Design of a new interface for the Sizing of Photovoltaic Installations

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Abstract - An autonomous photovoltaic installation consists of a photovoltaic generator, a charge control system and a converter allowing to obtain an alternative power. The objective of this work is the realization of a software of dimensioning of photovoltaic installations by determining the size of the subsystems which constitute it (generator, batteries, regulator, converters, etc.) According to the entry (daily energy consumed and monthly average solar radiation). A graphical interface under MATLAB was also realized and this in order to present the sizing model and to facilitate calculations. We present the graphical interface for the dimensioning of autonomous photovoltaic systems with a practical example of a house in southern Algeria (Ghardaïa).

Keywords: Photovoltaic, Dimensioning, Matlab, Load autonomy

I. Introduction

The exhaustion of fossil resources, more or less long term and the fight against greenhouse gas emissions according to the Kyoto Protocol, make it urgent to control consumption and diversification of energy sources, a fact that challenges stronger than ever the development of renewable energies [1-4]. Since the middle of 1990, renewable energies have become popular, which seems to be growing year after year. These energies are the oldest used by humanity, they are essentially drawn from the five elements: earth, water, air and fire and sun.

Solar radiation is the most shared energy resource on earth and the most abundant. The amount of energy released by the sun (captured by the planet earth) for one hour could be enough to cover the world's energy needs for a year. Part of this radiation can be exploited to directly produce electricity, it is the photovoltaic solar energy which designates the electricity produced by transformation of a part of the solar radiation with a photovoltaic cell. Several cells are interconnected and form a photovoltaic solar module. Several modules that are grouped in a photovoltaic solar power plant are called photovoltaic field. The term photovoltaic can denote either the physical phenomenon the photovoltaic effect or the associated technology. This mode of production does not require a distribution network. Indeed we can produce electrical energy where it is consumed: In villages, isolated houses (one third of the world population does not have access to electricity), communication relay, water pumping , refrigeration.

To size is to fix the size, the optimal characteristics of each element of a system whose configuration we know. Indeed, the dimensioning can finally lead to a change in the system, for example if it proves that technically optimal elements are very expensive, or unavailable, etc. [5-7]

The purpose of the design of a photovoltaic generator is to determine the peak power of the field of the solar modules and the capacity of the associated battery from the sunshine data of the site on the one hand and the electrical requirements of the user of somewhere else. These two elements are the most important because of the high cost that they total (more than 50% of taken of the installation) and the degree of satisfaction. This determination must make it possible to guarantee the supply of electrical energy throughout the year or possibly over a specific period. Radio metric data for a given region are generally available, month by month, and correspond to the average daily irradiation on a horizontal plane [8-10].

The data are generally expressed in KW / m² and the values of the sunshine are given at the latitude of the place considered, and also depend on its climatic conditions. In order to determine the mean daily (average) energy incident on the module plane, a fairly complex calculation is made from the sunlight data on the horizontal plane and the inclination given to the modules. The optimum inclination is determined by the dimensioning which directly takes into account the corresponding capacity of the storage batteries. However, the inclination chosen is generally close to the latitude [11-12].

II. Principle of Sizing Photovoltaic Systems

The sizing of a photovoltaic installation requires knowledge of the nature of the installation (autonomous, hybrid or network), the amount of solar energy received at the installation site, characteristics of the panels to use. As well as the

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characteristics of the other sources, the parameters of the conditioning stages and the energy requirement of the site. The objective is to determine the required area of photovoltaic panels to meet the energy needs of the site [13-15]
The dimensioning comprises 08 steps, the result of a step directly influences the result of the following steps (Figure.1). The steps below give a detailed description of the procedure to follow for the design of the autonomous photovoltaic system [16-19] :

- ✓ Determination of the user's needs: voltage, power of the devices and durations of use;
- ✓ Calculation of recoverable solar energy according to location and geographical location;
- ✓ Definition of photovoltaic modules, operating voltage, technology, total power to be installed;
- ✓ Definition of battery capacity and choice of technology;
- ✓ Choice of regulator;
- ✓ Choice of the inverter;
- ✓ Wiring plan: determination of wiring accessories and cable sections;
- ✓ Cost of the system.

II.1 Determination of the needs of the user

It is a question of estimating the consumption of supposedly known equipment. The objective is to obtain the average total consumption per day and per period (summer, winters, holidays ...).
The average total energy required each day E (Wh / d) is the sum of the energy consumption of the various equipment constituting the system to be studied, namely television, lighting lamps, electronic devices, etc .; It is given by the following law [2]:

$$\mathbf{E} = \sum_{\mathbf{i}} \mathbf{E}_{\mathbf{i}} \quad (1)$$

The average time of use is more difficult to define; it must be reported in season, the number of occupants and the mode of use.
For equipment that is not used daily and for all high-consumption equipment, start with the duration of the task's duty cycle. Thus, the consumption of each equipment can be calculated as follows [5]:

$$E_i = P_i \times t_i \quad (2)$$

The daily energy consumption of a device (Wh / j) in Ac = the power of this equipment (w) × the duration of use of each one (h).
For System uses inverters :

$$B_j = \frac{E_i}{\eta_{ond}} \quad (3)$$

B_j : The daily energy consumed of a piece of equipment $(^{Wh}/_{d})$ in DC.

η_{on} : Efficiency of the inverter

The production of photovoltaic electricity depends on the sun, the production is thus maximum at noon (solar time) on clear skies. L: the maximum value recorded is about 1000 W / m2 (so-called reference value).
This translates to an installation of 20 m2 in a daily output of about 2.8 kWp or 5 to 8 kWh which covers the needs for a home of four people.
The dimensioning of the PV module is intended to meet the daily needs of evaluated consumption (washing machine, refrigerator ..) and including lighting, household appliances of low consumption. The dimensioning of the PV panels is done according to the following formula

$$p_c = \frac{B_j}{E_{j^*} \quad \eta_{b^*} \quad \eta_i} \quad (4)$$

With:

P c: peak power of PV panels in (W),
E j: average daily radiation of the worst month in (kWh / m² / d)
η b: electrical efficiency of the batteries,
η i: electrical efficiency of the installation (taking into account the different losses and Converters).

II.2. Dimensioning and positioning of the PV module

The two extreme principles illustrate the reasoning used to confront the energy that the panel must provide and the energy that the panel can provide from the sun.

A simple solution is sure to choose a peak power such that during the least sunny month, the energy provided by the panel satisfies the needs, with a slope close to the latitude of the place. This is the solution generally adopted by companies marketing and installing photovoltaic systems. It leads, unfortunately to a significant waste of energy during other periods, and especially for the sunniest period.
To reduce this waste, and thus save on the peak power of the panel, it is possible to promote the exposure of the panel during the sunniest season by choosing an inclination greater than 10 to 20 ° (15 ° in general) at the latitude of the site and oversized the battery park to the real needs (mainly related to the numberPossible day without sun during this less sunny season.. It is then possible to size the sunny month on the month, but on months a little sunnier to fill the month's deficit in the sunny month thanks to a sufficient capacity of the battery.
The peak power is sufficient to meet the needs during the sunniest month and generally quite insufficient to meet winter needs.
Such sizing involves the use of a complementary source of energy. In a two-source system, it is then necessary to favor the use of solar energy during the sunnier months and therefore, to choose a low inclination of the modules (α = the latitude -10 ° to 20 °). This dimensioning finds its limit in the cost of complementary energy.

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The autonomy of a PV system is how long the system can run without PV panels producing electricity. This autonomy is fixed by the size of the batteries and we must take into account some basic principles during the design such as energy consumed, the average power.
Under-sizing batteries will be less expensive but they will be exposed to deep discharges and therefore to a shorter life while over-sizing will be more expensive. In the latter case, because of oversizing, the batteries will rarely be fully charged with consequent sulphation phenomena and ultimately a shorter life [20]. We thus see that undersizing as well as oversizing of batteries lead to the same result: the reduction of battery life, hence the importance of optimal sizing. The sizing of the batteries therefore requires special attention in order to increase the service life of the latter and at the same time reduce the overall cost of the system. The nominal capacity of the batteries is given by the following relation:

$$C_b = \frac{B_j * J_{AUT}}{U_{bat} * \eta_b * D_{ib}} \qquad (5)$$

C b: the nominal capacity of the batteries (Ah)
B j: Daily energy requirements (Wh)
AUT: the number of days of autonomy
U beats: the nominal voltage of the batteries (V)
η b: energy efficiency of batteries
D b: the depth of discharge of the batteries.

$$S = \frac{\rho * L * I}{\varepsilon * V_A} \qquad (6)$$

With :
ρ is the resistivity of the cable in Ω.m. This depends on the material. It is 1.7 × 10 -8 Ω.m for a copper cable.
L is the length of the cable in m
I is the current through which the cable goes in A
ε is the voltage drop in V
VA is the voltage at the start of the V-cable

III. Presentation of the graphical interface

In order to make data entry and display of results easier, we have created a MATLAB low software graphical interface (GUI). The graphical interface consists of two executable buttons (Figure 1). In reality this interface is in French, but it can easily be done in other long as English..Etc. As an example, figure 2 shows the main interface in English. The butter "close" to close the program and the button "Data of the installation": uses another graphical interface which contains two fields (Figure 1) one for data entry and the other to display the results of sizing is five executable buttons. The button "close" to close the program. The "back" button to go back. The "Calculation" button: executes the program that calculates the various parameters listed in the results display fields.
The Reset button runs a program that clears all results of the display computation to give the user the hand of correcting the errors entered from the new data.
The "next" button uses another graphical interface to calculate the section of the cable that contains two fields: one for data entry and the other to display the results is three executable buttons. The "close" button to close the program. The "back" button to go back. The "Calculation" button executes the program that calculates the different parameters listed in the result display fields. This graphical interface is software that gives the user a sizing result at a fraction of a second.

Fig. 1. Different interfaces of the software

The software is programmed to calculate results with great accuracy in a fraction of a second.

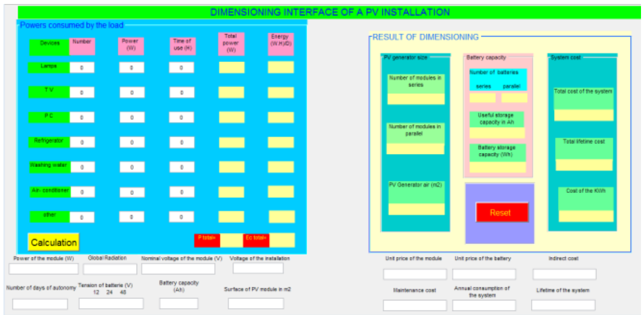

Fig.2. graphical interface for PV dimensioning in English

This figure clearly shows the different buttons created and the way we obtain the different sizing results for photovoltaic systems.

5. Calculation example

The photovoltaic system, the converter and the storage system are represented by figure 3.

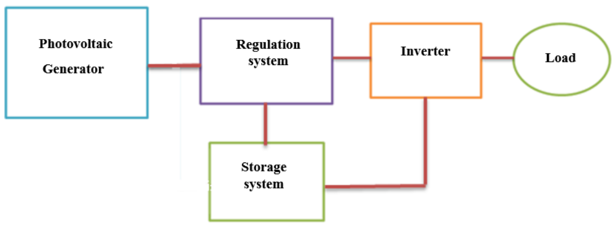

Fig. 3. Simplified diagram of a photovoltaic installation

The photovoltaic system Input parameters primarily concern a certain number of conditions essentially related to meteorological data of the site concerned, among other things the data of the overall inclined irradiation and the duration of

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the day must be known. The photovoltaic generator constitutes the source of the electrical energy; it is a series - parallel assembly of identical photovoltaic modules. The photovoltaic module is composed of a set of photovoltaic cells generally connected in series. These cells are the seat of the transformation of electrical energy by photovoltaic effect.

❖ Number of total modules

$$NMT= \frac{pc}{PM} \quad (7)$$

With:

PM: Power of the module in W

❖ The section of the cables, S, can be calculated by the following formula:

$$S = \frac{\rho * L * I}{\varepsilon * V_A} \quad (8)$$

ρ is the resistivity of the cable in Ω.m. This depends on the material. It is 1.7 × 10 -8 Ω.m for a copper cable.
L is the length of the cable in m
I is the current through which the cable goes in A
ε is the voltage drop in V
VA is the voltage at the start of the V-cable

❖ The initial total cost of the system is given by:

$$CT=AC.\ NMT + B.CB + CO \quad (9)$$

❖ Total lifetime costs are obtained by:

$$CDV=CT+COM \quad (10)$$

With:

COM: Cost of operation and maintenance + Battery replacement cost;

Finally, the cost price of KWh is given by the following formula:

$$CKWH= \frac{CDV}{N.CAS} \quad (11)$$

AC: Module cost;
B: Battery costs
CB: Battery capacity
C0: Indirect cost (Civil Engineering, Transport, etc.)
NMT: Generator Air
CDV: Total life cost
N: System life
CAS: Annual System Consumption

We need some data for input on the software, the data of the installation are:

- Number of days of autonomy 5d
- Average daily radiation of the worst month: E j = 6.6 [kWh / m² / d]
- Module power: 220W
- Rated module voltage: 28.4V
- Efficiency of the inverter: 0.9
- Battery voltage: 12V
- Unit capacity of a battery: 265 Ah
- Surface of a PV module in m2: 1,66
- conductors between panels and junction box: 14 m
- conductors between the junction box and the inverter: 20 m
- conductors between the batteries and the inverter: 15 m
- lifetime of the system: 25 years
- Unit price of the module 939,09 €
- Unit price of the battery: 485 €
- Indirect cost: 4490,39 €
- Maintenance cost: 1000 €
- Annual system consumption: 120 KWh

In table 1 the load profile of our house in Ghardaia is shown below (to optimize the daily consumption of the house and to present the specifications) The receivers will be powered by an inverter.
It is considered that the inverter is well used: its charge rate is high (0.75 to 1). The conversion efficiency is then 0.7 to 0.9 and 0.9 will be taken. Thus the power to be supplied to the inverter to dispose at its output of the energy required for the receivers (E cons) (under 220V) CA, is from:

$$Ec = \frac{E\ cons}{0.9} \quad (12)$$

Table. 1. Load profile

Devices	Nber	Power (w)	Time of use (h /d)	Energy (wh)
Room 1 (lamps)	1	20	6	120
Room 2 (lamps)	1	20	6	120
Living room (lamps)	2	20	6	240
Kitchen (lamps)	1	20	6	120
Loge (lamps)	2	20	6	240
Toilet (Lamp)	1	20	1	20
Bathroom (lamps)	1	20	1	20
Outdoor lamps	2	20	1	40
TV	1	70	6	420
PC	1	180	5	900
refrigerator	1	130	24	3120
Washing machine	1	360	1	360
Air- conditioner	1	1100	5	5500
TOTAL		**2160**		**12466.6**

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The sizing of our photovoltaic installation is based on the data used in an installation imposed by specifications that we took as an example.

Figure 4 shows the graphical interface in French. We can use other language as we mentioned before such as English or Spanish..etc.

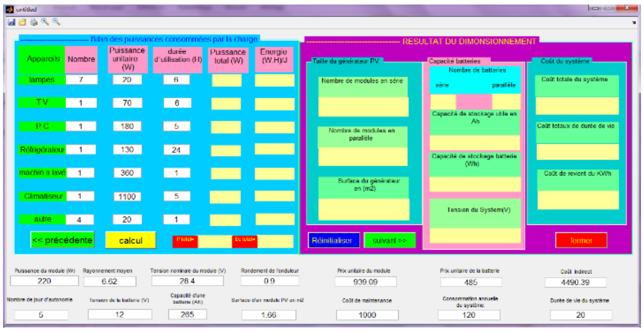

Fig. 4. Graphical interface realized

We obtained the calculation results provided by the sizing program and are represented by the following graphical interface (figure 5):

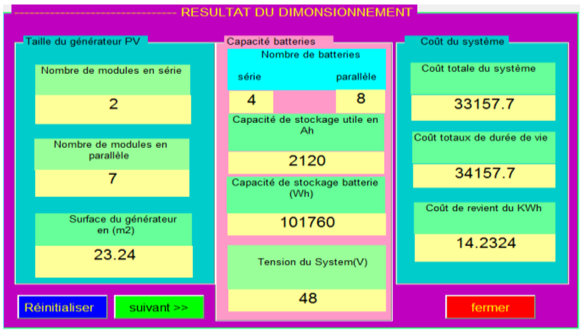

Fig. 5. Result of sizing calculated by the graphical interface realized

The graphical interface (Figure 6) gives the possibility of calculating the section of the drivers and displaying the results of the sections with norms by a simple example.

Fig. 6. The flat wiring interface

The result of the calculation of the section of the cables is displayed according to the international standards. The GUI displays the following result (Figure 7):

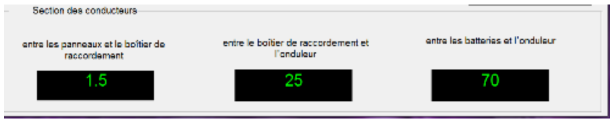

Fig. 7.Section of the cables

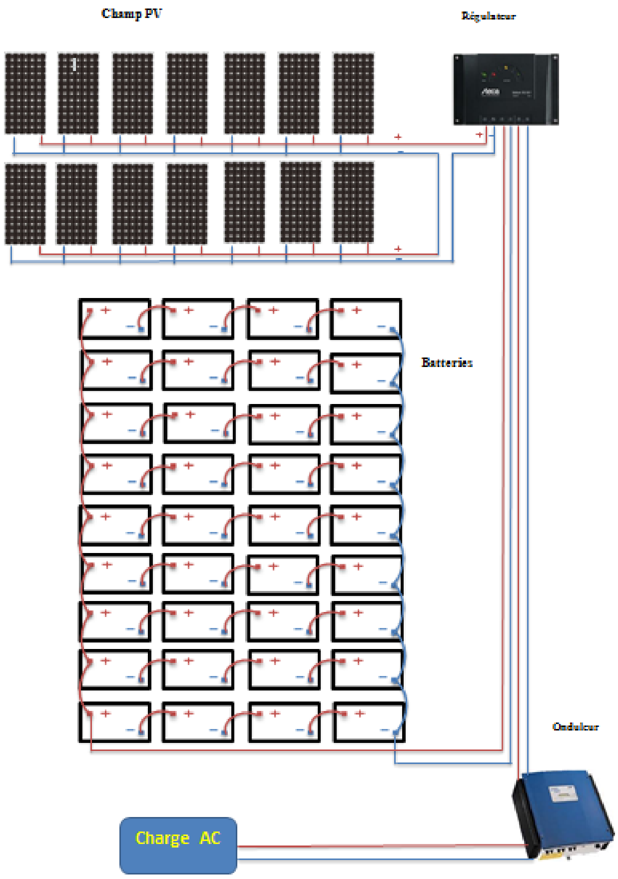

Fig. 8. Diagram of the photovoltaic system

The graphical interface made under the Matlab environment (GUIs) makes it easier to calculate the various parameters of the installation to achieve to meet the specifications. The external data is supplied to the calculation program via a file (Data.m) and the program calculates all the parameters necessary for the realization of the photovoltaic installation. As a perspective to this work, we can conduct a comparative study between the various sizing methods as well as an economic study on the influence of the cost price of the kilowatt hour from photovoltaics compared to other types of energy.

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IV. Conclusion

In a large number of applications, photovoltaics is simply the most cost-effective solution. Among these applications are isolated systems feeding cottages or remote residences, navigational aids of the Coast Guard, remote utility and military telecommunication sites, water pumping in the waterways. farms and emergency call stations on campuses or highways. This study concerns the realization of a program of dimensioning of autonomous photovoltaic installation by determining the size of the subsystems which constitute it (generator, batteries, regulator, converters, etc.) According to the input (solar radiation) and the output (load profile). A graphical interface under Matlab was also realized and this in order to present the sizing model and to facilitate calculations.

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