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Installation of solar power plant as power supply for street lighting in livestock area

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ABSTRACT

Sajen Village, in Pacet District, Mojokerto, already has a Village-Owned Enterprise (BUMDes) that is primarily involved in the management of livestock and agricultural products because has village treasury land. Farms with cows and goats are administered by cooperatives of farmers. Even though there is always a livestock supervisor on guard, one of the farm locations closest to the village hall uses makeshift lighting and has a low level of security. This is due to the limited electrical energy which is still sourced from the village hall. In addition, human resources in Sajen village also need to improve their soft skills and hard skills to develop the village and keep abreast of current issues. This initiated the idea of building an independent power plant in the livestock area as a useful energy source for village lighting and security. Off-grid system was built in the livestock area and has been successfully utilized to supply energy for the lighting and security sector in the livestock area. Off-grid systems refer to energy sources that are different from those used by the state power utility. Solar power plant also contributes a percentage of clean energy use in village areas and can be a pilot for further development.

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1. INTRODUCTION

Sajen Village has a great deal of potential for economic pursuits like farming and agricultural tourism. Most Sajen village residents are farmers and ranchers, which has resulted in the establishment of Village-Owned Enterprises (BUMDES) in the fields of animal husbandry and agriculture, which includes various types of vegetables. Livestock is the village's most important commodity, with 766 cattle breeders. BUMDES owns 150 goats and 14 cows in total (Rendi et al., 2023). This farm is located on a large plot of land that is managed by the village using traditional maintenance methods, so there are several challenges that must be overcome, including a lack of access to electricity on the large plot. As a result, the layout of BUMDES communal farms is critical to establishing a clean and orderly livestock area with environmentally friendly livestock and waste management. This, of course, can support the

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vision of Sajen village, which aims to improve the welfare of the village community through economic activities so that it can become self-sufficient. Against this backdrop, an environmentally friendly livestock development program that plays a role in improving the economy of the Sajen village community has been developed, and it is expected to become a model and education in the management of livestock (Rakhmadani, 2021).

Figure 1. The current condition is sometimes goats and cows

The approach offered to the people of Sajen Village is to provide education and training in the application of science and technology in installing solar panels. Solar Panel is equipment that can convert photons in sunlight into electrical energy. Here we will introduce the components and tools for making solar panels and how to assemble solar panels and connect them with other components and use them to produce electricity. The planned activities include: (1) Coordinating the implementation of community service; (2) Providing counseling on the application of solar panel science and technology to be carried out; (3) Providing counseling on installing solar panels for street lighting; (4) Adapting the equipment used in installing solar panels; (5) Practicing solar panel.

The training activities will be carried out in conjunction with solar power plant development activities for lighting in the livestock Area. Partners can expect the following impacts: (1) Increasing village community understanding of environmentally friendly livestock; (2) Improving village economy in livestock sector; (3) Creating good governance of BUMDes and Breeders Groups; (4) Preparing Sajen village to become an independent village and a reference village in livestock. This program's activities will include community service through science and technology implementation activities, as well as public education to produce appropriate documents and technology. This activity will involve lecturers and students from university with various disciplines. Activities will be carried out in collaboration with the government and the people of Sajen Village, without the establishment of hierarchies, but on an equal and mutually supportive basis.

This situation is related to the life of the Simpenan community, because the community requires electricity as the primary source to carry out daily activities such as teaching and learning, long-distance communication, washing, bathing, and other activities. With a solar power plant, it is hoped that the people who live in the area will take part in deceiving it and go directly to the field to apply solar power plant. In fact, due to a lack of information and practice in the field, the Simpenan area still lacks access to electricity as an energy source. Currently, the lack of electricity felt by the people of Sajen Village is no longer unusual, but this does not mean that the lack of electricity can be ignored. As a result, PLN through policies alone is insufficient unless balanced with direct technical assistance. In the meantime, we can study information about solar power plants through various counseling and applications for creating solar power generator circuits. However, if the government is willing to take this matter seriously, the cost will not be a significant difficulty.

The presence of this communal farm can encourage breeders to cooperate, assist one another, and supervise livestock so that the rearing process is more effective, especially with the adaptation of appropriate technology that can help the rearing process be more orderly and efficient. Furthermore, the use of new and renewable energy will assist Sajen village in becoming a pilot village in the use of clean and emission-free energy, which will become the village's main attraction. Furthermore, this technology will be used in street lighting and security systems. Because the lighting in the livestock area, livestock management and supervision can be carried out optimally with the good technology.

2. METHODS

To assist farmer groups in installing solar-powered streetlights, this activity was carried out in the early months of 2023, to be precise, from January to February. The method to be worked on for implementation is as follows: (1) Preliminary research This activity was carried out to obtain a true picture of the problems faced by partner groups on the ground. Direct discussions with Sajen Village, Pacet District, and Mojokerto were used to carry out the activity; (2) Determine the need for activities that will help the partner team solve its problem. The service team will have an idea about where to install street lighting in the livestock area after determining the needs of solar power plant; (3) In the process of installing a solar power plant, solar cells are used to supply street lighting. Installation of solar cells, solar cell control circuits, dry batteries as electrical energy storage, inverters to convert power from DC 12V to AC 220 Volts, and a series of monitoring panels consisting of voltage and current meters are part of the solar power plant installation activities. After that, the solar power plant is connected to street lighting. PLTS also has a place/casing and additional equipment for practicum purposes, such as solar cell covers and changing the tilt angle of the solar panels: (1) Evaluation and implementation After the solar power plant-based street lighting system is installed, each unit is tested. The final test for the lighting of the streetlights was completed. The event took place near a farm in Sajen Village, Pacet District, Mojokerto; (2) the community service team will then monitor and evaluate the implementation of a solar power plant-based street lighting system in Sajen Village, Pacet District, Mojokerto.

Solar Power Plant Installation Design

The proposed solution is to use solar cells to provide electricity to the people of Sajen Village, Mojokerto. This solar cell is a solar power plant in which this tool is powered by the sun and converted into electrical energy. This device is made up of several parts, including solar panels, controllers, batteries, inverters, and switches. The solar panel absorbs solar energy, which is then transferred to the controller. To increase security, the controller is divided into three connection parts, there are solar panels, batteries, and inverters, which can be disconnected and connected using a switch (Purwanto, 2020).

Batteries that are commonly used can be anything, but it is recommended that they can be charged up to thousands of times, such as motorbike or car batteries, which are known as accu. The battery in a solar power plant serves to stabilize the voltage output from the solar panel. Meanwhile, the inverter converts the DC voltage from the battery to AC voltage, which can be used as household electricity. Figure 5 depicts the working principle of a solar cell that can generate electricity for free. It is a series of schematic solar cells in a simplified form (Fatkhurrozi et al., 2019).

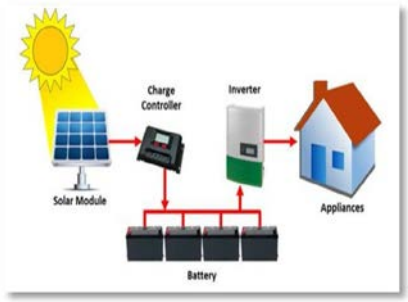

Figure 2. Solar power plant installation design
Figure 3. Solar module

Solar Module Specification

The photovoltaic cell, which converts solar radiation into electric current, is the fundamental component of a PV generator. The cell is composed of a thin layer of semiconducting material, typically silicon, with a thickness of about 0.3 mm and a surface area of 100 - 225 cm^2. Photovoltaic modules in the form of a collection of cells are available on the market. The most common has 36 cells in four parallel rows that are connected in series, with areas ranging from 0.5 to 1 m^2 (Sinarep et al., 2021).

Table 1. Datasheet of solar module

Trina Solar Monocrystalline	
Maximum Power	450 Watt
Maximum Power Voltage	41 Volt
Maximum Power Current	10.98 Amp
Open Circuit Voltage	49.6 Volt
Short Circuit Current	11.53 Volt
Maximum Series Fuse	20 Amp

Source: (Farhana, 2021)

A panel is a common structure that can be installed in a building that is formed by mechanically and electrically connecting several modules. Several panels connected in series form an array, and several arrays connected in parallel to produce the required power form a generator or photovoltaic field.

Specification of Solar Charge Control

Solar charge control, also known as solar charge controller or solar regulator, is a device used in solar power systems to regulate and control the charging process of batteries or energy storage systems. It acts as an intermediary between the solar panels and the batteries, ensuring that the batteries receive the appropriate amount of charge and protecting them from overcharging or over-discharging. The power supplied by the PV generator depends on the point at which the PV generator operates. In order to maximize the energy supply with PV generators, the generator will adapt to the load. single phase inverter circuit PWM 14 output signal so that the operating point always corresponds to the maximum power point (Maximum Power Point – MPP). For this purpose, a controlled chopper (DC-DC Converter) called Maximum Power Point Tracker (MPPT) is used in the inverter or in a separate module. MPPT calculates the instant by instant of the "Voltage - current" value pair of the generator at which the maximum available power is generated (Pujianto et al., 2022).

The MPPT system is used commercially to identify power points on a generator characteristic curve by causing, periodically, small variations of the load that determine the deviation from the voltage-current value and evaluating if the new product I-V is higher or lower than the previously selected one. Due to the required characteristics of the inverter performance requirements for standalone generation and for grid-connected generation the generator must have different characteristics (Nofriadi, 2021): (1) A standalone generator, the inverter must be able to provide the AC side voltage as constant as possible on generator production and varying load demands; (2) In a grid-connected generator the inverter will reproduce, as precisely as possible, the grid voltage and at the same time try to optimize and maximize the energy output from the PV panels.

Figure 4. Solar charge controller module

Table 2. STEC solar charge controller datasheet

STEC Solar Charge Controller	
System Voltage	12 Volt
Rated Current	100 Amp
Max PV Voltage	150 VDC
Max Power	1300 Watt

Specification of Inverter Module

The power conditioning and control system is carried out by an inverter which converts direct current (DC – Direct Current) to alternating current (AC – Alternating Current) and controls the quality of the power output to be sent to the grid, also by means of an LC filter in the inverter itself. The principle of the inverter scheme is as follows. The transistor, used as a static switch, is controlled by an open – close signal which, in simple mode, will output an alternating square wave (Hikmawan & Suprayitno, 2018). To obtain sinusoidal waveforms, a more sophisticated technique namely Pulse Width Modulation (PWM) is used or commonly called Pulse Width Modulation. The PWM technique allows regulation to be achieved on the frequency as well as on the rms value of the output waveform (Pangkung et al., 2021).

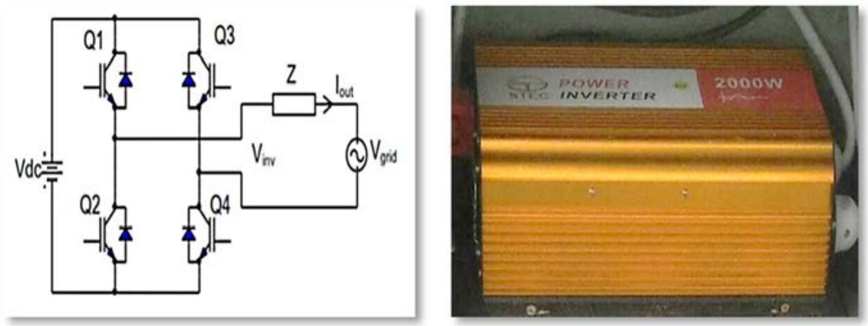

Figure 5. Schematic power inverter module

Table 3. STEC power inverter datasheet

STEC Power Inverter	
Output Waveform	Pure Sine Wave
Power Output	2000 Watt
Input Voltage	24 VDC
Output Voltage	220 VAC

Specification of Battery

The capacity of the battery used is 200 Ah with a voltage of 12 volts DC. The number of batteries used is 2 pieces, because the system voltage used is 24 volts, then the batteries are arranged in series, each of 2 pieces and then arranged in series. Figure 10 is the battery used to store solar power.

Figure 6. Battery Module

From the specifications of several supporting equipment that have been adjusted by the amount of load installed, namely in the form of street lights, then the equipment is assembled according to the schematic described in Figure 2. It should be noted in the installation of solar panels and batteries, avoid short circuits between polarities when performing the installation. When there is a short circuit between the polarities of course there is a very large increase in current.

3. RESULTS AND DISCUSSION

Results from the Installation of PLTS with an Off-grid System

The PLTS installation program was carried out in early 2023, on January 15 to be precise and finished on February 15. By carrying out several stages, namely planning, site selection, solar panel installation, inverter installation, and testing. At the planning stage, the number of solar panels needed is determined and the installation location is determined according to the site conditions (Rumokoy et al., 2020). Then, at the site selection stage, site conditions are measured and ensure the location meets the requirements for installing solar panels. At the stage of installing solar panels and inverters, installation is carried out according to a predetermined plan. Finally, at the testing stage, the solar power plant system is tested to ensure the system can function properly and meet the expected quality (Nurosyid et al., 2019). For selecting the location of the solar panel installation, it must be in an open place, and must not be covered by anything, such as high-rise buildings or shady trees that prevent it from receiving maximum photons. Figure 7 is the location of installing solar panels in open conditions so that the electricity generated can be maximized.

Figure 7. Construction of solar panel support poles

For overall operation, it is necessary to carry out a commissioning test so that the equipment is able to work optimally. In figure 8 students and lecturers are testing the solar power plant system which aims to evaluate the performance and performance of the photovoltaic solar power system. This test involves system components such as solar panels, inverters, and batteries, as well as conducting tests on the system as a whole to ensure that the system can work properly and according to the expected specifications. The purpose of this test is to ensure that the solar power plant system can produce energy with high efficiency, and can meet the energy needs of the user optimally (Alamtsa et al., 2021).

Figure 8. Inverter and SCC module test

To get maximum results in the design of a solar power generation system, it is necessary to determine the position of the support with a tilt angle of the solar panel of 300 to get the light intensity of solar energy properly. The number of solar panels was made as many as 8 modules, in order to get 3,200 WP power the solar panels were installed with 4 series then 2 parallel. In the connection with the support pole, the square panel holder is not permanently connected, but is designed so that it can be moved manually, making it easier to find good light intensity. We recommend that the solar panel support is placed about 4 meters from the ground. After designing the poles to support the solar panels, then immediately mount the solar panels on the support poles (Caroko et al., 2022).

So that the electrical energy produced can also be used in conditions such as at night (conditions when the solar panel is not exposed to the sun), the output of this solar panel must be connected to a storage medium, in this case a battery. But this is not directly connected from the solar panel to the battery, it must be connected to the solar charger controller (SCC) circuit, where in the circuit there is an automatic charger circuit. The function of the solar charger controller (SCC) is to regulate the output voltage of the solar panels and regulate the incoming current to the battery automatically. In addition, the SCC function is to cut off the flow of current from the battery to the load in the event of a short circuit or excessive load (Hayusman et al., 2021).

Commissioning Test Results

The results of testing the equipment, show the measurement data, with a load in the form of a continuous 250 watt lighting lamp showing data as shown in Table 9. The monitoring results show that the battery, which is fully charged from the solar panel, is then given a continuous loading of 250 watts, so only in usage for 3 hours has shown a decrease in inverter voltage by 20%. Therefore it is necessary to increase the current capacity of the battery.

Table 4. Current and voltage measurement data

Observation Time	Solar Panel Output		MPPT Output	
	Voltage (Volt)	Current (Ampere)	Voltage (Volt)	Current (Ampere)
09.00	16.2	1	13.8	1
10.00	17	3.5	13.5	3.5
11.00	17.2	4	13.5	4
12.00	17.3	4.5	13.7	4.5
13.00	17	4	13.5	3.5
14.00	17.1	3.5	13.5	3

After testing the current and voltage on the solar panel components and mppt, then proceed with testing the condition of the battery with full use for 8 hours. Some of the observed data is the inverter voltage then the output current of the battery with a total load of 250 watts. In use, it should not exceed the limit of the state of the charge of the battery. It is important to note that SOC is an approximation and may vary depending on factors such as battery age, ambient temperature and conditions of use. The results of testing the equipment, show the measurement data, with a load in the form of a street light of 250 Watts continuously showing data as in Table 5.

Table 5. Battery usage with street lights

Usage	Current (Ampere)	Inverter Voltage (Volt)	Current (Ampere)	Output Power (Watt)
1	12	220	1.76	250
2	10.8	198	1.58	250
3	9.6	176	1.40	250
4	8.4	154	1.23	250
5	7.2	132	1.05	250
6	6	110	0.88	250
7	4.8	88	0.70	250
8	3.6	66	0.53	250

Results of PLTS Installation and Maintenance training

In the solar power plant installation training activities there are a series of stages, namely first the participants fill out a pre-test questionnaire to find out the participants initial understanding before participating in the training, then the main event, namely the solar power plant installation training mentored by a resource person, then participants fill out a post-test questionnaire to find out whether the participants have understand every material presented during the training. To be able to identify community quality improvements, pre-tests and post-tests were carried out before the event started and after the event.

The pre-test results taken showed that there were still some participants who lacked understanding about the installation of the solar power plant system. Next, a summary of the post-test results of the solar power plant system installation training which shows an increase in participants understanding after attending the training. Meanwhile, the results of the analysis carried out with SPSS can be seen in Table 6.

Table 6. Results of solar power plant installation training analysis with SPSS 23 software

Pre - Post	T	df	Sig.
	-20.055	11	0.000

Table 7. Calculation results of paired samples statistics for solar power plant installation

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre Test	15.167	12	0.834	0.241
	Post Test	20.000	12	0.000	0.000

Based on the results of pre-test and post-test (Table 7), there are differences in the results before and after conducting the training. Participants who previously lacked understanding of solar power plant system installation, after participating in the training received an increase in self-understanding in the solar power plant system installation process, understanding checking and measurement procedures, and gaining basic knowledge about the working procedures and functions of the solar power plant system. In addition, the training participants also gain field experience to understand directly the electrical system of the tools that have been designed. In the future, the training participants are expected to be able to solve electrical problems independently in the solar power plant system and be able to implement work safety according to procedures.

Installing a Solar Power Plant can provide various benefits for the village. Solar power plant uses sunlight as an energy source to generate electricity. It is a clean and renewable energy source that produces no greenhouse gas emissions or air pollution. With access to affordable electricity, villages can increase their economic and development potential. Electricity can be used to support small businesses, such as home industry, food processing, or handicraft production. In addition, villages that have efficient it can also sell excess solar energy to the national grid and generate additional income.

From the solar modul test data in Table 5, the output voltage from the solar panel is around 15.8 – 17.3 VDC. However, the output voltage of the solar charger controller is more stable, which is an average of 13.5 VDC. This situation is the same every hour, this happens because in the solar charger controller there is a series of voltage and current regulators, therefore charging the battery every hour will always be stable so that overcharging will not occur. So even though the solar panels produce a nominal voltage of 17.3 VDC, the battery charging voltage is stable, which is an average of 13.5 VDC. This aims to prevent the battery from being damaged quickly, compared to when the solar panel is directly connected to the battery without going through the solar charger controller.

The process of charging the battery, which is the source of energy from solar panels, is very dependent on the condition of the level of brightness, sunlight radiation and weather, so the average output voltage and current from table 6, observations from 7.00 to 17.00 WIB is 16.7 V/1.5 A. Conversely, if the weather is cloudy or the solar panels don't get enough sunlight, the voltage and current obtained during the battery charging process will decrease. As shown in table 5, the output of the inverter shows that the output voltage is an alternating current that allows it to be used for 3 hours, namely 220 – 176 V with a working current of 1.76 - 1.08 A. However, the current and voltage that is distributed to charge the battery is very stable and regulated by the solar charger controller, which is 13.5 V, and the largest current is 4.5 A. But every day, of course, the weather and environment are different, this greatly affects the amount of power generated. If the voltage on the battery has reached its maximum voltage, which is equal to 13.7 V, the current flowing to the battery will automatically stop because it is equipped with safety equipment in the form of over charging. The best charging is shown in table 5, at 13.00 WIB the output voltage and current of the SCC reached its highest point 13.5 V / 5 A.

Table 8. Solar power plant maintenance management

Module Type	Maintenance Type	Period
Photovoltaic	Module Surface Cleaning	Every 1 month
	Checking the Electrical and Mechanical Connections of the Photovoltaic Module	Every 6 months
MPPT	Equipment Periodic Cleaning and Equipment Corrosion Check	Every 1 month
Inverter	General Maintenance consists of Visual Checking for Any Existing Damage, Checking for Abnormal Sounds, and Checking every Parameter of Inverter Operation	Every 3 months

Several types of equipment require periodic maintenance to maintain their function properly and maintain the life of the equipment so that it can be used longer. Without proper maintenance, solar power plant components such as solar panels, inverters and batteries can experience damage or wear and tear. This can lead to a decrease in overall system efficiency, which means that PV mini-grid will not produce the maximum power it should. In addition to the type of equipment, the Table 8 also contains specific types of maintenance performed on certain equipment as well as an effective schedule for carrying out periodic maintenance.

4. CONCLUSION AND RECOMMENDATIONS

From the results of the activity, it can be concluded the following, to change the 12V DC voltage from the battery (battery to 220 VAC) using an inverter with a capacity of 1000 watts. The average distribution of current and voltage from solar panel sources is 16.7 VDC, but the distribution for charging the battery is very stable with an average of 13.5 V because all charging distribution is regulated by the solar charger controller (SCC). From observations, the most effective time for charging the battery is in the morning at 07.00 – 13.00 WIB. While the maximum flow is obtained at 10.00 - 13.00 WIB. Training on solar power plant installation, maintenance and management of solar power plant can increase the ability of village officials, especially in terms of electricity related to the solar power plant system and environmental security. Solar power plant installation often involves training and knowledge transfer to village communities regarding the operation and maintenance of the PV mini-grid system. This provides an opportunity for village communities to be actively involved in the management and maintenance of the system, which in turn increases their community empowerment and technical skills.

The suggestions given for this activity are as follows, there needs to be good coordination, especially regarding work duties and the participation of both parties before carrying out activities. It is hoped that activities to strengthen and improve the quality of human resources will continue to be carried out routinely so that they can always carry out work evaluations from related parties.

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