### Abstract:

Off-grid photovoltaic (PV) solar systems represent a promising solution for decentralized energy generation, particularly in areas where access to the traditional grid is limited or non-existent. This abstract delves into the key aspects of off-grid PV solar systems, encompassing their components, functioning, advantages, challenges, and potential applications. Off-grid PV solar systems comprise solar panels, charge controllers, batteries, and inverters, all working in tandem to capture solar energy, store it efficiently, and convert it into usable electricity. The solar panels harness sunlight and convert it into direct current (DC), which is then regulated and stored in batteries through charge controllers. Inverters convert the stored DC electricity into alternating current (AC), enabling the powering of appliances and devices. The advantages of off-grid PV solar systems are manifold. They offer energy independence, enabling users to generate electricity autonomously, thereby mitigating reliance on centralized power grids and reducing utility bills. Additionally, off-grid PV solar systems are environmentally friendly, producing clean energy without emitting greenhouse gases or pollutants. They are also versatile and can be deployed in remote locations, providing electricity to off-grid communities, rural areas, and disaster-stricken regions.

However, off-grid PV solar systems also present challenges. The initial installation costs can be high, although they are often offset by long-term savings on utility bills. Additionally, the need for proper system sizing, maintenance, and battery management is crucial to ensure optimal performance and longevity. Furthermore, intermittency and variability in solar radiation can affect energy generation, necessitating appropriate system design and backup solutions.

Despite these challenges, off-grid PV solar systems hold immense potential for various applications. They are particularly well-suited for remote cabins, off-grid homes, RVs, boats, telecommunications infrastructure, and humanitarian projects in underserved regions. Moreover, advancements in solar technology, battery storage, and energy management systems continue to enhance the efficiency, reliability, and affordability of off-grid PV solar solutions.

In conclusion, off-grid PV solar systems offer a sustainable, reliable, and decentralized approach to electricity generation, with the potential to empower individuals, communities, and industries worldwide. By harnessing the abundant energy of the sun, these systems pave the way towards a cleaner, more resilient energy future



Figure 1. Off grid system equipment.

## **1-System Sizing:**

System sizing is the process of evaluating the adequate voltage and current ratings for each component of the photovoltaic system to meet the electric demand at the facility and at the same time calculating the total price of the entire system from the design phase to the fully functional system including, shipment, and labor.

## **1-1-Residence Device**

As a first step, the electrical devices available at the residence are itemized with their power ratings and time of operation during the day to obtain the average energy demand in Watt-hour per day as shown below in Table 1. The total average energy consumption is used to determine the equipment sizes and ratings starting with the solar array and ending with system wiring and cost estimate as explained below.

## 1-2-Sizing of the Solar Array

Before sizing the array, the total daily energy in Watt-hours (E), the average sun hour per day Tmin, and the DC-voltage of the system (VDC) must be determined. Once these factors are made available we move to the sizing process. To avoid under sizing, losses must be considered by dividing the total power demand in Wh.day-1 by the product of efficiencies of all components in the system to get the required energy E<sub>r</sub>. To avoid under sizing we begin by dividing the total average energy demand per day by the efficiencies of the system components to obtain the daily energy requirement from the solar array:



To obtain the peak power, the previous result is divided by the average sun hours per day for the geographical location Tmin.

$$P_{p} = \frac{\text{daily energy requirement}}{\text{minimum peak sun} - \text{hours per day}} = \frac{E_{r}}{T_{\text{min}}}$$
(2)

The total current needed can be calculated by dividing the peak power by the DC- voltage of the system.

$$I_{DC} = \frac{Peak \ power}{System \ DC \ Voltage} = \frac{P_p}{V_{DC}}$$

Modules must be connected in series and parallel according to the need to meet the desired voltage and current in accordance with: First, the number of parallel modules which equals the whole modules current divided by the rated current of one module Ir.

$$N_p = \frac{\text{whole module current}}{\text{rated current of one module}} = \frac{I_{DC}}{I_r}$$

Second, the number of series modules which equals the DC voltage of the system divided by the rated voltage of each module Vr.

$$N_s = \frac{system \, DC \, voltage}{module \, rated \, voltage} = \frac{V_{DC}}{V_r}$$

.

Finally, the total number of modules Nm equals the series modules multiplied by the parallel ones:

$$N_m = N_s * N_p$$

.

#### **1-3-Sizing of the Battery Bank**

The amount of rough energy storage required is equal to the multiplication of the total power demand and the number of autonomy days  $E_{rough}=E\times D$ . For safety, the result obtained is divided by the maximum allowable level of discharge (MDOD):

$$E_{safe} = \frac{\text{energy storage required}}{\text{maximum depth of discharge}} = \frac{E_{roug h}}{MDOD}$$

At this moment, we need to make a decision regarding the rated voltage of each battery  $V_b$  to be used in the battery bank. The capacity of the battery bank needed in ampere-hours can be evaluated by dividing the safe energy storage required by the DC voltage of one of the batteries selected:

$$C = \frac{E_{safe}}{V_b}$$

According to the number obtained for the capacity of the battery bank, another decision has to be made regarding the capacity  $C_b$  of each of the batteries of that bank. The battery bank is composed of batteries The total number of batteries is obtained by dividing the capacity C of the battery bank in ampere-hours by the capacity of one of the battery  $C_b$  selected in ampere-hours:

$$N_{battries} = \frac{C}{C_b}$$

The connection of the battery bank can be then easily figured out. The number of batteries in series equals the DC voltage of the system divided by the voltage rating of one of the batteries selected:

$$N_s = \frac{V_{DC}}{V_b}$$

Then number of parallel paths  $N_P$  is obtained by dividing the total number of batteries by the number of batteries connected in series:

$$N_p = \frac{N_{battries}}{N_s}$$

#### 1-4-Sizing of the Voltage Controller

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According to its function it controls the flow of current. A good voltage regulator must be able to withstand the maximum current produced by the array as well as the maximum load current. Sizing of the voltage regulator can be obtained by multiplying the short circuit current of the modules connected in parallel by a safety factor F<sub>safe</sub>. The result gives the rated current of the voltage regulator

$$I = I_{SC} * N_p * F_{safe}$$

The factor of safety is employed to make sure that the regulator handles maximum current produced by the array that could exceed the tabulated value. And to handle a load current more than that planned due to addition of equipment, for instance. In other words, this safety factor allows the system to expand slightly. The number of controller equals the Array short current Amps divided by the Amps for each controller:

$$N_{controller} = \frac{I}{Amps \ each \ controller}$$

### **1-5-Sizing of the Inverter**

When sizing the inverter, the actual power drawn from the appliances that will run at the same time must be determined as a first step.

#### **2-Problem and calculations**

Portable charging Station:

Goal: the 3d printing machine have 200w heating mat, total machine has 12 heating mats - so total

machine required power 3KW. Voltage :440v

Machine running timings are flexible, we can run the machine day or night.

expected run time is 4hrs a day.

During the machine usage we cannot charge the panels because total portable charging station should be taken into the workshop so we cannot produce current during the machine working.

The total setup is movable.

Space available is 1.5 m x.1.5 m \* 2 times. we can accommodate 2 panels

Required:

Which pv panel should be used? how much watt?

Which battery is used? how much Ah?

Which invertor is used?

which PV controller?

all this information in PV Syst required.

# 2-1-Manual calculation

Load name	Qty	Voltage	Current(A)	Power(W)	Use h/day	Use day/week	Divide by7	W.h Ac		
3D printing	1	440	6.81	3000	4	7	7	12000		
AC Total	Connected	Watts:		AC Average Daily Load:						
3000				12000						

# 2-1-1. Panel calculation

Specifications	
Cell type:	N type Mono-crystalline
Module type:	Glass/Foil
Manufacturer number:	JKM445N-54HL4R-V
Maximum Power (Pmax):	445 Wp
Glass front:	3,2 mm Low iron, tempered glass with Anti-Reflection Coating
Glass back:	1.6 mm / 2 mm highly transparent glass, White mesh
Frame:	Black anodized Aluminium Alloy
Connector:	MC4 compatible
Cable length:	each 1200mm +/-
Product Warranty:	15 years
Performance Warranty:	30 years linear warranty
Dimensions (L x W x H):	1762 mm x 1134 mm x 30 mm
Weight:	22 kg

**Figure2: Panel specifications** 

SPECIFICATIONS										
Module Type	JKM425 JKM4251	N-54HL4R N-54HL4R-V	JKM430 JKM430	N-54HL4R N-54HL4R-V	JKM435 JKM4351	N-54HL4R N-54HL4R-V	JKM440 JKM440N	N-54HL4R ↓-54HL4R-V	JKM4451 JKM445N	N-54HL4R I-54HL4R-V
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	425Wp	320Wp	430Wp	323Wp	435Wp	327Wp	440Wp	331Wp	445Wp	335Wp
Maximum Power Voltage (Vmp)	32.18V	29.99V	32.38V	30.10V	32.59V	30.33V	32.81V	30.56V	33.02V	30.76V
Maximum Power Current (Imp)	13.21A	10.67A	13.28A	10.73A	13.35A	10.78A	13.41A	10.83A	13.48A	10.89A
Open-circuit Voltage (Voc)	38.75V	36.81V	38.95V	37.00V	39.16V	37.20V	39.38V	37.41V	39.59V	37.61V
Short-circuit Current (Isc)	13.66A	11.03A	13.73A	11.09A	13.80A	11.14A	13.86A	11.19A	13.93A	11.25A
Module Efficiency STC (%)	21.3	27%	21.	.52%	21.7	77%	22.	02%	22.3	27%
Operating Temperature(°C)					-40°C~	+85°C				
Maximum system voltage			1000/1500VDC (IEC)							
Maximum series fuse rating					25	A				
Power tolerance					0~+	3%				
Temperature coefficients of Pmax					-0.299	%/°C				
Temperature coefficients of Voc					-0.25%	%/°C				
Temperature coefficients of lsc					0.045	%/°C				
Nominal operating cell temperatu	ire (NOCT	)			45±	2°C				
*STC: 🌺 Irradiance 1000	W/m <sup>2</sup>	Cell 1	ſempera	ture 25°C		AN	=1.5			
NOCT: Irradiance 800W/m² Mambient Temperature 20°C AM=1.5 9 Wind Speed 1m/s							d 1m/s			

#### **Figure3: Panel specifications**

$$I = \frac{P}{\sqrt{3}*440} = 3.95 \text{ A}$$

$$E_r = \frac{E}{\gamma overal} = \frac{3000}{0.8} = 3750 \text{ wh/day}$$

$$P_p = \frac{E_r}{T_{min}} = \frac{3750}{3.5} = 1071 \text{ wp}$$

$$Idc = \frac{Pp}{Vdc} = \frac{1071}{48} = 22.31 \text{ A}$$

$$Np = \frac{Idc}{Ir} = \frac{22.31}{13.48} = 1.65 \quad 1 \text{ to 2 panel is required}$$

$$Ns = \frac{Vdc}{Vr} = \frac{48}{33.02} = 1.45 \quad 1 \text{ to 2 panel is required}$$

Between 2 to 4 panels, we must select for this project. If we select 4 panels we have below calculations:

## 2-2-Batteries:

## Lead-Acid

Lead-acid batteries have been in use for decades and are one of the most common types of battery used in automotive and industrial applications. They have a low energy density (meaning they cannot hold much energy per kg of weight), but remain both costeffective and reliable and thus have become a common choice for use in a home solar setup.

Lead-acid batteries come in both flooded and sealed varieties and can be classified as either shallow cycle or deep cycle depending on the intended function and safe depth of discharge (DOD). Recent technological advancements have improved the lifespan of these batteries and lead-acid continues to be a viable option for many homeowners.



**Figure4: batteries specifications** 

#### SolarV®GEL Battery 150Ah 12V

SKU: 4112150 GTIN: 4260558571773 Category: <u>Gel Battery</u> Manufacturers: <u>SolarV</u>

- Gelled electrolyte technology
- AGM separator
- Recognized by UL & CE
  ABS container

Read online and download: Datasheet: SolarV Gel Battery 150Ah, 12V

#### 251.22 € 0% MwSt. - § 12 Abs. 3 UStG 298,95 €

incl. 19% VAT , plus <u>shipping costs</u> Old price: 350,95 €

Nom	inal Voltage	12 V		
<b>C</b>	20HR(10.5V)	150Ah		
Capacity	5HR(10.2V)	115.6Ah		
(25 C)	1HR(9.6V)	87.3Ah		
	Length	485±2mm		
	Width	172±1mm		
Dimension	Height	240±2mm		
	Total Height	240±2mm		
Арр	rox. Weight	44kg (70.4lbs)±4%		
Те	rminal type	T11		
Internal (Fully char	resistance ged, 25°C)	Approx. 4.2mΩ		
Capacity	40°C	103%		
affected by	25°C	100%		
temperature	0°C	88%		
(10HR)	-15°C	70%		
Self-discharge	3 month	Remaining Capacity 94%		
(25°C)	6 month	Remaining Capacity 88%		
	12 month	Remaining Capacity 75%		
Nominal o Tempe	operating rature	25°C±3°C(77°F±5°F		
Operating	Discharge	-15℃~55℃(5°F~ 131°F)		
range	Charge	-10°C~55°C(14°F~		



Dimensions



Figure5: battery specifications

Manufacturer model	Enjoysolar GEL 150Ah 12V
EAN Code	4260558571773
Article number	4112150
Capacity	150Ah
Dimension	485* 172* 240mm
Approx. Weight	44kg (96.8lbs)±4%
Terminal type	T11
Internal resistance	Approx. 4.2mΩ
Nominal operating temperature	25°C±3°C(77°F±5°F)
Float charging voltage(25°C)	13.50 to 13.80V Temperature compensation: -18mV/°C
Cyclic charging voltage(25°C)	14.10 to 14.40V Temperature compensation: -30mV/°C
Maximum charging current	30A
Terminal material	Copper
Maximum discharge current	1500 A(5 sec.)

#### **Figure6: battery specifications**

The amount of energy storage for 1 days :12000wh

 $Esafe = \frac{12000}{0.75} = 16000$ The capacity of the battery bank =  $\frac{16000}{12} = 1333.3$ Ah Nbatteries =  $\frac{1333.3}{150} = 8.89$ The number of series battery = 48/12 = 4The number of paralle = 8.89/4 = 2.22

HOME SOLAR PANEL	STORAGE BAT	TERY 🗸 ESS CO	DNTAINER - SOLAR PV SOL	LUTION V INVERTER & ELECTRICAL V CONTACT US
COLOR OFTICHS	G 12	EL AGM V 250AH	12V 250Ah Deep Rechargeable The VRLA battery is a part of th increasing the negative electro the battery to be sealed.	p Cycle AGM VRLA UPS Lead Acid Gel Solar Storage Battery e electrolyte is absorbed in the pole pieces and separators, thereby de's oxygen absorption capacity, preventing electrolyte loss, and enabling
			ITEM NO.:	6-GFM-250
	-		PRODUCT ORIGIN:	China
-	1		COLOR:	White/Black
() Sunpal	Voive Regulated	0007 AAA0	SHIPPING PORT:	Shanghai/Ningbo
CC	0001		VOLTAGE PER UNIT:	12
andra Andre Da Jak			CAPACITY:	250Ah@20hr-rate to 1.75V per cell @25°C
			WEIGHT:	Approx. 70.0 Kg (Tolerance±1.5%)
• [200]			TERMINAL:	FI4(M8)
			MAX DISCHARGE CURRENT	26004 (5 sec)

#### Figure7: 250Ah bateery specifications

Calculation with 250Ah battery

The amount of energy storage for 1 days :12000wh

 $\text{Esafe} = \frac{12000}{0.75} = 16000$ 

The capacity of the battery bank= $\frac{16000}{12}$ =1333.3Ah

Nbatteries= $\frac{1333.3}{250}$ =5.33

The number of series battery=48/12=4

The number of paralle= 5.33/4=1.33

2-3-charge controller:

 $I = I_{sc} * N_p * F_{safe} = 13.93 * 2 * 1.25 = 34.825$ 

2-4-Inverter sizing

3000 to 3500 w

## 3-PVsyst simulation

According to 4 simulations result that has been sent. This project can establish with 4 panels, but it cannot support all of your requirements. In Fig. 8 suggested PV power is 9190 Wp for this reason PVsyst offer 8 panels.

12.0 kWh/day       Requested autonomy       1.0 day(s)       Suggested capacity       300 Ah         Suggested PV Array       Detailed pre-sizing       Suggested RV power       9190 Wp (nom.)         Storage       PV Array       Back-Up       Simplified sketch         Sub-array name and Orientation       Pre-sizing Help       No sizing       Enter planned power       1.4         Name       PV Array       Tit       20°       Resize       or available area       6       m²         Select the PV module       Sort modules       © Power       Technology       JAM78-S10-435-MR       Since 20X       Q open	
Image     Detailed pre-sizing     Suggested PV power     9190     Wp (nom.)       torage     PV Array     Badk-Up     Simplified sketch       -Sub-array name and Orientation	
torage PV Array Back-Up Simplified sketch -Sub-srray name and Orientation Name PV Array Orient Fixed Titled Plane Tit 20° Azimuth 0° Select the PV module Available Now Sort modules Power Technology JA Solar V 435 Wp 37V Simon JAM78-510-435-MR Since 2021 C Open	
-Sub-array name and Orientation Name PV Array Tit 20° Orient. Fixed Tilted Plane Azmuth 0° Select the PV module Orientation	
Name     PV Array     Tit     20°       Orient.     Fixed Tilted Plane     Azimuth     0°       Select the PV module     Azimuth     0°       Available Now     Sort modules     Image: Comparison of the provided of the provide	
Tit         20°         Tit         20°           Admuth         0°         Resize         or available area         6         m²           Select the PV module         Sort modules         © Power         Technology           Available Now         Sort modules         © Power         Technology           JA Solar         435 Wp 37V         Si-mono         JAM78-S10-435-MR         Since 202X         C, Open	
Select the PV module         Sort modules         Power         Technology           Available Now         Sort modules         Power         Technology           JA Solar         435 Wp 37V         Si-mono         JAM78-S10-4135-MR         Since 202X         C, Open	
Available Now         Sort modules         ® Power         O Technology           JA Solar         435 Wp 37V         Si-mono         JAM78-S10-435-MR         Since 202 V         C, Open	
1A Solar V 435 Wp 37V Si-mono JAM78-510-435-MR Since 202X Q Open	
Approx. needed modules 2 Sizing voltages: Vmpp (60°C) 38.4 V	
Voc (-10°C) 58.0 V	
Select the control mode and the controller	
MPPT power converter	
2 Universal controller Morningstar	
Operating mode Max. Charging - Discharging current	
Operating mode         Max. Charging - Discharging current           O brect coupling         Mapping - 200 W 48 V 60 A 59 A Tristar TS MPPT 60 -600V-48V S	
Operating mode         Max. Charging - Discharging ourrent           Direct couping         MPPT 3200 W 48 V 60 A 59 A Tristar TS MPPT 60-600V-48V S           MPPT converter         Number of controllers 1	
Operating mode       Max. Charging - Discharging aurrent         Direct couping       Septilized W       48 V       60 A       59 A       Indiantis Meet Goldowidev       Image: Charging - Discharging - Di	
Operating mode       Max. Charging - Discharging current         Oirect couping       Saper 3200 W       45 V       60 A       Tristur 1s Mept Col-couv-AsV       Image: Col-couver 1         Mept converter       Number of controllers       1       Image: Col-couver 1       Imput maximum voltage       600 V       Associated Battery       3.20 KW         PV Array design       PV       Array design       Imput maximum voltage       600 V       Associated Battery       48 V	
Operating mode       Max. Charging - Discharging current         Orect couping       Sept 3200 W 48 V 60 A 59 A Trister TS MPPT 60 4000V-48V         MPT converter       Number of controllers       1       Image: Converter Converter       Image: Converter Converter       Sept 320 W 48 V 60 A 59 A Trister TS MPPT 60 400V-48V       Image: Converter Converter Converter       Image: Converter Converter Converter       Image: Converter Converter Converter       Image: Converter Converter Converter Converter       Image: Converter Converter Converter Converter Converter       Image: Converter Con	Aver. power 500 W
Max. Charging - Discharging aurrent         Operating mode       Exert 3200 W       48 V       60 Å       59 Å       Trister 15 Meet 60 400V/48V       EV       © Open         Direct coupling       Number of controllers       1       C       MPP Converter       3.20 kW         PV Array design       Mumber of modules and strings       Operating conditions:       More for controllers       307 V       48 V       48 V	Aver. power 500 W Daily energy 12.0 k
Operating mode       Max. Charging - Discharging current         Orect coupling       Way: Charging - Discharging current         Wetter coupling       Max. Charging - Discharging current         Direct coupling       Max. Charging - Discharging current         PV Array design       Input maximum voltage         PV Array design       Operating conditions:         Mod. In series       Soudd be:         Wopp (covc)       307 V	Aver, power 500 W Daily energy 12.0 ki Capacity 300 Al-
Operating mode       Max. Charging - Discharging current         Direct coupling       Max. Charging - Discharging current         MPPT converter       Max. Charging - Discharging current         MPPT converter       Number of controllers 1       Image: Max. Charging 2 Discharging current         VP Array design       Image: Max. Charging current       Image: Max. Charging 2 Discharging current         Number of controllers       Image: Max. Charging 2 Discharging current       Image: Max. Charging 2 Discharging current         VP Array design       Operating voltage       100-480 V       Controller's power       3.20 kW         VP Array design       Operating conditions:       Image: Controller's power       3.20 kW       48 V         Mod. in series       S       Operating conditions:       Image: Controller's power       48 V       Aver. power         No. strings       1       Operating conditions:       Image: Controller's power       48 V       Copare         No. strings       1       Operating conditions:       Image: Controller's power       2 In parallel, 48 V       Copare         No. strings       1       Operating       464 V       Autonomy       1.0 day       Stored ember	Aver. power 500 W Dally energy 12.0 k Capadity 300 A Stored energy 11.5 k
Operating mode       Max. Charging - Discharging aurrent         Direct coupling       Max. Charging - Discharging aurrent         Direct converter       Number of controllers         PV Array design       Operating conditions:         Whop (dorC)       307 V         Whop (dorC)       48 V	Aver. power 500 W Daily energy 12.0 ki Capacity 300 A Stored energy 11.5 ki Nom. Power 3.48 ki
Operating mode       Max. Charging - Discharging current         Orect couping       Max. Charging - Discharging current         Orect couping       Max. Charging - Discharging current         Operating mode       Status 155 MBPT convolves V         Operating mode       Max. Charging - Discharging current         Number of controllers       Imput maximum voltage         Operating mode       Status 155 MBPT convolves V         PV Array design       Imput maximum voltage         Number of modules and strings       Operating conditions:         Wopp (20%C)       359 V         Vop (20%C)       359 V         Voc (10%C)       359 V         Voc (10%C)       359 V         Voc (10%C)       9.9 A         Max. operating power       3.18 kW         PV Array       1 str. of 8 modules         No. strings       Impp (60%C)       9.9 A         Max. operating power       3.18 kW         PV Array       1 str. of 8 modules         Non. Poin       FV/Picoad       7.0 Av. daily eme	Aver. power 500 W Daily energy 12.0 k Capacity 300 Å/ Stored energy 11.5 k Nom. Power 3.48 k Av. daily energy 4.4 kW
Operating mode       Max. Charging - Discharging current         Direct couping       Max. Charging - Discharging current         PV Array design       Max. Charging - Discharging current         Mod. In series       S       Poperating conditions:         Mod. In series       S       Discharging current         Vertood loss       May (Charging - Discharging current)       Max. operating power         Jump (60-VC)       355 V       Vinc (-10/C)         Vertood loss       Non. Strings       Imput (Max. operating power         Jump (60-VC)       9.4 Max. operating power       3.18 kW         Nb. modules       8 Area       17 m <sup>2</sup> Is (MCC)       10.6 A       (at max. rmad and SPC)       3.48 kWo         Controller       Non. P	Aver, power 500 W Daily energy 12.0 k Capacity 300 AP Stored energy 11.5 k Nom. Power 3.48 k Nom. Power 3.20 k

Figure 8. simulation for full load with 8 panel.

In the Fig. 9. you can see simulation with 4 panels that is acceptable with pvsyst.

Av. daly needs Enter accepted PLOL 5.0 0 % 🕜 Battery (user) voltage 48 0 V 🕜	
12.0 kWh/day Requested autonomy 1.0 ( day(s) C Suggested capacity 300 Ah	
Suggested PV power 9190 Wp (nom.)	
Storana PV Array Backulan Simulifiad skatch	
De argumente and Calenthian	
Substrate and Crematorian Strategy and Strat	
Tit 20°	
Orient. Fixed Tilted Plane Azimuth 0° Resize or available area (6 m²	
Select the PV module	
Available Now V Sort modules       O Power       O Technology	
1A Solar V 445 Wo 38V SI-mono 1AM78-510-445-MR Since 2021 Open	
Approx. needed modules 2 Sizing voltages: Vmpp (60°C) 38.9 V	
Select the control mode and the controller MPPT power converter	
Universal controller     Morningstar	
Operating mode Max. Charging - Discharging current	
O Direct coupling	
I MPPT converter Number of controllers 1 ↔ MPP Operating voltage 50-120 V Controller's power 2.40 kW	
Input maximum voitage 150 V Associated Battery 48 V	
PV Array design	
Number of modules and strings Operating conditions: The controller power is slightly oversized. User's needs Household Ave	, power 500 W
should be: Vmpp (60°C) 78 V Night ratio 49.6% Dail	energy 12.0 kWh
mod, in series 2 Whop (20°C) 91 V Voc (10°C) 117 V	Capacity 300 Ah
No. strings 2 0 2 between 1 and 2 Diame interface 1000 M (m2)	lenergy 11.5 kWh
Overload loss 0.0% Overload loss 0.0% Imp (60°C) 20.1 A Max. operating power 1.63 kW DV Array 2 str. of 2 modules No	Power 1780 Wp
I Promitratio 0.74 Provinces 3.6 AV. data by mail Isc (60°C) 21.3 A (at max. irradiand 50°C) Controlling MOT converter Not	Power 3.40 kWh
In the induces of the second s	resholds acc. to volta
	Carloida acci to volta
🗶 Cancel	🖌 ок

Figure 9. Simulation with 4 panels

For battery calculation, Lead acid technology has been selected. Each battery has 150Ah capacity, Voltage is 12v and the catalogue attached with the report. Totally 8 batteries have been offered by the software. In manual calculation the number of batteries with 250Ah also calculated.Fig.10 shows simulation with pvsyst software.

Stand-alone system definition, Variant "New simulation variant", Variant	New simulation variant	-				-		х
Av. daly needs     Enter accepted PLOL     5.0 0       12.0 kWh/day     Requested autonomy     1.0 0       Cetailed pre-sizing       Storage     PV Array     Back-Up       Simplified sketch	% ? E day(s) ? S S	Battery (user) voltage Suggested capacity Suggested PV power	48 0 V 7 300 Ah 9190 Wp (nom.)					
Procedure       The Pre-sizing suggestions are based on         1 Pre-sizing       Define the deaired Pre-sizing conditions i         2 Storage       Define the battery pack (default checkb)         3 PV Array design       Design the PV array (PV module) and the         4 Back-Up       Define an eventual Genset         Specify the Battery set       Sort batteries by ● voltage ○ capacity ○○         Narada       12 V       150 Ah       Pb Sealed         Lead-acid       ○       ○       ● batteries in series       Number of batteries         2       ○       ● batteries in paralle       Number of elements         100.0       % Initial State of Wear (static)       ●       100.0       ● %	the Monthly meteo and i PLOL, Autonomy, Batter oxes will approach the pr control mode. You are a on manufacturer Gel MPG 12V 150 F Ba Ba St 48 Tr N	the user's needs definition y voltage) e-sizing) divised to begin with a university Since 2018 Since 2018 attery pack voltage obal capacity ored energy (80% DOD) tal weight b. cycles at 80% DOD total stored energy during the battery ifth	C Open 48 V 300 Ah 11.5 kWh 416 kg 1000 13176 kWh					
Operating battery temperature       Temper, mode     Average between TAt ∨       Fixed temperature     20 °C       The battery temperature is important for the aging of the battery. An increase of 10 °C divides the "static" battery life by a factor of		The controller pow oversize	er is slightly d.	User's needs Battery pack PV Array Controller	Household Night ratio 49.6% 2 in parallel, 48 V Autonomy 1.0 day 2 str. of 2 modules PV/PLoad 3.6 MPPT converter PV/PConv 0.74 Cancel	Aver, powe Daily energ Capacit Stored energ Nom. Powe Av. daily energ Nom. Powe Threshold	r 500 W y 12.0 k y 300 A y 11.5 k r 1780 y 9.0 k r 2.40 k s acc. tr	V kWh h kWh Wp Wh kW o volta

Figure10. Selecting Battery

All of loss calculated in the project, but wind and snow must calculate in the structure simulations. If you haven't all of information, Pvsyst allow you to select in by experience and this software set by default 3%.

hermal parameter	Ohmic Losses	Module quality - LID -	Mismatch	Soiling Loss	IAM Losses	Spectral correction
-Yearly soilin	g loss factor-	Default	9			
Year	ly loss factor	3.0 % 🗹				
	De Francisco Maler					

Figure11. Soiling Loss

For the simulation of the project at first the climate data and location must be added to the software. For this reason pvsyst use meteonorm database.Fig.14,Fig.15, Fig.16, respectively show the selecting the location for the project.

		Project su	mmary ——		
Geographical Site		Situation		Project settings	
Planegg		Latitude	48.11 °N	Albedo	0.20
Germany		Longitude	11.43 °E		
		Altitude	552 m		
		Time zone	UTC+1		
Meteo data					
Planegg	1000 0005 0	<i>v</i> -			
NASA-SSE satellite data	1983-2005 - Synthe	tic			
		System su	mmary —		
Stand alone system		Stand alone system	with batteries		
PV Field Orientation		User's needs			
Fixed plane		Daily household consur	ners		
Tilt/Azimuth	20/0°	Constant over the year			
		Average	12.0 kWh/Day		
System information					
PV Array			Battery pack		
Nb. of modules		4 units	Technology	Lead-acid, sealed,	Gel
Pnom total		1740 Wp	Nb. of units		8 units
			Voltage		48 V
			Capacity		300 Ah
		Results su	Capacity mmary —		300 Ah
Available Energy	1925 kWh/year	Results su	Capacity mmary 1106 kWh/kWp/year	Perf. Ratio PR	300 Ah 

Figure12. project summery and system summery.

-	Project: Germany_Project.	หม		-		x
	Project		🛨 New 📂 Load 💾 Save 🗊 Project settings 🏢 Delete 👗 Gient		0	
1	Project's name	Germany	Client name Not defined			П
	Site File	Planegg_Nasa_1983.SIT	NASA-SSE satellite data 1983-2005 Germany	Ì		
*	Meteo File	Planegg_Nasa_SYN.MET	NASA-SSE satellite data 1983-2005 Synthetic 0 i 🗸 🔯 🤇	)		
•			Simulation done (version 7.2.21, date 10/02/24)			Ī

Figure13. Selecting the location



Figure14.choosing the location



Figure15.Import data from metenoorm database

Meteonorm is unique combination of reliable data sources and sophisticated tools. From the below site you can achieve more information.

https://meteonorm.com/en/



Figure16.Import data from metenoorm database

One section of the results shows the equipment characterustics.in Fig. 17 all of information about the PV, Battery, controller have been calculated.

PV Array Characteristics							
PV module		Battery					
Manufacturer	JA Solar	Manufacturer	Narada				
Model	JAM78-S10-435-MR	Model	MPG 12V 150 F				
(Original PVsyst database)		Technology	Lead-acid, sealed, Gel				
Unit Nom. Power	435 Wp	Nb. of units	2 in parallel x 4 in series				
Number of PV modules	4 units	Discharging min. SOC	21.4 %				
Nominal (STC)	1740 Wp	Stored energy	11.7 kWh				
Modules	2 Strings x 2 In series	Battery Pack Characteristics					
At operating cond. (50°C)		Voltage	48 V				
Pmpp	1590 Wp	Nominal Capacity	300 Ah (C10)				
U mpp	80 V	Temperature	Average between fixed 20 °C				
I mpp	20 A		and External				
Controller		Battery Managemen	t control				
Manufacturer	Morningstar	Threshold commands a	s Battery voltage				
Model	Tristar TS MPPT 45 - 48V	Charging	55.2 / 49.7 V				
Technology	MPPT converter	Corresp. SOC	0.92 / 0.56				
Temp coeff.	-5.0 mV/°C/Elem.	Discharging	47.0 / 49.0 V				
Converter		Corresp. SOC	0.20 / 0.42				
Maxi and EURO efficiencies	98.5 / 97.7 %						
Total PV power							
Nominal (STC)	1.74 kWp						
Total	4 modules						
Module area	8.7 m²						

Figure17.simulation results for main equipments

Figure 18, Figure 19 and Figure 20 consumer information has been shown.

	Definition of da	aily household consu	mptions for the	year.	
onsumption	Hourly distribution				
-Daily con	sumptions				
Number	Appliance	Power	Daily use	Hourly distrib.	Daily energy
0	Lamps (LED or fluo)	0 W/lamp	0.0 h/day		0 Wh
0	TV / PC / Mobile	0 W/app	0.0 h/day		0 Wh
0	Domestic appliances	0 W/app	0.0 h/day		0 Wh
0	Fridge / Deep-freeze	0.00 kWh/day	0.0		0 Wh
0	Dish- and Cloth-washer	0.0 W aver.	0.0 h/day		0 Wh
1 ^	Other uses	3000 W/app	4.0 h/day	OK	12000 Wh
0	Other uses	0 W/app	0.0 h/day		0 Wh
	Stand-by consumers	0 W tot	24 h/day		0 Wh
0	Appliances info		Total daily Monthh	/ energy / energy	12000 Wh/day 360.0 kWh/mth
-Consump Years Seasor Month:	tion definition by C	Week-end or Weekly u	se		

Figure18.Importing consumer information in pvsyst

Definition of daily household	d consumptions for the year.
Other uses	
9H 12H 15H Total 4 H 18H 3H 0H 21H	
	Daily global consumption
	3.5
	0 3 6 9 12 15 18 21 24

Figure18.Definition of Daily consumptions for the year



Figure 19. Definition of Daily consumptions for the year in the PVsyst result

In the Fig.20 Main results have been studied and shows that specific production is 1106 kwh/kwp/year, Performance ration is 78.38% that is acceptable.

The Performance Ratio is the ratio of the energy effectively produced (used), with respect to the energy which would be produced if the system was continuously working at its nominal STC efficiency. The PR is defined in the norm IEC EN 61724.

In usual Grid-connected systems, the available energy is E\_Grid. In stand-alone systems, it is the PV energy effectively delivered to the user, i.e. E\_User - E\_BackUp. In pumping systems, this is E\_PmpOp.

The energy potentially produced at STC conditions is indeed equal to GlobInc \* PnomPV, where PnomPV is the STC installed power (manufacturer's nameplate value). This equivalence is explained by the fact that at STC (1000 W/m<sup>2</sup>, 25°C) each kWh/m<sup>2</sup> of incident irradiation will produce 1 kWh of electricity.

Namely, the PR is not dependent on the PV module efficiency. As an example an amorphous module and a crystalline high-efficiency module will lead to comparable PR. Only the low-light performance and temperature dependency will induce differences.

A tracking system will have a similar PR than a fixed sheds arrangement. Even sometimes slightly lower because the array temperature (related to GlobInc) may be higher.



### 4- conclusion:

According to my calculations this system need approximately 4.5 to 5 kw panels for working 4 hours continuously. Because of lack of space and the 445w panel we have close to 2 kw panel and for this reason we need 8\*150AH lead acid AGM battery.. For working more time, we need more panels with more power. Also the output of Inverter is 220 v and you need add small transformer for converting to 440V. The DC system voltage is 48 V and all of equipment must work in this voltage. All of information are in the Pvsyst results that attached to the report.

#### Attachment

1. How much efficiency reduces if we keep plates flat? Tilt angle zero





Figure1: Global on collector plane with 20 tilt : 421kwh/m2



Figure 2 :Global on collector plane with 20 tilt : 306kwh/m2

Difference between to tilt is : 421-306=115 kw/m2

2. Why we have so much unsed power? What happens to this unsed power.

The 2 panels for your project is enough, But PVsyst shows that you need more than 2 panels. In figure 3 you can see the Pvsyst simulation. According to manual calculation 2 panel is ok. I will add it in the report.

Number of modules and strings		Operating conditi	ons:	The controller power is slightly oversized.		
		should be:	Vmpp (60°C)	77 V		
Mod. in series	2	between 2 and 2	Vmpp (20°C)	90 V		
Nh. strings	2 ^	between 1 and 2	Voc (-10°C)	116 V		
ior ounigo	v	a betreen zond z	Plane irradiance	1000 W/m	2	
Overload loss	0.0%	(?	Impp (60°C)	19.9 A	Max. operating power	1.59 kW
Pnom ratio	0.73		Isc (60°C)	21.1 A	(at max. irrad and 50°C)	
Nb. modules	4	Area 9 m	Isc (at STC)	21.0 A	Array nom, Power (STC)	1.74 kW

Figure 3. PV Array Design

3. can be replace 635w with 445w panels i, because 445w panels are small fit(1762mmX 1134mm)exactly in door, i know power is less but we have so much unused power also so i think its not a such a big problem.

Yes. You can use 445w

4. Do we need 312 Ah Battery, how many the machine can run with such battery .

-Specify the Battery set				
speary are buttery see	_			
Sort batteries by <ul> <li>voltage</li> </ul>	O capacity O	manufacturer		
BYD $\checkmark$ 51.2 V	156 Ah Li LFP	B-Box PRO 7	.5 Since 2017 💛	Q Open
Lithium-ion $\checkmark$ The sele	ected battery is a module		Battery pack voltage	<b>51</b> V
1 🗘 🔽 modules in series	Number of modules	2	Global capacity	312 Ah
2 🔅 🗹 modules in parallel			Stored energy (80% DOD)	14.4 kwn
	Number of elements	96	l otal weight	<b>294</b> kg
100.0 🔆 % Initial State of Wear (nb. of cycles)			Nb. cycles at 80% DOD	7500
100.0 0 Minitial State of Wear	(static)		Total stored energy during the battery life	97 MWh

I sent you all information about battery. The capacity of each battery can be 156Ah , Global capacity is 312 Ah

5. we need AC output with 440V, where I can see that in your simulation file.

It depends on your charge controller and its output

6.why we selected hourly distribution different , usually we run machine 4 hours continuously , because if we stop the machine we need to re heat it takes more energy.

Because of calculation in bad conditions. Its possible to simulate continuedly.

7. if we use 4x 445w panels how much power we can produce per day?

I can send you new simulation with PVsyst

8.MPPT invertor which type and which brand?

In the report I will attach the information.

9.battery which brand and type , please send me the cost?

In the report I will attach the information.