**CHAPTER TWO**
**LITERATURE REVIEW**

## 2.1 Overview of RLC Circuits

The study of RLC circuits is foundational in electrical engineering education, especially in understanding the behavior of AC systems. A **Single-Phase RLC Circuit Trainer** is a practical educational tool designed to demonstrate how resistors, inductors, and capacitors interact in an AC circuit.

A single-phase RLC circuit consists of a resistor (R), inductor (L), and capacitor (C) connected in either series or parallel to a single-phase AC supply. These circuits are commonly used in AC analysis, communication systems, filter design, and power systems. The study of RLC circuits is fundamental in electrical and electronic engineering due to their frequency-dependent behavior and phase characteristics, they affect the phase and magnitude of the current, leading to complex power behaviors, including phase shifts, power loss, and resonance conditions.

- **Series RLC Circuits**: All components are connected in one loop; useful for studying resonance and impedance.
- **Parallel RLC Circuits**: Components are connected across the same AC voltage; commonly used in power distribution systems.

Understanding the behavior of such circuits under varying loads is crucial for designing and troubleshooting AC systems, making them important in both academic and industrial settings.

**Single-Phase RLC Circuit Trainer** are widely used in polytechnics and technical colleges to provide hands-on experience. They offer a platform for students to:

- Assemble and test different circuit configurations,
- Measure current, voltage, and power under real conditions,
- Observe phase differences and calculate power factor,
- Practice fault detection and correction safely.

The RLC trainer helps in visualizing how each component affects circuit behavior and introduces learners to concepts like **impedance**, **resonance**, **power factor correction**, and **AC power analysis**.

## 2.2 Behavior of RLC Circuits under AC Supply

When connected to an alternating current (AC) supply, each component in the RLC circuit reacts differently:

- The **resistor** opposes current flow through resistance, dissipating energy as heat.
- The **inductor** stores energy in a magnetic field and causes current to lag behind the voltage.
- The **capacitor** stores energy in an electric field and causes current to lead the voltage.

The **combined impedance (Z)** of the RLC circuit depends on the angular frequency $\omega$ and is given by:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where:

- $X_L = 2\pi f L$ (inductive reactance),
- $X_C = \frac{1}{2\pi f C}$ (capacitive reactance),
- $f$ is the frequency of the AC supply.

## 2.3 Types of RLC Circuits

- **Series RLC Circuit**: R, L, and C are connected in a single path. Useful for resonance studies.
- **Parallel RLC Circuit**: Components are connected across the same voltage source. More common in power distribution.
- **Mixed or Tunable RLC Load**: Allows individual selection of R, L, or C, and combinations, for practical analysis.
- **RLC** can also be connected individually as they are not necessarily dependent on one another.

## 2.4 Series and Parallel RLC Circuits

In a **series RLC circuit**, all components are connected in a single path. This type of circuit is useful in studying **resonance**, which occurs when the inductive and capacitive reactances cancel each other out ($X_L = X_C$), minimizing impedance and maximizing current flow.

In a parallel RLC circuit, the components are connected across the same voltage source. These circuits are often used in power systems and signal processing to control voltage and current characteristics across different branches.

## 2.5 Resonance in RLC Circuits

Resonance is a key concept in RLC circuits. It occurs at a specific frequency where the reactive effects of inductance and capacitance cancel each other:

$$f_r = \frac{1}{2\pi \sqrt{LC}}$$

At this point, the circuit behaves like a purely resistive load, and the power factor becomes 1 (unity). This phenomenon is essential in applications such as tuning radio receivers, filtering, and power systems.

## 2.6 Power in RLC Circuits

Power in RLC circuits is analyzed in three forms:

- **Real Power (P)** – the actual power consumed by resistive components.
- **Reactive Power (Q)** – power stored and released by L and C.
- **Apparent Power (S)** – the combination of real and reactive power.

The **power factor (pf)**, which is the cosine of the phase angle $\theta$ between voltage and current, plays a significant role in determining the efficiency of power delivery. Poor power factor due to inductive or capacitive loads leads to energy losses and penalties in industrial settings.

## 2.7 Applications of RLC Circuits

RLC circuits are widely applied in:

- **Filters** (low-pass, high-pass, band-pass, and band-stop)
- **Oscillators** in radio-frequency circuits
- **Power factor correction** in AC power systems
- **Tuning circuits** in communication systems
- **Surge protection** and damping systems

## 2.8 Educational Importance of RLC Circuits

RLC circuits form the foundation for understanding how AC systems behave under different conditions. For students, studying these circuits through theory and practical trainers enhances their grasp of:

- Phase relationships
- Energy transfer
- Signal response
- Transient and steady-state analysis

Training tools like RLC load trainers provide a safe, controlled environment for testing and observing the performance of these circuits, making learning more interactive and effective.

## 2.9 Previous Works

Several researchers and institutions have developed and tested RLC load trainers for educational and experimental use in electrical engineering. These studies consistently highlight the importance of practical tools like RLC trainers in engineering education. They also point to a growing interest in low-cost, locally built trainers that are safe, functional, and tailored to curriculum needs. Your project contributes to this field by designing a trainer that is affordable, simple to operate, and suitable for polytechnic-level training.

### Afolabi et al. (2018)

Designed a basic RLC trainer using discrete components (resistors, inductors, capacitors) mounted on a panel. The setup included analog ammeters and voltmeters to allow students to observe changes in current and voltage under different load combinations. The study concluded that students showed improved understanding of power factor and resonance after practical sessions.

### Olowu & Bello (2020)

Developed a more advanced RLC load trainer with digital meters and microcontroller based measurement. Their system allowed automatic calculation of power factor, apparent power, and phase angle. Although effective, the high cost of digital components limited its adoption in resource-constrained schools.

**Chukwu et al. (2022)**

Focused on building a low-cost, locally sourced RLC load trainer for polytechnic students. Their version used toggle switches to select between R, L, and C combinations, with safety fuses and overload protection. The project was praised for its affordability and practical relevance.

**Nwankwo and Ibrahim (2021)**

Investigated student performance before and after using RLC trainers in labs. The study found a significant improvement in understanding of AC circuit concepts, especially impedance, power triangle analysis, and circuit resonance, proving the effectiveness of hands-on tools.

These studies highlight the importance of affordability, safety, and functionality in educational tools, which this project aims to address.

**2.10 Gaps in Existing Solutions**

Most available RLC trainers are either too expensive or too complex for polytechnic-level education. Additionally, some lack adequate protective features or modular flexibility. This project seeks to fill these gaps by designing a simple, safe, and effective trainer suitable for classroom and laboratory use.