Water Flow Control System Based on Context Aware Algorithm and IoT for Hydroponic

Otrinanda Gandhi, Mohamad Ramdhani, Muhammad Ary Murti, Casi Setianingsih
School of Electrical Engineering
Telkom University
Bandung, Indonesia
otrinanda@student.telkomuniversity.ac.id

Abstract — Farming with using a hydroponic technique became a solution for future farming technique. Hydroponic uses water to provide nutrient and oxygen for the plant. Water must be distributed equally in all part of hydroponic pipes, so that every plants get same amount of nutrient. In order to control the water flow to be distributed equally, this research used servo valve controlled by microcontroller based on Internet of Things (IoT). Lastly, this research also observe the plant grows in the hydroponic that using this system. The result shows that the system can make the plant growth, like plant length and leave width will be more equal between growing tube.

Index Term — ***Valve, Water Flow Sensor, Hydroponic, Internet of Things.***

I. INTRODUCTION

Hydroponics is a farming technique without using soil as a growing medium. This technique uses water to replace the soil in supplying nutrients and oxygen needed for plants. In order for plants to grow normally, the water conditions must be adjusted according to the needs of the plant. These conditions are in the form of nutrient levels, pH levels and oxygen levels. [1] Water that has been adjusted to its condition also needs to be considered the amount of its administration to plants. To regulate the amount of water supplied, can be done by regulating the condition of the water flow. Too little water flow will cause a lack of the amount of nutrients available. But the flow of water that is too large will cause the oxygen content available in the water to be too little [1].

The recommended water flow for a hydroponic system ranges from 1 L / m to 2 L / m for each grow tube (channel / gully) [12]. When plants are just seedlings, the recommended flow rate is typically between 0.5 L / m to 1 L / m and can increase following greater plant growth. The amount of water supplied can also be affected by the length of the growing tubes (pipe / gully). The length of the growing tube affects the decrease in nutrient content between parts. Recommended length of growing tube is no longer than 10 to 15 m. Because the longer the growing tube, the difference in nutrient levels at each end will be even greater. [12].

In general, the amount of water flow can be regulated by adjusting the flow rate of the pump used to flow water to the growing tube. However, if the hydroponics used on an industrial scale with a length of growing tube exceeds that recommended, and only use one pump with a large flow rate. Then the shape of the growing tube can be changed. If in general the growing tube used is of type serial distribution.

This form arranges the growing tube into one long stream. The initial end of the growing tube is connected to the other end of the growing tube. So that there is only one flood gate at the beginning of the pipe, and one gate at the end of the pipe. This form can be modified so that the length of the water flow in the growing tube is not too long.

In this modification several growing tubes are strung together so that there are several short streams of water. This form connects all the initial ends of all growing tubes together, as does the end of the growing tube. so now there are several sluice gates at the beginning of the pipe and several sluice gates at the end of the pipe. This form of growing tube is called parallel distribution.

Now there are several streams of water in the growing tube, but the flow of water in each growing tube is not the same. Some growing tubes close to have a water flow above that is recommended, and some growing tubes will have a water flow. The difference in water flow is due to the shape of the growing tube circuit and its distance from the pump. This can be overcome by adding water valves at each end of the initial growing tube. Large water valve openings will be able to regulate the flow of water in accordance with what is desired.

The control system in this study is designed so that waterflow can be regulated automatically using a context aware control method. Although this method is quite simple in controlling a parameter, this method is considered sufficient to solve the need for this system. This method looks at the condition of water flow using sensors, this data is then sent to the controller. The condition of this water flow which then becomes a parameter that will determine what action needs to be taken so that the flow of water can be in accordance with the desired value.

In addition to controlling water flow automatically, this system can also monitor water flow conditions by using the IoT platform. Making it easier to use to monitor the flow of water in each growing tube, without the need to look directly.

II. RELATED WORK

Research about water flow control system and IoT monitoring has been done in recent years. For example, a research done by Kyoo Jae Shin about electrical valve for smart aquarium [6]. In this research, valve was moved by a DC motor actuator connected to valve. It used angle sensor to determine the aperture angle of the valve. This system can control valve aperture of aquarium water circulation pipe. But the accuracy is still low due to the unsuitable DC motor specification to turn accurately [6].

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To add the accuracy of valve aperture, actuator can be replaced to servo motor used in research by Rizal Khuzzai about electrical valve on home water pipe. Servo motor is connected to valve using gear to make the torque bigger. This system can control the aperture angle of the valve accurately with low error. But this system does not focus on water flow, because it does not use sensor to detect the water flow [7].

In monitoring water flow state, a research by M.M. Srihari has done, about Intelligent Water Distribution using Internet of Things [8]. This research used water flow sensor to detect the water flow after the valve was opened. Solenoid valve is used, it can open up and close fully only, without getting controlled. The detected water flow data will next be displayed on IoT based user interface, so it can be monitored easily and accurately [8].

Meanwhile, a research about context aware control system has been done by K. Deeba, about Context-aware Healthcare System based on IoT [9]. This research used context aware method to find the right context for respiratory rate data from sensor. This context will give the conclusion about respond or action that should be done to respiratory rate state, so that the countermeasures are better [9].

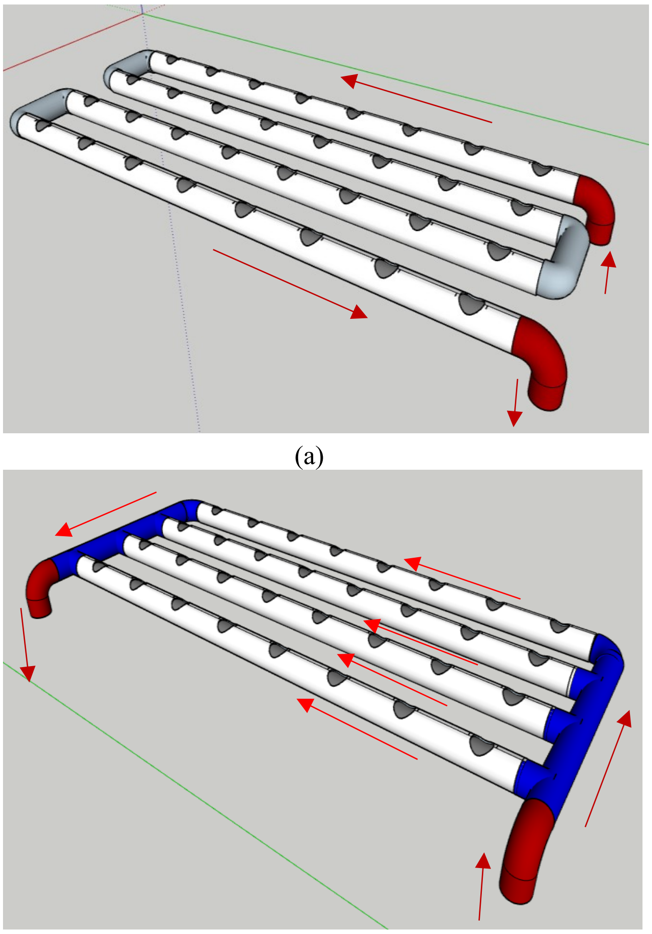
Those researches become the reference in designing water flow control system and IoT monitoring on hydroponic.

III. SYSTEM DESIGN

Smart Hydroponic is a system that able to automatically control the environmental condition around the plant on hydroponic. Those conditions are pH, nutrients, water flow, and humidity. In this study the focus is on controlling water flow, so that the magnitude can be adjusted and evenly distributed on all growing tubes in hydroponic heaters. So that the flow of water in each growing tube can be evenly distributed and the amount can be adjusted. This study uses growing tubes arranged in a parallel distribution form, and uses a water valve that is installed at the initial end of the growing tube.

This system uses water flow as a parameter to be controlled. The amount of water flow is read using a water flow sensor that is installed between the water valve and the growing tube. Data obtained by the sensor will be used as feedback which will correct the desired value with the value that actually occurred. The difference between these two values will be an error signal that will be processed by the controller to determine what action will be carried out by the system. Then the controller will give an order to the actuator to move so that the desired water flow state can be achieved. This system is a closeloop control system so that the system can control the flow of water automatically continuously.

In general, the form of hydroponic growing tube series used is a form of serial distribution. This shape produces a long flow of water, so it is difficult to control so that the flow of water can be evenly distributed in all parts. Whereas in this study using a parallel distribution circuit form. This form breaks the flow of water into several parts so that it is easier to control the flow of water.



(a)

(b)

Figure 1. Shape of growing tube (a) Serial distribution (b) Paralel distribution

This system uses an actuator that rotates the water valve, so that the flow of water can be controlled. By controlling the size of the water valve opening, the system can control the flow of water through. The actuator used in this system is a servo motor that is installed on a stand with a tap so that the rotation of the servo motor can rotate the water valve in one shaft. The servo motor used is a servo motor with a large torque, so it is strong enough to turn the valve.

In choosing the servo motor and valve used in this research, it uses a trial and error system to determine which servo motor is strong enough, and what kind of valve is quite easy to rotate. After conducting several experiments, in this study using MG995 servo motor with torque reaching 15 kg / Cm. And using a water valve with a type of Manual Rotary Ball Valve.

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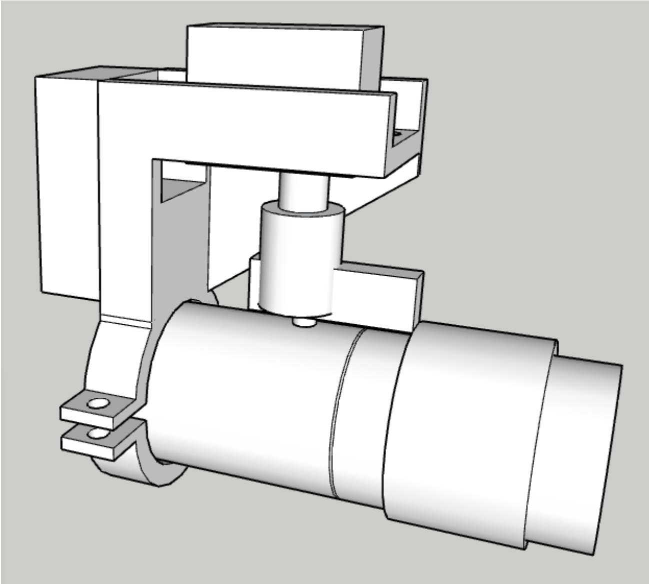

Figure 2. Hardware Design of Waterflow Control System

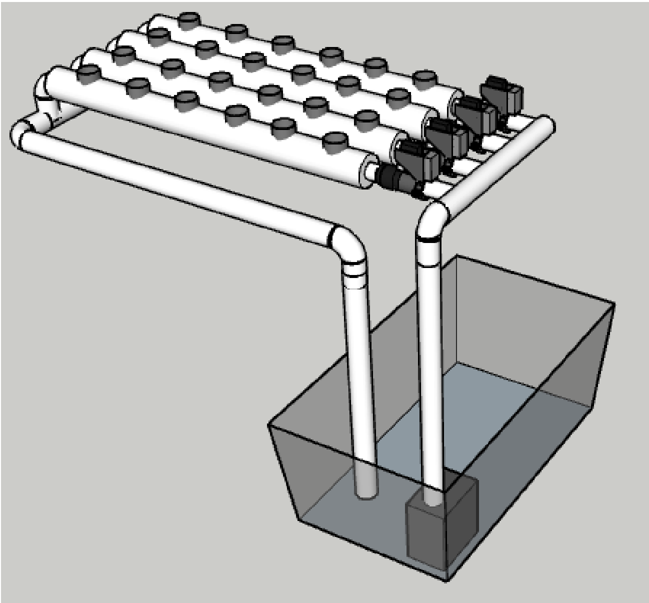

Figure 3. Hardware Design of Waterflow Control System at Hydroponic Growing Tube

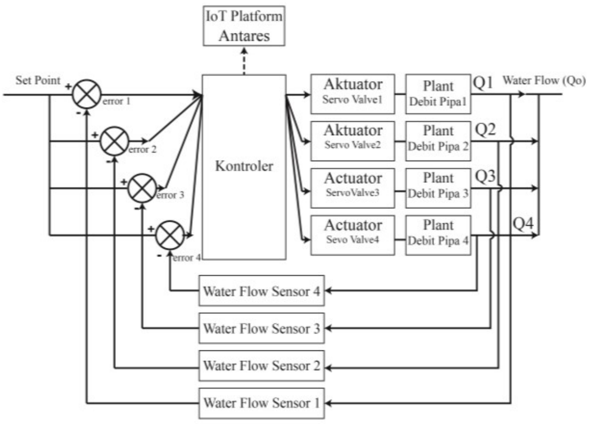

Figure 4. Block Diagram of Waterflow Control System

This system uses multiple input multiple output concept on four growing tube. Means, this system receives four inputs in the form of water flow in every tube that will next be given an output as the changes of aperture angle of the valve by the actuator. Input changes will not affect different output of the tubes, so that every tube is independent.

Water flow data is processed using Context Aware method in the controller. These data will decide the conclusion about ongoing conditions, based on the context. Next, the conclusion will decide the action. Water flow data will next be sent using internet communication via Wi-Fi to cloud storage on Antares IoT Platform. Saved data will be displayed as user interface on Antares website.

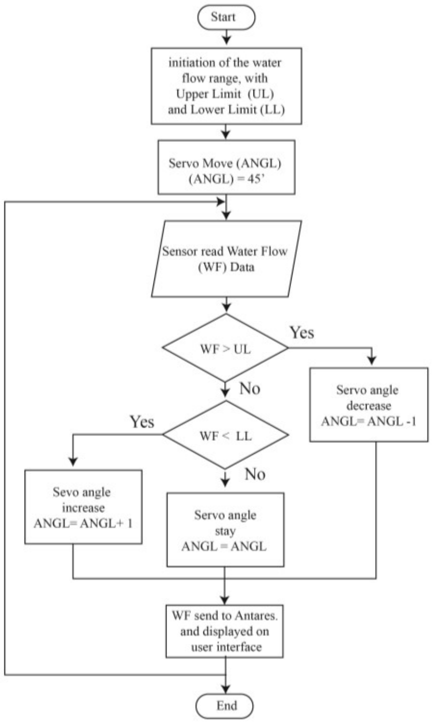

Figure 5. Water Flow Control Proses

Workflow of valve system control is started from determining the desired water flow limit. Next, valve will be opened and sensors in every circulation pipe will read different flow water values. Water flow data in the pipe will next be compared to the desired water limit. If it is greater, aperture angle of the valve will be reduced by 1 degree. If it is lower, aperture angle of the valve will be increased by 1 degree. Other condition will happen if water flow is in the desired water range, valve will stay still. It will be repeated so the water flow can be controlled and the distribution is equal in every pipe.

Context Aware Method that is used in this research consists of 3 parts, sensing, thinking, and acting. Sensing uses sensor to get the water flow data in hydroponic pipe. Thinking decides the conclusion of ongoing conditions. Next, acting decides the right action based on the conclusion.

$$\text{Water Flow (WF)} \begin{cases} \text{If} \quad LL \le WF \le UL \text{, then No Action} \\ \text{If} \quad WF \le LL \text{, then Valve Open Wider} \\ \text{If} \quad WF \ge UL \text{, then Valve Close Narrower} \end{cases}$$

*LL = Lower Limit , UL = Upper Limit

Figure 6. Contexts Algorithm

Contexts used in this system is:

- If the water flow read from sensor is in enough range, no action will be done.
- If the water flow read from sensor is lower than the range, pipe is lack of water, so there will be an action to enlarge aperture angle of the valve by increasing PWM value of the servo.
- If the water flow read from sensor is greater than the range, plenty of water flows in the pipe, so there will be an action to reduce aperture angle of the valve by reducing PWM value of the servo.

IV. EXPERIMENT RESULT AND ANALYSIS

Experiment is done to ensure that system can work according to the theory and design. In this step, few experiments are done to get the correlation between control variable and fixed variable. It is also done to find out the operation characteristic and things that can affect the operation system. It consists of 3 kinds of experiment.

A. Accuracy of Sensor

This experiment to find out the accuracy of sensor to read the water flow value. The waterflow value is proportional to the volume of water passing through the sensor. Therefore, the sensor readings of the value of the volume of water passing by the sensor are compared to the measurement results using a measuring cup

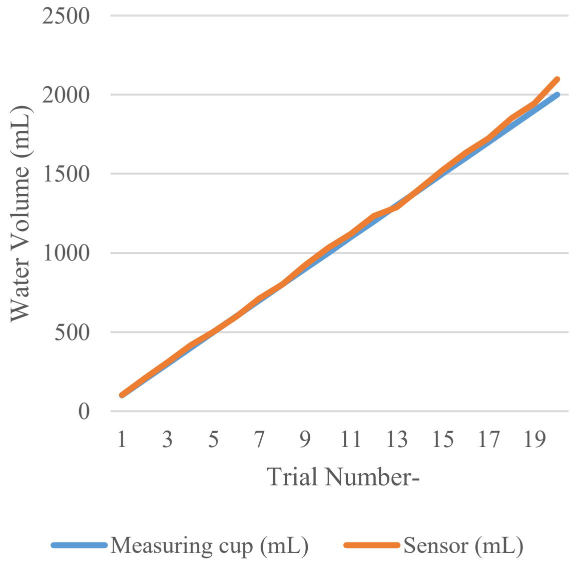

Figure 7. Sensor Accuray

Based on the experiment ,the results of observations of the volume of water passing through were obtained. These two data are compared and looking for the average difference.In this experiment, the average difference obtained from sensor readings at 2.1%, with the highest error generated at 4.9%. The difference obtained is relatively small, because it is still within the tolerance limit of the waterflow sensor, which is 5%

B. Performance of Servo

This experiment to find out the accuracy of motor servo to rotating at a certain angle. The value of set point that put into a controller is compared with the results of the angles produced by the servo and measured with angle ruler.

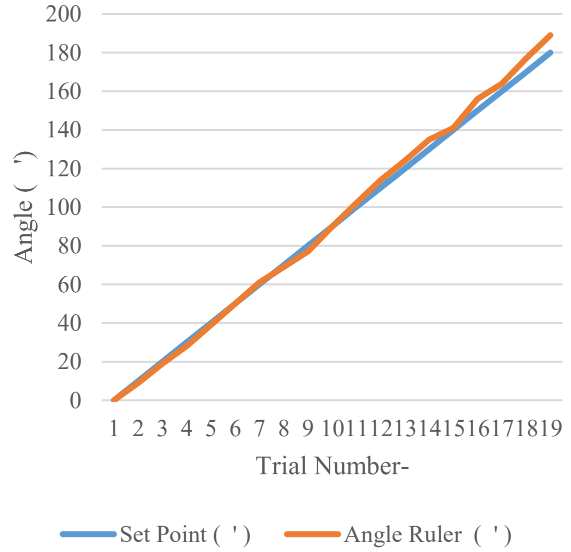

Figure 8. Servo Performance

Based on these observations, obtained angular motion by the servo. This value is then compared to the set point as the initial command to the servo. In this experiment, the average error from servo movement at 3.2%, with a maximum error at 10%. This error occurs because the load torque of the valve is large enough, so the performance of the servo motor to move the valve is slightly reduced. Despite having an error, the resulting angle difference is not too far away, so it does not affect system results.

C. Effect of valve openings on water flow

In regulating the amount of water flow that will pass through the growing tube, this system uses a water valve that is opened at a certain angle. With a minimum angle of 0 'and a maximum angle of 90'. To move water from water storage, the system uses a pump that produces a waterflow of 5L / m.

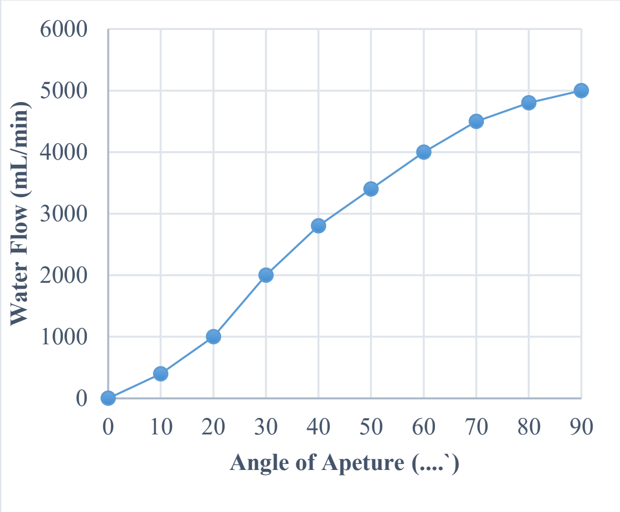

Figure 9. Servo Performance

D. Automatic Water Flow Control

This experiment is done in the purpose of finding out the ability of the system in controlling water flow in the desired water range, so water distribution can be equal with Context Aware Method. Experiment is done to control the water flow to stay in the range of 1 to 1.5 L/m. This range is based on the recommended value for each growing tube in the hydroponic.

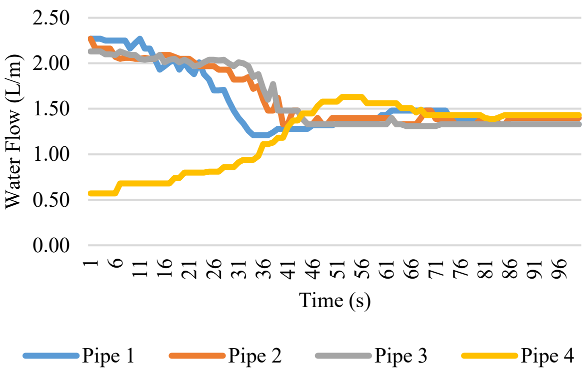

Figure 10. Changes of Water Flow.

Figure 10 shows that system can control water flow to stay in the desired range, and it also can adjust itself if there is any disturbance. System can control the flow until it is distributed equally in 43 seconds. At 50th second, there is disturbance in Pipe 4 and makes the flow rising above the range. But system can adjust it to stay in the range at 64 seconds. Next, water flow stays in the range though there is some ups and downs but this change is not that big and stay still in the range. This change is due to the unstable water flow from the pump and water ripple from valve movement.

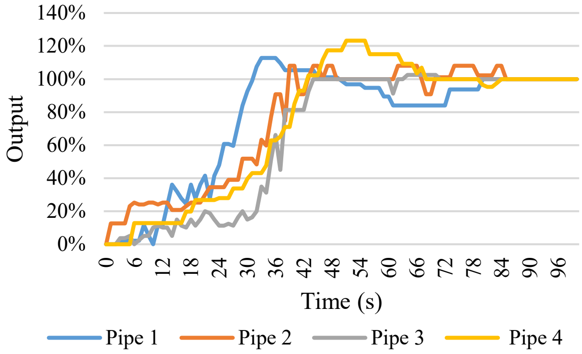

Figure 11. System Control Performance .

Figure 11 shows the performance of this system to control the water flow. The fastest pipe to reach the steady state is pipe 3, that is 60 s. But for the biggest overshoot error is pipe 4, that is 21%.

The system on pipe 1, reach the steady state at 80s and has an 13 % overshoot error . On the pipe 2, system reach the steady state at 87 s and the overshoot error is 8%. On the pipe 3, system reach the steady state at 60 s and don’t have an overshoot error. Lastly, on the pipe 4, system reach the steady state at 70 s, and has an 23% overshoot error.

E. IoT Monitoring

This experiment is done in the purpose of finding out the system ability in sending data from microcontroller to Antares IoT Platform. The received and stored data in cloud server will next be displayed through Antares user interfaces.

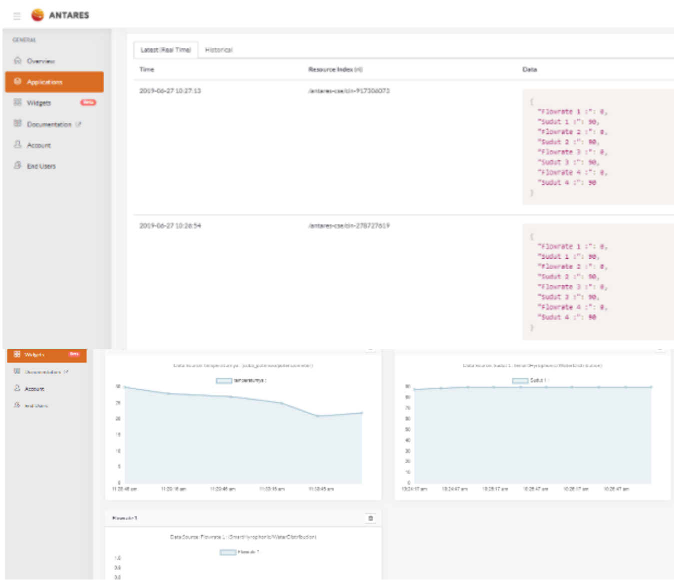

Figure 12. Antares User Interface

F. Observation of Plant Growth

This experiment is done in the purpose of finding out the growth process of the plant before and after smart hydroponic system is applied. Growth factors of bok choy can be seen from plant height, leaf width, and number of leaves.

Table 1. Plant Growth at 30th Days

	Without *Smart Hydroponic*				With Smart Hydroponic			
	Tube 1	Tube 2	Tube 3	Tube 4	Tube 1	Tube 2	Tube 3	Tube 4
Plant Height (cm)	10,5	10	9,9	8,1	11,1	10,9	11,2	11,1
Leaf Width (cm)	4,2	3,9	4,1	2,7	4,5	4,6	4,4	4,5
Numbe r of Leaves	8	8	8	8	9	9	9	9

Table 1 shows the differences of plant growth before and after smart hydroponic system is applied. The maximum difference of plant height before system is about 2,4 cm but after the system, the maximum difference is only about 0.3 cm. The maximum difference of leaf width before system is about 1.5 cm but after the system, the difference is only about 0.2 cm. But the number of leaves does not have significant different between plant before and after the system.

V. CONCLUSION

Based on the experiment result and analysis of valve control system and water distribution monitoring via IoT, it can be concluded that system can change the manual way of moving the valve, with 7.09% tolerance. In controlling water flow distribution, system can change and maintain it to the desired range. Then, to do the monitoring of water flow, system can display the data reading of the sensor through Antares User Interface. Meanwhile, system can affect the plant height and leaf width to grow equally in all parts of pipe, compared to manual without system.

VI. FUTURE WORK

Although system can control the water flow to reach the desired range and distribute it equally, next research can design a system that can distribute water faster and with more accurate result using different method. So that, all actuators can be connected one another to sensors, to get better performance on distributing water equally. In controlling and monitoring the water flow, system should use a more interesting and easier user interface.

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