Design of remote temperature monitoring system on automatic filling R125 Shinva machine using LM35 sensor and Arduino Uno microcontroller

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Abstract: This paper proposed the design of a remote temperature monitoring system of R125 Shinva's automatic filling machine. The R125 Shinva's automatic filling machine is one of the machines on SF company which main function is fulfilling the infusion liquid into the infusion packaging, this infusion liquid is mainly used for the human medical treatment. Based on the failure history data, this machine has the highest downtime among the others and one of the fatal failures is caused by the overheating of the heating element in the infusion liquid bag's transfer system. Using the proposed design, the temperature of the heating element can be monitored in real-time condition and giving notification to the maintenance team for the next maintenance action. With the power of cloud-based technology, the monitoring system not only on-site monitoring but also can use a web server monitoring, and mobile monitoring system.

Keywords: Maintenance system, temperature monitoring, cloud-based, Arduino Uno, LM35 sensor

1. Introduction

The machine maintenance monitoring system is one important aspect of the industrial maintenance department to ensure all the production machines are running well without any trouble. Using the power of the internet of things (IoT) currently, the remote monitoring system becomes popular and sophisticated for the industrial and manufacturing maintenance system. Systems that can do remote monitoring are increasingly needed to support maintenance activities, especially for the manufacturing company which has a nonstop production schedule [1]. Furthermore, the purpose of the company utilizes the concept of remote monitoring in their factory is to prevent any sudden breakdown that might be occurred when the machine on the way to the production process and minimize mistakes operator during their work [2].

SF company is one of the leading pharmaceutical manufacturing company in Indonesia. It had been operating to produced various kinds of medicines since 1975. SF company has four factories, the main factory is located in Industrial III Cimareme, Padalarang, West Java. The main plant is separated into two production plants; SVP or Small Volume Parenteral (small volume injection) and LVP or Large Volume Parenteral (large volume injection). Based on the historical maintenance data, the LVP production plant has more machine failure frequency, especially in the infusion producing machine department, that is the automatic filling Shiva machine. To reduce the frequency of failure, several actions are needed to improve machine performance. Increasing the value of performance and reliability of machines can be done in various ways, such us is designing preventive maintenance policies, optimizing spare part inventory, and others. Preventive maintenance is maintenance action that is carried out on a scheduled basis, where several activities such as inspection and repair, replacement, cleaning, lubrication, adjustment, and equalization are carried out periodically [3].

This preventive maintenance aims to extend the useful life of the asset, ensure optimum availability of installed equipment for production, services, and investment profit as much as possible, ensure the operational readiness of all equipment necessary in emergency activities and ensure the safety of any person using the facility [4], [5].

Shiva's automatic filling machine is one of the machines on SF company which the main function is fulfilling the infusion liquid into the infusion packaging, this infusion liquid is mainly used for the human medical treatment. Fig. 1 provides information about the amount of failure to each type of R125 Shinva machine.
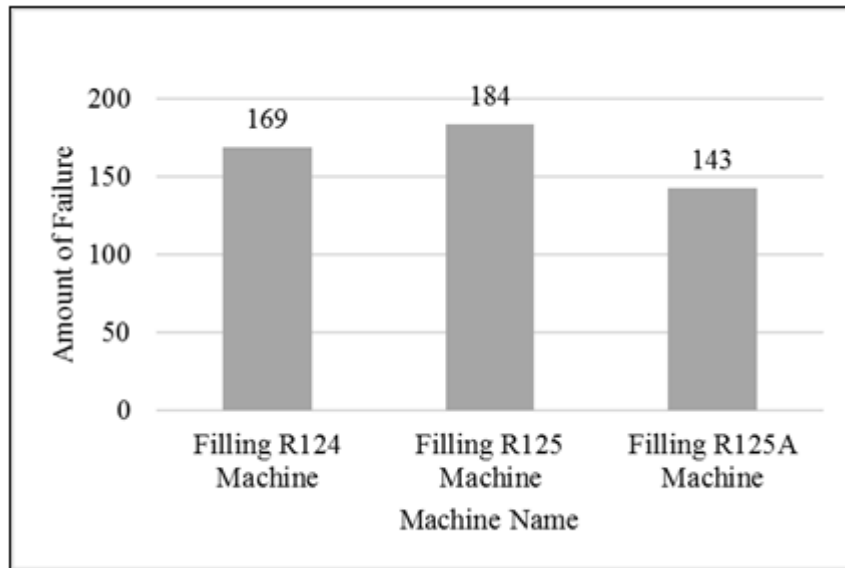

Fig. 1 - The failure data of the filling machine

From the Fig. 1, shows the failure data of the R125 Shinva filling machine, the failure has happened in the contour welding station which the main problem is an infusion liquid plastic bag was folded because the temperature of the gripper as a heating element of this system is not stable, mostly overheated. To prevent the overheated of this heating element, the monitoring of temperature is important to minimize the damages in the workstation contour welding. To reduce the frequency of damage, practical maintenance is needed. Therefore in this study will design preventive activities remotely by monitoring the condition of the machine through the internet network.

In this paper, we propose a basic design of a machine temperature monitoring system using an LM35 sensor and Arduino Uno microcontroller. Using the proposed design, the temperature of the heating element can be monitored in real-time condition and giving notification to the maintenance team for the next maintenance action. With the power of cloud-based technology, the monitoring system not only on-site monitoring but also can use a web server monitoring and mobile monitoring system. This paper organized as follow, section two provides a theoretical background and, part three contains the detail design of monitoring system, and finally, the conclusion, discussion, and some remark presented in section four.

2. Theoretical Background

To design a basic machine temperature monitoring system, several theoretical background and equipment's which used in this system are presented.

2.1 Internet of Things (IoT)

The Internet of Things is a very promising scientific development to optimize life based on intelligent sensors and smart equipment that collaborate through the internet [6]. With the internet of things system, it can facilitate human work, and support the formation of an industrial revolution 4.0 where human labor has been replaced using robots as workers.

2.2 Arduino Uno

Arduino Uno is a circuit board based on the Atmega328 microcontroller. This IC (integrated circuit) has 14 digital inputs/outputs (6 outputs for PMW), 6 analog outputs, 16Mhz ceramic crystal resonator, USB connection, adapter socket, ICSP header pin, and reset button. These things are what makes the Arduino Uno microcontroller can connect with a USB power cable or AC to DC power supply cable or battery [7]–[9].

2.3 Atmega 328

The Atmega 328 microcontroller is a small computer ("special-purpose computers") in one IC that contains the CPU, memory, timer, serial and parallel communication channels, input/output ports, ADC. A microcontroller is used for a task and runs a program on this small computer.[10]

2.4 Module Wifi ESP8266

ESP8266 is a wifi module that functions as a microcontroller enhancement with the function of connecting the microcontroller directly with wi-fi and making TCP / IP. ESP8266 can be assembled on an Arduino microcontroller. This module requires a power supply of 3.3 v with three modes of wi-fi, that are a station, access point, and combination of access point and station. The ESP8266 module is equipped with features that make the ESP8266 play a direct role like a microcontroller, these features are the processor, memory, and GPIO. This module can be programmed using the Arduino IDE software, which is by adding the ESP8266 library to the Arduino IDE software. Besides that ESP8266 has an affordable price so that many internet of things projects use the ESP8266 module for internet connection matters   [11].

2.5 Router TL-MR3420

TL-MR3420 router is a router that has IEEE 802.11N standard, this router can build a wireless network with a transmission speed of 300 Mbps. With this transmission speed, the router can penetrate the barriers of buildings such as offices, apartments, wall, so that it is suitable for the internet of things project. This router is equipped with a WPA / WPA2 encryption security system, which is better than the previous version of WEP encryption. The TL-MR3420 router is equipped with a 3G / WAN connection Backup feature that allows users to remain online even if a connection is lost. [12], [13]

2.6 IC LM35 Temperature Sensor

The LM35 IC temperature sensor was produced by National Semiconductor, a semiconductor manufacturer which specialized in analog devices and subsystem. The function of this device is detecting the temperature of a room or an object in electrical quantities. At the output, the IC LM35 sensor can change the quantities of temperature into quantities of voltage. The LM35 IC sensor requires a voltage source of DC 5 V and a DC consumption of 60 μA to work [14].

2.7 Use Case Diagram

Use case diagram is a diagram that is used to describe the interaction between users (actors) and the existing system. Actors are users who interact directly with the system itself [15], [16]

2.8 Arduino IDE (Integrated Development Environment)

Arduino IDE is software written using Java which is processed based on the processing of Avr-gcc, and other open-source software [17], [18]. Arduino IDE consists of three main systems, the first is an Editor Program, this is a window that allows users to write and edit programs in processing languages, second, the Verify / Compiler, this is a module that converts program code (processing language) into binary code. However, a microcontroller will not be able to understand the processing language, which is understood by the microcontroller is binary code, third an Uploader, is a module that loads binary code from a computer into microcontroller memory on an Arduino board.

2.9 Android Studio

Android Studio is an Integrated Development Environment - Integrated Development Environment (IDE) for the development of Android applications, based on IntelliJ IDEA [19] [20]. Android Studio is open-source software that functions as a tool to make various applications based on the Android operating system. This software is used to create applications that want to be able to run on gadgets or cellphones with the Android operating system.

3.   The Proposed of Monitoring System Design

The proposed monitoring system which will be discussed in this section consists of working principles of remote monitoring systems, hardware system design, software microcontroller design, server system design, interface data monitoring design, mockup for mobile application, and mockup for webserver design. The detail of system design will be explained step by step starting from the working principle of a remote monitoring system.

3.1 Working Principles of Remote Monitoring Systems

Fig.2 describes the general system workflow of the proposed monitoring system. The system consists of a heat detector using DHT 11 temperature sensor, a voltage source device, a device to connect to the internet using a Wifi ESP 8266 module, and cloud storage. To display the monitoring data, there is a device to monitor the temperature conditions of heat element components, which consist of a web servers' system, LCD for display system, and mobile applications system.
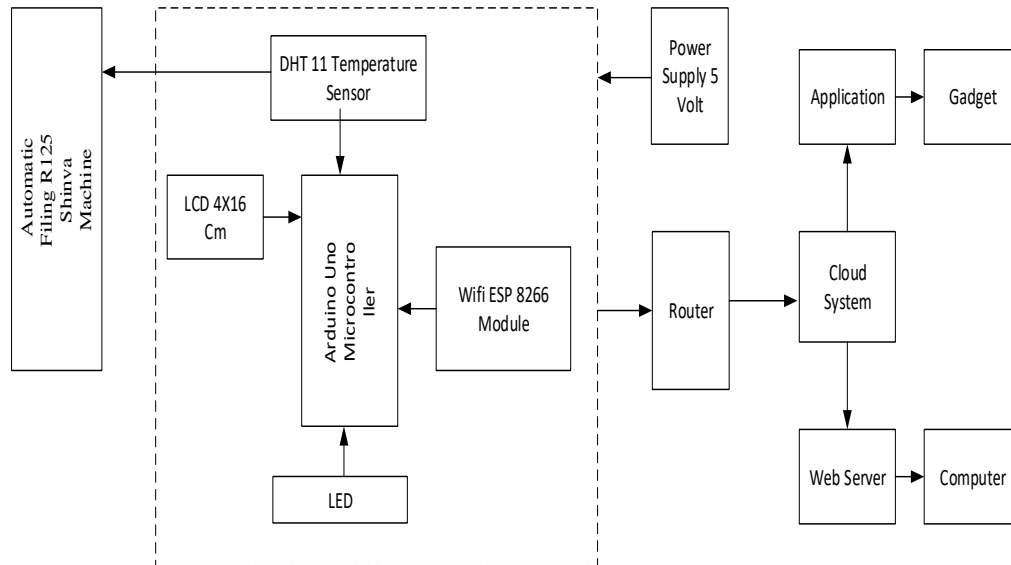
Fig. 2 - Working principles of remote monitoring systems

In principle, the remote monitoring system works automatically to detect and transmit the temperature data of the heat element components in the workstation contour welding of the machine. The temperature data of the heating element is collected and sent through the internet network, stored in a cloud-based system, then can be accessed by a user using the webservers system or mobile applications system.

3.2 Hardware System Design

The important thing in a remote monitoring system is a heat detector. The heat detector becomes the main component in this system, so the system can detect the temperature and sending data to users. The heat detector is composed of several supporting components, including:

1. Mikrokontroller Arduino Uno

2. Red LED, Green LED, and Yellow LED

3. IC LM35 Temperature Sensor

4. Resistor 220 Ohm

5. Power 5 Volt

6. LCD

7. Ground

The whole component works inside The Arduino Uno microcontroller. The Arduino Uno microcontroller functions as the main component in the device because the Arduino Uno Microcontroller is likened to a small computer that controls all the component tasks attached to the Arduino Uno Microcontroller itself. To simulate the proposed design, Proteus 8 Professional software is applied. The working process of temperature detection devices is the LM35 temperature sensor detects heat generated by heat element components on Automatic Filling R125 Shinva machine, then the sensor will send temperature data to the Arduino Uno Microcontroller. On the Arduino Uno Microcontroller, the data will be stored temporarily and processed before being sent to the cloud storage using a device that can connect the device to the internet, that is Wifi Module ESP 8266 and TL-MR3420 Router. If the above normal temperature is detected

which is more than 142ºC then the Arduino Uno Microcontroller will activate the red LED, indicating the heating element is overheating. If a temperature below normal which is less than 136ºC, then the Arduino Uno Microcontroller will activate the yellow LED. Whereas if the temperature detected is between 136ºC and 142ºC then the Arduino Uno microcontroller will activate the green LED which means safety.

Fig.3 is a scheme of hardware system design for the temperature monitoring system which is designed using Proteus 8 Professional software.
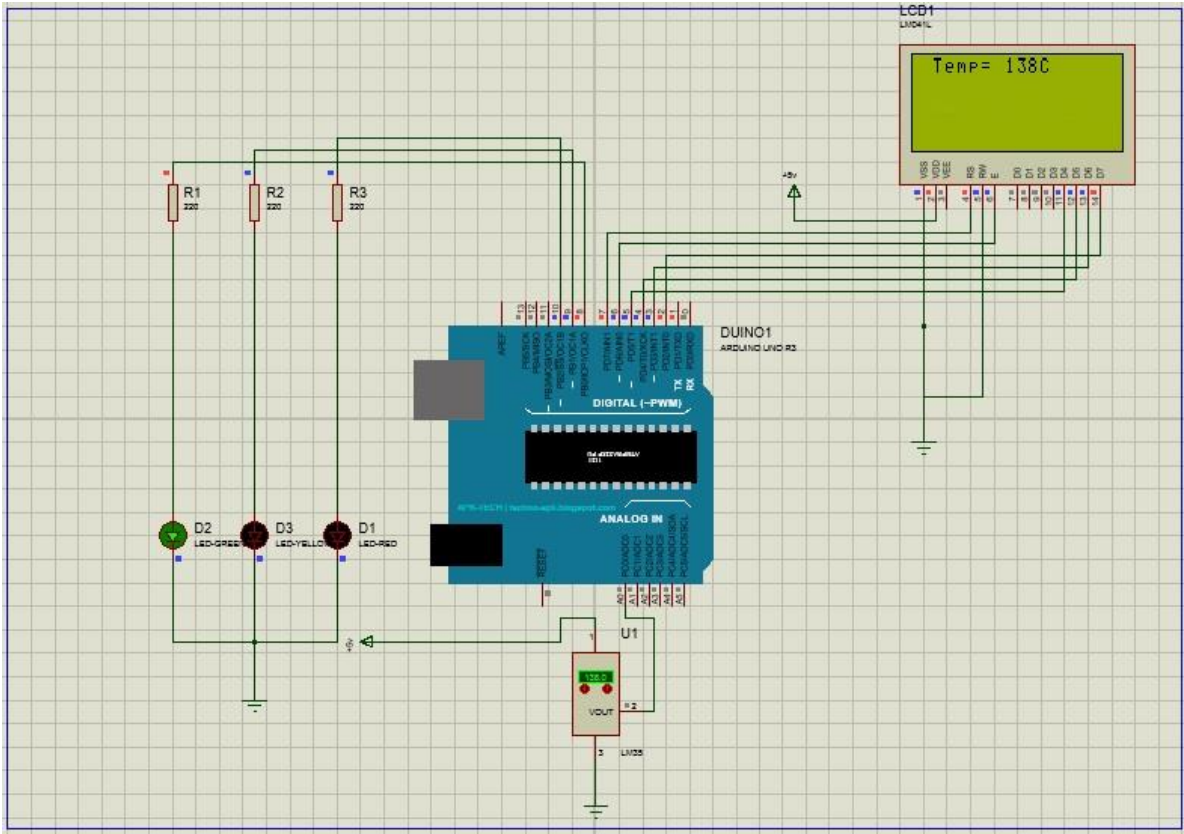

Fig. 3 - The hardware temperature monitoring system design

Fig. 3 shows the design temperature monitoring system design scheme using the Proteus 8 Professional software. In designing this remote monitoring tool, to connect the device to the internet which can be connected to cloud storage, this system design uses the ESP8266 wifi module because it has a wide range of signals and could work on a power supply of 3.3 volts. This monitoring system design used the TL-MR3420 router because it has the IEEE 802.11N standard and this router can build a wireless network with a transmission speed of 300 Mbps. With such specifications, the TL-MR3420 router can penetrate the barriers of office buildings during its operation.

3.3 Software Microcontroller Design

Fig. 4 explains the software microcontroller program workflow in general. When the tool is positioned in the 'On' condition, the program will read the time (hours) and dates, then read the temperature values sent by the LM35 sensor, then processed into digital quantities. The data is processed in the Arduino Uno Microcontroller. After that the Arduino Uno Microcontroller will send to two lines, the first line is the LCD line and the second line is the Cloud storage line. Cloud storage uses a database to store the temperature data. If Arduino reads above the normal temperature which is more than 142ºC according to the program, it will activate the red LED, and will also display a warning on the webserver and the application that says "HIGH TEMPERATURE". If the Arduino reads the temperature between 136ºC to 142ºC according to the program, the Arduino will activate the green LED and send a notification on the webserver and application that says "NORMAL TEMPERATURE". But if the Arduino reads the temperature below 136 ºC then the Arduino will activate the yellow LED and will display a notification on the webserver and the application that says "LOW TEMPERATURE".

The program flow will work looping as long as the tool is on as shown in Fig.4.
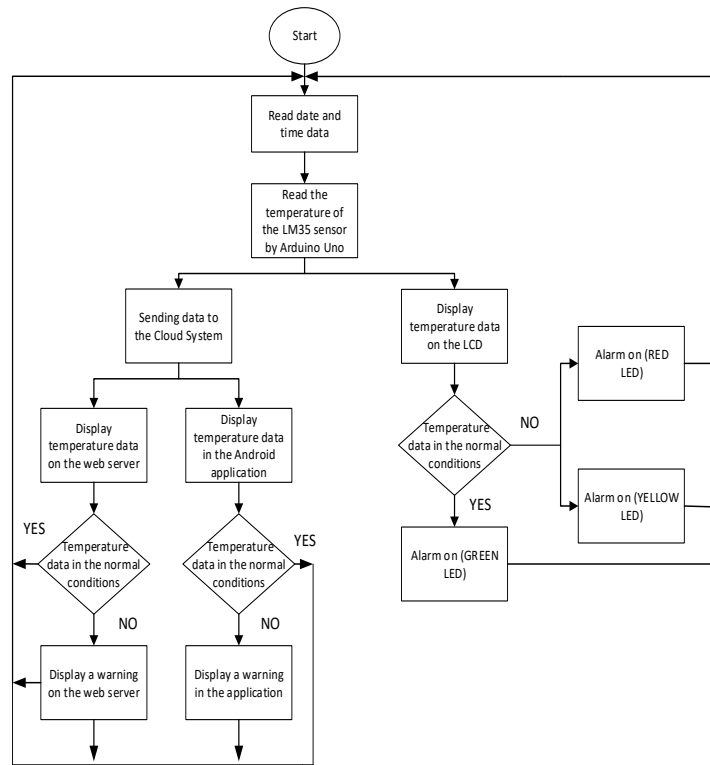

Fig. 4 - Software microcontroller design

For designing a remote monitoring tool system, the program is designed simply but may work properly in diverse work situations. The goal is to help the operator of the machine in monitoring the R125 Shinva automatic filling machine during the production process.

3.4 Server System Design

The server system design is composed of several main programs, which are configured and connected. In Fig. 5 it is explained that the first program is the program on the microcontroller which has been discussed in point 3.3. Then the second program is the bridge program. The function of the bridge program is to connect the microcontroller program with the MYSQL database program. In the bridge programs, there is no data storage process, unlike microcontroller programs and database programs. And the last is the webserver program and application program. The web server program functions to connect the database with the existing web server while the application program functions are to connect the user's application with the database.
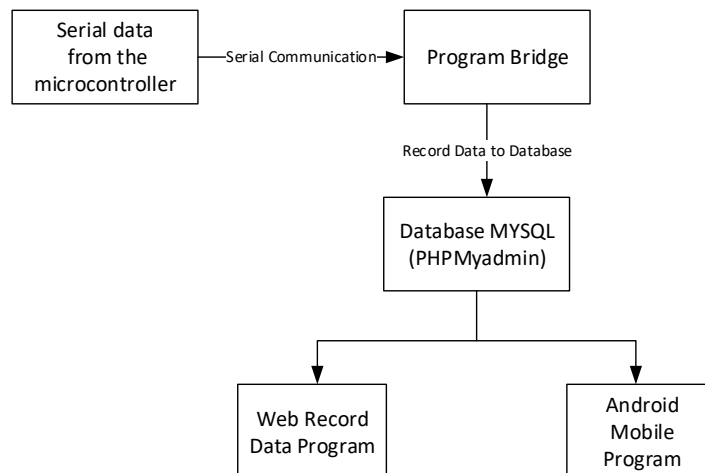

Fig. 5 - Server system design

3.5 Interface Data Monitoring Design

The design of the remote monitoring tool interface is made through two lines, first on-site and online. The on-site path is the operator, supervisor, or technician and the manager can monitor the temperature of the engine by looking at the LCD installed on the device. Then for monitoring via the online, by using a web server and application. The user interface design is configured through the three use case diagrams.

- Use case diagram of mobile application

   Fig. 6 shows the use case diagram that explained an actor in this system are operators, supervisors, and managers or maybe technicians. Actors have access rights to remote monitoring applications. However, related to access rights are divided into two, for operators and supervisors or technicians can access only the Login menu, Home, and View Temperature Data menu Now while the manager has different access rights that can access the entire menu on the application. The first stage after opening the application is to enter an existing username and password. Then in the application, the user can monitor the current temperature of the machine in graphical form, and can also see the monthly temperature change graph. For reminder/alarm problems, the mobile application will send an alarm in the form of sound when the temperature conditions are detected under abnormal conditions. From the data recorded in the database, it can be analyzed about the condition of the latest tools so that it can make it easier to make decisions to maintain the equipment or make changes to the equipment.

- Use case diagram of a web server

   In Fig.7 it is explained that actors in this system are operators, supervisors, and managers. Operators and supervisors have access rights to the remote monitoring Web Server in the Input URL menu, View Home menu, and View Temperature Data Now menu. The first step is to enter the URL that already exists on the web browser on the PC, then on the Web Server, the user can monitor the current temperature of the engine when choosing the View Temperature Current menu and can see the temperature change chart per month when selecting the Temperature Change View Chart menu Per month. The reminder/alarm on the webserver will send an alarm in the form of a notification on the webserver page if the temperature conditions are detected under abnormal conditions. From these data can be analyzed about the condition of the latest tools so that it can make it easier to make decisions to maintain the equipment or make changes to the equipment.

- Use case diagram of onsite monitoring

   An onsite monitoring design or at the machine location monitoring is shows in Fig.8, users can monitor via the LCD that has been installed on the machine. Its function is to display the latest temperature data so that the operator who is working or the supervisor and manager who is surveying the location can find out the temperature conditions on the machine. In addition to reminder problems, this remote monitoring tool is installed with three LEDs to indicate whether the temperature is in a state of high temperature, normal temperature, or low temperature. If the temperature of the component is in a high-temperature condition, the LED that will turn on is red, if under normal temperature conditions the LED that lights up are green, but if it is in a low-temperature condition, the illuminated LED is yellow.
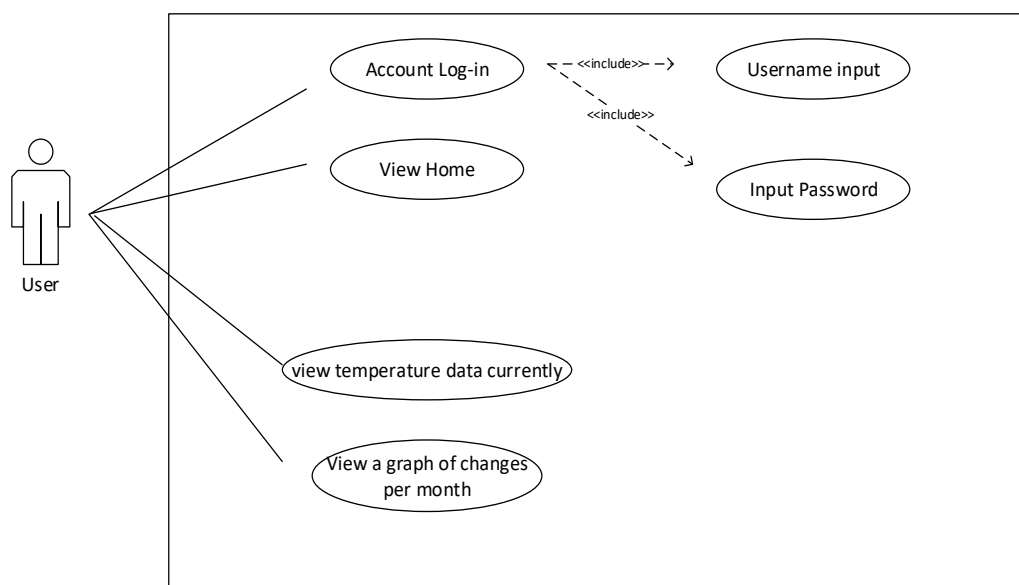

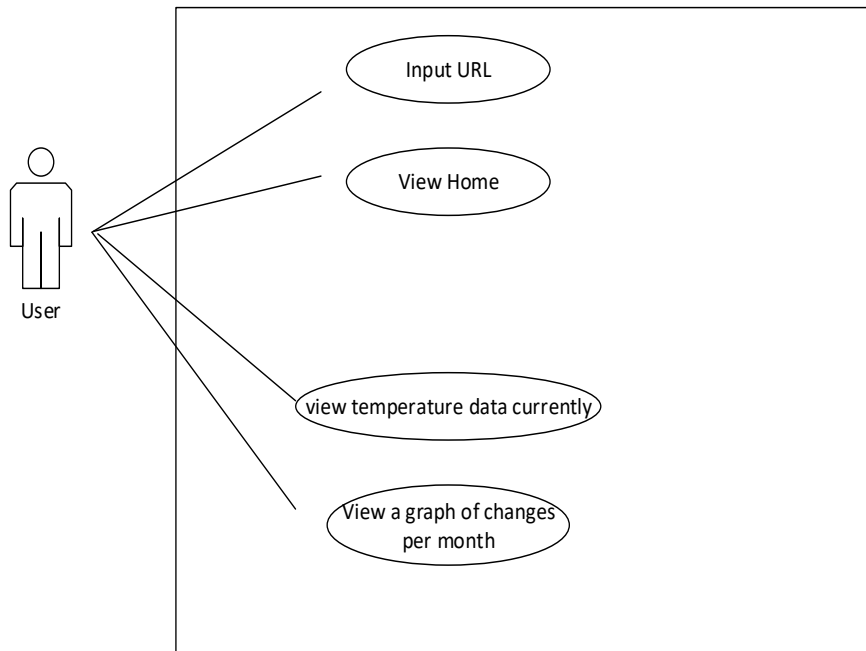Fig. 6 - Use case diagram of mobile application monitoring

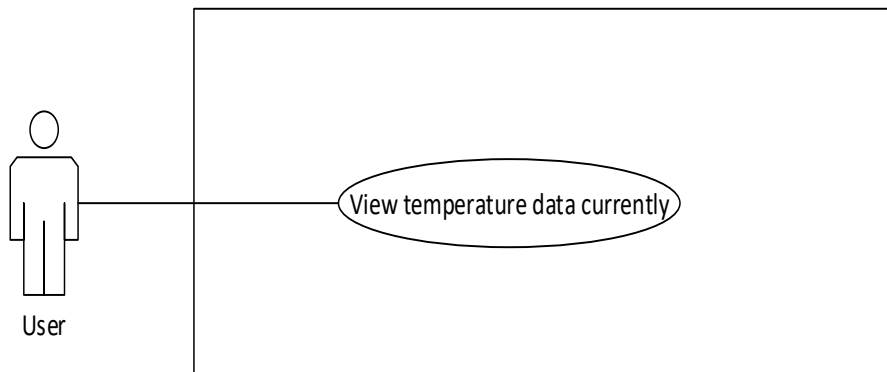Fig.7 - Use case diagram of web server monitoring

Fig. 8 - Use case diagram of onsite monitoring

3.6 Mockup for Mobile Application

The design of the remote monitoring application aims to facilitate users who are not in the area of the factory, to monitor the heat element components in the work station contour welding. If there is damage to the heat element component in the workstation contour welding, the user can find out and interact with the other user who is around the machine to act if necessary. The application works based on the internet network. If the application detects the data sent by the program is not normal, then the application will issue a warning sound. The remote monitoring application consists of four main pages, namely the login page, home page, current temperature data page, and previous temperature data page.

3.7 Mockup for Web Server

For designing the webserver display consists of four pages which consist of the input page URL / input web server address, the home page, the latest temperature data page, and the previous temperature data page. The function of this web server monitoring system is to monitor the temperature conditions of the heat element components in the work station of the contour welding through the computer in the office room or outside the office area. So, if the user is not on standby in the control room, the temperature monitoring activities can still be done. If there are temperature data that is not normal detected by the web server, it will issue an alert notification, so that the user interacts to decide what actions need to be done.

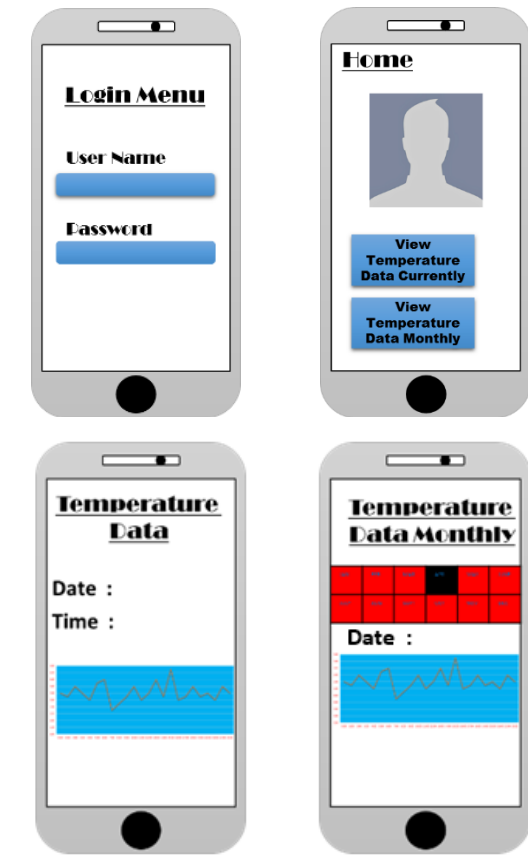Fig. 9 is shows the basic mockup for a mobile application which consist of four different mockup view.

Fig. 9 - Basic mockup for mobile application

Fig.10 shows the basic mockup for the webserver design of the temperature monitoring system. The design of the web server display consists of three pages, which is the URL input page/webserver address input page and the home page, the latest temperature data page, and the previous temperature data page.
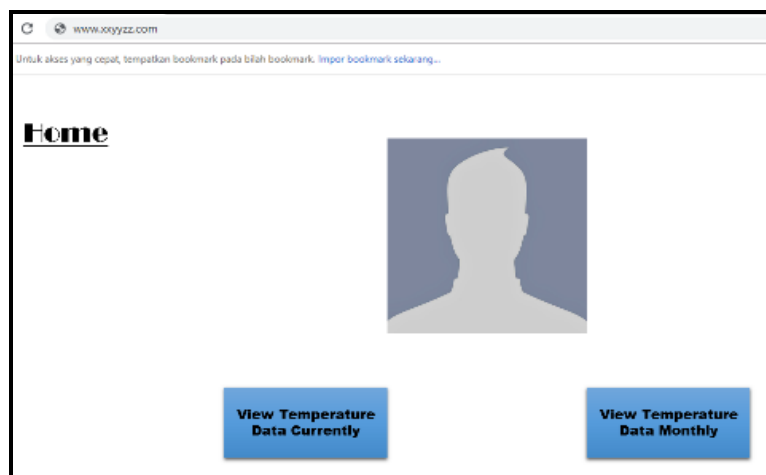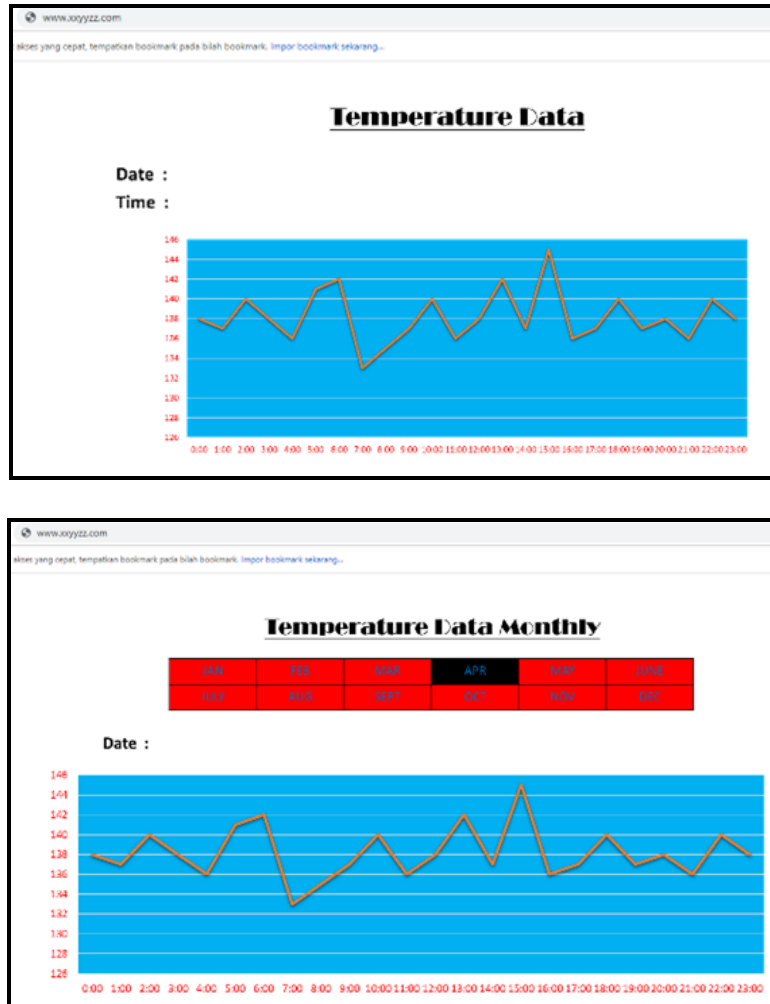
Fig.10 - Basic mockup for the webserver

4. Conclusion

In conclusion, by using this proposed design, the temperature of the heating element as a critical component at the workstation contour welding of R125 Shinva's automatic filling machine can be monitored in real-time condition and giving some specific notification for the maintenance team. With this notification, the maintenance team can do quick action to prevent the fatal failure of the machine. With the power of cloud-based technology, the monitoring system not only can be a monitor on site-company but also can use a web server monitoring, and mobile monitoring system. Meanwhile by applied this monitoring system, the reliability, availability, and maintainability of the machine could be increased, and reducing the maintenance cost overall. For the next, this proposed design must consider and explore in detail several challenges such as sensor capability and durability, Wi-Fi and internet connection, the infrastructure of IT, and trial error of this system to ensure the design can run well.

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