Reliability Analysis of Solar Power Plants as an Electricity Supply for Water Pumps for Rice Irrigation Needs in Kampung Lama Besintang Village

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Abstract

This study analyzes the reliability of an off-grid Solar Power System (PLTS) as an energy supply for an irrigation pump in Kampung Lama Besintang Village. The system consists of a 250 Wp monocrystalline panel, a 1600 W hybrid inverter, a 60 Ah 24 V lithium battery, and a 250 W water pump. Data were collected over seven days for solar radiation, electrical output, water flow rate, and system failure history over eight months. Reliability parameters MTBF, MTTR, and Availability were calculated. Results show MTBF of 1,435 hours, MTTR of 5 hours, and Availability of 99.65%. Daily energy production reached 1.13 kWh with a Performance Ratio of 99%. Water production was 9.597 m^3/day, meeting only 12.79% of the irrigation needs of a 0.5-hectare field. The optimal irrigable area was found to be 0.064 hectares. Main failure factors included dust accumulation, inverter overheating, and pump blockage. Recommendations include upgrading the PLTS capacity to at least 2,000 Wp, increasing battery capacity to 200 Ah, routine maintenance, and implementing drip irrigation. This study supports renewable energy development for sustainable agriculture.

Keywords: Off-Grid Solar PV, System Reliability, Irrigation Pump, MTBF, MTTR, Availability, Renewable Energy

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Introduction

Background

The agricultural sector in Indonesia faces challenges related to the availability of sustainable irrigation water, particularly in Kampung Lama Besintang Village, which heavily relies on rainfall and inefficient traditional methods during the dry season [1]. The use of conventional water pumps dependent on fuel or electricity from PLN, which is often interrupted, results in high operational costs, environmental damage, reduced crop yields, and financial losses for farmers.

The global energy crisis and climate change have driven the search for eco-friendly energy solutions, where Solar Power Plants (PLTS) show great potential in Indonesia, located on the equator with an average solar radiation of 4.8 kWh/m²/day [2]. Environmentally friendly solar-powered water pumps have low operating costs and do not require fuel, and they consist of durable components, even though they have been successfully implemented in other countries. However, there are technical and economic challenges such as power requirements, system efficiency, optimal design, and investment return analysis that need to be studied [3]. This study aims to analyse the reliability of solar power systems as an energy source for water pumps to meet irrigation needs in Kampung Lama Besintang Village, which is still rarely studied in Indonesia. This village was chosen due to its development potential, availability of water sources, extensive agricultural land, and support from local farmers. The research will evaluate reliability through technical analysis, efficient design, and performance testing to ensure a stable energy supply [4]. It is hoped that the results of this research can contribute to sustainable agriculture, national food security, the reduction of greenhouse gas emissions, and serve as an example for other agricultural regions in Indonesia.

Literature Review

Reliability of Solar Power Generation Systems

The reliable performance of a Solar Power Generation System (PLTS) is crucial to ensure an uninterrupted energy flow, reflecting the system's capacity to operate smoothly over a certain period, and is evaluated through three main metrics: Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), and Availability (A) [5]. The calculation of these indicators is formulated as follows:

$$MTBF = \frac{Total\ Operating\ Time}{Number\ of\ Failures}, MTTR = \frac{Total\ Repair\ Time}{Number\ of\ Failures},$$

$$Availability = \frac{MTBF}{MTBF + MTTR} \times 100\%$$

MTBF measures the duration of operation without interruptions, MTTR the average repair time, and Availability the frequency of system readiness. All three support preventive maintenance to enhance reliability [6].

Solar power generation

The energy production of PV systems is calculated from the instantaneous power obtained by multiplying voltage (V) and current (I), as well as the daily energy accumulation obtained from power multiplied by operating time (t): $P = V \times I$ dan $E = P \times t$ [7] using this formula in rooftop PV economic analysis to determine instantaneous power under various operational conditions.

System efficiency is estimated using the Performance Ratio (PR) as a correction factor compared to ideal conditions: $E\ PV = \frac{Wp \times H \times PR}{1000}$ where Wp is the panel capacity in Watt-peak, H is the daily solar radiation (kWh/m²/day), and PR is generally 0.7 – 0.85 to account for environmental and component losses [8].

Energy Requirements and Irrigation Water Pump

Analysis The energy requirement of an irrigation water pump is calculated from the pump power and operating hours using the formula: $E = P\text{pompa} \times t$

The water flow that can be pumped is expressed as: $V = Q \times 60 \times t$, where V is water volume (Litres), Q is pump flow rate (L/min), and t is operating time (hours) [9].

The hydraulic power of the pump is calculated as: $P\ h = p \times \text{g} \times Q \times H$, where ρ = 1000 kg/m³, g = 9.81 m/s², Q is volumetric flow rate (m³/s), and H is total head (m). The actual electrical power takes into account pump efficiency hpump: $P\ elec = \frac{P\ h}{\eta\ \text{pump}}$ where pump efficiency varies between 0.4 and 0.7 [10].

Design of PV System Capacity

The design of PV system capacity includes the calculation of solar panel and off-grid battery capacity using:

$$Wp\ needed = \frac{E\ required \times 1000}{\text{H} \times \text{PR}}, \qquad Battery\ Ah = \frac{E\ storage}{V\ system \times DoD}$$

with the DoD as the allowable battery depth of discharge to ensure operation during bad weather [11].

Research Methodology

Research Stages

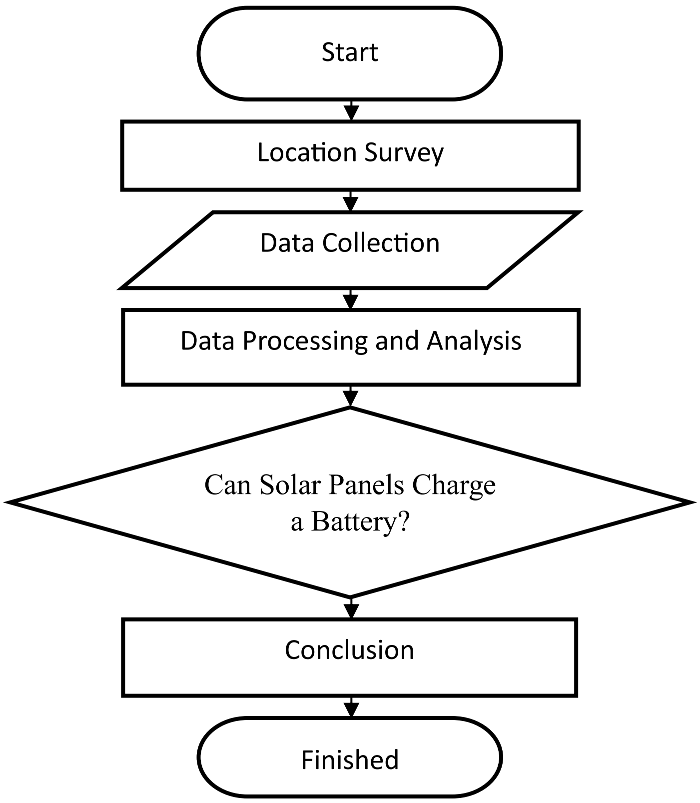

Figure 1. Research Stages

Type of Research

This study uses a quantitative method with a descriptive approach to examine the performance and reliability level of an off-grid Solar Power Plant (PLTS) system applied to rice field irrigation pumps [12]. The research is located in Kampung Lama Besintang Village, chosen due to its large solar energy resource potential to support irrigation [1]. The study was conducted over 7 days from 4 to 10 November 2025.

Research Object

The research object is a single unit of an off-grid Solar Power Generation System (PLTS). This system was chosen for its representation of independent energy solutions in remote areas [13]. The technical specifications of the off-grid PLTS under study are detailed in Table 1 below.

Table 1. PLTS Component System Specifications

Component	Specification	Description
Solar Panel	Monocrystalline 250 Wp	Quantity 1 Solar Panel
Total Capacity	250 Wp	Total Installed Power
Inverter	1600 W Efficiency 95 %	Hybrid Inverter
Battery	60 Ah 24 VDC	Lithium
Water Pump	Shimizu Ps 230 Bit 220 V	Power 250 Watt
Pump Flow Rate	50 Litres/Minute	Maximum
Well Depth 12 Metres		-

Figure 2. Research Object

Data Collection Techniques

Techniques Data collection in this study was carried out using several techniques detailed in Table 2. These techniques were selected to ensure that the data obtained is accurate, relevant, and comprehensive, thereby supporting an in-depth analysis of the performance of the off-grid PV system.

Table 2. Data Collection Techniques

Parameter	Instrument	Method	Frequency
Solar radiation	Solar Power Meter	Direct measurement	At the inverter output Every hour (07:00–17:00)
DC voltage	Digital Multimeter	Measurement at the panel output	Every hour
DC curren	Digital Multimeter	Clamp meter	Every hour
AC voltage	Digital Multimeter	At the inverter output	Every hour

Water flow	Water Flow Meter	Direct measurement	3x times a day (morning, noon, evening)
Panel temperature	Infrared Thermometer	Surface measurement	Every 2 hours Once
Hiatorical data	Interviews & Documents	Data verification	1x

Data Analysis

Data analysis is conducted in stages, including:

a. Calculation of PV system power and energy using the formula
   $P = V \times I$ and $E = P \times t$
   Example calculation: Voltage (V) = 240 volts, Current (I) = 5 amperes, Time (T) = 10 hours/day
   $P = 250 \text{ V} \times 5\ A = 1200\ Watts$ and
   $E = 1200\ Watts \times 10\ hours = 12.000 Wh = 12\ kWh/day$

b. Reliability calculation using the formula
   $MTBF = \frac{Total\ Operating\ Time}{Number\ of\ Failures}$, $MTTR = \frac{Total\ Repair\ Time}{Number\ of\ Failures}$ and $Availability = \frac{MTBF}{MTBF+MTTR} \times 100\%$
   Example calculation: Total operating time = 800 hours (1 month), Number of failures = 1, Total repair time = 4 hours
   MTBF= (800 hours)/1=800 hours, MTTR= (4 hours)/1=4 hours,
   Availability= (800 hours) / (800 hours+4 hours) ×100% = 99.5%
   $MTBF = \frac{800\ hours}{1} = 800\ hours, MTTR = \frac{4\ hours}{1} = 4\ hours, Availability = \frac{800\ hours}{800\ hours+4\ hours} \times 100\% = 99{,}5\%$

c. Calculation of water volume based on flow rate and operation duration
   $V = Q \times 60\ \times t$
   Example calculation: Flow rate (Q) = 20 litres/second, Duration (t) = 60 minutes = 3600 seconds
   $V = 20\ litres/second \times 3600\ = 72.000 \text{ litres} = 72 m^3$

d. Analysis of irrigation water requirements based on evapotranspiration and irrigation system efficiency.

All analysis results were compared to assess the adequacy of the PV system's capacity for the pump's energy needs and irrigation water volume [14].

Research Results

Overview of the PV System

The off-grid PV system studied serves as a power source to operate the irrigation water pump in the rice fields of Kampung Lama Besintang Village. This device uses a 250 Wp monocrystalline solar panel, a 1600 W hybrid inverter with 95% efficiency, a 60 Ah (24 VDC) lithium battery, and a Shimizu PS 230 BIT water pump with a power of 250 W and a maximum pumping capacity of 50 litres per minute. The system has been operational for approximately 8 months and is used daily by farmers to meet irrigation needs. The study was conducted through a series of direct field measurements over 7 days and records of the issues that occurred during the system's operation. In this way, the data obtained not only reflects its performance at the time but also the overall reliability of the system.

Figure 3. Overview of the PV System at the Location

Characteristics of Solar Radiation

During the study, solar radiation measurements were taken every hour. An average daily radiation of 4.55 kWh/m²/day was recorded, consistent with the characteristics of regions near the equator. Complete information on this solar radiation data can be seen in Table 3 below.

Table 3. Solar Radiation Data During the Measurement Period

Time	**Day 1 (04/1)**	**Day 2 (05/11)**	**Day 3 (06/11)**	**Day 4 (07/11)**	**Day 5 (08/11)**	**Day 6 (09/11)**	**Day 7 (10/11)**	**Average**
	W/m^2	W/m^2	W/m^2	W/m^2	W/m^2	W/m^2	W/m^2	W/m^2
07.00	139	132	168	158	135	126	114	138
08.00	320	325	318	330	319	321	315	321
09.00	450	461	421	399	430	474	363	428
10.00	650	626	712	615	587	552	635	625
11.00	750	723	767	852	735	789	741	765
12.00	710	709	618	735	775	718	658	703
13.00	580	565	655	678	722	765	598	651
14.00	420	448	498	522	462	408	438	456
15.00	280	232	292	308	245	298	325	282
16.00	170	188	155	168	208	202	182	181
Daily Total	**4.469**	**4.409**	**4.604**	**4.765**	**4.618**	**4.653**	**4.369**	**4.550**
kWh/m^2 /day	**4,46**	**4,40**	**4,60**	**4,76**	**4,61**	**4,65**	**4,36**	**4,55**

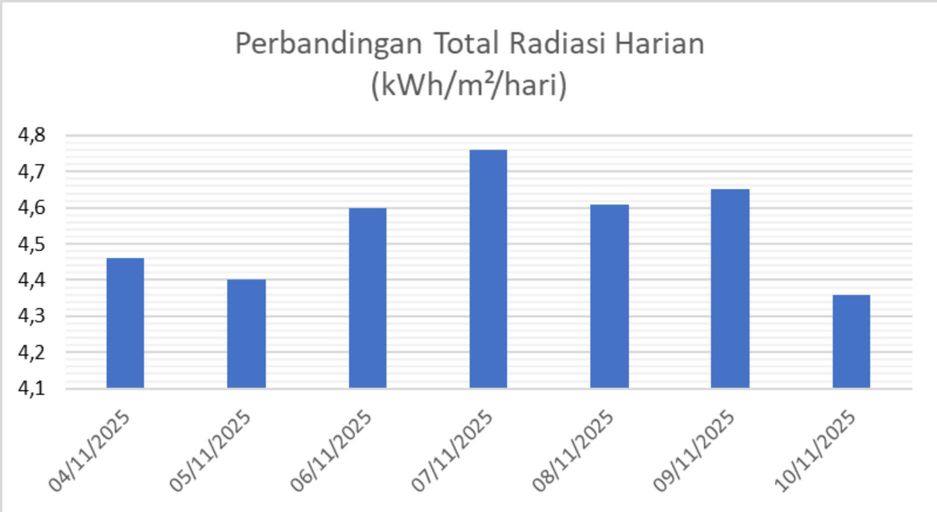

Figure 4. Daily Total Radiation Comparison Graph

Radiation gradually increased from 7 am, reaching a peak of 703 W/m² between 11 am and 12 noon, then decreased until the afternoon. This pattern produces 4.37 Peak Sun Hours (PSH), ideal conditions for 250 Wp solar panels to operate optimally. High radiation indicates an environment that supports maximum PV system output, so performance variations are likely caused by the system's components and operations.

Voltage and Current

DC voltage and current measurements on the panel output and AC on the inverter output were taken every hour simultaneously with solar radiation measurements. The measurement data are presented in Table 4.

Table 4. DC Voltage and Current Data of the Solar Panel and AC Output of the Inverter

Time	**Radiation W/m²**	**DC Voltage (V)**	**DC Current (A)**	**DC Power (W)**	**AC Voltage (V)**
07.00	138	16,23	2,93	34,50	205
08.00	321	23,92	5,36	80,25	210
09.00	428	26,91	6,26	107,00	215
10.00	625	28,01	7,30	156,25	220
11.00	765	30,00	8,00	191,25	225
12.00	703	29,32	7,66	175,75	223
13.00	651	28,59	7,45	162,75	222
14.00	456	27,64	6,49	114,00	218
15.00	282	22,62	4,99	70,50	212
16.00	181	18,46	3,40	45,25	208
Average	**455**	**26,32**	**6,28**	**113,65**	**216**

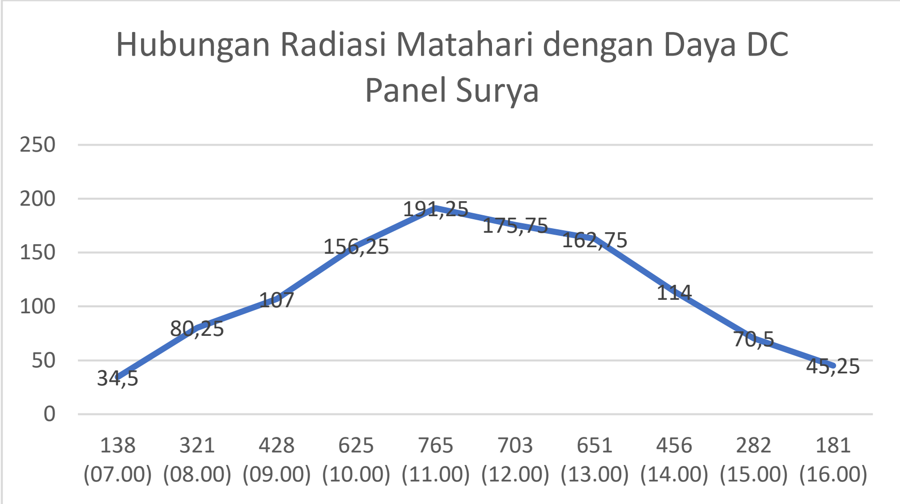

Figure 5. Graph of the Relationship between Solar Radiation and the DC Power of the Solar Panel

The DC voltage and current show a direct correlation with the intensity of radiation received by the panel. The average DC power produced during the measurement period is 113.65 W. Therefore, the solar panel efficiency can be calculated as follows:

Calculation of Solar Panel Efficiency where the known values are:

a. Area of a standard 250 Wp monocrystalline solar panel = 1.64 m²
b. Maximum power produced = 113.65 W (at 455 W/m² radiation

$$\eta\ panel = \frac{P\ output}{P\ input} \times 100\%$$

$$\eta\ panel = \frac{113{,}65\ W}{455\ \mathrm{W/m^2} \times 1{,}64\mathrm{m^2}} \times 100\% = \frac{113{,}65\ W}{746{,}2\ W} \times 100\% = 15{,}23\%$$

A solar panel efficiency of 15.23% indicates good performance for a monocrystalline panel, which typically has an efficiency between 17-22%.

Solar PV Energy Based on Daily Power

Based on measurements over 7 days, the daily energy produced by the PV system is calculated using the numerical integration method (hourly power summation).

Daily Energy Calculation: $E\ daily = \sum_{t=1}^{n} Pt \times \Delta t$

$$E\ daily = (34{,}50 + 80{,}25 + 107{,}00 + 156{,}25 + 191{,}25 + 175{,}75 + 162{,}75 + 114{,}00 + 70{,}50 + 45{,}25)\ Wh$$

$$E\ daily = 1.137{,}5\ Wh \div 1000 = 1{,}13\ kWh$$

Calculation using the performance ratio method: $E\ PV = \frac{Wp \times H \times PR}{1000}$

Where:

a. Wp = 250 Wp
b. H = 4,55 kWh/m²/day
c. PR = 0,75 (assumed for off-grid system with losses)

$$E\ PV = \frac{250\ \times 4{,}55\ \times 0{,}75}{1000} = E\ PLTS = 0{,}85\ kWh/day$$

Difference Analysis:

a. Measured energy: 1,13 kWh/day
b. Energy calculated with PR: 0,85 kWh/day
c. Difference: 1,13 – 0,85 = 0,28 kWh/day (32,94% higher)

This difference can be explained because a Performance Ratio of 0.75 is too conservative for the system, the solar panel conditions are very good and clean, and the inverter efficiency reaches 95% (higher than the general assumption of 85-90%). However, the actual energy is much higher (1.13 kWh), so the actual PR is: $PR\ aktual = \frac{E\ daily \times 1000}{Wp \times H}$

$$PR\ aktual = \frac{1{,}13\ \times 1000}{250 \times 4{,}55} = \frac{1.130}{1.137{,}5} = 0{,}99 \times 100\% = 99\%$$

A 99% value is very rare to find in off-grid PV systems, indicating that system losses are minimal, component efficiency is stable and the system is operating in good condition.

Water Pump Energy Requirement

The Shimizu PS 230 BIT water pump with a power of 250 W is operated on average 3.5 hours per day based on interviews and field observations.

Pump Energy Requirement Calculation: $E\ pump = P\ pump \times t\ pump$

$$E\ pump = 250\ W \times 3{,}5\ hours = 875\ Wh \div 1000 = 0{,}875\ kWh/day$$

With an energy production of 1.13 kWh/day, there is a surplus of 0.255 kWh (29%) each day. This energy surplus provides a safety margin against weather variations and keeps the battery's operating cycle healthy. Therefore, it can be concluded that in terms of electrical energy, the PV system is more than sufficient to operate the pump.

Energy System Efficiency

The total efficiency calculation from solar panels to water pumps can be calculated using the following formula:

$$\eta\ total = \eta\ panel \times \eta\ charge\ controller \times \eta\ battery \times \eta\ inverter$$

Where:

a. η panel = 15,23%
b. η charge controller = 98% (assumed for MPPT controller)
c. η battery = 95% (round-trip efficiency lithium)
d. η inverter = 95% (specification)

$$\eta\ total = 15{,}23\% \times 98\% \times 95\% \times 95\% = 0{,}1523 \times 0{,}98 \times 0{,}95 \times 0{,}95$$

$$\eta total = 0{,}13\%$$

The total system efficiency of 0.13% is a reasonable value for an off-grid solar PV system with batteries.

Analysis of Water Discharge and Volume

Water discharge measurements were carried out three times a day (morning, afternoon, evening) for seven days using a water flow meter. The data is presented in Table 5.

Table 5. Water Pump Discharge Data (litres/minute)

Day	Morning (08.00)	afternoon (12.00)	Afternoon (16.00)	Average
04/11/2025	45,2	47,6	45,5	46,1
05/11/2025	47,1	48,2	46,0	47,1
06/11/2025	44,6	45,3	44,1	44,6
07/11/2025	45,0	46,4	44,9	45,4
08/11/2025	46,7	47,9	45,4	46,6
09/11/2025	44,8	45,4	44,2	44,8
10/11/2025	45.1	46,7	44,5	45,4
Average	**45,5**	**46,7**	**44,9**	**45,7**

The average pump flow rate is 45.7 L/min, slightly below the maximum specification of 50 L/min. The dropin flow rate in the afternoon is due to battery voltage decline and reduced pump performance after several hours of operation.

Daily Water Volume

Calculation of the pumped water volume: $V = Q \times 60 \times t$

Where:

a. V = water volume (Litres)
b. Q = average pump discharge = 45,7 Litres/minutes
c. t = operating time = 3,5 hours

$$V = 45{,}7 \times 60 \times 3{,}5 = 9.597\ litres/day = 9{,}597\ m^3/day$$

It can be concluded that the water volume that can be pumped in one day is 9,597 litres/day with an average operating time of about 3.5 hours..

Hydraulic Power and Pump Efficiency

Analysis Pump Data:

a. Well depth (Total Head) = 12 m
b. Flow rate = 45.7 L/min = 0.000761 m^3/s
c. Pump electric power = 250 W

Hydraulic Power Calculation: $P\,h = p \times g \times Q \times H$

Where:

a. ρ = 1000 kg/m^3 (density of water)
b. g = 9,81 m/s^2 (gravitational acceleration)
c. Q = 0,000761 m^3/s
d. H = 12 m

$$P\,h = 1000\ kg/m^3 \times 9{,}81\ m/s^2 \times 0{,}000761 m^3/s \times 12\ m = 89{,}58\ W$$

Pump Efficiency Calculation: $\eta\ pump = \frac{Ph}{P\ elec} \times 100\%$

$$\eta\ pump = \frac{89{,}58\ W}{250} \times 100\% = 35{,}83\%$$

Pump efficiency of 35.83% falls within the normal range for this type of submersible pump (35-50%), although it is somewhat low. This indicates losses due to mechanical friction, internal leakage and hydraulic losses.

Irrigation Water Requirement Analysis

The rice field area served is 0.5 hectares = 5,000 m². For Ciherang rice variety during the vegetative phase, where the water requirement components are Evapotranspiration (ETc) = 6 mm/day, Percolation = 2 mm/day, and Land Preparation = 1 mm/day.

Theoretical Water Requirement Calculation:

$$Water\ Requirement\ = (ETc\ + Percolation + Other\ Needs) \times area$$
$$Water\ Requirement\ = (9\ mm/\ day \times 5.000\ m^2) = (0{,}009\ m \times 5.000\ m^2)$$
$$Water\ Requirement\ = (0{,}009\ m \times 5.000\ m^2) = 45\ m^3/day$$

The calculation of irrigation water requirement considers an irrigation efficiency of 60%, which is a common value for surface irrigation systems with good management [15].

$$Actual\ water\ requirement = \frac{45}{0{,}6} = 75\ m^3/hari$$

Irrigation Water Sufficiency Analysis

The following presents a comparative analysis of availability versus needs in Table 6 below.

Table 6. Comparison of Water Availability Vs Water

Parameter	Value	Description
Available water volume from the pump	9.597 m^3/day	Operation 3.5 hours
Irrigation water requirement	75 m^3/day	For 0.5 ha
Water shortage	-65,403 m^3/day	Insufficient
Fulfilment percentage	12,79%	Very low

Critical conclusion the current system is insufficient to meet the irrigation water needs for 0.5 hectares of rice field. It can only fulfil 12.79% of the total requirement.
With the current pump capacity, the land area that can be supplied:

$$Optimal\ area = \frac{Available\ volume}{Requirement\ per\ m^2}$$

$$Optimal\ area = \frac{9{,}597\ m^3/day}{75\ m^3/\ 5.000 m^2} = \frac{9{,}597\ m^3/day}{0{,}015} = 639{,}8 m^2$$

Serviceable optimal area = 639.8m² or 0.063 hectares. This means the current system is only suitable for serving an area of less than 0.1 hectares, not 0.5 hectares as initially planned.

Reliability Analysis of the PV System

Based on interviews with the head of the farmer group and maintenance over 8 months of operation (240 days), failure data was obtained as shown in Table 7.

Table 7. Historical System Failure Data.

No	Failure Type	Category	Date	Downtime Duration	Cause
1	Inverter total failure	Major	15/04/25	6 hours	Overheating
2	Pump jammed	Major	03/06/25	8 hours	Debris in impeller
3	MCB trip	Major	28/06/25	2 hours	Temporary overload
4	Panel efficiency drop	Minor	12/08/25	-	Thick dus
5	Pump performance drop	Minor	25/08/25	-	Flow rate decreased by 15%
6	Battery voltage drop	Major	10/10/25	4 hours	BMS protection
7	Panel dirty	Minor	02/11/25	-	Not cleaned
Total Major Failures		**4 Times**	**-**	**20 hours**	**-**
Total Minor Failures		**3 Times**	**-**	**-**	**-**

Explanation:

a. Major Failure: The system does not operate at all
b. Minor Failure: The system operates but with reduced performance

MTBF (Mean Time Between Failure) Calculation: $MTBF = \frac{Total\ Operating\ Time}{Number\ of\ Failures}$

Where:

a. Total observation time = 240 days × 24 hours = 5,760 hours
b. Actual operating time = 5,760 - 20 = 5,740 hours

c. Number of major failures = 4 times

Calculation: $MTBF = \frac{5.740\ hours}{4\ times} = 1.435\ hours$

Conversion to days: $MTBF = \frac{1.435\ hours}{24\ hours/day} = 59{,}8\ day$

The MTBF of 59.8 days means that on average the system experiences a failure requiring repair every 2 months. This indicates fairly good reliability for a small-scale off-grid PV system.

MTTR (Mean Time ToRepair) calculation: $MTTR = \frac{Total\ Repair\ Time}{Number\ of\ Failures}$

Where:

a. Total repair time (downtime) = 20 hours
b. Number of major failures = 4 times

Calculation: $MTTR = \frac{20\ hours}{4\ times} = 5\ hours$

Conclusion an MTTR of 5 hours indicates that the average time required to repair the system after a failure is 5 hours. This is considered fast because components are easily accessible, operators are trained, spare parts are available, and the system design is simple.

Availability Calculation (System Availability): $A = \frac{MTBF}{MTBF+MTTR}$

Calculation: $A = \frac{1.435}{1.435+5} = \frac{1.435}{1.440} = 0{,}9965 \times 100\% = 99{,}65\ \%$

Conclusion an availability of 99.65% indicates that the system is available and operational for 99.65% of the total time, experiencing only 0.35% downtime. This value is considered very good according to industry standards.

Conclusion

This study shows that the off-grid PV system has very good efficiency and reliability as an energy source for irrigation pumps. An MTBF of 1,435 hours, MTTR of 5 hours, and availability rate of 99.65% indicate that the system can operate stably with minimal disruptions, although four significant failures and several minor disturbances were detected during the observation period. In terms of energy performance, the system generates 1.13 kWh/day with a Performance Ratio (PR) of 99% and panel efficiency of 15.23%, thus meeting the pump's energy requirement of 0.875 kWh/day with a surplus of 29%. The pump operates at an average flow of 45.7 L/min and produces a water volume of 9.597 m^3/day, with a hydraulic efficiency of 35.83%, indicating that the mechanical performance of the pump is still optimal. However, the hydraulic capacity of the system is not yet sufficient to meet all irrigation needs. With a water requirement of 75 m^3/day for an area of 0.5 hectares, the system can only supply 12.79%, thus the effective service coverage is limited to 0.064 hectares. These results indicate that the PV system is adequate in terms of energy supply, but an increase in hydraulic capacity is still needed to support irrigation needs for a larger area.

Suggestion

To improve the efficiency of the PV system as a power source for irrigation pumps, it is recommended to increase the capacity of the solar panels to around 2,000 Wp and add batteries up to 200 Ah to ensure a more consistent energy supply under various weather conditions. Hydraulic performance should be optimised through the use of more efficient pumps and the installation of pre-filters to minimise the risk of blockages. The use of water-saving irrigation technologies such as drip irrigation is highly recommended to make better use of the available water volume. Additionally, regular maintenance of the panels, inverter, and pumps is crucial to reduce the likelihood of malfunctions and enhance system reliability.

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