Sizing of a Solar Parking System Connected to the Grid in Adrar

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Abstract. This paper presents a sizing study of a solar parking system connected to the grid. This system is installed in Adrar region, south west of Algeria. It is composed from photovoltaic panels, cables, converters. All these elements have been modeled and sized using analytical method. The proposed method is validated by simulation using PVSYST software.

The simulation results were discussed and compared with the analytical results. They proved the validity of the model to make a good system sizing for different applications.

Keywords: Solar parking · Electrical grid · Sizing · Simulation · PV system software

1 Introduction

Nowadays, the electrical energy production presents a very important issue, especially with the environment problems and the cost of the fossil energy. Face to these problems, the renewable energies and especially photovoltaic energy is used to fix them [1]. However, this latter requires a large area in its installation compared to the needed harvested electrical energy. In this context, a solar parking system is proposed and studied. The solar car park is used in order to benefit from the roof area by installing

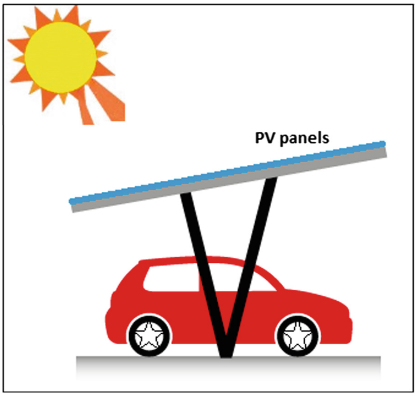

Fig. 1. The solar car park.

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photovoltaic panels, moreover for obtaining shadow and electrical energy. This latter can be used for different applications such as charging electrical cars and grid connection which is the used application in this paper [2]. Algeria has a high solar potential that encourage us to benefit it with an optimization way for a long time according to the literature estimation [3–5]. In this work, the solar car park is studied to be installed in Adrar with a power equals to 31.5 kWc, Fig. 1.

This paper is organized as following: in the second section; the modeling of the whole element of the solar parking system is given. The third section is reserved for the sizing of the car parking system. Then, the simulation of the system installed in Adrar using PVSYST, is presented in the fourth section. At the end, an investigation and evaluation comparison have been done between the analytical and the simulation results.

2 Modeling of the Solar Parking System

The sizing of the PV system passes by many steps, depending basically on the site potential and the required energy.

The estimated energy produced per day is given by:

$$\mathbf{E_c = P * Q * h} \tag{1}$$

Where:

E_c: The consumed energy (Wh/day).
P: Electrical power (W).
Q: Number of the used panels.
h: Time (hour).

2.1 Sizing of the Required Photovoltaic Generator

The peak power of the required panels for installation depends on the site irradiation. It is calculated by applying the following equation [6]:

$$\mathbf{P_C = \frac{E_c}{kI_r} = \frac{E_P}{I_r}} \tag{2}$$

P_c: Peak power in peak watts (Wc).
I_r: Average annual daily irradiation (kWh/m^2.j)

The total number of the installed PV modules is calculated by:

$$\mathbf{N} = \frac{\mathbf{P_c}}{\mathbf{P_u}} \tag{3}$$

P_u: unit peak power of the modules watts (W)

The number of the serial PV modules is given by:

$$\mathbf{N_s} = \frac{\mathbf{U_{ond}}}{\mathbf{U_{mod}}} \tag{4}$$

$\mathbf{U_{ond}}$: the input voltage at the terminals of the inverter.
$\mathbf{U_{mod}}$: the unit voltage of the modules

The number of the parallel PV modules is calculated by:

$$\mathbf{N_p} = \frac{\mathbf{P_c}}{\mathbf{N_s P_{mod}}} \tag{5}$$

$\mathbf{P_{mod}}$: the peak power of the PV module

2.2 Cables Sizing

It is very important to use cables that can support the current in both sides DC and AC. This can be achieved by a good sizing of the cable section. Moreover, the isolation must support the environment temperature and the temperature caused by Joule loses. The sections of cables that cause the least potential drop in voltage between the panels and the inverter/charger and between the batteries and the inverter/charger must be determined. The voltage drop must not exceed 3% [7].

The cable section can be obtained by using the following equation:

$$\mathbf{R} = \frac{\mathbf{\Delta U}}{\mathbf{I}} \tag{6}$$

$$\mathbf{S} = \frac{\rho \mathbf{L}}{\mathbf{R}} \tag{7}$$

$\Delta \boldsymbol{U}$: maximum voltage drop in the cable.
$\boldsymbol{I}$: current circulating in the cable.
$\boldsymbol{R}$: cable resistance

2.3 Converters Choice

The boost power (P_{-reg}) and the inverter power ($P_{\_ond}$) must be over the peak power (P_c), so it is necessary that:

$$\mathbf{P_{\_reg} \geq P_c} \tag{8}$$

$$\mathbf{P_{\_nd} \geq P_c} \tag{9}$$

2.3.1 Sizing of the Car Parking System

The above equations are used to apply this study on a solar parking. The real characteristics of the installed PV panels in the renewable energy research unit in the Saharian medium are [8]:

Type (Mono crystalline) whose construction parameters are given in the following table (Table 1):

Table 1. Characteristics of the used PV.

Maximum power ($\mathbf{P_{max}}$)	250 W
Open circuit voltage ($\mathbf{V_{oc}}$)	36.99 V
Court-circuit current ($\mathbf{I_{sc}}$)	8.768 A

The peak power which is needed according to the parking area is: $P_c = 31.5\,kW_C$ Hence, the PV module number is:

$$\mathbf{N = \frac{P_c}{P_U} = \frac{31500}{250} = 126\,panels} \tag{10}$$

The number of the serial PV is calculated by:

$$\mathbf{N_s = \frac{U_{ond}}{U_{mod}} = \frac{500}{36.99} = 14\,serial\,connections} \tag{11}$$

The number of the parallel PV is obtained as:

$$\mathbf{N_p = \frac{P_c}{N_s P_{mod}} = \frac{10500}{(14).(250)} = 3\,Parallel\,connections} \tag{12}$$

The cable section ***S*** is reached by the following equation:

$$\mathbf{R = \frac{\Delta U}{I} = \frac{0.02.30.75}{8.131} = 0.076\ \Omega} \tag{13}$$

$$\mathbf{S = \frac{\rho L}{R} = \frac{1.610^{-8}.12}{0.076} = 2.5\ \ 10^{-6} m^2 = 2.5\,mm^2} \tag{14}$$

In the following section, the same solar parking system will be presented and simulated using the PV system software, and then the results comparison will be obtained in both cases.

3 Simulation of the Solar Parking

3.1 Simulation of the Solar Parking in Adrar

PVSYST is useful software that allows simulating and verifying projects. It imports weather and geographically data to give results very closer to the real case. Furthermore, it can do a good sizing of the system and its production estimation with optimization.

In this part, the simulation of the solar parking connected to the grid is accomplished using PVSYST. This solar car parking is chosen in Adrar [6].

The sizing of the system using PVSYST has been passed by many steps such as, setting of the localization, PV type, inverter sort, the output power, and the kind of the load…etc., Fig. 2.

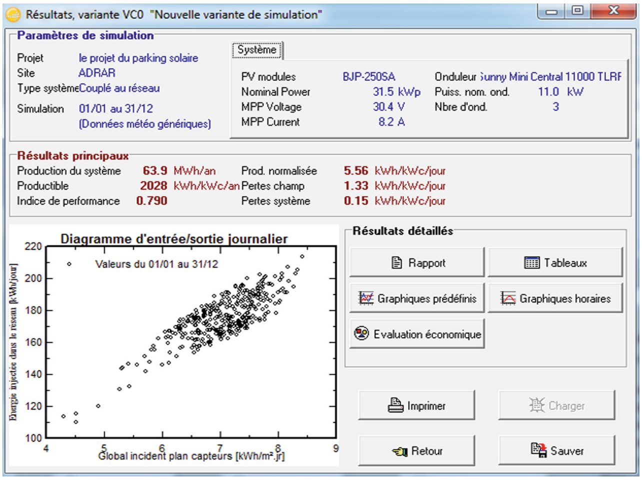

Fig. 2. Parameters setting and simulation in PVSYST.

PVSYST allows presenting different shapes of simulations, graphs, histograms and tables. The other simulation results using PVSYST are shown below (Fig. 3).

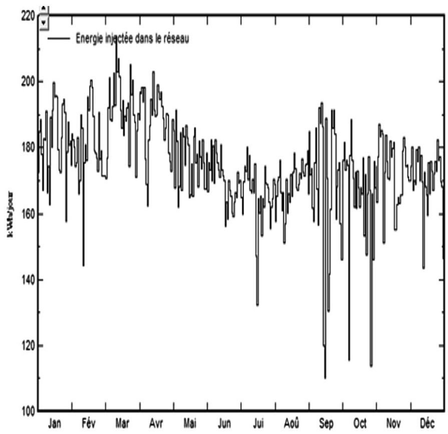

Fig. 3. Daily energy injected to the grid during the year.

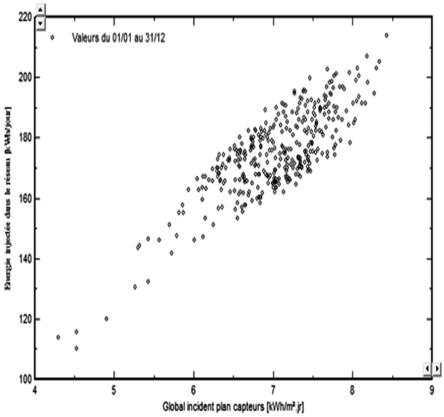

Fig. 4. Diagram of daily input/output.

It is seen that the daily produced energy is variable during the year; it reaches high values from autumn to spring months (September to April). However, it has lower values in summer, because the high temperature in Adrar reduces the PV efficiency (Fig. 4).

The diagram presented in the figure above shows the energy injected to the grid [kWh/day], in function of the global irradiation [kWh/m^2.day] during all the year in Adrar region.

As it is seen in “Fig. 5”, the energy injected to the grid increases proportionally with the irradiations.

The table below presents different variables obtained by simulation during the year in Adrar (Table 2).

Table 2. Balance sheet of simulation results during the year in Adrar.

	GlobHor kWh/m^2	DiffHor kWh/m^2	T_Amb °C	GlobInc kWh/m^2	GlobEff kWh/m^2	EArray kWh	E_Grid kWh	PR
Janvier	139.5	20.63	11.55	210.9	206.3	5790	5647	0.850
Février	144.5	27.83	14.82	192.7	188.8	5201	5068	0.835
Mars	200.6	36.59	20.17	234.8	229.6	6097	5939	0.803
Avril	221.3	45.17	23.81	227.1	220.9	5799	5653	0.790
Mai	242.1	57.62	29.14	225.3	218.3	5619	5469	0.771
Juin	240.9	58.44	33.76	215.1	208.3	5248	5099	0.753
Juillet	243.9	59.44	37.68	221.7	214.8	5275	5130	0.735
Août	227.3	59.49	36.76	224.4	218.0	5361	5225	0.739
Septembre	190.8	51.09	31.49	210.2	204.7	5183	5049	0.763
Octobre	164.4	42.37	26.47	207.3	202.7	5282	5146	0.788
Novembre	137.5	23.03	17.34	199.3	195.2	5323	5190	0.827
Décembre	126.4	19.54	12.97	197.7	193.5	5420	5284	0.849
Année	2279.1	501.26	24.72	2566.5	2501.0	65597	63897	0.790

Where:

GlobHor: horizontal globale irradiation
Diffhor: horizontal diffused irradiation
T-Amb: ambiant temperature
GlobInc: Global incident on collectors
GlobEff: Global "effectif", corr. pour IAM et ombrages
EArray: output effective PV energy
E-Grid: Energy injected to the grid
PR: performance Indicator

3.2 Comparison Between Analytic and Simulation Results

The table below presents the comparison between analytic and simulation results

Table 3. Comparison between analytic and simulation results.

Variable	Analytic results	Simulation results
Total number of panels (N)	126	126
Total number of serial panels (N_S)	3	3
Total number of parallel panels (N_P)	14	14
Section (S)	2.5 mm^2	2.5 mm^2

As it has seen according to the Table (3), it is obvious that a very good accuracy is noticed from the comparison between the simulation and the analytical results.

3.3 Experimental Scheme of the Photovoltaic Parking System

According to the analytical and simulation results, it is found that the solar parking is composed of 126 PV modules, each 14 PVs should have a serial connection in order to increase the voltage, the three groups of 14 PVs are connected in parallel for increasing the current [9], these three groups are connected to the grid via three boosts and three inverters, with a total power equals to 31.5 kWc, as it is shown in Fig. 5.

Thanks to the control applied on the inverter, it is noted that this latter insures the grid connection conditions in both sides, (The same voltage magnitude, the same frequency, the same phase delay) [10, 11].

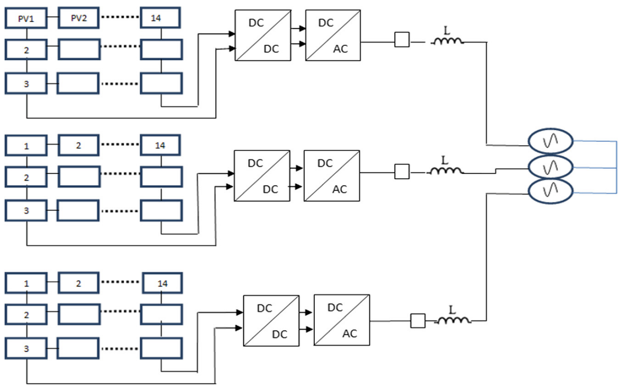

Fig. 5. Diagram of the car park connected to the grid.

4 Conclusion

In this work, a study of solar parking installed in Adrar (Algeria) was achieved. The elements system have been modeled and sized in analytical method. Then, the car parking system connected to the grid is simulated according to Adrar data. After that, the obtained results have been compared; it was found that the analytical and simulation results were similar, which confirm the good sizing of the system. Moreover, the system production and the irradiation are good during the year in Adrar, however, the energy produced decreases in summer months due to the high temperature.

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