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Economic and Environmental Modeling for Grid-Connected Hybrid Photovoltaic-Wind Power System in Hot Arid South Algeria

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Abstract

In this paper, a study is done on small-scale operations of 1.485 MW per day of hybrid renewable energy system (HRES) as a grid-assisted power generation including solar and wind energy. A comparison is made between a grid-connected with HRES and a standard grid operation focused on environmental and economic impacts. To simulate HRES, we have used climate data from Adrar region (27.59 ° N, 0.11 ° W) of south Algeria as an example of a typical hot arid climate. For this aspect, we have taken an average hour of global solar radiation, temperature and wind speed. In this study, the hybrid optimization model for electric renewable (HOMER) is employed. The optimum results are clearly shown 27.5% reduction in total emissions (CO_2, SO_2 and Nox). The renewable fraction (RF) of the optimized system is 27%. The simulation results also indicate that of a grid-connected HRES system is achieved considering reduction in the NPC and COE which are only equal to about 80% of energy consumption from standard grid.

Key-words: Environment, economy, hot arid, hybrid renewable energy system.

Résumé

Dans cet article, une étude est réalisée sur les opérations à petite échelle d'un système d'énergie renouvelable hybride (HRES) de 1.485 MW par jour en tant que production d'énergie assistée par réseau composée d'énergie solaire et éolienne. Une comparaison est faite entre une HRES connectée à un réseau et une opération de réseau standard axée sur les impacts environnementaux et économiques. Pour simuler HRES, nous utilisons les données climatiques de la région d'Adrar (27,59 ° N, 0,11 ° W) du sud de l'Algérie comme exemple de climat aride et chaud typique. Pour cela, nous prenons une heure moyenne de rayonnement solaire global, la température et la vitesse du vent. Dans cette étude, le modèle d'optimisation hybride pour les énergies renouvelables électriques (HOMER) est employé. les résultats optimaux montrent une réduction de 27,5% des émissions totales (CO_2, SO_2 et Nox). La fraction renouvelable (FR) du système optimisé est de 27%. Les résultats de la simulation indiquent qu'un système HRES connecté au réseau permet de réduire le NPC et que le COE ne représente que 80% de la consommation d'énergie du réseau standard.

Mots-clés : environnement, économie, aride chaud, système d'énergie renouvelable hybride.

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1. Introduction

Rising global warming concerns and depleted fossil fuel reserves have forced the world to seek energy from renewable resources [1, 2]. Renewable energy resources, such as solar and wind, are vast, and unlike fossil fuels, they are very well distributed all over the world [3]. Renewable resources such as solar and wind have the potential to become important sources of energy production in the future because of their environmental, social and economic benefits, in addition to public support and government incentives [4].

A hybrid renewable energy system optimally utilizing different renewable resources is used to ensure stable and reliable electricity generation. There are many literatures on renewable energies used and should improve the corresponding technical levels in hot arid region [3-5]. In order to ensure a stable and continuous supply, a hybrid energy system incorporating more than one type of energy component is introduced. The aim of this study is to discuss the environmental and economic factors for the evaluation of HERS. Also, this article has analyzed the environmental and economic benefits of HRES used in the arid environment. Adrar takes the example of the southern regions of Algeria.

2. System configuration

An HRES system typically includes more than one primary renewable energy component operating in parallel with a secondary non-renewable component as a back-up system. Our study focuses a photovoltaic-wind-grid hybrid power system. A general configuration of the HS system is shown in Figure 1. HOMER, the Micropower Optimization Model, is a versatile system design tool that facilitates power system design for a grid-connected application; the proposed scheme is shown in Figure A as implemented in the HOMER code.

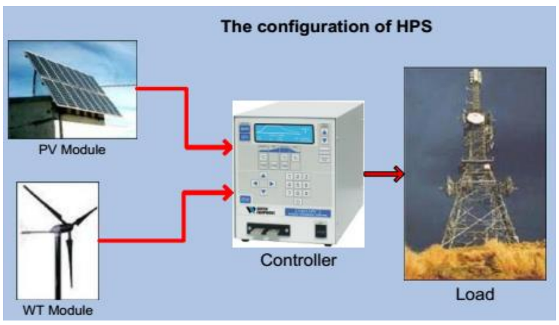


Figure 1. Configuration of a photovoltaic-wind-grid HRES

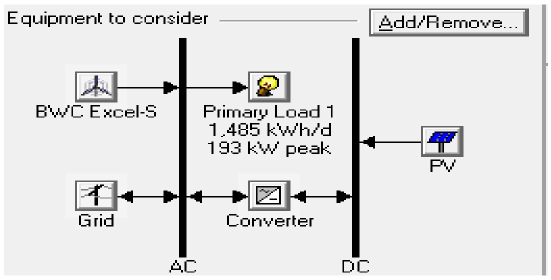


Figure 2. Scheme of the hybrid system in HOMER code

3. Hybrid renewable energy systems

3.1 *Electrical load*

The average daily load profile of the studied area is shown in Fig. 3. This profile is considered to be the same for all the days of the year and corresponds to the load profile usually encountered in the secluded regions in south Algeria. The daily energy consumption of load is 1485 kWh/d and a peak of 193 MW.

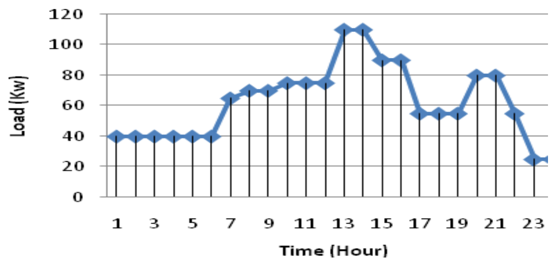


Figure 3. . Daily load profile of the site

3.2 Solar energy resources:

Average monthly solar radiation were obtained (MJ/m2 per day) of the Adrar weather station (27.59°N, 0.11°W) for the year 2005 were obtained (MJ/m2 per day) of the Adrar weather station (27.59°N, 0.11°W) for the year 2005. Figure 4 shows the monthly variation in solar radiation with the clearness index. These data serve as input to the HOMER for the analysis. Solar radiation is seen to be well distributed in the site with average monthly solar radiation of 5.8 kWh/m2 /day.

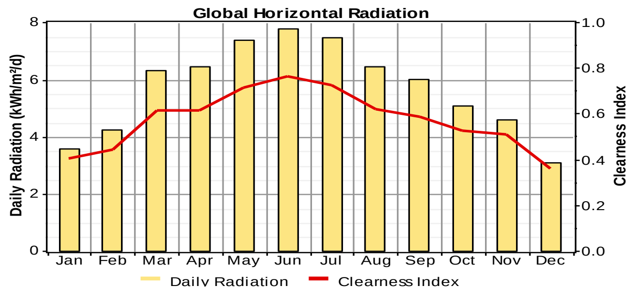


Figure 4. Average daily global solar radiation data of Adrar

3.3 Wind energy resources:

Wind speed data can only be obtained from U.R.E.R. of Adrar, Algeria. The average monthly wind speed, as shown in the fig 5 is between 5.72 and 8.5 m / s. Wind resources also show more wealth in the summer than in winter. As with solar resources.

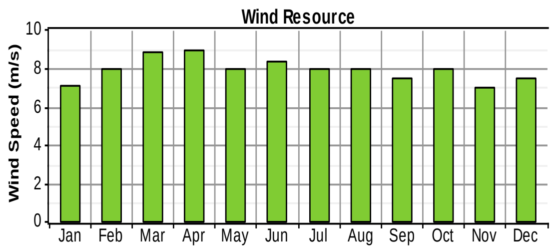


Figure 5. Average monthly wind speed data of Adrar

3.4 Photovoltaic arrays

Considering the market of renewable sources in Iran, installation and replacement costs for a 1 kW solar energy system are taken as $5000 and $4000 [6]. In this case five different sizes of PV array (0, 20, 30, 40 and 80kW) .

4.4 Grid

The grid plays a role of backup power component in the HPS. The electricity from the grid is consumed when the renewable energy resource is not enough to meet the load [7]. In addition to that grid power system does not need a battery because the grid has the functions of storage system.

4.5 Power converter

A power electronic converter is needed to maintain the flow of energy between the AC and DC buses. For a 1 kW system the installation and replacement costs were taken as $800 and $750, respectively [6]. Lifetime of a unit was assumed to be 15 years with an efficiency of 90%.

4.6 Wind turbine

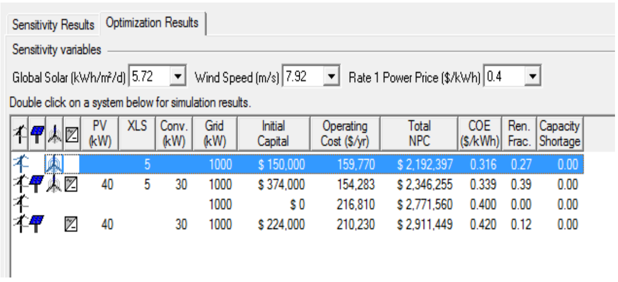
In this study, the wind turbine model is assumed to be BWC Excel-S 10 kW AC to simplify the analysis. The initial installation costs of wind turbines, replacement costs, and annual operational maintenance (O&M) costs of a turbine were assumed to be $30,000, $26,000 and $150/year, respectively [8]. The lifetime of a turbine and the height of a hub were assumed to be 30 years and 100 m, respectively.

4. Results and Analysis

The results of optimal systems and sensitivity analysis are provided in this study. Considering the price of electricity set at *$ 0.4 / kWh*, the photovoltaic system can be modified to identify an optimal system type for Adrar area.

4.1 Optimization results and analysis

Given the specific wind speed (7.92m/s), the solar irradiation (5.72 kWh/m2/day) and the grid electricity price (0.4 $/ kWh), the results of system optimization are summarized in Fig. 6


Sensitivity Results | Optimization Results

Sensitivity variables

Global Solar (kWh/m²/d) 5.72 Wind Speed (m/s) 7.92 Rate 1 Power Price ($/kWh) 0.4

Double click on a system below for simulation results.

PV (kW)	XLS	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage
	5		1000	$ 150,000	159,770	$ 2,192,397	0.316	0.27	0.00
40	5	30	1000	$ 374,000	154,283	$ 2,346,255	0.339	0.39	0.00
			1000	$ 0	216,810	$ 2,771,560	0.400	0.00	0.00
40		30	1000	$ 224,000	210,230	$ 2,911,449	0.420	0.12	0.00

Figure 6. The optimization results of the HOMER simulation.

In this case, a wind energy system appears to be the most economically feasible with a minimum total net cost (NPC) of $ 2,179,165 and a minimum cost of energy (COE) of 0.315 $/kWh. This is due to the abundance of wind energy in the Adrar. We recall that the COE of the wind turbine generator is more economical than solar panel array modules.

The figure 6 indicates that the economic performance of the optimized photovoltaic-wind-grid system is quite similar to the wind-gird system. This figure shows that the NPC is $ 2,346,255 and $ 0.39 / kWh when the renewable fraction was 39%. The reduced NPC and COE are just 85.3%.

Table 1. Compare the cost between standard grid and photovoltaic-wind-grid system

Types of Polluant (kg/year)	Standard grid	PV-wind-grid system
CO2	342,560	248,344
NOX	1,485	1,077
SO2	726	527

Table 2. Compare the emissions between standard grid photovoltaic-wind-grid system

Types of Costs	Standard grid	PV-wind-grid system
NPC ($/year)	2, 771,561	2,192,398
COE ($/kWh)	0.4	0.31

In Table 1, the comparison is done with the optimized photovoltaic-wind-grid system and Standard grid system. The NPC and the COE of the standard gird system are $2, 771,561 and $ 0.40/ kW respectively that the system by what we can say that photovoltaic-wind-grid system is more economical. Table 2 illustrated the emission of the standard grid system and the PV-wind-grid system (optimized system). As the main greenhouse gas, the carbon dioxide emission from the standard grid is 342,560 kg /year. We are found that CO2 emissions from the standard grid are 342,560 kg per year, while the optimal system only depletes 248,344 kg which means 27.5% reduction. On the other hand, the emissions of sulfur dioxide and nitrogen oxides from the PV-wind-grid system are less than 72.5 % of the standard grid system.

Figure 7 shows the monthly energy yield for each component of PV-wind-grid system. The PV array produces 66.142kWh/year (12% of total energy production) for the implementation under the specific load of electricity (1.485 MW/day). Also Wind turbines produce about 27% (149,076kWh/year) of the system total energy production (558,342kWh/year). The grid purchases share of 78% (343,124 kWh / year) of the total energy production in this system.

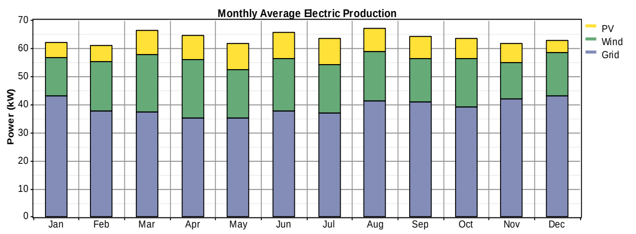


Figure 7. . Monthly average electric production of the PV- wind system

4.2 Sensitivity results:

In this work, a sensitivity analysis is carried out to study the effects of the variation of the solar irradiation and the speed of the wind. The implementation of the hybrid system is simulated in the long run by HOMER and based on its size search for predefined sensitivity values of components. Sensitivity analysis helps in exploring the effect of the changes in the available resource and economic condition. This analysis shows the range of the variables for which it makes sense to include the renewable energy in the system design. Three sensitivity parameters were considered in this study, namely: solar radiation, wind speed, and grid electricity price. The feasible systems are ranked based on increasing NPC, whereas the software eliminates all infeasible combinations. While solar power represents less than 1% of total energy production, wind power accounts for more than a quarter (27.5%). Therefore the wind energy resource has more impact on implementation. Fig. 8-11 reflects the cost, the renewable fraction and the variation of the emissions according to the variable sensitivity of the wind speed .Figure 8 shows that the NPC and the COE of the hybrid power system decrease when the wind speed changes from 6.9m s / to 8.8 m s .in Fig 9, the renewable fraction increased sharply when the wind speed is increased from 6.9 to 8.8 m/s.

We can also note the main emissions of carbon dioxide, sulfur dioxide and nitrous oxide decrease by 27.5 % as shown in Figures 10 and 11.

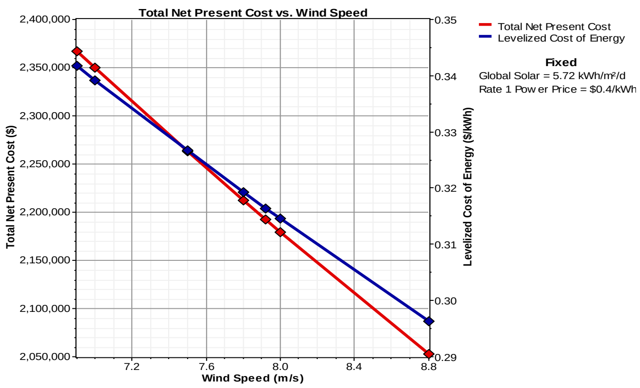


Figure 8. The relationship between cost and wind speed

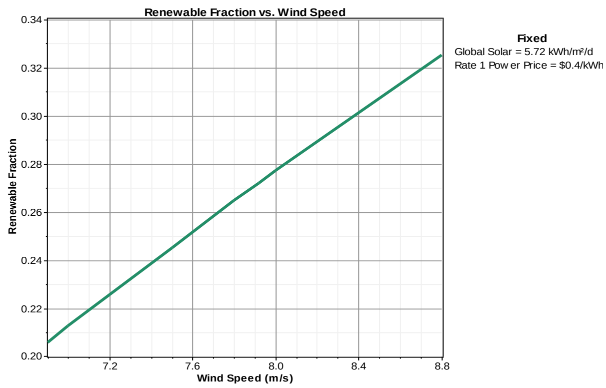


Figure 9. The relationship between RF and wind speed

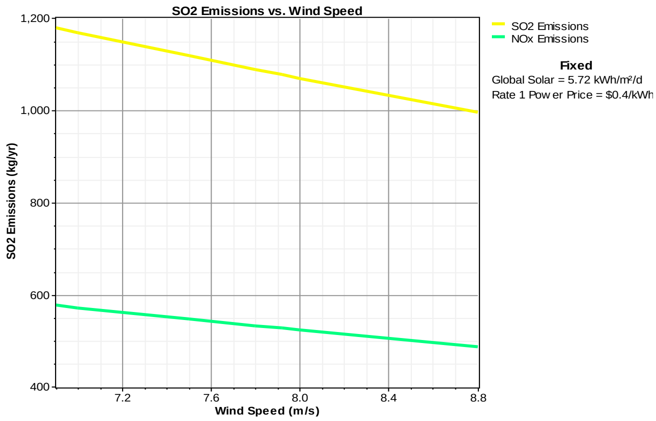


Figure 10. The relationship between SO2 (Nox) and wind speed

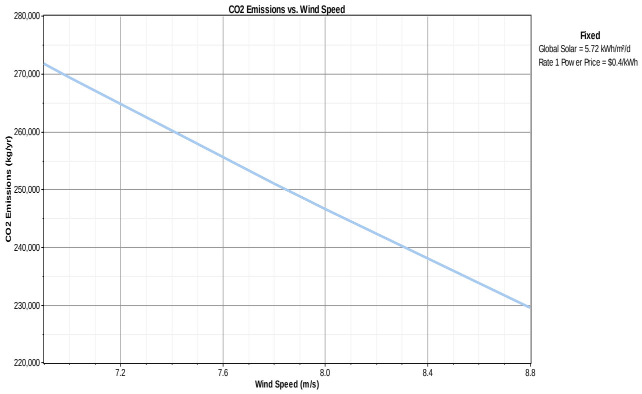


Figure 11. The relationship between CO_2 emissions and wind speed

5. Conclusion

In this study simulates a hybrid photovoltaic system in the arid environment using HOMER, (hybrid system optimization tools) is presented. We based on collecting solar and wind energy resources from the Adrar weather station, a typical hot arid climate. The simulation results from HOMER software illustrated that the PV-wind HRES configuration is the most economically and environmentally feasible. In the weather conditions of the Adrar region, the sensitivity analysis indicates that photovoltaic-wind-grid system is achievable site load. The latter confirmed that increasing wind speed contributes significantly to reducing NPC and COE emissions, and that the renewable fraction of the system also increases.

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