Techno-economic feasibility study for the use of photovoltaic energy on the south-east algerian farms

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Abstract - *This works aims to study the technological feasibility and economic viability of standalone Photovoltaic system for the electrification of farms in the south-east of Algeria. The PV system power plant is sized to supply potato farm in Akfadou-El Oued. The standalone PV system was designed and simulated using the Hybrid Optimization Model for Electric Renewable (HOMER). Simulation results showed that a high capital cost is needed to install the PV system with a high cost of energy reaches 30 DA/kWh.*

Résumé – *Ce travail tend à étudier la faisabilité technologique et la rentabilité économique du système photovoltaïque autonome pour l'alimentation en électricité des fermes dans le sud est algérien. La station PV est réalisée pour fournir une ferme de production de pommes de terre à Akfadou dans la wilaya d'El Oued. Le système PV autonome a été conçu et simulé en utilisant le Modèle d'Optimisation Hybride pour l'Electricité Renouvelable (HOMER). Les résultats de la simulation ont montré qu'un investissement important est à déployer pour l'installation du système PV avec un coût élevé de l'énergie atteignant 30 DA/kWh.*

Keywords: HOMER - Feasibility study - Solar photovoltaic energy - Water pumping systems - Sahara region.

1 INTRODUCTION

The production of the electricity in Algeria is mainly based on natural gas, 98 % of the generated electricity comes from gas. On the other hand, Algeria has huge potential for the development and use of renewable energies. In order to diversify energy sources and engage in sustainable energy use, the Algerian government has launched an ambitious program to develop renewable energies [1]. Renewable energy should achieve by 2030 more than 37% of national electricity production. The energy strategy is mainly based on the development of solar energy. Several feasibility studies of the renewable energy use in different regions in Algeria were carried out. Work [2] presents the development of a new software Dim Hybride dedicated for the sizing of wind photovoltaic hybrid energy systems in remote areas. Athors in [3] presents a feasibility study of renewable energy use in the Algerian dairy farming industry in Mitidja. Techno-Economic study of a hybrid system (PV/WIND) to provide electricity for a household in Batna was presented in [4]. Authors in [5] proposed a study and comparison of two options for solar and wind water pumping applications in the Adrar region.

In Algeria, photovoltaic energy is one of the most promising renewable energies. It is freely available, environment friendly and requires less maintenance. The implementation of photovoltaic energy will lead to economical, social and

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environmental benefits. El Oued, located at the south east of Algeria, has a huge potential of solar energy. The annual average solar irradiation reach 5.21 $kW/m^2/day$. Beside of that, El Oued shows growing in the agriculture field. It has become at the head of the producing regions of the potato with a contribution of 24% of national production. Furthermore, approximately 65% of its population are engaged in the agriculture sector. To contribute 37% of the electricity production from renewable energy by 2030, renewable energy sources would be adopted by agriculture farms progressively. In this context, this study aims to present a techno-economic optimization of the photovoltaic energy for standalone PV system used to electrify a Potato farm located in Akfadou-El Oued, Algeria. The system configuration is simulated and analyzed using the Hybrid Optimization Model for Electric Renewable (HOMER).

2. CASE STUDY

2.1 Site Characteristics

The wilaya of El Oued is located 510 km South-East of Algiers; the capital of Algeria. It has a hot desert climate (Kppen climate classification BWh). Winters are mild, with average temperatures around 11 °C in January. Summers are very hot with average temperatures around 32 °C, average maxima around 40 °C and the hottest days approaching 50 °C. Rainfall is light and sporadic, and summers are particularly dry [6]. The geographic position of El Oued is 33°21' N Latitude and Longitude of 6°5' E. The location of El Oued in Algeria is shown in figure 1, which represents also the Annual Global Horizontal Irradiation (GHI) of the whole country.

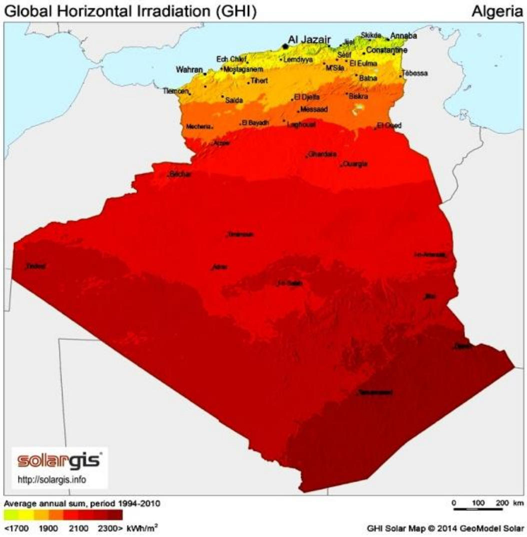


Fig. 1: Global horizontal irradiation of Algeria

GHI is the most important parameter for calculation of PV electricity yield. In simple language,

$$GHI = \text{Direct horizontal irradiation } (DHI) + \text{Diffuse horizontal irradiation } (DIF)$$

DHI is the irradiation component that reaches a horizontal Earth surface without any atmospheric losses due to scattering or absorption. DIF is the irradiation component that reaches a horizontal Earth surface as a result of being scattered by air molecules, aerosol particles, cloud particles or other particles. In the absence of an atmosphere there would be no diffuse horizontal irradiation [7]. Figure 2 represents the location of the Potato farm studied in this work. It is located (05) km in the environs of Trifaoui town.

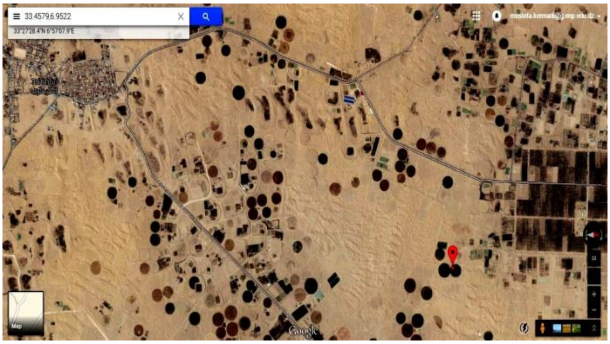


Fig. 2: Location of typical potato farm used in this study

Figures 3 and 4 represent respectively the monthly average of solar radiation and clearness index and the monthly average air temperature of El Oued obtained through HOMER from NASA Surface meteorology and Solar Energy Database [8]

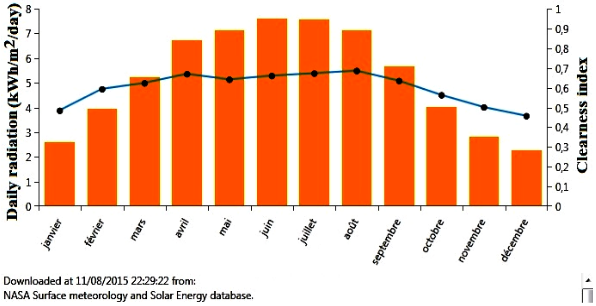


Fig. 3: El Oued monthly solar radiation and clearness index

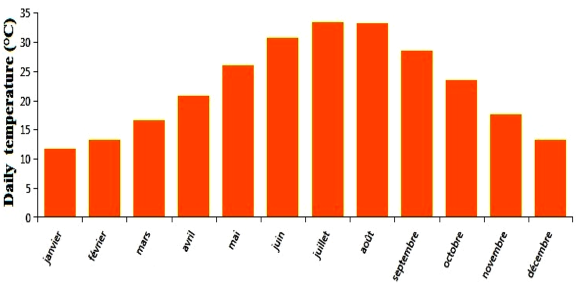


Fig. 4: El Oued monthly average air temperature

The clearness index shows that El Oued is a sunny area. The maximum solar radiation occurs in July with the irradiation of 7.58 kWh/m^2/day which is a very high value, and the lowest average irradiation is in the month of December with 2.25

kWh/m²/day. The Annual average solar irradiation is 5.21 kWh/m²/day which is a great potential for PV energy generation.

2.2 Electrical load profile of the farm

The estimation of the annual power electric load of the farm is an important step. The load of the potato farm is composed of two asynchronous motors. The first one is used to rotate the pivot shown in Figure 5 with power consumption of 1 HP. The second one is a submerged pump of 3 HP used to fulfill the irrigation process. Figure 6 shows typical diagram of a submerged pump. The total load is approximately constant equals to 4 HP ,i.e., $4 \times 745.69 = 2982.76$ W.

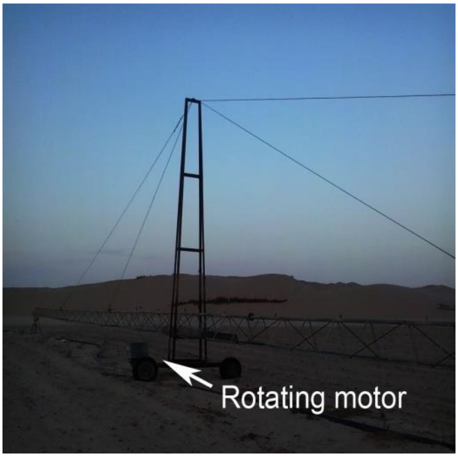


Fig. 5: The rotating pivot used for irrigation

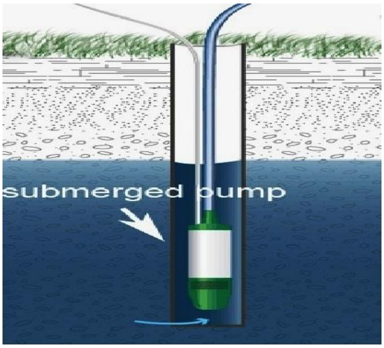


Fig. 6: Submerged pump diagram

Potato is cultivated in two seasons in the year. The first season start from February until May. The irrigation process is effectuated during the daytime. The number of irrigation hours, which varies between 8-12 h, is direct proportional to the ambient temperature.

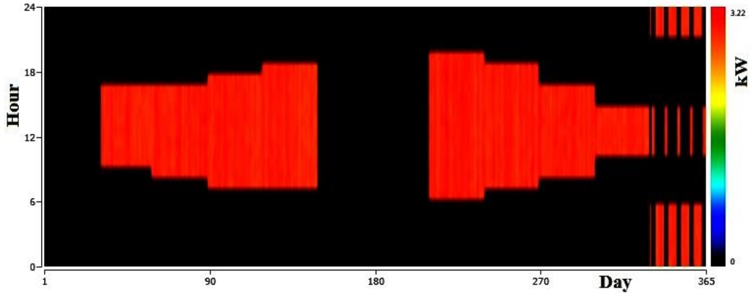


Fig. 7: Day-map of the load profile

In the second session, which start from August until December, the number of irrigation hours per day is less than that of the first season, varies between 5-12 h, due to the low ambient temperature in this season. In several nights in December, the ambient temperature falls to a very low levels (-2°C), the potato plant cannot support the frost at these nights. To prevent potato plants in such nights, the irrigation process is switched to the night, from 22:00 pm to 6:00 am, instead of the daytime. The Day-map shown in figure 7 represents the load profile of the farm for each hour throughout the 365 day in the year.

Figure 8 shows the average monthly load profile for each hour throughout the year.

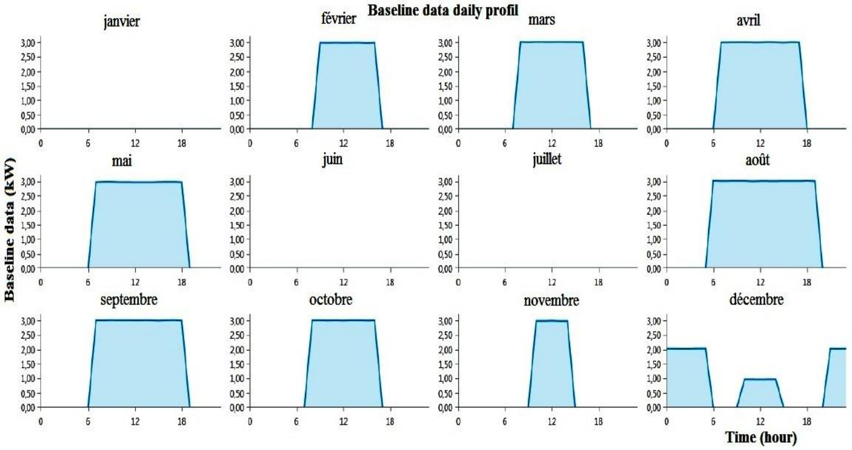


Fig. 8: Daily load profile for each month

Figure 9 shows the average monthly load for the potato farm. The load has an average consumption of 21.92 kWh/day.

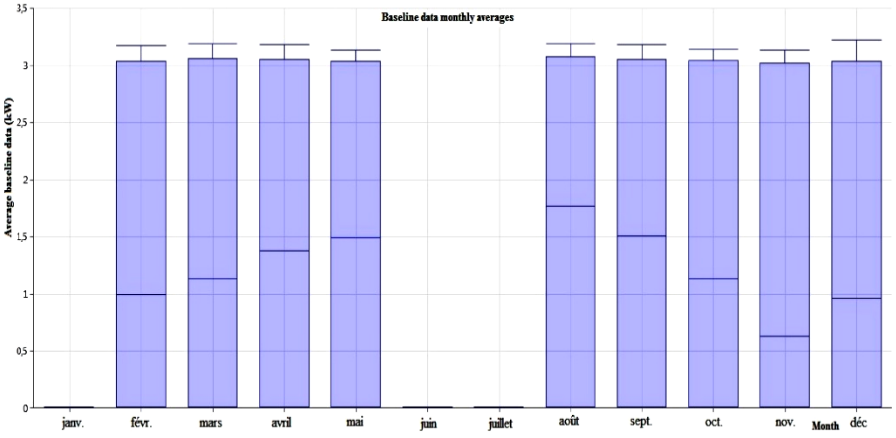


Fig. 9: Monthly average load for the farm

2.3 System configuration

The standalone PV system was designed using HOMER software. The system consists of PV system with Battery storage system linked to the 48-V DC bus, a DC/AC converter to supply the load from the DC bus.

Figure 10 shows the standalone PV system configuration used in this work.

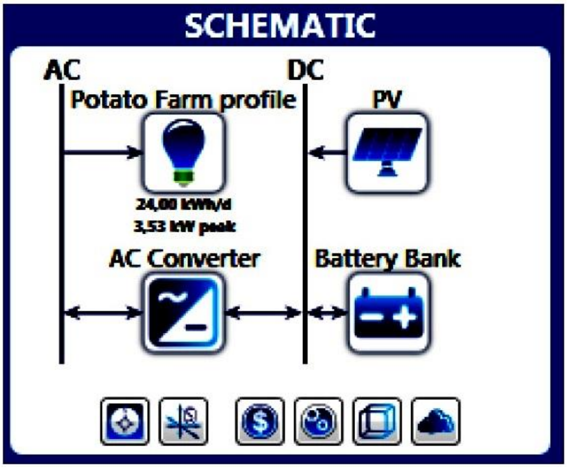


Fig. 10: The standalone PV system configuration

The total project lifetime was fixed to 25 years. The photovoltaic module from Condor [9] was used in this study with working lifetime of 25 years. The battery selected for the simulation has nominal capacity of 40 kWh, the battery lifetime throughput was fixed at 200 000 kWh. The battery throughput is defined as the change in energy level of the battery bank, measured after charging losses and before discharging losses. The lifetime of the battery estimated in years by dividing the battery lifetime throughput (kWh) by battery throughput during one year (kWh/yr). The lifetime of the AC/DC converter and the PV dedicated converter is 15 year.

3. RESULTS AND DISCUSSION

After introducing data inputs, size, price and resources, HOMER software provide several technologically feasible solutions basing on economic optimization [10]. The actual pricing of renewable energy equipment in Algerian market with the initial capital costs of the different components of the PV system are estimated in **Table 1**.

Table 1: Equipment cost of the PV system

Component	Unity price	Capacity installed	Total price
Photovoltaic polycristallin	100 000 DA/kW	15 kW	1 500 000 DA
Gel battery	20 000 DA/kWh	15 kW	1 600 000 DA
AC/DC converter	20 000 DA/kW	15 kW	10 000 DA
PV dedicated converter (MPPT)	20 000 DA/kW	15 kW	14 500 000 DA
PV System installation cost			1 500 000 DA

Figure 11 shows the optimization results, provided by HOMER, which is based on the lowest Net Present Cost (NPC).

Architecture				Cost					PV	Battery Bank	
PV (kW)	PVDC (kW)	Battery Bank	AC Converter (kW)	COE (€)	NPC (€)	Operating cost (€)	Initial capital (€)	O&M (€)	Capital Cost	Autonomy	Annual Throughput
15,0	7,00	2	5,00	0,302 €	36 970 €	253,30 €	33 400 €	0,00 €	16 400	80	2 113

Fig. 11: The optimization results for the standalone PV system

Figure 12 represents graphic columns of the NPC for each component in the PV system.

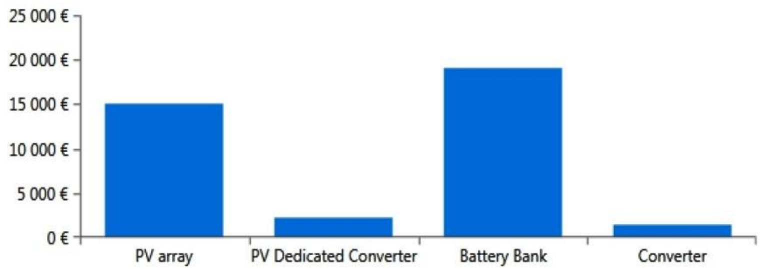


Fig. 12: NPC of each component sorted by component

Table 2 displays the values of all optimization variables. HOMER simulates the set of all possible combinations to these variables. The optimum sizes are highlighted in yellow.

Table 2: Possible configurations of the PV system

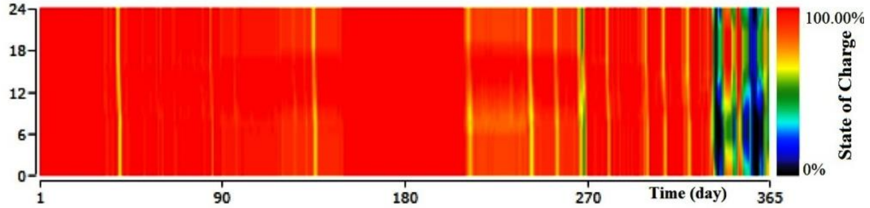
AC Converter Capacity (kW)	Battery Bank Strings (#)	PV Capacity(kW)	PV DC Capacity (kW)
5	0	12	6
0	2	15	8
10	3	18	7
	1		

Table 3 represents the costs associated with the optimum configuration in the PV system. Note that 1 Euro e is assumed to be equals to 100 DA.

Table 3: Costs associated with the PV system.

Component	Capital (€)	Replacement (€)	O&M (€)	Fuel (€)	Salvage (€)	Total (€)
PV array	15 000 €	0,00 €	0,00 €	0,00 €	0,00 €	15 000 €
PV Dedicated Converter	1 400 €	0,00 €	0,00 €	0,00 €	878,53 €	2 279 €
Battery Bank	16 000 €	6 354 €	0,00 €	0,00 €	-3 209 €	19 144 €
Converter	1 000 €	481,02 €	0,00 €	0,00 €	-98,43 €	1 383 €
System	33 400 €	6 835 €	0,00 €	0,00 €	-2 429 €	37 805 €

Figure 13 represents the Day-map of the battery storage bank state of charge (SOC). SOC drops to very low levels in the month of December due to the nightly irrigation.



4. CONCLUSION

Algeria is very rich in the solar resources and has a great potential of Photovoltaic energy generation. This research aims to contribute to the sustainable development of the agriculture sector and to promote the energy security of the country by diversification of energy sources. In this work, a standalone PV system has been sized and configured to meet the load of Algerian south-east farms. The data of electricity consumption of typical potato farm in El Oued has been provided. The optimal system configuration according to resource availability, load profile and national market specification has been determined using HOMER software. The designed PV system has total cost of 3 780 500 DA with cost of energy reaches 30 DA/kWh. Taking into account the simulation results and the actual price of renewable energy equipment, the system has very high cost and still unfeasible without the incentives of the competent authorities.

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