Control system development for monitoring nutrition of curly mustard plants in horizontal NFT hydroponic based-IoT

Liza Rusdiyana, Suhariyanto, Bambang Sampurno, Tania Ardiyanti Pratama
Department of Industrial Mechanical Engineering, Vocational Faculty, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia

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ABSTRACT

Agricultural technology with a hydroponic system provides an alternative for farmers and communities who have limited land. This research aims to make innovations with a hydroponic monitoring system that can be done remotely via the internet that combines 2 systems, namely horizontal technique and nutrient film technique (NFT). The sample used in this study was curly mustard seeds. To combine the 2 systems, researchers designed a hydroponic prototype system using internet of things (IoT) in the form of smart hydroponics in the Blynk application. This research uses literature studies for research reference and flowcharts to regulate the flow of the program to be researched. The results showed that by using the IoT and the Blynk application, owners can monitor the nutrient content and pH of curly mustard greens remotely. The system automatically controls nutrients and pH according to the desired settings. In the growth control system of mustard curly, the use of smart hydroponics is proven to be better. Harvestable plants at the age of 34 days. Unlike the conventional system, the harvest period is at the age of 40–45 days. Therefore, smart hydroponics is more efficient because it shortens the harvesting time and saves labor.

Corresponding Author:

Liza Rusdiyana
Department of Industrial Mechanical Engineering, Vocational Faculty
Sepuluh Nopember Institute of Technology
Surabaya, Indonesia
Email: liza@its.ac.id

1. INTRODUCTION

Food is a basic need for humans to be able to live a healthy, active, and productive life in the long term [1]. As a country that has relatively abundant potential food sources, Indonesia is an agricultural and maritime country, so it is important to manage natural resources optimally for the welfare of all its people [2]. With Indonesia's population continuing to grow, the need for sufficient food supplies to fulfill their lives is increasingly urgent [3]. Facing fluctuating global food prices and often unstable changes at the national level, the people of Indonesia, which is a country with a large population, need to utilize their own land to grow food at home [4]. Current climate change is also having a detrimental impact on food producers. Farmers have difficulty predicting the weather when they plant. Increasingly scarce land resources, especially due to the development of the industrial and service sectors, have made conventional agricultural activities less competitive due to high land prices [5].

The solution that emerged was the use of agricultural technology with a hydroponic system [6], which is an alternative for farmers and people with limited land. This technology allows the use of unused land such as building walls and house balconies for commercial agricultural activities, which can be an adequate source of income. The hydroponic system uses water as a planting medium [7]. This allows plants to obtain nutrients easily, improves growth quality [8], and eliminates dependence on land.

However, even though hydroponics does not require land [9], to achieve maximum results, hydroponic plants still need lots of sunlight and require routine nutritional monitoring every day [10]. Seeing this phenomenon, many people have practiced hydroponic vegetable cultivation, which on is in Pulorejo Village, Mojokerto. The vegetable cultivation implemented in this village is curly mustard greens, however, in the implementation of hydroponic cultivation, there are still obstacles in monitoring plants manually. Changes in nutrient levels are still not ideal and of course can hinder the growth process of vegetables, so cultivation owners must monitor plants regularly.

From these problems, the author was interested in conducting research on this hydroponic phenomenon. To overcome the obstacles that exist in Pulorejo Village, the author uses his own land to cultivate curly mustard greens hydroponically in his yard. Then the author will develop an innovation in the form of a hydroponic monitoring system that can be accessed remotely via internet. This tool is named "Smart Hydroponics" and will be used to increase the quality and quantity of vegetable crops. This tool is a unique form of technology because it is based on the internet of things (IoT) [11] and combines a nutrient film technique (NFT) system [12] and a horizontal system [13], which is efficiently used in cultivating vegetables using hydroponic techniques.

2. METHODS AND MATERIALS

The method used in this research is an experimental method by combining the NFT system and a horizontal hydroponic system which aims to design an IoT-based hydroponic prototype system whose condition can be monitored visually via an application or the web. Then, after making the hydroponic prototype is complete, the next step is to test the equipment for hydroponic planting, this aims to determine the efficiency of the equipment. The tools and materials used are multi netpot, horizontal NFT, ESP32, UV LED lamp, pH sensor, total dissolved solids (TDS) sensor, submersible pump, male to female jumper cable, 9 V power supply, 25 liter water tank, relay, and 2×7 LCD monitor. The research will be carried out at the Mojokerto Hydroponic Garden located in Pulorejo Village and the samples used in the research are curly mustard greens seeds as the researchers' experimental data.

Before carrying out the research, the researcher carried out an initial literature study first, to understand the basic working concepts of the device to be proposed, the main attention was focused on the integration between the electronic and mechanical components [14] to be used, as well as the overall design of the device itself. Then proceed with a field study to determine the conditions for growing hydroponic vegetables [15] and after that, existing problems will be analyzed and integrated with literature studies as problem solving. The research process is carried out by following the sequential steps shown in Figures 1 to 7.

- Workflow flow diagram can be seen in Figure 1.
- Flowchart of TDS and pH sensor program flowchart to ESP32 can be seen in Figure 2.
- Flowchart of RTC sensor flow process to ESP32 can be seen in Figure 3.
- Application flowchart on smartphone can be seen in Figure 4.
- IoT architect can be seen in Figure 5.
- Design of devices consist of hydroponic design can be seen in Figure 6 and hardware design can be seen in Figure 7.
- Android software and application system design.

In this research, researchers used ESP32 as the main programming tool. Two sensors, namely the pH sensor and the TDS sensor, are used to measure the acidity or alkalinity level of the solution. These sensors send data to the microcontroller, which functions as a trigger for pump performance to ensure the nutrients and pH levels in the solution remain appropriate [16]. Previously, the ESP32 had to be connected to a Wi-Fi network, and then the ESP32 would send this data which would be read by the Blynk application. The information received by Blynk can be accessed via smartphone [17].

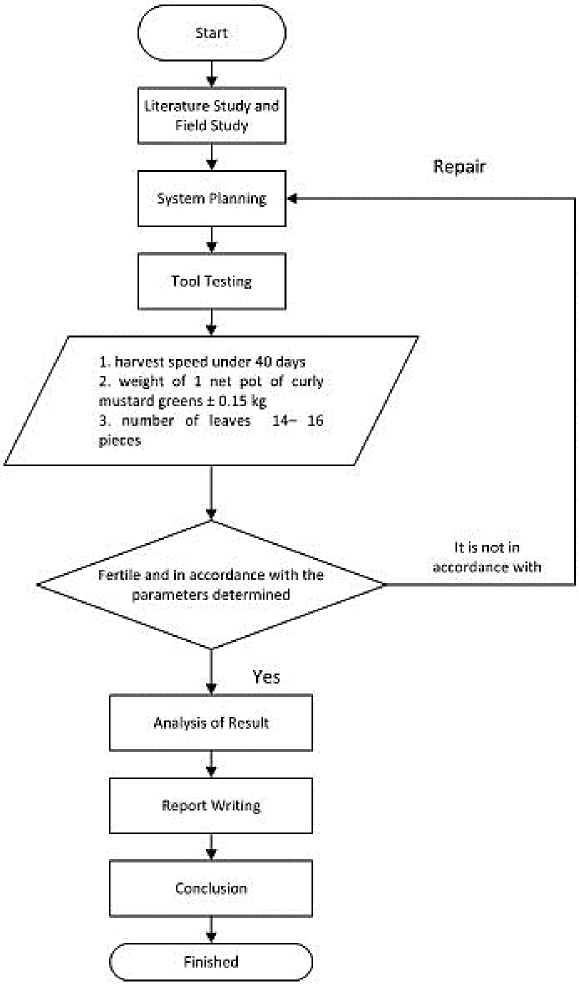

Figure 1. Flowchart of work flow

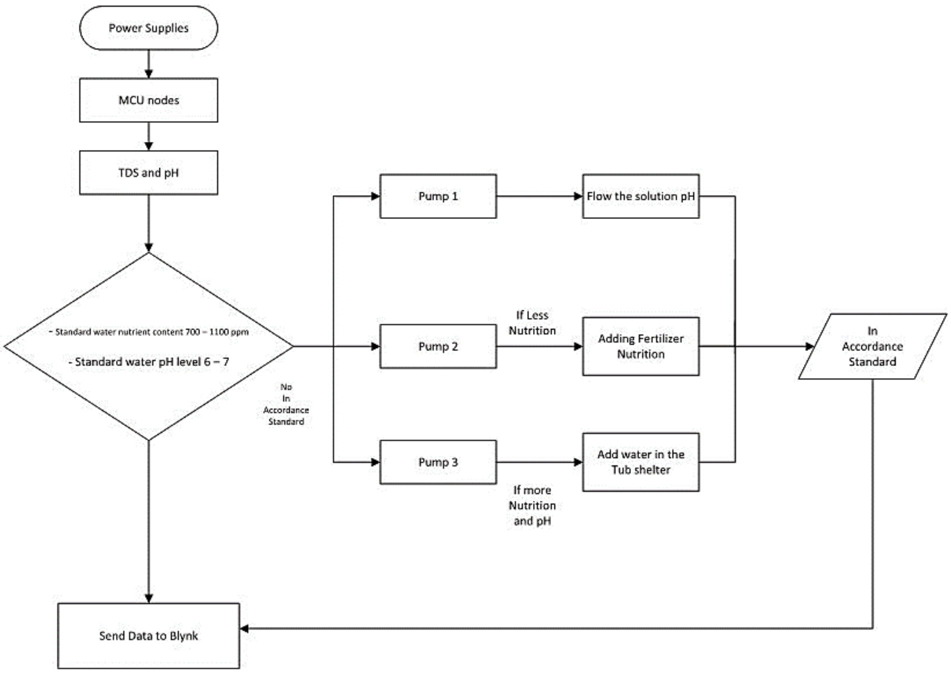

Figure 2. Flowchart of the TDS and pH sensor program flowchart to ESP32

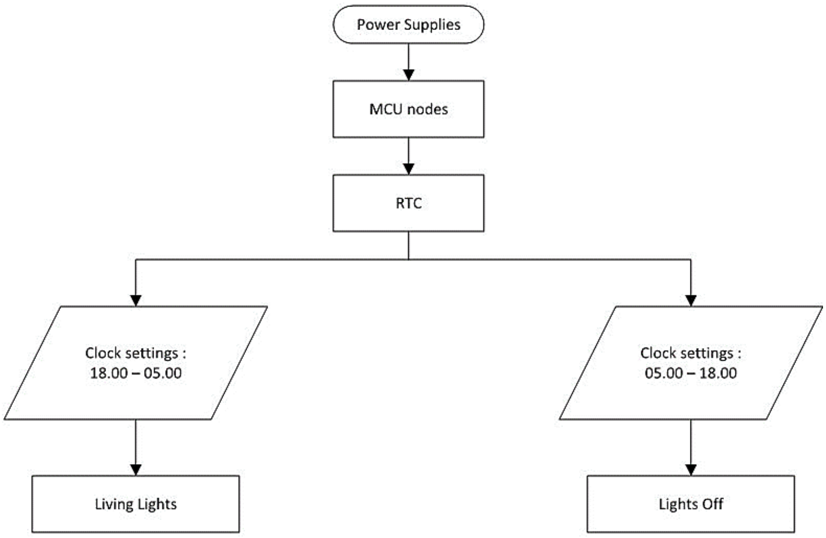

Figure 3. Flowchart of the RTC sensor flow process to the ESP32

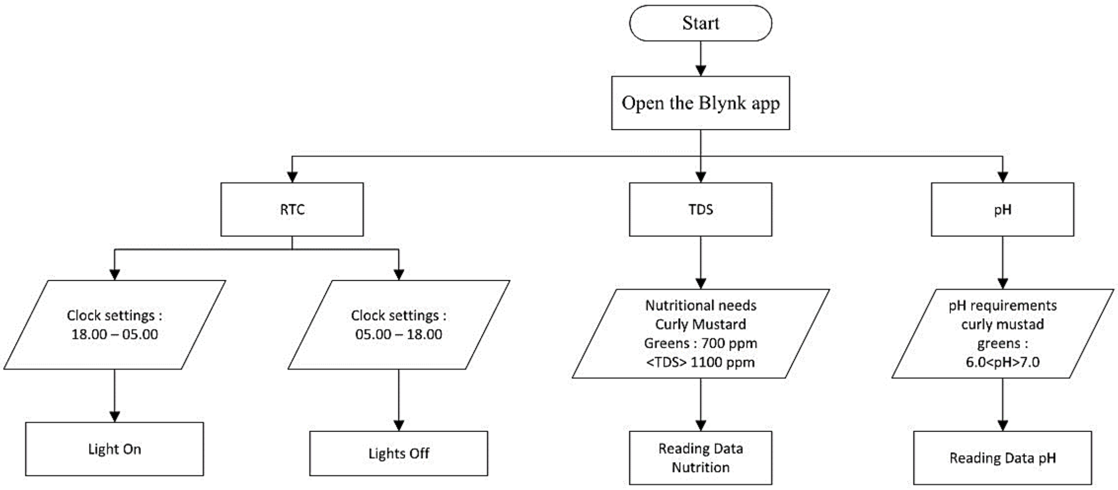

Figure 4. Application flowchart on smartphone

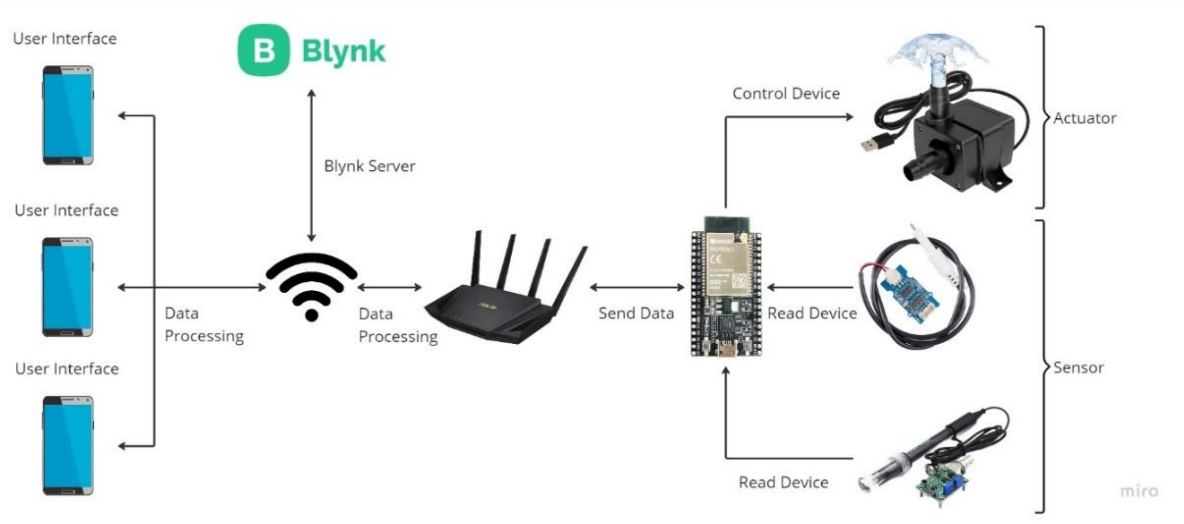

Figure 5. IoT architect

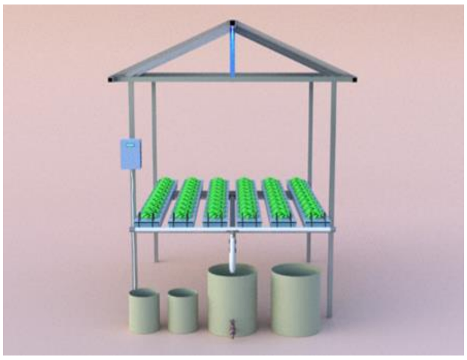

Figure 6. Hydroponic design

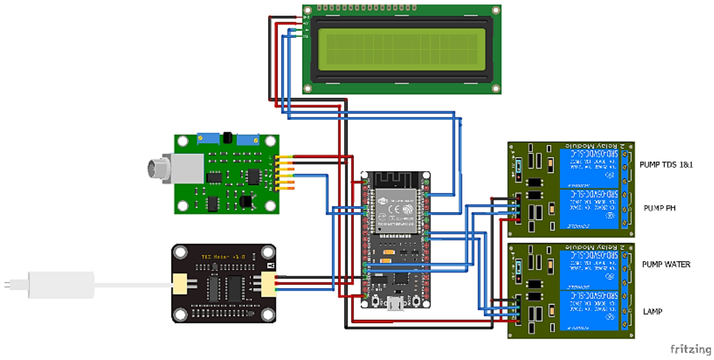

Figure 7. Hardware design

3. RESULTS AND DISCUSSION
3.1. Device model results
3.1.1. Control system hardware
The hardware control system that has been implemented consists of several main components. First, there is the ESP32 which functions as the main brain or system control center. Furthermore, there is a series of TDS sensors which are used to detect levels of dissolved nutrients in water [18], and a series of pH sensors which play a role in measuring the acidity level of water [19] to regulate the operation of the device according to a preset time program, a relay circuit is used which is connected to the pump and LED strip. To control the electricity supply [20], there is a series of switches that are used to disconnect or connect electrical power. Finally, the NodeMCU ESP32 WiFi circuit is used to transfer data from the sensors online to the Blynk platform. Control system in smart hydroponics can be seen in Figure 8.

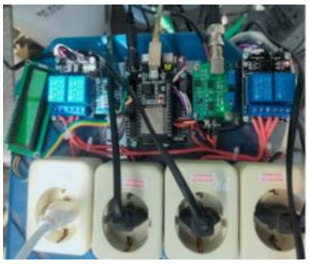

Figure 8. Control system in smart hydroponics

In this smart hydroponic system design model, the main controlling device is ESP32. There is also a TDS sensor and pH sensor which function as detectors, as well as the Blynk platform which acts as a data reader from the two TDS and pH sensors. All these components are connected to the ESP32 for efficient control and monitoring of the system.

3.1.2. Blynk application implementation
In this smart hydroponic system, the application used is Blynk, which can be downloaded from Google Playstore or accessed via the web version. Through the Blynk web platform, data regarding pH levels, nutrients, and lighting in the hydroponic system will be presented by [21]. In this research, there are two main software designs. First, the ESP32 programming design aims to run and control the hardware. This involves setting up the ESP32 Wi-Fi module to send sensor data to the Blynk server. Second, there is a display design in the Blynk application that allows monitoring sensor data. Thus, users can monitor and control the hydroponic system efficiently through the Blynk application [22]. Implementation of sensor data on the Blynk web can be seen in Figure 9.

3.2. Smart hydroponic system testing
Testing is carried out by testing several sensor modules that will be used in the smart hydroponic system, which are then connected to the ESP32. System testing aims to ensure that the device operates according to a predetermined program. There are three indicators that are considered in this test, namely the

nutrient pump performance test, the pH pump performance test, and the connectivity test with the Wi-Fi network. The system requires a Wi-Fi connection to access hydroponic system monitoring via the Blynk web platform. If there is no power supply and Wi-Fi connection, the system will not be able to operate optimally.

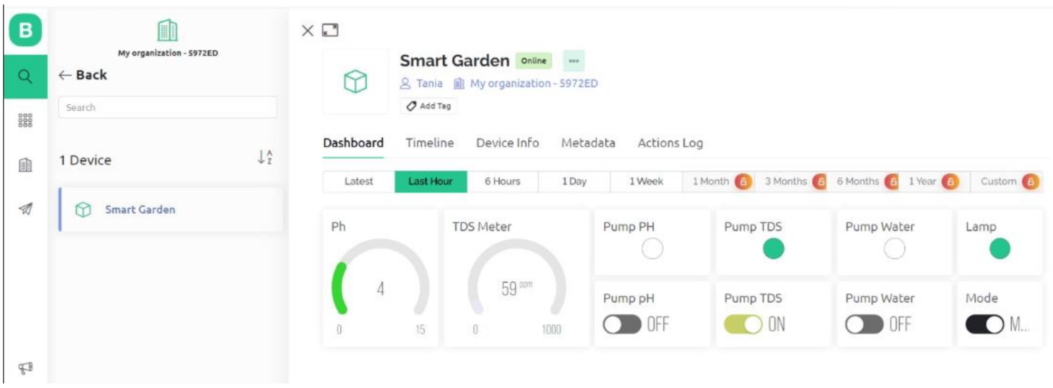

Figure 9. Implementation of sensor data on the Blynk web

3.2.1. Nutrient pump testing

In this test, researchers have programmed the system to respond to conditions when the parts per million (PPM) value is below 700, where in this situation, the nutrient pump will be activated. Then, the pump will be disabled when the PPM value reaches 1100 or more. Before starting the test, the researcher prepared a nutrient solution in a hydroponic tank with an initial PPM value of less than 700. After that, the nutrient pump would automatically be activated until the nutrient level in the solution reached the desired level. The TDS pump on can be seen in Figure 10.

3.2.2. pH pump testing

In this test, researchers have programmed the system to respond to conditions where the pH level of the solution is less than 6, which causes the pH pump to become active. The pH pump will be turned off when the pH level of the solution reaches above 7. Before starting the test, the researcher prepared an acid solution in a hydroponic tank that had an initial pH level below 6. In this way, the system can be tested to ensure that the pH pump functions according to the parameters predetermined pH. The pH pump on can be seein in Figure 11.

3.2.3. Water pump testing

In these trials, researchers have set the system to operate with nutrient and pH levels that exceed predetermined thresholds. As a result, the water pump will be activated until the nutrients and pH reach the desired or neutral level. Water pump on can be seen in Figure 12.

Figure 10. TDS pump on

Figure 11. pH pump on

Figure 12. Water pump on

3.2.4. LED light testing

LED light testing is carried out to verify that the device is operating according to the programmed schedule [23]. The researchers arranged for the LED lights to be active at intervals between 18.00 and 05.00, while in the period between 05.00 and 18.00, the LED lights were turned off. Direct observation results show that the LED lights function according to a predetermined schedule. Testing lights on at 6 PM (left) and turn off at 5 AM (right) in Figure 13.

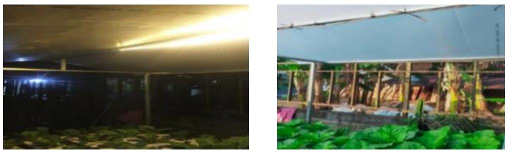

Figure 13. Lights on at 6 PM (left) and turn off at 5 AM (right)

3.3. Discussion

The hydroponic method of cultivating plants using smart hydroponics has various advantages compared to conventional monitoring methods. This advantage is mainly due to the ability to monitor and control nutrients and solution pH levels via IoT technology connected to a smartphone [24]. In this smart hydroponic system, if a nutrient deficiency or pH change is detected through monitoring, farmers can easily add nutrient solution or adjust the pH directly by activating the nutrient and pH pump via their smartphone. This has a positive impact on time and energy efficiency.

Apart from that, this system also allows regular monitoring and control of the condition of the nutrient tank and the pH of hydroponic plants, so that farmers do not need to manually add nutrient solutions or pH. Information such as ppm and pH levels can be continuously monitored and regulated remotely via a smartphone device. With this system, plants always receive an adequate supply of nutrients and optimal water pH conditions, which contribute to good growth and development.

The presence of light control is also one of the advantages of this hydroponic system, because it can ensure that the photosynthesis process runs well [25]. This encourages plant growth to be more efficient and faster. In contrast, to conventional methods, monitoring of nutrient tanks must be done manually in the field, and plant growth is very dependent on sunlight. Apart from the technical benefits, hydroponic plant cultivation also has profitable income potential. By utilizing empty land, farmers can generate income by selling vegetable and fruit products grown hydroponically. This method is considered safer because hydroponic plants tend to be cleaner, require less space, and are simpler to maintain compared to conventional farming methods.

4. CONCLUSION

From the results of the research that has been carried out, it can be concluded that by utilizing Web Blynk technology and the IoT, farmers can monitor nutrient content and pH levels remotely. Owners also have complete control over the nutrients and pH in their water tanks through Blynk's Web-integrated smart hydroponics system, which works automatically to regulate nutrients and pH according to settings predetermined by the grower. In the context of smart hydroponics, farmers can receive information about TDS and pH levels via the Blynk web platform. If deficiencies or imbalances are detected, farmers have the ability to control nutrients and pH directly through this web platform. They can activate the nutrient pump or pH pump to add the necessary liquid fertilizer or acid solution, ensuring that the plant's environmental conditions remain optimal. Thus, this technology provides flexibility and efficiency in managing hydroponic plant cultivation, as well as enabling more effective monitoring and control from a distance. It is hoped that this control system with internet-based technology can be realized by farmers in the future to monitor their crops over a distance more efficiently.

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BIOGRAPHIES OF AUTHORS

Liza Rusdiyana is a lecturer at the Department of Industrial Mechanical Engineering ITS, with expertise in Mechanical System Design. She completed Diploma Three education from Malang State Polytechnic, Bachelor and Post Graduated from Mechanical Engineering ITS. She can be contacted at email: liza@its.ac.id.

Suhariyanto is a lecturer at the Department of Industrial Mechanical Engineering ITS, with expertise in Machine Elements. He completed Bachelor Graduated from Mechanical Engineering ITS and Post Graduated from Basic Science Faculty in Indonesian University. He can be contacted at email: suhariyanto@its.ac.id.

Bambang Sampurno is a lecturer at the Department of Industrial Mechanical Engineering ITS, with expertise in Adaptif Control System. He completed Bachelor Graduated from Mechanical Engineering ITS. He complete Master and PostDoctoral from Mechanical Engineering in Institute Technology of Bandung. He can be contacted at email: itsbsampurno@gmail.com.

Tania Ardiyanti Pratama was born in Mojokerto, June 12 2000. She studied at the Department of Industrial Mechanical Engineering, Sepuluh Nopember Institute of Technology in 2019 with Principal Registration Number (10211910010046). The Industrial Mechanical Engineering Department takes the Energy Conversion Engineering Technology study program. She can be contacted at email: Niaardiyanti234@gmail.com.