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DEPARTEMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

OPTION: ELECTRICAL TECHNOLOGY

FINAL YEAR PROJECT REPORT:

TOPIC: DESIGN AND IMPLEMENTATION OF THREE PHASE MOTOR USING SINGLE PHASE SUPPLY AND CAPACITOR

Submitted in partial fulfillment of the requirement for the Award of Advanced Diploma in Electrical Technology

Presented by**:** RUKAMBA Jean Baptiste

Roll number: 202150285

Supervisor: Eng. GATESI Annuarita

Kigali, October 2024

DECLARATION A

I RUKAMBA Jean Baptiste declare that this research study entitled **“DESIGN AND IMPLEMENTATION OF THREE PHASE MOTOR USING SINGLE PHASE SUPPLY AND CAPACITOR”** is my original work and has not been presented for a degree or any other academic award in any University or Institution of Learning". No part of this research should be reproduced without the authors’ consent or that of ULK Polytechnic Institute.

Roll number: 202150285

Date: …. ../……. /2024

Signature:…………………

DECLARATION B

I certify that the candidate under my supervision carried out the work reported in this research project and it has submitted with my approval as the ULK Polytechnic institute supervisor.

Supervisor's names: Eng GATESI Annuarita

Signature………………… Date:…...................

DEDICATION

I dedicate this project report to

My Almighty GOD,

My beloved family

My Lecturers!

ACKNOWLEDGEMENT

I would like to express our appreciation to Almighty God for life he offered to me during all this time, and I thank everyone who contributed to the successful achievement that are observed at this stage of my life.

I also express our grateful thank to **ULK Polytechnic Institute** administration for its continuous lesson's delivery, accommodation and living facilities during these three years of study.

I grateful thanks all lecturers of electrical and electronics engineering department for their efforts in providing us the required knowledge.

In addition, I would like to thank my supervisor GATESI Annuarita for his support in preparing this project report.

Am highly indebted to our teachers and lecturers from primary schools, until the UPI for the knowledge they provided to me.

I owe deep gratitude to families for materials, financial and moral support.

My acknowledgements go to everyone who supported me in my everyday lives to reach this moment.

To all my friends who contributed positively to accomplish this research.

Am really expressing my heartfelt thanks to all of them.

ABSTRACT

The design and implementation of a 3-phase motor using a single-phase power supply with the aid of a capacitor addresses a key challenge in electrical motor systems, particularly in areas where 3-phase power is unavailable or impractical. 3-phase motors are known for their efficiency, reliability, and smooth operation, which makes them ideal for industrial applications. However, many environments only provide single-phase power, necessitating conversion techniques to operate these motors effectively.

This project explores the development of a phase conversion method using a start and run capacitor to create the required phase shift that allows a 3-phase motor to run on a single-phase power source. Capacitors are used to generate an artificial phase, thereby creating a pseudo-3-phase system. The design focuses on the optimal selection of capacitors to ensure the balance between phases, improve motor efficiency, and reduce vibration and noise. This approach is both cost-effective and practical for small to medium-scale motor applications.

The implementation involved the detailed analysis of the motor's electrical requirements, the calculation of capacitance values necessary to achieve proper phase shifting, and the design of the connection circuitry. Testing and performance evaluation showed that while the 3-phase motor operating with a single-phase input through a capacitor arrangement does not achieve the full performance of a true 3-phase power system, it is still adequate for many applications where high power or precision control is not critical.

This system provides a practical and affordable solution for running 3-phase motors in environments constrained by single-phase power supplies, making it a viable option for industries and small businesses like development country as Rwanda.

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LIST OF ABBREVIATIONS

C = Capacitor

P = Phase

N = Neutral

V = Voltage

VFD = variable frequency drive

CHAPTER 1: GENERAL INTRODUCTION

1.0. Introduction

Three-phase motors are widely used in industrial, commercial, and residential applications due to their efficiency, reliability, and ability to handle higher power loads compared to single-phase motors. However, in many areas, especially in rural or residential settings, only single-phase power supply is readily available, making it challenging to operate three-phase motors. This limitation can be a significant obstacle for applications that would benefit from the enhanced performance of three-phase motors.

The process of converting single-phase power to operate a three-phase motor typically involves costly equipment such as rotary phase converters or variable frequency drives (VFDs). However, a more cost-effective and practical solution can be achieved by using capacitors to create a phase shift, allowing a three-phase motor to run on a single-phase power supply. This approach is particularly advantageous because it reduces the need for expensive infrastructure upgrades and makes it possible to utilize three-phase motors in environments where only single-phase power is available.

1.1. Background of the study

Three-phase motors are renowned for their efficiency, high power output, and ability to maintain constant torque, making them the preferred choice for a wide range of industrial and commercial applications. However, despite their advantages, a major limitation is that they require a three-phase power supply, which is not always available, especially in residential, rural, and some small commercial settings. In contrast, single-phase power is more commonly supplied to these areas, restricting the use of three-phase motors unless an alternative power solution is introduced.

This challenge has led to the exploration of more economical and simpler methods, with the capacitor-based approach emerging as a viable solution.

The concept of using capacitors to convert single-phase power into a form that can drive a three-phase motor is based on the principle of phase shifting. When a single-phase supply is applied, only one alternating current (AC) wave is available, which does not create the rotating magnetic field needed to operate a three-phase motor. By introducing capacitors into the circuit, it is possible to create a phase shift, simulating the three-phase power needed for the motor's operation. The capacitors temporarily store and release electrical energy, producing the necessary phase displacement to generate a rotating magnetic field, enabling the motor to start and run efficiently.

1.2. Problem Statement

Three-phase motors are widely used in various industries due to their high efficiency, consistent torque, and superior power handling capabilities. However, their reliance on a three-phase power supply presents a significant challenge in areas where only single-phase power is available, such as in rural regions, small workshops, residential settings, and certain commercial applications. The lack of access to a three-phase supply limits the use of these motors, often requiring costly and complex solutions to convert single-phase power into a form that can drive three-phase motors.

Traditional solutions for converting single-phase power to three-phase power, such as rotary phase converters or variable frequency drives (VFDs), can be expensive, bulky, and require significant maintenance. These methods are not always economically viable for small-scale applications, leading to underutilization of three-phase motors or the use of less efficient single-phase motors, which results in reduced operational efficiency, increased energy costs, and compromised performance.

1.3. Research objectives

The following is a breakdown of the primary and specific aims of the research:

1.3.1 Main objectives

The main objective of this project is to design and implement a Three Phase Motor Using a Single Phase and Capacitor so that the operation of the Three Phase Motor in environments where only single phase power supply is available could be possible, despite the absence of a three phase power source.

1.3.2. Special objectives

The particular goals taken into consideration for the project are listed below.

a) To extend knowledge in three phase motors

b) To analyze the conversion of single-phase power into a simulated three-phase power supply using capacitors.

c) To enhance the knowledge in applications of capacitors in power supply systems

1.4. Research Questions

a) What are three phase motors?

b) Is it possible to supply three phase motors using single phase?

c) How can capacitors be used in power supply systems?

1.5. Scope and limitations

1.5.1. Scope

Design and Development: The project focuses on designing a capacitor-based circuit capable of converting single-phase power to operate a three-phase motor. This includes selecting suitable capacitor values for both starting and running the motor to achieve efficient performance

Cost and Efficiency Analysis: An analysis was conducted to compare the cost-effectiveness and energy efficiency of the capacitor-based approach with traditional phase conversion methods like rotary phase converters and variable frequency drives (VFDs).

Performance Evaluation: The project assessed key performance metrics such as torque, speed, power factor, and efficiency of the motor when operating on a single-phase supply with capacitors, comparing them to standard three-phase motor operation.

1.5.2. Limitation

Load Capacity: The ability to operate a three-phase motor on a single-phase supply using capacitors may be limited in terms of the maximum load the motor can handle. The performance might not be as efficient under heavy or fluctuating loads compared to a genuine three-phase power supply.

Power Factor and Efficiency: While capacitors can improve power factor, achieving the same efficiency and power factor as a true three-phase supply may be challenging. The project may not fully replicate the performance of a three-phase motor running on a standard three-phase power line.

Starting Torque: Motors operating with a single-phase supply and capacitors might experience lower starting torque, which could be a limitation in applications requiring high initial torque.

1.6. Significance of study

The study on the design and implementation of a three-phase motor using a single-phase power supply with capacitors holds significant value in various industrial, commercial, and residential contexts. The key contributions and benefits of this study include:

Addressing Power Supply Limitations: Many regions, especially rural and remote areas, have limited access to three-phase power supply. This study offers a practical solution that enables the operation of three-phase motors using the widely available single-phase power supply, thus overcoming a major infrastructure limitation.

Cost Efficiency: The traditional methods of converting single-phase to three-phase power, such as rotary phase converters or variable frequency drives (VFDs), can be expensive and complex. By using capacitors to achieve phase conversion, this study presents a cost-effective alternative, making three-phase motor technology more accessible for small businesses, workshops, and residential applications.

Improving Energy Efficiency: Three-phase motors are generally more efficient than single-phase motors in terms of power consumption and performance. By enabling the use of three-phase motors with a single-phase supply, this study promotes energy-efficient solutions, potentially reducing operational costs and contributing to sustainable energy use.

1.7. Organization of study

This study on the design and implementation of a three-phase motor using a single-phase line and capacitors is organized into the following chapters:

Chapter 1. General Introduction: This chapter provides a general introduction to the study, outlining the background, problem statement, objectives, research questions, and significance of the study. It sets the context for the research and highlights the motivation behind investigating the use of capacitors to operate a three-phase motor with a single-phase power supply.

Chapter 2. Literature Review: In this chapter, a comprehensive review of existing literature related to three-phase motor operation, single-phase power supply conversion, and capacitor-based phase shift techniques is presented. It covers previous studies, theories, and technologies that have been developed in the field, identifying knowledge gaps that this study aims to address. It also establishes the theoretical foundation for the project's approach.

Chapter 3. Research Methodology: the chapter describes all procedures and steps involving in conducting this research including: **Phase Conversion analysis:** Detailed analysis of how capacitors can be used to create a pseudo 3-phase system by shifting phases; **Mathematical Modeling:** Derivation of the equations governing phase shift, capacitor sizing; motor load, and motor efficiency.

Chapter 4. System design, analysis and implementation. This chapter is like the heart of the project and it highlights the research design, analysis and implementation which shows the feasibility of this project in real life.

Chapter 5. Conclusion and Recommendations: this chapter consists of the findings, challenges and recommendations based on the challenges met during research period. At the end of the report, references are provided.

CHAPTER 2: LITERATURE REVIEW

2.0. Introduction

The design and implementation of a three-phase motor using a single-phase power supply with capacitors represent a unique approach to addressing the limitations of power availability in areas with restricted access to three-phase electrical systems. Three-phase motors are widely preferred in industrial, commercial, and agricultural applications due to their superior efficiency, reliability, and performance compared to single-phase motors. However, the challenge arises when only a single-phase power supply is available, making it difficult and expensive to operate three-phase equipment.

This literature review aims to explore the existing research, theories, and technologies that have been developed in the field of phase conversion, focusing on methods for using capacitors to enable three-phase motor operation from a single-phase power source. It examines the principles of single-phase to three-phase conversion, the role of capacitors in creating phase shifts, and the performance characteristics of motors under different phase supply conditions. Furthermore, the review highlights the advantages and limitations of various phase conversion techniques, such as rotary phase converters, static phase converters, and variable frequency drives (VFDs), and compares them to capacitor-based methods.

2.1. Concept, opinions, ideas from authors/experts

2.1.1. Concepts

This section would delve into several key concepts that underpin the design and implementation of three-phase motors using a single-phase power supply with capacitors.

The project comprises a series of frameworks completed by various components together to accomplish tasks.

2.1.1.1. System components;

Circuit breaker

A circuit breaker is an electrical switch designed to automatically interrupt the flow of current in a circuit to prevent damage from faults such as overload**,** short circuits**,** or ground faults**.** It plays a crucial role in protecting electrical equipment and people by isolating the faulty circuit when excessive current flows through it.

Figure 1.Circuit breaker

2.1.1.2. Connector

A **connector** is a **device** used to join electrical circuits or components, enabling the transfer of **electricity, signals, or data**. Connectors provide a **temporary or permanent connection** between wires, cables, and devices, ensuring safe and efficient transmission in a wide range of applications.

Figure 2. Connectors

2.1.1.3. Motor

An **induction motor** is an **AC electric motor** that converts electrical energy into mechanical energy using the principle of **electromagnetic induction**. It is one of the most widely used types of motors in industries, households, and commercial settings because of its **robustness, simplicity, and reliability**.

Figure 3. Motor

2.1.1.4. Switch

A **one-way switch** is a simple **on-off switch** used to control the flow of electrical current to a single device or light from **one location**. When the switch is in the **ON position**, the circuit is completed, and the connected appliance or light operates. When in the **OFF position**, the circuit is broken, and the device turns off.

Figure 5. Electrical Switch

2.1.1.5. Indicator Light

An indicator light is a small visual signal device that uses a light source, such as an LED or incandescent bulb, to display the status of a system or equipment. It provides instant visual feedback to users about operating conditions, warnings, or faults in electrical circuits, machines, or appliances.

Figure 6. Indicator light

2.1.1.6 .Capacitor

A **run capacitor** is an electrical component used in **single-phase induction motors** to improve **performance and efficiency** during continuous operation. It provides a **constant phase shift** to one of the motor's windings (usually the auxiliary or start winding), allowing the motor to generate more **torque** and operate smoothly.

Figure 7.Capacitor

Phase Shift Creation: Explore how capacitors are used to create an artificial third phase in a single-phase system, which simulates the conditions of a three-phase supply.

Enhanced Capacitor Technologies:

- **Advanced Capacitor Materials**: Investigate new materials and technologies for capacitors that offer improved performance, longer lifespan, and better efficiency. This could include solid-state capacitors or capacitors with higher energy densities.

- **Smart Capacitors**: Explore the development of smart capacitors with built-in sensors and adaptive control mechanisms that automatically adjust capacitance based on real-time performance and load conditions.
- **Study on Motor Performance**: Research by T. S. Zhao and T. T. Wu ("Performance Analysis of Single-Phase Motors with Capacitors") examines how the performance of single-phase motors is affected when capacitors are used to simulate a three-phase supply. The study provides data on torque, efficiency, and power factor for various capacitor configurations.
- **Efficiency Improvements**: The paper by S. J. Wang et al. ("Efficiency Improvement in Single-Phase Motors Using Capacitor-Based Phase Shifting") investigates methods to enhance the efficiency of single-phase motors by optimizing capacitor values and configurations. The study highlights how adjusting capacitors can reduce power losses and improve overall motor performance.

Capacitor Technology and Phase Shifting Techniques

- **Capacitor Design and Sizing**: Research by M. A. Rahman ("Design and Sizing of Capacitors for Phase Shifting in Single-Phase Systems") provides theoretical and practical guidelines for selecting and sizing capacitors for use in single-phase to three-phase conversion. The study includes mathematical models and empirical data on capacitor performance.
- **Advanced Capacitor Technologies**: The study by H. K. Li and Y. L. Zhang ("Advanced Capacitor Technologies for Improved Phase Shifting") explores new capacitor technologies, such as solid-state capacitors, and their effectiveness in creating accurate phase shifts. The research discusses the advantages and limitations of these advanced capacitors.

2.2. Related study

When reviewing literature on the design and implementation of three-phase motors using a single-phase power supply and capacitors, several related studies and research areas provide valuable insights and context. These studies explore various aspects of motor performance, capacitor technology, phase shifting methods, and practical implementations. Here are some key related studies:

Performance and Efficiency of Single-Phase Motors with Capacitors

- Study on Motor Performance: Research by T. S. Zhao and T. T. Wu ("Performance Analysis of Single-Phase Motors with Capacitors") examines how the performance of single-phase motors is affected when capacitors are used to simulate a three-phase supply. The study provides data on torque, efficiency, and power factor for various capacitor configurations.

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Comparative Analysis of Phase Conversion Methods

- **Phase Conversion Methods**: The study by R. T. Adams et al. ("Comparative Analysis of Phase Conversion Methods for Motor Operation") compares capacitor-based phase shifting with other phase conversion methods, such as rotary phase converters and variable frequency drives (VFDs). The research evaluates the performance, cost, and applicability of each method.
- **Economic and Environmental Impact**: Research by C. R. Hughes and S. J. Brown ("Economic and Environmental Impact of Phase Conversion Methods") examines the economic and environmental implications of using capacitors versus alternative phase conversion technologies. The study provides insights into cost-effectiveness and sustainability.

CHAPTER 3: RESEARCH METHODOLOGY

3.0. Introduction

The research methodology for studying the design and implementation of a three-phase motor using a single-phase power supply and capacitors involves a structured approach to investigate and analyze the effectiveness, performance, and practicality of this technique. This methodology outlines the steps and methods used to achieve a comprehensive understanding of the phase-shifting process, capacitor configurations, and overall system performance.

3.1. Research design

3.1.1. Introduction

The research design outlines the structured approach to investigating the feasibility, performance, and optimization of running a three-phase motor on a single-phase power supply using capacitors. This design will guide the investigation through theoretical analysis, experimental validation, and practical application.

Experimental Design

- **Motor Selection**:

Choose three-phase motors of different sizes and types (e.g., induction motors, synchronous motors) for comprehensive analysis.

- **Capacitor Configuration**:

Select a range of capacitors with varying capacitance values and types (start capacitors, run capacitors)

- **Experimental Setup**:

Design and build experimental setups to simulate single-phase to three-phase conversion. This includes:

➢ Wiring configurations for connecting capacitors to the motor

➢ Measurement instruments for torque, efficiency, power factor, vibration, and noise.

- **Testing Protocols**:

❖ **Startup Tests**: Measure motor startup torque and behavior with different capacitor values.

❖ **Steady-State Tests**: Assess running torque, efficiency, and power factor during continuous operation

❖ **Load Tests**: Evaluate performance under varying load conditions and capacitor configurations.

❖ **Failure Mode Analysis**: Test system response to overloads and identify potential failure modes.

Data Analysis:

- **Statistical Analysis**:

❖ Analyze performance data using statistical methods to identify trends and correlations.

❖ Compare experimental results with theoretical predictions to validate models.

- **Comparative Analysis**:

❖ Compare the performance of capacitor-based systems with alternative phase conversion methods, such as rotary phase converters and VFDs.

Validation and Verification

- **Cross-Verification**:

❖ Validate experimental results against theoretical models and simulations.

❖ Ensure consistency and accuracy in experimental setups and data collection methods.

❖ **Benchmarking** Benchmark the capacitor-based system against established standards and alternative technologies.

3.2. Sample size

Determining the appropriate sample size is critical for ensuring the reliability and validity of the research findings. In the context of studying the design and implementation of a three-phase motor using a single-phase power supply and capacitors, the sample size encompasses the number of motors, capacitors, and test configurations used. Here's a structured approach to determine the sample size for various components of the research:

3.2.1. Three-Phase Motors

- **Number of Motors**:

❖ **Minimum Sample Size**: Typically, a minimum of 3 to 5 different motors should be tested to account for variability in motor types and sizes. This includes different power ratings and motor types (e.g., induction motors and synchronous motors).

❖ **Reasoning**: Testing a variety of motors helps generalize findings and assess performance across different applications. More motors may be included if budget and time permit, particularly for specific industry or application studies.

Capacitors

- **Number of Capacitors**:

❖ **Minimum Sample Size**: At least 5 to 7 different capacitors should be tested, including various capacitance values and types (e.g., start capacitors and run capacitors).

❖ **Reasoning**: This range allows for evaluating a broad spectrum of capacitor configurations to identify optimal settings and understand their impact on motor performance.

3.3.1. Sampling Procedure

3.3.1.1. Understand the Motor Ratings and Requirements

- **Motor Type**: Identify the type of 3-phase motor you will be using (induction motor is the most common).
- **Motor Power Rating**: Check the motor's power rating (kW or HP), voltage, and current ratings.
- **Speed (RPM)**: Determine the motor speed to ensure the system performs to expectations.

3.3.1.2. Determine Phase Conversion Method

Since you are using a single-phase power supply to drive a 3-phase motor, consider the following methods:

- **Capacitor Start and Run**: The most common method for small motors (up to around 5HP) involves using start and run capacitors to shift the phase of the single-phase input.
- **Rotary Phase Converter**: This method is more reliable for larger motors but is more complex.
- **Static Phase Converter**: This is similar to a capacitor method, but it only provides true 3-phase power during startup. It is not ideal for continuous operation but can work for motors running under light loads.

3.3. Research Instrument

For a research project focusing on the **design and implementation of a three-phase motor using a single-phase supply and capacitors**, the research instruments are primarily aimed at collecting data to assess the technical performance, efficiency, reliability, and practical usability of the system. The following research instruments can be employed:

Measurement of Electrical Parameters

- **Multimeter**: To measure basic electrical parameters like voltage, current, and resistance.
- **Purpose**: Check voltage levels and current drawn by the motor and capacitors.
- **Application**: Measure voltages at the motor terminals and across capacitors to ensure correct phase shifts.
- Example: Fluke 117 Digital Multimeter.
- **Power Analyzer**: To measure power consumption, power factor, and real/reactive power
- **Purpose**: Analyze the efficiency of the motor when using single-phase input and capacitor assistance.
- **Application**: Evaluate how much power is being consumed and how efficiently the motor is operating.
- Example: Fluke 435-II Power Quality Analyzer.
- **Oscilloscope**: For analyzing waveforms of voltage and current.
- **Purpose**: Observe the voltage phase shifts created by the capacitors and identify any waveform distortions.
- **Application**: Measure phase shifts between different motor windings and identify transient events during motor startup.
- Example: Tektronix TBS1202B Oscilloscope.

Capacitor Testing Instruments

- **Capacitance Meter**: To measure the actual capacitance values used in the system.
- **Purpose**: Ensure that the capacitors match the designed specifications for creating phase shifts.
- **Application**: Check both start and run capacitors to confirm they are functioning properly within the system.
- Example: Extech 380193 Capacitance Meter.
- **Power Factor Meter**: To assess how effectively the capacitors are improving the power factor of the motor.
- **Purpose**: Measure the power factor under different load conditions.
- **Application**: Evaluate the effectiveness of capacitors in improving motor performance by reducing phase imbalance.
- Example: Fluke 43B Power Quality Analyzer.

Thermal Monitoring Instruments

- **Infrared Thermometer or Thermal Camera**: To measure the temperature of motor components and capacitors.

- **Purpose**: Monitor the motor's thermal performance to prevent overheating.
- **Application**: Measure the surface temperature of the motor windings, capacitors, and other electrical components under different load conditions.
- Example: FLIR TG267 Thermal Camera.

- **Thermocouples**: To measure the internal temperature rise of the motor windings and capacitors.

- **Purpose**: Ensure that the temperature remains within safe limits during continuous operation.
- **Application**: Place thermocouples inside the motor housing or capacitor enclosures for detailed temperature data logging.
- **Example:** Omega Type J Thermocouples.

3.3.1. Choice of the research instrument

When selecting research instruments for the **design and implementation of a three-phase motor using a single-phase power supply and capacitors**, the choice of instruments should align with the specific objectives of the study. The primary aim is to measure the motor's performance, efficiency, and reliability under the altered conditions caused by single-phase power conversion. Below is a guide on the **choice of research instruments** for this type of project:

Multimeter (Electrical Measurement)

- **Rationale for Choice**: A digital multimeter is essential for measuring basic electrical parameters like voltage, current, and resistance. Since the motor will be running on a modified phase using capacitors, monitoring these values is crucial to ensure safe operation and proper phase splitting.

- **Why**: It's an essential tool for basic diagnostics and verification of correct voltage levels at various motor terminals and across the capacitors.
- **Example Use**: Measure the voltage across each phase and check the current drawn by the motor in real-time during startup and operation.

Oscilloscope (Waveform Analysis)

- **Rationale for Choice**: An oscilloscope is crucial for visualizing the voltage and current waveforms, especially to observe phase shifting and any waveform distortions introduced by the capacitors. Phase conversion introduces changes in waveforms that need detailed observation.
- **Why**: To understand how the capacitors are influencing the phase relationships and to check for any abnormalities or imbalances in the waveforms.
- **Example Use**: Monitor the phase shift created between the windings of the motor and verify the accuracy of the phase conversion.

Power Analyzer (Efficiency and Power Factor Measurement)

- **Rationale for Choice**: A power analyzer will provide insights into the efficiency of the motor system, measuring key parameters like real power, reactive power, power factor, and harmonic distortion. The use of capacitors for phase conversion can affect the power quality, and this tool is essential for assessing that.
- **Why**: Understanding the power factor and system losses is key to determining the success of the phase conversion. The analyzer helps in identifying any inefficiencies or excessive power consumption.
- **Example Use**: Measure real and reactive power in the system and monitor changes in the power factor when using different capacitor sizes or under varying load conditions.

3.3.2. Validity and reliability of the instrument

When designing a research study for the implementation of a three-phase motor using a single-phase power supply and capacitors, ensuring the **validity** and **reliability** of the research instruments is crucial for obtaining accurate and trustworthy results. Here's how you can assess the **validity** and **reliability** of the selected instruments in this context:

Multimeter (For Voltage, Current, Resistance Measurement)

➢ **Validity**:

- **Content Validity**: The multimeter accurately measures the electrical parameters (voltage, current, resistance) that are relevant to the performance of a motor and capacitor system. These parameters are fundamental to assessing system functionality, so the instrument is valid in terms of content.
- **Criterion Validity**: A high-quality multimeter, calibrated against known standards, can accurately measure electrical properties, ensuring that it produces valid results.

➢ **Reliability**:

- **Test-Retest Reliability**: A high-end multimeter should give consistent results when the same measurements are taken under the same conditions multiple times.
- **Inter-Instrument Reliability**: The results should be comparable with those obtained from similar multimeters from reputable brands.

Oscilloscope (For Waveform Analysis)

➢ **Validity**:

- **Construct Validity**: The oscilloscope can directly observe phase shifts, waveform distortions, and transients, which are key aspects of a motor's performance when converting single-phase power to three-phase. This makes it a valid instrument for measuring these characteristics.
- **Face Validity**: The oscilloscope is widely accepted as the correct tool for analyzing electrical waveforms and has an obvious direct connection to the study's objectives.

➢ **Reliability**:

- **Internal Consistency**: The oscilloscope should produce the same waveform patterns when the same input is applied repeatedly, ensuring reliable results.
- **Calibration Reliability**: Regular calibration ensures the oscilloscope remains accurate over time. Properly calibrated oscilloscopes will produce reliable, repeatable measurements.

Power Analyzer (For Power, Power Factor, and Harmonics Measurement)

➢ **Validity**:

- **Criterion Validity**: A power analyzer is valid for measuring key electrical performance indicators like real power, reactive power, and power factor, which are directly related to the efficiency and functionality of the motor and capacitor system.

- **Ecological Validity**: The power analyzer provides measurements under actual operating conditions, reflecting real-world motor performance, making it ecologically valid.

➢ **Reliability**:

- **Test-Retest Reliability**: It should consistently measure power parameters under the same load and electrical conditions.

- **Inter-Instrument Reliability**: Results from a high-quality power analyzer should closely match those from other similar devices, demonstrating reliability across different instruments.

Capacitance Meter (For Measuring Capacitor Values)

➢ **Validity**:

- **Content Validity**: A capacitance meter is specifically designed to measure capacitance values, which are crucial for phase shifting in the motor design. This ensures its relevance and validity in the study.
- **Face Validity**: As the instrument directly measures what it is supposed to (capacitance), it has high face validity.

➢ **Reliability**:

- **Test-Retest Reliability**: A capacitance meter should provide consistent capacitance readings under the same conditions, ensuring the reliability of the instrument.
- **Calibration Reliability**: Like other electronic measurement tools, it must be calibrated regularly to maintain reliability.

3.4. Data analysis and interpretation

The **data analysis and interpretation** of a three-phase motor using a single-phase supply with capacitors focuses on evaluating the system's electrical, mechanical, and thermal performance. The analysis helps determine whether the motor is operating efficiently and within safe parameters, and whether the design improvements (using capacitors) achieve the desired objectives of phase conversion, improved power factor, and overall motor performance.

Here is a detailed breakdown of how to approach data analysis and interpretation:

Organizing the Data

Data Categories:

- **Electrical Data**: Voltage, current, power factor, real/reactive power, harmonics, phase shift.

- **Mechanical Data**: Motor speed (RPM), torque (Nm), load conditions.
- **Thermal Data**: Motor temperature, capacitor temperature.

Power Factor:

- The **power factor** measures how efficiently the motor uses electrical power. Capacitors are added to improve this by reducing the reactive power.

- **Baseline Power Factor**: Expected to be low, indicating inefficient power use.
- **Post-Implementation Power Factor**: Should improve significantly after the capacitors are added.

Mechanical Data Analysis

Motor Speed (RPM):

- Compare the motor's rotational speed (RPM) before and after installing capacitors.

○ **Baseline Speed**: May be lower due to inefficiencies in the single-phase supply.

○ **Post-Implementation Speed**: The motor should achieve a more stable and possibly higher RPM after capacitors are introduced, indicating more balanced power distribution.

Torque:

- Use **torque sensor** data to measure the motor's torque under different load conditions.

○ **Baseline Torque**: Expected to be lower or inconsistent without capacitors.

○ **Post-Implementation Torque**: Torque should increase, and motor performance should stabilize, especially under varying loads.

Load Performance:

- Analyze motor performance under different load conditions (light, medium, heavy). Use RPM, torque, and power data to determine how effectively the motor operates under each load.

○ **Baseline Load Performance**: Lower or unstable performance, particularly under heavy loads.

○ **Post-Implementation Load Performance**: Improved stability and higher torque under load, demonstrating the motor's ability to handle diverse operational conditions.

3.5. Ethical consideration of the instrument

In research projects involving the design and implementation of a three-phase motor using a single-phase power supply and capacitors, **ethical considerations** play a significant role in ensuring the study is conducted responsibly. Ethical principles should guide the design, testing, and application of the system, especially when using research instruments. Below are key ethical considerations for this type of project:

Safety of Participants and Personnel

- **Description**: The design and testing of electrical systems, particularly those involving motors, capacitors, and power supplies, can pose significant safety risks. The instruments used in this study must be handled in ways that do not expose researchers or participants to physical harm, such as electric shock, fires, or equipment malfunctions.

- **Ethical Consideration**: Researchers must follow strict safety protocols to prevent accidents. This includes using properly calibrated instruments (like multimeters, oscilloscopes, and power analyzers) and ensuring they are operated by trained personnel. Adequate safety gear (insulated gloves, eye protection, etc.) should be used when working with high-voltage equipment. Additionally, testing must be done in environments that are designed to contain hazards, like using protective enclosures for rotating parts or high-voltage circuits.
- **Example**: Ensuring that the oscilloscope's probes and multimeter leads are rated for the voltage level of the motor system to prevent accidental electrical shocks.

Proper Use and Calibration of Instruments

- **Description**: Instruments like multimeters, oscilloscopes, and power analyzers must be used appropriately to collect accurate data. Improper use of instruments can lead to incorrect results, potentially leading to flawed conclusions and design decisions.
- **Ethical Consideration**: Ethical research requires that all instruments be properly calibrated before use to ensure the accuracy and validity of the data. Falsifying or neglecting to report issues with instrument calibration or misinterpreting data violates research integrity.
- **Example**: Regularly calibrating the power analyzer and torque sensor to ensure accurate measurements of motor performance, as neglecting this could lead to inaccurate conclusions about motor efficiency.

Environmental Impact

- **Description**: Electrical systems, particularly motors and capacitors, consume energy and may generate heat and noise pollution. Inappropriate disposal of test equipment or components like capacitors could also lead to environmental harm.

- **Ethical Consideration**: Researchers should be mindful of the environmental impact of the project. Minimizing energy consumption during testing, ensuring proper disposal of electronic waste (like failed capacitors), and using environmentally friendly components where possible are ethical responsibilities.

CHAPTER 4: SYSTEM DESIGN ANALYSIS AND IMPLEMENTATION

4.0. Introduction

The design and implementation of a three-phase motor using a single-phase power supply and capacitor-based phase shifting is a significant area of research in electrical engineering. Three-phase motors are highly efficient, reliable, and commonly used in industrial applications, but they are generally designed to operate with a three-phase power supply. In many residential and remote areas, where only single-phase power is available, there is a need to adapt three-phase motors to function effectively with single-phase power sources. This necessitates the use of phase-shifting techniques, often employing capacitors, to create an artificial third phase.

This chapter focuses on the system design, analysis, and practical implementation of running a three-phase motor on a single-phase supply, using capacitors to generate the necessary phase shift. The key challenge in this system lies in achieving a near-ideal phase displacement to enable the motor to operate efficiently while maintaining acceptable levels of torque and power.

4.1. System design

4.1.1. Project Block Diagram

Below is a block diagram that shows how to use a single phase system and capacitor to run a three phase motor. It is composed of seven blocks: supply, indicators, circuit breaker, switch motor, and capacitor.

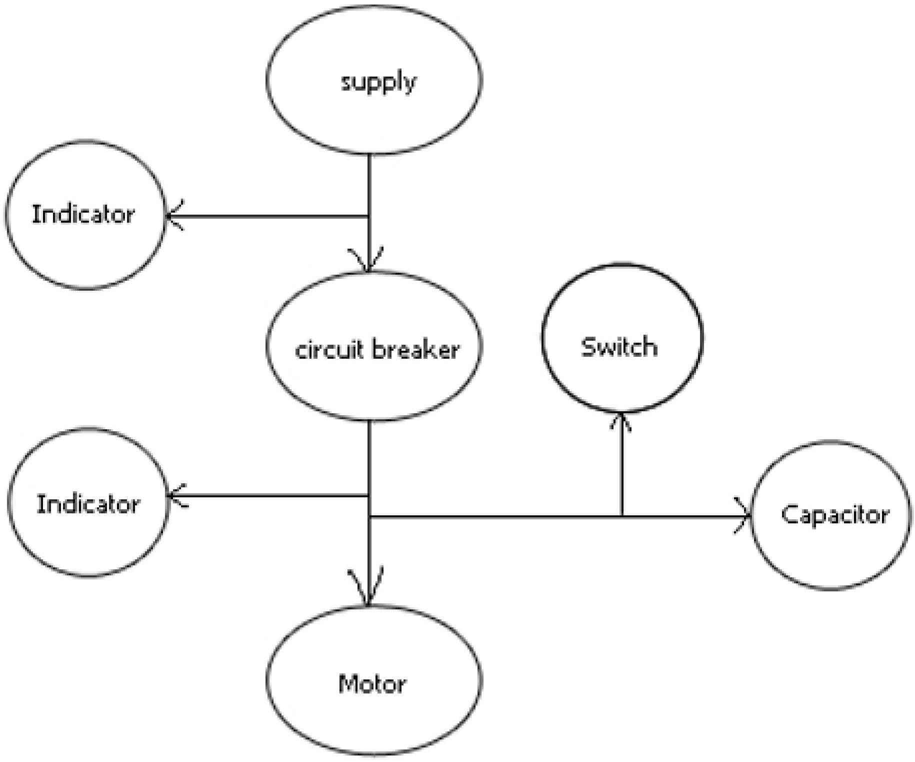

Figure 4. The block diagram of the designed system

4.1.2. Circuit diagram

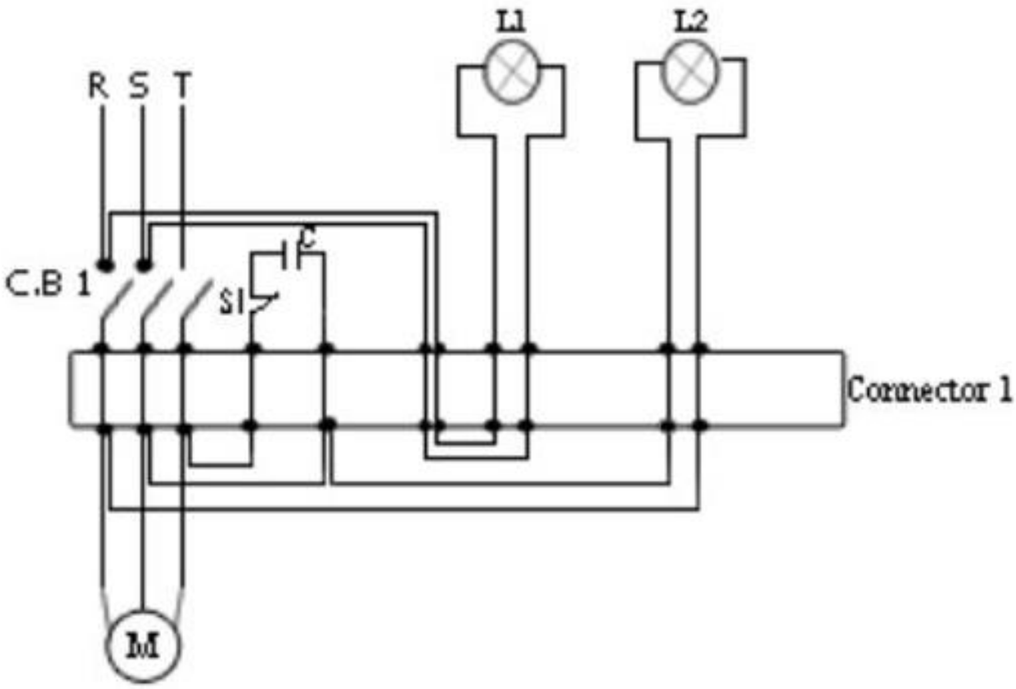

Figure 5. Circuit diagram of the system

4.2. Implementation

The implementation of a three-phase motor using a **single-phase line with capacitors** relies on **capacitive phase shifting** to simulate the missing phases. Although not as efficient as a traditional three-phase system, it is a **cost-effective solution** where three-phase power is impractical or unavailable. Proper capacitor selection, cooling mechanisms, and load management are essential for reliable performance. The project's appearance after completion is depicted in the following prototype.

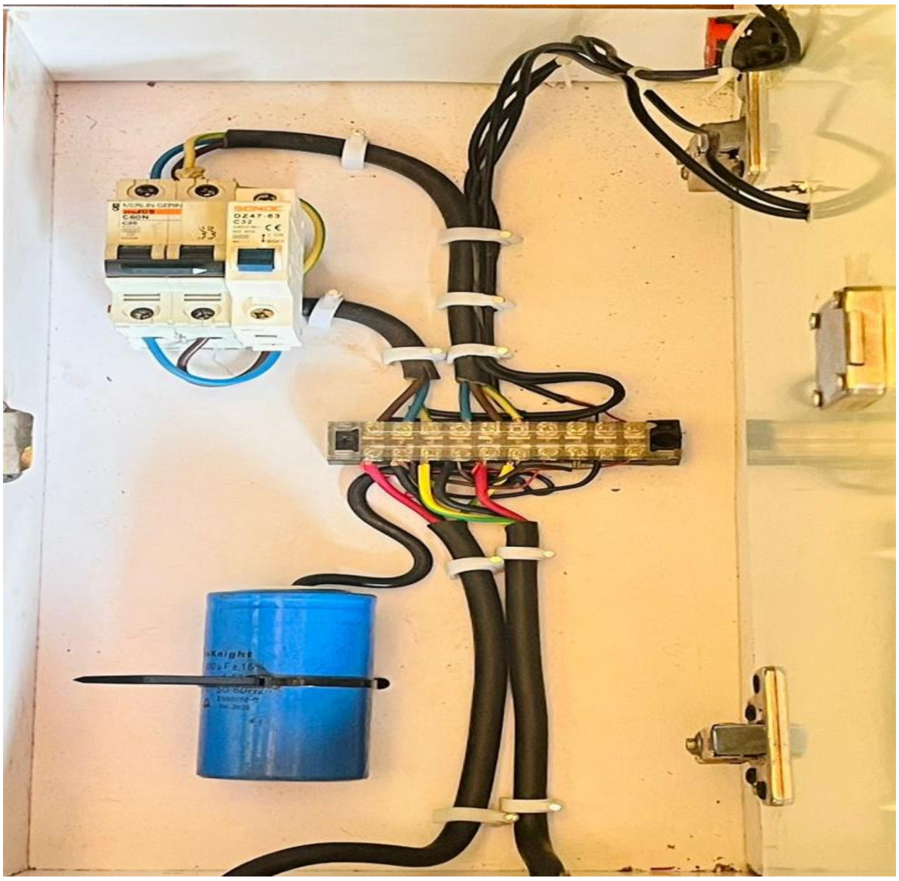

Figure 6. Assembled Project outlook

WORKING PRINCIPLE

The goal is to run a **3-phase motor** on a **single-phase power supply** by creating a **rotating magnetic field** using capacitors.

Running a **three-phase motor** on a **single-phase supply** involves certain challenges because the motor is originally designed to operate with three alternating currents that are 120° apart in phase. However, it is possible to achieve successful operation by using **capacitors** to create a phase shift, enabling the motor to start and run with reasonable efficiency. This setup is often used when only a single-phase supply is available, but the performance of a three-phase motor is desired.

4.3. COST ESTIMATION

Table of Cost Estimation

No	Name	Cost per unit/ Rwf	Quantity	Total cost/ Rwf
1	Distribution Box		1 pc	25,000
2	Supply Cable	2000	5m	10,000
3	Wires	200	3m	600
4	Circuit Breaker		1PC	12,000
5	Cable Fix		1 pc	1,500
6	Signal Lamps	2,000	2 pcs	4,000
7.	Switch		1 pc	2,000
8.	Capacitor		1pc	15,000
9.	Motor		1 pc	180,000
Total				250,100

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.0. Introduction

This chapter provides an overview of the entire project report, including its findings, obstacles, and suggestions for resolving those issues.

5.1. Conclusion

Three-phase motors are widely used in industrial and commercial applications due to their efficiency, reliability, and ability to handle larger loads. However, in many situations, only a single-phase power supply is available, particularly in residential or small-scale industrial settings. This presents a challenge when three-phase motors need to be used in such environments. To address this issue, a common approach is to design a system that allows a three-phase motor to run on a single-phase supply by using capacitors. Capacitors are employed to create a phase shift that simulates the three-phase power needed by the motor. This process, known as phase conversion, enables the motor to start and operate with reasonable efficiency, despite being connected to a single-phase power source. The design involves selecting appropriate capacitors and creating a wiring configuration that generates an artificial third phase from the single-phase input. The capacitor generates the necessary phase difference between the motor windings, allowing the motor to function as if it were connected to a true three-phase supply.

This method of using capacitors to power a three-phase motor from a single-phase supply offers a cost-effective and practical solution in locations where upgrading to a three-phase electrical system is not feasible. However, it comes with trade-offs in terms of efficiency and performance, which need to be carefully considered during the design and implementation phase.

The design and implementation of a three-phase motor using a single-phase supply and a capacitor offer a practical and cost-effective solution in environments where only single-phase power is available. While it can provide adequate performance for small to medium-sized motors, it has inherent limitations, including reduced efficiency and potential wear due to imbalanced phases. The choice of capacitor is crucial, as it directly affects the motor’s startup performance and running stability. This approach is most beneficial when a full three-phase supply is impractical or cost-prohibitive.

5.2. Recommendations

- Researchers have significant opportunities to **improve the design, performance, and reliability** of 3-phase motors powered by single-phase lines with capacitors.
- By addressing key challenges such as **efficiency, current imbalance, and power factor**, future work can make this solution even more practical and versatile. Collaboration with industries, testing in real-world environments, and exploring **new capacitor technologies** will further enhance the impact of this research.
- Implement **adaptive capacitor banks** that adjust capacitance dynamically based on load conditions, improving power factor and efficiency. Collaborate with **local businesses, manufacturing plants, and agricultural cooperatives** to test the performance of this motor design under real-world conditions.
- Explore joint projects with **Rwanda Energy Group (REG)** and **agricultural programs** to provide phase conversion solutions in remote areas.

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