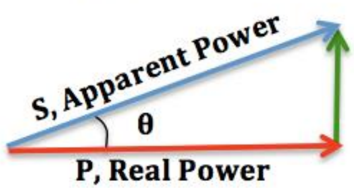
- Purpose of generators is to give us power so we can perform useful work
- Power can be broken down into 3 categories:
- Real Power (P)
  - which is transferred to the load to do work
  - Unit – Watt (W)
- Reactive Power (Q)
  - transfers no net energy to the load (used for energization)
  - Unit - volt-ampere reactive (VAR)
- Apparent Power (S)
  - Product of rms voltage and rms current (Combines P and Q)
  - Unit - volt-amperes (VA)

$$S^2 = P^2 + Q^2$$

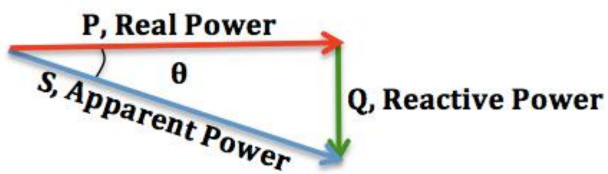
Power Factor

The ratio of active power to apparent power in a circuit is called the power factor

Lagging Power Factor



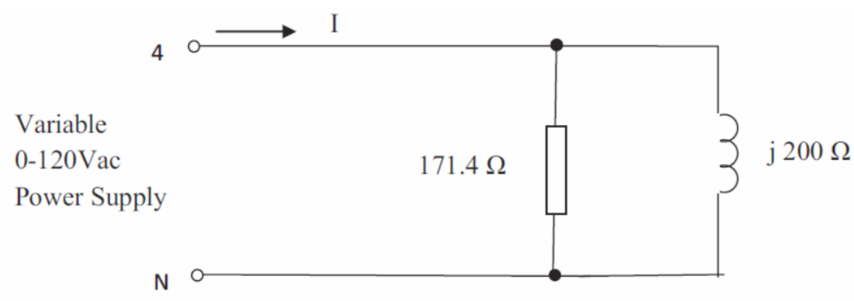
Leading Power Factor

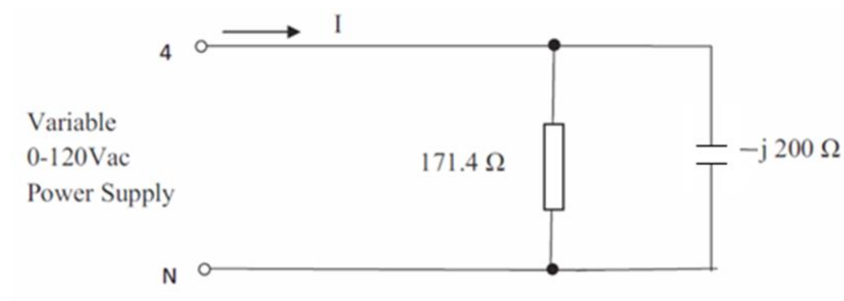


$$\cos\theta\text{, power factor} = \frac{P\text{, real power}}{S\text{, apparent power}}$$

As cos θ → 1, its maximum possible value, θ → 0 and so Q → 0, as the load becomes less reactive and more purely resistive

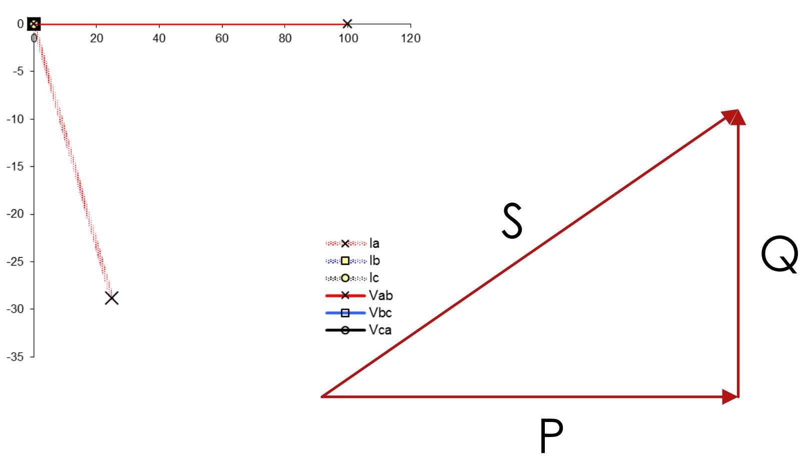
Single Phase Circuits

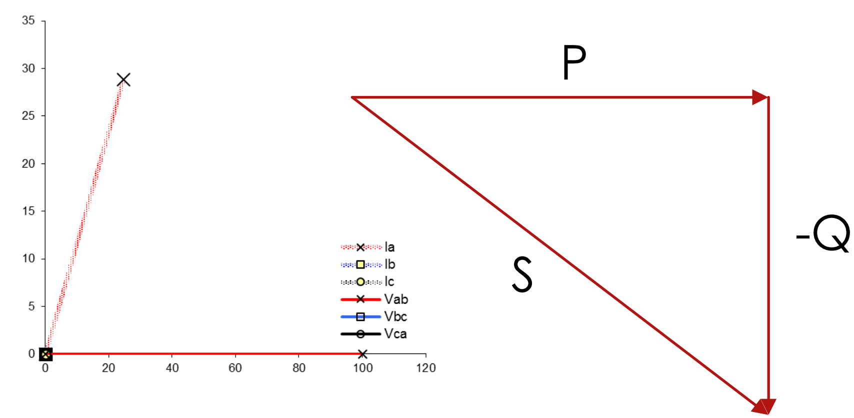




Inductive load characteristics

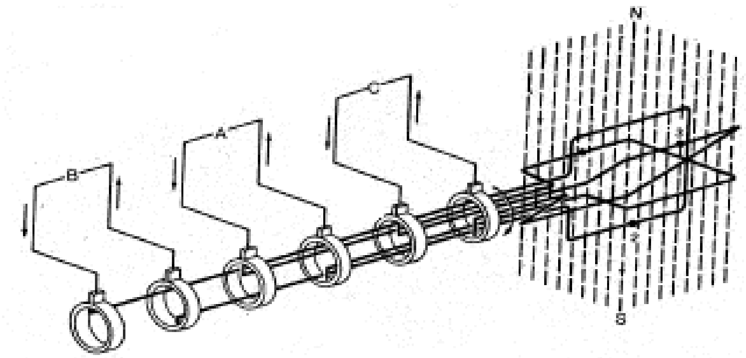
Capacitive load characteristics

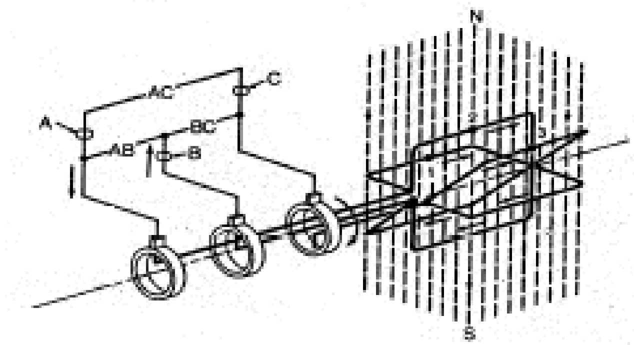


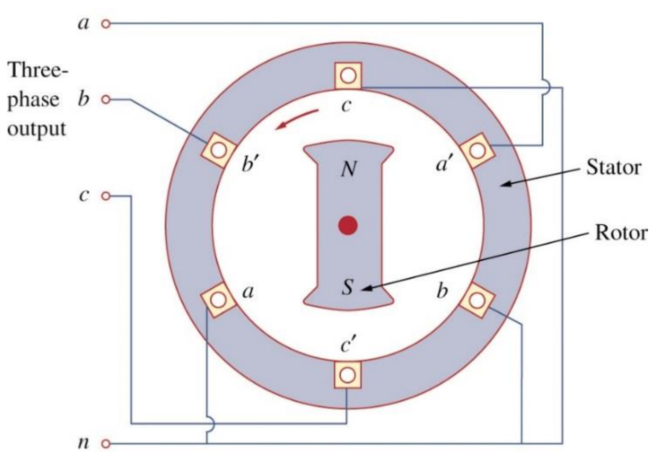


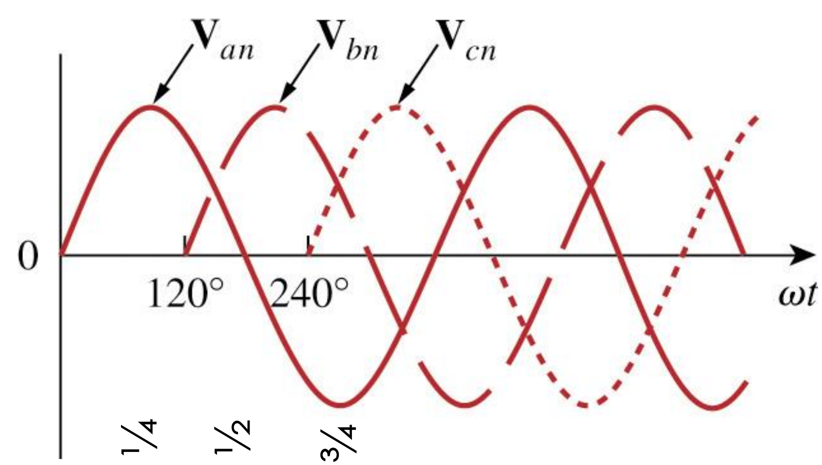
Three phase

- The three-phase generator has three induction coils placed 120° apart on the stator.

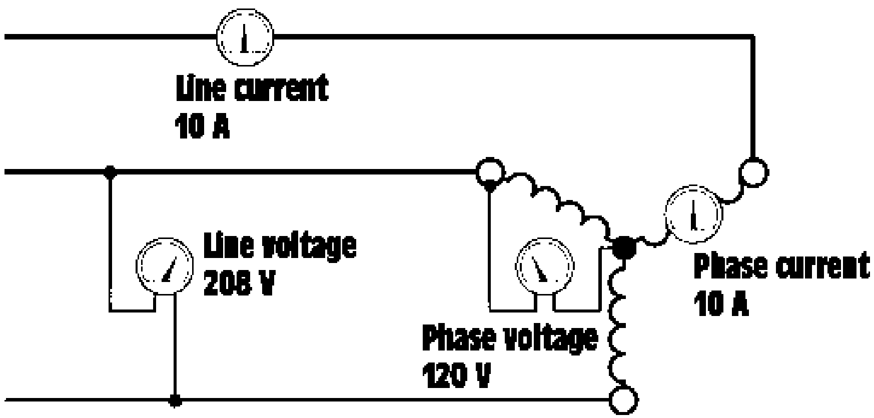






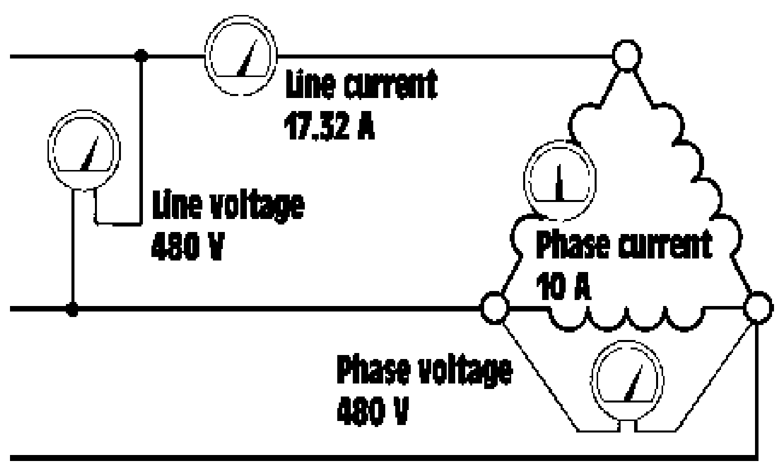


Wye and delta

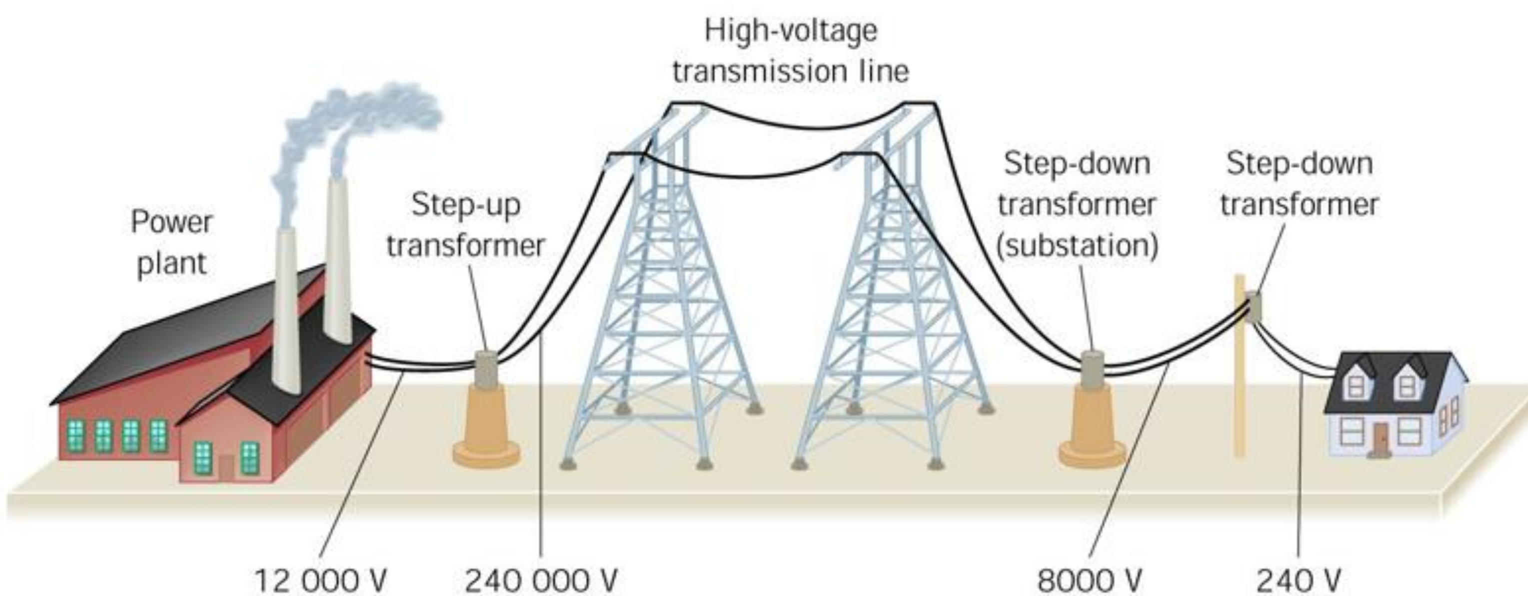


← Wye

Delta →



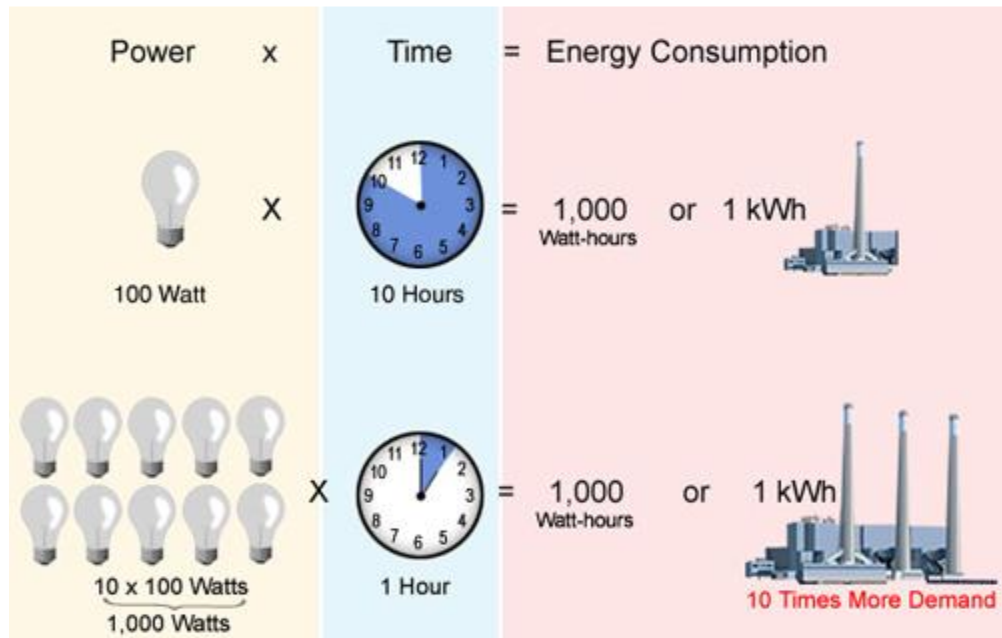
Power Network



Demand and Consumption

Demand = KW
Rate of using electricity

Energy Consumption = KWH
Electrical energy actually used



[1]

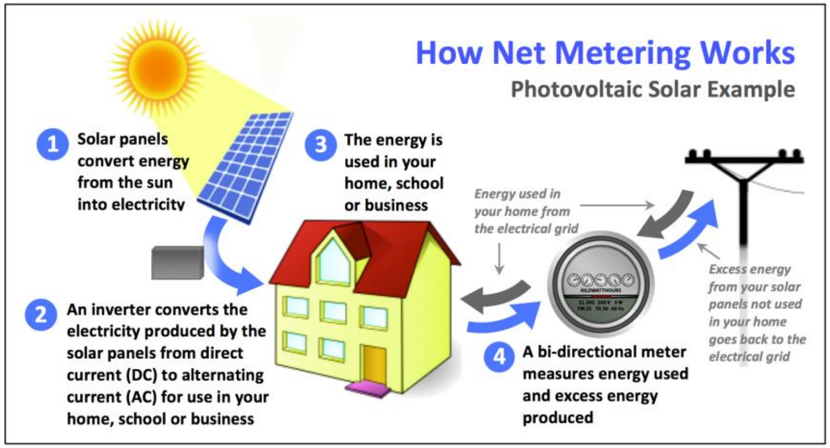
Demand and Consumption - Example

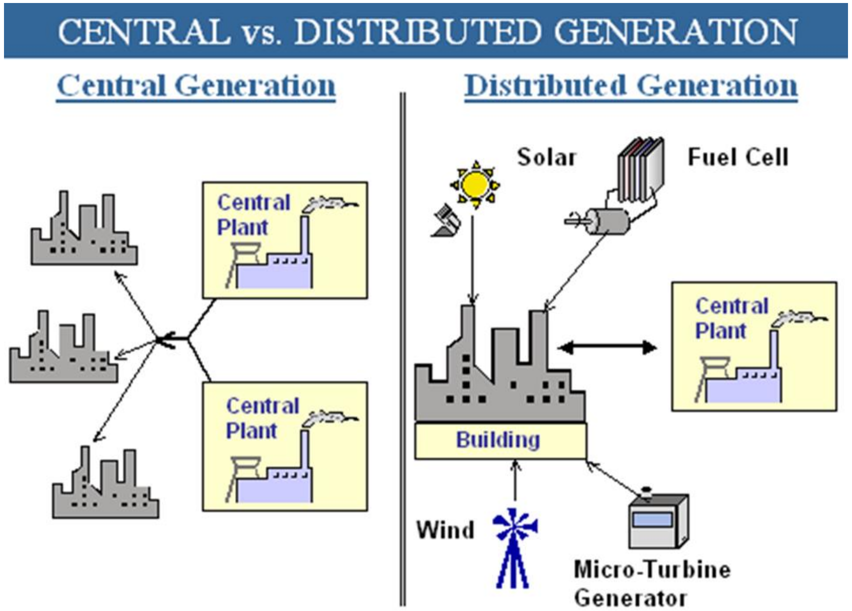
Example 1: Company A runs a 50 megawatt (MW) load continuously for 100 hours.
50 MW x 100 hours = 5,000 megawatt hours (MWh)
5,000 MWh = 5,000,000 kWh
Demand = 50 MW = 50,000 kW
Consumption: 5,000,000 kWh x .0437 = $218,500
Demand: 50,000 kW x $2.79 = $139,500
Total: $358,000

Example 2: Company B runs a 5 MW load for 1,000 hours.
5 MW x 1,000 hours = 5,000 MWh
5,000 MWh = 5,000,000 kWh
Demand = 5 MW = 5,000 kW
Consumption: 5,000,000 kWh x .0437 = $218,500
Demand: 5,000 kW x $2.79 = $13,950
Total: $232,450

[2]

How to reduce and rise of DG





Look back

- Reason we went with AC at the time:
  - Less losses over long distance transmission
  - DC power plants had to be close to users
  - AC plants could be far outside cities, removing large infrastructure from cities
  - Easier to manipulate voltage levels
  - No power electronics at the time (only until 1940s-1950s)

Why not consume in DC?

- What we are seeing today
  - PV Source - DC
  - Home energy storage batteries - DC
  - Cellphones, tablets, laptops, car chargers - DC
  - Electric Vehicles use batteries as form of storage – DC
  - Lighting, LED – DC
  - Computers, TVs, Coffee makers – DC
  - Datacenters use UPS - DC
  - IT Networks – PoE - DC
- Appliances such as heaters, washing machines, dryers, HVAC – DC or AC

Research needed

- Project research to evaluate AC vs DC microgrid.
- Project scope includes 11 Commercializable products ranging from DC Microgrid controllers, DC-DC Converters, Energy Management algorithms
- Announced October 2016
- Multiple industry partners and utilities involved.

enersource

SIEMENS

Toronto and Region Conservation for The Living City

Schneider Electric

MOHAWK COLLEGE

CINNOS Mission Critical Incorporated

SEL SCHWEITZER ENGINEERING LABORATORIES

OMICRON

McMaster University

Questions?

References

1. http://www.think-energy.net/KWvsKWH.htm
2. http://www.energysmart.enernoc.com/understanding-peak-demand-charges/