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CHERIF DEBABI &WALID ZOUAGHI

Dedication

To my mother and my father

To all members of the family

To my teacher the Almighty: ***Amhamed DERNOUNI***

To my partner and friend: ***ZOUAGHI WALID***

To all my friends who stood with me in this work

To all my dears

I devote this humble work

CHERIF DEBABI

Dedication

To my mother and my dear father

To my dear brothers

*To my professor: **Amhamed DERNOUNI***

*To my friend: **CHERIF DEBABI***

To all friends and to anyone who helped me from near or far

ZOUAGHI WALID

Table of contents

Chapter II:

Modeling of hybrid system (PV/wind turbine /GD) with HOMER® software

Chapter III: Results and discussion

Table list

Chapter II

Chapter III

Figure list

Chapter I

Chapter II

Chapter III

Symbols

η_{pv}: Instantaneous PV

P_{pv}: Output of the PV

G_t: global irradiance incident (W/m^2)

N: Number of modules

A_{pv}: Area of single module PV

η_r: reference efficiency PV

η_{pc}: efficiency of power tracking the power conditioning efficiency

β_t: Temperature coefficient of effencicy [0.004 to 0.006]

Tc: Temperature PV

T_{cref}: reference temperature

T_a: ambient temperature (°C)

P_W: Output of wind generator

V_{wind}: wind speed

P_{rated}: rated power

V_{cutin}: wind speed at hub height

P_R: the rated electrical power

V_c: the cut-in wind speed

V_R: the rated wind speed

V_F: the cut-off wind speed.

V_{href}: wind speed measured at the reference high H_0 and \alfa is the power law which varies

H: hub height

α_1: Power law exponent which varies with the elevation

C_B: battery bank capacity (Wh)

E_L: the load in (Wh)

S_D: the battery autonomy or storage days

V_B: the battery bank voltage

DOD_{max}: the maximum battery depth of discharge

T_{cf}: the temperature correction factor and ηB is the battery efficiency

η_B: battery efficiency [0.65 to 0.85]

σ: self-discharge of the battery bank

SOC (t): the states of charge of battery bank (Wh)

E_{Gen} (t): is the total energy generated by PV array

E_L (t): is load demand at the time t

H_{inv}: the efficiency of inverter and charge

η_B: efficiency of battery bank [%]

DOD_{max}: the maximum battery depth of discharge

$D_f(t)$: is the hourly fuel consumption of DG [L/h]

P_{Dg}: is the average power per hour of the DG [kW]

P_{Dgr}: is the DG rated power [kW]

α_D , β_D: are the coefficients of the fuel consumption L/h

Abbreviations

PV: Photovoltaic

Wind: Turbine Wind

DG: diesel generator

MW: Megawatt

NASA: National Aeronautics and Space Administration

KW: Kilo Watt

CO_2: Carbon dioxide gas

CO: carbon monoxide

KWh: Kilo watt hour

HA: Horizontal axis

VA: Vertical axis

VAWT: Vertical axis wind turbine

HAWT: Horizontal axis wind turbine

WT: Wind Turbine

DTS: Driver Train System

AC: Alternating current

DC: Direct current

MPP: Maximum power point

MPPT: Maximum power point tracking

LCE: Levelized cost energy

HOMER: Hybrid optimization model for electric renewable

HRES: Hybrid system renewable energy

NREL: National renewable energy laboratory

NPC: Net present cost

COE: Cost of energy

M&O: Maintenance and operating

DZD: Dinar Algerian currency

General introduction

Introduction

Many nations count on fossil fuels to meet most of their energy needs, but reliance on these fuels presents a challenge in the coming future. Fossil fuels are finite resources. Renewable energy resources, such as wind, solar and hydropower, offer clean alternatives to fossil fuels. They produce little or no pollution or greenhouse gases, and they will never run out.

Electricity is today the easiest form of energy to exploit. But before the consumption, it will have to be produced, usually in the electricity generation units of great power, transport it, and then distribute it to every consumer.Which represents a heavy financial burden for the electrification of premises in isolated sites of our country.

Installing power lines over hundreds of kilometers will not solve this problem. This is because of the presence of the stresses due to bad weather, whose wind of sand, the temperature gradients between the different seasons and that between night and day for the winter season. To this end, we thought to get around the problem by another solution namely the hybrid system.

Reliable access to electricity is a basic precondition for improving people's lives in rural areas, for enhanced healthcare, education, and for growth within local economies as well as to meet millennium development goal in Algeria

An important challenge for Algeria to take up is the implementation of health care and educational services in isolated coastal and mountainous regions of the north, high plains and desert regions of the south. Communities living there lack electricity for water sterilization, domestic use, medical services, education and irrigation. These remote areas are not supplied by power lines [1].

In Algeria, rural areas suffer from many problems that hinder the provision of electricity. Among these problems are:

The problem of distance and isolation, where it is difficult to connect electricity to these areas, diesel generator needs, as well as weather problems in these areas throughout the year, the problem of theft electric wiring repeated and air pollution problem.

In remote Algerian's villages, far from the grids, electric energy is usually supplied by diesel generators. In most of this cases, the supply with diesel fuel becomes highly expensive while hybrid/photovoltaic/wind generation becomes competitive with diesel only generation [2], [3] Photovoltaic/wind/diesel hybrid systems are more reliable in producing electricity than photovoltaic only/wind only systems, and often present the best solution for electrifying remote areas. The diesel generator reduces the photovoltaic/wind component while the photovoltaic/wind systems decrease the operating time of the generator, reducing the running costs of the diesel generator [4], the addition of storage reduces the start/ stop cycles of diesel generators thus, considerably reduce the fuel consumption [5] and [6].In order to effectively explain the benefits of Hybrid system . A program called HOMER [7] was used in this study. HOMER is sophisticated software developed by the National Renewable Energy Laboratory for analyzing the economics of small power systems, Which allows us to study the total cost of the hybrid system and the cost of 1KWh for electricity, compared with the classical system, after inputting the solar/wind resources along with the cost of equipment HOMER crunches the numbers to give us the "Optimal System Type" based purely on economics and availability of resources.

of These problems we start our work and scientific studies aimed at eliminating these problems and obstacles in order to facilitate and provide the full needs of these isolated areas, and from these areas we chose the area of Hassi ben Abdellah Ouargla located in the south-east of Algeria, Where we will be using the renewable hybrid energy system (wind turbine and photovoltaic and diesel generator) with battery storage, in an isolated house.

For to study system hybrid, we divided our topic to three chapters as shown below:

- First chapter: Consecrated about generality of hybrid system (photovoltaic & wind turbine and diesel generator) for to get an inclusive idea about components of the system and different tools.
- Second chapter: Modeling of hybrid system and Explain the work of HOMER®, as well as the identification of the study area and the presentation of meteorological data.
- Third chapter: Results and discussion of the simulation of the off-grid house area (Hassi Ben Abdellah) located in Ouargla city.

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[7] HOMER V-2 68 Beta, National Renewable Energy Laboratory (NERL), USA, http://nrel.gov/homer

CHAPTER I

Generality of solar pv and wind turbine systems

I.1 Introduction

As a result of the economic growth and demographic development, Algeria electricity demand is augmenting rapidly and the electric generating capacity has to increase as much as twice in the next decade [1]. With this growth in electric demand and the rapid depletion of fossil fuel, the Algerian government has realized the importance of renewable energies to preserve fossil fuels reserves and bring sustainable solutions to reduce the global climate change, especially greenhouse gas emissions [2]. Algeria has created a green momentum by launching an ambitious program to develop renewable energies and promote energy efficiency. This program leans on a strategy focused on developing and expanding the use of inexhaustible resources, such as solar and wind energies in order to diversify electricity sources [3–4].

I.2 History of wind power

Wind power has been in use since the tenth century for applications of water pumping, and grain grinding. At location, where sufficient wind energy exists, a large scale wind turbines have been installed to produce electricity. In the early 1930s, the Russians built a large windmill with a 100 ft diameter blade, but it had very low power conversion efficiency. Vermouth utility in the 1940s built a very large scale windmill of rated capacity 1.25 MW at a cost of $ 1.25 million. This project was abandoned, after one of its blades broke down due to fatigue failure.

NASA (National Aeronautics and Space Administration) entered into the wind power industry market with a wind power unit of 100 kW capacity at a cost of a million dollars. Concerns on environmental air quality during the 1980s, forced the energy industry for greater use of wind turbines to produce electricity. The design and successful operation of a large scale wind turbines encountered several challenges in reducing their capital costs, and ensuring smooth operations due to lack of constant angular velocity and torque that can produce the A.C power. It was difficult to achieve these features with wind turbines, as the wind blows with various velocities in different directions at a given location. Superior blade design shapes and tower configurations and materials achieved in the early 2000s, enabled rapid growth in wind power installations. At present, the cost of electricity produced from wind turbines is lower than 2.7cents/kWh in locations of high wind potential [5].

I.2.1Wind Energy Systems

Wind energy systems have been subject of research for decades. They consist of wind turbines and electrical generators. The first section covers the basics of VAWT. Initially in this section, aerodynamics of wind turbines is presented.

Subjects like control, dynamic vibration and noise emission in VAWT are covered.

Furthermore, a separate section is dedicated to a comparison between Horizontal Axis Wind Turbines (HAWT) and VAWT.

The role of a wind energy system is to capture mechanical energy in the airflow and convert it to electrical energy. Usually it consists of a wind turbine rotor, for the former purpose, and an electrical machine working as generator for the latter. The variation in the wind speed is one of the factors that affect the specifications of wind energy systems. In other words design of the wind systems components demands special consideration. The amount of accessible mechanical energy depends on the size of the wind turbine and the wind regime of the site [6].

I.2.2 Definition of wind energy

The wind turbine falls into the category of renewable energy receivers, which are eager to convert the kinetic energy of the wind into mechanical energy, they are generally used to produce electricity [7].

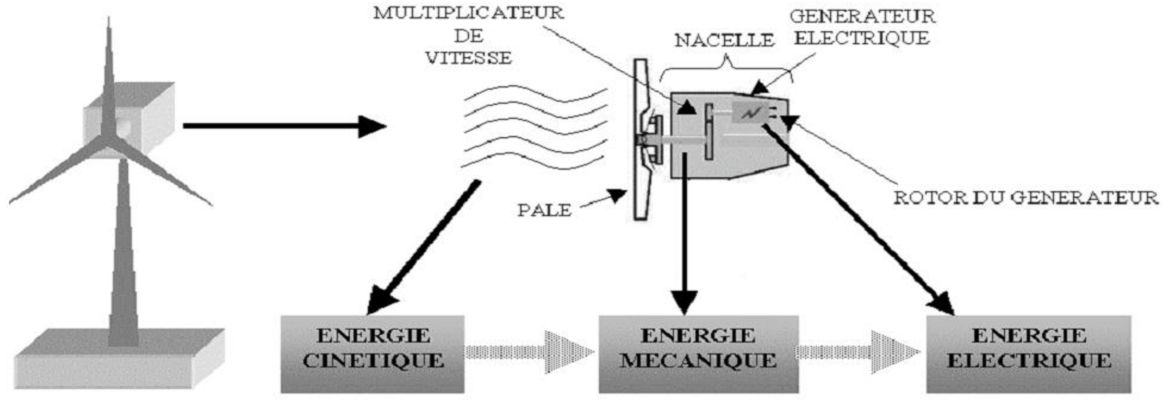

Figure I. 1: Transform the kinetic energy of the wind [7]

I.2.3 The typical wind turbine (Principle)

Wind turbines transform kinetic energy in the wind to electricity. Almost all commercial wind turbines are 'horizontal axis' machines with rotors using 2 or 3 airfoil blades. The rotor blades are fixed to a hub attached to a main shaft, which turnsa generator – normally with transmission through a gearbox. Shaft, generator, gearbox, bearings, mechanical brakes and the associated equipment are located inside the nacelle on top of the tower, see Figure I.2. The nacelle also supports and transfers structural loads to the tower, together with which it houses all automatic controls and electric power equipment.

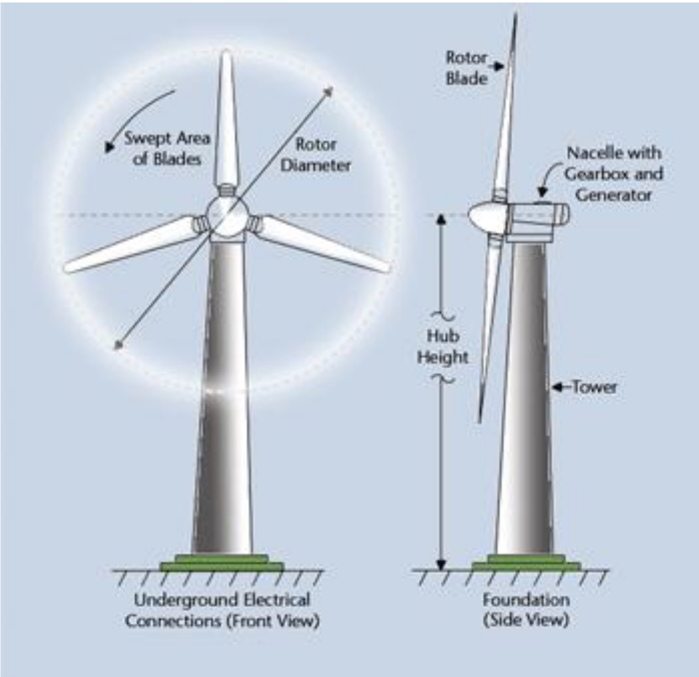

Figure I. 2: A sketch of a modern wind turbine

I.2.4 Different types of wind turbines

Wind turbines are divided into two large families: those with vertical axis and those with axis Horizontal [8]:

I.2.4.1 Vertical axis wind turbines

Although vertical axis wind turbines have existed for centuries, they are not as common as their horizontal counterparts. The main reason for this is that they do not take advantage of the higher wind speeds at higher elevations above the ground as well as horizontal axis turbines [9].

Figure I. 3: Vertical axis wind turbine (VAWT)

I.2.4.2 Wind turbines with horizontal axis

Horizontal axis wind turbines are based on the ancestral technology of windmills. They consist of several blades profiled aerodynamically in the manner of airplane wings. In this case, the lift, which is used in aeronautics to maintain an aircraft in flight, is used to generate a torque driving the rotation of the wind turbine. The number of blades used for the production of electricity typically varies between 1 and 3, the three-blade rotor being the most used because it is a compromise between the power coefficient, the cost and the speed of rotation of the wind sensor[10].

Figure I. 4: Horizontal axis wind turbines (HAWT)

I.2.5 Different parts of wind turbine

A wind turbine is composed by different elements; the main elements are listed in the (FigureI.5) and described in the following list [11]:

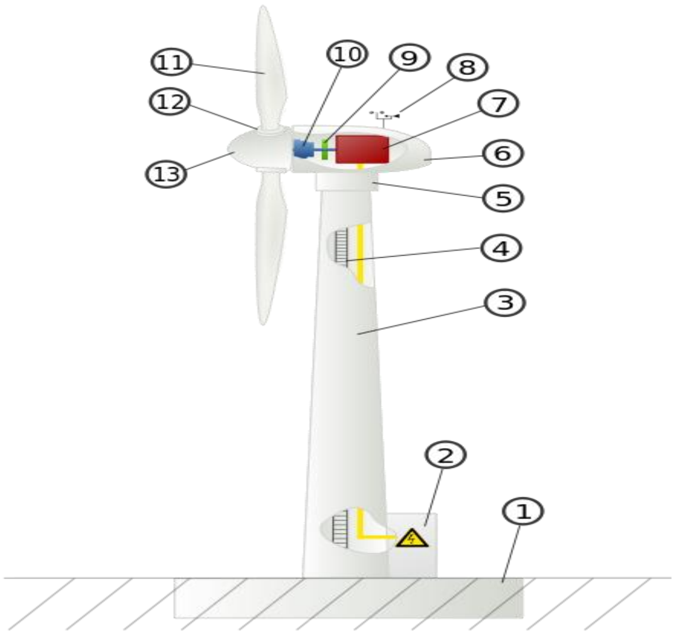

Figure I. 5: Different elements of wind Turbine

• Foundation (1): Transfers the vertical and horizontal loads to the ground; the configuration changes if the WT is placed onshore or offshore.

• Grid connection (2): In order to reduce electric losses, a transformer converts the medium voltage from the wind turbine generator to high voltage. The WT is not always connected to the grid, the WT is connected once the generator reaches the synchronous speed, and in other words, when the generator matches the grid frequency.

• Tower (3): Usually manufactured from steel or concrete. It consists of different sections bolted to each other. The tower has a ladder (4) inside or a lift to permit service and maintenance access to the top of the WT.

• Yaw control (5): Controls the turbine direction to always be on the direction of the wind.

• Nacelle (6): The housing of all the elements of the upper part of the WT. The main role of the nacelle is to protect the internal components of the WT against the environment. The nacelle is connected to the tower by the yaw assembly. There are heaters/coolers fans inside the nacelle to control the temperature. To facilitate the access of operators to bigger WT, the nacelle may include a helicopter-platform.

- Generator (7): The part of the WT that transform the mechanical energy to electrical energy.

It is placed at the top of the tower, inside the nacelle.

- Anemometer (8): To measure the wind speed, used for control systems.
- Mechanical brake (9): part of the drive train system.
- Drive train system (10):it is the part that transfers the energy from the rotor to the generator.
- There are mainly three types of drive train system: geared, direct-drive and hybrid.
- Blade (11): The part of the WT that converts the wind kinetic energy to a rotation of the rotor hub.
- Rotor hub (13): it connects the blades to the main shaft. It also contains the mechanism to control the pitch of the blades (12). The blade pitch control turns the blades to change the angle of attack with the goal of changing the rotation speed of the rotor.

I.2.6 The Betz limit on wind turbine efficiency

A German physicist Albert Betz concluded, no wind turbine can convert more than 16/27=(59%) of the kinetic energy of the wind into mechanical energy turning a rotor.

The theoretical maximum power efficiency of any design of wind turbine is 0.59. (I.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine.) This is called “Maximum Power Coefficient: Cpmax = 0.59”

$$P_{wind\ turbine} = \frac{1}{2} \rho C_p A V^3 \qquad (I.1)$$

In practice, wind turbine rotors deliver much less than the Betz limit. The efficiency of a turbine depends on different factors such as the turbine rotor, transmission train and the electrical generator. Normally the commercial turbine rotors have aerodynamic efficiencies in real conditions (power coefficients) which vary from 30% to 50%.

Gearbox and generator efficiencies can be estimated to be around 80% to 95% depending on size and quality of production.

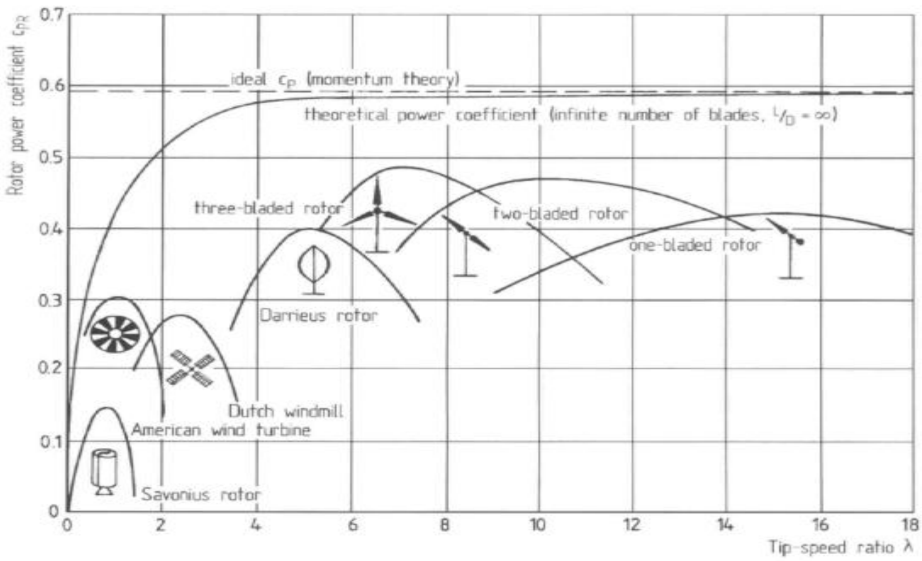

Figure I. 6: Wind turbine efficiency or power coefficient

I.2.7 Mechanical regulation of the power of a wind turbine

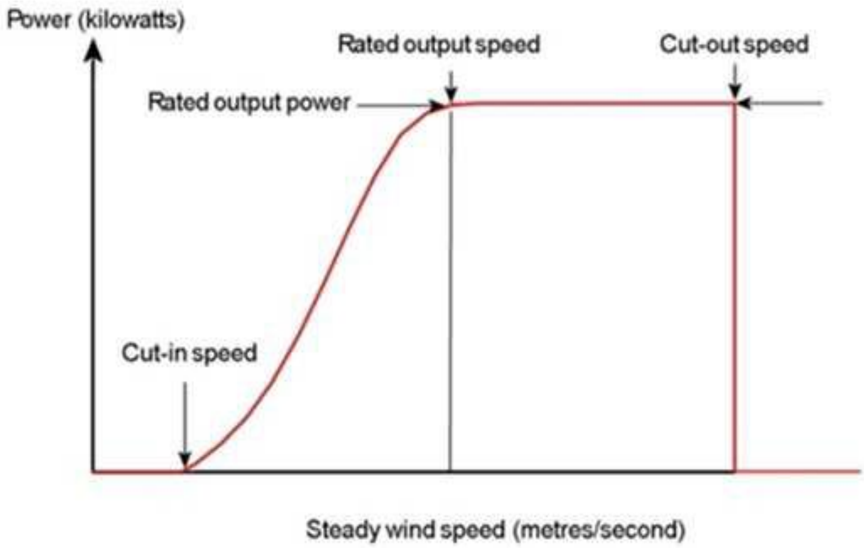

Figure I. 7: Typical wind turbine power output with steady wind speed

A. Cut-in speed

At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate. However, as the speed increases, the wind turbine will begin to rotate and generate electrical power. The speed at which the turbine first starts to rotate and generate power is called the cut-in speed and is typically between 2 and 4 m/s.

B. Rated output power and rate output wind speed

As the wind speed rises above the cut-in speed, the level of electrical output power rises rapidly as shown. However, typically somewhere between 12 and 17 m/s, the power output reaches the limit that the electrical generator is capable. This limit to the generator output is called the rated power output and the wind speed at which it is reached is called the rated output wind speed. At higher wind speeds, the design of the turbine is arranged to limit the power to this maximum level and there is no further rise in the output power. How this is done varies from design to design but typically with large turbines, it is done by adjusting the blade angles so as to keep the power at the constant level.

C. Cut-out speed

As the speed increases above the rate output wind speed, the forces on the turbine structure continue to rise at some point, there is a risk of damage to the rotor. This is called the cut-out speed and is usually around 25 m/s.

I.3 History of Photovoltaic

Apart from wind energy, solar energy is also abundantly available on Earth. The solar energy falling on Earth in a year is ten thousand times more than the existing fuel sources available on Earth. The elements such as silicon, germanium etc. used in making the PV cell is also copiously available on Earth. The PV cells can be classified as pollution-free as they do not produce any by-products that may contribute towards air/water pollution and also do not contain any moving parts that may cause noise pollution. The first PV cell introduced to the world was described in a paper dated back in 1877 [12]. In 1883, Charles [12] constructed a selenium solar cell, which was as popular as the silicon PV cell used today. During the early days, the efficiency of a solar cell, which is defined as the percentage of the solar energy falling on the surface of the PV cell, which was converted into electricity, was almost 1%.

During the first half of the twentieth century, the Chaplin-Fuller-Pearson team [13] developed a new PV cell made up of semiconductors. In the early 1950s, they utilized silicon slices in producing the PV cells and they succeeded in getting the efficiency up to6%. After further research, the efficiency of the current PV cells available in the market went up to 17%.

I.3.1 Photovoltaic Power Generation

Photovoltaic power system is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. PV power generation uses solar panels comprising a number of cells containing a semiconducting material. As long as light is shining on the solar cells, it generates electric power. When the light stops, the electricity stops [14].

I.3.2 Crystalline silicon cells

Since crystalline solar cells, i.e. mono and poly crystalline cells, currently dominate the terrestrial market other types such as thin film cells will not be revised in this report.

Crystalline silicon cells are built up using layers of silicon doped with either phosphorus or boron.

Adding various elements in the process of manufacturing will alter the cells properties. Adding boron creates a positively charged layer, which corresponds to missing electrons in the crystal lattice i.e. holes. Whereas phosphorus creates a negative layer i.e. having extra electrons fitted into the lattice.

These holes and electrons are usually referred to as electron-hole-pairs. It is these that constitute the majority of current produced from a silicon cell. The two doped silicon layers are then fused together with the positive layer on top. This creates a depleted region in the interface where holes and electrons diffuse onto their corresponding side. Thus setting up an electric field i.e. barrier which prevents further flow of electrons. The barrier is referred to as a P-N-junction which has resemblance of a diode, i.e. conducting current easily in one direction and heavily opposing current traveling the opposite direction. The P-N junction is the most important component of the photovoltaic cell. Since it ensures that the generated current travels in one direction i.e. forcing the current through the load as opposed to being able to travel in any direction.

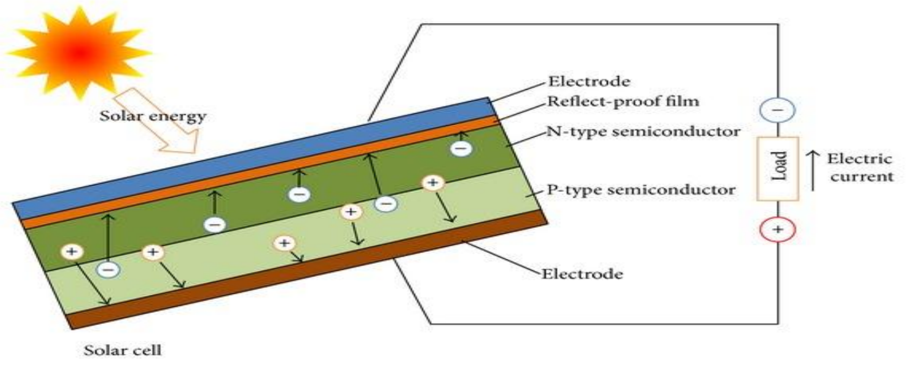

Figure I. 8: P-N-junction, Cell components and current movement

However, in order to make the cell conduct current a crossover voltage has to be applied. For silicon diodes the crossover voltage is usually around 0.6 Volts. Furthermore adding a contact in the front and back enables for the solar cell to collect electrons crossing the barrier.

Conversely, when light is shone onto the solar cell not all of the light is converted into current. A minimum energy, known as band-gap, is required in order to excite the electrons sufficiently enough to pass the barrier. As such diffuse and albedo light has a lower probability in producing electricity, since they are less energetic than direct light. Meanwhile, the light containing more energy than required will dissipate as heat, consequently lowering the performance due to increase in losses.

With the prior knowledge of how the crystalline cell are able to harness the suns energy. An equivalent circuit of photovoltaic cells can be represented by a diode, current generator and a resistor in parallel with an additional resistor in series as shown in Figure I.9.

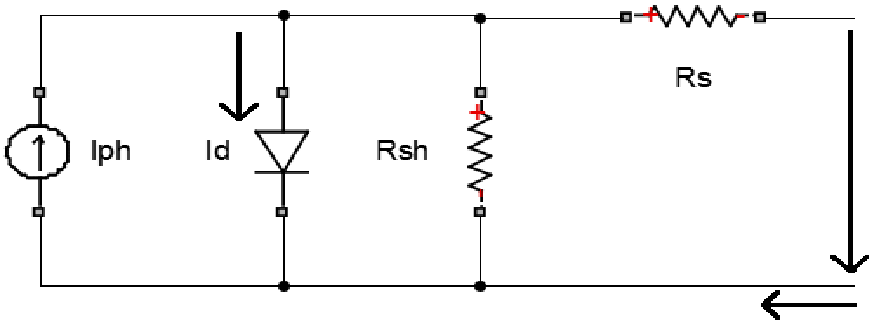

Figure I. 9: Equivalent circuit of a Photovoltaic cell

Rsh is the shunt resistance that compensate for leaking currents in the diode, *Rs* is the series resistance that correspond e.g. resistance in contacts. Iph represents the current generated when exposed to sunlight. The current going through the junction is denoted *Id* and is calculated through the formula:

$$Id = Io\,(e^{qV} / kT) - 1) \qquad (I.2)$$

Where *Io is* the reverse saturation current of the diode, *q* the charge of an electron, *V* the open circuit voltage, *K* the Boltzmann constant and *T* temperature. Hence, by applying Kirchhoff's law the output current, *I* is calculated through the formula below:

$$I = Iph - Id \qquad (I.3)$$

In addition the current I is almost directly proportional to the insolation which is shown in figure 13below, as the voltage is close to fixed for when insolation varies [15].

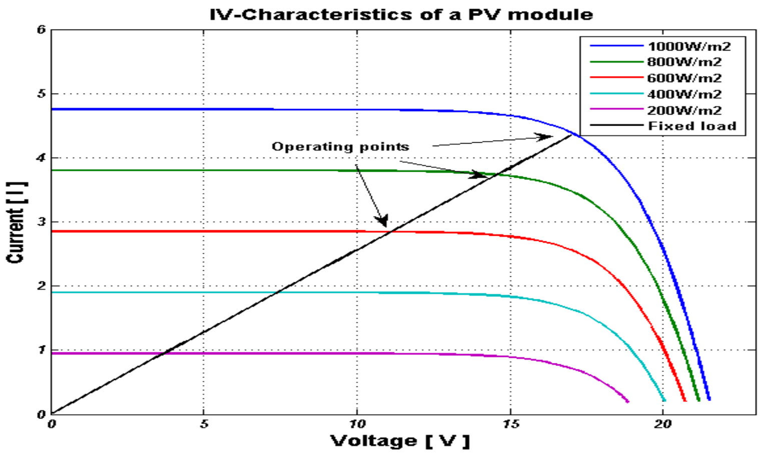

Figure I. 10: I-V characteristics of different levels of insolation

I.3.3 Performance

The silicon solar cell has a theoretical efficiency of about 45 %. However typical efficiencies range from 11-16% depending on type, i.e. mono or poly crystalline. The low efficiency is an intricate matter and is linked to quantum physics and the spectral distribution of sunlight.

As stated in previous sections the sunlight emits wavelengths ranging from ultraviolet to infrared. Consequently the energy required, i.e. bandgap, to make the jump may sometimes be redundant, while other times not. As such, excess energy will dissipate as heat which has a negative effect on the cell. If the cells temperature increases the performance is lower.

In order to for the cell to operate efficiently, the recommend band gap for the suns energy is between 1.0-1.6eV with the silicon cell having 1.1eV.

Furthermore, a single silicon cell is seldom applicable for powering any large loads due to the voltage level being too low. Connecting cells in series however raise the voltage meanwhile the current remains roughly the same, whereas in parallel coupling the relationship is reversed.

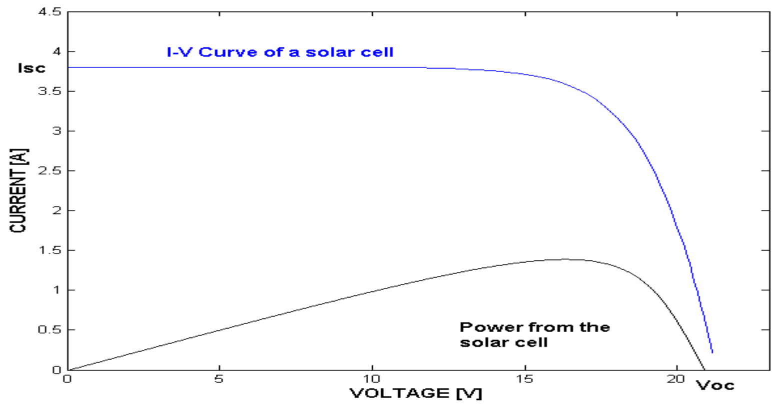

Figure I. 11: Typical I-V & P-V curve of a photovoltaic cell

As seen in figure I.11 above, the current level is somewhat constant over the majority part of voltage levels. Consequently, the power generated from the cells is almost entirely dependent on the insolation, i.e. P ≈ I. Moreover, the maximum extractable power from the cell is found through the formula:

$$Pmpp = Vmpp*Impp \quad (I.4)$$

Where Vm and Im corresponds to the point on the curve where the power output is at its maximum, i.e. where the product between Vm and Im are at its maximum. In addition, for every level of isolation there is a corresponding MPP i.e. the values of Vm and Im will change depending on isolation, depicted in (figure I.12) below.

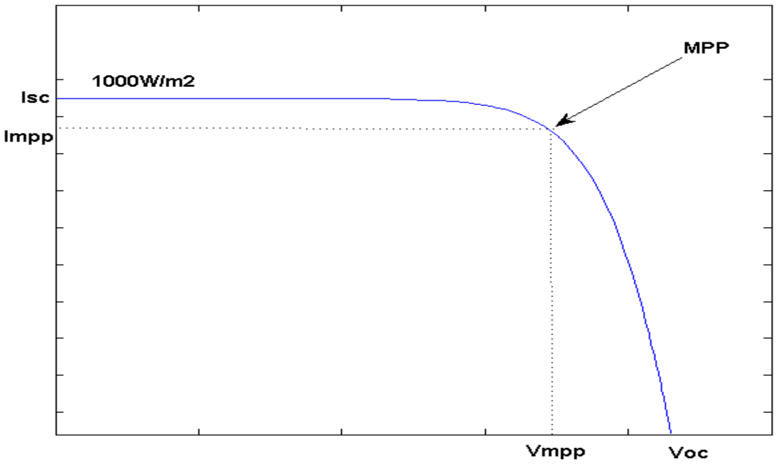

Figure I. 12: I-V characteristics of different levels of insolation

However, when connecting a load to the cell, or module, the MPP is not always obtained, as can be seen in figure I.12 for insolation levels below 1000W/m2. The reason for this is due to the load having an I-V-characteristic of its own. Thus, when connecting a load to the photovoltaic cell the voltage and current of the circuit changes. The new voltage and current for the circuit, i.e. cell and load, is decided upon were the I-V characteristics of the cell and load intersect, and is referred to as operating point.

Consequently, if the operating point is not situated at the MPP the full capacity of the cell is not obtained. Though, attaining the MPP can be through impedance matching, i.e. matching the resistance of the load with the cells inner resistance. Accordingly, a measurement of how the cell is performing might be of interest, and can be done through the formula:

$$FF = (Vm)/(VocIsc) \quad (I.5)$$

Where FF is a unit less factor that indicates how much of the cells potential energy is being used [15].

I.3.4 PV module and array

The solar cell is the basic building block of the PV power system. However it rarely used individually because it is not able to supply an electronic device with enough voltage and power. For this reason, many photovoltaic cells are connected in parallel or in series in order to achieve as higher voltage and power output as possible. Cells connected in series increases the voltage output while cells connected in parallel increase the current. The solar array or panel is a group of several modules electrically connected in series-parallel combination to generate required current and voltage and hence the power [14].

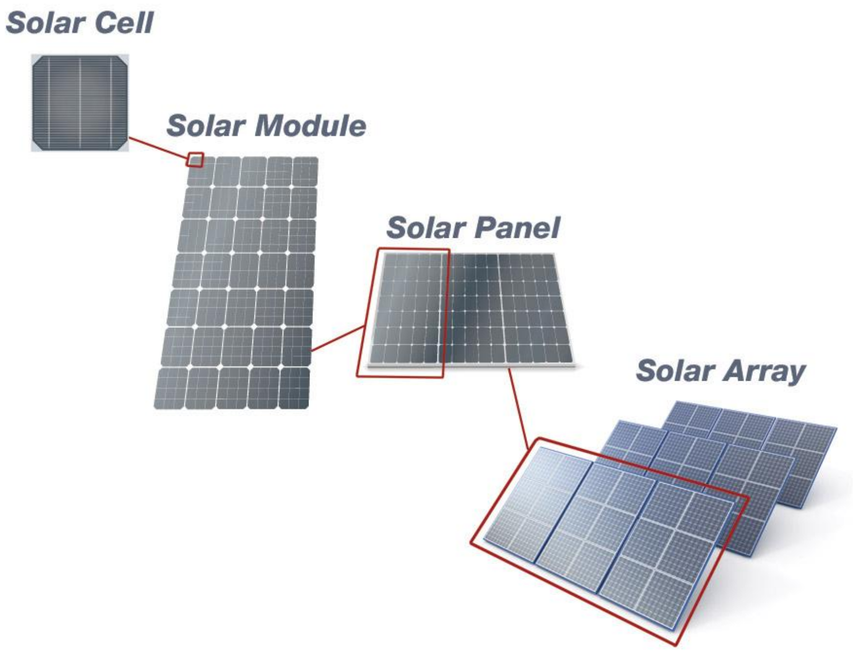

Figure I. 13: Photovoltaic array modules

I.4 Converter

The use of a DC-DC converter in solar and wind energy inverters is nowadays a preferred topology for control and enabling for MPP tracking. Though the converter is actually nothing more than a transformer for DC circuits i.e. it converts input voltage and current into the desired output voltage and current.

The converter has two modes; Buck and Boost. Boost refers to the case where the output voltage is higher than the input i.e. stepping up the voltage level. Consequently the buck mode is referred to the opposite case i.e. step down. Moreover since the converter is the equivalent of what transformers are for AC power, the energy put into the circuit is conserved: raising the output voltage reduces the output current, and vice versa. However, losses are inevitable during operation, i.e. switching, with typical efficiencies ranging from 85-95%. In addition, the DC-DC converter also has the ability in raising the output voltage to sufficient levels, enough for the inverter to start delivering power the load. Subsequently increasing the time when energy is produced [13].

I.5 Inverter

Inverters are used to transform DC current into AC currents.In the photovoltaics industry, we are going to take in our study about standalone inverter. Inverter is meant to operate isolated from the electrical distribution network and require batteries for proper operation. The batteries provide a constant voltage source at DC input of the inverter. Inverters can be classified briefly as:

- Square wave inverters
- Modified since wave Inverter
- Since wave inverter (quasi-sine wave)

Voltage and current waveforms produced by inverters are never perfect sinusoids (even for sine wave inverters); therefore some harmonic currents are expected during normal system operation. Total harmonic distortion is a measure of the harmonic content in current and voltage waveform. The type of inverter used will depend on the load that it will serve.

Resistive loads could tolerate square wave inverters that are able to produce almost perfect sinusoidal voltage and current waveforms in order to operate correctly. These tend to be more expensive and difficult to design. The designer should choose inverters according to load type and power requirement. Modern standalone inverters have software application embedded that monitor and control equipment operation.

I.6 Maximum Power Point Tracking (MPPT)

Maximum power point tracing (MPPT) system is an electronic control system that can be able to coerce the maximum power from a PV system. It does not involve a single mechanical component that results in the movement of the modules changing their direction and make them face straight towards the sun. MPPT control system is a completely electronic system which can deliver maximum allowable power by varying the operating point of the modules electrically [16].

I.6.1 Necessity of Maximum Power Point Tracking

In the Power Vs Voltage characteristic of a PV module shown in Figure I.12 we can observe that there exist single maxima i.e. a maximum power point associated with a specific voltage and current those are supplied. The overall efficiency of a module is very low around 12%. So it is necessary to operate it at the crest power point so that the maximum power can be provided to the load irrespective of continuously changing environmental conditions. This increased power makes it better for the use of the solar PV module. A DC/DC converter which is placed next to the PV module extracts maximum power by matching the impedance of the circuit to the impedance of the PV module and transfers it to the load. Impedance matching can be done by varying the duty cycle of the switching elements [17].

I.7 Storage system

I.7.1 Types of accumulators

Electrochemical accumulators, or batteries, are electrochemical devices that store energy in chemical form. They are used to store excess energy for later use. Among the types of accumulators, we have [18,19]:

- Lead batteries
- Nickel-cadmium accumulators (NiCd)
- Nickel Metal Hydride (NiMH) Accumulators
- Lithium accumulators

I.7.2 Main features of accumulators

A.1 Voltage

This is the electromotive force of the accumulator, a function of electrochemical couple used. A battery consists of basic elements with a nominal voltage of 2V (actually between 1: 9V and 2: 1V depending on the state of the load). There is of course 6, 12 or 24V batteries [18].

A.2 Charge voltage

This is the minimum voltage to apply for recharging effectively the accumulator; it is expressed in volts [18].

A.3 Battery capacity

Capacity is the amount of electricity that can be stored an accumulator (or a capacitor). This is the product of the time needed to completely discharge the element at a given intensity [18]. For historical reasons, it is expressed in ampere-hour (Ah) and sometimes in watt-hour (Wh).

A.4 Life time

The life of a battery is counted by number of cycles. acycle corresponding to a complete discharge and recharging of the battery [18].

I.8 diesel generator

Generators consist of an engine driving an electric generator. Generators run on a variety of fuels, including diesel, gasoline, propane and bio-fuel. Generators have the advantage of providing power on demand without the need for batteries. Compared to wind turbines and PV panels, generators have low capital costs but high operating costs.

I.9 Conclusion

This chapter has allowed us to give an overview of the hybrid energy system which combines three power electric generation systems (PV/Wind/DG), where the system can be a reliable solution to generate electricity in the remote area to be studied.

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CHAPTER II

Modeling of hybrid system (PV/wind turbine /DG) with HOMER® software

II. 1 Introduction

The area of Hassi Ben Abdellah in the state of Ouargla, climatic conditions, including solar irradiance, wind speed, temperature, and so forth, are always changing. Thus, there exist instability shortcomings for electric power production from photovoltaic (PV) modules, wind turbines and diesel generator.

In order to efficiently and economically utilize renewable energy resources of wind and solar energy applications, the optimum match design sizing is very important for solar-wind power generation systems with battery banks.

II.2 modeling of hybrid renewable energy system components

Different modeling techniques are developed by researchers to model components of HRES. Performance of individual component is either modeled by deterministic or probabilistic approaches. General methodology for modeling HRES components like PV, wind, diesel generator, and battery is described below [1]:

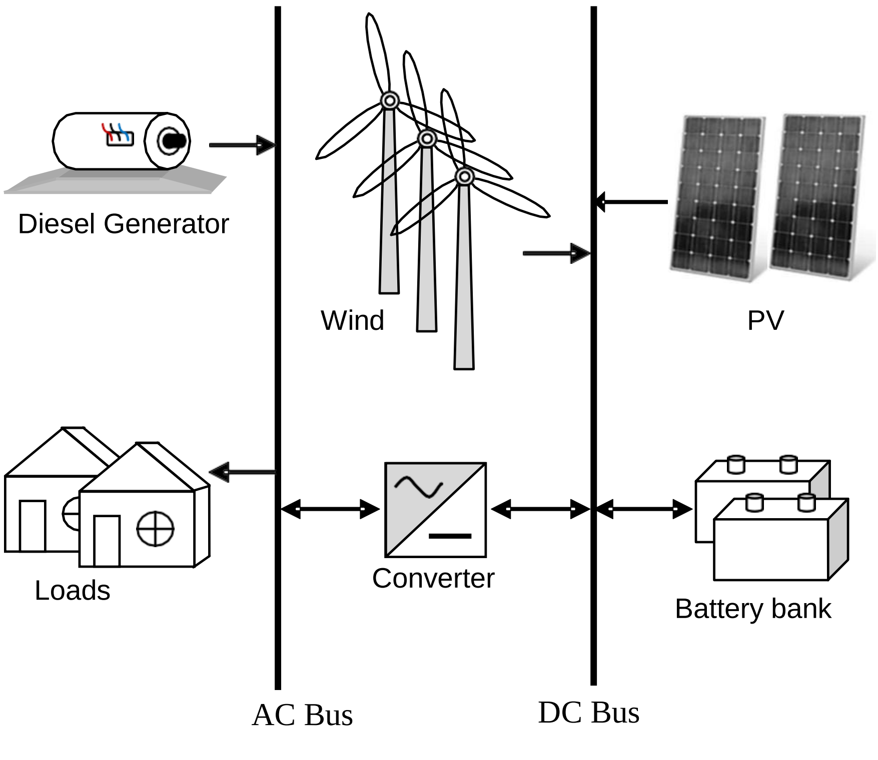

Figure II. 1: Configuration of system hybrid

Hybrid solar-wind-diesel power generation system coupled to battery bank consists of a PV module, a wind turbine, a diesel generator, a solar regulator a battery bank, and an inverter. A schematic diagram of the basic hybrid system is shown in Figure II.1. The PV module and the wind turbine work together to meet the load demand. When the renewable energy sources are sufficient, the generated power, after meeting the load demand, provides energy to the battery bank up to its full charge. The battery supplies energy demand to help the system to cover the load requirements, when energy from PV modules and wind turbine is inferior to the load demand. The load will be supplied by diesel generators whether power generation by both wind turbine and PV array is insufficient and the storage is depleted.

II.3 Hybrid PV/wind/Diesel System model

II.3.1 PV generator model

The hourly output power of the PV generator with an area A_{pv} (m^2) at a solar radiation on tilted plane module G_t (W/m^2) is given by [2]:

$$P_{pv}=\eta_{pv}.\, A_{pv}\, .G_t \tag{II.1}$$

Where η_{pv} represents the PV generator efficiency and is given by [3, 4]:

$$\eta_{pv} = \eta_r\, .\eta_{pc}\, .\, (1 - \beta\, (T_c - T_{cref})) \tag{II.2}$$

Where η_r is the reference module efficiency, η_{pc} is the power conditioning efficiency which is equal to 1 if a perfect maximum power tracker (MPPT) is used. β is the generator efficiency temperature coefficient, it is assumed to be a constant and for silicon cells the range of β is 0.004–0.006 per (°C), T_{cref} is the reference cell temperature (°C) and T_c is the cell temperature (°C) and can be calculated as follows [5]:

$$T_c = T_a + ((NOCT-20) / 800).G_t \tag{II.3}$$

Where T_a is the ambient temperature (C°) and NOCT is the nominal cell operating temperature (C°).η_{pc} β, NOCT and A_{pv}, are parameters that depend upon the type of module used. The data are obtained from the PV module manufacturers.

II.3.2 Wind turbine system model

The wind speed distribution for selected sites as well as the power output characteristic of the chosen wind turbine is the factors that have to be considered to determine the wind energy conversion system power output. Choosing a suitable model is very important for wind turbine power output simulations. The most simplified model to simulate the power output of a wind turbine [6] can be described by:

$$P_W(V) = \begin{cases} P_R \{(V^2 - V_c^2) / (V_R^2 - V_C^2)\} & V_C \leq V \leq V_R \\ P_R & V_C \leq V \leq V_R \\ & \text{Otherwise} \end{cases} \tag{II.4}$$

Where P_R is the rated electrical power; V_R is the cut-in wind speed; V_R the rated wind speed; and V_F is the cut-off wind speed. In this study, the adjustment of the wind profile for height is taken into account by using the power law that has been recognized as a useful tool to model the vertical profile of wind speed. The equation can be described by [7, 8]:

$$\frac{V(H)}{V(H_{ref})} = \left(\frac{H}{H_{ref}}\right)^{\alpha} \tag{II.5}$$

Where V (H) is the wind speed at hub height H, m/s; V (H_{ref}) is the wind speed measured at the reference height H_{ref}, m/s; α is the power law exponent. The determination of α becomes very important. The value of 1/7 is usually taken when there is no specific site data.

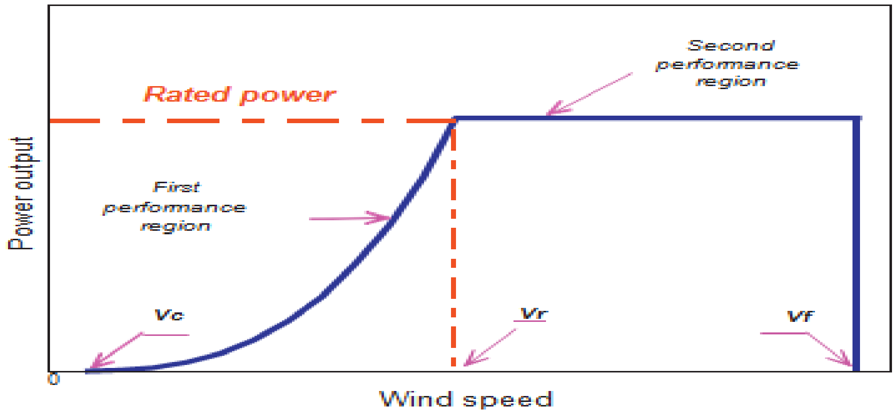

Figure II. 2: Power wind speed characteristic

II.3.3 Battery Bank Model

Battery bank storage is sized to meet the load demand during non-availability period of renewable energy source, commonly referred to as days of autonomy. Normally the number of days of autonomy is taken to be 2 or 3 days.

Battery sizing depends on factors such as maximum depth of discharge, temperature correction, rated battery capacity and battery life. The total capacity of the battery bank that is to be employed to meet the load is determined using the following expression [9].

$$C_B = \frac{E_L \cdot S_D}{V_B\,(DOD)_{max}\,T_{cf} \cdot \eta_B} \qquad \text{(II.6)}$$

Where E_L is the load in Wh; S_D is the battery autonomy or storage days; V_B is the battery bank voltage; DOD_{max} is the maximum battery depth of discharge; T_{cf} is the temperature correction factor and η_B is the battery efficiency.

Depending on the PV and Wind energy production and the load power requirements, the state of charge of battery can be calculated from the following equations:

- **Battery charging**

$$SOC(t) = SOC(t-1)\times(1-\sigma)+(E_{gen}(t)-E_L(t)/\eta_{inv})\times\eta_B \qquad \text{(II.7)}$$

- **Battery dicharging**

$$SOC(t) = SOC(t-1)\times(1-\sigma)+(E_L(t)/\eta_{inv}-E_{gen}(t)) \qquad (II.8)$$

Where SOC (t) and SOC (t - 1) are the states of charge of battery bank (Wh) at the time t and t - 1 , respectively; σ is hourly self-discharge rate; E_{Gen} (t) is the total energy generated by PV array and wind generators after energy loss of controller; E_L (t) is load demand at the time t ; η_{inv} and η_B are the efficiency of inverter and charge efficiency of battery bank, respectively. At any time t, the charged quantity of the battery bank is subject to the following two constraints:

$$SOC_{min} \leq SOC(t) \leq SOC_{max} \qquad (II.9)$$

The maximum charge quantity of battery bank SOC_{max} takes the value of nominal capacity of battery bank C_B, and the minimum charge quantity of battery bank SOC_{min} is determined by the maximum depth of discharge DOD:

SOC_{min}= (1-DOD).C_B. According to the specifications from the manufacturers, the battery's lifetime can be prolonged to the maximum if DOD takes the value of 30–50%. In this paper, the DOD takes the value of 50 %.

II.3.4 Diesel Generator Model

DG is the conventional source of energy which is used as a backup to supply the power deficiency in HRES. The hourly fuel consumption of DG is assessed using the following equation [10]:

$$D_F(t) = \alpha_D P_{Dg}(t) + \beta_D P_{Dgr} \qquad (II.10)$$

where, $D_f(t)$ is the hourly fuel consumption of DG in L/h, P_{Dg} is the average power per hour of the DG, kW, P_{Dgr} is the DG rated power, kW, α_D and β_D are the coefficients of the fuel consumption curve, L/kWh, these coefficients have been considered as 0.246 and 0.08145, respectively [11].

II.4 Site and data description

The houses located in the isolated areas are electrified by solar energy, wind power, diesel generator an economical alternative and climate of the region Ouargla:

The solar potential of Ouargla region is one of the highest in the world. The annual sunshine duration reaches 3900 hrs in the Sahara. The received energy is 2.65 kWh/m²/year in the Sahara. The wind is characterized by a moderated speed (2 to 6 m/s). The wind chart of Algeria, (Figure II.4), is provided by [12].

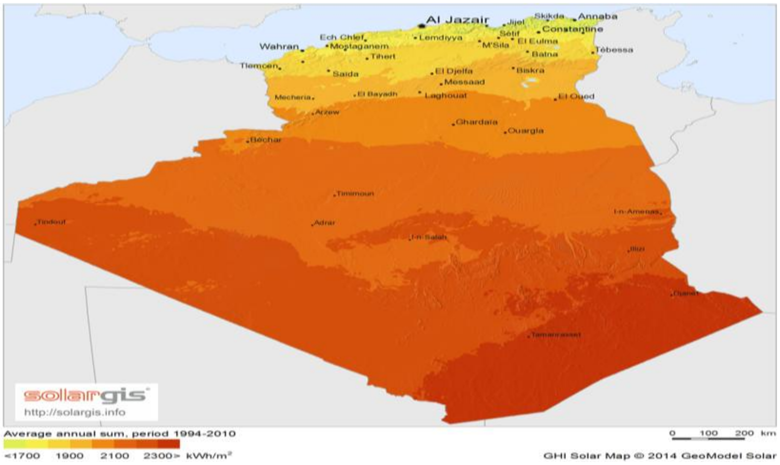

Figure II. 3: Algeria solar radiation Kw/m2/h [13]

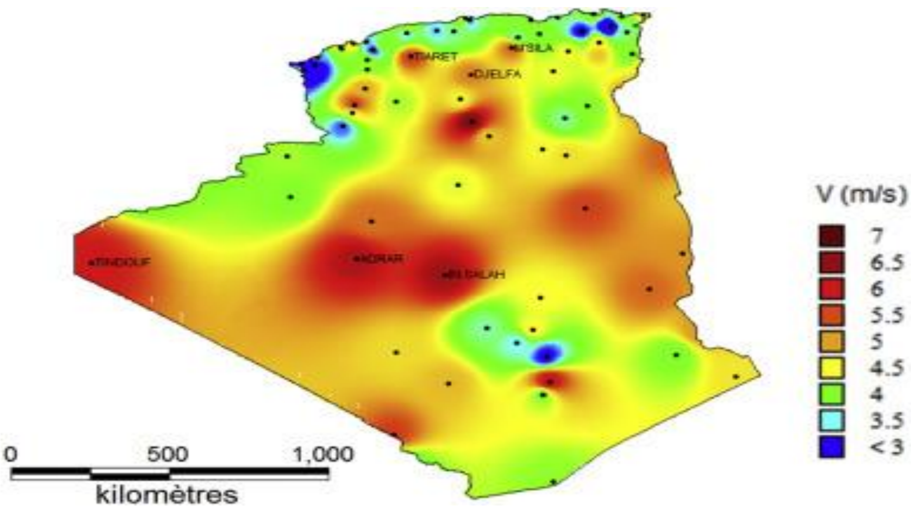

Figure II. 4: Algeria wind energy potential (m/s)

Hassi Ben Abdellah (Ouargla) Oasis are used as the wind-solar energy resource at (32°1.5'N, 5°28.1'E)

Figure II. 5: Location of Hassi Ben Abdellah (Ouargla) by satellite

II.5 Load profile

An important consideration of any power generating system is the load requirements and characteristics, not only for load itself but also for the efficiency and reliability of power transmission. The load factor for the project is important in the design process. The project team is usually distributed strategically.

Figure II.6shows the average daily load rate over a 24 hour program which consists of the PV/WT/DG and battery storage system is displayed in the hybrid system chart in Figure II.8 simulated studies using real weather data (solar radiation and wind speed) Hassi Ben Abdellah area in the state of Ouargla, The home requires electricity to provide lighting, cooling and operation of many household appliances such as TV LCD, Washing machine, Electric Oven, Mobile Phone Charge, Smoothing iron, Computer, Radio-Alarm clock and Water pump The total load demand of this house approximately is 34000 watt hour per day

Table II. 1: Details of consumption daily profile [20]

Time	**Refrigeration**	**Washing machine**	**Electric Oven**	**TV LCD**	**Economic lighting**	**Mobile phone charger**	**smoothing iron**	**Computer**	**Air conditioner**	**Alarm clock**	**Water pomp**	**(wh/day)**
00:00	200				12	5			500	6		723
01:00	200				12	5			500	6		723
02:00	200				12	5			500	6		723
03:00	200				12	5			500	6		723
04:00	200				12	5			500	6		723
05:00	200				12	5			500	6		723
06:00	200								500	6		1076
07:00	350		2000							6		2726
08:00	350									6	370	726
09:00	350							80		6	370	436
10:00	350	3000						80		6	370	3436
11:00	350	3000		250						6		3606
12:00	350		2000	250						6		2606
13:00	350								500	6		856
14:00	350								500	6		856
15:00	350								500	6		856
16:00	350								500	6		856
17:00	350						1100	80		6		1536
18:00	350					5				6		731
19:00	350		2000		60	5				6		2791
20:00	350		2000	250	60				500	6	370	3536
21:00	200			250	60				500	6		1016
22:00	200			250	60	5		80	500	6		1101
23:00	200				60	5			500	6		771
Total load AC (Wh/day)												33856

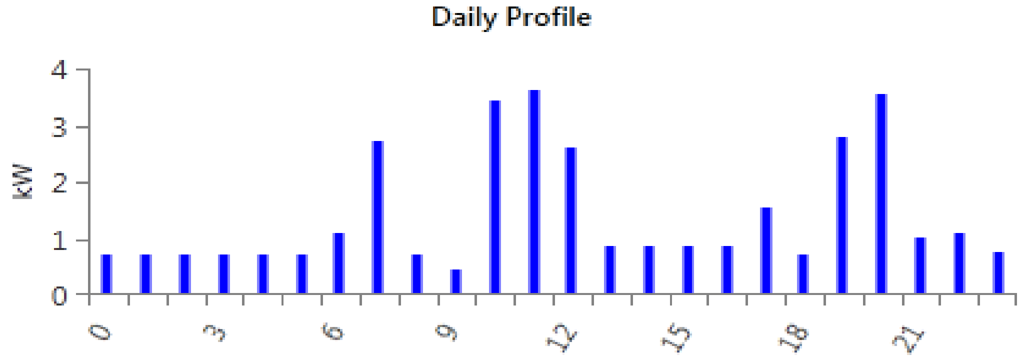

Figure II. 6: Daily load profile of the house

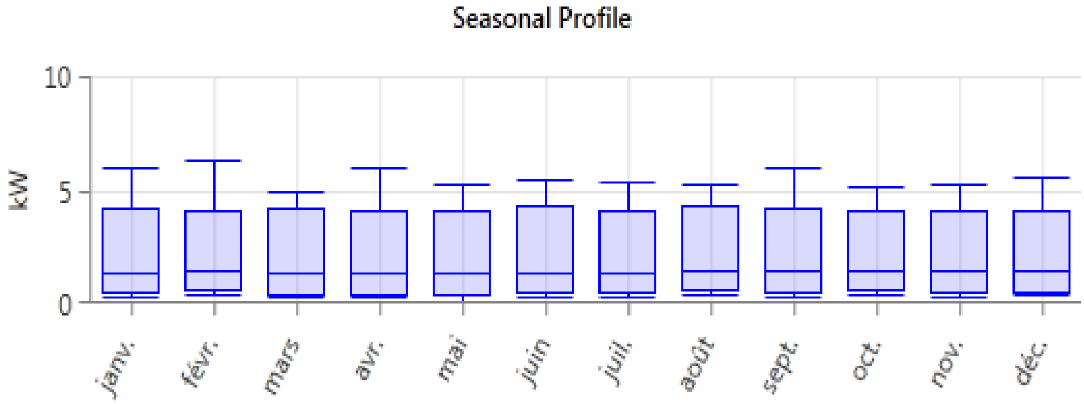

Figure II. 7: Seasonal profile electric load

II.6 The electrical structure of the hybrid system

We have chosen the model of renewable hybrid power generating system off-grid which is a combination of solar panels, wind generators, diesel generator and electric transformer with storage batteries shown in (figure II.8) solar panels, turbines and power generator within 24 hours in the presence of solar wind with speed Variable (3 m/s). Excess energy is stored extracted from sources of (solar panels, wind and diesel generator) with storage batteries .

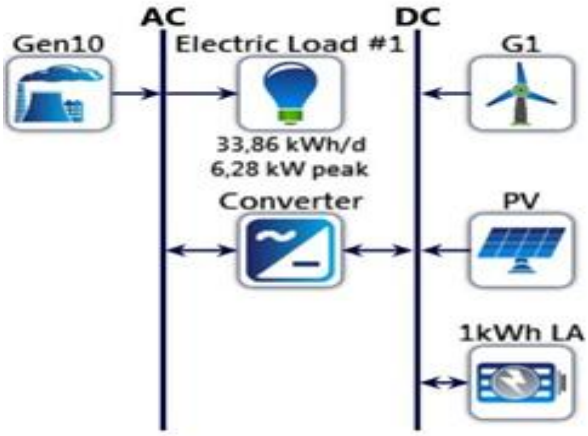

Figure II. 8: Schematic of system hybrid

II.7 Materials and Methods

HOMER simulates and optimizes hybrid power systems, which are standalone power plants that employ some combination of wind turbine, photovoltaic panels, or diesel generators to produce electricity [14].

The primary tool used in this research was the HOMER optimization model. The National Renewable Energy Laboratory (NREL), under the guidance of Peter Lilienthal and Tom Lambert, developed HOMER, a computer model for optimizing electrical resources. HOMER "simulates and optimizes hybrid power sys- tems, which are standalone power plants that employ some com- bination of wind turbines, photovoltaic panels, or diesel generators to produce electricity" (Lambert 2000). HOMER is capable of simulating more than 1000 different hybrid systems per minute. HOMER has two types of data windows: Inputs and Outputs. The Inputs provide the definition of the search space; the Out- puts provide the results. The Inputs consist of the following: loads, resources, components, and optimizations [15].

The house, require electricity for lighting, refrigeration, Washing machine ,Electric oven, Mobile phone charger, smoothing iron, Computer, radio Alarm clock, water pump, TV,. Simulations are based on a specific search space and certain sensitivities defining the optimum configuration of the renewable energies system. Monthly average local data regarding solar radiation taken (6kwh/m²/day) and wind speed is taken from (2.5 m/s to 6 m/s). The power systems are composed of PV panel, wind turbine, diesel generator, battery, and converter. Standard market prices and power generation statistics of each component provide the base input data for the optimization process. The input parameter for each component is specified under the categories: PV, wind turbine, diesel generator, battery and converter [16].

II.8 HOMER energy software

The HOMER software package used in our thesis, can simulate, analyze and model renewable energy or hybrid power systems that can include generation, cogeneration, solar PV systems, batteries, wind turbines, micro-turbines, hydropower, and fuel cells among other inputs [17].

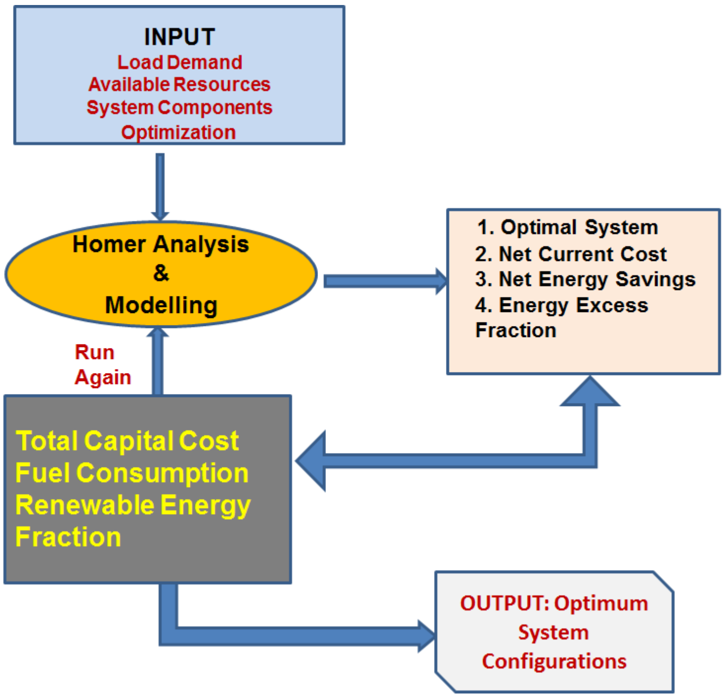

Figure II. 9: HOMER package architecture [17]

Simulation programs and software packages are the common tools for optimizing and evaluating the performances of the hybrid power or renewable energy systems, HOMER being one of the most used. By using such tools, the optimum configuration can be found by comparing the performance and energy production cost of different configurations. HOMER was originally developed at the National Renewable Energy Laboratory (NREL), United

States. A commercial version has been developed, upgraded and distributed by HOMER Energy.

It can be used to design, analyze and model micro-power and hybrid power system's configurations with various energy resources for economics and sizing to determine the optimal combination of them to meet the load demand and the user requirements. (Figure II.9) shows the basic architecture of this software package. It shows the calculation result of the number of cases of different renewable energy sources under weather conditions, load demands, capacity ranges, fuel costs, and carbon emission constraints to select the optimum system. HOMER software package can facilitate the design and analysis of hybrid power systems for both standalone and grid-connected applications.

Input information to be provided to HOMER includes: electrical loads (one year of load data), renewable resources, component technical details and costs, constraints, controls, type of dispatch strategy…etc. It designs an optimal power system to serve the desired loads, performing several simulations to ensure best possible matching between supply and demand in order to design the optimum system. It uses life cycle cost to rank order these systems, while can simulate the operation of a system by making energy balance calculations for each of the 8760 hours in a year. For each hour, HOMER compares the electric demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system. HOMER performs the energy balance calculations, system cost calculations for each of the considered system configuration, listing all of the possible system sizes, sorted by Net Present Cost.

II.8.1 Interfaces of HOMER Pro

The HOMER software is easy to use and its interface is similar to the usual software, so it has a menu at the top as well as icons that can be used without going into the menus. The HOMER interface can be considered to have three important areas as shown in (Figure II.10), the system definition area (house), the resource definition area (Design) and the results area (Results).

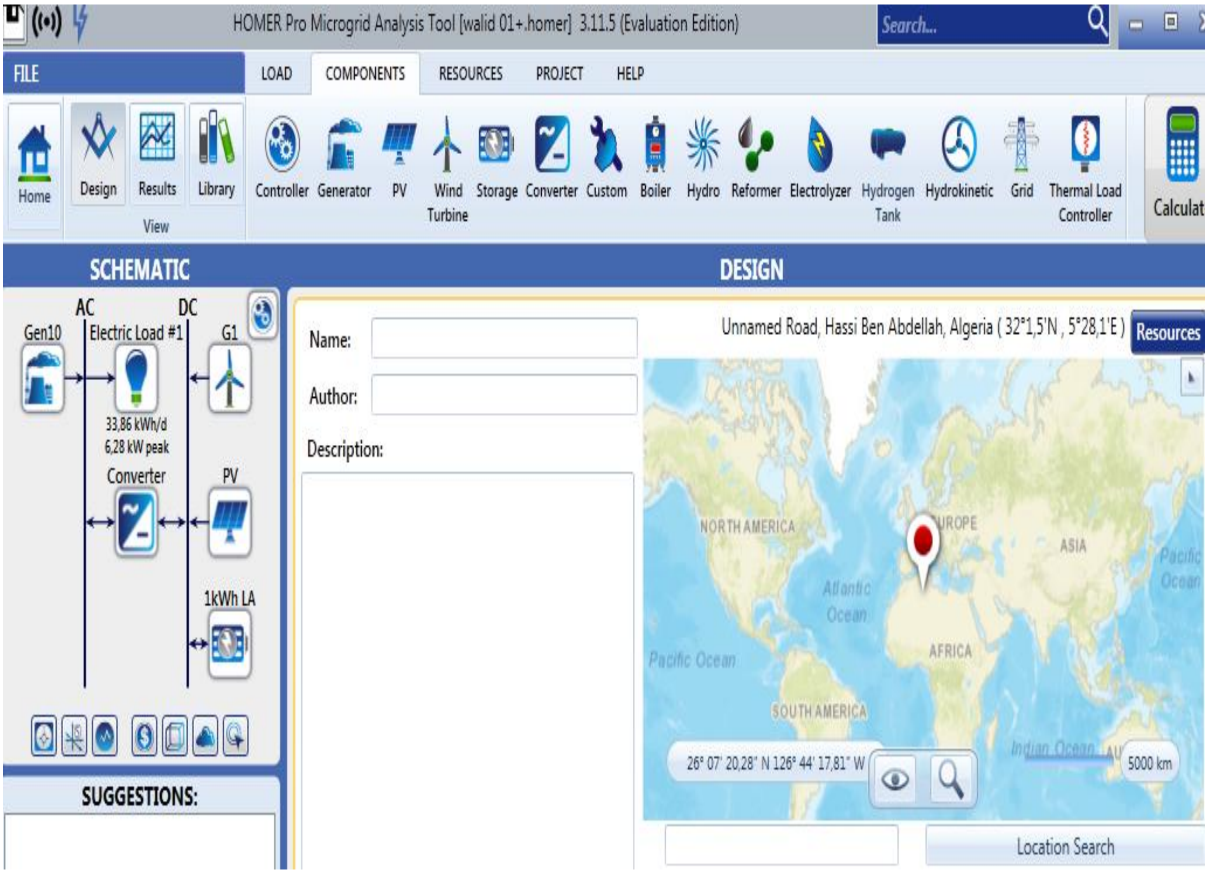

Figure II. 10: Interface Homer Pro

II.8.2 Start project information

This tape contains a set of tasks, load components, project resources, and instructions.

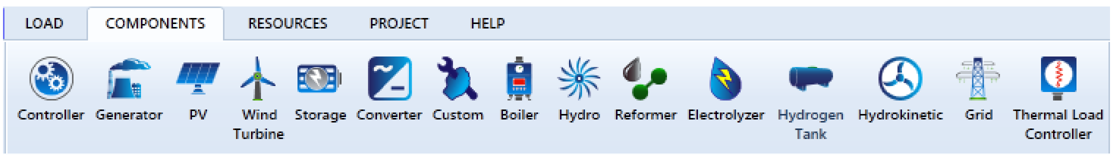

Figure II. 11: HOMER components

II.9 Data on Solar radiation, wind speed and temperature by HOMER® software

HOMER has its own wind and solar database that gives hourly, daily, monthly and annual averages. However, the wind resources are little bit more complicated than the solar resources because their inconsistence and variations. The wind speed and direction data from at least ten years of measurements is needed in order to have a good wind resource assessment and estimate (Figure II.13) is showing the power flow in a system consisting of wind turbine, PV panel, Diesel generator, storage unit and a load, while (Figure II.12) is giving the solar radiation for a selected loc

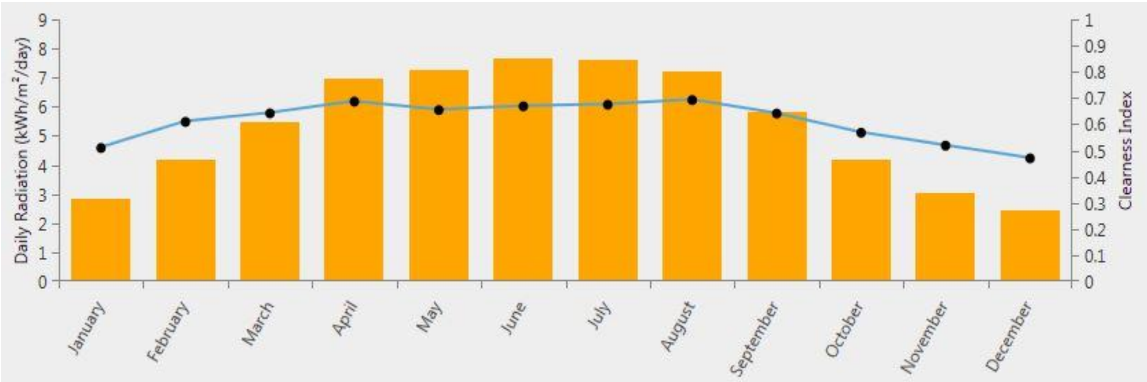

Figure II. 12: Typical annual profile of solar radiation [18]

Table II. 2: Monthly Average Solar Global Horizontal Irradiance (GHI) DATA

Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Clearness Index	0,509	0,608	0,641	0,686	0,653	0,668	0,674	0,692	0,640	0,567	0,517	0,469
Daily Radiation ($KWh/m^2/day$)	2,840	4,170	5,480	6,940	7,260	7,660	7,590	7,230	5,800	4,160	3,030	2,430

HOMER synthesizes solar radiation values for each of the 8760 hours of the year. Its algorithms produces realistic hourly data, being easy to use, requiring only the latitude and the monthly averages, while displaying realistic day to day and hour to hour patterns. The synthetic data are created with certain statistical properties that reflect global average value. However, generated data for a particular location will not exactly replicate the characteristics of the real solar radiation. But tests show that synthetic solar data produce virtually the same simulation results as real data. HOMER synthetic wind data generator is little different to use than the solar data as it requires four parameters, in order to generate wind statistics for this specific site. A user starts by specifying system parameters and hourly electrical load, wind and solar resource data. For each simulated hour the software calculates global irradiation at the photovoltaic array titled surface, calculates the output energy from the array, and performs energy balance at the DC and AC buses to determine amount of energy taken from or transferred to the electrical grid. Energy balance at the DC bus takes in consideration the storage component when present. The software keeps record of hourly, daily monthly and one year simulation results. It displays these results in a tabular format. Results also include economic analysis that takes into account investment costs and financial benefits projected over the life time of the project [17].

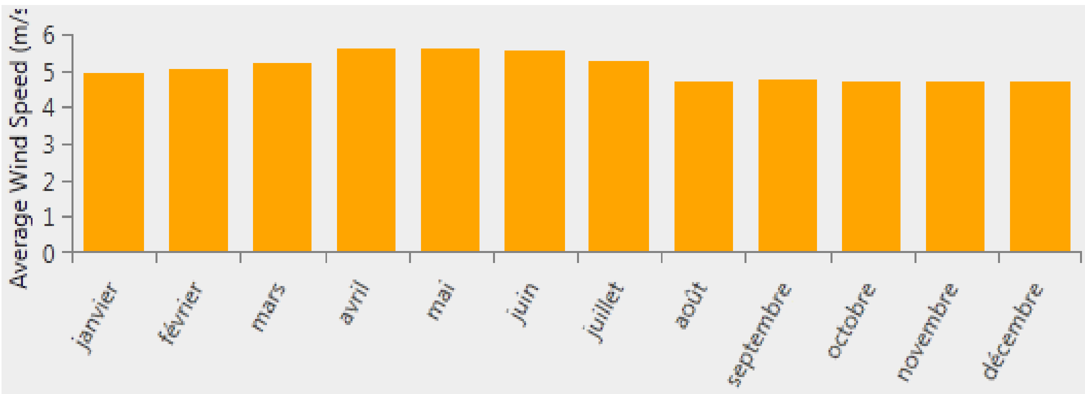

Figure II. 13: Monthly average wind speed data [19]

Table II. 3: Monthly Average wind speed DATA

Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Avreage (m/s)	4,92	5,06	5,23	5,61	5,63	5,57	5,28	4,70	4,76	4,68	4,71	4,68

And average of the air temperature by HOMER as seen below in (Figure II.14):

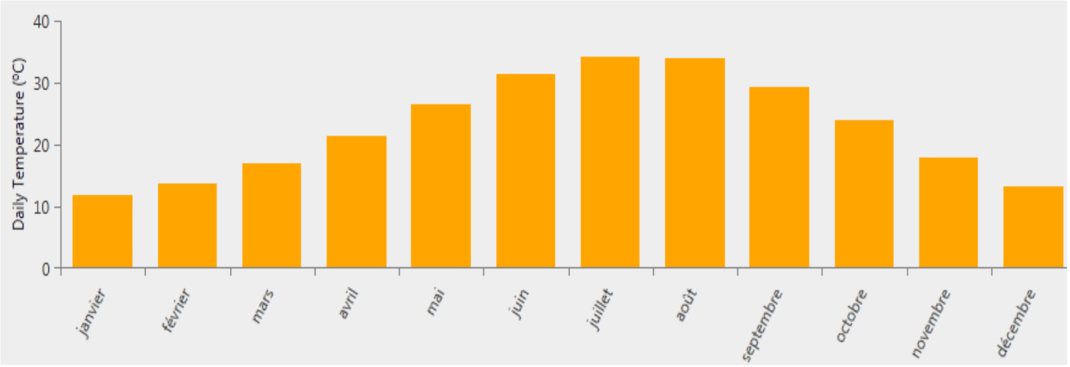

Figure II. 14: Average daily temperature [18]

Table II. 4: Daily Temperature (c°)

Month	January	February	March	April	May	June	July	August	September	October	November	December
Daily Temperature (c°)	11,80	13,65	17,09	21,33	26,50	31,44	34,08	33,93	29,34	23,84	17,82	13,29

II.10 Conclusion

In this chapter we the optimal sizing o of autonomous (hybrid PV/wind/GD) system with battery storage, with the explanation of the Homer program and how to use it, after the introduction of equipment and prices and meteorological data (sun, wind and temperature), to reach the goals to be achieved .The version (Homer pro 3.11.5) is used, which is available for free for 21 days (trial version), This program was developed in the National Laboratory of Renewable Energy in America(NREL).

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CHAPTER III

Results and discussion

III .1 Introduction

In this chapter, we will discuss the results obtained by two systems, the first is an off-grid (PV /wind /diesel generator hybrid system with independent storage batteries), and the second off-grid system is represented in only diesel generators, From these results we will choose the best suitable result to provide the necessary consumption for a standalone House in Ouargla In an isolated area in Hassi bin Abdellah village, we calculated these results by the HOMER® code of micro grid simulation program; Which selects the best models and options for appropriate technology based on cost, energy saving and reliability.

We Analysis and simulates the operation of the system with HOMER® based on the components chosen by the designer. In this process, HOMER® will perform the energy balance calculation based on the system configuration consisting several numbers and sizes of component. In this case of our study: PV array system, wind turbine, diesel generator with battery and converter are the components chosen for the analysis.

And then we search to determine the best feasible system configuration which can adequately serve the electric demand.

HOMER® simulates the system based on the estimation of installing cost, replacement cost, operation and maintenance cost, fuel and salvage.

III.2 Hybrid system (PV/ wind turbine/ DG) with batteries storage

III.2.1 Interpretation of simulation results

After selecting the components of the hybrid power system, (PV, wind turbines and diesel generator with storage batteries), the simulation of the HOMER® program gave us the number and quantity of the electric output for each limit. As shown in the following table:

Table III. 1: The optimal system architecture

Component	Name	Size	Unit
Generator	Generic 10kW Fixed Capacity Genset	10,0	kW
PV	Generic flat plate PV	6,35	kW
Storage	Generic 1kWh Lead Acid	14	strings
Wind turbine	Generic 1 kW	1	ea.
System converter	System Converter	4,54	kW

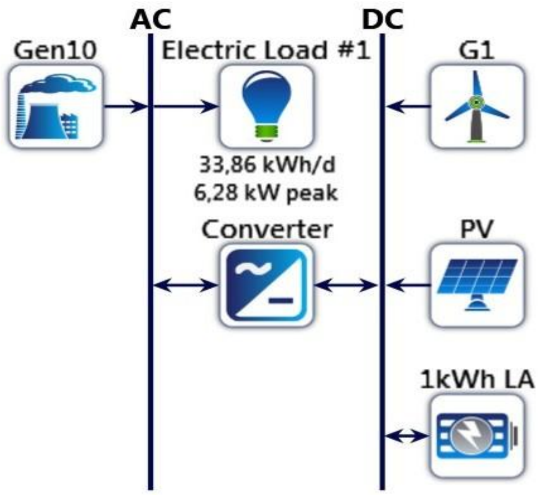
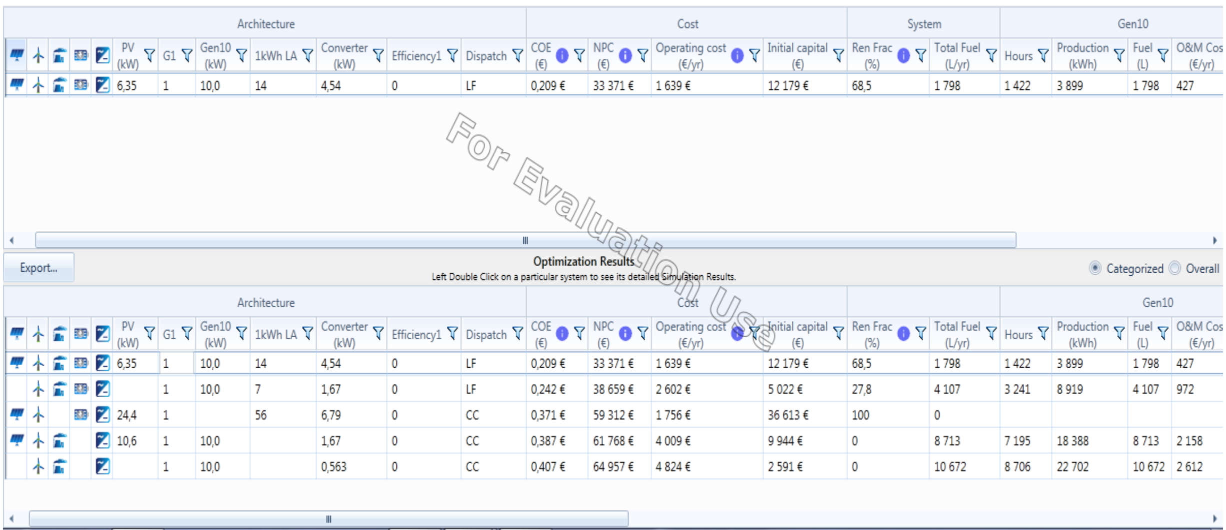


Figure III. 1: electrical assembly of the hybrid system

After simulations we got the following results



PV (kW)	G1	Gen10 (kW)	1kWh LA	Converter (kW)	Efficiency1	Dispatch	COE (€)	NPC (€)	Operating cost (€/yr)	Initial capital (€)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cos (€/yr)
6,35	1	10,0	14	4,54	0	LF	0,209 €	33 371 €	1 639 €	12 179 €	68,5	1 798	1 422	3 899	1 798	427

Export...

Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

Categorized Overall

PV (kW)	G1	Gen10 (kW)	1kWh LA	Converter (kW)	Efficiency1	Dispatch	COE (€)	NPC (€)	Operating cost (€/yr)	Initial capital (€)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cos (€/yr)
6,35	1	10,0	14	4,54	0	LF	0,209 €	33 371 €	1 639 €	12 179 €	68,5	1 798	1 422	3 899	1 798	427
	1	10,0	7	1,67	0	LF	0,242 €	38 659 €	2 602 €	5 022 €	27,8	4 107	3 241	8 919	4 107	972
24,4	1		56	6,79	0	CC	0,371 €	59 312 €	1 756 €	36 613 €	100	0				
10,6	1	10,0		1,67	0	CC	0,387 €	61 768 €	4 009 €	9 944 €	0	8 713	7 195	18 388	8 713	2 158
	1	10,0		0,563	0	CC	0,407 €	64 957 €	4 824 €	2 591 €	0	10 672	8 706	22 702	10 672	2 612

Figure III. 2: table of all calculation results the hybrid system

We noted that the best result used is hybrid system that contains (PV, wind, DG and batteries) was shown in the first line (figure III. 2).

This arrangement of net current cost and the order of results and values rated from the best to the least choice, where we noted that the best result appears in the first line because it consists of a suitable hybrid system (PV, wind turbine, DG and batteries) and at an appropriate cost.

We got the optimal result using HOMER® software:

Architecture							Cost				System		Gen10			
PV (kW)	G1	Gen10 (kW)	1kWh LA	Converter (kW)	Efficiency1	Dispatch	COE (€)	NPC (€)	Operating cost (€/yr)	Initial capital (€)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cos (€/yr)
6,35	1	10,0	14	4,54	0	LF	0,209 €	33 371 €	1 639 €	12 179 €	68,5	1 798	1 422	3 899	1 798	427

Figure III. 3: optimal results for the hybrid system (Hassi Ben Abdellah)

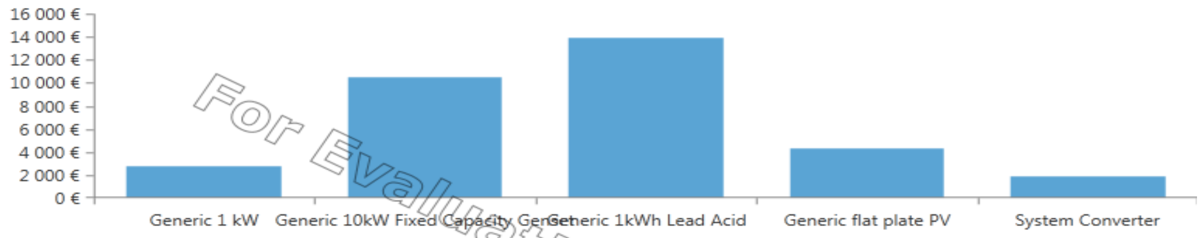
III.2.1.1 Discussion of the economic aspect

Cross-cutting issues of cost and reliability are the most important issues in the minds of those responsible for technology services, where economic cost plays an important role in selecting and evaluating this project.

As we note that the system of hybrid proverbs in economically term is technically analyzed through the results obtained to design the hybrid system model to an off- grid House.

Thus, in order to evaluate this project economically, it must be studied by the economic criteria of the renewable energy system.

Total estimated cost: the smaller cost (NPC) is (33 371 €) (4,646,641.74 DZD) with (Initial capital) value of (12 179€) (1,695,322.44 DZD), which in fact justifies this position from ranking and choice side.



Component	Capital (€)	Replacement (€)	O&M (€)	Fuel (€)	Salvage (€)	Total (€)
Generic 1 kW	1 672,00 €	533,05 €	904,93 €	0,00 €	-300,41 €	2 809,57 €
Generic 10kW Fixed Capacity Genset	750,00 €	634,97 €	5 514,88 €	3 718,17 €	-113,19 €	10 504,84 €
Generic 1kWh Lead Acid	4 200,00 €	8 236,17 €	1 809,85 €	0,00 €	-372,38 €	13 873,64 €
Generic flat plate PV	4 195,03 €	0,00 €	156,61 €	0,00 €	0,00 €	4 351,64 €
System Converter	1 361,94 €	577,83 €	0,00 €	0,00 €	-108,75 €	1 831,02 €
System	12 178,97 €	9 982,02 €	8 386,26 €	3 718,17 €	-894,73 €	33 370,70 €

Figure III. 4: Cost summary

The estimated total cost over 25 years of work at all project costs (Capital, Replacement, O&M, Salvage) is 33 371€(4,646,641.74 DZD) with levelized cost energy 0.209€/ KWh.

The results were allocated as follows:

Table III. 2: Net Present Costs (25years)

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 1 kW	1 672 € 230,688.97 DZD	904,93 € 124,817.50 DZD	533,05 € 73,530.55 DZD	-300,41 € -41,436.40 DZD	0,00 € 0,00 DZD	2 810 € 387,545.33 DZD
Generic 10kW Fixed Capacity Genset	750,00 € 103,478.90 DZD	5 515 € 760,687.00 DZD	634,97 € 87,593.93 DZD	-113,19 € -15,612.11 DZD	3 718 € 512,786.37 DZD	10 505 € 1,448,797.46 DZD
Generic 1kWh Lead Acid	4 200 € 579,481088 DZD	1 810 € 249,671.07 DZD	8 236 € 1,136,153.88 DZD	-372,38 €- 51,361.77 DZD	0,00 € 0,00 DZD	13 874 € 1,912,844.14 DZD
Generic flat plate PV	4 195 € 578,792.02 DZD	156,61 € 21,602.75 DZD	0,00 € 0,00 DZD	0,00 € 0,00 DZD	0,00 € 0,00 DZD	4 352 € 600,021.46 DZD
System Converter	1 362 € 187,917.69 DZD	0,00 € 0,00 DZD	577,83 € 79,701.72 DZD	-108,75 € -14,998.79 DZD	0,00 € 0,00 DZD	1 831 € 252,444.69 DZD
System	12 179 € 1,680,345.9 9DZD	8 386 € 1,156,688.3 DZD	9 982 € 1,376,845.4 3 DZD	-894,73 € -123,401.12 DZD	3 718 € 512,786.37 DZD	33 371 € 4,601,340.1 5 DZD

>>Reference: XE.com >>1 EURO = 139.167 DZD

This table (Table III. 2) show the total cost of the project during 25 years was 33 371€ based on (Capital) of 12 179 € (1,695,989.20DZD) followed by (Replacement) of 9 982, 02 € (1,389,779.63 DZD) after (O&M) of 8 386 € (1,166,220.50 DZD) and (Salvage) of -894, 73€ (-139.096 DZD).

Table III. 3: Annualized Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 1 KW	129,34 € 17,703.33 DZD	70,00 € 9,577.79 DZD	41,23 € 5,641.32 DZD	-23,24 € -3,179.83 DZD	0,00 € 0,00 DZD	217,33 € 29,715.04 DZD
Generic 10kW Fixed Capacity Genset	58,02 € 7,952.91 DZD	426,60 € 58,420.93 DZD	49,12 € 6,726.76 DZD	-8,76 € -1,199.22 DZD	287,62 € 39,374.46 DZD	812,59 € 111,241.54 DZD
Generic 1kWh Lead Acid	324,89 € 44,546.40 DZD	140,00 € 19,195.71 DZD	637,10€ 87,384.73 DZD	-28,81 €- 3,951.58 DZD	0,00 € 0,00 DZD	1 073€ 147,172.84 DZD
Generic flat plate PV	324,50 € 44,512.74 DZD	12,11 € 1,661.17 DZD	0,00 € 0,00 DZD	0,00 € 0,00 DZD	0,00 € 0,00 DZD	336,62 € 46,175.28 DZD
System Conver ter	105,35 € 14,451.21 DZD	0,00 € 0,00 DZD	44,70 € 6,123.80 DZD	-8,41 € -1,152.75 DZD	0,00 € 0,00 DZD	141,64 € 19,414.39 DZD
System	942,10 € 129,132.28 DZD	648,71 € 89,009.02 DZD	772,15 € 105,946.13 DZD	-69,21 € -9,496.25 DZD	287,62 € 39,473.16 DZD	2 581 € 345,218.11 DZD

Total estimated cost over a year of work at all project costs: (Capital, Replacement, O&M, Salvage) is 2 581 € (359,531.73DZD) with levelized cost energy 0,209€/ kWh (29,08 DZD/KWh).

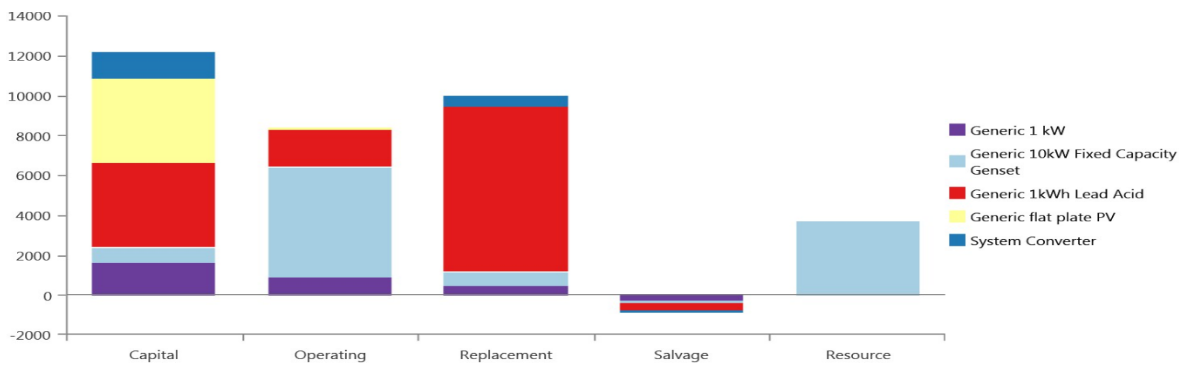


Figure III. 5: cost summary for the hybrid system during 25 years

We used the equipment nearly 25 years; and we have found that the project did not

Completely change all the components as we expected in begin of the project. Except for a few small parts after approximately every 5 years such as batteries that do not keep efficiency more than 5 years, some other small equipment such as electric wiring and some maintenance on diesel generator….etc.

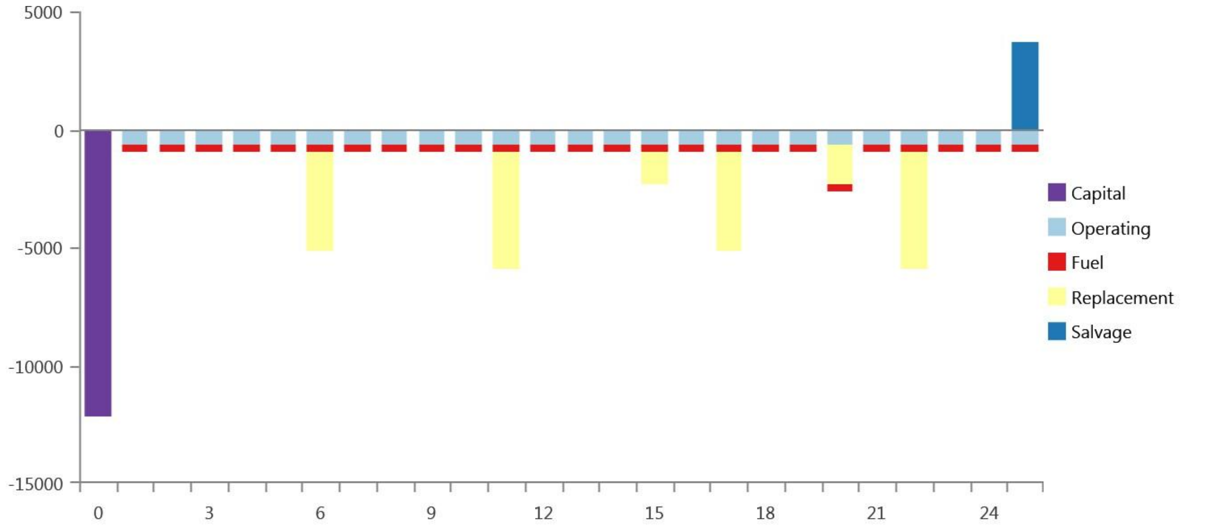


Figure III. 6: summary of operations and replacements throughout the operating life of the system

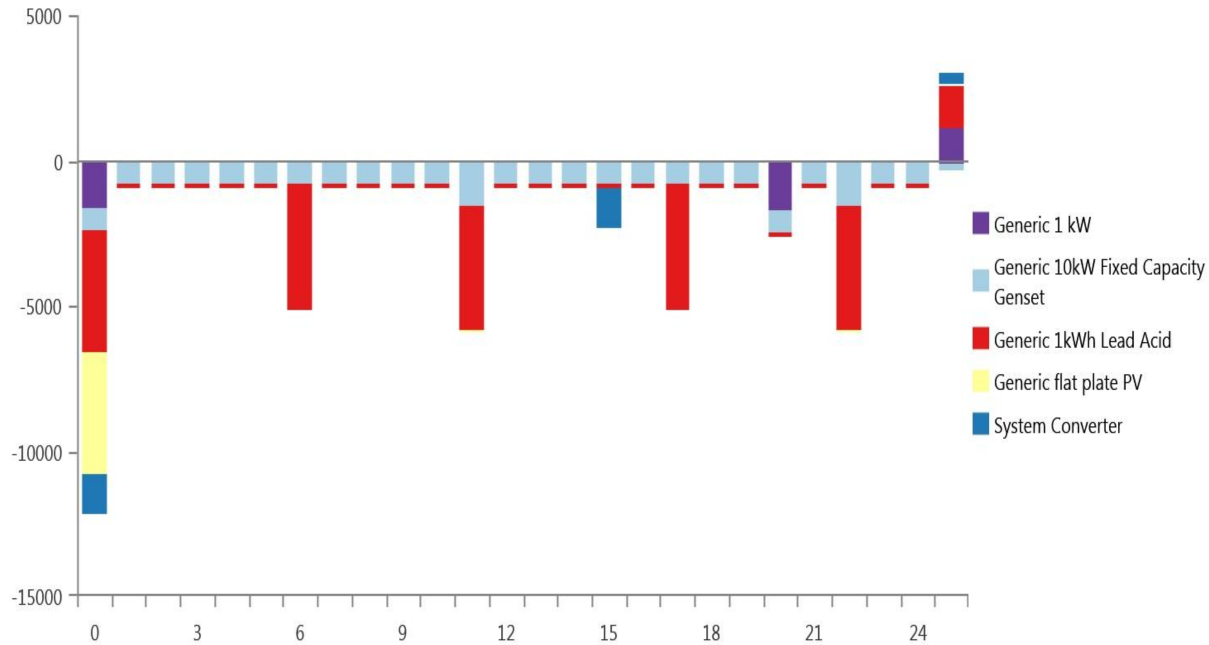


Figure III. 7: Summary of replacement devices

Noticed that the largest cost of the project was at the beginning (Capital cost). Some changes occurred regularly during the 25 years of the project, these changes including:

- Light O&M cost in diesel generator and fraction of batteries every year during the project period.
- Change for the batteries every 5 years.
- Change converter every 15 years.
- Change wind turbine after 20 years.

At the end of the project, the wind turbines, batteries and converter gained as a benefit of this project (salvage).

III.2.1.2Electrical output of the system

On the other hand, when we talk about electrical results, we find that the rate of production of this energy, which was obtained by: (PV, wind turbine, DG, with batteries bank) Distributed as follows:

Table III. 4: Production, consumption and quantity of PV-wind-DG system

	Production	
Production	**KWh/yr**	**Percent**
Generic flat plate PV	9 729	53,0 %
Generic 10kW Fixed Capacity Genset	3 899	21,2 %
Generic 1 Kw	4 726	25,7 %
Total	18 353	100 %
	consumption	
AC Primary Load	12 357	100 %
DC Primary Load	0	0 %
Deferrable Load	0	0 %
Total	12 357	100 %
	Quantity	
Excess Electricity	5 067	27 %
Unmet Electric Load	0	0 %
Capacity Shortage	0	0 %

Noticed that the amount of produced energy from the hybrid system is (18353KWh/yr) divided as:

- PV produced the largest amount which is (9729 KWh/yr) with 53%.

- Wind turbine produced (4726KWh/yr) with 25%.
- Diesel generator produced (3899KWh/yr) with 21, 2%.

Noticed that the total produced electrical energy is (18353KWh/yr) consumed as follows:

- The house consuming (12357KWh/yr).
- The rest quantity which is (5067KWh/yr), used in other services (irrigation).

Note

The overload in electrical output in our study (Excess Electricity) is caused by the diesel generator produces (10 KWh). This is due to the absence of a (5 KWh) diesel generator under the HOMER® program options (5 KWh enough for system).

Where the height following figures shows electric output for each of the (PV, wind turbine and diesel generator) during the months of the year, we say that the largest value of the production will be in April, up to about (2.3 KWh), and the lowest value in December about (1.8 KWh) This decline is due to the change of solar radiation during the year Hassi Ben Abdellah area.

These differences in the electric production of the hybrid system that in April we have a maximum electric production in wind turbine generator, and in December we have a minimum electric production by PV system.

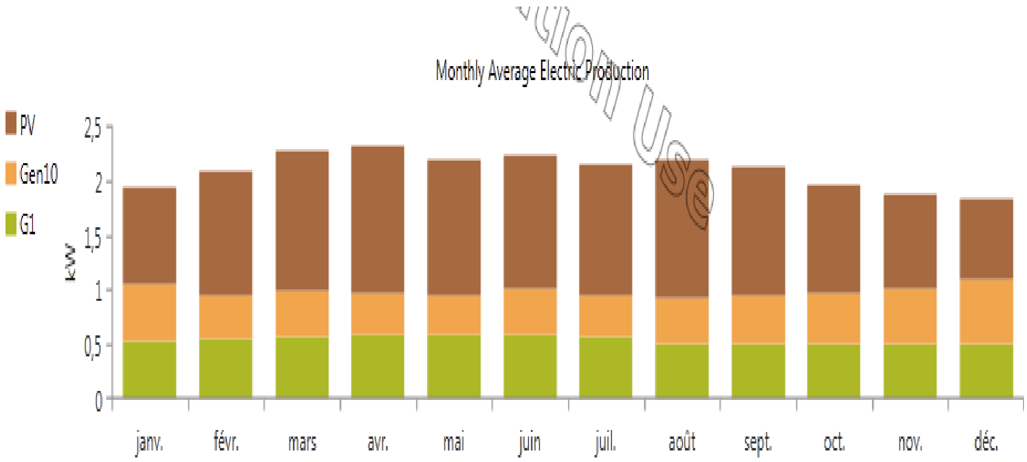


Figure III. 8: Total monthly energy produced by the hybrid system for one year

III.2.2 Generic flat plate (PV)

The production of the electrical energy begins after the sunset. in winter and autumn, the sunrise is between (6:00h/7:30h).(7:00h/16:00h) in this period, The electrical energy has different values. In spring and summer, the sunrise is between (4:30h/6:00h). The production is also variable.

a low Electrical energy is produced at the beginning of the sunrise around 7:00h to 9:30 with a different value (0.20KW) up to 2,50KW then the production is increased from 9:30h till 15:00h to reach its maximum value of value 5,53KW, and from 15:00h till sunset the low production is gradually decreased.

Table III. 5: Generic flat plate PV Electrical Summary

Quantity	Value	Units
Mainimum Output	0	KW
Maximum Output	5,53	KW
PV Penetration	78,7	%
Hours of Operation	4372	hrs/yr
Levelized Cost	0,0346	€/KWh

Table III. 6: Generic flat plate PV Statistics

Quantity	**Value**	**Units**
Rated Capacity	6,35	KW
Mean Output	1,11	KW
Mean Output	26,7	KWh/d
Capacity Factor	17,5	%
Total Production	9729	KWh/yr

Generic flat plat PV Output (kW)

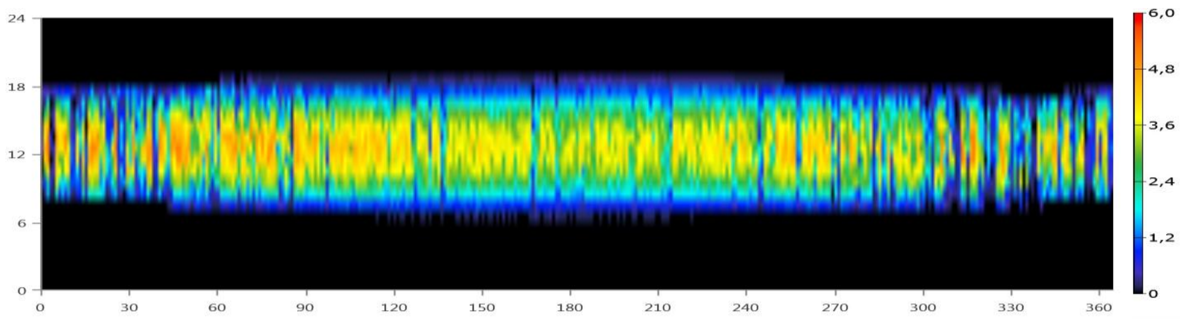


Figure III. 9: Total daily energy produced by the PV during one year

III.2.3 Wind Turbine (Generic 1KW)

The production of the electrical power produced by the wind turbine in winter is lower than the other seasons. And the availability of the wind power is limited in the period of (18:00h to 6:00h). During this period, the production varies from (0 to 1kwh). While we register the largest production capacity in months of April, May and June (about 0.98kw) in the operating period amounted to (7651 h/yr).

Table III. 7: Generic 1 kW Electrical Summary

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	0,987	kW
Wind Penetration	38,2	%
Hours of Operation	7 651	hrs/yr
Levelized Cost	0,0460	€/kWh

Table III. 8: Generic 1 kW Statistics

Quantity	Value	Units
Total Rated Capacity	1,00	Kw
Mean Output	0,539	Kw
Capacity Factor	53,9	%
Total Production	4 726	kWh/yr

Generic 1 kW Output (kW)

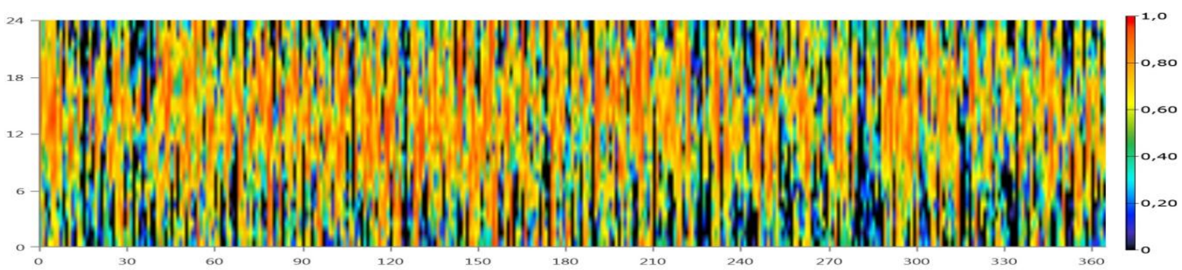


Figure III. 10: Total daily energy produced by the WT during one year

III.2.4 Storage batteries (Lead Acid 1Kwh)

The battery is an important and fundamental part in this system by saving electrical energy. Batteries are permanently used during all the day. Its load level is between 40 and 100% during the days of the year (2313 and 1855 KWh / year).

Table III. 9: Generic 1kWh Lead Acid Properties

Quantity	Value	Units
Average Energy Cost	0	€/kWh
Energy In	2 313	kWh/yr
Energy Out	1 855	kWh/yr
Storage Depletion	5,40	kWh/yr
Losses	463	kWh/yr
Annual Throughput	2 074	kWh/yr

Table III. 10: Generic 1kWh Lead Acid Result Data

Quantity	Value	Units
Autonomy	5,96	Hr
Storage Wear Cost	0,419	€/kWh
Nominal Capacity	14,0	kWh
Usable Nominal Capacity	8,41	kWh
Lifetime Throughput	11 200	kWh
Expected Life	5,40	Yr

Table III. 11: Generic 1kWh Lead Acid Statistics

Quantity	Value	Units
Batteries	14,0	qty.
String Size	1,00	Batteries
Strings in Parallel	14,0	Strings
Bus Voltage	12,0	V

Generic 1KWh Lead Acid State of Charge (%)

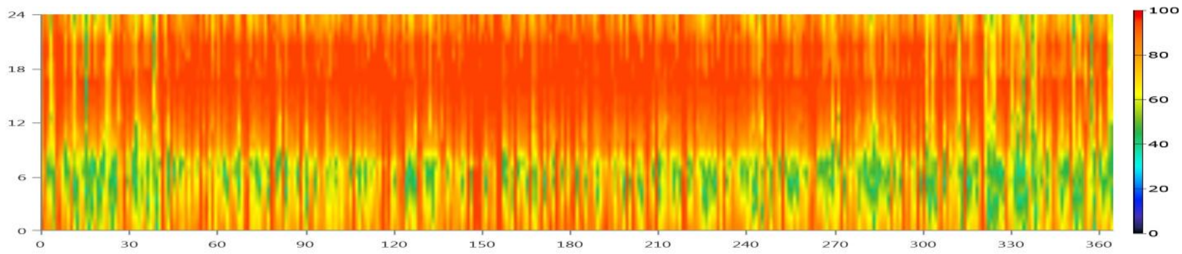


Figure III. 11: State of charge through a year

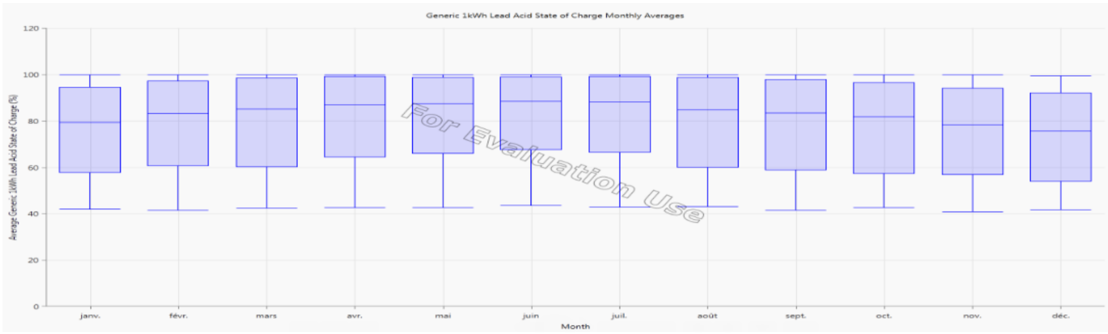


Figure III. 12: Charging battery through a year

It is used as the fundamental essential element for the generation of energy and this because of lack of renewable energy (meteorological conditions) on the one hand and Diesel monk on the other hand for various reasons, the difficulty the link with this remote area of fuel-producing areas. And therefore, it is the most important and the only bill in the continuation of the work and the progress of the project.

III.2.5 Diesel Generator

An analysis of the electric power of the diesel generator was registered throughout the year, which works in parallel with the storage batteries. The working periods of the generator are from (6:00-8:00), (10:00-12:00) and (18:00-22:00) which is similar during the months of the year with a total of (1422h) per year.

Maximum power produced by the generator is estimated at (5.79Kwh), at the period from 19:00h to 21:00h.

Table III. 12: Generic 10kW Fixed Capacity Genset Electrical Summary

Quantity	Value	Units
Electrical Production	3 899	kWh/yr
Mean Electrical Output	2,74	KW
Minimum Electrical Output	2,50	kW
Maximum Electrical Output	5,79	kW

Table III. 13: Generic 10kW Fixed Capacity Genset Fuel Summary

Quantity	Value	Units
Fuel Consumption	1 798	L
Specific Fuel Consumption	0,461	L/kWh
Fuel Energy Input	17 688	kWh/yr
Mean Electrical Efficiency	22,0	%

Table III. 14: Generic 10kW Fixed Capacity Genset Statistics

Quantity	Value	Units
Hours of Operation	1 422	hrs/yr
Number of Starts	930	starts/yr
Operational Life	10,5	Yr
Capacity Factor	4,45	%
Fixed Generation Cost	0,427	€/hr
Marginal Generation Cost	0,0458	€/kWh

Generic 10KW Fixed Capacity Genset Output (KW)

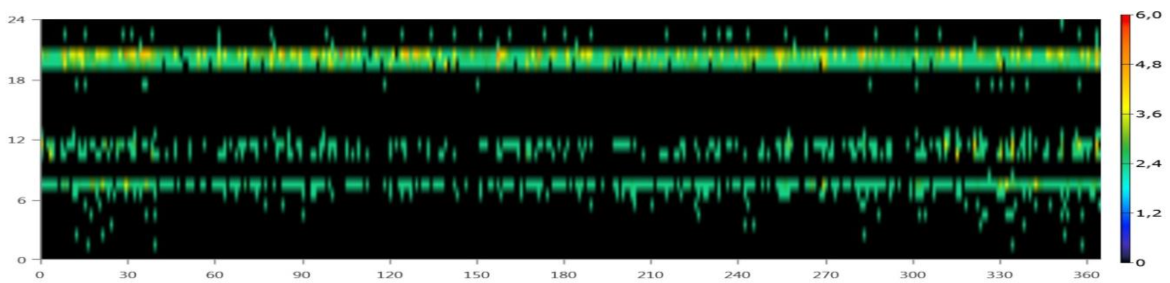


Figure III. 13: fixed capacity Genset output (KW)

III.3 Off- grid Diesel generator system

III.3.1 Interpretation of results simulation

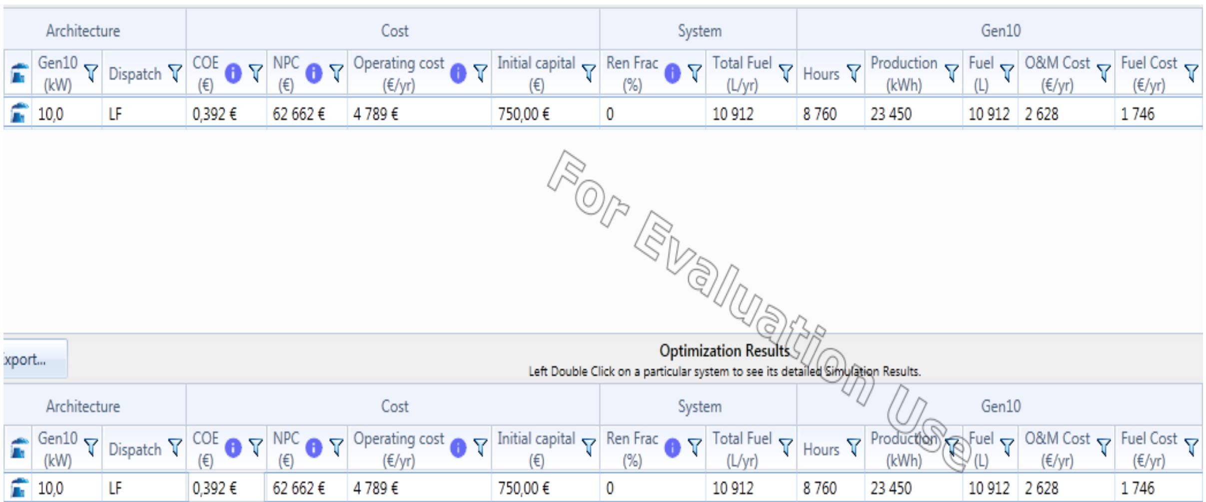
After the selection of a diesel generator which produce (10 kWh). We registered the results of simulation by HOMER® and the amount of electrical outputs.

Table III. 15: architecture of the System

Component	Name	Size	Unit
Generator	Generic 10kW Fixed Capacity Genset	10,0	kW

Figure III. 14: electrical installation of the DG autonomous system

After simulations we got the following results:



Architecture		Cost				System		Gen10				
Gen10 (kW)	Dispatch	COE (€)	NPC (€)	Operating cost (€/yr)	Initial capital (€)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cost (€/yr)	Fuel Cost (€/yr)
10,0	LF	0,392 €	62 662 €	4 789 €	750,00 €	0	10 912	8 760	23 450	10 912	2 628	1 746

xport...

Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

Architecture		Cost				System		Gen10				
Gen10 (kW)	Dispatch	COE (€)	NPC (€)	Operating cost (€/yr)	Initial capital (€)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cost (€/yr)	Fuel Cost (€/yr)
10,0	LF	0,392 €	62 662 €	4 789 €	750,00 €	0	10 912	8 760	23 450	10 912	2 628	1 746

Figure III. 15: table of all the calculation results for the autonomous system

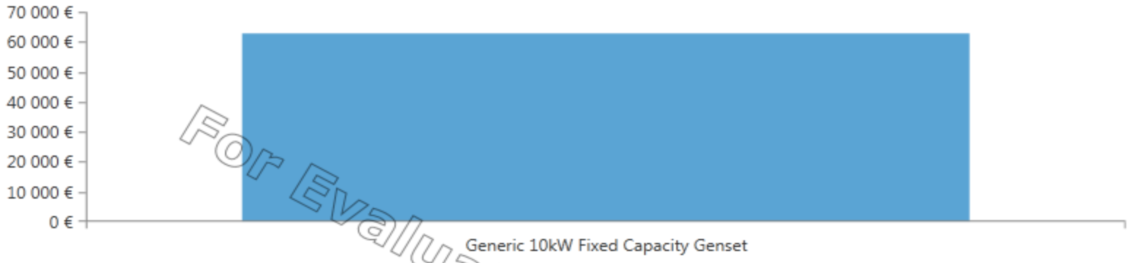
We noticed that the best option in the isolated system is shown in the results shown in (Figure III.16).

Architecture		Cost				System		Gen10				
Gen10 (kW)	Dispatch	COE (€)	NPC (€)	Operating cost (€/yr)	Initial capital (€)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cost (€/yr)	Fuel Cost (€/yr)
10,0	LF	0,392 €	62 662 €	4 789 €	750,00 €	0	10 912	8 760	23 450	10 912	2 628	1 746

Figure III. 16: Optimal results for the autonomous system

III.3.1.1 Discussion of the economic aspect

Note that this system has been technically analyzed through the results obtained from a House outside the network, and in order to evaluate this project economically, we study the costs of this project, and the results are as following:



Component	Capital (€)	Replacement (€)	O&M (€)	Fuel (€)	Salvage (€)	Total (€)
Generic 10kW Fixed Capacity Genset	750,00 €	5 441,00 €	33 973,51 €	22 569,46 €	-71,87 €	62 662,11 €
System	750,00 €	5 441,00 €	33 973,51 €	22 569,46 €	-71,87 €	62 662,11 €

Figure III. 17: Cost summary

This table show the total cost of the project during 25years was62662.11€ (8,674,916.85DZD) based on (Capital) of 750.00 € (103,666.33DZD) followed by (Replacement) of 5 441.00 € (752,063.03 DZD) after (O&M) of 33 973.51€ (4 696,244.41 DZD) and (Salvage) of-71.87€ (-9,935.46 DZD).

The result were allocated as follows

Table III. 16: Net Present Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
DG (10KW)	750,00 €	33 974 €	5 441 €	-71,87 €	22 569 €	62 662 €
System	750,00 € 102,767.63 DZD	33 974 € 4,655,510.85 DZD	5 441 € 745,574.40 DZD	-71,87 € -9,848.27 DZD	22 569 € 3,092,700.67 DZD	62 662 € 8,586,769.87 DZD

Table III. 17: Annualized Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
DG (10KW)	58,02 €	2 628 €	420,89 €	-5,56 €	1 746 €	4 847 €
System	58,02 € 7,949.84 DZD	2 628 € 360,056.43 DZD	420,89 € 57,665,20 DZD	-5,56 € -761,816 DZD	1 746 € 239,232.13 DZD	4 847 € 644,122.63 DZD

We noticed that the lowest cost of the project was at the beginning of the project, at the beginning we noticed a huge amount of repairs, and consumption of fuel increased significantly with changes and varieties through the 25 years.

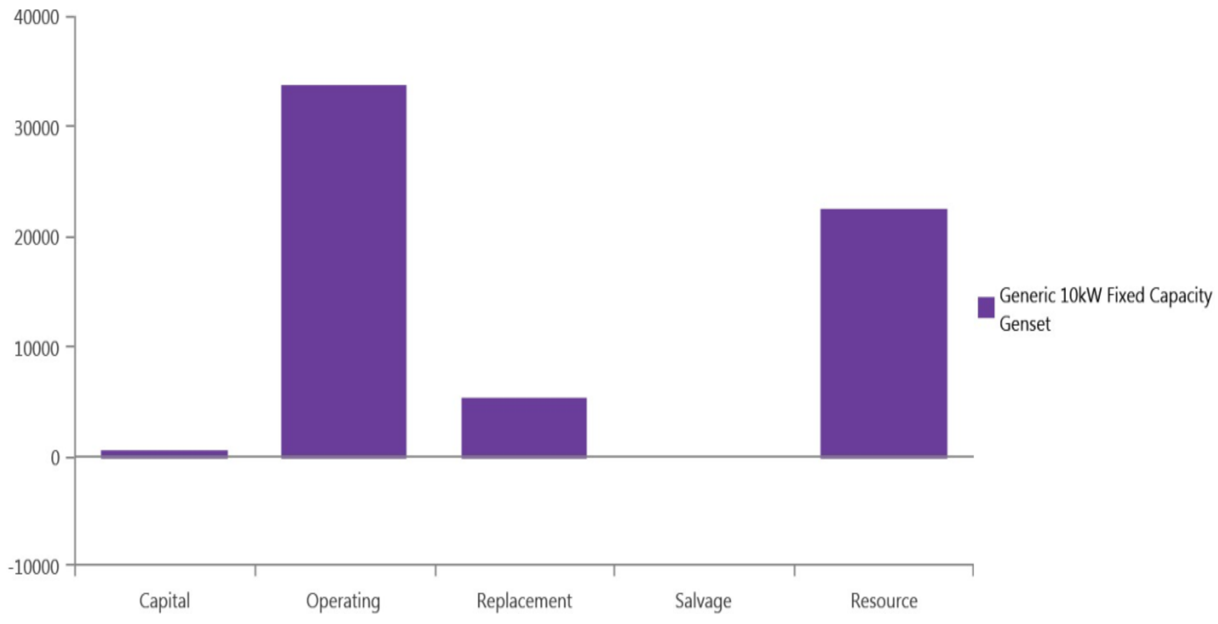


Figure III. 18: Cost summary for the system autonomous

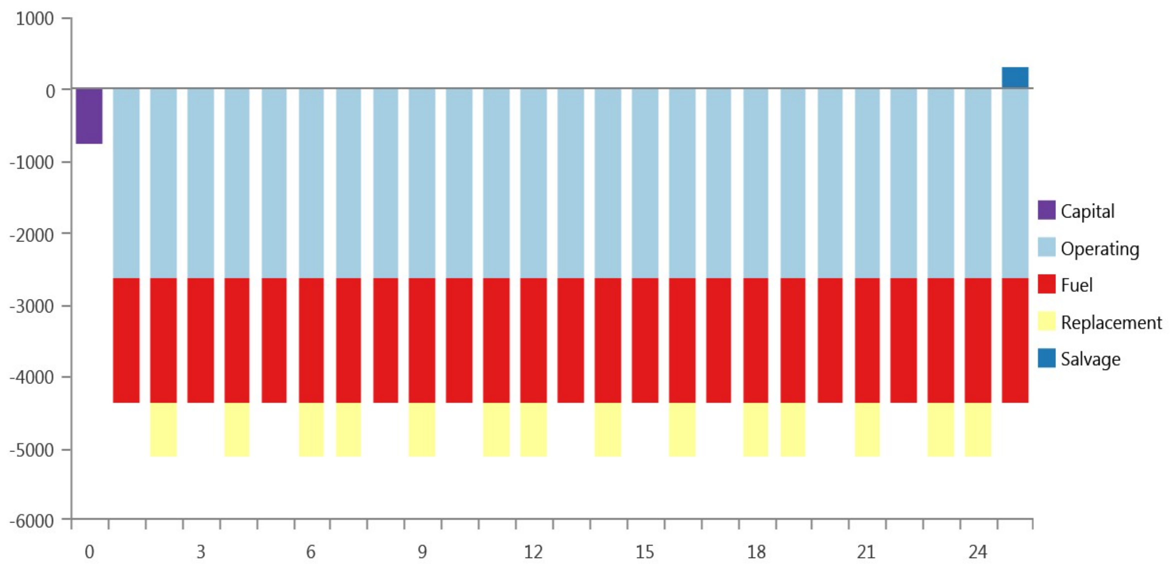


Figure III. 19: summary of O&M and replacements throughout the operating life of the diesel generator system

III.3.1.2 Electrical output of the system

On the other hand, we found that the rate of electrical power produced by the Diesel generator is distributed as following:

- Electrical Summary

Table III. 18: Excess and Unmet

Quantity	Value	Units
Excess Electricity	11 093	kWh/yr
Unmet Electric Load	0	kWh/yr
Capacity Shortage	0	kWh/yr

Table III. 19: Production Summary

Component	Production(kWh/yr)	Percent
Generic 10kW Fixed apacity Genset	23 450	100
Total	23 450	100

Table III. 20: Consumption Summary

Component	Consumption(kWh/yr)	Percent
AC Primary Load	12 357	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	12 357	100

- Generator: Generic 10kW Fixed Capacity Genset (Diesel)

Table III. 21: Generic 10kW Fixed Capacity Genset Electrical Summary

Quantity	Value	Units
Electrical Production	23 450	kWh/yr
Mean Electrical Output	2,68	KW
Minimum Electrical Output	2,50	KW
Maximum Electrical Output	6,28	Kw

Table III. 22: Generic 10kW Fixed Capacity Genset Fuel Summary

Quantity	Value	Units
Fuel Consumption	10 912	L
Specific Fuel Consumption	0,465	L/kWh
Fuel Energy Input	107 370	kWh/yr
Mean Electrical Efficiency	21,8	%

Table III. 23: Generic 10kW Fixed Capacity Genset Statistics

Quantity	Value	Units
Hours of Operation	8 760	hrs/yr
Number of Starts	1,00	starts/yr
Operational Life	1,71	Yr
Capacity Factor	26,8	%
Fixed Generation Cost	0,427	€/hr
Marginal Generation Cost	0,0458	€/kWh

We notice that the amount of energy produced by the diesel generator system is (23450Kwh), (12357KWh) is consumed and (11093KWh) is the remaining surplus of production.

- The minimum value produced by the generator is (2.50KWh) and the maximum value produced by the generator is (6.28Kwh).

The picture shows the working periods of the generator; starting at (6:00-8:00), (10:00-12:00) and (18:00-22:00), which is the same during the months of the year with a total of (8760 h) per year.

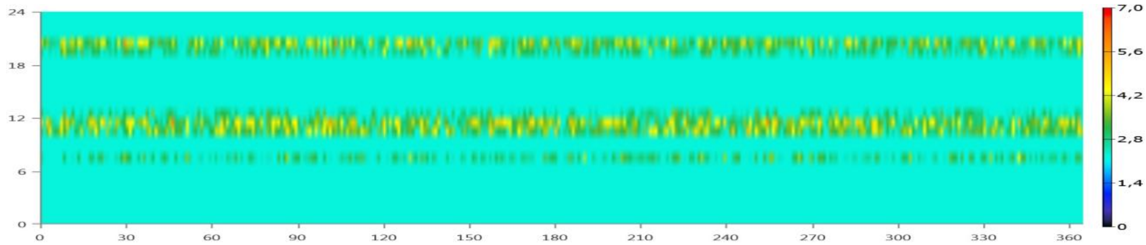


Figure III. 20: Capacity Genset Output (KW)

III.4 Comparison of hybrid system and diesel generator system

We have made a comparison between a hybrid system and a diesel generator system, and we take into consideration two aspects: economic and environmental (project costs and gas emissions ratio), aiming to choose the best economic system for the Off-grid house.

III.4.1 Economic side

Solar panels, wind turbines, diesel generators with storage batteries are all ideal solutions for the production and supply of electricity in isolated areas. After the results obtained during 25 years of this study, we found that:

-The cost of the hybrid system used by the total price (33371€) is as follows:

- (Capital cost) is 12 179 € (1,695,989.20DZD) followed by (Replacement cost) of 9 982,02 € (1,389,779.63 DZD) after (O&M) of 8 386 € (1,166,220.50 DZD) and (Salvage) of -894,73€ (-139.096 DZD)
- Total spent fuel during the year (1798 L)
- Average fuel per day is (4.93 L/day)

- The average fuel per hour is (0.205 L/h)
- Levelized cost of energy (0.209 €/KWh)(29.08DZD)

- The cost during 25 years of this study for off-grid diesel generator system is represented by the total price (62662€), which explained as follows:

- (Capital cost) is 750.00 € (103,666.33DZD) followed by (Replacement cost) of 5 441.00 € (752,063.03 DZD) after (O&M) of 33 973.51 € (4 696,244.41 DZD) and (Salvage) of -71.87€ (-9,935.46 DZD).
- Total spent fuel during the one year (10912L)
- Average fuel per day is (29.9 L/day)
- The average fuel per hour is (1.25 L/h)
- Levelized cost of energy (0.392 €/KWh)(54.55DZD)

The results of comparison between hybrid system and diesel generator of total costs after 25 years is estimated by HOMER®, were illustrated as follows in the table III.24:

Table III. 24: Total costs of different system hybrid and diesel

Component	Capital € (DZD)	Replacement €(DZD)	O&M € (DZD)	Resource € (DZD)	Salvage € (DZD)	Total€ (DZD)
System hybrid PV/wind/diesel	12 179 € 1,686,652.40 DZD	9 982 € 1,382,145.90 DZD	8 386 € 1,161,061.66 DZD	3 718 € 514,749.95 DZD	-894,73 € -123,847.54 DZD	33 371 € 4,620,061.02 DZD
System diesel generator	750.00 € 103,841.99 DZD	5 441 € 753,611.27 DZD	33 974 € 4,705,603.64 DZD	22 569 € 3,130,244.65 DZD	-71,87 € -9,969.13 DZD	62 662 € 8,689,193.41 DZD

III.4.2 Environmental side

Many suburbs need electricity; therefore, they are obliged to use the diesel generators. In this study we used the diesel generator in two different systems. The gas emissions were registered by the HOMER® program for each system, as shown in the tables below:

Table III. 25: Emission of pollutants during a year

Pollutant	Emission hybrid system	Emission diesel generator
Carbon dioxide	4 696 [Kg/yr]	28 506 [Kg/yr]
Carbon monoxide	35,5 [Kg/yr]	216 [Kg/yr]
Unburned hydrocarbons	1,29 [Kg/yr]	7,86 [Kg/yr]
Particulate matter	2,15 [Kg/yr]	13,1 [Kg/yr]
Sulfur dioxide	11,5 [Kg/yr]	69,9 [Kg/yr]

III.5 Conclusion

In this chapter, we scaled and simulated with the analysis of the obtained results. We found that the hybrid system (PV/Wind/GD/with batteries storage) that is nearly a25 year old fits the characteristics of the region and thus is used correctly compared with the diesel generator alone, in terms of cost and cleanliness of the ocean.

As the Levelized cost of energy (0.209 €/KWh) (29.08DZD), the cost of energy has proven to be largely dependent on the potential quality of renewable energy.

Summary and conclusion

Summary and conclusion

In our project we had found solution for the National Electricity Network in Algeria which faced many problems in supplying isolated and rural areas with electricity, and we achieved an economic solution for a renewable energy hybrid system and developed the standard of living in these areas and we have reached a solution to reduce the diesel consumption and the environmental pollution problem ,by using the HOMER® simulation program, which contains an interactive language that enables us to predict system tasks quickly and accurately.

We have found that the hybrid system (PV/Wind turbine/DG) with batteries storage is the optimal system to solve the problem of electricity in our region Hassi ben Abdellah, which enjoys the climatic conditions suitable for this system, where the average wind speed 3,6 m/s , and solar radiation during the days of the year.

The typical and less cost hybrid system given by the computer is as followed:

- 19 PV modules (6.35 KW)
- wind turbine (1KW)
- generator diesel (10 KW)
- 14 batteries (lead Acid)
- Converter (4.54 KW)

We found that the cost of energy (COE) in the hybrid system of our study is 0.209 €/kWh (29 DZD/KWh), whereas the initial capital required is12 179 € (1,686,652.40 DZD), and net present cost (NPC) is 33 371€ (4,620,061.02 DZD). And the total annual power output is 18353 kW / year, Total energy Solar panels produce the highest value for production of other energy.

On the other hand we studied diesel generator system alone in comparison with the hybrid system and got the cost of energy (COE) which is 0.392 €/kWh (54.55 DZD/KWh), whereas the initial capital required is 750.00 € (103,841.99 DZD) and net present cost (NPC) is 62 662€ (8,689,193.41 DZD).

Our study and comparison over 25 years allowed us to draw the following conclusions:

- ❖ The total cost of the hybrid system almost come on half (50%) the cost of the diesel system project (system hybrid: 33 37 € / system DG: 62 662€).
- ❖ Only the cost of (O&M) for the diesel system equals the total cost of the hybrid system.
- ❖ The cost of fuel consumption for the diesel system represents 67.63% of the total cost of the hybrid system project.
- ❖ The annual consumption ratio of fuel in the hybrid system is 16.47 % of diesel system alone.

The hybrid system is an environmentally friendly energy source that contributes to reducing greenhouse gas emissions, unlike the diesel system.

In our study, the amount of greenhouse gas emissions from diesel generator with hybrid system is relatively small compared to the percentage of gases produced by the diesel generator system alone, which greatly increases the appearance of global warming in the atmosphere.

- ❖ The diesel generator system Carbon dioxide is released28506 kg (CO_2), Unlike the hybrid system is released 16%.
- ❖ The diesel generator system Carbon monoxide is released 216 kg (CO), unlike the hybrid system is released 35.5 Kg (about16.43%).

Finally, this work allowed us to identify the optimal structure of the hybrid system (PV/Wind/DG) with batteries storage, by giving the user the necessary elements to determine the approach that leads to the best solution in terms of costs and needs.

- ✓ **Recommendation:** We propose a futuristic study of a hybrid system consisting of (solar panels, wind turbines and fuel cell ‘pile a combustible’) with storage batteries.

Appendix

A. Some of advantages and Disadvantages PV:

Here in that table below we have advantages and disadvantages of each kind of cell types:

Table1.1: Advantages and Disadvantages by solar cell technologies

Cell Type	Advantages	Disadvantages
Single Crystal Silicon	• Well established andtested technology • Stable • Relativelyefficient	• Useslotofexpensive material • Lotsofwastesinslicing wafers • Costly tomanfacture
Polycrystalline Silicon	• Wellestablishedandtested technology • Stable • Relativelyefficient • Lessexpensivethansingle CrystallineSi • Squarecellformoreefficient Spacing	• Fairly costlyto manifacture • Lotsofwastesinsclicing wafers • Slightlylessefficientthan singleCrystallineSi
Ribbon Silicon	• Doesnotrequireslicing	• Hasnotbeenscaledup tolarge-volume
	• Lessmaterialwastethansingle andpolycrystalline • Potentialforhighspeed	production • Complexmanfacturing
Amoorphous Silicon	• Verylowmaterialuse • Potential for highly automated andveryrapidproduction • Potentialforverylowcost	• Pronounced degradation in poweroutput • Loweffeciency

Table2: Details of capital,replacement and O&M costs

List of component	Capital Cost	Replacement Cost	O&M Cost
PV (6.35 KWh)	3,558.21€ 485,336.18 DZD	3,558.21€ 485,336.18 DZD	10.00€ 1,362.44 DZD
Wind turbine (1KWh)	1672.00€ 227,976.36 DZD	1672.00€ 227,976.36 DZD	70.00€ 9,547.63 DZD
Generator(10KWh)	750.00€ 102,359.23 DZD	750.00€ 102,359.23 DZD	0.300€ 40.9210 DZD
Storage (1KWh)	300.00€ 40,899.84 DZD	300.00€ 40,899.84 DZD	10.00€ 1,365.79 DZD
System Converter (4.54 KWh)	300.00€ 40,899.84 DZD	300.00€ 40,899.84 DZD	0.00€ 0.00 DZD

B. Profile in Hassi Ben Abdellah (Ouargla)

Figure A: Ac primary load daily profile

Figure B: Global Solar Daily Profile

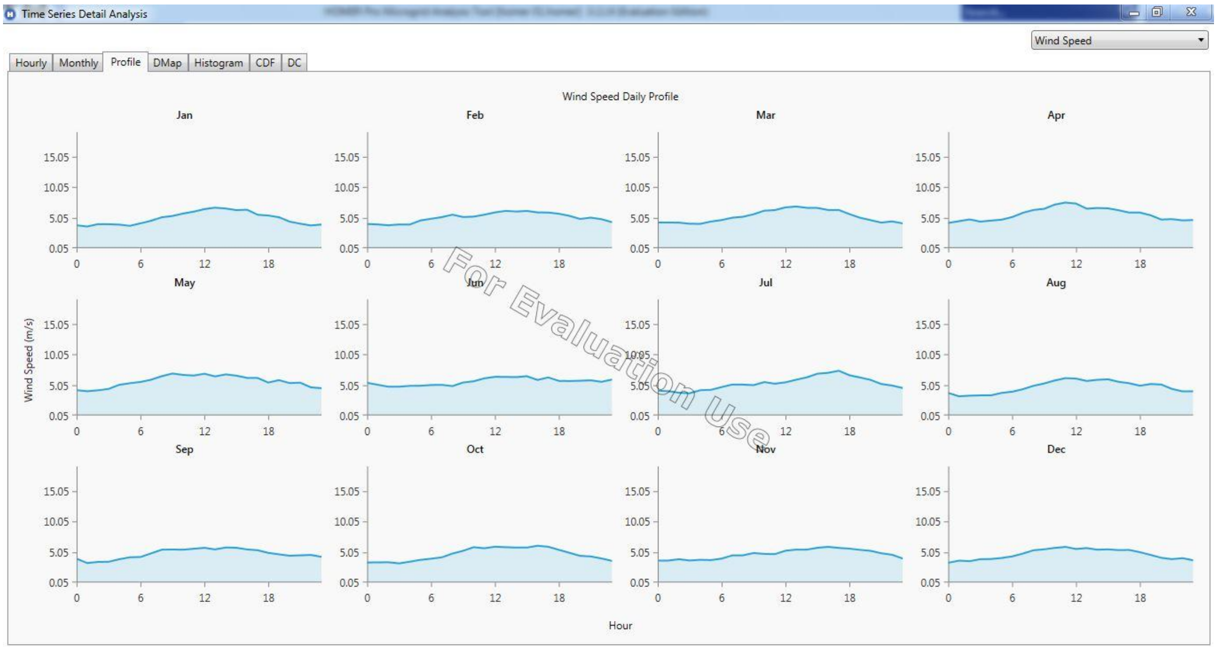


Figure C: Wind speed Daily Profile

Table 3: Configuration of Generic flat plate PV

Generic flat plate PV	
Manufacture	Generic
Rated Capacity	5,20 Kw
Operating temperature	47 c°
Temperature coefficient	-0.5 c°
Efficiency	13%
Electric Bus	DC
Capital initial	3,588.21 € (487,055.98 DZD)
Life time	25 years
Panel type	Flat plate

Table 4: Configuration of Wind Turbine G1

Wind turbine generic 1 KW	
Manufacture	Generic
Abbreviation	G1
Rated Capacity	1 KW
Hub Height	10 m
Electric Bus	DC
Capital Initial	1,672.00 € (228,865.29 DZD)
Life time	20 years

Table 5: Configuration of Battery Storage

Battery kinetic model	
Maximum capacity	83,4 Ah
Nominal capacity	1 kWh
Nominal voltage	12 V
Capacity ratio	0,403
Rate constant (1/hr)	0,827
Roundtrip efficiency	80 %
Maximum charge current	24 ,3 A
Maximum charge rate (A/Ah)	1
Life time	5 years
Capital initial	300.00 € (41,061.63 DZD)
Name	Generic 1KWh Lead Acid

Table 6: Configuration of System Converter

System Converter	
Name	System converter
Efficiency	95%
Life time	15 years
Capital Initial	300,00 € (41,061.63 DZD)

Table 7: Configuration of Diesel generator

Generic 10KW	
Name	Generic 10 KW Fixed Capacity Genset
Capacity	10 KW
Fuel	Diesel
Fuel curve intercpt	0,480 L/hr
Fuel curve slope	0,286 L/hr/KW
Initial intercpt	750,00 € (102,659.91 DZD)
Electrical Bus	AC
Minimum Load Ratio	25%
Life Time	15000 hours
Fuel	0,16 €

Abstract

In this memory we have simulated and dimensioned with the HOMER energy code, a totally autonomous hybrid system work with (photovoltaic panels, wind generators, diesel generators) with storage batteries to power a house off networks located at Hassi Ben Abdellah in Ouargla (Algeria), based on the metrological data given by the HOMER® code of the Ouargla region, we obtained the cost (€), the cost of energy (1 KWh/€), the toxic gases emission (kg /year) and optimal number and characteristics of Photovoltaic panels, wind generators, diesel generators) with storage batteries, we obtained a technical-economic study and a comparison with an autonomous diesel system.

Keys Words: hybrid system, Wind, isolated house, PV, Diesel Generator, HOMER Energy

Résumé

Dans ce mémoire nous avons simuler et dimensionner avec le code HOMER Energie , un système hybride totalement autonome fonctionnent avec (panneaux Photovoltaïques , générateurs éolien , groupes électrogène diesel) avec batteries de stockage pour alimenter une maison hors réseaux situé a Hassi Ben Abdellah wilaya de Ouargla (Algérie), en basent sur les données métrologiques données par le code HOMER® de la région de Ouargla , nous avons obtenus le cout (€), le coute de l'énergie (1KWh /€), les émission de gaz toxiques (kg /An) et nombre et caractéristiques optimale des (panneaux Photovoltaïques , générateurs éolien , groupes électrogène diesel) avec batteries de stockage, nous obtenus une étude technique-économique et une comparaison avec un système diesel autonome.

Mots clés : système hybride, éolienne, maison isolée, PV, Générateur diesel, HOMER Energie

ملخص

في هذه المذكرة قمنا بمحاكاة و نمذجة باستعمال برنامج الطاقة هومر ، حيث يعمل النظام الهجين مستقل تماما (الألواح الضوئية ، مولدات الرياح ، مولدات الديزل) مع بطاريات التخزين لتزويد منزل خارج الشبكة موجودة في حاسي بن عبد الله ورقلة (الجزائر) ، استناداً إلى البيانات المتيولوجية المقدمة من برنامج هومر لمنطقة ورقلة ، تحصلنا على التكلفة الإجمالية للمشروع (يورو)، وتكلفة الطاقة (1 كيلوات ساعي / يورو) ، وانبعاثات الغازات السامة (كلغ / سنة) والعدد الأمثل والخصائص كل من(الألواح الضوئية ، مولدات الرياح ، مولدات الديزل) مع بطاريات التخزين ، وقمنا بمقارنة هذه الدراسة اقتصادية مع نظام الديزل مستقل.

الكلمات المفتاحية :النظام الهجين,توربينات الرياح, منزل معزول,الألواح الشمسية,مولد الديزل,برنامج هومر