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# Study of a micro-grid with renewable energy sources with hydrogen storage

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**ABSTRACT:** We consider a micro-grid with renewable energy sources. The intermittency of productions and the desynchronization between production and consumption are solved by a hydrogen storage unit. The system consists of a photovoltaic generator, a wind turbine, an electrolyser, a fuel cell, a storage tank in the form of hydrogen (MgH2). DC-DC (Boost) and DC-DC bidirectional converters (Buck-Boost) as well as DC-AC and AC-DC (wind turbine) converters provide connection to the DC bus and the network. Hydrogen storage ensures continuity of supplies for demand. The study is positioned within the framework of the territorial energy transition program set up by in Comoros.

**KEYWORDS:** micro-grid, renewable energies, fuel cell, electrolyser, battery, hydrogen storage, static converters.

## 1 INTRODUCTION

The micro-networks integrating ER sources constitute a major challenge for the future energy gives based on the fact that the energy asymptotic trajectories of fossil origins that are inevitably decreasing [1] or even disappearing, as well as the societal constraints that will be highly damaging. The main drawback of renewable energy sources, more specifically for wind and photovoltaic power, lies in their strong intermittent nature. Indeed, the production of electrical energy from these sources is highly dependent on the variability of weather conditions and rotations of our planet. This intermittency is at the origin of a lower penetration in the global energy contribution and causes the problem of the continuity of the supply by the electrical networks.

To overcome this deficit, it is customary to use storage devices that are mostly aimed at two ends, the short and the long term. In general, short-term energy storage is provided by a classically battery-type system. Although this solution may be of interest for this situation, it nevertheless remains that batteries do not necessarily appear to us as always optimal solutions, neither in terms of ecology (highly polluting metallurgy, toxic materials, corrosive substances) nor in terms of durability [2], [ 3] and recycling. That is why, in terms of long-term storage, it is a hydrogen solution that has been considered. The latter solution consists of an electrolyser, a fuel cell and a storage tank. Hydrogen initially stored in tanks during periods of production in which consumption is low or absent, can be used thereafter to generate electrical energy during periods of under-production or even lack of production by the sources renewable energies. The production of electrical energy via the fuel cell will have the purpose of balancing production and demand and thus ensuring the stability of the network in terms of supply. The architecture of the proposed micro-grid constitutes a topology that allows energy management in the context of the most effective (wind, PV, PAC, electrolyser) to respond to high specific powers [4], [5], [6]. In the literature devoted to it, numerous studies have proposed to optimize the design and architecture of micro-networks in a multi-source context through various configurations [7], [8], [9].

Therefore, the main aim of the current article is to design and study the behavior of a micro-grid made up of various renewable energy sources, but also an electrolyser, a fuel cell and associated converters. With the aim of ensuring optimum quality of energy supply. We use HOMER (Hybrid Optimization of Multiple Energy Resources) which is a software developed by the National Renewable Energy Laboratory of Canada to design hybrid systems such as stand-alone renewable micro-grids [10], [11], [12] or hybrid systems ( HPS) connected to the network. HOMER evaluates hybrid systems from economic and technical points of view [13], [14], [15], [17], [18], [19], [20].

## 2 THE STUDY AREA AND THE PROFILE OF THE LOAD

The village considered in this study is Mbeni, which is located at 11 ° 30 'of latitude (south) and 43 ° 23' of longitude on the north eastern coast of the Comoros Islands. The site is in a region that receives daily solar irradiation ranging from 6.03 to 7.25 kWh / $m^2$, with an average wind speed of 3.7- 4.2 m / s at a height of fifty meters. The system we want to deploy consists of a wind turbine, a PV field, a PEM electrolyser, a PEM fuel cell and a hydrogen storage tank. In an electrical feasibility test, the profile of the primary load is the most significant data [16], so we will use this quantity. In electricity management, the balance between power generation and demand is the crucial issue for a stable operating objective. It is also necessary that load data be as accurate as possible, that is why in our study we used the actual load profile of electricity consumed without modifying anything (no smoothing).

We used 24-hour load records for the 365 days of a year. Figure 2 shows the profile of the seasonal load of the city of Mbeni, Figure 3 shows the daily profile of the load and Figure 4 the DMap (The DMap is a type of graph highlighting one year of hourly data, each time of the year is represented by a colored rectangle according to the amplitude of the data). According to these results, It is during the months of April, August, September and November that people consume the largest amount of energy in the evening between 17 and 22 hours.

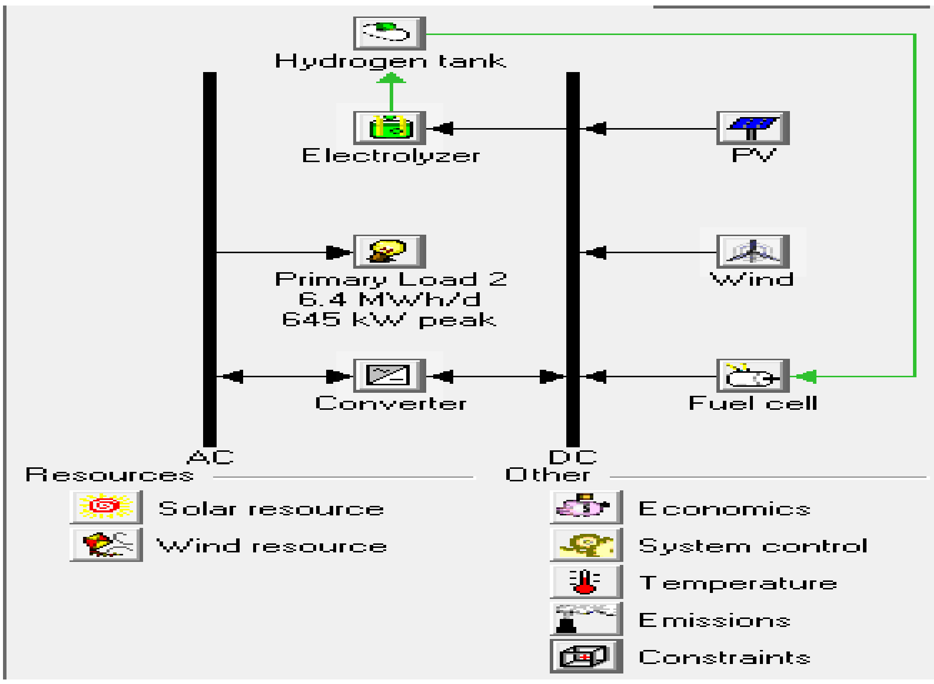


*Fig. 1. Architecture of a micro-grid based on ENR system and hydrogen storage*

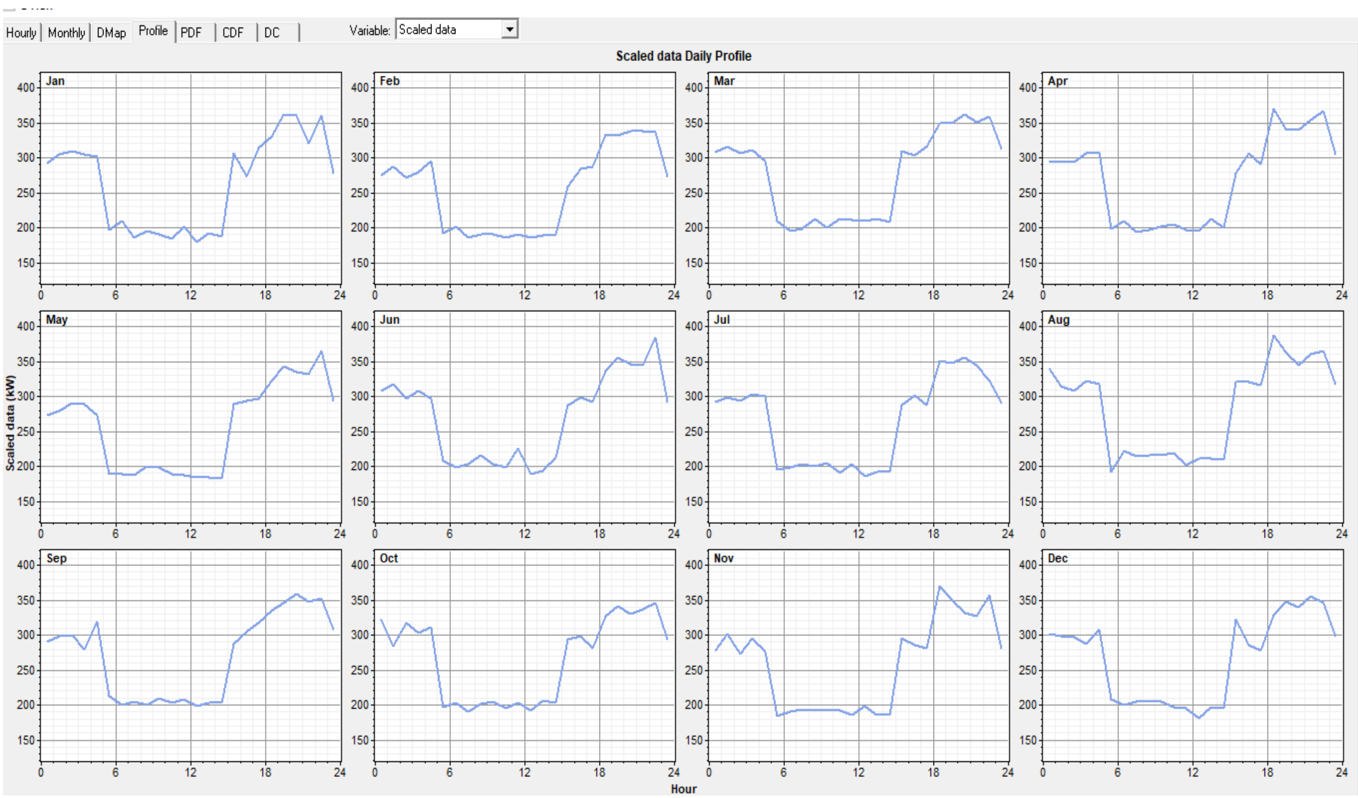


*Fig. 2. Daily seasonal profile of the load during the year*

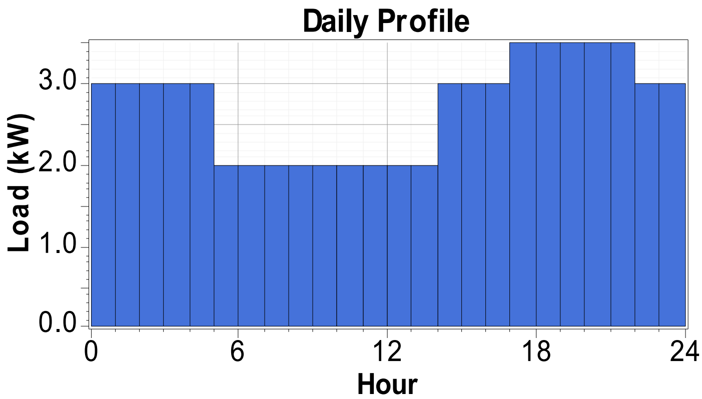


*Fig. 3. Daily profile of the load*

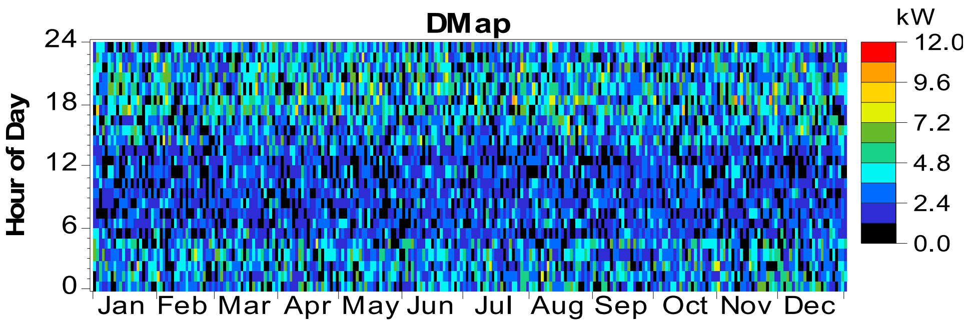


*Fig. 4. DMap*

In this study, two sources of renewable energy were considered: the wind and solar resources of the municipality of Mbeni. Monthly mean global solar radiation is shown in Figure 5.

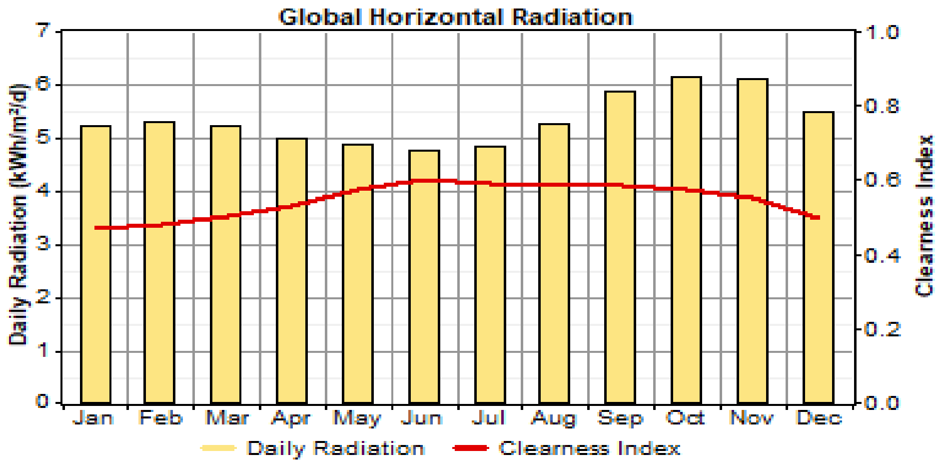


***Fig. 5. Solar irradiation***

$$I_{ph}= [I_{sc}+ K_i (T-T_{ref})] \times G/1000 \quad (1)$$

G: sunshine (W / m$^2$), $I_{sc}$: short circuit current under standard conditions (STC), $T_{ref}$: room temperature or cell junction and T temperature in Kelvin.

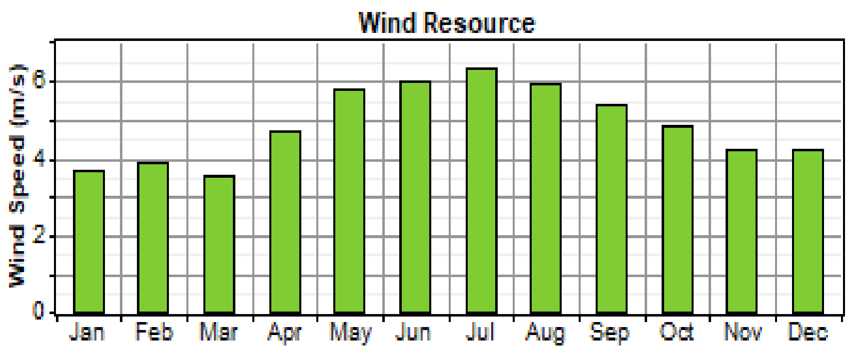


***Fig. 6. Wind speed***

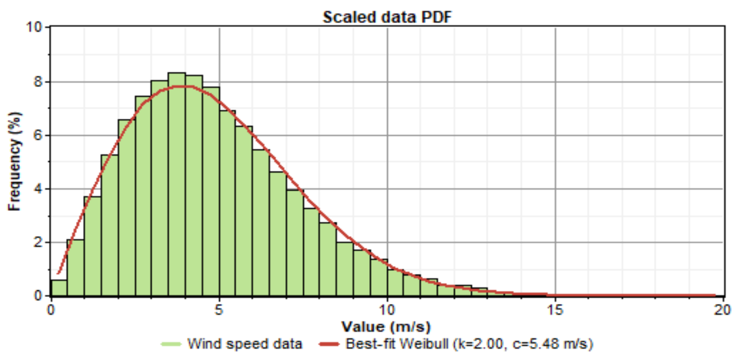


***Fig. 7. Probability Density of Wind Speed***

The monthly wind speeds are shown in Figure 6. The overall average wind speed is 4.85 m / s. Figure 7 shows the probability density of the wind speed in the Comoros. The potential of the study site in rural areas has been assessed from this density. As shown in Figure 6, the lowest wind speed is in March and the highest is in July. The power produced by the wind turbine is calculated by:

$$P_{mt}=1/2\ \rho \times A \times V^3 \times C_p \quad (2)$$

Where V represents the wind speed (m / s), ρ is the density of the air for a given temperature (kg / $m^3$), A is the rotation surface of the rotor ($m^2$) and Cp the power factor of the turbine.

## 3 Results and Discussion

The architecture of the micro-grid is simulated in various aspects depending on the variations of the load profile, the cost and the size of the components, the constraints of the system, the control strategy and the economy of the system. HOMER eliminates all unworkable combinations and classifies feasible systems according to the current net cost [22], [23].

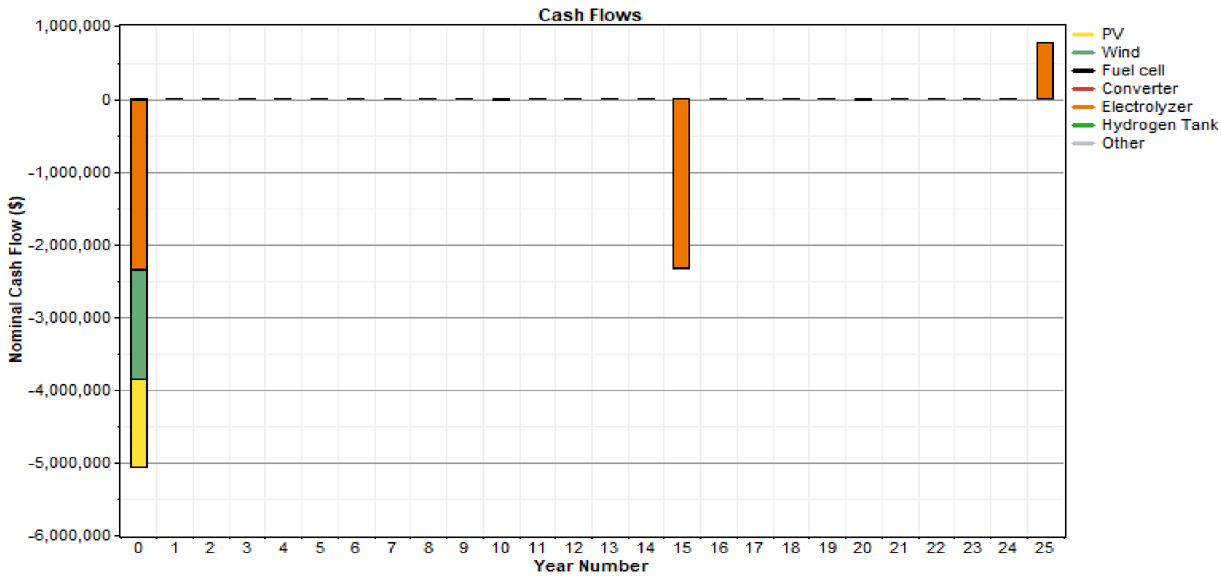


***Fig. 8. Summary of cash costs***

Figure 8 illustrates the cash flow for the system. Each bar in the graph represents total expenses. The first bar, year zero, indicates the investment cost of the system ($ 5,072,964). A negative value represents an expense, such as component replacement or operating and maintenance (O & M) costs. A positive value represents a recipe, which can be the sale of electricity (not expressed at this level) or the resale of components after the dismantling of the system at the end of the life of the project. At 15 years, the electrolyser, the fuel cell, the storage tank and the converter will be replaced as indicated on the same figure with the negative bar. The project was desired for a lifetime of 25 years.

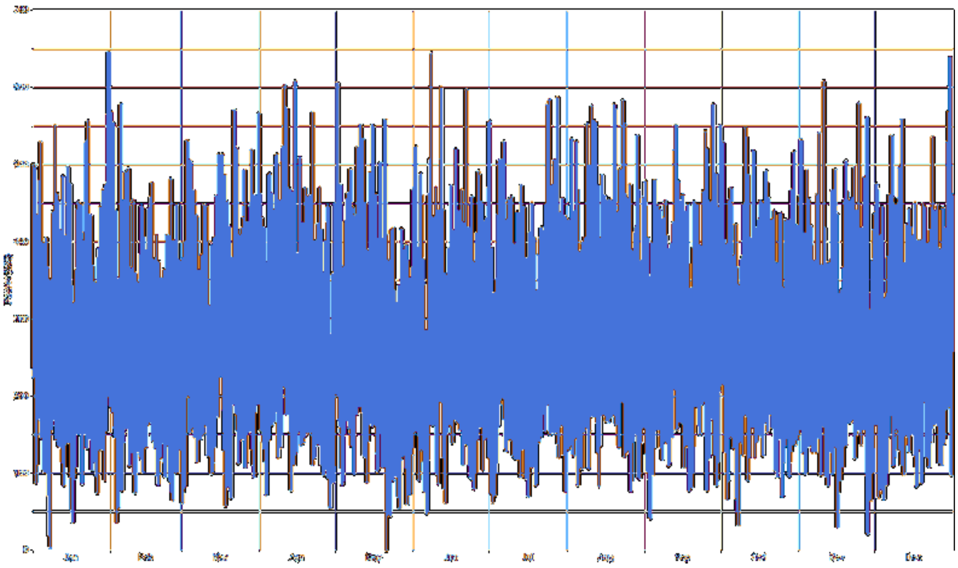

***Fig. 9. Annual change in the load represented by the city***

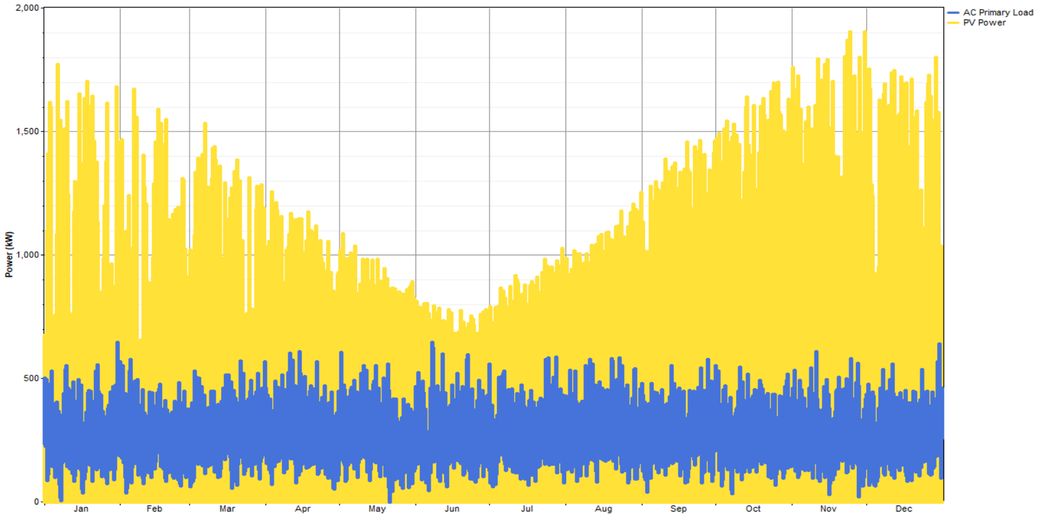


***Fig. 10. Annual change in PV load and production***

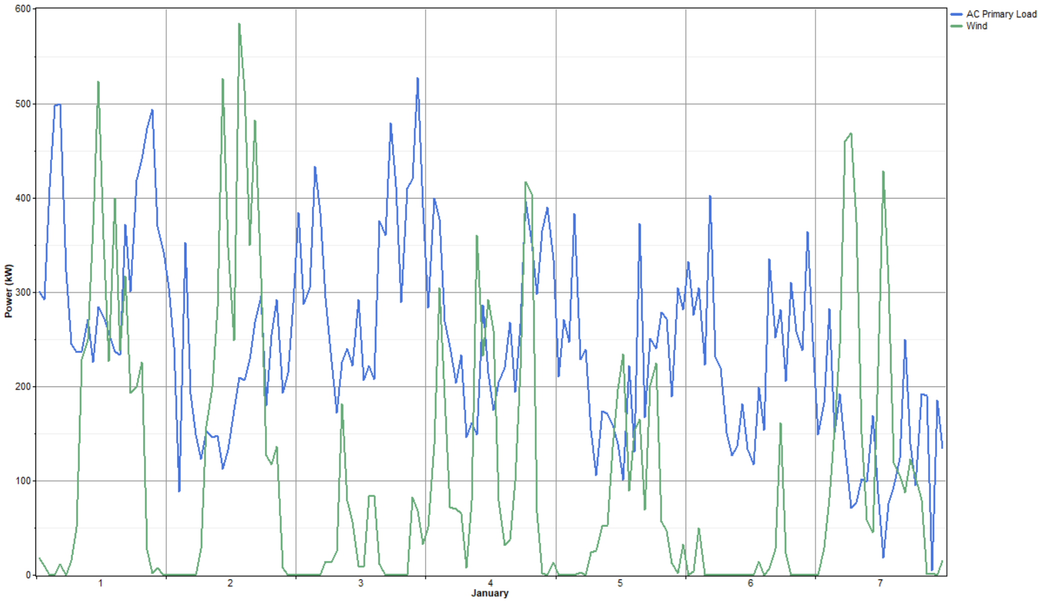


***Fig. 11. Power of the load and wind generation***

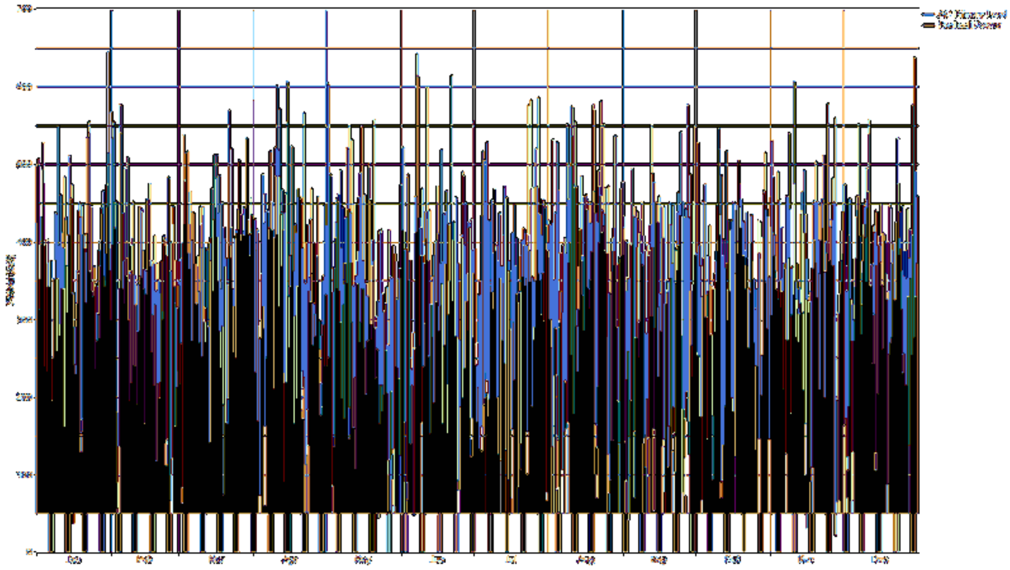

*Fig. 12. Monthly evolution of the energy corresponding to the charge and injected by the fuel cell*

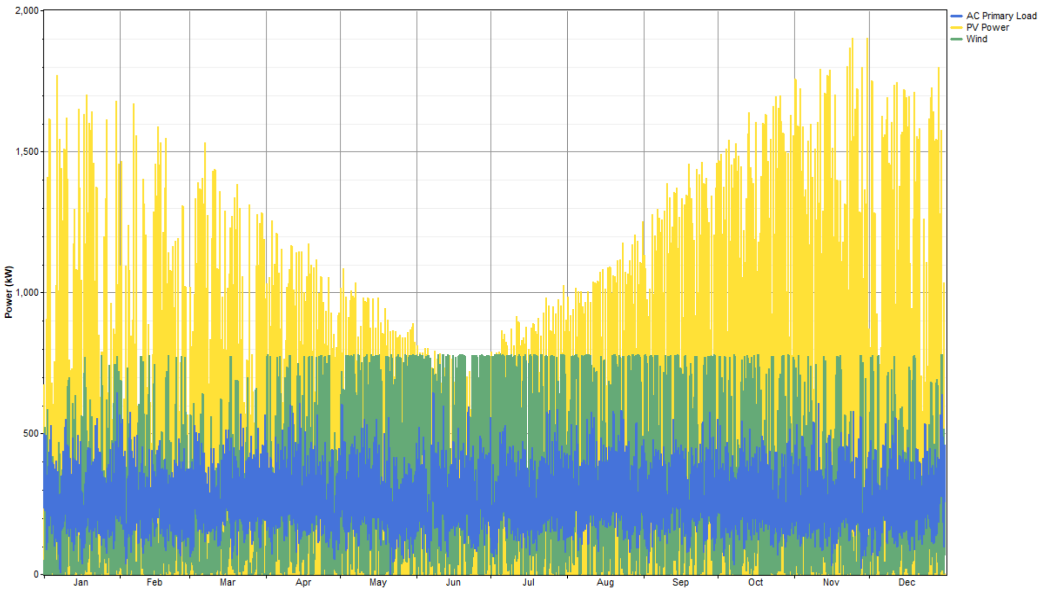


*Fig. 13. Monthly evolution of the energy consumed by the load and produced by the wind turbines and by the PV field*

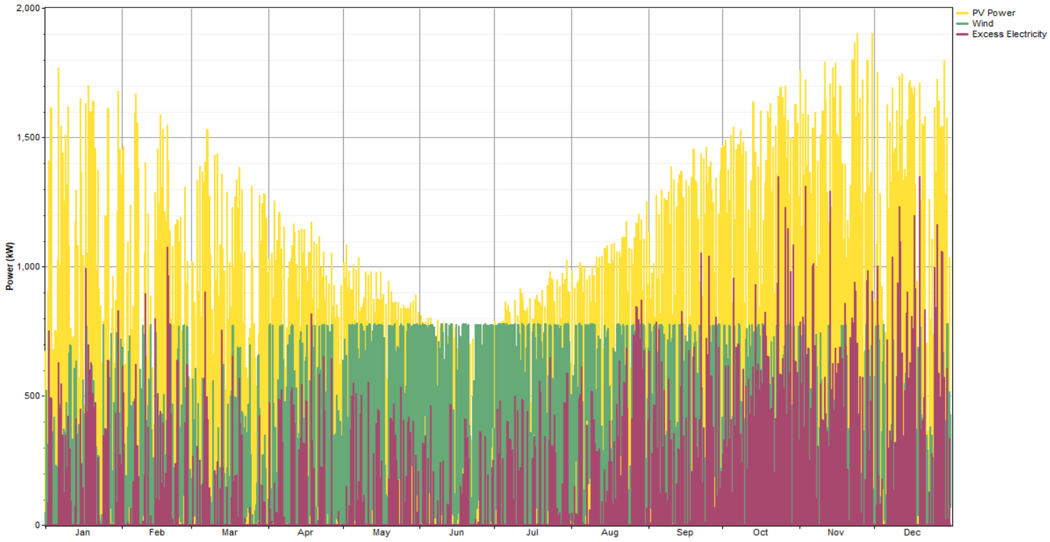


*Fig. 14. Variation in wind and PV production plus excess electricity generation in a year*

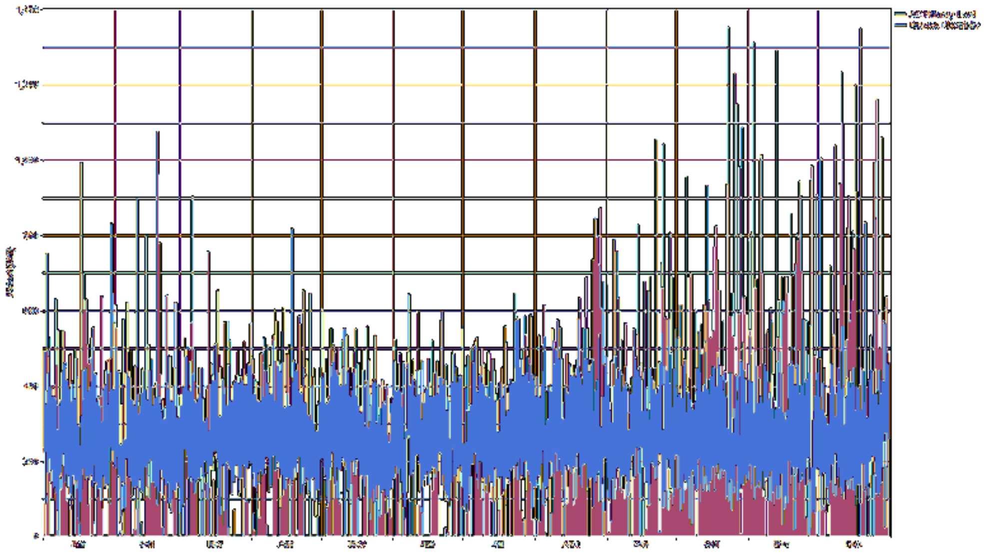

*Fig. 15. Variation in excess of electricity production superimposed on energy demand*

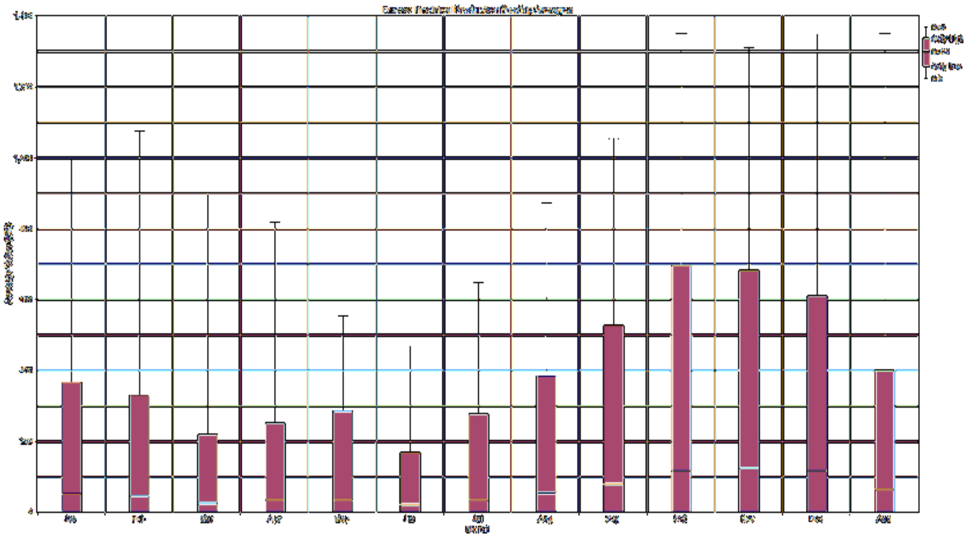

*Fig. 16. Evolution of the monthly average of excess power produced*

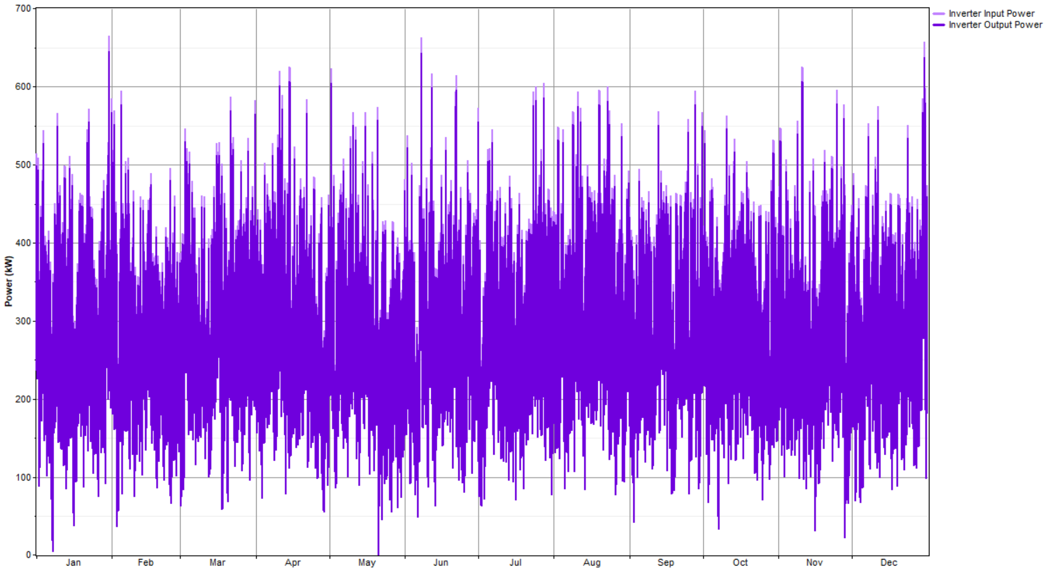


*Fig. 17. Variation of the annual hourly power at the input and output of the inverter*

Figures 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 show the energies produced monthly for wind, PV, fuel cell as well as stored.

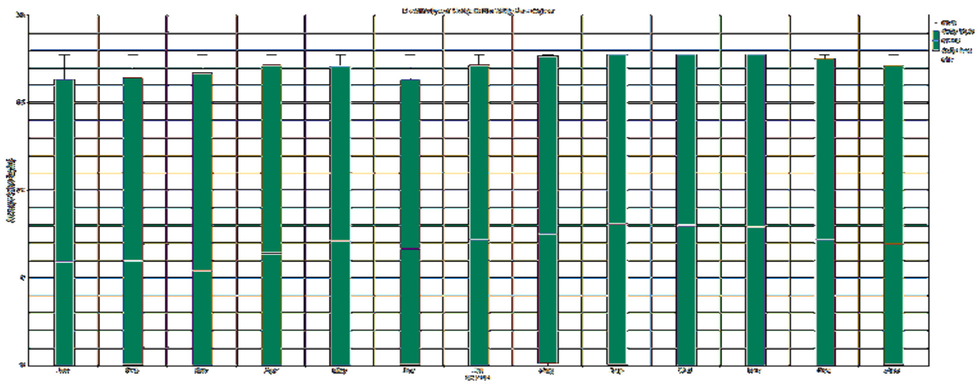

*Fig. 18. Variation of the average evolution of the power supplied by the electrolyser*

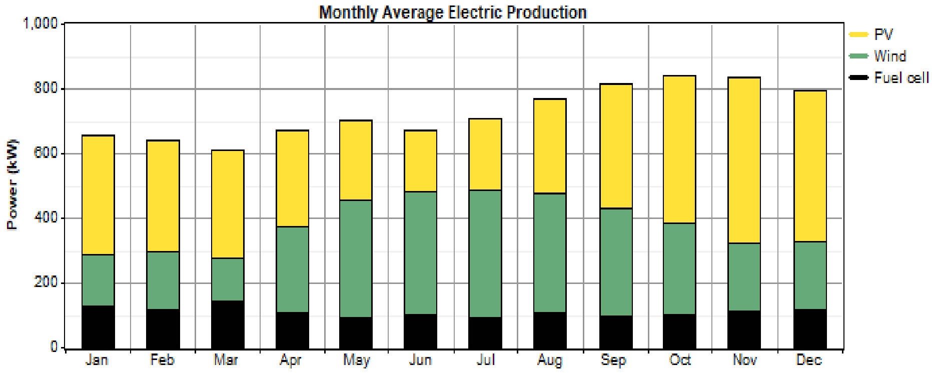


*Fig. 19. Energy production from different sources in a year*

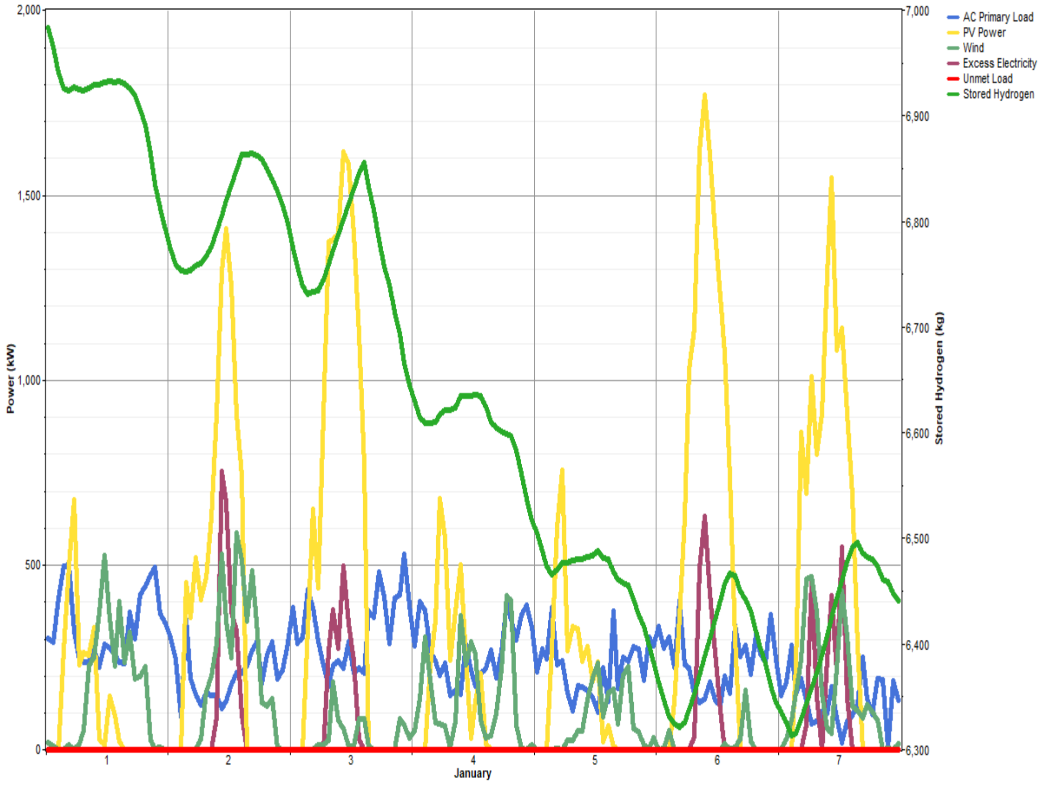


*Fig. 20. Variation of load, energies produced and excess of electricity production, demand for unmet load and hydrogen Storage*

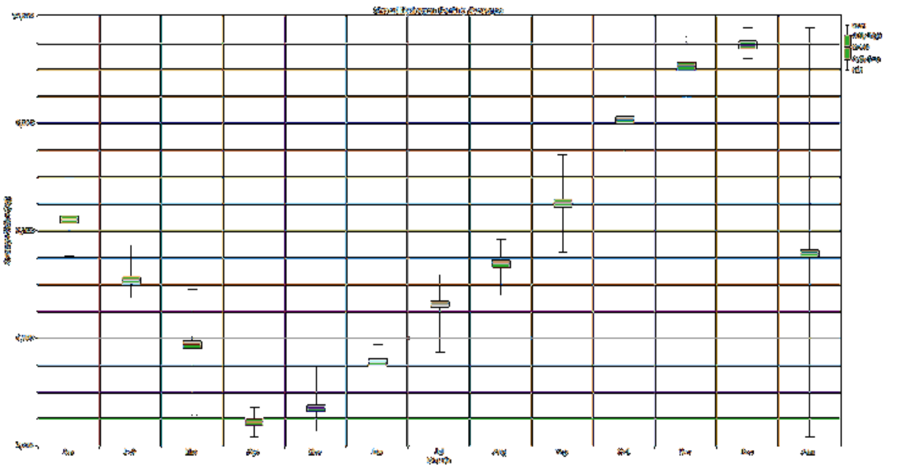

***Fig. 21. Evolution of the monthly average of hydrogen storage***

## 4 CONCLUSION

In this article, the study and design of a hybrid power system for a power supply in the Comoros was carried out using the HOMER software. The hybrid system consists of a wind turbine, a PV field, an electrolyser, a fuel cell, a hydrogen storage tank. The study was conducted using local wind speed and global solar irradiance data to optimize the system. Our results show that the best net total cost (NPI) of $ 5,072,964 and an energy cost of $ 0.1448 / kWh can be achieved by using a 500 kW converter, a 1000 kW electrolyser; a 1000 kW fuel cell, three 250 kW wind turbines, a PV field with a nominal capacity of 2250 kW and a 10000 kg hydrogen storage unit (these results only include capital expenditure and ignore the excess electricity produced). Similarly, PV penetration is 47%, wind turbine penetration is 38%, and 15% for the fuel cell. On the other hand, the simulation results of the HOMER software show that the PV-wind-H2 system (figure 20) is a solution in terms of autonomy, durability and environment. It also has an excess of electricity production of 538,138 kWh / year and an unmet load value that is zero. This excess of electricity will allow the community to carry out other projects that are blocked because of the shortage of energy such as the drinking water project for which the African Development Bank has been making investments for several years or the hospital care project such as the operating theater, the dental service and the creation of a cold room in the community market. Taking into account the results we have obtained, the following conclusions could be drawn: Solar resources in the Mbeni community area have excellent potential compared to wind energy which could be the second energy source to cover electrification.

- Indeed, we note that a PV-wind-H2 system is an appropriate solution for standalone applications.
- Thus, the production of electric energy via the fuel cell which is 15% will be able to balance the production and the demand and thus ensure the stability of the network in terms of supply.

## ACKNOWLEDGMENT

Thank you to the Central Head of the Electricity Company of Comoros as well as Head of Design Office who honored their promise by giving us the data. This work is so important to enable the people of this Comorian city to get out of the energy drain and to allow the future generations of my country to find studies in the coming years. We are looking for funding to carry out this project.

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