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Original Article

IOT based Solar Powered with USB Port of Smart Home Gardening System for Greener Plants

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Abstract - *The Internet of Things (IoT) is part of the application domain that provides mechanisms and methods to interconnect processes and technology to automate real-life activities such as home gardening. However, in urban areas, people interested in gardening are always busy with their daily life, causing the plants to be left without proper care, leading to abnormal growing conditions. Henceforth, this paper describes a system that proposes a home gardening turned intelligence that results in a fully automated home gardening via an Arduino Uno as the key controller. In addition, an android application is designed so that users can observe the parameters of the plant in real-time, such as power level, soil moisture level, water level and plant height. Thus, using the IoT coupled with solar power USB charger for remotely supervising the solar battery level and parameters of the plant anytime and anywhere. As a result, this system can significantly enhance the performance, monitoring and preservation of the garden plants. In the meantime, users will also be able to handle their plants with minimum human intervention regarding health and growth based on resource-efficient energy usage.*

Keywords - *USB, Urban, MIT, Arduino, IoT.*

1. Introduction

The significant advancement of IoT in recent years has given the world of information and communication technology a new dimension, while automation can rule the world [1, 2]. The IoT concept will make the sensors communicate with each other, thus being useful and powerful in the automation world [3, 4]. Furthermore, in this modern era, some people would also love to have their garden plants eco-friendly based on green power sources [5-6]. However, for some users, the busy lifestyle nowadays makes it impossible to look after the plants with proper care [7]. Once again, thanks to technology, this can be made possible by introducing an automated gardening system with a Universal Serial Bus (USB) port for a portable solar system that is currently developed [8-9].

The fundamental idea of this proposed project is that it responds automatically with the existing events occurring in reality, which can be influenced by the improvement processes that produce services accessible for better use and trigger actions with little or no human involvement [10]. In this context, the paper proposed a model that could efficiently take care of gardening plants on its own with almost no human intervention based on renewable energy [11].

Generally, plants do so much for humans, and it would be a lovely gesture to provide them with promising control conditions to grow that help to increase efficiency, thus beneficial to mankind [12-13]. Unfortunately, this is a tedious task requiring lots of man hours monitoring the plants' health and growth [14]. Time availability is the potential problem where most plants often get damaged or die due to environmental factors such as lack of water [15]. To overcome these challenges, the recent technological development in cloud application have given new possibilities for online storage in logging and viewing data for analysis and diagnostics [16]. From here, the technology provides the user with a helping hand to monitor the plant parameters efficiently [17].

The gardening modernization continues to develop, and the area involved is constantly broadened from time to time, from digital monitoring to depth of awareness and from a smart alert to command and control regulation in environmental policy, which proved to be extremely advantageous with IoT gardening [18]. However, these achievements have their specific application environments. It is difficult for many problems to obtain universal solutions, which may lead to the poor set-up condition of the plants that affect the ecological ecosystem [19] accordingly. From this point of view, this is a proposed unified project which combines the ecological element with the energy of the application layer, the transport layer's WiFi and the perception layer's cloud processing.

Despite the diversity studies for digital gardens about the respective paper benchmarking [17, 29], the gap for the research here reported that lack of plant height information as one of the plant quantification metrics. It is due to a relevant measure of plant stress brought on by a water and nutrient shortfall is plant height, a morphological aspect of plant growth. is a morphological characteristic of plant growth that is a useful indicator of plant stress resulting from water and nutrient deficit [20]. It also lacks numerical analysis with supportive graphical data. The proper help of using IoT devices for sensor-based monitoring can provide the solution for the identified research gap here.

The following contributions to this paper: The suggested method was created with two goals. The first goal is to create a prototype of an automated smart home gardening system based on IoT utilizing low-cost Arduino technology. The next objective is to integrate the system with cloud storage based on Android applications to facilitate the implementation of an automated smart home gardening system. The following is how the rest of the paper is organized: Section 2 summarizes a few related works, followed by Section 3, which elaborates on the system architecture, Section 4 shows the results and discusses them, and lastly, Section 5, that wraps up the project.

2. Literature Review

The following contributions to this paper: The suggested method was created with two goals. The first goal is to create a prototype of an automated smart home gardening system based on IoT utilizing low-cost Arduino technology. The next objective is that the system is integrated with cloud storage based on Android

Several studies related to the application of IoT in the practice of growing and cultivating plants are the implementation of IoT under the agriculture domain for environmental monitoring with temperature sensors, electrical conductivity sensors, humidity sensors, motion sensors, water level sensors, etc. [21]. With the development of open-source Arduino boards and networked sensors, it is now possible to build systems that can water urban green spaces or farms as needed while monitoring soil moisture in real-time.

The low cost of microcontrollers, together with the compatible cost of Arduino boards and cheap sensors, has produced many hardware development platforms, both proprietary movement and open-source movement, which bring the end users closer to electronics in a fast and straightforward way [22]. Designing economical IoT systems for numerous smart city applications in education and research projects has become useful. Many researchers proposed solutions based on interconnected devices that use popular microcontrollers such as ATMEGA328P that are supported on Arduino Uno, Duo or Mega system platforms.

Plant gardening has been modernized due to the rapid and broad use of computer and mobile technology in everyday life, providing access to an almost limitless quantity of internet material, including rich sensors and private data [23]. In this case, the Massachusetts Institute of Technology (MIT) App Inventor based on smartphone usage for web development platforms is proposed, which anyone may use to solve the corresponding real-world challenges [24]. Hence, the issue is that home gardening is what if the plants can tell the user when they are happy and require proper attention. It would be awesome, right! It would be helpful if users get notifications on their phones about their plant's health and needs. Implementing the MIT App Inventor allows the plants to be monitored and managed simultaneously. All the data will be transmitted to farmers, which have a precise controlling decision for their plants accordingly.

Unfortunately, most present IoT apps have been found to lack user-friendly features. A qualified technician was still required to install and modify an IoT system. For example, IoT in a Box offers hundreds of IoT sensors, but each sensor is rather costly because they are all wireless. As a result, the recommended solution is to use the Arduino system and the Universal Serial Bus (USB) to provide alternative plug-and-play features for sensors and a water pump.

Apart from the best argument that solar power is free and pure, the fundamental reason for humanity's migration to solar energy is its potential to create energy with no limits: There will be no additional drilling and exploration expenditures, and there will be no spills that might affect the environment since there would be no greenhouse gas emissions [25]. Currently, the supply of both water and power is insufficient to meet the needs of farmers. This mechanism is in place to address the water and electricity shortages. Furthermore, farmers may save money by using solar-powered irrigation systems [26]. Specifically, the auto Pulse-Width Modulation (PWM) solar charging based on the lithium-ion battery is considered in this project since it was optimized to extend the life of the batteries suitable for undersized areas such as home gardening. The hardware and software components employed in the proposed system are discussed in the next section.

The benchmarking for this project was done with the paper in [29] on the function and method for the smart home gardening systems. In contrast to this benchmarking paper solutions, this project approach aims to provide additional functions monitoring the battery level based on USB-solar and plant height with the plant growth status.

3. System Design

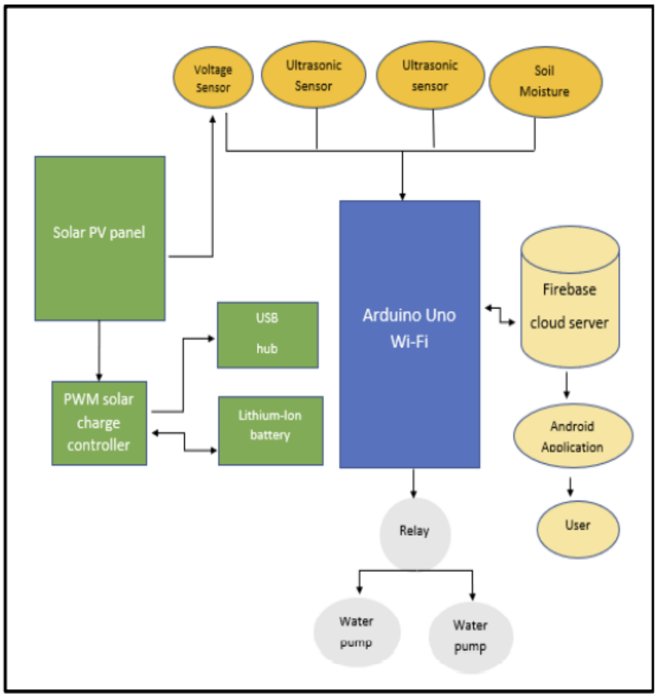

Fig. 1 Block diagram of the modified system

Figure 1 above depicts the USB Solar Technology-based Smart Home Gardening block diagram using the Arduino System. The main idea of this project is to develop smart home gardening using the solar PV system. The solar PV system will be the main supply source that will power up the smart home gardening system. The solar panel was selected, and the type of solar panel used is monocrystalline. It has high efficiency and good performance. Besides that, a solar PWM charger controller is used to keep and step down the power source from the solar panel, which is 18V to 12V. There will be a voltage sensor attached to monitor the solar voltage continuously. The PWM controller can charge the lithium-ion battery safely without any problem. The controller also has the output, which will be connected to the USB hub. The smart home gardening system will be connected to the USB hub. Smart home gardening has input sensors such as the soil moisture sensor, ultrasonic sensor, and relay, which control the water pump. Finally, all the sensor data will be sent to the Google Firebase cloud server and displayed in the MIT android application for the user. Besides that, all the sensor data will log in to the Google Firebase cloud server, which can be exported to Excel for analysis purposes.

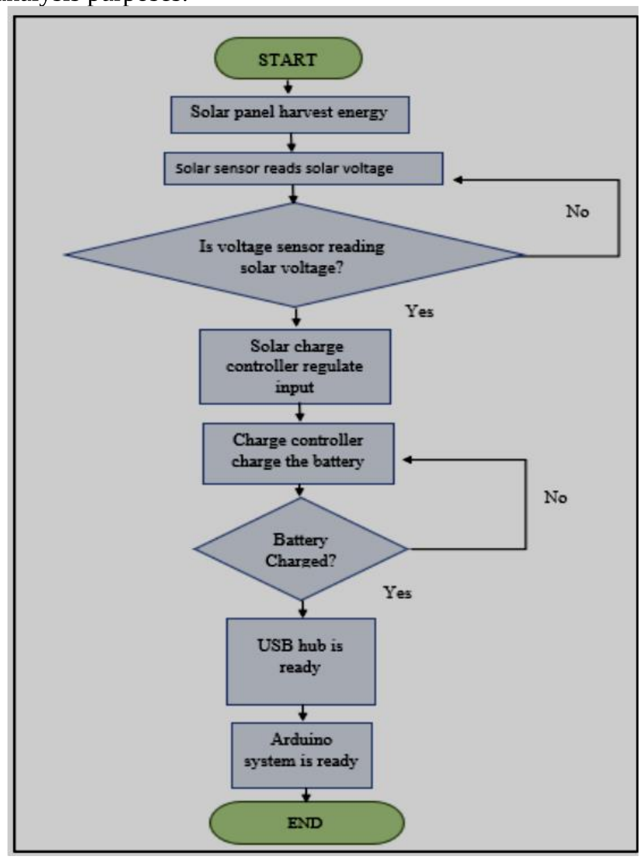

Fig. 2 Flowchart of the USB solar PV system

The project has two systems. Figure 2 shows the flowchart of the USB solar PV system. The project will start from the main system, which is the solar PV system, which has an 18V direct current at peak. The solar panel will harvest the energy from the sunlight, and a voltage sensor is attached. The voltage sensor will read voltage from the solar panel. Next, the PWM solar charge controller will control the input power from the solar panel. The charge controller will control the voltage and current input from the solar panel. The charge controller will help to handle the power source and charge the battery. If the battery is not full, the charge controller will recharge the battery so that there will be backup power during nighttime. The USB hub will be connected to the output of the solar charge controller. The Arduino system, the smart home gardening controller, will be connected to the USB output and the relay that controls the water pump.

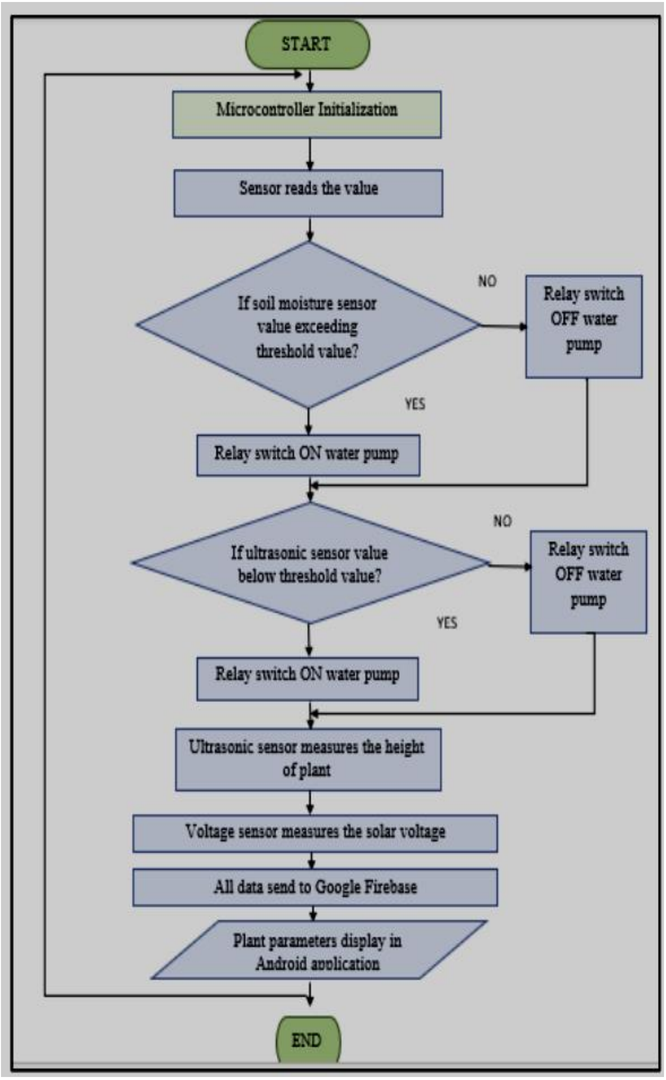

Fig. 3 Flowchart of the smart home gardening system

Figure 3 illustrates the process flow of the smart home gardening system, which is ready to operate. This system uses an Arduino Uno WiFi board. This system is programmed with Arduino software. The input will be the soil moisture, ultrasonic, and voltage sensor. Soil moisture will be placed in the plant pot to monitor the soil moisture level. If the sensor value exceeds, it shows the soil is dry, the relay will trigger, the water pump will ON, and if the value is below the relay state will also be below. Besides that, two ultrasonic sensors are used to monitor the water level in the tank and plant height. The ultrasonic sensor placed in the tank will monitor the water level; if the level is low, it will trigger the relay, and water will pump into the tank.

Consequently, the water pump will go OFF when water reaches a certain level. Finally, another ultrasonic sensor will be placed at a certain height from the plant pot to measure the plant's growth. The voltage sensor will read voltage values from the solar panel input and send data to the server. All plant parameters will be sent to the Google Firebase cloud server. An Android application will be linked with the Google Firebase cloud server so that any users can monitor the plant parameters, and the data logging function will store all the parameters.

The proposed project's main hardware development is the USB solar PV system. This system was built with a solar PV panel, solar charge controller, and lithium-ion battery pack. Figure 4 showed the complete set-up for the USB solar PV system and was placed under sunlight for testing the PWM solar charge controller and the battery pack. The full system hardware was placed in the electrical box for weather protection.

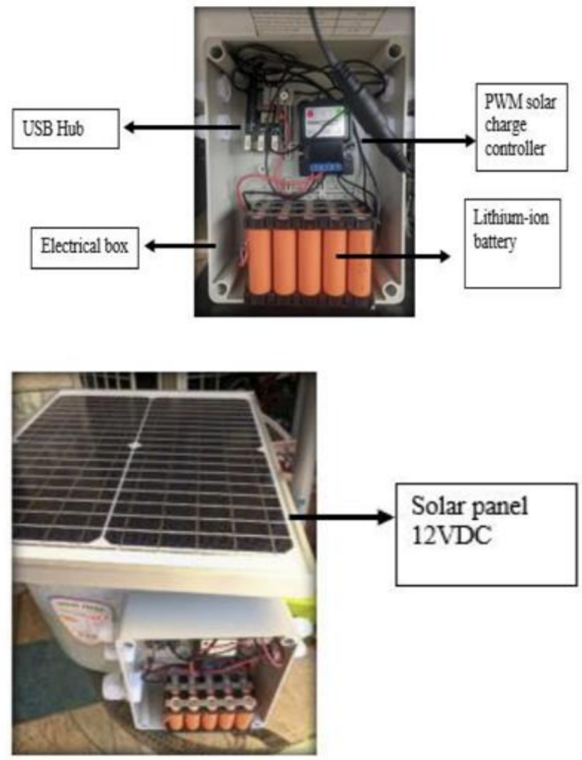

Fig. 4 Hardware connection of USB solar PV system

Figure 5 depicts the full system where it is developed and placed outdoor for analysis purposes. Two systems were placed in the electrical box for weather protection. The water tank, which has a water pump, was placed beside the plant pot and the solar panel. The water hose was pointed to the soil, and the soil moisture sensor probe dipped into the soil. The ultrasonic sensor is fixed above the plant. This system was further enhanced by using the block-based program and can link with any cloud server. The application was built and named Solar Smart Plant, which has a simple and clean user interface. This application is compatible with Android users, where Figure 6 shows an actual application interface of plant monitoring parameters displayed on smartphones.

Fig. 5 Full system development

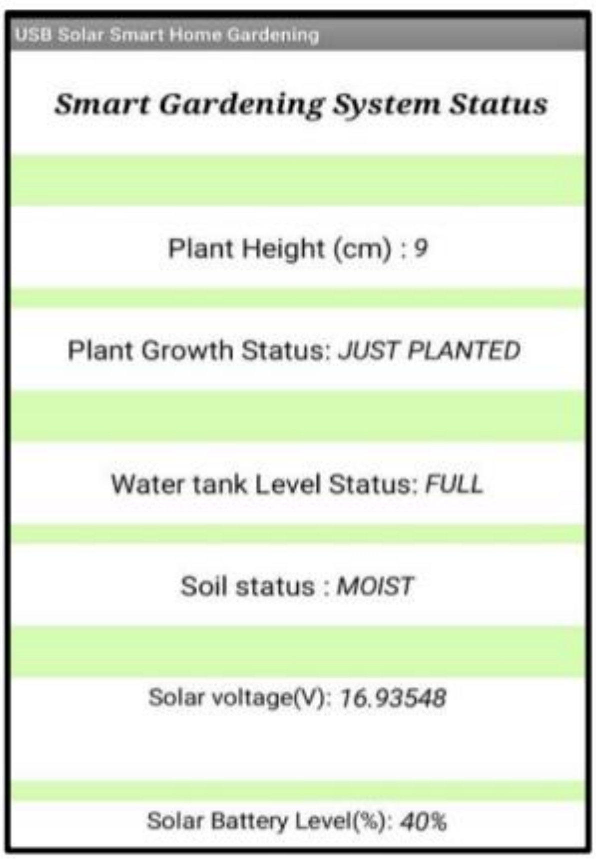

Fig. 6 Android application user interface

4. Results and Discussion

In this project, the system has the feature usage of IoT technology which helps to send the data to the users by creating a database using the Firebase service. The ultrasonic sensor testing was done to show that the sensor can measure the plant height and function well with Arduino programming. The height of the plant was logged in the cloud server for analysis.

Table 1. Amount of water consumed by the system and without the system

Days	Amount of water used by the proposed system (liters)	Amount of water without the used by the proposed system (liters)
1	35.5	0.7
2	37.8	0.7
3	36.2	0.7
4	34.6	0.6
5	40.1	0.5
6	34.7	0.6
7	39.5	0.5
8	38.7	0.6
9	32.6	0.4
10	35.0	0.6
11	33.5	0.5
12	36.6	0.5

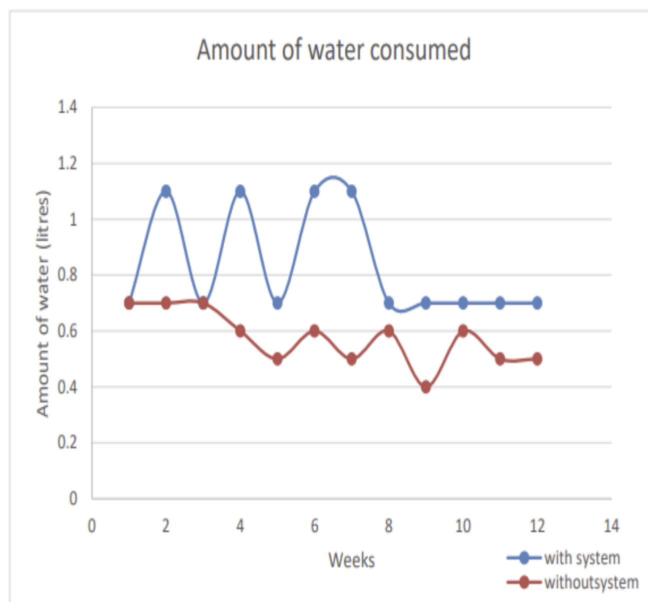

Fig. 7 Comparison graph of plant growth with and without system

Based on data from Table 1, a graph is produced on the amount of water consumed by the plant with and without the system. From Figure 7, the plant consumed a higher amount of water which is around 10 liters for 12 weeks, since the water is consumed more during hot weather, while plants without a system that needs manually watering the plant will consume around 6.9 liters because there is no consistency in watering those plants manually. By comparing the benchmarked journal [27], the system has a watering system. Still, there is no proper analysis of the water consumed, so this smart home gardening system has a good watering system, and the amount consumed can be logged.

Table 2. Comparison table of plant height with system and without the system

Weeks	Plant height with the proposed system (cm)	Plant height without the proposed system (cm)
1	25	25
2	26	25
3	26.5	26
4	27	27
5	28	27
6	29	28
7	30	28.5
8	32	29
9	34	30
10	35	31
11	35	31
12	36	31

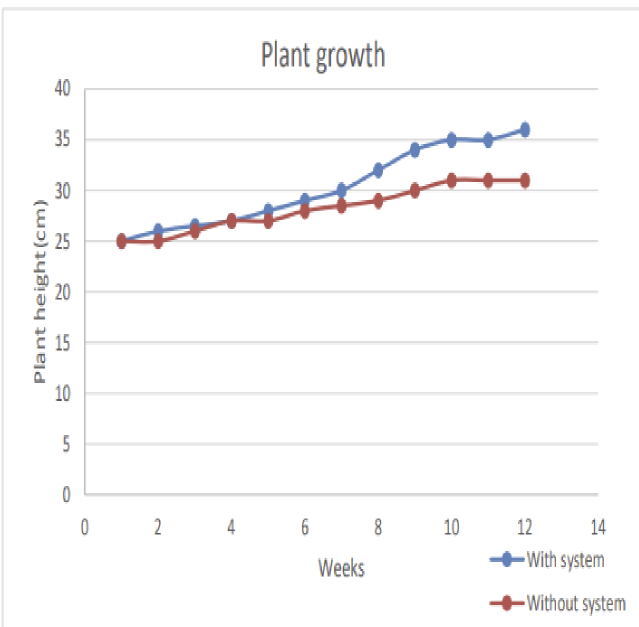

Fig. 8 Comparison graph of plant growth with and without system

Also, based on the data in Table 2, a smooth curve graph shows the plant's weekly growth with and without the system. The sensor was set up and placed near the plant pot in this system. The ultrasonic sense measures the height of the balsam plant. The sensor was placed at the height of 90cm. The value of the plant height will send to the Firebase server, and the value will be displayed on the smartphone application in a real-time manner. Besides that, the data will be logged in the Firebase server. All the data was exported to the Excel sheet weekly for analysis purposes. Figure 8 shows the comparison graph of plant growth with and without the system. The plant running with the system has better growth compared to the plant without the system. The plant growth without the system was measured using a measuring tape, and there will be zero error. By looking at the benchmarked journal [28], the proposed system doesn't have an ultrasonic sensor to measure the growth of the plants. By adding this ultrasonic sensor, the performance system based on the plant well-being can be improved, and the user can monitor the plant growth efficiently.

5. Conclusion

People who are interested in gardening are always busy with their daily routines, thus neglecting the plants' basic care. Due to unexpected weather conditions, the plant's growth could deteriorate due to negligence. Home gardeners must be more innovative by adding new concepts and features such as IoT and USB solar technology to their home gardening activity.

After much research was conducted and suitable methods were considered to design this system, the project was ready to be proposed. The proposed project title, the development of USB solar technology-based smart home gardening using the Arduino system, will be the best choice to innovate and improve home gardening activities. For the methodology part, the full explanation was done for the hardware and software implementation. The solar PV system is a USB hub that lets the smart home gardening system run stable without any problem. Besides that, it has a battery pack that can run the system for a long period. The hardware involved in this smart home gardening is the Arduino Uno WiFi, ultrasonic sensor, soil moisture, voltage sensor, and water pump. At the same time, for the software, the Arduino was the main software to build and upload the program. Besides that, the Google Firebase server helps to store data and send them to the Android application to monitor the plant parameters. The data analysis was done to check the overall system performance.

The data analysis was done for the solar PV panel output voltage during two different types of weather and the lithium-ion battery backup time. For the smart home, gardening analysis was done on the growth of the plant and the amount of water consumed. Finally, the USB solar PV system performs the analysis considerably well, and the implementation of IoT proves that this gardening system performs very well in every aspect based on the analysis done.

For future improvements, the USB solar technology system will have a new update on the hardware part, the solar PV panel. The solar panel needs to be upgraded to high output current to charge the lithium-ion battery faster. Besides that, upgrading the battery capacity will help the smart home gardening system run for longer hours without any power cut. This bigger capacity battery helps, especially during monsoon season. For the smart home gardening system, the microcontroller should be upgraded for better performance to transfer the data faster to the server and update the server without any error. The cloud server can be upgraded to the paid version so that many data logging functions can be furtherly used. Finally, the Android application must build a brand-new user interface so that it can be commercialized in Google play for every type of user.

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