The Utilization of 900 Wp off-grid Solar Power Plant for Product Intensification of a Hydroponics Farmer Group

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ABSTRACT

In collaboration with a group of hydroponics farmers, an activity as a part of community service implementation has been carried out in Pasuruan, Eastern Java. The activity aims to develop a 900 Wp solar power plant capable of providing energy for running the essential electrical devices for the hydroponics system uninterrupted. This idea is to resolve the energy issue when the outage occurs. Moreover, the reliance on the public grid also adds additional expense for the electricity bill. Based on the observation, the power plant reliably provides sufficient energy to turn on different hydroponics electrical devices. It can supply energy for 12 hours without charging to activate, in total, 160 Watt of diverse loads all night long. While during the day, solar panels deliver energy for the batteries recharging and the other loads. Some other facilities are also developed in this activity, including UV plastic roof and addition of the grow lights to promote the plants' growth acceleration. The plastic roof efficiently reduces the sunlight intensity to lower the heat experienced by the plants, transmits specific wavelengths crucial for growth, and prevents the rainwater from entering the nutrient water tank. Meanwhile, the grow lights stimulate faster growth and quickly recover the plants after receiving much heat that causes them to look wilt. As a result, the farmers are now less reliant on the public grid, and the hydroponics system is more weather-resistant.

KEYWORDS
Solar power plant;
Hydroponics;
UV plastic roof;
Grow lights

1. Introduction

The sustainability of food sources has to be well-maintained by implementing efficient and sustainable modern farming methods to suffice the basic needs of the continuously- growing population in the world [1-3]. Even though the conventional technique has been practiced for centuries, it is considered inefficient in using water and area. Moreover, the conventional method produces considerable pesticides runoff and causes soil deterioration [4-6]. The surge of food demand in the future leads humans to revolutionize the farming method to obtain superb quality and quantity of products.

Hydroponics, classified as Controlled-Environment Agriculture (CEA), is one of the solutions to rectify the drawbacks mentioned above that conventional farming encounters. As the name suggests, this method replaces the soil with nutrient-rich water as a medium for growing the crops on a specialized platform. One can flexibly and easily control the water condition, including the nutrient concentration and pH, enabling the crops to grow at an optimum rate. Furthermore, the product's quality and quantity are highly controllable [5, 7, 8]. Despite the fact that the crops can grow with static nutrient water in a tank, most hydroponics systems use flowing water which is supplied to the roots by utilizing the water pump. The hydroponics farm is often equipped with more electrical devices and specialized construction to provide better growth conditions for a larger or industrial scale. In other words, a hydroponics system demands continuous electrical energy to run the electric devices. The use of fossil-fueled electricity will add additional production costs. On the other hand, it also worsens climate change due to pollution, which the world is struggling to rectify. Hence, renewable energy

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sources are becoming a promising solution for long-term agriculture [5, 6, 8-11]. It is shown in several studies [12-32] that solar-powered electricity is an auspicious energy source for agricultural applications.

Due to its easiness and flexibility of operation, hydroponics farming can be operated by anyone without special knowledge from formal education. A group of farmers, namely "Hidroponikkoe" in Pasuruan, Eastern Java, has run hydroponics farming since the beginning of 2020. The group consists of four neighboring housewives having a hydroponics farming system in their yard, with bhok choy (Brassica rapa) and lettuce (Lactuca sativa) as the main products. They were trained by the agriculture and food security cadre of the Pasuruan district. As a result, they are currently able to deliver the products to consumers, either individual consumers or local restaurants in various places nearby. However, their operation still encounters several issues. First of all, the dependency on the public grid as a primary energy source to run the essential electrical devices for the system leaves them no other options for alternative energy sources during the outage on a sunny day. According to the report from the farmers, excessive evaporation causes the crops to wilt more when the nutrient water stops circulating due to an inactive water pump than when the pump is on. Secondly, the weather heavily influences the crops as the hydroponics installations are set up outdoor without any protection. Direct exposure to sunlight and rainwater leads to unstable yields and deterioration of the quality of crops. In the rainy season, the rainwater falls directly to the installation and enters the water tank. Consequently, it changes the nutrient concentration, which influences the growth of the crops. Moreover, it raises the need for nutrients as the rainwater washes it out of the tank.

According to all identified problems in the field, a community service program aims to develop several facilities to provide some support for the production process of that farmer group. A 900 Wp solar power plant is built to provide electric energy to operate all crucial electronic devices for hydroponics. The harvested energy is then distributed to entire installations in the house yard of every group member. This alternative energy source can undoubtedly reduce the dependency on the utility grid and lower the production cost since the farmers do not have to expense monthly electricity bills. Other than that, this activity also tries to minimize the influence of weather by building a protection roof made of UV plastic for individual hydroponics platforms. The UV plastic roof plays at least two critical roles for the crops. It reduces the direct radiation from the sun and simultaneously transmits a specific wavelength to allow the plants to grow at optimum conditions. Another benefit of the roof is preventing the rainwater from entering the hydroponics installations so that the nutrient concentration remains stable. In addition, this work will also give the hydroponics system additional lighting, called grow light, with a specific wavelength, as demonstrated in several studies [20-23]. The addition of grow light enables the plants to grow at night time. Therefore, it is possible for the farmers to intensify the yields per year due to a shorter harvest time. It is also a perfect occasion to introduce to people the merits of using renewable energy to gain awareness of climate change. Other than that, the facilities that have been developed become an actual site for learning agriculture and solar power plant system.

2. Method

There are some steps that the team must do sequentially before developing the solar power system. The steps are as follows:

1. Site survey

This stage plays a crucial role in gathering information as a part of planning. First of all, the team gathers information on potential products that the group can produce and its profitability by interviewing every group member. At the same time, the existing hydroponics platforms are also inspected to create modification designs and estimate the number of materials needed. The last survey is the aerial observation by means of a drone to obtain primary data for approximating the cable length as a part of electricity distribution planning.

2. Materials procurement

Since the survey has collected the data, the materials are then procured. The materials are as follows:

- The roof frame is constructed using steel C channels, also known as a C truss, with a thickness of 0.6 mm and 0.75 mm. They are assembled and screwed together with drilling screws size of 12x20.

- The roof is made from 200 micron UV plastic, with various sizes depending on the hydroponics platform's dimension, that will be held in place with a spring clip.
- The growth stimulator uses a 12V 40W of red and blue light during the nighttime for every hydroponics platform.
- Three modules of 300 Wp monocrystalline solar panel and the railing clamps, Solar Charge Controller (SCC) MPPT 60A 12/24/36/48 V, two deep cycle batteries VOZ 12 V/100 Ah, 500 Watt pure sine wave inverter.

3. Development stage

There are two main construction works in this activity. Considering that the hydroponics system already exists, the team does not need to build a new setup. Instead, the work is intended for modifying the existing platform to add the roof. Another construction work is aimed to build the solar panel mounting frame. Inasmuch as all construction works are completed, the installation of solar panel modules and the other components, such as grow light, SCC, batteries, inverter, and plastic roof, can be commenced.

4. Testing stage

A general check is a critical task to do by inspecting diverse aspects preceding the functional testing of the entire system. Some things need an inspection, including the tightness of the screws, bolts, the wire polarity connection, and the safety components condition. Functionality testing is then conducted whenever the entire system is checked and declared safe to operate.

5. Observation

This community service is designed unceasing. The activity is still not finished, albeit the system is confirmed working properly. Thus, post-activity observation is mandatory to maintain the system health and strengthen the cooperation between the team and the partner.

6. Socialization

One of the goals of this work is a transfer knowledge to the public. Some of the locals are trained to understand, maintain, and do troubleshooting the solar power plant they operate. Hence, the residents are expected to manage and scale up their business independently.

3. Results and Discussion

The initial survey carried out at the beginning of the program has compiled valuable data. According to some information withdrawn from the farmers through an interview, there is an imbalance in production and demand. It is caused by the harvest time relatively taking more days than the selling. Under normal conditions, the harvest time for bok choy and lettuce is around 35 and 45 days, respectively. The crops yield is not able to suffice the demand from the market.

(a) (b)

Fig. 1. (a) Initial condition of four hydroponics installations. (b) The location of all hydroponics system as seen from drone.

Furthermore, the farmers could suffer losses as the installations are set up outdoor, as shown in Fig 1, making them less tolerant of the weather. The initial survey also results in an aerial image that becomes fundamental knowledge to determine the best location to mount the solar panel modules.

Additionally, the aerial photo can be used to estimate the wire length for electricity distribution. By this observation, a modification design for adding the roof frame is created.

Fig 1 bottom is an aerial image presenting the location of four hydroponics platforms, with a red arrow at the right bottom indicating the true north. The survey suggests that location 1 is the best site for the solar power plant to be assembled. What is more, this site is an open area with few rays obstruction during the peak sun hour. It implies that the solar panel can produce optimum power from sunlight irradiation as a consequence of minimal shading caused by tall buildings or trees nearby. The harvested energy is then distributed to the rest of the locations.

Fig. 2. Development of aluminum frame for roof and solar modules mounting.

The progress of frame construction is commenced since all materials are available, and it is portrayed in Fig 2. Those roof frames provide a place for the grow light and the UV plastic roof to be clamped. As shown in the last row of Fig 2, adding the semi-transparent plastic roof is doubtless to reduce the effect of weather-related issues. It allows the sunlight to pass through for photosynthesis and, at the same time, reduces the light intensity that causes temperature rise to the plants. As a result, the plants do not get excessive heat and are still straight up during sunny days. The roof also effectively prevents the rainwater from infiltrating the nutrient water tank. It is very beneficial for the farmers because the nutrition concentration remains stable. Hence, in turn, it does not perturb the plants' growth. The farmers can also save more nutrition in the rainy season.

Fig. 3. All hydroponics system in entire sites are already powered with solar power plant.

Prior to the electricity distribution, a thorough examination is carried out to assess the reliability of the system. This procedure, comprised of several steps, is taken to ensure that the power plant will work appropriately in delivering energy to all electrical loads. In this stage, the team tirelessly scrutinizes every detail of the component that makes up the power plant. Some items need to be carefully assessed, including the condition of every solar module, wire polarity connection, power rating of components, safety switch, and over- current protection device. Those items are the essential things that everyone should prioritize to check as a part of safety operations. Immediately upon being declared safe to operate, the system is activated to power all electrical loads in location 1 for several days to examine its reliability in providing energy. The test result suggests that the solar power plant is reliable and capable of providing energy for electrical devices used in hydroponics installation. Therefore, the electricity distribution can be done.

Fig. 4. Socialization of the program and the poster of electrical safety.

The considerable evidence of energy distribution is presented in Fig 3. From the top left clockwise direction is the hydroponics system in site 1 and so forth. It shows the grow lights turned on, producing purple light as a combination of red and blue light. It should be noted that this activity took several weeks to complete, and the team worked sequentially according to the availability of the materials. Despite the frames having been entirely constructed, the UV plastic roof was not available yet. Thus, those grow lights were installed several weeks before the plastic roof. Due to the unavailability of the roof, the heat from the sun caused the plants to look wilt. This condition gave a chance to observe how the plants respond to the grow light. According to the first observation after sunset, the growing light stimulation caused the plants to go straight up faster than usual, and the farmers also confirmed it. It means that the plants do respond to the grow light. It accelerates the plants' growth and potentially increases the yields per year. Not only does the solar power plant provide energy for the grow light, but it also delivers energy for the water pumps.

Having the solar power plant installed does not mean eliminating the limitation. The system harvests solar energy and stores it in the batteries as a backup when the outage occurs or during nighttime. Certainly, the batteries undeniably have a maximum limit to store the energy that the farmers should figure out. Turning on numerous electrical loads simultaneously for a long time causes over-discharging of the batteries. It leads the system to shut down until the solar panels recharge the batteries. Considering the limitation mentioned earlier, load management education to the farmers was given to prevent over-discharging. The batteries can provide energy for, in total, 160 Watt of loads for 12 hours without recharging from solar panels, like at nighttime. While during the day, the system could convert the sun irradiation for recharging the batteries and supplying power to the loads simultaneously. By explaining the system's limitation to the farmers, they could manage loads that should be activated at night. As a result, there is no report of electricity supply issue in all sites as from its first operation. It indicates that the power plant is reliable in providing continuous energy for the loads.

Socialization is an imperative activity of this community development program. It is an excellent opportunity to introduce people to renewable energy, specifically solar power plant. On this occasion, the basic principle of the solar power system was given in an understandable way for the residents. Realizing that this program has built a system with a high potential hazard, an education of electrical safety for the residents is vital. The knowledge is delivered and demonstrated with a poster, as shown in Fig 4 right side. As reported by the leader of the group, this activity is expected to be sustainable in the future with new innovations and other impactful ideas. This activity was found to be advantageous for them.

4. Conclusion

The development of a 900 Wp solar power plant and the other facilities for a group of hydroponics farmers have been carried out. This activity has solved some issues encountered by the farmers. The power plant is capable of providing continuous energy, without reliance to the public grid, to operate the electrical devices used in the hydroponics system, such as the grow lights and water pumps. In total, the system can support 160 Watt of electric loads for 12 hours without charging, like at night time. It also shows that the plants responding the stimulation from grow lights. Particularly, the system is now more weather tolerant. The development of UV plastic as the roof protects the plants from the detrimental effect of weather. It reduces the sunlight radiation that causes extreme heat exposure to the

plants. The UV plastic also allows a specific wavelength to pass through, promoting optimum growth, and it prevents the rainwater from entering the nutrient water tank.

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Author Contribution

The activity aims to develop a 900 Wp solar power plant capable of providing energy for running the essential electrical devices for the hydroponics system uninterrupted. This idea is to resolve the energy issue when the outage occurs. Moreover, the reliance on the public grid also adds additional expense for the electricity bill.

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Conflict of Interest

The authors declare no conflict of interest.

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