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Design and Simulation of an Intelligent Standalone Solar Photovoltaic System with Battery Energy Storage for Rural Healthcare Facilities in Nepal

Sunny Kumar Sah, Ujwal Chaudhary, Bhrigu Raj Bhattarai*

Institute of Engineering, Department of Electrical Engineering, Paschimanchal Campus, Tribhuvan University, Pokhara, Nepal

*Author to whom correspondence should be addressed; E-Mail: bbhattarai@wrc.edu.np

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Abstract

In rural Nepal, frequent power outages and an unstable grid often stand in the way of life saving medical care. This project addresses this challenge by designing and simulating a self-sufficient, 12 kW "smart" solar system specifically for the health post in Rana Gaun, Jajarkot. Equipped with a 60kWh battery bank and high-efficiency power converters, the system is designed to handle a peak demand of 2710 W. At its core is an intelligent management system that automatically prioritizes electricity for critical needs like vaccine refrigeration and delivery room lighting ensuring these essential services never lose power, even when sunlight is low. Using PVsyst for solar profiling and MATLAB/Simulink for performance testing, the system was evaluated under various weather conditions. The results demonstrate that the design provides a steady, reliable energy supply. Additionally, the inclusion of a specialized LCL filter significantly improved power quality, reducing electrical distortion to levels safe for sensitive medical equipment. By bridging the energy gap, this smart solar solution offers a sustainable way to ensure that remote healthcare facilities can provide uninterrupted care to their communities.

Keywords

Solar standalone system, Intelligent backup system, Rural Health Infrastructure, Battery management system, Load Priority

1. Introduction

A standalone system is a self-contained device, software or machine that operates independently without requiring external connections, networks or other devices to perform its core functions. At the main core of many modern standalone systems is a solar (PV) technology used widely all over the world. Solar Photovoltaic (PV) systems operate on the principle of the photovoltaic effect, where semiconductor materials convert sunlight directly into DC electricity [1-3]. These systems are widely used in distributed energy applications due to their scalability and dependence on solar irradiation. Renewable energy, particularly solar power presents a high solar irradiance of about 3.6-6.2 kWh/m^2/day In Nepal. Nepal has 300 bright days and 6.8 hours of sunshine per day, indicating a significant potential for free and clean solar energy.

A fundamental approach to modelling a PV cell is through its equivalent electrical circuit. However, the operational success and sustainability of these microgrids are not guaranteed. Studies on existing microgrids in Nepal and other developing countries have identified several challenges that lead to performance issues and, ultimately, failure These include technical issues like inadequate system design, component failure (especially batteries), and a lack of skilled technicians for operation and maintenance [4-6]. The single diode model is widely used due to its balance of accuracy and simplicity. The model consists of a current source representing the photo-generated current, a diode representing the p-n junction, a series resistance (R_s) accounting for internal losses, and a shunt resistance accounting for leakage currents [7].

The energy generated by PV panels can be used immediately or can be stored in batteries, which serves as a backup power unit by storing electrical energy in chemical form and releasing it as needed [8-9]. In the remote corners of Nepal, a reliable source of electricity is often the difference between life and death. While the national power grid has expanded, many rural health posts and birthing centers still struggle with frequent outages or remain completely off the grid. This lack of power hits hardest where it is needed most: keeping life-saving vaccines cold, lighting delivery rooms during nighttime emergencies, and powering essential medical monitors. For years, healthcare workers in these communities have had to make do with whatever they had performing deliveries by torchlight or relying on expensive, noisy, and polluting diesel generators. When the power fails, the "cold chain" for vaccines is broken, leading to the heartbreaking waste of immunizations that children desperately need [10-12]. While important steps have been taken by organizations like UNDP and UNICEF to bring solar energy to these regions, many of these existing systems still use basic setups that lack the "intelligence" to manage energy efficiently during long stretches of bad weather. This is where smart technology comes in. By using microgrids small, localized power systems. we can combine solar panels with advanced battery management that monitors everything from temperature to energy levels. Unlike standard systems, a "smart" microgrid can think for itself, prioritizing power for a vaccine fridge or an oxygen concentrator over less critical needs [13-14]. This project explores how these intelligent systems can provide a more reliable, sustainable, and high-tech solution for Nepal's rural healthcare, ensuring that no clinic is left in the dark when a patient's life is on the line.

2. Methodology

The proposed system and research methodology, as illustrated in Figure 1, consists of a 12 kW photovoltaic (PV) system, a 300 V, 200 Ah battery energy storage system, and an intelligent load management and control system. The system is designed to efficiently manage and supply electricity to critical electrical loads in rural healthcare facilities, particularly rural health posts in Nepal, ensuring reliable and sustainable power for essential healthcare services.

The process begins with an extensive literature review to analyse existing solar energy systems, energy management systems and intelligent load management models, identifying gaps and best practices. Following this, the site selection is conducted based on factors such as energy demand, solar potential, and healthcare infrastructure needs. Detailed load profiling is also performed using smart meters to record real time energy consumption patterns of critical equipment, lighting and refrigeration system.

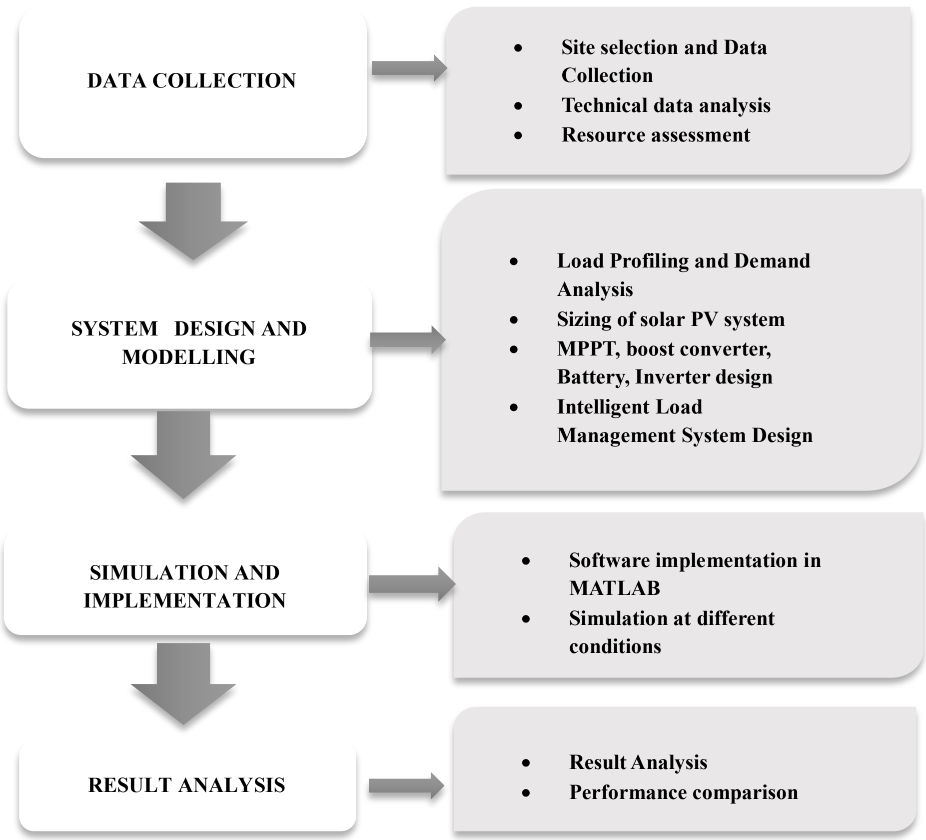


Figure 1: Proposed Research framework

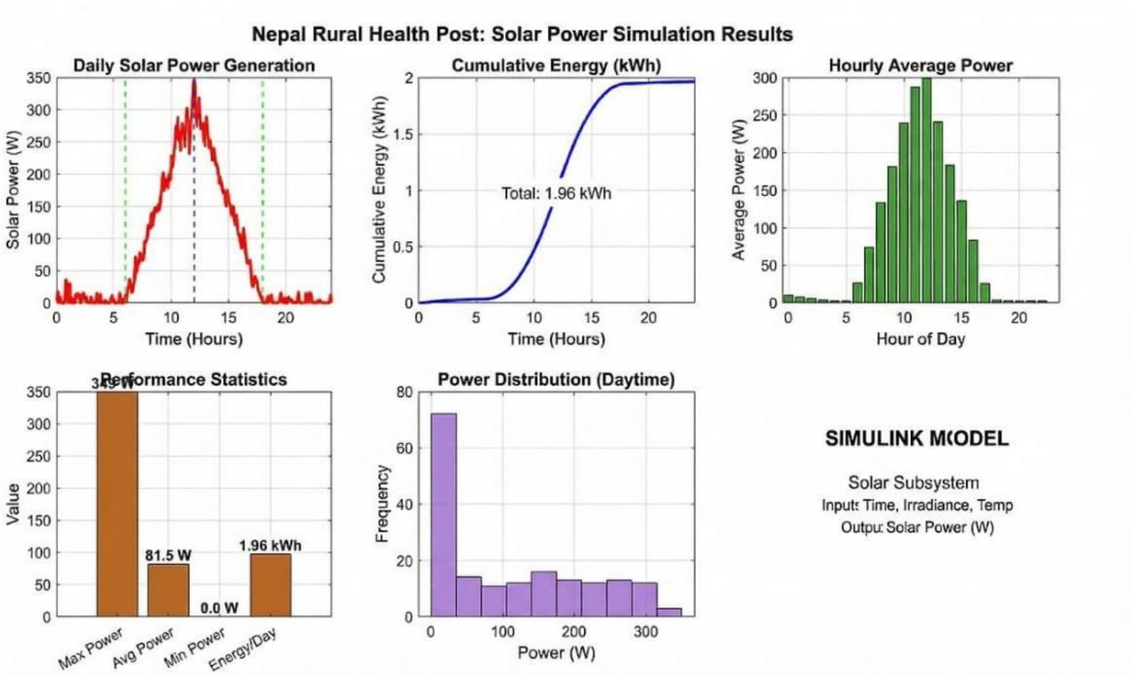


Figure 2: Solar power simulation results

Figure 2 shows MATLAB/Simulink-Based Simulation Results of the Solar Photovoltaic System for a Rural Health Post in Nepal.

2.1 Data Collection

The selected site is Ranagaun's health post, Jajarkot with Latitude 28.70° N and Longitude 82.19° E with altitude 1198m. Solar resource assessment can be carried out using NASAs Surface Meteorology and solar Energy (SSE) database and MeteoNorm 8.2 station is used to determine site-specific solar irradiance levels. This data is modeled in PVsyst to estimate energy generation potential. From the above result we conclude the particular place has the average global irradiance of 4.68 kwh/m^2/day and temperature as 20.3 °C. Considering the various parameters such as wind velocity as 1.6 and clearness index as 0.525 as per the particular location, In the modeling we have taken standard global irradiance of (1000,500,300,200) w/m^2/day and the overall temperature we have taken as 25 °C.

A techno-economic analysis evaluates the financial feasibility, comparing different systems configurations (PV, Battery storage) to optimize Levelized cost of energy and Net Present Cost. Additionally, Stakeholder consultations with local health authorities' utility providers and community leaders ensure regularity compliance and social acceptance. The feasibility study concludes with a risk assessment, identifying challenges such as battery degradation and cloudy-day resilience, along with mitigation strategies [15-16].

2.2 System Design and Modeling

The system design and modelling ensure the micro grid is optimized for reliability, cost and performance. Figure 3 shows the block diagram of the proposed MATLAB/Simulink model. The model simulates the solar PV system by using solar irradiance, temperature, and time as inputs to estimate the PV power output and evaluate the system's performance for rural healthcare applications.

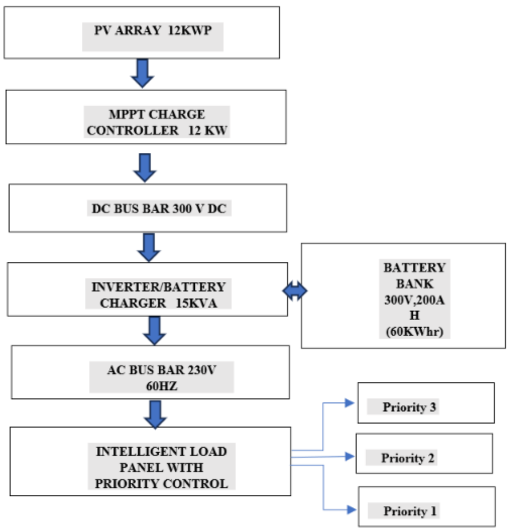


Figure 3 : Block diagram of Simulated model

2.3 Load Profiling and Demand Analysis

- We collected the data and measured the real time power consumption of health center loads (e.g. vaccine refrigerators, medical devices, lightning)
- We classified the most critical, Critical and non-critical loads according to the priority
- We developed daily load curve at different times.

- We generated best-case, worst-case and average-case scenarios for resilience testing

The maximum total load calculation of the Selected rural health post is 5.61 KW and peak load is 2.71 kW watt. According to the demand required in the particular health post, we have designed a PV Model of 12 kW, a battery and a grid system as a backup along with intelligent management system and predictive model to provide continuous and reliable electricity to reduce the power instability and outages in the particular health post. As practically the efficiency of solar is very less about 20% to 30%. Hence, we have designed the power of PV model of 12 kW with a battery backup of 60 kWh. For the rural health posts the required load are listed according to the demand in rural areas.

Table 1 presents the critical electrical loads considered for the proposed solar PV system. The selected equipment includes essential medical devices and lighting systems commonly found in rural health posts in Nepal. The loads are characterized based on their quantity, rated power, daily operating hours, and priority level to ensure uninterrupted operation of vital healthcare services.

Table 1: Most critical load characterization

Equipment	Quantity	Power(W)	Daily Hours	Priority
Vaccine refrigerator	2	150	24 (cyclic)	1
Delivery table light	2	100	2	1
Fetal Doppler	1	25	1	1
Oxygen concentrator	1	700	8	1
Suction machine	1	180	1	1
Autoclave	1	1500	2	1
Lighting	16	160	24	1
	Total =	2815 W		

Table 2 presents the secondary critical electrical loads considered in the proposed system, with a total connected load of 1,600 W. These loads are prioritized after the essential medical equipment.

Table 2: Critical load Characterization

Equipment	Quantity	Power(W)	Daily Hours		Priority
Ceiling fans	8	400	8		2
Computers	2	140	8		2
Microscope	1	30	4		2
Centrifuge	1	250	2		2
Communication radio	1	30	24		2
Water pump	1	750	2		2
	Total=	1600 W			

Table 3 summarizes the non-critical electrical loads with a total connected load of 1,200 W. These loads are supplied only when sufficient energy is available from the solar PV system and battery storage.

Table 3: Non-critical load characterization

Equipment	Quantity	Power(W)	Daily Hours	Priority
Staff quarters fans	4	100	6	3
Kitchen equipment	1	1000	2	3
TV/Entertainment	1	100	4	3
	Total=	1200 W		

From the above data the maximum peak load found is 2.71 kW with total connected load of 5.641 kW. The most essential connected load is 2.85 kW and essential load is 1.6 kW whereas the non-essential load was found about 1.2 kW and the total consumption of load in a day is 27695 Wh.

2.4 Solar (PV) and Battery Storage System Sizing

The required PV array capacity was determined based on the total daily energy demand of the rural health post and the available solar resource. To account for system losses, a battery charging efficiency of 80% was assumed. Accordingly, the daily energy required from the solar panels was calculated to ensure sufficient energy generation for reliable operation of the connected loads.

$$= \frac{\text{total consumption of load in a day}}{\text{efficiency}} \quad (1)$$

$$= \frac{27695}{0.8}$$

$$= 34618.75 \text{Wh/day}$$

$$\text{Ppv, rated}=\frac{\text{Edaily}}{\eta\text{system * PSH}} \quad (2)$$

$$=\frac{34618.75}{4.5*0.8}$$

$$= 9616.319\text{W}$$

For a 12-kW power required. We have taken a PV of 9 strings of 225 watts in series and 6 in parallel which generates a voltage of 272.16 V and current about 44.64 A for generating around 12 kW, with various solar irradiance of and temperature taken as 25 degrees Celsius.

Maximum Power point tracking (MPPT) is a control technique used in solar PV system to extract the maximum power from solar panel under varying environment conditions like solar irradiance, temperature etc.

It uses an algorithm called perturb and observe technique which works by continuously adjusting (perturbing) the operating voltage (Vref) and observing the change in power [17].

$$\text{Vref(k)=Vref(k-1)+}\Delta\text{V}\times\text{sign}\left(\frac{\text{P(k)-P(k-1)}}{\text{V(k)-V(k-1)}}\right) \quad (3)$$

For simulation, a more sophisticated incremental conductance method can be implemented:

$$\frac{dI}{dV}=-\frac{I}{V} \text{ at MPP}$$

$$\frac{dI}{dV}>-\frac{I}{V} \text{ left of MPP}$$

$$\frac{dI}{dV}<-\frac{I}{V} \text{ right of MPP}$$

Figure 4 presents the flowchart of the Perturb and Observe (P&O) maximum power point tracking (MPPT) algorithm used in the proposed photovoltaic system.

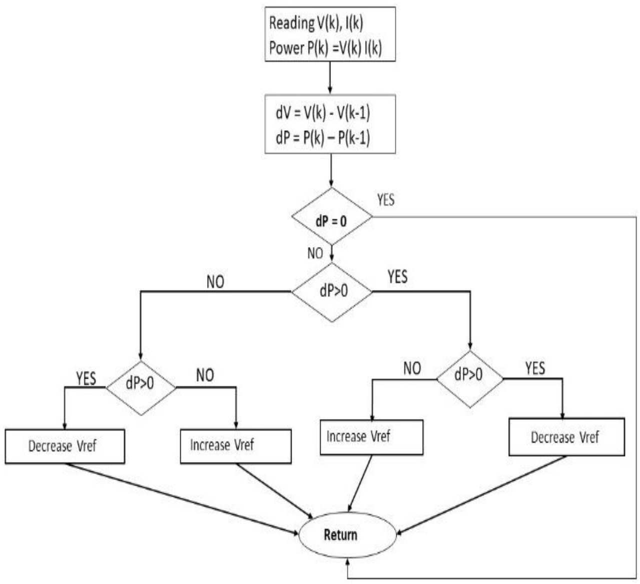


Figure 4: Perturb and Observe algorithm

2.5 Boost convertor Parameters

A boost converter is a DC-DC power converter that increases a lower input voltage to a higher output voltage. It uses an inductor, a switching transistor, a diode, and a capacitor to store and transfer energy efficiently. When the switch turns on, the inductor stores energy; when it turns off, the stored energy is released and added to the input voltage, producing a boosted output. Boost converters are commonly used in battery-powered devices, LED drivers, and power supplies where a higher voltage is needed from a lower source.

The boost converter interfaces PV array to DC bus. Average model:

$$\text{Vout} = \frac{\text{Vin}}{\text{1-D}} \tag{4}$$

$$D = 0.2214$$

For Inductance for the boost converter,

$$L = \frac{V_{in} * D}{I_{ripple} * F_{sw}} \tag{5}$$

$$= 45\ mH$$

For Capacitance of the boost converter

$$C = \frac{I_{out} * D}{V_{ripple} * F_{sw}} \tag{6}$$

$$= 362\mu f$$

For better regulation in the simulation the capacitance value taken is 1000 mf and inductance value as 1.5mH.

2.6 Battery Storage Sizing and Parameters

Since the daily energy consumption of load =27640 Wh. The critical load consumption is about 16595 Wh. The capacity of battery can be calculated as:

$$C_{bat} = \frac{E_{daily,critical} \times N_{autonomy}}{DoD_{max} \times \eta_{bat} \times V_{bus}} \tag{7}$$

$$= \frac{16595KWh * 3}{300 * 0.95 * 0.8} = 218.355$$

According to this the required battery size 300 V,200AH (60 kWh) is selected as per the availability in the market.

A bidirectional inverter was selected, modelled using a universal bridge inverter for simulation, and sized with a 20% safety margin to satisfy the peak load demand while ensuring reliable energy management system (EMS) operation. The standard inverter can be taken whose open circuit voltage is greater than 326.16 V i.e. 500 V and short circuit current greater than 16.08 A available in the market. As the power is about 2.710 kW. The selection criterion of inverter is done from standard table which is shown in appendix below. we need to select Inverter size as:

$$Inverter\ sizing = peak\ load * 1.25 = 3.5\ \text{kW}$$

Hence the size of inverter selected should be 5 kW standard available in the market.

A rule-based Energy Management System (EMS) was developed to enable real-time control through priority-based source switching and automatic shedding of non-critical loads during power shortages.

2.7 Control System Design

State Machine Implementation

The control algorithm is implemented using a State flow chart with three primary operating states. State transitions are determined by the battery state of charge (SOC), the PV generation level relative to the load demand, and the time of day and day of the week. The state transition conditions include hysteresis to prevent oscillation and frequent switching between operating states. The corresponding state transition criteria are presented in Table 4.

Table 4: State transition condition

Transition	Condition	Condition (exit with hysteresis)
State 1 to 2	SOC < 40%	SOC > 60%
State 2 to 3	SOC < 15% and PV insufficient	SOC > 20% and PV sufficient

2.8 Load Shedding Schedule

Load shedding is implemented based on SOC thresholds with time delays to prevent nuisance tripping and is shown in Table 5.

Table 5: Load shedding schedule

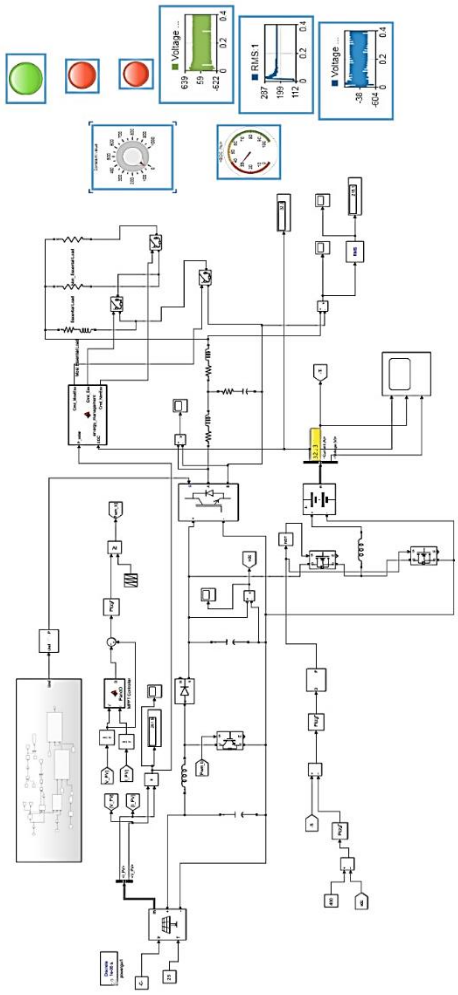
SOC Threshold	Action	Reconnection Threshold
< 60%	Shed Priority 3 loads	> 65% for 5 min
< 40%	Shed Priority 2 loads	> 40% for 10 min
< 15%	Shed all but minimum Priority 1	> 25% for 15 min

Priority 1 loads have three sub-priorities:

- 1A: Vaccine refrigerators, emergency lighting (never shed)
- 1B: Delivery suite equipment (shed only at <10% SOC)
- 1C: Other Priority 1 (shed at <15% SOC)

2.9 Implementation of the proposed system in MATLAB/SIMULINK

To begin the implementation, a solar panel with a standard solar irradiance of 1000w/m^2/day is taken and also the variation is done considering various scenarios. In the simulation for harvesting the maximum power output of the solar system we have taken a MPPT controller and used observe and perturb technique to implement in the model. Then a boost converter is designed according to the power and current rating which is used to amplify the voltage produced by the solar panel. Also, the bi directional inverter is required for converting ac to dc and dc to ac. The system also uses various PID controllers and PWM generators for providing control and switching action in the system. The voltage and current waveforms of solar with different irradiance, Battery voltage and current with SOC and DOD is also obtained, battery ac voltage after conversion and the solar panel ac voltage with and without filter were also analysed and examined. Also, various conditions of load prioritization were obtained controlling them through the Circuit breaker and MATLAB function though through coding. The complete simulation model is presented below in figure below. The version of MATLAB R2024b with Simulink version 11.2 was used to simulate this model. This model utilizes Simulink, Simscape electrical and State flow Libraries. The model was saved in SLX format. Figure 5 presents the complete MATLAB/Simulink implementation of the proposed solar PV–battery energy management system. The detailed MATLAB/Simulink subsystem models and component specifications are provided in Appendix A (Figures A1–A4 and Tables A1–A6).



3. RESULTS AND DISCUSSION

3.1 Solar MPPT Power Analysis

The irradiance when taken about 1000 W/m^2/day and temperature about 25 degree Celsius with PV string of 250 w of 9 panel in series with the 6 strings in parallel so that it produces the average output about 12 kW power. The output voltage produced in that condition as shown in figure is about 272.12 V and current about 44.64 A. When the irradiance is reduced to 500 W/m2.day and 100 W/m2.day then the current and voltages seems to be reduced to around 22 A, 266 V and 2 A 250 V as shown in the Figure 6.

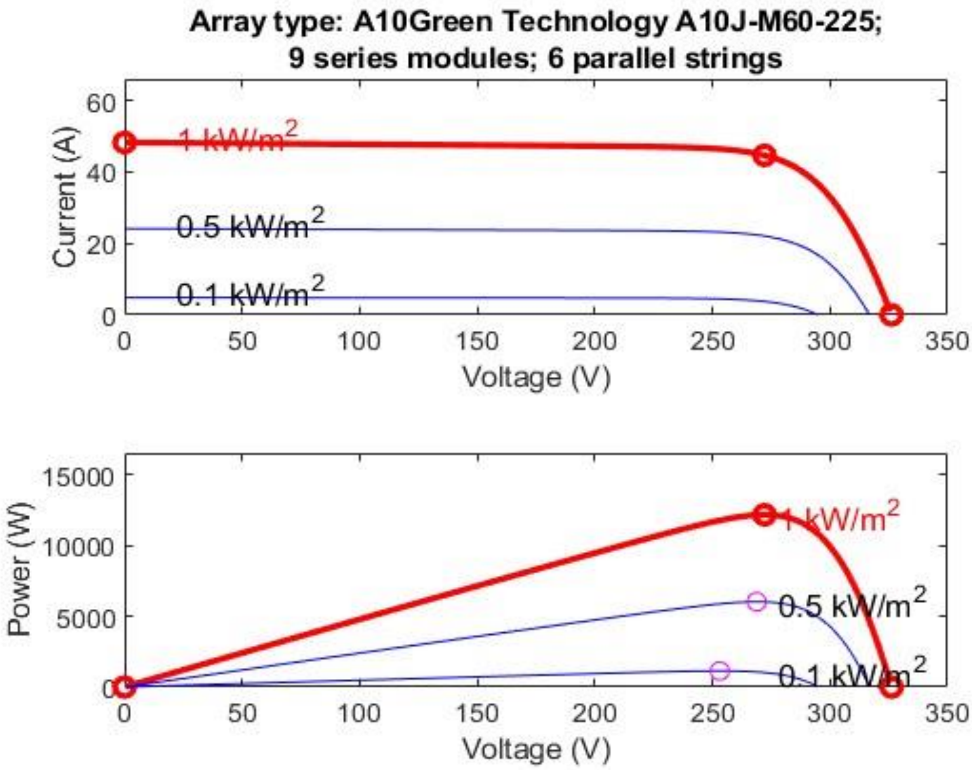


Figure 6 : Power output, current and voltage tracked by MPPT at various irradiance

The power output with time of the solar panel tracked by the MPPT controller shows the power fluctuation of the solar panel with various solar irradiance and 25°C.

3.2 Various Scenarios Analysis

Scenario 1: Normal operation with Solar with Battery Charging

- Maximum solar power with 1000 irradiance
- Medium solar power with 500 irradiances
- Low solar power with 200 irradiances

Scenario 2: Operation with no solar power with battery discharging

- Very less or almost no solar power with battery SOC at 80%
- no solar power with battery SOC at 50%
- no solar power with battery SOC at 30%

3.3 Maximum solar power with 1000 irradiance with battery charging

Model Design Dashboard

In this model design, when an irradiance of 1000 W/m^2/day and temperature 25 °C is taken for solar generation. As the power generated by the solar is sufficient, the battery is on charging state and all the connected loads are operating as shown in the Figure 7.

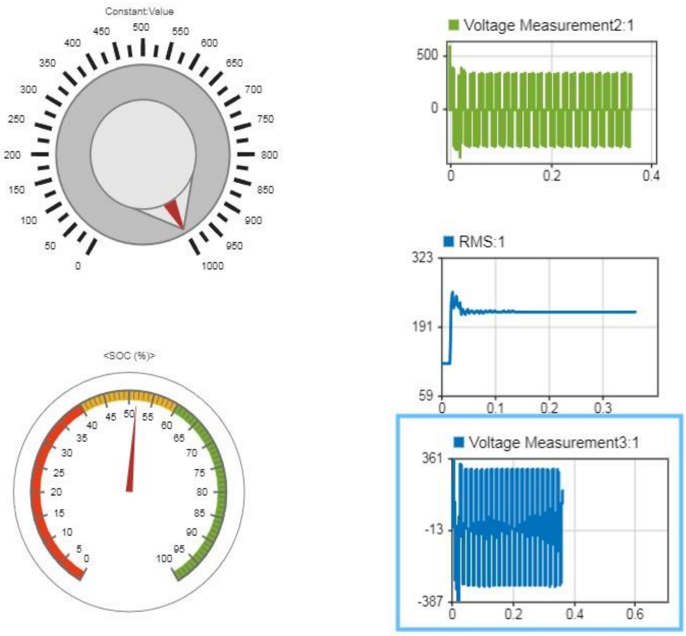


Figure 7: Maximum solar power with 1000 Irradiance with battery charging

3.4 Solar Power Output Tracked by MPPT

From the below graph as shown in Figure 8, we can clearly see the power generated by the solar power is about 12 kW which has been tracked by the MPPT which provides stable voltage with maximum power output.

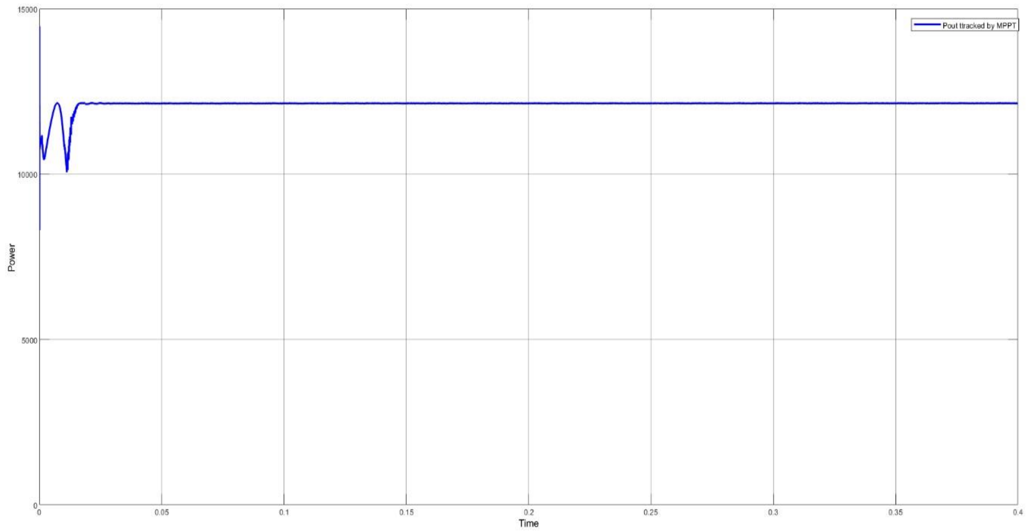


Figure 8: Solar power output tracked by MPPT

3.5 Battery Status, Current and Voltage

In Figure 9, the SOC of the battery initially is 51% and has been gradually increasing as the solar power is sufficient to supply all the loads of the rural health post equipment and can produce extra power to charge the battery. The current from the above graph can also be obtained which is in negative which means the battery is being charged and below 0. The Voltage obtained from the battery of 300V and 200A is producing around 320V.

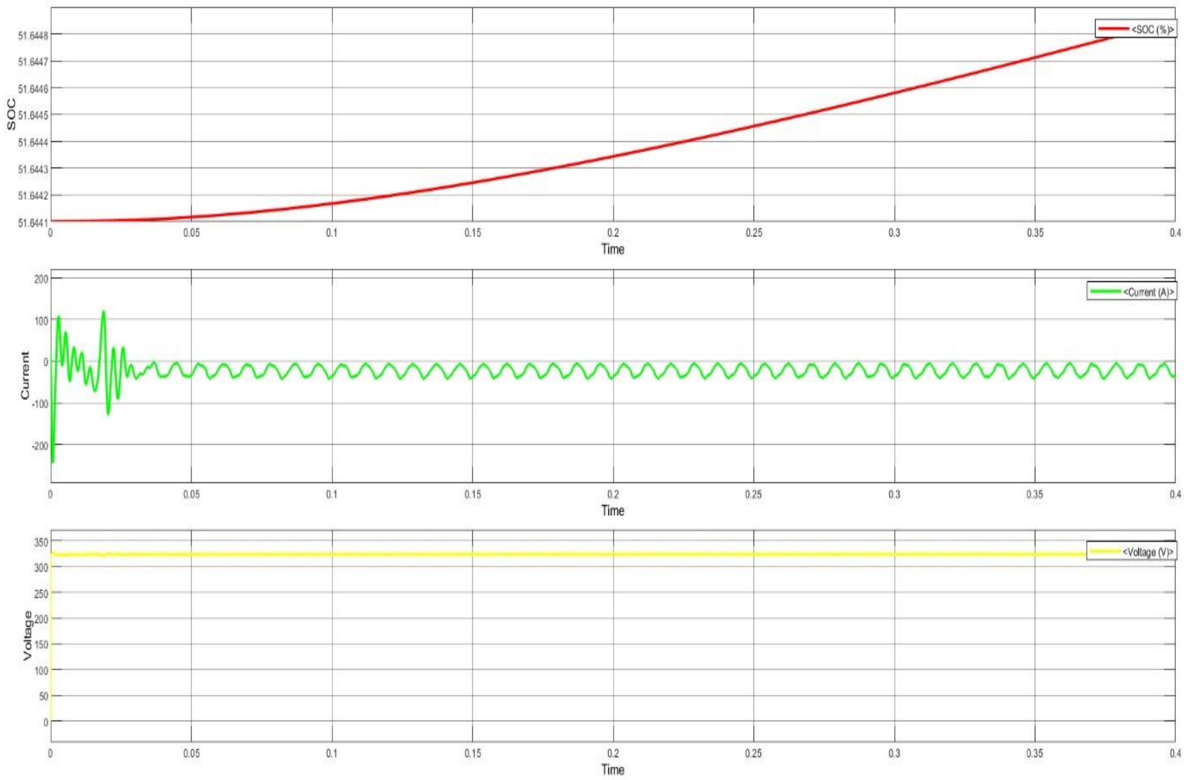


Figure 9 : Battery status, current and voltage

3.6 Unfiltered AC Voltage

The Voltage produced by the inverter after dc to ac conversion is in the form of square wave as obtained in the Figure 10 which seems to have harmonic distortions. The voltage obtained is about 350V AC as shown in the figure above. This square waveform signifies about the ac voltage generated through the solar panel.

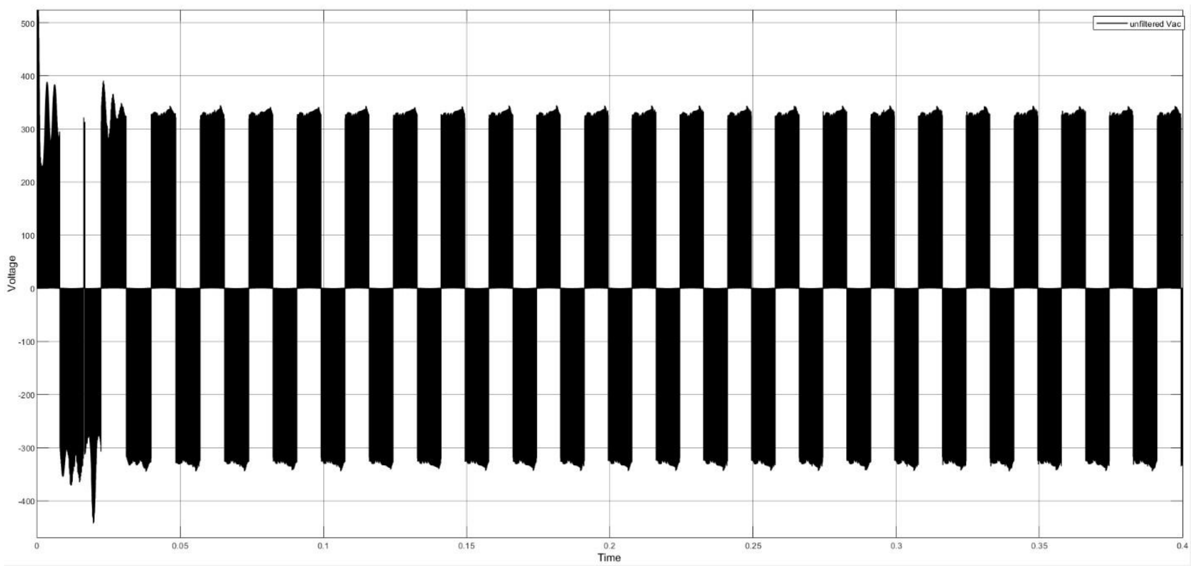


Figure 10 : Unfiltered AC voltage

3.7 Filtered Ac Voltage

After the LCL filter used to remove the harmonic distortion obtained in the square wave, a filtered AC voltage has been obtained with voltage about 350 V AC.

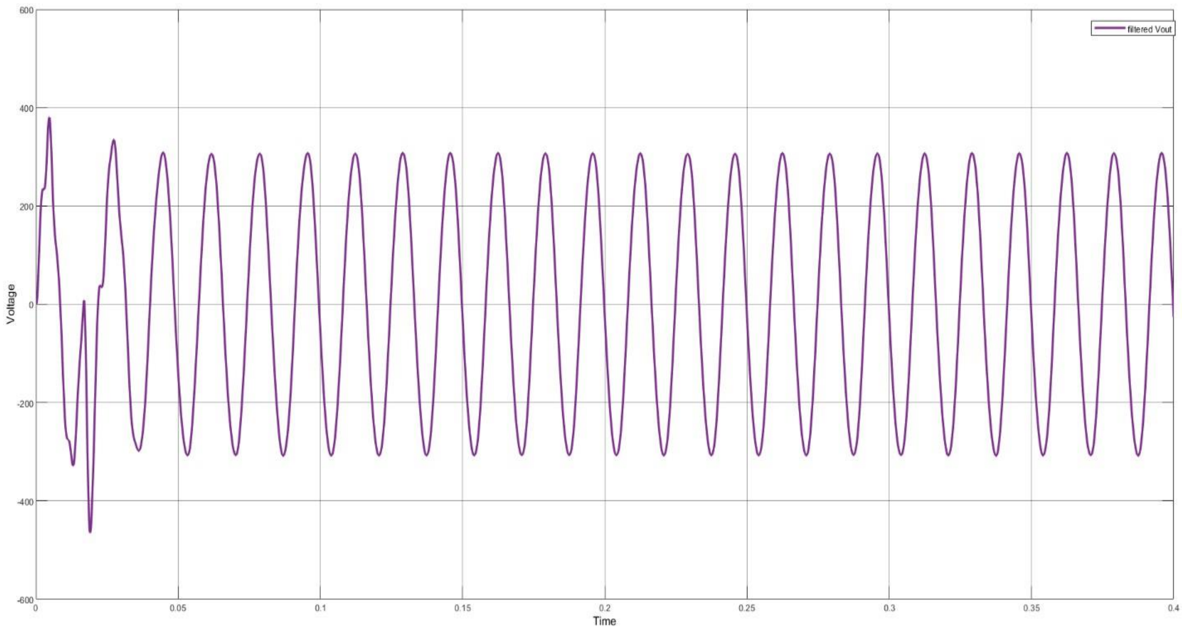


Figure 11: Filtered AC voltage

3.8 RMS Voltage Produced

The RMS voltage produced after using LCL filter obtained is around 220 V as shown in the Figure 12.

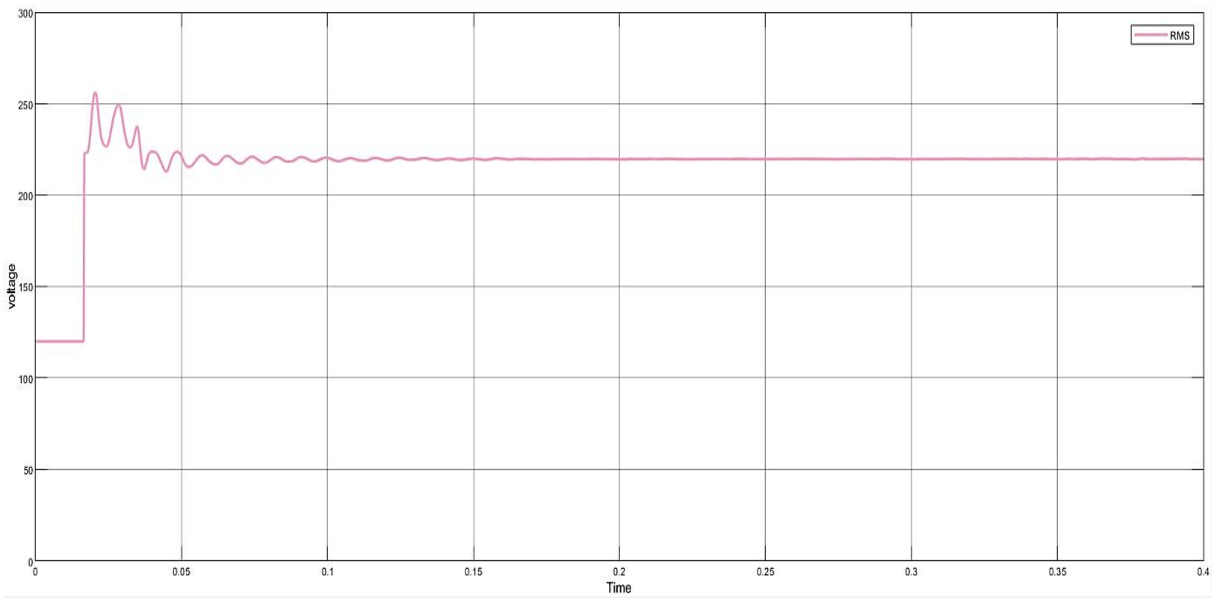


Figure 12: RMS voltage produced

Table 6 summarizes the simulation scenarios considered in this study and presents the corresponding system performance under different solar irradiance levels, battery state of charge (SOC), and power quality conditions. The results demonstrate the effectiveness of the proposed energy management strategy in ensuring reliable power supply and maintaining acceptable power quality for rural healthcare facilities.

Table 6: Different Scenario Analysis

Scenario Parameter	**Key Results & Observations**
Medium Sunlight (500W/m² irradiance)	The solar panels produce about 7 kW of power. This is enough to run all clinic loads, but the battery charges very slowly.
Low Sunlight (200 W/m² irradiance)	Solar output drops to 2 kW. Because this isn't enough for everyone, the system automatically shuts off non-essential loads to save power for critical medical needs.
Night/Very Low Light (SOC at 80%)	Solar power is negligible (~300 W). However, because the battery is nearly full (80%), it can safely power all loads through the night.
Cloudy / MidBattery (SOC at 50%)	Sunlight remains low (~2 kW). With the battery at half capacity, the system prioritizes only essential and most essential loads, cutting off everything else.
Cloudy / Low Battery (SOC at 30%)	Solar power is almost zero (~300 W). To prevent a total blackout, the battery provides power only to the most critical loads (like vaccine fridges).
Power Quality (Harmonics)	Without a filter, the power is dirty, with harmonic distortion reaching 13.03% to 15.75% in solar and battery respectively.
Filtered Output (Clean Power)	After passing through the LCL filter, the distortion drops to 2.53%. This provides a clean 220 V RMS signal safe for sensitive medical equipment.

3.9 Harmonic Analysis

The Harmonic distortion in the below unfiltered solar voltage before passing it through the LCL filter is very high. We can also conclude that the total harmonic is 13.03% as shown in the Figure 13.

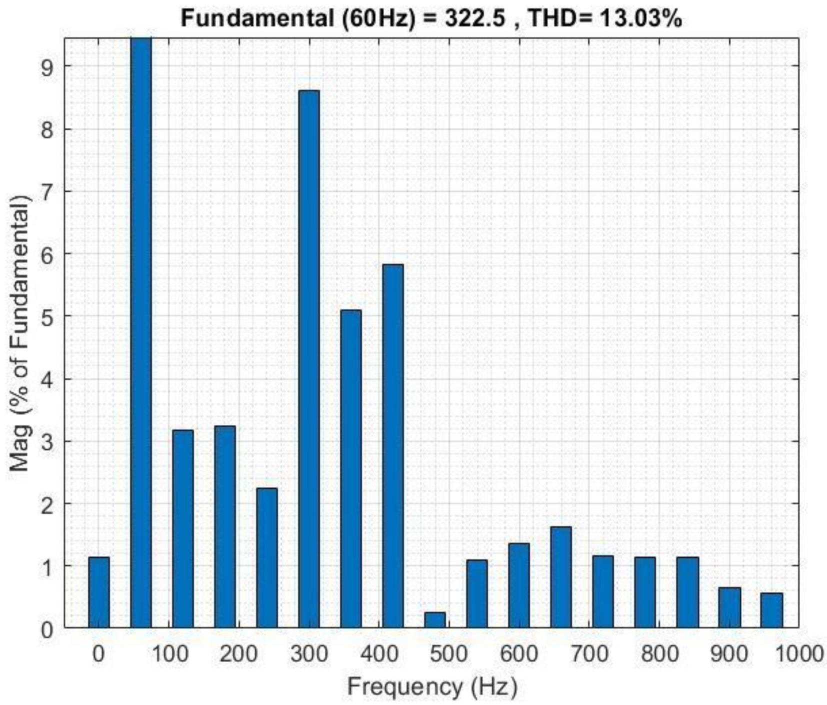


Figure 13: Harmonic distortion for unfiltered Ac voltage produced by solar inverter

The Harmonic distortion in the below unfiltered battery voltage before passing it through the LCL filter is very high. From the Figure 14, we can also conclude that the total harmonic is 15.75%.

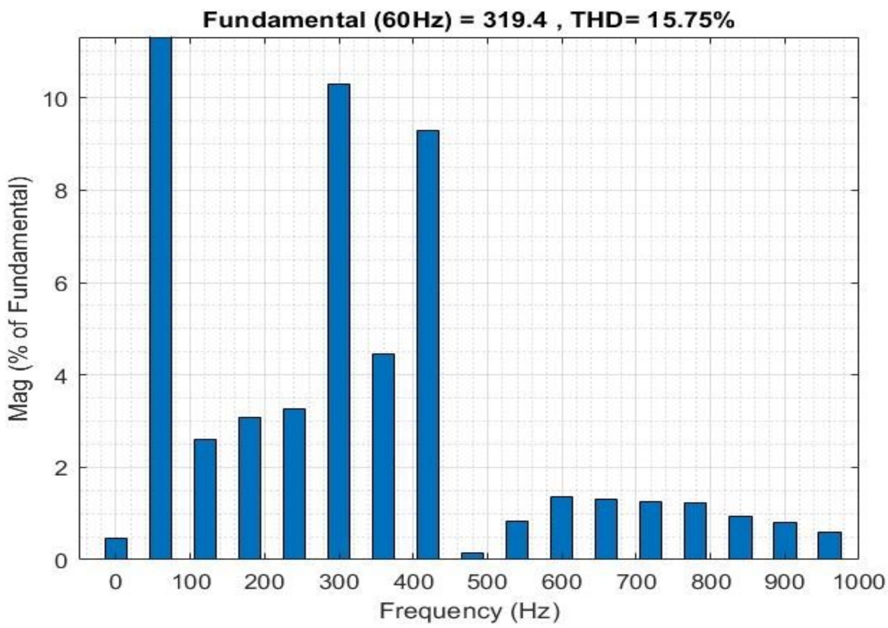


Figure 14: Harmonic distortion for unfiltered Ac voltage produced by solar inverter

The Harmonic distortion in the below filtered solar Ac voltage after passing it through the LCL filter is less from the Figure 14,we can also conclude that the total harmonic is 2.53% as shown in Figure 15 .

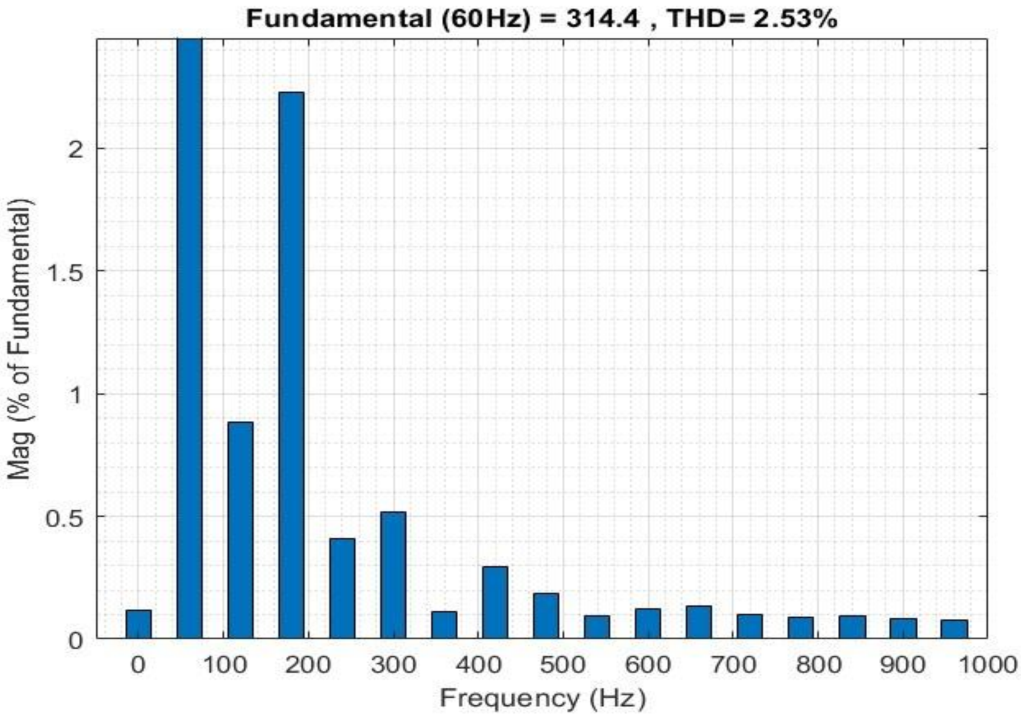


Figure 15: Filtered harmonic distortion of Solar voltage

The Harmonic distortion in the below filtered battery voltage after passing it through the LCL filter is less and we can also conclude that the total harmonic is 4.16 % as shown in the Figure 16.

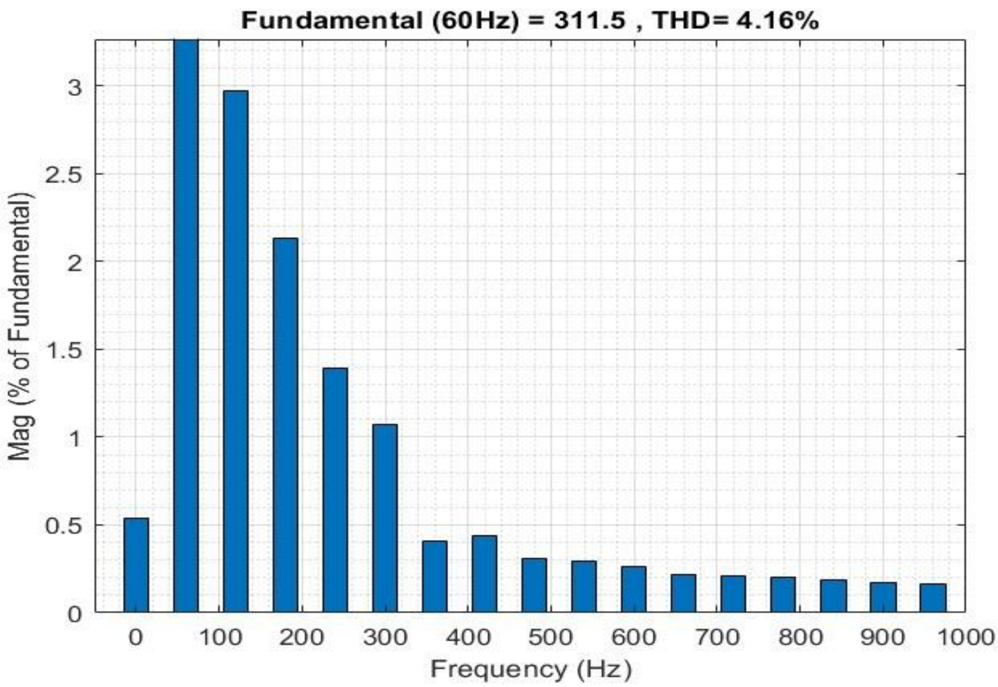


Figure 16: Filtered harmonic distortion voltage from battery

4. Conclusions

This project set out to design and simulate a standalone smart solar system with an intelligent storage system tailored specifically for rural health infrastructure in Nepal. By designing and simulating a "smart" standalone solar system specifically for the health post in Rana Gaun, Jajarkot, this study offers a practical and sustainable solution to the energy challenges facing rural healthcare in Nepal. Through careful planning, a system was developed that doesn't just provide power, but manages it intelligently. By categorizing the clinic's needs into three priority levels, the system ensures that if energy becomes scarce, power is never cut from the most critical equipment such as oxygen concentrators and refrigerators. Simulations in MATLAB/Simulink proved that even during periods of low sunlight or heavy clouds, these essential services remained active 99.5% of the time. A three-tier priority classification was established most essential loads (vaccine refrigerators, oxygen concentrators, delivery suite equipment), essential loads, and non-essential loads ensuring that life-saving functions receive uninterrupted power even under resource constraints. The total daily energy demand was calculated at 27.64 kWh with a peak load of 2.71 kW. Based on this demand and the site's solar resource (average global irradiance 4.68 kWh/m²/day) a 12kW photovoltaic system designed a 60kWh lithium-iron-phosphate battery bank (300 V, 200 Ah) was selected to provide storage, offering 80 % usable depth of discharge. A boost converter interfaced the PV array to the DC bus, while a bi-directional inverter with LCL filtering ensured high-quality AC output suitable for sensitive medical equipment. The control system employed a perturb and observe maximum power point tracking algorithm and a rule-based energy management system implemented in MATLAB/Simulink. Load, irradiance back THD less than 5% Furthermore, the inclusion of specialized filtering ensures the electricity produced is clean and safe for sensitive medical devices. Ultimately, the results show that this solar-based design is not only more environmentally friendly than traditional diesel generators but also more reliable and cost-effective in the long run. This project demonstrates that with the right technology and intelligent management, we can bridge the energy gap in rural areas, ensuring that no health post is left in the dark and that every community has access to the uninterrupted healthcare they deserve.

Conflicts of Interest Statement

The authors declare no conflicts of interest for this study.

Data Availability Statement

The data supporting the findings of this study are presented in the manuscript. Additional data will be provided upon request.

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APPENDIX A

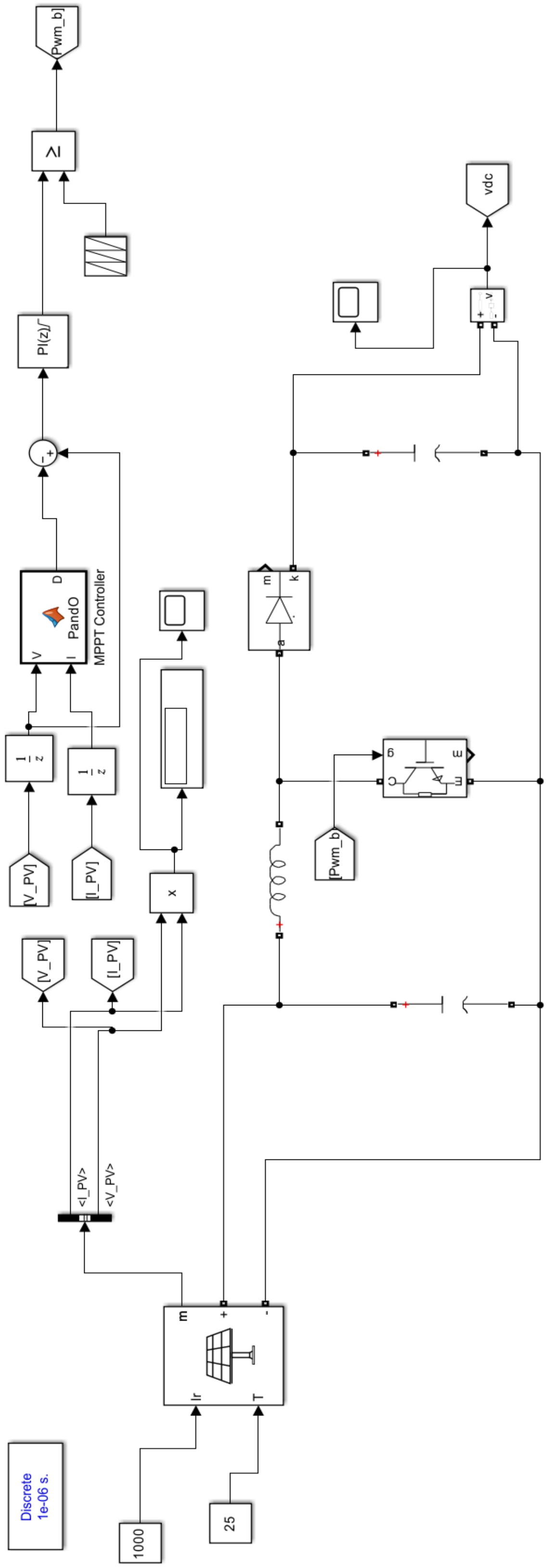

Figure A1: Solar, MPPT, Boost Converter design, in MATLAB Simulink

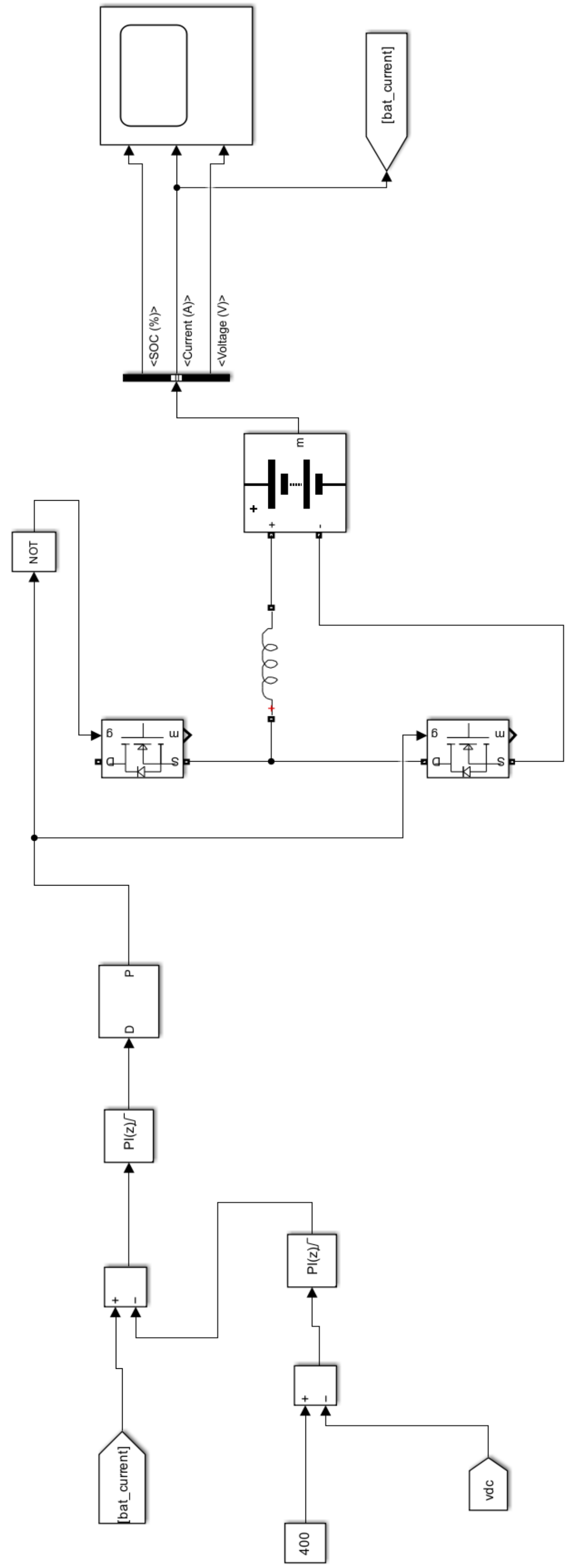

Figure A2 : Battery storage and control, in MATLAB Simulink

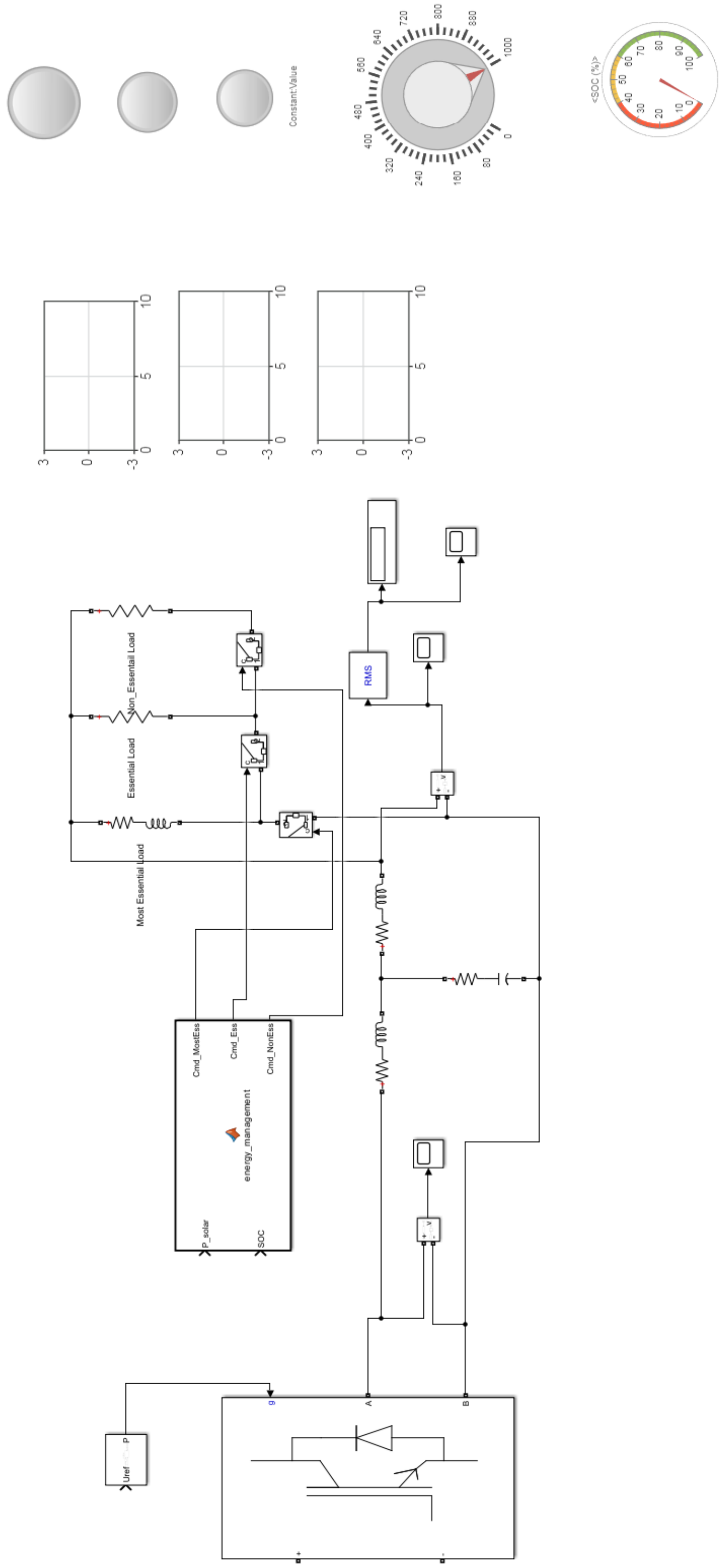

Figure A3: Inverter, filter and Loads design, with control system in MATLAB Simulink

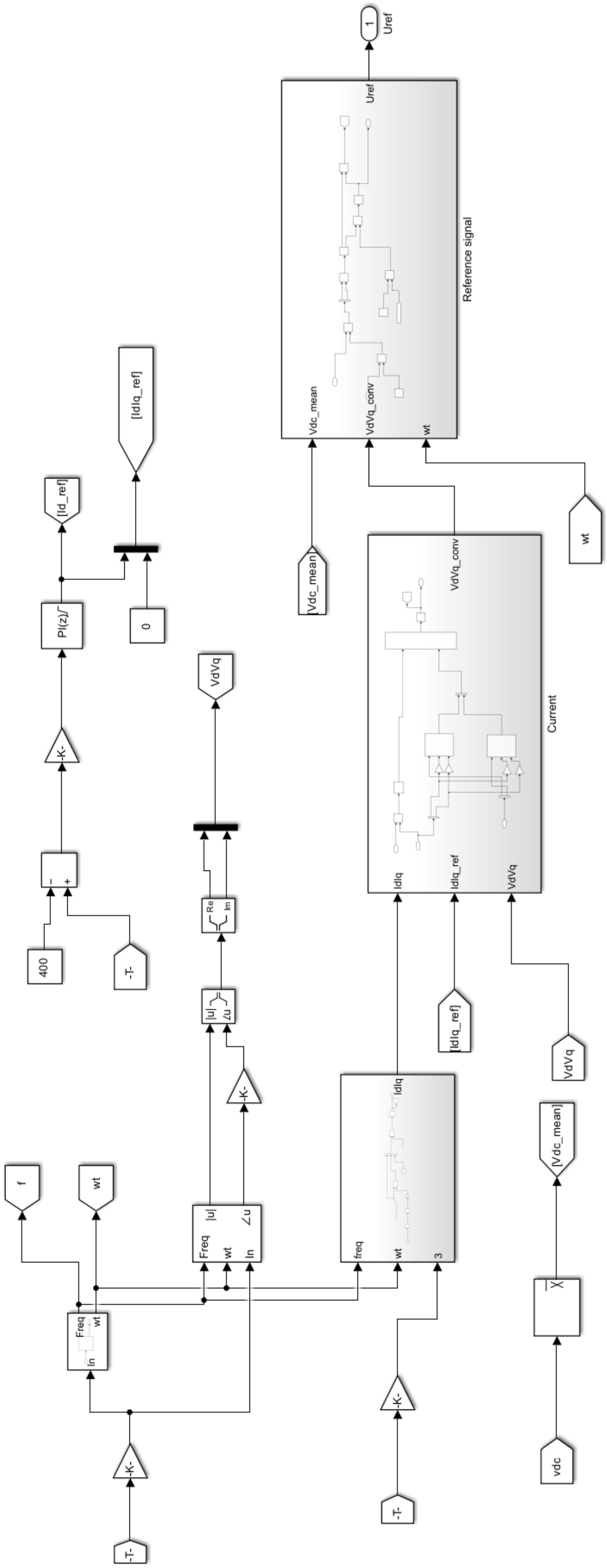

Figure A4 : Inverter control design, in MATLAB Simulink

Table A1 : PV array specification

Parameter	Specification
Module type	Mono-crystalline silicon
Module rated power	225 W
Number of modules	54
Array configuration	6 strings × 9 modules
Total installed capacity	12 kW
Module efficiency	80%
Temperature coefficient (Pmax)	-0.3624%/°C

Table A2 : Required parameters for selecting inverter, boost converter and battery

Max Power	224.9856 W
Voltage at open circuit (Voc)	36.24 V
Current at short circuit (Isc)	8.04 A
Voltage at maximum power	30.24 V
Current at maximum power	7.44

Table A3 : Charge controller specification

Parameter	Specification
Type	MPPT
Quantity	1 unit
Rated power per unit	12 kW
Maximum input voltage	600V DC
MPPT voltage range	200-500V DC
Efficiency	98%
Protection	Reverse polarity, over-voltage, overtemperature

Table A4 : Boost converter specification

Vinput	272.15V
Vout	350V
Input current	44.64
Voltage ripple	2.7215V
Current ripple	13.392A
Fsw	10 KHz
Inductance	1.5 mH
Capacitance	1000 microFarad

Table A5 : Battery bank specification

Parameter	Specification
Battery type	$LiFePO_4$
Nominal voltage	300V (94S,3.2Configuration)
Capacity	200 Ah
Usable energy	48 kWh (80% DoD)
Cycle life	4,000 cycles at 80% DoD
Expected lifetime	10-12 years

Table A6 : Inverter sizing and parameter

Maximum output voltage at open circuit	Voc=326.16 V(9*36.26)
Output voltage at maximum power	Vmp=181.44
Maximum Output current at short circuit	Isc=16.08(6 strings in parallel)
Output current at maximum power	Imp=14.88
Efficiency	95%