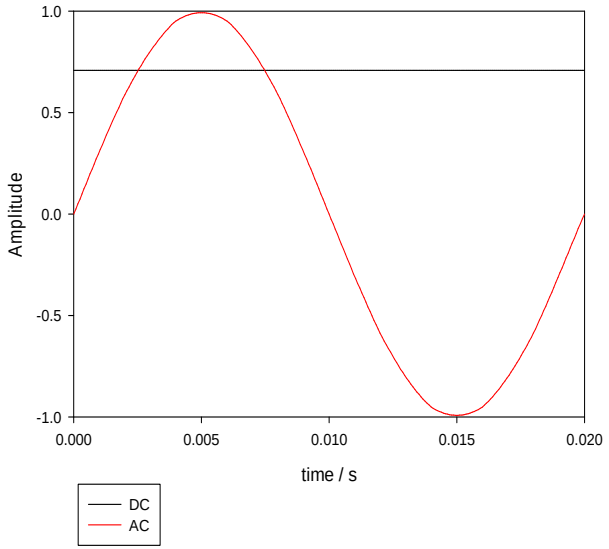
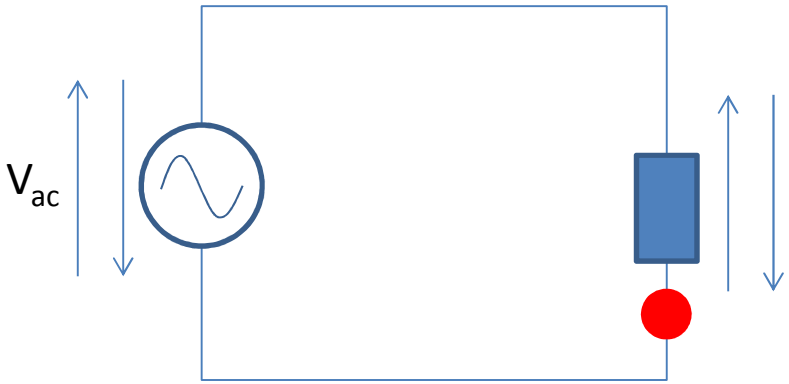
Electrical energy distribution

Re cap (1)
AC and DC

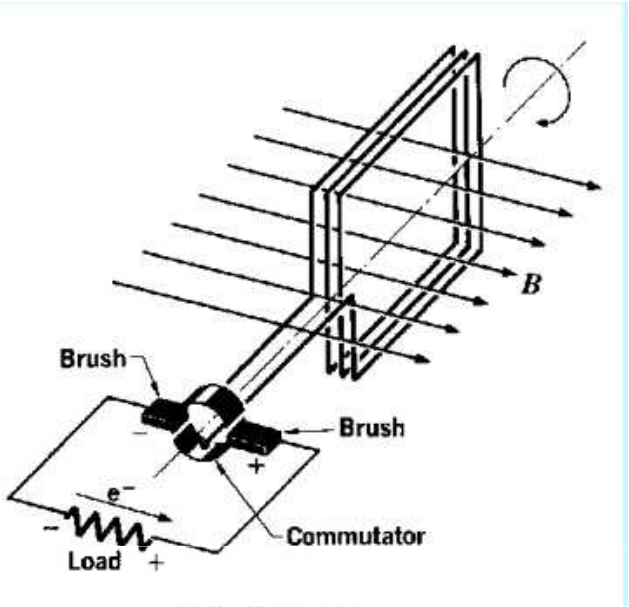
- DC
  - Single constant voltage (with some ripple)
  - Current only travels in one direction around a circuit
- AC
  - Sinusoidal variation of voltage
  - Current is pulled back and forth through a load



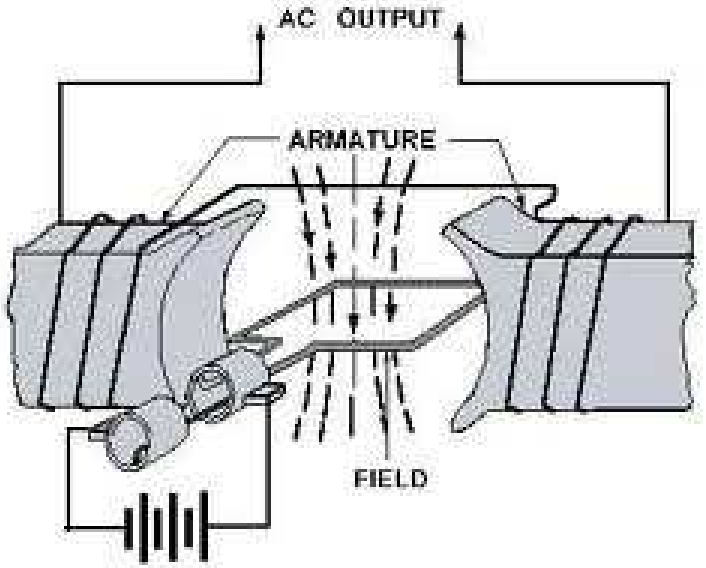


AC and DC generation

- DC generation: The dynamo
  - Commutator is a split ring

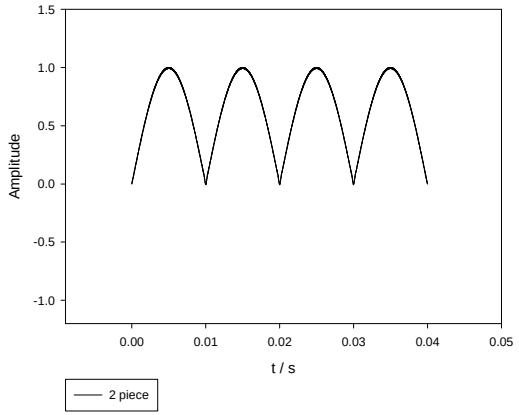


- AC generation: The alternator
  - Slip rings and brushes

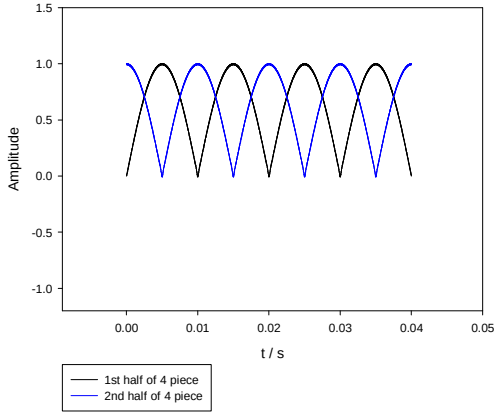


DC generation: The Dynamo

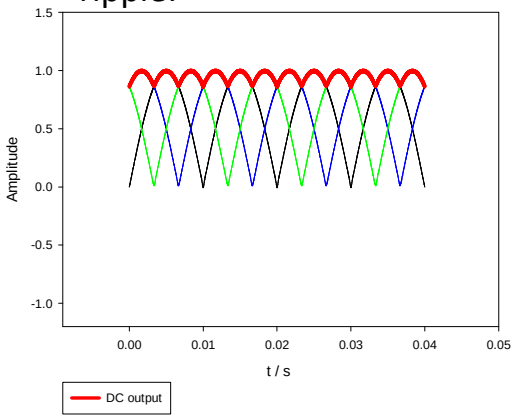
One pair (half rings) will give an output:



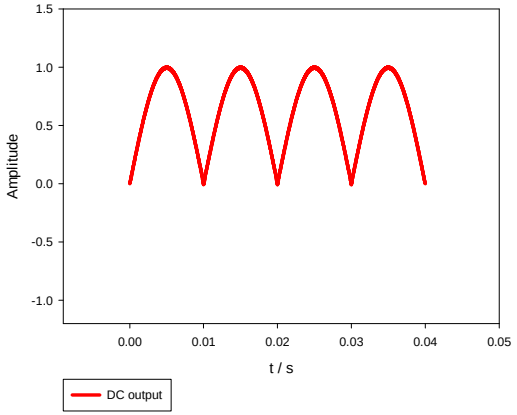
Two pairs (1/4 rings) will give two overlapping envelopes:



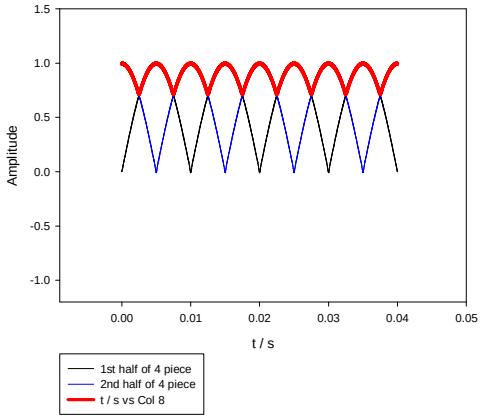
3 pairs (1/6 rings) will give 3 overlapping envelopes and even more reduced ripple:



Hence the DC is actually oscillation from 0 - 1V:



The DC ripples is greatly reduced:

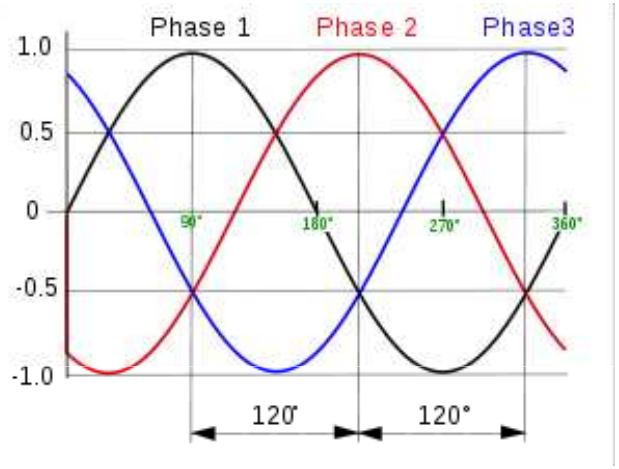


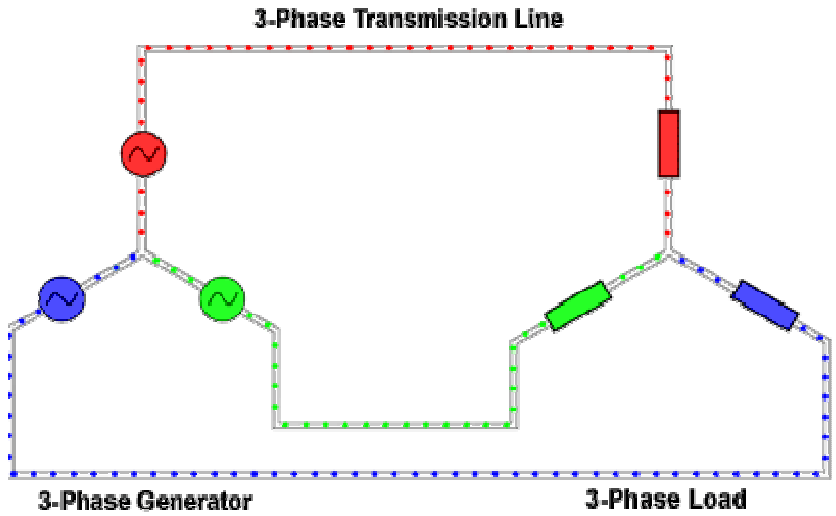
There is a trade off between the ripple level and the amount of power extracted for a dynamo of a given size!

More pairs are more complicated and expensive to implement

Re cap (2)
3 Phase AC

- AC
  - 3 Sinusoidal voltage displaced in time
  - Current is pulled back and forth from connecting wires...
  - ...if the 3 loads are equal the system in balanced

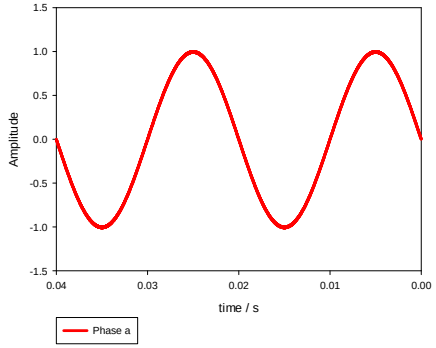


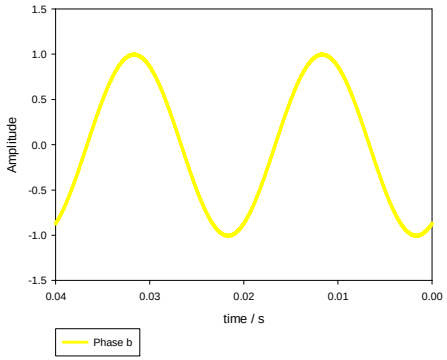


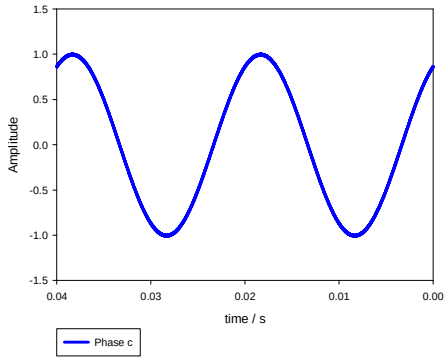
3 phase revisited

- Compared to single phase, 3 phase generators are:
  - Smaller
  - More efficient
  - Capture more power per revolution

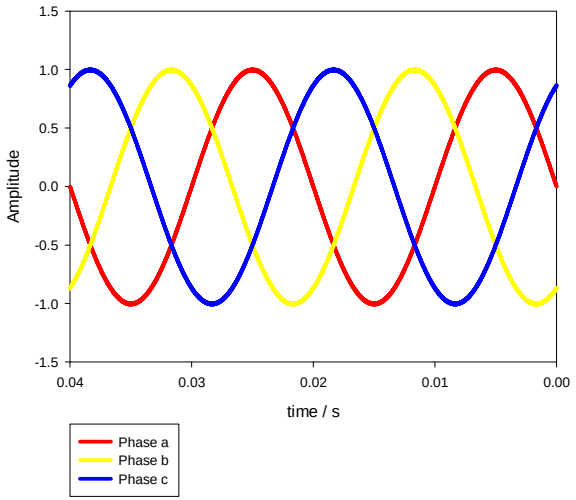
Phase and Line Voltages

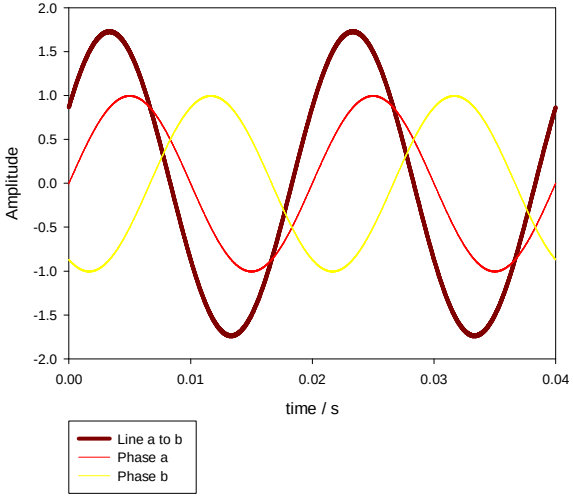


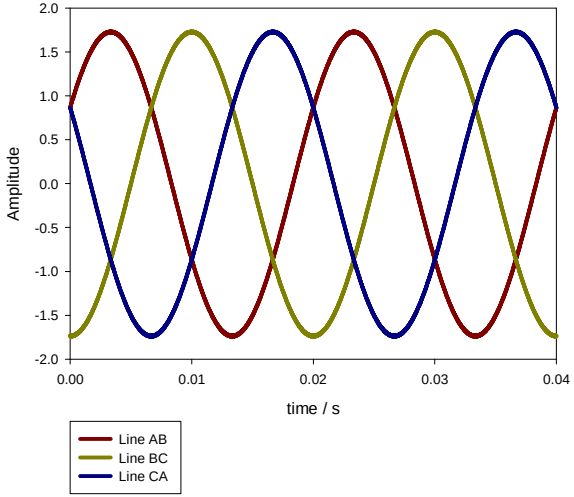




3 phase AC consists of 3 sinusoidal voltages displaced in time. A phase voltage is referenced to the central connection (the neutral line)





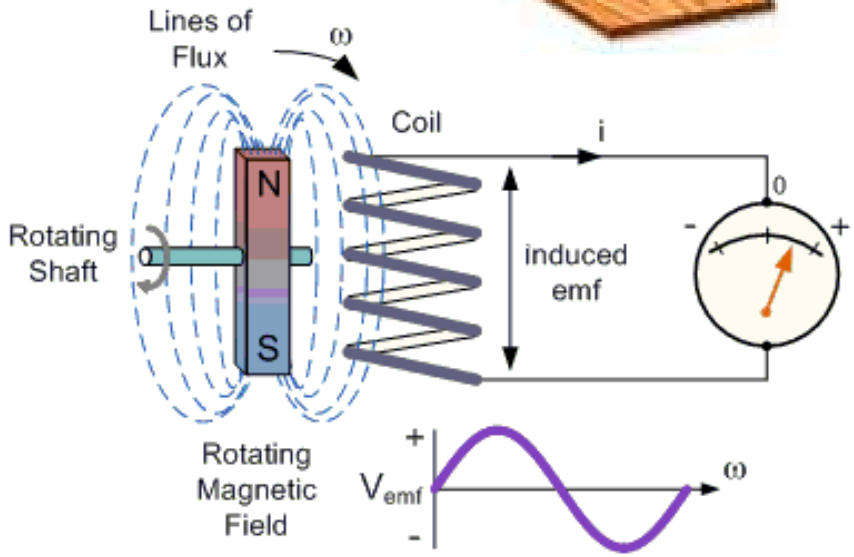


Left: 3 phase AC. Middle: Voltage between RED and YELLOW phases.
The Line voltage is the voltage between one phase and another phase.

$$V_{line} = \sqrt{3} V_{phase}$$

Re cap (3)
Static and induction

- Electricity (dc / static) was first discovered in 600BC
- Inductance (electro-magnetism) heralded a new age of electrical supply and usage
  - Pioneering work of Faraday
  - Eddy currents



Re cap (4)
Transmission

- Transmission loss is lower at higher voltage
- HVAC transmission at 400/275kV
- HVDC link
- Substation
  - Transformer
  - Circuit breaker

$$V_s = V_p \cdot \frac{N_s}{N_p}$$

Recap (4)

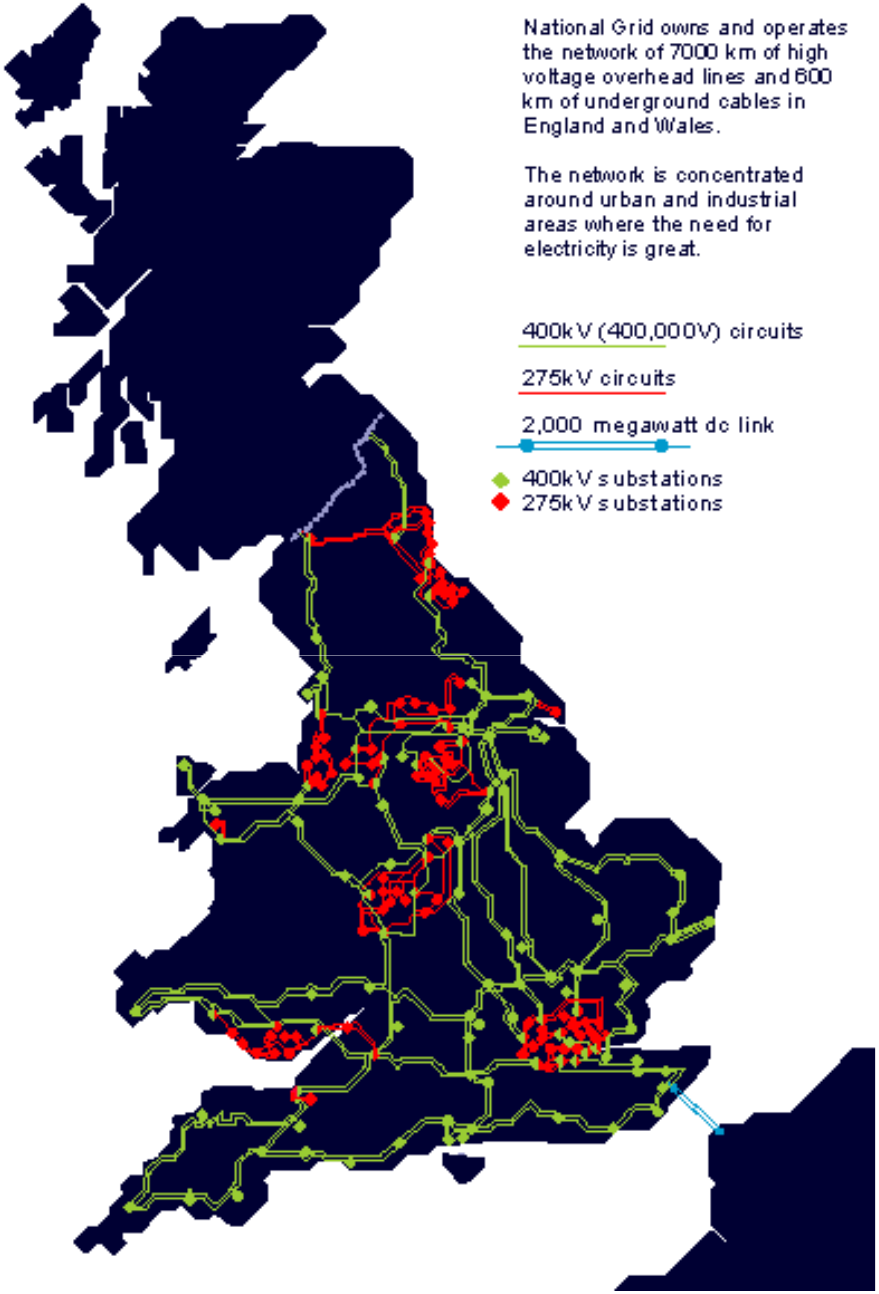
- Overground vs underground
  - Overground is much cheaper.
- Transmission network
  - Interconnecting nodes (substations)
  - Security of supply

UK Transmission Network

nationalgrid

7000 km of overhead line

600 km of underground cable



Electrical power systems

Comprise:

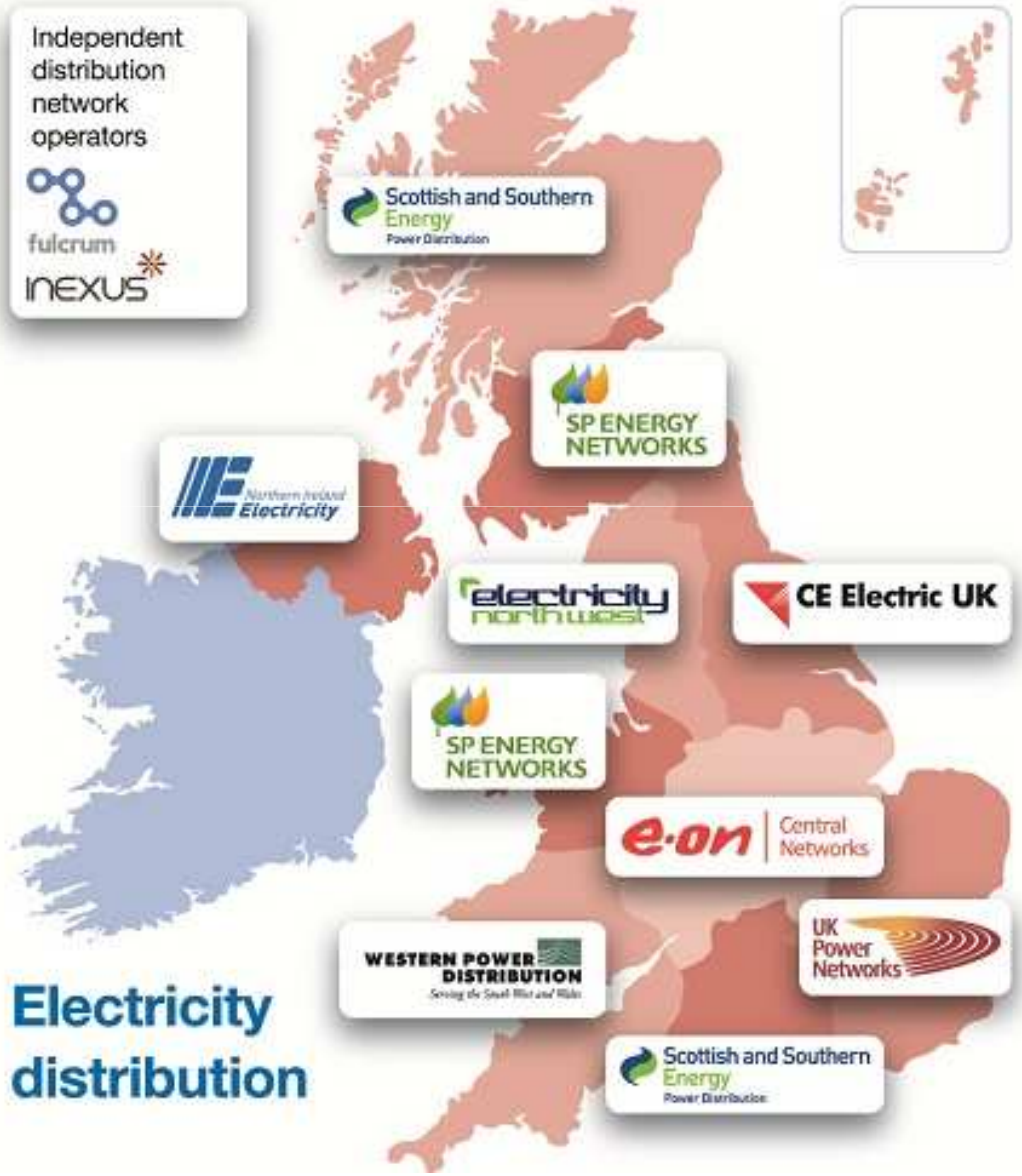
- Conductance path: Wire
- Insulation: Air/Ceramic/Plastic/Oil/SF6
- Switches: circuit breakers, fuses, disconnects
- Voltage transformation
- Loads

- Note all electrical systems contain these generic parts! Just on a different scale to cope with the different power and required protection.

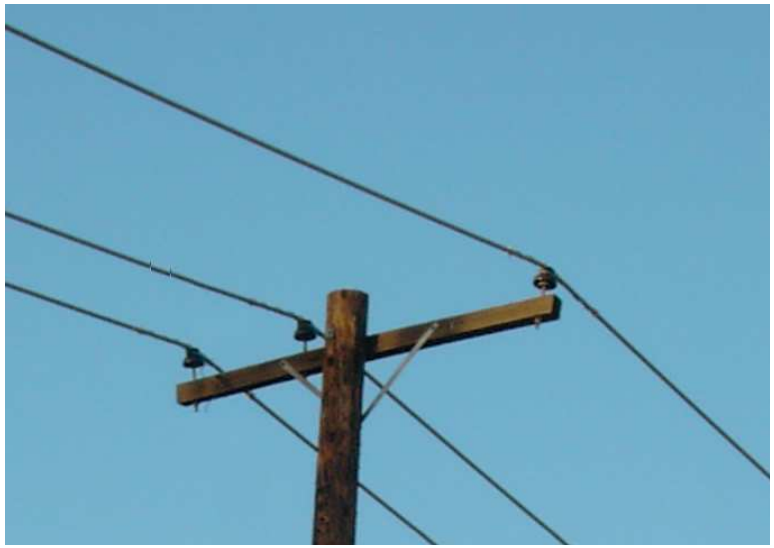
Characteristics of electricity

- No storage and no control over demand
  - Base demand
  - Peak demand
- Growing demand
  - Evolution vs forward planning
  - Wayleaves: Right of way
- Distribution and use of fuel
  - “Remoteness”
  - Fuel-generation-load

Distribution Network Operators



Distribution



Distribution Voltages in UK

132kV – sub-transmission

66kV

33 kV

11kV

6.6 kV

400V/230V

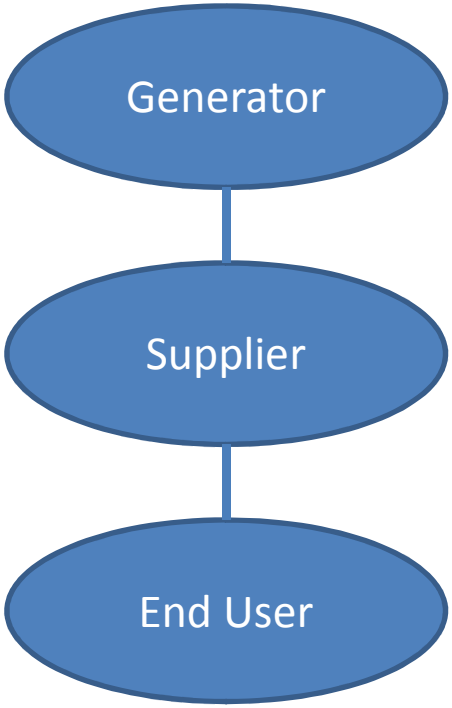
} **Poles / underground cables**

Supply: where to buy?

Supplier and consumer

- To supply electricity you must have:
  - a licence from the Office of Gas and Electricity Markets (OFGEM)
  - Codes of practice from Association of Energy Suppliers (AES)
- To entice people you may have:
  - Dual fuel discounts
  - Green energy

Electrical supply chain

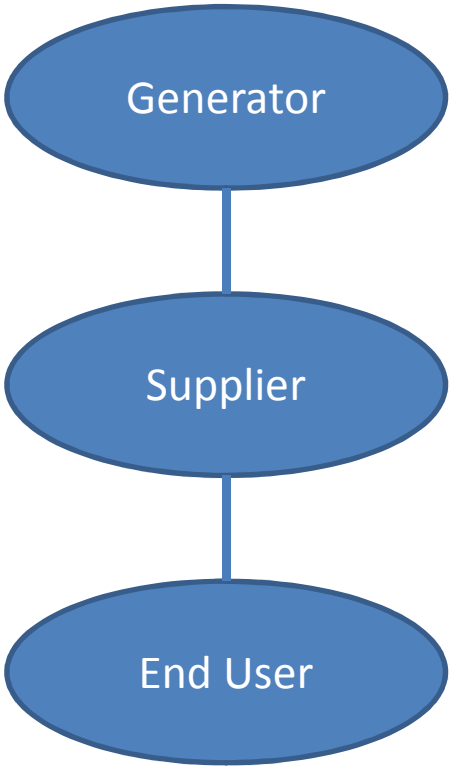


http://www.legislation.gov.uk/uksi/1988/1057/contents/made
http://www.adviceguide.org.uk/index/your_world/energy_index_ew/electricity_supply.htm

Supply: where to buy?

Generator and supplier

- Regulated utilities
  - Large scale production
  - Monopoly
- Additional regulation
  - Renewable energy
  - Small to medium scale
- Power purchasing agreement
  - Generator (seller)
  - Supplier (buyer)



3 phase residential distribution