



# Journal of Renewable Energies

*Revue des Energies Renouvelables*

journal home page : <https://revue.cder.dz/index.php/rer>

## New graphical interface for Sizing PV systems

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### Abstract

The objective of this work is to carry out a sizing program of the photovoltaic system isolated from the grid by determining the size of the subsystems that make up the photovoltaic generator, the batteries, the charge regulator and the transformers... etc. This depends on the energy consumed by the total loads, the average annual solar irradiation, and the characteristics of the module and battery as inputs. This program was realized in the form of a graphical interface. We will present as an applied example the sizing of a house located in the south of Algeria, in particular in Ghardaïa, and this program has been broadcast on other sites.

**Keywords:** Solar cells, System, Sizing, Graphical interface, Stand alone

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### 1. Introduction

Electricity is an essential factor for economic development in all countries of the world. Its importance increases with technical progress, industrialization and the need for modern comfort. Increasing its production means improving the quality of life and creating wealth. Electricity production, reduced to the number of inhabitants, is therefore a good indicator for measuring the development gaps between the different regions of the world [1].

In the past, fossil fuels were the sources of electricity. Fossil fuels represent all the energies resulting from the fossilization of living beings. The fossil fuels generally used are: oil, coal, wood and natural gas [2]. The major disadvantage of fossil fuels is that they are limited in quantity and are very non-renewable, hence the importance of renewable energies and particularly solar energy.

Solar energy is an energy source that depends on the sun. This energy is a renewable, clean and non-polluting energy. It comes from the direct transformation of a part of solar radiation into

electrical energy, this energy conversion is carried out through a cell called photovoltaic cell (PV) based on a physical phenomenon called photovoltaic effect which consists in producing an electromotive force when the surface of this cell is exposed to the sun. These photovoltaic panels combined with inverters, batteries and regulators make up a photovoltaic system. They can be either autonomous or connect to the power grid. The design of a photovoltaic installation requires a sizing method that takes into account the technical characteristics of each component as well as the characteristics of the place, namely latitude, temperature, solar irradiation... etc. Our job is to size an autonomous photovoltaic system by creating a graphical interface using Visual Basic software.

## **2. Review on sizing methods**

In the literature, the following methods of sizing photovoltaic systems are found:

- The quasi-static method qualifies as an empirical method;
- Dynamic methods for the optimal sizing of photovoltaic systems.
- Computer Methods - Artificial Intelligence Methods - Hybrid Methods [3]

### 2.1 Quasi-static methods

The different steps of the algorithm of these methods are:

Step 1: Site presentation and evaluation of the solar resource

Step 2: Determine the total power consumption

Step 3: Define the type of system to be installed Step 4: Determine the peak power for installation

Step 5: Storage sizing

Step 6: Battery regulator sizing Step 7: Sizing converters

Step 8: Wiring and protections

After the determination and correction of the algorithm, the sizing execution will be done manually and confirmed at the end by design software [4].

### 2.2 Quasi-static methods

These methods are based on mathematical equations comprising several parameters with internal interaction with each other and external with the parameters of the other equations. However, their resolutions still require correlation and convergence approaches [4].

#### 2.2.1 Simplified (intuitive) method

This method requires knowledge of the daily average global solar irradiation value of the least sunny month of the year (worst month, usually December). The energy consumed by the various

"Cj" equipment will be calculated. Then we can calculate the peak power of the Pc module, so the number of modules needed is obtained by a simple calculation knowing the peak power of a single Pcm module. The determination of the battery park is carried out from the taking into account of a certain number of days of autonomy Nj to ensure a zero production which must be between 4 and 10 days, in addition we must have the value of the working voltage U which is also necessary [4].

#### 2.2.2 Numerical methods for the optimal sizing of a PV system

In numerical methods, simulations are performed at each time interval; usually an hour or a period of daily time, in this method, the energy balance of the system will be calculated and classified as deterministic or stochastic approaches [4].

#### 2.2.3 Analytical methods for the optimal sizing of an autonomous photovoltaic system

In analytical methods, the independent components of the PV system are characterized by models. System performance can be estimated for different sets of achievable dimensions of system components. The best autonomous PV system configuration is evaluated mathematically and arithmetic based on reliability to determine the feasibility of the system by comparing one or more performance indicators of different configurations [5].

### 2.3 Computer Methods

There are many software tools to analyze, simulate and design a PV system. Most systems involve radiation estimation. The most used are PVsyst, PV\*SOL, PVGIS and RetScreen. There are other scaling software such as HOMER, CALSOL, TECSOL and PV planner that give indicators of the feasibility of the systems before the project starts.

#### 2.4 Artificial intelligence methods for optimal sizing of an autonomous photovoltaic system

Artificial intelligence (AIM) methods are used to overcome the unavailability of meteorological data for the sizing of a photovoltaic system [6].

It can handle the nonlinear fluctuation of the solar power source and can be categorized as a prediction algorithm such as artificial neural network (ANN) and genetic algorithm (GA) to predict the sizing ratios of a PV system and a search algorithm such as fuzzy logic (FL).

#### 2.5 Hybrid methods for the optimal sizing of an autonomous PV system

The hybrid method is an effective combination of two or more different techniques that are applied to achieve an optimal result for a specific design problem due to the disadvantages of previous processes [7].

### 3. Sizing of an autonomous system

Few steps are used to perform the sizing of each autonomous system:

✚ The sizing steps of a PV system according to the simplified (intuitive) method are:  
Evaluation of the average daily energy required by the load.

The energy to produce modules ( $E_p$ ) is given by the following formula:

$$E_p = \frac{E_c}{K} \quad (1)$$

$K$ : Overall correction factor, containing the various yields as well as a safety coefficient; it is expressed in (%) ( $0.65 \leq K \leq 0.9$ );

$E_c$ : Energy consumed by the load in Wh/d. Estimate of peak power required

✚ The peak power of the generator ( $P_c$ ) is given by the following formula:

$$P_c = \frac{E_p}{E_{in}} \quad (2)$$

$E_{min}$  : Minimum site irradiation in kWh/m<sup>2</sup>/d.

✚ Choice of the working voltage of the system  $v_s$ :

The working voltage is chosen according to the value of the peak power in the following way:

- For  $PC < 500 \text{ WC} \Rightarrow U = 12\text{V}$
- For  $500 \text{ WC} \leq PC \leq 2000 \text{ WC} \Rightarrow U = 24\text{V}$
- For  $PC > 2000 \text{ WC} \Rightarrow U = 48\text{V}$

✚ Calculation of the number of modules required

The number of total modules ( $NT$ ):

$$NT = \frac{P_c}{P_{mod}} \quad (3)$$

$P_{mod}$  : Rated power of the modules in (Watt).

The number of PV modules in series ( $N_s$ ) is given by the following formula:

$$N_s = \frac{v_s}{v_{nom}} \quad (4)$$

$v_s$  : System voltage in (V);

$v_{nom}$  : Rated voltage of modules in (V).

The number of PV modules in parallel ( $N_P$ ):

$$N_P = \frac{NT}{N_s} \quad (5)$$

✚ Estimated storage capacity Total battery

Capacity (CBAT) is given by the following formula:

$$C_{BAT} = \frac{E_C \cdot N}{V_s \cdot F_P \cdot \eta_{bat}} \quad (\text{Ah}) \quad (6)$$

N : Battery life in days;

F P : Battery discharge depth in %;

$\eta_{bat}$ : The energy efficiency of batteries in %.

✚ Calculation of the number of batteries needed

The number of batteries in series (Nbs) :

$$N_{bs} = \frac{v_s}{v_b} \quad (7)$$

$v_b$  : Battery voltage in (V).

The number of batteries in parallel (Nbp) :

$$N_{bp} = \frac{C_{BAT}}{C_e} \quad (8)$$

$C_e$  : Capacity of a battery element given by the manufacturer expressed in Ah

$$\text{The total number of batteries (Nbt): } N_{bt} = N_{bs} \times N_{bp} \quad (9)$$

✚ Sizing of the regulator

$$\text{The regulator current (Ireg): } I_{reg} = 1.5 * \frac{P_c}{v_s} \quad (10)$$

$$\text{The number of regulators: } N_{reg} = \frac{I_{reg}}{I_{reg1}} \quad (11)$$

✚ Inverter sizing

$$\text{Power of inverters (PInv) : } P_{Inv} = 1.25 P_{Load} \quad (12)$$

PLoad : This is the power of the load (W) [5].

#### 4. Proposal of new graphical interface

Visual Basic (VB) is a third-generation event-based programming language and integrated development environment, created by Microsoft for its COM programming model.

Visual Basic is directly derived from BASIC and enables rapid application development, graphical user interface creation, database access using CAD technologies, ADO and RDO, as well as creating ActiveX controls or objects.

The graphical interface consists of four windows (Fig. 1, Fig. 2, Fig. 3 and Fig. 4).

The first window (called form in VISUAL BASIC) is used to start the program. When you press the start button, the second window appears.

By introducing the power of each device and the duration of use the second window is used to give the value of the total power of the load by pressing the total power button (w) and the total energy of the load profile by pressing the total energy button (Wh/d). The delete button is used to delete all the values of the boxes (values entered or calculated) at the same time and finally the arrows on the left and right is used to return to the previous window or go to the third window.

In the third window you can calculate the size of the PV generator, size the photovoltaic modules, deduce the voltage of the PV generator and also size the batteries.

One can return to the previous window or go to the fourth window by the arrows on the left and right and erase the contents of all the boxes at the same time.

Fig. 1 shows the image of our new interface made under Visual basic.

On the first page we see the logo of the Applied Research Unit in Renewable Energies (URAER), the program icon, a photo that indicates the different components of an autonomous system a push button to trigger the sizing program.

Page1 (Fig. 2) shows the different types of loads to be supplied by the photovoltaic system as well as their powers and operating times.

In the first vertical column in yellow, the devices to be powered are shown.

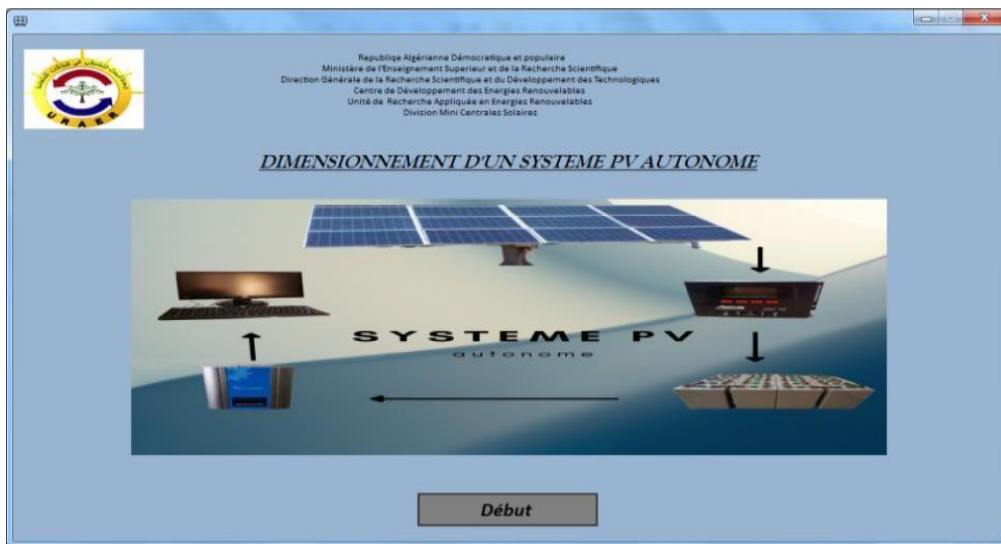


Fig 1. GUI Window 1

We enter the number of devices, the unit power of each device in vertical columns 1 and 2 respectively, the third column (Power) calculates the total power of each device just click on the box in gray in front of each device.

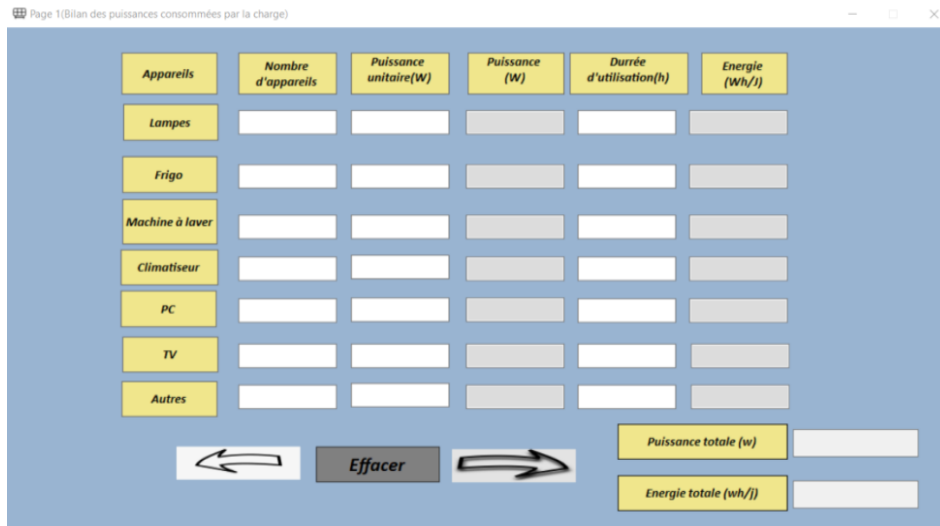


Fig 2. GUI Window 2

At the bottom right the two push buttons in yellow give the value of the total power and the total energy of the load. You can go back to the first window by the left arrow and in the same way you can go to the third window by the right arrow. The erase button allows you to erase the contents of all boxes with a single click. On page 2 (Fig. 3): First the peak generator power is calculated, the minimum site irradiation value and the energy to be produced by the panels are entered. And then, the introduction of the power of the modules, nominal voltage of the modules makes it possible to calculate the system voltage (12, 24 or 48V), the total number series and parallel of the modules.

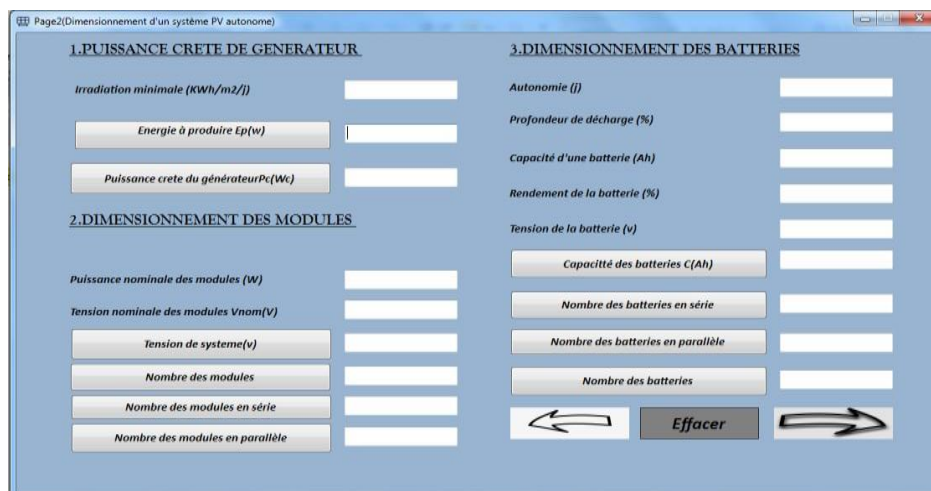


Fig 3. GUI Window 3

In page 3 (fig. 4), one can size the regulator and the inverter and erase the contents of all the boxes at the same time and there is an arrow for the return to the previous page.



Fig 4. GUI Window 4

## 5. Results and discussions

For the application of our new interface, we chose to size a house in Ghardaïa. The installation data are:

- Number of days of autonomy: 3
- Average daily radiation:  $E_{min} = 5 \text{ kWh/m}^2/\text{d}$  (Average annual site irradiation was used)
- Module power: 285W
- Rated module voltage: 24V
- Battery voltage: 12V
- Unit capacity of a battery: 100Ah
- Depth of discharge: 80%
- Battery efficiency: 97%
- The current of a single regulator: 100A
- Inverter efficiency: 100%

### Load profile

The house to be sized has the following load profile:

Table 1. Load profile of the sized house

Devices	Number of devices	Unit power(w)	Power (w)	Duration of use (h)	Energy (Wh/d)
Lamps	20	40	800	8	6400
Fridge	1	130000	130000	1	130000
Washing machine	1	360	360	1	360
Air conditioner	1	1100	1100	5	5500
PC	2	70	140	6	840
Other	1	400	400	4	1600



Sizing results displayed by the interface

We introduce the power and the duration of use for each device we obtain the calculation results provided by our interface as indicated in fig. 5.

Appareils	Nombre d'appareils	Puissance unitaire(W)	Puissance (W)	Durée d'utilisation(h)	Energie (Wh/l)
Lampes	20	40	800	8	6400
Frigo	1	130000	130000	1	130000
Machine à laver	1	360	360	1	360
Climatiseur	1	1100	1100	5	5500
PC	2	70	140	6	840
TV					
Autres	1	400	400	4	1600

Puissance totale (w) 132800  
 Energie totale (wh/l) 144700

Figure 5. Results displayed by the interface (page 1)

- ✓ The total power of the load = 132800W.
- ✓ Total energy = 144850Wh/d.
- ✓ After introducing the value of the average daily irradiation of Ghardaïa, we will have the following results:
- ✓ The number of modules in series=2
- ✓ The total number of modules =119.46≈120 modules
- ✓ The number of modules in parallel =59.73≈60 modules

After filling in the battery data in the corresponding boxes the interface displays the following results:

- ✓ The overall capacity of the batteries =11654.31Ah
- ✓ The number of batteries in series =4
- ✓ The number of batteries in parallel=116.54≈117 batteries
- ✓ The number of total batteries=468 batteries (because it is 4\*117)
- ✓ The number of total batteries=468 batteries (because it is 4\*117) Page 3 of the interface gives the following results after filling in the controller data and inverter data.
- ✓ Regulator current =1057.79
- ✓ Regulator number=10.63 ≈11 Inverter power =166000 W

## 6. Generalization of the model

The same example of the load profile will be applied in different sites.

- Timimoune: Average annual daily irradiation=5.52 kWh/m<sup>2</sup>
- Batna: Average annual daily irradiation =5.12 kWh/m<sup>2</sup>
- Algiers: Average annual daily irradiation =4.56 kWh/m<sup>2</sup> The following table summarizes the design results in the different sit:

Table 2. The sizing result at the different sites

Geographica llocation	Annual average daily irradiation (kWh/m <sup>2</sup> )	Total number of modules	Total number of batteries	Regulator current(A)	Inverter power
Timimoune	5.52	110	468	963.74	166000
Batna	5.12	118	468	1039.033	166000
Ghardaia	5	120	468	1063.97	166000
Algiers	4.56	132	468	186.88	166000

## 7. Conclusion

The graphical interface created under the Visual Basic environment makes it possible to facilitate the calculations of the different parameters of the photovoltaic installation in order to satisfy the specifications. This interface allows entering the values of the solar radiation and the electrical characteristics of the solar panels, batteries, charge controller and converter. Finally, the program calculates the different elements of the photovoltaic system. In the perspective of this work, we can make a comparative study between different methods of scaling. As an application of this software, an example of an autonomous system was applied to a house located in the city of Ghardaïa. Finally, the sizing program has been generalized to several other sites.

## 8. References

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