

Design and Development of a Three-Phase Induction Motor Speed Control System Using Altivar 61 Based on Temperature Sensor and Internet of Things (IoT)

Sukriyah Buwarda^{1*a}, Mutmainnah^{2b}, Muh. Fhadly Yakob^{3c}

^{1,2,3} Otomasi Sistem Permesinan, Politeknik ATI Makassar, Jl. Sunu No.220 Makassar, Indonesia, 90211

^{*a} sukriyah.buwarda@atim.ac.id,

^b innah@atim.ac.id,

^c 21OSP577@atim.ac.id



Abstract— The use of three-phase induction motors in industry is increasing due to their reliability, energy efficiency, and ease of maintenance. However, these motors are difficult to control in terms of speed because they operate at a constant rate. This study aims to design a three-phase induction motor speed control system using a Variable Speed Drive (VSD) Altivar 61, controlled by an ESP32 microcontroller based on the Internet of Things (IoT), with input from a DHT22 temperature sensor. The system can automatically adjust the motor speed according to the ambient temperature. The test results show that at a temperature of 28°C, the motor stops; at 30–34°C, the motor rotates at 560 RPM; at 36–38°C, it rotates at 1070 RPM; and at ≥40°C, the motor reaches 1486 RPM. The DHT22 sensor accuracy reaches 96.97%, and the system provides efficient motor speed control according to room temperature conditions.

Keywords— Three-Phase Induction Motor, VSD, IoT, DHT22 Temperature Sensor, ESP32

Introduction

The use of three-phase induction motors in industry is becoming increasingly widespread due to their reliability, including low power consumption and ease of maintenance. However, these motors have a drawback—they are difficult to control in terms of speed because they operate at a constant rate, whereas industrial applications often require motors with adjustable speeds to match varying workloads [1]. To maintain a constant motor speed during load variations, the voltage and frequency must be properly regulated [2].

One effective solution for controlling the speed of a three-phase induction motor is by adjusting the input frequency using a Variable Speed Drive (VSD) [3]. The VSD can control the motor's starting current and adjust the frequency as needed, enabling not only flexible speed regulation but also contributing to electrical energy savings. The motor's rotational frequency can be controlled based on the ambient temperature using a temperature sensor [4].

Research Method

A. Hardware

At the hardware design stage, the system was developed according to the block diagram of the three-phase motor speed control circuit. The room temperature is detected using a DHT22 temperature sensor. The digital temperature (°C) and humidity (%) data are then transmitted to the microcontroller.

A 5 VDC adapter serves as the main power supply, providing a 5-volt DC source to power the microcontroller and the DHT22 sensor. The microcontroller receives temperature data from the DHT22 sensor, processes the data, and determines the PWM signal to control the motor speed. It then sends the data to the I2C LCD for display and to the Blynk IoT Cloud for remote monitoring[5].

The I2C LCD displays temperature data and motor status locally using the I2C protocol to minimize communication pin usage with the microcontroller. The PWM Voltage Converter converts the PWM (Pulse Width Modulation) [1] signal from the microcontroller into a 0–10 V DC analog voltage, which serves as the control input for the Variable Speed Drive (VSD) to regulate the motor's frequency and speed.

The 12 VDC adapter supplies power to the PWM Voltage Converter module, enabling it to produce a stable analog voltage output (0–10 V). The Variable Speed Drive (VSD) regulates the output frequency and voltage supplied to the three-phase induction motor by interpreting the analog signal from the PWM converter to adjust the motor speed.

The three-phase induction motor acts as the main actuator that converts electrical energy into mechanical

energy (rotation), with its rotational speed controlled by the signal from the VSD. The Internet and Blynk IoT Cloud provide remote access to monitor temperature data and motor status in real time through the Blynk application. When the ESP32 module sends data to the Blynk Cloud server, users can view it via the application on their smartphone[6].

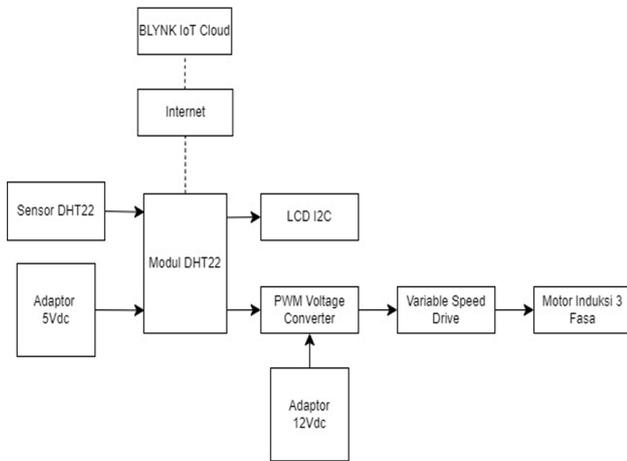


Figure 1. Diagram Block

B. Software

The process begins with the initialization of the system on the ESP32 microcontroller. After that, the system checks the connection to the Wi-Fi network. If the ESP32 is not yet connected to Wi-Fi, the process will continue checking until the connection is successful. Once connected, the DHT22 sensor starts operating to detect the ambient temperature. The detected temperature value is displayed on the LCD, along with the PWM (Pulse Width Modulation) value used to control the motor speed.

Next, the system evaluates the detected temperature and determines the PWM value and signal frequency to be sent to the Variable Speed Drive (VSD) in order to control the speed of the three-phase induction motor. The system flowchart is illustrated in Figure 2.

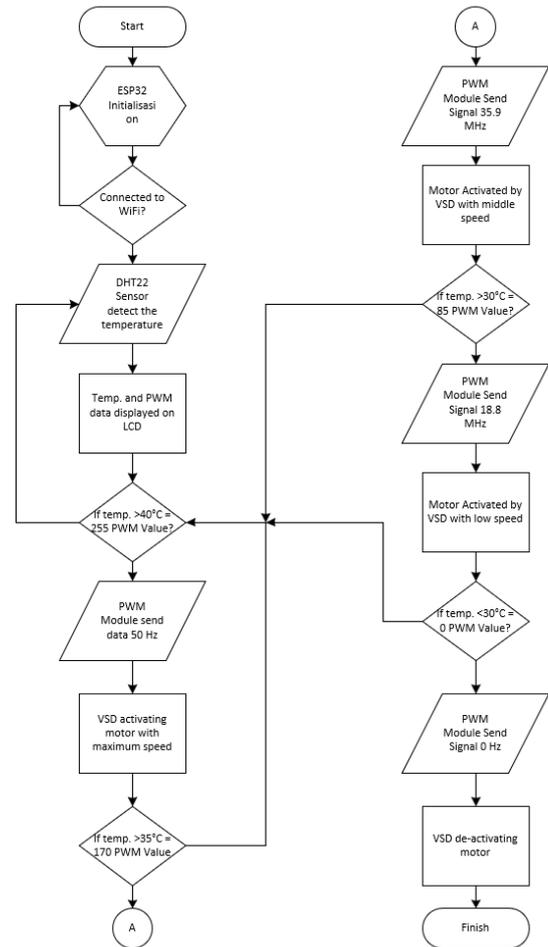


Figure 2. Flowchart

Results and Discussion

This study resulted in the development of a three-phase induction motor speed control system using a Variable Speed Drive (VSD) Altivar 61, which is automatically controlled based on room temperature variations. The system was developed using a microcontroller. The ESP32 microcontroller serves as the central controller, the DHT22 temperature sensor detects the ambient temperature, and the PWM to Voltage Converter module converts the PWM signal into an analog voltage that can be read by the VSD. To clearly and systematically illustrate the relationship between electrical or electronic components within the system ensuring proper and safe assembly, installation, and maintenance a wiring diagram is created, as shown in Figure 3.

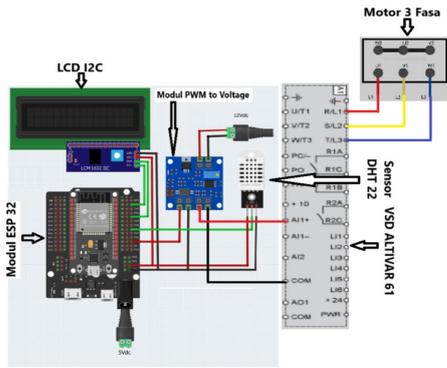


Figure 3. Wiring Diagram

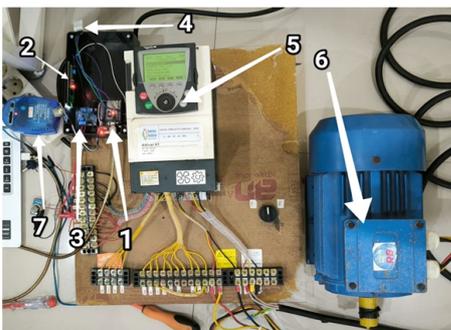


Figure 4. Design Results of the Motor Speed Control Device

Description:

1. ESP32-Wroom-32 Module;
2. LCD 16x2 I2C;
3. PWM Converter Module;
4. DHT22 Sensor;
5. Variable Speed Drive Terminal;
6. Three-Phase Induction Motor Terminals
7. Adaptor 12-24VDC Input;
8. Adaptor 5VDC Input

The D4 pin on the ESP32 is connected to the PWM to Voltage Converter module to send a 0–255 PWM signal, which is then converted into a 10 VDC signal. The 10 VDC output from the PWM module is connected to the AI1+ terminal of the VSD. The PWM signal is converted into a voltage so that the VSD can interpret it as a frequency input. The LCD is used to display the temperature value and the 8-bit output of the ESP32, which is connected to the ESP32 through pins D21 and D22.

Table 1. I/O List

No.	Component	Pin	Pin ESP32
1	LCD 16x2 I2C	GND	GND
		VCC	VCC
		SDA	D21
		SCL	D22
2		PWM IN	D4
		GND	GND
3		+	VCC
		OUT	D5
		-	GND

1. Validation of DHT22 Sensor Accuracy

The testing was conducted to determine the accuracy and precision level of the DHT22 sensor in measuring temperature compared to a standard measuring instrument (thermometer). The test was carried out within a temperature range of 28°C to 40°C, with each measurement repeated three times to obtain an average value. The test results are presented in Table 2.

Table 2. Temperature Sensor Validation Test Results

No	Termometer	Temperature Measurement				Accuracy (%)	Precision (%)
		1	2	3	Mean		
1	28	26	29	27	28	100.00	5.46
2	30	30	32	32	32	93.33	3.61
3	32	30	31	30	31	97.88	1.86
4	34	36	33	34	35	97.06	4.36
5	36	36	37	37	37	97.22	1.56
6	38	39	36	40	39	97.37	5.34
7	40	42	38	38	40	100.00	5.77

The data in Table 2 are presented in the linearity curve as shown in Figure 5.

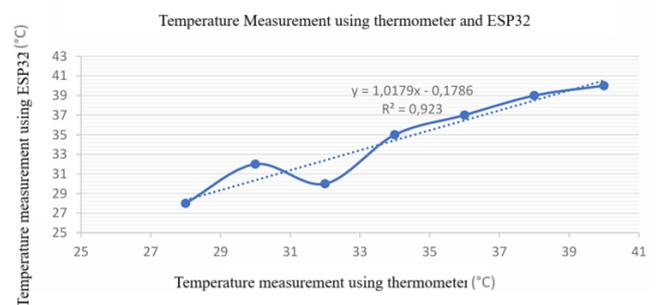


Figure 5. Temperature Measurement Linearity Graph

Figure 5 shows the temperature measurement linearity curve using a thermometer, which is used to evaluate the accuracy of the temperature sensor connected

to the ESP32 in measuring temperature compared to a standard thermometer. The graph indicates that the ESP32 measures temperature with fairly good consistency compared to the thermometer, although slight deviations are observed at certain points.

2. VSD Frequency (Hz) Testing Against ESP32 ADC Output

The measurement of VSD frequency (Hz) against the ESP32 ADC output, as shown in Table 3, was conducted using the Blynk application interface to display the 8-bit ADC output values from the ESP32.

Table 3. Measurement Results of VSD Frequency with 8-bit ADC Reading on ESP32.

No	ADC 8 Bit (out ESP32)	VSD Measurement				Freq (Hz)	Accuracy (%)	Precision (%)
		1	2	3	Mean			
1	44	9	12	10	10.33	8.63	80.23	14.78
2	81	16	14	15	15.00	15.88	94.44	6.67
3	114	25	21	25	23.66	22.35	94.12	9.76
4	152	30	33	32	31.66	29.80	93.75	4.84
5	184	34	34	35	34.33	36.08	95.16	1.68
6	220	42	41	41	41.33	43.14	95.82	1.40
7	253	47	50	48	50.33	49.61	97.43	3.16
					Mean	92.99	6.04	

Based on the measurement results of VSD frequency (Hz) against the ADC output of the ESP32 shown in Table 3, it was found that the frequency generated by the VSD was fairly accurate and close to the reference value, with an average accuracy of 92.99%. The precision value obtained was 6.04%, indicating that the variation in measurements was relatively small, or in other words, the measurements were fairly consistent.

3. Testing of Motor Rotational Speed (RPM) Against ADC Output of ESP32

The measurement of the three-phase induction motor rotational speed (RPM) against the ADC output of the ESP32 in Table 4 was carried out using a tachometer.

Table 4. Data of Motor Rotational Speed (RPM) versus 8-bit ADC Output

No	ADC 8 Bit (out ESP32)	RPM Measurement				Speed (Hz)	Accuracy (%)	Precision (%)
		1	2	3	Mean			
1	44	257	207	225	229	241	95.05	11.03
2	81	479	400	429	435	444	98.00	9.17
3	114	643	598	585	608	625	97.17	5.00
4	152	839	806	786	810	834	97.07	3.30

5	184	938	963	967	956	1010	94.65	1.64
6	220	1175	1195	1181	1183	1207	97.97	0.87
7	253	1302	1318	1387	1336	1389	96.19	3.38
						Mean	92.99	6.04

Based on the measurement results of the three-phase induction motor rotational speed (RPM) against the ADC output of the ESP32 shown in Table 4, an average accuracy of 96.59% was obtained, indicating that this measurement has a high level of accuracy.

4. Integrated Testing

To evaluate the overall performance of the system, an integrated test was conducted. The testing was carried out at temperatures ranging from 28°C to 40°C and vice versa. The test results are presented in Table 5.

Table 5. Integrated Test Results

No	Suhu (°C)	Output ESP32 to VSD to Motor		
		ADC 8 bit	Freq (Hz)	Speed (RPM)
1	42	255	50	1486
2	40	255	50	1486
3	38	170	35	1070
4	36	170	35	1070
5	34	85	18	560
6	32	85	18	560
7	30	85	18	560
8	28	0	0	0

Based on Table 5, it was found that at a temperature of 28°C, the 8-bit ADC value was 0, resulting in a VSD frequency of 0.0 Hz and a motor speed of 0.00 RPM, indicating that the motor was not rotating or was in an idle condition.

At temperatures between 30°C and 34°C, the 8-bit ADC value increased to 85, which raised the VSD frequency to 18.8 Hz and the motor speed to 560 RPM, indicating that the motor was operating at a low speed.

At temperatures between 36°C and 38°C, the 8-bit ADC value further increased to 170, resulting in a frequency of 35.9 Hz and a higher motor speed of 1070 RPM, indicating that the motor was operating at a medium speed.

At 40°C, the 8-bit ADC value increased again to 255, producing a frequency of 50 Hz and a high motor speed

of 1486 RPM, indicating that the motor was operating at a high-speed level.

5. Blynk Application Testing

The IoT-based Blynk application is used to monitor temperature to ensure it remains within a safe range. When the temperature increases, the system can be configured to adjust the PWM value accordingly. This enables monitoring and control of the motor speed based on temperature through an IoT platform. The test results shown in Figure 6 indicate that the display used for monitoring temperature and the 8-bit ADC output on the ESP32 functions properly according to the programmed system.

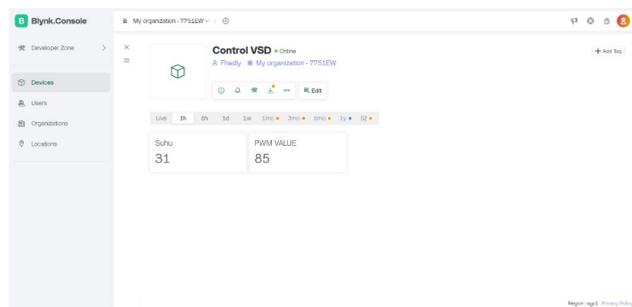


Figure 6. Display on the Blynk Application

Conclusion

The research results show that the control of a three-phase induction motor speed using a VSD Altivar 61 based on a DHT22 temperature sensor and IoT has been successfully developed. Based on the conducted tests, the results indicate that at a temperature of 28°C, the motor was inactive or in an idle state. At temperatures between 30°C and 34°C, the motor became active at an initial speed of 560 RPM. When the temperature increased to between 36°C and 38°C, the motor operated at a medium speed of 1070 RPM, and when the temperature reached 40°C or higher, the motor operated at a high speed of 1486

RPM. The motor gradually slowed down as the temperature decreased and stopped completely when the temperature returned to 28°C.

Acknowledgments

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