Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Modeling of System Elements

A. Djeradi, A. Medjelled, M. Teggare, R. Djekidel

Laboratory of semiconductor, University Amar Telidji of laghouat, Algeria

Due to the vast area of Aurar, the Aurar region in southern Algeria offers excellent wind and photovoltaic potentials. Based on this data, we combined diesel generators into a single hybrid system consisting of (PV panels, wind turbines and diesel generators) with storage batteries. We have operated and designed it in a house in the Aurar region (Algeria) using the HOMER® program and the results have been very impressive from an economic and environmental point of view, thus we have reached the desired goal of clean and economical production.
Keywords: Photovoltaic-wind-diesel-homer panels.

1. Introduction

Modeling is a method designed to represent a technological process in mathematical form. Its purpose is to theoretically study the behavior of certain parameters and optimize them while respecting a given constraint. In this regard, the modeling of the multi-source energy system PV-E-D is necessary to establish a direct relationship between the energy produced by the system and the user's demand. At the same time, the estimation of the system's adaptability properties for each period of the year is obtained through theoretical and experimental studies.

In this context, we will first present, in this chapter, the modeling of the hybrid PV-E-D system. This involves proposing the development of mathematical models for production systems to enhance the management of their operation, particularly in terms of the flow of production power based on given or estimated meteorological conditions.

2. Modeling of the Photovoltaic Production Chain

The purpose of this section is to describe the mathematical models of the various components of the photovoltaic production chain. This system is based on modular blocks, as illustrated in Figure 2-1.

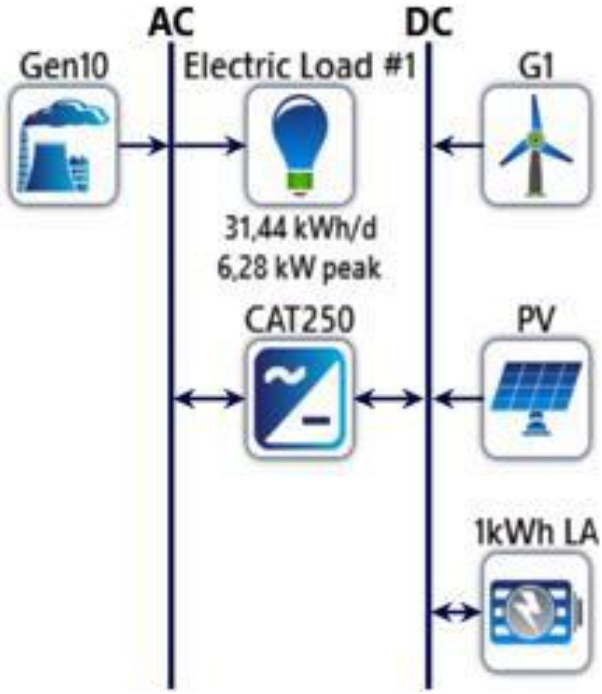

Figure 1: Photovoltaic Production Chain

Photovoltaic Field , DC/DC Converter , Inverter

2.1 PRESENTATION

The world is facing challenges in providing reliable and cost-effective services, which remains one of the main issues of this century with the advent of hybrid power systems. These systems have gained significant interest due to their success in overcoming the shortcomings and intermittent nature of renewable energy sources. In the generation and use of electrical energy, they have proven to be remarkably successful, especially in areas isolated from the main grid.

It is essential to trace the operation of this system and establish a means to control and model its elements, which is the focus of our study. We have chosen the region of (ADRAR) as the study area for this system. This region includes isolated areas such as farms and is rich in solar energy, wind speed, and temperature. The design of an optimal size matching is crucial for solar-wind energy production systems combined with battery banks. This is necessary to ensure the efficient and economical use of energy resources (wind and solar).

2.2 System Modeling

Previously, we recognized the importance of combining the following technologies: solar (PV), wind turbines, batteries, and a backup diesel generator (DG). In a single integrated hybrid system, the performance of the system components is modeled using either a deterministic or probabilistic

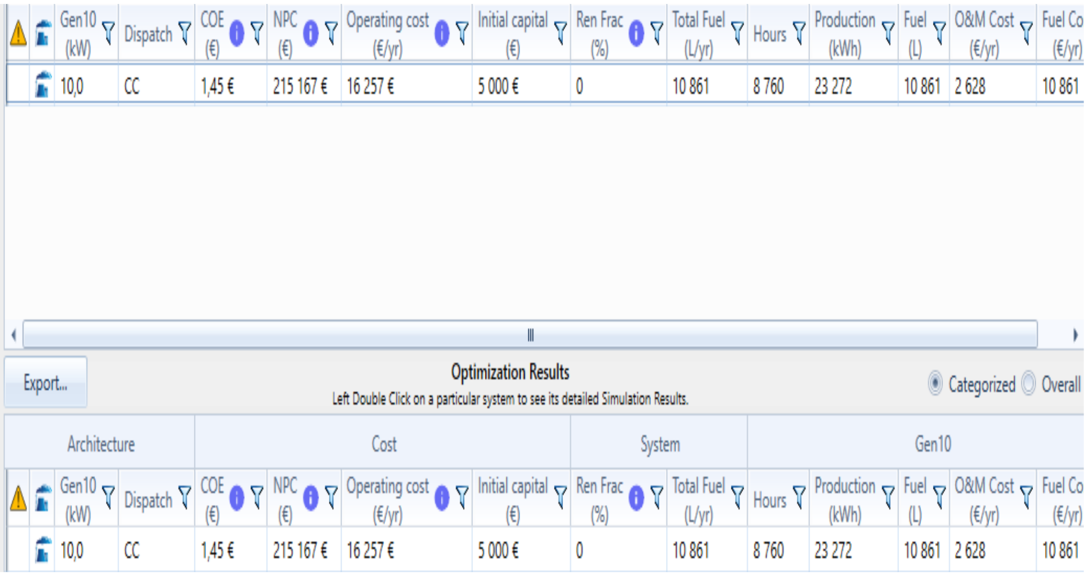

Figure 3: Table of All Calculation Results for the Autonomous System

Wind Speed Mapping in Algeria

The wind speed map below, established by the CDER, indicates the average wind speed at a height of 10 meters above ground level across the national territory, with a particular focus on the southern regions (Adrar).

2.3 Generating the Load Profile

The household requires electricity to operate various appliances, such as a television, washing machine, mobile phone charger, etc. Table 1 indicates that the total energy demand for this house is approximately 32,000 watt-hours per day.

The generation system considers the requirements for load, characteristics, efficiency, and reliability of power transmission. The load factor of the project plays a crucial role in the design process. The team is strategically distributed. Figure 6 illustrates the average daily load rate of the system over 24 hours, comprising PV/E/DG and a battery storage system within a hybrid system. The simulation was conducted using actual meteorological data (solar radiation and wind speed) from the Adrar region.

Table 1: Details of the Daily Consumption Profile

Quantity	Value	Units	Quantity
Electrical Production	859	kWh/yr.	
ean Electrical Output	2,59	kW	
Minimum Electrical Output	2,50	kW	
Maximum Electrical Output	5,79	kW	
Electrical Production	859	kWh/yr.	
Mean Electrical Output	2,59	kW	
Quantity	Value	Units	

Fuel Consumption	404	L
Mean Electrical Efficiency	21,6	%

Table 2: Generic Statistics of the Fixed-Capacity 10 kW Generator

Quantity	Value	Units
Hours of Operation	331	€ hrs./yr.
Number of Starts	283	starts/yr.
Operational Life	45,3	Yr.
Capacity Factor	0,980	%
Fixed Generation Cost	1,11	/hr.
Marginal Generation Cost	0,286	€/kWh
Operational Life	45,3	Yr.
Capacity Factor	0,980	%
Fixed Generation Cost	1,11	/hr.
Marginal Generation Cost	0,286	€/kWh

2.4 Materials and Modeling Methods

The system was simulated using the HOMER software. The simulation was based on the load and demand results obtained from one of the households listed in Table 1 for an off-grid period of 24 hours. The hybrid system components were selected based on the quality and cost parameters considered in this study (PV panels, wind turbines, diesel turbines, and a generator with storage batteries).

2.5 Definition of the Software Used

The HOMER software is used to simulate renewable and hybrid energy systems, providing cost-effective solutions for fuel consumption, energy requirements, environmental considerations, as well as optimal sizing and design for specific loads. Students can utilize this software to gain valuable insights into renewable energy systems and learn more about current practices in the renewable energy industry.

The HOMER software package employed here can simulate, analyze, and model renewable or hybrid energy systems, which may include cogeneration systems, solar/PV generation, batteries, wind turbines, small turbines, hydroelectric systems, and fuel cells, among other inputs.

2.6.1 HOMER Pro Interfaces

HOMER is easy to use and features a top menu as well as icons that can be utilized without navigating through the menus. The HOMER interface includes three important elements, as shown in Figure 2.11. Additionally, it contains a map to define the area, select, and load resources for the studied zone. 45

2.6.2 Photovoltaic Generator Model

The DC output of the photovoltaic generator can be modeled. It provides the hourly output power of the photovoltaic generator with a surface area of AP (m²) under full sunlight on a tilted plane unit Gt (W/m²), through:

Equation [2]:

$$\mathbf{Ppv = \eta pv.Apv \cdot Gt} \qquad \mathbf{(1)}$$

Where:

η_(PV) is the efficiency of the PV module under Standard Test Conditions (STC).

The solar cell's conversion efficiency is influenced by the cell temperature, which depends on the incident solar radiation and the ambient temperature. This efficiency is expressed through the following equation:

$$\mathbf{\eta pv = \eta r \cdot \eta pc \cdot (1 - \beta(Tc - Tcref\ ))} \qquad \mathbf{(2)}$$

- rd: is the efficiency of the reference unit.
- pc: is the power conditioning efficiency, equal to 1 if a perfect Maximum Power Point Tracker (MPPT) is used.
- β: is the temperature efficiency parameter of the generator, which must be constant. For silicon cells, the range is between 0.004–0.006 per °C.
- T_cref: is the reference temperature of the cell (°C).
- Tc: is the cell temperature (°C), calculated as follows:

$$\mathbf{Tc = Ta + (NOCT - 20\ 800\ )G\beta} \qquad \mathbf{(3)}$$

NOCT: is the Nominal Operating Cell Temperature (°C). Under standard conditions, Ta, NOCT = 20°C and G_β, NOCT = 800 W/m², for a wind speed of 1 m/s.

The DC output of the photovoltaic generator can be modeled. It provides the hourly output power of the photovoltaic generator with a surface area of AP (m²) under full sunlight on a tilted plane unit Gt (W/m²) through:

Equation [2]:

$$\mathbf{Ppv = \eta pv.Apv \cdot Gt} \qquad \mathbf{(1)}$$

Where:

η_(PV): is the efficiency of the PV module under Standard Test Conditions (STC).

The solar cell's conversion efficiency is influenced by the cell temperature, which depends on the incident solar radiation and the ambient temperature. This efficiency is expressed by the following Equation:

$$\eta pv = \eta r \cdot \eta pc \cdot (1 - \beta(Tc - Tcref)) \qquad (2)$$

- rd: is the efficiency of the reference unit.
- pc: is the power conditioning efficiency, equal to 1 if a perfect Maximum Power Point Tracker (MPPT) is used.
- β: is the temperature efficiency parameter of the generator, which must remain constant. For silicon cells, the range is between 0.004–0.006 per °C.
- T_cref: is the reference temperature of the cell (°C).
- Tc: is the cell temperature (°C), calculated as follows:

Equation:

$$Tc = Ta + (NOCT - 20\ 800\ )G\beta \qquad (3)$$

NOCT: is the Nominal Operating Cell Temperature (°C). Under standard conditions, Ta, NOCT = 20°C and G_β, NOCT = 800 W/m², with a wind speed of 1 m/s. 4 [3]

2.2.2 Wind System Model

There are many models for estimating wind turbine power, such as the linear model, Whipple parameter model [3], and quadratic model. Selecting an appropriate model for simulating wind power is crucial. In this study, the output power of a wind turbine is represented by a quadratic equation given as follows:

Equation:

$$Pwg(V) = \{PrV2 - Vcin\ 2\ Vmt\ 2 - Vdin\ 2 \quad Vcin < V < Vrat\ Pr \quad Vrat \leqslant V < Vcou\ 0 \quad V \leqslant Vcin \text{ and } V \geqslant Vcou\} \qquad (4)$$

PR: is the rated power of the turbine.

- Vaccin: is the cut-in wind speed.
- T: is the operating temperature.
- Virât: is the estimated wind speed.
- Cou: is the cut-off wind speed.

In this study, the wind height profile is adjusted to account for variations using the power law described in (5) as a useful tool for modeling the vertical wind speed profile. The equation used is provided as follows:

Equation [4]:

$$\mathbf{V = Vref\ (\ H\ Href\ )\ \alpha} \qquad (5)$$

- V: is the wind speed (m/s) measured at the height H (m).
- Réf: is the wind speed (m/s) measured at the reference height Href (m).
- a: is the wind speed law parameter. A typical value of 1/7 is used for low roughness surfaces and elevations.

In this section, we find a set of tasks, including components for loading, project resources, and instructions.

Figure 2-7: HOMER Components

2.8 Data on Solar Radiation, Wind Speed, and Temperature Using HOMER® Software

HOMER includes a specialized database that provides reliable estimates of daily, monthly, and annual resources for the studied sites and their nearby localities. Wind resources are more complex than solar energy resources due to their inconsistency and variability. Wind speed and direction data, covering at least one year of measurements, are required to achieve an accurate estimation of wind resources.

Figures (13), (14), and (15) illustrate the solar energy flux, wind resources, temperature, and the operation of a hybrid system composed of a wind turbine, a photovoltaic panel, a storage unit, and an inverter. 46

- Months: January, February, March, April, May, June, July, August, September, October, November, December.

Clearness Index 0,655 0,679 0,669 0,673 0,660 0,647 0,622 0,628 0,660 0,636 0,647 0,648 Daily Radiation (KWh/m2/day) 4,089 5,047 5,995 6,934 7,317 7,340 6,965 6,630 6,200 5,000 4,199 3,79447

The program includes a library of solar and wind energy resources worldwide, obtained from NASA data [11]. After entering the corresponding longitude and latitude, the area is identified, and the solar resource, wind resource, and temperature are established. These are critical factors for determining the proper functioning of the system.

The base load used for the case study simulation is determined using HOMER Pro. Monthly estimated files are downloaded for a period of 25 years, subject to a 10% random variation from day to day.

3. Conclusion

In this chapter, we defined and modeled the components of a system. We determined the optimal size of the autonomous system (PV/E/DG) with a storage battery in the Adrar region. Additionally, we provided an explanation and definition of the HOMER software, a tool that can significantly assist technology and engineering students in the design and analysis of renewable energy sources and systems while explaining how to utilize them effectively.

By inputting equipment specifications, prices, and meteorological data (sunlight, wind, temperature), the goal is to achieve the lowest possible cost, energy savings, and reliability based on the components selected by the designer. In this process, HOMER® calculates the energy balance based on the system configuration, including multiple numbers and sizes of components.

We identify the best possible system configuration that is suited to meet electricity demand with the lowest possible cost while maintaining quality and reliability. HOMER also calculates operating and maintenance costs, maintenance intervals, schedules, system resale value, and potential cost recovery.

References

1. Study of different structures of hybrid systems using renewable energy sources, Ludmilla Stroganov.
2. http://www.bsi-economics.org
3. https://www.edf.fr - Everything about solar energy production, 2018.
4. Renewable Energy Bulletin - No. 22, 2012, CDER.
5. https://www.fournisseur-energie.com
6. https://www.researchgate.net/figure/Solar-energy-profile_fig8_338838392
7. Rajesh None, S. S. (2015, November 07). A comprehensive assessment of maximum power point tracking techniques under uniform and non-uniform conditions.
8. Rajesh None, S. S. (2015, November 07). A comprehensive assessment of maximum power point tracking techniques under uniform and non-uniform conditions.
9. Alternative Energy Tutorials. (2021, November 05). Photovoltaic array or solar array uses PV solar panels. Retrieved May 05, 2021.
10. Boudes, F. B., Escorial, Y. C., & Ochoa, G. V. (2018). Optimization of a biomass, solar, and fuel cell hybrid energy system for a specific energy load using Homer.
11. https://eolienne.f4jr.org
12. Sameer Kasbah, student. Horizontal axis wind turbine. Retrieved May 05, 2021.
13. https://jardi-brico.com
14. Battery Aging and Characterization of Nickel Metal Hydride and Lead Acid Batteries. Retrieved May 20, 2021.
15. https://www.doitpoms.ac.uk/tlplib/batteries/battery_characteristics.php#1
16. https://www.doitpoms.ac.uk/tlplib/batteries/battery_characteristics.php
17. Rami, M. A. M., Bouchera, H. R. E. H., & Algardi, A. S. (2018). Optimal sizing of PV/wind/diesel hybrid microgrid systems using a multi-objective self-adaptive differential evolution algorithm. Renewable Energy, 121, 400–411.
18. Optimal sizing method for stand-alone hybrid PV/wind power systems. Retrieved May 7, 2021.
19. Lu, L., Yang, H. X., & Burnett, L. J. Investigation on wind power potential in Hong Kong islands – Analysis of wind power and wind turbine characteristics. Renewable Energy, 2002, 27:1–12.
20. Deaf, S., Norton, G., Béchamel, M., Haddadi, M., & Louche, A. (2008). Design and techno-

economic optimization for hybrid PV/wind systems under various meteorological conditions. Applied Energy, 85(10), 968–987.

21. Booker, A. L., Tan, C. W., & Lau, K. Y. (2019). Optimal sizing of an autonomous photovoltaic/wind/battery/diesel generator microgrid using a grasshopper optimization algorithm. Solar Energy, 188, 685–696.
22. https://www.cder.dz/vlib/revue/pdf/v017_n3_texte_2.pdf
23. Norton, G., Cristofori, C., Poggi, P., & Muesli, M. (2001). Wind hybrid electrical supply system: Behavior simulation and sizing optimization. Wind Energy, 4(2), 43–59.
24. https://energieplus-lesite.be - Wind turbine efficiency.
25. https://dspace.univadrar.edu.dz - Study of a hybrid system at Kabertene Central.
26. https://www.researchgate.net - The architecture of HOMER software.
27. Boudes, F. B., Escorial, Y. C., & Ochoa, G. V. (2018). Optimization of biomass, solar, and fuel cell hybrid energy systems for a specific energy load using HOMER Pro software. Int. J. ChemTech Res, 11, 335-340.
28. Lugano-Rojas, J. M., Monteiro, C., Dufo-López, R., & Bernal-Agustina, J. L. (2012). Optimum load management strategy for wind/diesel/battery hybrid power systems. Renewable Energy, 44, 288–295.