# OPTIMAL DESIGN AND COMPARISON BETWEEN RENEWABLE ENERGY, HYBRID ENERGY AND NON-RENEWABLE ENERGY SYSTEMS: CASE OF SKIKDA, ALGERIA

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ABSTRACT

In the present paper, an optimal design and comparison between three power systems : renewable system , non-renewable system and hybrid renewable system for a city in Skikda, Algeria, applied in term of technical and economic feasibility by simulation using HOMER. HOMER software (hybrid optimization model for electric renewables) simplifies the task of evaluating the different conceptions of power systems, off-grid and grid-connected, for a variety of applications. It can analyze and combine various energy sources to arrive at an optimal display configuration.

The results show that the hybrid energy system is preferred over the two other systems because the renewable system is very expensive and the the non-renewable system emits considerable amounts of the greenhouse gas

**Mots Clés:** *Renewable, Non-Renewable, hybrid, optimal design, HOMER.*

## 1. INTRODUCTION

Stand-alone renewable energy systems constitute an alternative to the grid connected systems. They include solar radiation, wind and hydraulic sources which are essentially inexhaustible resources. The amount and proportion of generated renewable energy are expected to rise so largely because of the ever diminishing supplies of gas and oil and also because of the international awareness and programs to support renewable energy generation [1]. The Combination of two or more different sources of energy is called a hybrid system. Hybrid systems such as wind-diesel or photovoltaic-diesel are now proven technologies for electric supply in remote locations [2]. The design of hybrid renewable energy systems requires appropriate dimensioning in terms of power as well as suitable choice of the system components according to the available resources. For this reason, simulation software packages constitute an essential tool for the analysis and the comparison of different combinations and alternatives. Analysis must take into consideration three main constraints: Firstly, the available renewable resources in a given region. Secondly, the load profile, and thirdly, the availability of financial resources [6].

Simulation and optimization of hybrid energy system can be achieved by various software which are nowadays available. Examples of that software include HOMER, HOGA and Hybrid2, which offer different background of application and simulation [3]. HOMER software is a user-friendly micropower design tool that simulates and optimizes stand-alone and grid connected power systems. Recently, it has widely been used in the field of renewable energy [5]. It can be used with any combination of wind turbines, PV arrays, run-of-river hydro power, biomass power, internal combustion engine generators, micro turbines, batteries, and hydrogen storage, serving both electric and thermal loads.

The objective of this work: find the optimal design for the proposed systems, that is to say the minimum cost of production and make comparison between them.

## 2. HOMER SOFTWARE AND POWER SYSTEMS COMPONENETS

HOMER (Hybrid Optimization Model for Electric Renewable) software has been developed by NREL (National Renewable Energy Laboratory) [7]. It performs hourly simulations of every possible combination of components entered and ranks the systems according to user-specified criteria such as cost of energy (COE) or Capital Costs (CC). HOMER has been extensively used as a sizing and optimization software tool [4]. Power systems can consist of any combination of wind, photovoltaic, diesel, and batteries… etc. In study we consider three proposed systems: The renewable energy system is shown in Fig.1. which consists of a photovoltaic to power the load. The non-renewable system is shown in Fig.2. which consists of a diesel generator and batteries to power the load. The hybrid renewable energy system is shown in Fig.3.which consists of a photovoltaic to power the load. The components of the studied systems are:

Photovoltaic module: The PV modules used with 250 W maximum power.
Converter: A converter is used which functions as an inverter and rectifier depending on the direction of power flow [10]. The inverter model used in this project is based on a power unit (4 kW).
Battery: Battery bank stores the electrical energy produced by the PV cells and the DG, and makes the energy available at night or on dark days (days of autonomy or no-sun-days) [9] The Surrette Trojan T-105 (6 V, 225 Ah) storage batteries are utilized in the system
Diesel generator: the use of diesel generators is very common in the hybrid power system to achieve required autonomy. The selection of a diesel generator depends on the category and nature of the load[8], The diesel generators utilized are of 5.5k.
Diesel Price : The diesel price used for the analysis is $0.18 per liter (according to[11].)
The overall summary of technical and economic parameters of the hybrid system component are presented in Table1, Table2 and Table3.

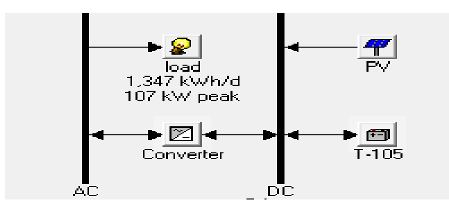


FIGURE 1. Schematic diagram of the renewable energy system

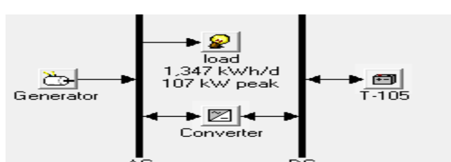


FIGURE 2. Schematic diagram of the non-renewable energy system

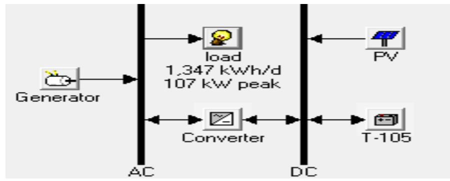


FIGURE 3. Schematic diagram of the hybrid renewable system

## 3. SOLAR ENERGY POTENTIAL

The solar radiation data was automatically generated with HOMER by inserting the coordinates (longitude and latitude of the region. The geographical coordinates of the data collection site were 36° 39' N latitude, 6° 50' E longitude and 132 m altitude above mean sea level. The monthly average of solar radiation and clearness index of the province of Skikda for one year obtained through HOMER are given in Fig.4. The solar radiation data for the selected remote area was estimated to range between 2.118kW h/m$^2$/day and 7.010kW h/m$^2$/day with an average annual solar radiation estimated to 4.55kW h/m$^2$/day. It can be noticed that more solar irradiance can be expected from the month of May to August while less solar irradiance is to be expected from November to February.

## 4. ELECTRICAL LOAD

An important step in the design of the hybrid system is the determination of electricity load. Fig.5. shows the monthly profile for the assumed electric load. The load has an average value of 1.347 kWh/day and a peak of 107kW.

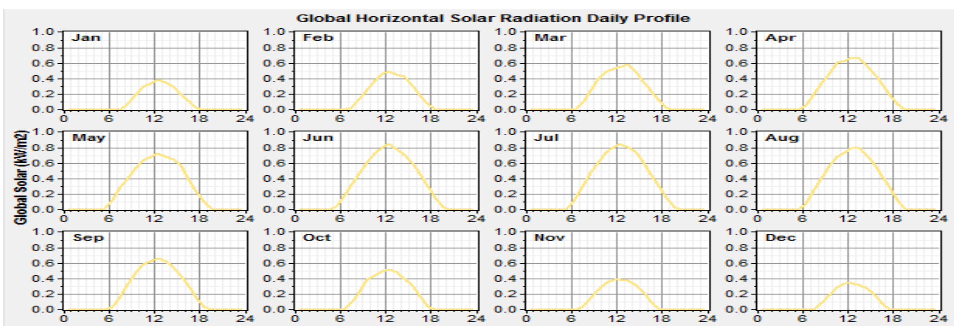


FIGURE 4. Monthly average daily radiation

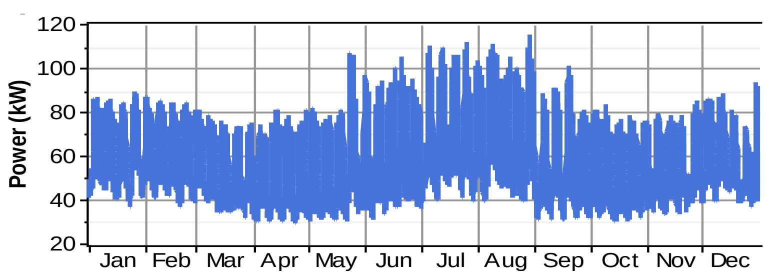


FIGURE 5. Daily load profile during a year.

## 5. HOMER SOFTWARE INPUT DATA

The capital, replacement, and O&M costs of various used equipment have given in the following tables.
Table 1 shows the Capital cost of the different components, Table 2 shows the replacement cost of the different components and Table 3 shows the maintenance cost for the of the components.

| Unit | Size | Capital Cost | Unit | Size | Capital Cost |
|---|---|---|---|---|---|
| PV panels | **0.250 KW** | **2500 $** | **Inverters** | **4 kW** | **329 $** |
| Diesel Generator | **5.5 kW** | **230 $** | **Batteries** | **1 6V** | **174 $** |

TABLE 1.The Capital Cost [12]

| Unit | Size | Replacement Cost | Unit | Size | Replacement Cost |
|---|---|---|---|---|---|
| PV panels | **0.250 KW** | **2500 $** | **Inverters** | **4 kW** | **329 $** |
| Diesel Generator | **5.5 kW** | **230 $** | **Batteries** | **6V** | **174 $** |

TABLE 2. The Inputs Of The Specific Replacement Cost[12]

| Unit | Size | O&M Cost | Unit | Size | O&M Cost |
|---|---|---|---|---|---|
| PV panels | **0.250 KW** | **0 $** | **Inverters** | **4 kW** | **10 ($/year)** |
| Diesel Generator | **5.5 kW** | **0. 5($/h)** | **Storage Batteries** | **6V** | **5($/Unit/year)** |

TABLE 3.The Inputs of the Maintenance Cost [12]

## 6. RESULTS AND DISCUSSIONS

A summary of the optimized results of the different system categories is shown below. It is interesting to note, that the diesel system shows the lowest Net Present Cost of all the systems investigated. As shown in Table5, the initial cost of the PV Stand-alone system is the highest among all the systems, the PV system uses no fuel, and the other systems Hybrid System and Diesel Generator pay from $246,789 and $398,152 per year, respectively. The levelized cost of energy COE gives the average cost of producing one kWh of electricity. Table 4 shows that the PV stand-alone system has the highest COE per kWh (1.751$), while the COE of Diesel ($0.209) and the COE of hybrid systems ($1.029).

For the non-renewable energy system, the total Net Present Cost (NPC) is $1,167,855. Diesel generator burns 192,848L of fuel per year and annual generator run time is 8,760 hours. Fig. 7 shows the monthly average electric production of the system which is totally produced by diesel generator . Diesel generator produces 488,662 kWh/yr. The total Net Present Cost (NPC) of hybrid system is $5,778,319. The system will consume only 119,534 liters of diesel fuel per year and annual generator run time is expected to be 5,828 hours. Fig. 6 shows the monthly average electric production of the system. Photovoltaic production is 70% with 692,861kWh/yr.

| System | NPC $ | Levelizd COE ($) |
|---|---|---|
| Renewable | **9,592,536** | **1.751** |
| Hybrid System | **5,778,319** | **1.029** |
| Non-renewable | **1,167,856** | **0.209** |

TABLE 4. Summary of the simulation results

| System | Initial Capital $ | Remplacement Cost $ | O&M Cost $ | Annual Fuel $ | Total NPC $ |
|---|---|---|---|---|---|
| Renewable | **8,843,425** | **470,964** | **278,146** | **0** | **9,592,536** |
| Hybrid System | **5,018,531** | **21,919** | **491,320** | **246,789** | **5,778,319** |
| Non-renewable | **11,128** | **25,591** | **733,319** | **398,152** | **1,167,856** |

TABLE 5 .The details of the NPC cost

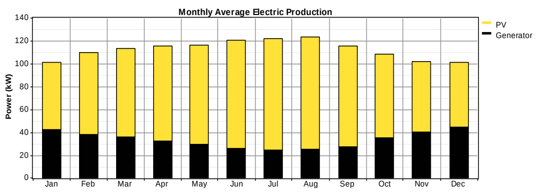


FIGURE 6. Monthly average electric production for hybrid energy system

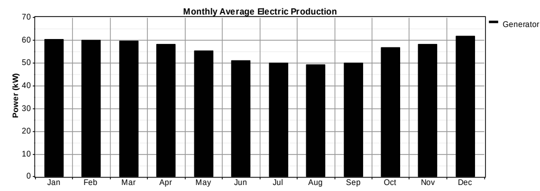


FIGURE7. Monthly average electric production non-renewable energy system

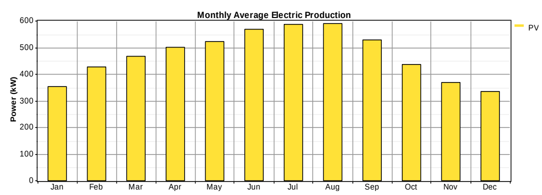


FIGURE 8. Monthly average electric production for renewable system

| System | Renewable system | Hybrid System | Non-renewable system |
|---|---|---|---|
| Carbon dioxide | **0** | **314,774** | **507,832** |
| Carbon monoxide | **0** | **777** | **1,254** |
| Unburned hydrocarbons | **0** | **86.1** | **139** |
| Particulate matter | **0** | **58.6** | **94.5** |
| Sulphur dioxide | **0** | **632** | **1,020** |
| Nitrogen oxides | **0** | **6,933** | **11,185** |

TABLE 6. Annual emissions of the three studied systems.

Diesel generator production is 30% with 291,895kWh/yr. The total Net Present Cost (NPC) of PV is 9,592,536. Fig. 8 shows the monthly average electric production of the system. Photovoltaic production is 100% with 1,108,916kWh/yr. The total NPC of the renewable system is only about 1.6 times of the hybrid and 8.2 times of the diesel system.

## 7. CONCLUSION

This paper compared three different systems: The first system is renewable energy system and the second is a hybrid system and the third is non-renewable energy system. This comparison is done using HOMER software. From the economical analysis it is easy to notice that, the renewable system is the most expensive way to generate electricity among the other systems, but in terms of carbon dioxide emissions, it is more environmentally sound because the system emits no $CO_2$ during the electricity production, while the Diesel generator system emits considerable amounts of the greenhouse gas, the results show the renewable system and the hybrid renewable energy system significantly reduce the running time of diesel generator and this helps to reduce the emission level.

From an environmental standpoint, in terms of pollutant emission and economic feasibility, the hybrid energy system is preferred over the two other systems.

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