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Design of Web-Based Human Machine Interface (HMI) for Electric Tube Furnace

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ABSTRACT

The furnace at the UPT Integrated Laboratory at the University of Diponegoro has automatic temperature control and is equipped with a control display but can't be monitored in a separate room. In this research, a web-based control and monitoring system was built on an electric tube furnace, so that the operator could control and monitor the plant through a Human Machine Interface (HMI). HMI could be accessed from a separate room. The system was built using an STM32F103C8T6 microcontroller and ENC28J60 Ethernet module. As a result, the HMI can carry out supervision and control properly. Data transmission to the server has an average interval time of 12.5 seconds, reading data from the server has an average interval time of 9.2 seconds, and the HMI response to new data entered is 0.8589 seconds.

Keywords: *HMI, Web, ENC28J69, Furnace*.

1. INTRODUCTION

Cremate process is a method to find out a level of substances contained in a substrate. Ash content can be obtained directly by burning the material at high temperature (500-600^{o}C) for several hours (2-8 hours). [1]. Cremate process usually done by the furnace. Most furnaces are equipped with a separated monitoring system. Monitoring process run less effectively because needed to integrate the information come from each monitoring system. The unified monitoring process can be carried out by Human Machine Interface (HMI), which become part of an interactive system (software or hardware). HMI provides information and control action needed by the operator to operate the plant. The monitoring process is needed to determine the condition of the plant temperature in real time. Temperature recording is also carried out to determine the temperature overshoot, which can affect the quality of the test material. An action to deactivate heating process immediately is needed when overshoot happens to protect the material quality.

Several studies developed web-based HMI for as a basis for controlling devices. The related work designed a SCADA system (Supervision of Data Supervision and Retrieval) for prototyping hot room internet-connected devices, using an ATmega16 microcontroller and ESP8266 Wi-fi module as a data communication module through the internet. The results of the SCADA system experiment showed that monitoring, controlling, and data from the prototype hot room was carried out through a Human Machine Interface (HMI) can be done wirelessly [2]. Other studies developed HMI using AT8535 microcontroller and W5100 Ethernet module as data communication modules with the internet. As a result, a control and monitoring system that can be used as an efficient system. W5100 Ethernet module connected to WIZ110SR module could working well transmit serial data to packet data converters. The information is accessible to users through a computer network [3].

This research designed a prototype of a Web-based temperature monitoring system on an electric tube furnace. Reading of data received from the cloud database and sending the acquisition data to the cloud database done by the microcontroller [4]. Access communication with database and HMI on the web server using an internet connection via an Ethernet module interface that connected to the router.

2. SYSTEM DESIGN

Control and monitoring process of electric tube furnace performance can be done online, utilizing the web display so it runs more flexible because the HMI page can be accessed anywhere [5].

The data plant obtained by the STM32F103C8T6 is sent to a cloud database via an internet connection that bridged by the Ethernet module ENC28J60 that connected to the nearest router using an RJ45 cable. This connection makes STM32F103C8T6 were able to send and read data from the connected database. Data in the cloud database is obtained using a PHP function and displayed on the HMI. Control plant from HMI is done by giving the temperature and time setpoint values, then set point set in the database could be read by STM32F103C8T6. The entire system designed is shown in Figure 1 [6].

2.1 Microcontroller Design

In this research, microcontroller STM32F103C8T6 is used as the center of PID control interface and support the "triac" system to perform AC current control properly in a closed loop. This microcontroller has a powerful performance to carry out the process of controlling and data acquisition simultaneously. The placement of IO pins on the microcontroller is shown in Table 1. The analog output is coming from the ENC28J60 module which is the temperature movement and digital output actuate buzzer such as a warning.

2.2 ENC28J60 Design

Figure 2 shows the ethernet module circuit with a built-in RJ45 connector. Sending and reading data from the cloud database is done with the Ethernet module. VCC pin is connected to the + 3.3V source and the GND pin to ground. MISO, MOSI, CLK, and CS pins are connected to a microcontroller that is useful for SPI communication which is shown in Table 2.

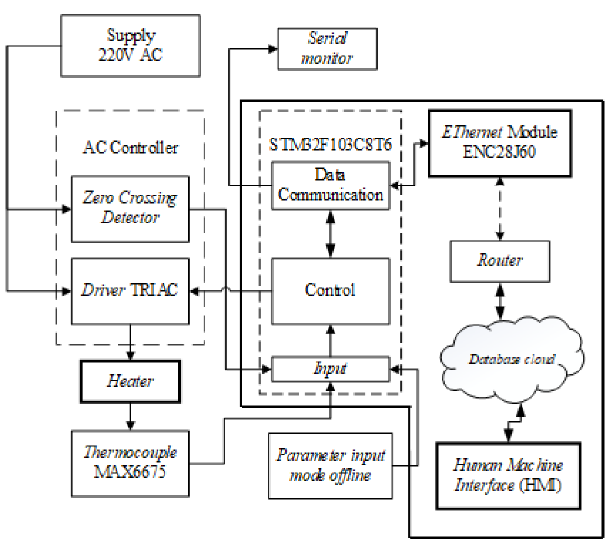

Fig. 1. System Diagram Block

Table 1: Pin Placement on Microcontroller

I/O	Signal	Kind	Pin on microcontroller
Output	ENC28J60 Module	Analog	PA4
Output	Buzzer	Digital	PB10

2.3 Software Design

Software design contains a design for STM32F103C8T6, design database, and design HMI.

2.3.1 Software Design

Software design for STM32F103C8T6 microcontroller includes construction of two-way communication process (sending data to a cloud database and receiving data from a cloud database).

a. Reading from database

Consists of two stages, the first stage is reading the PHP files, the second stage is data parsing. Data reading begins by executing a list of PHP files which is doing request to a web server. Parsing data after reading, done to retrieve the needed data as the system input.

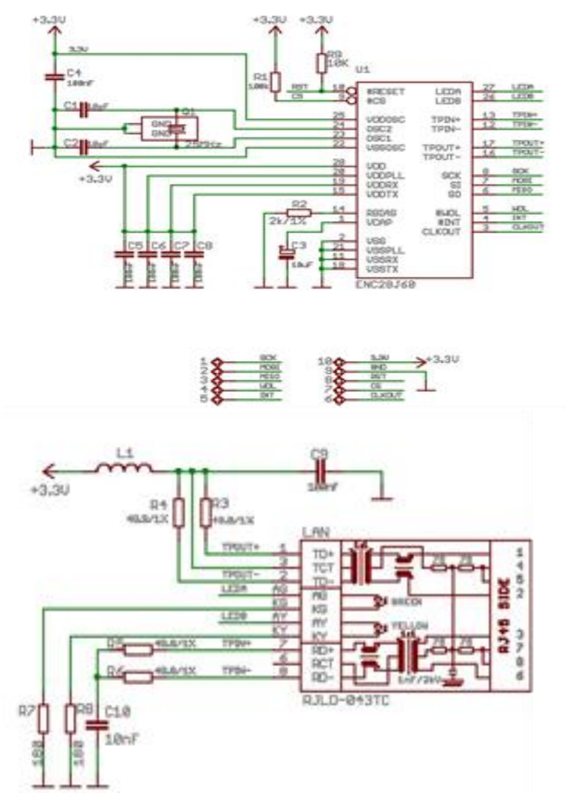

Fig. 2. Ethernet modules and circuits

Table 2: Pin Placement on ENC28J60

I/O	Ethernet Modul Pin	Kind	Pin
Input to microcontroller	MOSI	Digital	PA7
Output from microcontroller	MISO	Digital	PA6
Output from microcontroller	SCK/CLK	Digital	PA5
Output from microcontroller	SS/CS	Digital	PA4

b. Data transfer to the database

Data transmission of temperature reading, alarm status and the value of Kp, Ki is transferred to the database using HTTP POST parameter via PHP files. Data is sent using the POST method.

2.3.2 Database System Design

The database system is used as a data communication between the microcontroller and the HMI web display. Database system designed with one database and five tables in it. Two tables are used for data exchange and others are used for system login administration. Based on Figure 3, designed database system consists of HMI blocks, databases, and plant electric tube furnaces.

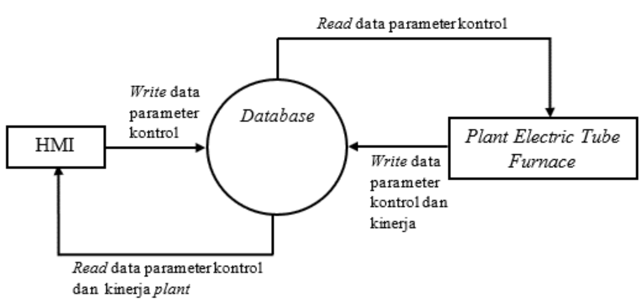

Fig. 3. Data Flow Context Diagram in Database System

2.3.3 Design of HMI System

Monitoring system through web-based HMI has algorithm as follows:

1. Start
2. Receiving data plant in the database.
3. Display the login form on the electric tube furnace online page
4. Enter your username and password.
   - If the username and password are incorrect: a password or username appears incorrectly and returns to the login page.
   - If the username and password are correct: notification appears as "user level" and enters the HMI page according to the detected level.
5. Access the HMI Engineer level for the username and password that matches the level engineer.
6. Operator level HMI access for correct username and password operator level
7. Finish

Based on the algorithm, there are two access modes of the HMI page, Operator mode and Engineer mode. Complete flowchart of system algorithm shown in Figure 5.

3. RESULT AND ANALYSIS

3.1 Design HMI System

HMI communication is done by making a connection to a web server via the internet network. Figure 4 shows the response obtained when connecting to the web server to get the IP address of the web server.

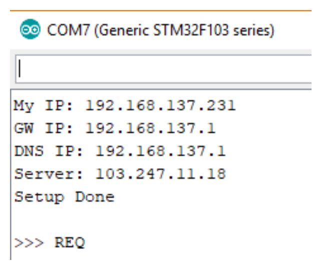

Fig. 4. Successfully Connected to a Web Server

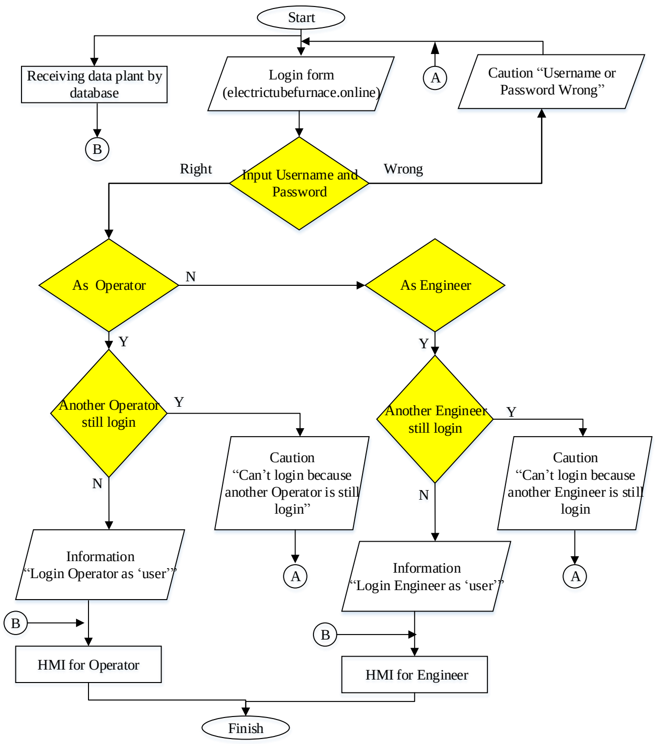

Fig. 5. Flowchart HMI Full System

Figure 4 also shows that getting DNS web server and IP is successful. The device can access a web server. Failure to get connection example is shown in Figure 6.

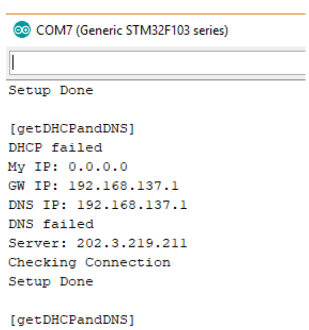

Fig. 6. Failure to Connect with a Web Server

Figure 6 shows fail to obtain an IP from the server, so it cannot send and receive data to/from the database and could not be remotely monitored by the system.

3.2 Communication System Test

Communication system test divided into 2 stages. The first stage is testing data transmission and the second stage testing data reception.

3.2.1 Testing of sending data to the database

Testing of data acceptance to the database is done by sending data from the plant in the form of temperature, Kp value, Ki value, and high temperature value. Delivery recapitulation results are shown in Table 3.

Table 3: Time interval for sending data to the database

No.	**Data**	**Time Interval**
1.	0 to 1	10 sec
2.	1 to 2	10 sec
3.	2 to 3	10 sec
.....	....	....
21.	20 to 21	10 sec
22.	21 to 22	10 sec
23.	22 to 23	10 sec
24.	23 to 24	30 sec
Average		12.5 sec

The average time for sending data to the database including reconnecting process was 12.5 seconds. Length of the reconnecting process is also determined by the strength of the internet network that was being used and the condition of the data traffic on the web server.

3.2.2 Testing of sending data to the database

Testing the receive data from the database is done by sending 4 data from the database to be read by the microcontroller and then used as a system input. Recapitulation data results are shown in Table 4.

Table 4: Time interval for receiving data from the database

No	**Data**	**Time Receiving Data**
1.	1	9.84 sec
2.	2	4.75 sec
3.	3	3.75 sec
.....	.....	.....
18.	18	10.60 sec
19.	19	9.43 sec
20.	20	9.65 sec
Average		9.2 sec

From Table 4 can be seen that the microcontroller can receive data from the web with an average of every 9.2 seconds. This process generates parsing data that was directly used for the control process and the monitor-readable serial value that would change as data changes in the database.

3.1 HMI Test

3.3.1 Login System

Login system test is done by using two different usernames and passwords from two different levels. The login form is shown in Figure 7. The results of the login system test are shown in Figure 8, Figure 9, and Figure 10.

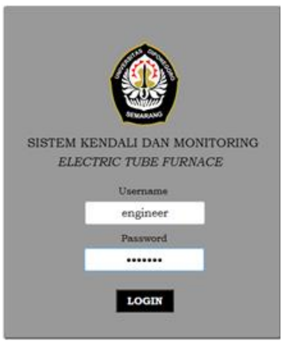

Fig. 7. Login Page

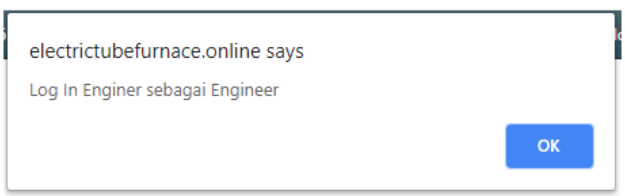

Fig. 8. Successfully Login Response for Engineer

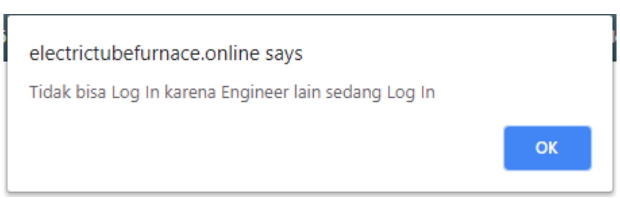

Fig. 9. Failed to Login Response for Engineer

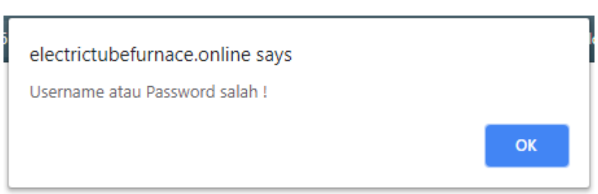

Fig. 10. Failed to Login because of wrong Input Data

3.3.2 Operation in HMI

Testing of START, STOP, LOGOUT, data processing, and graphic buttons are done by clicking the button on the HMI display. The actions that carried out of each button will be detailed in Table 5. The result of pushing the button can be shown in Figure 11, 12, 13, 14 and 15.

Table 5: Time interval for receiving data from the database

No	Button	Action
1	START	HMI for Engineer: Input data from HMI to database, input 'ON' status in table, change furnace illustration color to light grey. HMI for Operator: Input data from HMI to database, input 'ON' status in table, input Kp, Ki default value (Kp = 26.8431, Ki = 0.2687), furnace illustration color turn to light grey.
2	STOP	HMI for Engineer: update Kp and Ki data in table become 0, update 'DONE' status in table, furnace illustration color turn to dark grey.
		HMI for Operator: update Kp and Ki data in table become 0, update 'DONE' status in table, furnace illustration color turn to dark grey.
3	LOGOUT	HMI for Engineer: bring back to the login form.
		HMI for Operator: bring back to the login form.
4	Processing Data	HMI for Engineer and Operator: show data acquisition in table form.
5	Graphic	HMI for Engineer and Operator: show data acquisition in table graphic.

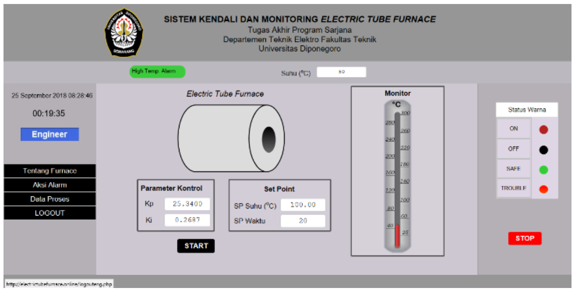

Fig. 11. Response for pushing the 'START' Button

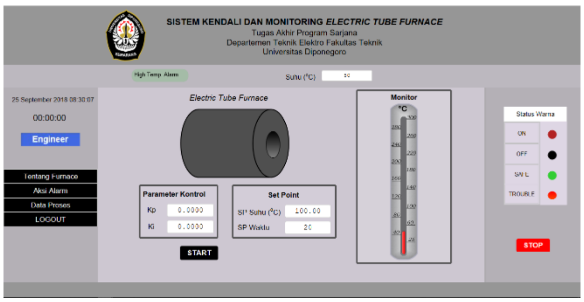

Fig. 12. Response for pushing the 'STOP' Button

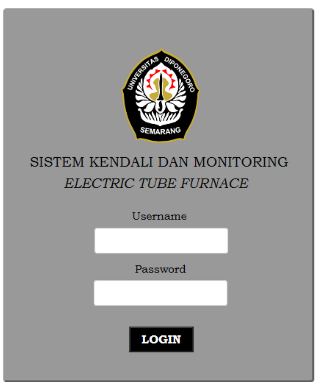

Fig. 13. Response for pushing the 'LOGOUT' Button

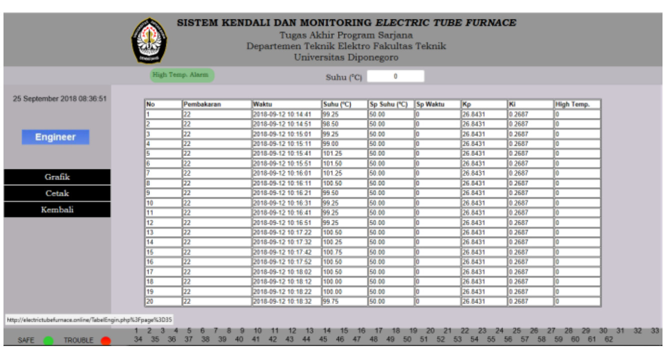

Fig. 14. Data Acquisition in Table Form

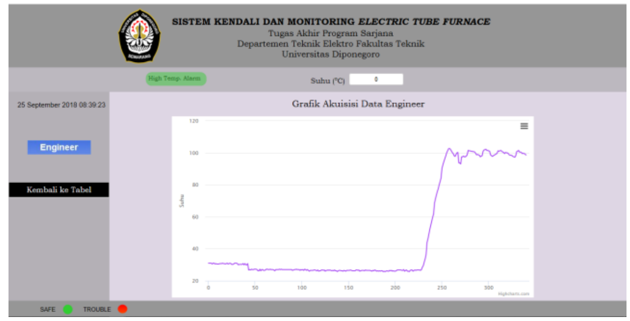

Fig. 15. Data Acquisition in Graphic Form

4. CONCLUSION

The entire system works well. All HMI facilities were tested and the success rate of the trial was 100%. Send and receive process runs smoothly. Timeliness of execution also depends on the sstate of the internet connection and connection with the server. The average time of sending data to the database with the reconnecting process that occured is 12.5, the average time to receive data from the database by the microcontroller takes 9.2 seconds. In addition, the login system works well, so that the protection of the control page runs well. The database system that is created, can run well. Commands to access and manipulate data on the database by the microcontroller or by the HMI is also run well. Data acquisition by a database which can then be displayed in the form of tables and graphs on the HMI page is running well and is in accordance with the condition of the original plant.

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