UNBALANCE LOAD DETECTION USING SIMULINK SOFTWARE

A PROJECT REPORT

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND COMPUTER SCIENCE

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ABSTRACT

This project presents the modelling and analysis of a three-phase electrical system to detect unbalanced load conditions using MATLAB/Simulink. Three-phase systems are widely used in power distribution due to their efficiency and ability to handle large power demand. Any imbalance in phase voltages or currents can cause neutral current flow, overheating, reduced efficiency, and equipment failure. The developed Simulink model consists of a three-phase source, measurement blocks, and a configurable load. The system measures voltages, currents, and neutral current to determine unbalance. Simulation results show that the magnitude of neutral current and the deviation of phase currents serve as reliable indicators of load unbalance. The model effectively demonstrates how unbalanced loads affect three-phase system performance, making it suitable for educational, diagnostic, and research applications.

1. Introduction

Three-phase systems form the backbone of modern electrical power networks due to their inherent advantages over single-phase systems: constant power transfer, higher load capacity, and improved efficiency. A crucial requirement for proper operation is load balance, meaning each phase should carry roughly equal current and voltage magnitudes with 120° phase displacement.

Unbalanced loads occur due to:

- Unequal phase impedances
- Non-identical single-phase loads connected across phases
- Asymmetrical faults
- Equipment malfunction

An unbalanced system results in:

- Excessive neutral current
- Voltage fluctuations
- Overheating in transformers and motors
- Increased power losses
- Reduced system lifetime

Therefore, detecting unbalance early is essential in both industrial and utility systems. This project uses Simulink to model such behaviour and provide a clear method to identify unbalanced conditions.

2. Objective

The primary objectives of this project are:

1. To design a three-phase electrical model in Simulink.
2. To apply both balanced and unbalanced load conditions.
3. To measure three-phase voltages, currents, and neutral current.
4. To visually interpret the level of load unbalance using scope outputs.
5. To validate unbalance detection through neutral current magnitude.

3. Components Used

The Simulink model uses standard Simscape Electrical components. Major blocks include:

3.1 Three-Phase Source

- Provides a symmetrical three-phase voltage supply
- Phase-to-phase supply voltage: typically, 400 V (or user-defined)
- Phase angle displacement of 120°

3.2 Three-Phase Load

- Configurable RL load
- Used to simulate both balanced and unbalanced operating scenarios

3.3 Measurement Blocks

- Voltage Measurement block to measure phase voltages
- Current Measurement block to measure phase currents
- Neutral Current Measurement to detect load imbalance

3.4 Scopes

Scopes are used to visualize:

- Line voltages
- Phase currents
- Neutral current waveform

3.5 Calculation Blocks

- Subsystem containing mathematical functions
- RMS calculation blocks

❖ Absolute and subtraction blocks to compute deviation between phases

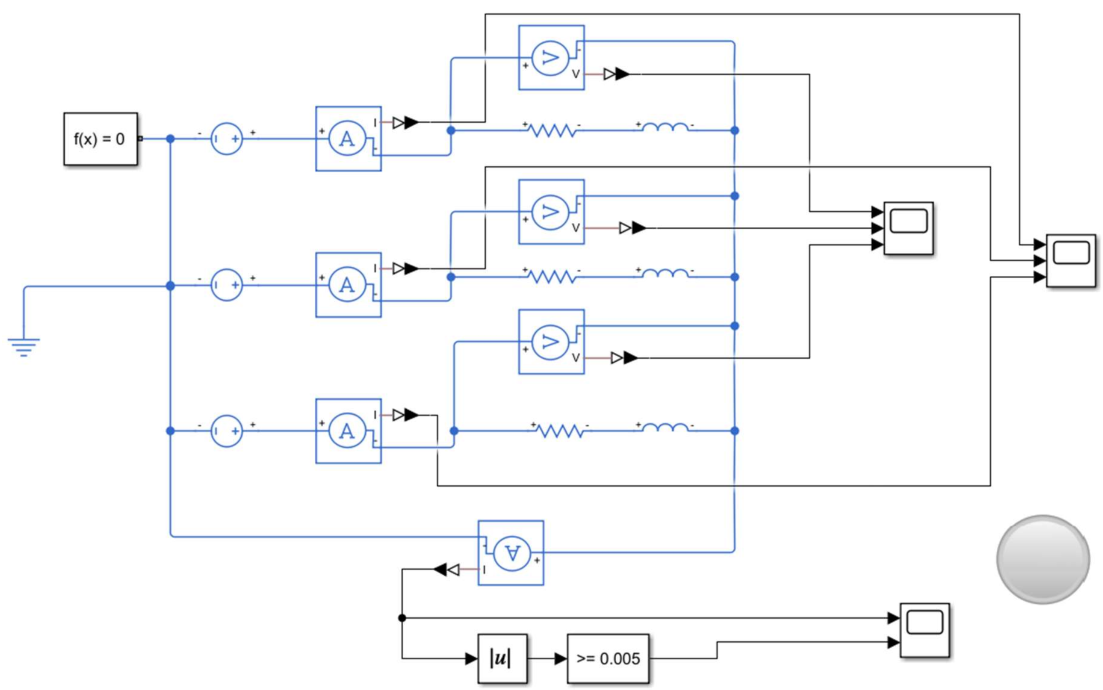
3.6 Lamp Idicator

A **Lamp block** from the *Simulink Dashboard Library* is used as a **visual indicator** to show whether the load is balanced or unbalanced.

- The lamp turns **Green** when the system is balanced.
- The lamp turns **Red** when unbalance is detected based on the neutral current threshold.

This provides an intuitive and real-time display of system status during simulation.

4. Simulink Model Description



The Simulink model is divided into the following functional sections:

4.1 Source and Load Section

A three-phase voltage source is connected to a load through measurement blocks. The load is modeled in two configurations:

a. Balanced Load:

All three phase impedances are equal.

b. Unbalanced Load:

One or more phases have different impedances.

Example:

- Phase A = 20 Ω

- Phase B = 25 Ω
- Phase C = 15 Ω

4.2 Measurement Section

a. Voltage and current measurement blocks capture instantaneous values.

b. Neutral current is measured by connecting the neutral wire to a current sensor.

4.3 Unbalance Detection Logic

To detect unbalance, two main parameters are used:

4.3.1 Phase Current Deviation

If phase currents differ significantly:

$$I_{\max} - I_{\min} >> 0$$

then the load is unbalanced.

4.3.2 Neutral Current

In a perfectly balanced system:

$$I_N = 0$$

When unbalanced:

$$I_N > 0$$

This is the most direct and reliable indicator.

4.4 Lamp Indication System

The lamp indicator receives the output from the detection subsystem:

- If $I_N <$ threshold, lamp = Green (Balanced Load)
- If $I_N \geq$ threshold, lamp = Red (Unbalanced Load)

This helps users quickly identify system status without analyzing waveforms.

4.5 Scope Section

Three main scopes are included:

1. Phase Voltage Scope
2. Phase Current Scope
3. Neutral Current Scope

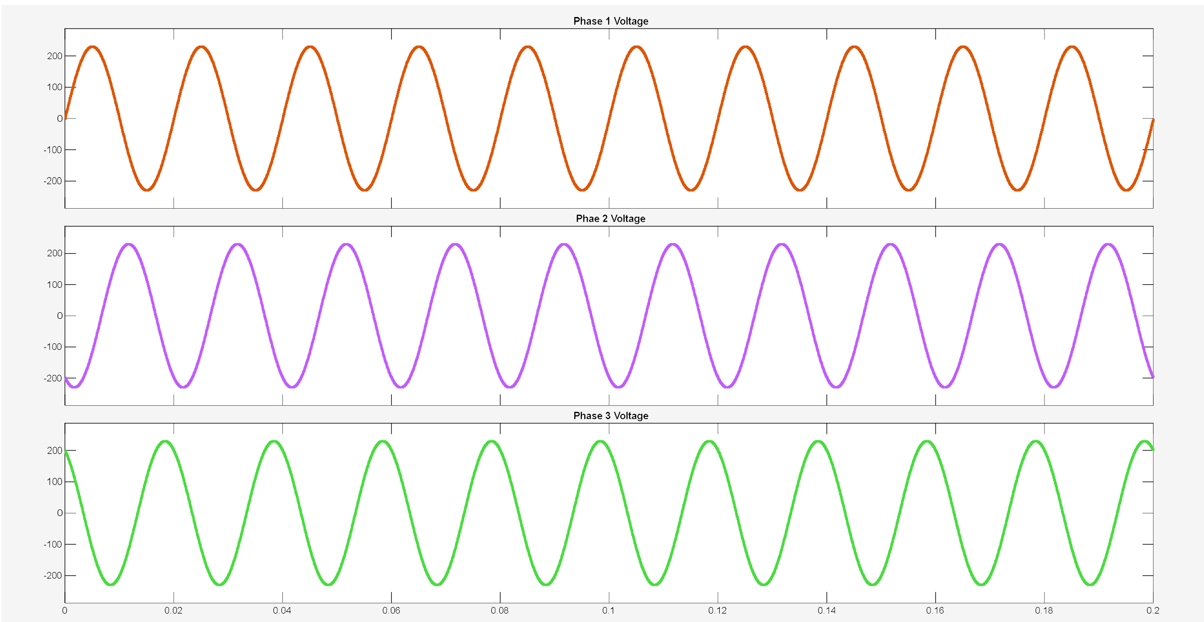
Waveform distortions or magnitude differences indicate unbalance.

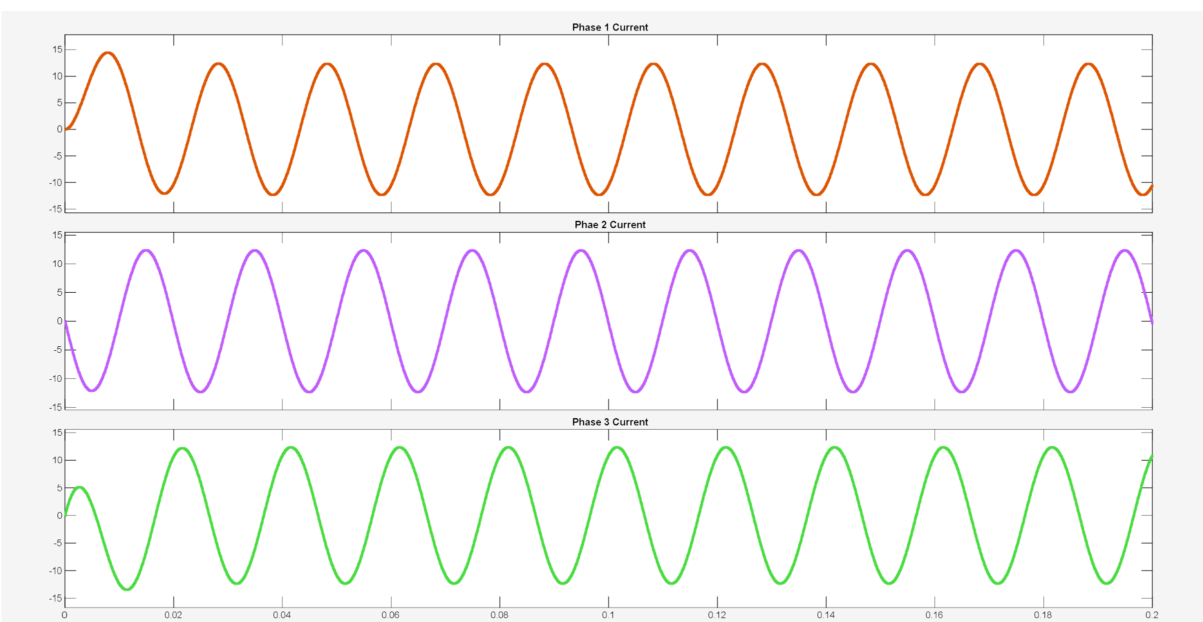
5. Simulation Output and Observations

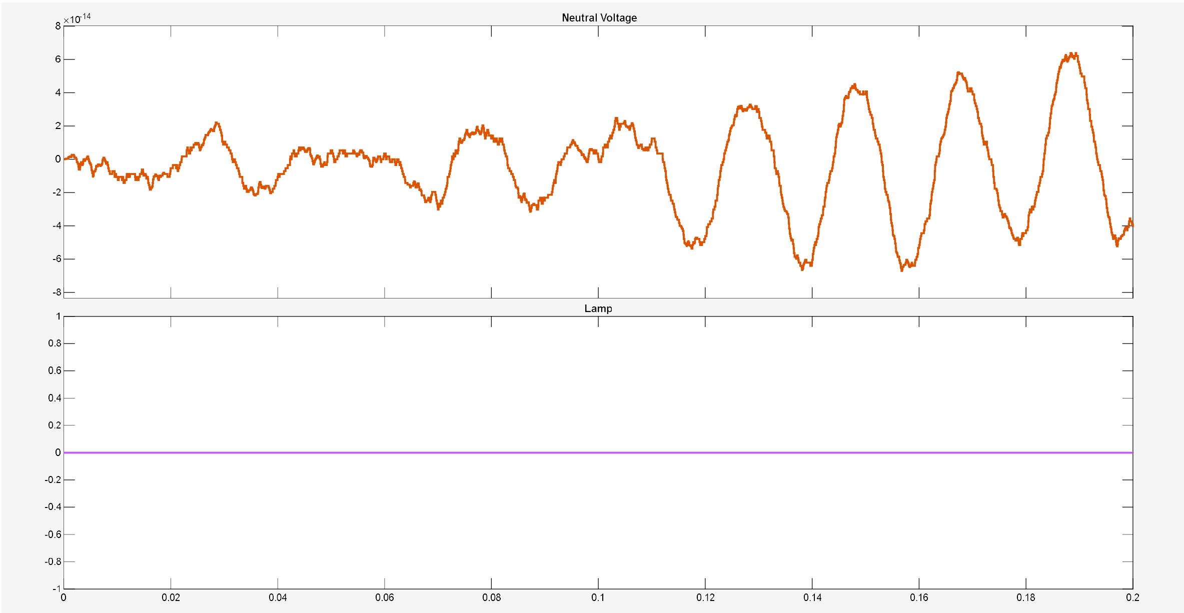
The following observations can be made from the scope outputs:

5.1 Balanced Load Case

- Phase voltages are equal in magnitude and 120° apart.
- Phase currents have equal amplitude.
- Neutral current waveform is zero or extremely small.
- Smooth sinusoidal waveforms on all scopes.

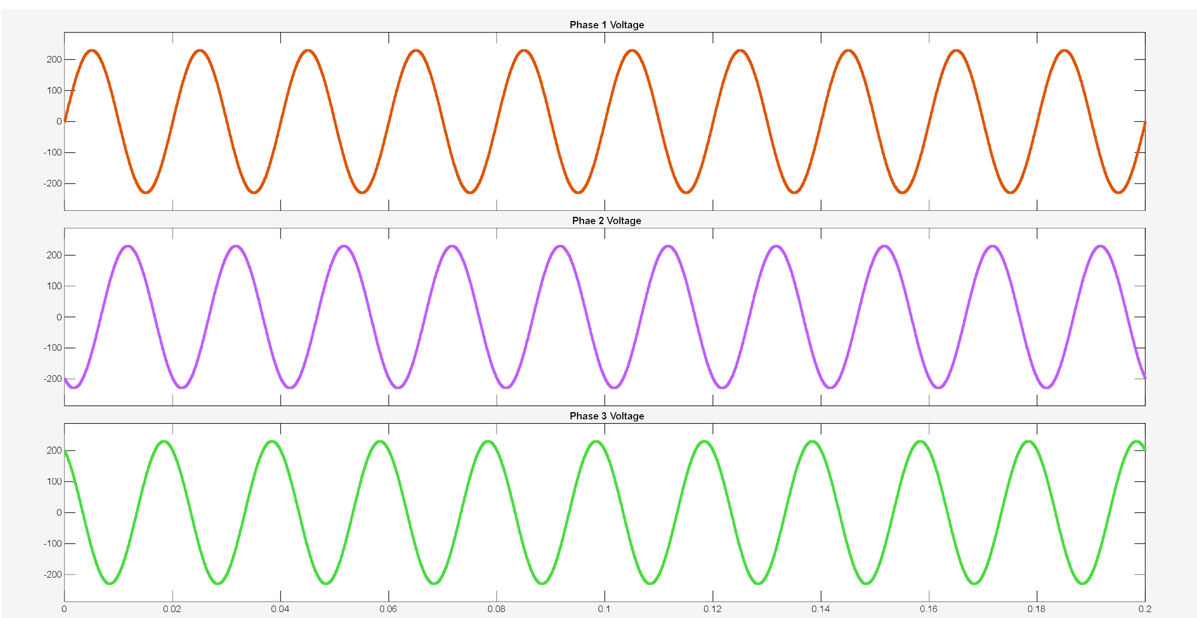


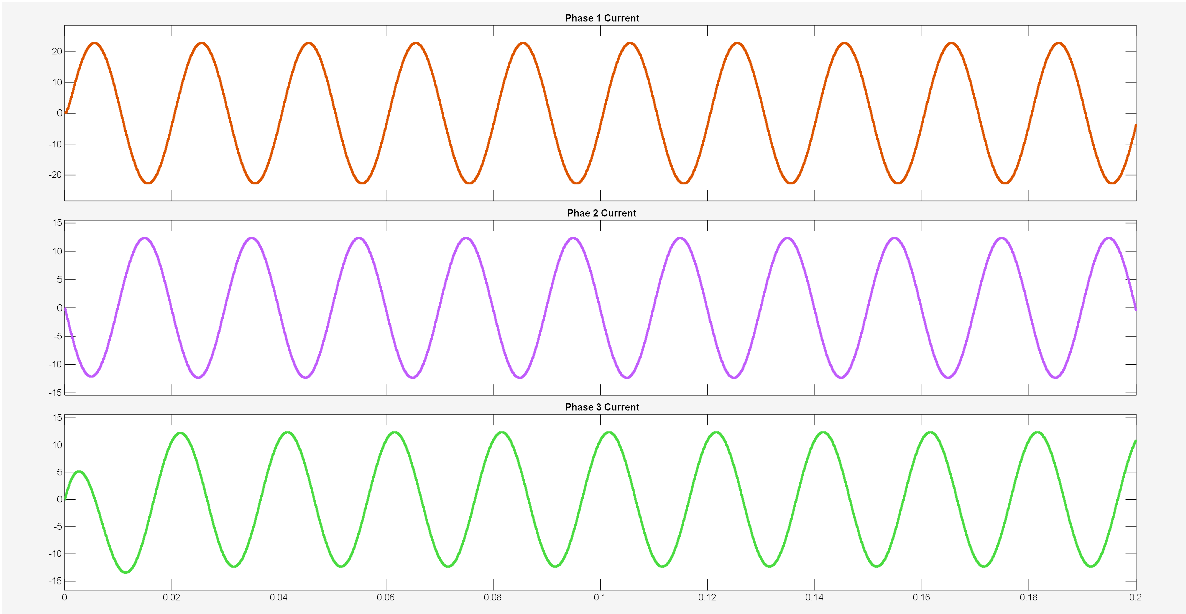


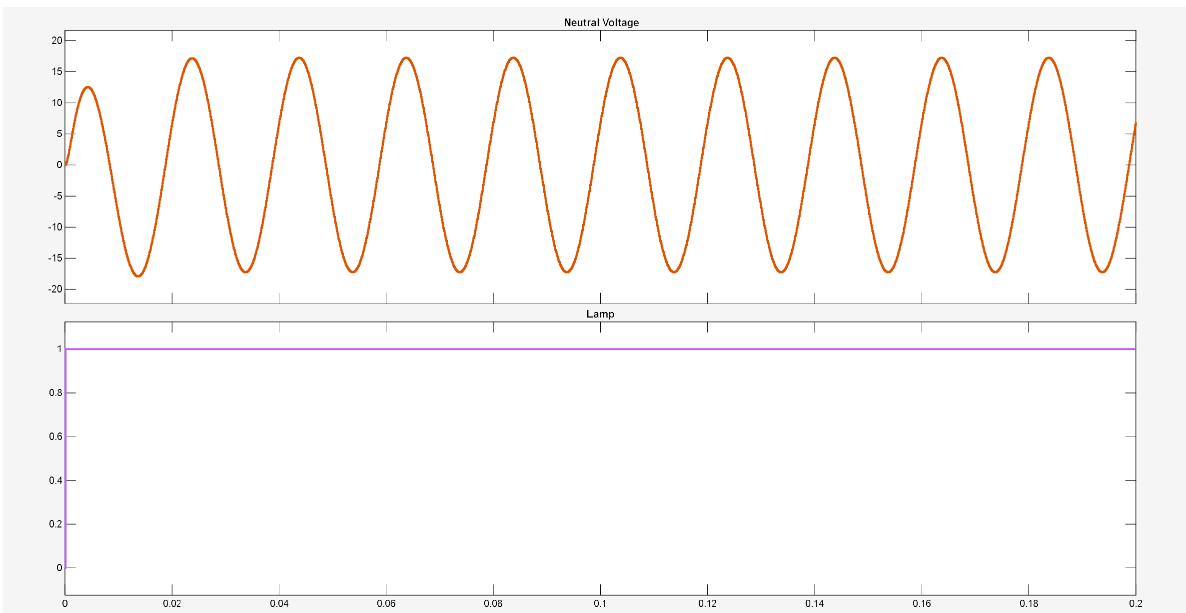


5.2 Unbalanced Load Case

- One or more phase currents differ in magnitude.
- Voltage drop across the load becomes asymmetrical.
- Neutral current waveform shows noticeable amplitude.
- The neutral current becomes the key diagnostic indicator.







5.3 <u>Lamp Behaviour Analysis</u>

The lamp provides quick visual feedback:

- Immediate color change when load parameters change
- Serves as a real-time status indicator
- Useful for students and engineers to identify unbalance instantly without detailed waveform interpretation

The lamp turns green during balanced operation and red during unbalanced operation.

When the load is balanced,  and when it is unbalanced,  .

5.4 Current Deviation Analysis

When load impedance is changed in one phase:

- Current in that phase increases or decreases.
- Current imbalance is clearly visible in the scope.

5.5 Effect on System Stability

Under unbalanced load:

- Line loss increases
- Voltage fluctuations occur
- Overall power quality deteriorates

These are clearly demonstrated through the simulation results.

6. Results

Based on the simulations conducted:

1. Under balanced loading, the system operates symmetrically with equal phase currents and nearly zero neutral current.
2. When unbalanced impedances are introduced, the neutral current increases significantly, indicating deviation from ideal balance.
3. The difference between the magnitudes of phase currents becomes more pronounced as the level of unbalance increases.
4. Scope waveforms clearly display the imbalance through distinct amplitude variations and waveform distortions.
5. The lamp indicator provides a clear and intuitive visual representation of system status.
6. During unbalanced load conditions, the lamp automatically changes from green to red, accurately reflecting the increased neutral current.
7. The simulations confirm that neutral current is a reliable and sensitive parameter for detecting load imbalance.
8. Users can easily identify unbalance through both the scope displays and the lamp indicator, making the model highly user-friendly.
9. Overall, the model successfully detects load unbalance using simple, effective, and easily interpretable measurement techniques.

The results validate that the proposed Simulink model is a reliable tool for studying and identifying unbalanced load conditions in three-phase systems.

7. Conclusion

This project demonstrates how load unbalance in a three-phase system can be efficiently detected using Simulink. The model clearly shows the relationship between load imbalance and neutral current flow. By observing current deviations and neutral current magnitude, the unbalanced condition can be easily identified. The simulation provides valuable insights for electrical engineering students, researchers, and practicing engineers working with power systems. This methodology can also be extended for fault detection, protection system design, and real-time monitoring applications.