

Design Of Full Bridge Cyclo-Converter for Speed Control of Single-Phase Induction Motor Using IOT

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Abstract— This project presents the design and implementation of a cycloconverter-based speed control system for a single-phase induction motor using thyristor switching. Conventional induction motors operate at constant speed when supplied with fixed frequency AC power, making speed control difficult. To overcome this limitation, a cycloconverter is used to convert fixed-frequency AC input into variable-frequency AC output without an intermediate DC stage.

The proposed system utilizes a full-bridge cycloconverter circuit using SCRs (Silicon Controlled Rectifiers), which are triggered using a microcontroller from the 8051 family. The microcontroller generates firing pulses synchronized with the input AC supply using a zero-cross detection circuit. By controlling the firing sequence of SCRs, the system produces output frequencies such as F , $F/2$, $F/3$, and $F/4$, enabling effective control of motor speed.

The system also incorporates IoT-based control using an ESP32 module, which allows remote operation through a mobile interface. The ESP32 communicates with the microcontroller and controls both the power supply (via relay module) and operating modes. This enhances the flexibility and usability of the system by enabling wireless monitoring and control. The output waveforms obtained from the cycloconverter are stepped in nature and contain harmonic distortion; however, they are suitable for applications such as motor speed control. The performance of the system is validated through waveform analysis, frequency variation, and motor speed observations. The results confirm that the speed of the motor varies proportionally with the supply frequency.

The proposed system is simple, cost-effective, and suitable for low-speed applications. The integration of IoT further improves the system by enabling smart control and automation. This project demonstrates an effective approach for AC motor speed control using power electronics and embedded systems.

Index Terms— Cycloconverter, Single-Phase Induction Motor, Speed Control, Thyristor (SCR), 8051 Microcontroller, IoT-Based Control

II. INTRODUCTION

In modern power electronics, controlling the speed of induction motors is an important requirement in both industrial and domestic applications. Conventional induction motors are designed to operate at a constant speed determined by the supply frequency. However, many applications require variable speed operation, which cannot be achieved directly using a fixed-frequency AC supply.

To overcome this limitation, power electronic converters such as cycloconverters are used. A cycloconverter is a device that converts AC power at one frequency directly into AC power at another lower frequency without using an intermediate DC link. This makes the system more efficient and reduces circuit complexity.

In this project, a thyristor-based full bridge cycloconverter is used to control the speed of a single-phase induction motor. The system uses Silicon Controlled Rectifiers (SCRs) arranged in a dual bridge configuration to generate variable frequency output. The output frequency is controlled by switching sequences of SCRs, which are triggered using pulses generated by a microcontroller.

The block diagram (shown in your image) consists of:

- Transformer and rectifier for power supply
- Voltage regulator for stable DC supply
- 8051 micro-controllers for control logic
- Opto-isolator for isolation and zero-cross detection

- Dual SCR bridge for AC-AC conversion
- Induction motor as load

The 8051 microcontroller plays a crucial role in this system. It generates triggering pulses for SCRs based on the selected mode using slide switches. Different frequency outputs such as F, F/2, F/3, and F/4 are generated, which directly control the motor speed.

Opto-isolators are used to provide electrical isolation between the low-power control circuit and high-power SCR circuit, ensuring safety and reliable operation. Zero-cross detection helps in synchronizing the firing pulses with the AC waveform.

Thus, the project demonstrates an effective and economical method for controlling the speed of a single-phase induction motor using a microcontroller-based cycloconverter system.

III. LITERATURE REVIEW

Several researchers have worked on cycloconverters and motor speed control techniques. A summary of important contributions is given below:

1. Early research focused on thyristor-based cycloconverters, where phase control techniques were used to generate variable frequency output. These systems were mainly used in high-power

industrial applications like rolling mills and traction systems.

2. Researchers later introduced dual bridge cycloconverter configurations, which improved output waveform quality and allowed bidirectional power flow.
3. With the advancement of digital electronics, studies were conducted on microcontroller-based cycloconverters, where controllers such as 8051, PIC, and AVR were used for generating precise firing pulses.
4. Some works focused on zero-cross detection techniques, which improved synchronization of SCR triggering with AC supply, reducing harmonics and improving efficiency.
5. MATLAB/Simulink-based studies were carried out to analyze waveform characteristics, harmonic distortion, and system performance before hardware implementation.
6. Recent research has also explored PWM-based AC-AC converters and matrix converters, which offer better waveform quality but are more complex and costly compared to traditional cycloconverters.

These studies highlight that microcontroller-based cycloconverters provide a cost-effective and efficient solution for low-power motor control applications.

IV. METHODOLOGY

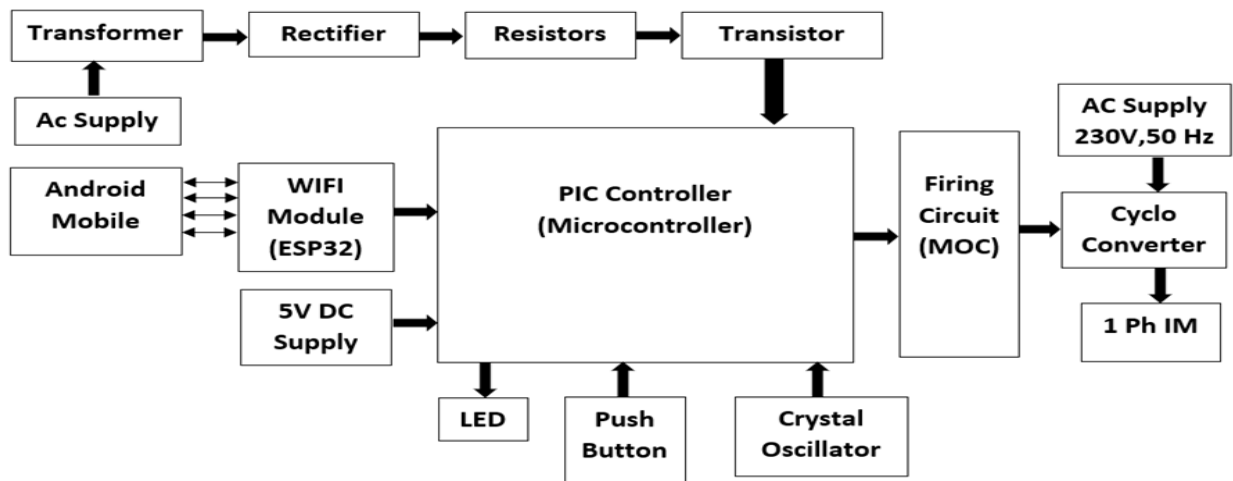


Figure 1: - Block Diagram of Proposed System

A. Block Diagram and Working

The proposed system integrates power electronics and embedded control to achieve efficient speed control of a single-phase induction motor using a cycloconverter.

The block diagram consists of power supply units, control circuitry, communication modules, and the main power conversion stage.

1. Power Supply Section

The system is powered by a 230V, 50Hz AC supply. This AC input is first fed into a transformer, which steps down the voltage to a safer level. The reduced AC voltage is then converted into DC using a rectifier. The rectified output is filtered using resistors and associated components to obtain a stable DC voltage. A transistor-based regulation stage ensures proper voltage levels before supplying it to the PIC microcontroller and other low-power components. Additionally, a regulated 5V DC supply is provided specifically for the microcontroller and peripheral devices.

2. Control Unit (PIC Microcontroller)

The PIC microcontroller acts as the central control unit of the system. It is responsible for generating control signals for the cycloconverter based on user input and programmed logic.

1. A crystal oscillator provides the required clock signal for precise timing and synchronization.
 2. A push button is used for manual control or mode selection.
 3. An LED indicator is used to display system status.
- The microcontroller processes inputs and generates firing pulses for switching devices in the cycloconverter.

3. Wireless Communication Module

An ESP32 WIFI module is interfaced with the PIC microcontroller to enable wireless control.

1. The system can be operated using an Android mobile device.

2. Commands sent from the mobile are received via WIFI and processed by the controller.

3. This allows remote adjustment of output frequency and motor speed.

4. Firing Circuit (MOC)

The output signals from the PIC microcontroller are given to a firing circuit using MOC (opto-isolator).

1. It provides electrical isolation between low-power control and high-power circuit.
2. It ensures safe triggering of thyristors in the cycloconverter.
3. Proper synchronization of firing pulses is achieved for accurate control.

5. Cycloconverter Unit

The cycloconverter is the main power conversion stage. It directly converts fixed-frequency AC input into variable frequency AC output without an intermediate DC stage.

1. Thyristors are triggered in a specific sequence to produce a lower frequency output.
2. The firing angle control determines the output waveform and frequency.

6. Load (Single-Phase Induction Motor)

The output of the cycloconverter is supplied to a single-phase induction motor (1 Ph IM).

1. By varying the output frequency, the speed of the motor is controlled.
2. This method is efficient for low-speed, high-torque applications.

Circuit Diagram

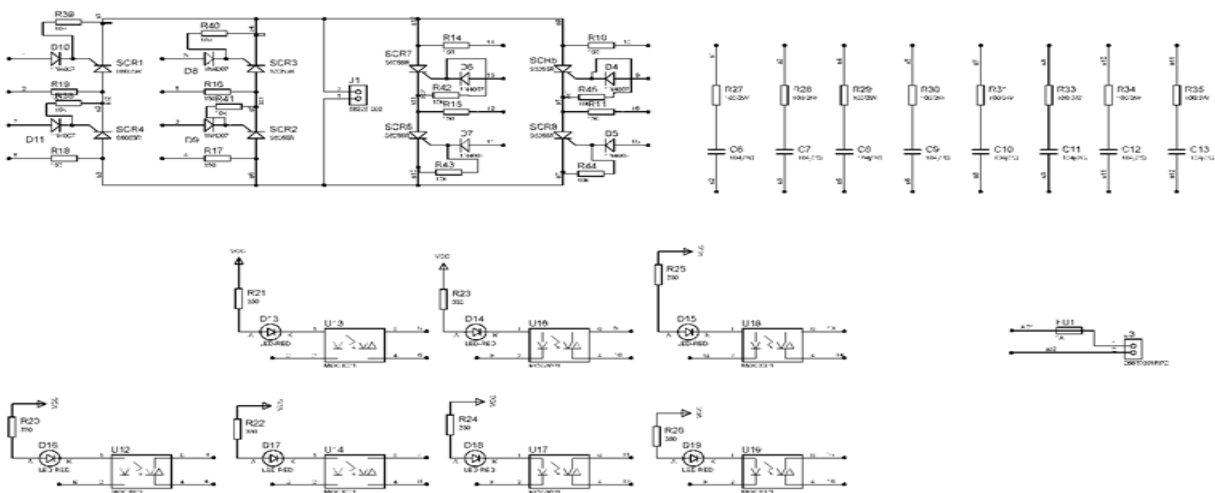


Figure 2: - Schematic Diagram of Control Circuit

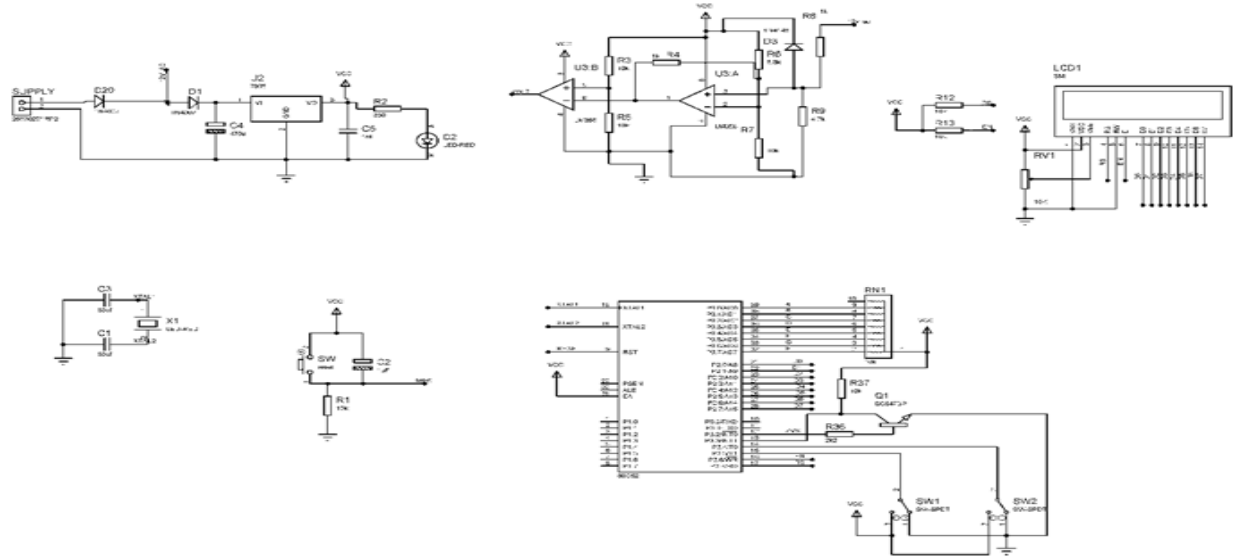


Fig 3: - Schematic Diagram of Power Circuit (Cycloconverter)

The complete system is divided into two main sections: the control circuit and the power circuit, interconnected through opto-isolators to ensure electrical isolation between low-voltage and high-voltage components.

The control circuit includes a regulated power supply, zero-crossing detection, microcontroller unit, and driver circuitry. The AC input is converted into 5V DC using a rectifier, filter, and voltage regulator to power the control components. A zero-crossing detector synchronizes the microcontroller with the AC supply. The microcontroller (AT89S52) processes inputs and generates firing pulses, which are amplified using a transistor driver and passed through opto-isolators for safe triggering.

The power circuit consists of a full-bridge cycloconverter using SCRs. These SCRs are triggered in a controlled sequence to convert fixed-frequency AC into variable-frequency AC. Snubber circuits are used to protect the SCRs from voltage spikes. The output is supplied to a single-phase induction motor, whose speed is controlled by varying the output frequency.

Additionally, an ESP32-based IoT module enables wireless control. It communicates with a mobile application to switch the system ON/OFF and select operating modes (F, F/2, F/3, F/4). This replaces manual control and enhances system flexibility and user convenience.

B. System Design

1. Hardware Design

The hardware design of the proposed system is divided into three major parts: the control unit, power conversion unit, and IoT interface. The control unit is centered around a microcontroller (AT89S52 or PIC), which acts as the brain of the system. It is powered by a regulated 5V DC supply derived from a step-down transformer, bridge rectifier, filter capacitors, and a voltage regulator. A crystal oscillator is connected to provide a stable clock signal for precise operation, while push buttons are used for manual input and LEDs are used for status indication.

The firing and interfacing circuit includes transistor drivers and opto-isolators (MOC series), which provide electrical isolation between the low-voltage control circuit and the high-voltage power circuit. These components ensure safe and reliable triggering of power devices. The power circuit consists of a full-bridge cycloconverter implemented using SCRs (thyristors). These SCRs are arranged in such a way that they can generate both positive and negative half cycles of the output waveform. Snubber circuits, consisting of resistors and capacitors, are connected across the SCRs to protect them from voltage spikes and switching transients.

The cycloconverter receives a fixed 230V, 50Hz AC input and converts it into a variable frequency AC output, which is supplied to a single-phase induction motor. By controlling the firing sequence of the SCRs,

the frequency and voltage of the output can be varied, thereby controlling the speed of the motor.

In addition to the conventional hardware, an IoT module (ESP32) is integrated into the system to enable wireless control. The ESP32 is interfaced with the microcontroller and a relay module. The relay is used to switch the main power supply ON or OFF remotely. The ESP32 receives commands from a mobile device over WIFI and forwards appropriate control signals to the microcontroller, eliminating the need for manual switches.

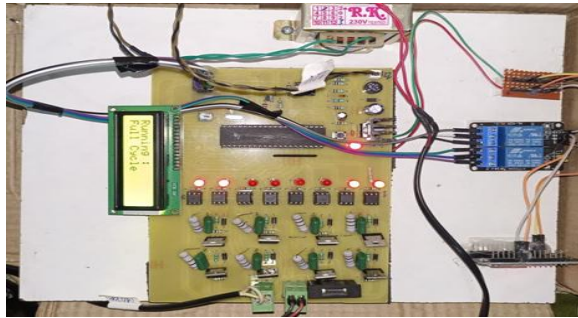


Figure 4: - Hardware implementation of IoT-based cycloconverter for speed control of single-phase induction motor

2. Software Design

The software design of the system includes programming of both the microcontroller and the IoT module. The microcontroller is programmed using Embedded C language with development tools such as

Keil (for 8051) or MPLAB (for PIC). The program is designed to generate precise firing pulses for the SCRs based on the input AC waveform. Synchronization is achieved using signals from the zero-crossing detection circuit, ensuring that switching occurs at the correct instants.

The microcontroller software also handles mode selection and system control. Different operating modes such as F, F/2, F/3, and F/4 are implemented by controlling the firing sequence and timing of SCRs. The program continuously monitors input signals from switches or the IoT module and updates the output accordingly. Proper delay routines and interrupt mechanisms are used to maintain accurate timing and reliable performance.

The IoT module (ESP32) is programmed using the Arduino IDE. It connects to a WIFI network and communicates with a mobile application or web interface. The ESP32 receives user commands such as speed selection and power control. Based on these commands, it performs two main functions: controlling the relay for switching the system ON/OFF and sending digital signals to the microcontroller for mode selection.

The integration of embedded programming and IoT technology enables real-time control, remote accessibility, and automation of the system. This improves flexibility, reduces manual intervention, and enhances overall system performance.

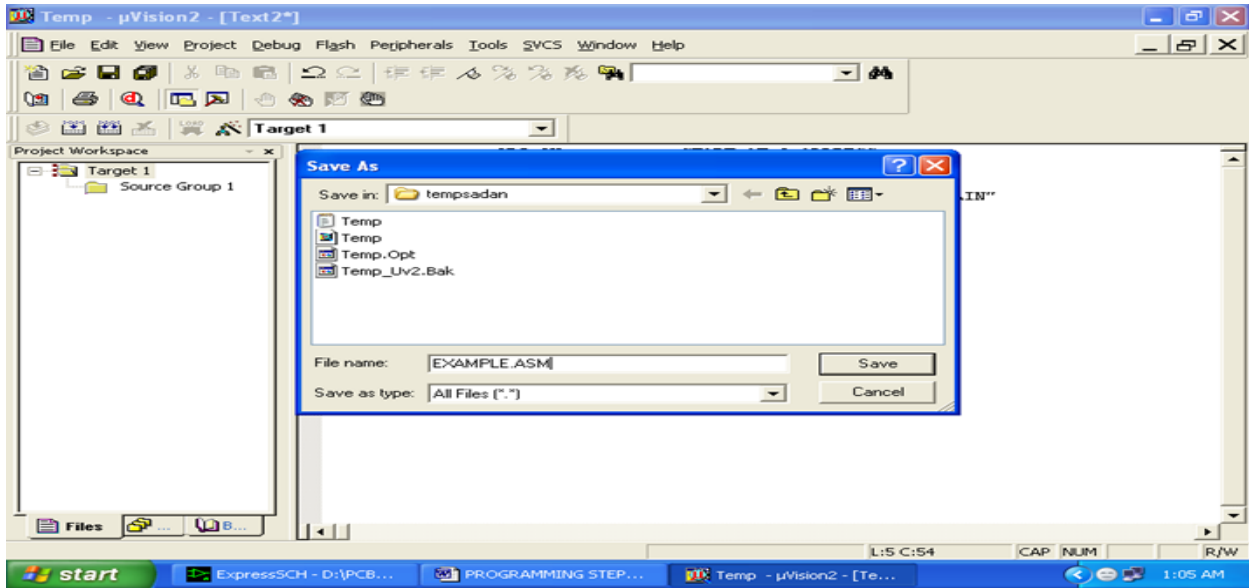


Figure 5: - Keil µVision environment used for programming the 8051 microcontrollers (AT89S52) for cycloconverter control

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FINAL_CODE_IOT | Arduino IDE 2.16
File Edit Sketch Tools Help
Select Board
FINAL_CODE_IOT.ino
12 #include <WiFi.h>
13 #include <WiFiClient.h>
14 #include <BlynkSimpleEsp32.h>
15
16 // Removed LCD code
17
18 // Relay pin definitions
19 #define RELAY1_PIN 18
20 #define RELAY2_PIN 19
21
22 char ssid[] = "project";
23 char pass[] = "raspberry";
24 BlynkTimer timer;
25
26 // Helper function to update status on V2
27 void updateStatus() {
28   int r1 = digitalRead(RELAY1_PIN); // HIGH=off, LOW=on
29   int r2 = digitalRead(RELAY2_PIN);
30   String status = "";
31
32   if (r1 == HIGH && r2 == HIGH) {
33     status = "Running: Full Cycle";
34   } else if (r1 == LOW && r2 == LOW) {
35     status = "Running: f/4 Cycle";
36   } else if (r1 == LOW) {
37     status = "Running: f/3 Cycle";
38   } else if (r2 == LOW) {
39     status = "Running: f/2 Cycle";
40   } else {
41     status = "Unknown";
42   }
43 }
    
```

Figure 6: - Arduino IDE program for ESP32 showing WIFI connectivity, relay control, and IoT-based mode selection logic

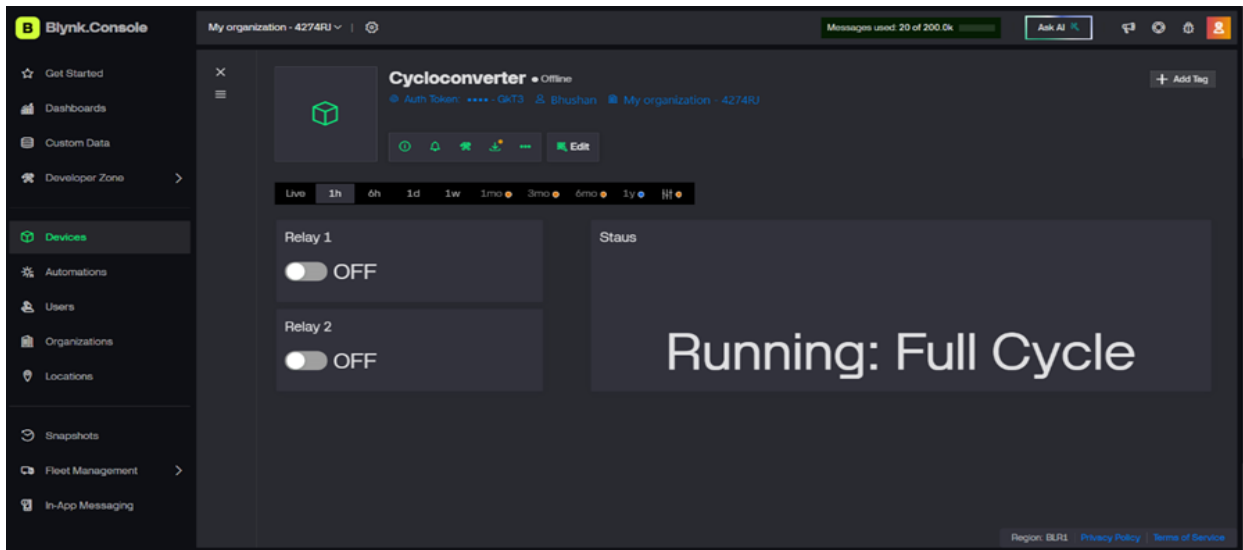


Figure 7: - Blynk IoT dashboard interface showing relay control and system status (Full Cycle mode)

C. Input & Output Waveforms

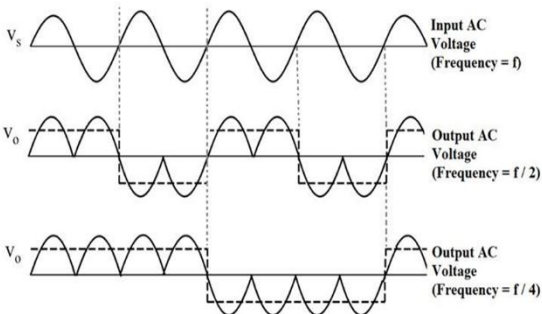


Figure 7: - Cycloconverter input-output waveforms

V. ADVANTAGES

1. Direct AC-to-AC conversion reduces circuit complexity and eliminates the need for an intermediate DC stage.
2. Improved efficiency due to reduced power conversion losses.
3. Provides smooth and precise speed control of the induction motor.
4. Simple and compact design makes the system easy to implement.

5. Reliable operation using SCR-based switching devices.
6. Opto-isolators ensure safe electrical isolation between control and power circuits.
7. Cost-effective solution using easily available components.
8. IoT integration enables remote monitoring and control through mobile devices.
9. Multiple operating modes (F, F/2, F/3, F/4) provide flexible speed control.
10. Suitable for low-speed, high-torque industrial applications.

VI. APPLICATIONS

1. Used for speed control of induction motors in industrial drives.
2. Applied in conveyor systems for controlled material handling.
3. Utilized in pumps for regulating water flow and pressure.
4. Used in fans and blowers for energy-efficient airflow control.
5. Applied in compressors for controlled operation in refrigeration systems.
6. Used in industrial automation for precise motor control.
7. Suitable for IoT-based smart control and remote monitoring systems.
8. Widely used in laboratory setups for educational purposes.
9. Applied in HVAC systems for efficient temperature control.
10. Suitable for low-speed drive applications requiring high torque.

VII. CONCLUSION

In this work, a cycloconverter-based system for speed control of a single-phase induction motor has been successfully designed, developed, and analysed. The system effectively converts a fixed-frequency AC input into a variable-frequency AC output without the need for an intermediate DC stage, thereby improving efficiency and reducing circuit complexity. The use of SCR-based full-bridge cycloconverter enables reliable and controlled operation, making it suitable for low-speed, high-torque applications.

The incorporation of a microcontroller allows precise control of firing angles and synchronization with the AC supply, resulting in smooth and accurate motor speed control. Furthermore, the integration of IoT technology using the ESP32 module enhances the system by enabling wireless operation, remote monitoring, and easy mode selection through a mobile application.

The experimental and simulation results confirm that the system performs effectively under different operating modes such as F, F/2, F/3, and F/4. Overall, the proposed system is efficient, cost-effective, and adaptable, making it suitable for modern industrial and smart control applications. Future improvements can include reduction of harmonics, implementation of advanced control techniques, and expansion to higher power applications.

VIII. ACKNOWLEDGMENT

We have great pleasure in expressing our sincere regards and deep sense of gratitude to our Project Guide,

Dr. C. S. Hiwarkar, for his valuable guidance, continuous support, and insightful suggestions throughout the project.

We would also like to express our deep sense of gratitude to Dr. (Mrs.) S. S. Ambekar, Professor and Head, Department of Electrical Engineering, K. D. K. College of Engineering, Nagpur, for her encouragement and support. We are grateful to the Principal, Dr. Valsson P. Varghese, and Vice-Principal, Dr. Avinash M. Badar, for being a constant source of inspiration and motivation.

We would also like to acknowledge our team members, Bhushan Bhimte, Payal Shahu, Sakshi Nimje, Sanket Kalbande, Pankaj Shinde, and Kaushal Nasare, for their dedicated efforts and collaboration in bringing this system to completion.

Last but not least, we would like to thank the entire Electrical Engineering Department, our parents, and all our friends who have directly or indirectly helped us in completing this project successfully.

IX. REFERENCE

- [1] M. Srinivas and B. Gopal, "Android based speed control of induction motor using cyclo-converter," *NT-JECSE J.*, vol. 10, 2018.

- [2] B. Kaule and M. R. Bachawad, "IoT based monitoring and speed control of an induction motor," *Int. J. Eng. Res. Appl. (IJERA)*, Nov. 2020.
- [3] P. R. Lole, K. D. Adhav, S. D. Gholap, S. R. Karkade, and P. G. Medewar, "Speed control of induction motor by using cyclo-converter," *IOSR J. Electr. Electron. Eng. (IOSR-JEEE)*, Proc. NCETET Conf.
- [4] Sharma and S. Sisodiya, "A survey on single phase to three phase cyclo-converter fed induction motor," *Int. J. Sci. Res. Dev. (IJSRD)*, vol. 3, no. 10, pp. 815, 2015.
- [5] Patil, R. Aute, P. Mhaske, and N. Patil, "Survey on thyristor using cyclo-converter," *Int. Res. J. Eng. Technol. (IRJET)*, vol. 3, no. 4, pp. 514, Apr. 2016.
- [6] Brindha, T. Porselvi, and R. Ilayaraja, "Speed control of single and three phase induction motor using full bridge cycloconverter," in *Proc. Int. Conf. Power, Energy, Control and Transmission Syst. (ICPECTS)*, IEEE, Feb. 2018.