CHAPTER ONE

INTRODUCTION

1.1 Background

Electric power systems are the backbone of modern civilization, and understanding their behavior under various loads is essential for electrical engineers and technicians. One common load type is the RLC load, which combines resistive (R), inductive (L), and capacitive (C) elements. In real-world systems, most electrical devices exhibit a combination of these properties. The study of RLC circuits, especially under alternating current (AC) conditions, provides insights into power factor, phase relationships, resonance, and energy consumption.

Resistive loads are electrical devices or components that oppose the flow of electric current purely through resistance, without introducing any reactance (inductance or capacitance). In resistive loads, the current and voltage are in phase, meaning they rise and fall together with no phase difference.

Examples are Incandescent, light bulbs, Electric heaters, Electric stoves, Toasters, Electric irons.

KEY CHARACTERISTICS OF RESISTIVE LOADS:

- Power factor = 1 (or 100%): All the power drawn is used and converted into heat or light.
- No magnetic field or energy storage: Unlike inductors or capacitors, resistors do not store energy.
- Ohm's Law applies directly:
- V=IR

An **Inductive load** is any electrical component or device that contains a coil of wire (an inductor) and stores energy in a magnetic field when current flows through it. In AC circuits, inductive loads cause the current to lag behind the voltage, creating a lagging power factor.

Examples are: Electric motors (e.g., fans, pumps), Transformers, Ballasts in fluorescent lamps, Relays and solenoids, Inductive coils in power supplies.

KEY CHARACTERISTICS OF INDUCTIVE LOADS

- **Current lags voltage** (due to magnetic field buildup and collapse).
- Introduces **inductive reactance** $XL=2\pi fLX_L = 2\backslash pi\ fL$XL =2πfL, where:
    - F is frequency,
    - L is inductance.
- **Power factor is less than 1** (lagging).
- Consumes **real power (P)** and **reactive power (Q)**.

Capacitive loads are electrical components or devices that **store energy in an electric field** by accumulating charge on plates separated by an insulator (a capacitor). In AC circuits, capacitive loads cause the **current to lead the voltage**, creating a **leading power factor**.

Examples are, Capacitor banks used in power factor correction, Some types of fluorescent lamp ballasts, Long transmission lines (due to cable capacitance, Synchronous, condensers, Power electronic circuits with capacitor filtering.

KEY CHARACTERISTICS OF INDUCTIVE LOADS

- **Current leads voltage** (opposite of inductive loads).

- Introduces capacitive reactance XC=12πfCX_C = \frac{1}{2\pi_fC}XC =2πfC1where:
  F is frequency,
  C is capacitance.

- **Power factor is less than 1** (leading).
- Consumes **reactive power**, not real power.
- Used in **power factor correction** to offset inductive effects.

A **Single-Phase RLC Load Trainer** is an educational tool designed to help students and trainees study the individual and combined effects of resistance, inductance, and capacitance in an AC circuit. It allows practical experimentation with different load configurations and real-time monitoring of voltage, current, power, and power factor. This project aims to design and build a functional RLC load trainer that can serve as a practical teaching aid in laboratories and technical training centers.

1.2 Problem Statement

Many students struggle with visualizing and practically applying the principles of AC circuits and RLC load analysis due to limited access to suitable lab equipment. Existing training setups often lack flexibility, making it difficult for students to experiment with different configurations and analyze real-time results for various load combinations. Without this practical experience, understanding the fine distinction of AC power, reactive power, and power factor correction becomes challenging.
The absence of such practical exposure also leaves gaps in essential skills related to analyzing circuit behavior and correcting power factors, which are crucial for real-world electrical engineering applications.
Therefore, there is a need for a cost-effective and locally designed trainer that can simulate various RLC load conditions.

1.3 Aim and Objectives

Aim:

The aim of the project is to design and construct a single-phase RLC load trainer for educational and practical analysis of AC circuits. It will enable students to investigate the fundamental principles of AC circuit analysis, specifically focusing on power factor, resonance and load interaction.

Objectives:

- To design a modular trainer that allows selection of R, L, and C loads individually or in combination.
- To enable measurement of current, voltage, power, and power factor.
- To analyze the behavior of RLC circuits under varying load conditions.
- To provide a safe, easy-to-use learning tool for students in electrical and electronics engineering programs.

1.4 Significance of the Study

This project provides a practical solution for electrical engineering students to understand and experiment with RLC circuits. The trainer will serve as a low-cost, reusable laboratory tool that enhances student learning and supports hands-on technical education. It also promotes local innovation and reduces dependence on expensive imported training kits.

1.5 Scope of the Project

This project focuses on the design and construction of a single-phase RLC load trainer that operates on standard 220V AC supply. The trainer will include selectable resistors, inductors, and capacitors, measurement meters (analog or digital), and protective components to ensure safe operation. The study does not cover three-phase systems or digital simulations but is limited to physical implementation and manual observation.

1.6 Limitations of the Study

- The trainer is designed for single-phase AC supply only.
- Component values are fixed and may not cover the full range of industrial scenarios.
- The project is constrained by available resources, time, and local component availability.