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Techno-economic study of a hybrid system (PV/WIND) to provide electricity for a household in Algeria

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Abstract: Algeria's geographic location has several advantages for the development and use of renewable energy, namely, solar energy and wind energy. In addition, Algeria has huge deposits of natural gas, 98% of electricity comes from gas. Therefore, currently, the production of electricity from renewable energies depends primarily on their competitiveness with economic gas.
The objective of this work is to study the technological feasibility and economic viability of the electrification project by a hybrid system (PV / wind) connected to the grid of a residential home located in Batna-Algeria. The HOMER model is used in this study to size the proposed system and determine the optimum configuration.

Keywords: Renewable energy; Techno-economic; Hybrid system; Household; HOMER; Batna.

1. Introduction

Algeria, located in the MENA region, has impressive solar resources [1-3]. Besides, the wind map shows some potential regions [4, 5]. Algeria is also a major producer and exporter of natural gas. The Algerian authorities have fixed the target to achieve a share of 10–12% of renewable energy sources in primary energy supply by 2020 [6]. To reach this target, the integrating of renewable energy in the building sector should be a major priority, as stated by [7, 8]. In Algeria the building stock is about 7 million and the residential sector is responsible for more than 41% of the total national energy consumption [9].

In order to ensure stable and continuous power generation by renewable energy, a hybrid system including more than one energy source is integrated. In many situations, a PV/Wind system is the more reliable hybrid combination, as outlined by several review papers [10-12]. As discussed in details in [13], there are tow schemes, autonomous [14-18] and grid connected systems [19-21]. The last option avoids the issues of storage systems. In Algeria, since it is produced by natural gas the grid electricity cannot be economically competed by renewable energy. Nevertheless, the integration of renewable energy can be at least partially.

This paper presents a techno-economic optimization of a PV/Wind grid connected system for supplying electricity to a residential house in the city of Batna, Algeria. The region of Batna has considerable resources in solar and wind energy, as assessed in [22]. The considered house has a maximum load demand of 84kWh/day and a peak of 9.5 kW. The computation is performed by HOMER [23].

The first step in the study is the evaluation of solar and wind potentials in the region of Batna. The assessment of the power electric load of the house, over a year, is an important step. Then, after introducing the inputs like component types, its sizes, number of units, and economic data, several scenarios can be proposed. HOMER can select those that are technologically feasible based purely on economics and availability of resources and those that meet the electricity needs of the house.

2. Site characteristics

Batna is located in the North East of Algeria at 1048 m above sea level. Figure 1 shows the location of Batna. The region of Batna is extends form 4° to 7° East longitude and from 35° to 36° North latitude. Batna has a semi-arid climate, summer is moderately hot and dry and winter is chilly and wetter, average temperature range of 35°C in summer and 4°C during winter. Wind speed varies between 2 and 4 m/s as shown in Figure 1 [1].

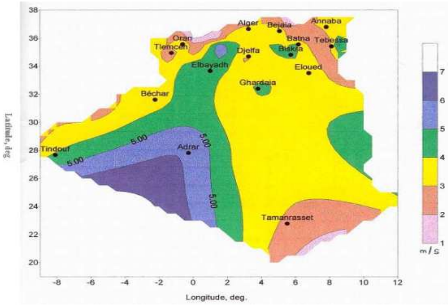


Figure 1: Wind map of Algeria

2.1. Solar energy potential

The solar radiation data was generated automatically with HOMER by inserting the coordinates (longitude and latitude) of the region. Monthly average of solar radiation and clearness index of Batna for a year obtained through HOMER are given in Figure 2.

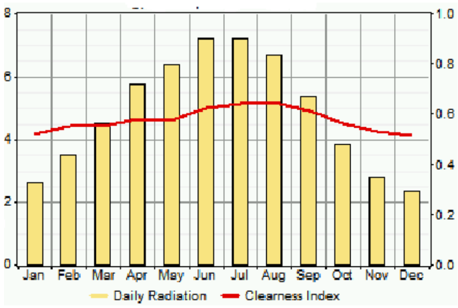


Figure 2: Monthly solar radiation and clearness index

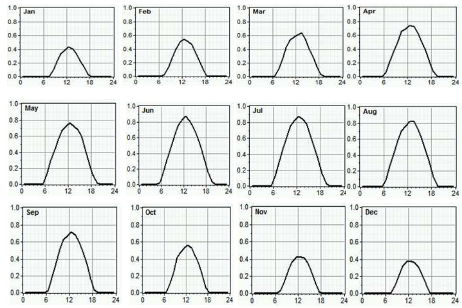


Figure 3: Daily profile of solar radiation

The solar radiation in Batna reaches its minimum of 2.3kWh/m^2/day in December and its maximum of 7.2kWh/m^2/day in June and July, and the annual average is 4.8kWh/m^2/day. At the same time, the figure 3 shows that solar radiation in summer is higher than winter season, and the maximum solar radiation occurs at 12:00h.

2.2. Wind energy potential

Wind data was collected every 3 h at 10m above ground level (AGL) in the meteorological station of Batna, located near Batna International Airport. The data presented in the paper are issued from one year (2008) measurements.

Long term seasonal wind speeds were found to be relatively higher during the period from March to May (spring season) and November month as shown in figure 4. April is the windiest month with 4.9 m/s wind speed while January and February are the least windy month of the year with a speed over 2.5 m/s. Batna annual average of wind speed was found to be 3.9 m/s for the studied period.

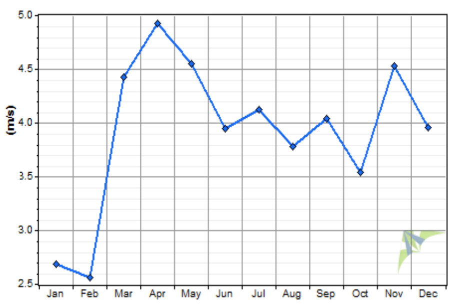


Figure 4: Monthly wind speed profile of Batna

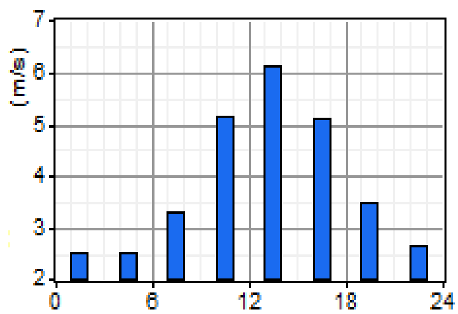


Figure 5: Hourly wind speed data of Batna

We notice that Batna site is windy in the afternoon than the morning, see Figure 5, higher wind speeds were observed between 09:00 and 17:00 and it decrease during the night.

3. Electrical load

An important step in the design of the hybrid system is the determination of electricity load. We chose an existing grid-connected 2-story single family house. It is equipped with all kind of devices to provide comfort to the occupants: lighting (lamps), fridge, TV, washing machine, air conditioner...

Figure 6 shows the monthly profile for the assumed electric load of the home. The load has an average value of 84kWh/day and a peak of 9.5 kW. The lower consumption is seen during September to December while relatively higher load requirements are found during the rest of the period of the year.

The load shows a bigger value in summer, because air conditioner which is a main electricity consumer is used more frequently in this season, and the smaller demand is in autumn.

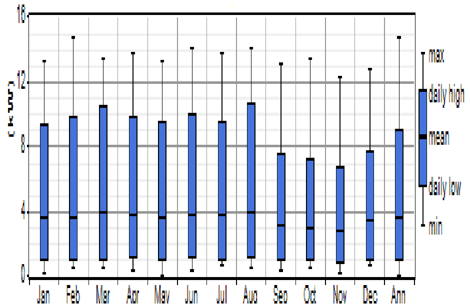


Figure 6: Monthly load profile

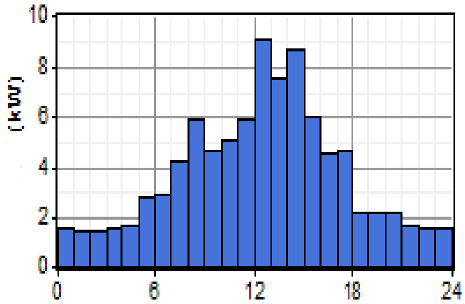


Figure 7: Daily load profile

Figure 7 shows that the consumption is important in the daytime. There are three peaks: in the morning at 9:00 h, at noon, and in the afternoon around 14:00 h.

4. Presentation of the case study

The proposed hybrid system is connected to the grid, and is consisted of an AC wind turbine, solar photovoltaic (PV) modules and a power converter. The cost of 1kWh of electricity from the grid is 0.06$ (4.1DA). Figure 8 shows the general configuration of the investigated hybrid system. The grid plays the role of a backup power component in the hybrid system when the renewable energy resource is not enough to meet the load.

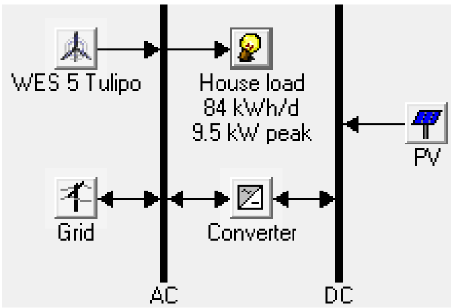


Figure 8: Scheme of the hybrid system

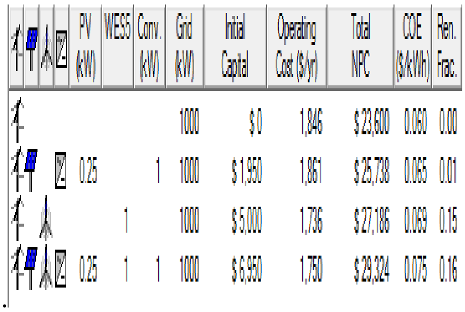
Equipment prices used in this study are shown in Table 1[18]. The project life time is taken as 25 years.

Tableau 1: Price of the equipment

Equipement	Initial cost *($/kW)*	Replacement *($/kW)*	Operating and maintenance *($/kW/year)*
PV	5000	2500	3
WES5	5000	4000	50
Converter	700	700	10

4. Results and discussion

HOMER presents a list of feasible systems classified by lifecycle cost as summarized in Figure 9; the first four options will be analyzed



	PV (kW)	WES5	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
				1000	$ 0	1,846	$ 23,600	0.060	0.00
	0.25		1	1000	$ 1,950	1,861	$ 25,738	0.065	0.01
		1		1000	$ 5,000	1,736	$ 27,186	0.069	0.15
	0.25	1	1	1000	$ 6,950	1,750	$ 29,324	0.075	0.16

Figure 9: Optimization results

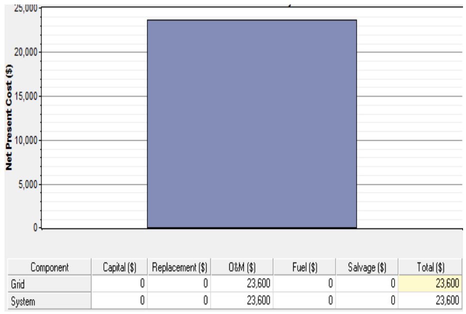


Figure 10: Cash flow summary

From Figure 9, it can be observed that the first and the cheapest scenario is when electricity supplied to the house comes totally from the grid, which sells 1kWh of electricity at 0.06$ (4.1 DA). Indeed, the initial capital is totally zero and the operating cost is 1,846$/year. The operating cost was calculated by multiplying total energy purchased (30,770 kWh/year) with the purchase price of 0.060$/kWh. From Figure 10, the total NPC of the grid only configuration came from the grid since the grid was the only supply to the load. The second most cost-effective scenario is when the solar energy supports the grid by supplying 1% of the house load. The wind energy has no place. With 99% from the grid and 1% from PVs, 1 kWh costs 0.065$. In the third scenario the wind turbine delivers yearly 15% of electricity to the house, the rest is supplied by the grid, without the participation of solar energy. The wind/grid connected house buys electricity at 0.069$/kWh. The hybrid PV/wind system comes as the fourth economically feasible system, by a price of 0.075$/kWh. In this scenario the fraction of renewable energy is supplying electricity to the house is 16%.

The PV/wind/grid connected design contains one 0.25kW PV array, one WES5 wind turbine and a 1kW power converter, with a total NPC of 29,324$ and a COE of 0.075$/kWh. The monthly energy yield of each component of the system is shown in Figure 11. As can be noticed, the share of wind turbine in supplying the electricity is more than that of PV in the whole year.

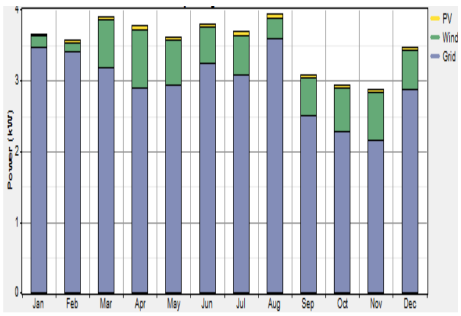


Figure 11: Monthly average electric production

The chart shows that the photovoltaic array produces 396kWh/year (1%) and the wind turbine module produces 4527kWh/year (15%).

5. Conclusion

The paper studied the techno-economic feasibility of integrating renewable energy in supplying electricity to a household in Batna, Algeria. It is about an existing house already connected to the grid. The chosen option was a PV/Wind grid connected system. The simulations were performed by HOMER. The selected wind turbine technology was the AC WES 5 Tulipo. In the region of Batna the specific wind speed is about 3.9 m/s, and the average solar irradiation is around 4.8kWh/m^2/day. The electricity delivered by the grid is the cheapest, 4.1 DA/kWh. The cost-effective scenario integrating renewable energy suggests that only 1% of the yearly house load can be supplied by solar energy. In this case the cost of electricity is 0.065$/kWh. Afterwards, at higher cost of electricity, 0.065$/kWh, the share of renewable energy can increase to 15%, guaranteed only by the wind turbine. By a price of 0.075$/kWh the hybrid PV/wind system can supply 16% of electricity to the house, 15% form the wind turbine and 1% form the PVs.

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