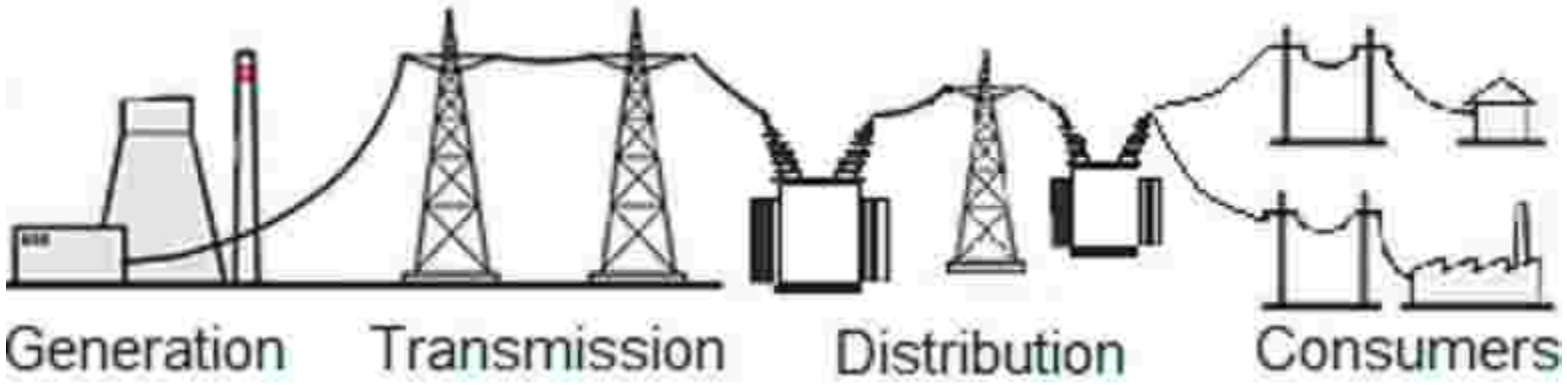
EE 1102 – Fundamentals of Electrical Engineering



Overview

Prof Rohan Lucas

Who is Rohan Lucas




- BSc Eng – 1969, MSc – 1971, PhD – 1974, CEng, FIESL, IntPE, FIEE
- Senior Professor, Electrical Engineering, KDU (Teaching from Intake I, ~1981)
- Emeritus Professor, University of Moratuwa (Taught from 1st Batch, 1970)
- A friend to my students, past and present - http://prof.rohan.lucas.lk/
- Notes and Past Papers published on the website

Learning outcomes

After successful completion of this module, you should be able to

1. Use correct SI units correctly
2. Project an overall picture of Electrical Engineering
3. Perform DC and AC calculations
4. Apply network theorems to the solution of circuits
5. Explain the functioning of a domestic wiring system.

Outline Syllabus

Overview of Electrical Engineering (2 hrs)

Role of Electrical Engineer, Introduction to Generation, Transmission, Distribution and Utilisation.

SI Units (2 hrs)

Basic and supplementary units, Derived units, Symbols

Basic DC circuit analysis (4 hrs)

Circuit elements, Circuit laws, Circuit solutions with DC.

Network Theorems (4 hrs)

Ohm's Law and Kirchhoff's Laws, Other network theorems.

Alternating Current theory (8 hrs)

Sinusoidal waveform, phasor and complex representation, Impedance and Admittance, Power and Energy, Power factor. Solution of simple R, L, and C circuit problems by phasor and complex variable methods.

Electrostatic and Electromagnetic theory (4hrs)

Basic Laws, Calculation of field and force

Electrical Installations (4 hrs)

Fuses, miniature circuit breakers, earth leakage circuit breakers, residual current circuit breakers, earthing, electric shock. Wiring regulations, basic domestic installations.

"What will he Grow to be?"

Cartoon in *Punch* magazine
25th June 1881, London

- *King Steam* and *King Coal* discussing *Baby Electricity's* chance of success in life.
- *Baby Electricity* feeding from the bottle "storage of force".
- Prior to 1881
  - Steam used to drive machinery
  - Coal gas widely used to obtain light

Muscle Power

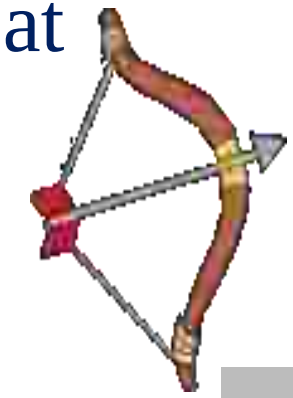
- Stone age man used spears to hunt animals
  - had to be close enough to succeed
- He invented the bow and arrow
  - bow is slowly bent by hunter in more than a few seconds and energy is stored in the springy wood
  - arrow released in fraction of second and moves at many times velocity that man could have thrown at
  - can operate from a much further distance

Original muscle energy in man

- potential energy in the bow
- kinetic energy in the arrow.

Man gets his energy from the food he eats.

Principle of conservation of energy



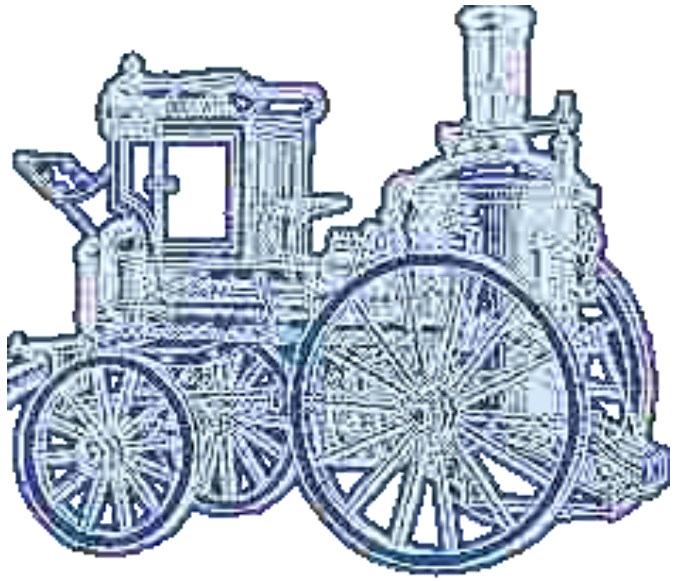
Early non-muscle power

- First forms of non-muscle power

water wheel

wind mill

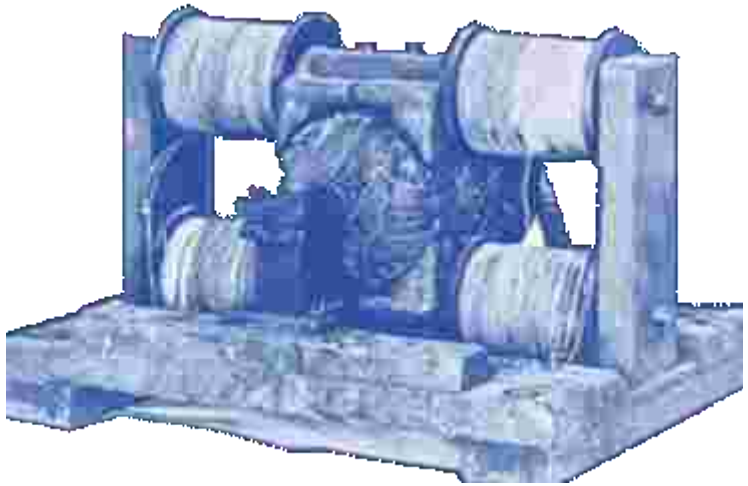
steam engine

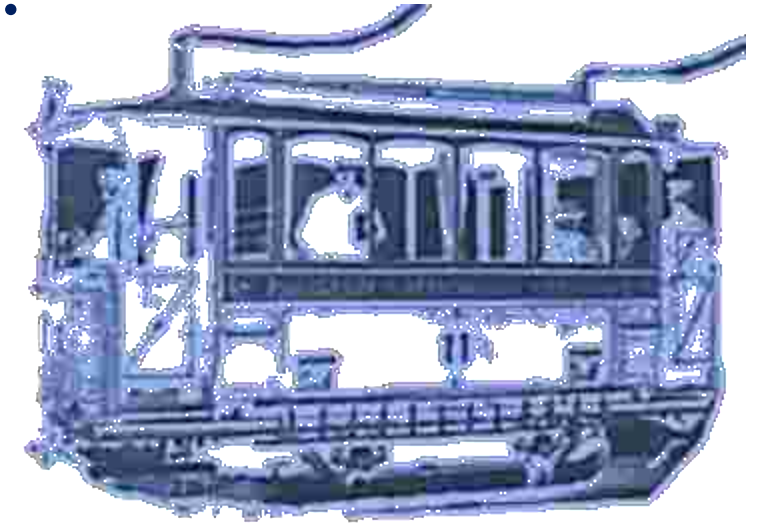


- Invention of steam engine in1780s led to an ever increasing material progress.

Non-muscle power

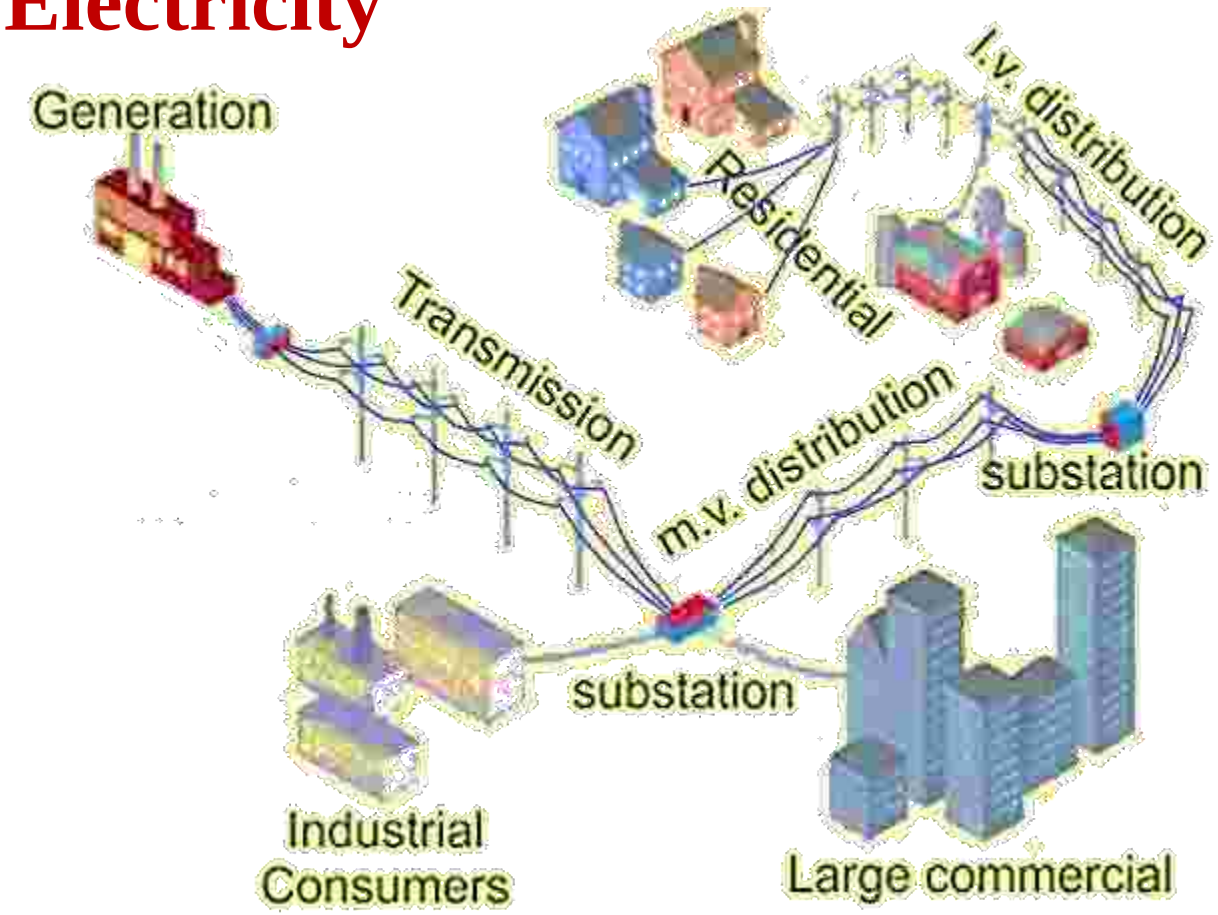
- Discovery of Electro-magnetic induction
- by Michael Faraday in 1831
- and construction of first dynamo
- led to Electricity gaining ground
- for lighting and power in 1881.





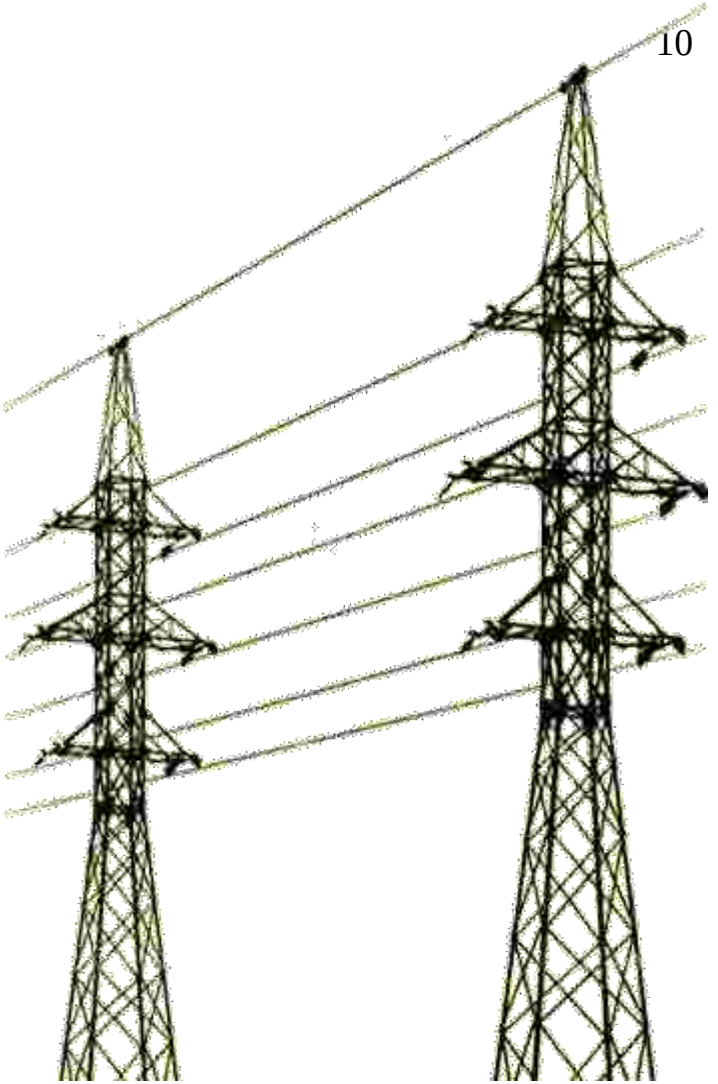
Generation, Transmission, Distribution and Utilisation of Electricity

- Generation, transmission and distribution
  - directly concerned with
  - electrical power
  - handled by supply authorities
- Utilisation
  - by all walks of people
  - for all types of purposes
  - (day to day activities in home,
  - office or other workplace)

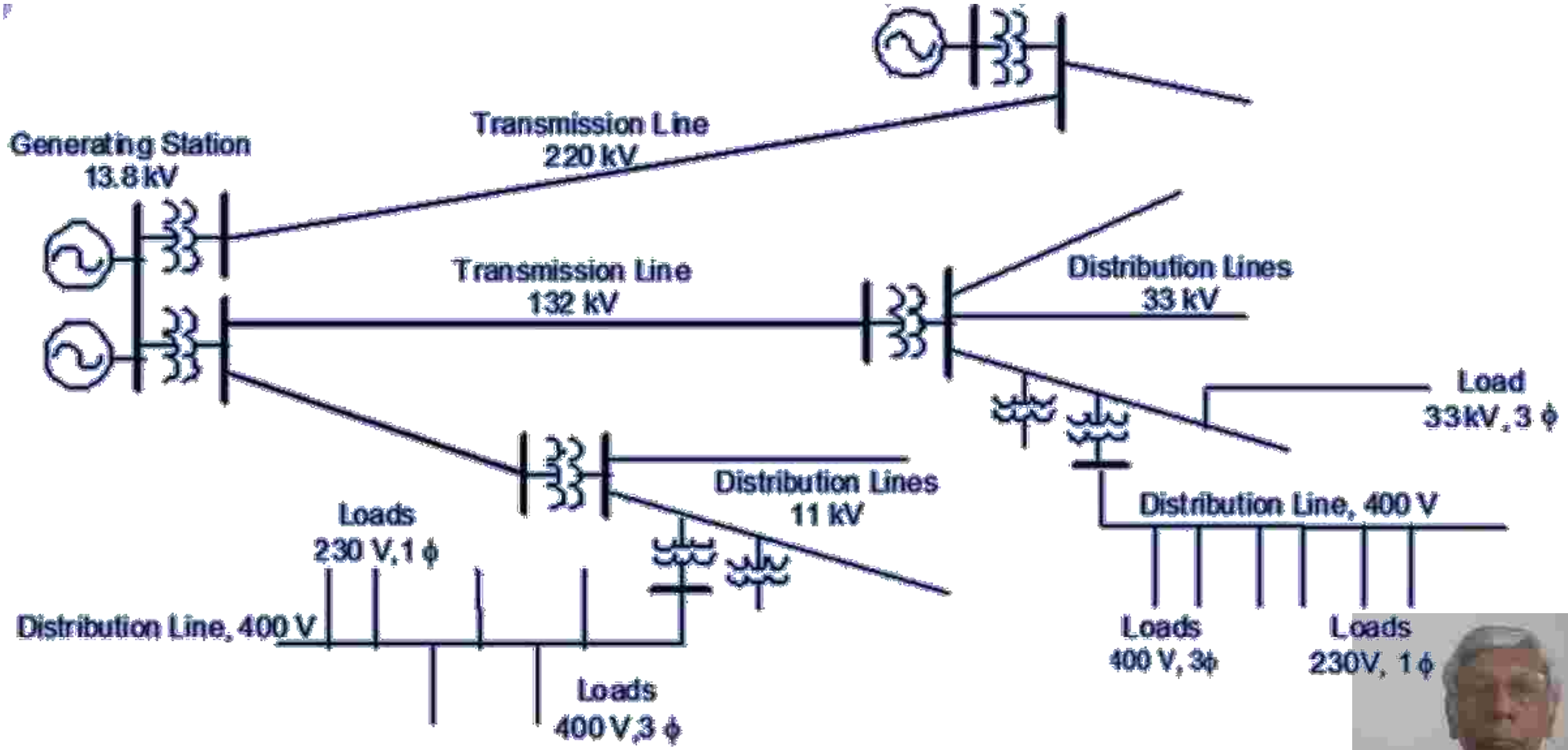


Generation, Transmission and Distribution

- Consumer uses electricity day to day
  - home, office or other workplace
  - Not feasible to produce where required.
- Electricity is produced centrally
  - 12 to 15 kV (in generating stations)
- Power is transmitted in bulk
  - 132 kV and 220 kV.
- Power is distributed at medium voltage
  - 3 phase, 11 kV (Lanka Electricity Company)
  - 3 phase, 33 kV (Ceylon Electricity Board).
- Stepped down for low voltage distribution
  - 3 phase, 400 V
  - (usually rated 100 kVA, 250 kVA, 400 kVA)



Typical arrangement of a power system



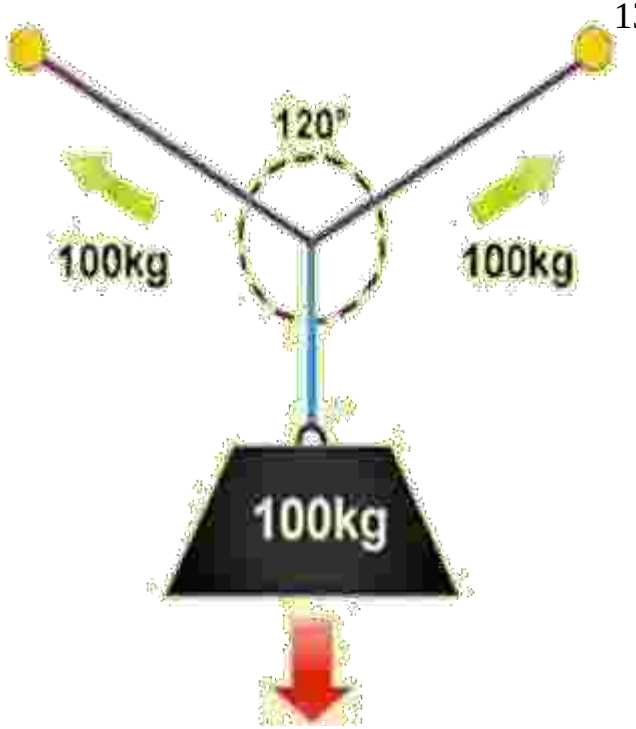
Utilisation

There are two levels of Utilisation

- Medium voltage 11kV or 33 kV three-phase
  - Big industries (such as Steel Corporation)
  - large workplaces (such as University of Moratuwa)
- Low voltage 230 V 1-phase, or 400 V 3-phase
  - Home
  - Office
  - Higher voltages not at all safe
  - lower voltages not economical as they require larger currents and hence larger size conductors

Use of Three Phase

- Forces along 3 sides of equilateral triangle add up to zero.
- 3 currents, equal in magnitude but with phase angles differing by 120^0 (or 2p/3 rad), would add up to zero.



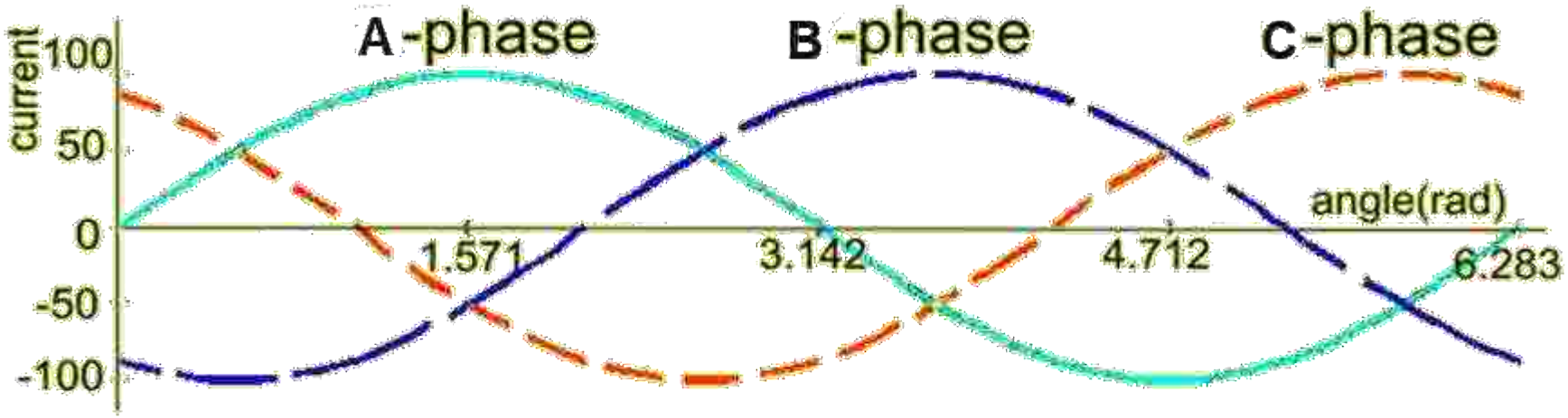


Figure - Three phase waveforms

Use of Three Phase

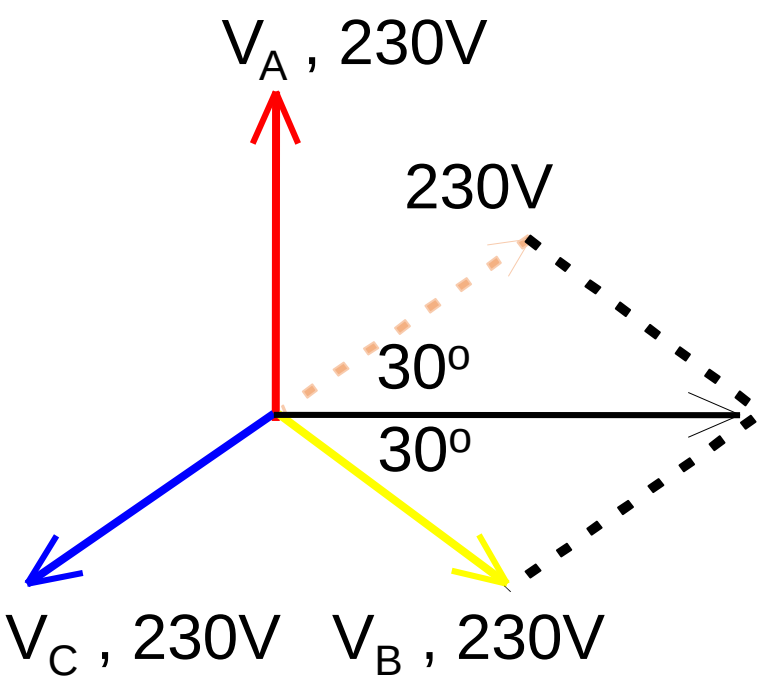
Power distribution normally carried out using 3 phase.

When electricity to various households are balanced equally into three phases, neutral current would be almost zero.

$$I_{Neutral} = I_A + I_B + I_C \approx 0$$

and total power loss would be significantly reduced.

Phase and Line Voltage



$V_{BC} = V_B - V_C$

With live to neutral voltage 230 V,

Voltage between two live wires

$= 2 \times 230 \times \sqrt{3}/2 = 400$ V.

Low voltage distribution to house is

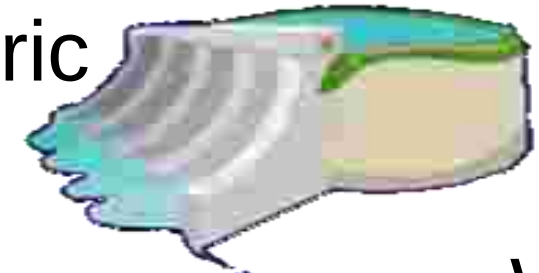
Three phase: 400 V, 50 Hz.

Single phase: 230 V, 50 Hz.

Bulk Energy Sources

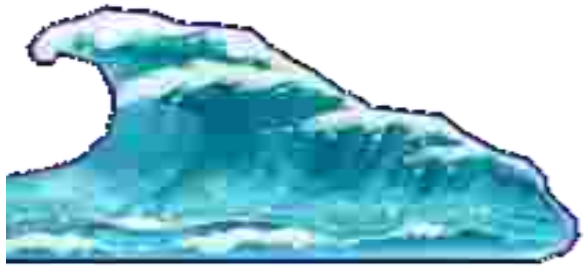
Renewable energy sources

Hydro-electric



Geothermal

Wave



Solar

Wind

Bio-mass

Non-renewable energy sources

Coal

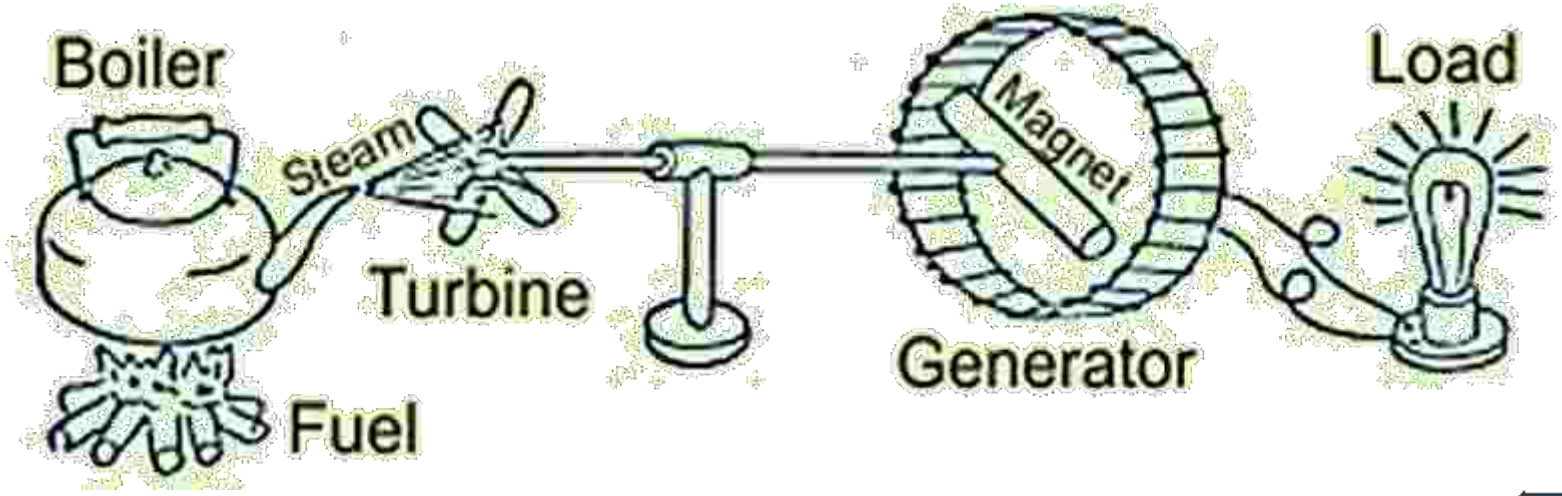
Oil

Nuclear

Hydro-electric power

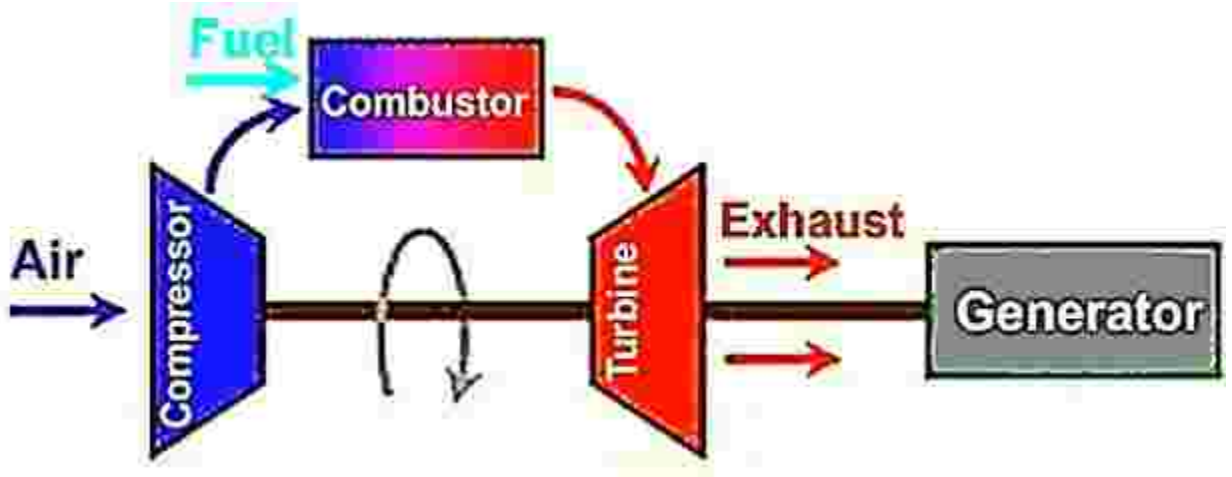
- Oldest form of large scale
- energy conversion
  - used in ancient water wheels.
- Energy of water (potential or kinetic)
  → rotational (mechanical) energy in turbine
  → electric energy in generator.
- Although water, which gives energy, is free
  - a high capital construction cost associated
- Micro-hydro and mini-hydro plants also used
  - Connect directly to m.v. or l.v. distribution network
  - Not to transmission network.

Conventional thermal power (Coal & Oil)



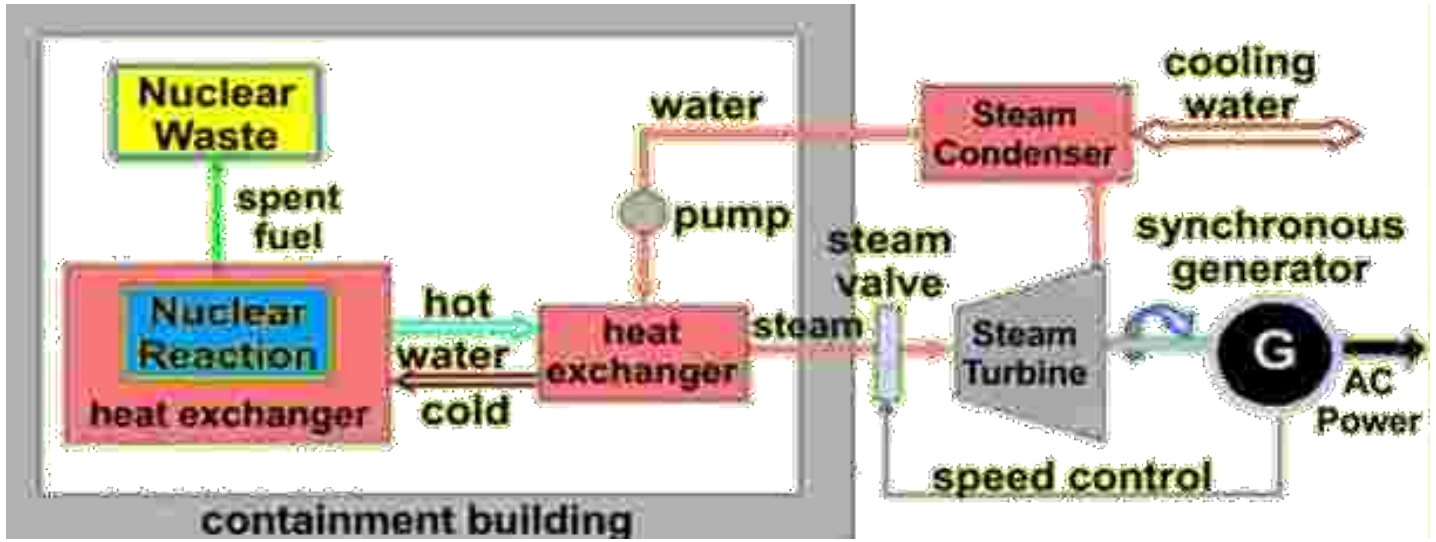
- Burning Fuel (coal/oil) in boilers produces steam at high temperature and pressure
  - chemical energy → thermal energy
- Steam is used to rotate steam turbine
  - thermal energy → mechanical energy (kinetic)
- coupled to an electric generator
  - mechanical energy → electrical energy
- efficiency of thermal stations is low (around 40%)

Gas turbines



- Gas turbine plants also operate by burning oil
- Energy transfer is through compressed gasses produced in the combustion chamber under high pressure which drives the gas turbine.
- Gas turbine is mechanically coupled to electrical generator to produce electricity.

Nuclear Power Plants

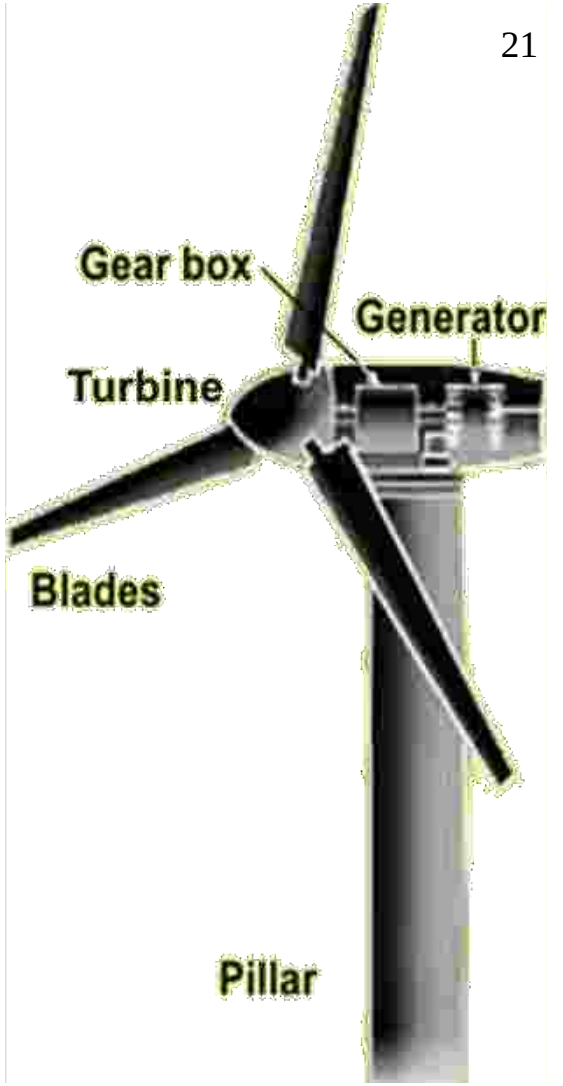


- Energy stored in the nuclei of the atoms of the fuel.
- Energy released by splitting of a nucleus (*fission)*.
- High kinetic energy (million times that in a chemical reaction).
- Uranium U^{235} is a commonly used fuel.
- Fast moving fragments hit surrounding atoms producing heat and further fissions. The chain reaction is controlled.
- Heat generated used to produce steam to drive steam turbine coupled to electrical generator

Wind Power Plants

Wind is continuously regenerated in atmosphere under influence of energy radiated from the Sun.

- ~ 20% of solar energy is converted to wind energy
- Kinetic energy in wind used to turn a wind turbine
- Energy produced in wind turbine $\propto$ (wind velocity)^3
- Wind turbines mounted on tall towers for greater efficiency as wind velocity higher at higher altitudes.
- To obtain large scale electric power, a large number of wind turbines are arranged in a wind farm.
- A disadvantages of wind power is that it is not continuously available
- Over 200 MW wind farms installed in coastal belt in Sri Lanka.



Solar Energy

- Energy generated by sun is due to nuclear fusion.
- Energy received on earth from sun is over 10,000 times present energy requirement of earth.
- Average solar radiation received by earth 0.2 kW/m^2
- Sun's rays concentrated by lenses or mirrors.
- Heat used to produce steam to drive steam turbines.

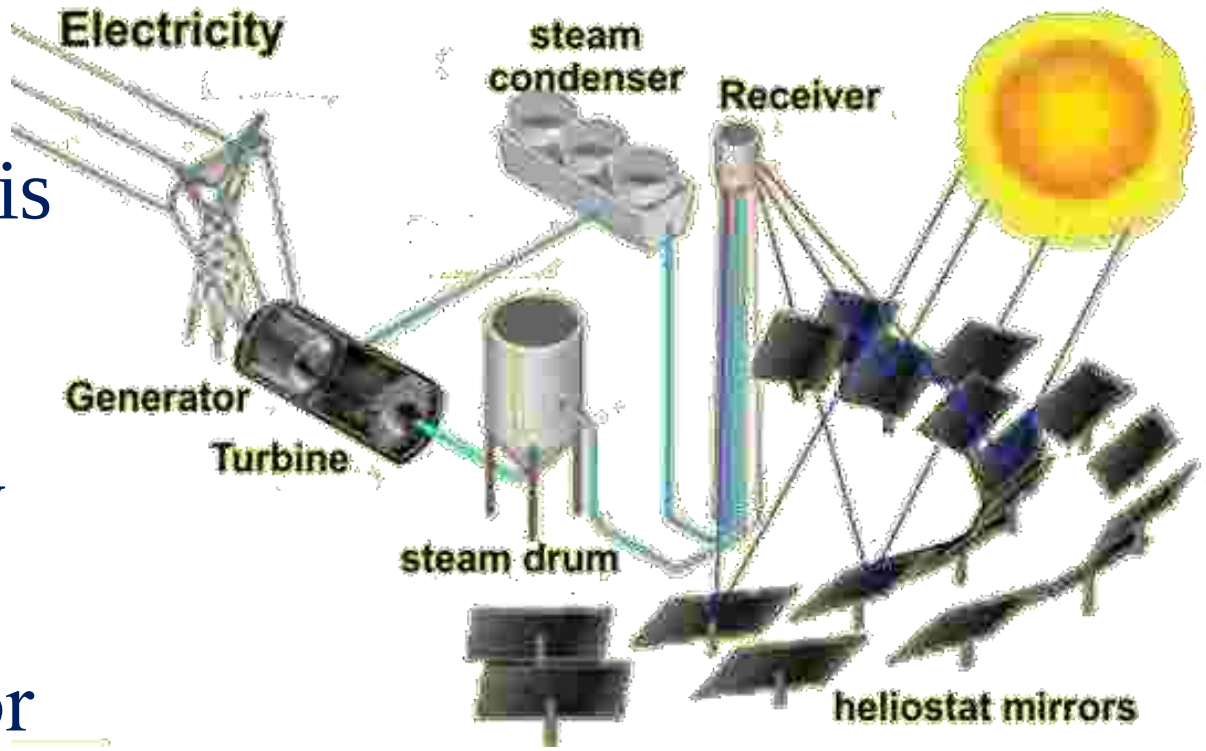
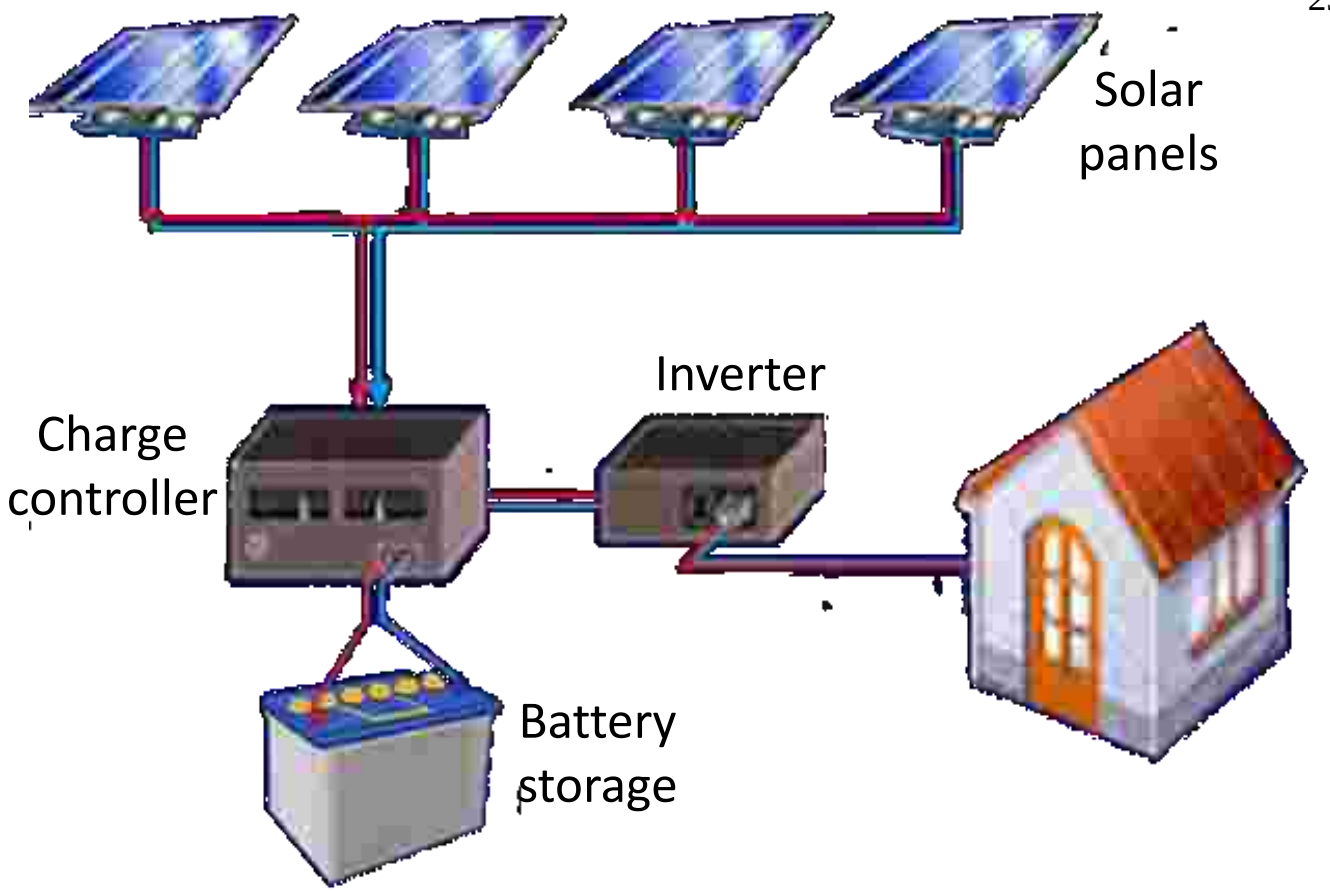


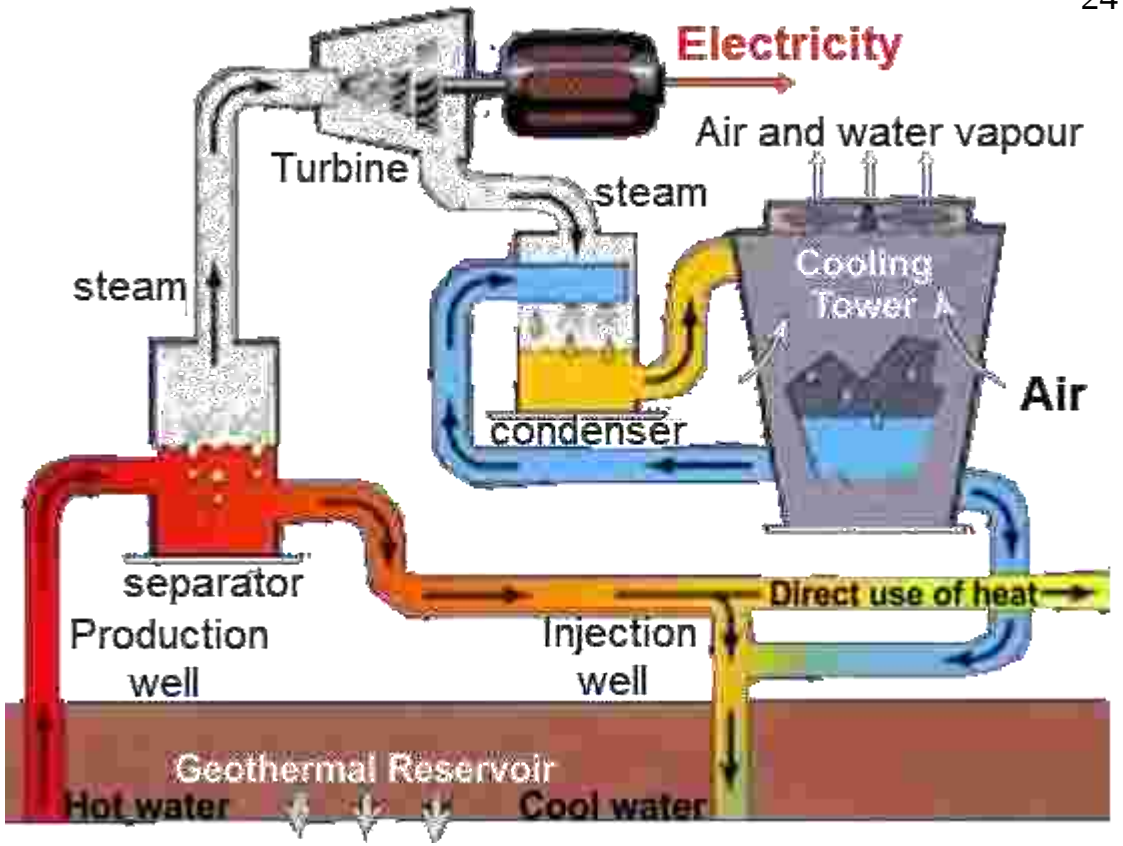
Photo-voltaic power

- Uses solar panels.
- Converts solar radiation directly to electricity.
- Relatively expensive.
- May require storage as electricity not produced when most needed for.
- May be supplied to the National Grid.
- An important use is in powering remote power applications



Geothermal Energy

- Heat from inside the earth.
- Earth temperature increases from 20^0C at surface to 1000^0C at 40 km depth.
- Energy obtained from high pressure steam or hot water, produced by ground water coming into contact with molten rock.



- circulated through heat exchanger to produce steam to run a steam turbine.
- water can be pumped into a cavity created in hot rock to obtain hot water and steam.

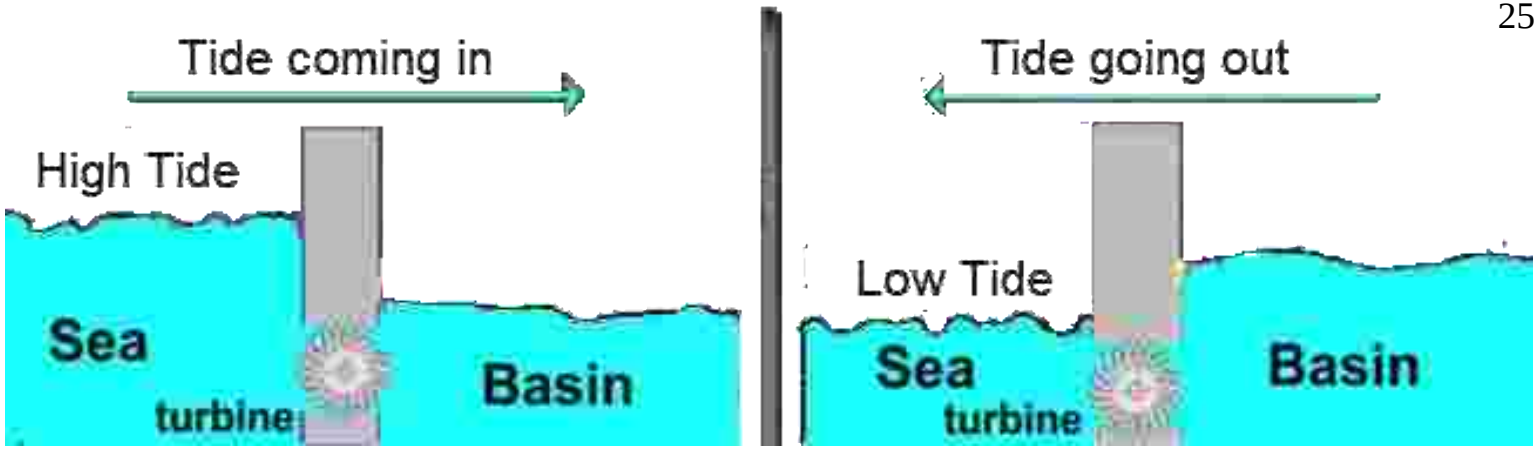
Ocean Energy

Developed in 3 ways.

(a) tidal power,

(b) ocean waves and

(c) ocean thermal gradient



Tide occurs twice a day and rises and falls by as much as 10m.

- When tide rises, water flows into basin and when tide falls, water flows out.
- This vast amount of energy transfer used to generate electrical energy

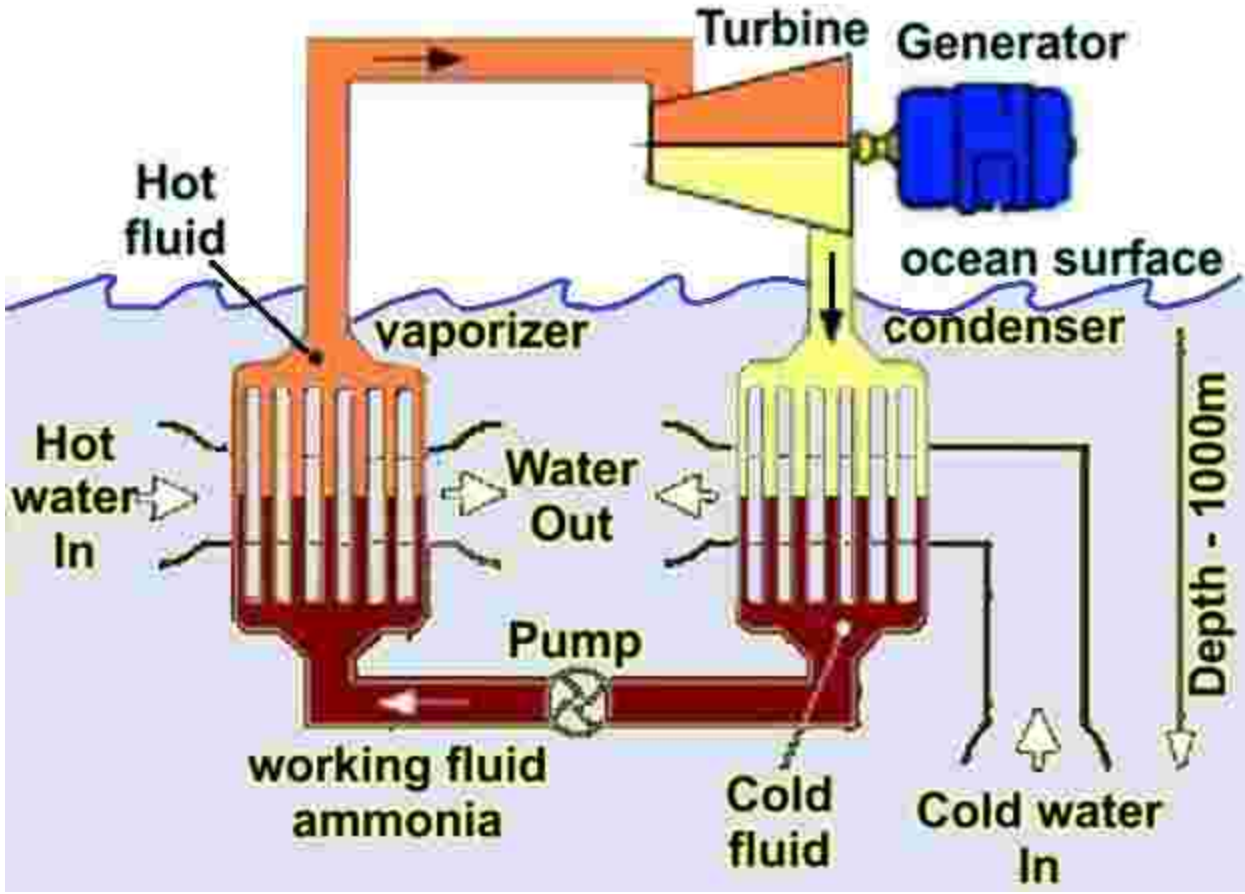
Ocean waves are created by the wind and a vast amount of energy is available in the waves.

- 1 km long, 1m high wave would contain about 10 MW of power.
- Reciprocating generators are commonly used.
- The mechanism to trap the wave energy would be moored in the middle of the ocean (say 80 km from shore).

Ocean thermal energy conversion (OTEC)

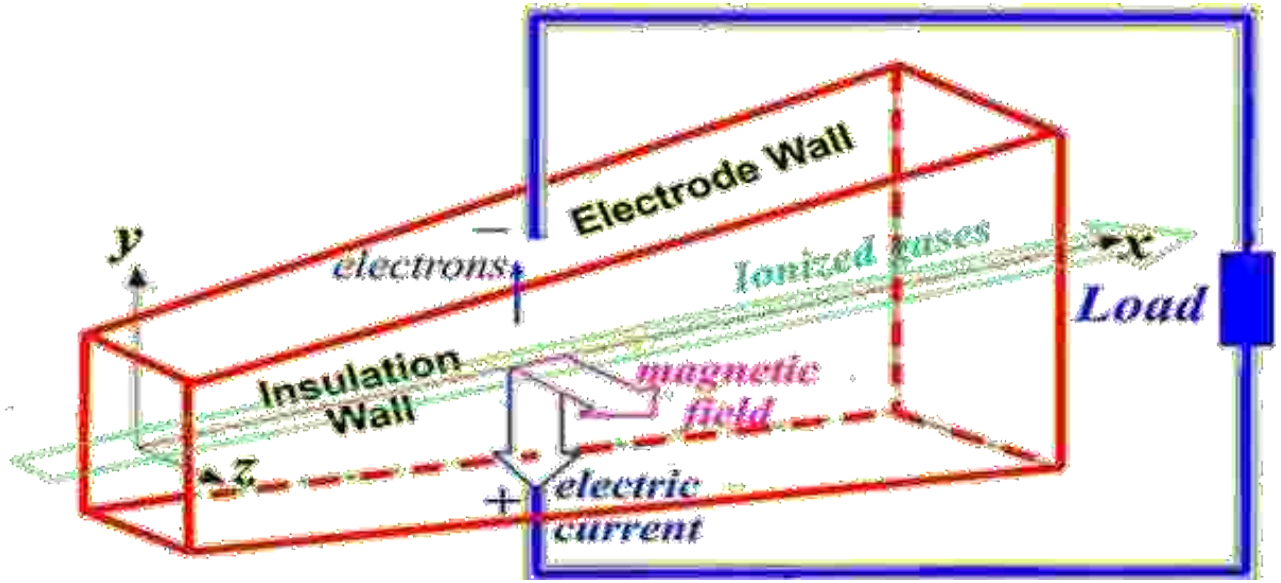
Uses natural temperature difference between warm surface water (25^0C) and cooler ocean bed at 5^0C.

Due to low temperature difference, turbines use fluids such as ammonia as the working fluid.



About 50 km away from coast line in Sri Lanka, in Mannar, Trincomalee and Unawatuna, are some of the best sites for OTEC in the world.

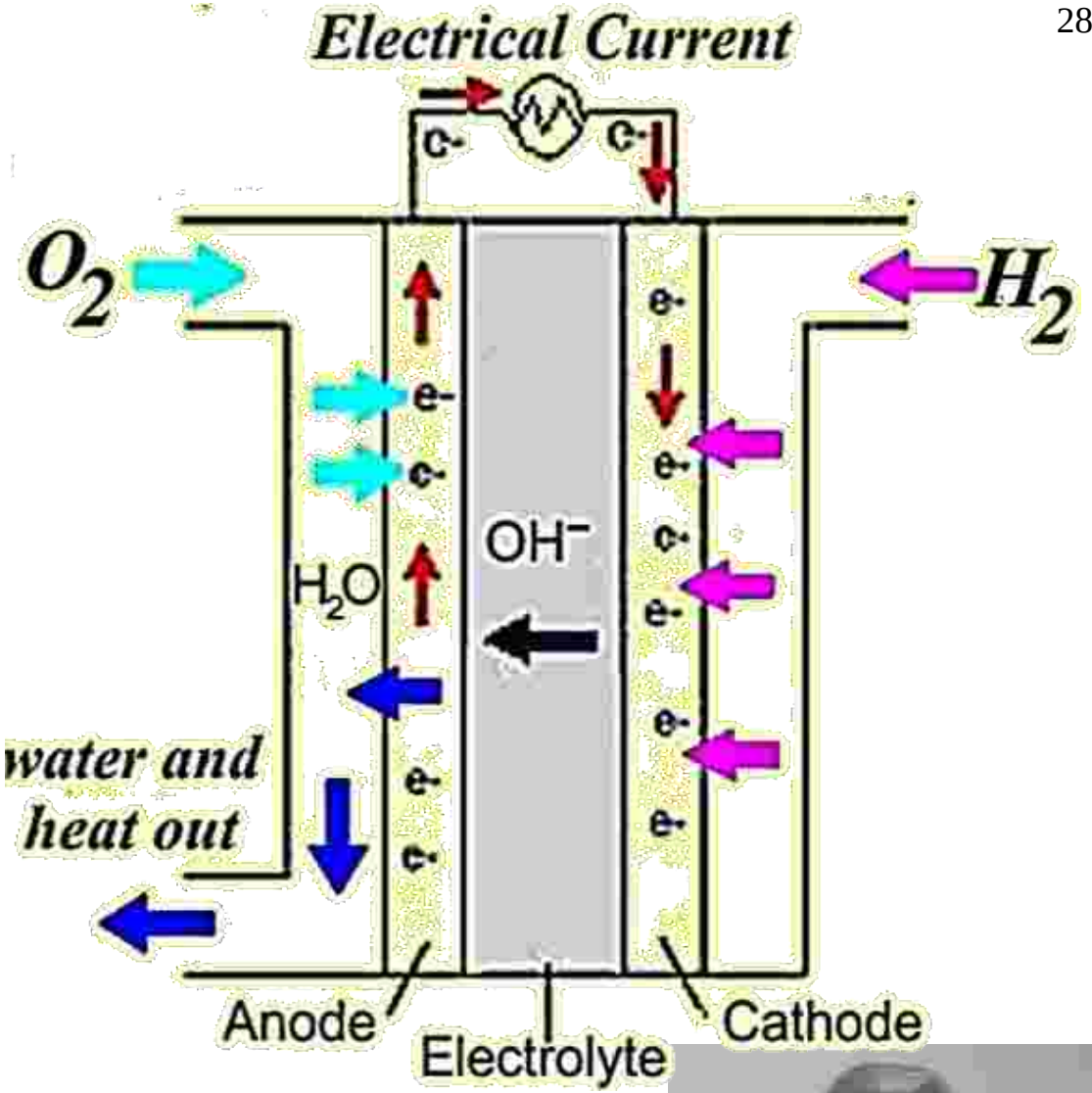
Magneto hydro-dynamic (MHD) Generation



- MHD generation is based on Faraday's laws of induction.
- Conductor is gas at very high temperature and pressure where it is conductive.
- Gas may be seeded with small amount of vaporised metal
- Gas passes through a pipe (whose cross-section gradually increases from beginning to end) across which a magnetic field is applied (in a perpendicular direction to the flow of gas).
- Emf induced in circuit in third mutually perpendicular direction.

Fuel Cells

- Uses hydrogen-oxygen interaction through a catalyser to yield a flow of electrons in external load.
- Each cell ~ 0.7V
  - sufficient modules in series yield output voltage ~11-15kV
- Can reach power outputs of ~ 1 MW.



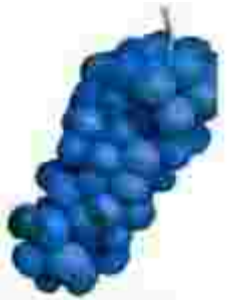
Biomass energy

Animal waste

Wood

Landfill gas

Crop Residue



Alcohol Fuel

Garbage

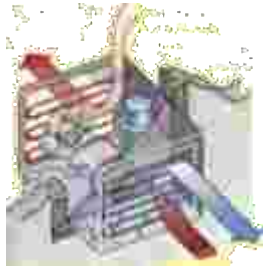
- Biomass is abbreviation for biological mass,
  - living material provided by given area of earth's surface.
- Biomass energy may be obtained from forests, vegetation and animal refuse.
- In various forms, probably the major supplier of energy in Sri Lanka.

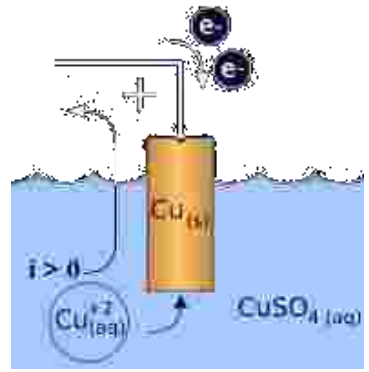
Utilisation

- Electric Lighting
- Electric Drives and Traction
- Electrical Heating and Welding
- Refrigeration and Air Conditioning
- Electrochemistry and Electrometallurgy
- Electronics
- Telecommunication
- Information storage and transmission
- Biomedical Engineering





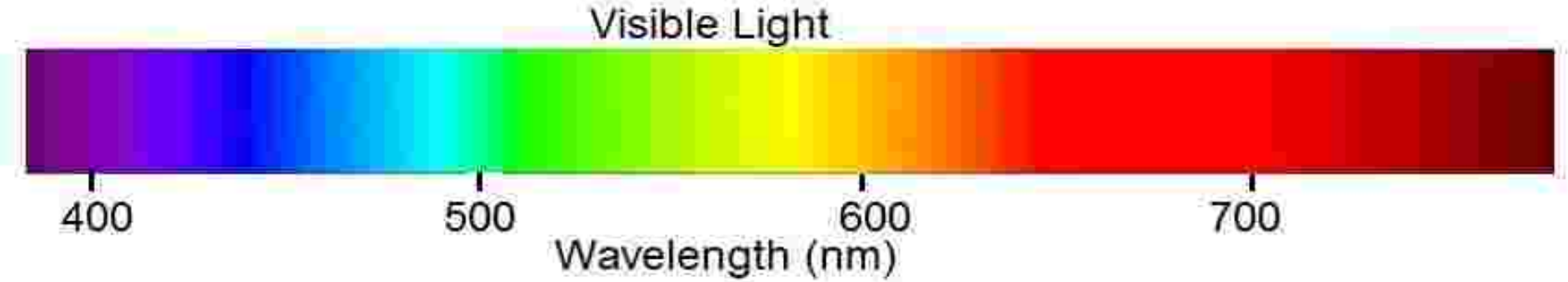




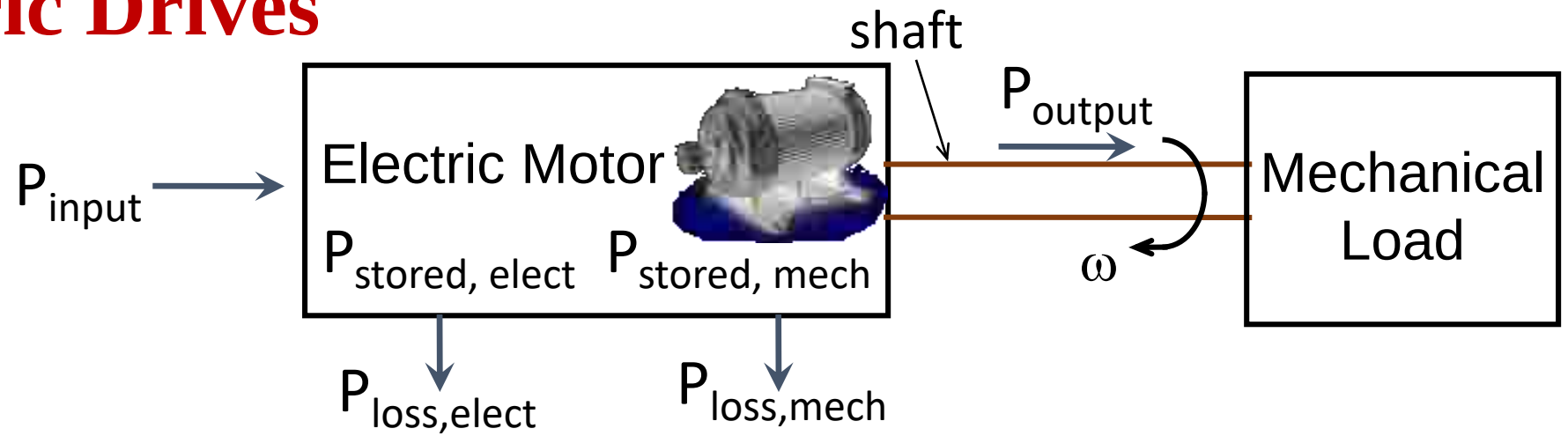

Electric Lighting

- Light is electromagnetic radiation of a wavelength to which the eyes are sensitive (380 nm to 780 nm)
  - bounded by infra-red radiation of 780 to 10,000 nm and ultra-violet radiation of 10 nm to 380 nm wave length.
  - eye most sensitive to yellow-green (wavelength = 555 nm)
  - colour associated with various wavelengths are



Wave length (nm)	380-420	420-495	495-566	566-589	589-627	627-780
Colour	violet	blue	green	yellow	orange	red

Electric Drives

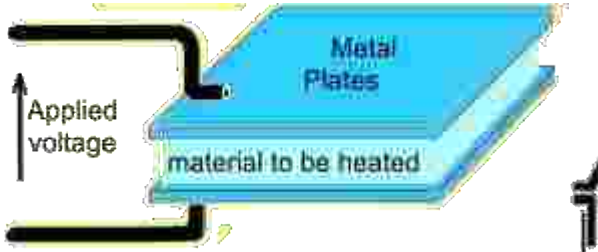


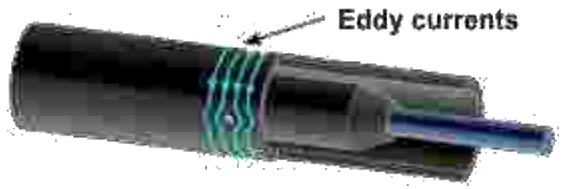
electrical input = mechanical output + energy stored + energy dissipated

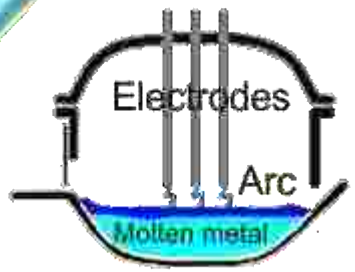
- Universally used in industry due to various advantages
  - May operate on either a.c. or d.c.
- Most applications use a.c. induction motors
  - operate at almost constant speed and low starting torque
- For variable speed drives and high starting torque
  - In the past d.c. preferred
  - Now a.c. motors controlled modern power electronics.

Electrical Heating

- Heating by electric current extensively used in industrial and domestic applications
  - relatively high efficiency (>75%), clean, easy to control, low maintenance and easily protected against overheating
- Electric heating can be obtained from
  a) resistance heating
  b) induction heating
  c) eddy current heating
  d) dielectric heating, and
  e) electric arc heating.

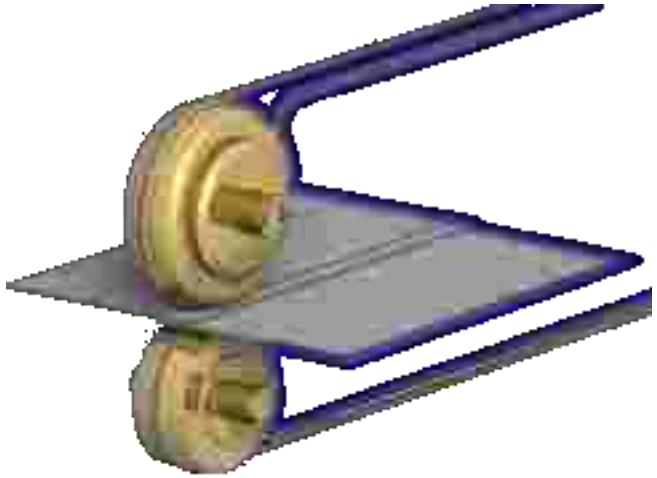


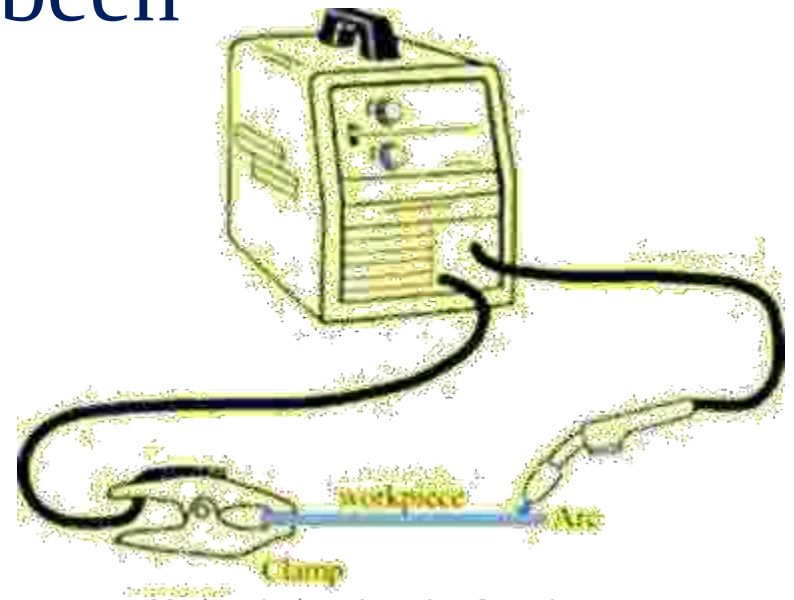




Electric Welding

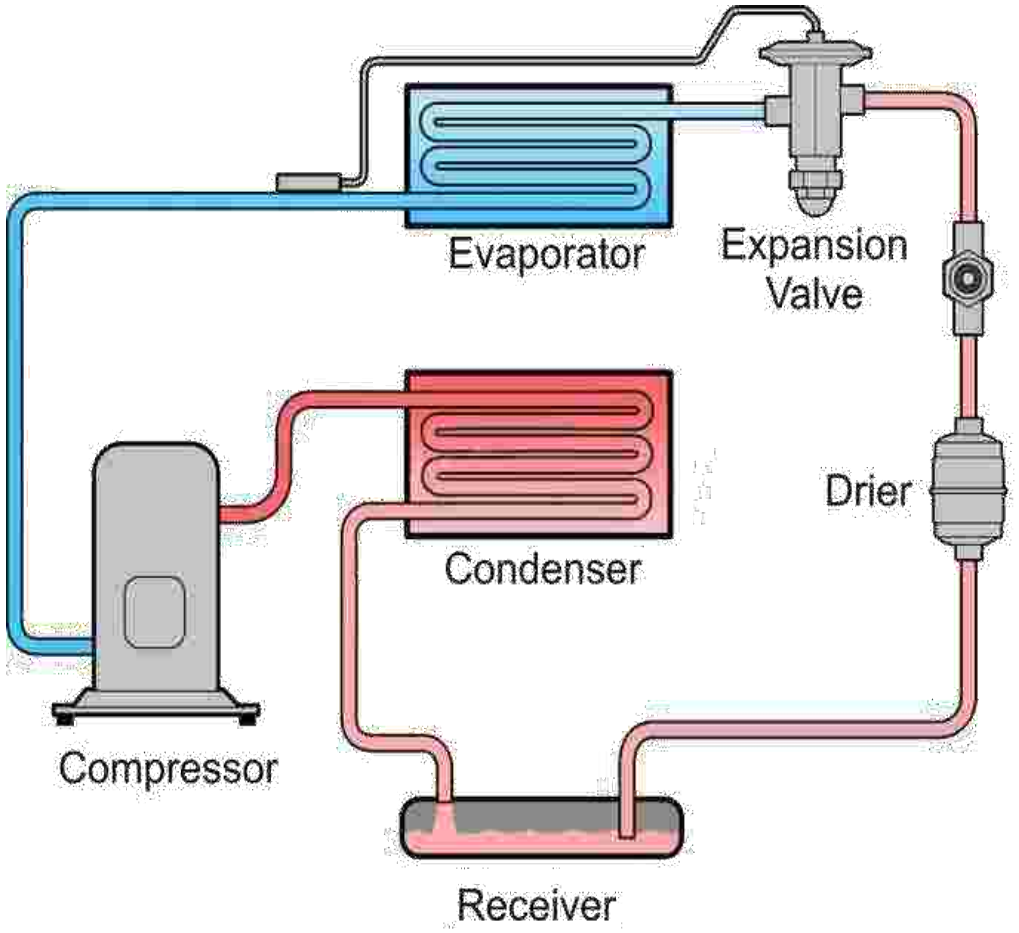
- A very high electric current produces heat needed to melt and join two metals together.
- Due to the reliability of the welded joints, electrical welding has been adopted in many fields of engineering.
- Types of electric welding are
  - resistance welding
  - arc welding





Air Conditioning

- Control of temperature, humidity and purity of air.
- Air conditioning in Sri Lanka only cools but not heats
  - in cold countries both modes available.
- Working substance in cooling type of air conditioner is refrigerant vapour

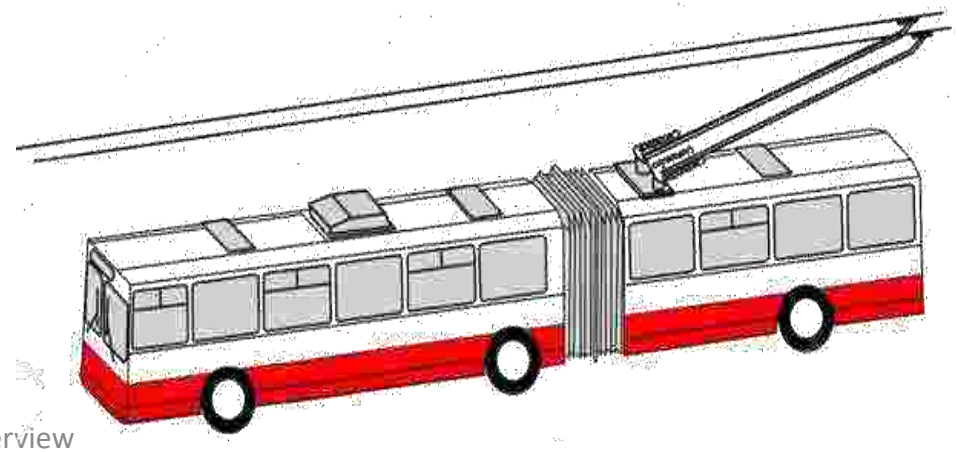


Light sources

- *Incandescent filament type* – emit light at high temperature ~ 3000 ^{o}C. Efficacy ~ 10 to 20 lm/W
- *Fluorescent type* – transform ultra violet rays into radiation in the visible spectrum. ~ 50-80 lm/W.
- *Gas discharge type* – operate on visible radiation when an electric discharge occurs in a gas or metal vapour. Sodium vapour lamp ~ 100 lm/W.
- *Electric Arc type* – Light is emitted when electric arc is formed between two electrodes in a gas.
- *Light Emitting diode* – Light emitted, with a wavelength and colour determined by energy released, when electrons and holes combine when a potential is applied ~ 60 to 140 lm/W

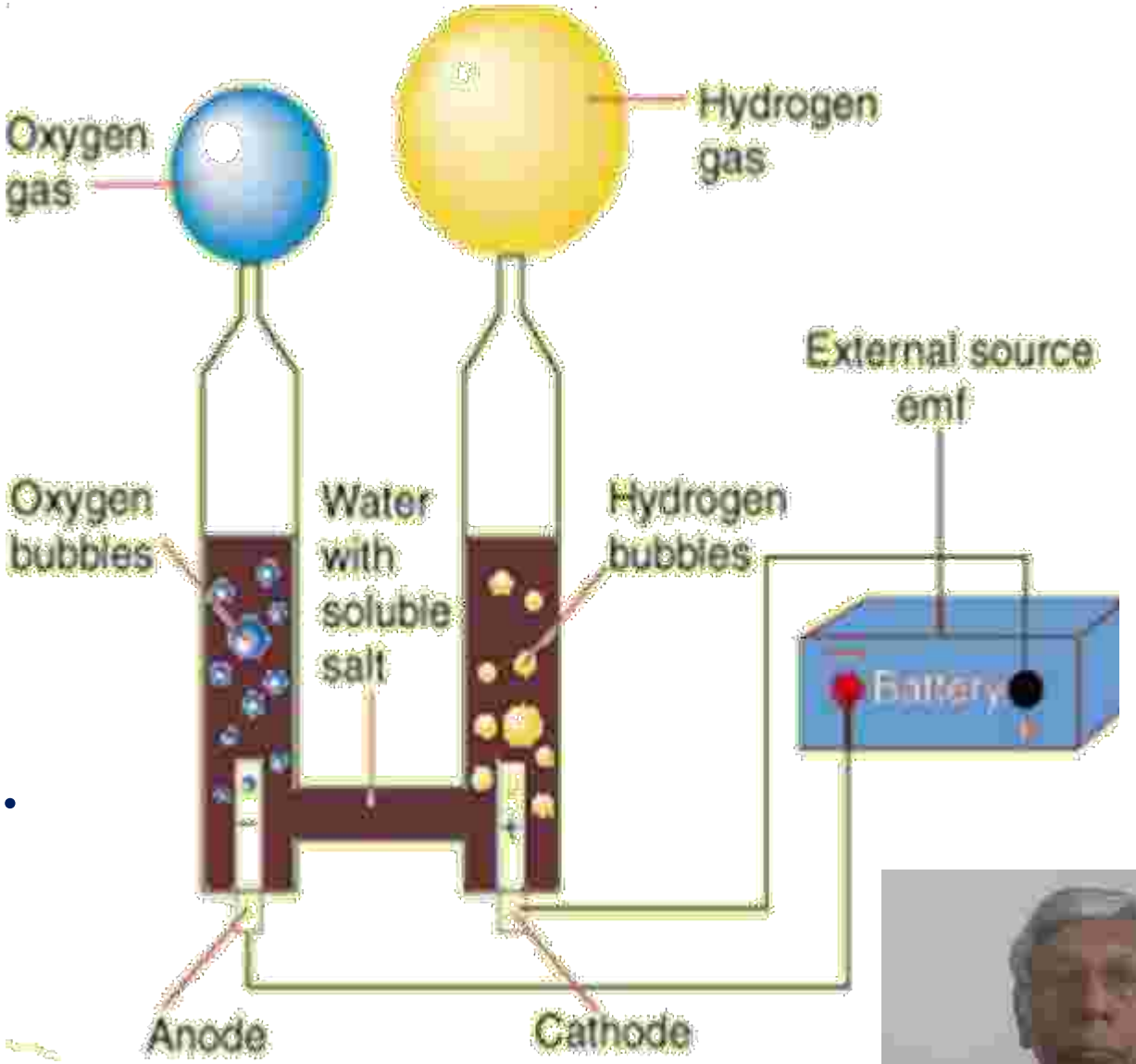
Electric Traction

- Two major application
  - electric vehicles, electric hoists
- Good controllability of speed and torque of electrical drives without resorting to lossy gears.
- Allows Internal Combustion (IC) engine in a hybrid vehicle, supplying power to the generator, to run at relatively low range of speeds, even at high running speeds of the train.
  - enhances efficiency and cuts down wear and tear of engine



Electrochemistry and Electrometallurgy

- Electrical energy extensively used in metallurgical and chemical industries.
- Extraction and refining of metals are similar electrochemical processes.



Electronics

- Electronics deals with flow of electrons and other charged particles through gases, vacuum and semiconductor materials.
- Principle electronic devices are the vacuum tubes, gas-filled tubes, and semiconductor devices like selenium rectifiers, silicon diodes, transistors and silicon controlled rectifiers.

Information storage and transmission

- The computer is the most powerful tool designed by man.
- A complex electronic machine capable of storing, processing, manipulating and retrieving large volumes of data/ information at incredibly high speeds.

- Applications in every field of industrial, commercial and business activity, science and space research, medical diagnostics

Biomedical Systems

- The bioelectrical engineer assists the regulation and uses bioelectric signals for diagnostic purposes
- Developments have led to the invention of the pacemaker, defibrillator, and electrocardiograph.
- The monitoring of many other bioelectric functions by means of electrodes plays an important part in surgical recovery rooms and intensive-care units.

End of Presentation