Energy Storage & Transmission

By

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كلية الهندســـــة بشبرا

FACULTY OF ENGINEERING- SHOUBRA

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Lecture (2)

INTRODUCTION

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Energy Definition

- Energy is the amount of force or power when applied can move one object from one position to another.

- Energy defines the capacity of a system to do work.

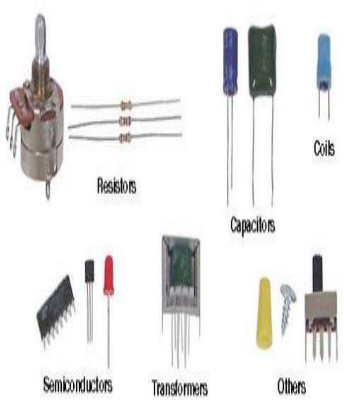
- Energy are broadly classified into two main types:

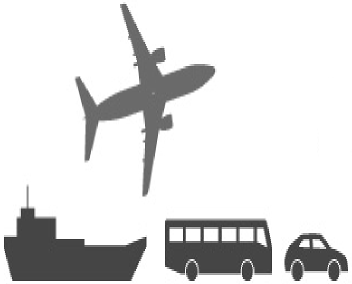
  - Renewable Energy **- Non Renewable Energy**

Energy Applications

Energy Uses

- Electronics
- Transportations
- Heat
- Computers
- Communications

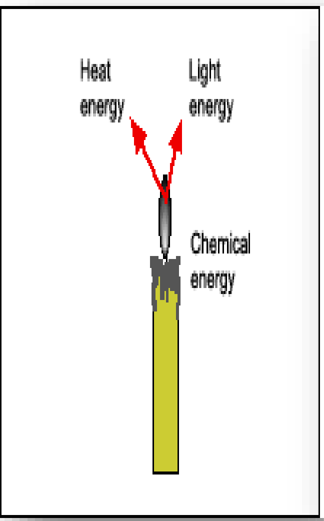


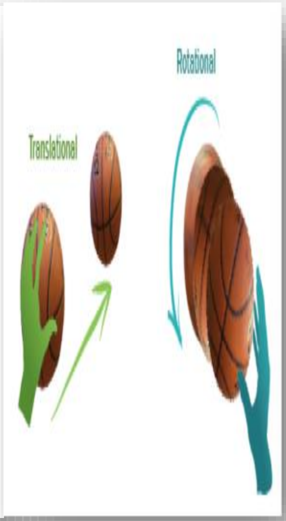


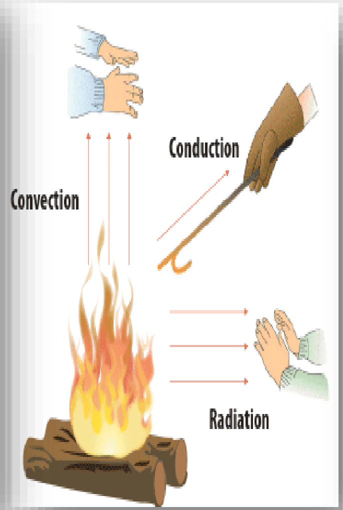
Common Forms of Energy

The six most common forms of energy:

Chemical | Kinetic | Rotational | Solar | Thermal | Nuclear







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Electricity

Changes

Life style

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Five key questions

1. What is the electrical energy?
2. How do we produce electric energy?
3. Why do we think the electrical energy is important?
4. What are the resources of electrical energy?
5. What about renewable energy resources?

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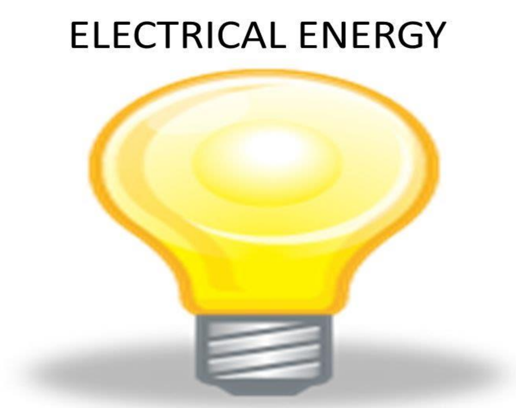
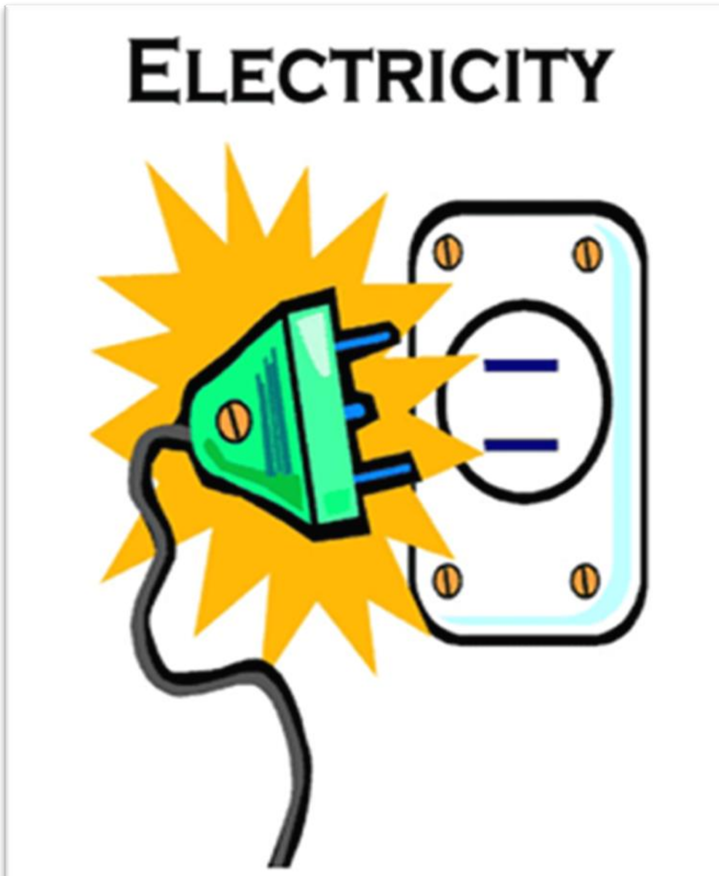
1. What is the Electric Energy?

- It is one of the most important energy forms.
- Energy cannot be created or destroyed.
- In all devices and machines, including electric circuits, energy is transferred from one type to another.



The Idea

Electricity is flowing Electrons



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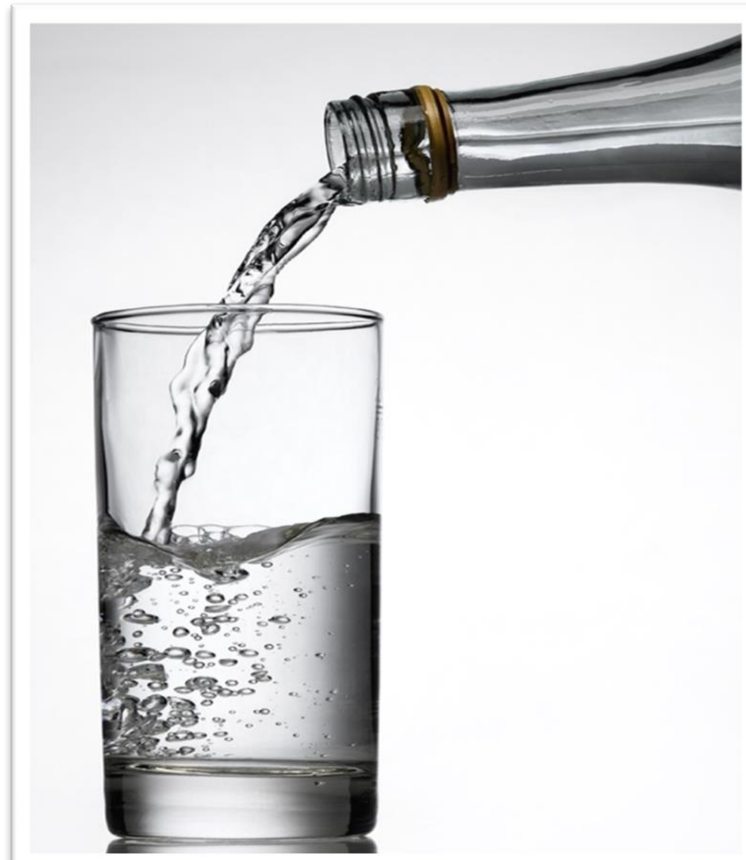

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Terminology

1. **Voltage**

- Measured in Volts.
- Electrical potential.
- “Height” of water on one side of a dam compared to the other side.

2. **Current**

- Measured in Amps.
- Rate of electron flow.
- “Speed” at which water flows through the dam.

3. **Resistance**

- The opposition of a material to the flow of an electrical current.
- Depends on

  * Material

  * Cross sectional area

  * Length

  * Temperature

4. **Watt**

- Measure of Power.
- Rate of electrical energy.
- Not to be confused with Current.
- Watt-hour (Wh) is a measure of energy:

  * Unit quantity of electrical energy (consumption and production).

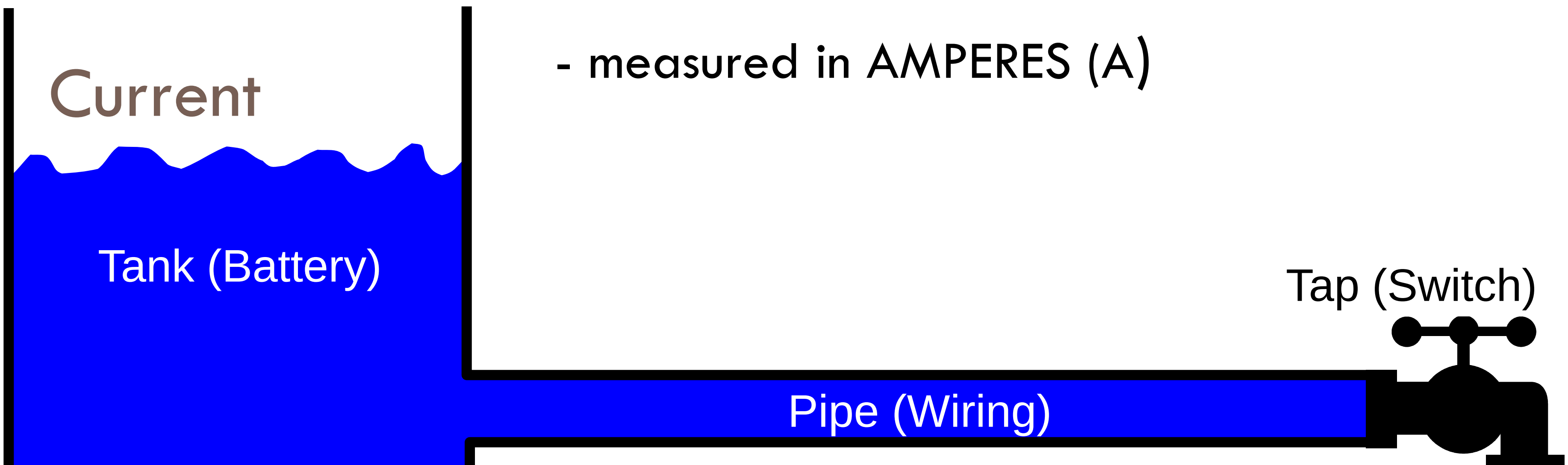
  * Watts x hours = Watt-hours.

  * 1 Kilowatt-hour (kWh) = 1000 Wh

Current

The flow of electric charge

- measured in AMPERES (A)



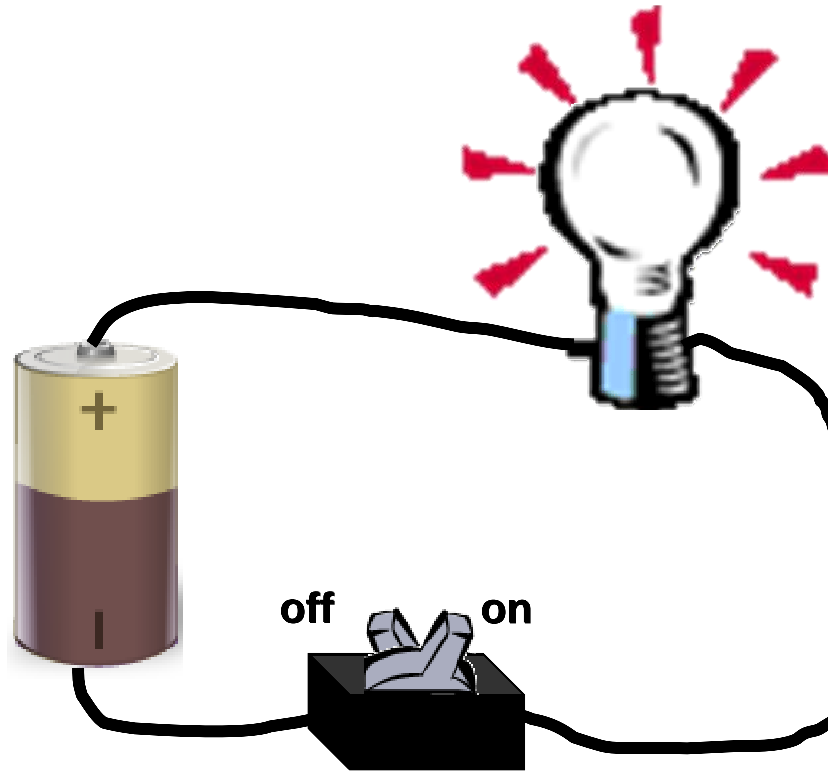
When the tap (switch) is off, is there any flow (current)?

NO

When the tap (switch) is on, is there any flow (current)?

YES

Current in a Circuit



When the switch is off, there is no current.

When the switch is on, there is current.

2. How do We Produce Electric Energy?

Magnetic field + movable conductor = electricity

Edison and Swan

Nearly 40 years went by before a really practical DC (Direct Current) generator was built by Thomas Edison. In 1878 Joseph Swan, a British scientist, invented the incandescent filament lamp and within twelve months Edison made a similar discovery in America.

- Swan and Edison later set up a joint company to produce the first practical filament lamp. Prior to this, electric lighting had been crude arc lamps.
- Edison used his DC generator to provide electricity to light his laboratory and later to illuminate the first New York street to be lit by electric lamps, in September 1882. Edison's successes were not without controversy, however - although he was convinced of the merits of DC for generating electricity, other scientists in Europe and America recognized that DC brought major disadvantages.

3. Why do we think the Electrical Energy is important?

- Electricity is a part of modern life and one cannot think of a world without it.
- Electricity has many uses in our day to day life.
- We can say that the electric energy is the source of life.
- Imagine life without electricity!!!!!!!!!!

4. What are the resources of electrical energy ?

Electric energy resources can be classified as

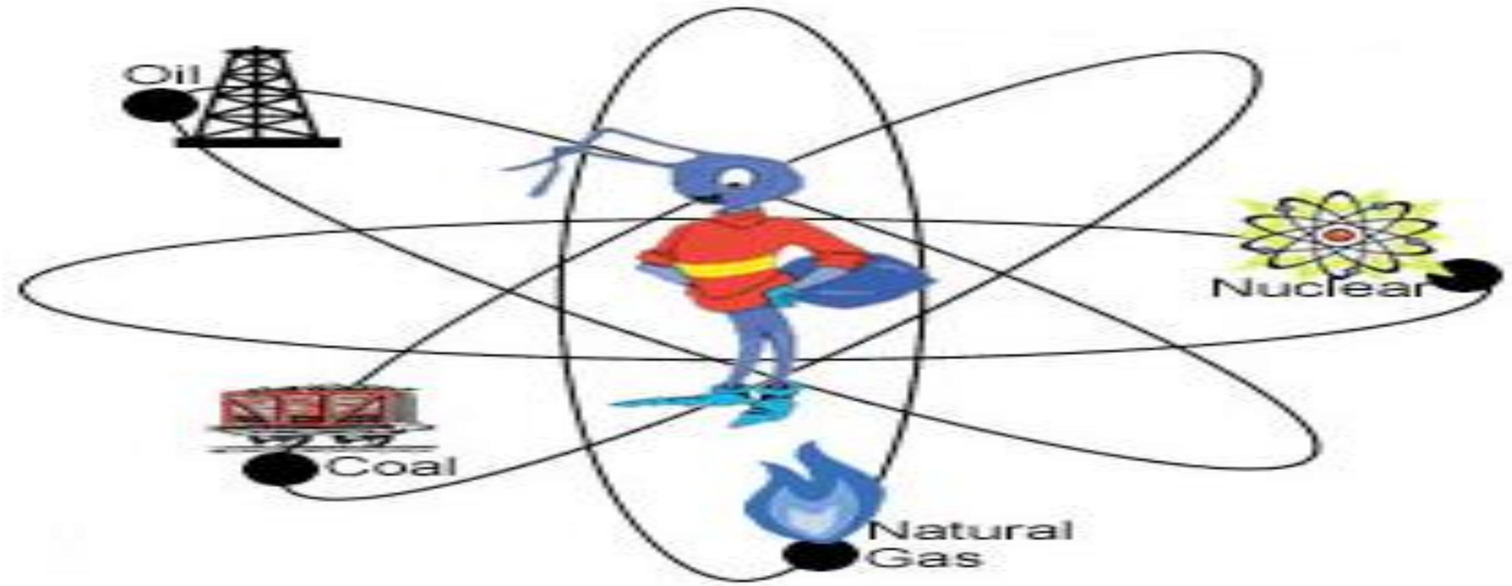
According to its nature

Non-renewable	***Renewable***

Most of our electricity comes from the burning of the fossil fuels coal and gas.

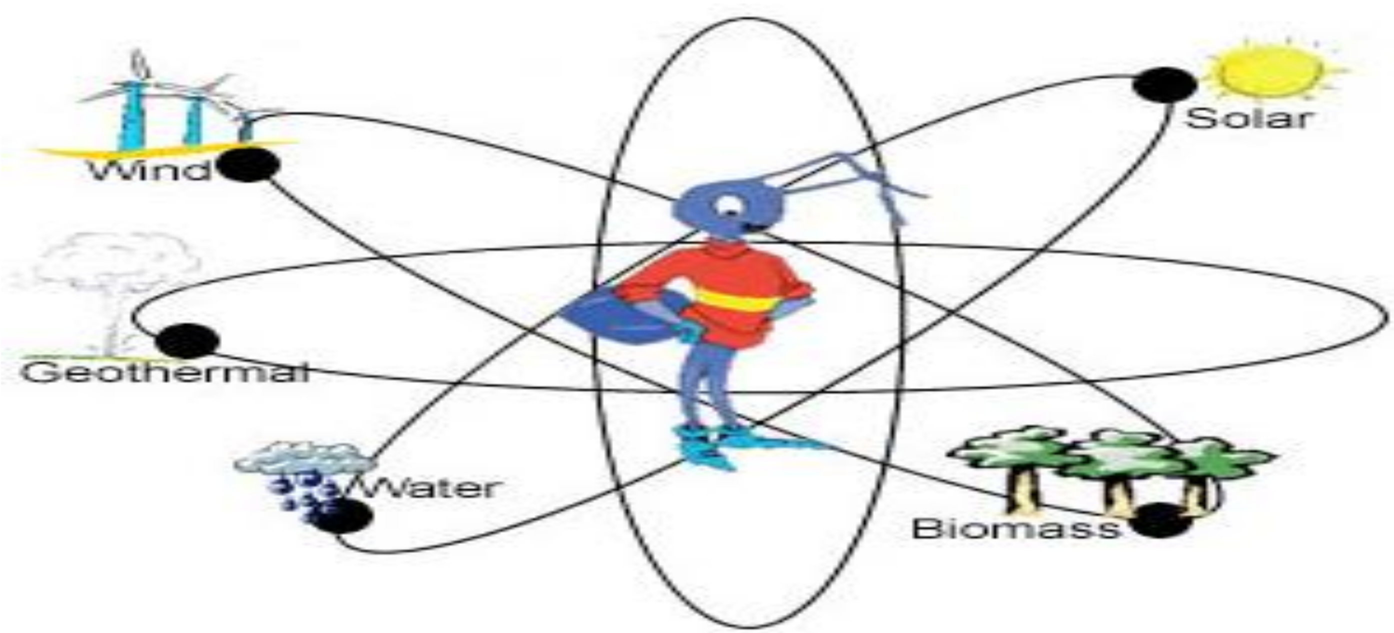
1. **Non-renewable energy & its types**

- Sources are not environmental friendly and can have serious affect on our health.
- They are called non-renewable because they can not be re-generated within a short span of time.
- Non-renewable sources exist in the form of fossil fuels, natural gas oil and coal.



2. Renewable energy & its types

- Recourses found in nature i.e. Sun, wind, rain, and tides. That are self regenerated, that can be replaced or renewed without harming the environment or contributing to the greenhouse effect.
- These sources are normally used to produce clean energy. This production doesn’t lead to climate change.



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What's wrong with this picture?

- Pollution from burning fossil fuels leads to an increase in greenhouse gases, acid rain, and the degradation of public health.

- Egypt carbon dioxide emissions is at a current level of 212.15M, up from 209.77M one year ago. This is a change of 1.13% from one year ago.

Energy Dilemma

The fact

X 2

Energy demand

VS.

The need

÷ 2

Co_2 emissions

Result

Frequent power outages

Rising energy prices

Climate change

Conflicts for resource access & control

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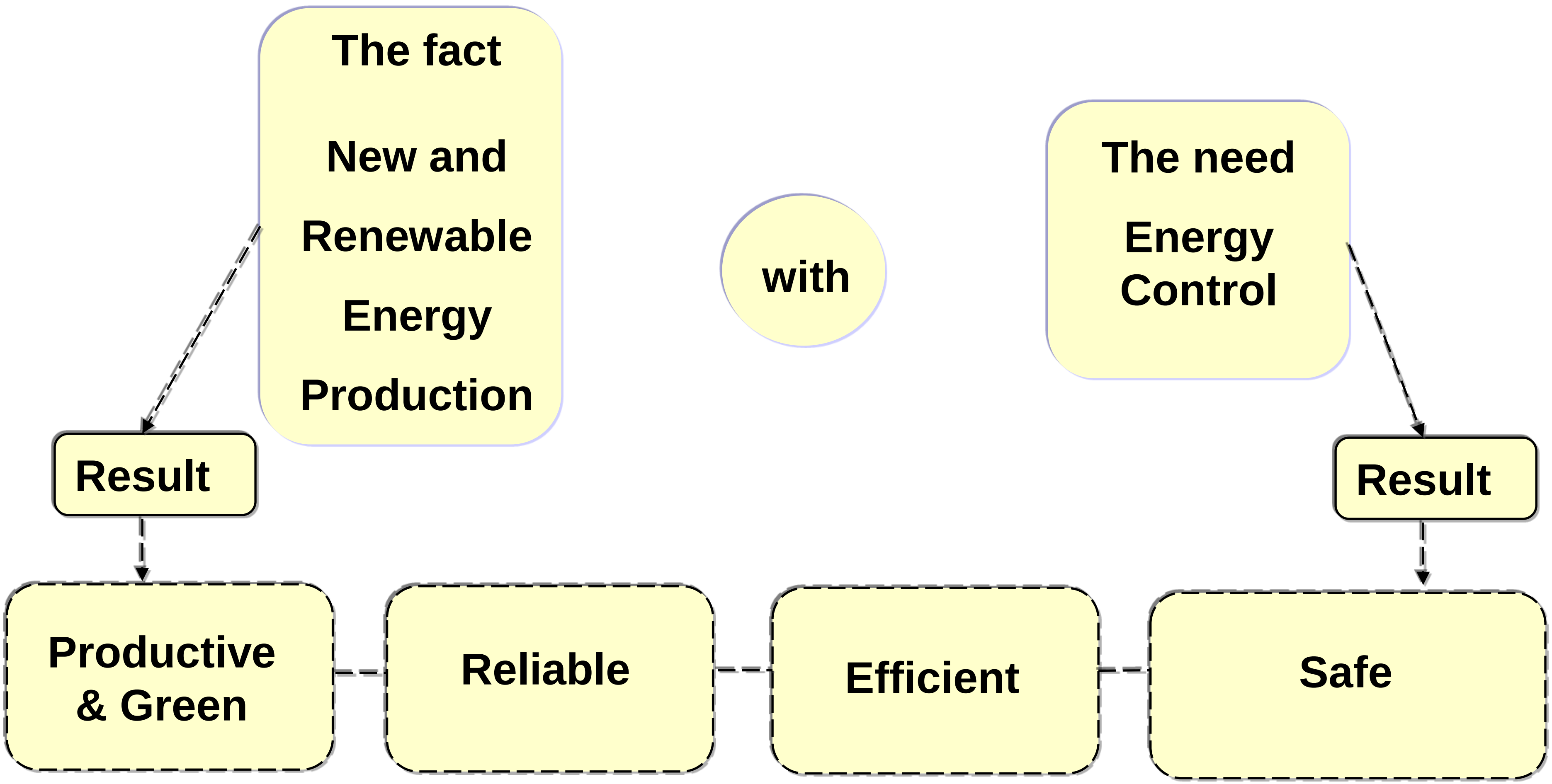
Proposed Solution



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Classifications of main drivers behind the focus on renewable energy

Environmental drivers

- ❖ *Limiting green house gas (GHG) emissions*
- ❖ *Avoidance of the construction of new transmission circuits and large generating plants*

Commercial drivers

- ❖ *General uncertainty in electricity markets favors small generation schemes*
- ❖ *DG is a cost effective route to improved power quality and reliability*

National/regulatory drivers

- ❖ *Diversification of energy sources to enhance energy security*
- ❖ *Support for competition policy*

Why Sustainable Energy Matters?

- The world's current energy system is built around fossil fuels

Problems:

1. Fossil fuel reserves are ultimately finite.
2. Two-thirds of the world' s proven oil reserves are locating in the Middle-East and North Africa (which can lead to political and economic instability).
3. Detrimental environmental impacts (mining operations &Combustion).

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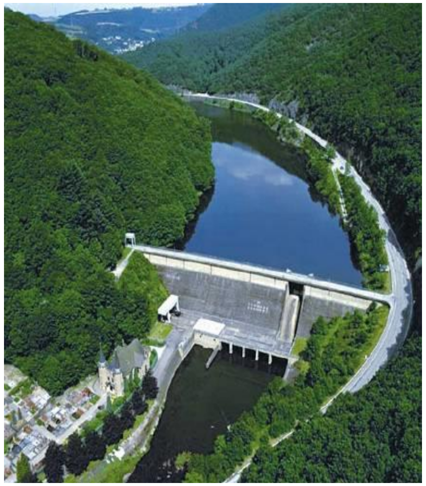
Making the Change to Renewable Energies

Solar

Geothermal

Wind

Hydroelectric



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Transmission
&
Distribution
&
Consumption

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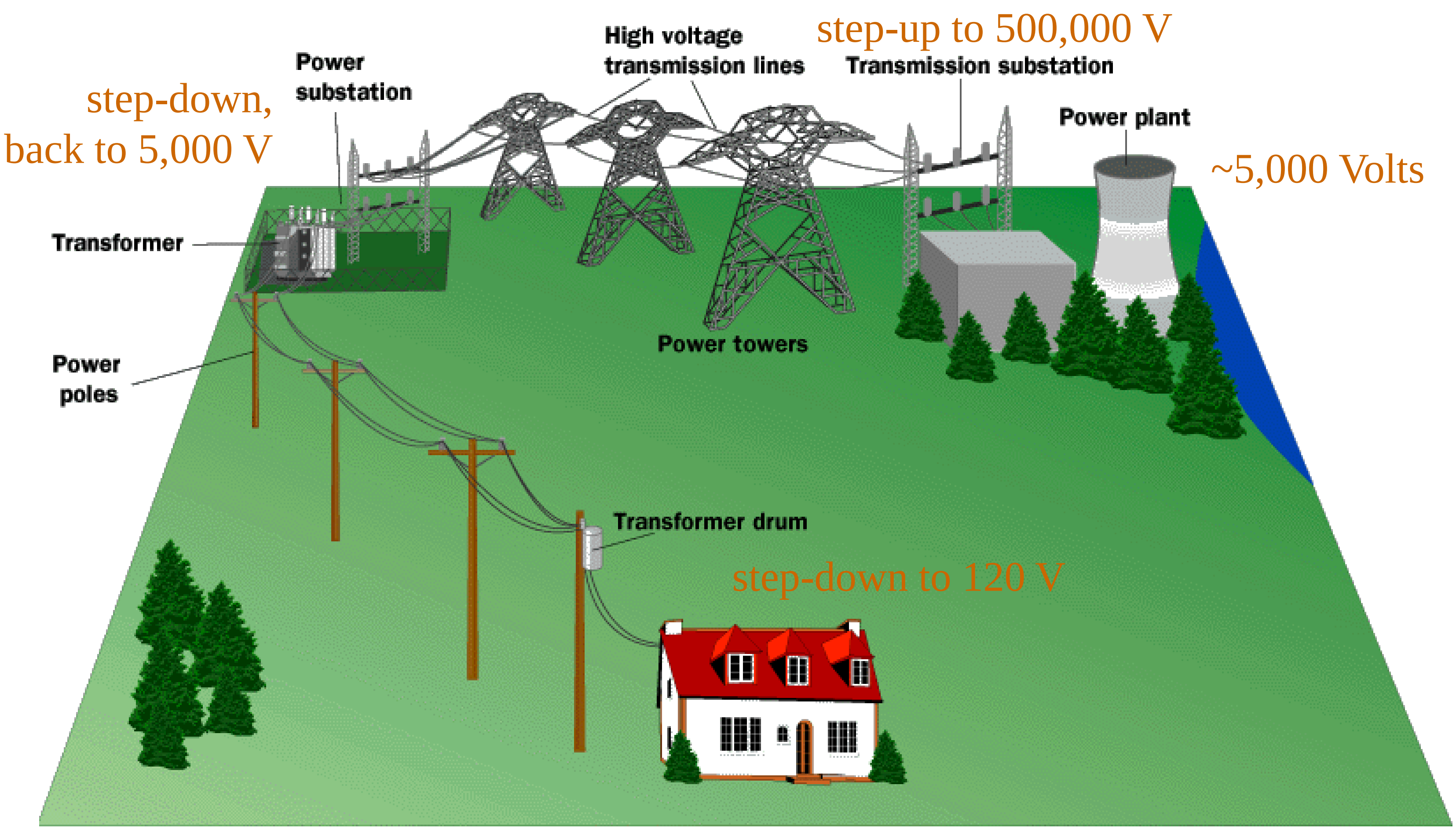
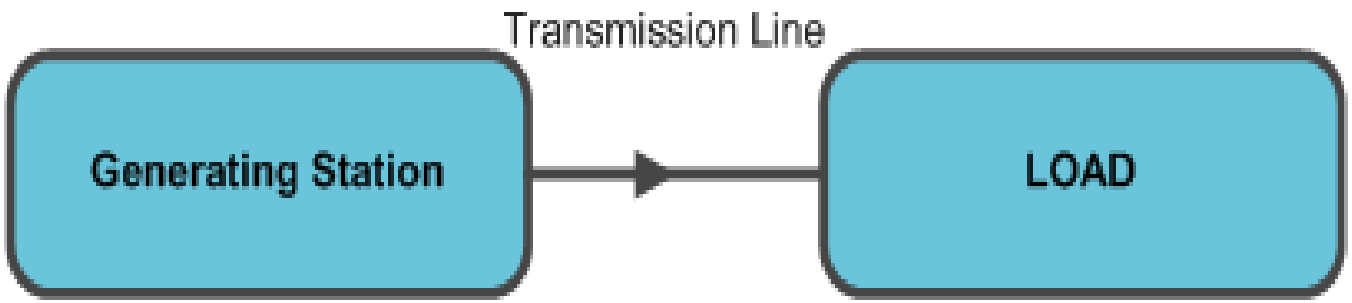
Concept of Energy Transmission



Purpose of Electrical Transmission System

- The purpose of the electric transmission system is the efficient interconnection of the electric energy producing power plants or generating stations with the loads.

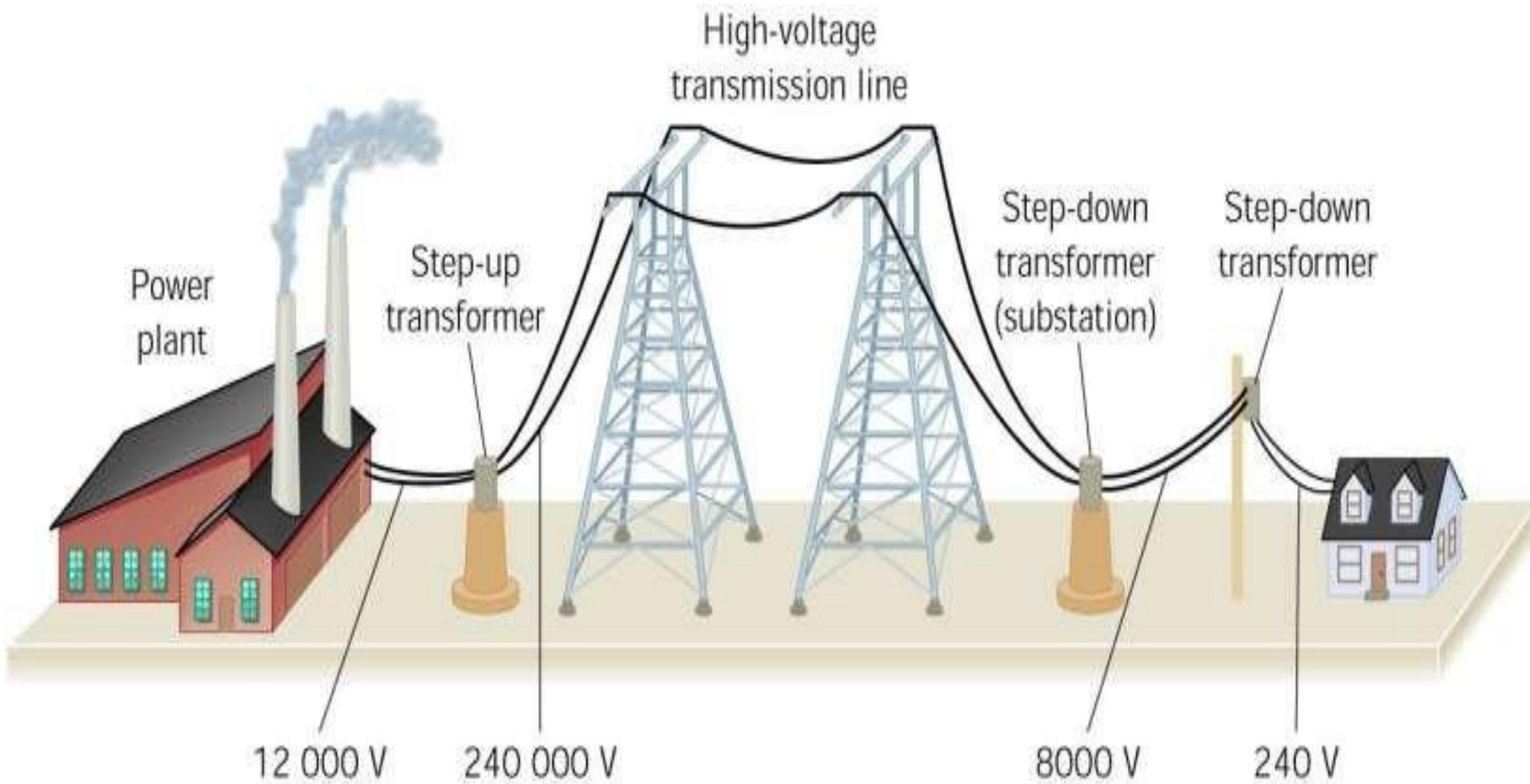


Main Parts of Power System

Four main parts :

- Generation System
- Transmission System
- Distribution System
- Consumer (LOAD)

Simplified Diagram of Power System



1. Generation System

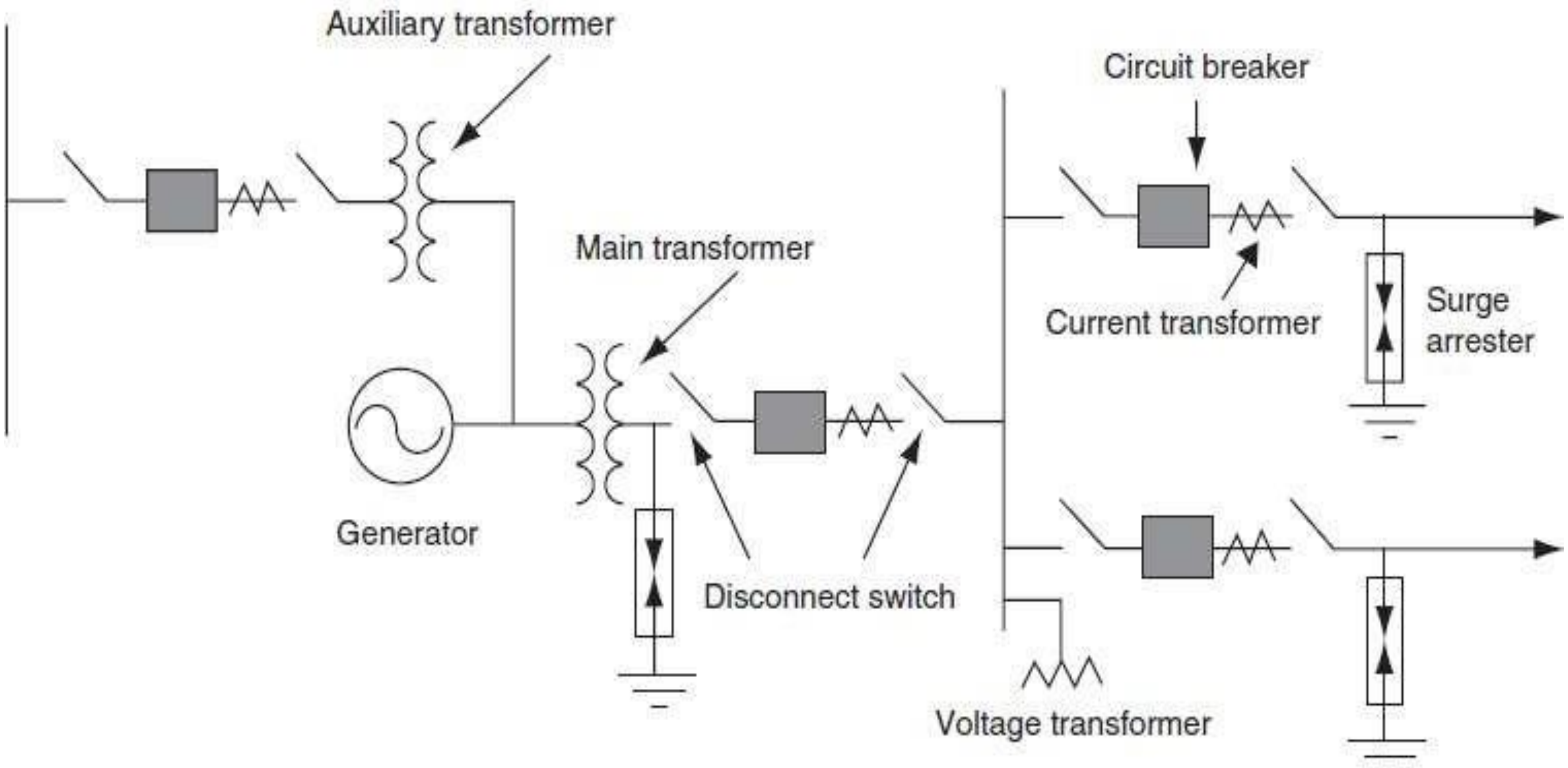
- **The commonly used power plants are:**

A. Thermal Power Plant.
B. Nuclear Power Plant.
C. Hydro Power Plant.
D. Gas Turbine Power Plant.
E. Combined Cycle Power Plant.

Basic idea of generation

- Prior to the discovery of Faraday's Laws of electromagnetic, electrical power was available from batteries with limited voltage and current levels.
- For a given amount of power, the current magnitude ($I = P/V$), hence section of the copper conductor will be large.
- Thus generation, transmission and distribution of D.C power were restricted to area of few kilometer radius with no interconnections between generating plants.

One-Line Diagram of Generating Station



(Simplified Connection Diagram)

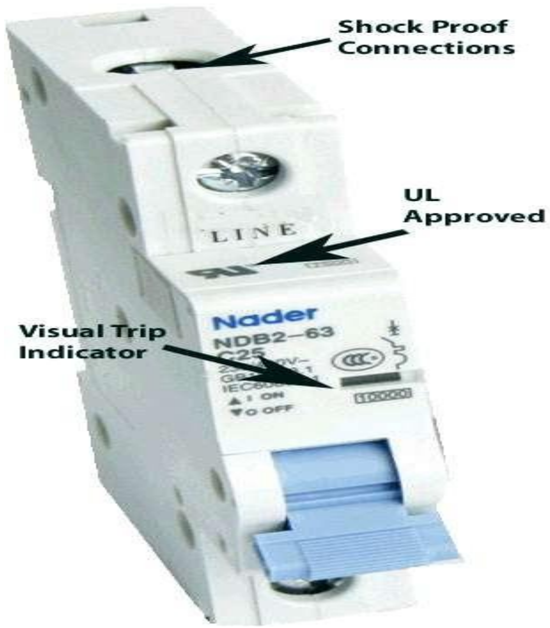
Main Parts of Generating Station

A. Circuit Breaker (CB):

A circuit breaker is an automatically operated electrical switch, designed to protect an electrical circuit from damage caused by fault current or short circuit

- **Types based on Insulators**

I. Oil Circuit Breaker.
II. Air Circuit Breaker.
III. SF6 Circuit Breaker.
IV. Vacuum Circuit Breaker.
V.



B. Disconnect Switch

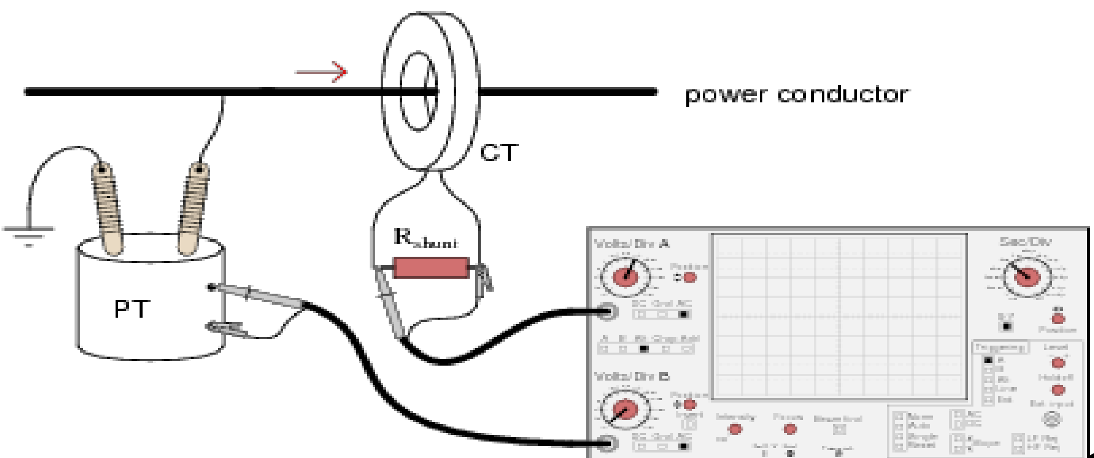
Provides visible circuit separation and permits CB maintenance. It can be operated only when the CB is open i.e. in no-load condition.

C. Surge Arrester

Used for protection against lightning and switching over-voltages. They are voltage dependent, nonlinear resistors. The arrester provides a low-impedance path to ground for the current from a lightning strike or transient voltage and then restores to a normal operating condition.

D. Current Transformers (CT) and Potential Transformers (PT)

- Used to lower the magnitude of the current and voltage to be measured.
- The CT and PT is used to solve this problem. The CT and PT works on the principle of transformer and lowers the current and/or voltage at a lower value which can be safely and easily measured.



2. Transmission System

Basic idea of Transmission

- The huge amount of power generated in a power station (hundreds of MW) is to be transported over a long distance (hundreds of kilometers) to load centers to cater power to consumers with the help of transmission line and transmission towers.

- To give an idea, let us consider a generating station producing 120 MW power and we want to transmit it over a large distance.
- Let the voltage generated (line to line) at the alternator be 10 kV. Then to transmit 120 MW of power at 10 kV, current in the transmission line can be easily calculated by:
- For 3-phase

$$I = \frac{P}{\sqrt{3}\, V_L \cos\theta} \quad \text{where } \cos\theta \text{ is the power factor}$$

$$= \frac{120 \times 10^6}{\sqrt{3} \times 10 \times 10^3 \times 0.8}$$

$$\therefore I = 8660 \text{ A}$$

- if transmission voltage were chosen to be 400 kV, current value in the line would have been only 261.5 A.

- Standard transmission voltages used are 132 kV or 220 kV or 400 kV or 765 kV depending upon how long the transmission lines are.

- after the generator we must have a step up transformer to change the generated voltage (say 10 kV) to desired transmission voltage (say 400 kV) before transmitting it over the transmission lines.

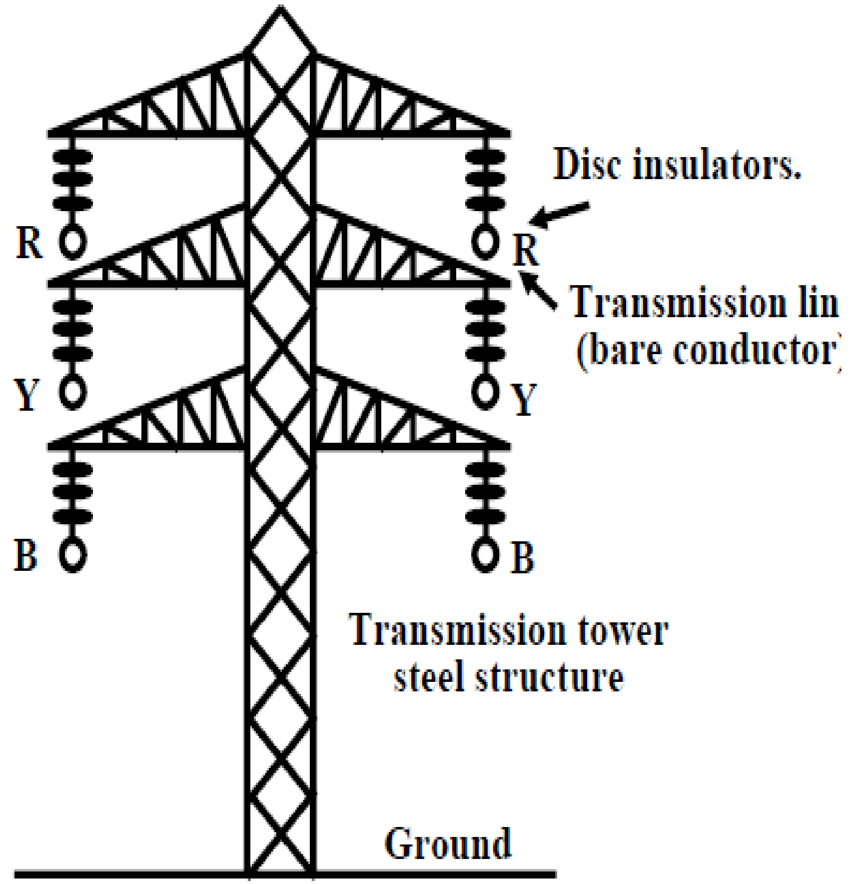
Main Parts of Transmission Line

A. **Conductor.**

B. **Earth wire.**

C. **Insulator.**

D. **Transmission Tower.**



Transmission tower

Design Methodology

- Gather preliminary line design data and available climatic data.
- Select reliability level in terms of return period of design.
- Calculate climatic loading on components.
- Calculate loads related to safety during construction and maintenance.
- Select appropriate correction factors, if applicable, to the design components such as use factor, strength factors related to numbers of components, quality control, and the characteristic strength.
- Design the components for the above loads and strength.

Selection of Transmission Voltage

- Standard Voltage: 66,110,132, 220, 400 KV

- Tolerances - $\pm$10% up to 220 KV & $\pm$5% for 400 KV

- Selection Criterion of Economic Voltage

1. Quantum of power to be evacuated
2. Length of line
3. Voltage regulation
4. Power loss in Transmission
5. Initial and operating cost

Voltage level in a power system

Transmission level:

400 kV, 230 kV, 220 kV, 132 kV, 110 kV, 66 kV

Primary distribution level:

33 kV, 22 kV, 15 kV, 11 kV, 6.6 kV, 3.3 kV, 2.2 kV

Secondary distribution level:

400 V (line to line) 230 V (phase)

Transmission Line

i. Overhead transmission line.

ii. Underground transmission line.

I. Overhead transmission line

- An overhead power line is a structure used in electric power transmission and distribution to transmit electrical energy along large distances.
- It consists of one or more conductors (commonly multiples of three) suspended by towers or poles.
- Since most of the insulation is provided by air, overhead power lines are generally the lowest-cost method of power transmission for large quantities of electric energy.

II. Underground transmission line

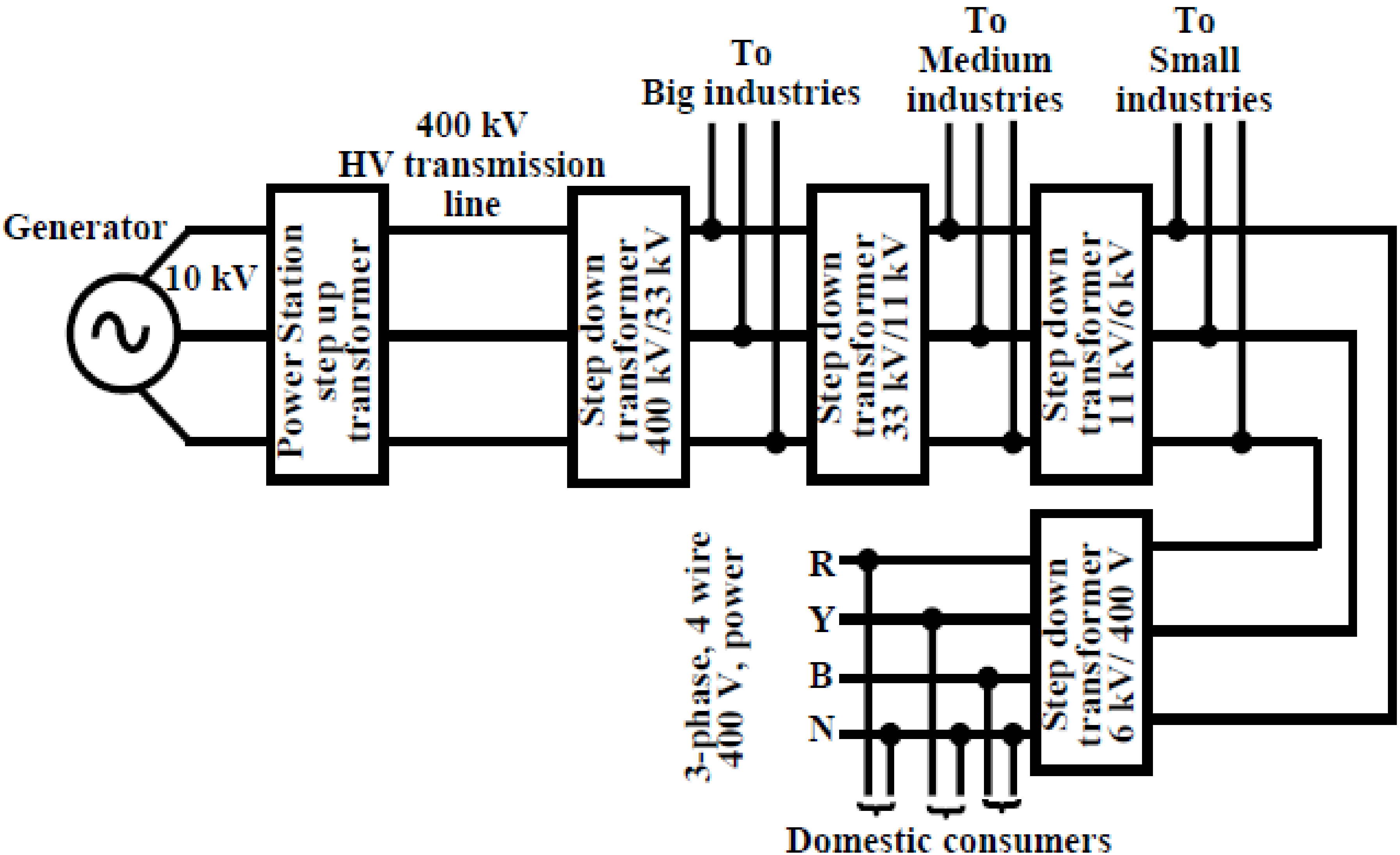
- Undergrounding is the replacement of overhead cables providing electrical power or telecommunications, with underground cables.
- This is typically performed for fire prevention and to make the power lines less susceptible to outages during high wind thunderstorms or heavy snow or ice storms.
- Undergrounding can increase the initial costs of electric power transmission and distribution but may decrease operational costs over the lifetime of the cables.

Transmission Line Models and Calculations

- Classification of transmission lines according to line length:
- Short transmission line $\leq$ 80 km
- Medium transmission line 80 : 240 km
- Long transmission line $\geq$ 240 km

Substations

- Substations are the places where the level of voltage undergoes change with the help of transformers.
- Apart from transformers a substation will house switches (circuit breakers), meters, relays for protection and other control equipment.
- a big substation will receive power through incoming lines at some voltage changes level of voltage using a transformer and then directs it out wards through outgoing lines.
- At the lowest voltage level of 400 V, generally 3-phase, 4-wire system is adopted for domestic connections.
- The fourth wire is called the neutral wire (N).



Typical voltage levels in a power system.

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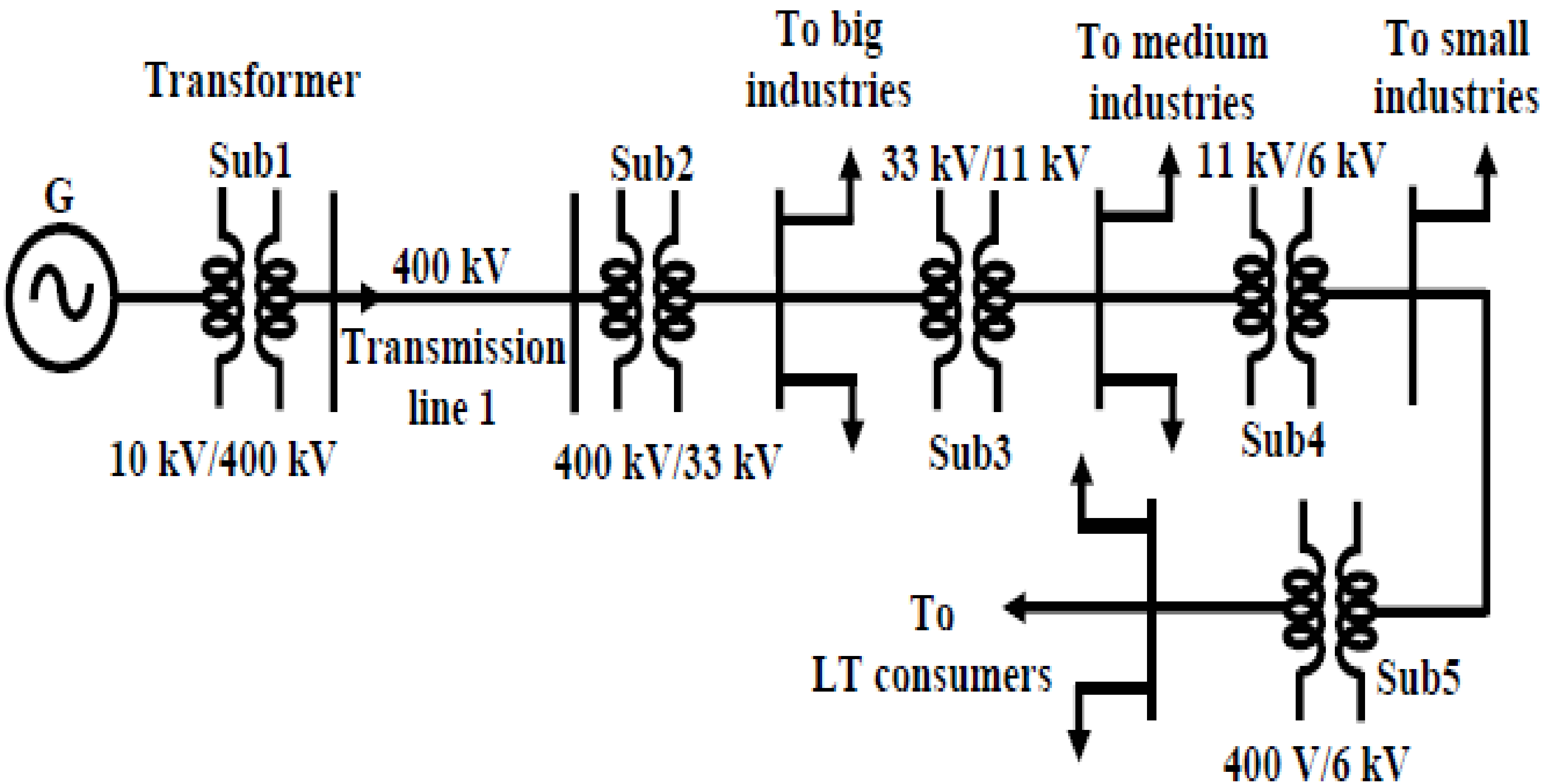
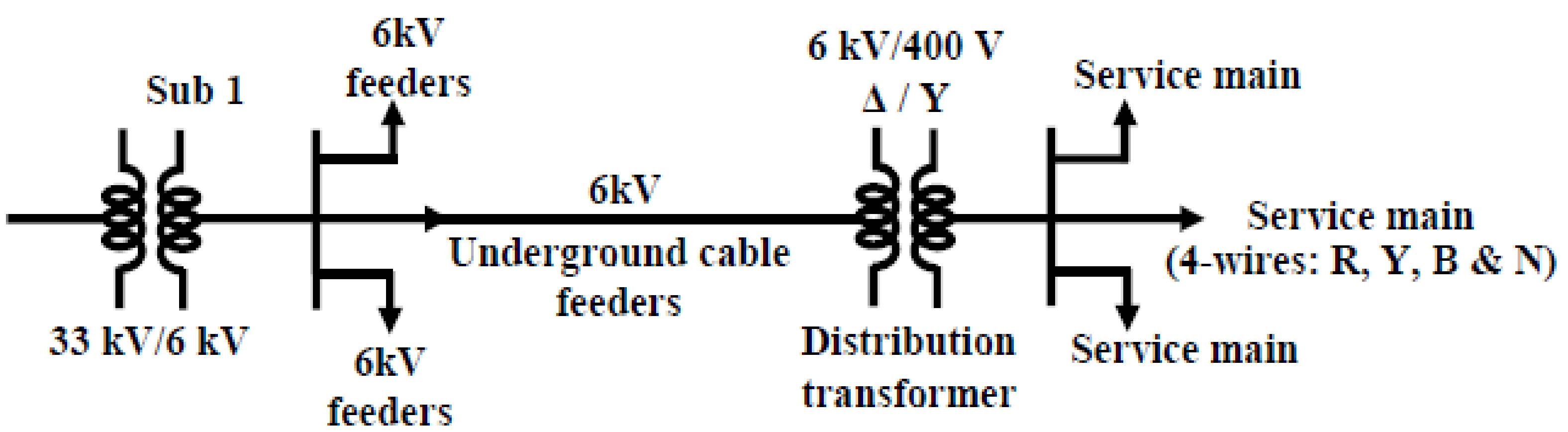
Single line representation of power system



3. Distribution System

- The loads of a big city are primarily residential complexes, offices, schools, hotels, street lighting etc. These types of consumers are called LT (low tension) consumers.
- LT consumers are to be supplied with single phase, 220 V, 50 Hz. this is achieved in the substation receiving power at 33 kV.



Typical Power distribution scheme.

- Power receive at a 33 kV substation is first stepped down to 6 kV and with the help of under ground cables (called feeder lines).
- power flow is directed to different directions of the city. At the last level, step down transformers are used to step down the voltage form 6 kV to 400 V.
- These transformers are called distribution transformers with 400 V, star connected secondary.
- From the secondary of these transformers 4 terminals (R, Y, B and N) come out.
- the neutral taken out from the common point of star connected secondary.
- Voltage between any two phases (i.e., R-Y, Y-B and B-R) is 400 V and between any phase and neutral is 240 V(=400/√3 .

4. Consumer

- At the load centers voltage level should be brought down at suitable values for supplying different types of consumers.
- Consumers may be:

1. **Big industries**, such as steel plants.
2. medium and small industries.
3. offices and domestic consumers.

- Electricity is purchased by different consumers at different voltage level.