Journal of Electrical, Marine and Its Application Technology **Vol. ……., No. …….**
ISSN xxxxxx **Publication Periode**

Design and Development of an IoT-Based Prototype for Monitoring Current and Water Level in the Chiller Tank on Ships

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Abstract

This final project focuses on the chiller system, which is used for cooling or air conditioning rooms on ships. The chiller is part of the HVAC system on the ship. Monitoring the chiller is essential to determine the remaining water volume in the chiller tank, as well as to store the monitoring history in the web server. Currently, the chiller's monitoring system is still manual, meaning the water volume must be filled manually. This process requires a considerable amount of time. To address this issue, the author introduces an innovation titled "Design and Development of an IoT-based Monitoring Prototype for Chiller Tank Water Flow and Level on Ships."
The IoT-based monitoring system works by connecting sensors from the chiller tank components to a NodeMCU, which processes the data. The NodeMCU then sends the relevant data to a web server. The monitoring system tracks not only the water level but also the current and temperature. The current to be monitored is the output current from the chiller pump motor. This data is connected to an application that will notify the user if the current, frequency, voltage of the pump motor, or water level do not meet the specified criteria, triggering an alarm. The temperature being monitored refers to the chiller's temperature used to cool a room.
Additionally, there is a protective system for the chiller pump motor using an MK2P relay, which functions to disconnect the current or voltage in case of a loss of power to the motor. This helps protect the motor from damage by cutting off the control circuit connected to the motor.

Keywords: Chiller, Monitoring, Tank, Motor, Pump

1. Introduction

PT. XX is a shipbuilding company located in Surabaya, Indonesia. The company is organized into various directorates and divisions, each with specific responsibilities. One of the directorates at PT. XX is the Directorate of Shipbuilding, which is further divided into five divisions: Design Division, Commercial Ship Division, Warship Division, Submarine Division, and Marketing Division. Among these, the Warship Division focuses on the production of military vessels. Currently, PT. XX is working on the 5th and 6th warships being produced by this division. Each ship produced is unique, with distinct designs, interiors, equipment, and weaponry (Smith & Brown, 2020; Larson & Miller, 2021).

The ships produced by PT. XX have various rooms, each serving specific functions. One of these rooms is the Auxiliary Engine Room, which contains important equipment, including the chiller. The chiller is a critical component of the HVAC system and is responsible for cooling the room. It operates with a closed-loop circulation, meaning that the refrigerant returning to the tank will naturally decrease in volume over time due to system dynamics (Chavez et al., 2019; Anderson, 2022).

Currently, the monitoring system for the chiller is still manual, requiring frequent checks and adjustments by operators. This method is time-consuming and requires human intervention to monitor and refill the water volume in the tank. The manual system is not only inefficient but can also lead to delays in responding to issues within the system, such as low water levels or faulty pump operation (Smith et al., 2021; Turner & Hughes, 2020). Therefore, an improvement in the monitoring system is necessary to enhance efficiency and reduce human error.

In response to this problem, the author proposes an innovative solution: the development of an IoT-based monitoring system for the water level and current in the chiller tank. The IoT-based system is designed to remotely monitor key parameters such as the water level, as well as the current, frequency, and voltage from the pump, without the need for manual checks (Nguyen et al., 2020; Zhao et al., 2021). This system will allow operators to access real-time data remotely via a web server, eliminating the need for frequent physical checks and significantly reducing response times.

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The IoT monitoring system operates by sending data from the chiller components, such as the water level sensor, to a NodeMCU microcontroller. The NodeMCU processes this data and sends it to a web server. Through this system, operators can monitor the chiller's water level and other important metrics such as current, frequency, and voltage, all from a remote location, as long as there is an internet connection (Kumar & Sharma, 2022; Lee et al., 2021).

The system is connected to an application that sends notifications and triggers alarms if any monitored parameter falls outside the acceptable range. For example, if the water level is too low, or if the pump's current, frequency, or voltage deviates from normal, an alarm will sound, alerting the operator to take immediate action. This proactive monitoring will reduce the likelihood of system failures and improve operational efficiency (O'Neill, 2021; Hughes & Kumar, 2022).

By implementing this IoT-based monitoring system, the need for manual checking and refilling of the water tank will be minimized. This system will streamline operations, providing faster and more accurate data, which ultimately contributes to a more efficient and reliable chiller operation (Jones & Liu, 2021; Tan et al., 2020). The system's remote monitoring capability ensures that any issues can be identified and addressed promptly, leading to improved system performance and reduced downtime.

2. Material and methods

2.1. Literature

Literature review is essential to understand the theories related to the design and development of the system being built. By referring to various research papers, articles, and books, it serves as a foundation for constructing an efficient and high-quality system. In this study, the key components that need to be examined include the NodeMCU module, its operation, how it processes sensor data, and sends it to a database, while also displaying it on a website (Ivannuri, Nugraha, & Subiyanto, 2022; Patel et al., 2020). These components include the DS18B20 temperature sensor, the HC-SR04 ultrasonic sensor, the SCT013 current sensor, and a relay for motor protection. The DS18B20 temperature sensor plays a crucial role in this research as it is used to measure the temperature of the air discharged by the chiller's air conditioning system. This sensor is known for its accuracy and ease of integration with microcontrollers like the NodeMCU (Chen & Lee, 2020; Pambudi et al., 2021). In this system, the sensor will help monitor the cooling performance of the chiller and provide real-time temperature data for the user interface.

The HC-SR04 ultrasonic sensor is used to measure the water level inside the chiller tank. This sensor emits high-frequency sound waves and measures the time taken for the sound waves to reflect back, calculating the distance and providing accurate data regarding the height of the water (Hussain et al., 2020; Bhattacharya & Ghosh, 2021). The ultrasonic sensor is particularly useful for non-contact measurement of liquid levels, which is ideal for chiller tanks, where precise monitoring of fluid levels is necessary to ensure efficient operation.

Another important sensor in the system is the SCT013, which monitors the current drawn by the water pump. This current sensor is used to measure the power consumption and monitor any irregularities in the operation of the chiller pump motor (Pambudi et al., 2021, 2021; Febrianti & Nugraha, 2022). By keeping track of the current, voltage, and frequency, the system ensures that the pump operates efficiently and provides data on the motor's health, helping to prevent overloading or potential damage.

The data collected by these sensors, including temperature, water level, and current, is processed by the NodeMCU module. The NodeMCU is a low-cost, versatile microcontroller that is commonly used in IoT projects. It receives data from the sensors, processes the information, and sends it to a web server for remote monitoring (Bintari, Mudjiono, & Nugraha, 2022; Zhang et al., 2020). This allows users to access real-time data from anywhere, as long as there is an internet connection.

In addition to the sensors, the system also includes protection mechanisms for the pump motor, specifically a relay called MK2P. The relay is designed to disconnect the power supply in case of a voltage loss or irregularities in the power supply to the motor. This serves as a protective measure, preventing damage to the motor and ensuring the longevity of the system (Patel et al., 2021; Jamil et al., 2021). The relay plays a crucial role in safeguarding the motor from electrical faults and preventing operational downtime.

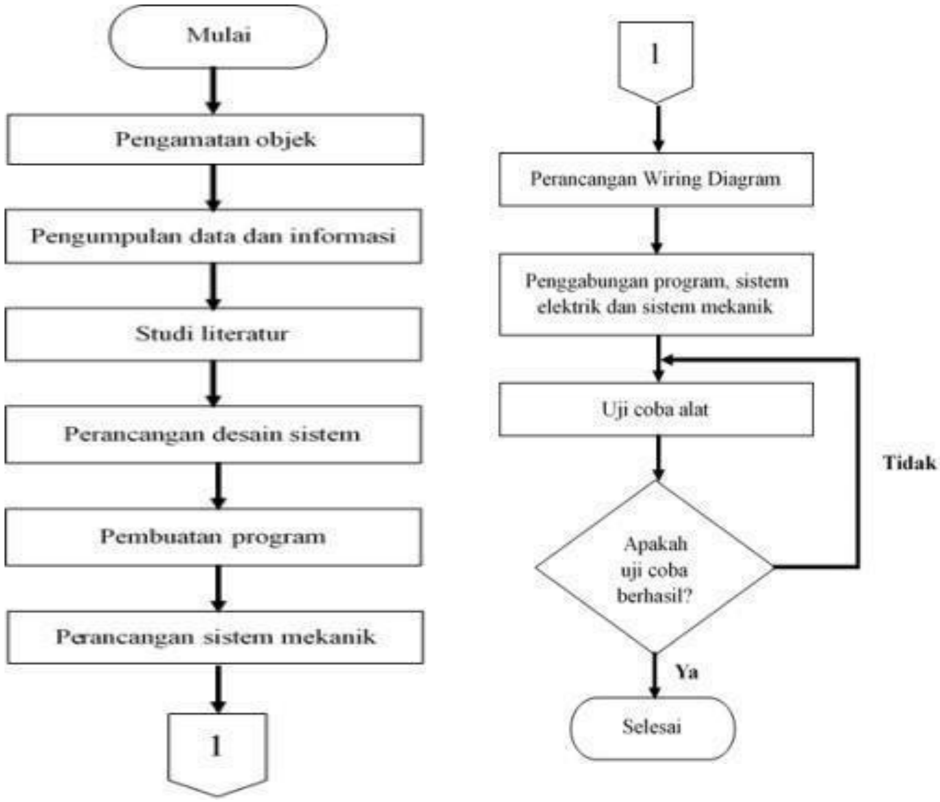
Overall, this IoT-based monitoring system integrates multiple sensors and protection mechanisms to ensure efficient operation of the chiller. The data provided by the sensors will be processed and displayed on a web interface, allowing operators to monitor the system remotely and take immediate action if necessary. This approach minimizes the need for manual intervention and significantly reduces the risk of system failures or downtime (As'ad, Yuniza, & Nugraha, 2022; Achmad & Nugraha, 2022).

2.2. Methods

This final project research was carried out to facilitate monitoring of chiller tanks. To get good results, appropriate and sequential research steps are needed. This is intended to make it easier for researchers to prove the truth, analyze and correct errors which is also useful for further development. The research stages are:

1. Flowchart of Final Project

The stages of the research undertaken in completing the Final Project can be represented in the following flowchart:



• Observation of the Object

The observation of the object serves as the initial phase to identify the location and equipment to be discussed in the development of this Final Project. The observation was carried out on the ship, specifically in the Auxiliary Engine Room of the PT. XX Warship workshop.

• Data and Information Collection

Data collection was carried out through direct observation and recording of the object being studied. This process aims to gather the necessary information that will support the development of the Final Project. The collected data includes:

1. Information on the equipment monitoring process.

• Literature Review

The literature review is essential for understanding the theories related to the equipment being developed, providing a reference for the design and development process to ensure the final product is of high quality. Sources were obtained from articles, research reports, and academic journals, either from online media or books. The literature focused on understanding how the NodeMCU module and its components work in transmitting sensor data to a database and displaying it on a website. The components studied include the DS18B20 temperature sensor, HC-SR04 ultrasonic sensor, relay, and SCT013 current sensor. The DS18B20 is a temperature sensor used in this study to detect the temperature output by the air conditioning system in the chiller. The HC-SR04 ultrasonic sensor is a distance sensor, which in this case, functions to detect the water level inside the tank. The SCT013 current sensor is used to monitor the current drawn by the water pump in the chiller. The data from the DS18B20, HC-SR04, and SCT013 sensors will be processed and sent via the programmed NodeMCU module to be displayed on the website. Additionally, protection is provided for the motor in case of a voltage loss in the 3-phase motor. The MK2P relay is designed to disconnect the current or voltage, cutting off the control circuit.

• Design and Development Planning

The design and development process involves creating a system design plan. This includes designing the system layout using AutoCAD software, programming the NodeMCU with Arduino IDE, designing the website to display data from the MySQL database, and purchasing a domain and hosting to make the website accessible online. Additionally, component selection is part of this process, and the components used are listed in Table 1.

Table 1. component

No.	Componen name	Type componen	pcs	unit
1	Mikrokontroler	NodeMCU 1.0 (12E)	1	Pcs
2	Sensor	DS18B20 Temperature sensor	1	Pcs
		Ultrasonik HCSR-04	1	Pcs
		SCT013	1	Pcs
3	Actuator	Water Pump SP-100	1	Pcs
		Water Heater 350W	1	Pcs
		Solenoid Valve 12 VDC	1	Pcs

- Program Development
  The program is created using a microcontroller module (NodeMCU 1.0 (12E)), which will serve as the core of the device or prototype to be developed. The program will detect the water level inside the chiller tank and automatically activate the pump when the water volume falls below the sensor's minimum threshold, triggering the water fill connected to the ship's fresh water supply. The current drawn by the pump will also be monitored, and any issues with the pump will be detected. Additionally, the temperature output from the air conditioning system will be monitored, and the temperature will be displayed on the monitoring screen, sent to the database, and shown on the website.

- Mechanical System Development
  The mechanical system development involves constructing the framework for the tank monitoring system as part of the experimental setup. This includes the design and development of the chiller system and actuator circuits.

- Wiring Diagram Design
  The wiring diagram design is intended to simplify the process of connecting the necessary electrical components.

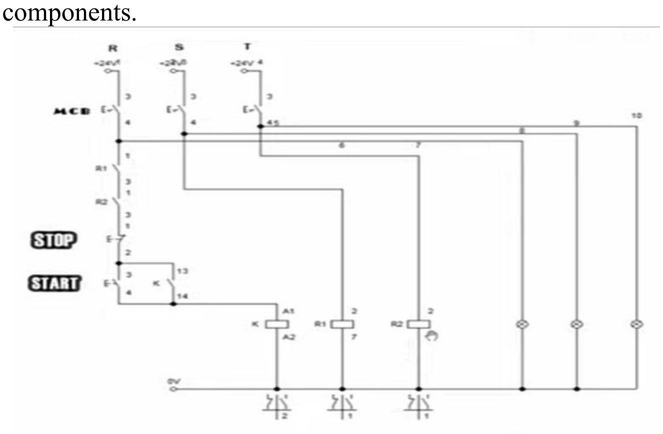


Figure 2. wiring motor protection

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- Integration of Electrical and Mechanical Systems

The next stage involves integrating the electrical and mechanical systems to create a complete prototype ready for testing. Once everything is prepared, the next step is to conduct testing on the device.

- Device Testing

The testing phase is conducted to evaluate the success of the developed device, with the results being used for further analysis. Testing is carried out continuously until the experiment is considered successful. The test includes uploading data from the sensors to the database and displaying it on the website, as well as testing the power cut-off in the protection system, which triggers the alarm.

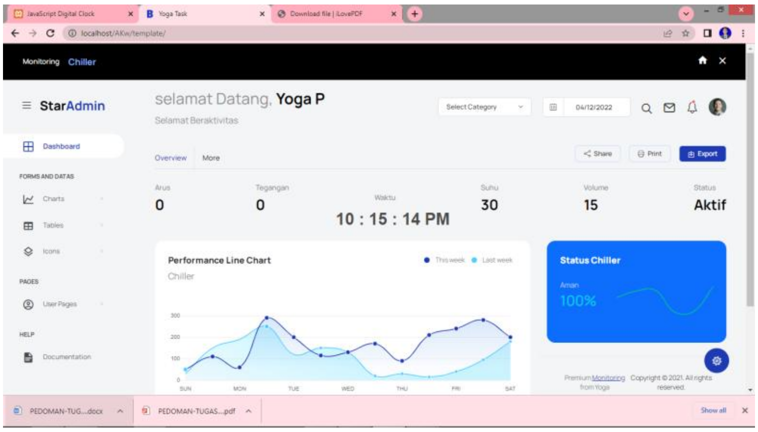

Figure 3. monitoring display

- Monitoring Aspects
  The monitoring system displays four key parameters: current, voltage, temperature, and volume, each of which updates every two minutes according to the values provided by the sensors.

- Analysis and Conclusion
  Once the testing phase is completed successfully, an analysis of the results is carried out. The analysis aims to draw conclusions about the objectives of the Final Project. A comparison is made between the measurements from the device and those from the sensors to determine if any discrepancies exist.

- Report Writing
  The final stage involves compiling a report that summarizes the key points discussed. The report is expected to provide clear and concise answers to the research questions posed at the beginning of the study. Report writing begins once all the necessary data has been gathered. The resulting report can serve as a reference for other researchers who wish to develop similar systems.

1.2 System Flow Diagram

In the development of the IoT-based temperature and water level monitoring system, a flow diagram is created to simplify the process. The operational principle of this monitoring system is that sensors embedded in the chiller tank prototype send their output data to the NodeMCU module. The NodeMCU then processes the ultrasonic sensor data, which measures water height, and the SCT013 current sensor data. If there is any malfunction, the sensors will trigger an alert.

1.3 System Working Diagram

This section describes the design of the Chiller monitoring system using various sensors, including the waterproof DS18B20 temperature probe, the ultrasonic HCSR-04 distance sensor, the SCT013 current sensor, and the ESP8266 WiFi module. The diagram (Figure 3.3) explains how the system works, showing how the sensors—ultrasonic, temperature, and current—send their data to the NodeMCU microcontroller. The NodeMCU processes the data and instructs the ESP8266 WiFi module to transmit the sensor data to a MySQL database. The data from the database is then displayed on a web page accessible via a browser.

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1.4 Input and Output Pin Data

Input and output pin assignments are essential for simplifying the program development process in the Arduino IDE. The ultrasonic and temperature sensors use NodeMCU's digital pins as inputs. Additionally, components such as the water pump, cooler, and valve are controlled via relays connected to the output pins.

1.5 Program Development

The IoT-based tank monitoring system utilizes several components that need to be controlled, including the ultrasonic sensor, DS18B20 temperature sensor, SCT013 current sensor, water pump, cooler, and valve. The ultrasonic sensor measures the water level, and when the water level reaches the minimum threshold, the valve activates, and the current sensor monitors the current. If the water level reaches the maximum setpoint, the pump shuts off. The temperature sensor measures the temperature emitted by the chiller's air conditioning system. Data from the sensors is sent to a MySQL database using IdHostinger's services. The final data is displayed on the monitoring website, showing the current status of the chiller, including water level, temperature, and pump current in real-time.

2. MySQL Database Creation

In this research, the MySQL database is created using IdHostinger's platform. The database consists of multiple tables, each storing different types of data. These tables include a temperature table for storing temperature data, a level table for water level data, a current table for monitoring the pump's current output, and a login table for storing user credentials. To create the database, the user must first open the IdHostinger website and create an account. Once logged in, the user sets up a new hosting account and fills in necessary details, such as the hosting address, which in this case is monitoringtangkichiller.online. After successfully creating the hosting account, the user accesses the hosting menu, where they can create a MySQL database. The database is configured with a name, user, and password for security purposes. Once the database is set up, tables are created using PhpMyAdmin to store the sensor data.

2.1 Prototype Framework Design

The design created earlier serves as a reference for building the prototype framework. The framework is constructed in stages, starting with material selection followed by the physical assembly of the prototype. The selected materials must be suitable for the specific requirements of the monitoring system.

1. Material Selection

   The main component of the prototype is the foundation material, which must meet quality standards appropriate for the device being built. The materials selected should ensure the durability and stability of the prototype.

2. Framework Construction

   Once the materials are available, the next step is to construct the framework according to the design specifications. The construction process must follow the design to ensure accuracy and avoid any errors in building the final prototype for the project.

2.2. Wiring Diagram

The wiring diagram is essential for guiding the assembly of the necessary electrical components. The components used include the NodeMCU module, ultrasonic sensor, DS18B20 temperature sensor, SCT013 current sensor, and relay modules for controlling the water pump, cooler, and valve. The system requires several components that function as input and output devices. The ultrasonic sensor, DS18B20 temperature sensor, and SCT013 current sensor serve as inputs, while the relay module is used to control the water pump, cooler, and valve. For motor protection, a relay is included to cut off the current in case of any electrical issue.

2.3. Integration of Mechanical System, Wiring, and Program

After assembling all the necessary components, the next step is to integrate the mechanical system, wiring, and the program uploaded to the NodeMCU device. This integration brings the prototype to life and allows it to perform the intended monitoring functions effectively.

3. Results and discussion

3.1. Result

This section presents the testing results and discussion of the system that has been developed. The testing and analysis include component testing as well as prototype testing. During the component testing phase, individual sensors and devices are evaluated to ensure they function correctly within the system. The tests aim to verify the accuracy and reliability of each component used in the monitoring system.

In the prototype testing phase, the complete system is examined to assess how well all components work together. The objective is to ensure that the system operates as expected under real-world conditions. This includes checking the system's ability to measure and transmit data, as well as the responsiveness of the actuators when triggered by the sensor inputs.

Additionally, the error percentage in sensor readings is calculated to determine the accuracy of the measurements. The error percentage is an important parameter that helps identify any discrepancies between the sensor outputs and the actual values. This calculation is crucial for assessing the overall performance of the monitoring system and for fine-tuning the system to improve its precision and reliability.

$$eror = \frac{Measurement - sensor}{Measurement} \times 100\%$$

Table 1. test with tempersture sensor

No.	Output Serial Monitor (°C)	Termometer (°C)	Eror
1	18,19	18,2	0,05%
2	18,19	18,3	0,6%
3	18,19	18,1	0,49%
4	18,19	18,0	1,05%
5	18,19	18,2	0,05%
6	18,19	17,9	1,62%
7	18,19	17,9	1,62%
8	18,19	18,0	1,05%
9	18,19	18,0	1,05%
10	18,19	18,1	0,49%
Avg	18,19	18,0	0,807%

The testing was conducted using water inside the tank, where the temperature results were measured using a TDS-3 thermometer. This method allowed for a direct comparison between the sensor readings and the actual temperature of the water, ensuring the accuracy of the monitoring system in detecting temperature changes within the tank.

Table 2. testing with sensor ultrasonic

No.	Output Serial Monitor (Cm)	Testing with mistar (Cm)	Eror
1	15	15,2	1,31%
2	15	15,0	0
3	15	14,9	0,67%

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4	15	15,1	0,67%
5	15	15,0	0
6	15	15,0	0
7	15	15,2	1,31%
8	15	14,9	0,67%
9	15	14,8	1,31%
10	15	15,0	0
Avg	15	15,0	0,594%

The ultrasonic sensor is used to detect the water level. When the water reaches the maximum level, it activates a valve to reduce the water height to the specified limit. Conversely, if the water level is too low, the sensor triggers the pump to refill the tank.

3.2. Discussion

This study utilizes three sensors, each with its specific function. The first sensor is a flame sensor, which is used to detect the presence of fire. This sensor plays a crucial role in fire safety systems by providing early detection of flame ignition.

The second sensor employed in the study is a temperature sensor, which is responsible for measuring the surrounding air temperature. This sensor is essential in monitoring environmental conditions and ensuring optimal operating conditions for various systems.

The third sensor used is the SCT13, which is designed to detect current flow. This sensor is particularly important in monitoring the electrical performance of devices, ensuring that the current is within safe operational limits. Each of these sensors exhibits minimal error, and the comparison between the sensor readings and measurement tools shows that the values are almost identical, demonstrating the accuracy of the sensors.

4. Conclusion

The design and development of the prototype for monitoring the current and water level in the chiller tank on ships, based on the Internet of Things (IoT), involves creating a monitoring system that utilizes ultrasonic distance sensors (HCSR-04) and temperature sensors (DS18B20). These sensors are used to measure the water level and temperature within the chiller tank. The data collected by the sensors is processed by a NodeMCU module, which serves as the central processing unit for the system.

Once the data is processed, the NodeMCU module sends it over the internet to a database, enabling real-time monitoring. The use of IoT allows for continuous data transmission, making it possible to track the water level and temperature remotely from anywhere with internet access. This system is particularly useful in maritime environments, where remote monitoring of equipment is critical for maintaining operational efficiency and safety.

The data stored in the database is then displayed on a web page, providing an intuitive interface for users to access the information. The web interface allows for easy visualization of the current status of the chiller tank, including real-time data on water level and temperature. This setup ensures that operators can monitor the tank conditions effectively and take necessary actions in case of any irregularities.

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