Optimization of Solar Power Huts: Efforts to Accelerate Electrifying Agriculture for Farmer Groups in West Plembutan, Gunungkidul

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Abstract. The use of modern agricultural tools is expected to be able to boost the productivity of farming businesses, namely through electrifying agriculture. Generally, in remote areas, it is difficult to provide a source of electricity except by generating electricity from renewable sources such as solar energy. In general, the solution to the problem at hand lies in the transformation to solar energy applications. It is necessary to immediately build a solar-powered electric hut on the land of the farmer group. In its use, this solar power hut will be prioritized to supply the energy needs of irrigation pumps in the dry season. In addition, the availability of this resource will support modern agricultural patterns by utilizing electrically powered equipment and even being able to apply agricultural automation technology. As a result, a solar-powered electrical installation with a panel power of 400 WP with the support of a 12 VDC 200 Ah battery was installed. The total power during the day ranges from 1920 Wh assuming 80% usage. This result is quite helpful for irrigation systems in the dry season. For other low-power electrical equipment applications such as automatic water sprayers, this solar power is very capable.

1 Introduction

Plembutan Village is one of 13 villages in the Kapanewon Playen area, Gunungkidul Regency, Special Region of Yogyakarta. The area reaches 533.9 hectares which is divided into 11 hamlets, 42 RTs and 11 RWs. The orbital distance from the Kapanewon/sub-district government center is 3 km, the distance from the district capital is 7 km and the distance from the provincial capital is 40 km.

According to the analysis of regional typology, it shows that most of the Plembutan sub-district is agricultural land (Fig. 1) and the largest number of jobs of the population is farmers, which reaches 1556 people. In relation to these conditions, challenges and demands arise for farmers to begin to transition conventional methods to modern farmers, at least starting to utilize the technology that supports them. Therefore, the Ngudi Subur farmer group was chosen as a pilot project to facilitate solar electric huts to pioneer modern agriculture. The

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Ngudi Subur Farmers Group (Poktan) is a horticultural farmer community located in the Padukuhan area of West Plembutan, with active members of 26 farmers. The agricultural potential in the village consists of rainfed rice fields ± 2 ha, moorland ± 13 ha (for horticultural crops), and yard farmland in the range of 5 ha. Areas with very limited irrigation resources force farmers to rely on the rainy season so that productive land can only be used twice per year.

Fig. 1. Typology of the agricultural area of Plembutan village

The potential of poktan agricultural products is very promising, fertile soil with abundant crops can be obtained when well water reserves are still available after the rainy season (Fig. 2). The habit of moorland farmers to plant chili peppers with conventional irrigation, which they call the term "nyetren", is not able to last for a long time because the water reserves are insufficient.

Fig. 2. Potential of Ngudi Subur farming products

There is a potential water source (irrigation well) in the area, the obstacle is that the water source point is far from the land with inadequate facilities. Until now, the irrigation well has not been able to reach the land. Based on initial observations, it is known that generally the farming methods used by members of the Ngudi Subur group are conventional methods (Fig. 3), they do not yet have modern agricultural facilities and infrastructure, especially supporting electrifying agriculture.

Until now, with the low quantity and quality of agricultural production, the members of the poktan have not felt an improvement in the economy. An effort is needed to accelerate the improvement of the economic level through mentoring and facilitation activities for conventional farmers to modern farmers. Without technological engineering such as moorland irrigation systems, the potential of agricultural land owned by poktan members becomes abandoned and barren, especially in the dry season (Fig.4), in stark contrast to the condition of water sufficiency (Fig.2). In relation to electrifying agriculture, it is very important to find the right solution for remote land that is far from the power source of the state electricity company.

Fig. 3. Conventional farming pattern of group members.

In the current era, the transition of conventional agriculture to modernization requires a touch of technology. Farmers have switched to electric-based agricultural tools and machinery, from previously using fossil fuel equipment which is expensive and damages the environment. However, related to the size of the agricultural area, it will generally experience power grid constraints, this is due to the distance from the location to the settlement. The independent construction of the power grid will of course absorb a very large cost, especially the purchase of very long cables. In addition, if each land creates an electricity network, it will pose its own danger from non-standard installations, and network chaos [14].

Fig. 4. Without irrigation engineering, productive land becomes abandoned.

Regarding the issue of climate change, the application of renewable energy is inevitable. An example is solar energy, through solar cells that are available in abundance in the universe has great potential as an environmentally friendly electricity source. According to Hariyati et al. [10], solar energy is very environmentally friendly and is easily stored in batteries as an energy reserve. Devices to take solar energy into electrical energy are called solar cells [16], or also called Photovoltaic (PV) [8]. PV is usually assembled in a module because of the small power output, this is greatly influenced by the intensity of sunlight [12].

Solar energy that can be used for the entire Indonesian mainland with a value equivalent to 12,000 GWp per day [13].The Indonesian government has officially passed regulations related to the provision of electricity to people in border areas, disadvantaged areas, isolated areas and outer islands. This is useful to provide insight into the use of renewable energy [15]. The implementation of solar lighting systems in public facilities marks a pivotal step towards the realization of smart electricity infrastructure [5][12]. Solar lighting harnesses the abundant and renewable power of the sun, offering a viable alternative to traditional energy sources [9].

Considering the potential of solar energy that is friendly to many people, it needs to be a priority program as a solution to the electricity problem in remote lands to support the improvement of agricultural systems in a modern direction. In addition, the risk of very small hazards is assessed appropriately in its application on agricultural land.

One of the solutions chosen is the utilization of renewable energy sources through the application of solar electricity [6]. The initial investment does look large, but if calculated at operational costs from year to year, it will be more economical and promising. In addition, the security and safety of farmers is a priority.

2 Methodology

2.1 Planning of a Solar Powered Electric Hut

Calculating electrical load involves determining the total power consumption of all devices and systems within a specified area or facility [4][1]. A hut will be built with partners independently, then a solar PV installation will be built in the hut. Four solar panels with a capacity of 100-Watt peak (WP) each will be assembled in parallel to produce an output power of 400 WP. Connecting the cells in parallel will produce higher currents [7]. Therefore, a 50 Ampere MPPT type solar charge controller (SCC) will be used to supply a 12 VDC 100 Ah VRLA battery. In this condition, assuming the sun is hot for 5 hours/day, theoretically there will be 12-13 VDC electricity equivalent (400 W x 5 h) = 2000 Wh or 2 kWh. Storage efficiency is proportional to change taken in the reaction path by the battery between charge and discharge processes [2].

In the application of electric-powered agricultural machinery, it is very likely that electricity is needed in the form of a 220 V AC, therefore a DC to AC inverter is needed. Therefore, a pure sine wave inverter with a capacity of 1000 W will be installed. The inverter will work at a minimum voltage in the range of 10 VDC, therefore if applied to an AC load of 220 V it will only provide power in the range of 300-600 Watts. The concept that will be applied to this solar electric hut is the off-grid method. Two important aspects in designing solar water pumping system are analyzing piping system to determine the type of pump used and the power system planning to ensure the system operates properly [3].

2.2 Irrigation Engineering

Based on the observations that have been made, it is known that the maximum distance that can be reached from the well point to the moor location is in the range of 100 meters (Fig.5). The addition of PVC pipes will be chosen in size of 1.5 inches so that the water supply can be maximized. In this condition, it is considered sufficient to use a 200-Watt booster pump. The height of the 2000–5000-liter reservoir when it is at the highest land location will be installed at a maximum height of 1.5 meters above the ground. Based on calculations, the water will be able to reach all moor locations to the maximum.

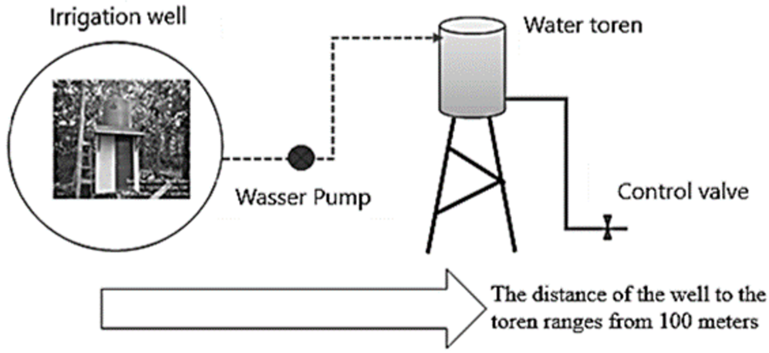

Fig. 5. Irrigation facility engineering

3 Results and Discussion

The first physical activity carried out was the procurement and installation of a Solar Power Plant. According to the plan, at the partner location, supporting components have been installed including pole frames and supports, 4 solar panels of 100 WP each assembled in parallel with a total power of 400 WP, VRLA 100 Ah 12 V batteries, Box panels consisting of Solar Charge Controller type MPPT 50 Ampere, and DC to AC inverter 220 Vac 1000 Watt.

Fig. 6. Setting up solar panels with parallel circuits.

The mast frame is made separately from the support frame to make it easier to install on site. The frame is made in a simple way to support 4 solar panels with a total load of 32 Kg and a support frame in the range of 8 Kg. Solar panels are assembled in parallel with a total area of 27,336 cm^2 (Fig. 6). During the day, the installed system will be used to supply electrical energy to water pumps with a working voltage of 220 VAc and a total power of 200-250 Watts. Therefore, this system is equipped with an inverter that is used to convert the DC power source to 220 VAc. The selection of MPPT Controller is carried out so that the charging current from the solar power plant can work optimally.

Fig. 7. The main water reservoir has a capacity of 5000 liters.

The availability of backup electricity through a 200 Ah 12 V VRLA battery, will be able to output ±2400 VDC of electrical power, but the maximum is only 80% at night. It is therefore sufficient to turn on lighting lamps or modern low-power agricultural equipment. If it is to supply the load needs with AC electricity such as booster pumps and other equipment, the installed system can provide a maximum power of 200 - 500-Watt hours (Wh).

The next stage after the installation of solar power is the construction of a water reservoir. A 5000-liter storage tank is installed in the water source area (Fig.7). At this location, the water source is sucked from the well using a submersible with a large power equivalent to 2 HP, so for this system absolutely use electricity taken from the State Electricity Company. Initial planning related to electrical installation has been adjusted to the load of the submersible pump that will be used. At the location of the drilled well, electricity is installed with a power of 3500 VA 1 phase each to support the performance of a submersible pump with a power of 2 HP.

Fig. 8. Installation of valves and distribution networks.

The final stage of this irrigation development activity is the installation of a water distribution pipe; therefore, the installation of the distribution network is adjusted to the plan along 240 meters or equivalent to 60 PVC pipes. This network pipe will be supported by a 250-Watt plunger pump to fill the reserve reservoir with a capacity of 2000 liters. The pipe, which was originally planned to be buried in the ground, was installed on the ground with the aim of avoiding damage due to land cultivation due to the position of the pipeline on land owned by farmers. To regulate the water distribution process, valves (Fig.8) are installed at several points of pipeline branches in the land area. In addition, to maintain safety and water use, the control tub is given a lockable cover/door.

4 Conclusions

So far, farmers have not been able to use electricity because electricity sources are not available on agricultural land. In addition, the threat of electric shock in several lands that use high-voltage electricity independent installations that do not meet the standards, shows the lack of understanding of farmers regarding electricity utilization procedures. In remote land areas, it is difficult to provide a source of electricity except by generating electricity from renewable sources such as solar energy through transformation to solar energy applications. In addition, with the availability of electricity sources in remote land, it will support modern agricultural patterns by utilizing electric-powered agricultural equipment, and can even apply agricultural automation technology.

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References

1. A. Fokeev, B. Subgatullin, and Y. E. Ahmed, "Methods of electrical loads calculation and selection of electrical power equipment," in *2019 International Conference on Electrotechnical Complexes and Systems (ICOECS)*, 2019: IEEE, pp. 1-6.
2. A. Gurung, Q. Qiao, Joule, **2**, 1217-1230 (2018).
3. A. A. Setiawan, D. H. Purwanto, D. S. Pamuji, N. Huda, Energy Procedia 47, 7-14(2014).
4. A. Wisnujati, L. K. Wardana, and S. Ma'arif, "Pemberdayaan Masyarakat Desa Banguntapan Bantul Melalui Pembuatan Unit Usaha Tempe Kedelai," *Journal of Community Development,* vol. 5, no. 1, pp. 46-56, 2024.
5. E. A. Etukudoh, Z. Q. S. Nwokediegwu, A. A. Umoh, K. I. Ibekwe, V. I. Ilojianya, and A. Adefemi, "Solar power integration in Urban areas: A review of design innovations and efficiency enhancements," *World Journal of Advanced Research and Reviews,* vol. 21, no. 1, pp. 1383-1394, 2024.
6. G. E. Halkos and E.-C. Gkampoura, "Reviewing usage, potentials, and limitations of renewable energy sources," *Energies,* vol. 13, no. 11, p. 2906, 2020.
7. H. Eteruddin, D. Setiawan, A. Atmam. *Web Based Raspberry Monitoring System Solar Energy Power Plant.* IOP Conference Series: Earth and Environmental Science, 469(1), 012051. (2020).
8. J. Milanezi jr, R.S. Ferreira jr, J.P.C.L. da Costa, M.A.M. Marinho, R.A. Shayani, R.T. de Sousa jr, *Energy Harvesting Photovoltaic System to Charge a Cell Phone in Indoor Environments*, in Proceedings of the 2014 International Conference on Composite Materials & Renewable Energy Applications (ICCMREA), 22-24 January 2014, Sousse, Tunisia (2014).

9. R. Apanavičienė and M. M. N. Shahrabani, "Key factors affecting smart building integration into smart city: technological aspects," *Smart Cities,* vol. 6, no. 4, pp. 1832-1857, 2023.
10. R. Hariyati, R., NMHWA. Qosim, Energi Dan Kelistrikan, **11**(1), 17–26 (2019).
11. R. Magrissa, Pengaruh Intensitas Cahaya terhadap Efisiensi Sel Solar pada Mono-Crystalline Silikon Sel Solar. Https://Adoc.Tips/Pengaruh-Intensitas-Cahayaterhadap-Efisiensi-Sel-Solar-Pada.Html. Retrieved November 20, 2022.
12. S. E. Bibri and J. Krogstie, "Environmentally data-driven smart sustainable cities: Applied innovative solutions for energy efficiency, pollution reduction, and urban metabolism," *Energy Informatics,* vol. 3, no. 1, p. 29, 2020.
13. S. Julajaturasirarath, W. Jonburom, N. Pornsuwancharoen, Procedia Eng., **32**, 522-530 (2012).
14. S. Sutoyo, F. Yudhanto. *Supporting Secluded Farm Electricity Using Solar-Powered Hut: Electrifying Agriculture Preparation in Gunungkidul*. E3S Web Conf., 425 -04006. (2023).
15. S. Sutoyo, MA. Shomad, Surya Abdimas, **7**(1), 8-17 (2023).
16. Z. Salam, K. Ishaque, H. Taheri, *An Improved Two-Diode Photovoltaic (PV) Model for PV System*, in Proceedings of the 2010 Joint International Conference on Power Electronics, Drives and Energy Systems (PEDES) & 2010 Power India, 20-23 December 2010, New Delhi, India (2010).