# Numerical simulation of Hybrid Generation System: a case study

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**Abstract -** *Objective of this study is to simulate an hybrid wind-photovoltaic-diesel generator to supply a load in Tamanrasset region, this solution is proposed to overcome defects of zone isolation, Not important and also scattered in this region. Algeria among the countries, which have a very important renewable deposit. However, part of renewable energies in the national energy balance still very low. In this context, work presented in this paper is a contribution to use of hybrid system - Wind-Photovoltaic-Diesel with storage batteries to be installed in Tamanrasset region, in order to reduce greenhouse gas emissions. To validate hybrid system for electrical energy generation, simulation results will be presented by HOMER software based on actual geographical information of studied region.*

***Key Words:*** *Renewable Energies, Hybrid System, Homer, solar wind system.*

## 1. INTRODUCTION

Global warming and pollution caused by fossil fuels, which have become harmful to human life. Growth in global electricity demand, thus rapid depletion of hydrocarbons requires use of renewable energies [1] which are non-polluting, practical and economical.

Only 6.4% of total renewable energy sources available in the world are used today as sources of inexhaustible electrical energy. In order to compensate for defects of each energy source, there has been an increasing tendency to combine them with diesel generators, which gives a hybrid system of energy generation.

For isolated sites of conventional power grid, the possibility of being connected with this network remains a major problem to the fact that price of extension is prohibitive in parallel with the increase in fuel prices also. Highlighting the price of generators based on renewable energy are experiencing a steady decline in price at the same time increasing reliability, these benefits have led to significant use of generation of electric power by renewable energies [2].

The relation between its renewable energies and the limits of use, with regard to variation of resources and the fluctuation of loads according to annual and daily periods linked to climatic conditions, are the subject of a more general solution at the level of Generation of electric power, one that leads to introduction of hybrid systems, to serve as electric power to telecommunication relays, border posts, isolated housing, dispensaries ... etc

## 2. OPTIMIZATION WITH HOMER SOFTWARE

For the hybrid system study; We used HOMER software, which was developed by National Renewable Energy Laboratory (NREL) in United States and supports design evaluation of various electrical power generation systems connected to an electrical grid Classic or not, for variety of applications. It allows to analyze and to combine between different sources of energy in order to arrive at displaying an optimal configuration of a system capable of supplying energy to specified site in a feasible manner according to certain technical and economic criteria [3].

To simulate a hybrid system, all elements of the hybrid system must be defined, using the components defined in the software library such as wind turbines, photovoltaic panels, generators and static converters, etc. If it is necessary to add a component that does not exist in the list of elements defined by default, the software allows us to add it by introducing all its technical characteristics as well as its cost. You can also modify the characteristics of a component already existing in the library.

Also HOMER simulates the operation of a system by making hourly energy budget calculations at each element for 8760 hours in a year. He finds the least expensive combination that meets specific electrical and thermal loads. HOMER simulates several configurations; it optimizes the cost for a given life cycle and generates sensitivity results for most situations.

### 2.1Geographical site

The city chosen for the study is located in the south of Algeria, whose latitude 22 ° 5 and longitude 5 ° 3 is the town of Tamanrasset[4].

We will present a hybrid system based on photovoltaic panels and wind turbines and as a backup alternative, diesel generators and energy storage batteries. To do this, we must have all the solar radiation data, wind speed for the chosen site, load profile to be fed by the system, initial cost of each component (diesel, renewable energy generator, batteries, and converters), cost of fuel and lifetime of the project.
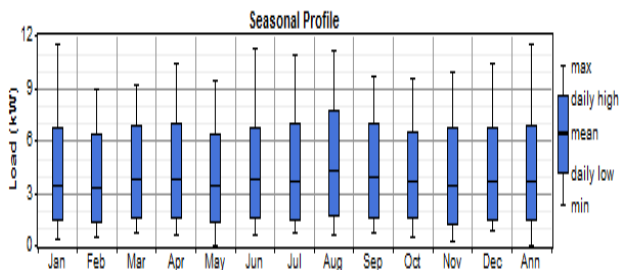


**Fig -1**: Seasonal load profile

Figure 1 shows the load profile to be supplied. The simulation process of chosen hybrid system; was analyzed to see if the use of power system will be possible or not. It is important to note that these houses presented in the example study are already connected to the network; the additional objective is to see the possibility of using a hybrid system to supply them with electrical energy. The daily load is 88 KWh.

However, information on renewable energy sources such as solar and wind data is presented in Figures 2, 3, 4, 5 and 6.
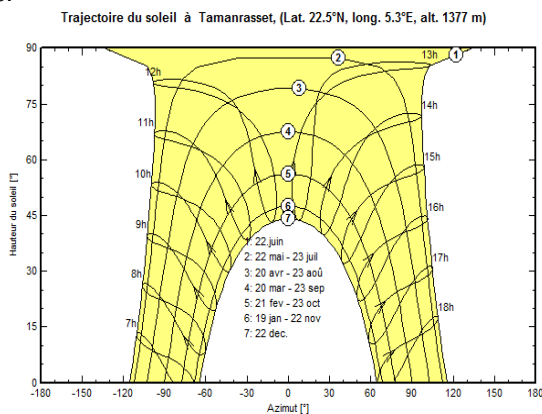


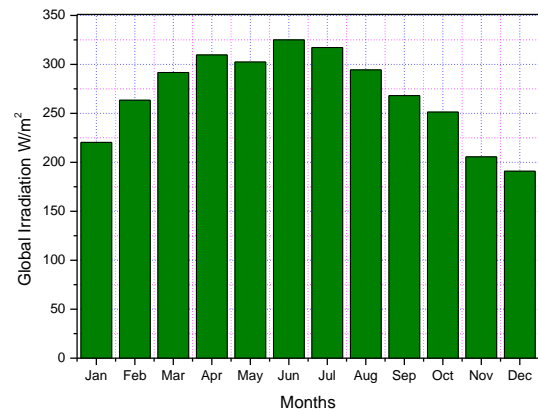**Fig -2**: Sun trajectory and sunshine in Tamanrasset.



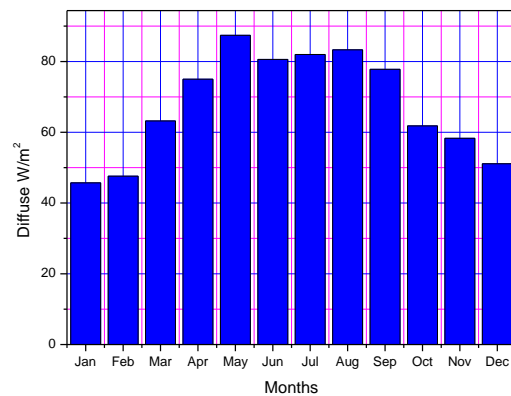**Fig -3**: Profile of global irradiation in Tamanrasset

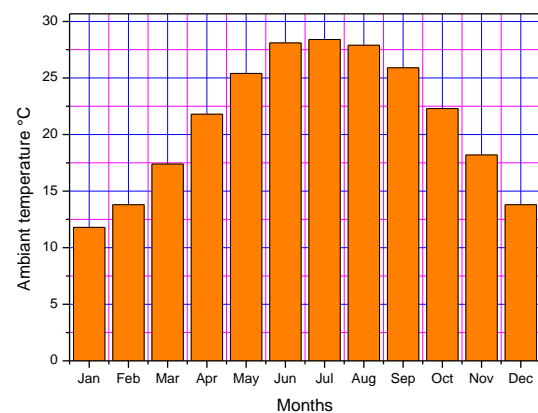

**Fig -4**: Tamanrasset diffuse radiation



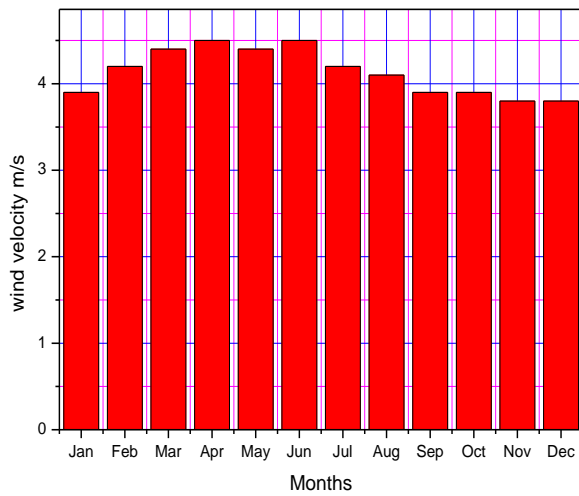**Fig -5**: Ambient temperature in Tamanrasset

Fig -6: Wind speed at Tamanrasset
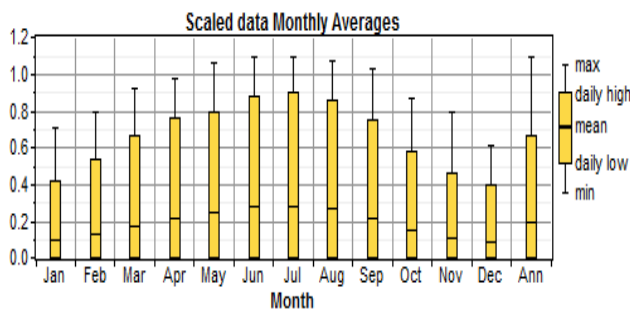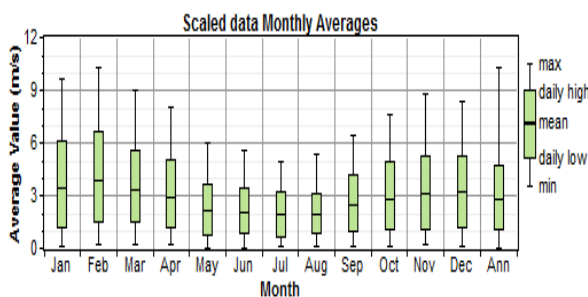


**Fig -7**: Yearly load profile



**Fig -8**: Yearly landfill profile

## 2.2  The simulation steps by HOMER

We have defined each element of our facility based on all the characteristics and data provided.
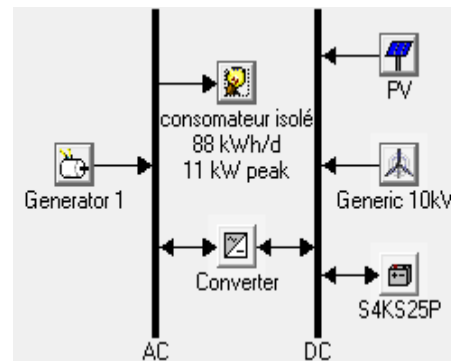The diagram is shown in Fig 4.



**Fig -9**: Hybrid system architecture on HOMER

The hybrid system model presented by HOMER can be simulated by introduction of many factors such as the cost of components, the availability of resources. Another major factor in this digital implementation is evaluation of the project life which is estimated for 25 years. Calculations presented by the software take into account the investment capital, depreciation, operating costs, maintenance costs, replacement costs and the fuel cost. All its estimates are part of proper functioning of studied system.

## 3. REVIEW OF OPTIMIZATION PROBLEM AND ITS PROPOSED SOLUTION

### 3.1  Adopted models of individual sources

The paragraph below presents a brief model of power generated by the following individual sources: solar, wind, and mini-hydro generators.

  ➤  Analytical model of Solar Energy Generation

According to previous works done by [5][6][7][8], the model of power generated by a PV module can be given by the formula below:

$$P(t) = n_r[1 - \beta(T_c - T_{cret})].\, A.\, G(t) \qquad (1)$$

Where nr is the reference module efficiency, Tcref is reference cell temperature in degree Celsius, A (m2 ) is the PV generator area and G(t) is the solar irradiation in tilted module plane (Wh/m2 ), β is the temperature coefficient, Tc is the cell effective temperature.

  ➤  Analytical model of Wind Energy Generation

The model of wind power can be derived from works done [9][10][11] as follow:

$$P_m(t) = \frac{1}{2}\rho A C_p V_w^3(t) \qquad (2)$$

Where:

- $C_p$ is the coefficient of performance also called power coefficient

- A is the swept area by the turbine' blades (m$^2$ )

- $\rho$ is the air density (kg/m$^3$ )

- $V_w$ is the wind speed (m/s)

- Analytical model of Mini-hydro generators

The general formula for the determination of hydraulic power is shown by[12] [13][14] as follow:

$$P_m = \eta_t \rho g H Q(t) \qquad (3)$$

Where: $P_m$ is the mechanical power produced at the turbine shaft (Watts), $\rho$ is the density of water (1000 kg/m$^3$ ), g is the acceleration due to gravity (9.81 m/s$^2$ ), Q is the water flow rate passing through the turbine (m$^3$ /s), H is the effective pressure head of water across the turbine (m) and $\eta_t$ is the efficiency of the turbine.

## 3.2 Assumption

With reference to[11] the following assumptions are made:
Each module is considered independent at the construction level and therefore their various cost of electricity will be estimated separately.
There exist numbers N$_s$ , N$_w$ and N$_h$ representing respectively the total number of solar plant, wind power plant and mini-hydro power plant respectively in existence.

## 3.3 Optimization problem formulation

Considering the unit costs of electricity C$_{us}$, C$_{uw}$, C$_{uh}$, generated respectively by the solar, wind and hydropower plants, the cost of electricity generated by the hybrid energy system over a period of time T was expressed in the previous paper, [11], as follows:

$$CE = a_s C_{us} \eta A G T + a_w C_{uw} \frac{1}{2}\rho A C_p V_w^3(t) + a_h C_{uh} \rho g H Q(t) \quad (4)$$

The unit cost of electricity is further evaluated based on equation 5 below:

$$C_u = \frac{C_c \cdot CRF + C_0}{E_T} \qquad (5)$$

Where C$_c$ represents the capital cost of investment, CRF is the capital recovery factor, C$_o$ is the operation and maintenance cost and E$_T$ is the total energy generated over a year.
The objective function is given as follow (4)
Minimize CE subjected to the following constraints:

1. The power generated by the hybrid system should meet the demand at any given time as expressed below:

$$a_s \cdot P_s(t) + a_w \cdot P_w(t) + a_h \cdot P_H(t) \geq P_d(t) \qquad (6)$$

2. The total power generated should be within range of minimum and maximum power that can be generated

$$P_{min} \leq a_s \cdot P_s(t) + a_w \cdot P_w(t) + a_h \cdot P_H(t) \leq P_{max} \qquad (7)$$

3. Variables should also stay between bounds as follow

$$\begin{cases} 0 \leq a_s \leq N_s \\ 0 \leq a_w \leq N_w \\ 0 \leq a_h \leq N_h \\ 0 \leq a_w , a_w , a_h \\ G_{min} \leq G \leq G_{max} \\ V_{min} \leq V_w \leq V_{max} \\ Q_{min} \leq Q \leq Q_{max} \end{cases} \qquad (8)$$

With the assumption that the irradiation G, the wind velocity V$_w$ and the water flow Q are all constant during the period T, the problem was considered as a linear optimization function subjected to linear inequalities constraints.

## 3.4 Proposed solution

The solution to the above optimization problem is constructed around the linprog function of Matlab and can be described by the following algorithm.
1. Initialize an index variable to N that will serve for iteration.
2. Get the input load data, wind velocity, solar irradiation and hydro data (water flow and total head) as well as necessary data to evaluate the unit cost of electricity per individual sources
3. Calculate the power generated by individual sources of renewable energy generator using the models described above
4. Create decision variables for indexing
5. Define lower and upper bounds for all variables
6. Define linear equality and linear inequality constraints
7. Define the objective function
8. Solving the linear optimization problem with the function linprog of Matlab
9. Save result
10. Increase the index N by 1

11. If index N is less than or equal to 12 (for the twelve months in a year), repeat processes from 2 to 10 , 12. Display result
13. Stop

## 3. RESULTS AND DISCUSSIONS

The simulation of our hybrid system by HOMER gives us the optimal combination of elements of hybrid system. It is presented according to a net present value (NPC) and according to different technical system constraints. Our case deals with a simulation of an hybrid system that contains two renewable energies, photovoltaic and wind energy sources, and another diesel generator, with presence of batteries and converters, this system is isolated from the grid (off grid system).

After several iterations, HOMER gives the best technical-economic solution of the proposed system. Fig.5

| | PV (kW) | G10 (kW) | Label | S6CS25P | Conv. (kW) | Initial Capital | Operating Cost ($/yr) | Total NPC | COE ($/kWh) | Ren. Frac. | Diesel (L) | Label (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 5 | 10 | 2 | 10 | $ 31,400 | 2,240 | $ 60,040 | 0.146 | 0.76 | 7,465 | 4,308 |

**Fig -10**: Optimal solution given by HOMER

Each generator produces energy individually; In figure.11, the contribution of each source to overall production of studied system, can be seen.
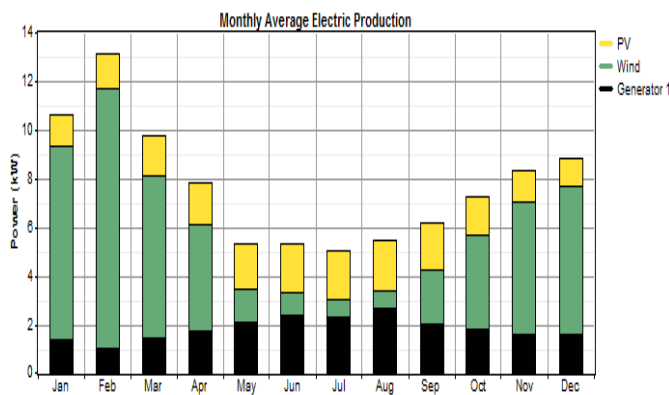


**Fig -11**: Average power produced by each source

Tab.1; Presents the rate of electric power generation for each generator throughout the year.

**Table -1:** Annual Energy produced by each Generator

| Production | Kwh/y | % |
|---|---|---|
| PV | 14.736 | 22 |
| Wind | 36.873 | 54 |
| G.Diesel | 16.076 | 24 |
| Total | 67.685 | 100 |

From Table 1, it can be seen that the production of energy by hybrid system during a full year of operation ensures continuity and availability. It can be seen that more than 70% of energy is produced by renewable energy generators (54% for wind and 22% for photovoltaic panels), which contributes to the reduction of greenhouse effect on our planet. There is a variation in energy production for each generator throughout the year, it appears that the wind generator participates with a great power produced in the autumn and winter season; this power decreases with the decrease in wind speed during spring and summer. However, the photovoltaic generator production increases with evolution of solar irradiance and duration of sunshine. Production of diesel generator develops to meet demand for load and to compensate the discontinuous and random nature of renewable energies. Energy production study for each generator is illustrated as follows.

### 4.1 Photovoltaic Generator

The operating parameters of photovoltaic generator are shown in the following table 2:

**Table -2:** Information about photovoltaic generator

| Variable | Value |
|---|---|
| Operational time | 4.358h/y |
| Average power produced | 1.7kw |
| Maximum power produced | 10.4kwh |
| Total energy production | 14.91kwh/y |

Fig. 12 shows a DMAP presentation of energy production by photovoltaic generator, this type of graph shows one year of hourly data, each hour of year is presented by a color that simulates precise information of a Value of data. This presentation makes it possible to see more clearly the information useful for an easy and concrete interpretation.
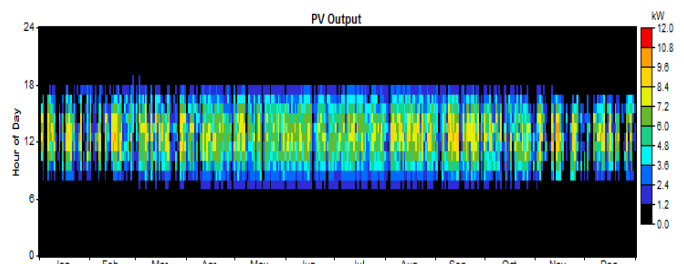


**Fig -12**: DMAP of hourly production by photovoltaic generator

It can be noted that the operating period of photovoltaic generator is limited in winter months between 7 am and 5 pm, and conversely during the summer season, it stabilizes between 6 am and 6 pm. The production of photovoltaic generator is zero in the peak hour at 20:00, which introduces in parallel the operation of other

generators or use of energy stored in batteries to meet the load demand.

## 4.2 Wind Generator

The operating parameters of wind generator are shown in Table 3:

**Table -3:** Information about energy production by wind generator

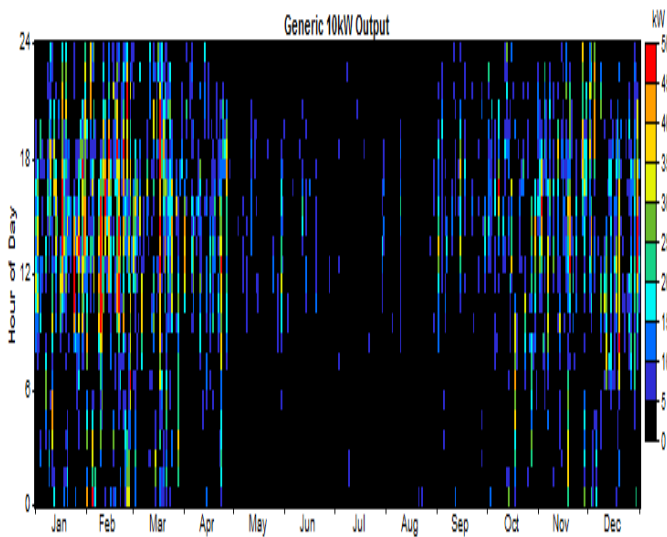| Variable | Value |
|---|---|
| Operational time | 6087h/y |
| Average power produced | 4.2kw |
| Maximum power produced | 48.2kwh |
| Total energy production | 36.873kwh/y |



**Fig -13**: DMAP of hourly production by photovoltaic generator

As shown in Fig. 13, the wind generator runs all day, which is well shown in the DMAP graph. The production of wind energy has benefited from the great values throughout the autumn and winter months, which is well translated by clear colors, unlike the month of spring and summer where the wind speed decreases , Wind production decreases in parallel.

## 4.3 Diesel Generator

The operating parameters of diesel generator are shown in following table

**Table -4:** Information about energy production by diesel generator

| Variable | Value |
|---|---|
| Operational time | 4.308h/y |
| Average power produced | 3.73kw |
| Maximum power produced | 10kwh |

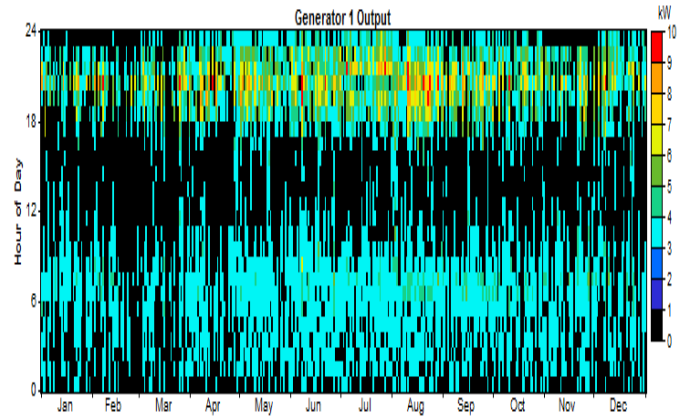| Fuel used annually | 7465L/y |
|---|---|
| Specific use of fuel | 0.464L/kwh |
| Total energy production | 14.91kwh/y |



**Fig -14**: DMAP of hourly production by DG

From Fig.14, diesel generator works as a back-up tool and participates in energy generation when energy generation from renewable energy decreases.

## 5. CONCLUSIONS

Work presented in this paper concerns hybrid systems with multiple sources of electric power, for autonomous operation to reduce greenhouse gas emissions and reduce the high cost of supplying electric power in remote sites, where the extension of conventional power lines is costly. Hybrid systems based on renewable energy seem to be of considerable importance. Our work has therefore focused on the optimization by Homer software of an autonomous hybrid system (photovoltaic-wind-diesel) with an energy storage device. The simulation example is applied to a region of the city of Tamanrasset, the global load data, wind speed, solar radiation and fuel cost are used as entered for the software. The results obtained favor the installation of wind turbines and photovoltaic panels, with the presence of batteries and diesel generator as a perfect solution for the generation of energy in this precise place.

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## BIOGRAPHIES

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