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Three Phase Motor Speed Monitoring and Control System Using Raspberry Pi and Node RED in Molding Production at PT XYZ

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ABSTRACT

PT XYZ is a company that produces the largest automotive tools in Gresik. In producing the tool, a molding process is needed as a mold maker. In the molding process at PT XYZ, furan resin is used as a bonding agent and mixed with a catalyst in the appropriate proportion to produce a sand mold. Three-phase motor speed control in the molding process is very much needed so that the production process reaches maximum targets. The use of VFD in motor speed control can facilitate operators in the process of mixing materials for molding. Raspberry Pi combined with Node RED is an alternative as a cheap and efficient 3-phase motor speed monitoring and control system. The speed control of 3 phase motors on VFD can be done using Raspberry Pi with the help of Node RED as a communication bridge with VFD with Modbus protocol. The speed of 3 phase motors on VFD has an error percentage of 1.362% when compared to the UNI-T 373 tool. So that the monitoring and control system of 3 phase motors using Raspberry Pi and Node RED in molding production at PT XYZ is in accordance with the researcher's expectations and the system that has been designed can be implemented at PT XYZ.

INTRODUCTION

Three-phase motors are very important for the industrial world because they can drive many equipment with large and stable power. Applications that require high torque, such as heavy machinery, pumps, compressors, conveyors, and other industrial devices, often use three-phase motors (Biswal et al., 2021). The electromechanical components of this motor are very important for today's industrial applications. To ensure the smooth operation of manufacturing plants on high-voltage alternating current systems, they drive various machines and equipment. There are many types of induction motors, and 3-phase induction motors are one of them. Thus, this 3-phase induction motor can be considered as a widely used driving tool in industry. This is due to its simple and sturdy construction, affordable price, and easy maintenance (Bahgat et al., 2024).

PT XYZ Company is the largest automotive tool producing company in Gresik. To produce these automotive tools, molds are needed to print the automotive tools. The molding process is a material forming technique using molds to produce products according to the design desired by the company (Selvaraj et al., 2022). At PT XYZ, molds are used as a tool to form metal materials that have been melted or in a soft state, so as to produce products with specific shapes, sizes, and details (Fu et al., 2020). The 3-phase motor at PT XYZ is used in the process of mixing materials to make molds which are then used to produce automotive tools. (Alfita et al., 2024).

The Raspberry Pi Foundation develops a credit card-sized minicomputer. Internet of Things (IoT) is one of the projects using this device. The Raspberry Pi has USB ports, HDMI, and a socket for a microSD card, and can run operating systems such as Raspbian, which is based on Linux (Arigela et al., 2024). The Raspberry Pi is a controller that has many advantages, such as requiring little power and making a web server relatively easy compared to a microcontroller (Kamarozaman et al., 2021). In this study, the Raspberry Pi with Node RED to replace the role of a regular PC.

Node RED is a browser-based software used to create Internet of Things (IoT) applications with visual programming in the form of flows (Lin et al., 2024). This flow consists of a number of interconnected nodes, each of which performs a specific function according to the system created. The NodeJS platform is used by Node-RED, which runs on a server and serves devices connected to the server (Muhammad et al., 2020). Node RED in this study is used to communicate with VFD (Variable Frequency Drive) with the MODBUS protocol.

Modbus is a communication protocol developed by Modicon in 1979 for use in its PLCs. Modbus is an open protocol, meaning that it is documented and distributed openly, so people can use it freely or with a certain license (Găitan et al., 2020). The modbus protocol has many versions on serial ports, as well as ethernet. There are several types of modbus, namely modbus TCP/IP, modbus RTU, modbus ASCII, modbus Plus, and modbus UDP (Chang et al., 2020). The use of the modbus protocol in this study was used to communicate with the VFD (Variable Frequency Drive) in the molding raw material mixer system at PT XYZ.

VFD (Variable Frequency Drive) is an electronic component that works to convert alternating current into direct current, then convert it back into alternating current with a frequency and voltage that can be changed as needed (Loureiro et al., 2024). VFD is used to regulate motor speed, torque, and direction of rotation. VFD devices are usually set using the modbus protocol with PLC or other devices such as raspberry pi or microcontrollers (Elamanov et al., 2024). In the molding process at PT XYZ, VFD is used to regulate the motor speed.

Based on this background, the study aims to create a monitoring and control system for motor speed in the molding process at PT XYZ. Motor speed control in the molding process will affect the results of mixing raw materials for molding. Monitoring motor speed, frequency, and current will facilitate the condition of the motor in the raw material mixing process. If the speed of the 3-phase motor drops and the current increases, then it is certain that the 3-phase motor is in poor condition because there is a problem with mixing raw materials. So that the operator in molding production will quickly fix the problem and the process can return to normal. The use of raspberry pi for monitoring and controlling 3-phase motors will facilitate the placement of tools because the tool is small and does not require a lot of power than using a PC.

RESEARCH METHODS

This study conducted research and development to design 3 phase motor monitoring and control using Raspberry Pi and Node RED in molding production at PT XYZ. The research method used can be explained as follows:

Literature Study

Literature study at this stage, a literature study was conducted to study the concepts of molding production at PT XYZ, such as the Internet of Things (IoT), namely Raspberry Pi and Node RED, and 3-phase motors. In the molding production process, PT XYZ uses furan resin as a bonding agent and is mixed with a catalyst in the appropriate proportion to produce sand molds. The literature study also includes a review of previous relevant studies to understand and identify the research gaps being studied.

Needs Analysis

This needs analysis stage includes collecting and analyzing the needs of a 3-phase motor monitoring and control system using Raspberry Pi and Node RED in molding production at PT XYZ. Activities carried out include interviews with stakeholders (such as machine operators and technicians in the area being studied), field observations, and analysis of all existing possibilities. PT XYZ's problem for molding production is the mixing system that depends on the type of material. The type of material mixed will affect the rotation speed of the 3-phase motor. From these problems, a 3-phase motor monitoring and control system is needed in the mixing process in molding production at PT XYZ using Raspberry Pi and Node RED.

a. Raspberry Pi

Raspberry Pi is a mini computer that can be installed with several OS that support raspberry pi such as Raspberry Pi OS. Raspberry Pi OS is based on Linux so it has good reliability and requires little memory (Karthikeyan et al., 2024). In this study, raspberry is used as a mini PC that can be installed with Node RED so that it can communicate with the MODBUS protocol to communicate with VFD (Variable Frequency Drive).

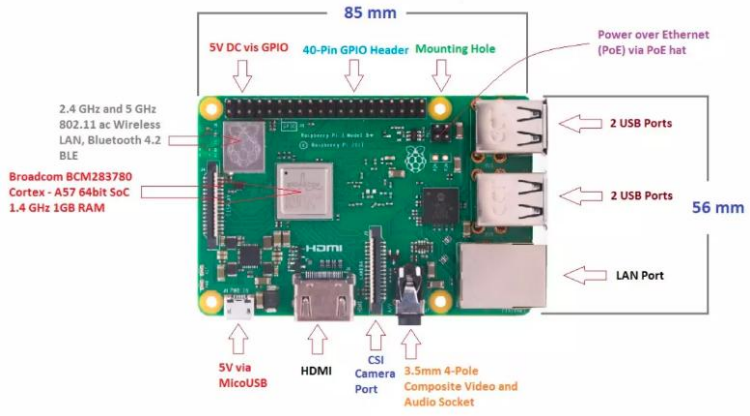

Figure 1. Raspberry Pi 3B+

b. Node RED

Node RED has several protocols that support other hardware protocols such as the common ones are MQTT and Modbus. Node RED with the modbus protocol can be used to communicate with PLCs and other devices such as VFDs (Variable Frequency Drives) so that many other researchers use it as SCADA (Das et al., 2024).

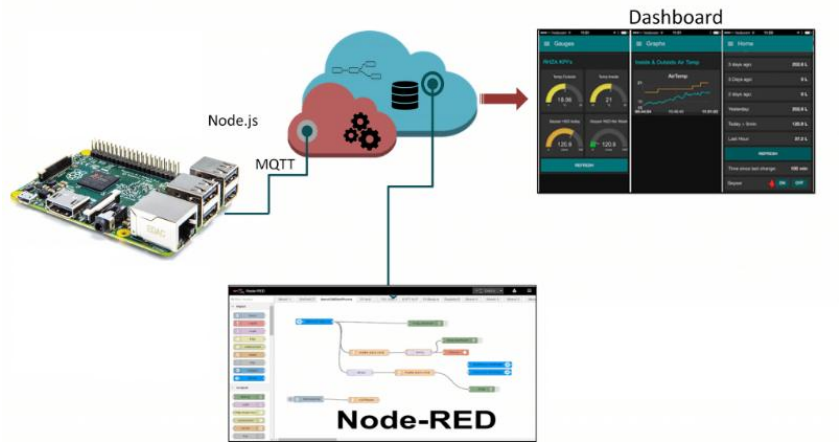

Figure 2. Node – RED

c. MODBUS

The modbus protocol is generally used for communication with PLCs and other instrumentation devices such as VFDs. In this study, VFD has a modbus protocol that can be used to retrieve information such as voltage, 3-phase motor frequency, current used and speed of the 3-phase motor (Radoglou et al., 2020).

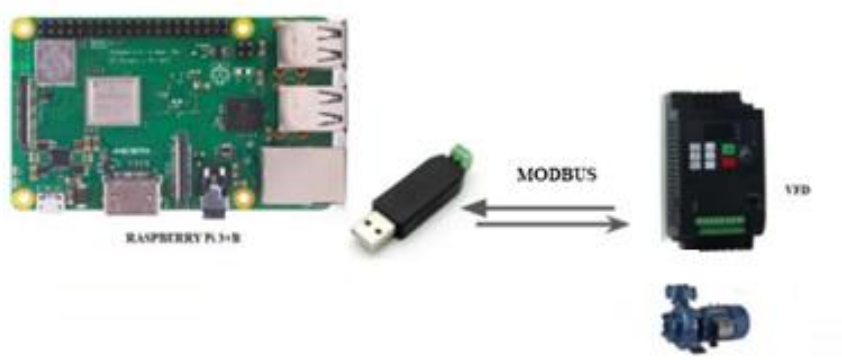

Figure 3. Modbus protocol with VFD

d. Serial UART to RS 485 Module

RS 485 is commonly used in long-distance communication between instrumentation devices in the industrial world. The master and slave architecture is used to communicate between several PLCs and several industrial device devices (Zamani et al., 2023). The weakness of this system is that if one of the cables is not properly connected, an error will occur in communication between one slave and another (Parian et al., 2020). In this study, the use of RS 485 to communicate between Raspberry Pi and VFD (Variable Frequency Drive) with a master and slave architecture.

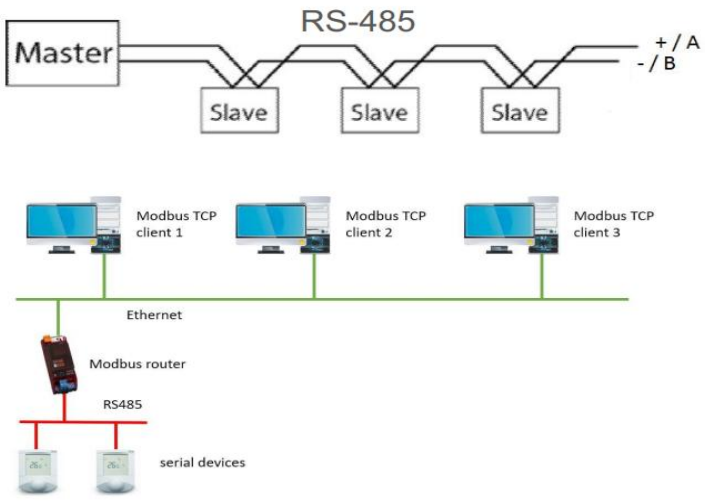

Figure 4. Master and slave architecture in RS 485

e. VFD

Variable Frequency Drive in industry is used to regulate the speed of 3-phase motors by changing the frequency value of the 3-phase motor. Adjusting the frequency of the 3-phase motor allows the motor to be regulated and controlled by the designed system (Raherimihaja et al., 2020).

In addition to being able to regulate the speed of the 3-phase motor, VFD can also be used to view the current, voltage, and speed of the 3-phase motor. In this study, the use of VFD in molding production at PT XYZ was used to stir basic materials for molding such as furan resin, catalyst, and sand. So that it is easier for the operator to see and regulate the speed of the 3-phase motor on the mixer machine at PT XYZ.

Figure 5. Variable Frequency Drive

3. System Design

Figure 6 shows a block diagram of the system designed using a Raspberry Pi as a mini PC using Raspberry Pi OS. Raspberry Pi as a replacement for PC is installed with Node RED so that it can be used to communicate with VFD with the Modbus protocol (Yue et al., 2020). VFD is used to regulate the speed of the 3-phase motor by changing the frequency of the 3-phase motor. Raspberry Pi that has Node RED installed can be used for SCADA with Node RED as its interface (Zare et al., 2020). Node RED has the advantage of supporting several current protocols such as MQTT (Jones et al., 2021).

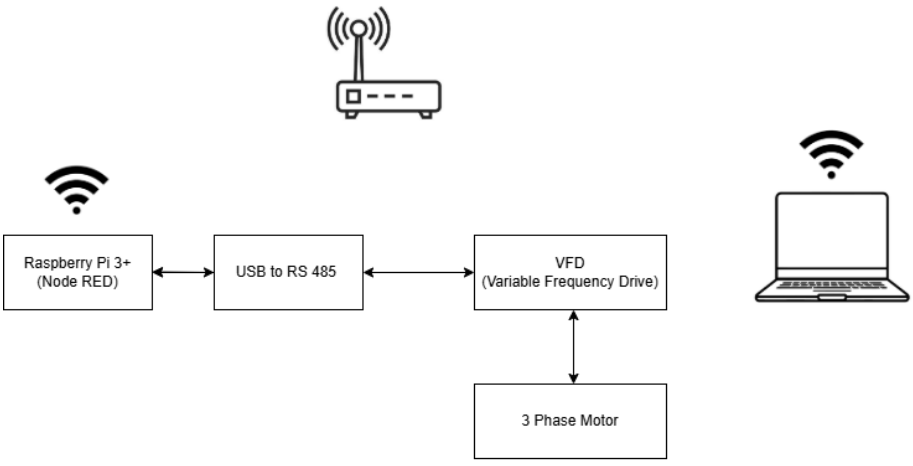

Figure 6. Block diagram of the system being designed

Hardware Design

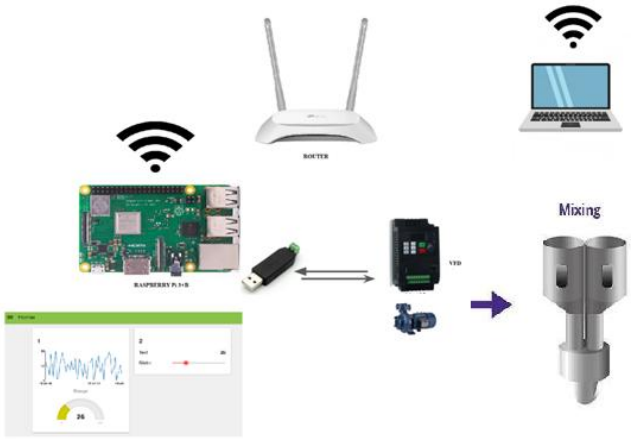

Figure 7. Designed system hardware design

Figure 7 shows the hardware design designed in a 3-phase motor monitoring and control system using Raspberry Pi and Node RED in molding production at PT XYZ. This study aims to regulate the speed of the 3-phase motor and can control the direction of rotation of the 3-phase motor. Raspberry Pi with the help of RS 485 communicates with the VFD. The use of RS 485 in this system is because the VFD supports RS 485 with Modbus RTU as its protocol. The use of Node RED makes it easier for the VFD to communicate with the Raspberry Pi as its master control so that it can be accessed via a PC via the Internet of Things.

Software Design

Figure 8 shows the results of the designed Node RED display. Motor speed settings can change the motor speed value on the Node RED display. To control the direction of motor rotation to the right or left, press the right or left button on the Node RED. In addition to being able to control the direction of motor rotation, this system can provide information such as the voltage of the 3-phase motor and the current of the motor, making it easier for operators in the molding process at PT XYZ to find out the condition of the 3-phase motor in the process of mixing materials for making molding.

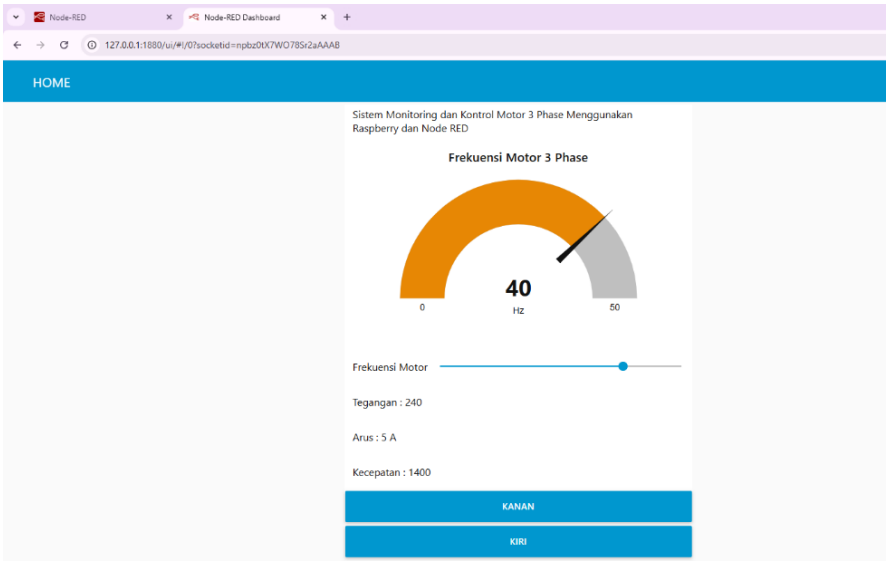

Figure 8. Node RED view on Raspberry Pi

System Work Process

Figure 9 shows the flowchart of the system that has been created. The system will receive the motor frequency desired by the operator in the process of mixing molding materials at PT XYZ. The motor frequency setting will affect the speed of the 3-phase motor. The higher the frequency, the faster the 3-phase motor rotates. The speed setting of the 3-phase motor is very important because the composition of the material mixed for each molding to be made is different. The difference in the composition of the material makes the operator always adjust the speed of the 3-phase motor so that it can be mixed evenly without damaging the mechanics of the motor. After the frequency is set, the speed, voltage and current data from the motor are taken. Monitoring the current and speed is also very important so that there is no increase in current if the motor cannot rotate properly. To control the direction of motor rotation, the operator can press the right or left button on the Node RED dashboard.

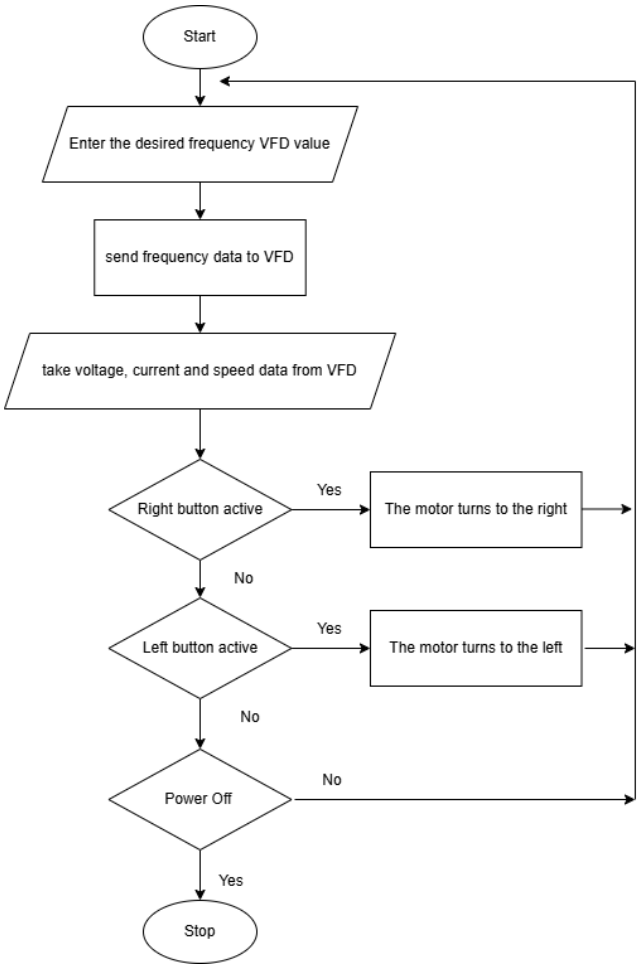

Figure 9. Flowchart of the system created

RESULTS AND DISCUSSION

After designing the system, the next step is for the researcher to test the system that has been created. The initial test carried out was to compare the motor speed listed on the VFD with a motor speed measuring instrument that is already on the market, namely UNI-T 373. Changes in frequency on the VFD will also change the output speed of the 3-phase motor (Bahgat et al., 2024). The change in speed will be compared by UNI-T 373 to determine the speed error in the tool that has been designed.

Three phase motor speed testing

This test was conducted to calibrate the output speed of the VFD with an industry standard tool such as UNI-T 373. Motor speed control is very important in the molding material mixing process at PT XYZ so that the results obtained are even in the mixing process. Figure 10 shows a system that has been designed to see the results of motor speed testing with a measuring instrument available on the market, namely UNI-T 373. Table 1 shows the results of the 3-phase motor speed test with 10 test data. From this test, the results of the speed error between the VFD controlled by Node RED and the UNI-T 373 tool have an error percentage of 1.362%. From the error percentage of 1.362%, it can be assumed that the 3-phase motor monitoring and control system using Raspberry Pi and Node RED in molding production at PT XYZ has complied with industry standards and works as expected. Changes in the frequency of the 3-phase motor controlled by the inverter affect the motor speed, motor voltage and motor current (Raherimihaja et al., 2020). The integration between Raspberry Pi and Node RED has been proven to create a reliable and inexpensive system for monitoring and control (Lin et al., 2024).

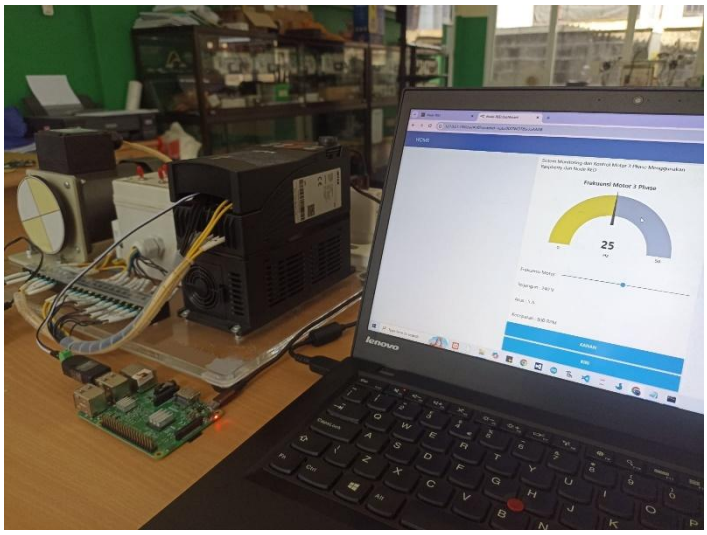

Figure 10. 3 phase motor speed testing

Table 1. Results of 3 phase VFD motor speed testing using the UNI-T 373 tool.

No	Node RED RPM	UNI-T 373 RPM	% error
1	200	210	4,7 %
2	260	260	0 %
3	280	280	0 %
4	300	300	0 %
5	450	461	2,3 %
6	480	480	0 %
7	500	511	2,15 %
8	600	610	1,63 %
9	700	711	1,54 %
10	750	760	1,3 %
	% average error		1,362 %

Testing with the whole system

Figure 11. Overall system testing

Overall system testing is carried out to determine whether the system is working properly and according to plan. Figure 11 shows that the frequency on the VFD is the same as the display on the RED Node. Every frequency change on the RED Node will change the frequency value on the Variable Frequency Drive (VFD). The direction of rotation of the 3-phase motor can also be controlled via the RED Node by pressing the right or left motor direction button. So it can be concluded that the 3-phase motor monitoring and control system using Raspberry Pi and RED Node in molding production at PT XYZ works as expected. Figure 12 shows the frequency response to the speed of the 3-phase motor. The higher the frequency sent to the Variable Frequency Drive (VFD), the higher the speed of the 3-phase motor.

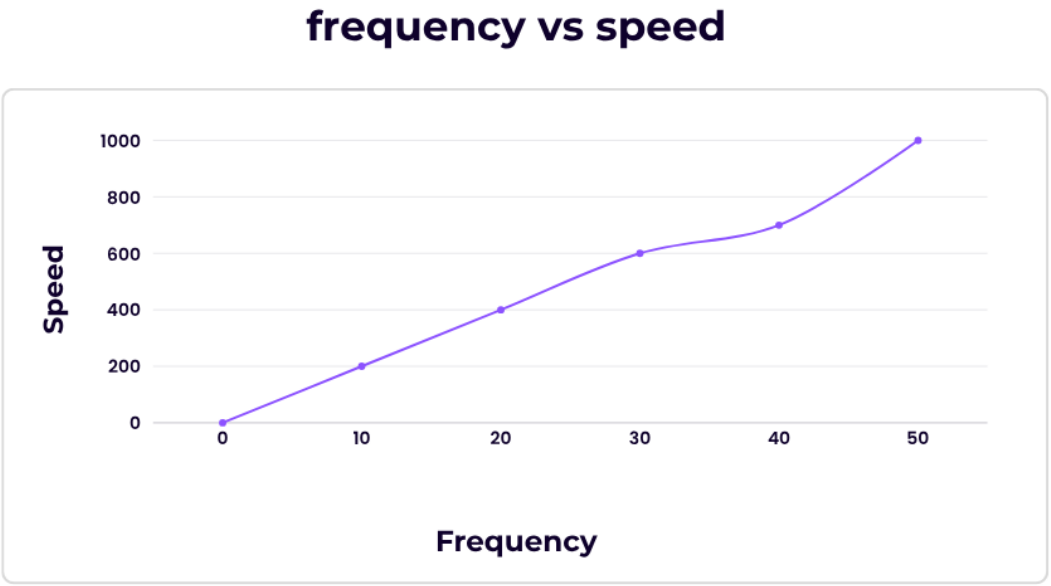

Figure 12. Testing the change in motor frequency against the speed of a 3-phase motor

CONCLUSION

From several tests conducted, it can be concluded that Raspberry Pi can be used as an alternative to PC to install Node RED and create SCADA easily and cheaply. The use of Node RED on Raspberry Pi makes it easy to create a monitoring and control system with the Modbus protocol. The frequency setting of the 3-phase motor on the VFD can be done using Raspberry Pi

with the help of Node RED as a communication bridge with the VFD with the Modbus protocol. The speed of the 3-phase motor on the VFD has an error percentage of 1.362% when compared to the UNI-T 373 tool. So that the 3-phase motor monitoring and control system using Raspberry Pi and Node RED in molding production at PT XYZ is in accordance with the researcher's expectations. As a further development, the researcher suggests that the system can be developed with the Grafana dashboard so that the display is better and more informative and the use of Modbus TCP IP will make it easier to integrate Raspberry Pi into SCADA.

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