Design and Implementation of Sensor Node in Evapotranspiration-Based Irrigation Scheduling System

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***Abstract* – To determine the irrigation scheduling of the system, data on the amount of water is needed to find out how long and how often the irrigation watering plants / land is needed, to find out this requires a reference evapotranspiration value which will be multiplied by the land area to determine the amount of water to be watered, The evapotranspiration value itself is obtained from weather data taken on the ground, to retrieve the weather data, a sensor node is needed that can collect weather data which will later be converted into reference evapotranspiration data and converted again into data on the amount of water needed by the land.**

***Keywords* — Evapotranspiration, Irrigation, Node Conversion, Land, Sensor.**

I. Introduction

In irrigation scheduling, the important thing to determine is to determine the watering time and the amount of water given to the plants. In order for plant growth to be maintained optimally, the moisture content in the soil needs to be maintained at an adequate amount. For that, it is necessary to schedule the right irrigation or irrigation.

To determine the right irrigation schedule, one method that is often used is the irrigation scheduling based on the plant evapotranspiration rate (ET). What is meant by evapotranspiration rate is the amount of water that moves from the ground to the air in a certain time as a result of the evaporation process in the soil and transpiration in plants. This evapotranspiration is a quantity that describes the water consumption of plants. The scheduling of evapotranspiration-based irrigation will keep the water content in the soil constant, by providing water in an amount that is in accordance with the evapotranspiration of the plants since the last irrigation. So that water lost since the last irrigation can be returned to the next irrigation in the right amount.

Based on this, an irrigation scheduling system that consists of sensor nodes is designed to measure weather conditions consisting of air temperature and humidity, solar radiation, and wind speed. This parameter will be used to calculate the estimated reference evapotranspiration rate (ETo). The calculated ETo estimated value will be used for calculating the amount of water lost to plants since the last irrigation, then sent to the actuator node which will regulate the operation of the irrigation system so that the water supplied to plants is in accordance with these calculations, this data line always passes through the Gateway.

II. Literature Review

A. LoRa

LoRa (Long Range) is a long-distance communication protocol developed by SemTech. LoRa technology works using chirp spread spectrum (CSS) technology which utilizes the spread spectrum modulation technique, where messages are spread over a wide frequency band such as radio bands. By utilizing this technique, the message sent becomes more resistant to interference such as noise, so that the message can be transmitted over long distances. Because it was developed for long-distance transmission with low power consumption, LoRa is one of the networks chosen for the development of the Internet of Things (IoT).

B. TTGO LoRa32

TTGO LoRa32 is a variation of the ESP32 microcontroller. In general, the two microcontrollers have the same work function both as a controller and for communication. However, what distinguishes LoRa32 from ESP32 is the existence of the LoRa communication protocol. Communication on the ESP32 is only limited to WiFi and Bluetooth networks, but on LoRa32, there is LoRa as an additional communication protocol. This causes LoRa32 to be used for long distance communication.

C. ADS1115

ADS1115 is a precision analog to digital converter with 16-bit resolution, data is transmitted via a compatible I2C interface, there are 4 addresses that can be accessed on this module. And the ADS1115 operates at a supply voltage of 2.0V to 5.5V, this module can convert data at a speed of 860 samples per second and a accuracy of 256mV, and can operate at temperatures of -40 ° C to + 125 ° C.

D. SHT-31

SHT-31 is a sensor module that functions to measure the temperature and permeability of ambient air, where this sensor can work at 2.4V to 5.5V supply voltage, the temperature sensor can operate at temperatures of -40 ° to 90 ° C and for flexibility it can work at 0 – 100% RH. The data received is sent via the I2C interface.

E. JL-FS2

JL-FS2 is a wind speed sensor that measures wind speed with a range of 0 to 30 m / s, this sensor can operate both at temperatures of -20 ° to 60 ° C and at humidity 10% - 95% RH. This sensor has a resolution of 0.1 m / s with a three-wire output.

F. GY-49

GY-49 is an electronic module that contains a sunlight sensor where this sensor can detect how much sunlight is received in LUX units, the sensor in question is MAX44009 where this sensor can read sunlight with a very wide range of 22-bit which if translated the range is 0.045 lux to 188000 lux, the received data is sent via the I2C interface.

III. Specification and Design

A. Sensor Node Specification

In the sensor node design process, there are several specifications that need to be met, among others:

1. Able to measure ambient weather data.
2. Able to send data to the gateway.
3. Able to work for a long time.

B. Sensor Node Design

At the sensor node design stage, the following components are used:

1. LoRa32 Microcontroller
2. Modul RTC
3. Modul ADS1115
4. Level Shifter
5. SHT-31
6. JL-FS12
7. GY-49
8. Modul Step-up 5V
9. Modul Step-up 9V
10. Rechargable Battery
11. Solar Panel

By using these components, sensor nodes are arranged with a system design as shown in Figure-1.

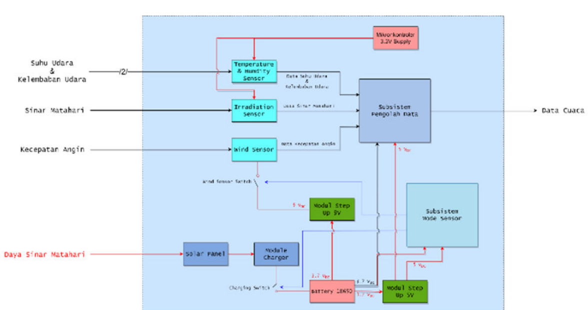

Figure 1 Sensor Node System Design

In the sensor node system, there is a subsystem of mode settings and data processing. The subsystem is composed of a microcontroller and an RTC module. The sensor mode subsystem consists of a microcontroller and an RTC module. The RTC module is used to adjust the timing of the switching state of the mode setting subsystem from sleep mode to active mode and the time source can be read by the microcontroller. The wake time is set in the microcontroller program. Wake time is made every 1 minute, while delivery time is 1 hour. The microcontroller is programmed to provide control signals that regulate the opening and closing of the charging switch and step up switch, as well as for communication with the data processing subsystem. In active mode, the charging switch is turned off, and the step up switch is turned on so that the data processing subsystem turns on and starts working. This state is maintained until the mode returns to sleep, which is also true for send mode

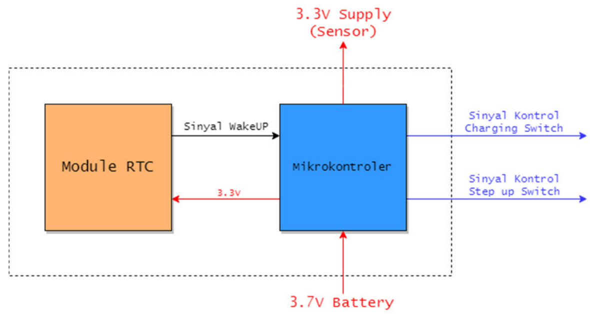

Figure 2 Mode Setting Subsystem

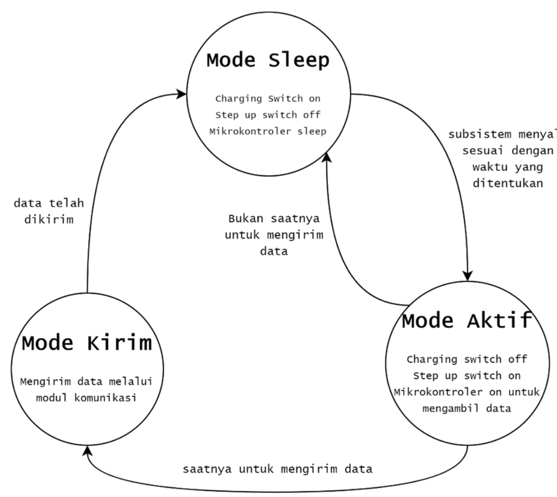

Figure 3 State Diagram of Mode Setting

The data processing subsystem will perform the functionality of forwarding the weather data taken by the sensor, the data will be read through I2C communication, where each sensor will have its own address which has a 3.3V data output while analog data requires a container to be read together via I2C communication. It takes an ADC module in the data processing subsystem, but the ADC module has a 5V data output, so a level shifter is needed to decrease the data output to 3.3V. The weather data that has been read will be processed according to the needs of the evapotranspiration data where the mean data of wind speed, air temperature and humidity will be taken. Meanwhile, the light data will take the amount of solar radiation.

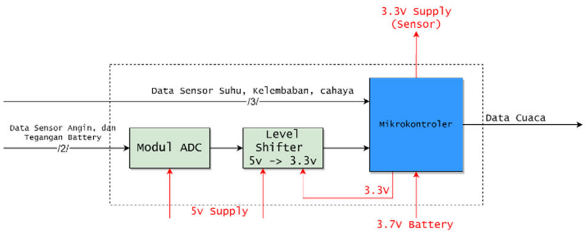

Figure 4 Data Processing Subsystem

The step up switch and charging switch in Figure-1 are realized by a switching circuit using a BJT and MOSFET. Figure-6 is a switching circuit for a step up switch. 1 stage BJT NPN is used for switching on the microcontroller side and 1 PMOS for 9V step up switching on the downside. This configuration is used so that the 9V switch step up can be active high. This active high characteristic is needed because the step up switch must be held in OFF in sleep mode, while in sleep mode the output voltage of the HIGH microcontroller signal can be quite low compared to the conditions in active mode. If the switching circuit is active low, to keep the step up switch OFF, in sleep mode, the microcontroller must give a HIGH signal. However, a lower voltage in sleep mode can cause the NPN BJT in the first stage to not fully ON, so the PMOS on the step up side of the module is not OFF. The value of the 10 kΩ resistor used is determined so that the NPN BJT can still be in a saturation state when ON, and the 100 kΩ resistor is chosen because switching is not done with high frequencies.

The charging switch in Figure-7 is similar to a step up switch, but the NPN BJT is replaced with an optocoupler, and the MOSFET is replaced with NMOS so that when the microcontroller is off the charging switch is on (Active High). Optocoupler is used because the microcontroller ground is the negative terminal of the battery, while the charging circuit is switched between the negative side of the battery and the charger module. This causes a difference in the value of the ground voltage from the microcontroller (GND) to the negative side of the charger module (SOLAR)..

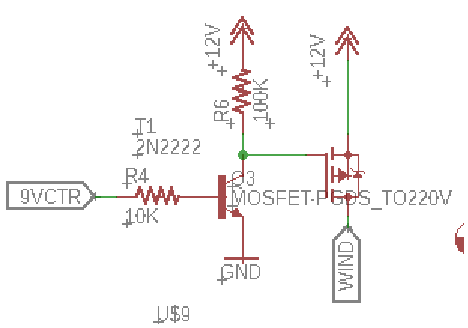

Figure 5 Step Up Switching

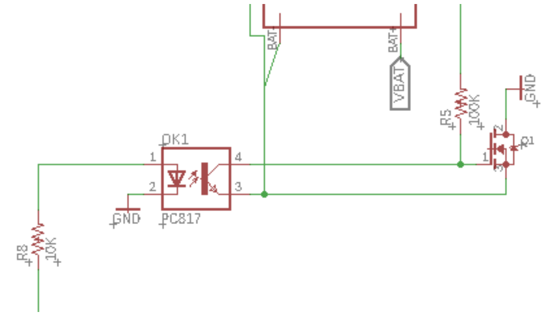

Figure 6 Charging Switching

Since the sensor nodes will be installed in open land, it is necessary to have a container that can store the system and protect it from external disturbances such as rainwater. For this reason, 4 enclosures were designed with the following design.

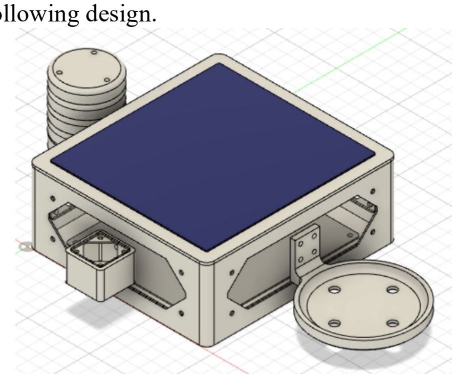

Figure 7 Casing Design (Full)

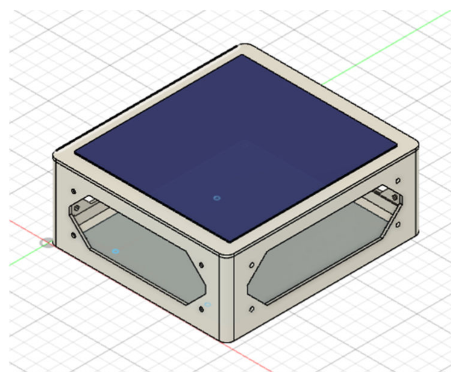

Figure 8 Main Case Design

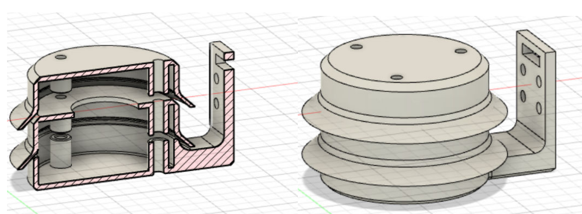

Figure 9 Temperature and Humidity Holder Design

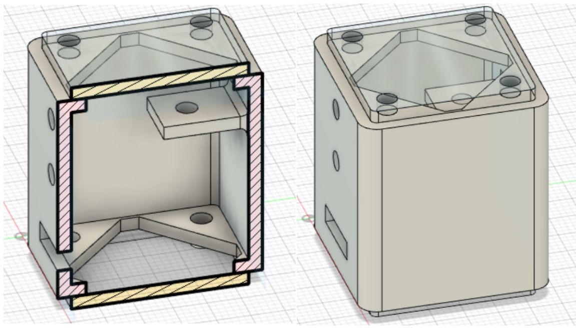

Figure 10 Light Sensor Holder Design

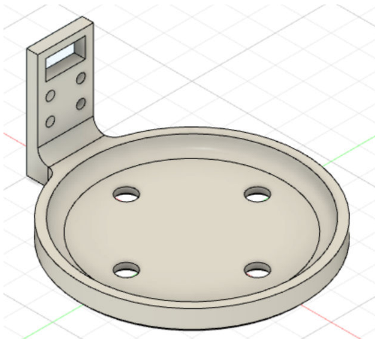

Figure 11 Wind Sensor Holder 4esign

IV. Implementation and Testing

From the system design arranged in Figure 12 and Figure 13, the sensor node system is realized with a schematic arrangement and PCB design as follows.

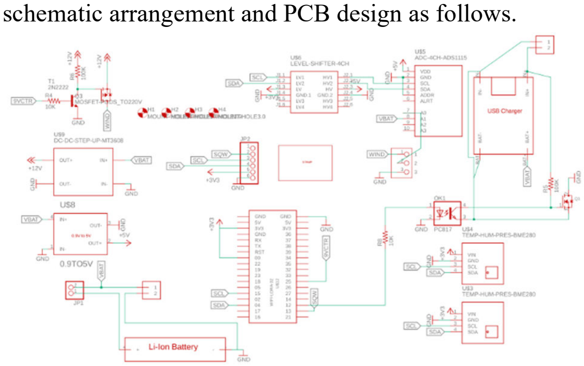

Figure 12 Sensor node circuit schematic

After installing the components on the PCB and storing them in the casing, the final result of the system is as shown in Figure 15 and Figure 16.

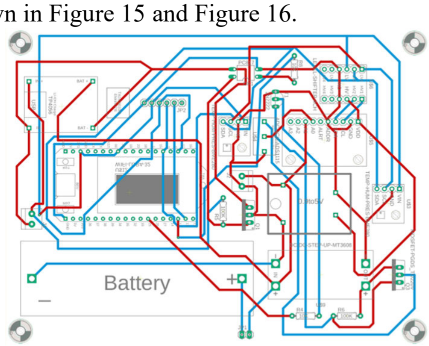

Figure 13 Board Design Node Sensor

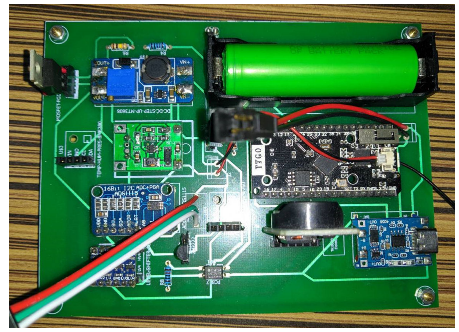

Figure 14 Printed PCB + Several Components Installed

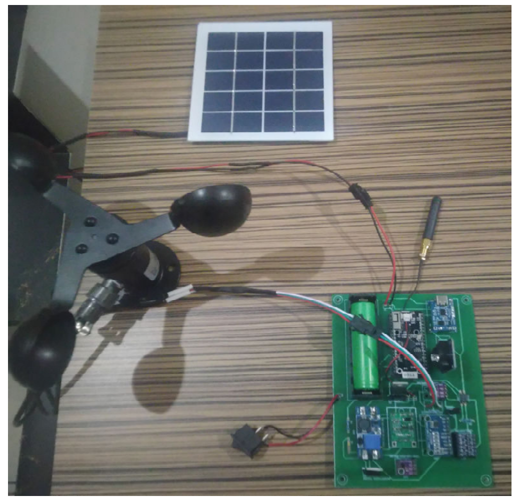

Figure 15 PCB + All Components Installed

Figure 16 Complete Installed Sensor Nodes

To ensure that the system can work according to specifications, several tests are carried out on the sensor nodes, namely testing all sensors to see the weather data taken and then testing the power on the sensor nodes by looking at the functionality of the switching circuit compared to the current data drawn from the rechargeable battery.

A. Power Consumption Test

To save power consumption, sensor nodes perform measurements and transmissions at certain times. Apart from that, the sensor nodes are in sleep mode with low power consumption. In order to minimize power consumption in sleep mode, components that consume high enough power even when idle need to be turned off, and turned on only when the measurement is being carried out. At the sensor node, the component that consumes a high enough power is the wind speed sensor. For this reason, a switching circuit is used using the NPN BJT and PMOS MOSFET. In this section, the measurement of current consumption in each working mode of the sensor node is carried out, and the results are compared with the conditions if the switching is not performed.

From the implementation results, the switching circuit to save power consumption can work. To measure current consumption, a multimeter is used to measure the current drawn from the battery, the following results are obtained:

Mode	Voltage	Current
Sleep	4.03V	10mA
Aktif	4.03V	170mA

From the results of these measurements we can conclude that the switching circuit in sleep mode can save power up to 94.1%.

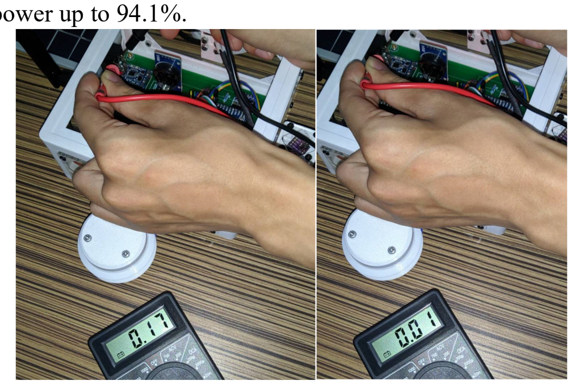

Figure 17 Testing Switching Circuits

In addition to testing the utility of the switching circuit, it must be ensured that the utility of the switching meets the specification requirements that the circuit can last a long time if left on the farm, therefore a sample is made for 24 hours, the sensor node is left on the page to see the battery condition of the node. Sensor, the result can be seen as Figure 18.

We can see in Figure 18 that after 24 hours the battery which was previously only 3.78 V with self-recharge from the solar panel, at the same time the next day the battery from the sensor node increased to 4.06 V even though it has been running for 24 hours, then the sensor node will be able to survive. In quite a long time.

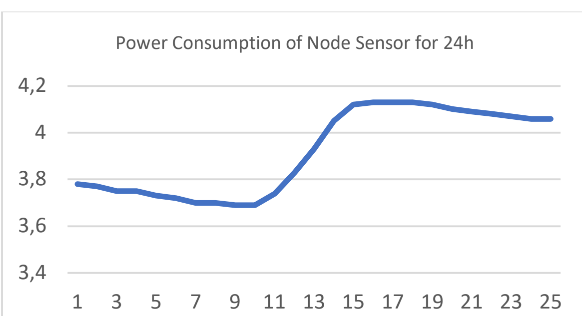

Figure 18 Power Consumption Testing

B. Humidity Sensor Test

To test the air humidity sensor readings, the sensor node will be placed outside and made to work to take 30 samples where each sample will be taken every minute then the reading will be compared with the commercial air humidity meter product, namely UT333 mini temperature humidity meter, the reading results are obtained as Figure-19.

As can be seen that the sunlight intensity sensor already has the same graphic form as the UT333 commercial sensor, and the error from the humidity sensor does not exceed the 5% RH specification limit, which is 3.997% RH, which indicates that the humidity sensor is good.

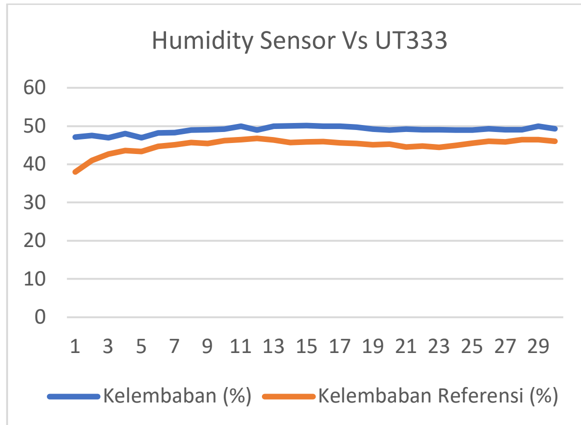

Figure 19 Humidity Sensor Graph

C. Temperature Sensor Test

To test the temperature sensor readings, the sensor node will be placed outside and made to work to take 30 samples where the reading will be taken every minute then the reading will be compared with a commercial temperature measuring product, namely UT333 mini temperature humidity meter, readings are obtained as shown in Figure 20

Even though it is good and has a similar output form, the temperature sensor still has an error of 0.647 ° C with a reference temperature from the UT333 sensor> ± 0.5 ° C, so the temperature sensor is considered not good in this case.

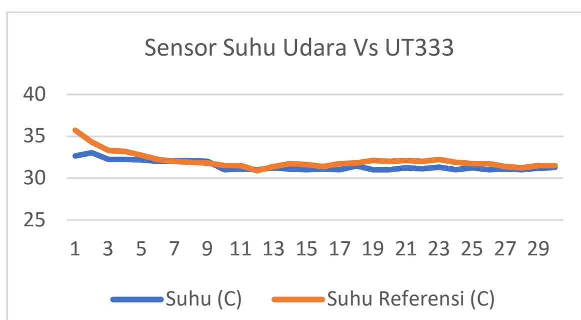

Figure 20 Temperature Sensor Graph

D. Light Sensor Test

To test the readings of the Sun Light Intensity sensor, the sensor nodes will be placed outside and made to work to take a sample of 30 times where each sample will be taken every minute and then the reading will be compared with a commercial solar light intensity meter, UT383 mini light meters as follows:

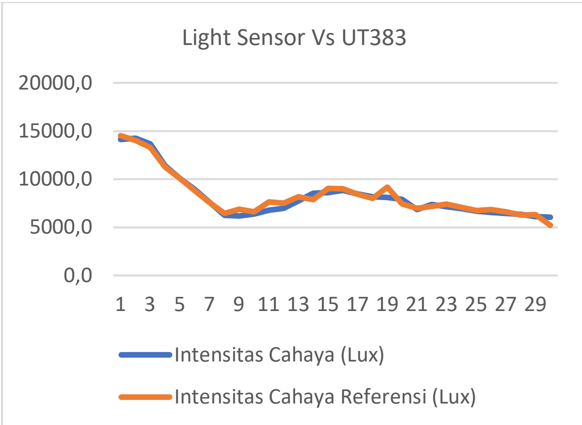

Figure 21 Light Sensor Graph

As can be seen that the sunlight intensity sensor already has the same graphic form as the UT383 commercial sensor, and the error from the sunlight intensity sensor does not exceed the specification limit, which is ± 10% of the actual value, which is 4.07%, which indicates that the humidity sensor is good.

E. Wind Sensor Test

To test the wind speed sensor readings, the sensor node will be placed in front of the electric fan and made to work to take 30 samples where each sample will be taken every minute then the reading will be compared with the commercial wind speed measuring product, namely UT363 mini anemometers, obtained results such as in figure 22:

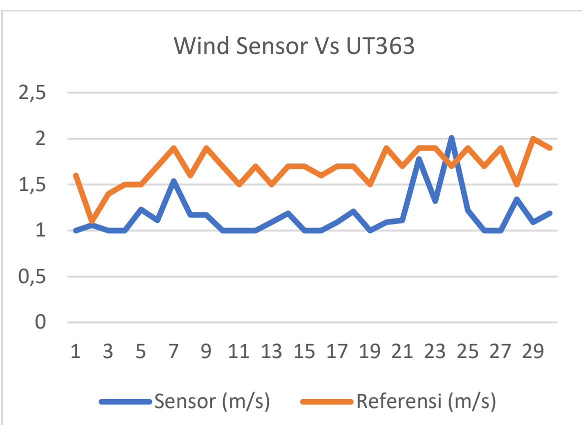

Figure 22 Wind Sensor Graph

Even though it is good and has a similar output form, the wind speed sensor is still far apart from the reference wind speed from the UT363 sensor> ± 0.5m / s where the average error is 0.537m / s, then the temperature sensor is considered not good in this case..

V. Conclusion

From the design, implementation, and testing carried out, the sensor node has been successfully designed and implemented with almost all specifications met. Sensor nodes have a small power consumption in the switching mode, which is only 10mA and from that factor, the power taken from the battery is very small, so the sensor nodes can last a very long time because there is a self recharge factor, besides that the sensor on the sensor node meets the specifications, has an accuracy of ± 5% on the humidity sensor, and ± 10% accuracy on the light intensity sensor. Specifications that have not been met are that some sensors have output data whose errors exceed the limits of the main specifications, namely temperature sensors and wind speed sensors, both sensors still need further development in terms of calibration and precision so that they can be used properly and there are no data errors far of the data it should be.

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