Maxwell Inductance–Capacitance Bridge: Construction & Analysis

Virat Parmar
Department of Electrical Engineering
National Institute of Technology Agartala

November – December 2024

Acknowledgement

I express my sincere gratitude to the Department of Electrical Engineering for providing the opportunity to carry out this project titled *"Maxwell Inductance–Capacitance Bridge: Construction & Analysis."*

I am deeply thankful to the faculty of Electrical Measurements and Instruments for their constant guidance, valuable suggestions, and encouragement throughout the execution of this work. Their insights greatly enhanced my understanding of AC bridge circuits and practical measurement techniques.

I would also like to acknowledge the laboratory staff for their support in providing the required components and test instruments. Finally, I extend my thanks to my classmates for their cooperation during experimentation and documentation.

1. Introduction

Accurate measurement of electrical parameters such as inductance, capacitance, and resistance is fundamental to electrical engineering. AC bridge circuits are widely employed for this purpose due to their high precision and reliability. Among these, the Maxwell Inductance–Capacitance Bridge occupies an important position in the measurement of inductance and series resistance of medium-Q coils.

Unlike bridges that require a standard inductor, the Maxwell Bridge uses a standard capacitor, which is inherently more stable, accurate, and readily available. This characteristic makes the bridge particularly suitable for laboratory and calibration applications.

The bridge operates on the principle of impedance comparison. When an AC supply is applied and the bridge is balanced, the detector indicates a null condition. At this point, the unknown inductance and resistance can be determined using simple balance equations derived from AC circuit theory.

In this project, a Maxwell Inductance–Capacitance Bridge was practically constructed and tested using a laboratory inductor. The experimentally obtained values were compared with known specifications to evaluate the accuracy and effectiveness of the setup.

2. Project Objectives

The primary objectives of this project are:

- To study the working principle of the Maxwell Inductance–Capacitance Bridge.
- To design and assemble a functional AC bridge circuit.
- To experimentally measure the inductance and series resistance of an unknown inductor.
- To validate theoretical balance equations through practical observations.

3. Theory of Maxwell Inductance–Capacitance Bridge

The Maxwell Inductance–Capacitance Bridge is an AC bridge used for determining the value of an unknown inductance by balancing it against a known standard capacitor and non-inductive resistors.

In the bridge configuration, the unknown inductor with inductance L_1 and series resistance R_1 is placed in one arm. The opposite arm consists of a standard capacitor

C_4 connected in parallel with a variable resistor R_4. The remaining two arms contain non-inductive resistors R_2 and R_3.

An AC supply is connected across one diagonal of the bridge, while a null detector is connected across the other diagonal. At balance, the impedance ratios of the opposite arms are equal. By equating the real and imaginary components of the impedance equation, the balance conditions are obtained as:

$$L_1 = R_2 \times R_3 \times C_4$$

$$R_1 = \frac{R_2 \times R_3}{R_4}$$

These expressions show that the inductance measurement is largely independent of frequency, making the bridge suitable for accurate laboratory measurements.

4. Circuit Diagram

The Maxwell Inductance–Capacitance Bridge consists of four arms arranged in a square network. The AC supply is applied across one pair of opposite nodes, while the detector is connected across the other pair.

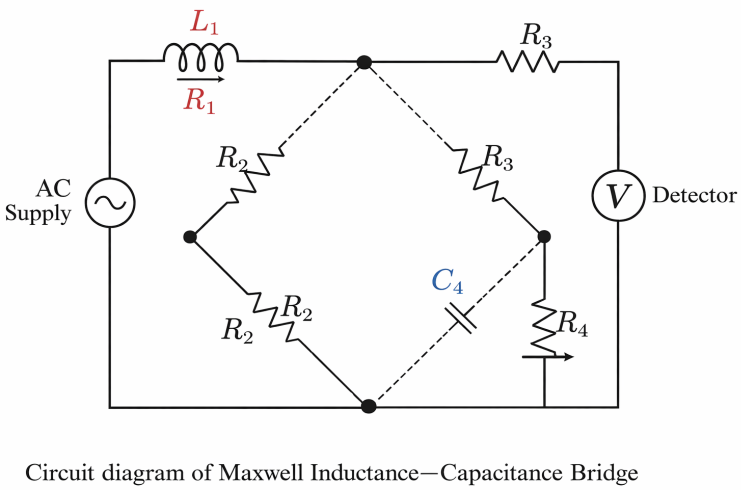

Figure 1: Circuit diagram of Maxwell Inductance–Capacitance Bridge

5. Working Principle

The working principle of the Maxwell Bridge is based on balancing the impedance of the unknown inductive arm with the impedance of a parallel resistance– capacitance arm.

When the bridge is balanced, the voltage across the detector diagonal becomes zero, indicating that both the magnitude and phase of voltages in the opposite arms are equal. This null condition ensures that the real and imaginary components of impedance are matched.

The balance is achieved by adjusting the variable resistor until the detector shows minimum or zero deflection. The inductance and resistance of the unknown coil are then calculated using the balance equations.

6. Apparatus Required

- Unknown inductor (approximately 1 H)
- Non-inductive resistors R_2 and R_3
- Variable resistor R_4
- Standard capacitor C_4
- AC supply (Variac)
- Digital multimeter

7. Experimental Procedure

1. The circuit was assembled according to the Maxwell Bridge configuration.
2. The unknown inductor was connected in one arm of the bridge.
3. Fixed resistors were placed in the remaining arms.
4. AC supply was applied across the bridge.
5. The variable resistor was adjusted until minimum detector reading was obtained.
6. Balanced values were recorded and used for calculation.

8. Observations and Calculations

Observed Values:

- $R_2 = 2.2\ k\Omega$
- $R_3 = 882\ \Omega$
- $R_4 \approx 27.14\ k\Omega$
- $C_4 = 0.47\ \mu F$

Calculation of Inductance:

$$L_1 = 22000 \times 882 \times 0.47 \times 10^{-6} = 0.911\ H$$

Calculation of Resistance:

$$R_1 \approx 65\ \Omega$$

The calculated values closely matched the known specifications of the inductor.

9. Advantages and Disadvantages

Advantages

- High measurement accuracy
- Simple and reliable balance equations
- Frequency-independent operation
- Suitable for medium-Q inductors

Disadvantages

- Not suitable for low-Q inductors
- Requires stable AC supply
- Manual balancing can be time-consuming

10. Applications

- Measurement of unknown inductance
- Determination of series resistance of inductors
- Calibration of inductive components
- Educational and laboratory demonstrations

11. Conclusion

In this project, a Maxwell Inductance–Capacitance Bridge was successfully constructed and analyzed to determine the inductance and series resistance of an unknown inductor. The experimental results showed close agreement with theoretical values, validating the accuracy of the bridge.

The experiment provided valuable insight into AC bridge balancing, impedance comparison, and practical electrical measurement techniques, thereby reinforcing core concepts of Electrical Engineering.