Journal of Energy Systems

2022, 6(2)

2602-2052 DOI: 10.30521/jes.985078 Research Article

Analysis and optimizes of hybrid wind and solar photovoltaic generation system for off-grid small village

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Submitted: 02.09.2021
Accepted: 15.03.2022
Published: 30.06.2022

Abstract: As an effective means of providing power to remote and off-grid areas of developing countries, where rural electrification problems are most common, hybrid renewable energy systems are considered. HOMER simulated and configured wind turbine, photovoltaic, battery bank, and converter for the electricity demand of the Mander rural community, which has 37 families with household sizes of 7 members, as a remote village in Northern Iraq in this article. The hypothesis project was also evaluated using the parameters *Net Present Value* and *Simple Payback Period*. Daily energy consumption of 173.120 kWh and peak electricity consumption of 32.14 kW were measured for the outcome of the selected site. The proposed system produced 68.458 kWh/yr (13.7 percent) by the wind turbine, PV created 432.354 kWh/yr. (86.3 percent), and 265 operating batteries with a total operating cost (TOC) and costs of energy (COE) of $9.195 and 0.365 $/kWh, respectively. This survey emphasized the role of solar photovoltaic and wind turbine as hybrid renewable energy systems HRESs in the sustainable supply of electricity in rural areas of northern Iraq.

Keywords: *Hybrid, Load demand, Off-grid, Remote area, Renewable energy*

Cite this paper as: Rasool, N.M., Abbasoğlu, S., & Hashemipour, M., Analysis and optimizes of hybrid wind and solar photovoltaic generation system for off-grid small village. *Journal of Energy Systems* 2022; *6*(2): 176-187, DOI: 10.30521/jes.985078

1. INTRODUCTION

Throughout the previous decade, the OGPS (Off-Grid Power Systems) application vanished from exclusive RES (Renewable Energy System) had been growing, despite that, these resources are generally irregular [1,2]. The system of off-grid energy is collected of units of energy generation, energy consumed by appliances and a battery. In either devolved or underdeveloped nations, the plan of electrical systems is being reached [3,4]. This is attributable to several variables, namely lower moving within the photovoltaic prices, wind power technologies and improved storing, as well as a micro hydraulic charge and decreasing charges in battery-containing power storage systems.

Subsequently, according to Kempener et al [5] for the operation of those power systems of electricity in each residential and commercial operator, there is a promising horizon. Otherwise, in developing international locations, there are more than one million people lacking access to this necessity power that is electrical power [5] its miles especially because of its far-flung topographical region. Therefore, as it has been explained before, the O-GPS suit of this sort will be the feasible response to the problem of grid admission for the power supply in these remote locations.

In the northern Iraq district, as indicated by an examination [6], it was reasoned that power inclusion in rustic terrify. This study is completed ores are about 80%. As indicated by an investigation in 2014. As per a measurement government report in 2014, the age of power in the region district originates from gas and fuel assets [7].

Consequently, provide green energy from renewable energy sources as clean energy that the objective of this project is to integrate wind and solar energy in a distant place. The objective of this study's integrated energy generation is to supply continual electricity power for relatively small projects using battery storage through day and night. This could gain with hybrid solar and wind energy systems (SWHES).

The demand of rural or provincial areas or a whole network is met by hybrid-energy systems and frameworks, multiple generators and capacities components. Notwithstanding photo voltage, wind, and diesel generators, little plants of hydro-power, and other electric vitality wells could be additional such as predictability, to content the vital requirement such that convulsions the nearby geology and various attraction places. This sort of vitality system and frameworks can tackle this issue, which exist in the investigation zone that can be outlined as Oil and energy crisis in the site, contemplate. Customary power age will turn into a troublesome undertaking later on and expanding the creation of power likewise to satisfy the needs of developing populace. In addition, toxins discharged from the traditional power age will influence nature, the transmitting generation will affect the environment, and the transmission power loss is additionally one explanation behind remote spots. By concentrating on what are the benefits of utilizing a hybrid renewable power system; how to plan diverse elective plans of the mixture vitality system? Also, contamination emanations of the system, particularly in far off.

As regards that, wind and solar power are the maximum promising of the renewable power sources because of its obvious limitless ability especially for far off region. The circumstance of them emerges as exclusive from one region to any other want to be analyzed before set within the place. Thus, electricity planners have to observe the wind power, solar electricity, and other potential assets on the location of the site, similar to the power request.

Distinctive researches have been accomplished with solar and wind power generating technology and the use of renewable electricity required system. The literature stands with the classification of the exceptional machine system alone as following.

1.1. PV Array Modelling Solar

Due to its intrinsic optimal conditions, such as non-compliance with fuel prices, concern of fuel source and infrastructure reliability, the PV generation is increasing its value as a sustainable renewable energy source [7]. In other words, PV generation is getting extended importance as an economically sustainable power source due to its natural good conditions like nonattendance of fuel costs, fuel supply issue and structure constancy with for all intents and purposes zero upkeep. A p-n intersection or junction is a rudimentary object in the solar cell which is factory-made in a semi-conductor of the layer. The radiation of electromagnetic of solar power can rightfully be changed into power by the impact of PV. A PV system is a connectivity of components according to the rate of an equivalent of the solar panel, which in opportunity is produced in either a parallel or series with a number of photovoltaic cells. The electricity generated from alone or individual module is rarely sufficient for business usage, so that the units are connected to forming an array of weight.

The module relationship in a collection is the equal as that of the module cells [8]. The Photovoltaic panels are constructed with blended parallel or serial photovoltaic cell combinations that are commonly shown via a basic equal circuit version [8]. The Photovoltaic device simulation electricity generation model consists of different measures: radiation of Solar on the surface of the photovoltaic plate, Photovoltaic collection energy model, and Photovoltaic module version for temperature [9].

1.2. Wind Turbine

The response to international electricity demand and pollution problems is crucial for wind power and energy. With a median wind pace of 7.1 m/s, annual wind electricity manufacturing is envisioned as nearly [10]. Wind turbines are utilized to produce electricity from wind power. In another word, Power supply depends on the power of wind in wind turbines. The wind turbines are generated based on the speed of the wind and on the turbine's operation. The physical highlights, which can be summarized in, number of required as (measures, planes and axes, sharp edge numbers) and the manufactured controller are grouped with wind turbines. Core configuration wind turbines: cab be summarized as: level rotor plane found turbines, vertical turbines or flat wind turbine rolling bearings. Cutting-edge turbines: turbines of three, two and one-blade [10].

The power result of wind turbine is a component of the three wind speeds remember the cut-in speed, the cut-out speed, and the rated speed of the wind turbine. At the point when the rated speed is lower than the cut-in speed, yield force of WT will be insignificant; therefore, for this situation WT is in standing" mode. Besides, to be securely during crisis conditions or when wind speed is over the removed speed, WT ought to be halted overlooked. Since, the rated speed shift through suitable qualities, yield energy will have a cubic relationship against wind speed. Where wind speed lies between the cut-out qualities and the evaluated qualities, the result is adapted to the most extreme appraised esteem through command over streamlined power.

1.3. Modeling of Hybrid Solar - Wind System

Wind turbines, Photovoltaic cells, battery, controllers, inverters, and wires form part of a hybrid wind and solar system [11]. In order to satisfy the load demands the PV panel and wind turbine operate together. The produced impact of solar power will continue to charge the battery bank till it is completely charged, also at a particular moment in time when vital resources (Sun-base wind) are wealthy. Otherwise, at what time critical resources are low, the batteries discharges vitality in order to support the photovoltaic cluster and the wind turbine cover heap requires, before the capacity is exhausted [12].

The simulation of the hybrid wind and solar system primarily needs individual mechanisms to be presented. In order to predict the systemic presentation, energy sources should also be clearly designed in cooperation sources and combined to supply reliability [13]. The resulting mixture will successfully transmit control if the predictions of power generation from these individual sources are adequately correct [11]. In addition, a hybrid device might be built to be enabled through the electronic power boundary in disconnected or grid connected mode.

The remainder of the paper is separated as pursuing general data about the procedure for the demonstrated system and qualities of the chosen area to study. At that point, another part exhibits the system determination dependent on the computational apparatus used. After that reproduction results and exchanges are given. At last, the finishes of the present examination are displayed.

2. METHODOLOGY

The methodology of the research can be qualitative (simulation primarily based). The method of the related equations is the first step of the approach. Air temperature, radiation of solar, the speed of the wind are used as inputs for the HOMER pro in the generation of solar energy, the power of wind and turbine-PV hybrid generation. The best solar cell collection and systems of turbines are selected to provide the energy produced from such renewable assets. The next stage is to explore wind and solar energy system combination depending on its output traits.

2.1. Site Selection and Demography

The climate is continually changing for particular areas and localities, together with solar irradiation, wind speed, temp and so on. As a result, destabilization weaknesses emerge from the production of electric power from such a wind farm and PV modules. The analysis and primary suit are highly essential to system of PV and wind turbine as well as with rechargeable batteries, so that the renewable energy reserves of sun power parcel and wind are used efficiently and economically. The distant is the choice for this study is Mander rural in Erbil governance where's a small village in a high mountainous vicinity. According to the previous studies, the provinces with the Mander and some other villages are located under the lower or non-power electricity coverage.

This study is accomplished in Mander, as it has been mentioned above, one of the sites under the non-coverage of the power of distribution of power delivery of the purpose region. Regarding to Geographical aspect, it's placed within the (36°16'17.36) latitude and (44°32'48.32) longitude. Mander is 401 meters high, based on the level of the sea. With regard to demographic and residential ratios, there are roughly 37 households with 222 inhabitants. The climate and meteorological conditions are semi-arid and four major seasons can be clearly seen there, wet and cold in winter and warm and dry in summer. As explained in Fig. 1, the average temperature lays between 2 and 30 °C in Fig. 1(b), radiation has been explained in Fig. 1(c). Also, the average wind speed is between 4.250 and 8.280 m/s as in Fig. 1(d) and the wind speed changes with height as in Fig. 1(e).


TURKEY
Mosul
Irbil
SYRIA
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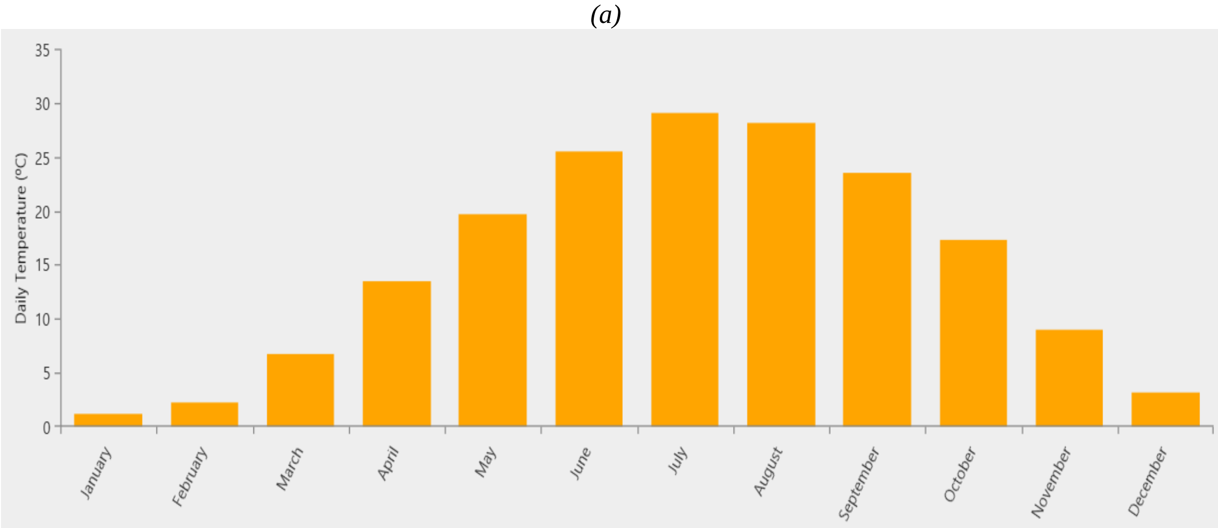
IRAN
IRAQ
Baghdad
JORDAN
An Najaf
Basra
SAUDI ARABIA
KUWAIT
Erbil

(a)


Daily Temperature (ºC)
35
30
25
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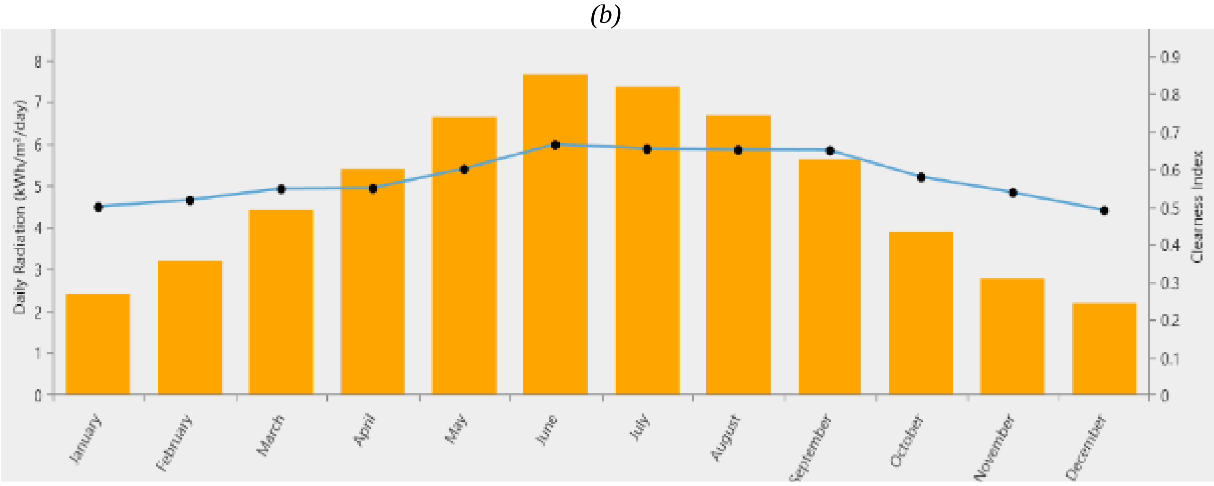
10
5
0
January
February
March
April
May
June
July
August
September
October
November
December

(b)


Daily Radiation (kWh/m²/day)
8
7
6
5
4
3
2
1
0
Clearness Index
0.9
0.8
0.7
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0.5
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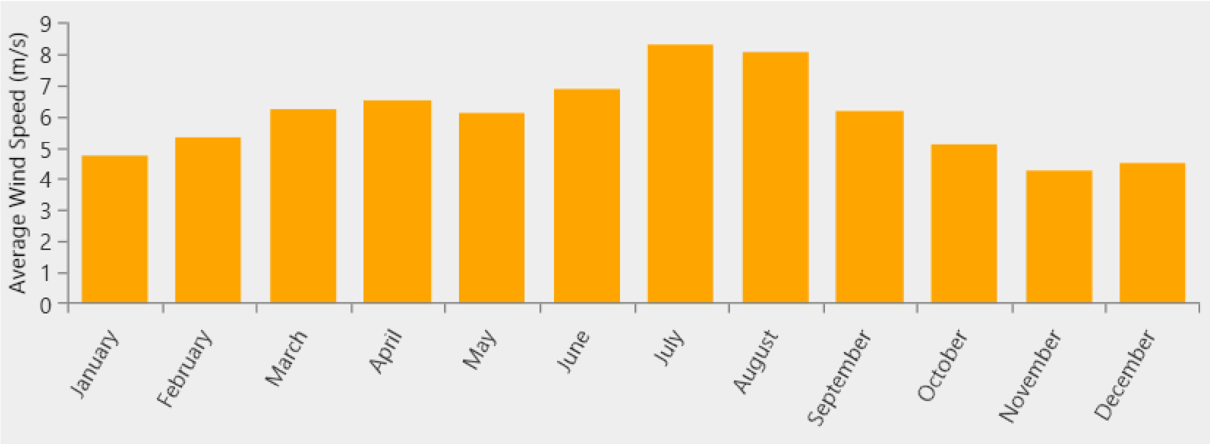
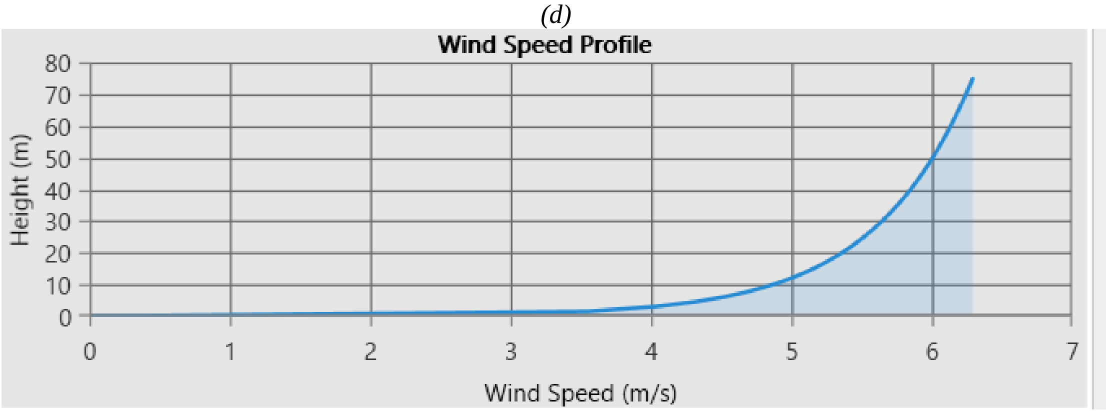
(c)



(d)



(e)

Figure 1. (a) Site study (b) The average temperature (c) Daily radiation (d) Monthly wind speed (e) wind speed with height.

2.2. Electricity Load Demand

The demand for electricity does not surpass urban areas in a far-off rural village. For two different seasons that they are summer (April to October) and winter (November to March), the application trends in appliances and the usage of energy in production applications have been analyzed separately.

Table 1. The electric load in the village.

Type	Appliances in Summer	Total (Wh/day)	Appliances in Winter	Total (Wh/day)	Annually (kWh/day)
Domestic (Wh/day/home)	CFL bulb (4 x 20W x 9 h/day), TV (1 x 120W x 7 h/day), Ceiling fan (3 x 40W x 9 h/day)	2760	CFL bulb (12 x 20W x 9 h/day), TV (7 x 120W x 7 h/day), Ceiling fan (0 x 40W x 9 h/day)	1800	
	No. of homes(37)	102120	No. of homes (37)	66600	
School	CFL bulb (3 x 20W x 4 h/day), Ceiling fan (3 x 40W x 4 h/day), Computer (2 x 300W x 2 h/day)	1920	CFL bulb(6 x 20W x 4 h/day), Ceiling fan (0 x 40W x 4 h/day), Computer (2 x 300W x 2 h/day)	1560	173.120
Mosque	CFL bulb (5 x 20W), Ceiling fan (2 x 40W)	620	CFL bulb (5 x 20W), Ceiling fan (0 x 40W)	300	

In this research type, the power required estimation for the energy evaluation is a vital part of it. The estimation of demand for energy for one of a kind places, including Mander has been pointed out in previous research [14]. The electric load for all 37 families, which each of them composed of 7 members, in the study area is 173.12 kWh is a total electricity consumption per day [14] as has been explained in Table 1. As the load factor in these places appears to be low, over the 24-hour cycle, some demand has been strategically allocated to increase the system load factor. The load of the village was split into two significant categories.

The first step and initial stage of the technique in the approach was to use the components to monitor power generation, speed of the wind, solar radiation, and temperature. Then, they were entered in the HOMER block for generating energy output of wind and solar HWS system. It picked the proper and right Photo voltage range and model of wind turbine models to provide the electricity power generated from clean energy resources. The next stage of the method was to investigate the HSW electricity system based on the features of the output.

2.3. Photovoltaic Array Model

The ambient temperature degree is known and once the solar radiation on Photovoltaic panels, the electricity production of the photo voltage unit be able to be considered simply, and correctly (fig. 2) . The description of fill variables can also be used to measure the maximum power generated from PV module by equation [15]. The use of HOMER as a program simulating in this research has been used to calculate and determine the maximum output of electricity provided by VP. Correspondingly, the Sharp NU-U245P1 Photovoltaic Module's cost per watt peak was then considered to be $2.5/Wp, including installation costs. The substitute cost for PV module is $2.5/Wp and the lifespan of PV modules is 25 years.

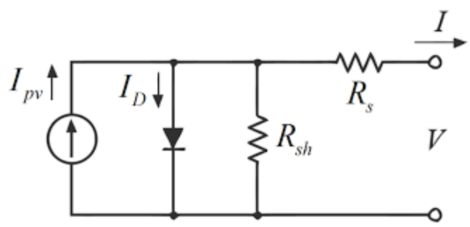


Figure 2. Photovoltaic module equivalent circuit.

Both voltage and current distinguishing equation of a cell of solar is given as [16].

$$I = I_{pv} - I_{sh}\left(exp^{q\left(\frac{v+IR_S}{nKT}\right)} - 1\right) - \frac{V+IR_S}{R_{Sh}} \qquad (1)$$

where:

I_{ph}: is a photocurrent or current of light-generated,
I_{sh} : is the dark current cell saturation,
$q = 1.6 \text{ x } 10^{-19}$C is a charge of the electron,
($= 1.38 \text{ x } 10^{-23}$ J/K) is a constant “Boltzmann”,
T is the temperature of working of the cell,
n is a factor of ideal, R_{Sh} is a resistance “shunt”, and R_S is a resistance “ series”.
The ideal factor n is dependent on PV technology” [16].

2.4. The Electrical Power Generated by the Wind Turbine

A generic 3 kW turbine, including the tower and construction costs, was considered for the current study site at a cost of $18,000, while the cost of replacing the generator is $18,000, while the cost of maintaining the turbine is $180,000 per year for a 25-year lifetime. The equation is as given bellow [16]:

$$p = \frac{1}{2}C_e \rho A V_1^3 \qquad (2)$$

Where, P_ω is energy extracted from wind turbine with modifications in wind velocity.

C_e is the upstream wind strength fraction, with 0.59 as a maximum price.
V_1 is the wind velocity in m/s,
ρ is the air density in kg/m^3 and A is the area swept by the rotor blades in(m^2).
V_1 is the wind speed in m/s (find in the table)
ρ is the density and equals to 1.225 kg/m^3 (constant)
C_e = 0.59 (constant).
A = 9.6 m^2 (constant)

2.5. Battery and Power Converter

The device proposed requires battery storage to supply the village with daily electricity. During the surplus generation, the battery bank should store energy and, if necessary and in the required time, supply the energy. For this analysis, generic 1 kWh Lead Acid batteries have been selected. The nominal capacity is 12V and 83.4Ah normal capacity with an estimated life of service of twelve-year expected. The battery cost estimates $300 has been considered, while one unit costs $300 and $10 per year for replacement and operation, and maintenance. To connect the AC and the DC bus, it must be specified that the converter is included. For the converter, the cost of capital per kW is considered to be $100, while the costs of the replacement shall be $100 and maintenance and service shall be $100.

2.6. Power from the Hybrid

The hybrid entire powers of this scheme, the power of the hybrid is the entire generated-power with the aid of the HWSs, equal to the summation of photovoltage-power which is the power-produced through the solar cells, and wind-power is the energy produced via the wind energy. HOMER calculates capital costs for each component to an annualized expense through a lifetime using the true discount rate. The hybrid total powers of this system shown in the equation below [16]:

$$P_{HY} = P_{PV} + P_W \tag{3}$$

2.7. Cost of the Projects

The amount of funding for this project consists of wind turbines, photovoltage, and storage as equation below [17]:

$$cost = cost(wind) + cost(solar) + cost(battery) \tag{4}$$

Additionally, supplying an area to set up the system ought to be brought also. It is developed a high quality layout for a solar-wind hybrid energy, wherein the variables which might be optimized over encompass the variety of photovoltaic modules, the wind turbine top, the quantity of wind turbines, and the turbine rotor diameter, and the intention is to limit expenses. It is developing a premiere layout for a HSW electrical power, in which the variables which are optimized overreach them has a special circumstance for calculating the specified cost. For wind turbine, these expenses are a couple of the variety of turbines of wind established, Nw [17]:

$$cos(Wind) = N_w\ C_{wm} + \left(0.1\left[\frac{h}{10} - 1\right] + 1\right) N_w\left(2.449r^{2.7} + C_{wf}\right)\left(\frac{i^*(1+i)^{Y_{proj}}}{(i+1)^{Y_{proj}} - 1}\right) \tag{5}$$

For PV the cost is a summation of solar arrays Ns.

$$Cost(Solar) = N_s C_{sm} + N_s C_{sc}\left(\frac{i^*(1+i)^{Y_{proj}}}{(i+1)^{Y_{proj}} - 1}\right) \tag{6}$$

3. RESULTS AND DISCUSION

3.1. Description of the System

Fundamentally, the proposed HES includes Solar cells, and wind turbine. There are many researches in different locations international [15,18] In which it is justified to utilize the electrical generator: as holdup strength for the duration of height hours (peak hour); periods with few tiers of radiation of the sun and wind velocities; and to lessen the fee of power (COE) of the HES. However, there is indeed a fossil necessity in research, where products impact ecology and the environment due to greenhouse gas emissions. Despite the chemical stoichiometry component, emissions are modest while an electric power generator utilizes diesel as a fuel and not gas online today [16,19-22].

Fig. 3 demonstrates the layout and design of HES simulation in Homer Pro software with an explanation of AC and DC type for each production source. So, from the figure below, it can be clearly seen that Wind generated electricity in AC and PV-A create power in DC; the financial institution for the battery is charged and discharged in DC. In alternating current (AC), the electric generator generates power; in turn, the transformer changes electricity from DC to AC, in a way known as an inversion, to meet the need for electricity within AC.

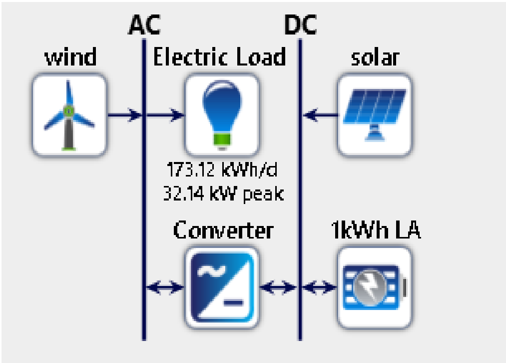


Figure 3. Use HOMER to plan and model a HRESs scheme.

3.2. Optimization System

HOMER conducts thousands of simulations repeatedly for optimal hybrid system design. The HOMER Pro program as a tool of simulation is used for the efficiency and sensitivity analysis of different groupings of the power system of hybrid components. Different combinations of solar photovoltaic systems, wind turbines, batteries, and converters have been tested. Capital input sensitivity parameters were obtained based on component sizes, a total of 4809 possible device designs, and 1143 simulations. HOMER uses the overall NPC as its principal system selection criterion. Table 2 offers the effects of categorized optimization and demonstrates the most efficient configuration for each type of system. Potential device settings are described in their overall NPC ascending order

Table 2. Optimization results, in a three classification form of architecture, cost and system.

Architecture									Cost				System	
(PV)	(wind)	(battery)	(converter)	PV (kW)	wind	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
✓	✓	✓	✓	273	13	265	33.7	CC	$0.365	$297,593	$9,195	$178,722	100	0
✓		✓	✓	378		284	53.5	CC	$0.425	$346,779	$13,732	$169,262	100	0
	✓	✓	✓		111	921	62.7	CC	$1.27	$1.04M	$32,613	$615,571	100	0

The optimal device type is the wind, PV, and battery system, according to the results of the simulation. The most viable hybrid device is composed of 265 batteries bank and a converter with 33.7 kW with 273 kW PV modules and 13 wind turbines of 20 kW. In this circumstance, 100% of the renewable share is reached with a 0.365 $/kWh of COE as shown in above Table that is the total optimization outcomes are presented. Initial capital investment of approximately $178,722 is required for the project being studied, with a total NPC $297,593. The simple payback period is also 6.12 years.

Also, it can be seen that the individual solar cell system had also shown a 0.425 $/kWh of COE of and an additional higher COE of 1.27 $/kWh for the wind-alone system. From the current simulation study, it is apparent that a single, only PV or wind turbine based on the cost of renewable energy compared to the planned system of wind/PV/batteries is more is expensive.

Table 3 shows that the COE (0.292 $/kWh) of the optimized diesel hybrid system is less than 0,365 $/kWh COE for the optimized hybrid power system for PV, Wind, and battery as stated before, according to the simulation results. It is true that the standalone hybrid electrical system proposed is significantly more costly than the hybrid and diesel generator system, but the environmental perspectives are not effective as wind and PV systems.

Table 3. Optimization results of hybrid and diesel.

Architecture											Cost					System	
					PV (kW)	wind	Gen (kW)	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)		Ren Frac (%)	Total Fuel (L/yr)
					74.7	10	36.0	124	15.4	LF	$0.292	$238,330	$10,522	$102,313		85.7	3,221

3.3. Electricity Production

Fig. 4 displays descriptions of wind turbine-produced energy and solar photovoltaic for that system. It is clear here that the PV produces the maximum capacity. The wind turbine provided 68,458 kWh/yr (13.7 percent), the PV array created 432,354 kWh/yr of the village's total primary power needs (86.3 percent). A green hybrid energy system also benefits from replacing nonrenewable sources with renewable energy sources, which decreases the amount of GHG added to the local environment.

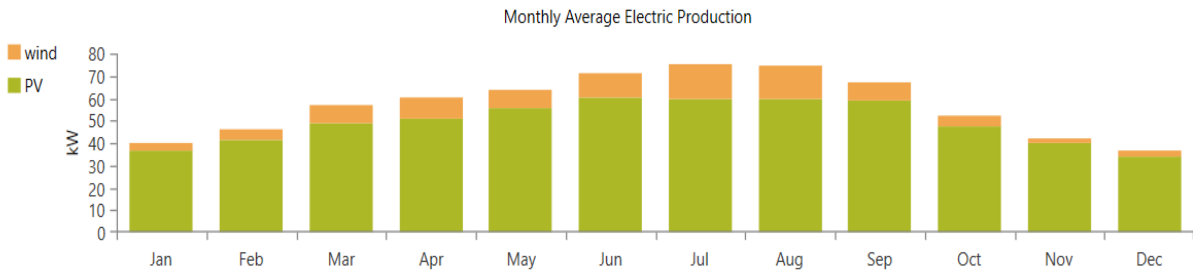


Figure 4. Power generation by PV and wind turbine in HWS system.

4. CONCLUSION

Providing green energy from renewable energy sources as clean energy that the objective of this project is to integrate wind and solar energy in a distant place and using as a SWHES for a village is located under the lower or non-power electricity coverage. Homer Pro in hybrid power system dimensioning and optimization method was used to identify the likely hybrid formations and their explanations. In the present situation, individual source of RES cannot provide full and economically will be unsustainable loads. Therefore, the most feasible alternative has been a HRE with a solar cell, wind turbine, and battery bank. This configuration comfortably satisfies the energy requirements of the considered population. The hybrid power system proposed included a 13 kW wind turbine, 273 kW PV panels, a 265-battery bench, and a 33.7 kW converter. There were 297, 5 93 dollars in NPC, $0.365 per kWh in COE, and 6.12 years in the SPP. A renewable energy fraction of 100 percent could be reached by the proposed hybrid method. The proposed system would minimize greenhouse emissions by (100 percent) per year in the local environment with all these benefits if introduced. The proposed Mander hybrid system can be used for electrification with similar conditions in whichever remote rural northern Iraq. As a movement of the steady oil price increase and a decline in capital and renewable system operating and sustaining costs, renewable energy systems are recommended to partly meet the load requirements in some areas.

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