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RESEARCH ARTICLE

AUTOMATION AND MOBILE PHONE BASED-MONITORING OF HYDROPONIC FARMING STYLE USING SOLAR ENERGY

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ABSTRACT

Indonesia's plantation land has reduced significantly over the years, and hydroponics could be a suitable candidate for future plantation in urban areas because it is efficient in land use. The hydroponic system is relatively easy in terms of the maintenance required, making it possible to automate using a simple microcontroller. In this research, an automation system is designed to monitor and control hydroponic plants. Solar power plants and batteries power the energy required by the system. The measured parameters include solution conductivity, solution temperature, and room temperature. The three parameters are sent every twenty seconds to the smartphone and displayed on the Blynk application. And when there is a deviation from the optimum value, there is a control to adjust it. Blynk application can be easily used by farmer without needing extensive learn. Made this automated system is possible to be use and implemented by every person. The structure built can work properly, and the sensor can detect temperature and conductivity parameters precisely so that the control equipment can provide the appropriate compensation.

KEYWORDS

Hydroponic, IoT, Microcontroller, Automation

1. INTRODUCTION

In the Agricultural production system, land availability for fields and plantation become significant factors in production quantity. The world's increasing population grows the demand for agriculture production. Thus, the area and productivity of agricultural production must increase as well. However, in Indonesia, farmland and fields tend to decrease due to conversion to non-agricultural land (Adimihardja, 2006). This aggressive land conversion occurs in Java is shown in Figure 1, with an average conversion from field and paddy fields to non-agricultural land, respectively, 5% and 9%.

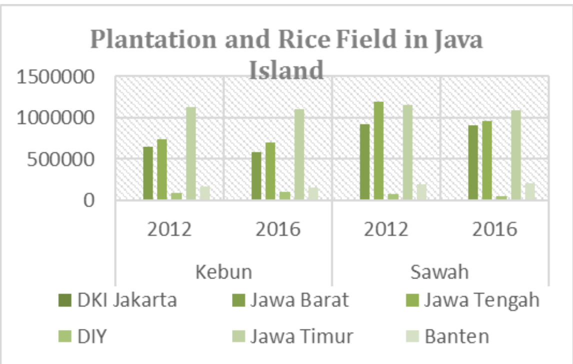

Figure 1: Rice Field and Plantation land in Java Island (Pusat Data dan Sistem Informasi Pertanian Sekertariat Jendral - Kementrian Pertanian, 2017)

The hydroponic system can be a solution for modern agriculture production. The hydroponic system offers an efficient solution in terms of water and land usage than conventional agricultural methods (Kementrian Pertanian BPTP Riau, 2018). The hydroponic system also allows urban farmers to farm on residential land without needing land that is dedicated to the farm field so that the application of hydroponics to housing in urban areas could be considered possible.

Apart from land saving, the hydroponic system also has advantages in agricultural production effectiveness and less influenced by environmental conditions (Yamaguchi, et al., 2018). In this study, hydroponic crop is nurtured through automation system. ESP32 is chosen as microcontroller due to easiness to connect with smartphone. This system will be supported by environmentally friendly energy from solar power plants and utilizing batteries as a medium for energy storage.

2. LITERATURE REVIEW

Substantially, plants can live in the soil if nutrients are available. In Hydroponic, these nutrients are provided in water with special treatment. And turns out hydroponic plants can live and give the same results, just like the conventional method (Pascual, et al., 2018). Some types of hydroponics that are commonly used are the Wick System, Nutrient Film Technique, Deep Water Culture, Drip System, and Flow System. In the Nutrient Film Technique (NFT) method, the nutrient solution is continuously streamed to the plant's roots using a PVC pipe with the recirculation technique (Kementrian Pertanian BPTP Riau, 2018).

Parameters that influence nutrient uptake and nutrient availability in the solution include solution acidity, electrical conductivity, nutrient composition, and temperature. The primary nutrients that are considered

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essential for plant growth include nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur. The composition of these nutrients will determine the value of the electrical conductivity and osmotic potential in the solution (Trejo-Tellez & Gomez-Merino, 2012).

Ion concentration is another parameter that also determines growth and productivity in plants. ions from dissolved salts will produce an osmotic pressure where this value can represent the dissolved nutrient levels. Therefore, the measurement of the solution's electrical conductivity is used as a benchmark for measuring dissolved nutrients. In soil culture, soil acts as a buffer to maintain specific pH and EC value for plant growth. In hydroponic system, the buffer is absent thus it is important to maintain an environment suitable for plant growth. A high EC value can prevent nutrient absorption, while a low EC value can affect plant health and yield.

Another parameter that will determine nutrient availability is the solution's acidity level (pH). The solution must not have a pH above 7 because it will cause Fe^{2+}, Mn^{2+}, PO_3^{-4}, Ca^{2+}, and Mg^{2+} to be insoluble and reduce salt levels (Resh, 2004). The optimum pH level for plant growth is between 5.5 - 6.5 (Trejo-Tellez & Gomez-Merino, 2012) It was found that in the absence of intervention, the pH value will decrease from day one to day five so that a solution is needed to raise the pH. The amount of pH lowering solution is given per day is constant at 2.6 ml and is able to maintain the optimum pH value in a 10-liter water container (Saaid, et al., 2015).

pH and electrical conductivity have a relationship that changes in one side will effect the other parameter. pH measurement is based on hydrogen ion concentration. More hydrogen ion will generate more alkaline substance, on the other hand increasing negatively charged ion will make it more acidic. Since ions carry positive or negative charges, electrical conductivity will occur. The higher ion concentration will generate higher level of conductivity. Material that is strongly acidic and strongly alkaline are good conductor, yet material closer to pH neutral will be less conductive (Meywes, 2019).

The temperature will affect the level of oxygen absorbed by plants. Besides, temperature will also influence fertilizer solubility and root absorption capacity. In lettuce, cooler air temperatures during the harvest period will increase the quality of lettuce. In contrast, low temperature will reduce the nutrient levels in plants but positively contribute to increasing growth speed (Gent, 2016). However, the ideal temperature of the hydroponic system is 18^0C - 26^0C.

The effects of light quality on hydroponic plants, particularly lettuce, were studied in 2015 (Chen, et al., 2015). Observation of the effect of white LED (Control condition), red white LED (T1) (R: W = 1: 4), red-white LED (T2) (R: W = 1: 1) was observed. Growth of roots and shoots increases under lighting conditions using red LED light. Shoot mass increased 40.3% to 66.7% and root mass increased 62.5% to 91.7%. At T1 and T2 conditions, it was found that the sugar and vitamin C content increased but nitrate decreased when the red light intensity increased. Based on this research, it can be concluded that lettuce grows best when it combines red and white lighting.

3. Proposed System

In this research, the hydroponics system will be equipped with an automation system to measure basic parameters and control functions when there is a deviant parameter. The automation system will monitor the plant's nutritional condition through the electrical conductivity sensor in the solution. The experimental setup is depicted in Figure 2.

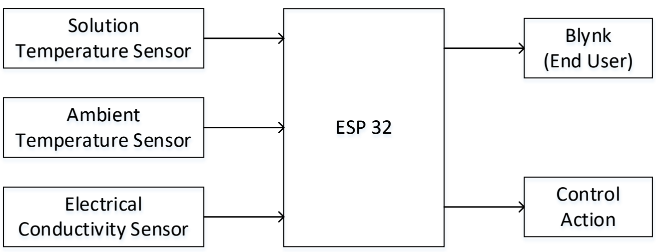

Figure 2: Hydoponic Automation Flowchart

When a low EC value is detected, the sensor system will automatically add AB mix solution, on the other hand, if the EC value is detected high, the system will automatically add water to the solution bath. Since pH and EC has a strong relationship, the measurement of pH could be represented through Electrical Conductivity value.

It is also equipped with monitoring of the temperature's solution. The tendency that might occur is that the solution's condition will be hotter than the optimum temperature. In order to overcome this situation when the temperature is high, the fan will be automatically turned on to cool the solution in the tub. Temperature monitoring is also carried out - in the environment (ambient temperature) when the temperature value is high, the sprinkle pump will shower the leaves and stems of the plant to reduce heat.

Temperature and conductivity data will be sent to the farmer's cell phone for monitoring purpose. Farmers can monitor the condition of their garden directly. The automation system and pumps will be powered by a solar power plant installed in the hydroponic installation. This system is expected to be a solution for urban residents to garden with minimal maintenance, environmentally friendly, and affordable electricity costs.

3.1 Input Subsystem

The Input system is collecting all the parameters that measured by the sensor. Sensor will send measured data to Microntroller for further processing every 1 second. The sensors used in this automation system are DHT22 for measuring ambient temperature, MAX6675 Thermocouple for measuring solution temperature, and EC module for measuring electrical conductivity in solution. Microcontrollers compare the input value with the nominal value to decide if any action is necessary to be done. Each action duration is set 20 seconds last.

3.2 Solution Subsystem

The electrical conductivity value of the solution needs to be measured periodically because it will determine the levels of dissolved nutrients. The higher the conductivity value, the higher the dissolved nutrient content. On the other hand, the lower the conductivity value indicates a low dissolved nutrient level. The ideal EC value depends on the crops type which is summed up in Table 1.

When the electrical conductivity sensor in solution tank detects low value, tap from AB mix tank will be opened for 2 seconds. The next measurement is taken after 20 second to ensure if electrical conductivity has reached the nominal value. Meanwhile, when the electrical conductivity value is higher than nominal value, tap from water will be opened for 2 seconds. Water will dilute dissolved nutrient which reduce the measured electrical conductivity.

Table 1: Optimum Range of Electrical Conductivity for Hydroponic Corps

Crops	**Electrical Conductivity (mS/cm)**
Asparagus	1.4 to 1.8
Basil	1 to 1.6
Bean	2 to 4
Banana	1.8 to 2.2
Broccoli	2.8 to 3.5
Celery	1.8 to 2.4
Carnation	2 to 3.5
Zucchini	1.8 to 2.4
Cucumber	1.7 to 2
Eggplant	2.5 to 3.5
Marrow	1.4 to 1.8
Okra	2 to 2.4
Pak Choi	1.5 to 2
Peppers	0.8 to 1.8
Parsley	1.8 to 2.2
Rose	1.5 to 2.5
Spinach	1.8 to 2.3
Strawberry	1.8 to 2.2
Tomato	2 to 4

3.3 Temperature Subsystem

In tropical climates, the temperature tends to rise above the ideal value for hydroponic system thus it is necessary to monitor the temperature in solution and environment. The control system is built to keep the solution and environment temperature between 18^0C and 30^0C. When the solution's temperature sensor, MAX 6675 detect temperature more than 30^0C, fan will automatically be turned on to cool the solution through the heat sink for two seconds. Meanwhile, when the environment's temperature is more than 30^0C, water will be sprayed on the stems and leaf to reduce the ambient temperature until it reaches below 30^0C.

3.4 Monitoring Subsystem

Temperature and electrical conductivity measured value will be sent to Blynk application every 1 second. The farmers could monitor the hydroponic system remotely through a smartphone. The Blynk program shows the environmental temperature, solution temperature, and solution conductivity in chart. Farmers can also see if the control equipment is operating or not.

3.5 Power Subsystem

This hydroponic resource will be powered by solar power generation system to promote environmentally friendly energy. A 100-Watt Peak Solar Panel are used in combination with the battery 15000 mAh, 12 Volt to provide stable output power.

3.6 Algorithm

The summary of system algorithm is depicted in Figure 3.

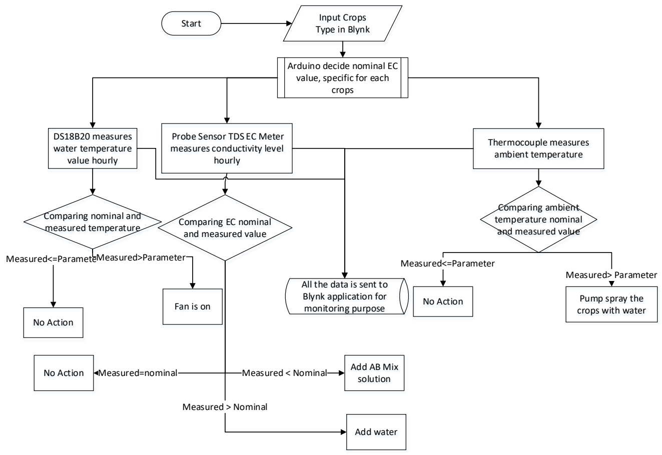

Figure 3: Automation Hydroponic Algorithm

3.7 Coding

The script for this experimental work is depicted in Figure 4. Arduino IDE is utilized for configuring ESP32. The program allows the ESP32 to receive data from sensors and process it for display on the Blynk application. Besides, logic is arranged so that there will be a control action to return the parameter to its nominal value when there is a deviation from the temperature and electrical conductivity parameters.

The first section of the code is defining electrical conductivity nominal value for each crops in micro Siemens. If user has not specified any crops, blynk will show "Not Selected" and the conductivity range will set between 800-4000 microSiemens. The next section is defining the output and input pinMode. The automation system will have four output for sprinkle pump, one solenoid valve between AB mix and solution tank, one solenoid valve between water pipe and solenoid tank, and fan. Thus, it need 4 relay to control those equipments.

In the third section, input from sensor is defined for monitoring puropose and further processing. The measured value will show in blynk application and in log. The next step is set the value whether the control equipment is working or not. And the last section is comparing the measured and nominal value. If there is any deviation, control equipment will take an action to bring the measured value back into the nominal.

```
BLYNK_WRITE (V5) {
 switch (param.asInt()) {
   case 1 : /* Asparagus   */ecmin = 1400; ecmax = 1800; break;
   case 2 : /* Basil       */ecmin = 1000; ecmax = 1600; break;
   case 3 : /* Bean        */ecmin = 2000; ecmax = 4000; break;
   case 4 : /* Banana      */ecmin = 1800; ecmax = 2200; break;
   case 5 : /* Broccoli    */ecmin = 2800; ecmax = 3500; break;
   case 6 : /* Celery      */ecmin = 1800; ecmax = 2400; break;
   case 7 : /* Carnation   */ecmin = 2000; ecmax = 3500; break;
   case 8 : /* Zucchini    */ecmin = 1800; ecmax = 2400; break;
   case 9 : /* Cucumber    */ecmin = 1700; ecmax = 2000; break;
   case 10 : /* Eggplant   */ecmin = 2500; ecmax = 3500; break;
   case 11 : /* Marrow     */ecmin = 1400; ecmax = 1800; break;
   case 12 : /* Okra       */ecmin = 2000; ecmax = 2400; break;
   case 13 : /* Pak Choi   */ecmin = 1500; ecmax = 2000; break;
   case 14 : /* Peppers    */ecmin = 800; ecmax = 1800; break;
   case 15 : /* Parsley    */ecmin = 1800; ecmax = 2200; break;
   case 16 : /* Rose       */ecmin = 1500; ecmax = 2500; break;
   case 17 : /* Spinach    */ecmin = 1800; ecmax = 2300; break;
   default: /* Belum dipilih*/     ecmin = 800; ecmax = 4000; break;
    Serial.println("Unknown item selected");
  }
}
void setup() {
 Serial.begin(115200);
 dht.begin();
 ec.begin();
 ads.setGain(GAIN_ONE);
 ads.begin();
 Blynk.begin(auth, ssid, pass);
 pinMode(relay1, OUTPUT);
 pinMode(relay2, OUTPUT);
 pinMode(relay3, OUTPUT);
 pinMode(relay4, OUTPUT);
 pinMode(relay5, OUTPUT);
 pinMode(wspin,  INPUT);
 pinMode(lightpin,  INPUT);
 float t = dht.readTemperature();
 float T = thermocouple.readCelsius();
 voltage = ads.readADC_SingleEnded(0) / 10;
 ecValue = ec.readEC(voltage, temperature);
 ec.calibration(voltage, temperature);
 ws = analogRead(wspin);
 light = analogRead(lightpin);
 Serial.print("\nEC:");
 Serial.println(voltage, 4);
 Serial.print("Suhu Air = ");
 Serial.println(T);
 Serial.print("Kelembapan = ");
 Serial.println(h);
 Serial.print("Suhu Udara = ");
 Serial.println(t);
 Serial.print("EC Min = ");
 Serial.println(ecmin);
 Serial.print("EC Max = ");
 Serial.println(ecmax);
 Serial.print("Sensor Air = ");
 Serial.println(ws);
 Serial.print("Sensor Cahaya = ");
 Serial.println(light);

 Blynk.virtualWrite(V1, voltage);
 Blynk.virtualWrite(V2, T);
 Blynk.virtualWrite(V3, t);
 Blynk.virtualWrite(V4, h);
 Blynk.virtualWrite(V6, ecmin);
 Blynk.virtualWrite(V7, ecmax);
 Blynk.virtualWrite(V8, ws);
 Blynk.virtualWrite(V9, light);
  //sensor suhu air
   if (T > 34)
   {
     digitalWrite(relay1,LOW);
   }
   else
   {
    digitalWrite(relay1,HIGH);
   }

   //sensor suhu udara
   if (t > 39)
   {
     digitalWrite(relay4,LOW); // Sprinkler Nyala
   }
   else
   {
     digitalWrite(relay4,HIGH);
   }
```

```
    //sensor cahaya
    if (light > 5000)
    {
      digitalWrite(relay5,LOW); // Lampu Nyala
    }
    else
    {
      digitalWrite(relay5,HIGH);
    }
}

void relay(){
  digitalWrite(relay2,HIGH);
  digitalWrite(relay3,HIGH);
  //sensor EC
  static unsigned long lastime=0;
  const long interval=5000;
  unsigned long now=millis();
  if (now-lastime>interval){
    voltage = ads.readADC_SingleEnded(0) / 10;
    ws = analogRead(wspin);
    if (ws < 2800) // Run apabila air belum penuh
    {
      if (voltage < ecmin)
      {
        digitalWrite(relay2,LOW);
      }
      else if (voltage > ecmax)
      {
        digitalWrite(relay3,LOW);
      }
    }
    delay(3000);
    lastime=now;
  }

}
```

Figure 4: Monitoring and Automation Coding for ESP32

4. System Implementation

The proposed system contains several subsystems as discussed above. Sensors acquire data from the environment and send it to microcontroller as shown in Figure 5 Analog to Digital converter is utilized between sensor and ESP32 to present a stable measurement. This figure contains ESP 32 that connect into 5V relay box and terminal for accepting power from Solar Panel. ESP32 is connected to 5V relay box to control the sprinkle pump, water tap, and solution tap.

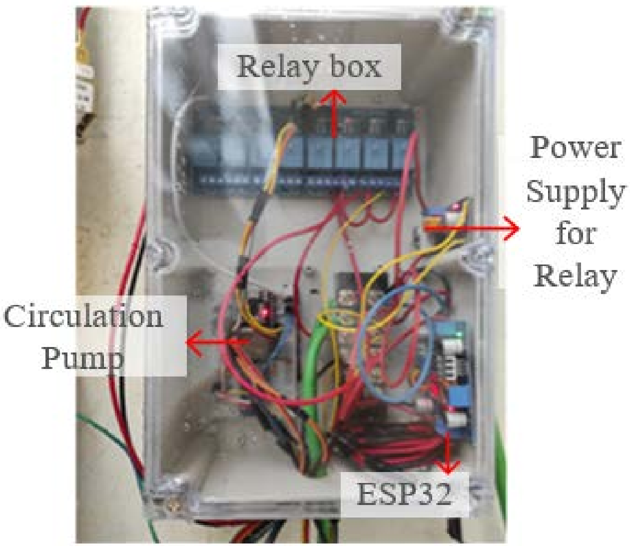

Figure 5: Microcontroller Setup

Figure 6 depicted arrangement for temperature sensor and fan. Electrical conductivity is placed in the box to measure the solution conductivity value. All these sensors are connected into the ESP32 module and all of the control equipment is controlled by relay module. Figure 7 shows the hydroponic array with Bok Coy as the crops.

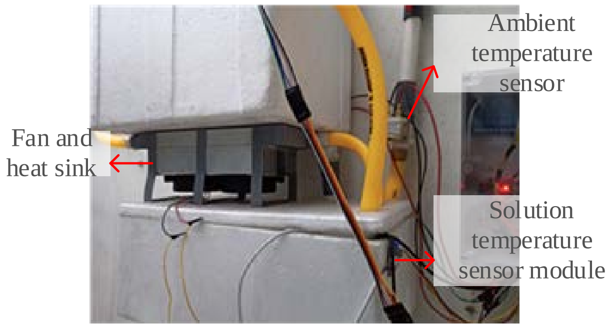

Figure 6: Fan for Cooling Hydroponic Solution

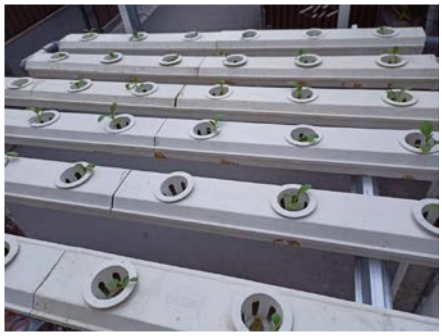

Figure 7: Bok Choy Hydroponic Array

The display of Blynk application is depicted in Figure 8, it show the fluctuation of solution temperature, ambient temperature, and electrical conductivity over the time. Blynk application also present the status of fan, tap, and sprinkle pump through 1/0 value. When those equipment are working, the value will be 1 otherwise it will be 0.

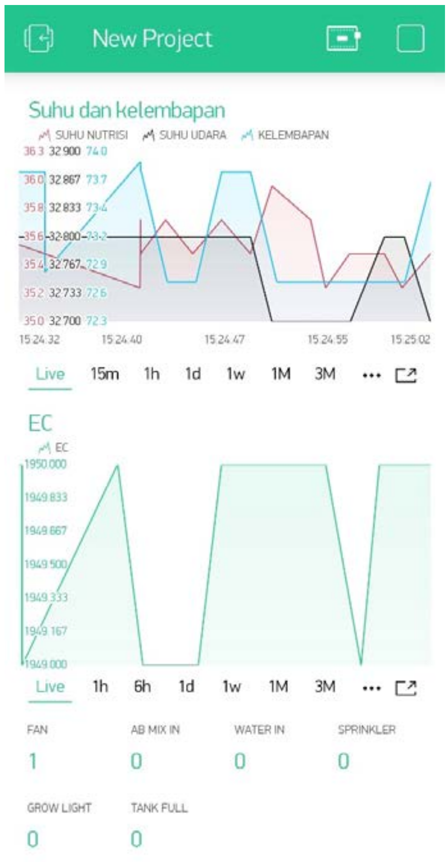

Figure 8: Blynk Interface

4.1 System response to temperature change

Figure 9 is presenting the relay works when sensor detected high ambient temperature. Relay turns the sprinkle pump on to reduce the temperature around crops. At that time, the relay for sprinkle is on, which can be seen from fan value. The measurement look fluctuative due to dense scaling.

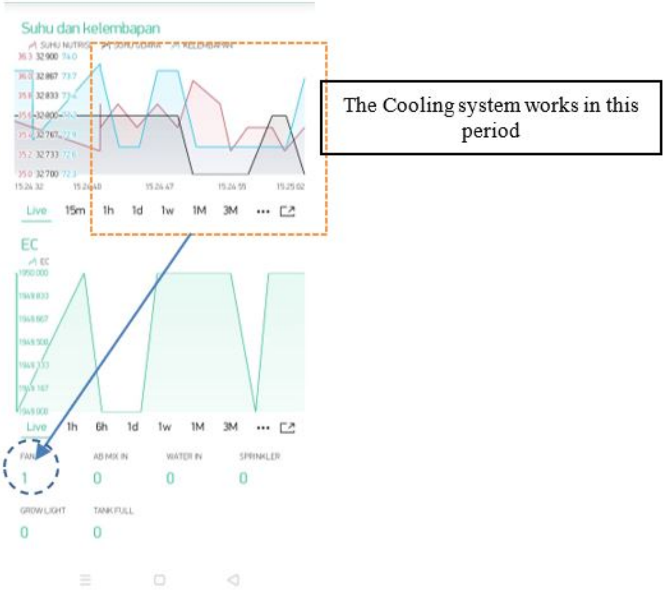

Figure 9: System Response During High Ambeint Temperature

4.2 system response to ec change

Figure 10 shows the relay works when high electrical conductivity is detected thus tap between water tank and solution tank is open for 2 seconds. The first conductivity value is about 1.6 mS, and after the water tap is open in 2 second, the conductivity drop into 0.8 mS.

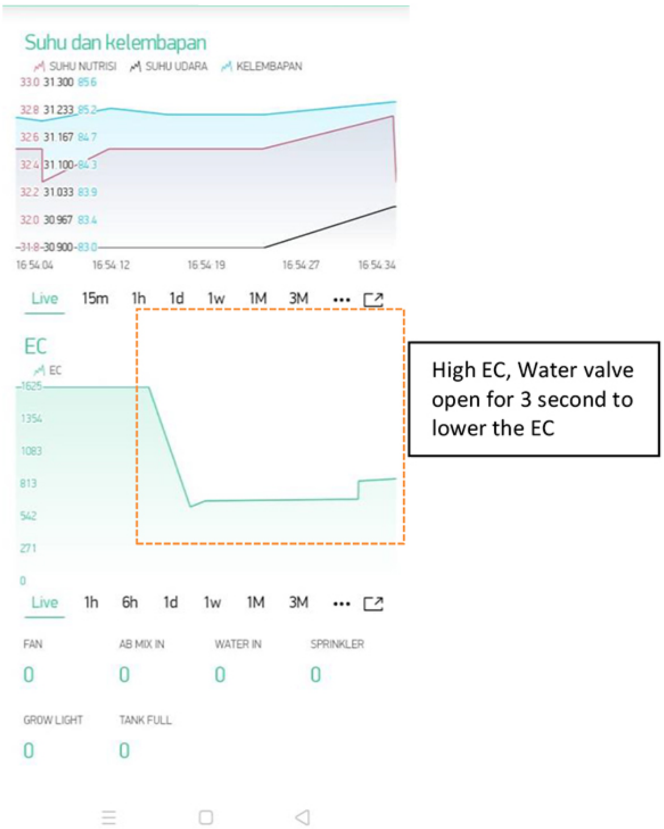

Figure 10: System Response During High Electrical Conductivity

3. Conclusion and Further Research

A hydroponic farming urges monitoring on several parameters and combination of various sensors and IoT enable farmer to observe it remotely. Proposed system could monitor three critical parameters of hydroponic system, electrical conductivity, ambient temperature, and solution temperature and send it to farmer's smartphone. Blynk application facilitate famer to monitor those parameters in simple way. The measurement shows a good data stability which indicate that sensor and microcontroller works properly. The system also displays a good control action for all the three parameters. Thus, this research shows that automation could be employed for hydroponic cultivation.

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