Analysis of the implementation of three-phase Variable Frequency Drive on the prototype of a rice drying machine

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Abstract. The prototype of the rice drying machine is a device used for rice dryers that are not weather dependent. The driver of this prototype rice drying machine uses ½ HP induction motor as its main mover. To be able to adjust the rotation of the induction motor using Variable Frequency Drive (VFD) brand LS iC5 with 1 HP power. The rotation needed to rotate the load can be done by changing the frequency and voltage so that the rotation speed of the induction motor can be adjusted as needed. From the testing of a no-load induction motor with a frequency adjustment range from 5 Hz to 13 Hz, the induction motor speed is 142.8 rpm (rotation per minute) to 375.3 rpm. The measured voltage is 76.5 V to 116.7 V and the measured current is 2.5 A to 1.6 A. From the results of the test of a no-load induction motor it can be concluded that the ratio of frequency to voltage is directly proportional while the ratio of frequency to current is inversely proportional. In testing induction motors with a frequency adjustment range from 5 Hz to 9 Hz, they produce the same conclusions as to the induction motor load testing. VFD is certainly appropriate to be used as a speed regulator as needed.

1. Introduction

Currently, there are still many farmers in Indonesia, especially rice farmers still using conventional methods in utilizing post-harvest yields. This can be seen in post-harvest processing which is done by drying rice in the open using the help of sunlight for a long time. This is because the drying time is also very dependent on weather conditions. Although the heat from the sun is not always stable / changing, it is necessary to innovate to streamline the drying process in a modern and efficient way. So that it can utilize post-harvest yields easily, efficiently, and does not depend on the weather (time).

Induction motors are usually used in industrial application credits to their comparative benefits against other electrical machines [1]. The velocity of the induction motor can be adjusted by different methods such as poles and voltage adjusting, connecting the resistance in the rotor circuit, etc., but the mainly efficient method is adjusting the supply frequency and voltage to the motor [2–4]. More than 40% of global energy use, is made up of electric machines [1]. In recent times, variable frequency drives (VFD) have been commonly used in many industries because of its high efficiency and high-speed response [5,6]. Frequency is straight proportional to the rpm of the motor i.e. advanced the frequency, advanced is the velocity of the motor and vice-versa [7].

This study aims to analyze the use of VFD on a prototype of a rice drying machine. The analysis is carried out on the motor no-load testing, the motor with load testing, and engine performance testing.
using VFD. The effect of VFD implementation in regulating the motor rotation speed on engine performance is discussed.

2. Methods

In the design of a prototype drying machine prototype consists of a rice drying chamber which is driven by a 3 phase induction motor, the speed of the driving motor is regulated using a variable frequency drive. The construction of tools and components is shown in Figure 1.

![Figure 1. Construction and component of rice drying machine prototypes.](image)

Previous to the initiation of VFDs, there was no other method for an induction motor to change high overload torques (200% –280%) over a wide speed range as mandatory for various industrial requests [8]. VFD is chosen by taking into account the specifications of the motor and the need to use the speed regulator. Motor specifications that are used as a reference are motor power, motor voltage, and motor frequency. To determine the VFD power capacity to be used, it is necessary to know how much motor power is used. In this study, an induction motor with a motor power of 370 W / 0.5 HP was used. Based on the motor power, the VFD used must have a capacity above the motor used. The VFD used has a capacity of 750 W / 1 HP. Previous studies using VFD have ensured that the higher frequency causes faster motor rotation [9,10].

After the VFD capacity has been determined, then to start the VFD configuration is to enter the induction motor data. There are four configuration parameters for entering the motor data on the VFD LS iC5. The H30 Motor Power parameter is 0.370 kW, the H33 Motor Current parameter is 2.09 A, the H31 Motor Speed parameter is 1390 rpm, the F21 Frequency Max parameter is 50 Hz.

The next step is to determine acceleration and deceleration. Acceleration is the time it takes the motor to reach maximum speed and deceleration is the time it takes the motor to stop. This configuration is needed to reduce the current surge which can damage the device. The configuration parameters needed to enter acceleration and deceleration are the Acc parameter of 3 second (s) and the Dec parameter of 3s.

The third step is to determine the motor speed limit on the VFD to keep the motor safe. The configuration parameters to determine the motor speed limit on the LS iC5 VFD are the F25 parameter of 50 H and the F26 parameter of 50 Hz. VFD is connected to the motor whose specifications are suitable for setting the motor rotation speed. Figure 2 is wiring on VFD and three-phase induction motor. Induction motor combine with VFD are acceptable as opportunities for assignation energy efficiency necessities in Europe [11].
Figure 2. Wiring on VFD and three-phase induction motor.

3. Results and discussion

The results of the design of motor speed control using a VFD prototype in the form of a rice pressing machine. Figure 3 is the result of making a machine and VFD layout design. The layout of the VFD on the electrical panel is designed so that the VFD is protected from all possible damage, neat and easily modified so that when troubleshooting occurs, it can be handled easily. After designing the construction and configuration of the motor speed, testing the speed of the motor without a load with a frequency range of 5 Hz - 13 Hz and the motor load with a frequency range of 5 Hz - 9 Hz to regulate the speed of three-phase induction motors, the results of the tests that have been carried out are shown in Table 1.

Figure 3. VFD layout design on the electrical panel.

After designing the construction and configuration of the motor speed, testing the speed of the motor without a load with a frequency range of 5 Hz - 13 Hz shown in Figure 4 (a) and the motor load with a frequency range of 5 Hz - 9 Hz to regulate the speed of three-phase induction motors, the results of the tests that have been carried out are shown in Figure 5.

Figure 4. No-load motor experiment (a) and machine performance experiment (b).
Testing the performance of the tool is done by providing variations in the weight of rice to be dried, dryer round, and dryer temperature. The results of testing the performance of a rice dryer prototype are shown in figure 4 (b). Before drying the rice, a temperature setting is carried out which will be used to dry the rice. The temperature setting is varied according to the weight of the rice, in the first test with an initial weight of 1 kg a temperature of 50°C is used. The temperature setting is done before the rice is put into the drying chamber after the temperature in the drying chamber reaches the specified temperature, the rice is put through the dryer door. The drying drum rotation in the test with an initial weight of 1 kg is set with a 197.6 rpm dryer rotation speed obtained from a 7 Hz frequency with a setting using VFD. In testing with an initial weight of 1 kg requires a drying time of 30 minutes for the rice to dry, the drying process is carried out until the rice reaches a moisture content of 12-14% and or a mass lower than 50% of the initial mass. Determination of indications that rice is dry or not yet dry can use two methods, first by using a moisture tester and a second method by comparing the results of drying dried rice with a drying machine with rice that has been previously dried. After dry rice with an initial weight of 1 kg, the final weight loss of rice after drying becomes 0.85 kg, i.e. there is a reduction of 150 g from the initial weight of rice before drying.

The ratio of frequency to voltage is directly proportional when the frequency rises the voltage rises. Comparison of Frequency to current is inversely proportional when the frequency goes up then the current goes down. The ratio of frequency to rotation is directly proportional to the rotation when the frequency goes up, the rotation of the motor will go up. In testing with a 4 Kg load, the motor cannot rotate the 5 Hz and 6 Hz frequency diaphragm because at that frequency the supply input voltage on the motor is small so the motor cannot rotate the load.

4. Conclusion
VFD LS iC5 can regulate the speed of the motor in several speeds, the authors themselves use the Frequency range of 5 Hz - 13 Hz for testing the speed of the induction motor without a load so that the motor rotation is measured at 142.8 rpm for a frequency of 5Hz and 375.3 rpm at Frequency 13 Hz. In testing the speed of a loaded induction motor, a sample load of 1 kg is used with a frequency range of 5 Hz - 9 Hz, the measured speed of a motor with a 5 Hz frequency of 132.9 rpm, and 257.7 rpm at 9 Hz Frequency. The use of motor speed which is used to rotate the drying chamber so that it can stir is used 5 Hz - 8 Hz frequency. This limit is because when testing a motor with a load of more than 8 Hz, a high vibration occurs on the tool, this is because the motor is unable to rotate the load due to the lack of supply voltage received by the motor. By using VFD, we can adjust the motor performance by changing the Frequency parameters as needed by changing the Frequency and limited to the maximum Frequency used according to motor specifications so that the use of the motor can be more efficient.

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References

[1] Rengifo J, Romero J and Aller J M 2018 Efficiency Evaluation of Induction Motors Supplied by VFDs IEEE Third Ecuador Technical Chapters Meeting (ETCM) 1-6

[2] Kumar D 2018 Performance Analysis of Three-Phase Induction Motor with AC Direct and VFD IOP Conference Series: Materials Science and Engineering 331 012025

[3] Li C, Xu D and Wang G 2017 High efficiency remanufacturing of induction motors with interior permanent-magnet rotors and synchronous-reluctance rotors IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific) 1-6

[4] Gulyaev A, Fokin D, Shuharev S and Ten E 2017 Effect of different methods of pulse width modulation on power losses in an induction motor IOP Conference Series: Earth and Environmental Science 19 012042

[5] Baek S, Cho Y, Cho B G and Hong C 2019 Performance Comparison between Two-Level and Three-Level SiC-Based VFD Applications with Output Filters IEEE Trans. Ind. Appl. 55 4470–4779

[6] Swamy M M 2019 A Novel Four-in-One Variable Frequency Drive Topology IEEE Trans. Ind. Appl. 55 4834–4845

[7] Ramesh S, Ashok S D, Naulakha N K, Adithyakumar C R, Reddy M and Reddy S K 2018 Energy Efficient Hydraulic Clamping System using Variable Frequency Drive in a CNC Machine MS&E 376 1 012124

[8] Kozlowski M 2013 Wound rotor to induction motor and VFD conversion case study IEEE Trans. Ind. Appl. 49 1221–1227

[9] Eriyadi M and Putra I M L 2020 Implementasi Pengatur Kecepatan Motor Pada Mesin Conveyor Penyortir Logam Otomatis JTT (Jurnal Teknologi Terapan) 6 1 32-38

[10] Pavithra G and Rao V V 2019 Remote monitoring and control of VFD fed three phase induction motor with PLC and LabVIEW software Proc. Int. Conf. I-SMAC (IoT Soc. Mobile, Anal. Cloud) 329–335

[11] Agamloh E B 2017 Power and efficiency measurement of motor-variable-frequency drive systems IEEE Trans. Ind. Appl. 53 766–773