



THE ISLAMIC UNIVERSITY OF GAZA

FACULTY OF ENGINEERING

Electrical Circuits Lab 2

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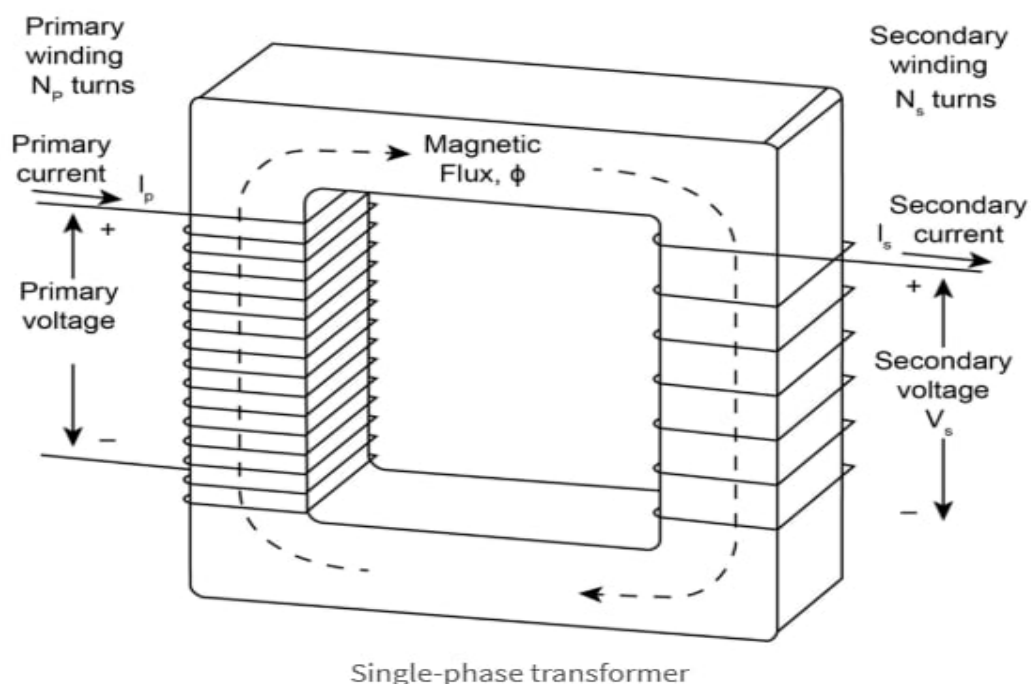
Theoretical Study: Single Phase Transformer

1. Objectives

- Understand the operational and electromagnetic principles of transformers.
- Classify the different types of transformers based on their construction.
- Analyze the voltage and current waveforms during single-phase transformer operation.

2. Theory & Principle of Operation

A transformer is a static electromagnetic device that transfers electrical energy between two or more circuits through **Electromagnetic Induction** without changing the frequency. It is primarily used to step up (increase) or step down (decrease) AC voltage levels.

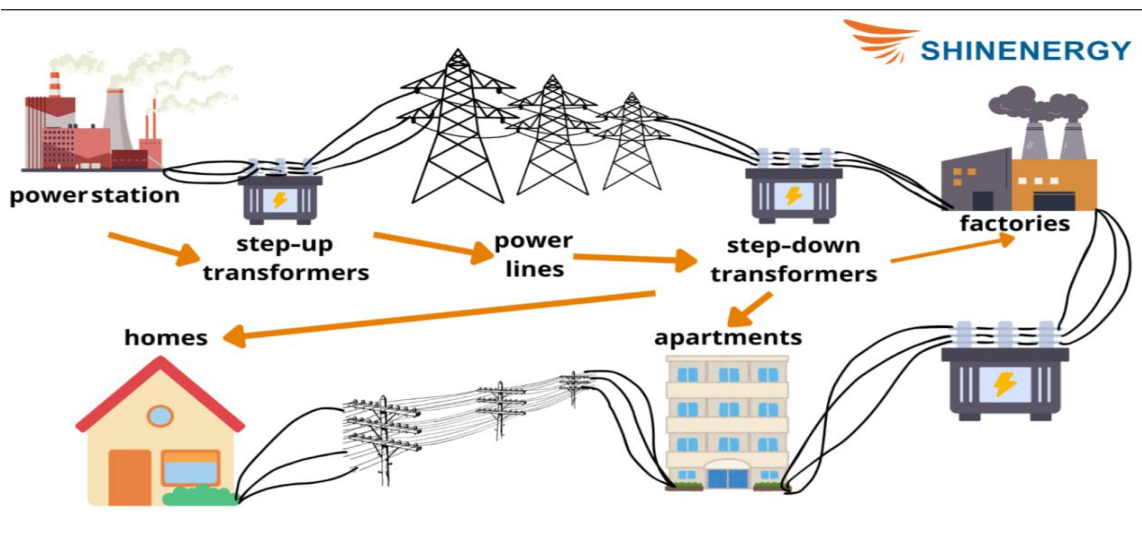


- **Primary Winding:** The coil connected to the input AC power source, responsible for receiving energy and generating the magnetic flux.
- **Secondary Winding:** The coil connected to the load, responsible for delivering the induced energy at the modified voltage level.

3. Transformer Construction

- **Core Loss Reduction:** To minimize energy losses (such as heat from eddy currents), the magnetic core is built using **thin laminations** insulated from one another rather than a solid iron block.
- **Material Selection:** These laminations are made of **silicon-sheet steel** because of its high magnetic permeability and low magnetic core losses, providing an efficient path for the magnetic flux.

4. Types of Transformer



Electrical grids require alternating voltage levels for economic and safety reasons:

- **Economically:** Long-distance power transmission requires **high voltage** to minimize power losses in the transmission lines.
- **Safety-wise:** Domestic consumption requires **low voltage** to protect lives and consumer devices.

The primary distinction is that a step-up transformer raises the output voltage, while a step-down transformer reduces it.

5. Turns Ratio Determines Transformer Function

The primary factor defining whether a transformer steps voltage up or down is the **number of turns (N)** in its windings. Voltage is directly proportional to the number of turns:

A. Step-Down Transformer

- **Structure & Behavior:** The number of primary turns is greater than the secondary turns ($N_1 > N_2$). The input voltage is high while the output voltage is low.
- **Typical Ratings & Uses:** Common output values include 110v, 24V, 20V and 10V. Used in doorbells and residential voltage converters.

B. Step-Up Transformer

- **Structure & Behavior:** The number of secondary turns is greater than the primary turns ($N_2 > N_1$). The input voltage is low while the output voltage is high.

- **Typical Ratings & Uses:** Output ratings reach 11,000V or higher. Used in power generation plants, X-ray machines, and microwaves.

 **Important Note:** A transformer is bi-directional. If the input supply is connected to the low-voltage winding, it operates as a **step-up** transformer. If connected to the high-voltage winding, it acts as a **step-down** transformer.

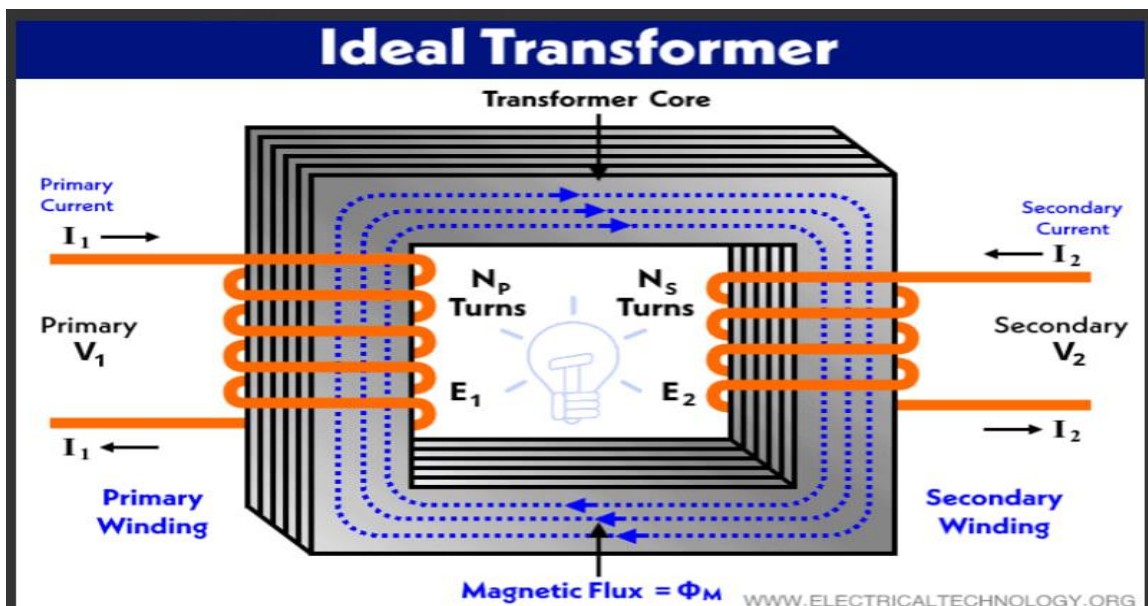
6. Ideal Transformer Model & Voltage-Current Trade-off

An ideal transformer is a theoretical model operating with zero energy losses.

The relationship between the number of turns (N), voltage (V), and current (I) is governed by the **turns ratio (a)**:

E_1 : primary voltage
 I_1 : primary current
 E_2 : secondary voltage
 I_2 : secondary current
 N_1 : primary turns
 N_2 : secondary turns
 a : turns ratio

$$a = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$



The Current Trade-off (Current is Not Constant):

Because total power must remain constant in an ideal transformer, **voltage and current are inversely proportional**. Any change in voltage happens directly at the expense of the current:

- **In a Step-Down Transformer:** As the voltage is stepped *down* on the secondary side, the current simultaneously steps *up* to balance the power.
- **In a Step-Up Transformer:** As the voltage steps *up* on the secondary side, the current automatically steps *down*.

Conclusion: Current never remains constant between the primary and secondary sides; it changes **inversely** to the voltage.

"Engineers look at the world, not for what it is, but for what it could be"