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Constant Torque Control of Induction Motor Using Variable Frequency Drive Based on Internet of Things

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ABSTRACT

Many industrial devices operate using movements operated by electric motors. One type of motor that is widely used in industry is the three-phase induction motor. In order for the motor to operate according to needs, the motor needs to be controlled, such as controlling the rotation speed, controlling the direction of rotation, braking and starting current. Induction motor control in today's industry often uses power converters packaged in the form of Variable Speed Drive (VSD) modules. The use of this VSD allows control of induction motors with various methods, such as the scalar method (constant Volt/Hertz) or the vector control method. The VSD module also allows remote control and monitoring of the motor using the internet, so that the reliability of motor control can be improved. This study proposes control and monitoring of induction motors using the Omron 3G3JX-A VSD based on the Internet of Things (IoT). The motor is controlled using the scalar method in a constant torque configuration, so that the motor can operate more efficiently. The control and monitoring system is designed using PLC Omron CP2E-N, VSD Omron 3G3JX-A with CX-Programmer software, Node-red and Web server for remote access on smartphones. The design of the three-phase induction motor control and monitoring system based on IoT was tested and validated through laboratory experiments. The test results show that the proposed motor control and monitoring system has worked well according to the objectives. The motor can be controlled remotely using a smartphone and also from a PC.

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1. INTRODUCTION

The industrial world requires a system that works effectively, efficiently and reliably. Therefore, industry requires automatic technology [1]. Many industrial devices operate using movements that can be rotary or linear. This movement is usually driven by an electric motor. In industry, various types of electric motors are used as a source of driving power, including servo motors, DC motors, induction motors and others [2]. Induction motors are a tool that is never absent in industry, both small and large scale industries [3]. Induction motors that are often used in industry are 3-phase induction motors, because 3-phase induction motors are used as drivers for equipment both at full speed and relatively constant speed [4].

Induction motors cause large voltage drops and surge currents which cause large voltage drops in the PLN supply voltage for small electric motors [5]. However, induction motors with constant speed require greater power, causing waste of electrical energy [6]. In addition, waste of electrical energy can occur when starting induction motors which currently still use conventional methods. To overcome this problem, a way is needed to save electrical energy, especially in the operation of electric motors. One of the operations of an electric motor is by controlling the rotation speed, controlling the direction of rotation (forward and reverse), braking (breaking) and starting current [7]-[8]. One of the efforts that can be made to save the use of electrical energy in motor operation is by using a Variable Speed Drive (VSD), which is a power converter module that can produce varying voltages and frequencies, so that it is compatible for use in controlling electric motors [9]. The use of VSD allows the motor to be controlled using various methods, such as the scalar method (Volt/Hertz control) or the vector control method [10]. In addition, advances in information technology allow VSD to be controlled and monitored remotely using the internet [11]. IoT certainly makes it easier for users to control and monitor in real time [12]-[13]. By utilizing IoT in a remote control and monitoring system, work efficiency can be increased, and users can perform maintenance on equipment when the IoT sensor detects a system failure [14]-[15].

This study proposes control and monitoring of induction motors using VSD based on (IoT) which allows the motor to be controlled and monitored from smartphones and PCs. The control system is designed using Omron 3G3JX-A VSD and CP2E-N PLC. The IoT concept is designed using CX-programmer and Node-Red software. Monitoring and control will be carried out using a PC and smartphone, one for the web server and one as a client. To increase the efficiency of motor operation, the motor control system with VSD is designed using the scalar method in a constant torque configuration. The control and monitoring system is implemented for a 0.75 kW three-phase induction motor. The proposed system is tested and validated through laboratory experiments. This concept is expected to improve the reliability and efficiency of induction motor control which is widely used in the industry.

2. METHOD

The design and manufacture of the induction motor speed control and monitoring system using a constant torque-based VSD proposed in this study was carried out using an experimental research method. The research stages include design, hardware assembly, programming and system testing with various scenarios to evaluate the overall performance of the tool. The materials used include hardware such as PLC Omron CP2E-N, VSD Omron 3G3JX-A, and induction motors, as well as software developed using Cx-programmer and Node-red. Three-phase induction motors are controlled with varying speeds using a constant torque-based scalar control method. Motor speed variations are carried out using the VSD external terminal which is made in five speed levels. Apart from that, the direction of rotation of the motor is also controlled in the form of forward and reverse. The motor can be controlled remotely using IoT facilities using a smartphone, as shown in Figure 1.

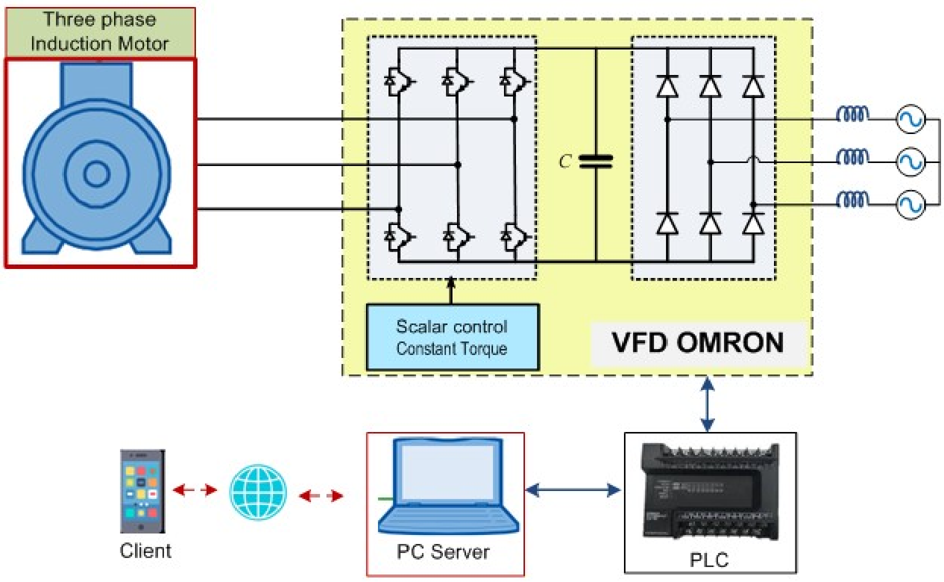

Figure 1. The scheme of proposed system

Three-phase induction motor speed control system using Omron VSD based on scalar control can be applied in various methods. One of them is the constant torque method. This method is applied when the motor is operated with power below the motor nameplate rating. In this area, the motor speed can be varied by adjusting the voltage or frequency below the motor frequency rating, as shown in Figure 2.

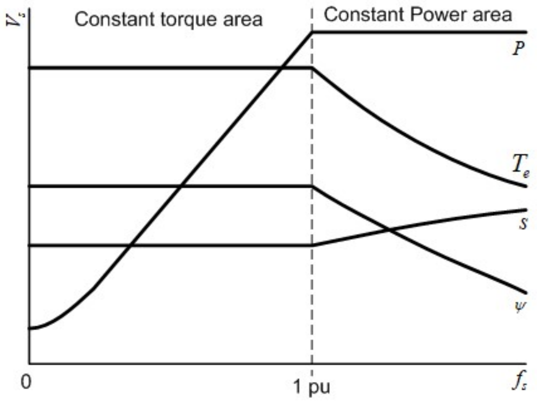

Figure 2. Operation zone of induction motor based on scalar control

All control processes are centered on the Omron CP2E-N PLC. To regulate the motor speed level, the external VSD terminal is activated by the PLC via the PLC digital output terminal, as shown in Figure 3. There are three PLC output terminals used for five motor speed variations and two output terminals for variations in motor rotation direction. All terminal pins are controlled via speed level buttons and motor rotation direction which are displayed on the control screen, namely smartphone and PC server.

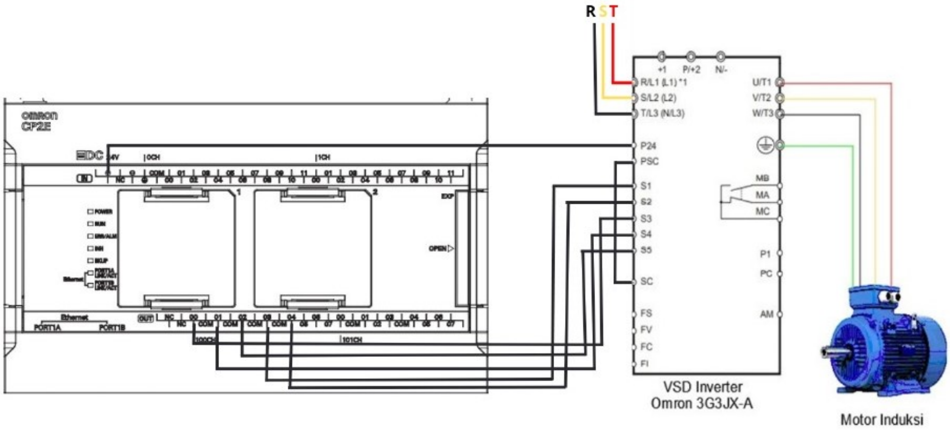

Figure 3. PLC circuit for VSD

Figure 4 illustrates the design of the control screen display on a PC or smartphone using Node-red software. On the control screen there is a main menu to start and stop the control system, setting the direction of motor rotation in the form of forward or reverse and the motor speed level. The motor reference speed is made in 5 levels presented with frequency data, ranging from 0 to 50 Hz. This control screen can be accessed via the internet network, either using a PC or using a smartphone.

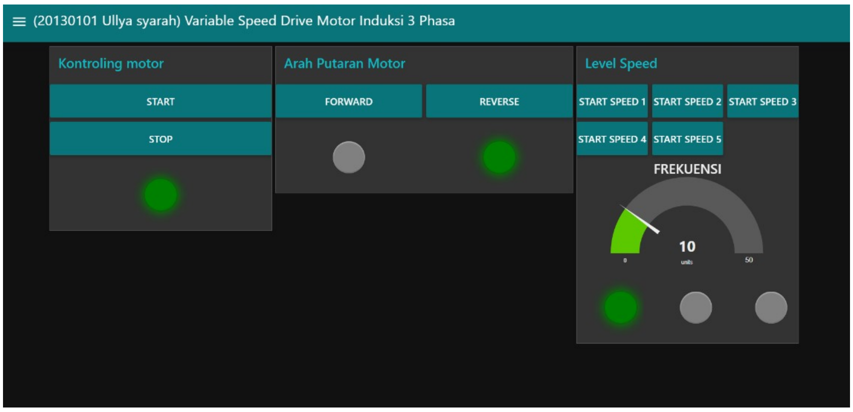

Figure 4. Display of control screen with node-red application.

3. RESULTS AND DISCUSSION

The design of a three-phase induction motor control and monitoring system based on constant torque using VFD was tested and validated in the laboratory. The test was carried out on a 0.37 Kw 3-phase induction motor. The IoT-based control and monitoring system was implemented using one PC server and one smartphone. Figure 5 shows the hardware installation for this test..

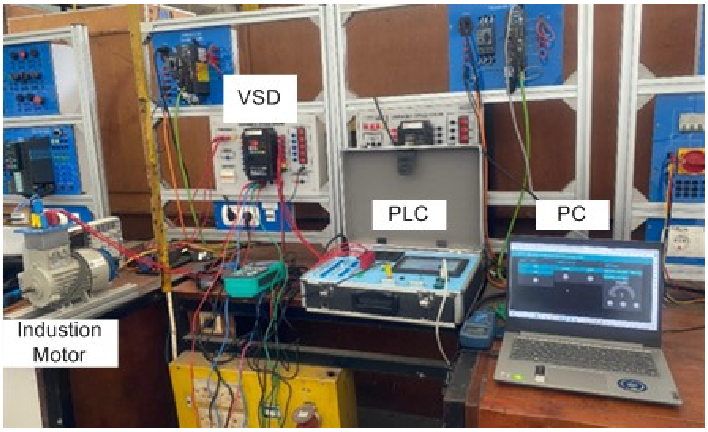

Figure 5. Hardware installation

The first test was conducted by operating the motor at a reference speed of level 1 with forward and reverse rotation directions. The speed of level 1 was set with a reference frequency of 10 Hz. Operation was carried out from a PC server and smartphone. Figure 6 shows the control screen display when the motor is operated at a speed of level 1 with forward and reverse rotation directions.

Figure 6. PC server screen at first test

The control screen display in Figure 6 shows that the control and monitoring of the induction motor from the PC server has been successfully carried out. The motor frequency data shows that the frequency is the same as the reference frequency. The same thing also applies when the motor is operated from a smartphone, as shown in Figure 7.

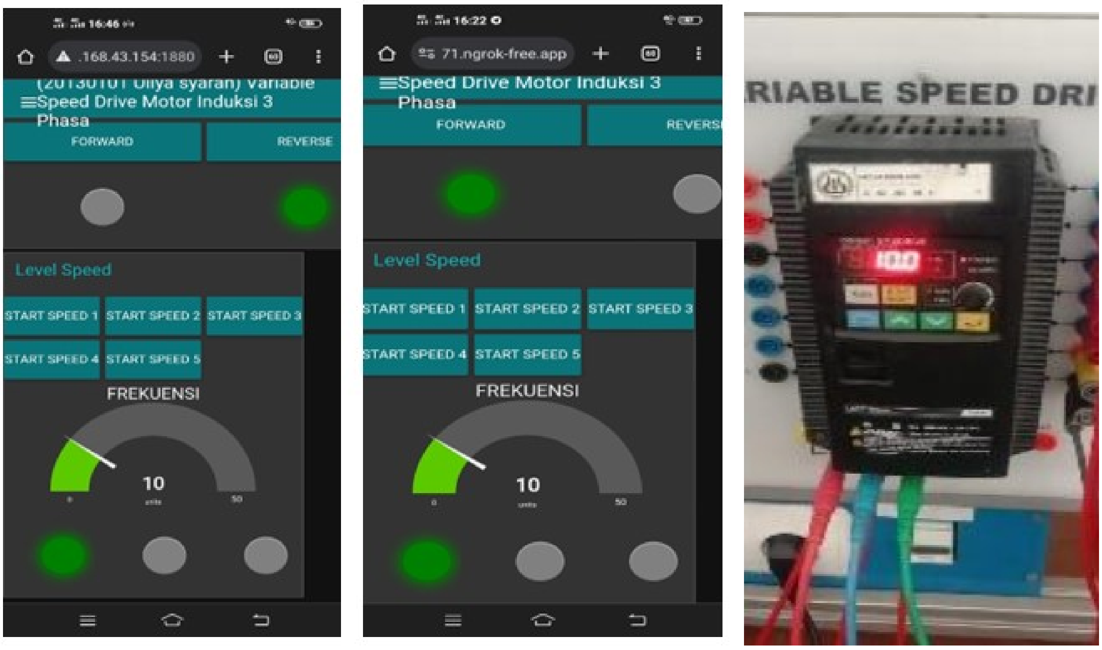

Figure 7. Smartphone screen at first test

When the motor speed is set with a reference frequency of 10 Hz, the motor operates at a speed of 308.1 rpm with a stator voltage of 130 Volts and a current of 1.12 Ampere. Based on this data, the ratio of the motor voltage and frequency is 13. This result shows that the motor is operating at a rotational speed below the motor speed rating, which is 1435 rpm. This result also shows that the motor voltage is also below its rated voltage. This shows that the motor is operating in the constant torque zone.

Next, testing was carried out with varying frequencies and rotation directions. Frequency variations were made in 5 types according to 5 levels of motor speed. Frequency variations start from 10 Hz for speed level 1, 20 Hz for speed level 2 and up to 50 Hz for speed level 5. The test results are summarized in Table 1.

Table 1. Experimental Results

Frequency	Speed (rpm)	Voltage (Volt)	Current (A)	V/Hz
10	308,1	130	1.12	13
20	597,3	213	1.31	10.65
30	904	277	1.11	9.2
40	1187	332	1.04	8.3
50	1495	388	0.94	7.76

Table 1 data shows that when the speed is increased to level 2 with a reference frequency of 20 Hz, the motor speed is 597.3 rpm with a voltage of 213 Volts. While the motor current is 1.31. These results show that the greater the set point frequency, the motor speed increases. This also applies to the voltage value. This shows that the motor speed control is done by changing the voltage and frequency whose values are directly proportional. This is inversely proportional to the voltage and frequency ratio value, where when the motor speed is increased, the V/Hz ratio decreases, as shown by the data in Table 1. At the maximum reference frequency of 50 Hz, the motor operates at a speed of 1495 rpm and a voltage of 388 Volts. This indicates that the motor operates at a higher speed than its rating, which is 1435 rpm. This difference could be caused by the reading of the measuring instrument or other errors. But this value is still within the permissible tolerance limit.

All test results show that the three-phase induction motor control system with a cage rotor using IoT-based VFD with a constant torque control scheme has successfully controlled the speed and direction of the motor rotation as desired. The motor has been successfully operated and monitored from a PC server or from a smartphone using an internet network. This shows that the control of the induction motor with the IoT-based constant torque method has been in accordance with the objectives.

4. CONCLUSION

This study proposes the control and monitoring of three-phase induction motors using IoT-based VFDs. The control carried out includes speed control, starting, braking and direction of motor rotation. This can be done using Omron 3G3JX-A VFDs. IoT-based control and monitoring are implemented using PLCs with displays using PCs and smartphones. The IoT system is designed using the node-red application. The motor control system is designed based on scalar control with a constant torque method. Speed control is done by creating a motor speed set point in 5 speed levels. The test results show that the proposed system has successfully controlled and monitored the induction motor, both from a PC and a smartphone. This shows that the proposed system has worked well.

REFERENCES

[1] M. M. A. ME and M. M. Madhunisha, "Smart Internet of Things Based Induction Motor Parameter Monitoring and Control System," *Int. J. Recent Technol. Eng.*, vol. 9, no. 6, pp. 253–256, 2021.

[2] S. Madakam, R. Ramaswamy, and S. Tripathi, "Internet of Things (IoT): A Literature Review," *J. Comput. Commun.*, vol. 03, no. 05, pp. 164–173, 2015.

[3] M. G. Ioannides, A. P. Stamelos, S. A. Papazis, E. E. Stamataki, and M. E. Stamatakis, "Internet of Things-Based Control of Induction Machines: Specifics of Electric Drives and Wind Energy Conversion Systems," *Energies*, vol. 17, no. 3, 2024.

[4] F. Hanifah and M. Yuhendri, "Kontrol dan Monitoring Kecepatan Motor Induksi Berbasis Internet of Things," *JTEIN J. Tek. Elektro Indones.*, vol. 4, no. 2, pp. 519–528, 2023.

[5] K. Mykoniatis, "A real-time condition monitoring and maintenance management system for low voltage industrial motors using internet-of-things," *Procedia Manuf.*, vol. 42, no. 2019, pp. 450–456, 2020.

[6] K. S. Rekha and D. S. Ravi, "Induction Motor Condition Monitoring and Controlling Based on IoT," *Int. J. Electron. Electr. Comput. Syst.*, vol. 6, no. 9, pp. 75–81, 2017

[7] S. Vadi, R. Bayindir, Y. Toplar, and I. Colak, "Induction motor control system with a Programmable Logic Controller (PLC) and Profibus communication for industrial plants — An experimental setup," *ISA Trans.*, vol. 122, pp. 459–471, 2022.

[8] I. Rifaldo and M. Yuhendri, "Sistem Monitoring Kecepatan Motor Induksi dengan HMI Berbasis PLC," *JTEIN J. Tek. Elektro Indones.*, vol. 3, no. 2, pp. 319–325, 2022.

[9] P. M. Akotkar, V. S. Karale, and D. A. U. Jawadekar, "Condition Monitoring Of Three Phase Induction Motor Based on IOT," *Int. J. Electr. Eng. Ethics*, vol. 3, no. 4, pp. 1–7, 2020.

[10] G. M. Sung, Y. S. Shen, L. T. Keno, and C. P. Yu, "Internet-of-Things Based Controller of a Three-Phase Induction Motor Using a Variable-Frequency Driver," *2019 IEEE Eurasia Conf. IOT, Commun. Eng. ECICE 2019*, pp. 156–159, 2019.

[11] R. Azizipanah-Abarghooee and M. Malekpour, "Smart Induction Motor Variable Frequency Drives for Primary Frequency Regulation," *IEEE Trans. Energy Convers.*, vol. 35, no. 1, pp. 1–10, 2020.

[12] D. Zellouma, Y. Bekakra, and H. Benbouhenni, "Field-oriented control based on parallel proportional–integral controllers of induction motor drive," *Energy Reports*, vol. 9, pp. 4846–4860, 2023.

[13] M. G. Ioannides *et al.*, "Design and Operation of Internet of Things-Based Monitoring Control System for Induction Machines," *Energies*, vol. 16, no. 7, 2023.

[14] M. Irfan, N. Saad, R. Ibrahim, and V. S. Asirvadam, "Development of an intelligent condition monitoring system for AC induction motors using PLC," *BEIAC 2013 - 2013 IEEE Bus. Eng. Ind. Appl. Colloq.*, pp. 789–794, 2013.

[15] S. N. Mahsahirun, N. R. N. Idris, Z. M. Yusof, and T. Sutikno, "Fundamental elements of constant volt/hertz induction motor drives based on dspace ds1104 controller," *Int. J. Power Electron. Drive Syst.*, vol. 11, no. 4, pp. 1670–1685, 2020.