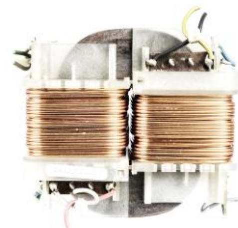
Transformers

& Power Transmission



Magnetism and electromagnetism

Scan to access this file online

Allan Chafukira

Introduction

In this sub-topic we are going to discuss the following:

- What is a transformer?
- Types of transformer.
- Working of a transformer.
- Transformer Efficiency.
- Power Transmission.
- Environmental Impacts of power generation and transmission.
- Examples
- Summary
- Quiz

Transformer

- A **transformer** is a passive electrical device that **transfers** electrical energy from one electrical circuit to another circuit by **electromagnetic induction**.
- A electrical transformer has the **ability to change** electrical energy (voltage) or EMF from a **low value to a higher** value, and from a **higher value to a low value**.
- A transformer is basically a **voltage control device** that is used in the **distribution and transmission** of AC (alternating Current).
- A transformer is made up of **two separate coils** namely: the **primary coil** and the **secondary coil**.
- The coils are wrapped (wound) on the same **laminated soft iron core**.
- The soft iron core is made up of insulated sheets of iron riveted together.
- **Figure 1** below show an illustration of a simple transformer.

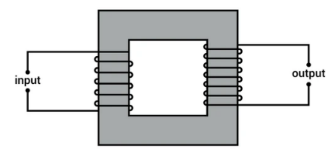


***Figure 1**: Transformer*

Transformer

Primary Coil

- This coil is connected to the **power supply (input)** side of the transformer when the transformer is in operation.
- In a drawing, the primary coil is mostly located on the left hand side of the transformer.

Secondary Coil

- This coil is connected to the **load (output)** side of the transformer when the transformer is in operation.
- In a drawing , the secondary coil is located on the right hand side of the transformer.

Types of transformers

- Depending on the number of turns in the primary and secondary coils, we have **two** types of transformers: **Step-up** transformers and **Step-down** transformers.

Step-up Transformer

- In this type of transformer we have **more number of turns in the secondary coil** than in the primary coil.
- Step-up transformers are used to change low supply voltage to high output voltage, thus to say; the secondary output has high voltage than the primary input voltage.

Transformer

Step-down Transformer

- In this type of transformer we have **more number of turns in the primary coil** than in the secondary coil.
- It is used to convert high primary input voltage to low secondary output voltage.
- **Figure 2** shows an illustration of both step-up and step-down transformers.

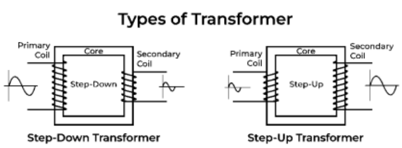


Figure 2: *structure of a transformer*

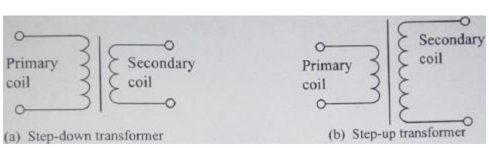
- **Figure 3** shows diagrams of real transformers.

***Figure 3**: real examples of transformers*

Note: the term step-up and step-down refer to the output voltage of the transformer.

Transformer

- In a circuit, a transformers are represented by the following symbols:



- **Note:** A transformer transfer electrical energy from one coil to another by **mutual induction**.
- **Mutual induction** is the process where a changing magnetic field in one coil of wire induces a voltage in another nearby coil.

How a transformer works

- When an alternating current is applied at the primary coil, a changing magnetic field is produced. The soft iron core links this produced field to the secondary coil. In the secondary coil, the changing magnetic field produces an alternating electromotive force through mutual induction.

Ideal Transformer

- This is an imaginary transformer that has **no** looses and **no** leakage flux.
- In other words an ideal transformer gives an output power **exactly equal** to the input power, thus **100% efficiency**.

Transformer Efficiency

- In transformers, efficiency is used to indicate how effective a transformer is in transferring the input energy to the output energy.
- This efficiency is the ratio of the power output to power input expressed as a percentage.
- The formula for calculating the efficiency of a transformer is given by:
- Efficiency (η) = $\frac{power\ output}{power\ input} * 100\%$
- For an ideal transformer the efficiency is 100%, but for a well designed transformer is around 98%.
- The ideology of an ideal transformer is used to calculate the efficiency of other transformers.
- So in an ideal transformer we know that power input = power output, thus:

$$\mathbf{V_p I_p = V_s I_s}$$

- Where: $\mathbf{V_p}$ = primary voltage $\mathbf{I_p}$ = input current
  $\mathbf{V_s}$ = secondary voltage
  $\mathbf{I_s}$ = output current
- So

Efficiency (η) = $\frac{V_s I_s}{V_p I_p} * 100\%$

Transformer Efficiency

So if we know the input voltage and the number of turns on the primary and secondary coils, we can also calculate the transformer's output voltage as follows:

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

- Where: $\mathbf{V_p}$ = primary voltage
  $\mathbf{V_s}$ = secondary voltage
  $\mathbf{N_s}$ = number of turns on secondary coil
  $\mathbf{N_p}$ = number of turns on primary coil

Now in an ideal transformer, when voltage is stepped up, the current is stepped down and vice versa.

- In an ideal transformer, power is conserved and the current (**I**) in the coil is inversely proportional to number of turns (**N**).

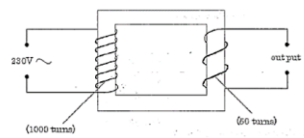
$$\frac{\mathbf{I_s}}{\mathbf{I_p}} = \frac{\mathbf{N_p}}{\mathbf{N_s}}$$

- This is so because the **power** remains constant and the relationships between voltage and current is **inversely** proportional. (Power = Voltage (V) * Current (I)
- Therefore, in an ideal transformer:

$$\frac{\mathbf{V_s}}{\mathbf{V_p}} = \frac{\mathbf{I_p}}{\mathbf{I_s}}$$

Examples

1. A transformer with efficiency of 80% works at 4KW and 100V. If the secondary voltage is 200V. Calculate the primary and secondary currents respectively.
2. In an ideal transformer, the voltage and current in the primary coil are 200 V and 2A respectively. If the voltage in the secondary coil is 250 V. Calculate the current in the secondary coil.
3. State any **two** factors that affect the magnitude of induced emf in a conductor.
4. **Figure 1** is a transformer diagram.



a. Name the type of transformer in Figure 1.
b. Give a reason for your answer in 4a.
c. Calculate the output voltage of the transformer.

</code> giya edulab

Factors affecting the efficiency of a transformer

a. **Resistance of the coils**
- Higher resistance leads to more heat loss and decreases efficiency.
- As current flows in the coils, the wires heat up due to resistance, and energy is lost in the form of heat.
- This method of losing energy is called joule heating, and it is minimized by using thick copper wire with less resistance.

b. **Eddy currents**
- These are small induced currents in the core of the transformer as the magnetic field changes.
- These currents heat up the core and energy is lost in the form of heat, and it is minimized by laminating and insulating the core.

</code> giya edulab

Factors affecting the efficiency of a transformer

c. **Hysteresis losses**
- This is the energy that is required for magnetization and demagnetization of the core, and this energy heats up and is lost as heat energy.
- This energy loss reduces the efficiency of the transformer.
- This hysteresis loss is minimized by using a core made of soft magnetic material that is easy to magnetize.

d. **Flux or magnetic leakage**
- Some of the magnetic flux doesn't link with the secondary windings, which leads to inefficiencies in the performance of the transformer.
- This is also called **flux leakage**.
- This can be minimized by designing a core in such a way that almost all the magnetic flux is transferred to the secondary coil.

Power Transmission

- Power transmission refers to the process of **transferring** electrical energy **from one place to another**.
- This transfer is **from** the **electrical power generation station to various consumers** such as industries, business offices, and town houses.
- The electric energy from power stations is delivered to consumers through **cables** which are carried by structures called **Pylons**.
- A collection of these cables and pylons forms a network of power transmission called the **National Grid System**.

- **Figure 4** shows a simple illustration of the National Grid System.

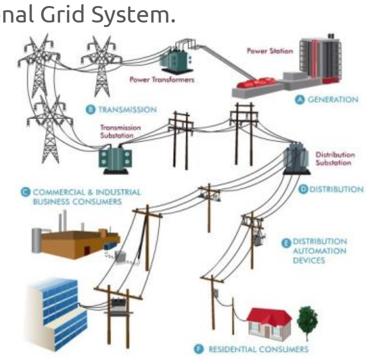


Figure 4: *National Grid System*

Power loss in transmission lines

- The cables that transfer electric energy are also called **power transmission lines**.
- As electric power is being transferred through the transmission cables, some electric **power is lost due to** the **electric resistance** of the cable.
- This power loss is in the **form of heat** in the transmission cable.
- Since the electrical resistance of a wire is directly proportional to the length of the wire and, inversely to the cross-section area, **thick transmission wires** are used to **minimize** the power loss

Ways of minimizing power loss in transmission lines

- Electric current is transmitted at very high voltage and very low current.
- Use good conductor cables with low resistance such as copper.
- Use very thick transmission cables.
- Reduce the transmission distance.

Environmental Impacts of power generation and transmission

Group reading assignment

In groups of **two**, read and come up with summary notes on **the environmental impacts** of the following sources of power generation.

- Hydroelectric power
- Nuclear energy
- Fossil Fuels
- Solar energy
- Geothermal energy
- Biomass

Summary

- The transformer, in a simple way, can be described as a device that steps up or steps down voltage.
- In a step-up transformer, the output voltage is increased, and in a step-down transformer, the output voltage is decreased.
- The step-up transformer will decrease the output current, and the step-down transformer will increase the output current to keep the input and output power of the system equal.
- The formula for calculating the efficiency of a transformer is given by:
- Efficiency (η) = $\frac{power\ output}{power\ input} * 100\%$
- A transformer's efficiency can be affected by the following factors:
  - Resistance of the coil
  - Eddy currents
  - Hysteresis losses
  - Flux leakage
- Power transmission refers to the process of transferring electrical energy from one place to another.
- The electric energy from power stations is delivered to consumers through **cables** which are carried by structures called **Pylons** in a system called **National Grid System**.

</code> giya edulab

Quiz

1. What is a transformer?
2. Describe a step-down transformer.
3. Define mutual induction.
4. Explain any **two** factors that affect the efficiency of a transformer.
5. What is alternating current?
6. A transformer having an efficiency of 90% is working on 200V and 3 KW power supply. If the current in the secondary coil is 6A, Calculate the voltage across the secondary coil, and the current in the primary coil respectively.
7. An AC emf of 240V is applied to a step-up transformer having 150 turns on its primary coil and 3500 turns on its secondary coil. The secondary current is 0.15A. Calculate the secondary emf, power input, primary current, and Efficiency.
8. State any **two** ways to minimize power loss in power transmission lines.
9. Draw a circuit symbol of a step-up transformer.
10. Define the term voltage.

</code> giya edulab