Chapter 45
Optimal Design and Comparison Between Renewable Energy System, with Battery Storage and Hydrogen Storage: Case of Djelfa, Algeria

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Abstract Algeria's energy mix is almost exclusively based on fossil fuels (Meriem in Renewable Energy in Algeria Reality and Perspective, pp. 1–19, 2018) [1], especially natural gas. However, the country has enormous renewable energy potential, mainly solar, which the government is trying to harness by launching an ambitious renewable energy and energy efficiency programs (Ministry of Energy and Mining of Algeria in Renewable Energy and Energy Efficiency Program, 2011) [2]. Despite being a hydrocarbon-rich nation, Algeria is making efforts to harness its renewable energy potential. The renewable energies could represent an economic solution for the case of isolated sites, but their intermittency needs a storage system, that could be either by the use of batteries or hydrogen technologies. However, these two storage systems still face challenges, especially economic ones. This study deals with an economic study of several configurations of renewable energy systems, it aims to compare between the conventional storage systems and the new technologies of the hydrogen. In this study, HOMER will be used to simulate three configurations for a school on the high land region of Algeria named Had-Saharry. Many configurations will be simulated using HOMER in order to have an over view about the techno-economic feasibility and the use of hydrogen for the storage. The system has been designed according to the school's load profile. Then compare between the costs of the systems and their performance on the Algerian high lands weather conditions. As result the systems with batteries proved to be less expensive than the hydrogen storage, as well as, the hybrid system (PV, WECS) proved to be cost effective.

Keywords Renewable · Hybrid · Storage · Batteries · Hydrogen · HOMER

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45.1 Introduction

Algeria is the biggest African country and among the biggest exporter of gas and it possesses the world's fifth largest natural gas reserves. Despite of being a hydrocarbon reach country Algeria has an huge renewable energy (RE) potential mainly solar and wind. In order to diversify the sources of energy used and reduce the carbon emission, Algeria has started in 2011 an ambitious renewable energy program that aims to generate 22,000 Mw from RE s by 2030 [2].

Renewable energies represents a green alternatives and cost effective system for remote and isolated areas [3], but it still face the intermittency issue that pose the storage problems. It exist to ways to store energy, either by the use of the batteries, which are not environmentally friendly, and the hydrogen storage system, which still a new technology.

45.2 Materials and Methods

HOMER (Hybrid Optimization Model for Electric Renewable) software was used in this study to model and optimize the systems because it is a techno-economic tool. HOMER software is developed by NREL (National Renewable Energy Laboratory), it determines optimal size of its components through carrying out the techno-economic analysis. It simulations possible combination of components entered and ranks the systems according to user-specified criteria such as cost of energy (COE). The software requires six types of input data for simulation and optimization including meteorological data, load profile, equipment characteristics, and search space, economic and technical data [4]. In this study, we consider three proposed configurations:

The first one is a photovoltaic (PV) system with a battery storage then with hydrogen storage system Fig. 45.1 represents the systems.

The second configuration represents a WECS (Wind Electricity Conversion System) with a batteries then hydrogen storage system Fig. 45.2 represents the systems.

The third configuration represents a hybrid (PV, WECS) system with batteries then with a hydrogen storage system, Fig. 45.3 represents the systems.

The components used on configurations are:

- **Module**: the PV modules used on this system are a polycrystalline panels with a maximum of 275 W and an efficiency of 17%.
- **Wind turbines**: a wind turbine from AWS HC 3.3 kW and a rated power of 3.3 kW, 4.65 rotor diameter and 12 m hub height.
- **Battery**: Battery bank stores the electrical energy produced by the PV, and makes the energy available at night or on dark days (days of autonomy or no-sun-days). The batteries used on this system are BAE SECURA SOLAR 9 PVV (2 V, 2.92 kWh).

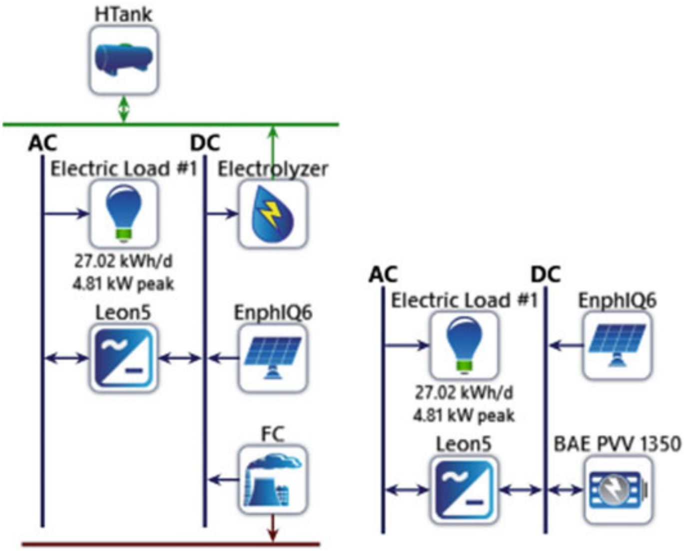

Fig. 45.1 Configuration 01 (PV system)

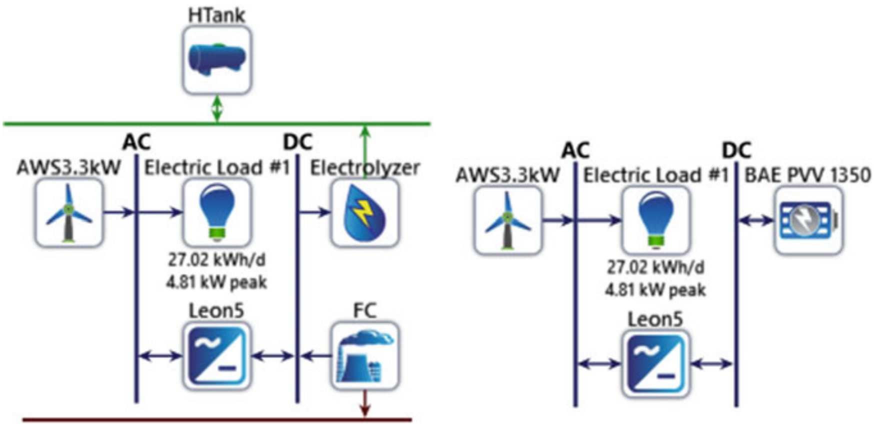

Fig. 45.2 Configuration 02 (WACS system)

- **Converter**: The inverter model used in this project is Leonics S-219Cp 5 kW it was chosen based on the power unit (5 kW).
- **Fuel cell and electrolyzer**: the choice of these components were generic, connected to the DC bus with an search space 1, 3, 5, 10, 20 kW.
- **Tank**: The tank chosen search spaces were 1, 3, 5, 10, 20 kW.

The overall summary of economic parameters of the different components according to [5–7] are presented in Table 45.1.

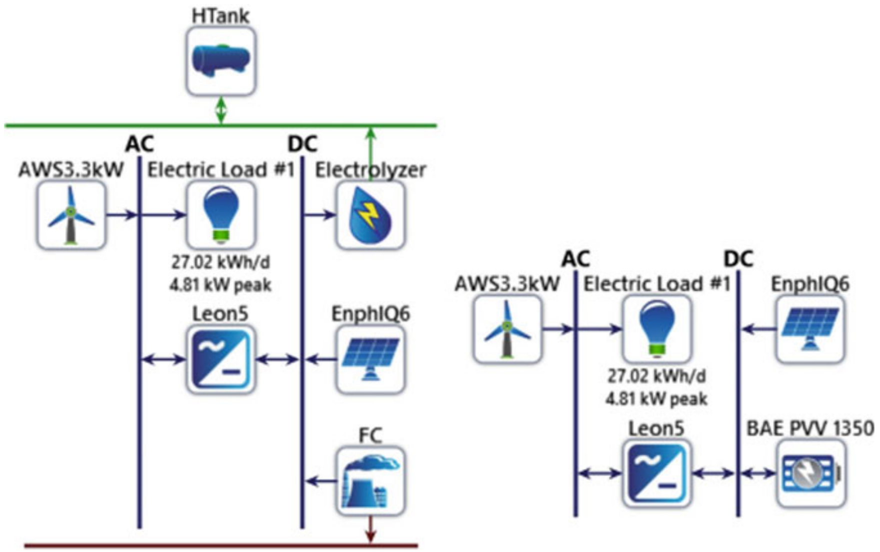

Fig. 45.3 Configuration 03 (hybrid system)

Table 45.1 Investment, replacement and O&M costs by components

Investment ($/kw)		Replacement ($/kW)	O&M ($/kW)
PV	2500	2000	25
WECS	1000	800	100
FC	3000	2500	0.15/op.hr
Tank	1500	1200	30
Electrolyser	2000	1600	20

45.2.1 Solar Energy Potential

The geographical coordinates of the data collection site were 35°21.3’ N latitude 3°21.8’ E longitude and 1140 m altitude above mean sea level. From these geographic data HOMER, generate automatically the solar radiation and the wind speed on the location

The monthly average of solar radiation and clearness index of the province for 22 years obtained through HOMER. The solar radiation data for the selected remote area was estimated to range between 2.17 and 7.42 kW h/m2/day with an average annual solar radiation estimated to 4.76 kW h/m2/day. Notice that more solar irradiance can be expected from the month of May to August while less solar irradiance is to be expected from November to January.

The wind speed is around 4.6 m/s; it is almost constant during the year. The highest value is 5 m/s in the period of December–April.

Fig. 45.4 Monthly load profile

45.2.2 *Electrical Load*

An important step in the design of the system is the determination of electricity load. Figure 45.4 Shows the monthly profile for the assumed electric load. The load has an average value of 27.02 kWh/day and a peak of 4.81 kW.

45.3 Results

The PV system with the batteries gives a total electricity production of 35,804 kwh/year, while the PV system with hydrogen storage gives 53.503 kWh/yr 92.4% from PV and 7.61% from FC Table 45.2 represents the COE, investment cost O&M/year and the NPV. Figure 45.5 represents the share costs of components in each system

The WACS system with the batteries gives a the total electricity production of 31,745 kwh/yr, while the WACS system with hydrogen storage gives 29,214 kWh/yr a 88.9% from WACS and 11.1% from FC Table 45.3 represents the COE, investment

Table 45.2 Costs of the configuration 01

Conf	COE ($/kWh)	Investment ($)	O&M ($/yr)	NPV ($)
(PV, batteries)	0.477	62,597	2034	110,391
(PV, FC)	1.26	113,112	7567	290,916

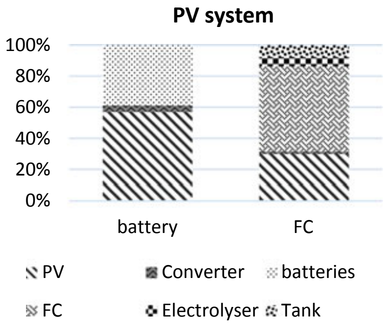

Fig. 45.5 The cost of each component on the two systems

Table 45.3 Costs of the configuration 02

Conf	COE ($/kWh)	Investment ($)	O&M ($/yr)	NPV ($)
(WECS, batteries)	0.602	50,596	3783	139,489
(WECS, FC)	1.04	57,333	7815	240,964

cost O&M/year and the NPV. Figure 45.6 represents the costs share of components in each system

The hybrid system (PV, WECS) with the batteries gives a the total electricity production of 21,336 kwh/year 40.6% from wind and 59.4% from PV, while the hybrid system with hydrogen storage gives 24,278 kWh/yr. A 30.6% from PV, 10% from FC and 95.4% from WACS. Table 45.4 represents the COE, investment cost O&M/year and the NPV. Figure 45.7 represents the share costs of components in each system.

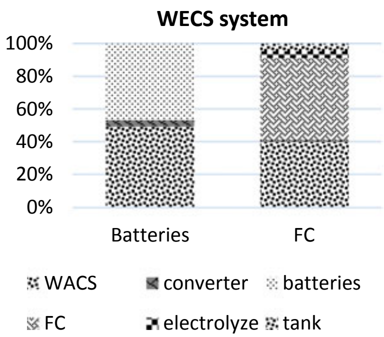

Fig. 45.6 The cost of each component on the two systems

Table 45.4 Costs of the configuration 03

Conf	COE ($/kWh)	Investment ($)	O&M ($/yr)	NPV($)
(PV, WECS, batteries)	0.397	36,295	2374	92,066
(PV, WECS, FC)	0.994	52,863	7556	230,389

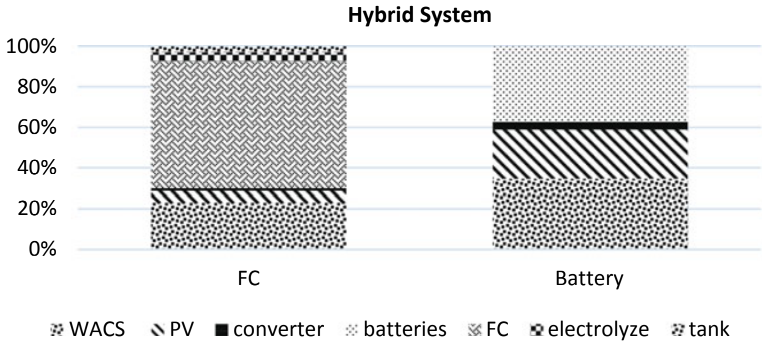

Fig. 45.7 The cost of each component on the two system

45.4 Conclusions

From the economical analysis, it is easy to notice that, the hybrid renewable system with a battery storage is the most economic way to generate electricity among the other systems. The use of hydrogen is expensive especially with the PV system even though it is more environmentally friendly than the batteries, which represent a big challenge in the recycling and waste management.

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