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Monitoring and Analysis of Induction Motor Behavior Using Haiwell Cloud SCADA with Tension Control Method

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Abstract – In the modern industrial sector, monitoring the condition of induction motors is the main key to maintaining efficiency and reliability. Internet of Things (IoT) technology in the monitoring system can be done in real-time, to provide convenience in monitoring induction performance. Haiwell Cloud SCADA-based monitoring system to analyze the behavior of induction motors in real-time voltage, current, speed, frequency, and temperature. This system integrates a tension control method using a magnetic powder brake to simulate changes in the load dynamically. The results show that at a low torque of 0 – 6 Nm, the induction motor operates stably at a speed close to synchronous with a low stator current. However, at torques above 8 Nm, there is a significant voltage drop, and the stator current increases four times compared to the nominal current, and there is a temperature increase of up to 35^{o}C, which represents an increase in power losses. This research offers a combination of IoT-based monitoring and tension control methods. IoT-based monitoring systems help users easily monitor the performance of induction motors in real-time and anticipate potential problems before failures occur.

Keywords: Haiwell Cloud SCADA, Internet of Things, Monitoring, Powder Brake

I. INTRODUCTION

The era of the Industrial Revolution 4.0 has made technological civilization in the fields of education and industry increasingly rapid. Starting from the application of steam engines in the era of the Industrial Revolution 1.0 to significant changes in the era of the Industrial Revolution 4.0 in the digital fields of technology, physics, and biology [1][2][3]. In the modern industrial era, the application of induction motors has become a very important part of various industrial sectors, such as elevator systems, conveyor systems, and cutting machines that require a high level of accuracy and control. However, in their application, induction motors often face challenges in their operational technicalities, including load discontinuity, overtemperature, and the potential for mechanical failure that can affect the performance and life of induction motors [4], [5].

Conventional monitoring methods are often less effective, especially real-time monitoring in complex industrial environments. Internet of Things (IoT)-based technology and cloud computing have become widely used solutions in monitoring the condition of equipment remotely [6]. Previous research has developed IoT-based monitoring systems for induction motors, such as the implementation of IoT systems for monitoring induction motor parameters using telegram-based sensors [7]. Another study, discusses the application of IoT systems for induction motor monitoring that is integrated with wireless communication-based sensors [8]. However, the study was limited to the analysis of the behavior of induction motors against variable load variations.

In addition, research that develops a Raspberry Pi-based monitoring system allows the monitoring of induction motor parameters in real-time [9]. This approach is quite innovative, but the system does not integrate the tension control method to simulate the changes of the induction motor, to understand the dynamic behavior of the induction motor under various operating conditions. Research related to monitoring the condition of induction motors using IoT carried out by [10], However, it only focuses on data analysis without active control over the load.

Based on the limitations of previous research, this study offers a new approach by integrating a cloud-based monitoring system with a tension control method using a powder brake. as an effective solution to simulate the loading of an induction motor by varying the current injection to the powder brake. So that it will produce braking torque that can be adjusted precisely [11], [12]. This combination not only monitors in real-time but also analyzes the behavior of induction motors due to load variations with more precision. Using Haiwell Cloud SCADA, this research contributes to data management and behavior analysis of induction motors that are more accurate than conventional monitoring systems.

This study aims to develop a cloud-based monitoring system that can analyze the effect of braking torque variations on the main parameters of induction motors, such as voltage, current, temperature, speed, and frequency. Thus, the potential for early operational failure can be reduced and become the basis for efficient and reliable predictive maintenance [13], [14]. This system is expected to reduce the risk of operational disruption, increase efficiency, and extend the operational life

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of induction motors.

II. METHODS

The study conducted is experimental to develop a cloud-based monitoring system to analyze the behavior of induction motors by the specifications in Table 1. The main parameters monitored include speed, temperature, current, voltage, and frequency. The motorcycle loading system uses a tension control method with a powder brake that produces braking torque through variations in the injected electric current. The monitoring process uses *Haiwell Cloud SCADA* which is integrated with *Human Machine Interface (HMI)* and *smartphones*. The performance of the computer used to integrate the cloud system uses *an Intel core i5, 16 gigabytes of RAM,* and *Nvidia GeForce RTX*. 3-phase induction motor as the object under study is paired with sensors to measure operational parameters in real-time.

Table 1. Induction Motor Specifications

Type	FL-80A-2
Power	1 HP
Voltage	220/380 VAC
Speed	2825 RPM

The data obtained from sensor measurements is sent through a *Programmable Logic Controller (PLC)* which is then able to be integrated with *the cloud* for data storage. Cloud systems allow data visualization through human-machine interfaces often referred to as *Human Machine Interface (HMI).*

A. *Induction Motor Mathematical Model*

In this mathematical model of induction motors, the equation of stator voltage and electromagnetic torque with the d-q *(direct-quadrature)* framework is used in determining the behavior of induction motor [15], [16]. Equation (1) is a mathematical model of stator voltage which is shown as follows.

$$V_s = R_s i_s + \frac{d\lambda_s}{dt} j\omega_s \lambda_s \quad (1)$$

The stator voltage equation in an induction motor is the most important factor, as it represents the relationship between the stator current, magnetic flux, and voltage in the motor. The equation functions in understanding and analyzing induction motors. In addition, the magnetic torque in the induction motor is useful as an evaluation of the dynamics of the induction motor against sudden changes in load, to find out the change in torque over time. The mathematical model is shown in Equation (2).

$$T_e = \frac{3}{2} \cdot \frac{P}{2} \cdot (\lambda_{ds} i_{qs} - \lambda_{qs} i_{ds}) \quad (2)$$

Based on the equation V_s Represents Voltage *d-q* stator; $R_s i_s$ Represents rotor resistance and current in the rotor; ω_s Represents the angular velocity of the stator, λ_s is the D-Q flux stator, dan i_d, i_q Represents the current of the D-1 stator.

B. *Tension Control Method*

Tension control is a method that utilizes a Magnetic Powder Brake (MPB) as an electromagnetic brake that functions to provide braking torque in industrial applications, especially induction motors simultaneously. In this tension control, is modeled by regulating the input current so that it produces the appropriate torque to analyze the system's response to changes in motor characteristics. The mathematical modeling for braking torque is represented through equation (3).

$$T = k \,.\, \Phi \,.\, A \,.\, \sin(\theta) \quad (3)$$

Equation (4) is magnetic flux Φ and magnetic fields B related to electric current I Through Ampere Law.

$$\Phi = B \,.\, A \quad (4)$$

With,

$$B = \mu_0 \,.\, \mu_r \,.\, \frac{N \,.\, I}{l} \,.\, A \quad (5)$$

So that,

$$\Phi = \mu_0 \,.\, \mu_r \,.\, \frac{N \,.\, I}{l} \,.\, A \quad (6)$$

The magnetic flux equation in equation (6) is substituted in equation (3) to be,

$$T = k \,.\, \mu_0 \,.\, \mu_r \,.\, \frac{N \,.\, I}{l} \,.\, A^2 \,.\, \sin(\theta) \quad (7)$$

The material, geometric, and angular constants possessed by the magnetic powder brake are combined into a single constant in equation (8)

$$k_t = \mu_0 \,.\, \mu_r \,.\, \frac{N \,.\, A^2 \,.\, \sin(\theta)}{l} \quad (8)$$

So that,

$$T = k_t \,.\, I \quad (9)$$

In equation (9), T represents braking torque in units N_m, The torque constant is represented by k_t with units N_m/A, and I represents the magnitude of the current flowing on the powder break magnetic coil in *Ampere*.

This system allows precise control of torque by regulating the amount of input current applied to the magnetic powder break, so that its effect on the behavior of the induction motor can be analyzed under various loading conditions.

C. *Integrasi Sistem Cloud*

In this study, the integration of cloud systems uses Haiwell Cloud SCADA which can support data storage, data analysis, and data processing in real-time. The system architecture is designed with sensors to acquire data from induction motors, which will later be sent to the cloud, where it is stored and analyzed. The data acquisition process is carried out using sensors attached to the induction motor to carry out the process of measuring parameters such as voltage (V), current (I), Frequency (f), and temperature (T). The data read by the sensor is sent to a gateway connected to the cloud with MQTT and Modbus TCP/IP communication protocols using ethernet, wifi, and 4G/5G network connections to ensure a stable and secure data transmission process. So that it can be accessed by users via the web or mobile devices.

III. RESULT AND DISCUSSION

This study implements a monitoring system based on Haiwell Cloud SCADA to monitor and analyze the behavior of induction motors with a tension control method that uses magnetic powder brakes. This system can provide real-time data in the form of speed, current, voltage, temperature, and frequency. An illustration of the series of research processes carried out is shown in Fig. 1. In the figure, (1) a magnetic powder brake is used to simulate the variation of the load of the induction motor; (2) the induction motor to be tested for its characteristics by the specifications contained in Table 1; (3) a

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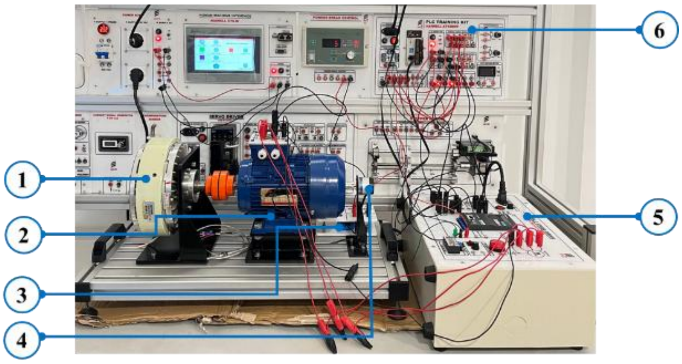
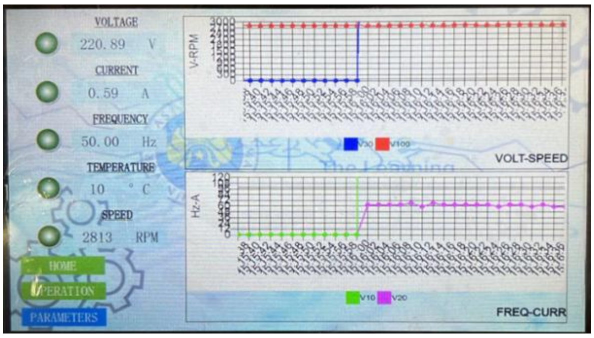
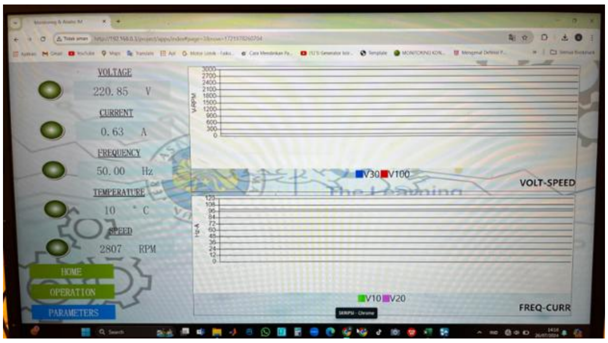


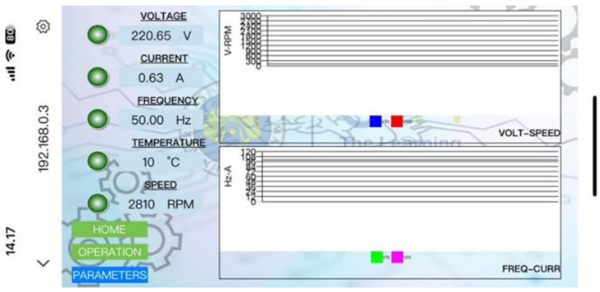
Fig. 1. *Monitoring and analysis system with tension control*



(a)



(b)



(c)

Fig. 2 (a) Monitoring Through HMI; (b) Monitoring Through PC; (c) Monitoring Through Smartphones

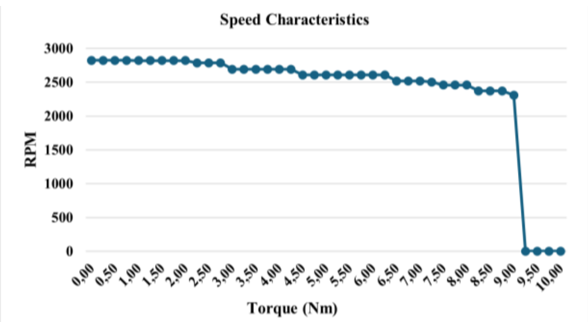


Fig. 3. Torque and Speed Relationship

temperature sensor used to detect the temperature on the induction motor; (4) rotary encoder which serves as induction motor speed detection; (5) Variable Speed Drive as an induction motor driver integrated with voltage, current and frequency sensors; (6) Centralized control system with PLC capable of reading and analyzing every sensor detection parameter.

A. Monitoring Induction Motor Behavior

The designed cloud system successfully acquires data and displays it on a dashboard that can be accessed through HMI, PC, and smartphone. Fig. 2 shows the induction motor parameter monitoring display via SCADA.

The recorded data shows that under light load conditions at 0 – 6 Nm of torque, the induction motor operates in a stable condition with a speed close to synchronous with a relatively small stator current. However, in conditions of high torque loads of more than 8 Nm, there is a significant decrease in stagnation, in line with the increase in current and motor temperature. This process is in line with [8], which shows that IoT-based induction motor monitoring is more responsive than conventional methods. However, the research conducted by the researcher in this paper provides an approach related to the integration of tension control methods to analyze the effect of load changes on the behavior of induction motors in depth.

B. Torque Analysis on Induction Motor Speed

The rotational speed of the induction motor is greatly affected by the magnitude of the load simulated by the braking torque using a magnetic powder brake. The measurement results show that the speed of the induction motor decreases with the amount of braking torque and increases the slip on the rotor, as shown in Fig.3.

Based on Fig. 4, The results of the study show that at low torque of 0 – 6 Nm, the speed of the induction motor tends to be stable with a relatively small slip and experiences a slight decrease in speed. This phenomenon is due to the frictional force of the magnetic powder brake can still be balanced by the electromagnetic torque of the induction motor. However, as the brake torque increases at 9 Nm, the speed of the motor decreases significantly, causing an increase in rotor slip. However, when the loading torque reaches 10 Nm, the motor is overloaded and stops spinning.$0{,}00\ Nm 10{,}00\ Nm$.

This representation is in line with the mathematical model of induction motors regarding an increase in load torque increasing slippage, resulting in a decrease in motor speed. This is supported by [5], related to non-linear speed changes due to increased rotor resistance

C. Current Analysis of Torque

A significant decrease in speed has an impact on the current behavior of the induction motor. An increase in brake torque causes the motor load torque to increase, so the stator current tends to increase because the relationship between the torque and the stator current is shown in Fig. 4. In the no-load condition or in the condition of low braking torque, the current drawn by the stator is relatively small, as much as 0.59 A to 1.19 A, indicating the basic load of the induction motor under normal conditions. However, when the brake torque increases to $9{,}00\ Nm$, the stator current increases to 4 amperes or about 4 times the nominal current. So when compared to the nominal current of the induction motor, there is an increase in current by 4 times. Significant current increases cause power losses in the motor, which impacts efficiency and potential overtemperature.

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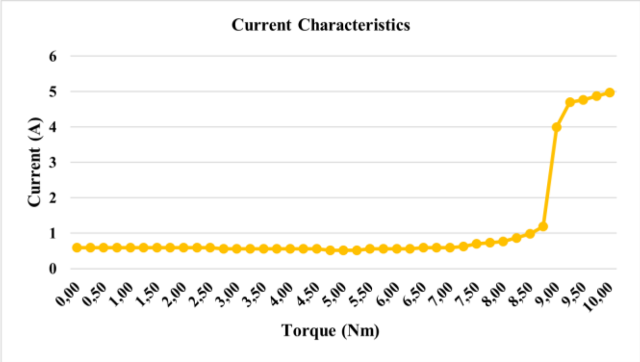

Fig. 4. Torque and Current Relationship

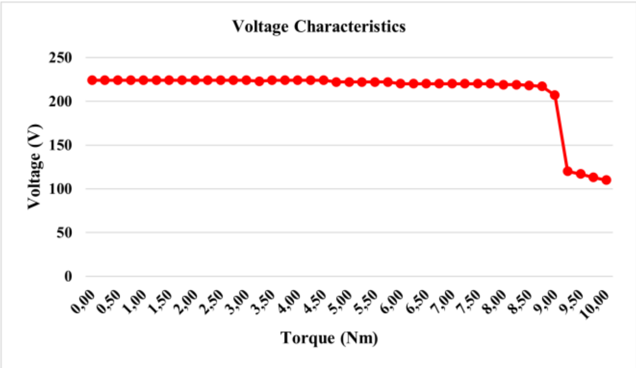

Fig. 5. Torque and Voltage Relationship

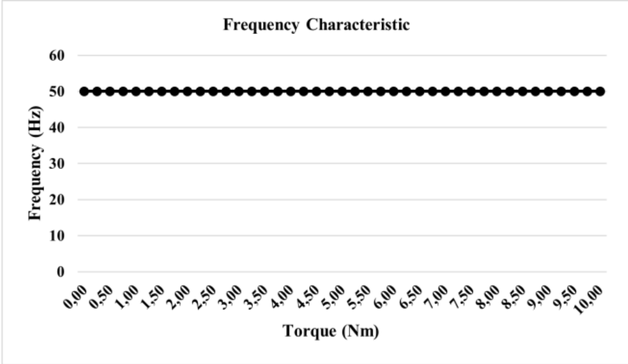

Fig. 6. Torque and Frequency Relationship

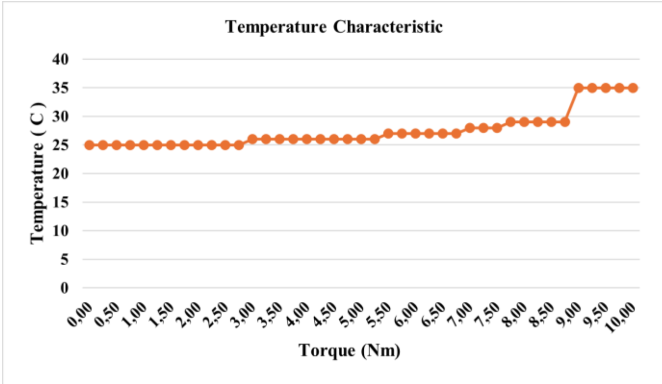

Fig. 7. Karakteristik suhu akibat peningkatan torsi beban

The results of the analysis of recorded data show that the relationship between torque and stator current is in line with research related to the increase in current in induction motors in direct proportion to the increase in slip, which will later have an impact on the power dissipation and temperature of the motor [9].

D. Voltage Analysis of Torque

This increase causes the voltage measurement results to remain stable at low torque but experience a significant decrease when the torque exceeds 8 Nm, as represented in Fig. 5.

Based on the observed curve, the motor voltage is relatively stable in the range of 220 – 230 V when the torque is at 0 – 8 Nm. This shows that the system is still normal without interference. However, when the incubation load torque exceeds 8 Nm, there is a very significant voltage drop. Until the torque is about 9 Nm. At a load torque of more than 9.5 Nm, there is a voltage drop of up to 100 V, which indicates that the voltage drop is beginning to occur due to an increase in the impedance of the stator circuit. If this condition is not responded to further, it can cause the induction motor to operate outside the optimal limit, which has the potential for long-term damage. This reinforces studies related to voltage drops due to increased loads can lead to increased daytime losses and reduced efficiency [17].

E. Frequency Analysis of Torque

The results of the measurement of the effect of torque on the frequency of the induction motor are shown in Fig. 6. The induction motor operates at a fixed frequency supply of 50 Hz, which indicates that VSD does not perform any frequency variation in motor speed control. According to Fig. 6, because the frequency is fixed, the rotor speed can only change as a result of slip variations affected by braking torque. When there is an increase in torque, the holding force acting on the rotor increases and causes the rotor speed to decrease and increase the slip on the motor. This increase is caused by power losses due to increased current in the stator and rotor windings

F. Temperature Increase Due to Overload

The main challenge in the operation of induction motors is the increase in temperature due to overloads, which can reduce the service life of components. The characteristics of the temperature change of the induction motor due to torque variation are shown in Fig. 7.

Based on Fig. 9, it shows that in the condition of low load torque (0 – 6 Nm), the motor temperature is relatively stable in the range of 25ºC – 27ºC, which represents that heat dissipation due to power losses in the stator and rotor is still at a reasonable level. However, when the load torque increases to 9 Nm, there is a significant temperature rise, reaching 35ºC, which indicates that the induction motor produces excessive heat dissipation due to the effect of increased current on the induction motor. This is in accordance with the explanation in the study which explains that the increase in motor temperature is influenced by increased slippage and power losses due to overload.

IV. CONCLUSION

The results of the study on Monitoring and Analysis of Induction Motor Behavior Using Haiwell Cloud SCADA with the Tension Control Method with magnetic powder brake show that the increase in braking torque causes a decrease in motor speed, an increase in rotor slip, and an increase in stator current up to four times the nominal current without load. In addition, voltage drops occur at torques of more than 8 Nm as well as increases of up to 35°C, which can accelerate the reduction in the service life of induction motors.

The cloud-based monitoring system allows real-time monitoring and detection of potential operational disruptions.

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Thus, improving the efficiency and reliability of induction motors in industrial applications. In the application of this technology, predictive maintenance strategies can be optimized, reducing the risk of system failure, and extending the life of the motorcycle. As further development, the system is combined with artificial intelligence and tested on industrial load types to expand its application in the manufacturing and industrial automation sectors.

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