PV SYSTEM SIZING

- Define load, location, inclination
- Determine irradiation
- Calculate installed power to fulfil load
- Calculate number of modules
- Define system specs

(battery, charge regulator, inverter)

PV SYSTEM SIZING

Example

Stand alone system for the Algarve (37ºN)

Equipment	Power	Usage	Daily load (kWh)
3 lights	100 W	3 h/day	0.90
2 lights	60 W	2 h/day	0.24
Fridge	150 W	10 h/day	1.50
Freezer	150 W	10 h/day	1.50
Iron	1000 W	1 h/day	1.00
TV	60 W	4 h/day	0.24
Washing machine	2.2 cycle	Twice week	0.63
Dish washer	1.9 kWh/cycle	Once a day	1.90
Total daily load			**7.91**

PV SYSTEM SIZING

Step 1

Choose least unfavourable month

Typically December, but could be September for a summer house

Step 2

Choose modules' inclination

Typically latitude + 10º, but could be latitude -10º for a summer house

PV SYSTEM SIZING

Step 3

Determine irradiation (Inclination: 37º + 10º = 47º)

Month	Monthly irradiation (kWh/m^2)	Daily irradiation (kWh/m^2)
Jan	98.2	3.3
Feb	108.2	3.6
Mar	135.1	4.5
Apr	158.3	5.3
May	169.5	5.6
Jun	166.0	5.5
Jul	184.4	6.1
Aug	197.9	6.6
Sep	163.5	5.4
Oct	144.0	4.8
Nov	109.8	3.7
Dec	98.7	3.3

PV SYSTEM SIZING

Step 3

Calculate irradiation

PSH: Peak Solar Hours (hours @1kW/m^2 = kW/m^2/day)

Worst month: PSH = 3.3 h/day

Step 4

Define system configuration

Stand alone requires battery

AC appliances require inverter

PV → Cables → Charge regulator → Battery → Inverter → Load

PV SYSTEM SIZING

Step 5

Calculate installed power

PV → Cables → Charge regulator → Battery → Inverter → Load

Required power:

$$P_{PV} = \frac{Load}{\eta_{cable} \times \eta_{reg} \times \eta_{bat} \times \eta_{inv}}$$

$$P_{PV} = \frac{7.91 kWh/day}{0.69} = 11.5 kWh/day$$

Typical

η_{INV} = 95%

η_{BAT} = 80%

η_{REG} = 95%

η_{CAB} = 95%

PV SYSTEM SIZING

Step 5

Calculate installed power

Required power:

$$P_{PV} = \frac{Load}{\eta_{cable} \times \eta_{reg} \times \eta_{bat} \times \eta_{inv}} \qquad P_{peak} = \frac{P_{PV}}{PSH}$$

$$P_{PV} = \frac{7.91kWh/day}{0.69} = 11.5kWh/day \qquad P_{peak} = \frac{11.5kWh/day}{3.3h/day} = 3.48kWp$$

PV SYSTEM SIZING

Step 6

Choose operating voltage V_{DC}

Typically multiple of 12V

Determine minimum section of cabling (ΔV<3%):

$$s(mm^2) = \frac{length(m) \times current(A)}{56 \times \Delta V}$$

Cheaper (thinner) cables require higher operating voltage. Let's choose V_{DC}=48V.

PV SYSTEM SIZING

Step 7

Calculate string length, from the module voltage, V_m (assume 12V; string with 4 modules)

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

Step 8

Calculate number of strings

(assume 50Wp module)

$$N_p = \frac{P_{peak}}{P_m \times N_s} = \frac{3.48kWp}{50Wp \times 4} = 17.4 \approx 18$$

PV SYSTEM SIZING

Step 9

Calculate total number of modules,

$$N = N_s \times N_p = 4 \times 18 = 72$$

and its area (assume module area A_m=0.4m²)

$$A = N \times A_m = 72 \times 0.4 \approx 30m^2$$

PV SYSTEM SIZING

Step 10

Determine battery capacity

Choose autonomy *(n = 5 days)*

$$C_B = \frac{n \times load}{depth}$$

$$C_B = \frac{5days \times \left(\frac{7.91kWh/day \times \eta_{cab}}{V_{DC}} \right)}{0.7} = \frac{5 \times \left(\frac{7.91 \times 0.95}{48} \right)}{0.7}$$

$$C_B = 1118Ah$$

PV SYSTEM SIZING

Step 11

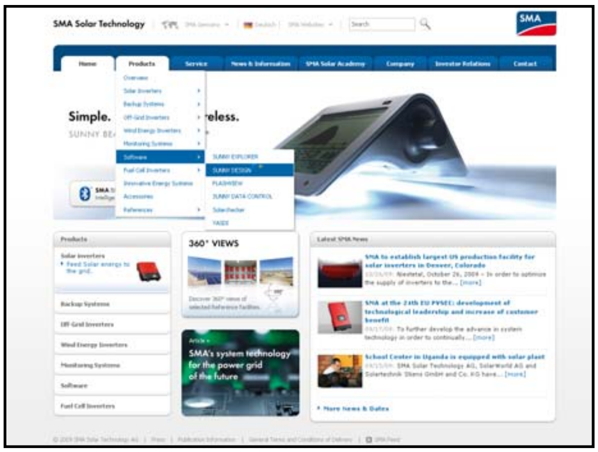
Choose charge regulator and the inverter

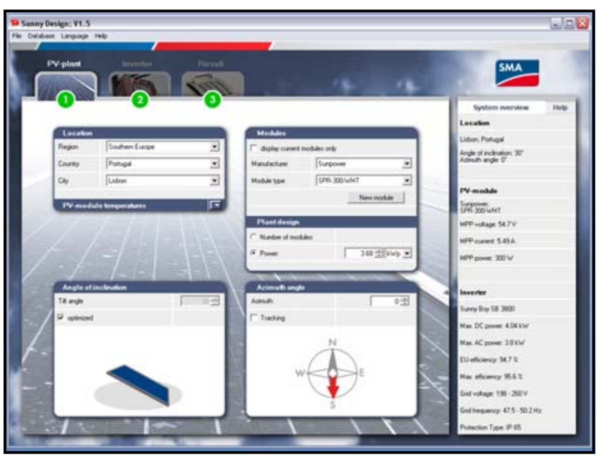
Relevant parameters:

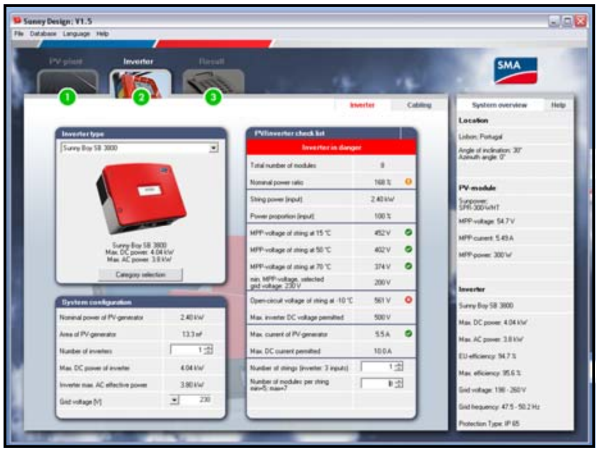
- $V_{in} = V_{DC}$ = 48V
- $I_{in} = P_{peak} / V_{DC}$ = 3480/48 = 72.5 A
- $V_{out} = V_{DC}$ = 48V
- P_{out} = (300 + 120 + 150 + 60 + 2200) ~ 3300 W
  assuming that we won't wash and iron at the same time...
- $I_{out} = P_{out}/V_{out}$ = 3300 / 48 ~ 70 A

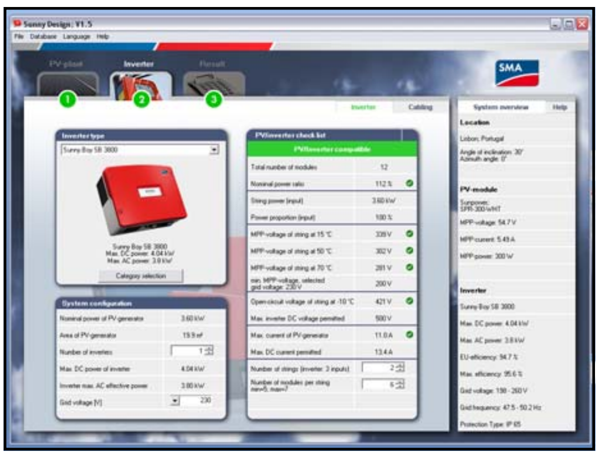
PV SYSTEM SIZING

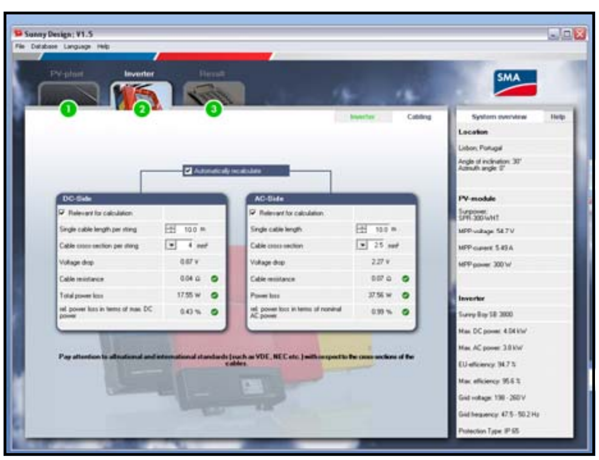
But the easiest, and most practical, option is to use sizing software from e.g. inverter companies...

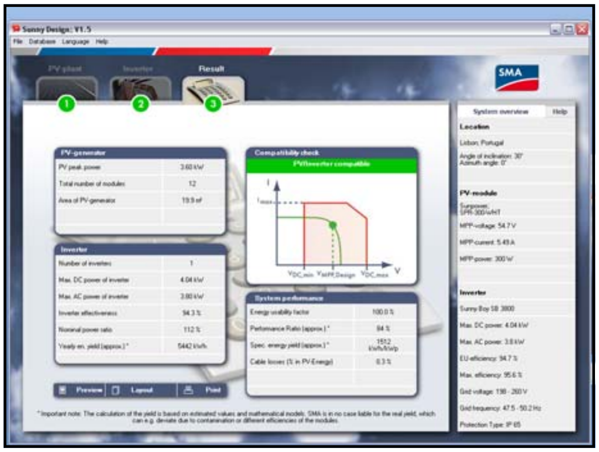





Sunny Design: V1.5
PV-plant
Inverter
Result
SMA
Inverter
Cabling
System overview
Help
Inverter type
PV/inverter check list
Inverter in danger
System configuration
Location
PV-module


Sunny Design: V1.5
PV-plant
Inverter
Result
SMA
Inverter
Cabling
System overview
Help
Inverter type
PV/inverter check list
PV/inverter compatible
System configuration
Location
PV-module


Sunny Design: V1.5
PV-plant
Inverter
Result
SMA
Inverter
Cabling
System overview
Help
DC-Side
AC-Side
Location
PV-module



PV SYSTEM SIZING

Design rules

- All strings must have the same voltage
- Minimize module mismatching
- Avoid shading
- Higher inverter efficiencies for high input voltage: maximize string length

PV SYSTEM SIZING

Design rules

- minimum inverter input voltage >
  > MPP voltage @ +70ºC
- maximum inverter input voltage <
  < Open circuit voltage @ -10ºC

PV SYSTEM SIZING

Design rules

- Power ratio between 90...110%
  (= input power inverter/nominal power PV generator)
- Start at **90%**
- **+5%** if annual yield **1200...1600kWh/kWp**
  (+10% if annual yield >1600kWh/kWp)
- **+5%** if ambient temperature **> 30ºC**
  (+10% if ambient temperature > 40ºC)
- **+5%** if single axis **tracking**
  (+10% if dual axis tracking)

HOMEWORK (individual)

SYSTEM DESIGN

Design a stand alone system for your hometown. Use real equipment, i.e. modules, charge regulator, inverter, batteries (include datasheets).

Equipment	Power	Usage
5 lights	20 W	3 h/day
3 lights	60 W	2 h/day
Fridge	150 W	10 h/day
Freezer	150 W	10 h/day
Iron	1000 W	1 h/day
TV	60 W	4 h/day
Washing machine	2.2 cycle	Twice week
Dish washer	1.9 kWh/cycle	Once a day