Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 75 (2015) 963 – 968

Energy Procedia

The 7th International Conference on Applied Energy – ICAE2015

Techno-economic impacts analysis of a hybrid grid connected energy system applied for a cattle farm

T.Nacer[a,*],A.Hamidat[b], O.Nadjemi[a]

[a]*Department of Electronics, LabSET, Saad Dahlab University Blida 1, B.P.270, Route de Soumaa, 09000 Blida, Algeria*
[b]*Centre de Développement des Energies Renouvelables, CDER, BP62 Route de l'Observatoire Bouzaréah, 16340 Algiers, Algeria*

Abstract

Increase in energy demand has made the renewable resources more attractive. Representing the largest sources of renewable energy, Solar and wind systems are expanding due to the rapid depletion of fossil fuel resources and the growing evidence of the global warming phenomena. This study aims to investigate the techno-economic impacts of a hybrid grid connected PV/wind energy system applied for a medium cattle farm in the north part of Algerian desert. The target location is a medium farm of 20 dairy cows in Ghardaia city, with the total annual electrical energy consumption of 6.716kWh, and a peak demand of about 7.7kW. The system is optimized using the National Renewable Energy Laboratory's (NREL) HOMER software according to the net present cost (NPC) value. Furthermore, three scenarios are proposed to assess the system configuration according to its impact on both technical and economic balance of the farm. It is found that under the specific climatic conditions of the studied location, the three optimized systems satisfy the typical farm load of 18kWh per day. The second scenario optimized system meets the requirement of paying back the total costs of system investment during the system's lifetime and the third scenario optimized system enhances the grid reliability by decreasing the power grid peak load by 70kW and feeding to the grid 119MWh annually.

Peer-review under responsibility of Applied Energy Innovation Institute

Keywords: Techno-economic assessment; impact analysis; hybrid PV/wind system; grid connected system; cattle farm.

1. Introduction

Algeria's electricity demand is growing rapidly on average 9.5% annually in the last five years as result of the economic growth and demographic development [1]. This electric consumption is expected to continue in the same level in the coming years. The peak load is observed in particular for summer period and it is caused by the afternoon use of air conditioning units due to the high temperature inducing power

* *E-mail address:* nasser_tar@yahoo.fr

Peer-review under responsibility of Applied Energy Innovation Institute
doi:10.1016/j.egypro.2015.07.292

shortage and a relatively low level of electric availability. Therefore, the electric generating capacity has to increase, as much as twice in the next decade [2].

As consequence of the Rapid depletion of fossil fuel resources and the growing evidence of the global warming phenomena, the Algerian government has adopted a new energetic and environmental policy which consists on encouraging the use of grid connected alternative energy systems by ensuring premium feed in tariff [3].The assessment of such systems for their techno-economic feasibility is of utmost importance.

2. Data collection and site description

The study area is Ghardaia city located in northern-central Algeria in the Sahara desert and lies along the left bank of the Wadi Mzab. It covers an area of 590 km^2 with an average altitude of 570m. Although the hot desert climate conditions, this region is considered as a dairy basin that provides milk and dairy products to more than 90 thousands inhabitants. The Ghardaia dairy herd overall has nearly 1500 cows, mostly of modern dairy breeds with about 13 head reported on an average farm.

2.1. Load modeling for the farm

The studied farm is a medium size farm of 20 dairy cows with the total annual energy consumption of 6,716kWh.

Based on measured electric consumption of farming equipments and farmer husbandry practices observation, the seasonal load profile (Fig.1) was developed. The peak energy demand is estimated to be around 7.7kW primarily due to the energy usage for water pumping during the summer. Energy consumption is generally higher in the summer than the winter because of the hot climate requiring more water and more locally prepared concentrated fodder.

The daily load profile of the farm can be divided into three regions. The time duration between 4AM and 7AM and between 4PM and 7PM represents high power consumption period due to the usage of milking machines and the cooling of the milk, moderated power consumption period starts at 7 o'clock in the afternoon and end at 4 o'clock in the morning due mainly to the lighting, the rest of the day represents low power consumption.

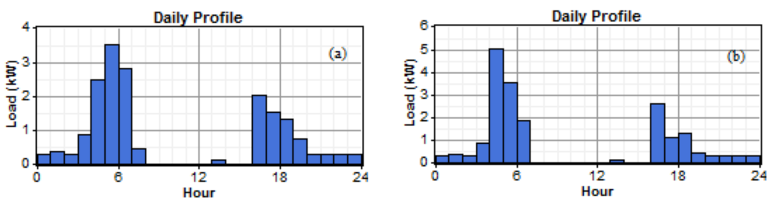

Fig. 1. Load profile of the cattle farm: (a) winter/autumn season, (b) summer/spring season.

2.2. Solar radiation

The solar radiation data for the studied location (32°30'N latitude and 3°38'E longitude) was obtained from the NASA Surface Meteorology and Solar Energy (SSE) database[4]. The daily global horizontal radiation and clearness index over the year are shown in Fig.2. The global horizontal solar radiation ranges from 3kWh/m2/day to 7.4kWh/m2/day, with a scaled annual average value of 5.4kWh/m2/day. It is obvious from Fig.2 that the most and least solar global irradiance is observed in June and December, respectively. In comparison to other locations around the globe, the solar resources of the studied area are above the average which makes it an ideal location for photovoltaic application.

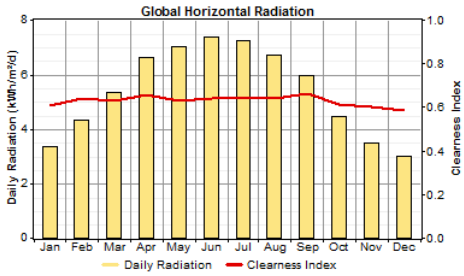

Fig. 2. Daily global horizontal radiation and clearness index

2.3. Wind data

Long term wind speed data (from 2006 to 2010) for Ghardaia location is recorded by the Algerian National Meteorological Office using an anemometer at a height of 10 m above ground level [5].The annual average wind speed measured is 3.4m/s. Monthly wind speed ranges from 2.8 m/s to 4.5 m/s, which occur during October and April, respectively. The average monthly profiles of daily wind speed data for the studied location is illustrated in Fig. 3.

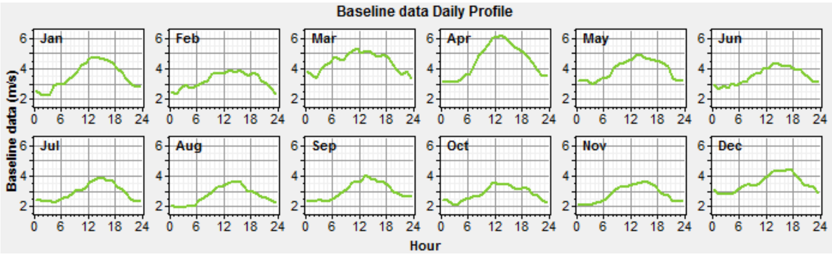

Fig. 3. Monthly profiles of daily wind speed.

3. Components of the hybrid system

In a hybrid grid connected PV/Wind energy system, there are four main components such as PV modules, wind turbines, grid, and converter. The hybrid system as modelled by HOMER is illustrated in Fig. 4. In this context, it is required to input the technical specifications for each system component. The detailed techno economic information for the system components is presented in Table.1.

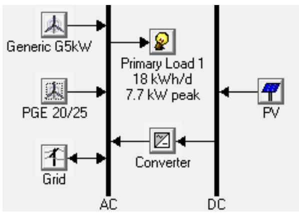

Fig. 4. Hybrid grid connected PV/wind energy system model.

3.1. PV module

The photovoltaic module ALPV230 from Algerian photovoltaic company (ALPV) was employed in this study. The rated power of the module is 230Wp with 13.9% efficiency. The initial capital cost was \$500 with an operating and maintenance (O&M) cost of \$20/year. The working life time was fixed to 25 years. This period is taken as the total project lifetime.

3.2. Wind turbine

Two models of wind turbines have been selected for the simulation. The PGE25 manufactured by PGE Energy of Canada and the generic G5 wind turbine. The power curves of the two wind turbines (Fig.5) show a low cut-in wind speed of 3.5m/s. Their rated capacity are 25kW AC and 5kW AC, respectively. The purchase cost of a unit is taken to be \$50,000 and \$12,000 while their replacement cost is to \$45,000 and \$10,000 and the operating and maintenance cost are \$2000 and \$1,000 per year for the PGE25 and G5 wind turbines respectively.

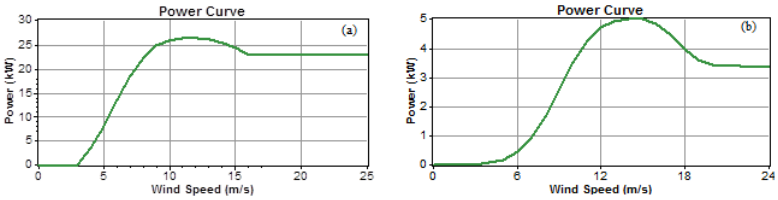

Fig. 5. Wind turbines power curve: (a) PGE25, (b) G5.

3.3. Converter

A power inverter is needed to maintain the flow of energy between the DC and AC buses. Several rated powers of the converter are considered according to the photovoltaic power generation. The efficiency of the inverter is assumed to be 90%. Its initial purchase cost is taken to be \$700 per kW while its replacement cost is assumed to be \$500.

3.4. Grid

Algerian power grid is managed by the National company Sonalgaz, Electricity tariffs are regulated by the Regulation Commission for Electricity and Gas, the most common tariff for agricultural farm is the rate E43 which consist of day rate tariff of \$4.4cents/kWh (6:00am to10:30pm) and night rate tariff of \$1cents/kWh (10:30 pm 6:00am). The electricity sellback price is assumed to be four times the purchasing tariff of conventional electricity.

4. Hybrid system optimization analysis

HOMER software is a commonly used simulation program to optimize and design hybrid system configurations. All grid connected systems can meet the load demand at any time making the technical feasibility assured for all hybrid grid connected configurations. The assessment criterion for the first scenario in the present study is based on renewable fraction RF and the electricity flow between the system and the grid. This criterion makes the load transparent to the grid. Moreover, the system will proceed as a backup to grid during peak demand periods due to the special shape of the farm load curve. The second scenario is based on the net present cost (NPC) and cost of energy (COE) providing a hybrid system with a zero cost of energy. The third scenario consists on the design of a hybrid system that generates a maximum amount of renewable power without caring about the investment cost. The system for this scenario is constrained by the available roof area taken as 250m^2 and the land area allows the installation of maximum two wind turbines.

5. Results and discussion

In the optimization process, HOMER performs an hourly time series simulations over one year for all technically feasible configurations. Then feasible systems are classified by their types and ranked according to their net present cost NPC. The most economic system is selected for each class and presented as HOMER optimal configuration. Fig.6 presents the results of the NPC optimization. As indicated in Fig.6, the optimal grid connected hybrid PV-Wind system configuration consists of 86 photovoltaic modules, 2 PGE25 wind turbine and 15kW inverter. This configuration suggested by HOMER cannot be technically optimal because of the undersized inverter implying a huge excess electricity of 1MWh/year.

To perform the proposed scenarios, HOMER results are reevaluated using calculation tools such as Excel or Matlab. The configurations representing energy losses due to the inverter size are deleted. Then, results are ranked according to net purchased electricity, cost of energy and total electricity production for the three scenarios respectively.

Table. 1. Techno-economic characteristics of the hybrid system components

Component	Model	Size (kW)	Initial cost ($)	Replacement cost ($)	Maintenance &Operating cost ($)	Lifetime (year)
PV module	ALPV230	0.23	500	350	20/year	25
Wind turbine	PGE20/25	25	50,000	45,000	2,000/year	20
	G5	5	12,000	10,000	1,000/year	20
Converter	Generic	-	700/kW	500/kW	0	15
Grid	Sonalgaz	80	0	0	0.044/kWh(day tariff)	-
					0.001/kWh(night tariff)	
					-0.176/kWh(sellback)	

5.1. Scenario I

The optimal hybrid system for this scenario is found to be 12 PV modules, 1 G5 wind turbine and 5kW inverter. This system sells back 110% of purchased electricity to the grid. The total net present value of the system is $28,595 with a cost of energy of $0.305/kWh. The share of electricity production is 42% from PV modules, 18% from wind turbine and 40% from the grid.

5.2. Scenario II

The optimal hybrid system for the second scenario is found to be 48 PV modules, 1 PGE25 wind turbine and 15kW inverter. This system initial cost is $84,500 with an annual income from selling electricity to the grid of $6,966. The cost of energy of the hybrid system is a negative value with the lower initial investment and the higher renewable energy fraction of 96%.

5.3. Scenario III

The hybrid system that produces the largest amount of energy consists of 90 PV modules, 2 PGE25 wind turbine and 20kW inverter. The total electricity production is 133,393kWh of which 98% are renewable electricity. The net electricity injected annually to the grid is about 120MWh with an average of 328 kWh daily. This energy is mostly injected at the afternoon period, reducing then the grid peak load and providing enough energy to feed a small village of 70 houses. The characteristics of the resulting three optimal grid connected hybrid PV-wind systems are illustrated in Table.2.

	PV (kW)	G5	PGE25	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	19.78		2	15	80	$ 153,500	-14,152	$ -45,951	-0.485	0.98
			2		80	$ 100,000	-10,041	$ -41,518	-0.439	0.96
	19.32			15	80	$ 52,500	-3,698	$ 378	0.004	0.88
					80	$ 0	177	$ 2,498	0.026	0.00

Fig. 6. HOMER optimization results for the cattle farm system.

Table. 2. Optimal grid connected hybrid PV-wind systems for the cattle farm system

Scenario	PV (modules)	WT	Inverter (kW)	Initial cost ($)	COE ($/kWh)	Electricity Production (kWh/y)	Net electricity (kWh/y)	RF (%)	CO2 (kg/y)	Payback time (y)
I	12	1xG5	5	21,500	0.305	13,650	-78	57	-49	-
II	48	1xPGE25	15	84,500	-0.144	69,778	-57,599	96	-36,403	10.80
III	90	2xPGE25	20	159,000	-0.470	133,393	-119,615	98	-75,597	10.00
HOMER	86	2xPGE25	15	153,500	-0.485	131,573	-117,154	98	-74,042	9.89

6. Conclusion

The current study analyses the techno-economic impacts of hybrid grid connected PV-wind system on the balance of a medium cattle farm located in Ghardaia city (Algeria). By means of HOMER simulation software, it has been shown that the hybrid grid/PV/wind (86 PV modules and 2 PGE25 wind turbine) is the economically optimal solution. Furthermore, three scenarios are proposed to determine the system technical boundaries. The zero net electricity, zero energy cost as well as the maximum net electricity production systems are identified. The added value of this study is to demonstrate the techno-economic and environmental impacts of using grid connected hybrid systems according to their levels of integration and give the opportunity for the investor to choose the optimal system for his farm.

References

[1] Fateh Bélaïd, Fares Abderrahmani. Electricity consumption and economic growth in Algeria: A multivariate causality analysis in the presence of structural change. *Energy Policy2013*;**55**:286–95.

[2] *Algerian energy and mines ministry*. www.mem-algeria.org.

[3] *Officiel gazette of Algerian republic 2004;* **19**: Decree n°92-04.

[4] NASA Surface meteorology and Solar Energy. http://eosweb.larc.nasa.gov/sse/.

[5] Farouk Chellali, Adballah Khellaf, Adel Belouchrani, Abdelmadjid Recioui. A contribution in the actualization of wind map of Algeria. *Renewable and Sustainable Energy Reviews* 2011; **15**: 993–1002.