Functions and analyzes of the SMA Solar System

16.01.2017

EnDev-Project Liberia

energising development

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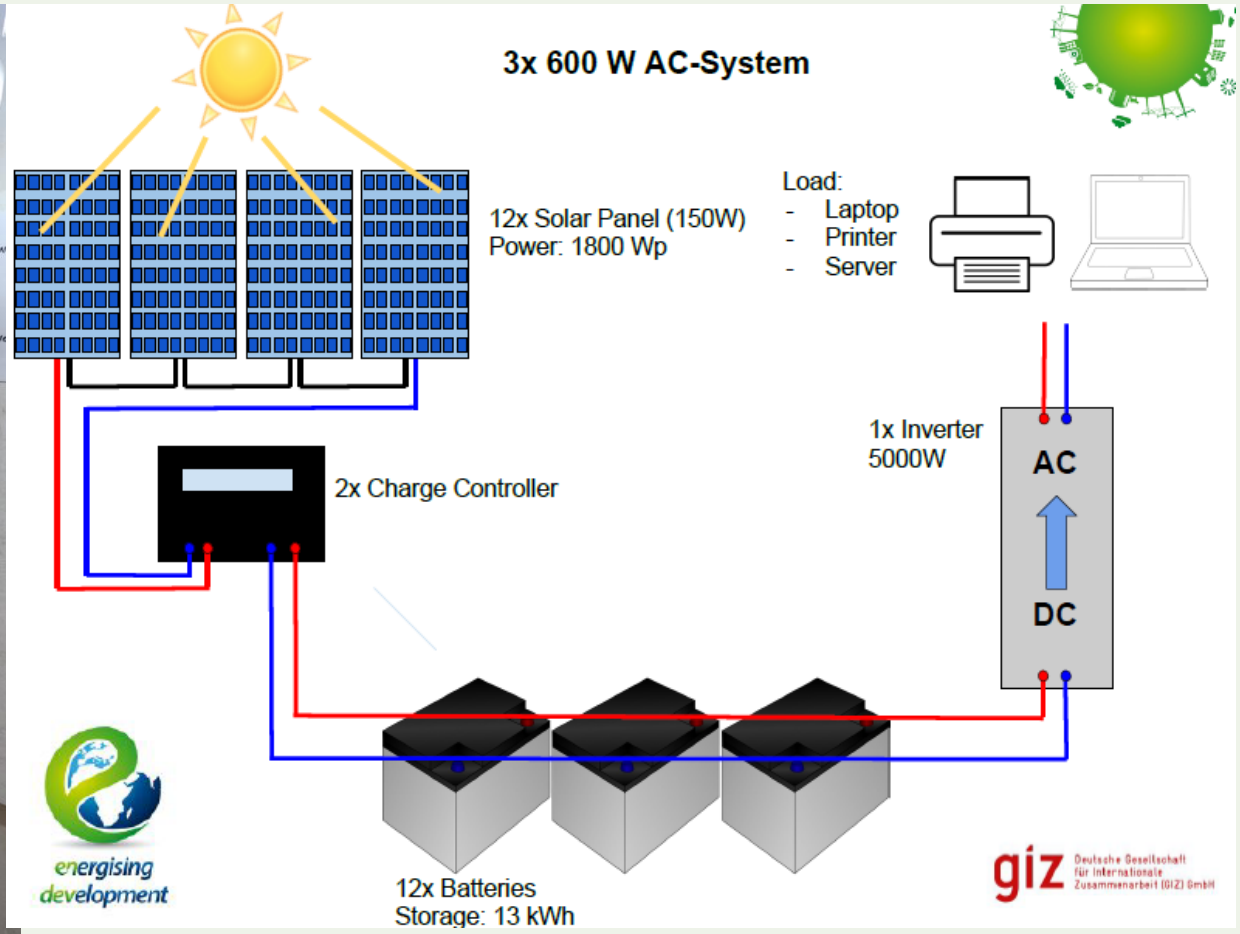
1. Introduction (Components of the Solar System)
2. Load shedding function
3. Sunny Portal
4. Economic Calculation
5. Visualisation with sunny portal

1. Introduction

Old System



Old System

Potential to improve:

- Batteries are connected in parallel
- Charge Controller parallel
- Panels parallel
- Reduced monitoring
- Inverter Quality
- Parallel running Systems

1. Introduction New System

1: Battery bank

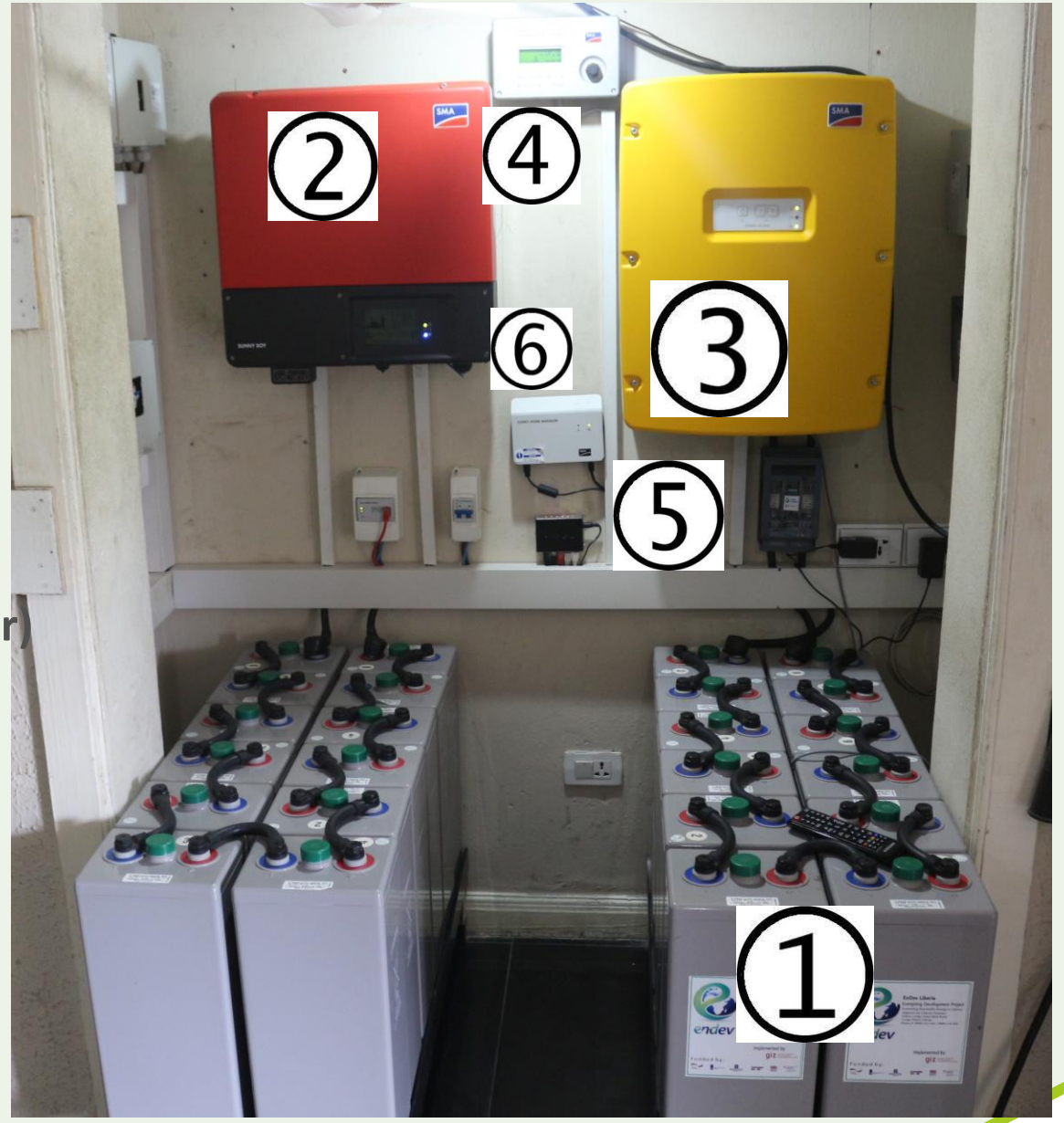
2: Sunny Boy (Solar Inverter)

3: Sunny Island (Battery Inverter)

4: Remote Control

5: Batfuse

6: Sunny Home Manager



1. Introduction

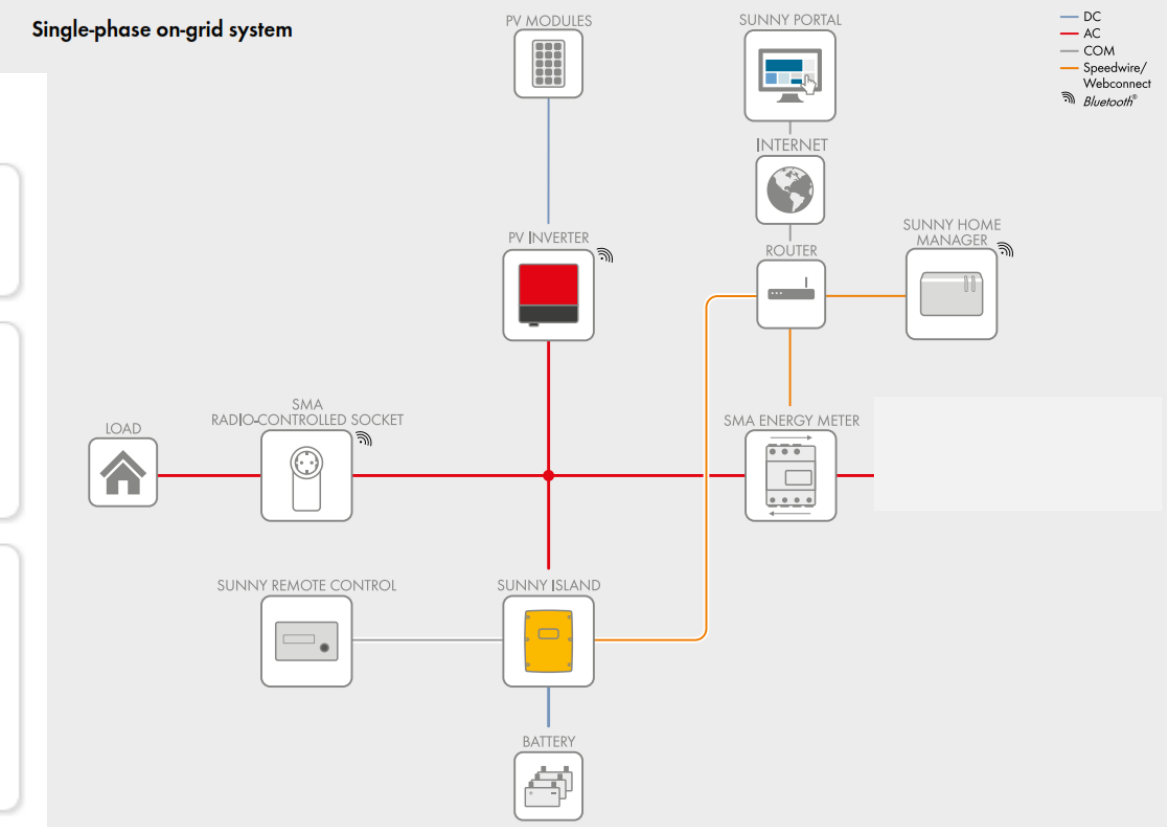
New System

PV System Profile | EnDeV-Office AC-System

Location:	Monrovia, Liberia
Operator:	EnDev-Liberia
Commissioning:	25/08/2017

PV system power:	3.600 kWp
Annual Production:	approx. 5,911 kWh (1,642 kWh/kWp)
CO2 avoided:	Approx. 4.1 tons per annum
Nominal battery capacity:	26,304 Wh
Battery type:	Valve Regulated Lead Acid battery (VRLA)

Modules:	12 x SolarWorld poly 12 x Solarworld poly
Azimuth angle:	-70°, 110°
Angle of inclination:	15°
Communication:	Sunny Home Manager
Inverter:	Sunny Boy 4000TL-21 Sunny Island 8.0H



2. Load-shedding function

Different Priorities

① Light, Laptop, Printer, Internet,

Off at
50 % SOC

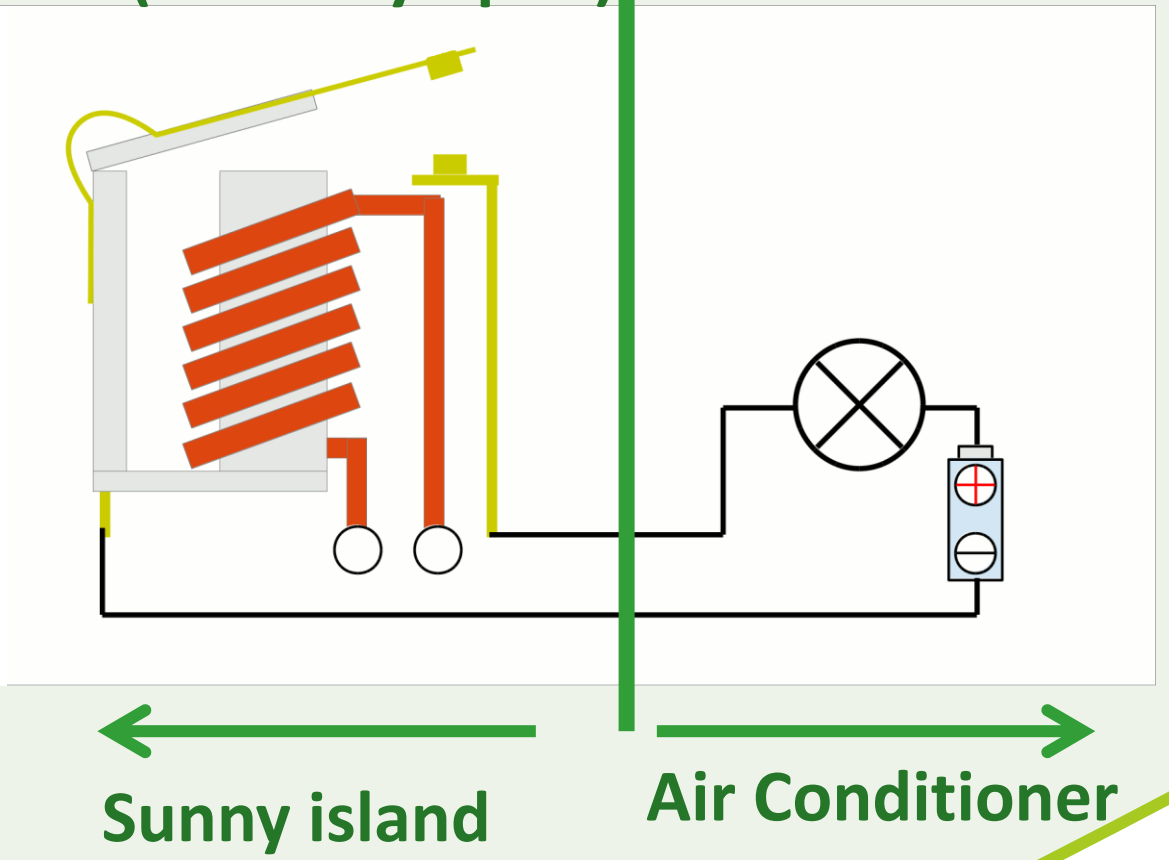
② Air Conditioner

Off at
70 % SOC

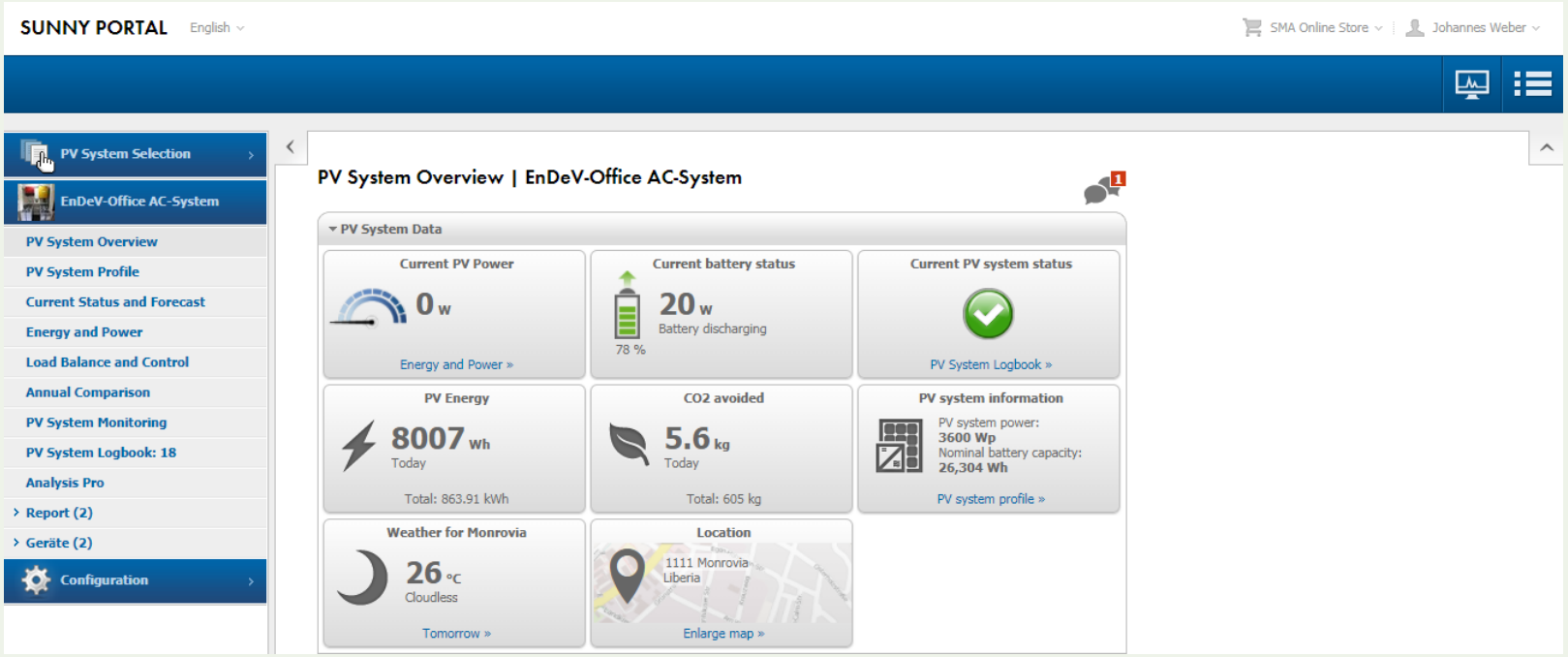
SOC: State of Charge

2. Load-shedding function

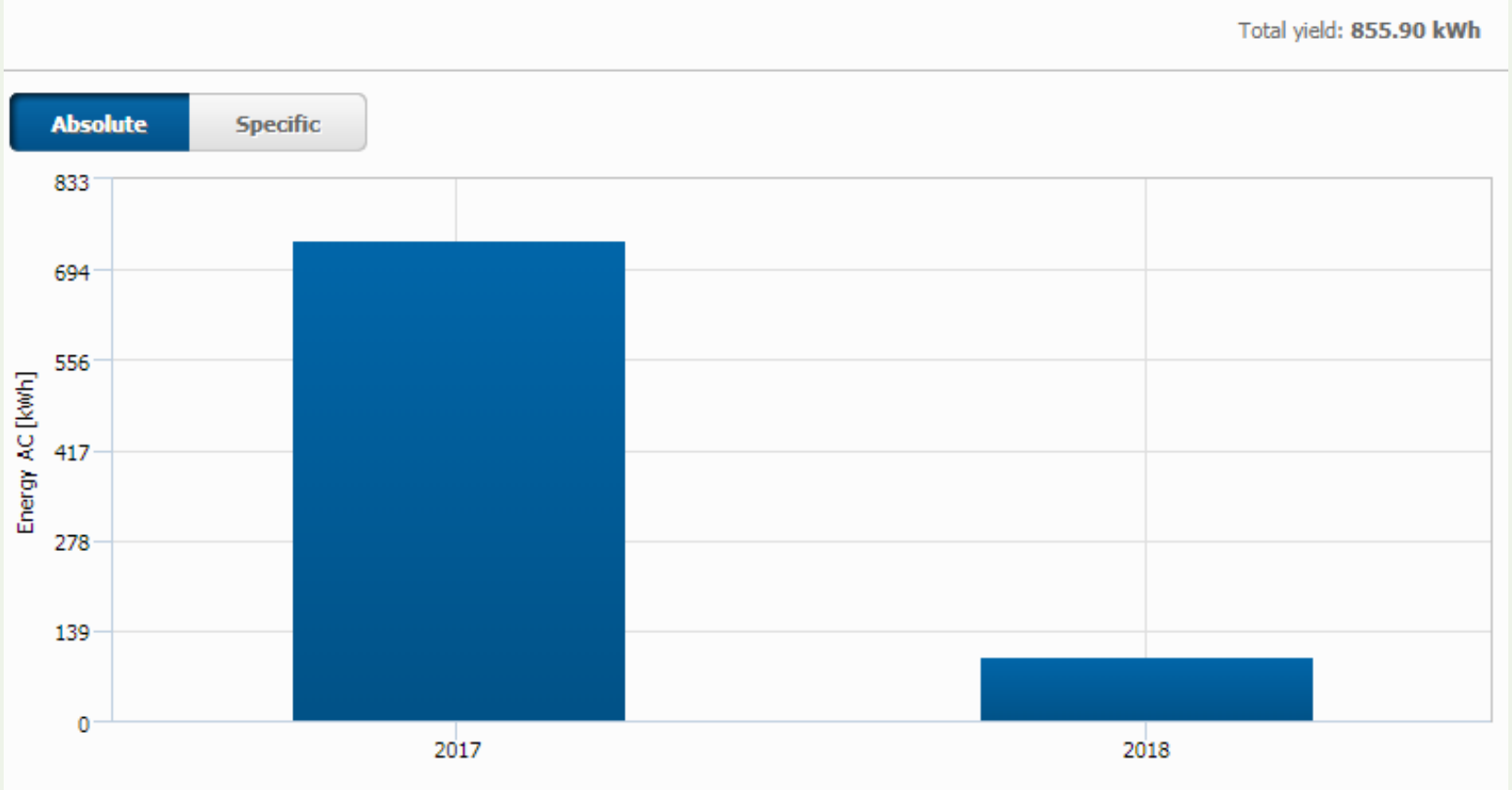
Multifunctional relay in the „Sunny island“



3. Sunny Portal



4. Economic Calculation



855.90 kWh → September 2017 – 16.01.2018 = 135 Days

855.90 kWh/135 days = 6.34 kWh

4. Economic Calculation

Panel: 0,60 US$/Wp → 3.6 kW = 3600W x 0,60 US$ = **2.160 US$**

Batterie: 270 US$/kWh → 26 kWh * 270 US$/kWh = **7.020 US$**

Sunny Island: **2.400 US$**

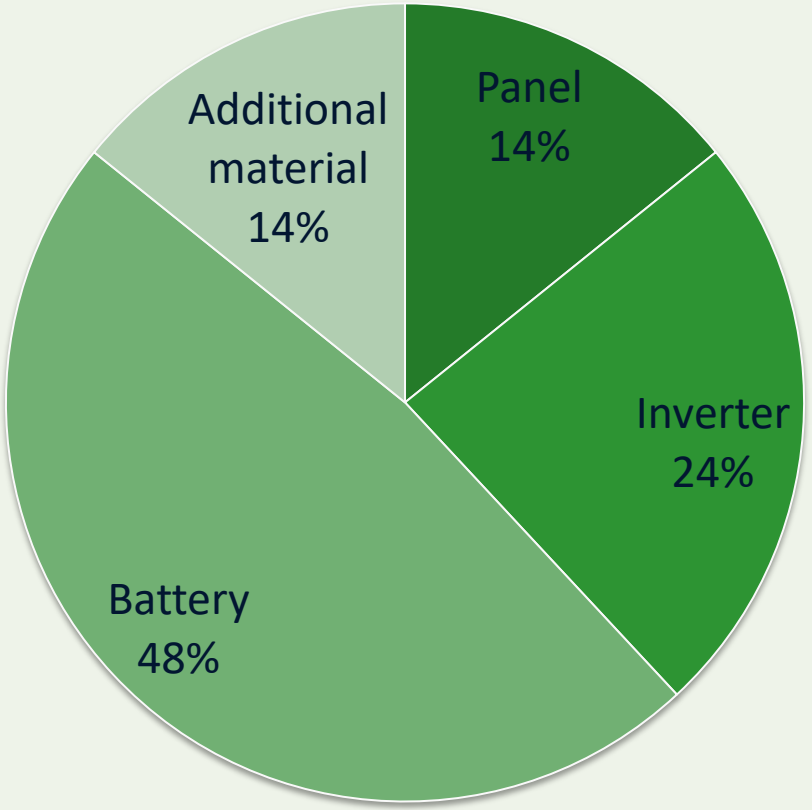
Sunny Boy: **1.100 US$**

Additional material:
Cable, Communication, Support Structure etc. = **2.000 US$**

Total Cost: 14.680 US$ = 4.077 US$/kW

4. Economic Calculation

Cost allocation in percent %



4. Economic Calculation

Calculation over 15 years

Actual Consumption per day: 6.34 kWh

Power Source	Cost per kWh	Cost per day	Reliable
Generator	0,75 US$	4.7 US$	Yes
IPP with 3 A		4.5 US$	No
LEC	0,37 US$	2.34 US$	No
Solar System	0,42 US$	2,66 US$	Yes

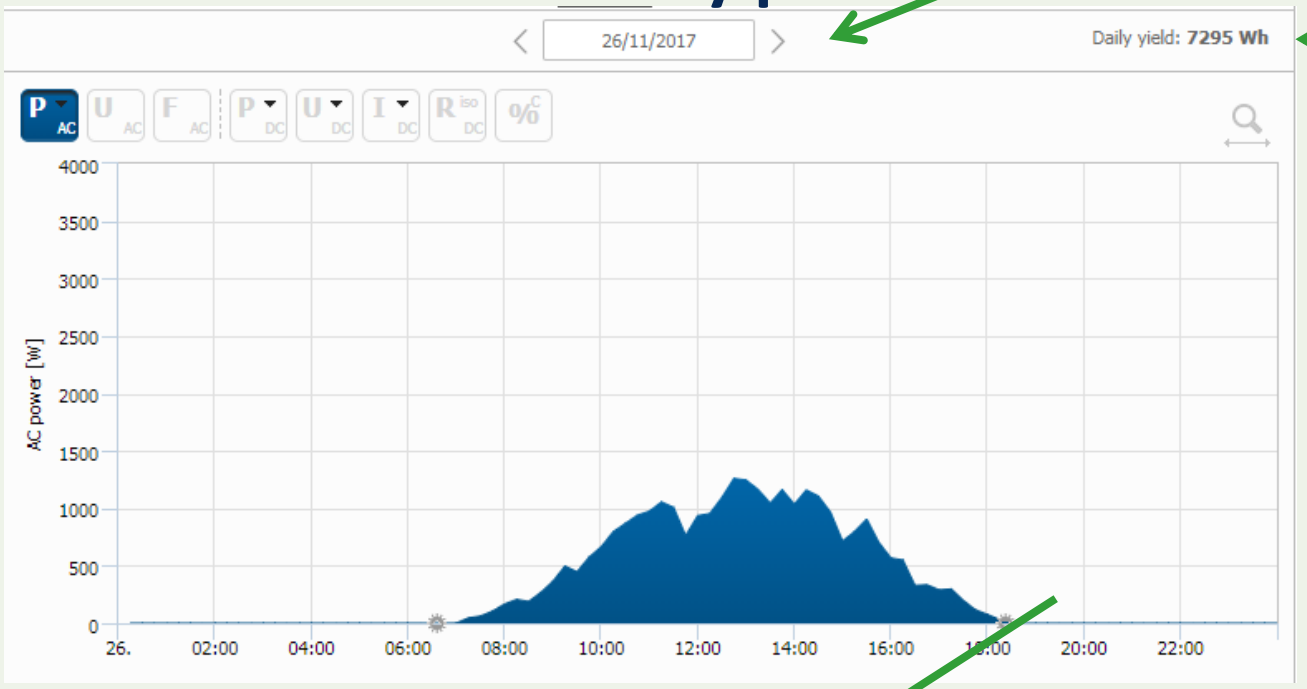
Possible Consumption per day: 12 kWh

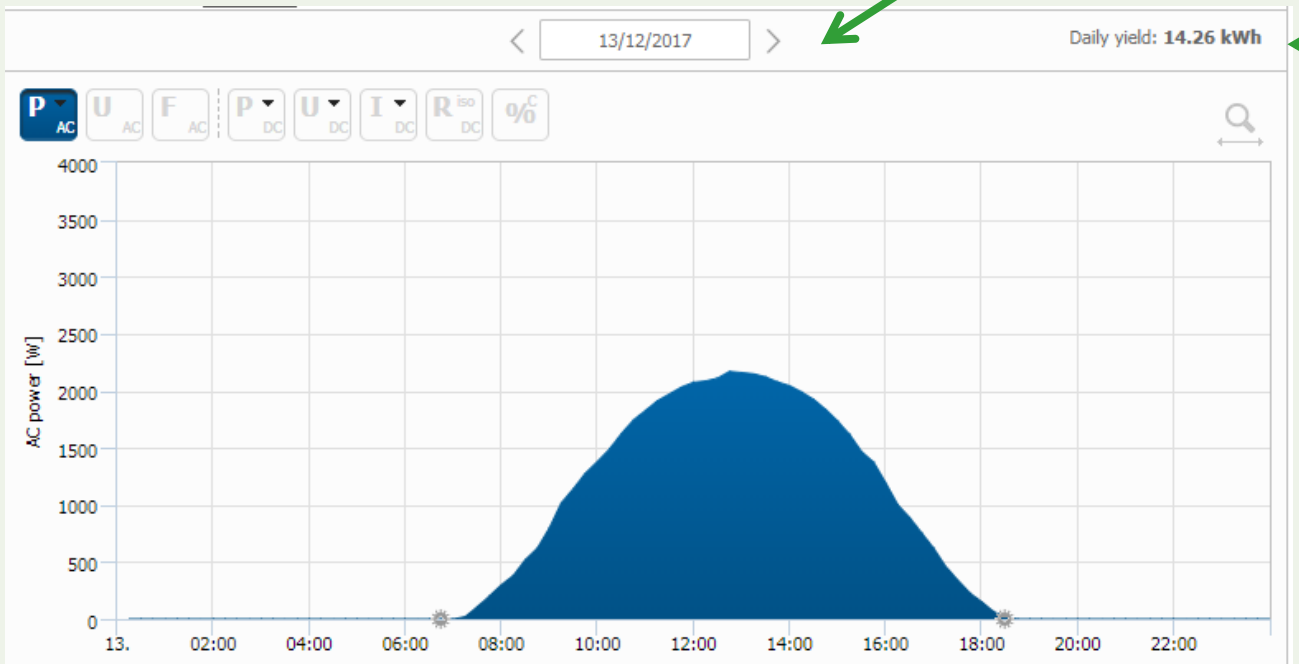
Power Source	Cost per kWh	Cost per day	Reliable
Generator	0,75 US$	9 US$	Yes
IPP with 6 A		8.5 US$	No
LEC	0,37 US$	4.4 US$	No
Solar System	0,22 US$	2,66 US$	Yes

→ You save 1,8 US$/day (compare LEC), 5,80 US$/day (Compare IPP)

5. Visualisation with sunny portal

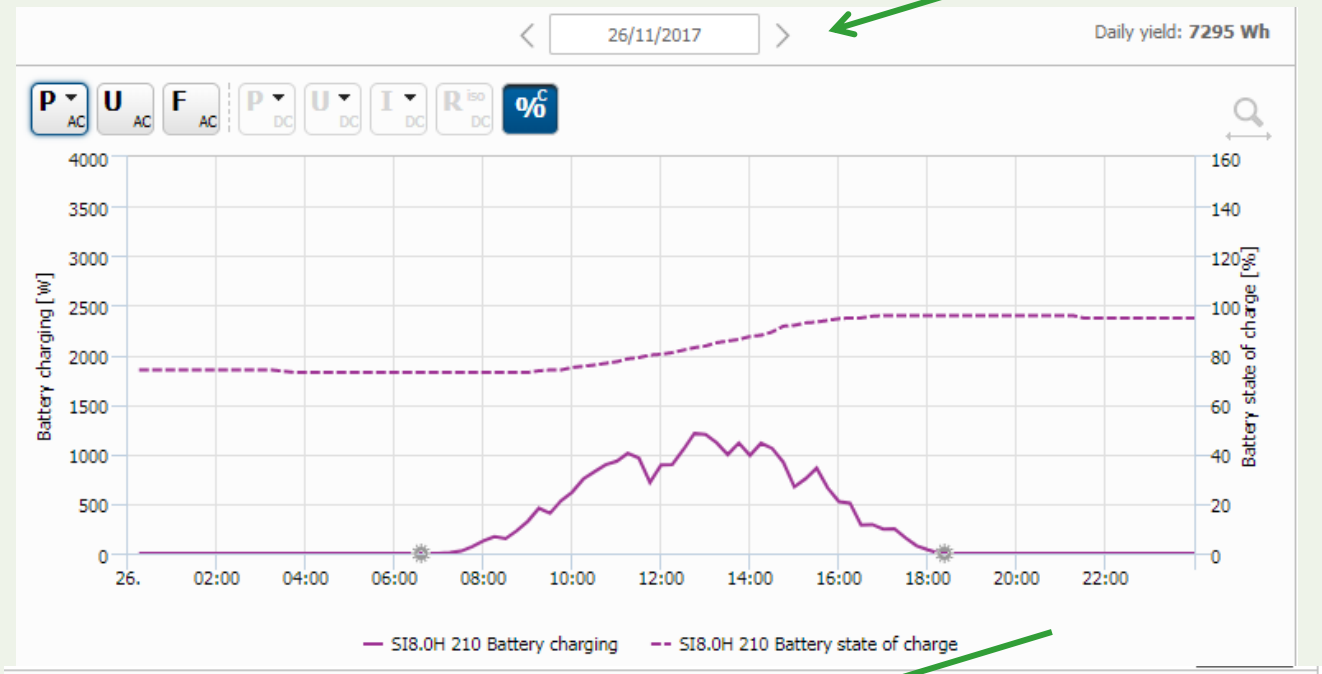
Energy from the sun for all appliances and charging the battery

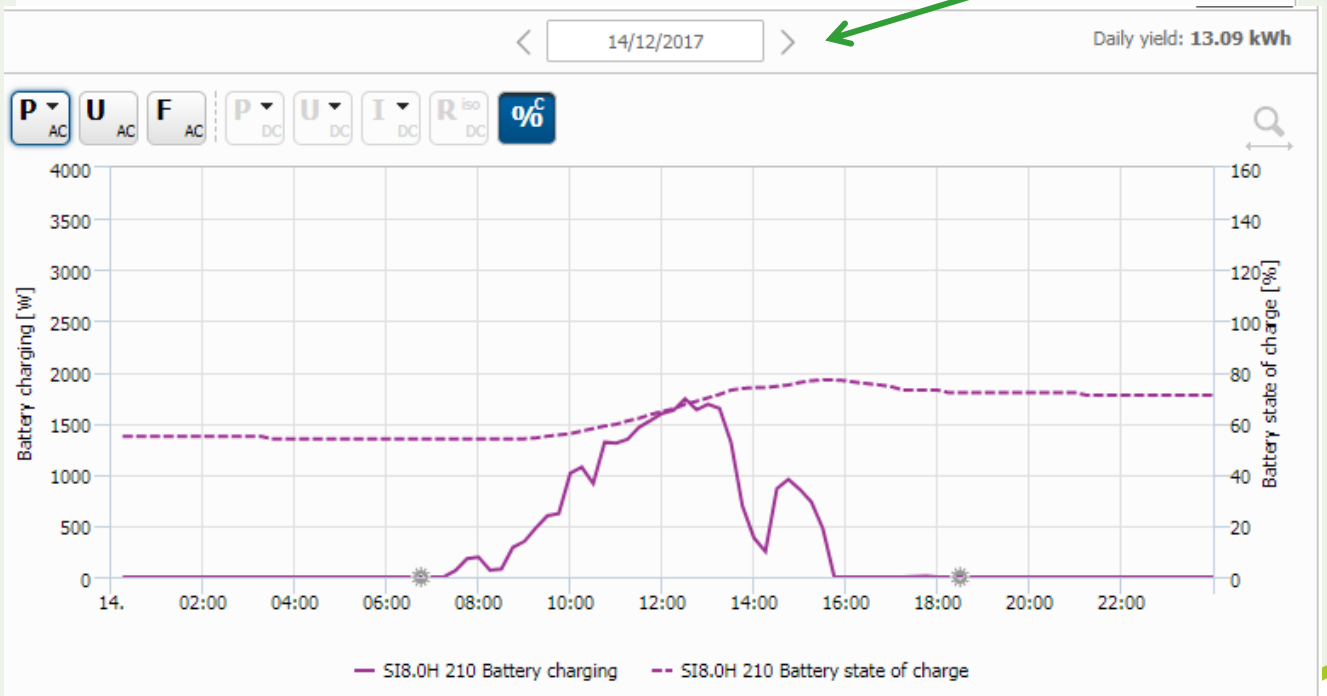




5. Visualisation with sunny portal

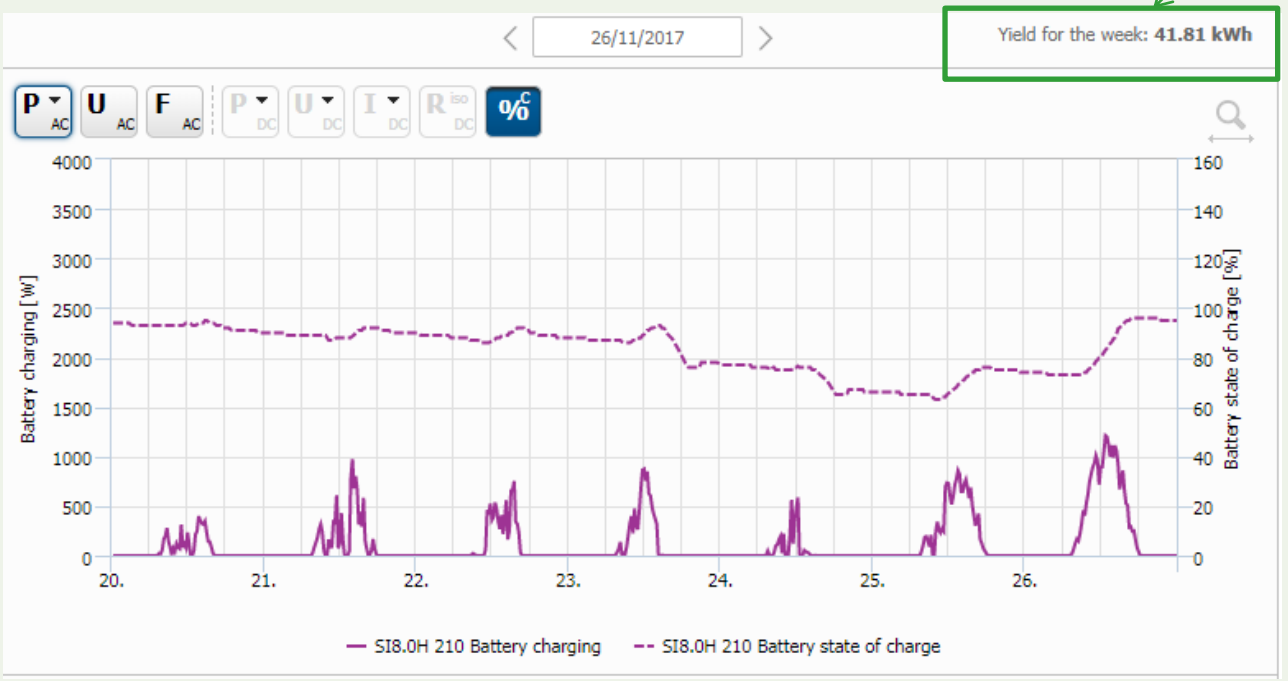
Charging behavior and State of charge of the battery





Visualisation with sunny portal

Charging



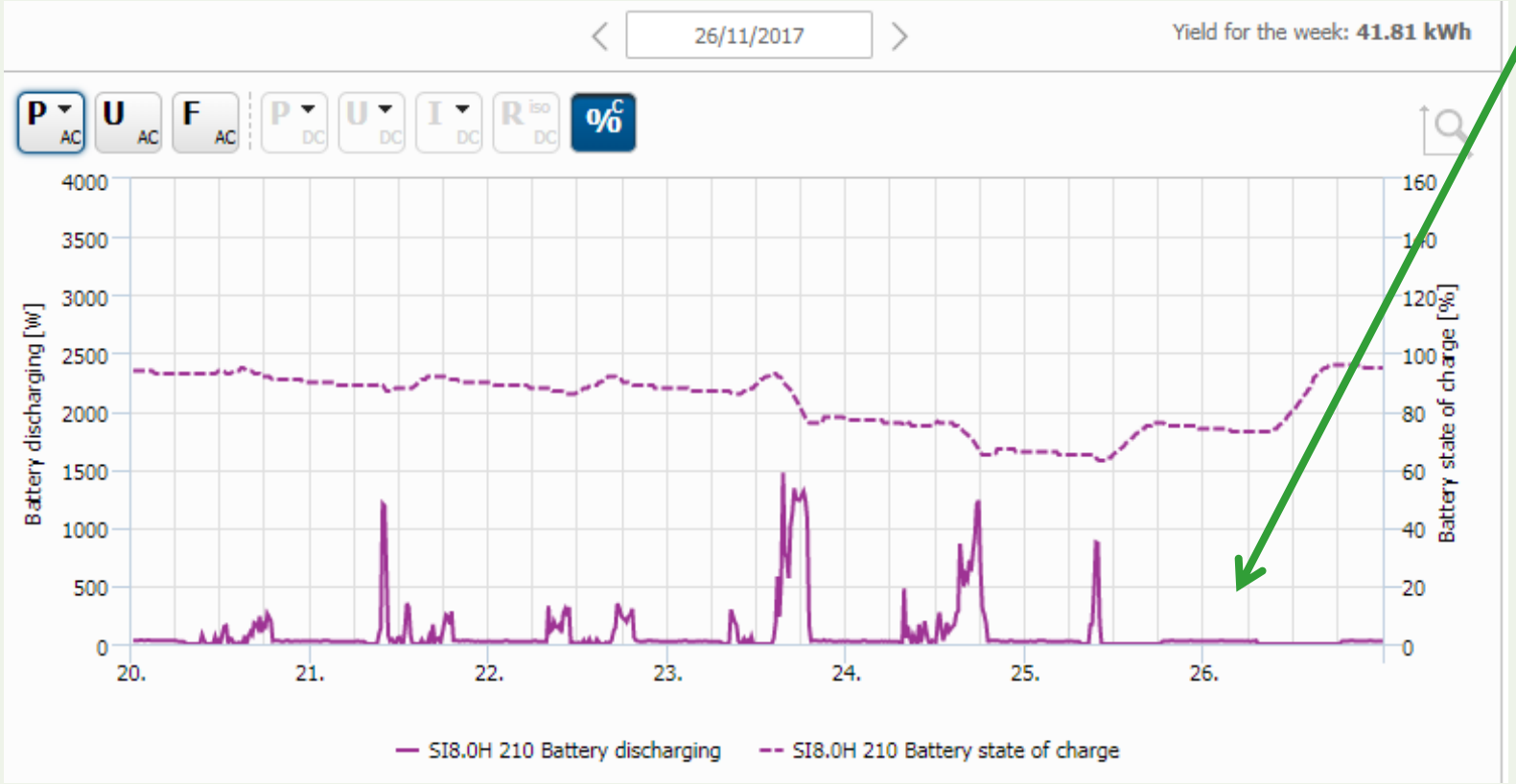
40% Difference in state of charge = 10 kWh

75% of the energy comes directly from the sun
25% of the energy goes through the battery

Visualisation with sunny portal

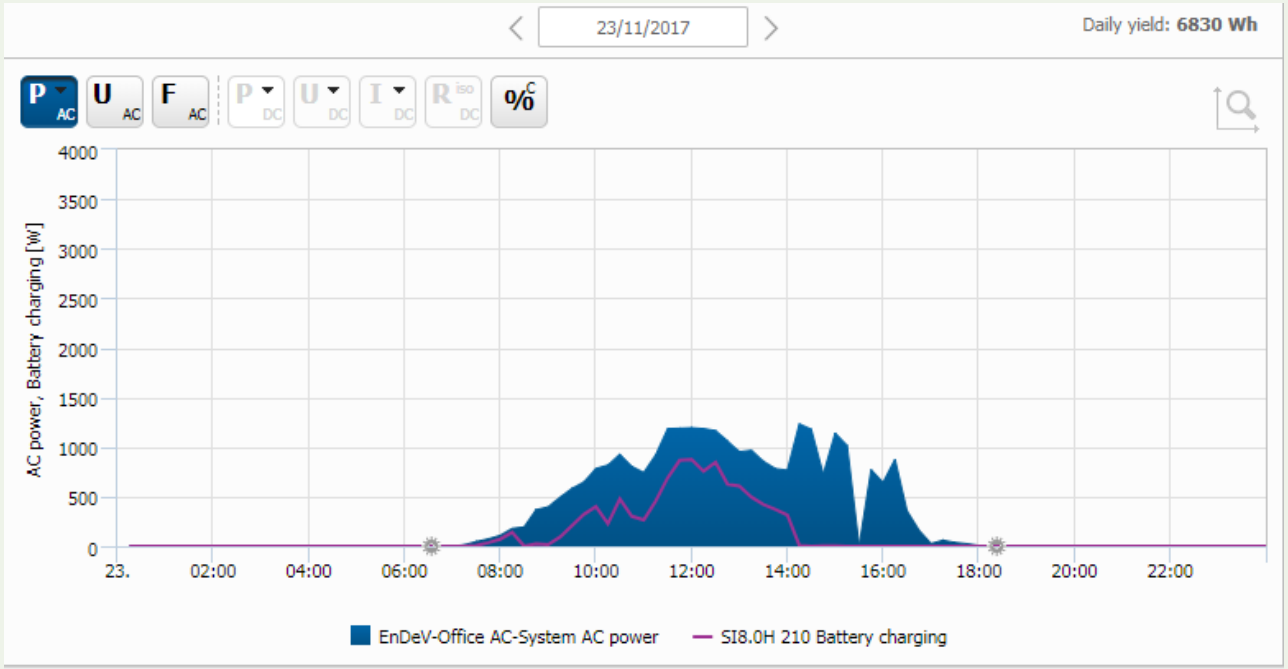
Weekend

Discharging

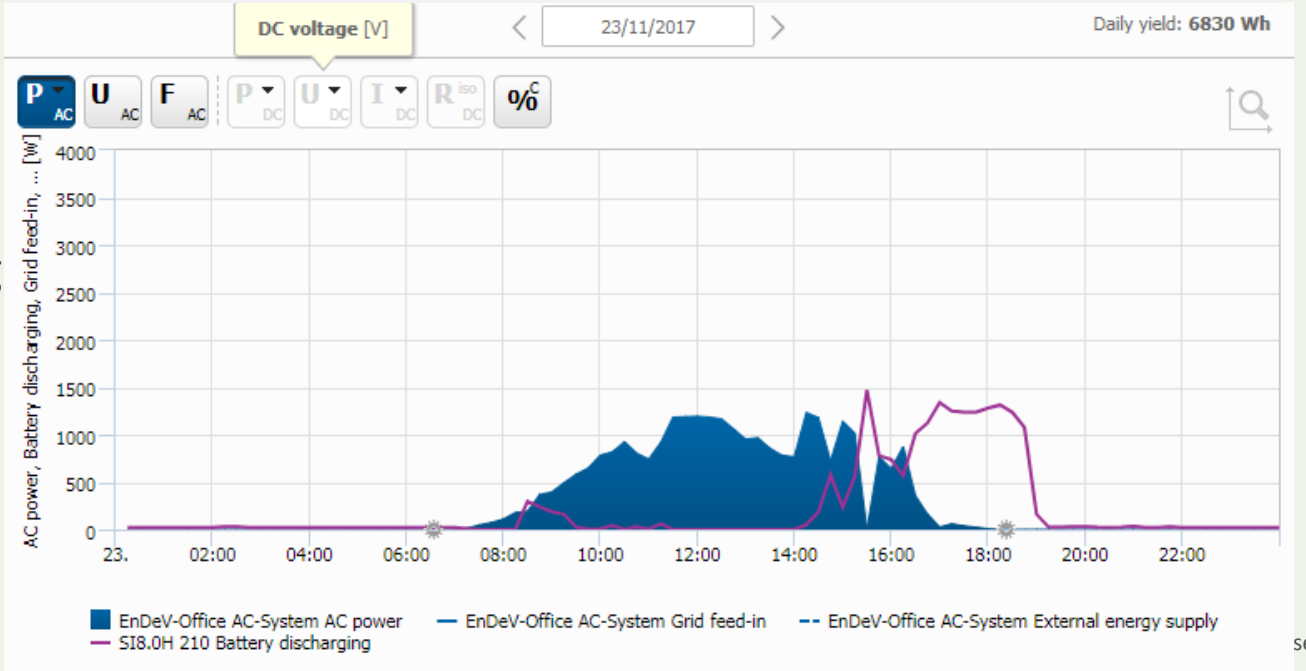


Visualisation with sunny portal

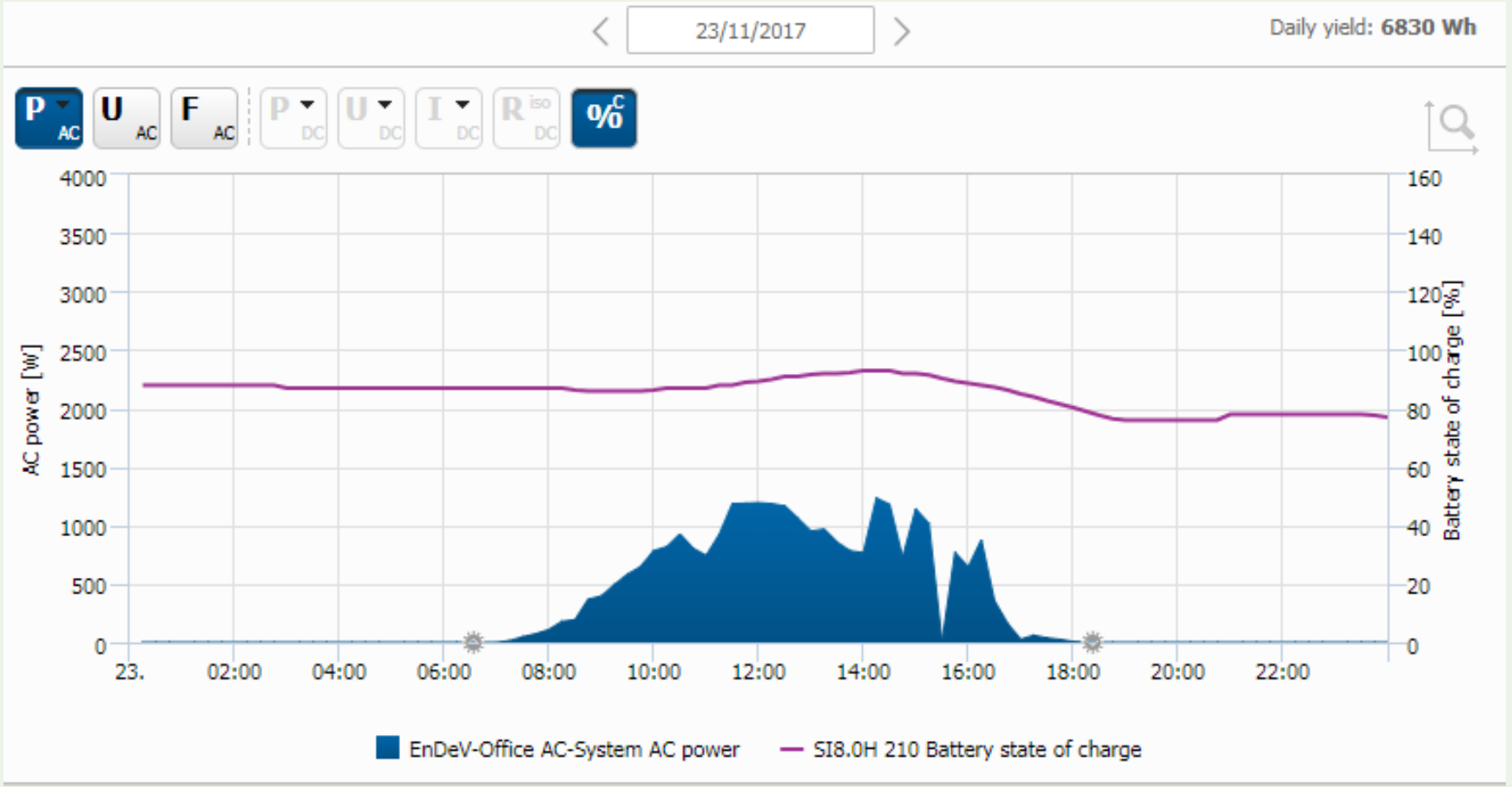
Charging



Discharging



Visualisation with sunny portal



Next Time

- System Grounding
- Load management
- More analyzes from the batteries
- What you want to know??

Thank you

15.01.2018

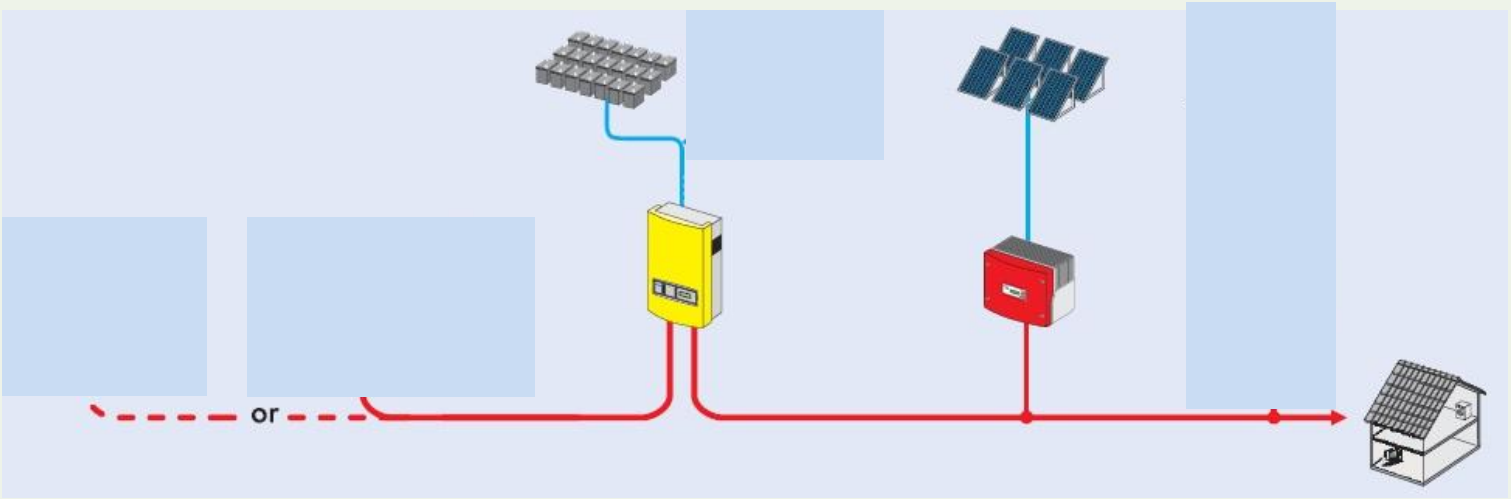
EnDev-Project Liberia

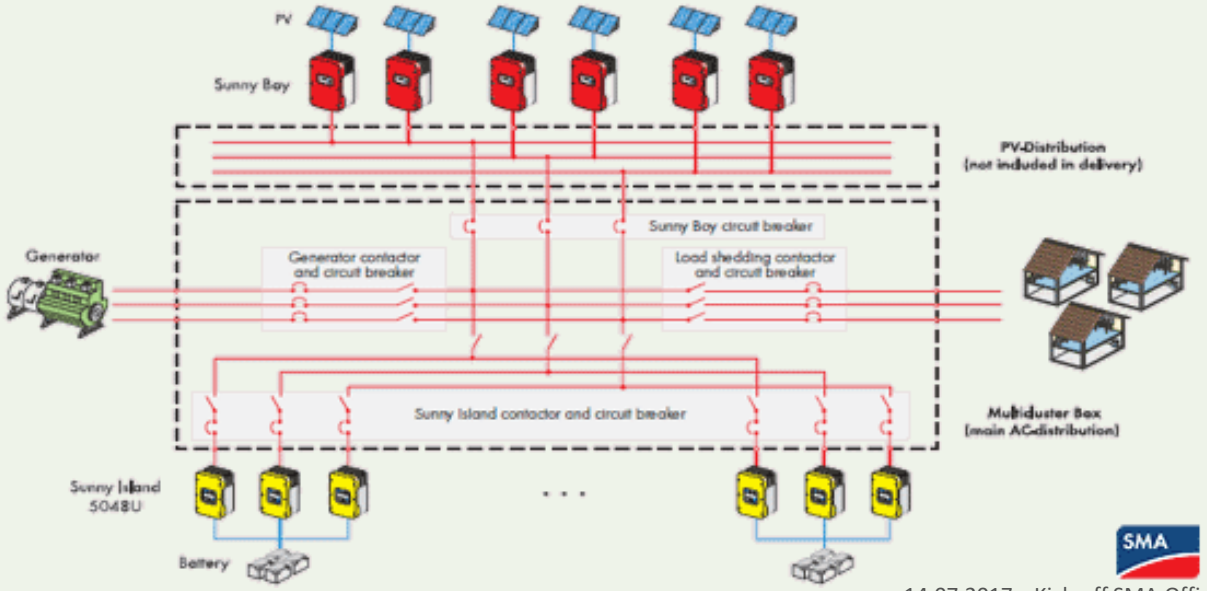
Why we install a SMA-System?

- *Flexibel*
- *Durability*
- *Monitoring*
- *Less losses*

Why we install a SMA-System?

Flexibel





Why we install a SMA-System?

Durability

Simply robust

- Can be used anywhere thanks to degree of protection IP54
- Extended temperature range thanks to OptiCool
- Durable and reliable thanks to the interaction of tried and trusted technologies

Operating temperature range	-25 °C ... +60 °C	-25 °C ... +60 °C
Protection class (according to IEC 62103)	I	I
Climatic category according to IEC 60721	3K6	3K6
Degree of protection according to IEC 60529	IP54	IP54

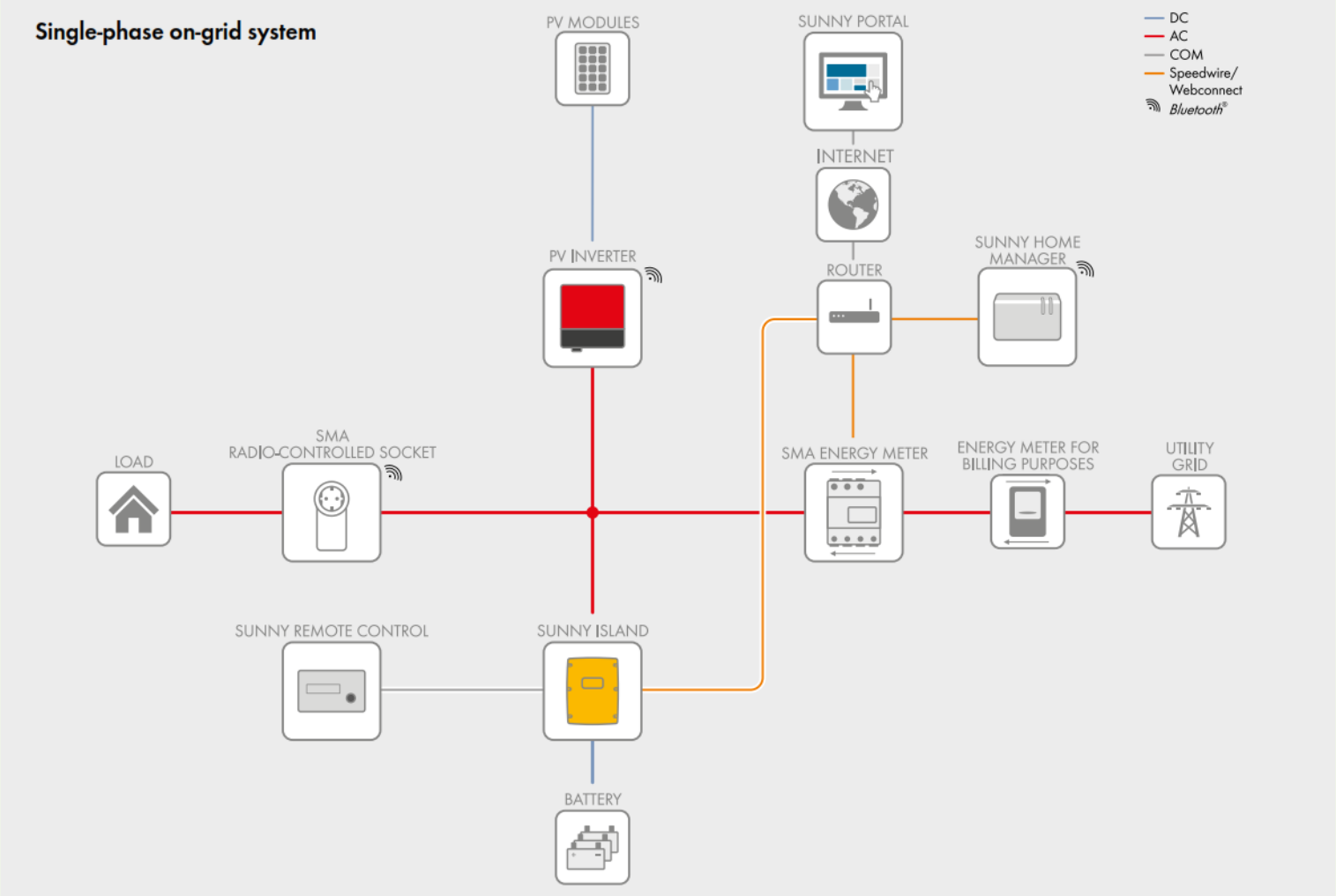
What means IP 54?

IP
0
1
2
3
4
5
6
7
8
9

pressure on

Why we install a SMA-System?

Monitoring

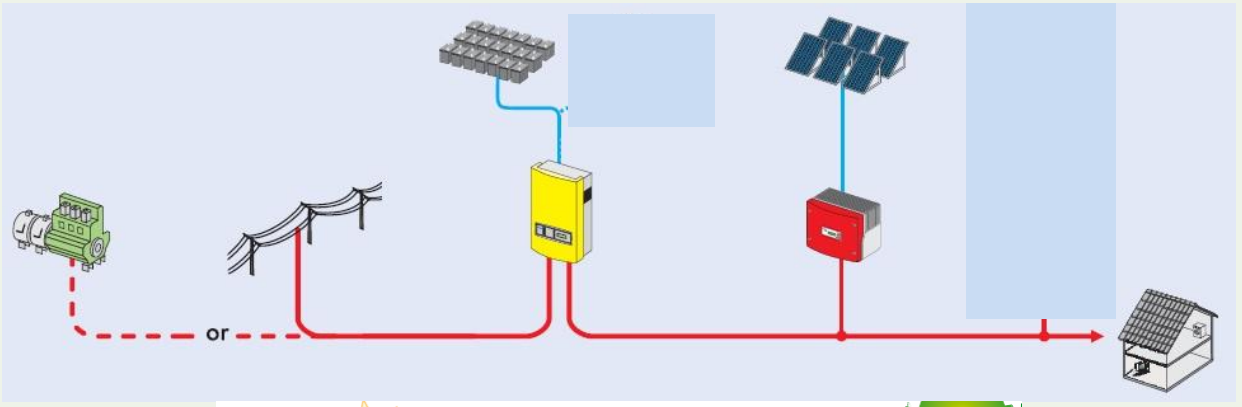


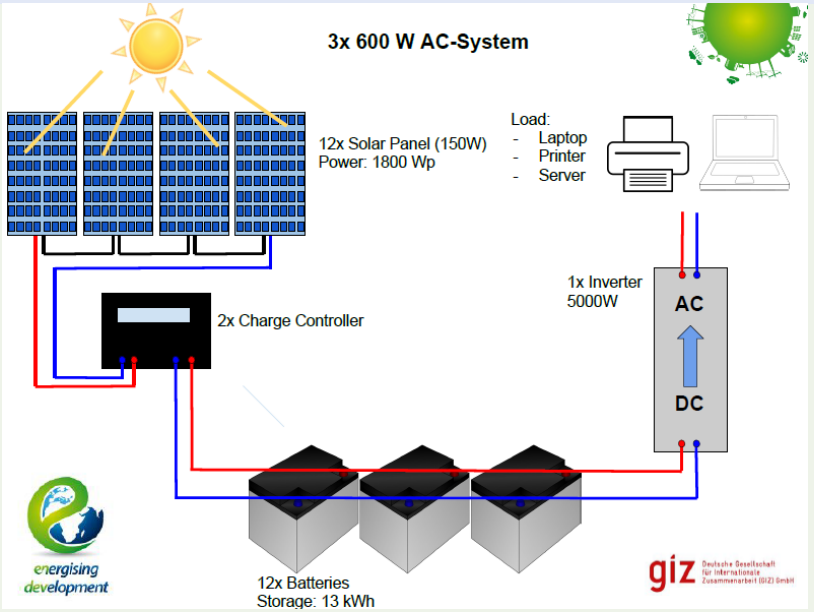
Why we install a SMA-System?

Monitoring

Why we install a SMA-System?

Less losses





Why we install a SMA-System?

Less losses

P=[W]

P=[W]

AC: 230V
DC: 12 / 24 /48V

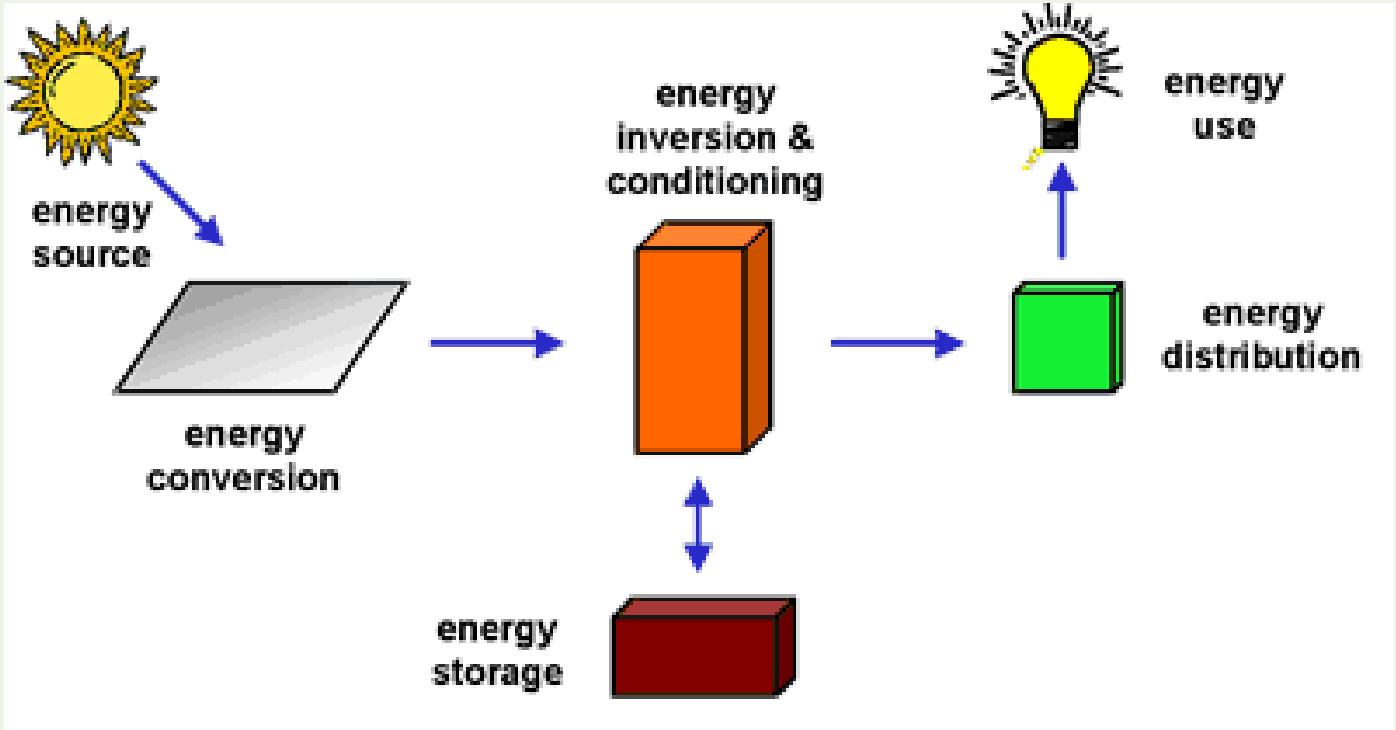
AC: less current
DC: high current

What that means for the current?

AC: small voltage drob
DC: big voltage drob

What that means for the voltage?

System Design

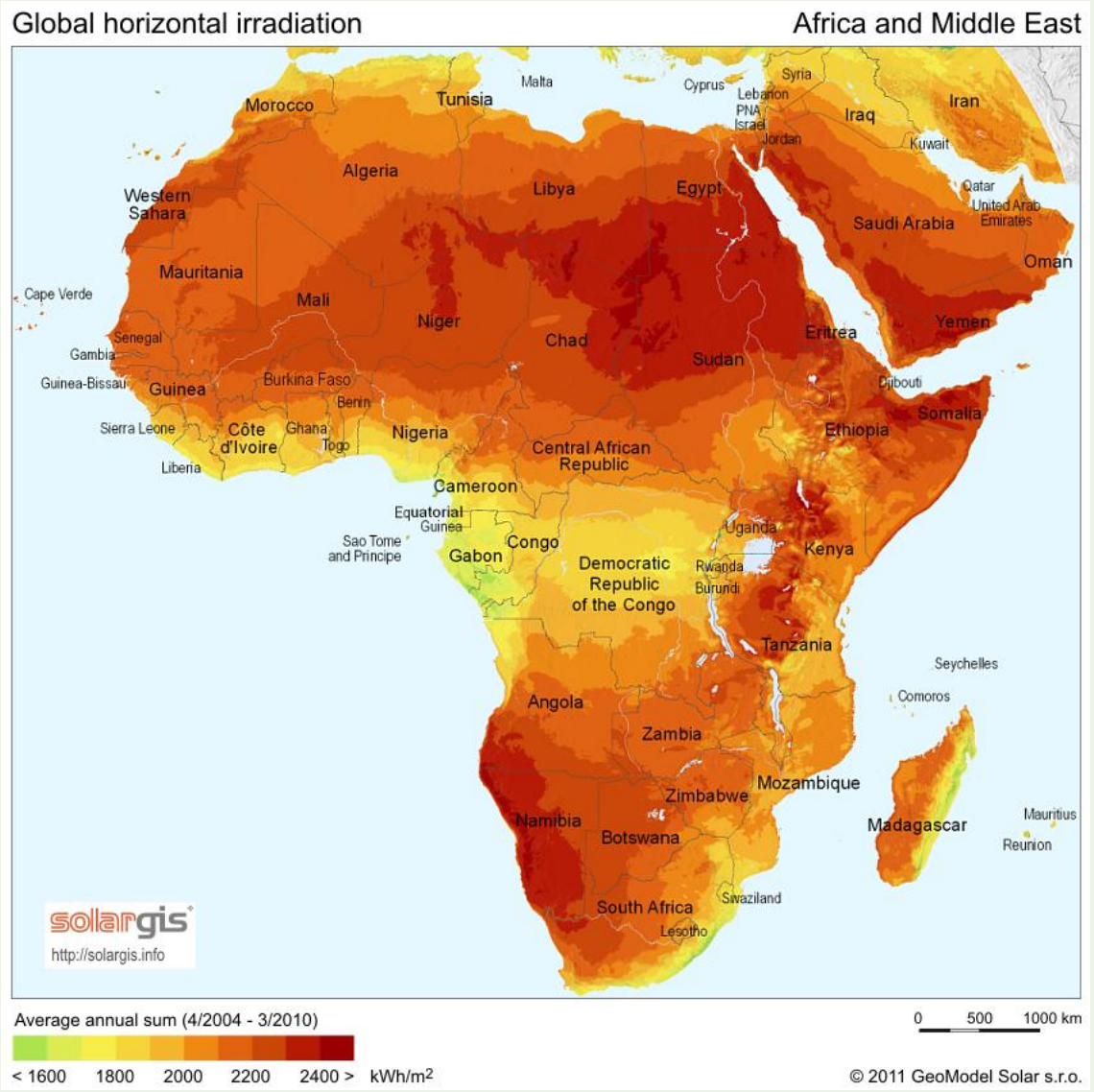


Load

No.	Load	Power Rating/equ	QTY	Max.Power(W)	Estimated Running Hour/24hr(Hr)	Energy Consumption/24hr(W	% Factor/24hr (1=100%	Efficient Energy Consumption/24hr(Wh	% Of Daily Energy Consumption
1	Desktop	350	2	700	8	5600	1	5600	27,47
2	Laptop	65	8	520	8	4160	0,5	2080	10,20
3	Internal Light	12	20	240	8	1920	0,5	960	4,71
4	External Light	15	20	300	12	3600	1	3600	17,66
5	Printer	550	1	550	0,5	275	0,2	55	0,27
6	Refrigerator	150	1	150	6	900	1	900	4,42
7	Peculator	2000	1	2000	0,08	160	1	160	0,78
8	Phone Charger	5	19	95	8	760	0,7	532	2,61
9	Tablet	5	3	15	8	120	0,8	96	0,47
10	Electric Iron	1200	1	1200	1	1200	1	1200	5,89
11	Water Pump	550	1	550	2	1100	1	1100	5,40
12	Ventilator	40	16	640	6	3840	0,5	1920	9,42
13	Electric Calculator	10	2	20	8	160	0,5	80	0,39
14	Projector	550	1	550	2	1100	1	1100	5,40
15	Internet Device	100	1	100	10	1000	1	1000	4,91
16				0		0		0	0,00
17				0		0		0	0,00
18				0		0		0	0,00
19				0		0		0	0,00
	TOTAL			7630		25895		20383	100

→ Measure the consumption

System Design



System Design

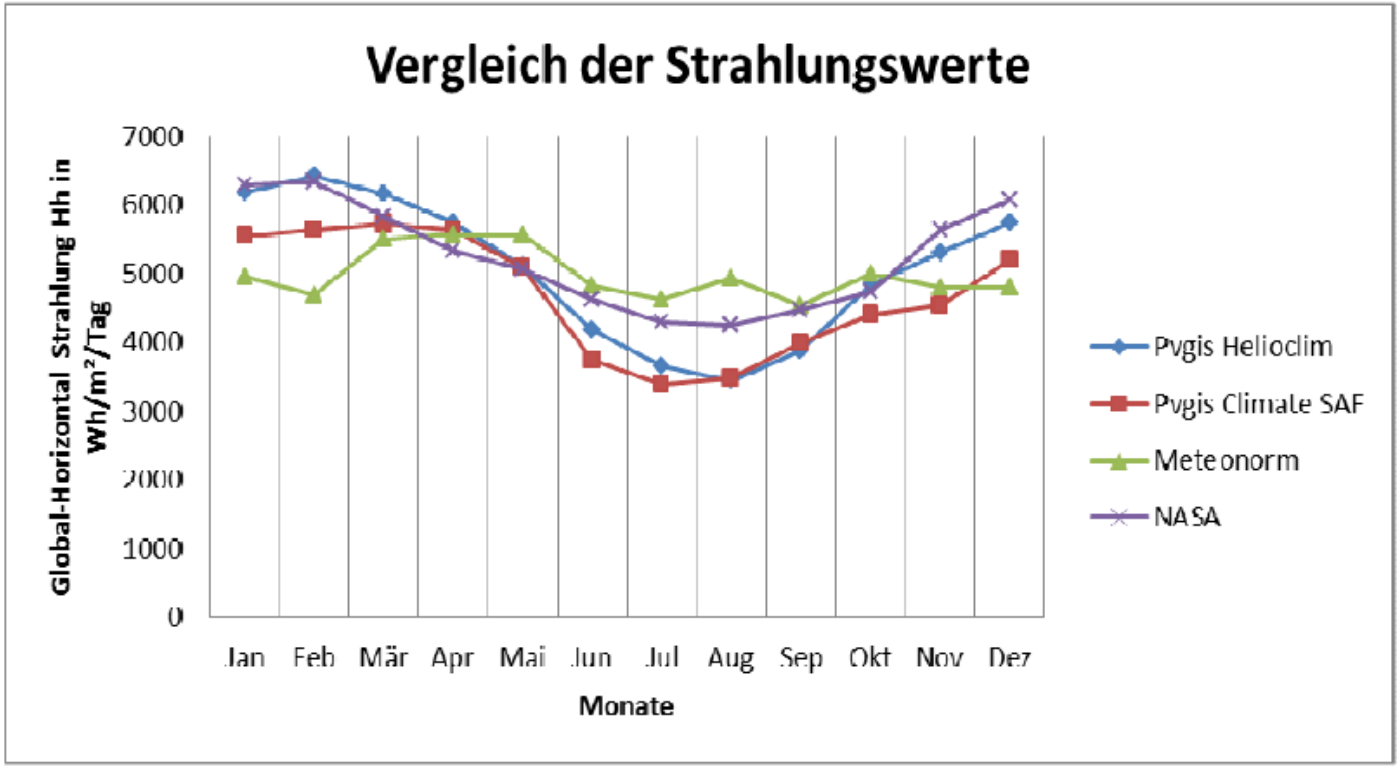


Abbildung 3.5: Vergleich der Strahlungswerte, Quelle: Eigene Grafik

Tabelle 3.9: gemittelte Werte

Monate:	Jan.	Feb.	März	Apr.	Mai	Juni	Jul.	Aug.	Sep.	Okt.	Nov.	Dez.
H_h	5880	5516	5629	5402	5150	4206	4066	4006	4271	4621	4804	5219

Globale Einstrahlung auf horizontaler Ebene H_h in Wh/m²/Tag

Calculation

- Size the System according to the weakest month

- Production: 4000 Wh/day/m²
- Consumption: 8400 Wh/day
- 30 % System looses -> 8400 Wh / 0,70 = 12000 Wh/day
- 15 % Panel efficiency (85% looses) -> 1200 Wh / 0,15 = **80000 Wh/day**

A=80000 Wh/day / 4000 Wh/day/m² =20 m²

$$P_{PV,Nenn} = A_{PV} \bullet \eta_{PV} \bullet 1000 \frac{W}{m^2}$$

P= 20 m²*0,15*1000W/m² **= 3 kW**

System Design

New Situation

PV Power

- Power: 3.9 kW
- Panels: 26x150W

Battery Capacity

- Battery: 548 Ah @C10 (2.1V)
- Capacity: 27 kWh (24 Batteries)

Equipment

- Sunny Boy 4000TL
- Sunny Island 8.0H
- Sunny Home Manager

Type overview

Capacities, dimensions and weights

Type	C_{100}/1.85 V Ah	C_{50}/1.85 V Ah	C_{24}/1.83 V Ah	C_{10}/1.80 V Ah	C_5/1.77 V Ah	max.* Weight kg	max.* Length L mm	max.* Width W mm	max.* Height H mm	Fig.
4 OPzV solar.power 250	287	264	243	204	189	18.3	105	208	420	A
5 OPzV solar.power 310	359	329	304	255	236	22.3	126	208	420	A
6 OPzV solar.power 370	430	395	365	306	283	26.5	147	208	420	A
5 OPzV solar.power 420	478	453	428	391	346	29.9	126	208	535	A
6 OPzV solar.power 520	574	543	513	470	415	35.1	147	208	535	A
7 OPzV solar.power 620	670	634	599	548	485	42.1	168	208	535	A
6 OPzV solar.power 750	847	802	762	682	595	48.7	147	208	710	A
8 OPzV solar.power 1000	1130	1070	1016	909	793	65.9	215	193	710	B
10 OPzV solar.power 1250	1412	1337	1270	1137	992	80.5	215	235	710	B
12 OPzV solar.power 1500	1695	1604	1524	1364	1190	94.6	215	277	710	B
12 OPzV solar.power 1700	1955	1870	1785	1545	1372	110.0	215	277	855	B
16 OPzV solar.power 2300	2607	2493	2380	2060	1829	152.9	215	400	815	C
20 OPzV solar.power 2900	3258	3117	2975	2574	2287	186.5	215	490	815	D
24 OPzV solar.power 3500	3910	3740	3570	3089	2744	222.3	215	580	815	D

C_{100}, C_{50}, C_{24}, C_{10} and C_5 = Capacity at 100 h, 50 h, 24 h, 10 h and 5 h discharge

* according to DIN 40742 data to be understood as maximum values

Components

1 pc. PV-Inverter, SMA Sunny Boy 4000 TL

1 pc. Battery Inverter, SMA Sunny Island 8.0
with Speedwire communication + CAN

1 pc. Communication, SMA Sunny Home Manager Set HM BT 10 Set

10 pcs. PV module, SW 150 WP R6A

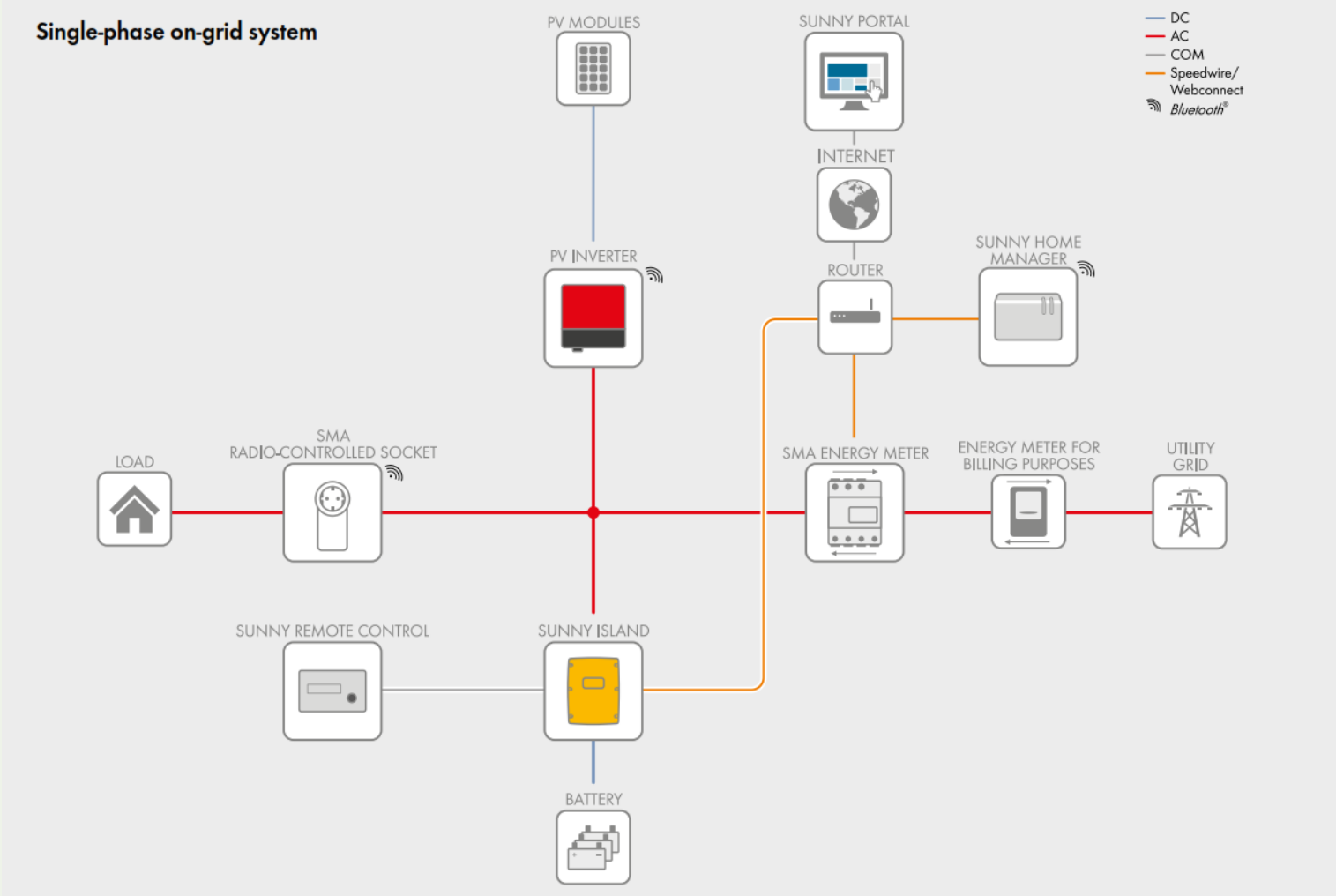
2 Sets Roof Support Structure for 4 panels SW150;
incl. Profile, anchor bolts, middle and side clamps,
bolts, nuts etc.

1 pc. Smart TV, Samsung K5579 80cm (32")

100 m Cable H07 RN-F - 1 x25mm² flexible

200 m Cable H07 RN-F - 1x4mm² flexible

Components

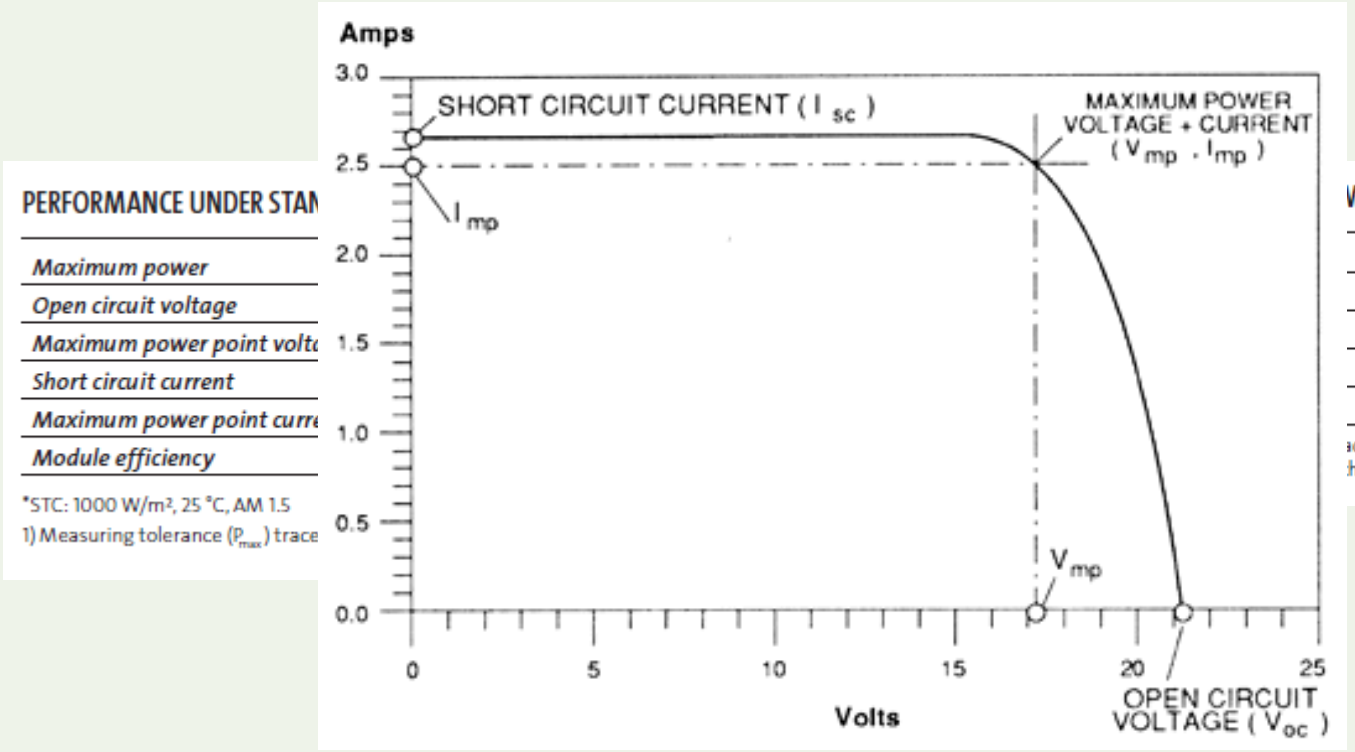

Single-phase on-grid system
PV MODULES
SUNNY PORTAL
DC
AC
COM
Speedwire/ Webconnect
Bluetooth®
INTERNET
PV INVERTER
ROUTER
SUNNY HOME MANAGER
LOAD
SMA RADIO-CONTROLLED SOCKET
SMA ENERGY METER
ENERGY METER FOR BILLING PURPOSES
UTILITY GRID
SUNNY REMOTE CONTROL
SUNNY ISLAND
BATTERY

Components

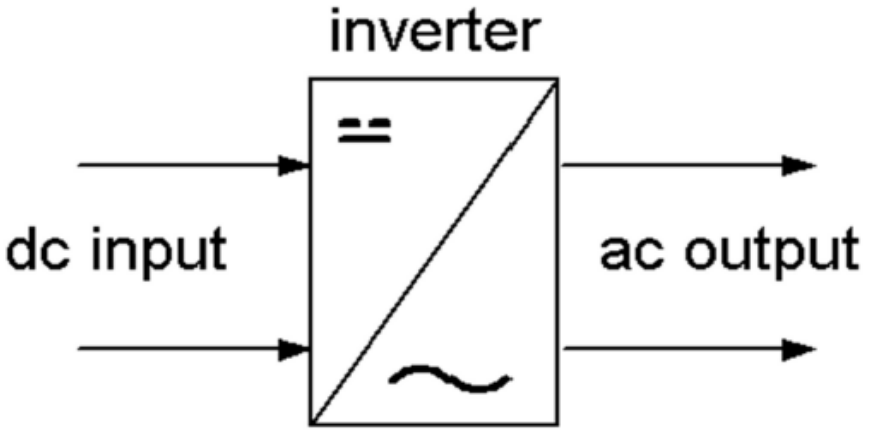
Solar Module

Sunmodule®
SW 150 POLY R6A

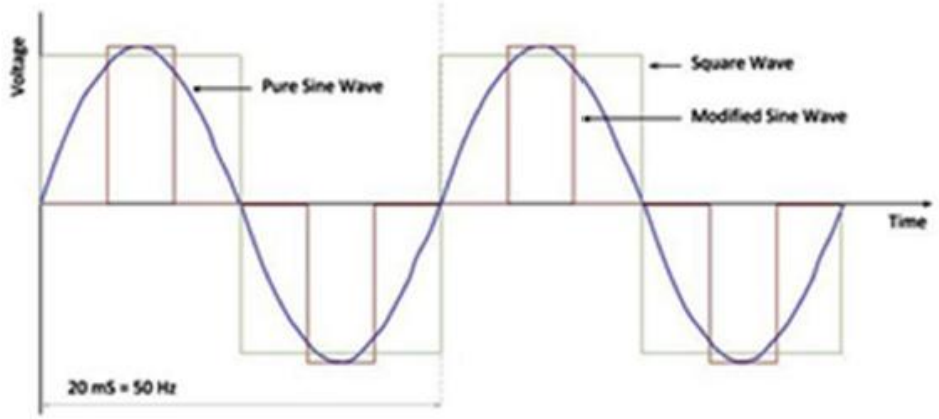
PDF:
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&cad=rja&uact=8&ved=0ahUKEwjlpIKL4obVAhVpIcAKHZDZBwgQFgg8MAM&url=https%3A%2F%2Fwww.solarworld-usa.com%2F~%2Fmedia%2Fwww%2Ffiles%2Fdatasheets%2Fsunmodule-off-grid%2Fsunmodule-off-grid-poly-solar-panel-150-r6a.pdf&usg=AFQjCNHjDt6OH7xWVD6MsqkJLUbJlM1FGw



Inverter



Inverters have an input side and an output side



Types of output waveform

- Square wave (cheap simple)
- Modified sine wave (middle class)
- Pure sine wave (bst class)

Components

Sunny Boy 4000TL (Grid –tie inverter)

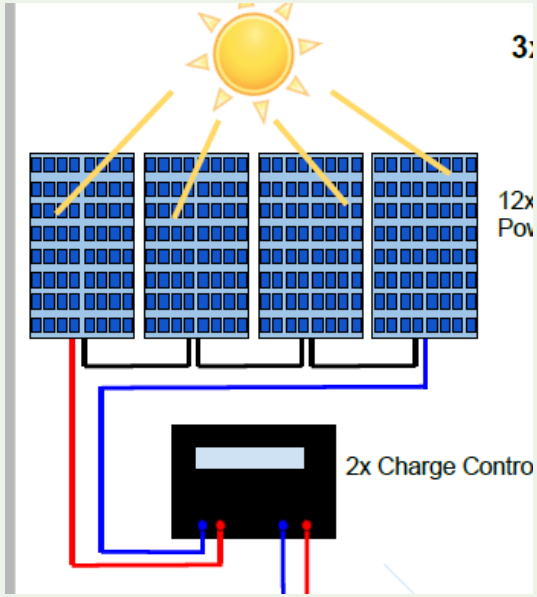
- What means 4000?
- How many strings we have?
- Why we have ….strings?
- How I can connect the panels

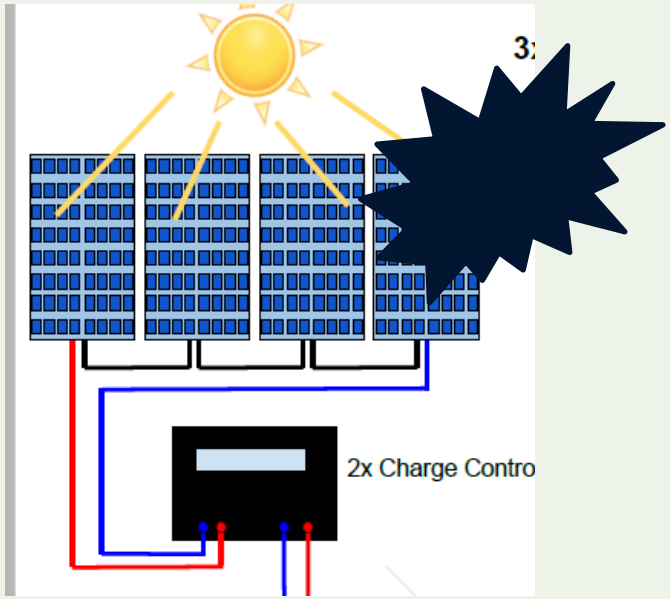
Datasheet: http://files.sma.de/dl/15330/SB5000TL-21-DEN1551-V20web.pdf

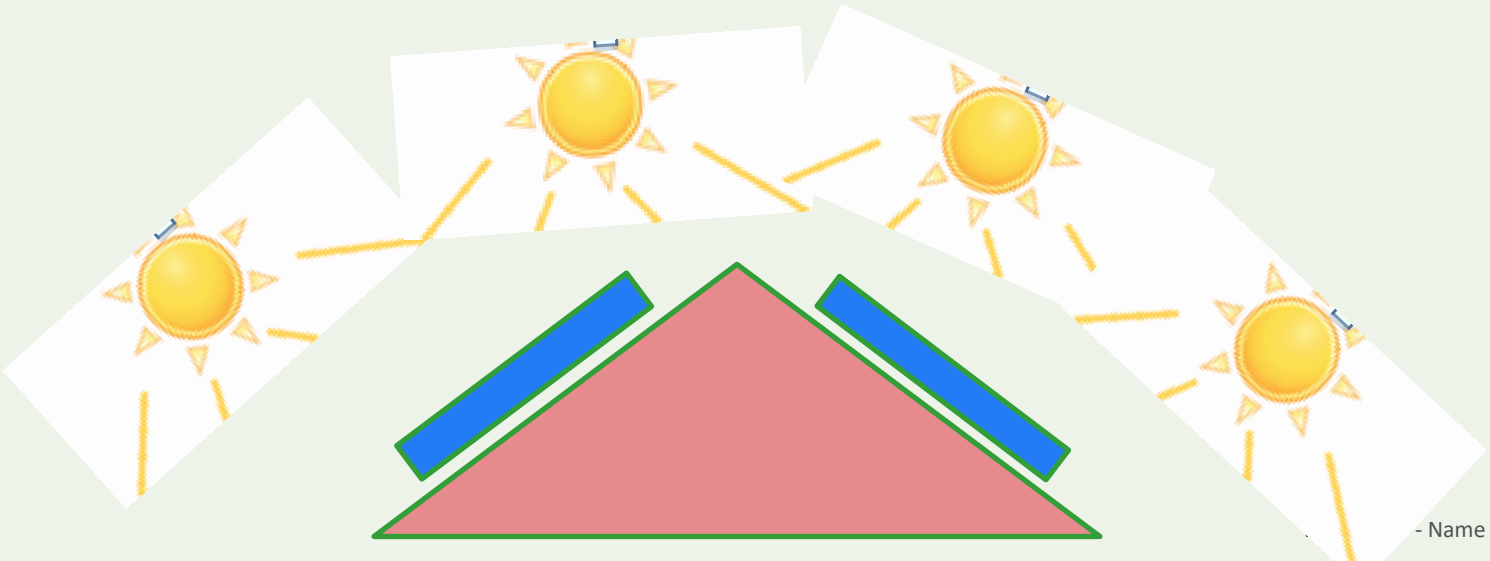
Technical Data	Sunny Boy 4000TL
Input (DC)	
Max. DC power (at cos φ = 1)	4200 W
Max. input voltage	750 V
MPP voltage range / rated input voltage	175 V to 500 V / 400 V
Min. input voltage / initial input voltage	125 V / 150 V
Max. input current input A / input B	15 A / 15 A
Max. input current per string input A / input B	15 A / 15 A
Number of independent MPP inputs / strings per MPP input	2 / A:2; B:2
Output (AC)	
Rated power (at 230 V, 50 Hz)	4000 W
Max. AC apparent power	4000 VA
Nominal AC voltage / range	220 V, 230 V, 240 V / 180 V to 280 V
AC power frequency / range	50 Hz, 60 Hz / −5 Hz to +5 Hz
Rated power frequency / rated grid voltage	50 Hz / 230 V
Max. output current	22 A
Power factor at rated power	1
Adjustable displacement power factor	0.8 lagging to 0.8 leading
Feed-in phases / connection phases	1 / 1
Efficiency	
Max. efficiency / European Efficiency	97 % / 96.4 %

Components

Why two strings?







Components

Combination of Panels and Sunny Boy 4000TL

How many Panels per String we should use? Have in mind we want to reach 3.9 kW

3.9 kW / 150W = 26 / Two Strings / 26 Panels /2 = 13 Panels per String

Maximum power	P_{max}	150 Wp

How we can know that we have the right Inverter (Sunny Boy)

Maximum open circuit voltage from the string fits into the range of Inverter. (22.5V*13 = **292,5V**) → This is for 25°C

Max. input voltage	750 V
MPP voltage range / rated input voltage	175 V to 500 V / 400 V
Min. input voltage / initial input voltage	125 V / 150 V

Components

Combination of Panels and Sunny Boy 4000TL

What is the minimum Voltage we have?

Panel

Maximum power point voltage	V_{mpp}	18.3 V

Inverter

MPP voltage range / rated input voltage	175 V to 500 V / 400 V
Min. input voltage / initial input voltage	125 V / 150 V

Maximum power point voltage from the string fits into the range of Inverter. (18.3V*13 = **238V**) → This is for 25°C

Does the Temperature play a role?

Situation for 75°C
50 * 0,31%= 15% → 238/1,15 = 207V

THERMAL CHARACTERISTICS	
NOCT	46 °C
TK I_{sc}	0,051 %/K
TK U_{oc}	-0,31 %/K
TK P_{mpp}	-0,41 %/K

Batteries

- Lead-Acid Battery

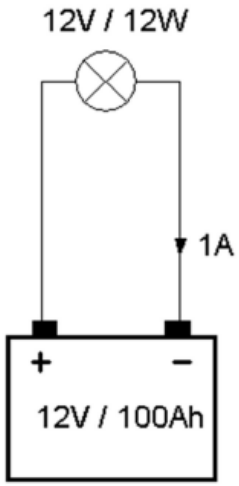
vented

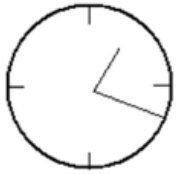
- Wet battery
- Liquid
- Maintenance needed
- Longer lifetime/cheaper

sealed

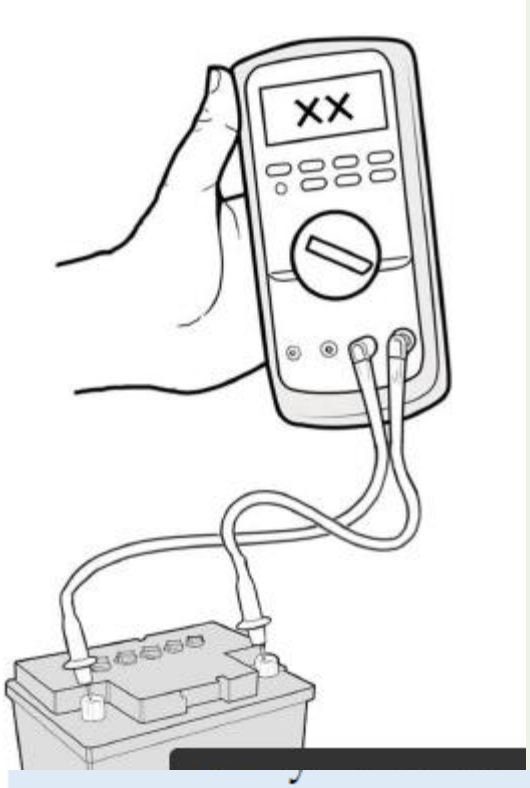
- Dry battery
- Gel or absorbed by a sponge
- No maintenance
- Less lifetime / bit moe expensive

Battery





100 Ah battery for a 12 W load



On a 12 V lead-acid battery, when you measure (at rest):

Voltage reading	*SoC*
12.9 V	100%
12.7 V	75%
12.5 V	50%
12.3 V	25%
12.1 V	0%

Lifetime Battery

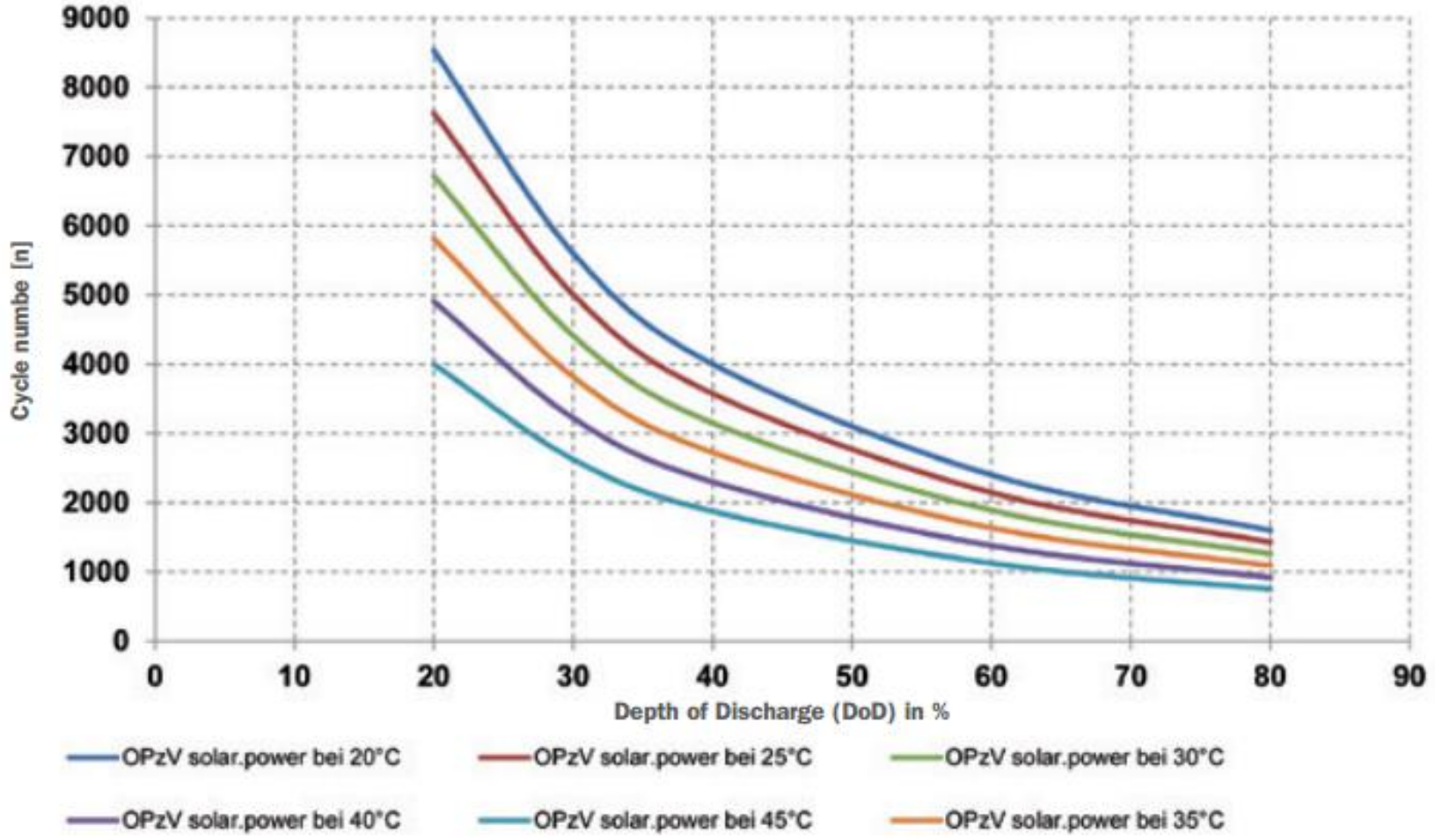


Fig. 7–10: Cycle lifetime of OPzV solar power depending on DoD and temperature

Sunny Island

Maximum power: 6590 Watt (With buffer: 7100Watt

Technical data	Sunny Island 6.0H	Sunny Island 8.0H
AC output (loads / stand-alone grid)		
Rated grid voltage / AC voltage range	230 V / 202 V ... 253 V	230 V / 202 V ... 253 V
Rated frequency / frequency range (adjustable)	50 Hz / 45 Hz ... 65 Hz	50 Hz / 45 Hz ... 65 Hz
Rated power (for Unom / fnom / 25 °C / cos φ = 1)	4600 W	6 000 W
AC power at 25 °C for 30 min / 5 min / 3 sec	6 000 W / 6 800 W / 11 000 W	8 000 W / 9 100 W / 11 000 W
Rated current / maximum output current (peak)	20 A / 120 A	26 A / 120 A
Total harmonic factor output voltage / power factor with rated power	< 4 % / -1 ... +1	< 4 % / -1 ... +1
AC input (PV array, grid or MC box)		
Rated input voltage / AC input voltage range	230 V / 172.5 V ... 264.5 V	230 V / 172.5 V ... 264.5 V
Rated input frequency / allowable input frequency range	50 Hz / 40 Hz ... 70 Hz	50 Hz / 40 Hz ... 70 Hz
Maximum AC input current	50 A	50 A
Maximum AC input power	11 500 W	11 500 W
Battery DC input		
Rated input voltage / DC voltage range	48 V / 41 V ... 63 V	48 V / 41 V ... 63 V
Maximum battery charging current	110 A	140 A
Rated DC charging current / DC discharging current	90 A / 103 A	115 A / 136 A
Battery type / battery capacity (range)	FLA, VRLA / 100 Ah ... 10 000 Ah	FLA, VRLA / 100 Ah ... 10 000 Ah
Charge control	IUoU charge procedure with automatic full charge and equalization charge.	IUoU charge procedure with automatic full charge and equalization charge
Efficiency / self-consumption		
Maximum efficiency	95 %	95 %
Self-consumption without load / standby	< 26 W / < 4 W	< 26 W / < 4 W

Electrical protection device

- SPD (Surge Protection device)

- Panel disconnection

Electrical protection device

- Fuses (BatFuse, for House installation)

How can I size it?

Grounding

Grounding

Connecting a solar system to the ground electrode

Next Week

- Batteries
- Sunny Boy
- Sunny Island
- Protection devices
- Cable size

Thank you for your attention.

Funded by:

Coordinated by:

Calculation

- Actual energy demand: 4 kWh/day + 2 kWh/day

How much more energy per day do we have with the system extension?

- PV power: 3.9 kW (@STC)

4.5 Full Sunhours
-> 1000W/m² for 4.5 hours per day (in average)

3.9 kW * 4.5 H = 17,55 kWh

30% losses
17,55 kWh /1,3 = **13,5 kWh**

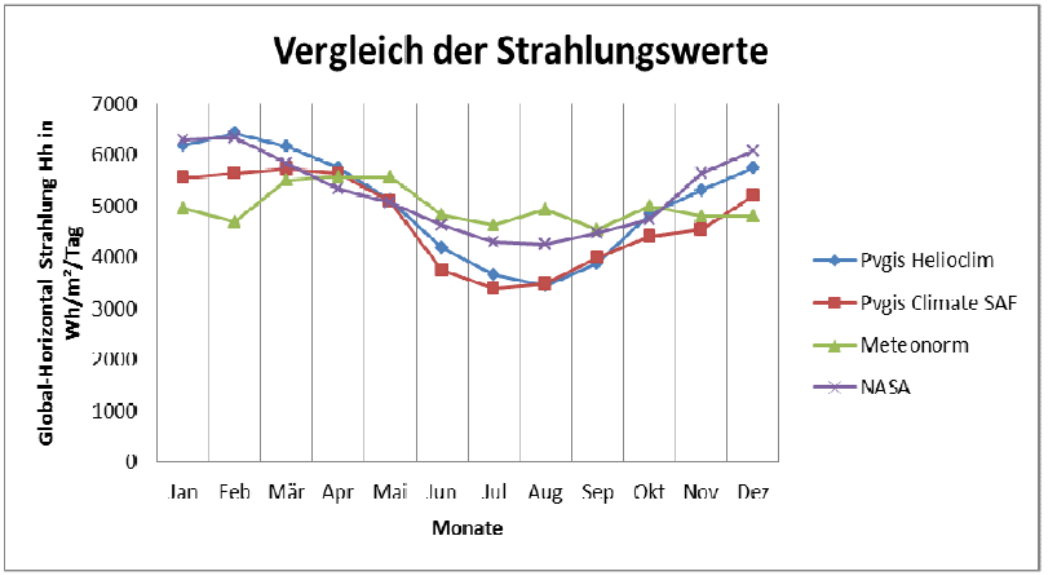


Abbildung 3.5: Vergleich der Strahlungswerte, Quelle: Eigene Grafik

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