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doi:10.15199/48.2023.04.31

# Optimal Planning of Hybrid (Solar-Wind) Energy System Using HOMER Pro. Simulator.

***Abstract.*** *The goal of this article is to develop a hybrid (solar-wind) system to cover the necessary load of a residence in the Aski Mosul region. Because of high fuel prices and a lack of natural gas production in Iraq, the government's energy is insufficient to serve a significant number of people in distant areas. For simulation, HOMER Pro software is used, and the results indicate the influence of the hybrid system on electric power. The findings of this study demonstrate that the employment of this method is quite beneficial in distant areas.*

***Streszczenie****. Celem tego artykułu jest opracowanie hybrydowego (słoneczno-wiatrowego) systemu do pokrycia niezbędnego obciążenia rezydencji w regionie Aski Mosul. Ze względu na wysokie ceny paliw i brak wydobycia gazu ziemnego w Iraku, energia rządu jest niewystarczająca, aby obsłużyć znaczną liczbę ludzi w odległych obszarach. Do symulacji wykorzystano oprogramowanie HOMER Pro, a wyniki wskazują na wpływ układu hybrydowego na moc elektryczną. Wyniki tego badania pokazują, że zastosowanie tej metody jest całkiem korzystne w odległych obszarach. (Optymalne planowanie hybrydowego (****Projektowanie słoneczno-wiatrowego) systemu energetycznego z wykorzystaniem HOMER Pro. Symulator****.)*

**Keywords:** Hybrid system, Solar system, Wind system, HOMER Pro software.
**Słowa kluczowe**: hybreydoqwy system wytwarzania energii, oprogramowanie HOMER

## Introduction

There has been a significant trend in affluent countries toward sustainable energy suppliers and boosting the effectiveness of the green energy.This is due to the fast growth in the cost of conventional or fossil fuels, which causes air pollution and global warming. [1]. The expense of grid expansion in far places is prohibitively expensive, and the cost of fuel climbs dramatically with distance. Sources of clean energy, such as photovoltaics, wind energy, in addition to hydro energy,offer a viable replacement to diesel generators for generating power. Individual fluctuations in photovoltaic systems and wind energy can bemitigated by adopting hybrid sustainable energy systems with batteries [11]. Hybrid systems' services range from modest power supply for distant homes to delivering electrical energy to villages .

In this work, the HOMER Pro tool is usedto assess a proposed hybrid renewable power system at Aski Mosul village to assess its viability in comparison to the national electrical grid; additionally, for additional information about optimization, two systems standalone and gridconnected are considered to be studied.

Because a comparable research has not been done previously on this site, and to compare the production to that of a PV system of the same rating, the recommended model in this page cannot be exactly compared among different models accessible at other sites. since input characteristics like wind, solar, and temperature can surely change from one site to another, resulting in varying optimal solution outcomes that may not be properly compared.

1.

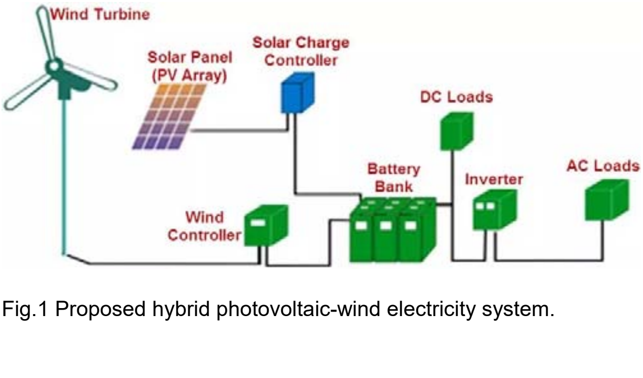


Fig.1 Proposed hybrid photovoltaic-wind electricity system.

## System Description

The suggested hybrid wind-solar power system of electricity using a battery bank and a local grid depicted in Figure.

The photovoltaic system produces energy during days with blue skies, while wind systems supply electricity for load during the day and night on overcast days and nights. Figure 2 shows a plan for an on-grid and off-grid solar-wind hybrid power system in western Mosul.

Fig. 2 Depicts the case study site (West Mosul) on a globe map.

The explanation for choosing this site is that it is a suitable site for the construction of a renewable energy plant because it is characterized by a relatively high irradiance and a relatively moderate temperature because it is located near the Tigris River and the Mosul Dam Lake, and the average wind speed in this site is good and encourages the use of wind power.

Solar irradiance and wind speed statistics of the locationhave been determined via the National Aeronautics and Space Administration's surface meteorology and solar energy project (SSE) (NASA) [2], It gathers meteorological and statistics on insolation for the planet to aidthe creation of renewable and sustainable energy systems [2]. The longitude and latitude of the location are 42°43'29.55" E and 36°30'50.77" N, as shown in the HOMER Pro computer software. The average monthly irradiance is shown in Figure 3 on an annual basis of 5.37 (kWh/m$^2$/day), whereas Figure 4 shows the yearly average mean daily wind speed per month of 4.35 (m/s) [1]. In addition, the mean monthly average ambient temperature shown in Figure 5.

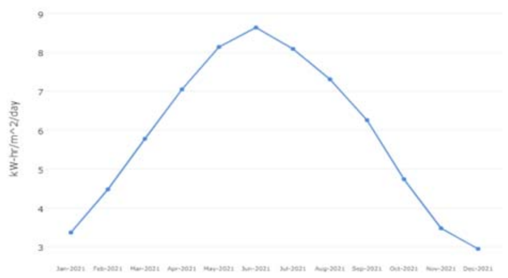


Fig. 3 Average monthly irradiance

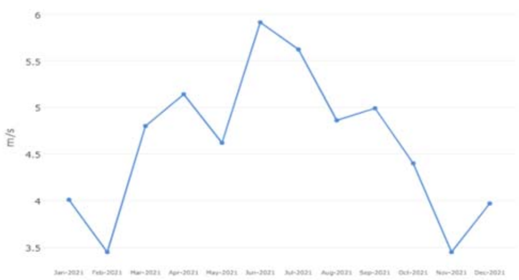


Fig. 4 Monthly average wind speed at 50m hight in 2021.

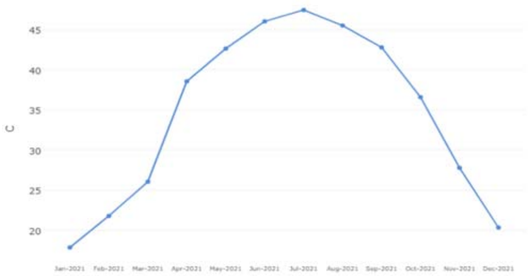


Fig. 5 Monthly average ambient temperature

**Relationship between wind speed and power**

The kinetic energy of mass (m) in air travelling at speed V is given in joules by the following

(1) kinetic energy = $\frac{1}{2}\, m\, V^2$

The flow rate of kinetic energy per second in watts is the power in flowing air.

(2) Power=$\frac{1}{2}(\textbf{mass flow per second})V^2$

IfP, ρ , A and V stand for powerof air (watts),air density (kg/$m^3$),swiped area by theblades ($m^2$) and air velocity (m/sec).

The velocity of volumetric flow is AV, air mass velocity in kg per sec is AV, and the mechanical power given by upstream wind is in watts [2]:

(3) $P=\frac{1}{2}\,(\rho AV)V^2 = \frac{1}{2}\rho AV^3$

The net annual power (WE) in (kWh) generated by wind turbine may be expressed by the following equation:

(4) $W_E = \sum_{t=1}^{Nh} Ntr\ Ptr\ (v_t)$

Where (Nh) denotes the total number of hours in a year, (t) denotes the hour of the year, (Ptr) denotes the output power in kW as a function of the mean wind velocity for a particular hour, and (Ntr) denotes turbines number at the location [1].

**Photovoltaic system**

A PV array is formed by connecting many solar cells in series and parallel to produce solar module. These cells collect short-wave radiation and change it to direct current power. The solar array's total annual energy contribution (Epv) is computed by HOMER Pro using the equation [4]:

(5) $E_{pv} = Y_{pv}\ x\ PSH\ x\ F_{pv}\ x\ 350\ day / yr$

where,$Y_{pv}$ is PV array's maximum capacity(KW) and PSH stands for peak solar hour (h),the equivalent daily average solar irradance $F_{pv}$ is the PV derating factor that accounts for the effects ofwire losses, dust,temperature, and other variables on the solar array's output energy. The derating factor is defined as the connection between expected and actual output, also known as PV efficiency [4].

**HOMER Pro based model**

A computer model known as the Hybrid Optimization Model for Electric Renewables (HOMER) developed in the United States by the National Laboratory of Renewable Energy (NREL) supports designers in developing renewable energy technologiesutilized on both standalone and off-grid installations., as well as to facilitate the assessment of power generation technologies through a wide range of combinations. [5],[6]. Figure 6 shows a flowchart of the HOMER Pro simulation procedureswhich describes all of the simulation processes in full[1].

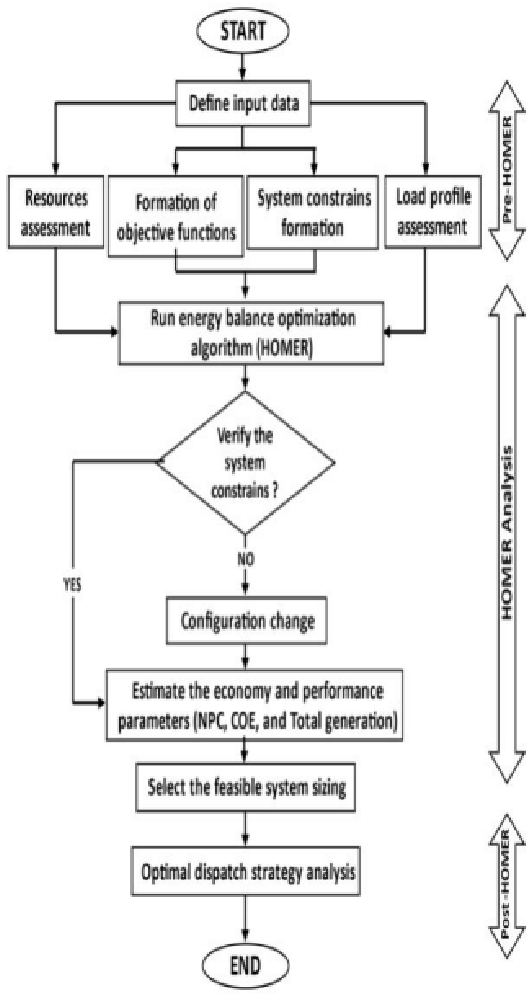


Fig. 6 Flowchart of the HOMER Pro simulation method.

Figures 7 and 8 depict the hybrid energy model developed as part of the HOMER Pro scheme. This model includes a generic 1.5 kW wind turbine, a generic 0.28 KW PV flat panel, an electronic converter, a generic 6.46 kWh lead acid battery, and a residential load [13].

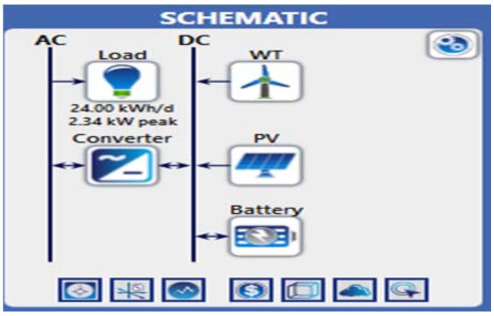


Fig. 7 HOMER Pro layout for a standalone model (off-grid)

**Optimization analysis**

HOMER Pro will simulate all feasible hybrid system solutions and then provide a list of potential system configurations (different combinations of system components) organized in ascending order (lowest to highest)in total net present cost (TNPC). Best hybrid power system configuration has the lowest cost compared to alternative designs [7]. The cost of energy (COE) is describedby HOMER Pro as the system's mean cost per kWh of usable energy generated,COE is determined by dividing annual cost of generating electricity by the sum of usable energy produced. Equation (6) represents the COE:

(6) $COE = C_{ann,tot} / (E_{AC} + E_{DC} + E_{grid,sales})$

where, $C_{ann,tot}$is the total annual cost ($/yr. ), $E_{AC}$ represents the AC main load serviced (kWh/yr), $E_{DC}$ represents the DC load (kWh/yr), and $E_{grid,sales}$ represents overall grid sales (kWh/yr) [8].

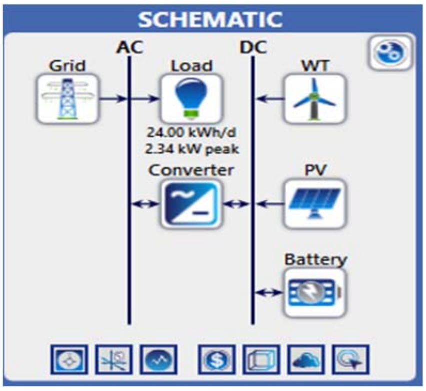


Fig. 8 HOMER Pro layout for a standalone model (on-grid).

TheNPC is determined by HOMER Pro utilizing the relationship inequation (7), where ($C_{ann,tot}$) is the total annual cost in dollars per year, (CRF) is the capital recovery factor, ($R_{proj}$) is the project lifespan in years, and i is the interest rate percentage.

(7) $$C_{NPC} = \frac{Cann,tot}{CRF(i,Rproj)}$$

(8) $$CRF= \frac{i(i+1)^{Rproj}}{[(i+1)^{Rproj}-1]}$$

To achieve the lowest cost with the off-grid and on-grid designs, the model was set up to simulate the same electrical load of a small level of energy consumption dwelling in Aski Mosul village, whose vital load is (4.8 - 24) KWh/day, as showninFigure 9.

Table 1. Model Parameters.

| Inputs | Wind Turbine | PV 1 KW | Battery 538 Ah | Converter 2 KW |
|---|---|---|---|---|
| Capital Cost | 400 $ | 1000 $ | 500 $ | 300 $ |
| Replacement Cost | 400 $ | 800 $ | 450 $ | 300 $ |
| Operation & Maintenance | 1 $ | 10 $ | 10 $ | 2 $ |
| Lifetime | 10 yrs | 25 yrs | 10 yrs | 25 yrs |
| Hub Height | 30 m | | | |
| Efficiency | | 16.8 % | | 95% |
| Derating Factor | | 88 % | | |
| Operating temperature | | 45 | | |
| Initial SOC | | | 100 % | |
| Minimum SOC | | | 20 % | |
| Nominal Voltage | | | 12 V | |
| Nominal Capacity | | | 6.64 KWh | |
| Maximum Capacity | | | 538 Ah | |


Fig. 9 Daily load profile of Water Treatment Project.

A PV flat panel of 1 KW is used, the wind unit is a 950 W 24 V DC, a lead acid battery of rated capacity 6.46 kWh, and 2 KW converter are also used to support the hybrid system's off-grid design.

The grid unit capacity is10kW, energypriceis0.1$kWh, and sellback price is 0.05$kWh; during renewable energy lack or outage, the grid supplies energy to meet the load demand. Furthermore, the excess of energy available can be sold to the grid [12].

**Results and discussion**

A home load is employed in the suggested hybrid system in this article. Assume the project has a life of 25 years. Figures 10 and 11 show the suggested model's optimization outcomes in bothoff-grid and on-grid architectures. Regardless of the influence of sensitive factors, optimization advancement has been carried out throughout each conceivable selection of variables of thissystem. Figure 12 depicts total yearly production of the proposed model as 32,148 kWh/yr with a home load consumption of 29,547 kWh/yr.

| Architecture | | | | | | | | Cost | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | PV (kW) | WT | Battery | Converter (kW) | NPC ($) | COE ($) |
| | | | | 6.58 | | 7 | 1.93 | $18,409 | $0.0907 |
| | | | | 8.33 | 1 | 10 | 1.33 | $22,608 | $0.109 |

Fig. 10 Optimization findings for the Off-Grid model.

| PV (kW) | WT | Battery | Grid (kW) | Converter (kW) | NPC ($) | COE ($) | Energy Purchased (kWh) | Energy Sold (kWh) |
|---|---|---|---|---|---|---|---|---|
| 16.7 | 1 | | 10.0 | 11.1 | $10,361 | $0.0140 | 3,552 | 20,787 |
| 16.8 | 1 | 1 | 10.0 | 11.1 | $11,327 | $0.0161 | 2,050 | 19,456 |
| 17.2 | | | 10.0 | 11.1 | $12,353 | $0.0170 | 4,247 | 20,233 |
| 17.4 | | 1 | 10.0 | 11.1 | $13,308 | $0.0192 | 2,736 | 19,021 |
| | 1 | | 10.0 | 1.13 | $19,043 | $0.0861 | 7,024 | 86.0 |
| | 1 | 1 | 10.0 | 0.729 | $19,648 | $0.0896 | 6,888 | 8.81 |
| | | | 10.0 | | $21,900 | $0.100 | 8,760 | 0 |
| | | 1 | 10.0 | 0.0833 | $22,981 | $0.105 | 8,756 | 0 |

Fig. 11 Optimization findings for the On-Grid model.

| Production | kWh/yr | % |
|---|---|---|
| Generic flat plate PV | 26,515 | 82.5 |
| Wind Turbine | 2,081 | 6.47 |
| Grid Purchases | 3,552 | 11.0 |
| Total | 32,148 | 100 |

| Consumption | kWh/yr | % |
|---|---|---|
| AC Primary Load | 8,760 | 29.6 |
| DC Primary Load | 0 | 0 |
| Deferrable Load | 0 | 0 |
| Grid Sales | 20,787 | 70.4 |
| Total | 29,547 | 100 |

Fig. 12Power generation and consumption at the HOMER Pro on-grid model.

COE (Cost of Energy) calculated using HOMER Pro is 0.014$, whereas grid power is 0.1$kWh. Renewable energy contributed 88.97% of the total. The derivative-free technique in HOMER Pro sugests the optimal contribution percentage among sourcesto effectively deliver required power to the load. The cost of energy of off-grid system COE 0.0907$ is significantly higher than that of on-grid system COE 0.014$, as shown in Fig. 10. Total NPC of off-grid and on-grid system is 18,409 dollars for the former and 10,361 dollars for the latter.
The monthly energy production of the On-grid and Off-grid systems is depicted in Figures. 13 and 14,respectively.

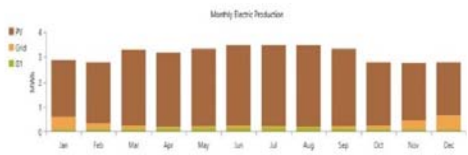

Fig. 13 Monthly energy prodection of the On-grid arrangement.

Figu. 14 Monthly energy production of the Off-grid arrangement.

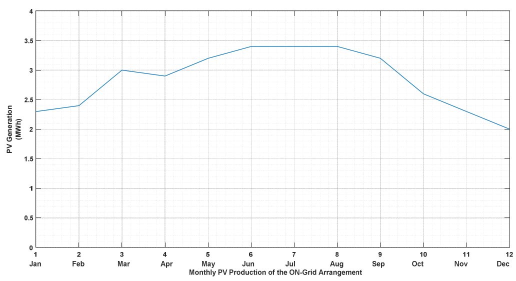

Fig. 15 Monthly PV production of the ON-grid arrangement.

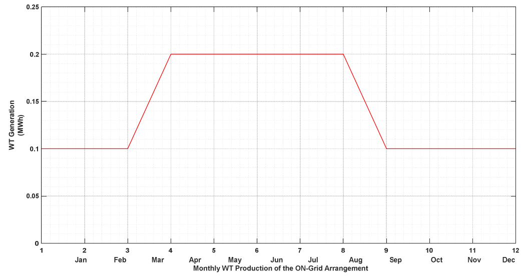

Fig. 16 Monthly WT production of the ON-grid arrangement.

The monthly PV and wind turbine generation for ON-grid arrangement are shown in figure 15 and figure 16 respectively.

The monthly PV and wind turbine generation for Off-grid arrangement are shown in figure 17 and figure 18 respectively.

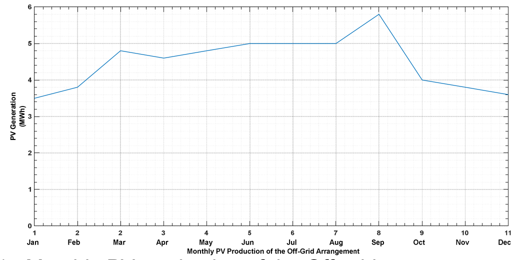

Fig. 17 Monthly PV production of the Off-grid arrangement.

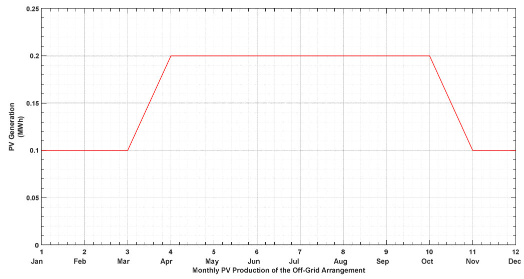

Fig. 18 Monthly WT production of the Off-grid arrangement.

## Conclusions

This study contrasts two hybrid systems,on-grid andoff-grid,without accounting for effect of sensitive factors. Because of the ease of access to solar and wind data, this study was conducted in western Mosul, north of Iraq.The suggested system's simulation results indicate that a hybrid solar-wind energy system connected to grid is less expensive than off-grid and local grid alternatives for same load whereas COEs of on-grid, off-grid and local grid are 0.014 $kWh, 0.0907 $kWh and 0.1 $kWh respectivly.

A small wind turbine was employed in accordance to the wind speed in the region in an attempt to invest in wind energy. However, due to the low speed of the monsoon winds in the region in general, the usage of wind turbines in generating electrical energy at the site is not viable due to their low energy production (2081 KWh/year) as compared to the PV production (26,515 KWh/year) at the same wattages as shown in the monthly electric production results.


## *Acknowledgements*

*The authors are extremely thankful to the (Northern Technichal University / Techical Engineering College) for the facilities they offered, which assisted inimproving the quality of this study.*

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