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College of Engineering  
Department of Electrical Engineering



# **A General Controlling Board of Variable Frequency Drive**

A graduation project submitted to the Department of Electrical Engineering, in partial fulfillment for the requirements for the award of the degree of Bachelor of Electrical Engineering

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**Maysan, Iraq**

**2024**

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

((قُلْ هَلْ يُسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لَا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُولُو الْأَلْبَابِ)) (النمر: 9)

صدق الله العلي العظيم

# SUPERVISOR CERTIFICATION

I certify that the preparation of this project entitled (*A General Controlling Board of Variable Frequency Drive*) prepared by (*Sajad Mohammad Ashour ,Mahdi Salih Hassan ,Sajad Jumaa Namah and Ali Dhihad Abdul Hussein*) was under my supervision at **Electrical Engineering Department, University of Misan** in partial fulfilment of the requirements for the degree of Bachelor of Science in **Electrical Engineering**.

**Signature:**

**Supervisor Name:**

**Scientific Degree:**

**Date:**

# CERTIFICATE OF EXAMINERS

We certify, as an examining committee, that we have read this project report entitled "**A General Controlling Board of Variable Frequency Drive**" examined the students (**Sajad Mohammad Ashour ,Mahdi Salih Hassan ,Sajad Jumaa Namah and Ali Dhihad Abdul Hussein**) in its contents and found the project meets the standard for the degree of Bachelor of Science in Electrical Engineering.

Signature:

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# **DEDICATION**

*To my parents and to our family who made this accomplishment possible.*

## ACKNOWLEDGEMENT

*Praise be to ALLAH who enabled us to complete this work under his benediction.*

*Cordial thanks and deepest gratitude to our supervisor (Lec. Mohammad Hassan and Assistance Lec . Rabieh Hadi ) for being assistance and for the continuous encouragement and suggestions from him which helped us to successfully complete this project.*

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*Finally, sincere gratitude and appreciation and love to our families for their encouragements and supports and for all things they have given us.*

## **ABSTRACT**

This study focuses on the development and implementation of a general controlling board for Variable Frequency Drives (VFDs) in industrial applications. The general controlling board serves as a centralized system for monitoring and controlling multiple VFDs, allowing for enhanced efficiency, flexibility, and reliability in industrial processes. The abstract outlines the key objectives and components of the general controlling board, including its design, functionality, and integration with existing systems. It highlights the benefits of centralized control, such as optimized performance, reduced maintenance costs, and improved safety. Furthermore, the abstract discusses potential future enhancements for the general controlling board, including integration with artificial intelligence technologies, development of user-friendly interfaces, and integration with renewable energy sources. Overall, this study provides valuable insights into the development and implementation of a general controlling board for VFDs, offering practical solutions to improve efficiency and productivity in industrial settings.

*Keywords – VFD , Motor Indictor , Delta-Star Connection*

# LIST OF FIGURES

<b>Figure (2.1)</b>	VFD Circuit Diagram	6
<b>Figure (2.2)</b>	Drive Output Waveform Components	8
<b>Figure (2.3)</b>	Simulation Circuit of VFD	10
<b>Figure (3.1)</b>	VFD ZQ300 Series	12
<b>Figure (3.2)</b>	Circuit Breaker 3-Phases	13
<b>Figure (3.3)</b>	Selector (0-2)	15
<b>Figure (3.4)</b>	Delta Star Connections	10
<b>Figure (4.1)</b>	Figure (4.1 ) Block Diagram of proposed system.	18
<b>Figure (4.2)</b>	Front interface of system implementation	19
<b>Figure (4.3)</b>	Rear interface of system implementation	19

# TABLE OF CONTENTS

Dedication	I
Acknowledgement	II
Abstract	III
List of Figures	IV
Table of Contents	V

## **Chapter One: Introduction**

1.1 Introduction	1
1.2 Historical Overview	1
1.3 Problem Statement	2
1.4 Objectives	3
1.5 The Significant of the project	4
1.5 Chapters Layout	4

## **Chapter Two: Principle Of VFD**

2.1 Introduction	5
2.2 VFD Operation	5
2.3 Constant V/F Ratio Operation	7
2.4 How Drive Changes Motor Speed	7
2.5 Advantages of VFD	9
2.6 Simulation Circuit of VFD	9

## **Chapter Three: Main Components of the project**

3.1 Introduction	11
3.2 VFD ZQ300 Series	11
3.3 Circuit Breaker	12

3.4 Indictor Motor	14
3.5 Selector (0-2 )	14
3.6 AC Voltmeters and Ammeter	15
3.7 Delta-Star Connections	15
<b>Chapter Four: Implementation</b>	
4.1 Introduction	17
4.2 Circuit Implemented	17
<b>Chapter Five: Conclusion and Future Work</b>	
5.1 Conclusion	20
5.2 Future Work	21
<b>References</b>	23

# Chapter One

## Introduction

### 1.1 Introduction

A Variable Frequency Drive (VFD) is a sophisticated electronic device used to control the speed and torque of electric motors. It accomplishes this by varying the frequency and voltage of the electrical power supplied to the motor, allowing for precise adjustment of motor speed and acceleration.

At the heart of a VFD is a power conversion system that converts incoming AC power into DC power using rectification, then converts it back into AC power with a controllable frequency and voltage using inversion techniques. This enables seamless control over motor speed and torque, making VFDs an essential tool in industrial automation and process control.

VFDs find extensive use across various industries, including manufacturing, HVAC, water and wastewater treatment, mining, and renewable energy. They are employed in a diverse range of applications such as:

- Controlling conveyor belt speeds in manufacturing facilities.
- Regulating pump speeds for water distribution systems.
- Adjusting fan speeds in HVAC systems for energy efficiency.
- Optimizing compressor operation in industrial processes

### 1.2 Historical Overview

- *1960s-1970s*: The earliest iterations of VFD technology emerged, primarily for industrial applications requiring variable speed control of electric motors. These early systems were often large, cumbersome, and expensive.

- *1980s*: Advancements in semiconductor technology led to the development of more compact and affordable VFDs, expanding their use beyond heavy industry into commercial and residential sectors.
- *Late 1990s*: Digital signal processing (DSP) and microprocessor technology began to be integrated into VFD designs, enhancing control accuracy and reliability.
- *Early 2000s*: VFDs became increasingly sophisticated, with features such as sensorless vector control, regenerative braking, and built-in communication protocols for integration into automation systems.
- *Mid-2000s*: VFDs saw widespread adoption across various industries including manufacturing, HVAC (Heating, Ventilation, and Air Conditioning), water treatment, and renewable energy generation.
- *Late 2000s to Present*: Continued advancements in VFD technology have led to improved energy efficiency, enhanced diagnostics, and greater integration with industrial automation and control systems.

### **1.3 Problem Statement:**

Variable Frequency Drives (VFDs) play a crucial role in controlling the speed and torque of electric motors across various industrial and commercial applications. However, the current state of VFD control boards lacks a unified and versatile solution that can effectively accommodate diverse motor types, communication protocols, and control algorithms. Existing control boards often suffer from limited compatibility, complex configuration processes, and lack of scalability, leading to inefficiencies, increased downtime, and higher maintenance costs, there are a lot of challenges like :

- **Compatibility Issues:** Existing VFD control boards may not support a wide range of motor types and communication protocols, limiting their applicability in diverse industrial environments.
- **Complex Configuration:** Configuring VFD control parameters and settings can be time-consuming and complex, requiring specialized knowledge and expertise.
- **Scalability Constraints:** Scalability is often a challenge with current control boards, making it difficult to expand or modify control systems to accommodate changing operational requirements.
- **Reliability and Maintenance:** Reliability issues and frequent maintenance requirements of existing control boards can lead to unplanned downtime and increased operational costs.
- **Integration Challenges:** Integration with existing automation systems and compatibility with emerging Industry 4.0 technologies pose additional challenges for VFD control boards.

## **1.4 Objectives**

The objective of this research is to design and develop a general controlling board for Variable Frequency Drives (VFDs) that addresses the aforementioned challenges. The proposed controlling board aims to offer:

- **Versatility:** Support for a wide range of motor types, communication protocols, and control algorithms to enhance compatibility and flexibility.
- **Simplicity:** Simplified configuration processes and user-friendly interfaces to reduce setup time and enhance usability.
- **Scalability:** Modular design and expandable architecture to facilitate system scalability and future expansion.

- **Reliability:** Enhanced reliability features and predictive maintenance capabilities to minimize downtime and maintenance costs.
- **Integration:** Seamless integration with existing automation systems and support for Industry 4.0 technologies to enable advanced data analytics and remote monitoring capabilities.

## **1.5 The Significant of the project**

Developing a general control panel for Variable Frequency Drives (VFDs) holds significant importance in the field of industrial automation and process control. By addressing the challenges associated with current control panel solutions, the proposed system can achieve improvements in operational efficiency, reduce maintenance costs, and enhance overall system performance across a variety of industrial applications.

This project is crucial as it aims to provide a comprehensive solution for controlling Variable Frequency Drives (VFDs) in a way that enhances industrial process efficiency and reduces maintenance and operating costs.

## **1.6 Chapters Layout**

- **Chapter One:** Introduction
- **Chapter Two:** Principle of VFD
- **Chapter Three:** Components of the project.
- **Chapter Four:** Design and implement the project
- **Chapter Five:** Conclusion and Future Plan.

# Chapter Two

## Principle Of VFD

### 2.1 Introduction

The Variable Frequency Drive (VFD) sector is growing rapidly and it is now more vital than ever for technicians and maintenance workers to keep VFD installations working properly. Variable Frequency Drives (VFD) vary the speed of motor by changing voltage and frequency of the electricity supplied to the motor. Maintaining the name plate volts/hertz ratio is necessary to prevent excessive heating of the motor and to ensure correct power factor[1] . The primary function of the variable frequency drive is this.

1. Due to its durability and extended lifespan without maintenance, variable frequency drives, or AC drives, are used to steplessly adjust the speed of squirrel cage induction motors, which are primarily employed in process plants.
2. The VFD regulates the motor's speed by adjusting the output voltage and frequency using an advanced microprocessor-controlled electronic device.
3. The inverter and rectifier modules make up the VFD. An inverter changes DC voltage back into AC voltage after a rectifier transforms AC voltage into DC voltage.

### 2.2 VFD Operation

Understanding the three fundamental components of a VFD—the rectifier unit, DC bus, and inverter unit—is necessary to comprehend the fundamental ideas underlying its operation[2] . The three phase supply is fed with a three phase full wave diode, where it is converted from an AC to DC supply[2]. The supply voltage is first passed through a rectifier unit. The DC bus is

equipped with a filter section that removes harmonics produced during the AC to DC conversion. The last component consists of an inverter section which contains with six IGBT (Insulated Gate Bipolar Transistor) where the filtered DC power is being transformed to quasi sinusoidal wave of AC supply which is provided to the induction motor attached to it.

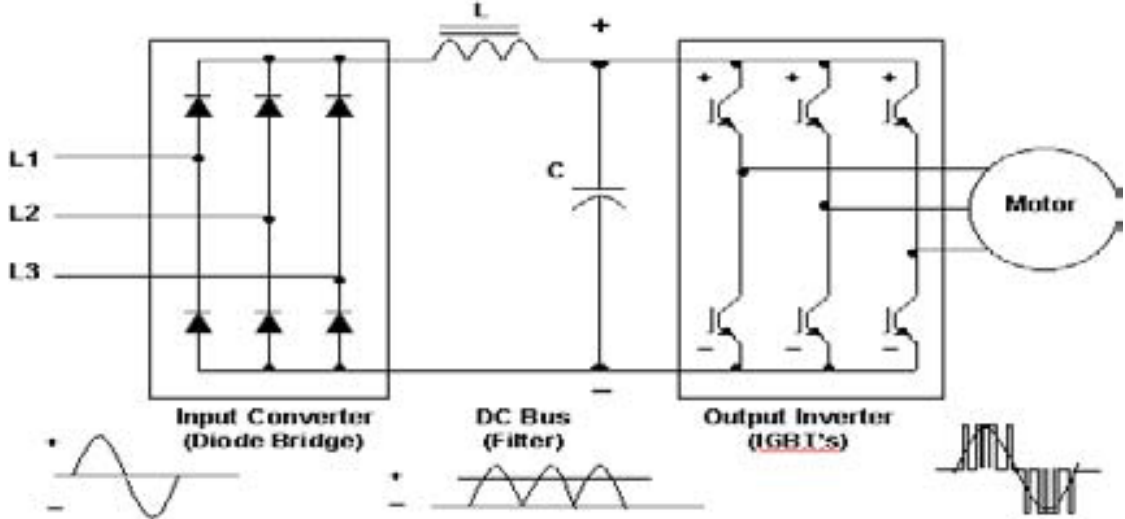


Figure (2.1 ) VFD Circuit Diagram

As is well known, frequency affects a motor's synchronous speed (rpm). Therefore, we may adjust the synchronous motor speed by changing the power supply's frequency using a VFD:

$$Speed (rpm) = \frac{Frequency (HZ) * 120}{No. of Poles}$$

where frequency is equal to the power supply's electrical frequency in hertz (Hz).

No. of Poles is the motor stator's total number of electrical poles.

As a result, we can easily change a motor's speed by altering the frequency that it receives. Changing the number of poles on the motor is another method of adjusting its speed; however, this would require physically altering the motor. Pulse width modulation drives allow a motor's speed to be adjusted by providing the output voltage and frequency required. An inverter that uses pulse width modulation (PWM) generates pulses with

different widths that are combined to create the desired waveform. adjusted Frequency Drives (VFDs) are speed control drives because the frequency is more easily adjusted than the motor's poles.

### **2.3 Constant V/F Ratio Operation**

For the following reason, all Variable Frequency Drives (VFDs) keep the output voltage-to-frequency (V/f) ratio constant at all speeds[3]. The motor's phase voltage  $V$ , frequency  $f$ , and magnetic flux  $\phi$  are connected by the following equation:-

$$V = 4.444 f N \phi_m$$

Or

$$V/f = 4.444 N \phi_m$$

Where  $N$  = number of turns per phase.

$$\phi_m = \text{magnetic flux}$$

The motor performance would be severely distorted if the same voltage was applied at the lower frequency because the magnetic flux would rise and saturate the magnetic core. By maintaining a constant  $\phi_m$ , it is possible to avoid the magnetic saturation.

Furthermore, the product of rotor current and stator flux determines the motor torque. The constant flux needs to be kept at its specified value in order to maintain the rated torque at all speeds[4] . This is essentially accomplished by maintaining a constant voltage-to-frequency (V/f) ratio. In order to prevent magnetic saturation caused by high flux or lower than the rated torque caused by low flux, the motor voltage must be lowered in the same proportion as the frequency.

### **2.4 How Drive Changes Motor Speed**

Pulse width modulation drives allow a motor's speed to be adjusted by

providing the output voltage and frequency required. The necessary waveform is constructed by combining pulses of different lengths produced by a pulse width modulation (PWM) inverter.

Certain converters employ a diode bridge to lower harmonics. PWM lessens unwanted heating by creating a current waveform that more closely resembles a line source[2]. PWM drives have power factors that are almost constant—that is, very close to unity—at all speeds. PWM devices provide the ability to run many motors on a single drive.

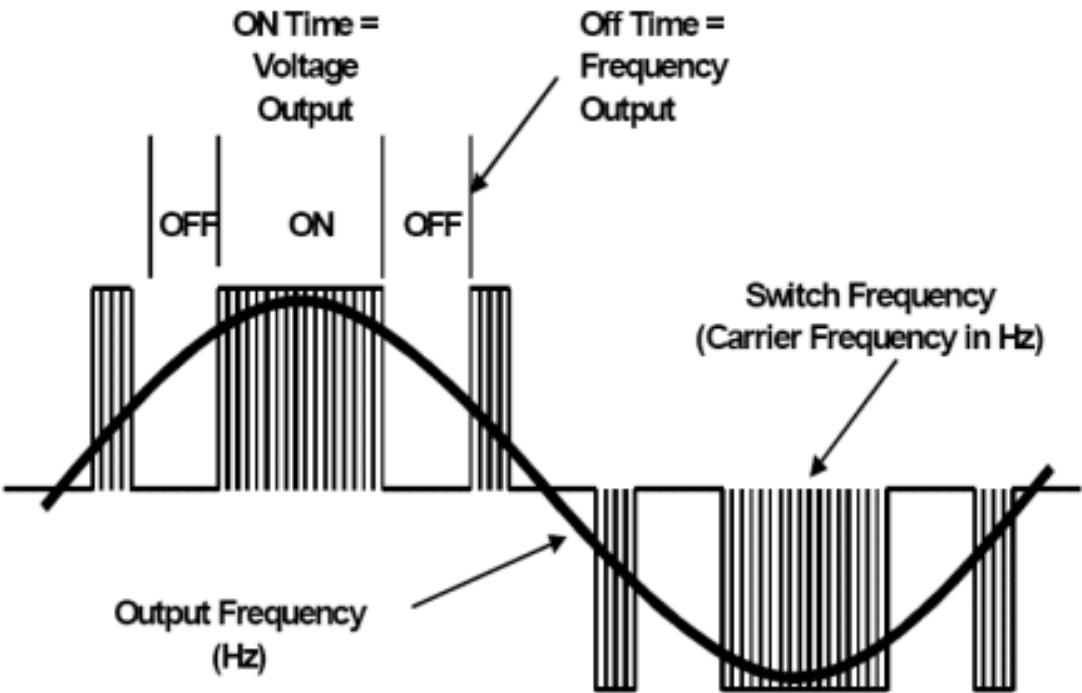


Figure (2.2) Drive Output Waveform Components

As a result, the power device switch's ON/OFF speed determines the carrier frequency. Another name for it is switch frequency. Therefore, PWM (Pulse Width Modulation) has more resolution the higher the carrier frequency. Compared to the previous SCR-based carrier frequency, which ranged from 250 to 500 times per second, the usual carrier frequency varies from 3 KHz to 4 KHz, or 3000 to 4000 times per second. Thus, it is evident that the output waveform's resolution increases with carrier frequency. It is also observed that the carrier frequency reduces the drive's efficiency by raising the drive

circuit's temperature.

## **2.5 Advantages of VFD**

1. Significant energy savings at reduced speeds.
2. Longer-lasting spinning parts as a result of slower operation.
3. A lower volume of vibration and noise.
4. Reduction of mechanical and thermal strains.
5. Reduced KVA
6. Elevated power factor

## **2.6 Simulation Circuit of VFD:**

Power electronics switches with forced commutation, such as IGBTs, MOSFETs, and GTO, are used. Pulse Width Modulation (PWM) feeds the asynchronous machine with newer techniques like Voltage Sourced Converters (VSC) replacing older ones like the DC motor and Thyristor Bridge[5]. Combining pulse width modulation with contemporary control techniques like field-oriented approach or direct torque control methods can yield the same flexibility in speed and torque control as a DC machine. This section describes a simulation of an AC drive operating an asynchronous machine.

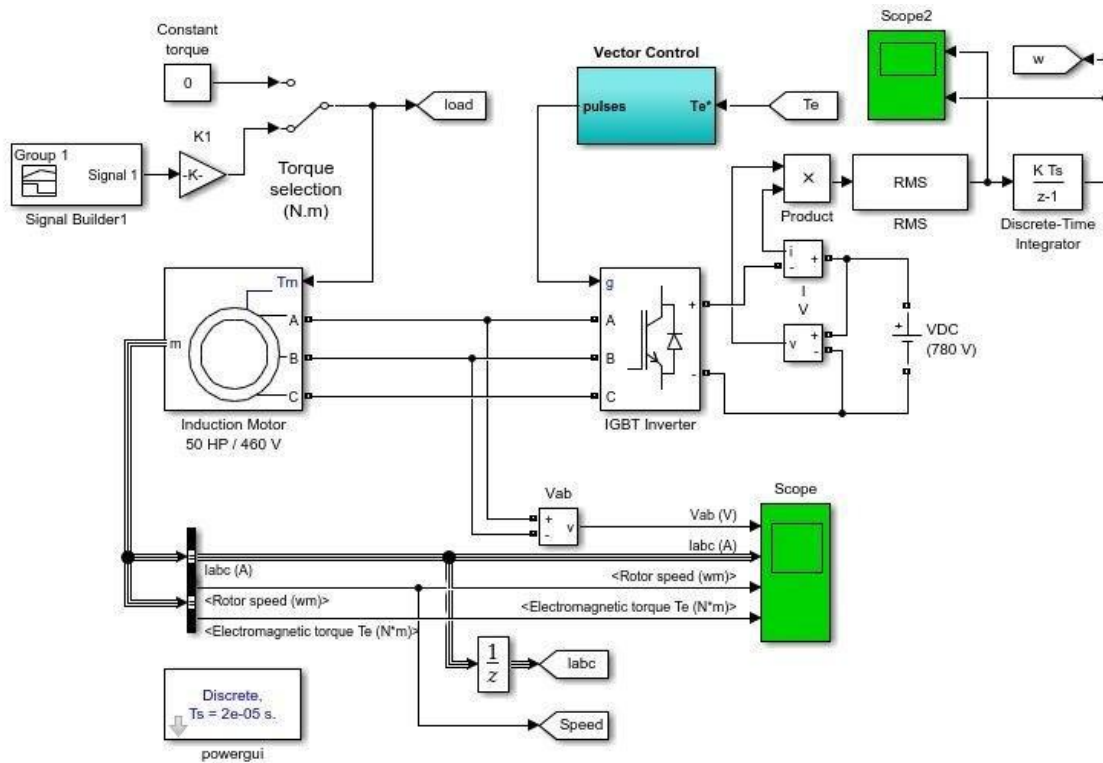


Figure (2.3 ) Simulation Circuit of VFD

The four most prevalent three-phase machines in the simulation library are the permanent magnet synchronous machine, the simplified and full synchronous machine, and the asynchronous machine. The machine below has two modes of operation: generating mode and driving mode.

When connected with linear and nonlinear components like transformer line loads, breakers, etc., these machines may be used to imitate electromechanical transients in an electrical network. When paired with power electronics devices, they can be used to simulate drives. The simulation's power electronics library includes GTO, MOSFET, IGBT, thyristors, and diodes. Three Phase Bridges were created by connecting these various blocks to one another [3] . Using the Pulse Width Modulation (PWM) approach, an inverter is used to simulate a 3 HP, 4 pole motor. Using the PWM approach, the output voltage's frequency and amplitude may be adjusted. The motor speed is then controlled by these adjusted voltage and frequency.

# **Chapter Three**

## **Main Components of The project**

### **3.1 Introduction**

We have used multiple elements in our project to achieve the best results

### **3.2 VFD ZQ300 Series**

ZQ300 is a high-performance inverter with ZEST ELECTRIC that integrates vector frequency conversion technology.

With high-performance current vector technology, it can easily drive induction motors. The technical and performance problems encountered so far in equipment such as cables, machine tools, metal products, petrochemicals, natural gas, lifting equipment, pulp and paper, textiles, printing and dyeing, ceramics and other industries can be easily solved.

High performance, high quality, high power density design, and significant improvements in ease of use, maintainability, environmental protection, installation space and design standards can further optimize the user experience[6].



Figure (3.1 ) VFD ZQ300 Series

### 3.2 Circuit Breaker

A circuit breaker is an essential component in electrical systems that helps protect circuits and electrical equipment from overloads, short circuits, and faults. A 3-phase circuit breaker, specifically, is designed to handle three-phase electrical power , which is commonly used in industrial and commercial applications.



Figure (3.2 ) Circuit Breaker 3-Phases

A 3-phase circuit breaker serves to interrupt the flow of current in a circuit when abnormal conditions, such as overloads or short circuits, occur. It ensures the safety of electrical systems and equipment by quickly disconnecting power when necessary to prevent damage or hazards.

Inside a 3-phase circuit breaker, there are contact points that open and close to control the flow of current. These contacts are typically made of copper or other conductive materials. The circuit breaker includes a trip mechanism that detects abnormal conditions in the circuit, such as excessive current flow, and triggers the contacts to open and interrupt the circuit. When the contacts open, an arc may form between them due to the electrical current. The circuit breaker contains mechanisms to extinguish this arc safely, such as arc chutes or arc extinguishing chambers. The circuit breaker can be manually operated or automatically tripped by sensing devices such as thermal or magnetic sensors [7].

### **3.4 Indictor Motor :**

A three-phase induction motor is a type of electric motor widely used in industrial and commercial applications due to its robustness, reliability, and efficiency. It operates on the principle of electromagnetic induction, where a rotating magnetic field is produced within the motor by the flow of alternating current (AC) through its stator windings.

When connected to a three-phase AC power supply, the stator windings generate a rotating magnetic field that induces a current in the rotor[8]. This induced current creates a second magnetic field in the rotor, which interacts with the stator's magnetic field, causing the rotor to rotate. The speed of rotation, known as the synchronous speed, is determined by the frequency of the AC power supply and the number of poles in the motor. Three-phase induction motors offer numerous advantages, including high reliability, low maintenance requirements, and wide-ranging torque and speed capabilities. They are utilized in various applications, including pumps, fans, compressors, conveyors, and machine tools across industries such as manufacturing, HVAC, water treatment, and agriculture.

A three-phase induction motor used for a period of two hours combines the robust performance of induction motors with the flexibility of temporary operation to fulfill specific industrial or commercial requirements efficiently.

### **3.5 – Selector (0-2 )**

Three-phase induction motors offer numerous advantages, including high reliability, low maintenance requirements, and wide-ranging torque and speed capabilities. They are utilized in various applications, including pumps, fans, compressors, conveyors, and machine tools across industries such as manufacturing, HVAC, water treatment, and agriculture.

In summary, a three-phase induction motor used for a period of two hours combines the robust performance of induction motors with the flexibility of

temporary operation to fulfill specific industrial or commercial requirements efficiently.



Figure (3.3) Selector (0-2)

### **3.6 AC Voltmeters and Ammeter**

AC voltmeters and AC ammeters are indispensable tools for electrical engineers, technicians, and professionals working with AC electrical systems. They provide accurate measurements of voltage and current, enabling users to analyze, monitor, and maintain electrical circuits effectively. Whether in analog or digital form, these instruments play a vital role in ensuring the safety, efficiency, and reliability of AC power systems.

### **3.7 Delta-Star Connections**

Delta-Star Connection, also known as Delta-Wye Connection, is a type of electrical connection used to connect three-phase motors to Variable Frequency Drives (VFDs). This type of connection enables balancing of current, voltage, and power in electrical circuits[9]

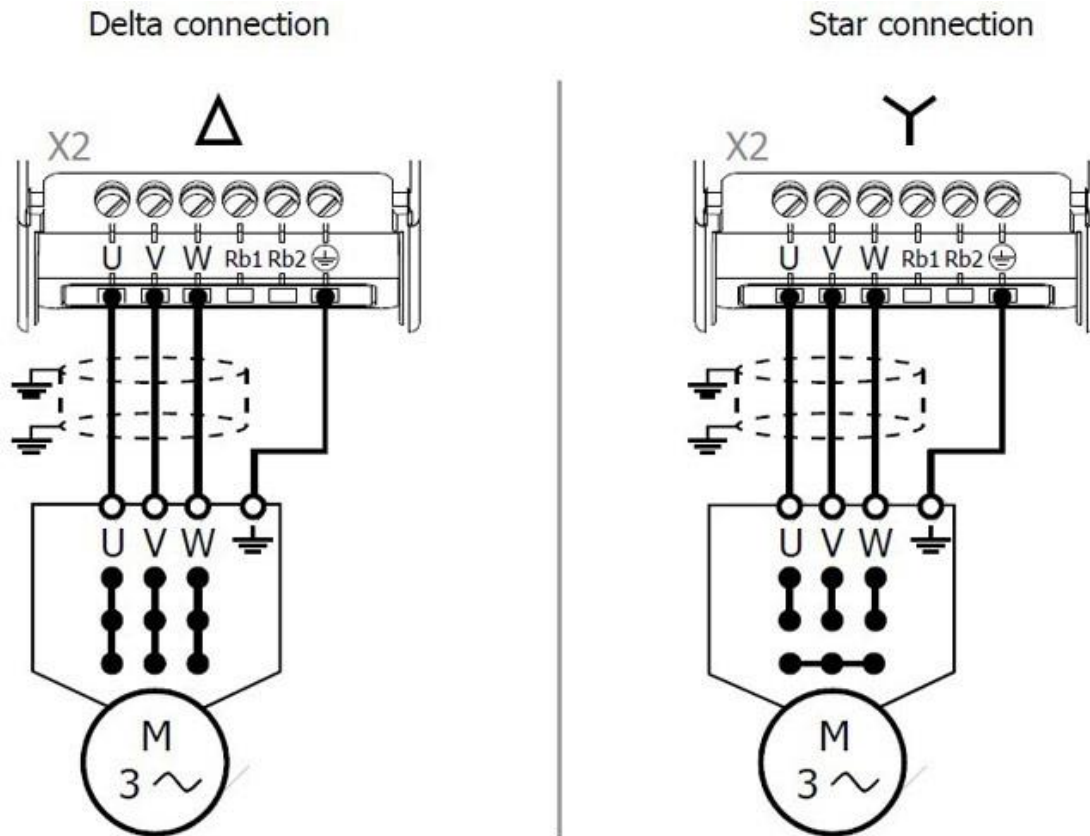


Figure (3.4 ) Delta Star Connections

In Delta connection, each terminal of each motor winding is connected to another terminal of another winding, forming a closed loop. Delta connection results in balanced phase currents, and the motor operates with higher current than rated current when using this connection. In Star connection, each terminal of the motor is connected to a common central point called the "Y point"[10]. Star connection results in balanced phase voltages, and the motor can operate with lower current than rated current when using this connection. Delta-Star connection is used with VFDs to provide better balance between phase currents, voltages, and power[11]. This connection allows VFDs to use lower voltages than three-phase AC motors, helping to reduce power losses and improve system efficiency.

# Chapter Four

## Implementation

### 4.1 Introduction

In our work, we have used many elements like ( VFD , Circuit Breaker , light bulb , Push Button ( 2 On, 1 Off ) , AC Voltmeter and Ammeter , Selectors ,wires and Indicator Motor.

### 4.2 Circuit Implemented

In the circuit setup described, a circuit breaker is used to supply power to the control board. The Variable Frequency Drive (VFD) receives its power from a single-phase line and provides three output terminals. These terminals are connected to the motor in either a delta ( $\Delta$ ) or star (Y) configuration, depending on the motor's wiring.

The motor's rotation direction is controlled using additional outputs from the VFD labeled x1, x2, and com. These outputs determine whether the motor rotates forward or backward. Typically, x1 is connected to initiate forward rotation, while x2 is connected to initiate reverse rotation. The com terminal serves as a common connection point.

To control the motor's rotation direction, a selector switch is used. The selector switch allows the user to choose between forward, reverse, or off positions. Depending on the position selected, the switch connects either the x1 or x2 terminal to the motor's input terminals, thus determining the motor's rotation direction.

Additionally, the com terminal can be used for motor operation or shutdown. By connecting this terminal to the appropriate control circuitry, the motor can be turned on or off as needed.

Overall, this setup allows for precise control over the motor's rotation direction and operation, enhancing the flexibility and functionality of the

system.

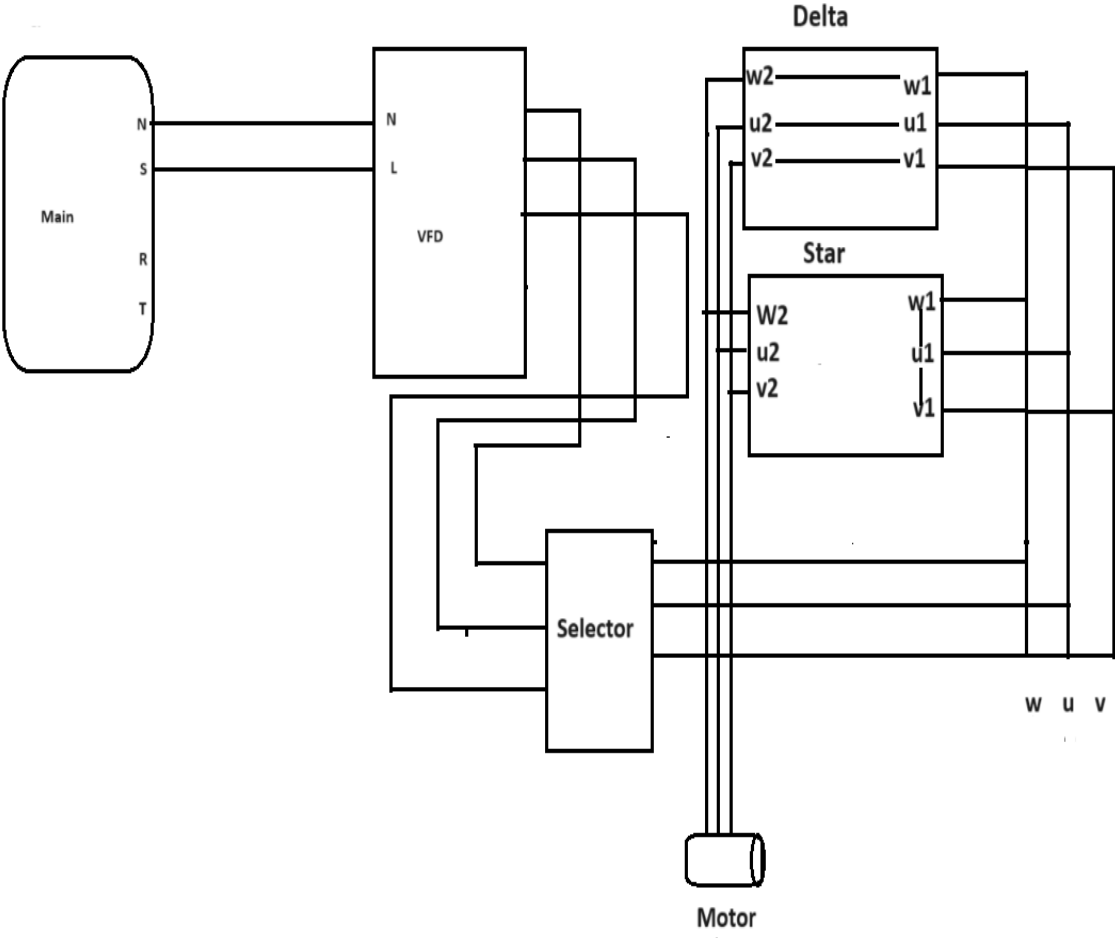


Figure (4.1 ) Block Diagram of proposed system

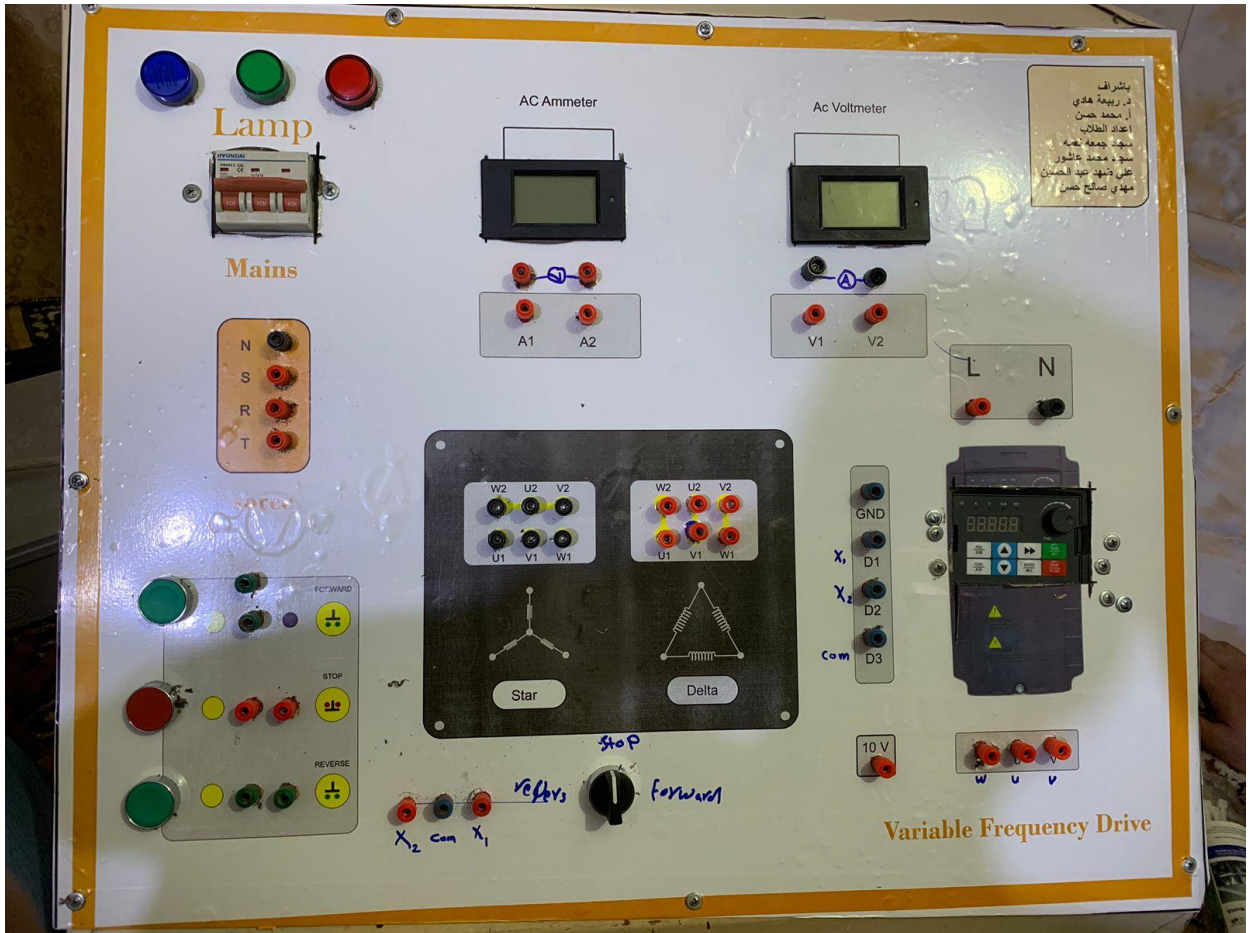


Figure (4.2) Front interface of system implementation

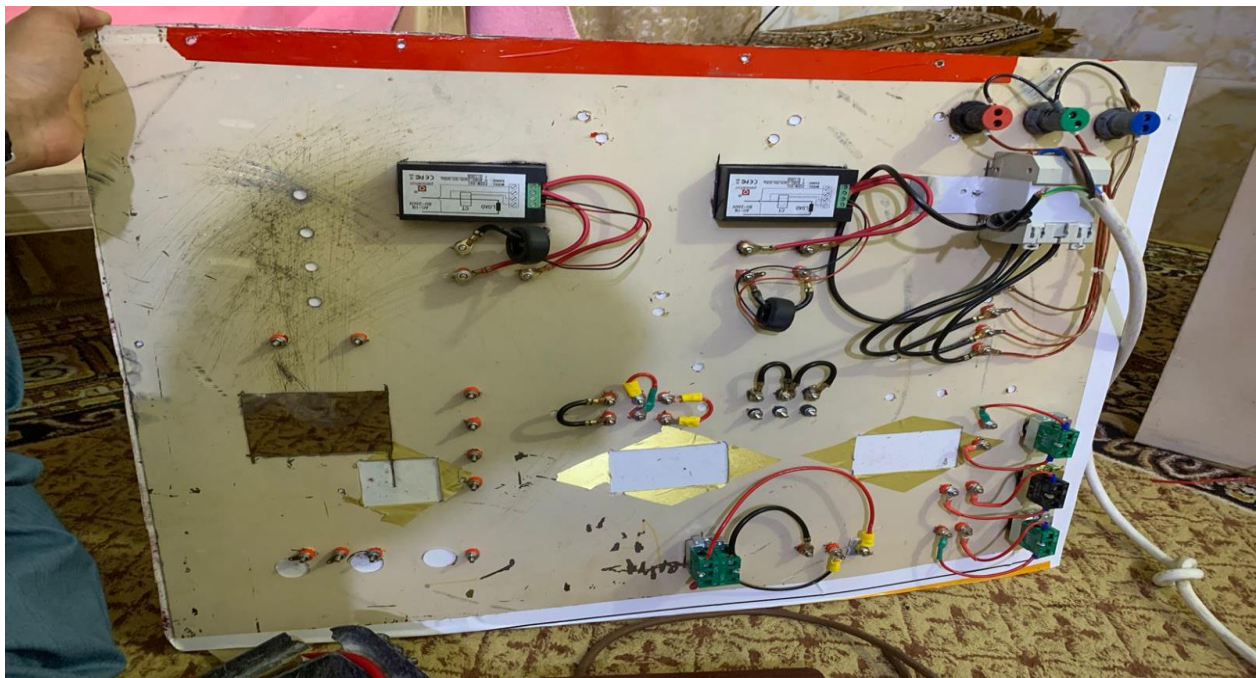


Figure (4.3) Rear interface of system implementation

# Chapter Five

## Conclusion and Future Work

### 5.1 Conclusion

In conclusion, the implementation of a general controlling board for Variable Frequency Drives (VFDs) offers numerous benefits for industrial applications. Enhanced control is achieved through centralization, allowing for precise monitoring and adjustment of various parameters such as motor speed, current, and voltage. This level of control enables operators to optimize performance and efficiency.

Additionally, the board provides flexibility in controlling individual or groups of VFDs, allowing for tailored adjustments to meet specific operational requirements. This adaptability ensures compatibility with various motor configurations and operating conditions.

Moreover, by optimizing operating parameters and responding to changing load conditions, the controlling board enhances overall system performance. This leads to increased productivity, reduced downtime, and improved product quality.

Furthermore, the ability to monitor and control VFDs centrally helps reduce energy consumption, minimize maintenance costs, and extend equipment lifespan, contributing to a more sustainable and economical operation.

Lastly, the implementation of advanced monitoring and protection features enhances safety and reliability in industrial environments. Alarms and shutdown protocols ensure timely responses to potential faults, minimizing risks to personnel and equipment.

Overall, a general controlling board for Variable Frequency Drives offers a comprehensive solution for optimizing motor control and enhancing operational efficiency in industrial settings.

## 5.2 Future Work

As a future plan, we propose several enhancements to further develop the general controlling board for Variable Frequency Drives (VFDs):

- **Integration with Artificial Intelligence Technologies:** Explore the application of advanced AI techniques like machine learning and big data analytics to improve the control panel's performance. This could involve leveraging AI for better maintenance predictions and continuous performance analysis.
- **User Interface Development:** Enhance the user interface to be more intuitive and efficient. This could include features such as interactive graphs and customizable control panels for a comprehensive view of system performance.
- **Software and Smart Applications Development:** Develop mobile apps and smart software for remote system control and easy monitoring of transformer performance. Consider incorporating features like mobile notifications for early issue alerts.
- **Integration with Renewable Energy Technologies:** Explore how the control panel can integrate with renewable energy sources like solar and wind power to enhance energy efficiency and reduce environmental impact.
- **Enhancement of Security and Protection Technologies:** Improve security features to ensure system and data safety. This could involve implementing encryption and two-factor authentication for enhanced access control.
- **Continuous Improvement and User Engagement:** Continuously improve the control panel based on user feedback. Organize training sessions and workshops to educate users about new features and their effective usage.

Implementing these enhancements can significantly improve the efficiency and effectiveness of the general controlling board for VFDs across various application areas.

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