Design a Microcontroller-Based Automatic Microgreen System with Solar Panel

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***Abstract* — This research was conducted to design a microcontroller-based automatic microgreen system integrated with solar panel as the main source of energy. This prototype includes hardware and software that were connected to control the lighting automatically. Primarily, this system consisted of a microcontroller that functions as a center controller, a water sensor to detect water availability, relay as an automatic switch, water pump to maintain the growing media humidity, and UV lamp to give artificial lighting. These components got power from a solar panel connected to a battery and solar charge controller to be able to be more stable. Microcontroller processed the data from sensor and gave instruction to actuator (relay, RTC and lamp) according to the designed program. In this research, the method used is experimental, where the testing uses measuring tools in the laboratory. Thus, system was able to run automatically, and efficient in energy, due to the use of sustainable solar panel energy source.**

***Key words*— Microcontroller; Microgreen; RTC; Solar Panel; UV Lamp**

I. INTRODUCTION

One of the city farm choices that currently become popular in urban residents is microgreen. Microgreen is a kind of vegetable and herbal plant which beneficial for health because rich in nutrition, antioxidant, vitamin, mineral, and enzyme, and easy to digest. Microgreens are young plants that can be harvest in 7 or 14 days after sown, have soft texture, and can function as seedlings. There is another opportunity for microgreen cultivation, i.e., short harvest time and higher nutrition and nutrients compared to mature vegetables of the same kind. Microgreen treatment is practical because only need one time showering per day, friendly with environment, low cost, and does not use pesticide compost, so it is safe to eat in fresh condition. [2].

Growing media is the main factor which is important to microgreen growth, and can be divided into two, organic dan inorganic. Organic growing media such as humus, rice husks, charcoal, fern stems, compost, moss and cocopeat, while inorganic such as sand, gravel, broken bricks, rockwool, clay, and vermicompost. These growing media function as a storage to keep the hara element, control the temperature and air humidity, and affect the process of root growth.[3].

Several previous researches had been done related to microgreen, like Microgreens as Agriculture Plant Cultivation Alternative (Noor Rizkiyah dkk, 2022), Pakcoy Microgreens Production and Growth in Various Growing Media: Liquid Organic Compost of Cow Urine (Haslinda dkk, 2024), Growth and Quality of Various Microgreen Plant at Different Growing Media (Vira Sani dkk, 2024), Implementation of Solar Charge Controller for Battery Charging using Hybrid Energy at Electric Motorcycle (Bartsa Dilla dkk, 2022).

This research designed a microcontroller-based automatic microgreen system with solar panel, conducted in IoT and Telecommunication Laboratory, Universitas Katolik De La Salle Manado. Through this research, hopefully system can work automatically, and efficient in energy, because using the sustainable energy, i.e., solar panel.

II. RESEARCH METHOD

A. Literature Review

At this step, author collected various data and relevant source of information, to support the research related to microcontroller-based automatic microgreen system design that was integrated with solar panel energy.

B. System Design

This step brought author to design a microcontroller-based automatic microgreen system that was integrated with solar panel as the main energy. The design consisted of hardware and software which were connected each other to automatically control the lighting.

In general, system had a microcontroller that functions as control center, water level sensor to detect water availability, relay as automatic switch, water pump to keep the growing plant humidity, and UV lamp to give artificial lighting. All these components got power supplied from solar panel connected to battery and solar charge controller so the energy supply will be more stable.

Microcontroller processed the data from sensor and gave instruction to actuator (relay, RTC, and lamp) according to the designed program. Thus, system would be able to work automatically, more energy efficient due to using sustainable energy. These are clearly shown in figure 1.

The block diagram of microcontroller-based automatic microgreen system using solar panel energy was designed to integrate the functions of controlling and sustainable energy supply. Several prime components were solar panel, solar charger, battery, microcontroller, RTC, current/voltage sensor, LCD monitor, relay, water pump, UV lamp, and microgreen table as the growing plant. Solar panel functions to capture the sunlight energy, and convert into DC electrical energy. This energy then adjusted by solar charger to become more stable before being stored in battery, making the good safe of energy availability, day and night.

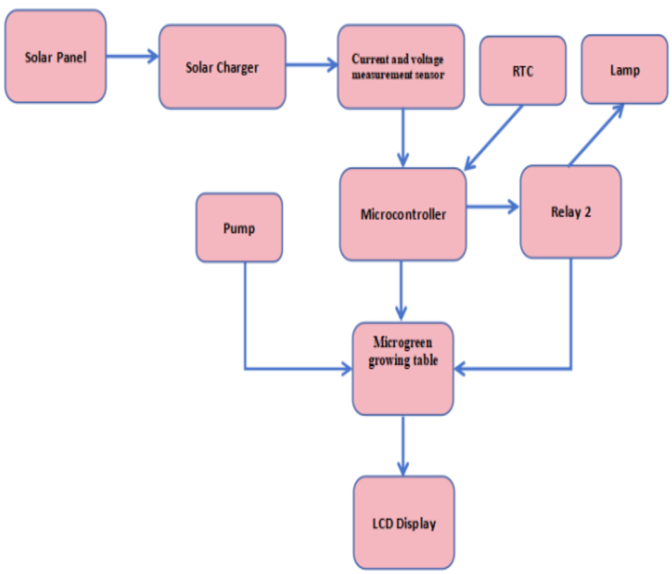

Figure 1. System block diagram

Battery was the main source that supply the power for microcontroller and all the system devices. Microcontroller ruled as the control center which processing the input from RTC (Real Time Clock), that gave *real-time* information to organize shower and lighting schedule time, and the current/voltage sensor which monitoring the power condition from solar panel and battery. Based on that data, microcontroller sent signal to relay. Relay controlled the UV lamp that give additional light for indoor microgreen plant, while the water pump will keep the growing plant humidity at microgreen. LCD monitor was set to display the *real-time* information of system status, includes voltage, current, water pump status, and UV lamp condition. With this design, system was able to work alone and automatically, started from energy supply until the process of showering and lighting. The integration of solar panel made the system efficient was for energy, environmentally friendly, and suitable for sustainable urban farm in small scale.

III. RESULTS AND DISCUSSION

A. Tools and Materials

Based on figure 1 at the system block diagram, tools and materials were prepared for data collection:

1. Microgreen table
2. Microcontroller
3. RTC (Real Time Clock)
4. Relay
5. UV lamp
6. Current and voltage sensor
7. Water pump
8. Solar panel
9. Battery
10. Cable
11. LCD 2x16

Before using, all the tools and materials need to be tested first, so every component can function properly. After finish doing the test, the next step is to design the system based on the block diagram shown in figure 1.

B. Hardware Design

The hardware design of microcontroller-based automatic microgreen plant is shown in figure 2.

The hardware system in this research aimed to develop automatic control system for microcontroller-based microgreen plant. The design is given in figure 2. On the left side of figure 2, it can be seen that the solar panel functions as main energy source which supply the electric power to microcontroller for operating the whole system.

Microcontroller ruled as a control center that organize the whole components in system. In the operation, microcontroller was connected to relay module that functions as an electronic switch to control the UV light ON OFF condition.

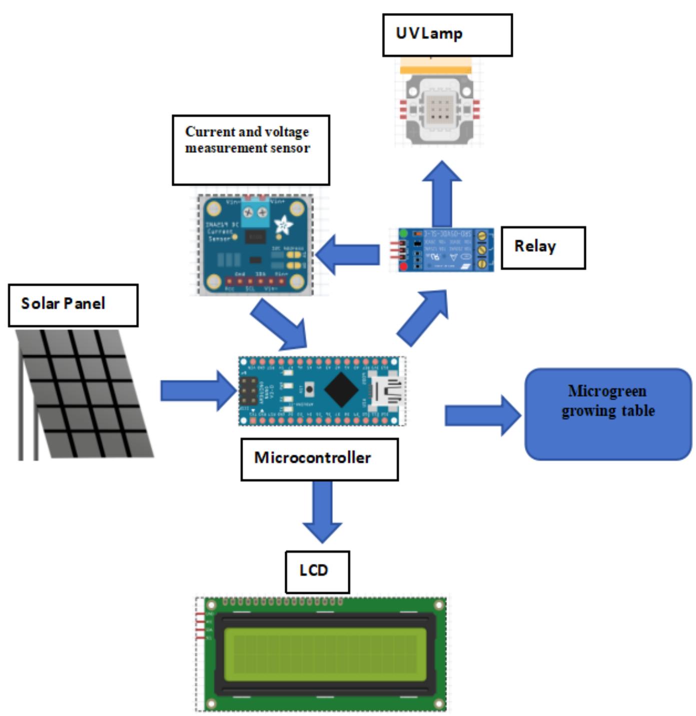

Figure 2. Hardware design

UV light was used as an additional lighting source to support the growth of microgreen plant, especially when the light intensity was not enough. Besides that, system was equipped with current and voltage sensor for monitoring the current and voltage level of UV light. Measurement data from the sensor was sent to microcontroller for further processing as part of the monitoring system. The information about system condition, such as current, voltage, and the status of lamp operational, were displayed through LCD screen so the user would be easier in doing monitoring.

Microcontroller was also integrated with microgreen table as the main media for plant growing. Thus, the whole hardware system design formed a connected system between energy source, controlling process, and monitoring, so it would be able to increase the automatization and efficiency in microgreen plant cultivation.

C. Data Collection

The data collection in this research was done through current and voltage parameter testing which directly measured or using microcontroller. The observed parameter was solar panel voltage, battery voltage, pump voltage, lamp voltage, load voltage (pump and lamp were in active condition), and the load and unload voltage.

The measurement process was done gradually in several specific time interval, to know the characteristic and system performance. All measurement data then documented and analyzed to calculate the solar panel-based power system performance in supporting operational devices.

D. SCC System Voltage Testing

This testing tested the voltage of system Solar Charge Controller (SCC) which aimed to get the energy supply stability from solar panel to the load and system component. The measurement was conducted in several conditions, i.e., when the system being loaded and unloaded, with the observed parameter (voltage of every part of the system). The result can be seen in table 1.

TABLE 1
SCC SYSTEM VOLTAGE TESTING

No	Panel Voltage (Volt)	Battery Voltage (Volt)	Pump Voltage (Volt)	Lamp Voltage (Volt)	Unloaded Voltage (Volt)	Collected Data
1	14.59 V	13.92 V	15.05 V	14.01 V	15.17 V	13:05
2	15.47 V	14.76 V	15.11 V	14.80 V	15.06 V	13:20
3	15.62 V	14.85 V	15.25 V	14.29 V	15.18 V	13:35
4	15.12 V	14.43 V	15.17 V	14.45 V	14.80 V	13:50
5	15.03 V	14.20 V	14.42 V	14.0 V	14.57 V	14:10 WITA

Table 1 shows the voltage measurement result at solar panel power generation system, using SCC in several specific time interval. The observed parameter were solar panel voltage, battery voltage, pump voltage, lamp voltage, and the unloaded voltage. The process of data collection was conducted 5 (five) times, from 1.05 pm until 2.10 pm.

Based on the collected data, the voltage of solar panel was between 14,59 V until 15,62 V, which shown that the sun lighting condition was relative stable during testing. Battery voltage was recorded between 13,92 V until 14,85 V, that indicated that the battery could store and distribute the energy well. In other hand, the voltage of pump was recorded between 14,42 V until 15,25 V, and the lamp voltage between 14,00 V until 14,80 V. The unloaded voltage was between 14,57 V until 15,18 V.

The testing result shown that there was a difference of voltage value between loaded and unloaded condition. When the system was loaded, voltage mostly decrease compared to unloaded condition. This matter is natural because of the power consumption of connected load. As a whole, the voltage fluctuation value was still in acceptable limits, so it can be concluded that the system can work stably in distributing energy to all components.

E. UV Lamp Current and Voltage Monitoring Testing Using INA219 Sensor

Before doing data collection, we conducted a connection design and configuration between INA219 sensor and microcontroller. INA219 sensor was used to do real-time current and voltage monitoring through I2C-based communication. System was also equipped with RTC module to record the time, LCD as the information display media, and relay which functions as a load controller. Table 2 shows the pin configurations and the relationship between components in system, like INA219 sensor, RTC module, LCD, and relay that were connected to microcontroller.

Pin configuration was done according to each component function, and the system requirements, so the monitoring and controlling process can run optimally.

INA219 sensor was connected to 5V voltage source and ground, and used the I2C communication line through pin SDA and SCL that each connected to pin A4 and A5 od microcontroller. This sensor functioned to do current and voltage measurement and monitoring in real-time.

RTC module was also configurated using I2C communication at pin A4 (SDA) and A5 (SCL), and got supplied from pin 5V and GND. This module was essential in preparing accurate time information, so each data of measurement can be recorded according to collection data time. Meanwhile, I2C-based LCD was used as a display media to output the system parameter information, i.e., current, voltage, and time.

TABLE 2
PIN CONFIGURATION

No	Components	Components Pin	Microcontroller Pin
1	Sensor INA219	VCC	5V
		GND	GND
		SCL	A5
		SDA	A4
2	RTC	VCC	5V
		GND	GND
		SCL	A5
		SDA	A4
3	LCD (I2C)	VCC	5V
		GND	GND
		SCL	A5
		SDA	A4
4	Relay	VCC	VCC
		GND	GND
		IN	D7

This LCD was connected to same communication line, made available for several communication devices to communicate in one bus I2C efficiently.

On the other side, relay module was connected to pin 5V and GND as power supply, and input pin D7 of microcontroller. Relay functioned as an actuator that control the load, such as lamp and other components, based on microcontroller instruction.

With that configuration, all the components in system can work coordinately and integrated. The use of I2C communication brought efficiency in microcontroller cabling and pin configuration. Overall, this design supports optimal, accurate, and real-time monitoring process and system controlling.

The following table 3 gives the testing data from lCD monitoring using INA 219 sensor, for panel and UV lamp current and voltage.

The above table 3 shows the result of measuring electric parameters in several specific time interval. The observed parameter was solar panel voltage, lamp voltage, flowing current, and the data collection time. The process of measurement was done 5 (five) times from 1.41 pm until 2.54 pm.

TABLE 3
ELECTRIC PARAMETER MEASUREMENT

No	Panel Voltage	Lamp Voltage	Current	Collected Data
1	14.6 V	5.03 V	0.78 A	13: 41 WITA
2	14.4 V	5.05 V	0.75 A	13: 58 WITA
3	14.4 V	5.05 V	0.75 A	14 : 21 WITA
4	14.4 V	4.51 V	0.70 A	14 : 36 WITA
5	14.6 V	4.53 V	0.79 A	14 : 54 WITA

Based on the testing result, the solar panel voltage was between 14,4 V - 14,6 V, which showed that the energy supply relative stable during data collection. The lamp voltage was varied between 4,51 V - 5,05 V at the load side. Meanwhile, the flowing current varies from 0,70 A to 0,79 A.

As a whole, the measurement result showed that the system had quite good stability, shown by not too significant current and voltage value fluctuation. This changing value of current and voltage lamp was predicted affected by load condition and the variation of solar panel energy supply. However, the values were still in normal limit, so the system can operate well and support the load performance.

TABLE 4
THE MEASUREMENT OF VOLTAGE, CURRENT, AND LAMP STATUS

No	Voltage	Current	Lamp Status	Collected Data	Picture
1	4.3 V	0.32 A	ON	17 : 33 WITA	
2	0.9 V	0.0 A	OFF	18 : 11 WITA	

Table 4 shows the results of electrical parameter tests, including voltage, current, and the lamp's operational status at specific data collection times.

Furthermore, the table also includes visual documentation to verify system conditions during the testing process. These measurements aim to evaluate the system's response to changes in the lamp's status, which are automatically controlled based on time.

Based on the test results, at 5:33 pm (central time), the lamp was on, with a voltage of 4.3 V and a current of 0.32 A. These values indicate electrical energy flow to the load, indicating that the lamp was actively operating at that time.
Subsequently, at 6:11 pm, the lamp was off, indicated by a voltage drop to 0.9 V and a current of 0.0 A. This condition indicates no current flow in the system, so the lamp load was not operating.

The change in the lamp's operational status from on to off occurred between 5:33 pm and 6:11 pm, indicating the implementation of a time-based control mechanism in the system.

Thus, the designed system is able to regulate the operation of the lights automatically according to predetermined time parameters, thereby supporting efficient energy use and improving overall system performance.

IV. CONCLUSION

The designed and developed system can functioned well according to our research approach. The solar panel could produce relatively stable electric energy stored in a battery, adjusted by the Solar Charge Controller (SCC), to support the Power consumed by all system components.

The test results shows that the power supply system has good stability, both loaded or unloaded condition. The voltage value from solar panel, battery, pump, and lamp, are in normal range with relatively little fluctuation, so it can support the system performance.

The test using INA219 sensor shows that the system can do real-time current and voltage monitoring with consistent results. The current and voltage values for loaded UV lamp are in normal range, indicates that the sensor and microcontroller can work optimally in electric parameter monitoring process.

The time-based lamp controlling using RTC module was also given the results that match out design. The change in lamp’s status condition from ON to OFF happened in specified time, so the system can arrange the lighting automatically according to microgreen plant requirements.

Overall the designed system was success in integrating the automatic monitoring and controlling function, and the effective of sustainable energy sistem utilization, make this output as an efficient and environmental friendly in microgreen plant cultivation.

Suggestion : Add environmental sensor, such as temperature, humidity, pH, and TDS sensor, for increasing the accuracy of plant growth condition monitoring. Develop Internet of Things (IoT)-based system, such as through the integration with platform Firebase or mobile application, so the data can be accessed in real-time remotely. Use higher capacity batteries or apply Battery Management System (BMS) to improve the energy storage efficiency. Apply adaptive and smart control method, such as fuzzy logic algorithm, to optimize the system performance in managing the energy and plant condition. Do longer testing to evaluate the system reliability and stability in real operational condition.

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