République Algérienne Démocratique et Populaire

Ministère de I 'Enseignement Supérieur

et de la Recherche Scientifique

Université Kasdi Merbah -Ouargla

Faculté des sciences appliquées

Département génie Electrique

Mémoire

Présenté pour 1'obtention du diplôme de

MASTER

Spécialité:

Electrotechnique industrielle

Présenté par:

MIMMI Soumia

Thème :

Study and optimization of standalone PV-wind-Diesel Battery Hybrid System In Remote Site In ALGERIA

Soumis au jury composé de :

Mr LAAROUSSI BEN YAKHELEF	MCB	Président	UKM Ouargla
Mme BOUALI Khadidja	MCA	Examinateur	UKM Ouargla
Mr DERNOUNI Mhammed	MA	Encadreur / rapporteur	UKM Ouargla

Année universitaire 2019 / 2020

Remerciement

Nous remercions notre Dieu ALLAH qui nous aide et nous a donne la puissance pour réaliser ce travail.

Je remercie mon Encadreur Mr Dernouni Mhammed et les membres de jury qui vont évaluer ce travail.

Dédicace

Je dédie ce modeste travail

A ma chère mère, Et les

membres de ma famille précisément

mes deux sœurs

TABLE OF CONTENTS

Table list

Figure List

Symbols

η_{pv}**:** Instantaneous PV

P_{pv}**:** Output of the PV

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

N :Number of modules

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]

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 η_B 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)

EGen (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 [%]

$D_f(t)$: 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

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 renewable energy system

NREL: National renewable energy laboratory

NPC: Net present cost

COE: Cost of energy

M&O: Maintenance and operating

DA: Dinar Algerian currency

GENERAL INTRODUCTION

GENERAL INTRODUCTION

The electrification of the isolated places by the extension of the electric networks is economically impracticable, considering the high costs of electricity to deliver by the electric network, the continuation of the electrification by the diesel group, increases the costs for the high costs of maintenance of the diesel group, the ideal solution is the use of the hybrid system for renewable energy (solar photovoltaic and wind). [14]

Hybrid power system based on new and renewable energy sources, especially photovoltaic and wind energy, are an effective option to solve the power-supply problems for remote and isolated areas far from the grids.[13]

Properly chosen renewable power sources will considerably reduce the need for fossil fuel leading to an increase in the sustainability of the power supply .At the same time, conventional power sources aid the renewable sources in hard environmental conditions, which improves the reliability of the electrical system.[12]

To realize that study , we divided the work to three chapters :

The first chapter we are going to introduce about general ideas of each part of the hybrid system (photovoltaic system, wind turbine system ,diesel generator system, the converter and the battery storage)where we based on the performance of all the components of the hybrid system .

While in the second chapter we are going to model an size every component of the hybrid system and Explain the work of HOMER ® pro, also the identification of the remote area (EL MENIA) and the presentation of meteorological data.

By the end, in the third chapter we will present the simulation results of the micro-grid in EL MENIA area then we are going to discuss them also the simulation results of the Diesel generator alone with the same house load and discuss them too by comparing between the two results

And conclude by choosing the affordable cost of all the components of the hybrid system and which one in economical for the user end healthier for the environment .

CHAPTER I

Generality about the hybrid system

I.1 Introduction:

In rural areas particularly in the developing world, where most of the population up to 80% is located, more than 1billion people lack the essential energy services to satisfy the most basic needs and to improve their social and economic status. The cost of grid for rural electrification in area extension, sometimes very high due to a low density level of population, leads often various organizations to explore alternative solutions.

The choice of diesel power generation has been considered for a long time as the most economical and reliable alternative , but this solution is not always the most profitable and induces several environmental and practical nuisances for the user: high operating costs energy dependence for the user(and for the country),fuel transportation problems, complicated maintenance, useful life of five years but frequently less due to maintenance problems no guarantee of uninterrupted generation , sound nuisance and oil waste production.

A renewable energy system (mainly PV or wind) may be a good solution to supply small and medium energy loads. it can provide an uninterrupted supply of electricity (particularly attractive for systems as telecommunications security installations, water supply and cooling),it’s easy to install and requires a low maintenance and has a high reliability .it particularly than an engine generators utilization.

Solar energy system cannot provide a continuous source of energy due to the low availability during no-sun period and during winter. The wind system cannot satisfy constant load due to different magnitude of wind speed from one hour to another. So there are big problems using these energy sources separately [1].

In order to achieve the high energy availability required in some application such as: lighting, remote areas electrification and telecommunications, it’s necessary to oversize the rating of the generating system. But it is also possible to use hybrid system combination of 2 renewable energy sources.

In general, the variation /fluctuations of solar and or wind energy generation do not match the time distribution of the load demand on a continuous basis. But the association of these tow random sources allows to achieve a high availability and generally to reduce the energy storage size conducting to a lower electricity generation cost.

Nevertheless, the elaboration of such an hybrid system is accompanied by problems regarding the design as :X the choice of the correct size of each component; X the economical optimization of the Kwh production cost.

I.2 History of wind power:

Wind energy has been used for thousands of years for milling grains pumping water and other power mechanical applications. But the use of wind energy as an electrical supply with free pollution what makes it attractive and takes more interest and used on a significant scale.

Attempts to generate electricity from wind energy have been made since the end 19 the century. small wind machines for charging batteries have been manufactured since the 1930s.wind now is one of the most cozy-effective methods of electricity generation available in spite of the relatively low current cost of fossil fuels .the technology is continuously being improved both cheaper and more reliable, so it can be expected that wind energy will become even more economically competitive over the coming decades [2].

I.2.1Wind energy system:

The wind energy conversion systems are designed to convert the energy of wind movement into mechanical power. With wind turbine generators, this mechanical energy is converted into electricity and the use of the electricity depends on the type of the wind turbine.

The nowadays turbine there configuration based on the direction of the axe the rotating part vertical or horizontal. They range in size from the smallest turbine that produce 10 or100 watt to the largest that produce megawatts of power.

I.2.2The definition of wind energy:

The wind energy or (wind power) refers to the process of creating electricity using the wind, or air flows that occur naturally in the earth's atmosphere modern wind turbines are used to capture kinetic energy from the and generate electricity[3].

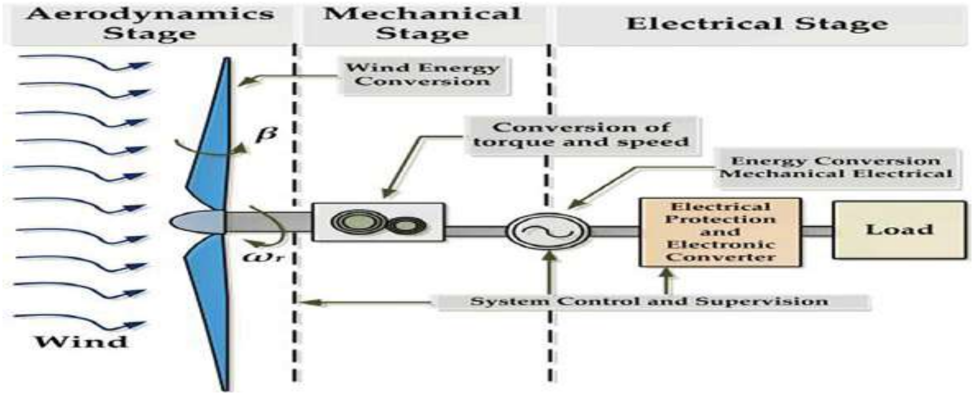
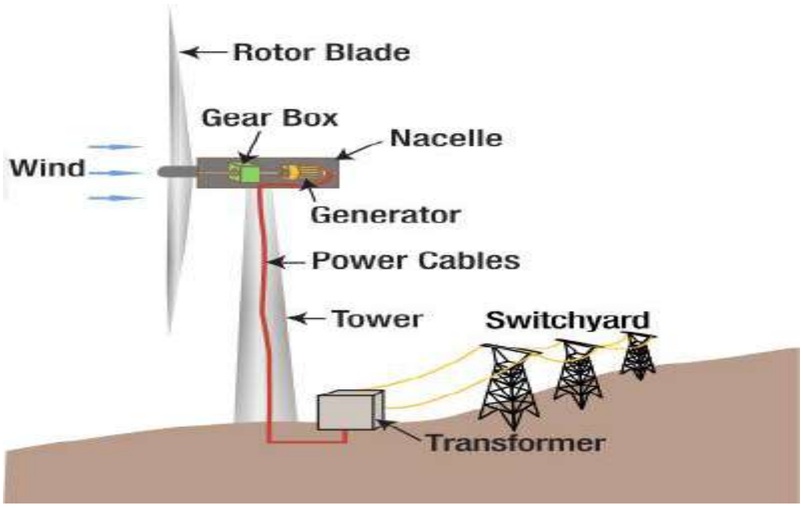


Figure I.1:the energy conversion of wind energy turbine

I.2.3The typical wind turbine (principal):

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



FigureI.2: illustration of a modern wind turbine

I.2.4The different types of wind turbines:

Wind turbines are divided into two large families: those with vertical axis and those with horizontal axis [4].

I.2.4.1Vertical axis wind turbines:

Vertical axis wind turbines have blades that go from top to bottom. The most common types of these turbines are Savories and one of the most popular in the world market, Durries. These turbines can harness winds from any direction without the need to reposition the rotor when the wind direction change

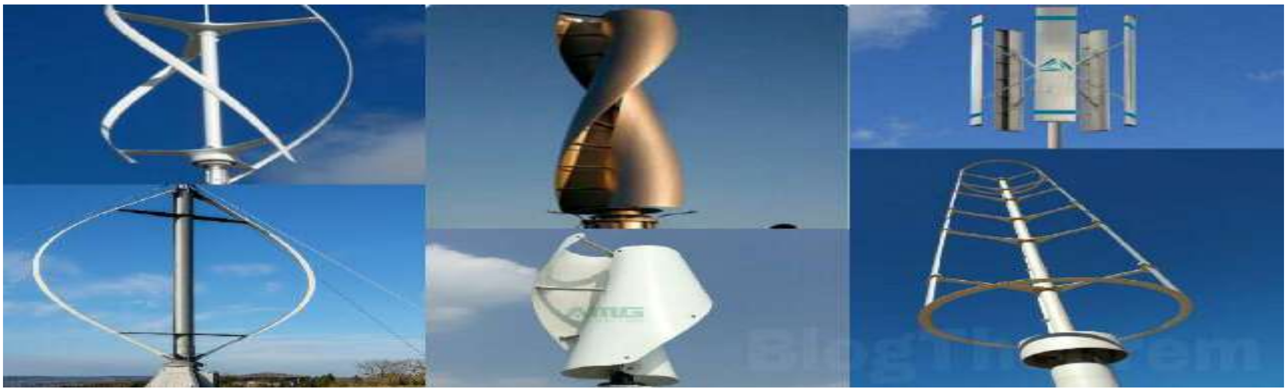


Figure I.3: the vertical wind turbine

I.2.4.2 Horizontal axis wind turbines:

Most wind machines being used today are the horizontal-axis type. Horizontal-axis wind machines have blades like airplane propellers. Horizontal axis wind turbines predominantly have 2 or 3 blades, or a large number of blades. The later are described as high-solidity devices and include the multi blade wind turbines used for water pumping on farms. In contrast, the swept area of wind turbines with 2 or 3 blades is largely void: only small fraction of this area appears to be solid.

Figure I.4: the horizontal wind turbine.

I.2.5The component of wind turbine:

A wind turbine consists of the following four main parts:

The base, tower, nacelle, and blades, as shown in figure (I.5). The blades capture the wind's energy and spin a generator in the nacelle. The tower contains the electrical circuits, supports the nacelle, and provides access to the nacelle for maintenance while the base is made of concrete and steel and supports the whole structure.

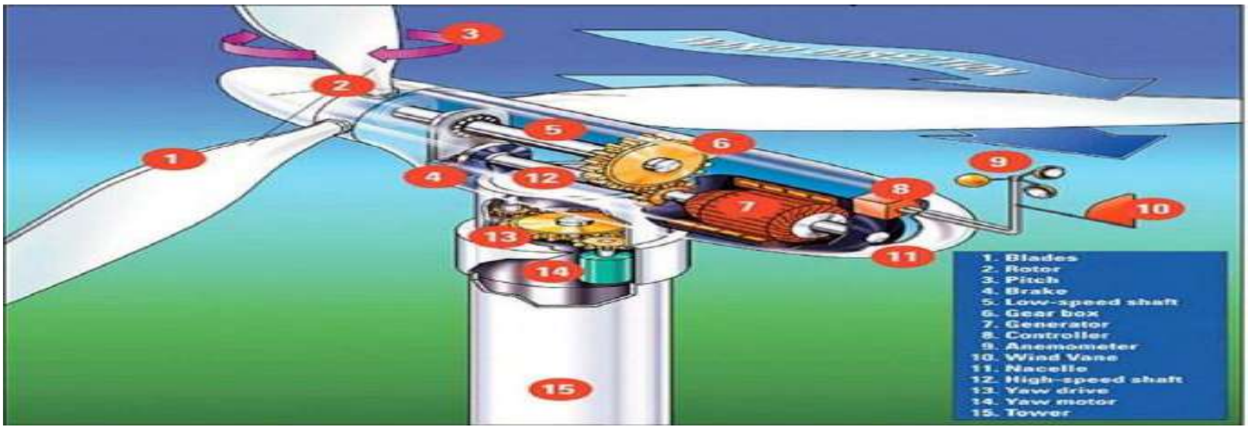


Figure I.5: the component of wind turbine

I.2.6 The Betz limit on wind turbine efficiency:

In 1919 the physicist Albert Betz proves that no wind turbine can ever harness more than exactly sixteen twenty- sevenths (59.2592…. %) of kinetic energy in wind into mechanical energy to turn the turbine rotor.

Otherwise the wind that passes through the turbine dose slow down. This is also why wind turbine can never have 100% efficiency, because that will stop the wind and make it pile up by the turbine.yhe most that can get out is about 59% or to be exact $2^4/3^3$.

The theoretical maximum power efficiency of any deign of wind turbine is 0.59 this is called maximum power coefficient C p max =0.59

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

Where

ρ : Air density Kg/m^3

A: Cross sectional area of wind parcel,m^2

V: The wind speed, m/sec.

In practice, wind turbine rotor deliver much less than the Betz limit. The efficiency of the turbine depends on different factors such as the turbine rotor, transmission train and the electric generator. Normally the commercial turbine rotor has aerodynamic efficiencies in real conditions 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.

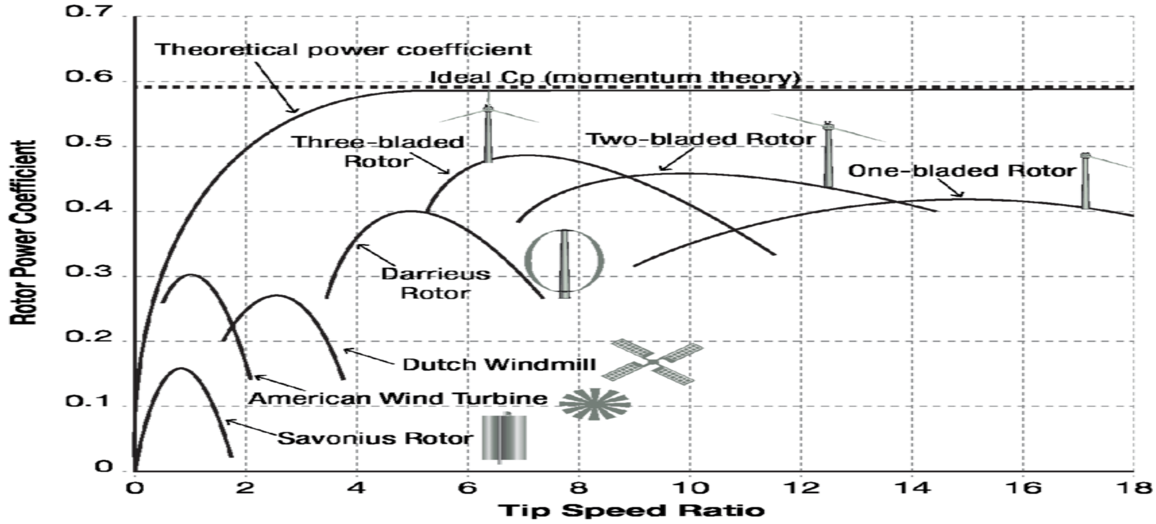


Figure I.6: the wind turbine efficiency or power coefficient

Figure I.7:the Betz limit law

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

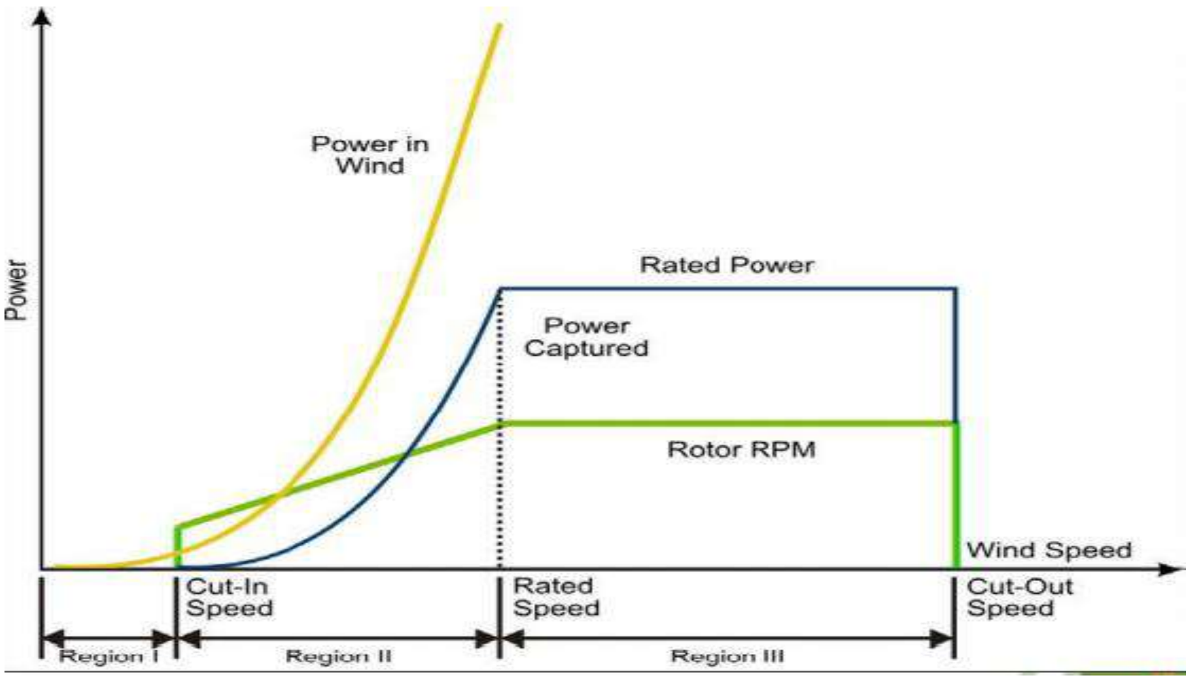


Figure I.8: the typical wind turbine power output with wind speed

The illustration above in figure (I.8) depicts the components of a power curve.

The Y axis is the amount of power the turbine is designed to produce.

The X axis is the wind speed.

A/cut –in speed

It is the wind speed required for the turbine to start producing power. The wind must reach this speed before the turbine's control system turns the turbine on .

B/rated output power and rate output wind speed

It is the wind speed required for the turbine to reach its maximum power output .so for a 3 MW turbine to reach its full output of 3 MW, the wind speed must reach the rated output speed.

C/cut-out speed

It is the wind speed that will cause the turbine to shut down and go into a safety mode to protect the turbine from damage.

I.3 History of photovoltaic:

The photovoltaic effect is the transformation of solar energy ‘’photon’’ in to electricity .it was discovered in 1839 by the French physicist A. BECQUERL .A photovoltaic cell is mainly made from doped silicon (semiconductor P-N junction).

When a cell is exposed to electromagnetic solar radiation, the photons of light transmit their energy to the atoms of the junction .this energy allows the electrons to release atoms thus generating electrons (N charges) and holes (p charges).

These charges are then kept separated by an electric field which constitutes ‘’a potential barrier ‘’.once the charges p and N have been isolated ,it suffices to close the circuit between these 2 zones (P and N) to set the electrons in motion and thus create an electric current.

The solar energy falling on earth during a year is ten thousand times more than the existing fuel sources available on earth. The element such as silicon, germanium ect ,Used in making the PV cells are also copiously available on earth. the PV cells can be classified as pollution free as they do not produce any by product 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 in1877 [5]. in 1883, Charles 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, Chaplin-Fuller-Pearson team [6] 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 to 6%. After further research, the efficiency of the current PV cells available in the market went up to 17%.

I.3.1Photovoltaic power generation:

A solar cell is considered the basic part in the photovoltaic system; it is a device that converts light energy into electrical energy by the photovoltaic effect. Solar cells are often electrically connected and encapsulated as a module. The PV modules often have a sheet of glass on the front (sun up) side allowing light to pass while protecting the semiconductor wafers from the elements (rain, hail, ect). Solar cells are also usually connected in series in modules, creating an additive voltage .connecting cells in parallel will yield a higher current. Modules are then interconnected, in series or parallel, or both to create an array with the desired peak DC voltage and current [7].

I.3.2Crystalline silicon cells:

Rigid panels comprised of silicon cells sandwiched between protective glass sheets are the dominant solar technology on the market .they are generally the most cost effective and efficient in energy production ; however ,they are more susceptible to the effects of shade and high temperature ,which reduce the amount of electricity these types of panels can produced and we have two types of crystalline silicon cells are used in industry .the first in mono-crystalline produced by slicing wafers (up to 150mm diameter and 350microns thick) from a high –purity single crystal boule. the second is multi-crystalline silicon, made by sawing a cast block of silicon first into bars and then wafers .the main trend in crystalline silicon cell manufacture is toward or both mono and multi-crystalline Si, a semiconductor homo-junction is formed by diffusing phosphorus (an doping N- type) into the top surface of the boron doped (P-type) SI wafer to allow the passage of current as show the figure (I.9).

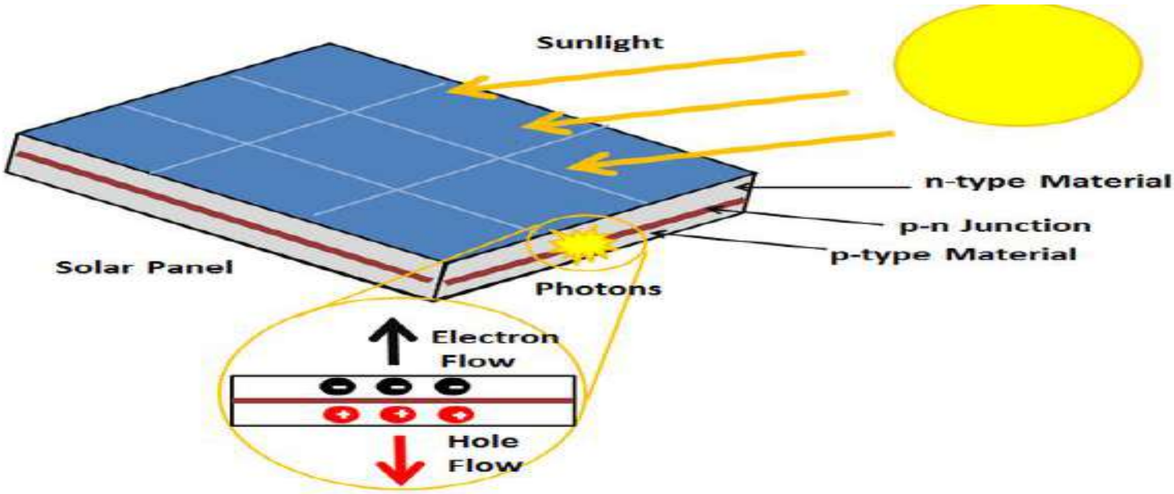


Figure I.9: P-N junction and cell components

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus- doped (N-type) silicon on top of a thicker layer of boron –doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light stimulated electrons, resulting in flow of current when the solar cell is connected to an electrical load.

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.10).

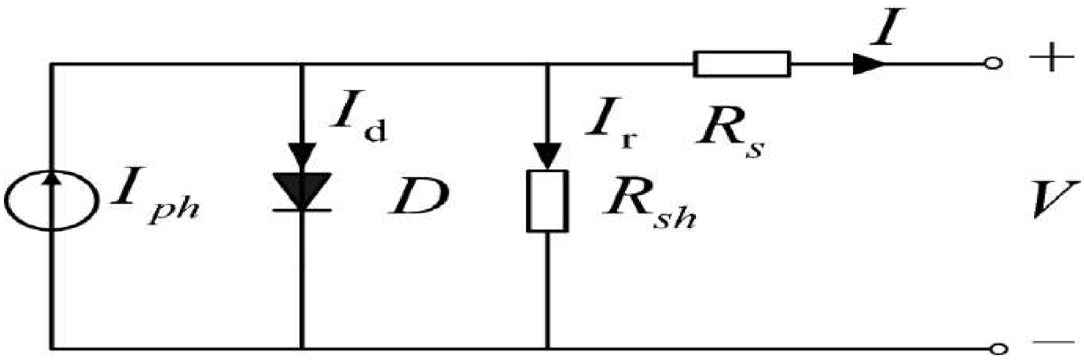


Figure I.10: equivalent circuit of a PV cell

R_{sh} is the shunt resistor that compensate for leaking current in the diode

R_s is the series resistor that correspond e.g. resistor in contact.

I_{ph} represents the current generated when exposed to sunlight.

The current going through the junction is denoted I_d and is calculated through the formula:

$$I_d=I_0((e^{qV}/KT)-1)$$

Where

I_0 : is the reverse saturation current of the diode ,

q :the charge of electron

v :is the open circuit voltage

K: is the BOLTZMAN constant

T: is the temperature

And by applying Kirchhoff's law the output current I is calculated through the formula below:

$$I=I_{ph}-I_d$$

Regardless of size , a typical silicon PV cell produces about 0.5-06 volt DC under open –circuit, no-load condition .the current (power) output of a PV cell depends on its efficiency and size (surface area) and is proportional the intensity of sunlight striking the surface of the cell.

In addition the current I is almost directly proportional to the insolation which is shown in figure (I.11) below, as the voltage is close to fixed for when insolation varies [8].

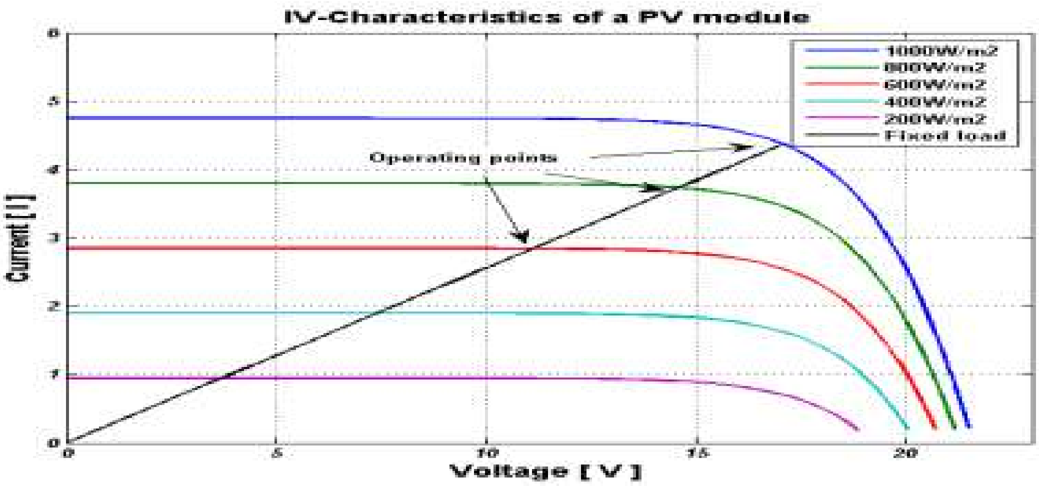


Figure I.11: characteristics of different levels of insolation

I.3.3 Performance:

The photovoltaic solar cells convert the suns radiant light directly into electricity. With increasing demand for a clean energy source and the sun's potential as a free energy source, has made solar energy conversion as part of a mixture of renewable energy sources increasingly important. As a result, the demand for efficient solar cells, which convert sunlight directly into electricity, is growing faster than ever before.

Photovoltaic cells are made almost entirely from silicon that has been processed into an extremely pure crystalline from that absorbs the photons from sunlight and then releases them as electrons, causing an electric current to flow when the photoconductive cell is connected to an external load. There are a variety of different measurements we can make to determine the solar cell's performance, such as its power output and its conversion efficiency.

The main electrical characteristics of a PV cell or module are summarized in the relationship between the current and voltage produced on a typical solar cell (I-V) characteristics curve. The intensity of the solar radiation that hits the cell controls the current (I), while the increases in the temperature of the solar cell reduce its voltage (V).

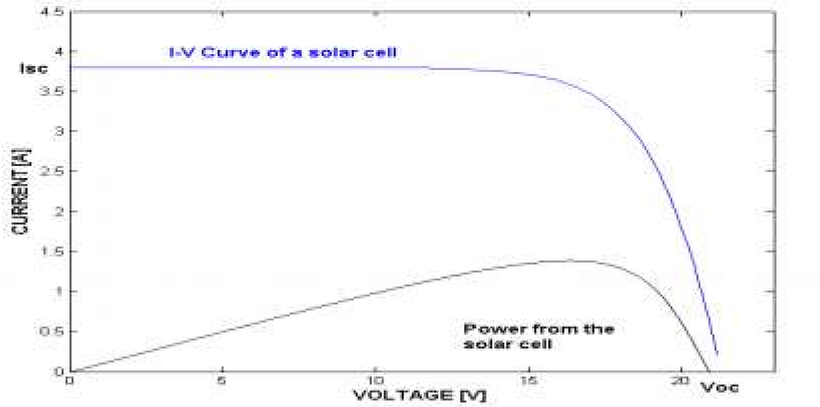


Figure I.12: the typical I-V and P-V curve of a photovoltaic cell

Solar cells produce direct current (DC) electricity and current times voltage equals power, so we can create solar cell (I-V) curves representing the current versus the voltage for a photovoltaic device.

Solar cell(I-V) characteristics curves are basically a graphical representation of a solar cell summarizing the relationship between the current ant the voltage at the existing conditions of irradiance and temperature .(I-V) curves provide the information required to configure a solar system so that it can operate as close to its optimal peak power point(MPP) as possible

$P_{mpp}=V_{mpp}*I_{mpp}$

Where V_{mpp} and I_{mpp} corresponds to the point on the curve where the power output is at its maximum in addition, for every level of insolation there is a corresponding MPP i.e. the values of V_{mpp} and I_{mpp} will change depending on insolation, depicted in figure (I.13)below.

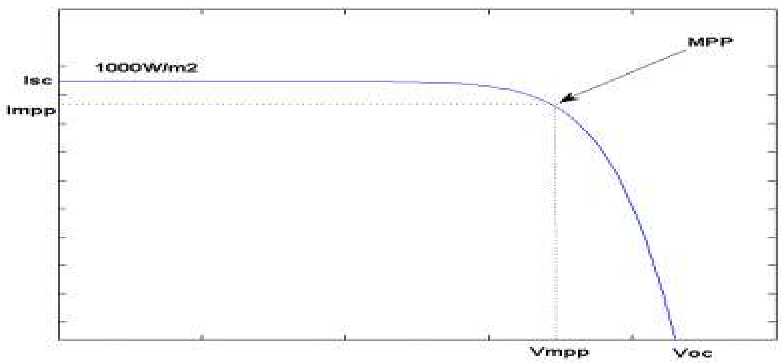


Figure I.13: I-V characteristics of 1000w/m^2

I.3.4PV module and array :

A photovoltaic module consists of multiple PV cells connected in series to provide a higher voltage output or in parallel to provide a higher current output and a multiple modules composed a solar panels model. However a photovoltaic array is system composed of multiple PV modules.

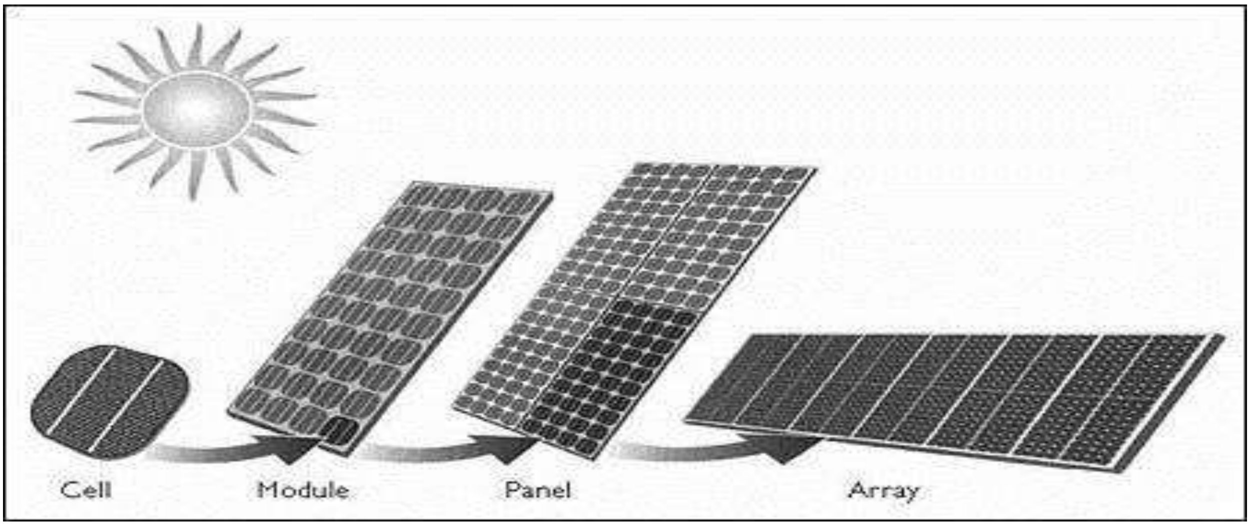


Figure I.14: photovoltaic array modules

I.4Converter:

The DC -DC converter is used in solar and wind energy with a specific topology for control and enabling for DC circuits for example it converts input voltage and current into desired output voltage and current.

The converter has two modes; buck and 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 [9].

I.5Inverter:

The inverter is essential in the hybrid system where a storage system and a backup diesel generator are involved in the system .it can transfer power simultaneously in both directions .the inverter can supply DC and charge the batteries so it provides a path from the AC bus to the DC bus in this case it acts as rectifier circuit which changes AC diesel generator voltage to DC voltage .in the other way ,it provides path from DC bus to the AC load so it acts as an inverter which changes DC voltage to AC voltage needed by the electric load .

I.6Maximum power point tracking (MPPT):

The solar panels have a nonlinear voltage-current characteristic, with a distinct maximum power point (MPP),which depends on the environmental factors such as temperature and irradiation .in order to continuously harvest maximum power at any point of time from the solar panels ,MPPT algorithms need to be employed .the calculations result in an output that delivers maximum current at the required voltage at any point in time .during low light leel situations it will compensate for the low light level and find the new point at which the solar cell delivers its maximum power output.

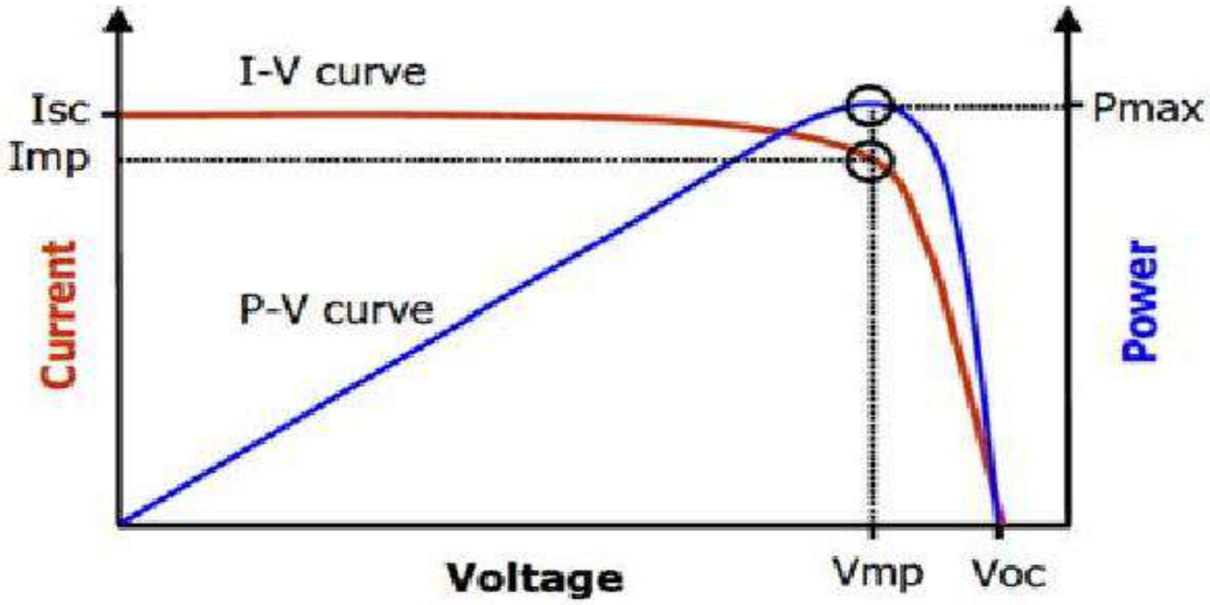


Figure I.15: the I-V and P-V characteristic with MPPT

I.6.1Necessity of maximum power point tracking:

The maximum power point tracking is a electronic technique commonly used with the photovoltaic (PV) systems to maximize the power extraction under all conditions and therefore maximize the array efficiency and minimize the overall system cost.

I.7 Storage system:

I.7.1The type of accumulators:

The batteries or accumulators are electrochemical devices that store energy in chemical form. They are used for storing the excess energy for later use .according to the types of the batteries. There are [10,11]:

A/Lead-Acid batteries.

B/Nickel-Cadmium accumulators (NiCad).

C/Nickel Metal Hybrid accumulators (NiMH).

D/Lithium accumulators.

I.7.2The main features of accumulators:

A-Voltage:

It is the electromotive force of the accumulator, a function of electrochemical couple used.

A battery consists of basic elements with a nominal voltage of 2 volt actually between 1:9volt and 2:1volt depending on the state of load .there is of course 6,12or 24 batteries [10].

B-charge voltage:

It’s the minimum voltage to apply for recharging effectively the accumulator; it is expressed in volts[10].

C-battery capacity:

The 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

For historical reason, it’s expressed in Ampere-hour (Ah) and sometimes in Watt-hour (Wh)[10].

D-life time:

The life time of battery is counted by number of cycles. Cycle corresponding to a complete discharge and recharging of the battery [10]

I.8 Diesel generator:

The diesel generator should be selected to cover the load so its rating is determined according to specifications. The optimum selection of the generator rating is such that the generator with other sources shall provide load with power it needs at all cases. a practical approach for large loads is to employ multiple units, e.g. a set of each unit to achieve maximum fuel efficiency

I.9 Conclusion:

In this chapter we try to give a general clue about the hole parts of the hybrid system consist of the photovoltaic's panel , the wind turbine system , the diesel generator and the storage battery ,that going to be the judicious solution to electrification a clinic in remote area.

References:

[1] Ozdamar A, Ozbalta N, Aki+n A, Yildirim E.D. An application of a combined wind and solar energy system in Izmir. Renewable and Sustainable Energy Reviews 2005; 9:624–637.

[2] Boyle G., 2004, Renewable Energy, OXFORD university press.

[3] Belghitri Houda, Modélisation, Simulation Et Optimisation D‟un Système Hybride Eolien-Photovoltaïque. Mémoire De Magister 2010.

[4] Bogdan,SB,Salameh,ZM ,1996 «Methodology for optimally the combination of abattery bank and PV array in a wind/PV hybrid system » IEEE transaction on Energies conversion 11(2),367-375.

[5] “Renewable Energy” Godfrey Boyle second edition (2008)

[6] Design of a Wind-Solar Hybrid Power Generation System in Sri Lanka, Master of Science Thesis 2015

[7] Kaldellis, J. K. and D. Zafirakis (2011). "The wind energy (r) evolution: A short review of a long history." Renewable Energy **36**(7): 1887-1901.

[8] Matilda Kjellander, Anders Tengvall, Bachelor “Design of a small scale hybrid photovoltaic and wind energy system”, Thesis Halmstad 2014-06-03

[9] Design of a Wind-Solar Hybrid Power Generation System in Sri Lanka, Master of Science Thesis 2015

[10] BOUZID, Z. (2014). Dimensioning of autonomous photovoltaic systems based on the concept of hourly usability. Application to southern Algeria (Master thesis, University of Tlemcen, Algeria).

[11]Berndt, D. (1997). Maintenance-free batteries : lead-acid, nickel-cadmium, nickel-metal hydride ; a handbook of battery technology ;* nickel/cadmium nickel/metal. Research Studies Prés.

[12]Austilio Bauen A sustainable and reliable energy source, bioenergy.

[13]Elhadidy, M.A., &Shaahid, S.M.(2004a). Promoting applications of hybrid (wind+photovoltaic+diesel+battery) power systems in hot regions. *Renewable Energy*, *29*, 517–528.10.1016/j.renene.2003.08.001.

[14]Josh Agen broad ,Kelly Carlin, Kendall Ernast ,Stephen Doig .Mini grids in the money

CHAPTER II

Modeling of hybrid system PV/wind turbine/diesel generator using HOMER software

II.1 Introduction:

The area of El MENIA in the state of GHARDAIA, 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]:

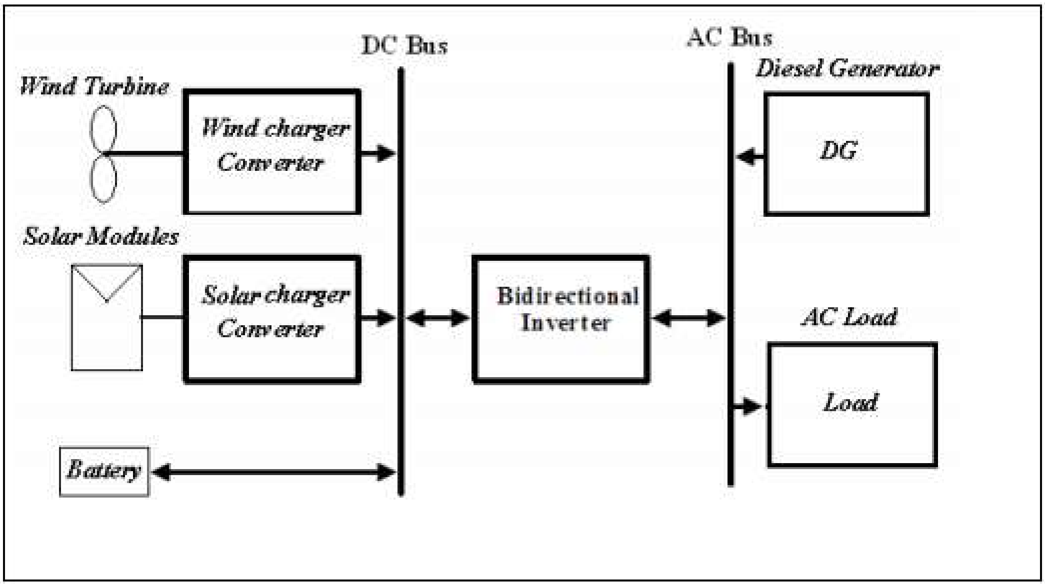


Figure II. 1: Configuration of system hybrid

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]:

$$P_{pv}=\eta_{pv}\,.A_{pv}\,.G_t \qquad \text{(II.1)}$$

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

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

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]:

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

Where Ta is the ambient temperature (C°) and NOCT is the nominal cell operating temperature (C°).ηpc β, NOCT and Apv, are parameters that depend upon the type of module used. The data are obtained from the PV module manufacturers.

II.3.2Wind 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:

$$P_w(V) = \begin{cases} PR & Vc \leq V \leq VR \\ PR\{(V2 - Vc2)/(VR2 - Vc2)\} & Vc \leq V \leq VR \\ & \text{Otherwise} \end{cases} \quad (II.4)$$

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] :

$$\frac{V(H)}{V(\mathrm{Href})} = \left(\frac{H}{\mathrm{Href}}\right)^{\alpha} \quad (II.5)$$

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.

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].

$$c_B = \frac{E_L . S_D}{V_{B\ (DOD)_{max}T_{cf.\eta B}}} \quad \text{(II. 6)}$$

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**

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

- **Battery discharging**

$$SOC(t) = SOC(t-1) \times (1-\sigma) + (E_L(t)/\eta_{inv}-Egen(t)) \quad \text{(II.8)}$$

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:

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

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]:

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

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 EL MENIA:

The solar potential of the EL MENIA 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].

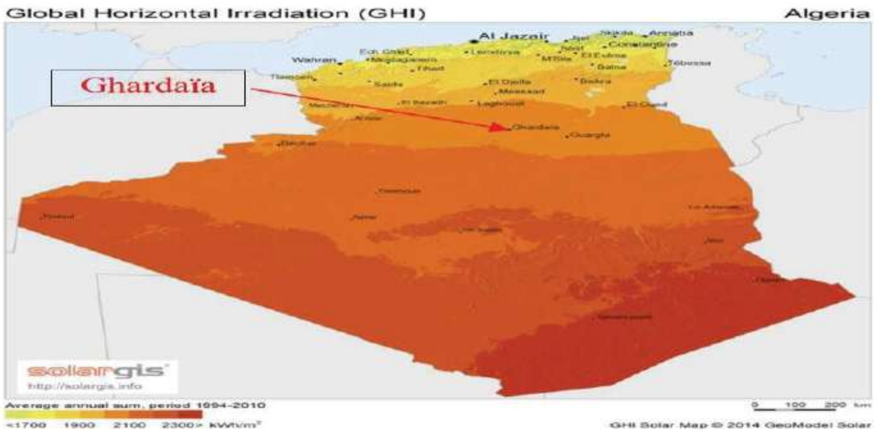


Figure II.2:Algeria solar radiation Kw/m^2/h

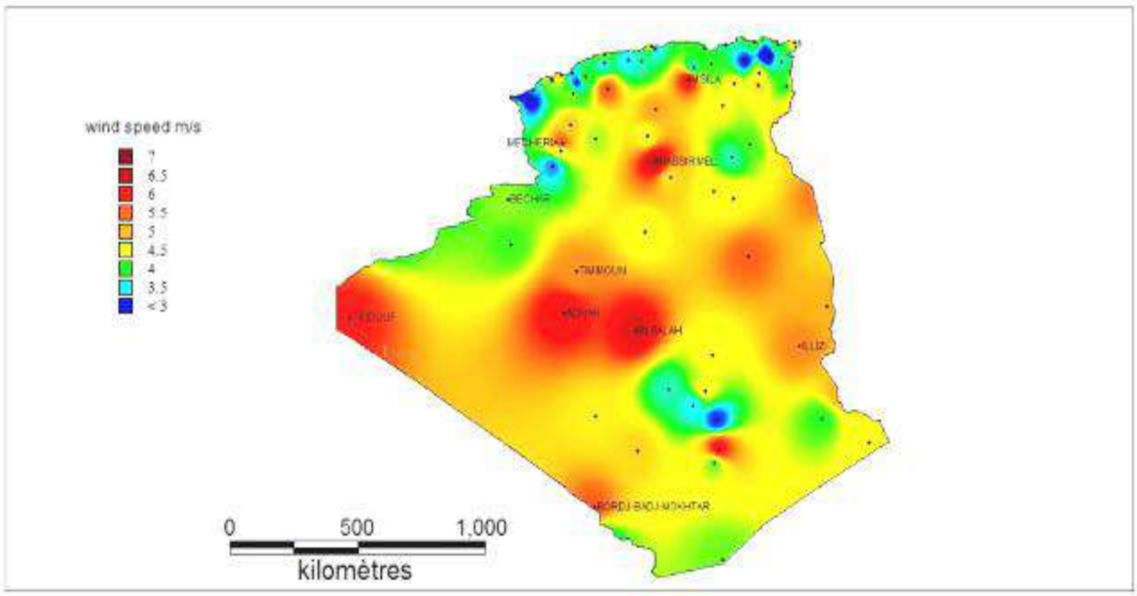


Figure II.3:Algeria wind energy potential (m/s)

EL MENIA (GHARDIA) Oasis are used as the wind-solar energy resource at (30°35.0‘‘N, 2°53.0‘‘E)

Figure II.4: location of EL MENIA(GHARDAIA) 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) ELMANIA area in the state of GHARDIA, 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

Time	Refrigerator	Washing machine	Electric oven	TV LCD	Economic Lightning	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

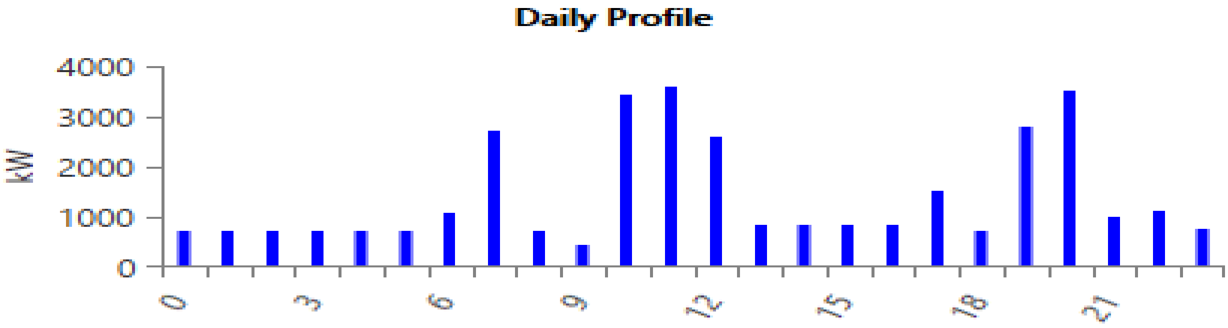


Figure II.5:Daily load profile of the house

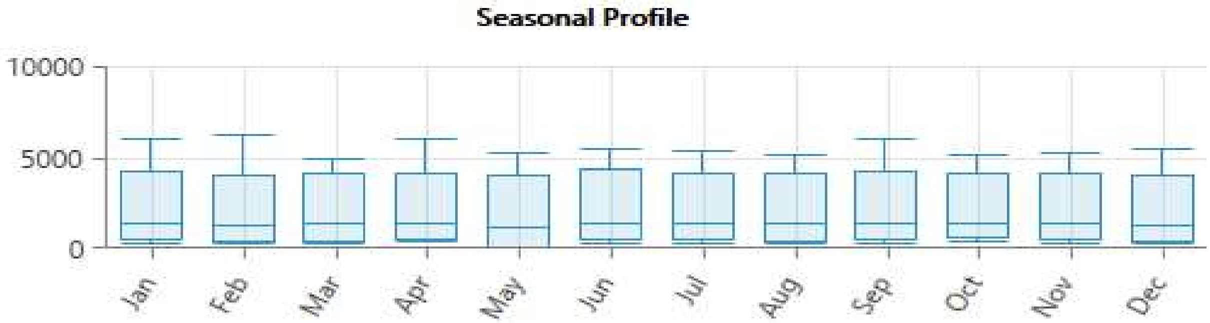


Figure II.6: seasonal profile electric load

II.6 The electrical structure of 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.

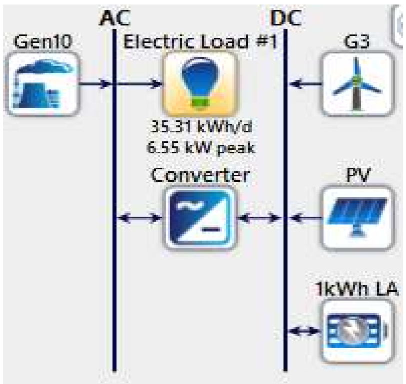


Figure II.7:schematic of system hybrid

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 (5.80kwh/m²/day) and wind speed is taken(5.45m/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].

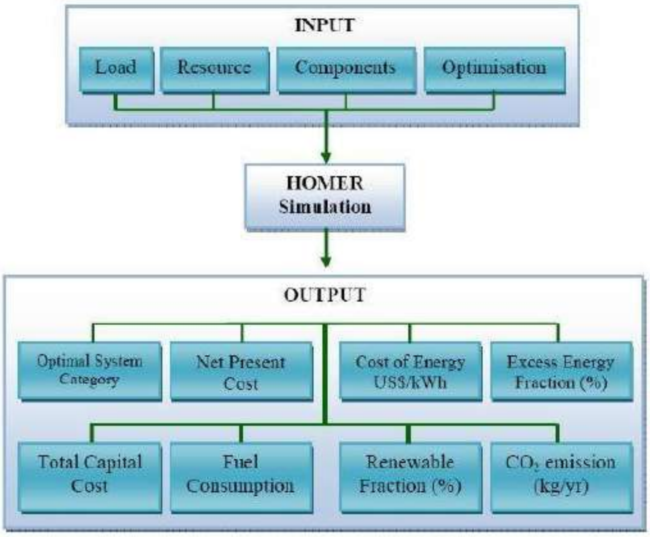


Figure II.8:HOMER package architecture

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.8.1Interfaces 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).

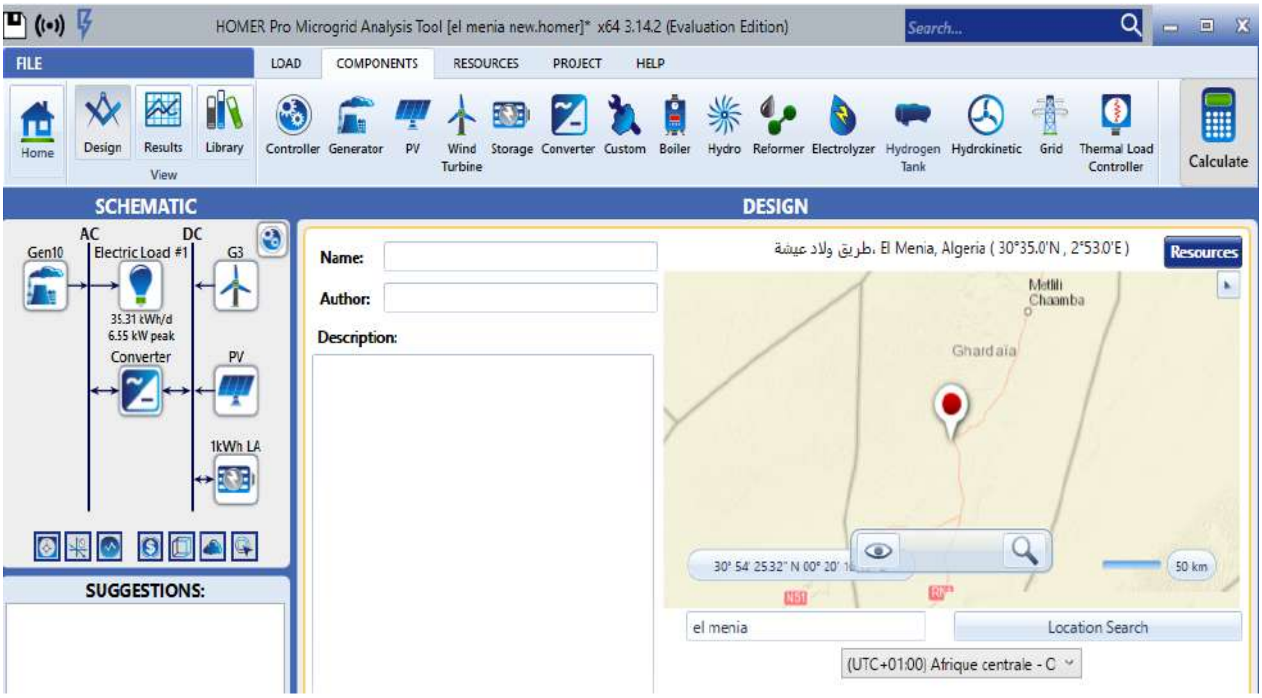


Figure II.9:interface HOMER pro

II.8.2 Start project information

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

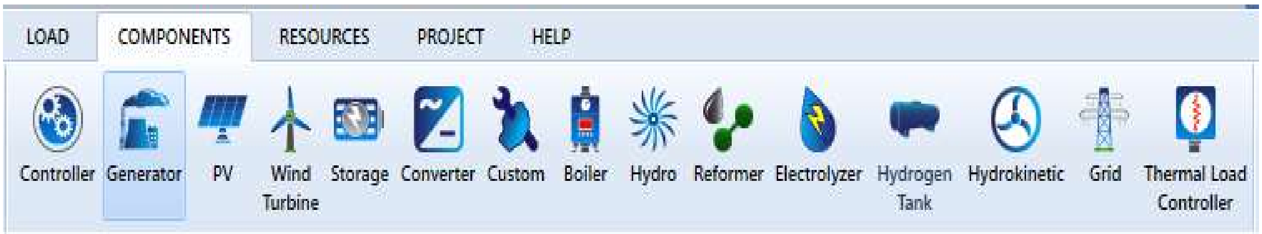


Figure II.10:HOMER components

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.11:typical annual profile of solar radiation [18]

Table II.2: Monthly Average solar global horizontal irradiation

Month	January	February	March	April	May	June	July	August	September	October	November	December
Clearness Index	0.582	0.654	0.677	0.710	0.686	0.693	0.707	0.705	0.685	0.619	0.595	0.544
Daily Radiation (Kwh/m^2/day)	3.390	4.640	5.480	7.270	7.630	7.920	7.940	7.380	6.260	4.630	3.600	2.950

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.12:monthly avrege 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
Average wind speed(m/s)	5.330	5.390	5.750	5.970	6.010	5.660	5.790	5.170	5.240	4.990	5.000	5.090

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

Figure II.13:Avrage daily temperature [18]

Table II.4:the daily temperature(c°)

Month	January	February	March	April	May	June	July	August	September	October	November	December
Daily temperature (c°)	11.800	13.650	17.090	21.330	26.500	31.440	34.080	33.930	29.340	23.840	17.820	13.290

II.10Conclusion

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).

References

[1] KarakiSH, Chedid,RB, Ramadan R. Probabilistic performance assessment of autonomous solar–wind energy conversion systems. IEEE Trans Energy Convers1999;14(3):766–72.

[2] T. Markvart, „Solar Electricity‟, John Wiley & Sons Inc., 2000.

[3] M.A. Habib, S.M.A. Said, M.A. El-Hadidy and I. Al-Zaharna, „Optimization Procedure of a Hybrid Photovoltaic Wind Energy System‟, Energy, Vol. 24, N°11, pp. 919 – 929, 1999.

[4] M. Kolhe, K. Agbossou, J. Hamelin and T.K. Bose, „Analytical Model for Predictingthe Performance of Photovoltaic Array Coupled with a Wind Turbine in a Stand-Alone Renewable Energy System Based on Hydrogen‟, Renewable Energy, Vol.28,N°5,pp.727– 742, 2003.

[5] S. Diaf, G. Notton, M. Belhamel, M. Haddadi and A. Louche, Design and TechnoEconomical Optimization for Hybrid PV/Wind System under Various Meteorological Conditions‟, Applied Energy, Vol. 85, N°10, pp. 968 – 987, 2008.

[6] R. Pallabazzer, „Evaluation of Wind-Generator Potentiality‟, Solar Energy, Vol. 55, N°1, pp. 49 – 59, 1995.

[7] L. Lu, H.X. Yang and J. Burnett, „Investigation on Wind Power Potential on Hong Kong Islands – An Analysis of Wind Power and Wind Turbine Characteristics‟, Renewable Energy, Vol. 27, N°1, pp. 1 – 12, 2002.

[8] A. Ilinka, E. McCarthy, J.L. Chaumel and J.L. Retiveau, „Wind Potential Assessment of Quebec Province‟, Renewable Energy, Vol. 28, N°12, pp. 1881 – 1897, 2003.

[9] M.K. Deshmukh and S.S. Deshmukh, „Modeling of Hybrid Renewable Energy Systems‟, Renewable and Sustainable Energy Reviews, Vol. 12, N°1, pp. 235 – 249, 2008.

[10] Sharafi M., ELMekkawy T. Y. Multi-objective optimal design of hybrid renewable energy systems using PSO-simulation based approach. Renewable Energy 2014; 68: 67–79.

[11]Dufo-López R., Bernal-Agustín J. L. Multi-objective design of PV-wind-diesel-hydrogen-battery systems. Renewable energy 2008; 33(12): 2559–2572.

[12]http://www.geni.org/globalenergy/library/renewable energyresources/world/africa/windafrica/wind-algeria.shtml.

[13]http://geosun.co.za/wp-content/uploads/2014/11/SolarGIS-Solar-map-DNI-Algeriaen.png

[14]T. Lambert HOMER: The Hybrid Optimization Model for Energies Renewables. Available http://www.nrel.gov/internationa/tools/homer/homer.html.

[15]Lambert, Tom (2000) HOMER: The Hybrid Optimization Model for Electric Renewables [online]. Available: http://www.nrel.gov/international/tools/homer/homer.html (July 11, 2000).

[16] W. Jennings: Optimization of electric power systems for off-grid domestic applications: An Argument for Wind/Photovoltaic Hybrids. NREL

[17] Annual conference & Exposition June15-18, 2014, Indianapolis (Paper ID #8779) Dr. Radian G Belu, Drexel University (Tech.), Dr. Richard Chiou, Drexel University (Eng.), Ms. KETKI GHAISAS, Drexel University, Prof. Tzu-Liang Bill Tseng, University of Texas, El Paso

[18] NASA surfaces meteorology and solar energy database period (July 1983-June 2005)

[19] NASA monthly averaged values over 10 year period (July1983-June 1993)

[20]www.energie.developpement.blogspot.fr / energuide.be

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 GHARDAIA In an isolated area in EL MENIA (EL GOLIA)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

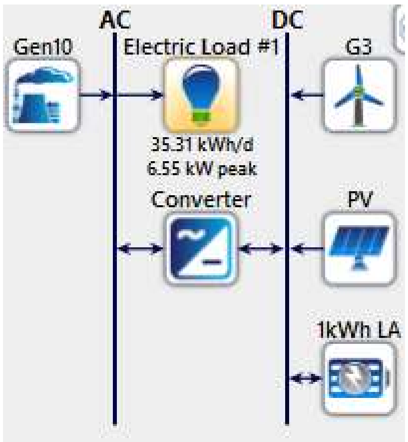
III.2.1 Interpretation of simulation results

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

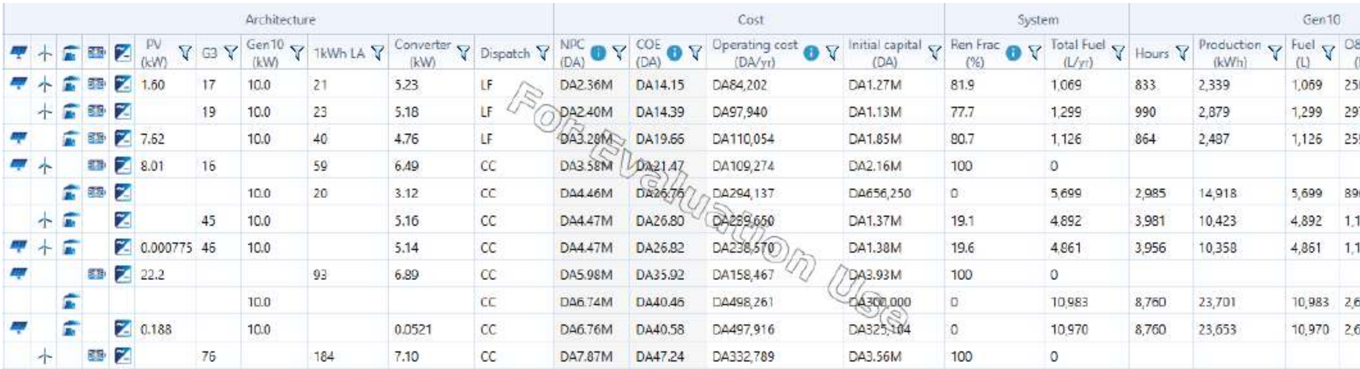
components	Name	Size	Unit
Generator	Generic 10kW	**10.00**	**K W**
PV	Generic flat plate PV	**1.60**	**K W**
Storage	Generic 1kWh Lead Acid	**21.00**	**String**
Wind turbine	Generic 3kW	**17.00**	**ea.**

System converter	System Converter	5.23	K W



FigureIII.1: electrical assembly of the hybrid system

After simulations we got the following results



PV (kW)	G3	Gen10 (kW)	1kWh LA	Converter (kW)	Dispatch	NPC (DA)	COE (DA)	Operating cost (DA/yr)	Initial capital (DA)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)
1.60	17	10.0	21	5.23	LF	DA2.36M	DA14.15	DA84,202	DA1.27M	81.9	1,069	833	2,339	1,069
	19	10.0	23	5.18	LF	DA2.40M	DA14.39	DA97,940	DA1.13M	77.7	1,299	990	2,879	1,299
7.62		10.0	40	4.76	LF	DA3.28M	DA19.66	DA110,054	DA1.85M	80.7	1,126	864	2,487	1,126
8.01	16		59	6.49	CC	DA3.58M	DA21.47	DA109,274	DA2.16M	100	0			
		10.0	20	3.12	CC	DA4.46M	DA26.76	DA294,137	DA656,250	0	5,699	2,985	14,918	5,699
	45	10.0		5.16	CC	DA4.47M	DA26.80	DA239,650	DA1.37M	19.1	4,892	3,981	10,423	4,892
0.000775	46	10.0		5.14	CC	DA4.47M	DA26.82	DA238,570	DA1.38M	19.6	4,861	3,956	10,358	4,861
22.2			93	6.89	CC	DA5.98M	DA35.92	DA158,467	DA3.93M	100	0			
		10.0			CC	DA6.74M	DA40.46	DA498,261	DA300,000	0	10,983	8,760	23,701	10,983
0.188		10.0		0.0521	CC	DA6.76M	DA40.58	DA497,916	DA325,104	0	10,970	8,760	23,653	10,970
	76		184	7.10	CC	DA7.87M	DA47.24	DA332,789	DA3.56M	100	0			

Figure III.2: table of all calculation results of 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				
PV (kW)	G3	Gen10 (kW)	1kWh LA	Converter (kW)	Dispatch	NPC (DA)	COE (DA)	Operating cost (DA/yr)	Initial capital (DA)	Ren Frac (%)
1.60	17	10.0	21	5.23	LF	DA2.36M	DA14.15	DA84,202	DA1.27M	81.9

Figure III.3 : optimal results for the hybrid system(EL MENIA)

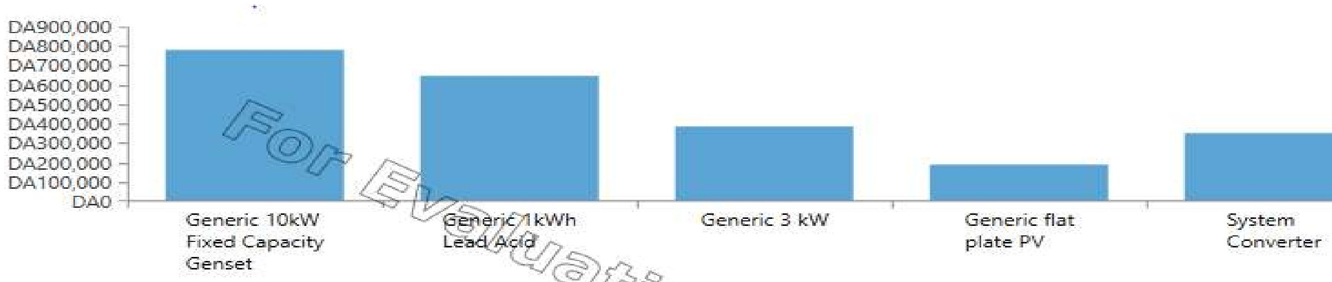
III.2.1.1Discussion of the economic aspect

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 2,360,000 DA with (Initial capital) value of 1,270,000DA which in fact justifies this position from ranking and choice side.



Component	Capital (DA)	Replacement (DA)	O&M (DA)	Fuel (DA)	Salvage (DA)	Total (DA
Generic 10kW Fixed Capacity Genset	DA300,000.00	DA107,181.03	DA3,230.59	DA414,522.11	-DA43,958.87	DA780,
Generic 1kWh Lead Acid	DA210,000.00	DA432,417.36	DA2,714.78	DA0.00	DA0.00	DA645,
Generic 3 kW	DA306,000.00	DA97,555.05	DA39,558.20	DA0.00	-DA54,978.53	DA388,
Generic flat plate PV	DA191,434.46	DA0.00	DA206.23	DA0.00	DA0.00	DA191,
System Converter	DA261,538.91	DA110,964.12	DA0.00	DA0.00	-DA20,884.57	DA351,
System	DA1,268,973.37	DA748,117.56	DA45,709.80	DA414,522.11	-DA119,821.96	DA2,357,

Figure III.4:cost summary

The estimated total cost over 25 years of work at all project costs (Capital, Replacement, O&M, Salvage) is 2,357,500.89DA with levelized cost energy 14.15DA.

The results were allocated as follows:

Table III.2:Net present cost(25year)

Name	Capital	Operating	Replacement	Salvage	resource	Total
Generic 3KW	**306,000.00 DA**	**39,558.20 DA**	**97,555.5 DA**	**-54,978.53 DA**	**0.00 DA**	**388,134.72 DA**
Generic 10KW fixed capacity genset	**300,000.00 DA**	**3,230.59 DA**	**107,181.03 DA**	**-43,958.87 DA**	**14,522.11**	**780,974.87 DA**
Generic 1KWh lead Acid	**210,000.00 DA**	**2,714.78 DA**	**432,417.36 DA**	**0.00 DA**	**0.00 DA**	**645,132.14 DA**
Generic flat plate PV	**191,434.46 DA**	**206.23 DA**	**0.00 DA**	**0.00 DA**	**0.00 DA**	**191,640.69 DA**
System converter	**261,538.91 DA**	**0.00 DA**	**110,964.12 DA**	**-20,884.57 DA**	**0.00 DA**	**351,618.46 DA**
System	**1,268,973.37 DA**	**45,709.80 DA**	**748,117.56 DA**	**-119,821.96 DA**	**414,522.11 DA**	**357,500.89 DA**

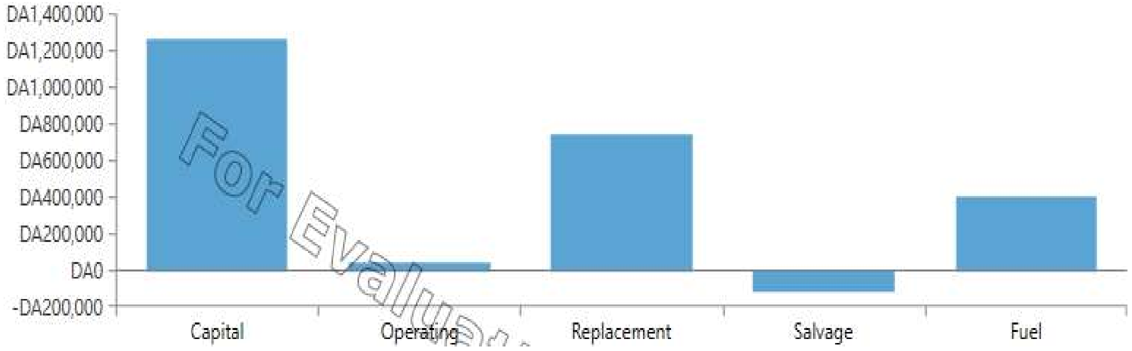


Figure III.5:Cost summary for the hybrid system during 25 years

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.

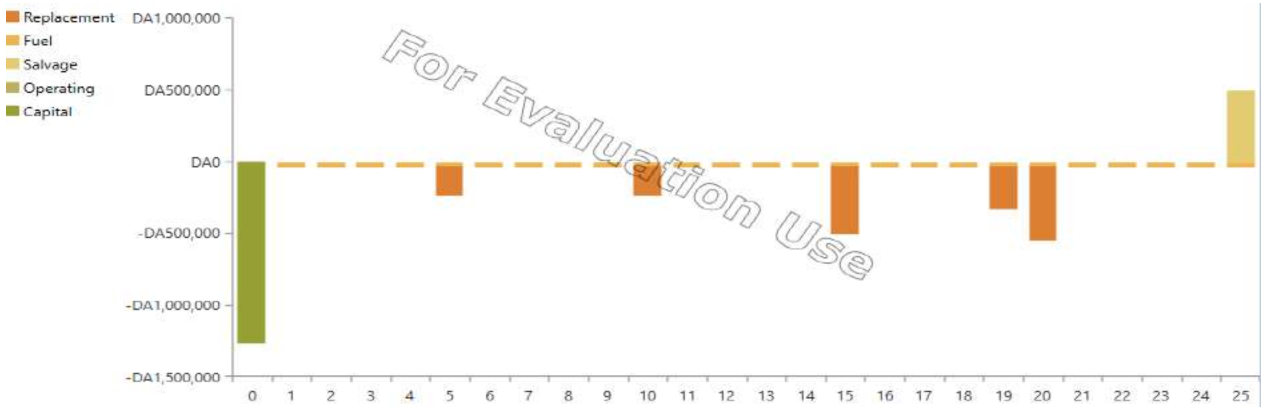


Figure III.6:Summary of operations and replacements throughout the operating life of the system

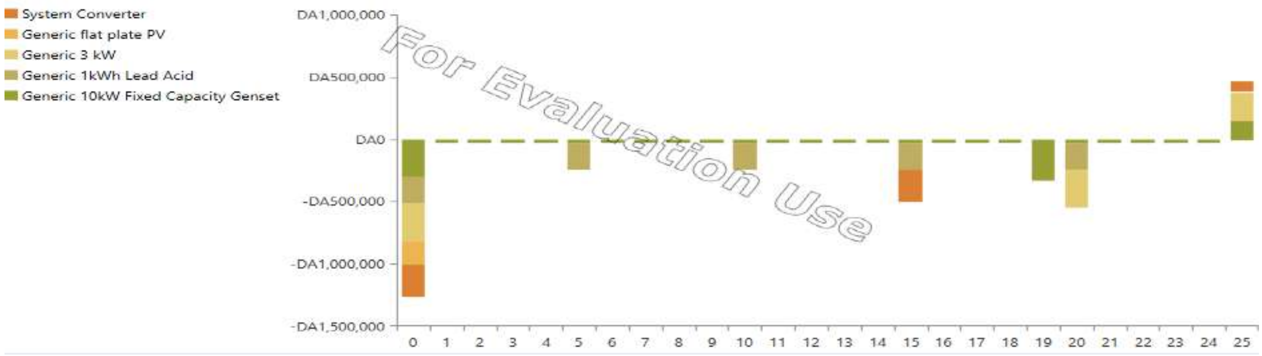


Figure III.7:summary of replacement devices

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).

Electrical 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.3: Production, consumption and quantity of PV-wind-DG system

Production		
Production	KWh/yr	Percent%
Generic flat plate PV	2,947	5.29
Generic 10KW fixed capacity genset	2,339	4.20
Generic 3KW	50,455	90.5
Total	55,741	100
Consumption		
AC Primary load	12,890	100
DC Primary load	0	0
Deferrable Load	0	0

Total	12,890	100
Quantity		
Excess Electricity	41,497	74.4
Unmet Electric Load	0	0
Capacity shortage	0	0

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

- ✓ PV produced produced (2,947 KWh/yr) with 5.29%.
- ✓ Wind turbine produced the largest amount which is (50,455KWh/yr) with90.5%
- ✓ Diesel generator produced (2,339KWh/yr) with 4.20%.

Noticed that the total produced electrical energy is (55,741KWh/yr) consumed as follows:

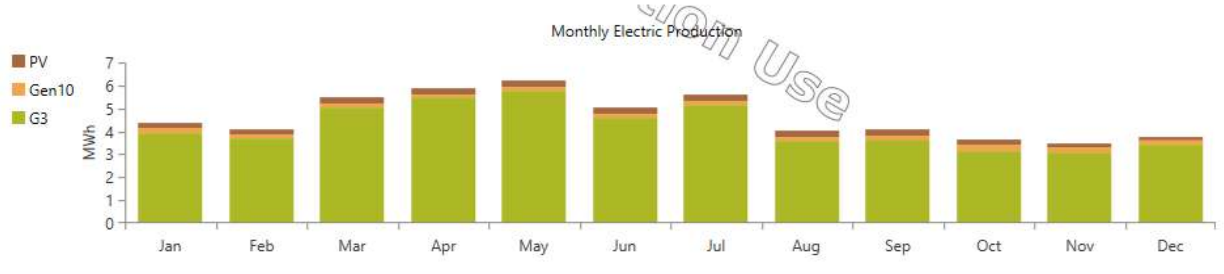
- ✓ The house consuming (12,890KWh/yr).
- ✓ The rest quantity which is (41,497KWh/yr), used in other services (irrigation).

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 May, up to about (6.4 KWh), and the lowest value in November about (1.8 KWh) This decline is due to the change of solar radiation during the year in EL MENIA (EL GOLIA).

These differences in the electric production of the hybrid system that in May we have a maximum electric production in wind turbine generator, and in November we have a minimum



electric production by PV system.

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

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 (0.01KW up to 0.99KW)then the production is increased from 9:30h till 15:00h to reach its maximum value of value 1.63KW, and from 15:00h till sunset the low production is gradually decreased.

Table III.4: Generic flat plate PV Electrical Summary

Quantity	Value	Units
Mainimum Output	0	KW
Maximum Output	1.63	KW
PV Penetration	22.9	%
Hours of Operation	4,388	Hrs/yr
Levelized Cost	5.03	DA/KWh

Table III.5: Generic flat plate PV statistics

Quantity	Value	Units
Rated Capacity	1.60	KW
Mean Output	0.336	KW
Mean Output	8.07	KWh/d
Capacity Factor	21.1	%
Total Production	2,947	KWh/yr

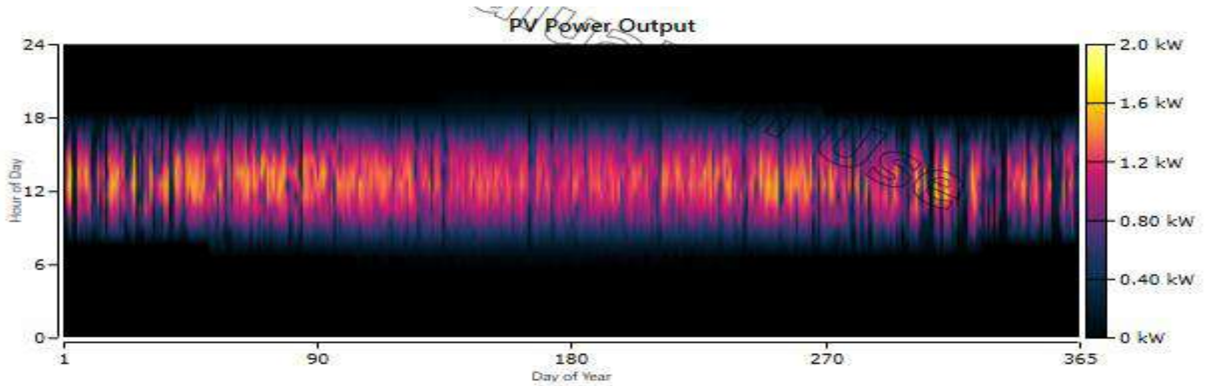


Figure III.9:Total daily energy produced by the PV during one year

Wind turbine (generic 3KW)

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 (0.05 to 0.57kwh). While we register the largest production capacity in May (about 51.0kw) in the operating period amounted to (6,399hrs/yr).

Table III.6: Generic 3KW Electrical summary

Quantity	Value	Units
Minimum output	**0**	**KW**
Maximum output	**51.0**	**KW**
Wind Penetration	**391**	**%**
Hours of Operation	**6,399**	**hrs/yr**
Levelized cost	**0.595**	**DA/KWh**

Table III.7: Generic 3KW statistics

Quantity	Value	Units
Total Rated Capacity	**51.0**	**KW**
Mean Output	**5.76**	**KW**
Capacity Factor	**11.3**	**%**
Total Production	**50,455**	**KWh/yr**

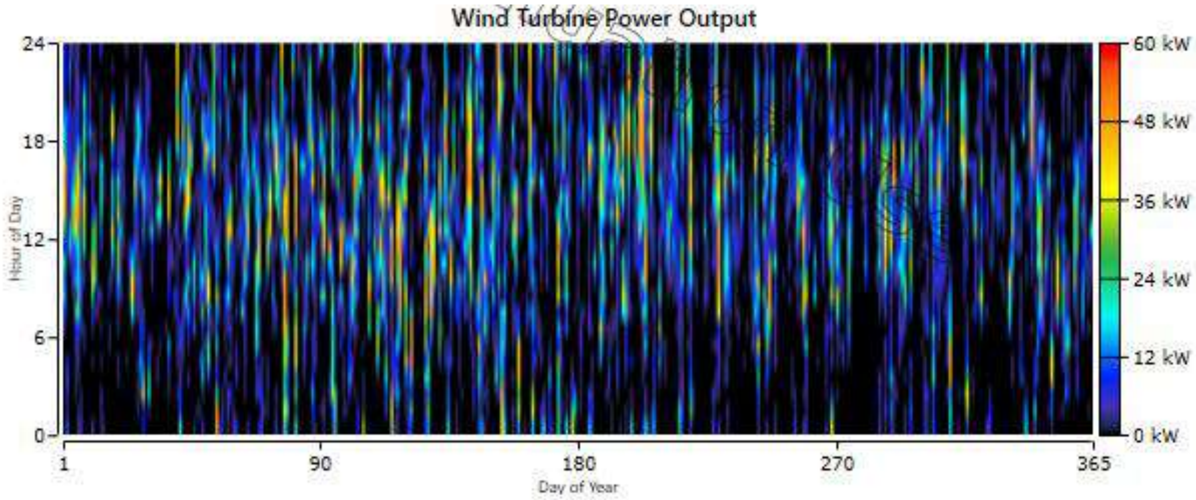


Figure III.10:Total daily energy produced by the wind turbine during one year

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 (3,750KWh/yr and 3,003 KWh / yr).

Table III.8: Generic 1KWh Lead Acid properties

Quantity	Value	Units
Average Energy cost	0	DA/KWh
Energy in	3,750	KWh/yr
Energy out	3,003	KWh/yr
Storage Depletion	4.22	KWh/yr
Losses	750	KWh/yr
Annual Throughput	3,358	KWh/yr

Table III.9: generic 1KWh Lead Acid Result Data

Quantity	Value	Units
Autonomy	8.57	Hr
Storage wear cost	14.0	DA/KWh
Nominal Capacity	21.0	KWh
Usable Nominal Capacity	12.6	KWh
Lifetime throughput	16,790	KWh
Expected life	5.00	Yr

Table III.10: Generic 1KWh Lead Acid statistics

Quantity	value	Units
Batteries	21.0	Qty
String Size	1.00	Batteries
String in Parallel	21.0	Strings
Bus Voltage	12.0	V

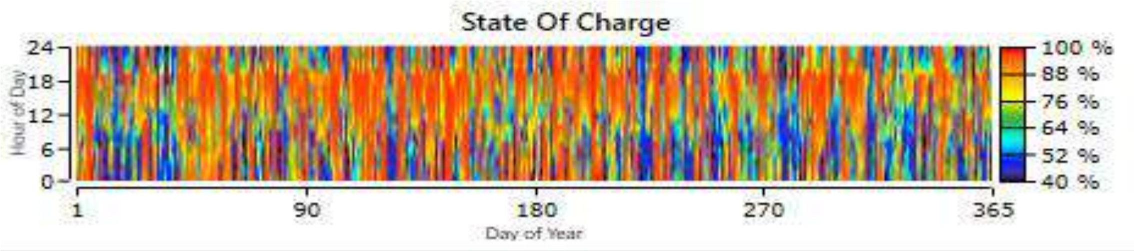


Figure III.11: state of charge through a year

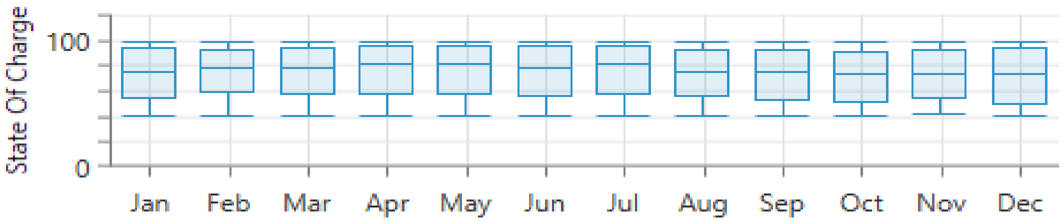


Figure III.12:charging battery through a year

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 (7:00-9:00), (10:00-12:00) and (18:00-22:00) which is similar during the months of the year with a of (1422h) per year.

Maximum total power produced by the generator is estimated at (6.31Kwh), at 8:00 Pm.

Table III. 11: Generic 10kW Fixed Capacity Genset Electrical Summary

Quantity	Value	Units
Electrical production	2,339	KWh/yr
Mean electrical output	2.81	KW
Minimum electrical output	2.50	KW
Maximum electrical output	6.31	KW

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

Quantity	Value	Units
Fuel consumption	1,069	L
Specific fuel consumption	0.457	L/K
Fuel energy input	10,517	KWh/yr
Mean electrical efficiency	222	%

Table III. 13: Generic 10kW Fixed Capacity Genset Statistics

quantity	Value	Units
Hours of operation	833	Hrs/yr
Number of stars	612	Starts/yr
Operational life	18.0	Yr
Capacity factor	2.67	%
Fixed grneration cost	34.7	DA/hr
Marginal generation cost	8.58	DA/KWh

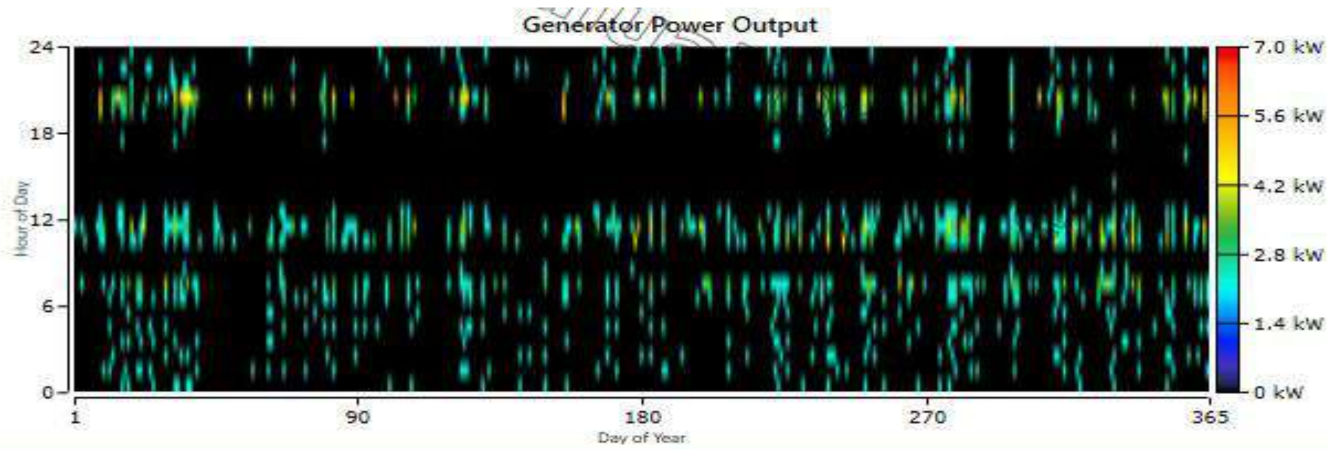


Figure III. 13: fixed capacity Genset output (KW)

III.3 Off-grid diesel generator system

III.3.1Interpretation 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. 14: architecture of the System

Component	Name	Size	Unit
Generator	**Generic 10KW Fixed Capacity Genset**	**10.0**	**KW**

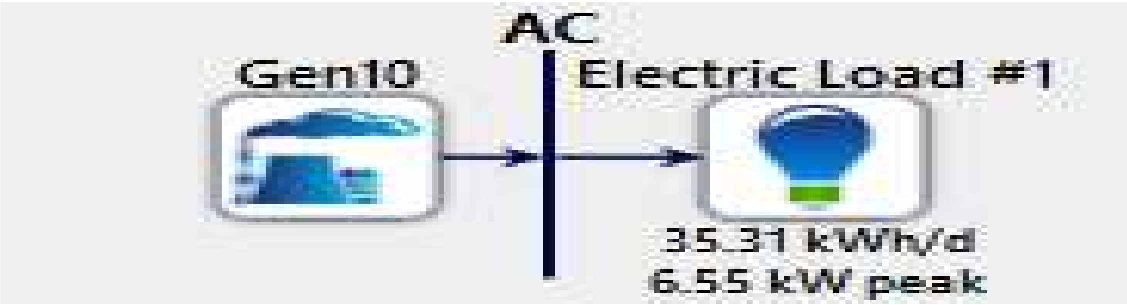


Figure III.14: electrical installation of the DG autonomous system

After simulations we got the following results:

Architecture		Cost				System		Gen10				
Gen10 (kW)	Dispatch	NPC (DA)	COE (DA)	Operating cost (DA/yr)	Initial capital (DA)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cost (DA/yr)	Fuel Cost (DA/yr)
10.0	CC	DA6.74M	DA40.46	DA498,261	DA300,000	0	10,983	8,760	23,701	10,983	2,628	329,502

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	NPC (DA)	COE (DA)	Operating cost (DA/yr)	Initial capital (DA)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cost (DA/yr)	Fuel Cost (DA/yr)
10.0	CC	DA6.74M	DA40.46	DA498,261	DA300,000	0	10,983	8,760	23,701	10,983	2,628	329,502

Figure III.16: results for the autonomous system

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 (DA)	Replacement (DA)	O&M (DA)	Fuel (DA)	Salvage (DA)	Total (DA)
Generic 10kW Fixed Capacity Genset	DA300,000.00	DA2,176,401.39	DA33,973.51	DA4,259,644.56	-DA28,746.94	DA6,741,272.52
System	DA300,000.00	DA2,176,401.39	DA33,973.51	DA4,259,644.56	-DA28,746.94	DA6,741,272.52

Figure III.17: cost summary

This table show the total cost of the project during 25years was 6,741,272.52DAbased on (Capital) of 300,000,00DA followed by (Replacement) of 2,176,491.39DA after (O&M) of 33,973.51DA and (Salvage) of

-28,746.94 DA.

The results were allocated as follows:

Table III. 15: Net Present Costs

Name	Capital	Operating	Replacement	salvage	Resource	Total
DG(10KW)	300,000.00 DA	33,973.51 DA	2,176,401.39 DA	-28,746.94 DA	4,259,644,56 DA	6,741,272.52 DA
System	300,000.00 DA	33,973.51 DA	2,176,401.39 DA	-28,746.94 DA	4,259,644,56 DA	6,741,272.52 DA

Table III. 16: Annualized Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
DG(10KW)	23,206.31DA	2,628.00DA	168,354.18DA	-2,223.70DA	329,502.16DA	521,466.94 DA
System	23,206.31DA	2,628.00DA	168,354.18DA	-2,223.70DA	329,502.16DA	521,466.94 DA

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.

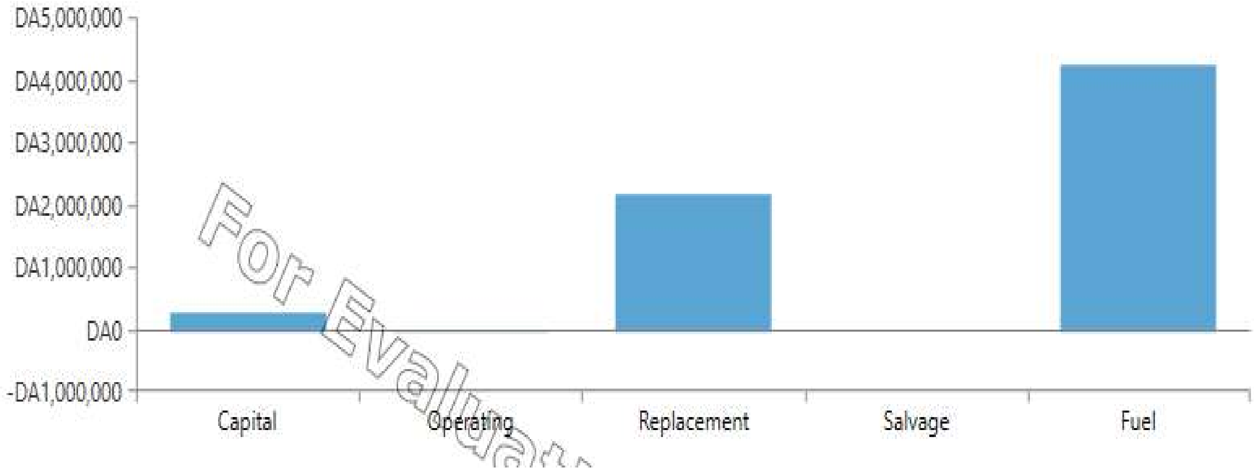


Figure III. 18: Cost summary for the system autonomous

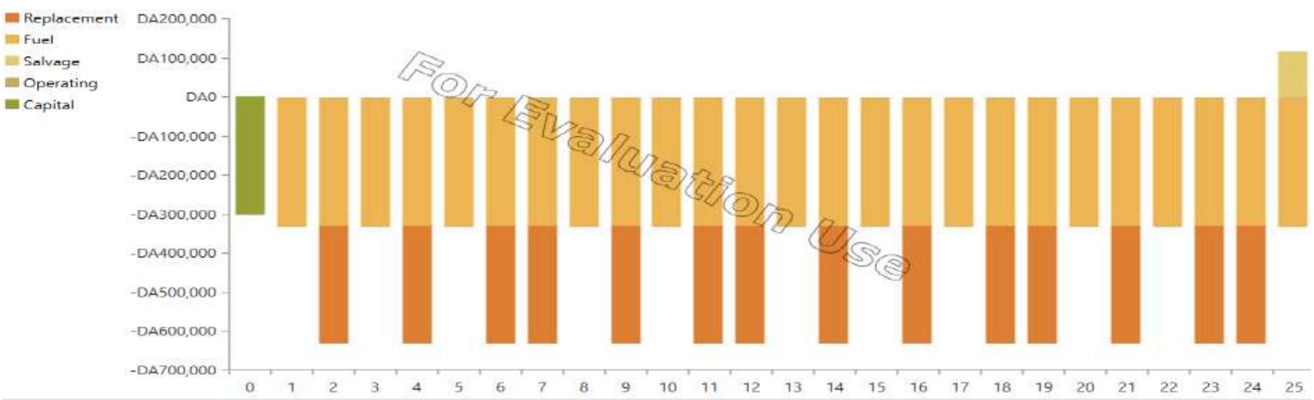


Figure III. 19: summary of O&M and replacements throughout the operating life of the diesel generator system

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. 17: Excess and Unmet

Quantity	Value	Units
Excess Electricity	10,811	KWh/yr
Unmet electric load	0	KWh/yr
Capacity shortage	0	KWh/yr

Table III.18:production summary

Component	Production (KWh/yr)	Percent
Generic 10KW fixed capacity Genset	23,701	100
Total	23,701	100

Table III.19:consumption summary

Components	Consumption (KWh/yr	Percent
AC primary load	12,890	100
DC primary load	0	0
Deferrable load	0	0
Total	12,890	100

- Generator: Generic 10KW Fixed capacity Genset(Diesel)

Table III. 20: Generic 10kW Fixed Capacity Genset Electrical Summary

Quantity	value	Units
Electrical production	23.701	KWh/yr
Mean electrical output	2.71	KW
Minimum electrical output	2.50	KW
Maximum electrical output	6.55	KW

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

Quantity	Value	Units
Fuel consumption	10,983	L
Specific Fuel consumption	0.463	L/KWh
Fuel energy input	108,077	KWh/yr
Mean electrical efficiency	21.9	%

Table III. 22: Generic 10kW Fixed Capacity Genset Statistics

Quantity	Value	Units
Hours of operation	8,760	Hrs/yr
Number of stars	1.00	Stars/yr

Operational life	**1.71**	**Yr**
Capacity Factor	**27.1**	**%**
Fixed generation cost	**34.7**	**DA/hr**
Marginal generation cost	**8.58**	**DA/KWh**

We notice that the amount of energy produced by the diesel generator system is (2,701Kwh), (12,890KWh) is consumed and (10,811KWh) 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 (6.55Kwh).

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.4Comparison 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.4.1Economic 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 2,357,500.89DA is as follows:

- The Capital cost is 1,268,973.37DA followed by (Replacement cost) of 748,117.56DA after (O&M) of 45,709.80 DA and (Salvage) of -119,821.96DA.
- The total spent fuel during the year (1,069 L)
- The average fuel per day is (4.93 L/day)
- The average fuel per hour is (0.205 L/h)
- The levelized cost of energy 14.15DA

-The cost during 25 years of this study for off-grid diesel generator system is represented by the total price 6,741,272.52DA which explained as follows:

- The capital cost is 300,000.00DA followed by (Replacement cost) of 2,176,401.39DA after (O&M) of 33,973.51DA and (Salvage) of – 28,746.94DA.
- The total spent fuel during the one year (10,983L)
- The average fuel per day is (30.1L/day)
- The average fuel per hour is (1.25 L/h)
- The levelized cost of energy 40.46DA.

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. 23: Total costs of different system hybrid and diesel

component	Capital(DA)	Replacement(DA)	O&M(DA)	Resource(DA)	Slavage(DA)	Total(DA)
System hybrid PV/Wind/Diesel	**1,268,973.37**	**748,117.56**	**45,709.80**	**414,522.11**	**-119,821.96**	**2,357,500.89**
System Diesel generator	**300,000.00**	**2,176,401.39**	**33,973.51**	**4,259,644.56**	**-28,746.94**	**6,741,272.52**

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. 24: Emission of pollutants during a year

Pollutant	Emission hybrid system	Emission diesel generator
Carbone dioxide	4696 Kg/yr	28,694 Kg/yr
Carbone monoxide	35.5 Kg/yr	217 Kg/yr
Unburned hydrocarbons	1.29 Kg/yr	7.91 Kg/yr
Particulate matter	2.15 Kg/yr	13.2 Kg/yr
Sulfur dioxide	11.5 Kg/yr	70.4 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 environment

As the Levelized cost of energy 14.15DA , the cost of energy has proven to be largely dependent on the potential quality of renewable energy .

CONCLUSION

Conclusion

We have found that the hybrid system (PV/Wind turbine/DG) with battery storage is the optimal system to solve the problem of electricity in EL MENIA, 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 components are as follows:

- ✓ 6 PV modules (1.60 KW)
- ✓ 6 wind turbines (3KW)
- ✓ Dieselgenerator (10 KW)
- ✓ 10 batteries (lead Acid)
- ✓ Converter (5.23KW)

We found that the cost of energy (COE) in the hybrid system of our study is 14.15DA, whereas the initial capital required is1,270,000DA, and net present cost (NPC) is2,360,000DA. And the total annual power output is55,741kWh/ year, Total energy wind turbine 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 40.46DA, whereas the initial capital required is300,000DA and net present cost (NPC) is6,740,000 DA.

Based on the simulation results and discussion previously presented, we conclude that :

- The total cost of the hybrid system almost 35% of the cost of the diesel system project (system hybrid:
- 2,375,500DA/ system DG: 6,741,272DA).
- the (O&M) cost of the hybrid system is 1.73% of the(O&M) cost diesel system
- The consumption of fuel in the hybrid system is 10 % of diesel system alone.
- The emission of Carbon dioxide from the hybrid system is16% compared to the diesel generator system.
- The emission of Carbon monoxide from the hybrid system is16.3% compared to the diesel generator system.

- This is an important point to be taken into consideration,the amount of greenhouse gas emissions from diesel generator is higher than the hybrid system that's why we choose the hybrid system in order to help the reduction of greenhouse gases and the air pollution which is healthier for the environment .

We highly recommend that two futuristic studies which are: Supplying electricity to the remote area in EL MENIA using a hybrid system (PV, Wind energy and Fuel cell instead of the diesel generator).

Or another combination using a hybrid system (PV, Wind energy and Hydraulic energy because EL MENIA is known by the water abundance).

Abstract

In this master study we had found a 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.

The homer Energy micogrid software was 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 needs and costs

Key words: hybrid system, wind turbine system, isolate house, PV, Diesel generator, Homer

ملخص

في هذه الدراسة الرئيسية وجدنا حلاً لشبكة الكهرباء الوطنية في الجزائر التي واجهت العديد من المشاكل في تزويد المناطق المعزولة والريفية بالكهرباء ،وحققنا حلاً اقتصاديًا لنظام هجين للطاقة المتجددة وطورنا مستوى المعيشة في هذه المناطق ولقد توصلنا إلى حل لتقليل استهلاك الديزل ومشكلة التلوث البيئي،باستخدام برنامج محاكاة HOMER® ،والذي يحتوي على لغة تفاعلية تمكننا من التنبؤ بمهام النظام بسرعة وبدقة. سمحت المحاكاة باستعمال برنامج homer Energy micogridبتحديد الهيكل الأمثل للنظام الهجين (PV / Wind / DG) مع تخزين البطاريات ، من خلال إعطاء المستخدم العناصر اللازمة لتحديد النهج الذي يؤدي إلى أفضل حل من حيث الاحتياجات والتكاليف.

الكلمات المفتاحية :النظام اهلجني,توربينات الرياح, منزل معزول,األلواح الشمسية,مولد الديزل,برنامج هومر

Résumé

Dans cette étude de master, nous avions trouvé une solution pour le réseau national d'électricité en Algérie qui faisait face à de nombreux problèmes d'approvisionnement système hybride d'énergie renouvelable et développé le niveau de vie dans ces zones et nous avons trouvé une solution pour réduire la consommation de diesel et le problème de pollution de l'environnement, en utilisant le programme de simulation HOMER, qui contient un langage interactif qui nous permet de prédire rapidement et précisément les tâches du système. Le logiciel Homer Energy micogrid nous a permis d'identifier la structure optimale du système hybride (PV / Wind / DG) avec stockage de batteries, en donnant à l'utilisateur les éléments nécessaires pour déterminer l'approche qui conduit à la meilleure solution en termes de besoins et frais.

Mots clé : un system hybride , éolien ,zone isolée, PV ,groupe électrogène batterie de stockage , Homer