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Development of a Miniature Diskmill Machine Monitoring System Based on IoT

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***Abstract*— Embedded System are microprocessor-based computer systems designed within a system or machine to perform specific functions. This research aims to conduct Research and Development of IoT-based Embedded Systems in the design of a disk mill machine, where IoT is used as a control and security system to monitor and control the working parameters of the disk mill machine in real-time for the design of specialized industrial products at PT Karya Tepat Santoso. With the current technological advancements, the design results of an embedded system machine using an Arduino microcontroller open up opportunities for further development such as adding control features and monitoring the machine using the internet-of-things concept with a mobile application to monitor machine security or systems connected to the internet. Thus, this research can contribute to technological innovation from programming IoT embedded systems in related machines that can potentially be expanded according to industry needs.**

Keywords*— Embedded System Design, Arduino, Control and Safety, Disk Mill Machine, Machine Security Monitoring.

I. INTRODUCTION

The Internet of Things is a concept aimed at expanding the benefits of an internet connectivity network that is continuously connected to an internet infrastructure [1]. In practice, IoT is a collection of objects with sensors that meet the needs of the installed system and are connected to a network. Each programmed sensor generates data information which is then processed by the IoT system for further processing and analysis into useful data for monitoring the object [2]. With the development of the internet and technology today, in theory, the internet allows everyday objects to connect to the internet, not just computers and smartphones, but also household door locks, home lighting, and motorcycle security systems. PT Karya Tepat Santoso is a new startup company producing raw materials such as structural iron and custom machinery, one of which is a Diskmill machine. The Diskmill machine is often operated manually, which carries risks of workplace accidents, unmonitored machine damage, and operational errors that can decrease work efficiency. Therefore, project managers at the company require an automated control system that not only simplifies the machine operation process but also enhances safety and extends the machine's lifespan. The objectives of this research are: (1) To design and implement a control and safety system for an Arduino-based miniature Diskmill machine. (2) To develop a mobile application for monitoring the miniature Disk Mill machine by utilising sensors to detect the machine's condition and provide early warnings.

II. LITERATURE REVIEW

A. Arduino

Arduino is an open-source microcontroller platform for designing electronic projects that use hardware and software that is easy to access or use. The Arduino microcontroller PCB can read inputs from sensor detection, button presses or other messages and convert them into outputs such as motor activation, turning on LED lights, and other outputs by providing a set of instructions to the Arduino microcontroller PCB using the Arduino programming language and the Arduino IDE software for device design code development. Arduino is programmed using a language similar to C/C++. This platform is used in various applications, from simple ones such as lighting up a house through smart home design to more complex applications like IoT (Internet-of-Things) systems, automatic control systems, and robotics projects.

B. Diskmill Machine

The Diskmill machine is a type of grinding machine that generally uses two discs as a medium to crush or grind materials. The Diskmill is a milling tool used to grind solid raw materials into fine powder, but it is also often used for grinding low-fibre materials [3]. This machine is widely used in the processing industry for raw materials, food, and agriculture, such as grinding rice, corn, fish, and animal feed ingredients. The machine functions to grind materials into smaller particles, and its use can expedite the processing of materials to help improve productivity and production efficiency. The fine particles exit through the outlet.

C. Internet of Things

The Internet of Things, abbreviated as IoT, is a concept of a network where various physical devices such as sensors, vehicles, appliances, and other devices are connected to each other via the internet and exchange data without direct human interaction, with the general aim of facilitating machine automation and improving efficiency in various applications, for example, enhancing operational efficiency by automating tasks and monitoring device conditions in real-time. To support the implementation of IoT, several integrated basic technologies or modules are required, such as sensors, Bluetooth, relays, and others. IoT is the relationship between humans and devices or between devices that utilise the internet network as a bridge for exchanging data and information [4].

D. Flutter

Flutter is an open-source framework developed by Google for building multi-platform applications using a single codebase. By using Flutter, software developers can create

applications for mobile devices, the web, and computers using the Dart programming language. What distinguishes Flutter from other multi-platform software development kits is that Flutter does not use bridging like other multi-platform approaches, changes to the platform, such as updates to Flutter versions, mostly do not disrupt the application's performance [5].

E. SIM800L

The SIM800L is a GSM/GPRS communication module. This module supports 2G GSM networks and can be used to send and receive SMS, make phone calls, as well as GPRS data connections. The module is small in size and can be integrated into IoT projects that require long-distance communication over cellular networks. The SIM800L module can be used to send and receive SMS, make and receive calls, and enables communication on IoT devices without a Wi-Fi connection, making it suitable for use in remote areas. The SIM800L module can be used for monitoring devices via SMS and functions as an SMS gateway when connected to a microcontroller [6]. This module will be used in the design to send warning messages when an error occurs in the machine.

F. HC-05

The HC-05 is a Bluetooth-based wireless communication module designed to support wireless communication. This module is used in the miniature Disk Mill machine as communication for the designed machine control. The principle of operation of the HC-05 works by converting serial data from the microcontroller into Bluetooth signals. The HC-05 Bluetooth module requires two resistors with values of 4.7 thousand Ohms and 2 thousand Ohms for the module to function properly for transmission with Arduino. The HC-05 module is easy to use in wireless communication, especially in converting serial port readings to Bluetooth.

III. METHODOLOGY

A. R&D Research Methods

The Research and Development (R&D) method is a research approach aimed at developing and producing new products that can be used to solve specific problems. It can be concluded that R&D serves as a bridge between theory and practice through the creation of a product to address an issue, involving a systematic process from initial research, product development, to implementation. The product can be a technological application or other products relevant to user needs[7]. The general stages for implementing the R&D method are:

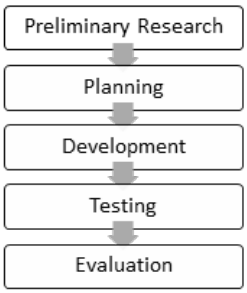

Fig. 1. R&D Research Methods

B. Results of the Preliminary Interview Research

Explaining the results of interviews with expert sources about related machines such as the need for machine safeguards and their opinions if the machines are designed with IoT technology. The results of the interviews can be seen in table i.

TABLE I. INTERVIEW RESULT TABLE

Question:	Answers:
What are the main functions required to control a disk mill machine?	1. Pneumatic Cylinder for Input 2. Control Ampere 3. Phase Failure 4. Star Delta
What safety measures are needed to reduce the likelihood of damage to the disk mill machinery?	1. Pneumatic Cylinder to determine the amount of material input with the machine valve 2. Control Ampere to limit the motor load of the disk mill 3. Phase Failure to prevent damage to the 3-phase motor in case one of the cables (phase) is without voltage or insufficient power.
What do you think about the machine having an automatic warning feature if an error occurs?	To prevent damage, there must be an automated warning feature.
For example, if an error occurs, what do you think about a machine being able to automatically report warnings to a phone via the internet?	There are many benefits of these automatic features for the efficiency of machine operational costs.

The interview data were analysed to meet the design requirements of the monitoring application functions, as shown in the following Table ii.

TABLE II. APPLICATION FEATURE REQUIREMENT ANALYSIS TABLE

No	Application Features	Accepted	Description
1	Determination of the amount of incoming material flow.	No	Lack of funds.
2	Operating the machine.	Yes	
3	Controlling the electrical current limit of the machine.	Yes	
4	Machine notification	Yes	
5	Machine notification history log	Yes	
6	Backup notification history log	Yes	

C. Equipment Needs

Explaining the requirements for the IoT system design project, the components and other equipment for the design purposes on the Arduino microcontroller can be seen in the following table iii.

TABLE III. IOT SYSTEM DESIGN COMPONENT EQUIPMENT

Name	Unit
Arduino Nano	1
Arduino Nano I/O *Expansion Shield*	1
1-Channel Relay	1
Voltage Sensor DC 0-25v	1
Current Sensor ACS712	1
Push-Up Button	2
Breadboard	1
LCD I2C	1
Rotary Encoder	1
SIM800L	1
Stepdown L2596	1

HC-05 Bluetooth	1
10k Ohm Resistor	2
20k Ohm Resistor	2
Power Outlet	1
Power Supply 9v 1a Adapter	1
Power Supply 9v 2a Adapter	1
Avometer	1
small screwdriver	1
Jumper Cable	As much as needed

D. *Arduino Design Plan*

For the design of the embedded system of the miniature Disk Mill machine. It can be seen in the following design Figure 2.

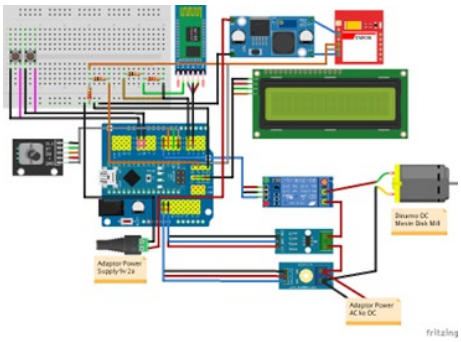

Fig. 2. Design of the Embedded System Machine Arduino

E. *IoT Machine System Flowchart Arduino Design Plan*

The flowchart visualising the depiction of the developed IoT system process can be seen in the following figure 3.

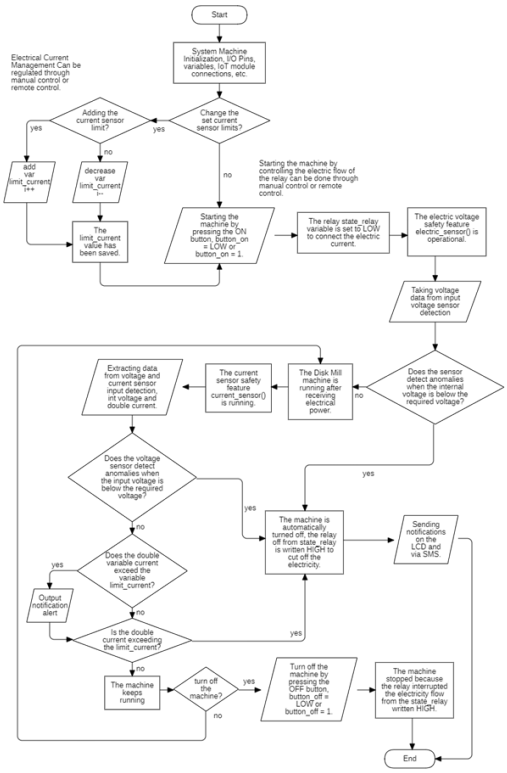

Fig. 3. Flowchart Diagram for Embedded System of Miniature Disk Mill

F. *Entity Relationship Diagram*

An Entity Relationship Diagram shortened ERD is a type of diagram used to model the structure of an application database. This diagram illustrates the variables and data types of a table within the system database, as well as the associative relationships between tables. In the development of an IoT application for monitoring miniature machines, the following diagram depicts the table structure for storing the history of machine breakdowns in the application that will be created.

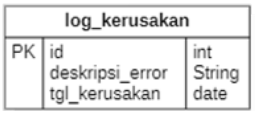

Fig. 4. ERD of the IoT Mobile Application for Miniature Disk Mill Machine

G. *Testing Plan for IoT and Miniature Disk Mill Machine Application*

To analyse the performance and data results from the testing of the miniaturised embedded system design, the system testing data will be documented in the form of a testing table, charts, and a black box method for mobile applications. The testing table is a systematic document used to record, organise, and evaluate the functional testing results of the Arduino device. This table contains tests designed to ensure that every function and performance in the Arduino-based project works as expected, with charts for a clearer overview, and black box testing, which is the process of testing applications without knowing the underlying code for mobile application feature testing.

IV. RESULTS AND DISCUSSION

A. *Photographs of the Miniature Machine Design*

The following Figure below is a photo of the design of a miniaturised disc mill machine with Arduino IoT components.

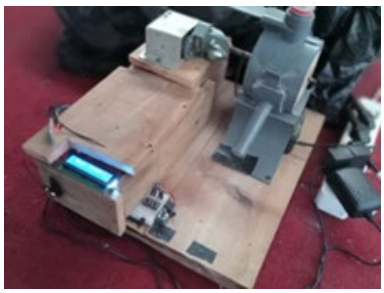

Fig. 5. Photograph of the Design Results for the Miniature Disk Mill Monitoring Machine

In the machine, particularly in the engine compartment on the left side in figure 5, is the result of the design of the IoT system for the miniature machine, which comprises IoT components including a physical controller and an LCD interface, a GSM and Bluetooth communication module for communication between the machine and the Android application, current and voltage sensors to detect the electrical supply to the machine, a relay to connect the electrical flow, a step-down LM and resistor to reduce voltage and signal from the communication module according to specifications. The

design results of the components for the IoT system can be seen in figure 6 below.

Fig. 6. Photograph of the IoT System Design Results in a Miniature Machine

B. Results of Mobile Application Development

The following images are screenshots of the control and monitoring application that was developed, starting with the control page to manage a miniature disk mill using Bluetooth, as shown in figure 7.

Fig. 7. Bluetooth Control Page

Secondly, the result of the SMS page development to view the damage notification messages sent from the machine can be seen in figure 8 below.

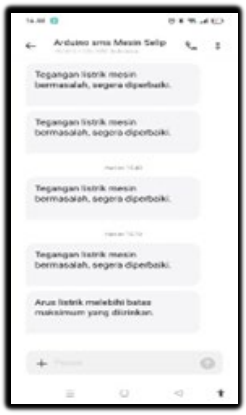

Fig. 8. SMS Notification Page

Thirdly, the development results of the damage history page of the machine with notification delivery via Bluetooth communication to determine the machine faults that have occurred along with the management of its recovery database can be seen in the layer capture in the following figure 9.

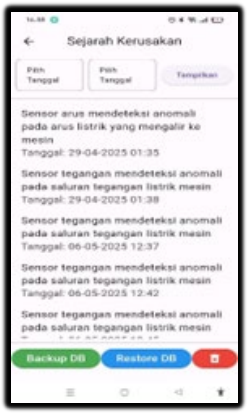

Fig. 9. History of Damage Page

C. Results of Testing the IoT System Functionality for the Miniature Disk Mill Machine

The development of the IoT system in the machine can be seen in table iv, which shows the results of the development for each module installed in the miniature disk mill.

TABLE IV. TABLE OF IOT MACHINE SYSTEM FUNCTION TEST RESULTS

No	Function	Result	Description
1	On Button	Functioning	
2	Off Button	Functioning	
3	Encoder Driver Ampere Setting	Functioning	
4	Bluetooth control	Functioning	Used with a mobile application
5	SMS Notification	Functioning	It takes a moment of about more than 10 seconds to activate normally.
6	Electrical Connection Relay	Functioning	
7	Voltage Sensor	Functioning	
8	Current Sensor	Functioning	
9	LCD Display	Functioning	

D. Results of Black Box Testing for the Mobile Application

For testing the mobile application for monitoring miniature machines, a black box method was used for testing the application's features, with table v providing a detailed explanation of the tests that have been conducted.

TABLE V. BLACKBOX TESTING RESULTS TABLE FOR THE APPLICATION

No	Feature being tested	Testing scenario	Test results	Description
1	Bluetooth button	Pressing the Bluetooth switch	Bluetooth is enabled and can search for Bluetooth devices.	When activating Bluetooth within the application, it always requires activation permission.
2	Search Button	Press the search button and then press HC-05.	The mobile application is connected to the machine.	

3	On Button	Press the on button after connecting to the machine.	The machine is turned on and sends notifications to the application.	There is a notification bug due to signal interference from the running engine dynamo.
4	Off Button	Pressing the off button after pressing the on button when connected to the machine	The machine stopped and sent a notification to the application.	
5	Add Current Limit	Press the increase current button after connecting to the machine.	The machine adjusts the current limits of the machine and provides notifications.	
6	Reduce Current Limit	Press the decrease current button after connecting to the machine.	The machine adjusts the current limits of the machine and provides notifications.	
7	SMS button	Pressing the SMS navigation button.	Enter the SMS page.	
8	Damage History Button	Pressing the History navigation button.	Enter the Damage History page.	
9	*Backup and Restore database*	Press the backup button, then press delete and then press restore database.	The recovery of historical database damage can be managed.	When using the application for the first time, permission from Android will be requested.
10	Set the time of damage	Setting the time settings on the history page	The application displays the history of damage at the specified time.	

E. Bluetooth Control Performance Testing Results

In testing the performance of machine control using the application, trials were conducted to determine the system's response to the machine at different distances to assess the feasibility of machine control using Bluetooth communication by issuing commands to operate the machine and set current limits. The results of the performance test via Bluetooth communication can be seen in figure 10 and in detail in table vi, the distance is measured by metres and the delay response time is measured by seconds.

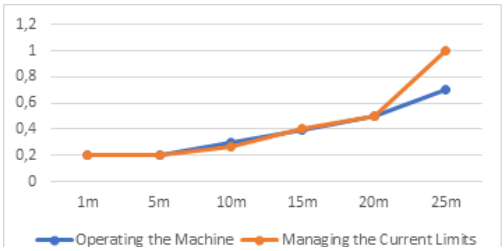

Fig. 10. Bluetooth Control Performance Graph

TABLE VI. BLUETOOTH CONTROL PERFORMANCE RESULTS TABLE

No	Type of Command	Distance	System Response	Connection Lost	Delay	Result
1	Operating the Machine	1	Yes	No	0,2	Functioning
2	Managing the Current Limits	1	Yes	No	0,2	Functioning
3	Operating the Machine	5	Yes	No	0,2	Functioning
4	Managing the Current Limits	5	Yes	No	0,2	Functioning
5	Operating the Machine	10	Yes	No	0,3	Functioning
6	Managing the Current Limits	10	Yes	No	0,27	Functioning
7	Operating the Machine	15	Yes	No	0,39	Functioning
8	Managing the Current Limits	15	Yes	No	0,4	Functioning
9	Operating the Machine	20	Yes	Yes	0,5	Unstable
10	Managing the Current Limits	20	Yes	Yes	0,5	Unstable
11	Operating the Machine	25	Yes	Yes	0,7	Unstable
12	Managing the Current Limits	25	Yes	Yes	1	Unstable
13	Operating the Machine	28	No	Yes	Disconnected	Not Functioning
14	Managing the Current Limits	28	No	Yes	Disconnected	Not Functioning

F. Results of Notification Testing to the Application

The next trial is testing notifications during electrical anomalies on the miniature machine. The notification performance testing consists of two methods, namely SMS Gateway and Bluetooth as follows:

1) SMS Gateway Notification Performance: The performance results of the response and SMS replies sent by the machine to mobile application averaged 0.5 seconds in a stable phone network using an SMS gateway, as shown in figure 11 and table vii.

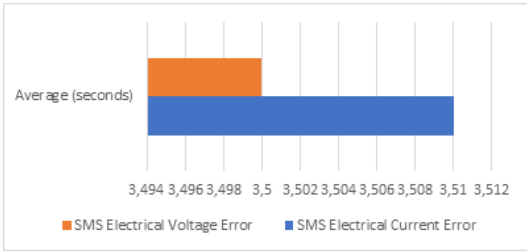

Fig. 11. Notification Test Results Graph with SMS Gateway

TABLE VII. NOTIFICATION PERFORMANCE TEST RESULTS WITH SMS GATEWAY

No	Type of Notification	System Response	SMS reply	Average delay (seconds)	Result
1	Electrical Voltage Error	Yes	Yes	3,5	Functioning
2	Electrical Current Error	Yes	Yes	3,51	Functioning

2) Bluetooth Notification Performance: The test results send notifications via Bluetooth from the machine to the Android application. It is noted that after the machine is turned on, there is a delay programmed for the starter of the machine for 3 seconds. The time measured is the seconds after the starter with an average delay of 1 second, as shown in figure 12 and table viii.

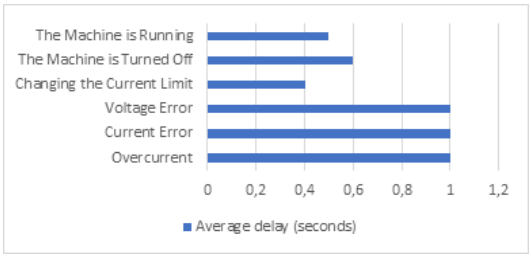

Fig. 12. Notification Testing Results to the Application Graph via Bluetooth

TABLE VIII. TESTING RESULTS FOR NOTIFICATIONS TO THE APPLICATION TABLE VIA BLUETOOTH

No	Type of Notification	Notification Sent	Delay (seconds)	Result
1	The Machine is Running	Ya	0,5	Functioning with bugs due to engine vibrations
2	The machine is turned off	Ya	0,6	Functioning
3	Rubah Batas Arus	Ya	0,4	Functioning
4	Voltage Error	Ya	1	Functioning and recorded in the database
5	Current Error	Ya	1	Functioning and recorded in the database
6	Overcurrent	Ya	1	Functioning with bugs due to engine vibrations

V. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The conclusion drawn from the development of the IoT system for monitoring miniaturised disk mill machines is that the miniaturised machine can be used as if it were the actual miniaturised disk mill, from the IoT control system design, and can be monitored when an error occurs in the electrical supply to the miniaturised machine, ensuring the machine's safety through programmed safety sensors. The developed mobile application can control the miniaturised machine and receive alert notifications from the machine, as well as store the timestamp of any malfunctions for monitoring purposes.

B. Recommendations

The suggestions provided by the author for further development and related IoT system research are as follows:

1) To design communication using integration with messaging applications such as WhatsApp for future research.

2) For the communication module, especially the GSM module, it is advisable to solder directly to avoid network communication bugs.

3) To design a debit input system to determine the materials entering the machine by measuring the electric current flowing, as the electric current increases, the machine valve will close more.

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