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Design of software dedicated to the sizing of photovoltaic solar installations

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Abstract

This article presents the development of software aimed at sizing photovoltaic solar installations, representing a significant advancement in optimizing the design and efficiency of solar systems. This software offers the possibility to accurately determine the dimensions of the components, taking into account environmental parameters, energy needs, as well as technical constraints, with the aim of achieving a reliable, efficient, and economical installation. This document presents a comprehensive reference framework regarding the software design process, the methodologies applied for sizing, as well as the analysis of the obtained results and their experimental validation.

Keywords: Design; Sizing; Photovoltaic Solar Installation

1. Introduction

The exploitation of renewable energies, particularly photovoltaic solar energy, presents itself as a sustainable alternative to contemporary energy issues. Nevertheless, an optimal configuration of photovoltaic systems requires precise sizing to ensure adequate energy production while controlling costs. Automated sizing software significantly contributes to the simplification of these operations by allowing the integration of local climatic parameters, energy consumption profiles, as well as various technical configurations [2, 4, 9]. The present study aims to develop a high-performance, intuitive, and comprehensive tool designed to assist engineers and technicians in this complex process.

2. System design

2.1. Design of the solar photovoltaic system

It consists of an association of elements whose characteristics must be carefully chosen to achieve optimal operation [1]. The synoptic diagram of our installation is given in Figure 1.

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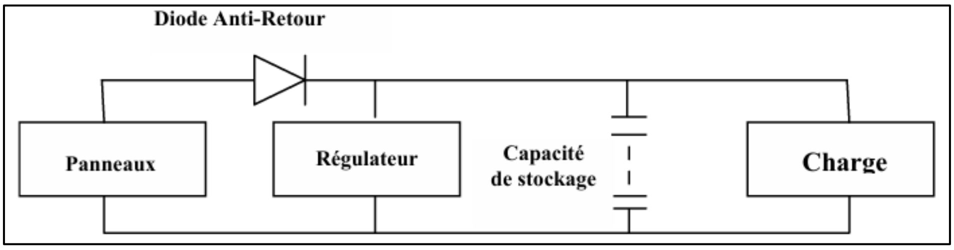

Figure 1 Solar photovoltaic system [1].

The energy consumed by the load depends on the number of hours of emission and standby.

2.2. Software design

The overall design of the software is based on the complete modeling of the photovoltaic system, including [5]:

- The PV module: electrical characterization, efficiency according to temperature and irradiation.
- The inverter: conversion efficiency, operating range.
- The batteries: capacity, deep discharges, life cycles.
- The consumers: daily and seasonal load profiles.

The software was architected following a modular model, facilitating the integration of new features and maintenance. The user interface was designed to be intuitive, allowing for easy entry of technical and environmental data [3]. Integrated databases collect data on irradiation, temperature, and standard consumption, with the possibility of importing specific data [6].

Figure 2 shows the flowchart of the design of our software for sizing an autonomous solar installation.

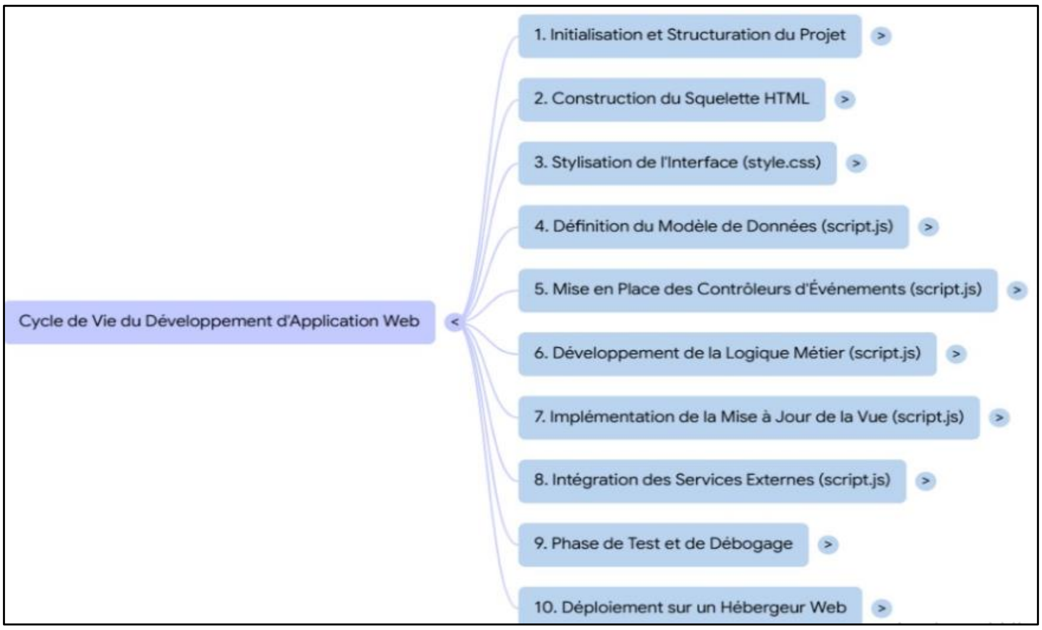

Figure 2 Flowchart of the software [8].

2.3. Sizing method

In order to determine the optimal sizing of the photovoltaic (PV) system coupled with storage batteries, the following considerations were taken into account [5, 7]:

The daily electrical production from a photovoltaic surface is proportional to the total solar irradiation incident on that surface, and is exhaustively characterized by its efficiency and active surface area.

The efficiency of the batteries remains constant during the charging and discharging phases, and the storage system is fully defined by the capacity Eb expressed in kilowatt-hours (kWh) and by the value of its efficiency, which are considered invariant throughout the system study, although they usually depend on the fluctuations of the charging and discharging current.

Demand remains stable throughout the study period, although it may fluctuate during the day, with the average daily value remaining constant.

During the envisioned usage period, it is considered that the efficiencies of the conversion elements, including the DC/DC regulators and the DC/AC inverter, remain constant.

The excess energy generated by the field is stored in the batteries.

Global irradiation on an inclined plane:

$$\mathrm{IGI} = \mathrm{R} \times \mathrm{IGH} \tag{1}$$

$$\mathrm{R} = \frac{\mathrm{Drh}}{\mathrm{IGH}} \mathrm{R_b} + \frac{\mathrm{Drh}}{\mathrm{IGH}} \left(\frac{1+\cos(\beta)}{2}\right) + \left(\frac{1+\cos(\beta)}{2}\right) \rho \tag{2}$$

Drh: Direct horizontal irradiation

Dfh: Diffuse horizontal irradiation

IGH: Global tilted irradiation

$$\mathrm{R_b} = \frac{\cos(\mathrm{L})\cos(\delta)\cos(\mathrm{AH}) + \sin(\mathrm{L}-\beta)\sin(\delta)}{\cos(\mathrm{L})\cos(\delta)\cos(\mathrm{AH}) + \sin(\mathrm{L})\sin(\delta)} \tag{3}$$

2.4. Sizing of the PV field:

Once the site's resource assessment is completed, we still need to choose the components of the PV system (modules, battery charge controller, inverter).

Daily energy provided by the module Under standard temperature and lighting conditions (T=25°c, Gcs=1000), the energy delivered by a module is expressed in the following form [7]:

$$\mathrm{E_p} = \mathrm{P_m} \times \left(\frac{\mathrm{IGI}}{\mathrm{Gcs}}\right) \times \mathrm{P} \tag{4}$$

$\mathrm{E_p}$: Daily energy provided by the module (Wh)

$\mathrm{P_m}$: Module power under desired conditions (W)

IGI : Minimum annual average daily irradiation (KWh/m^2)

P : Global correction factor, taking into account various efficiencies as well as a safety coefficient (%)

The total number of panels Np constituting the PV generator is given by the following expression:

$$\mathrm{N_p} = \frac{\mathrm{E_{ch}}}{\mathrm{Ro} \times \mathrm{Rr}} \times \frac{1}{\mathrm{E_p}} \tag{5}$$

Ro : Inverter efficiency

Rr : Regulator efficiency

$\mathrm{E_p}$: Daily energy provided by the module (Wh)

$\mathrm{E_{ch}}$: Daily energy consumed by the load (kWh)

The power of the generator is equal to:

$$PG = N_{ps} \times N_{bp} \times P_m \tag{6}$$

The total surface area of the generator is:

$$S_t = N_p \times S_m \tag{7}$$

S_m : Surface of a module.

Energy output from the photovoltaic field:

$$ESG = E_p \times N_p \tag{8}$$

Sizing of the storage park:

The determination of the battery park is carried out by taking into account a certain number of days of autonomy to ensure at zero production. This number of days varies depending on the authors but also depending on the applications and the geographical location (between 3 days and 3 weeks). [7].

2.5. Storage Capacity:

$$C_{sto} = (E_{ch}/(P_f \times R_b) \times Aut) \tag{9}$$

The storage capacity in ampere hours (Ah):

$$C_{ah} = C_{sto}/T_{eo} \tag{10}$$

C_{sto} : Storage capacity

Aut : Autonomy in days

- P_f : Depth of discharge (%)
- R_b : Battery efficiency (%)
- T_{eo} : Inverter input voltage (V)
- C_{ah} : The storage capacity in ampere-hours (Ah)

2.6. Description of the algorithm

The sizing method has the following inputs:

Step 1: Input of consumption information: On the homepage, click the " ⚡ Start" button to access the application.

Figure 3 shows the sizing start page.

Figure 3 Start of sizing.

Step 2: Enter the equipment:

You are in the Dry Season tab. Fill out the table by adding all the electrical appliances you use during this period.

For each device, specify the Name, Quantity (Qty), Power (W), and Usage Time per day (h/day).

Click on "Add" to insert new lines if necessary.

Adjust the Sunshine (h/day) value for the dry season if the default value does not match your locality.

Step 3: Switch to the rainy season:

Click on the Rainy Season tab.

Repeat the operation by entering all the equipment used during this period. It is important to fill in both seasons because the calculation will be based on the most unfavorable one to ensure autonomy throughout the year.

Figure 4 shows the parameters and energy consumption.

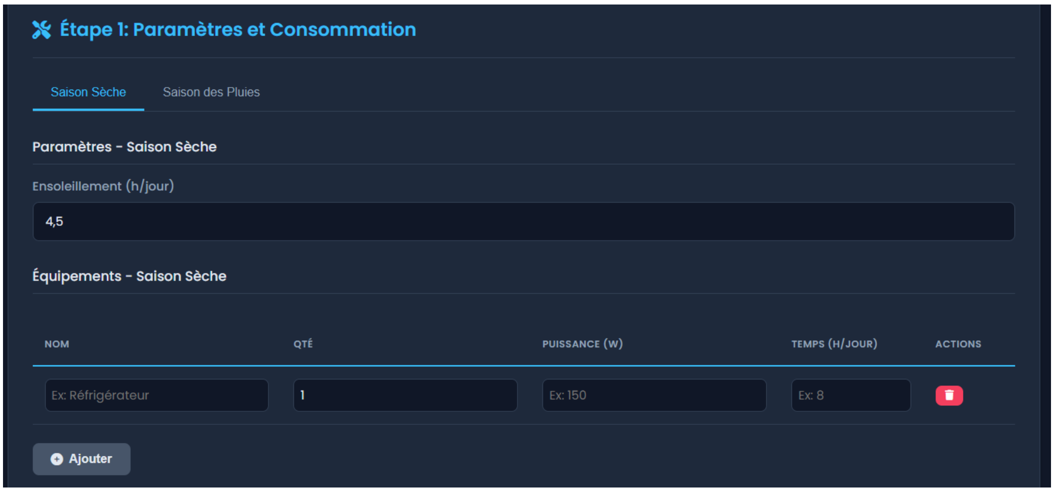

Figure 4 Parameters and consumption.

Step 4: Calculate: Once all the information is entered for both seasons, click on the "Calculate & View Results" button, Figure 5.

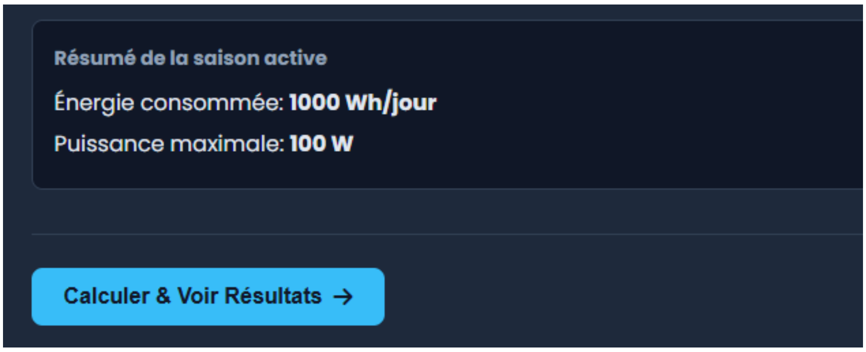

Figure 5 Summary of the active season.

3. Result and Validation

The application now presents you with the calculation results. You will find the number of solar panels, batteries, the power of the inverter and the necessary regulator there, Figure 6.

Figure 6 Sizing results**.**

After reviewing the results, click on the "View Proforma" button to proceed to the final step.

3.1. Generation of the Proforma Invoice:

Customer information: Fill in the Client Name field and, if you wish, modify the Company Name.

Enter the unit prices: The proforma table is pre-filled with the quantities of materials calculated in the previous step, and this is the most important step: You must now enter the unit price for each component (panels, batteries, inverter, etc.) in the corresponding fields. The total costs will update automatically.

Add items (Optional): If you need to add additional costs (such as specific accessories, etc.), click on "Add Item" and fill in the details.

Add the conditions: In the "Terms, conditions, and notes for the PDF" section, you can add information that will appear on the final document (for example, the validity period of the offer).

Generate the PDF: Once all the prices are entered and the total amount seems correct to you, click on the "Generate PDF" button.

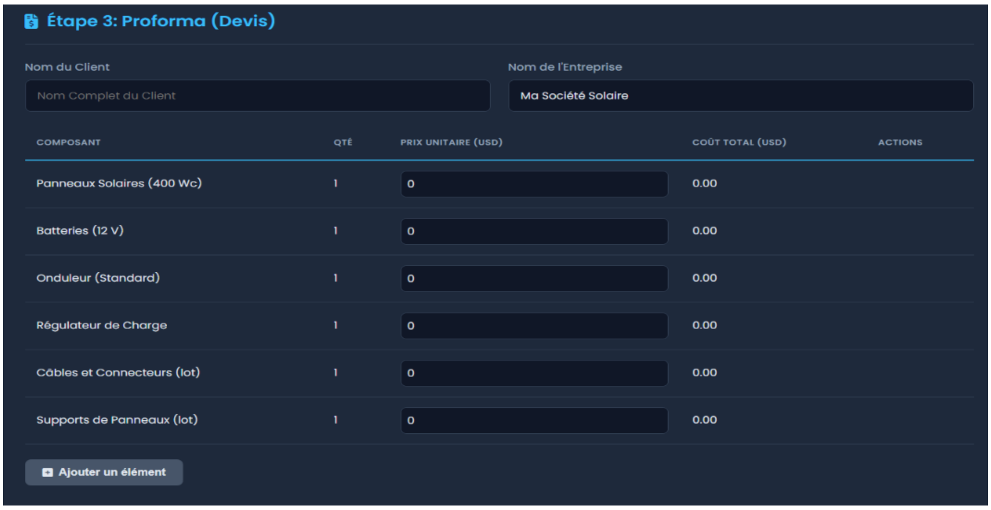

Figure 7 Proforma (Quote).

Your proforma invoice will then be downloaded onto your device in PDF format, Figure 8.

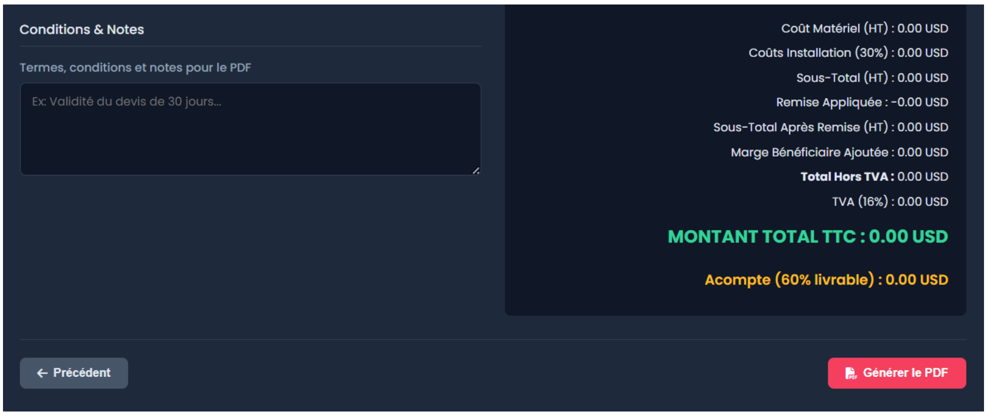

Figure 8 Final results.

In short, the numerical simulations carried out using the software were compared with the experimental data from the test bench, in various application contexts, notably residential and tertiary. The results obtained highlight a strong concordance (deviations of less than 5%) between the predicted energy production and the measured energy production. The recommended sizing allowed for the achievement of energy availability and autonomy objectives, while minimizing oversizing and related costs. The software also demonstrated an ability to promptly adjust to parametric variations, providing significant flexibility to the design process.

4. Conclusion

The development of the software for sizing photovoltaic solar installations presented constitutes a comprehensive, reliable, and accessible solution for professionals in the field. The integration of rigorous calculation methods, an intuitive user interface, and thorough experimental validation gives this tool the ability to optimize the design of photovoltaic systems.

Therefore, this approach contributes to the democratization and reliability of solar installations, encouraging their rapid deployment to support the overall energy transition. The future evolution of the software presents favorable prospects, due to the continuous technological and functional improvements expected.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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