DESIGN, AND COMPARATIVE ANALYSIS OF THE HYBRID RENEWABLE ENERGY SYSTEM: A CASE STUDY OF IRAQI REGIONS

2022
MASTER THESIS
ELECTRICAL-ELECTRONICS ENGINEERING

EMAN MOHAMMAD SAMI AL-JANABI

Thesis Advisor

Assoc.Prof.Dr. Ziyodulla YUSUPOV

DESIGN, AND COMPARATIVE ANALYSIS OF THE HYBRID RENEWABLE ENERGY SYSTEM: A CASE STUDY OF IRAQI REGIONS

Eman Mohammad Sami Ali AL-JANABI

T.C.
Karabuk University
Institute of Graduate Programs
Department of Electrical-Electronics Engineering
Prepared as
Master Thesis

Assoc.Prof.Dr. Ziyodulla YUSUPOV

KARABUK
June 2022

I certify that in my opinion the thesis submitted by Eman Mohammad Sami Ali AL-JANAB titled "DESIGN, AND COMPARATIVE ANALYSIS OF THE HYBRID RENEWABLE ENERGY SYSTEM: A CASE STUDY OF IRAQI REGIONS" is fully adequate in scope and quality as a thesis for the degree of Master of Science.

Assoc.Prof.Dr. Ziyodulla YUSUPOV ....

Thesis Advisor, Department of Electrical and Electronics Engineering

This thesis is accepted by the examining committee with a unanimous vote in the Department of Electrical and Electronics Engineering as a Master of Science thesis. June 9, 2022

Examining Committee Members (Institutions)		Signature
Chairman	: Assist.Prof.Dr. Tarik Adnan ALMOHAMAD (KBU)	....
Member	: Assoc.Prof.Dr. Ziyodulla YUSUPOV (KBU)	....
Member	: Assist.Prof.Dr.Musaria Karim MAHMOOD (AYBU)	....

The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

Prof. Dr. Hasan SOLMAZ ....

Director of the Institute of Graduate Programs

"I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well."

Eman Mohammad Sami Ali AL-JANABI

ABSTRACT

M. Sc. Thesis

DESIGN, AND COMPARATIVE ANALYSIS OF THE HYBRID RENEWABLE ENERGY SYSTEM: A CASE STUDY OF IRAQI REGIONS

Eman Mohammad Sami Ali AL-JANABI

Karabük University
Institute of Graduate Programs
The Department of Electrical and Electronics Engineering

Thesis Advisor:
Assoc.Prof.Dr. Ziyodulla YUSUPOV
June 2022, 89 pages

In the last decades, electric energy consumption increased with the evolution of modern life and overpopulation. Attention has begun to turn toward finding alternative ways to generate electricity and reduce dependence on traditional energy resources like natural gas and oil. In long term these alternatives are less expensive environmentally friendly, renewable, and sustainable. Iraq uses fossil fuels to generate electricity which significantly affects Iraq's environment and economy. The generated electricity does not meet consumer needs; there is a significant gap between energy output and consumption with frequent interruptions in electricity and a severe daily shortage in supplying Iraqi homes, especially in the summer period. Most regions of Iraq have retained old stations and grids, the rehabilitation of these stations and grids is considered very expensive, needs working hands and has huge budgets.

As a result, Iraq began to import natural gas and electricity from neighboring countries. At the same time, Iraq has a huge potential of renewable energy resources for electricity generation. The main objective of this thesis is to design and analyze the effectiveness using of hybrid system based on renewable energy with the distribution network to compensate and fill the shortfall of energy supply by taking into account the load profile. A case study had conducted for three residential Iraq's regions – Altun Kupri, Khanaqin and Fallujah. The optimization solutions for integrating hybrid energy systems to the national grid of Iraq have executed by using HOMER Pro program.

The simulation and optimization results show that the best system for the three regions is "PV – Diesel generator – Battery storage – Inverter – Utility grid" hybrid system. Fallujah's system has been the least expensive among the three regions: with the net present cost (NPC) of US $939,984, the cost of energy (COE) is US $0.0448 per 1 kW, operating cost 24289 US $/year, initial capital cost 625982 US $, and 31.6 % renewable fraction.

Key Words: Electric power system, Hybrid Renewable Energy System, HOMER, Cost of Energy, Net Present Cost

Science Code : 90502

ÖZET

Yüksek Lisans Tezi

HİBRİT YENİLENEBİLİR ENERJİ SİSTEMİNİN TASARIMI VE KARŞILAŞTIRMALI ANALİZİ: IRAK BÖLGELERİ ÖRNEĞİ

Eman Mohammad Sami Ali AL-JANABI

Karabük Üniversitesi
Lisansüstü Eğitim Enstitüsü
Elektrik-Elektronik Mühendisliği Anabilim Dalı

Tez Danışmanı:
Doç. Dr. Ziyodulla YUSUPOV

Hazıran 2022, 89 sayfa

Son yıllarda, modern yaşamın evrimi ve aşırı nüfusla birlikte elektrik enerjisi tüketimi arttı. Dikkatler, elektrik üretmenin ve doğal gaz ve petrol gibi geleneksel enerji kaynaklarına bağımlılığı azaltmanın alternatif yollarını bulmaya yönelmeye başladı. Bu alternatifler daha ucuz, çevre dostu, yenilenebilir ve sürdürülebilirdir. Irak, Irak'ın çevresini ve ekonomisini önemli ölçüde etkileyen elektrik üretmek için fosil yakıtlar kullanıyor. Üretilen elektrik tüketici ihtiyaçlarını karşılamıyor; Elektrikte sık sık kesintiler olması ve özellikle yaz döneminde Irak evlerinin arzında ciddi bir günlük kıtlık ile enerji üretimi ve tüketimi arasında önemli bir boşluk var. Irak'ın çoğu bölgesi eski istasyonları ve şebekeleri elinde tuttu, bu istasyonların ve şebekelerin rehabilitasyonu çok pahalı kabul ediliyor, çalışan eller gerektiriyor ve büyük bütçeleri var. Bunun sonucunda Irak, İran'dan doğalgaz ve elektrik ithal etmeye başladı. Aynı zamanda, Irak, elektrik üretimi için büyük bir yenilenebilir enerji kaynağı potansiyeline sahiptir.

Bu tezin temel amacı, yük profilini dikkate alarak enerji arzındaki açığı telafi etmek ve doldurmak için dağıtım şebekesi ile yenilenebilir enerjiye dayalı hibrit sistemin kullanımının etkinliğini tasarlamak ve analiz etmektir. Irak'ın üç yerleşim bölgesi - Altun Kupri, Khanaqin ve Felluce için bir vaka çalışması yapıldı. Hibrit enerji sistemlerinin Irak'ın ulusal şebekesine entegrasyonu için optimizasyon çözümleri HOMER Pro programı kullanılarak gerçekleştirilmiştir. Simülasyon ve optimizasyon sonuçları, üç bölge için en iyi sistemin "PV – Dizel jeneratör – Akü depolama – İnverter – Şebeke şebekesi" hibrit sistemi olduğunu göstermektedir. Felluce'nin sistemi üç bölge arasında en ucuzu oldu: 939.984 ABD Doları net bugünkü maliyeti (NPC) ile enerji maliyeti (COE) 1 kW başına 0.0448 ABD Doları.

Anahtar Kelimeler : Elektrik güç sistemi, Hibrit Yenilenebilir Enerji Sistemi, HOMER, Enerji Maliyeti, Net Bugünkü Maliyet

Bilim Kodu **:** 90502

ACKNOWLEDGMENT

First of all, my gratitude goes to the Most Gracious, the almighty Allah, we have no knowledge except what Allah taught us and given us. It’s my pleasure and honor for me to have the chance to express my heartfelt special thanks and genuine appreciation for every people who provided me with ideas and support in different ways to complete this thesis. The list is long it is impossible to mention all of them here, but I will try it because I cherish and value each contribution that made me grow and develop. It is to them that I owe my deepest gratitude. This thesis contains far more than the conclusion and culmination of years of study These pages also represent my connections with many wonderful and inspiring people I've met while my postgraduate studies.

I would like to take the opportunity to give thanks to my advisor, Assoc. Prof. Dr. Ziyodulla YUSUPOV, who allowed me to work under his supervision thanks for his great undisputable interest, insightful comments, observations, correct feedback, and his high morals and humanity thanks for your time throughout the preparation of this thesis.

My thanks and appreciations go to Omer Farhan AL-HARDANEE for his exceptional guidance, continuous encouragement, valuable assistance, and suggestions throughout my study, when I ask him I find an answer to every question. It’s my pleasure to convey my special gratitude to Mohammed ALBABA for his help and deep scientific and linguistic proofreading, he led me, guided me, made things easier in my eyes, and supported me in my most difficult times. My thanks go to Eng. Obaida Amer AL-NIDAWI for providing me very useful data & information.

This effort would not have been feasible, and I will not be able to complete it without my family's unending support, contributions, and sacrifices. Especially, my father Dr. Mohammad sami who raised me on a love of science but he passed away a few months ago (may Allah have mercy on him, may Allah forgive him, and placed him into his havens), he could not share the joy of my success. Great thanks to my mother Nuzhah for her kindness, pure love, and her prayer that lights my way. Thanks, gratitude, and appreciation to my dear husband Dr. Firas for his support me in all my pursuits,

encouragement, patience, and belief in my abilities and he made me feel that anything was possible. I do not forget my beloved sons (Abdullah, Mosab, and Suhaib) and daughters (Islam, and Arwaa) who are more self-reliant, manage their lives, and they have achieved more than their age. All my forgiving, generous, and loving relatives thank you for everything. Moreover, I would like to thank all my best friends and colleagues who have shared with me the best moments during my study for the Master's degree. Last but not least my thanks to everyone who contributes to completing this effort.

CONTENTS

Page

Page

<u>**Page**</u>

Page

LIST OF FIGURES

Page

Page

Page

LIST OF TABLES

Page

SYMBOLS AND ABBREVIATIONS

SYMBOLS

v	:	velocity of wind
r	:	Blade's radius
ρ	:	Air's density
A	:	Rotor Area of a wind turbine
P_w	:	wind power
O&M	:	Operation and maintenance
PV	:	Photovoltaic

ABBREVIATIONS

HRESs	:	Hybrid Renewable Energy Systems
RF	:	Renewable Fraction
AC	:	Alternating Current
DC	:	Direct Current
COE	:	Cost of Energy
OPEC	:	Organization of Petroleum Exporting Countries
HAWT	:	Horizontal Axis Wind Turbines
NASA	:	National Aeronautics and Space Administration
UNEP	:	United Nation Environment Program
VAWT	:	Vertical Axis Wind Turbines
HOMER	:	Hybrid optimization model for electrical renewable
IKN	:	Iraq Knowledge Network
NPC	:	Net Present Cost
GHI	:	Global Horizontal Irradiance

PART 1

INTRODUCTION

This introduction offers an overview of the electricity problem in Iraq's electric power systems over the past years, followed by an explanation and identification of the problem and the motivation of the study. The introduction contains the research aim and methodology of the thesis as well. The introduction is stamped with a thesis layout.

1.1. OVERVIEW OF IRAQ'S ELECTRIC POWER SYSTEMS

The need for electricity rises year by year due to growth in population and developments in the economic and social lifestyle. This increase in electrical demand cannot be met without the help of inexhaustible renewable energy sources; therefore, generating electricity from traditional sources alone has become very difficult [1]. The use of clean energy reduces global warming and environmental pollution, but using one kind of clean energy resource such as the energy of wind is not appropriate to cover the electric demand due to lack of the necessary reliability, so it is required to resort to the use of hybrid renewable energy systems (HRESs). HRES contains two or more types of renewable energy resources. It is becoming more popular due to the promising economy, especially with the drop in crude oil export prices from Iraq. It can be combined with traditional electricity generation sources to give perfect solutions and very good results to generate an endless energy covering rural and urban areas. Solar, wind, and other renewable energy resources need continuous research and development to improve their performance, develop methodologies for correctly estimating their output, and integrate them reliably with traditional generating sources [2,3]. Figure 1.1 [4] shows closely the energy supply in Iraq from 1990 until 2019. Iraq does not depend on renewable energy resources in energy supply except for a tiny percentage that almost does not appear in the chart. The maximum energy production depends on oil at first, followed by natural gas and hydroelectric.

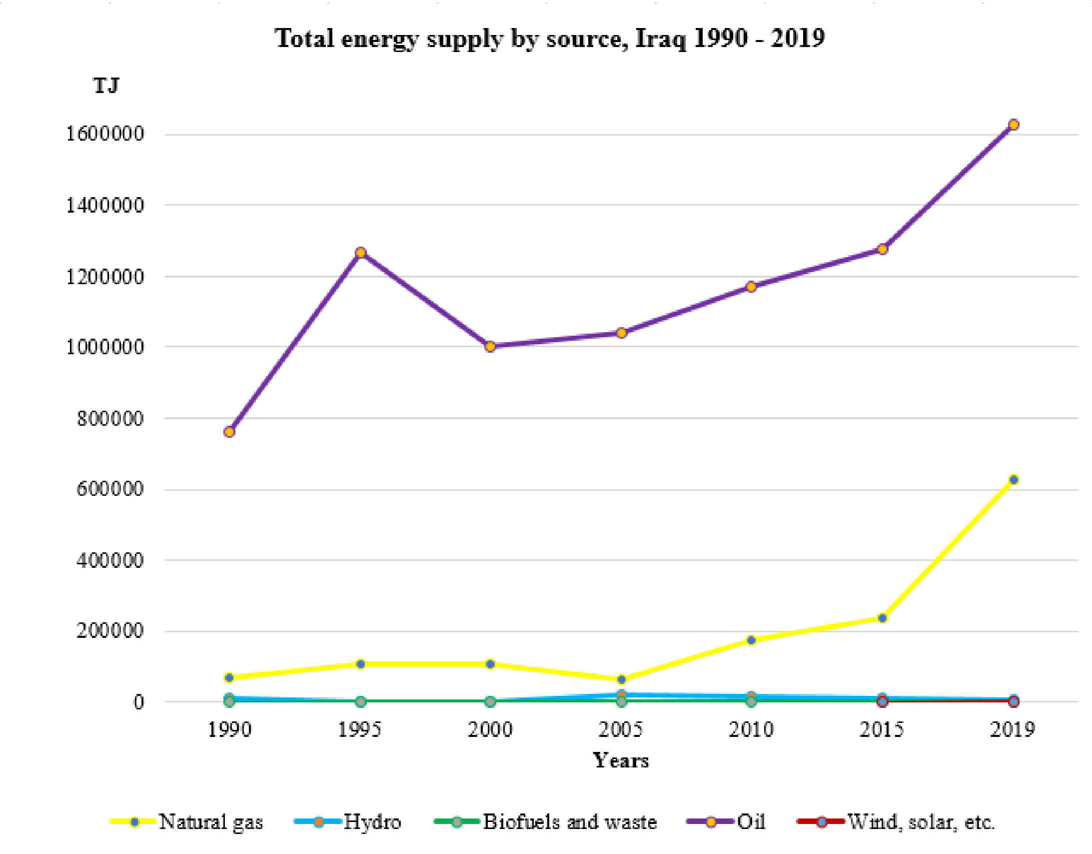


Figure 1.1. Total energy supply by source in Iraq (1990-2019) [4].

Electricity is a requirement to improve the lives of people at every place and anytime, a supporter of economic growth, and it is the heart of development and prosperity. Although the fact that the second producing country of crude oil, is Iraq according to the Organization of Petroleum Exporting Countries (OPEC) and the fifth country in the world in oil reserves, electricity in Iraq has suffered and continues to suffer from severe neglect since the eighties of this century. It needs immediate attention and radical solutions. The electricity problem is a complicated issue and a challenge that the government of Iraq must sternly face because it is one of the essential services in Iraq. In 2011, a poll conducted by the Iraqi Knowledge Network (IKN) showed that electricity in Iraq was a lousy service. The service was assessed as unsatisfactory or the worst by 79% of Iraqi households. Iraq relies on crude oil to revive its economy; crude oil production has grown year by year from 2013 to early 2020. In 2018, Iraq's oil exports amounted to nearly 91%. However, the drop in oil prices led to a reduction in production, the deterioration of the economy of Iraq, and significantly impacted the dilapidated electricity sector. Electricity generation in Iraq depends on oil and natural gas with more than 97% and the rest is from hydroelectric energy. Of course, fossil fuels have adverse effects on the environment [5-8].

Table 1.1 shows the total amount of power needed for each region in Diyala (as an example of one governorate in Iraq), the actual power supply, and the power supply ratio, according to the electricity department of Diyala governorate in Iraq in 2021. The power supply rate is no more than 67% of the energy needed. The total required power for Diyala equals to 1,255 MW, actual power supplied equals to 795 MW, and 63% percentage supply power. This information is from the Republic of Iraq / ministry of electricity / Diyala electricity office.

Table 1.1. The demand and production of electricity in Diyala.

	City	Required Power	Actual Power Supply	Power Supply Ratio
1	Baquba	625MW	380MW	60%
2	Al Khalis	200MW	135MW	67%
3	Al Muqdadia	135MW	85MW	63%
4	Khanaqin	180MW	120MW	67%
5	Bladroze	115MW	75MW	65%

1.1.1. Electricity Problem in Iraq

To address a complex issue like the problem of electricity, it is necessary to know the problem's history and its causes, followed by a description of the current situation regarding power supply, demand, and new developments. Resolving the issue requires a detailed discussion of the aim, difficulties, weaknesses, opportunities, and looking into all of the aspects that help in making an informed decision and the solution will be already proposed [8]. Since 1980, the electric grid in Iraq has deteriorated. During the Gulf War in the early 1990s, a US-led coalition struck Iraq's energy facilities (1990-91). In the aftermath of the war, the rehabilitation of the facilities was severely limited due to the United Nations Security Council's harsh economic sanctions against Iraq. The sanctions continued till 2003. Terrorists keep on targeting the electricity infrastructure all around the country, making it harder to provide service. The problem was exacerbated, and the situation got worse as the electricity was cut off for long hours, between (14-20) hours per day. The need for electricity in Iraq has also increased dramatically over pre-2003 levels, due to the growing population and the import of appliances that lack energy-saving considerations. This scenario has been exacerbated by irresponsible usage by some Iraqis who regard energy as a right that they can get at a cheap or free cost. Also, there are problems related to power stations and their deterioration, and others related to fuel depletion, neglecting renewable energy resources, and issues related to the concept of rationalizing consumption and electricity tariffs. As a result, the government has limited political leeway to raise rates to decrease or eliminate wasteful and needless energy use. So, we understand from all this that economic recovery is difficult for a country drained by wars, inept governance, and terrorism unless infrastructure is rebuilt. The electricity sector in Iraq needs quick intervention [7, 9]. Since 2011 until now, even though 98% of households are attached to the national grid, there is no any single governorate that exclusively uses the national grid as a supplier of electricity without relying on personal diesel generators (generators for one house or generators for the whole residential complex), as shown in Figure 1.2

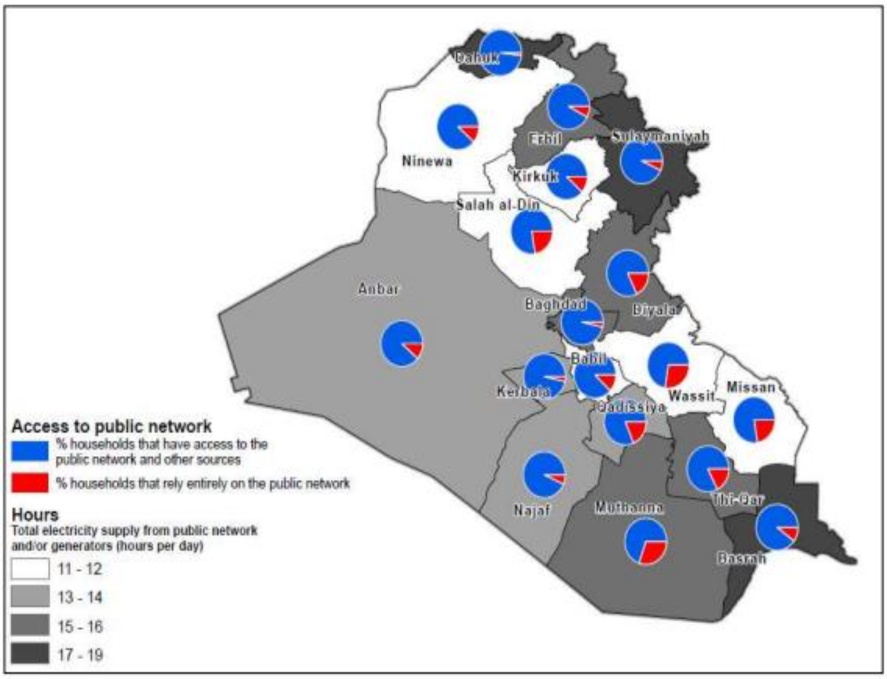


Figure 1.2. Customer's access to the public network by provinces of Iraq [8].

Iraq started importing electricity from neighboring countries and according to 2018 statistics, Iraq imported about 1,300 MW of power from Iran, also, Turkey supplied Iraq with 100 MW of electricity, in addition, there were some plans to import 3,000 MW from Saudi Arabia. In 2019, approximately 23% of the electricity in Iraq was produced from Iran's natural gas, and at the same time, Iran was providing electricity to Iraq of a percentage of 5% of its needs which affected the Iraqi economy significantly, so, Iraq imported over 80% of Iran's electric power exports. Some expectations show a rapid increase in demand for electricity by 4 times during the coming years, and the maximum demand will be in 2035 [9]. Figure 1.3 shows the annual electricity imports of Iraq during 1980-2020. This massive import put Iraq in a difficult position to pay off the accumulated debts. The year 2020 has brought new issues to Iraq's electrical situation, including political turmoil, a drop in oil prices, and the Covid-19 epidemic that Iraq reported its first symptom on February 21, 2020. After five months, the total number of cases documented is 129,000 with about 100 deaths every day. Iraqi economic progress ambitions have been harmed by the crisis. As a result of the better-trained foreign maintenance staff returning home due to the pandemic, technical problems at the power plants have not been addressed. Most Iraqis now have power for 12 hours per day [10].

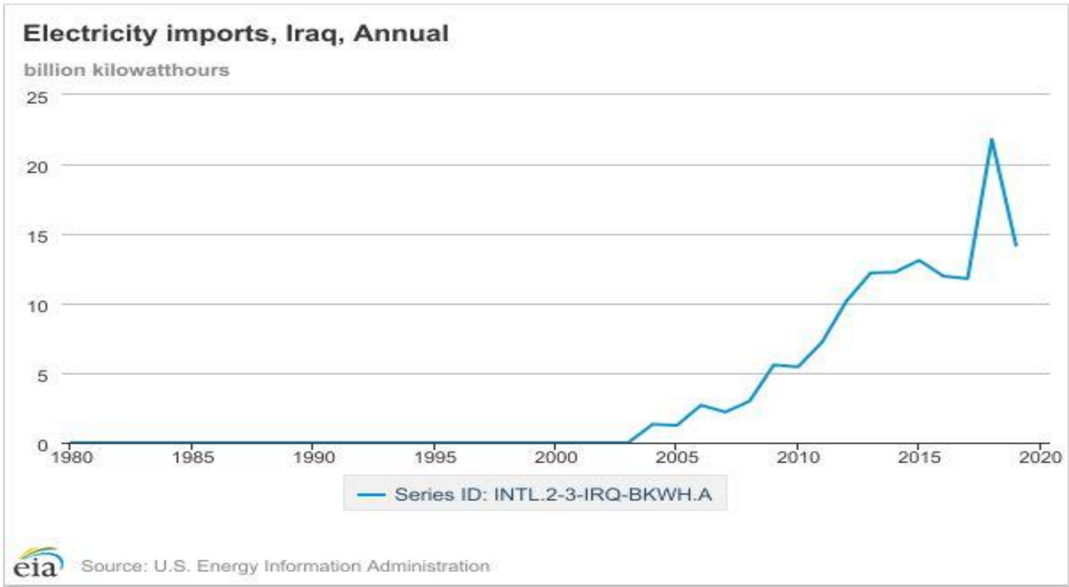


Figure 1.3. Annual electricity imports of Iraq.[11]

This part of the thesis was written on the night of December 13, 2021, with a power outage that lasted for 12 hours. At that time, the charging of laptops, mobiles, and some other household appliances and devices depended on the neighborhood's diesel generator. In light of the worsening crisis of electricity shortage, reduced hours of supply electricity for the population, and the severe heatwave in Iraq, the private and neighborhood generators that provide current to homes become an additional financial burden that weighs on Iraqis more and more. Monthly subscription prices for these generators, determined according to the number of Amperes, reach in the summer at an average rate of about 50 dollars and significantly more. The fewer hours of electricity provided by the grid, the more hours operated by the generators. Every Iraqi home needs at least 4-5 amperes of electrical generators to perform some necessary household chores, to turn on some electrical appliances such as refrigerators and televisions, without the ability to operate modern air conditioners, water heaters, dishwashers, and clothes washers that require a large number of amperes, which means in the event of a subscription with ten or twenty amps, the cost will rise to hundreds of dollars per month, that the majority of Iraqi citizens are unable to pay [12].

The phenomenon of large electric generators is widespread in various Iraqi cities and towns with their loud noises and dark smoke. Sometimes there is more than one generator in a residential neighborhood, the randomly extended electrical wires from generators cause imminent danger and appearance that distorts the environment, as shown in Figure 1.4.

Figure 1.4. The neighborhood's diesel generators and wires.

1.2. PROBLEM MOTIVATION

Energy production for the population of Iraq is one of the most pressing issues. In Iraq, electric generation based on fossil fuels leads to exhaustion of fossil fuels and has negative environmental consequences. Electric power does not meet the demand for various reasons, lack of fuel required for power plants due to ongoing wars, including the collapse of transmission lines due to the saboteurs' bombing, administrative corruption, and a lack of maintenance work. It is self-evident that rehabilitating the grid and extending the transmission line in those places will be prohibitively expensive, it will also take time [3]. All of that makes Iraq far from generating adequate electrical power. There is a significant generating power deficit, as the operating period is not more than half a day, notably in January and July. As a result, Iraqis must pay additional electricity fees for private diesel generators in the neighborhood to compensate for the lack of electricity for the rest of the day. A hybrid system that consists of renewable energy resources was found as the best system that provides an urgent alternative, especially that Iraq has very good potential in the field of renewable energy like solar radiation, as the average solar radiation in Iraq is roughly equal to what is found in North Africa, and also wind speed is high, particularly in the highest Mountains [13,14]. There are little few scientific studies and research linked to HRESs in Iraq. Therefore, this thesis will be a real contribution because there has not been similar work for the three selected sites (Altun Kupri-Khanaqin-Fallujah). Also, there is no design that contains all the components that we have proposed in this thesis. Most studies either ignore the existence of the national network or assume that it provides the load with a high capacity (999,999 kW), and this does not exist in reality in Iraq. In this thesis, 200 kW was determined as the national grid's purchasing capacity, and the remaining demand was covered by the usage of the suggested system which depends on hybrid energy.

1.3. RESEARCH OBJECTIVES OF THE THESIS

The objectives of this thesis are:

- To design a hybrid renewable energy system, consist of PV panel, wind turbine, diesel generator, and battery to eliminate the lack of electricity supply with the lowest cost.
- Techno-economic and environmental analyzing and comparison of hybrid renewable energy system for three regions of Iraq.
- To execute the optimization for integrating hybrid energy systems to the grid in three regions of Iraq using HOMER Pro program.

1.4. THESIS LAYOUT

The thesis is split into six parts. The first part presents the introduction, that includes an overview, and provides information on the potential renewable energy resources in

Iraq, problem identification and motivation of the study, research aim, methodology, and thesis layout.

Part 2**:** Includes a literature review of related works. This literature review is based on an optimization approach by using HOMER program in different countries. It also provides information on the different types of energy resources. Other data regarding the hybrid system and its components have been included, such as information about photovoltaic system, wind energy, converter, diesel generator, and battery.

Part 3: The available estimates of solar radiation, wind speed and temperature for three specific places in Iraq were examined and analyzed in this section. Data analysis of solar and wind energy resources was included in specific locations that are Altun Kupri, Khanaqin and Fallujah.

Part 4: Covers the suggested load profile of the selected cities, also the components employed in the proposed hybrid energy system.

Part 5: Focuses on the proposed hybrid energy system, including a comparative study among the six lowest cost systems proposed by HOMER software with their features and results, as well as financial analysis, evaluation and environmental impacts [15].

Part 6: This is the final chapter that wraps up the previous work and explains the research, and illustrates the conclusion and recommendations. This section examines the data from parts 3 and 4 to emphasize the shortcomings and contributions of the suggested approach. It also summarizes the findings of the thesis, conclusions, and suggestions.

PART 2

THE HYBRID SYSTEM

2.1. LITERATURE REVIEW

Scientific studies and research on energy generation from renewable and non-polluting sources have increased, several studies have addressed solar energy and wind energy, combined with the economic aspect, sustainable development, and climate conservation. To help facilitate the researcher's task, HOMER program is used for design purposes, calculating the cost and efficiency and giving several options to improve the system's work in addition to several data and tables. Through the literature review, it was noticed that there are few scientific studies and research linked to HRESs in Iraq. Therefore, this thesis will be unique and will be a real contribution because there is no similar work for the three selected sites (Altun Kupri, Khanaqin, and Fallujah). Also, there is no design in the literature review that contains all the components that we proposed in this thesis. Most studies either ignore the existence of the national network or assume that it provides the load with a high capacity (999,999 kW), and this does not exist in reality. The literature review will be related to articles published in multiple countries using HOMER Pro software.

The report [16] was to assess the technological, environmental, and economic sides viability for six hybrid scenarios for five isolated locations in Chad and identify the best optimum solution for four types of household (medium village, large village, a small town, and a large municipality) in rural areas of Chad. The primary goal of this effort depends on the multi-criteria analysis approach. The following criteria are used to compare these scenarios: net present cost (NPC), low cost of energy (LCOE), low CO_2 emission rate, and renewable energy penetration rate. The project began by determining the energy requirements of households in Chad's rural areas. The electrical demand required to supply the communities was then estimated. Finally, the most acceptable technical-economic option for electricity architecture is picked for each district. Finally, they concluded that the government should fund fuel prices to encourage the adoption of plentiful renewable energy options.

According to reference [17], three on-grid scenarios were suggested for Zerbattiya (a remote region in Iraq) by using HOMER program. The problem of this region was that supplying electricity from the grid does not exceed 75% of the electrical demand, where the need for electricity increases at a rate of 1% every year. The authors say that the least expensive and most suitable system that is connected to the grid, consists of wind turbines and batteries. The result appeared that the cheaper scenario has 61 wind turbines, 12 converters, and 4 batteries with COE equal to 0.0349 $/kWh.

The study [18] provided the technological, and economic analysis of the viability of a multi-source system for serving a stand-alone household load in eight Moroccan towns. This study is the first research to include places in Morocco with varying climatic conditions by using HOMER software. According to the simulation findings, the system of PV / battery is the best in term of economic. In Morocco, a system that has PV and battery is the cheapest way to provide the power because the sun of Morocco is shining for a long time, and low wind speed is not enough to support wind turbines. In addition, employing a hybrid system reduces the number of batteries necessary, that particularly beneficial for environmental protection. Also, the Pearson correlation based on the Statistical Package for the Social Sciences (SPSS) software was utilized to see the relation between the proposed system’s costs and the amount of solar radiation for every location. It was indicated that the price of the system is being affected by the standard deviation and level of solar radiation, and the cities with the lowest NPC had the most significant solar radiation average values and the shortest solar radiation standard deviation.

The work of [19] simulated a hybrid power system for most urban structures, a wind turbine was attached to a grid-connected building, and two scenarios were represented (with sellback and without sellback price). A hybrid optimization model by using HOMER was investigated in the comparison study, and the optimum design layout for renewable energy resources was analyzed by using HOMER software. The study found that a proposed system with a sellback property was the best which consisting of PV, wind turbine, battery, and the grid, also, it is producing 61.6 kW per year. The reasoning was formed with the case study resulting from the practical data sheets of a building in Iraq. The report recommends activating the sellback ability with hybrid systems for critical economics.

The paper of [20] dealt with off-grid and with on-grid systems for evaluation and optimization study by HOMER program. In Duhok /Iraq, the simulation showed the hybrid system, which is on-grid, is less expensive than the other system which is off-grid for load profile that is the same with neglecting the sensitivity variables. In addition, the proposed hybrid system that connected to the grid had a lower cost than the national grid, as the proposed system cost was (0.0618 $/kWh) while the national grid unit was (0.1 $/kWh).

The report of [21] suggested a hybrid system that has PV and wind turbines connected to the grid in Colombia by using HOMER. Three steps were taken, the first one was finding that Nazareth, Rancho Grande, and Puerto Bolivar were the best sites in terms of longitude and latitude. The second step paid attention to the economic aspect, prices, and taxes. This step showed that Rancho Grande was the best location. The third step paid attention to Rancho Grande to choose the best installation of PV and wind turbines. The simulation result showed that the best system consists of 441 PV panels, 3 wind turbines, and NPC of 11.8 M dollars.

The article [22] provided the technological, economic analysis of the viability of photovoltaic systems during outage grid periods for a household in Baghdad by using HOMER pro with five control strategies. The results showed that when the batteries were allowed to be charged from the grid, the system will be less expensive. When the batteries were not allowed to be charged from the grid, the system will have a high renewable fraction and lower emissions. When a diesel generator was added, the system emission increased and the cost went less.

According to reference [23], four hybrid renewable energy systems were designed in Rwanda. The result appeared that a PV/ hydro/ battery off-grid system was the optimal choice.

The research of [24] developed a structure for a solar power state on-grid based on HOMER software and management of home energy system appropriate for Bangladeshi conditions. This research introduces measuring, the entire thermal designing, and simplifying of six separate PV frameworks with certain cost calculations for Bangladesh.

The article [25] dealt with the feasibility study of an independent system which relies on energy resources that are renewable. That system was applied to a small school in Al-Nasyria, Iraq, and compared between an off-grid system and an on-grid system with a diesel generator by using HOMER pro.

The report of [26] designed a system which is hybrid that has PV panels, wind turbines, and a converter with a grid connection for Seashore of Baluchistan to reduce the fee that must be paid for the electricity coming from the grid. The authors analyzed four cases and evaluated the energy generated, NPC, emissions, COE, electrical production, and consumption by HOMER software. The result showed a reduction of 64% of emissions with (66,405 M$/year) operation cost.

The article of [27] offered an on-grid PV system for a customer of Al-Najaf in Iraq. HOMER software was used to examine the system-designed features in terms of cost and emissions. The solar data in HOMER were replaced with data from NASA databases that are related to solar energy and surface meteorology. Renewable energy resources provide 41% of the total power supply, while the grid accounts for 59%. Finally, grid electricity suppliers will sell excess power as feed and tariff.

The study in thesis [3] focused on renewable energy in Turkey, especially solar energy and wind energy. The author chose Urla/Izmir and Cubuk/Ankara to evaluate the suggested system that contains PV solar panels, wind turbines, converter, battery, and diesel generator for providing the requested electricity. HOMER was used for the simulation and the optimization. The author concluded that Urla, which is in Izmir, is better than Cubuk that is in Ankara regarding availability of solar rays and speed of wind, so the proposed system will be more effective in Urla and its result will be better than Cubuk. HOMER suggested two-hybrid systems and the first system has the lowest cost.

The work [28] employed the weather conditions data (temperature, relative humidity, solar irradiation, and wind speed) for Baghdad to know the optimum renewable system of solar-powered lighting in the university of technology. HOMER results showed the PV system's usage was the cheapest in Baghdad, the initial cost was up to 23,200 dollars, operating costs are 284 $/year, 20 batteries, and a converter of 4 kW.

The article of [29] designed a hybrid system that has PV panels, diesel generators, and wind turbines in rural areas in Muqdadiyah, Diyala, Iraq by using HOMER pro. Simulation results found that solar and wind power might potentially replace traditional energy sources and would be a practical alternative for generating electricity in remote regions. The result was PV panels of 8 kW, a diesel generator of 20 kW, 48 batteries, and a convertor of 16 kW. If the wind speed in the region is at a low level, it is not economically feasible to generate power using a wind turbine.

Depending on HOMER, the paper of [30] completed a comparative life cost analysis on two stand-alone systems, proposed renewable power supply signal lights at an unprotected crossing in the UK. As a result, the suggested system was lower costs after 20 years, maintenance cost less than the nonrenewable system at risk crossings, and from a theoretical standpoint, it was capable of delivering electricity to the signal protection. It has been demonstrated that it does not enhance the danger already present at the crossing and delivers an overall advantage throughout its lifetime.

The study of [31] suggested a battery electricity storage system stores electricity from renewable energy resources to be served for the demand. The study also evaluated and compared technologies of battery in terms of the economy by using HOMER pro. A PV / on-grid system simulation was created, in Jordan, that has different types and variable sizes of batteries to know their impact on the energy's cost, and also, determine the required lower price for each kWh.

The authors in reference [32] suggested a good economic way to integrate a solar-wind system with a diesel station that exists in Taxila, Pakistan, which is connected to the grid, when there is no energy from the grid, the diesel station works as a standby source for generating electricity. Three scenarios were studied, the first one was depending on the diesel station when load-shedding hours. The second one was using a HRES with a grid connection. The third one was the system that depends on a HRES only without a grid. All these scenarios were implemented by HOMER. This paper was characterized by dealing with the periods of load-shedding. The authors concluded that the third scenario could not supply the large load demand.

The article of [13] proposed two hybrid energy systems, a stand-alone system and on-grid system in a small town, Balad Rus, Diyala, Iraq, to find the best combination among energy sources. The author saw that the result of optimization of a dependent system is better in terms of economics in comparison with a grid system by using HOMER software.

The paper of [33] studied three scenarios in Mosul, Iraq by using HOMER software, the first system was an off-grid system, and the second system was on-grid. The third system was through replacing water heating systems with solar water heaters. The results of the simulation indicate that the first scenario was an expensive system, the second scenario was low cost but it must have a large area for PV panels, and the third scenario is the best system.

2.2. ENERGY RESOURCES

Energy is a necessary component of our daily lives. If there were no energy, no machine would work. There are two methods to generate electrical energy as shown in Figure 2.1[38]. The first one is by using traditional energy sources, often known as nonrenewable energy sources, that include generators which rely on oil, coal, and natural gas. Nuclear energy is another nonrenewable energy source employed in nuclear power plants [3]. Approximately, eighty-five percent of power used in our world comes from them. Wealthy nations rely on nonrenewable energy sources [34]. The second is to use renewable energy resources that can be classified into five kinds: solar, wind, biomass, water (hydro), and geothermal. Presently, there is a growing interest in utilizing renewable resources as scientists are focusing to develop more acceptable technologies to utilize renewable resources for obtaining more energy through increasing and improving their efficiencies. Indeed, there will be lots of vacancies for job seekers like engineers, researchers, and workers [3]. Today, our world needs to focus on those resources to meet the required electricity while conserving them for future generations. Energy is critical to a country's socioeconomic progress and human well-being. It is far easier to save energy than generating it [35]. The classic method of generating energy is based on oil and natural gas combustion and other fossil fuels, which increases pollution emissions in the environment and the greenhouse effect [36,37].

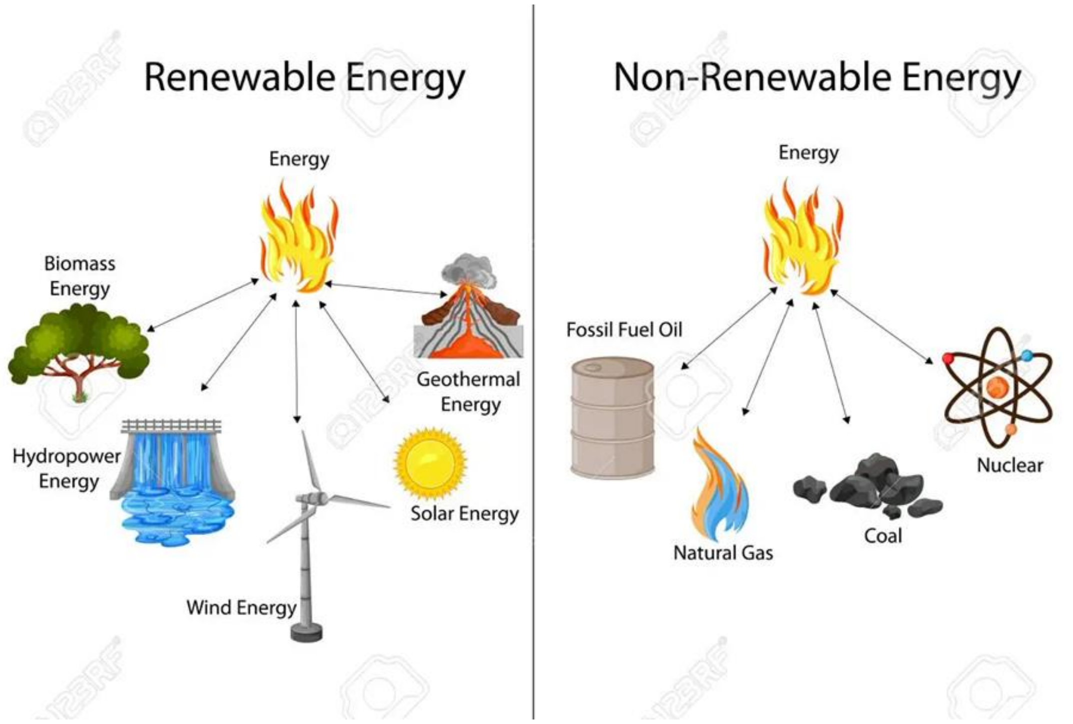


Figure 2.1. The renewable and non-renewable energy.[38]

2.3. THE SOLAR ENERGY

2.3.1. Overview

The traditional method of generating power was based on the combustion of oil and natural gas, which raises polluting emissions in the environment and the greenhouse effect. Furthermore, a study was done by United Nations Environment Program (UNEP) discovered that more than two billion people around the world are suffering from a serious lack of electrical supplies. Solar energy is an unlimited and sustainable energy resource that is clean, abundant, silent, and beautiful, also, it is environmentally friendly because there are no polluting emissions. The solar energy's amount which reaches the earth's surface is approximately 1.8 × 1011 MW. This amount of energy is more than the present average energy consumption which means the sun produces enough energy to meet the demand of the whole planet [37].

Twenty years ago until now, electrical firms have been devoting their efforts toward renewable energy as the perfect selection for keeping the globe safe and renewed for the benefit of generations. Solar radiation may be changed into different forms that are helpful and practical [3].

Most renewable energy resources derive their energy directly or indirectly from the sun, for instance, energies of wave and wind are obtained in an indirect. When the earth absorbs solar energy, it distributes it over the earth in form of ocean currents and winds. Furthermore, the radiation of solar stimulates water's vaporization from the seas which eventually leads to rain, forming flowing water that can be used for producing energy by the name of hydroelectric energy. Additionally, biofuels are produced because of the photosynthesis process by the help of solar rays [35].

2.3.2. PV System and its Components

Solar energy has been used in different ways. A photovoltaic system (PV) is the best effective method to utilize solar energy that turns the radiation of sun into energy [37]. The photovoltaic system, which employs semiconductor cells, is a well-known technique for generating electrical energy from solar radiation. Nowadays, crystalline silicon is the primary semiconductor material that is used to produce solar cells [3]. PV solar panels made up a relatively modest portion. However, there has been a vast increase in PV solar panel installation, which is probably continuing in the future years.

A PV system contains many components, including a solar panel, that is an important component of the solar system, electrical connections, wires, mechanical connections, mountings, batteries for off-grid and on-grid systems, and converters that transform the solar panels' output which is Direct Current (DC) to Alternating Current (AC). As shown in Figure 2.2, a module is a collection of cells, and the collection of modules will make the arrays and panels. The solar module comprises multiple photovoltaic cells joined in parallel or series. In reality, the arrangement and placement of solar cells within a module is a significant matter to generate electricity [37].

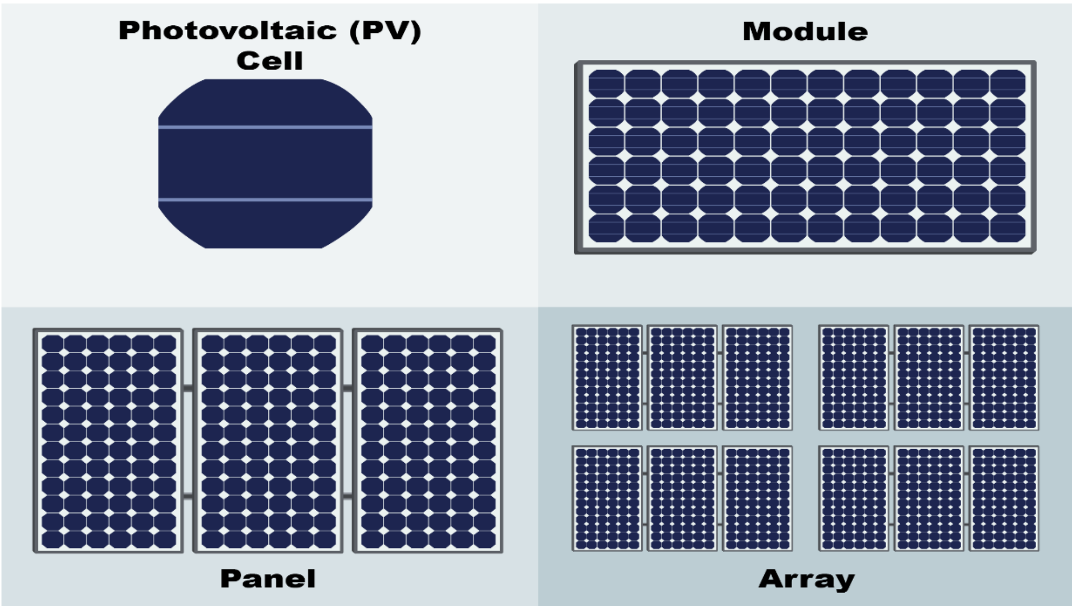


Figure 2.2. The details of a photovoltaic solar panel.[37]

There are many components of PV systems, but essential elements of them are shown in Figure 2.3.

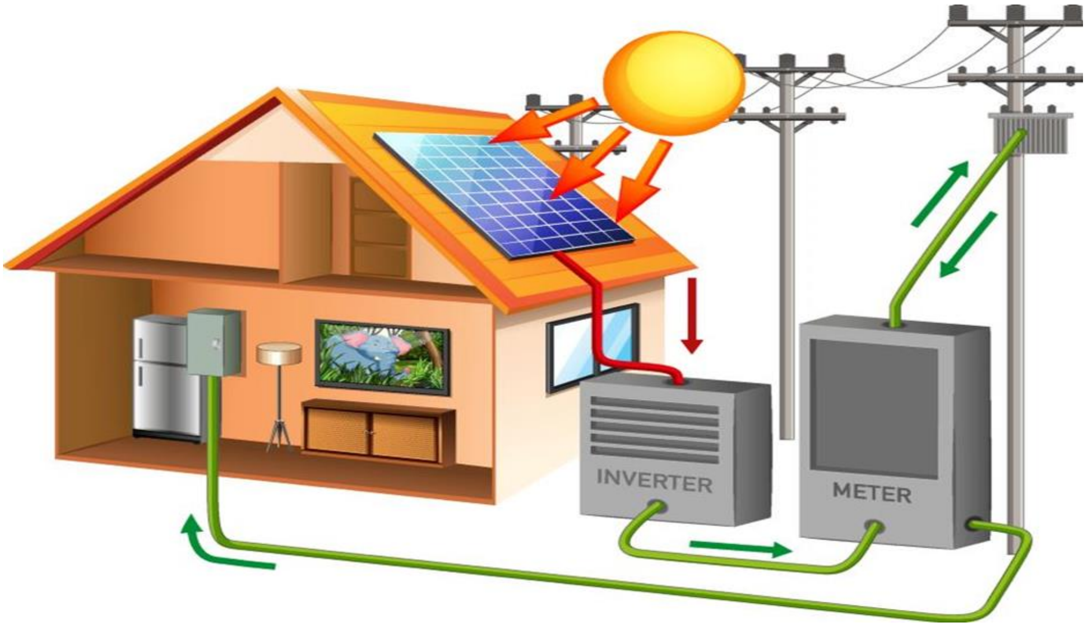


Figure 2.3. The important working components of the PV system.

Photovoltaic panels: are the most expensive component of a PV system. Their positioning and installation have a far impact on operating system performance than any other system component as illustrated in Figure 2.4.

Figure 2.4. Photovoltaic panels.

Converter: Of course, there is a huge need for power converters as the energy produced is various according to the climate condition, and renewable energy like PV panels will be connected to the grid by using converters which convert the DC output to AC to make it suitable to connect to the grid. There are four different types of converter:

- DC to AC, that is utilized for the energy of PV panels,
- AC to AC, that is utilized for the energy of wind turbines
- AC to DC, that is utilized for charging mobiles and laptops.
- DC to DC, that is utilized for making different values for the voltage of DC, [39].

So, the basic electronic converter which is the Buck converter as shown in Figure 2.5 [41], is stepping down the input DC voltage and its output is less DC voltage than the input. It contains semiconductors, a switch, a diode, and an element at least to store energy like a capacitor [40].

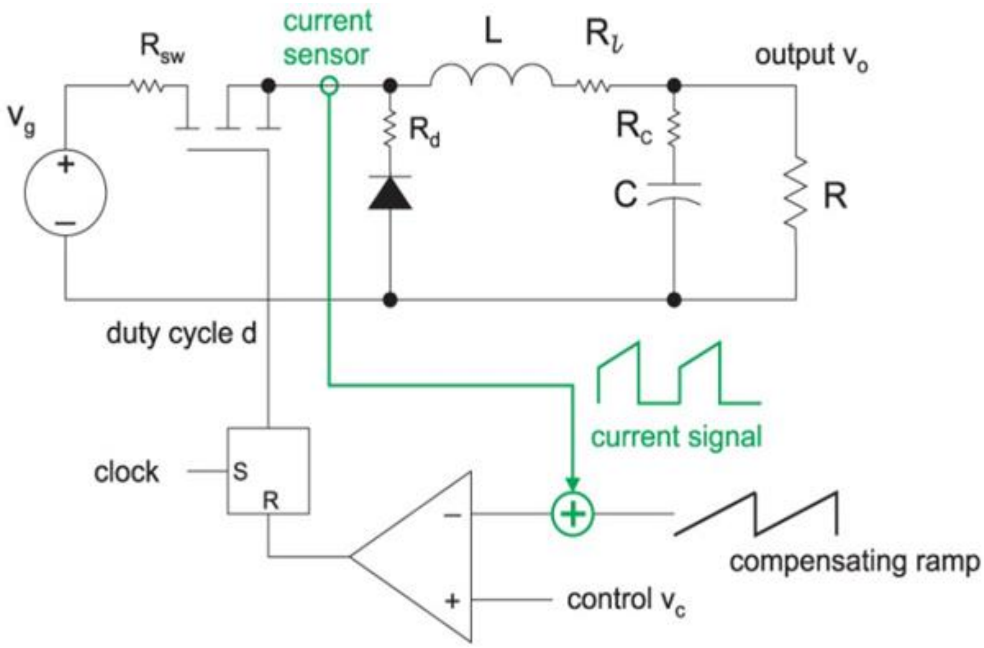
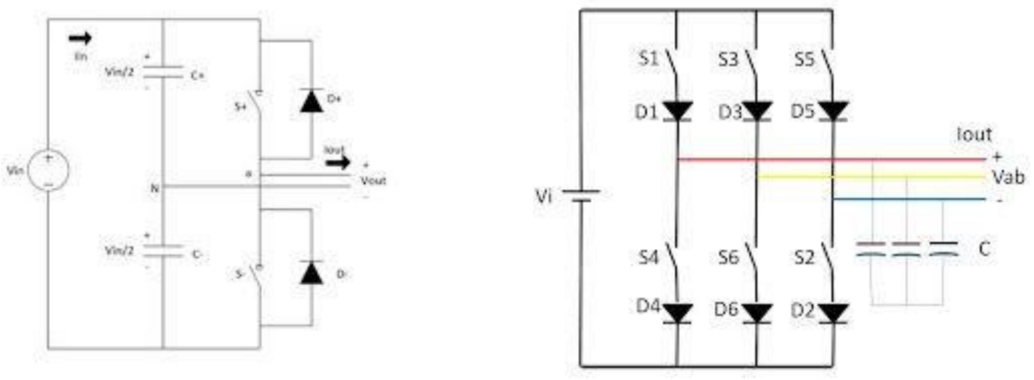


Figure 2.5. Buck converter.[41]

By using two switches, AC voltage will show up and by using some filters, the wave of sinusoidal will be created, the equivalent circuit for single phase and three phase are illustrated in Figure 2.6 [42].



(a) (b)

Figure 2.6. The equivalent circuit for (a)single-phase inverter (b)three-phase inverter [42]

For our case, a DC-to-AC converter is needed and converter types is shown in Figure 2.7. The converter converts high-current signals and low voltage from solar panels to 120 VAC (or 240 VAC), which is immediately consistent with the power plant.

Figure 2.7. Types of converters.

Disconnect switches as shown in Figure 2.8 are crucial at work and must be put within the reach of people [34].

Figure 2.8. Disconnect switches.

2.3.3. Advantages of PV System

- PV systems generate green, clean, environmentally friendly energy because they do not produce harmful emissions during power generation. Solar energy is a natural energy that is free, available and abundant. It is existing everywhere there is sunlight.
- Solar panels have a promising future, as they are very feasible from an economic point of view because their prices are constantly and rapidly decreasing, and it is expected that price decline will continue more and more in the coming years.
- For photovoltaic systems, the operating and maintenance costs are low, compared to wind turbines, because the photovoltaic systems do not contain moving mechanical parts, except in the sun-tracking bases so their breakages are less and require less maintenance when compared with other systems.
- Photovoltaic systems are an effective solution to peak demand because when solar energy is increasing, the efficiency of the panels increases too, and at the same time, the consumer needs more electricity to operate the cooling devices, meaning that by the increase in radiation, demand reaches its peak in the summer months and the panels work perfectly.
- Photovoltaic systems are easy to install.

- Photovoltaic systems are silent that do not emit noise and for that, many people prefer them in different areas.
- Photovoltaic systems are well suited to smart energy networks.
- Photovoltaic systems directly generate power from the sun.

2.3.4. Disadvantages of PV System

- Solar energy, like other renewable energy resources, has some challenges like there is no sun at night and the sky may be overcast or rainy during the day. As a result, photovoltaic systems are less reliable.
- Solar energy panels need more equipment such as inverters that convert DC to AC. PV system also needs batteries to supply energy continuously, especially for off-grid systems, which will lead to increase in the price.
- Although PV panels neither need short period maintenance nor operating prices, they are quickly destroyed.
- Solar panel efficiency is quite low (between 14 and 25 percent).
- Land-mounted Photovoltaic modules need quite large areas. Often, land area is dedicated to this goal for a range of 15-20 years or more [43,44].

2.4. THE WIND ENERGY SYSTEM

2.4.1. Wind Overview

Everything that moves has kinetic energy, and scientists and researchers are harnessing the kinetic energy of the wind to produce electricity. Wind energy is produced via using a wind turbine that is harnessing the energy of wind which pushes its blades, that are attached to the rotor which spins the generator producing power.

Wind energy is a green, inexhaustible, clean, healthy, economical, and abundant energy resource. Every day, wind farms collect the energy of wind and convert it into electricity all over the world. Wind energy is becoming increasingly crucial in keeping our world so wind turbines give us the chance to transform the wind's power to electrical energy by rotating the blades in a clockwise direction. The wind turbine's primary shaft will be able to revolve, which is attached to the gearbox inside the nacelle which converts wind power to electricity and sends it to generator. Then, electricity is routed through a transformer where levels of voltage are adjusted to suit grid requirements [45]. The theoretical wind power Pw which is usually measured in kW is calculated by the formula:

$$P_w = \frac{1}{2} * \rho * A * v^3 \tag{2.1}$$

Here, air's density is ρ and its unit is (kg/m^3), ν represents the velocity of wind and its unit is (m/s), whereas A is the area that in our case will be the rotor area of a wind turbine and given as [37].:

$$A = \pi r^2 \tag{2.2}$$

Where: r – the blade's radius

2.4.2. Wind System and its Components

A wind system consists of a wind turbine installed on the tower for gaining access to greater wind speed. Wind systems require balance-of-system elements in addition to the tower and turbine.

2.4.2.1. Turbines

Most of the tiny wind turbines produced today are horizontal axis, upwind devices with two or three blades. Typically, these blades are composed of a composite material (fibreglass). The framework to which the tail and rotor generator are attached is known as the turbine's frame. The blade's diameter sets the quantity of produced energy. Swept area is defined by the diameter of the rotor. The tail keeps the wind turbine pointed in the direction of the wind.

2.4.2.2. Towers

Tiny wind turbines are placed on top of the tower because the speed of wind increases as the tower rises, and the electricity produced by turbines also rises. For example, when the height of the tower increases from 60 to 100 feet, the electricity generated increases by 25% and the price rises by ten percent of the system's total price [34]. Towers are classified into 2 types: self-supporting (free-position) and supported with wires (guyed). Each tower basic type also has a tilt-down version. Although tilt-down towers are costly, they make maintenance easier. During severe weather, like hurricanes, leaning towers could be lowered toward the ground.

2.4.2.3. Balance of System Components

The components required for a wind system may vary depending on the application. The elements necessary for a water pumping system, for example, will be very different from those required for a residential application. The components needed are vary depending on the system if it is an on-grid, off-grid, or hybrid system. The components for the residential on-grid system may contain some elements as follows [46]:

- Wiring.
- Grounding system.
- An inverter.
- A controller.
- The tower.
- Switch
- Batteries.

2.4.3. Types of Wind Turbine

Wind turbines convert kinetic energy to electric energy. Three major elements influence the amount of energy produced: wind speed, tower height, and swept area which is proportional to the rotor diameter.

There are two types of wind turbine:

1) Horizontal Axis Wind Turbines (HAWT)
2) Vertical Axis Wind Turbines (VAWT).

Their names were determined to correspond to the axis that was employed, either horizontal or vertical. The most famous form utilized today is the HAWT, which includes two, three, or even more blades. The most famous form has three blades. In terms of blade side, VAWT differs from the HAWT as illustrated in Figure 2.9. The turbine's blades are moving from the bottom to the higher side.

The wind turbines, on the other hand, might be installed in one of two locations. In that situation, the name of the wind turbine will be determined by its location, which might be (onshore) or (offshore) as shown in Figure 2.10 (a, b). The onshore wind turbine is installed on land whereas an offshore wind turbine is installed offshore.

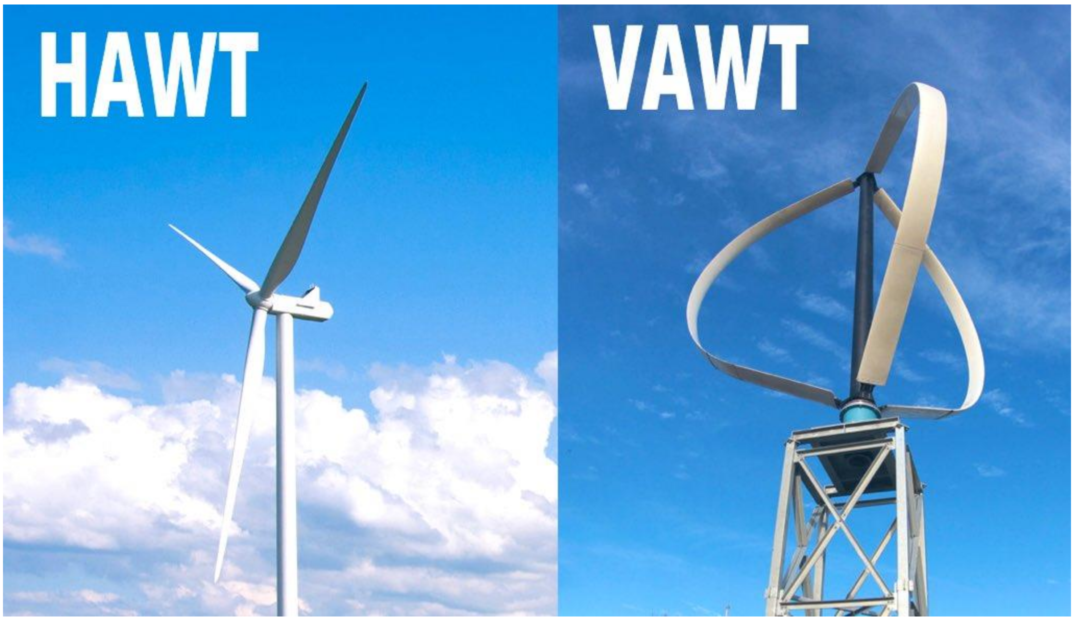


Figure 2.9. Wind turbines: horizontal axis, and vertical axis.

(a) (b)

Figure 2.10. (a) Onshore wind turbine (b) Offshore wind turbine.

2.4.4. Advantages of wind system

- Wind energy is a sustainable and efficient resource of energy, in contrast to fossil fuel supplies, it will never run out. As a result, wind turbines are a viable option for successfully meeting our projected energy demands.
- Using wind energy to create electricity significantly reduces our reliance on fossil fuels. As a result, fossil fuel reserves like coal, oil, and natural gas will last longer.
- Wind energy is relatively cheap. It is one of the inexpensive resources of energy. Electricity from wind farms is sold at a fixed price for a long time (i.e., more than twenty years), without the need of fuel.
- Relatively low upkeep and maintenance. A new generation wind farm can run for many years before it has to be maintained.

2.4.5. Disadvantages of wind system

- Wind turbines hardly run at 30% of their maximum capacity. As a result, if the weather conditions do not cooperate fully with wind turbines, it is doubtful that energy will be produced utilizing the turbines. As a result, for the time being, it will have to rely on the local utility provider. Another significant disadvantage is that when the wind gets too strong or if a storm occurs, wind turbines can be seriously damaged. A lightning strike on wind turbines is the most dangerous and unpleasant situation that may occur during a storm.

- Land-based wind turbines are frequently clustered in rural locations, distant from towns and cities. Transmission lines are important to be built as they transfer the electricity from wind farms to urban areas.
- The turbines occupy an area of land that not only may have a great value but also be more profitable if it is used for purposes other than generating electricity. For example, fertile lands are used for agricultural production rather than investing in electricity generation.
- The level of noise is about 50 to 60 decibels. The quantity of noise emitted by wind turbines has disrupted the lives of many nearby inhabitants. Despite protections in place to keep them away from densely populated regions, they are often built too close to residential areas. As a result, new wind farms usually meet strong public opposition these days. One can also object that these large turbines cause visual pollution and are unsightly. They believe that the magnificence of the surrounding landscape would be destroyed by these colossal entities.
- Wind turbines are commonly mentioned as a possible threat to wildlife, including birds and bats [47].

2.5. HYBRID RENEWABLE ENERGY SYSTEM

The combination of two, three or more renewable resources is called a hybrid system, renewable resources such as photovoltaic panels, wind turbines, biomass, hydropower, etc. to provide heat, electricity, or both. The hybrid energy system, which includes PV panels and wind turbines, is the most often utilized. The high reliability of employing photovoltaic modules in addition to wind turbines is the reason to use them together, and it is impossible to rely on one power source at any time. The hybrid PV / wind power system will be significantly better than using each separately [15]. Solar and wind energy now give a better choice for generating power by combining them. Wind energy has reliability challenges, while solar energy is subject to various weather occurrences, making it unpredictable. Both of these systems cannot provide beneficial results on their own. There are difficulties satisfying energy demands by relying on a single renewable energy resource with climate change [26].

2.6. HOMER Software

HOMER is abbreviation for the Hybrid Optimization Model for Electrical Renewable, Natinal Renewable Energy Laboratory (NREL) in US developed and improved it. HOMER seems to be the most important and popular software to simulate and optimize the hybrid systems that are HRESs because it has many valuable features. It is widely used, easy to utilize and well suited to the implementation of optimization and economic feasibility. HOMER is a short name for the Hybrid Optimization Model for Electrical Renewable. HOMER analyses and simulates multiple system components using input data to find the best technical configuration with the lowest life-cycle cost. The key determinants for ensuring economic metrics of energy systems using HOMER tool are net present cost (NPC), and cost of energy (COE). Electricity’s cost from the grid, capital cost, install cost, maintenance and operating cost, and replacement cost (for all system components during the project lifetime) are included in NPC, which is the system's life-cycle cost. It means the present cost of all components' operating and installing costs over the lifetime of the project, minus the present cost of all gains generated over the lifetime of the project. If electricity is sold to the grid, the total (NPC) decreases [48,49]. HOMER uses and calculates COE and defined it as the average cost for every one kWh of power generated via the system. The total cost of the installed components when the project begins is defined as the initial capital cost [50]. The method to design a hybrid renewable energy system which was used in this thesis depends on the popular Hybrid Optimization Model for Electrical Renewable (HOMER) software which has the features of simulating many possibilities for energy systems to find the best hybrid energy system in order to be approved in real life. By using HOMER program and performing a simulation for the entire system, the hybrid system gives loads of Altun Kupri, Khanaqin, and Fallujah the required energy. The suggested hybrid system in this thesis consists of photovoltaic (PV) modules, wind turbine generators, and other components such as a converter.

PART 3

ANALYSIS OF THE RENEWABLE ENERGY RESOURCES IN IRAQI REGIONS

3.1. A CASE STUDY

Iraq is located in southwest Asia, spanning longitudes 38°45′ and 48°45′ E, and latitudes 29°5′ and 37°22′ N. The highest temperature in January is 16°C whereas in July varies between 48–50°C. The lowest temperature in January is 4°C and in July is 31°C. The country's wind speed is below a medium wind speed which is in December and January at 2.5 m/s, reaching in July 4.1 m/s. Dust storms are exacerbated by northerly winds, especially in spring and fall. The average actual effulgence (shine of the Sun) in June is 11.4 hours per day, whereas it is 6.3 hours per day in January. In October, relative humidity fluctuates from 25 percent to 73.8 percent [51].

Based on the terrain of Iraq, three different regions were chosen as a case study, one in the north of Iraq Altun kupri/ Kirkuk, the other in the east of Iraq Khanaqin/ Diyala, and finally, Fallujah/Anbar, which is approximately in the middle of Iraq as shown in Figure 3.1. Iraq's climate can be classified into two main parts. In contrast, the astronomical position of Iraq and its distance from the seas made its climate characterized by continental, and it is located within the warm tropical region in its southern half and within the cold region in its northern half. The sun's rays are vertical or almost vertical during the summer and tilted or almost slanted during the winter season. The day period during summer is longer than it is in winter, with an increase of 3 hours and 48 minutes. The sky of Iraq is clear and free of clouds, and its air is characterized by low atmospheric humidity, which helps in reaching the largest value of solar radiation directly to the earth’s surface. Most of the ground in Iraq is free of vegetation cover [52]. The northern half of Iraq is similar to the Mediterranean climate, where the temperature is lower and wind speed is high, especially in mountain ranges.

The second half is central and southern Iraq. The area from central Iraq to the outlying area of south Iraq has the same climatic characteristics in all climatic classifications where the temperature is high, and the wind is substantial [53,54]. The usage of solar energy in Iraq is influenced by various variables, including the solar radiation intensity, the solar energy characteristics, and Iraq's geographical location and climate. These three regions (Altun Kupri/Kirkuk, Khanaqin/Diyala, and Fallujah/Anbar) have high solar radiation and wind speed possibilities according to the database of NASA. Despite the availability of renewable energy resources, Iraqi consumers face a continuous electricity outage. The proposed method for energy generation using a hybrid renewable energy system depends on two renewable energy resources - solar radiation and wind speed.

Moreover, solar irradiance and winds are the most interesting and extensively used renewable energy resources on the planet. The energy of Iraq, in particular, is still suffering from a large deficit, and it is experiencing significant issues. Outages continue to be a daily event for most families since the rise in electrical consumption exceeds the expansion of production capacity, particularly during hot months. The gap between peak electricity demand and network maximum power supply has grown [51].

Figure 3.1. The location of Altun Kupri, Khanaqin, and Fallujah in Iraq.

Figure 3.2 shows the average yearly global irradiation in Iraq. The maximum value is shaded in red in the southwest areas that has 2,191 kWh/m^2 solar radiation. Then the radiation intensity gradually decreases as we head north until we reach the far north, which is shaded in green and has solar radiation of 1,753 kWh/m^2 [55].

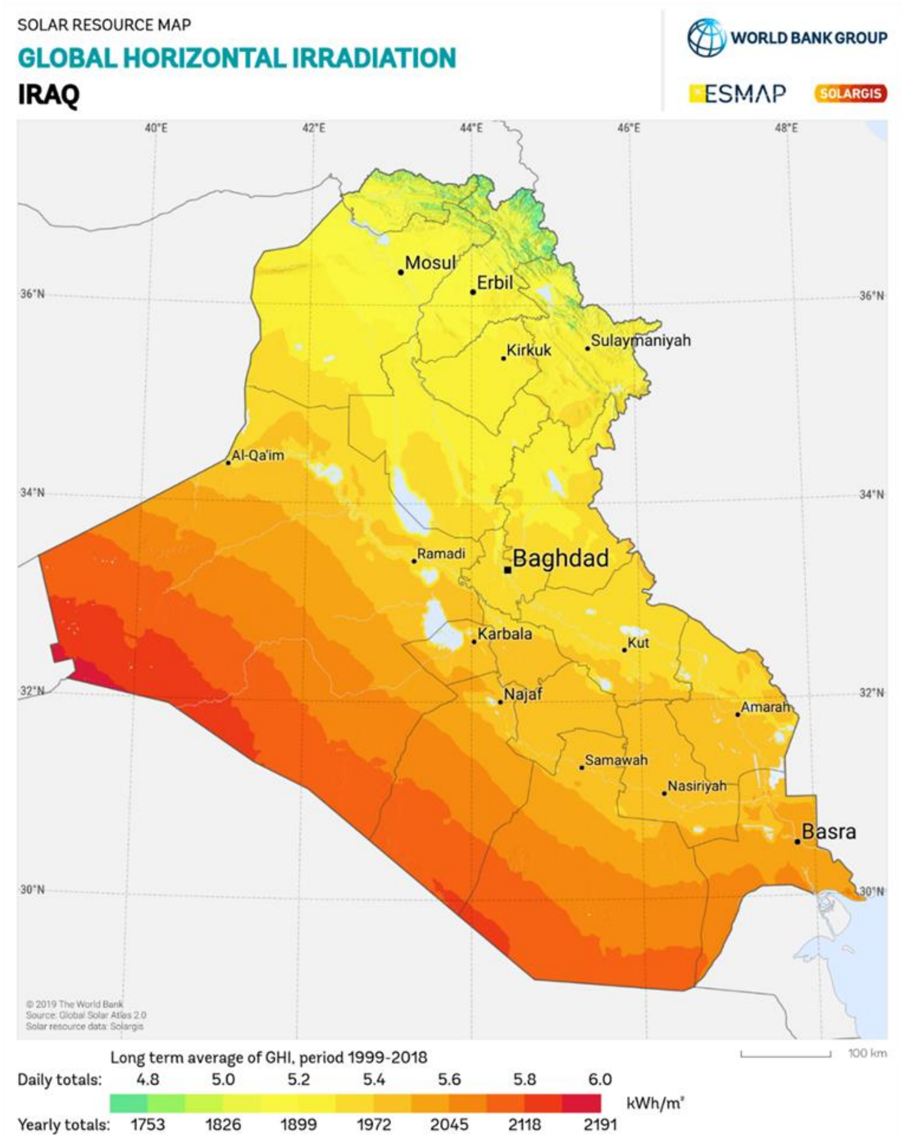


Figure 3.2. The global horizontal irradiation in Iraq.

The map of wind power density in Iraq is displayed in Figure 3.3. The power density of wind refers to the energy's amount that is available for one square meter of one turbine. It can be measured at different heights from the ground. The maximum rates of wind power density are found in the west, east, and middle parts of Iraq, which are shaded in green.

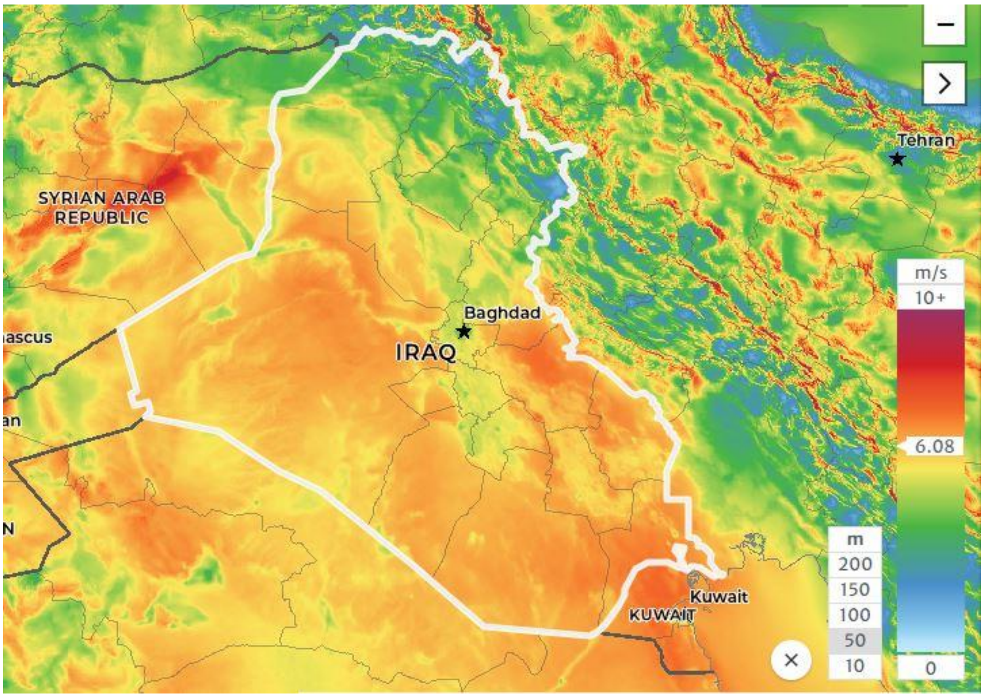


Figure 3.3. Shows a map of potential wind speed in Iraq. Whenever the area's color is close to red, the wind speed is high, and vice versa; whenever the area's color is approached light blue, the wind speed is low [55].

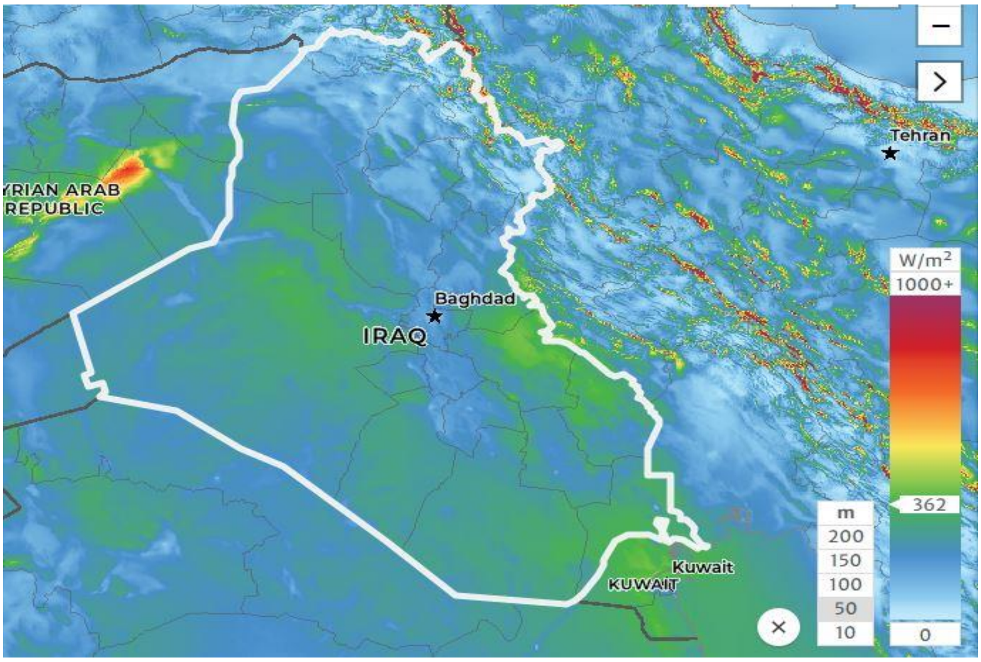


Figure 3.4. Wind power density in Iraq

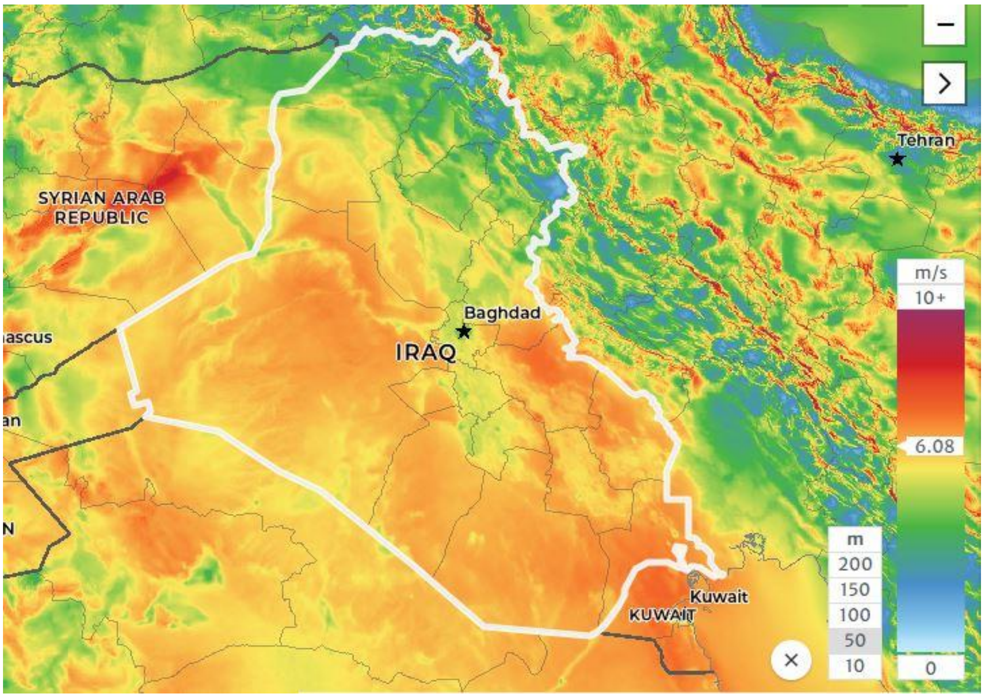


Figure 3.5. Wind speed in Iraq

Three regions, that have high potential of solar radiation and wind speed were selected in Iraq to apply the simulations on. The selected regions have different locations in terms of longitude and latitude, and are not near each other. Also, there are not many research papers and theses that are discussing those areas, so this thesis focused on applying the hybrid renewable energy system in those areas in order to enrich the scientific content in this field.

3.1.1. Altun Kupri / Kirkuk

Altun Kupri is located on the northern side of Iraq, in northwest Kirkuk governorate, with an area of 1,239 km^2. According to statistics in 2013, it has a population of about 9,275 people. It is necessary to note that the last accurate census was in 1997, and each estimate of the population of Iraq is based on the 1997 census, in addition to the estimated growth rate of 3% [56,]. Altun Kupri, like other cities in Iraq, suffers from a weakness in electricity generation.

3.1.2. Khanaqin / Diyala

The location of Khanaqin is on Iraq's east side near Iran's borders, on the northern side of Bagdad, in Diyala governorate with an area of 3,915 km^2. According to statistics in 2015, it has a population of about 21,2069, and the estimated population in 2020 is about 23,9057 [57]. Electricity generation there is almost nonexistent and reliance on importing electricity from Iran, the neighboring country.

3.1.3. Fallujah / Anbar, Iraq

Fallujah is located approximately in the middle of Iraq, roughly 69 kilometers west of Baghdad, in Al Anbar governorate with 4,205 km^2. According to statistics in 2015, it has a population of about 38,3269 people, and the estimated population in 2020 is about 429,560 [58]. In Fallujah, solar radiation and wind speed are high. The capability of solar irradiance and wind speed were evaluated for three places which are Altun Kupri, Khanaqin, and Fallujah. This thesis is unique because no similar study has been conducted on these three sites. Based on the findings of past studies and their data[59,60], and according to data collected from the National Aeronautics and Space Administration database, it shows that the selected regions have high potential solar radiation and wind speed that make them favorable for project work which lead to improve the electrical energy output..A comparison will be made among Altun Kupri, Khanaqin, and Fallujah by using HOMER software which has the advantage of collecting statistics of solar irradiance and wind speed directly from NASA database. For the chosen regions, all data has been obtained from NASA website depending on the longitude and latitude values for the three areas. The specific site in Altun Kupri is highlighted with a marker as indicated in Figure 3.5, where latitude and longitude are (35°45.4′N, 44°8.5′E) successively. The specific site in Khanaqin is highlighted by a marker, as indicated in Figure 3.6. Latitude and longitude are (34°14.5′N, 45°27.3′E) successively. The site in Fallujah is highlighted via a marker as illustrated in Figure 3.7 whereas latitude and longitude are (33°20.7′N, 43°46.9′E), sequentially.

Figure 3.6. The chosen location in Altun Kupri.

Figure 3.7. The chosen location in Khanaqin.

Figure 3.8. The chosen location in Fallujah.

3.2. SOLAR, TEMPERATURE, AND WIND ENERGY ASSESSMENT OF ALTUN KUPRI

HOMER application provides users with database of monthly average of air temperature; the monthly solar irradiance; the monthly clearness index data. The data have been taken based on the website of NASA's prediction of the worldwide energy resource database for the duration from 1/1/2010 to 31/12/2021. The monthly wind speed averages at fifty meters above the earth’s surface for the selected region by online.

3.2.1. Solar energy assessment of Altun Kupri

The monthly solar average values of Global Horizontal Irradiance (GHI) and the clearness index in Altun Kupri are shown in Figures 3.8 and 3.9 respectively. It is clear from Figure 3.8 that the maximum solar radiation occurs in June (8.083 kWh/m^2/day) and July (7.775 kWh/m^2/day) in the summer season. The clearness index represents the purity of the atmosphere layers and its range between 0-1. It means the solar radiation quantity that reaches the earth after traveling through the layers of the atmosphere towards the earth [3]. Figure 3.9 shows the clearness index values with the daily radiation average for all months for 11 years. It has a value between 2.49 and 8.083 (kWh/m^2/day) and an annual average of 5.21 (kWh/m^2/day) for Altun Kupri.

.

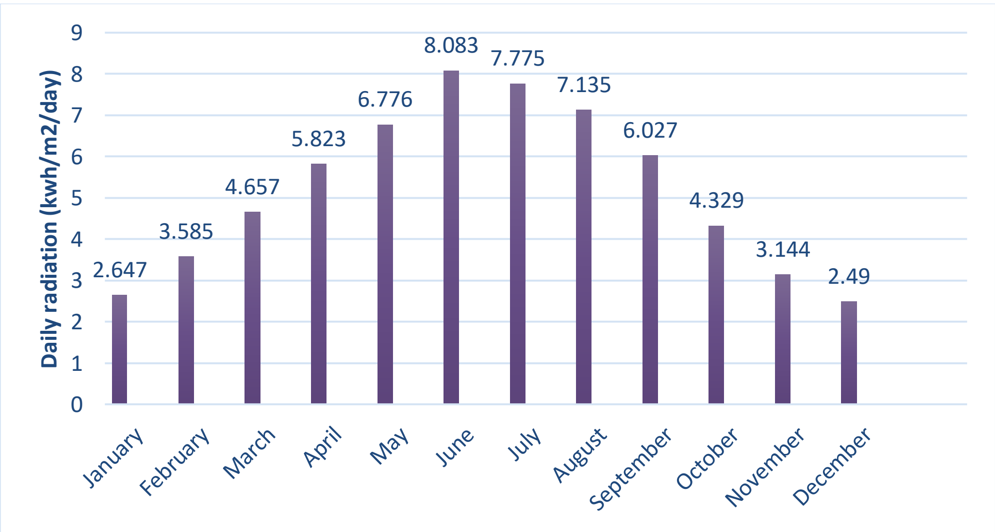


Figure 3.9. Monthly solar radiation in Altun Kupri.

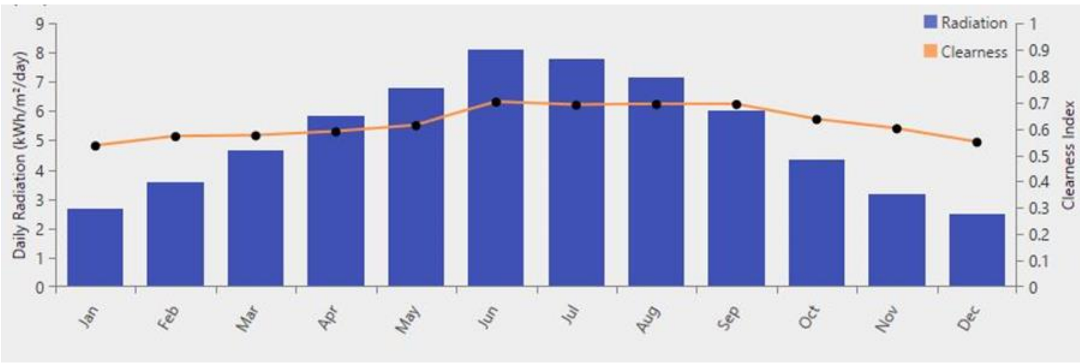


Figure 3.10. Monthly average solar irradiance and clearness index for Altun Kupri.

3.2.2. Temperature assessment of Altun Kupri

Figure 3.10 shows the monthly temperature and the Annual average (°C) which is approximately equal to 19.91°C.

Figure 3.11. Monthly average temperature data in Altun Kupri.

3.2.3. Wind Energy Assessment of Altun Kupri

Figure 3.11 indicates the monthly average values of wind speed in Altun Kupri at a height of 50 meters above the ground. The wind speed annual average value is 4.57 m/s, with wind speed values for Altun Kupri ranging between 4.159 – 5.095 m/s. As it is noticeable, there is no significant difference between wind speeds during the year's months. However, the highest speed of wind occurs in June that has a value of 5.043 m/s, whereas its value in July is 5.095 m/s, and in August equals to 4.983 m/s.

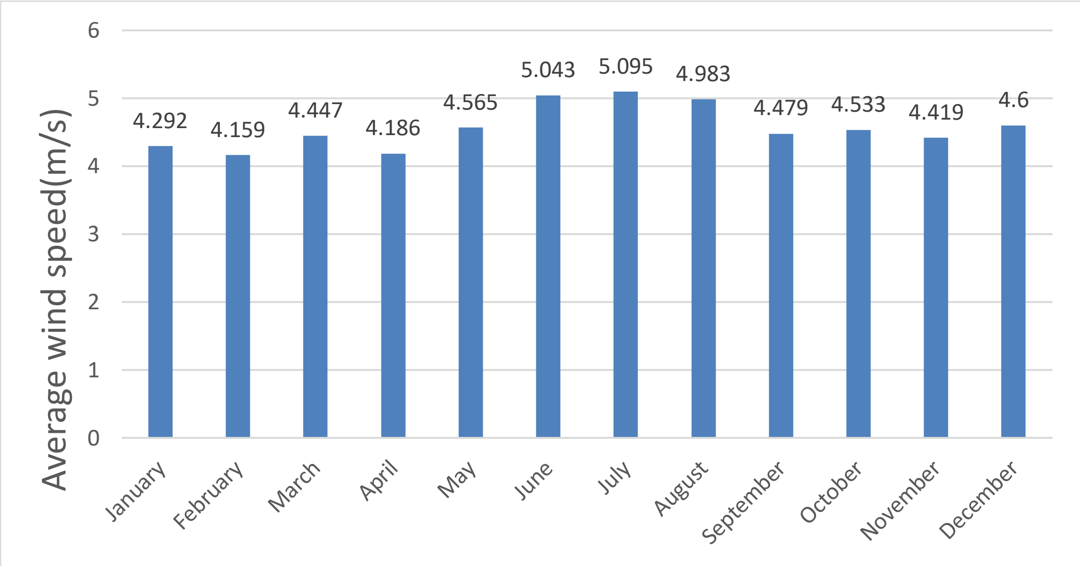


Figure 3.12. The Monthly Average of Wind Speed in Altun Kupri.

3.3. SOLAR, TEMPERATURE, AND WIND ENERGY ASSESSMENT OF KHANAQIN

As we explained earlier about NASA database merit, that is included in HOMER application, it allows users to obtain the data of monthly solar irradiance, monthly clearness index data, wind speed and other data. The data was obtained for the same time duration from 1/1/2010 to 31/12/2020.

3.3.1. Solar and Wind Energy Assessment of Khanaqin

The monthly solar average values of Global Horizontal Irradiance (GHI) and the clearness index in Khanaqin are shown in Figures 3.9 and 3.10. As it is shown in Figure 3.12, the maximum solar radiation is 8.191 kWh/m^2/day that occurs in June, whereas in July, the value approximately equals to 7.857 kWh/m^2/day in the summer season. As we mentioned previously, the clearness index represents the pureness of atmosphere layers. Figure 3.13 shows its value with a daily radiation average for all months for 11 years. The average daily radiation has a value between 2.664 - 8.191 (kWh/m^2/day) and an annual average of 5.36 (kWh/m^2/day) for Khanaqin.

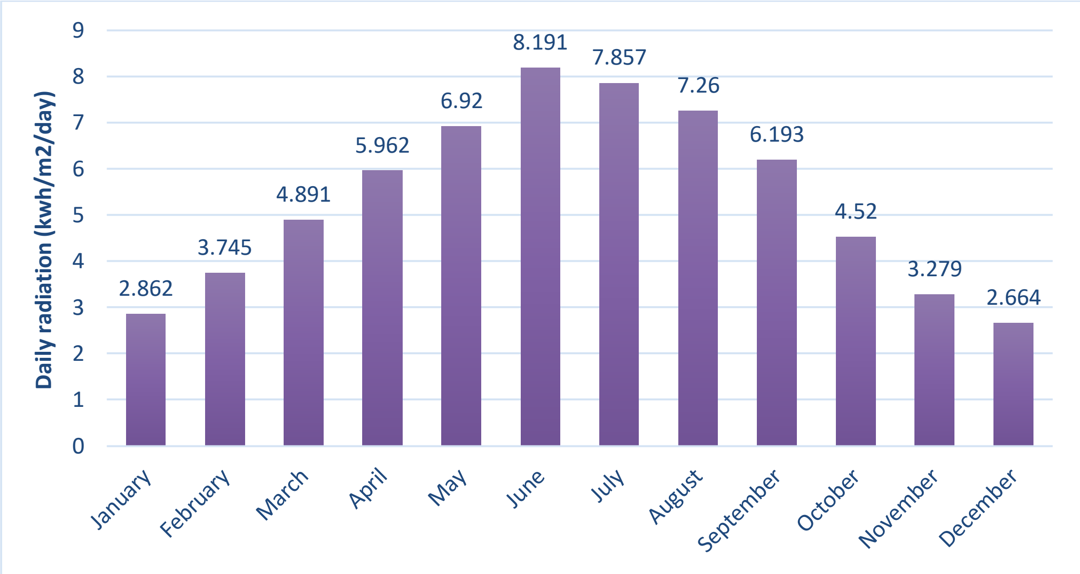


Figure 3.13. Monthly solar radiation in Khanaqin.

Figure 3.14. Monthly average solar irradiance and clearness index for Khanaqin.

3.3.2. Temperature assessment of Khanaqin

Figure 3.14 shows the monthly temperature, with an annual average of 23.29ºC.

Figure 3.15. Monthly average temperature data in Khanaqin.

3.3.3. Wind energy assessment of Khanaqin

The wind speed values of Khanaqin are downloaded from NASA website database for the time duration from 1/1/2010 to 31/12/2020 and it provides average wind speed statistics for each month. Figure 3.15 indicates the value of the monthly average for wind speed in Khanaqin at a height of 50m above the ground. The wind speed annual average is 5.21 m/s, with wind speed values for Khanaqin ranging between 4.42 – 6.389 m/s. As it is noticeable, there is no significant difference between wind speeds during the year's months. However, the highest speed of wind occurs with a value of 6.331 m/s in June and a value of 6.389 m/s in July, whereas in August is 6.058 m/s.

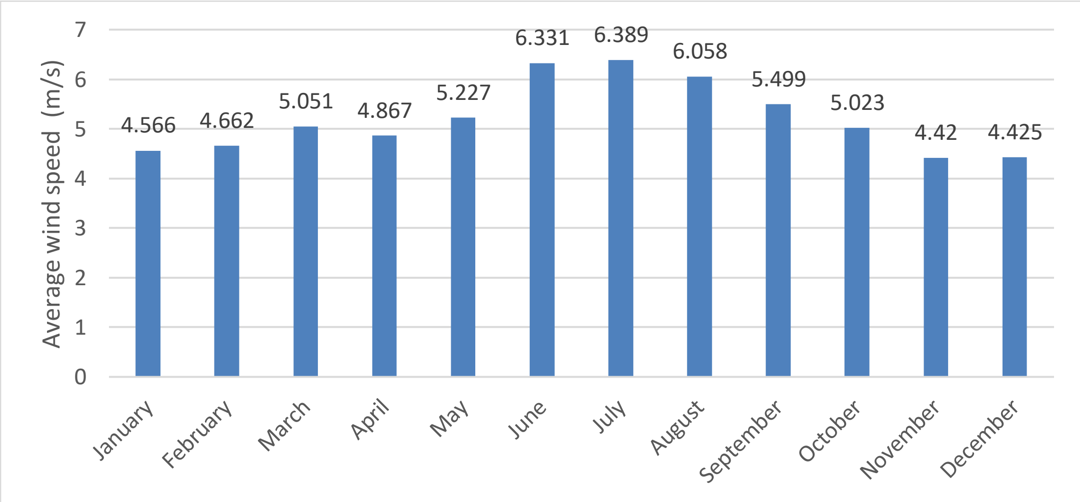


Figure 3.16. Monthly average values of wind speed in Khanaqin.

3.4. SOLAR, TEMPERATURE, AND WIND ENERGY ASSESSMENT OF FALLUJAH

The data is collected based on the website of NASA database for the time duration from 1/1/2010 to 31/12/2020.

3.4.1. Solar Energy Assessment of Fallujah

The monthly solar average values of Global Horizontal Irradiance (GHI) and the clearness index in Fallujah are shown in Figure 3.16 and Figure 3.17, respectively. It is obvious from Figure 3.16 that the maximum solar radiation occurs in June (7.869 kWh/m^2/day) and July (7.59 kWh/m^2/day) in the summer season. Figure 3.17 shows the clearness index values with the daily radiation's average for all months for 11 years. It has a value between 2.845 and 7.869 (kWh/m^2/day) and an annual average of 5.4 (kWh/m^2/day) for Fallujah.

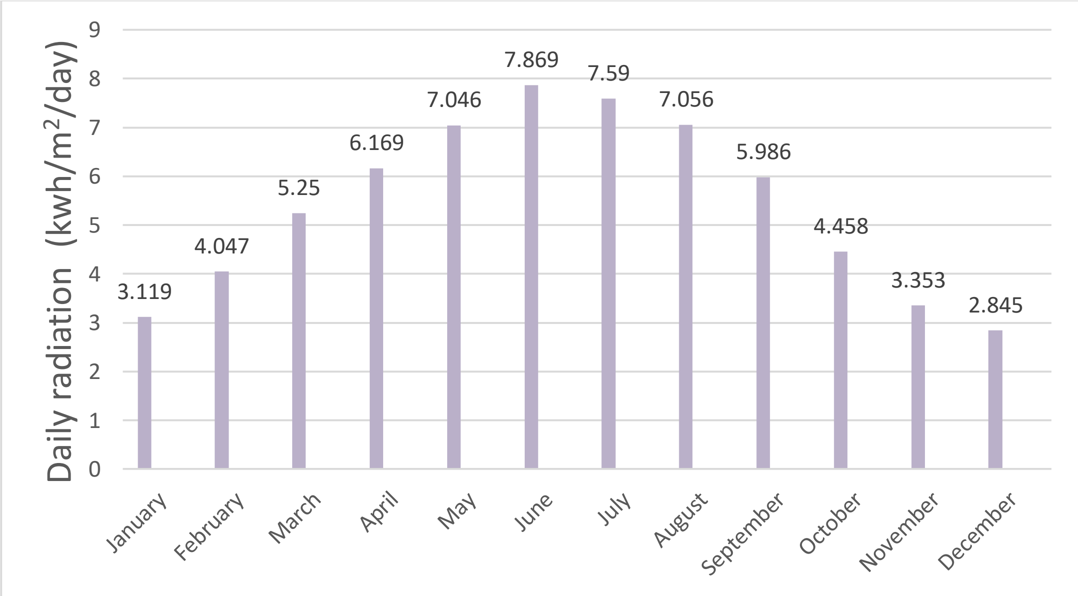


Figure 3.17. Monthly solar radiation in Fallujah.

Figure 3.18. Monthly average solar irradiance and clearness index for Fallujah.

3.4.2. Temperature assessment of Fallujah

Figure 3.18 shows the monthly temperature and annual average equal to 23.63°C.

Figure 3.19. Monthly average temperature data in Fallujah.

3.4.3. Wind Energy Assessment of Fallujah

The wind speed values of Fallujah are downloaded from NASA website for the time duration from 1/1/2010 to 31/12/2020 and it provides average wind speed statistics for each month. Figure 3.19 indicates the value of the monthly average for wind speed in Fallujah at a height of 50m above the ground. The wind speed annual average is 5.58 m/s, with wind speed values for Fallujah ranging between 4.566 – 7.459 m/s. As it is noticeable, there is no significant difference between wind speeds during the year's months. However, the highest speed of the wind occurs with a value of 7.04 m/s in June and a value of 7.459 m/s in July, whereas in August is 6.69 m/s.

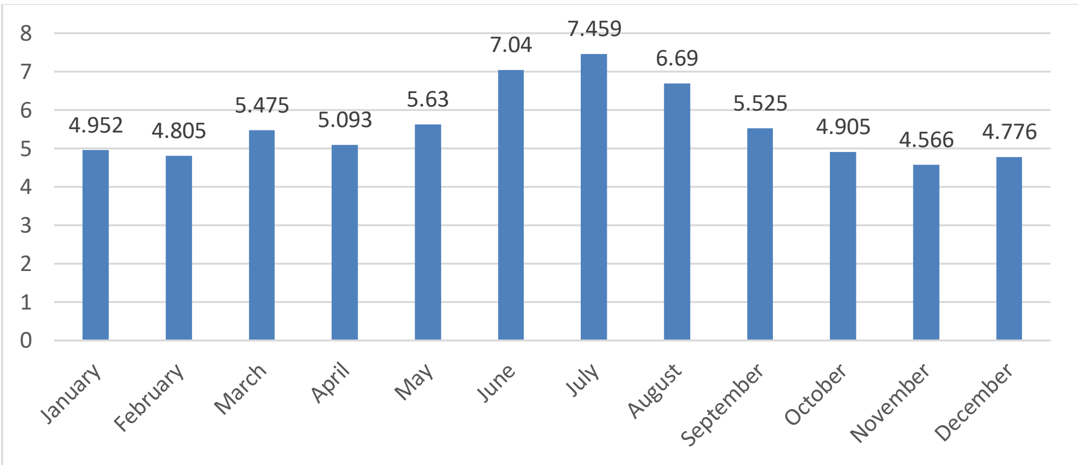


Figure 3.20. The Monthly average wind speed in Fallujah.

PART 4

THE HYBRID SYSTEM'S DESIGN

4.1. LOAD PROFILE

The first step consists of defining the load profile and energy demand of each region. The load profile must be set carefully because the remaining components of the hybrid system will be selected according to the load profile. In this study, the load profile is for residential complexes – Altun Kupri, Khanaqin, and Fallujah in Iraq where approximately 600 people are living in each regine. The need for electrical energy changes during the day, the month, and the year. The load has different values during the day because the electric demand changes depending on the devices and locations requiring electricity at other times. Despite the different values of electricity demand, the monthly peak load was in July. The load profile is measured based on the average working periods of the devices from 00:00 until 23:00 every day in 2021.

4.1.1. Load Profile of Altun Kupri

Figure 4.1 and Figure 4.2 show the daily and seasonal load profiles of Altun Kupri. We note that the increase in consumption of electrical energy was in the evening and at night between (12:00-22:00), and the maximum increase was from 18:00 to 20:00.

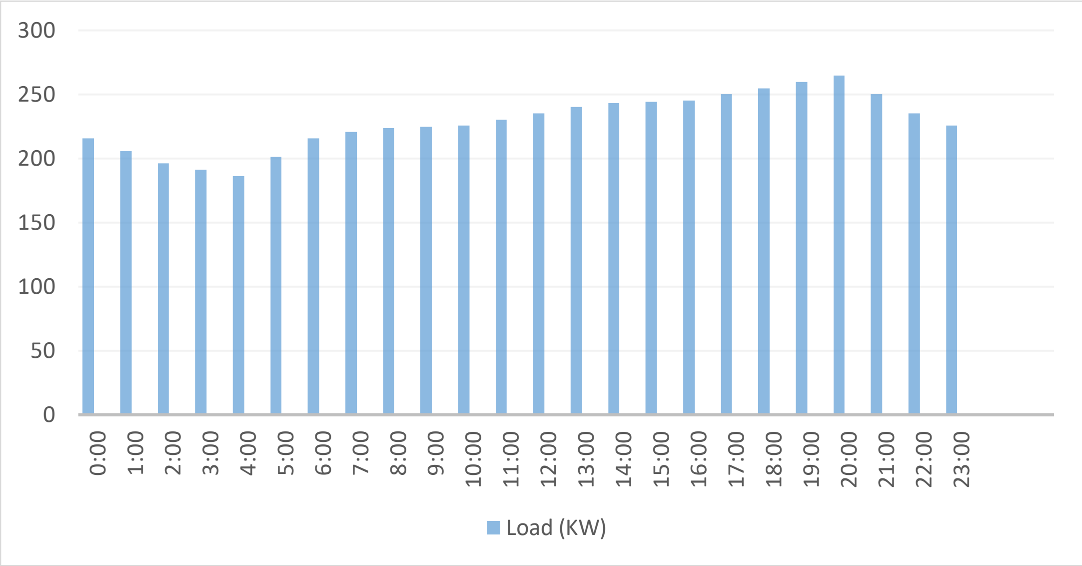


Figure 4.1. The daily load profile for Altun Kupri.

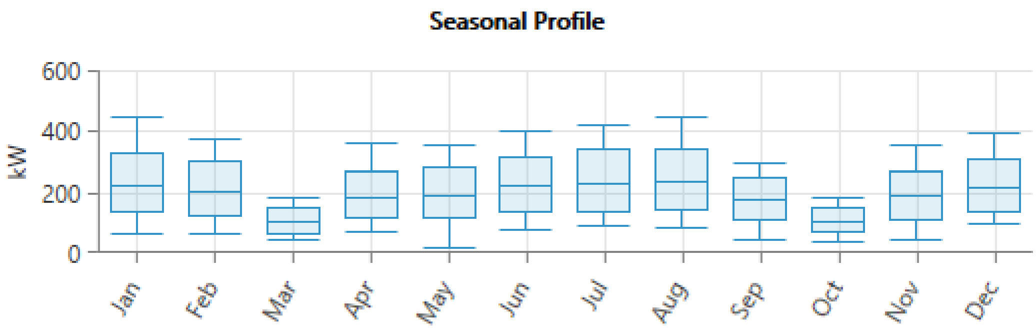


Figure 4.2. Seasonal load profile for Altun Kupri.

4.1.2. Load Profile of Khanaqin

The daily and seasonal load profiles of Khanaqin are presented in Figures 4.3 and 4.4, respectively. The increase in consumption of electrical energy was in the evening and at night between (14:00-21:00), and the maximum increase at (20:00) o'clock.

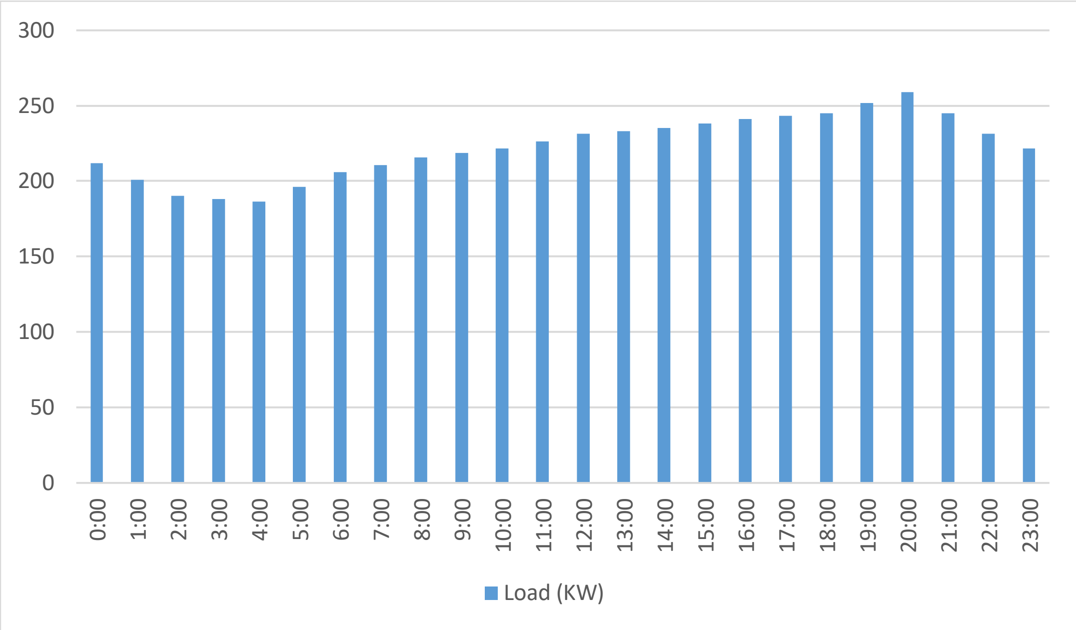


Figure 4.3. The daily load profile for Khanaqin.

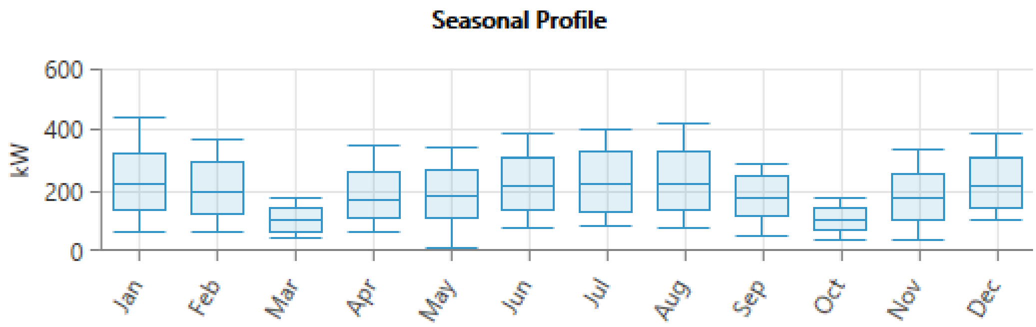


Figure 4.4. Seasonal profile for Khanaqin.

4.1.3. Load Profile of Fallujah

For Fallujah city, Figure 4.5 and Figure 4.6 show the daily and seasonal load profiles, respectively. The increase in consumption of electrical energy was in the evening and at night between (14:00-22:00), and the maximum increase at (20:00) o’clock.

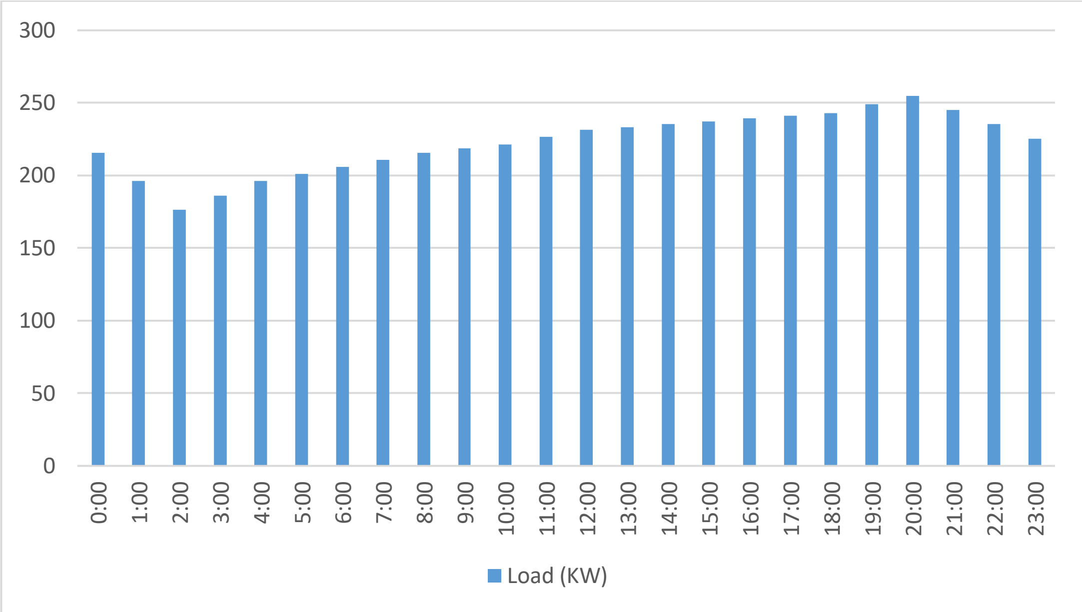


Figure 4.5. The daily load profile for Fallujah.

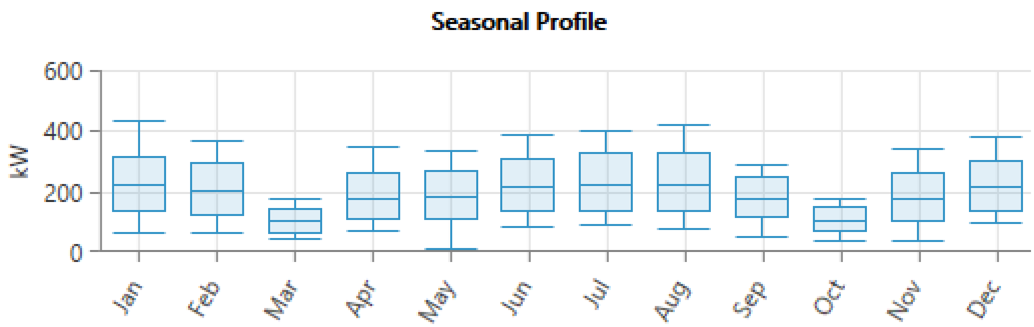


Figure 4.6. Seasonal profile for Fallujah

4.2. COMPONENTS OF THE HYBRID SYSTEM

Determining the appropriate size and construction for a hybrid power system necessitates a thorough understanding of its elements, components, and evolution during the project's lifespan. The easiest method to gain such knowledge is by designing the power plant and testing all feasible combinations. HOMER undertakes the improvement, gives several suggestions, and chooses the best designs in terms of cost [61].

4.2.1. Photovoltaic Panel

Some factors must be considered when selecting the PV panel that will be utilized to achieve the greatest electrical energy output in the given site while also being efficient in the proposed hybrid PV/wind system. Several elements of a PV panel that cannot be overlooked include the PV panel's capacity, its kind (poly-crystalline or mono-crystalline), the PV panel's efficiency, and its lifetime. The proposed PV panel supplies electric power in direct current (DC) with many sizing options. Following the simulation, HOMER software recommended the optimal size of the PV panel to be employed.

LONGI Solar manufactures the chosen PV panel as shown in Figure 4.10. It has the model of LR6-60PB-295M with high efficiency (up to 18.3%), Mono technology, and an advanced 5BB design to improve energy output. Its energy yield is better, excellent performance of low radiation, and temperature coefficient, high power output with less operating temperature, and lower hot spot risk by using an optimum electric design.
The cutting-edge technology provides improvements to take advantage of the low-irradiance in the morning, evening, and overcast days, enhancing the module's energy production and the total energy yield of the solar system. The characteristics of the proposed PV model are shown in Table 4.1. This type of solar panel is widely available in Iraq, more efficient and suitable for Iraq's weather, especially when the temperature increases and gets very high.

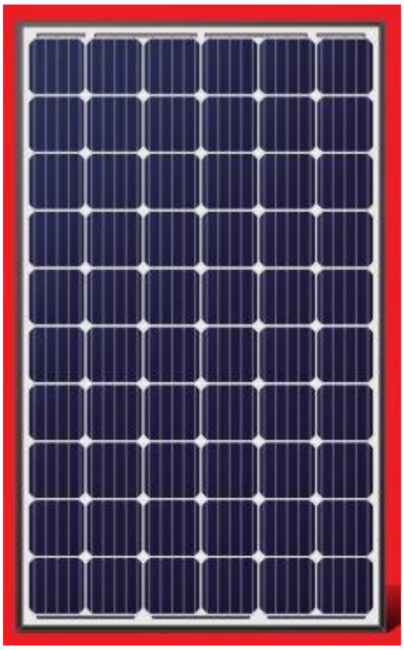


Figure 4.7. LONGI Solar panel.

Table 4.1. LONGI Solar LR6-60PB-295M characteristics.

Name	LONGI Solar LR6-60PB-295M
Abbreviation	LR6-60PB
Panel Type	Flat plate
Dimension	1650/991/40mm
Weight	18.2 (kg)
Max. Rated Capacity	295 (W)
The Voltage at Max. Power (V_{mp})	31.8 (V)
Current at Max. Power (I_{mp})	9.28 (A)
Open Circuit Voltage (V_{oc}/V)	38.9 (V)
Short Circuit Current (I_{SC}/A)	9.85 (A)
The Efficiency of the Module	18 %
Operating Temperature	47 °C
Temperature Coefficient	-0.410
Lifetime (years)	25 years

Figure 4.11 illustrates the P-V curve and the I-V curve of the selected LONGI Solar panel with the model's name LR6-60PB-295M that is included in the model's datasheet. Standard Test Conditions (STC) that are 1000 (W/m^2) irradiance, 25^{o}C cell temperature, and 1.5 spectrum air mass were used.

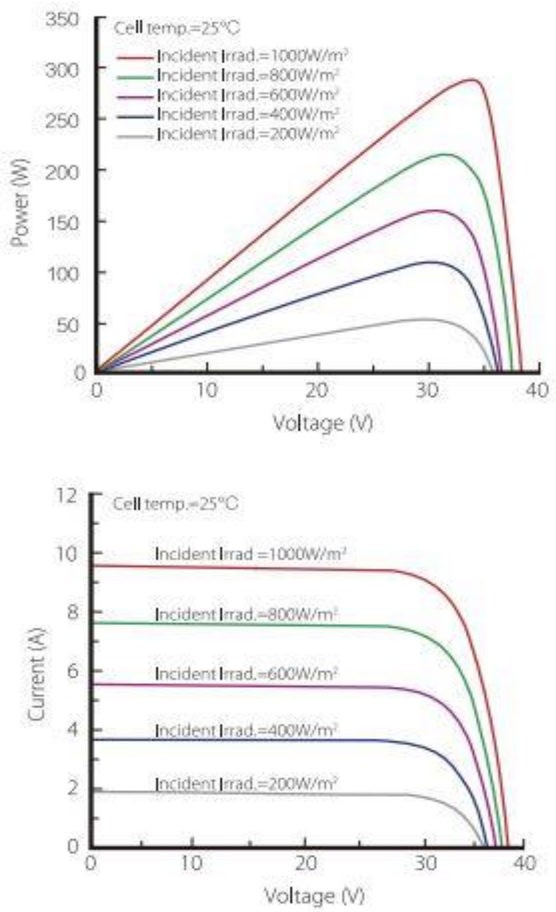


Figure 4.8. The curve of P-V and I-V of the LONGI Solar panel LR6-60PB-295M.

Capital cost, operation and maintenance cost (O&M), and replacement cost for 1 kW of electrical energy, which is produced via solar panels, are presented in Table 4.6 [62].

4.2.2. Wind Turbine

The produced electricity from wind turbines in a hybrid PV/Wind system depends on the wind speed of the chosen site, which may be accomplished by utilizing only one turbine that produces enough energy or a group of smaller turbines that produce less energy. Some key aspects to consider while selecting a wind turbine are capacity, cut-in wind speed, lifetime, tower height, and other aspects. The wind turbine that was chosen generates AC. A generic wind turbine that has a rated capacity of 10 kW was chosen as shown in Figure 4.12. The following Table 4.2 illustrates the features of it.

Figure 4.9. Wind turbine.

Table 4.2. Generic 10 kW wind turbine specifications [63].

Name	Generic (10 kW)
Abbreviation	G10
Manufacturer	Generic
Rated Capacity	10,000 (W)
Rotor Diameter	22 (m)
Cut-in Wind Speed	3 (m/s)
Hub Height	24 (m)
Rated Wind Speed	12 (m/s)
Cut-out Wind Speed	21 (m/s)
Lifetime	20 years

Capital cost, operation and maintenance cost (O&M), and replacement cost for one turbine (10 kW) of electrical energy, which is produced via wind turbin, are presented in Table 4.6 [20].Figure 4.13 displays the wind turbine power curve of the selected turbine as HOMER program offers it.

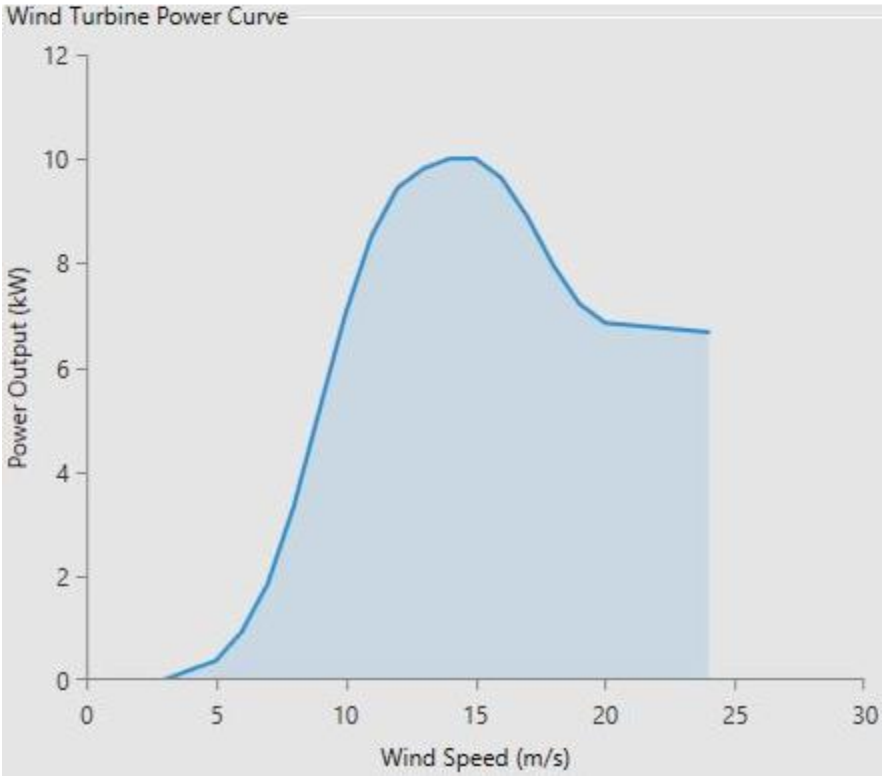


Figure 4.10. Wind turbine power curve.

4.2.3. Converter

Many models can be discovered in HOMER library when selecting the converter; it has a vast catalog that is well-organized due to the converter's or inverter’s capacity and other several parameters. In this research, a bidirectional converter was used because of various energy resources that produce DC and AC. Also, using the power from batteries and converting it to AC after charging it. A Leonics converter that has the model of MTP-4117H with a capacity of 300 kW was chosen as shown in Figure 4.14. The converter specifications are shown in Table 4.3.

Figure 4.11. The Leonics converter.

Table 4.3. A Leonics MTP-4117H 300 kW specifications.

Capacity	300 (kW)
Nominal Voltage	480 (VDC)
Max. Battery Current	850 (A)
Inverter Efficiency	96%
Rectifier Efficiency	94%
Max. Charging Current	418 (A)
Lifetime	10 years
Rectifier Relative Capacity	80%

The capital cost, the replacement cost, and the operation and maintenance cost (O&M) for (1kW) capacity for chosen converter, are presented in Table 4.6. According to HOMER software which has given thess costs.

4.2.4. Battery

HOMER suggests the number of batteries utilized when simulations are done. HOMER also contains a battery library with all of its specifications. An Infinity green power battery that has the model of (HAD-100AH-16S) was utilized for this experiment with Li-Ion LFP as shown in Figure 4.15. Table 4.4 displays the features of the chosen battery.

Figure 4.12. Infinity battery.

Table 4.4. The Infinity green power HAD-100AH-16S Li-Ion LFP properties.

Nominal Voltage	48 (V)
Nominal Capacity	4.8 (kWh)
Nominal Capacity	100 (Ah)
Warranty	3 (years)
Standard Charging Current	20 (A)
Max. Discharge Current	100 (A)
Discharge cut-off voltage	43.2 (V)
Lifetime	25 years

Capital cost, operation and maintenance cost (O&M), and replacement cost for one battery are presented in Table 4.6. These costs are from the local market in Baghdad and other governorates.

4.2.5. Generator

The diesel generator ought to be selected to function as a support generator in the designed system to provide the peak load with electricity with the assistance of renewable energy resources. The generator generates alternating current (AC), linked to an AC bus. One generator is taken to meet the electricity demand in case the grid status is out of order and the output power is zero from PV panels. The backup generator used is a Generic 25 kW Fixed Capacity Genset model that has an energy capacity of 25 kW as shown in Figure 4.16. It has a lifetime of 15,000 hours which is about 1.712 years. Table 4.5 displays the properties of the chosen generator.

Figure 4.13. Diesil generator.

Table 4.5. The Generic 25 kW Fixed Capacity Genset properties.

Type	Generic 25 kW Fixed Capacity Genset
Capacity	25 (kW)
Fuel curve intercept	0.825 (L/hr)
Fuel curve slope	0.273 (L/hr/kW)
Lifetime (hours)	15000 (hr)
CO emission	16.34 (g/L fuel)
Unburned HC emission	0.72 (g/L fuel)
Fuel sulfur to PM emission	2.2%
NOx emission	15.359 (g/L fuel)
Particulates	0.098 (g/L fuel)
Minimum Load Ratio	25%
Carbon Content	88%
Density	820 (kg/m3)
Sulfur content	0.4%
Lower Heating Value	43.2 (MJ/kg)

The replacement and capital prices were evaluated to be $12,500 and $12,500, successively for a Generic 25 kW Fixed Capacity Genset, with a maintenance cost of 0.75 $/h, the fuel price is to be 1.0$/L. All these costs are present in homer and the local market as shown in Table 4.6.

4.2.6. Utility Grid

The three regions considered in this study suffer from a lack of energy supply from the national grid. It covers approximately 50% of the total energy load, see Figure 4.17. The electricity is cut off for long hours, about 12 hours a day, or more, especially in July. In this regard, the use of a hybrid system depends on renewable energy resources that is connected to the national grid as a way to compensate for the lack of energy supply was suggested. Therefore, the purchasing capacity from the national grid was determined at 200 kW, and the remainder of the electricity demand was provided by utilizing the suggested hybrid system. According to a report from the Iraqi Ministry of Electricity, the price for buying energy (power rate definition) is 10 Iraqi Dinars per kWh which equals to 0.0068 $/kWh according to the dollar price on 31/12/2021.

Figure 4.14. Utility grid.

Table 4.6. Cost of component.

Type of Component	Capital Cost	Replacement Cost	O&M ($/Y)
PV	617 ($/kW)	431 ($/kW)	6.17 ($/kW)
Wind Turbine	17,000 $	17,000 $	120 $
Storage	5,000 $	3,500 $	100 $
Converter	600 ($/kW)	600 ($/kW)	0 ($/kW)
Generator	12,500 $	12,500 $	0.75 $

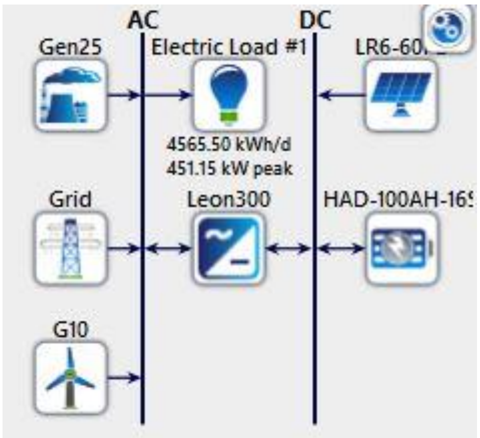
PART 5

RESULTS AND DISCUSSIONS

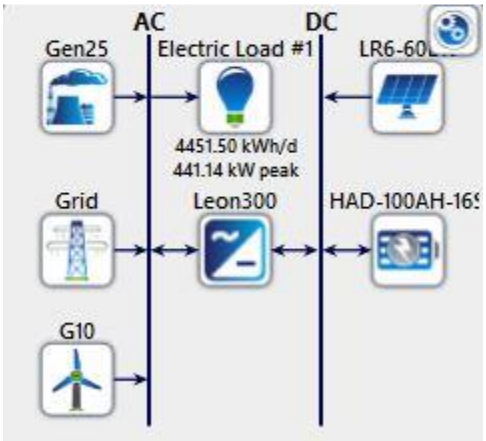
5.1. INTRODUCTION

In three different regions of Iraq (Altun Kupri, Khanaqin, and Fallujah) three housing complexes including about 150 homes, or approximately 600 people have chosen for our case study and their location are determined by HOMER program. The next step was selecting the components for the hybrid system, such as PV panels, wind turbines, batteries, and other components, according to the appropriate specifications for the load profile. The costs of all components were entered in HOMER depending on many scientific research, commercial companies, and local markets in Iraq. The database contains many types like solar radiation and wind speed that can be taken directly from NASA website after choosing the location on the map according to its longitude and latitude, then, HOMER will apply the data in the system during the simulations HOMER will list the best hybrid energy systems in respect of the available data like solar radiation, wind speed, costs and some other factors.
We referred to all that extensively in the previous part.

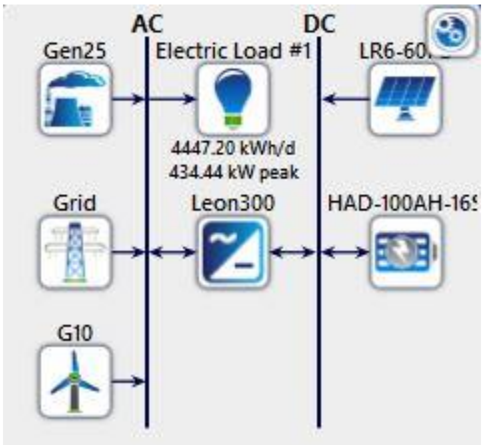
Figure 5.1 (a, b and c) represents the suggested hybrid systems for the three regions that are Altun Kupri, Khanaqin, and Fallujah, including the components that were used through the simulation via HOMER. The elements in the figures have names, such as (LR6-60PB) for the solar panel, (G10) for the wind turbine, (HAD-100Ah-16S) for the battery, (Gen25) for the diesel generator, the converter (Leon300), and the grid. The simulation process also comprises solar panels' capacities, wind generators, batteries, converters, diesel generators, and capital prices, as well as the components' lifetime and many other properties.



(a)



(b)



(c)

Figure 5.1. HRES for (a) Altun kupri, (b) khanaqin, and (c) Fallujah.

5.2. TECHNO-ECONOMIC EVALUATION OF ALTUN KUPRI

5.2.1. Simulation by Using HOMER PRO

The simulation results of three different regions are executed for the following six Cases:

1. The hybrid PV/diesel generator/battery/converter/and grid system.
2. The hybrid PV/wind turbine/diesel generator/battery/converter/and grid system.
3. The hybrid PV/battery/converter/and grid system.
4. The hybrid PV/wind turbine/battery/converter/and grid system.
5. The hybrid wind turbine/diesel generator/battery/converter/and grid system.
6. he hybrid wind turbine/battery/converter/and grid system.

Also, HOMER has conducted optimization and sensitinity results.

5.2.2. The Optimization Results

HOMER analyses and simulates the multiple system components using input data to find the best technical configuration with the lowest life-cycle cost. The key determinants for ensuring economic metrics of energy systems using HOMER tool are NPC and COE. After simulation processes for suggested systems were completed, HOMER organizes the results into a list based on their (COE), initial capital cost, and (NPC). As illustrated in Figure 5.2

Export...

Optimization Results

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

Architecture							Cost				System	
LR6-60PB (kW)	G10	Gen25 (kW)	HAD-100AH-16S	Grid (kW)	Leon300 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
506		25.0	60	200	208	CC	$1.09M	$0.0507	$26,458	$749,639	34.8	2,387
511	2	25.0	57	200	208	CC	$1.11M	$0.0517	$26,476	$771,431	35.9	2,229
492			73	200	236	CC	$1.15M	$0.0532	$25,979	$810,481	35.8	0
415	1		80	200	329	CC	$1.26M	$0.0584	$30,021	$869,969	33.6	0
	41	25.0	139	200	203	CC	$2.14M	$0.0992	$47,177	$1.53M	26.3	4,659
	53		172	200	218	CC	$2.52M	$0.117	$48,774	$1.89M	31.1	0

Figure 5.2. The optemazation result for Altun Kupri.

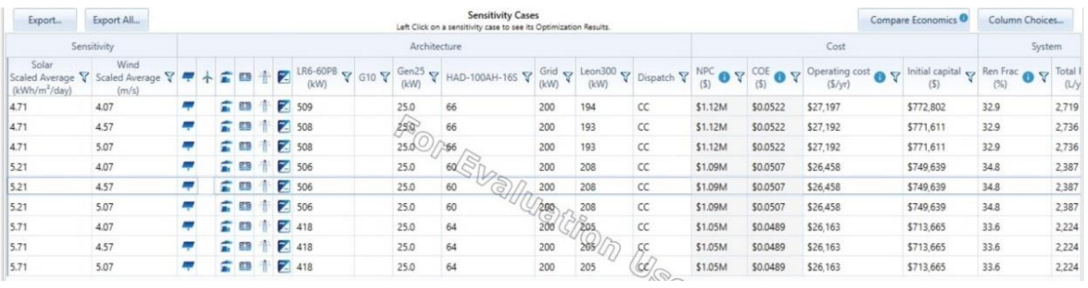
The optimization results for six scenarios are as follows:

1. In the first scenario, the hybrid system comprises a PV system, a battery, a diesel generator, a converter, and a grid. It has 506 kW solar panels, 25 kW diesel generator, 60 batteries, 208 kW converter, 200 kW provided from the grid, with (COE) of 0.0507 dollars per kWh, (NPC) of 1.09M dollars, an initial capital cost of 749,639 dollars, an operating price 26,458 dollars per year, and a 34.8% renewable fraction.
2. In the second scenario, the hybrid system comprises a PV system, a wind turbine, a battery, a diesel generator, a converter, and a grid. It has 511 kW solar panels, two wind turbines, 25 kW diesel generator, 57 batteries, 208 kW converter, with (COE) of 0.0517 dollars per kWh, (NPC) of 1.11M dollars, an initial capital cost of 771,431 dollars, an operating price 26,476 dollars per year, and a 35.9% renewable fraction.
3. In the third scenario, the hybrid system comprises a PV system, a battery, a converter, and a grid. It has 492 kW solar panels, 73 batteries, 236 kW converter, with (COE) of 0.0532 dollars per kWh, (NPC) of 1.15M dollars, an initial capital cost of 810,481 dollars, an operating price of 25,979 dollars per year, and a 35.8% renewable fraction.
4. In the fourth scenario, the hybrid system comprises a PV system, a wind turbine, a battery, a converter, and a grid. It has 415 kW solar panels, one wind turbine, 80 batteries, 329 kW converter, with (COE) of 0.0584 dollars per kWh, (NPC) of 1.26M dollars, an initial capital cost of 869,969 dollars, an operating price of 30,021 dollars per year, and a 33.6% renewable fraction.
5. In the fifth scenario, the hybrid system comprises a wind turbine, a battery, a diesel generator, a converter, and a grid. It has 41 wind turbines, 25 KW diesel generator, 139 batteries, 203 kW converter, with (COE) of 0.0992 dollars per kWh, (NPC) of 2.14M dollars, an initial capital cost of 1.53M dollars, an operating price of 47,177 dollars per year, and a 26.3% renewable fraction.
6. In the sixth scenario, the hybrid system comprises a wind turbine, a battery, a converter, and a grid. It has 53 wind turbines, 172 batteries, 218 kW converter, with (a COE) of 0.117 dollars per kWh, (NPC) of 2.52M dollars, an initial capital

cost of 1.89M dollars, an operating price of 48,774 dollars per year, and a 31.1% renewable fraction.

5.2.3. The Sensitivity of the System

Sensitivity testing is a method of determining the model's sensitivity when the model's parameters and structure are changed. When HOMER analyses the system's optimization for uncertainty variables, for example, solar radiation, price of diesel fuel, and wind speed, this is known as the sensitivity of the system. For each input variable, HOMER performs a sensitivity analysis with multiple values. The sensitivity variable refers to the multiple values specified for input assumptions. The system was simulated using two sensitivity variables: solar radiation and wind speed together with changing COE, NPC, and Renewable Fraction values as system outputs. All of the schemes are simulated in the search spaces by HOMER. The sensitivity parameter for solar radiation was set as (5.21, 5.71, 4.71) whereas the sensitivity parameter for wind speed was set as (4.57,5.07,4.07) to study the input of the system and the extent of the economic impact on the system whether it is increased or decreased. Each input variable can specify one or more sensitivity variables, and the sensitivity analysis can be one or more dimensional, regardless of the sensitivity variables' number. During it, HOMER evaluates the effect changing of the parameters. Eventually, a table is presented contains various hybrid system designs, with the total COE, NPC, and operating price of every structure ranked from the least to the top value. HOMER displayed the optimal system that has the least total COE, NPC, and operating price,as shown in Figure 5.3.


Export... Export All... Sensitivity Cases Left Click on a sensitivity case to see its Optimization Results. Compare Economics Column Choices...

Sensitivity		Architecture							Cost					System	
Solar Scaled Average (kWh/m²/day)	Wind Scaled Average (m/s)	LR6-60PB (kW)	G10	Gen25 (kW)	HAD-100AH-16S	Grid (kW)	Leon300 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total (L/y
4.71	4.07	509		25.0	66	200	194	CC	$1.12M	$0.0522	$27,197	$772,802	32.9	2,719
4.71	4.57	508		25.0	66	200	193	CC	$1.12M	$0.0522	$27,192	$771,611	32.9	2,736
4.71	5.07	508		25.0	66	200	193	CC	$1.12M	$0.0522	$27,192	$771,611	32.9	2,736
5.21	4.07	506		25.0	60	200	208	CC	$1.09M	$0.0507	$26,458	$749,639	34.8	2,387
5.21	4.57	506		25.0	60	200	208	CC	$1.09M	$0.0507	$26,458	$749,639	34.8	2,387
5.21	5.07	506		25.0	60	200	208	CC	$1.09M	$0.0507	$26,458	$749,639	34.8	2,387
5.71	4.07	418		25.0	64	200	205	CC	$1.05M	$0.0489	$26,163	$713,665	33.6	2,224
5.71	4.57	418		25.0	64	200	205	CC	$1.05M	$0.0489	$26,163	$713,665	33.6	2,224
5.71	5.07	418		25.0	64	200	205	CC	$1.05M	$0.0489	$26,163	$713,665	33.6	2,224

Figure 5.3. Sensitivity cases for Altun Kupri.

5.2.4. Results and Discussions for ALTUN KUPRI

HOMER performs optimization and sensitivity analysis before presenting results in table form for various hybrid system configurations, and the optimization results for different system components are illustrated in Figure 5.2. The compared optimization results of the base case with six systems scenarios are presented in Table 5.1. A comparison for the system in terms of economic and technical benefits was conducted to get actual results.to face the challenges of Iraq in terms of power generation, Pollution's impact rate and other details

Table 5.1. Comparison between systems in terms of cost and percentage of renewable fraction for Altun Kupri.

	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
NPC ($)	1.09M	1.11M	1.15M	1.26M	2.14M	2.52M
COE ($/KWh)	0.0507	0.0517	0.0532	0.0584	0.0992	0.117
Operating Cost ($/yr)	26,458	26,476	25,979	30,021	47,177	48,774
Initial Capital ($)	749,639	771,431	810,481	869,969	1.53M	1.89M
Ren. Frac. (%)	34.8	35.9	35.8	33.6	26.3	31.1

The previous results demonstrated that the hybrid system which consists of PV panels, diesel generator, converter, battery, and grid system, which is the first case, has the least COE that is the best system to choose. The NPC values between the base case system and the least price system design are shown in Figure 5.4. Two lines that are the lowest cost system and base case system run in parallel to each other. The accumulated cash flow over the life of the project in the graph shows the system's strategy of saving money during the project life-cycle through comparing the base case system (grey line) to the best system (blue line) [48].

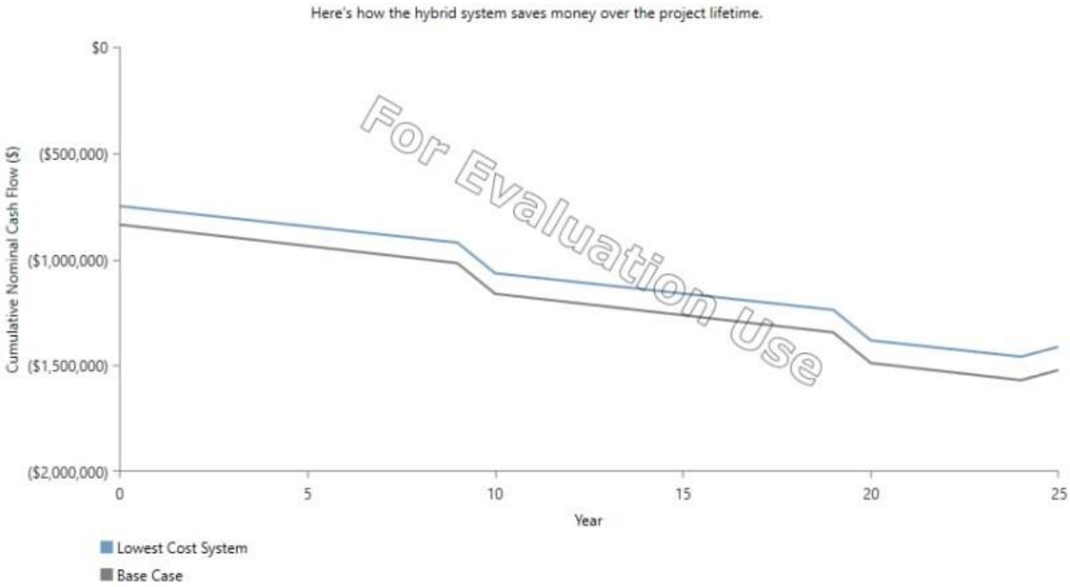


Figure 5.4. Comparison of NPC between lowest cost system and base case system in Altun Kupri.

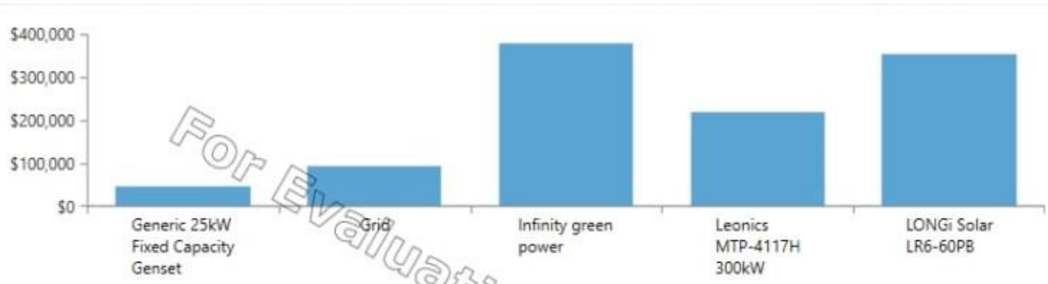
The yearly power production and consumption summary for the first system (case1) are shown in Figure 5.5 which shows the monthly average power production share for case 1 that contains PV/battery/converter/diesel generator, and a grid. Because the electricity generated from the grid cannot fully meet the system's electricity demand, PV systems and diesel generators are mainly and continually used throughout the day during the year [43-48]. As previously stated, the thesis's primary goal is to create a hybrid system in areas that suffer from a lack of energy supply. In this regard, we proposed using a hybrid system that combines renewable energy with the grid in parallel to compensate for the required electricity.

In the first system, if there is any energy that is more than the area's demands, it will be charged to the batteries because the total production is 1,897,065 kWh/yr and the total consumption equals to 16,655,746 kWh/yr. The PV system produces 42.7% of the total energy, 0.394% from a diesel generator, while the grid produces 56.9% of the total energy. The cost summary is illustrated in Figure 5.6.

Production	kWh/yr	%
LONGi Solar LR6-60PB	810,486	42
Generic 25kW Fixed Capacity Genset	7,483	0.3
Grid Purchases	1,079,096	56
Total	1,897,065	10

Consumption	kWh/yr	%
AC Primary Load	1,665,746	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	1,665,746	100

Figure 5.5. Electric production and consumption for Altun Kupri.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic 25kW Fixed Capacity Genset	$12,500.00	$0.00	$4,043.08	$30,855.54	($913.31)	$46,485.30
Grid	$0.00	$0.00	$94,860.20	$0.00	$0.00	$94,860.20
Infinity green power	$300,000.00	$0.00	$77,565.10	$0.00	$0.00	$377,565.10
Leonics MTP-4117H 300kW	$124,708.51	$110,172.19	$0.00	$0.00	($14,937.45)	$219,943.26
LONGi Solar LR6-60PB	$312,430.53	$0.00	$40,389.51	$0.00	$0.00	$352,820.04
System	$749,639.04	$110,172.19	$216,857.89	$30,855.54	($15,850.77)	$1,091,673.90

Figure 5.6. The cost summary for Altun Kupri.

For the first hybrid system, the annual PV power output for one year, battery's state of charge, and generator power output are illustrated in Figures 5.7, 5.8, and 5.9 respectively. All information was shown by colors based on 360 days a year on the horizontal axis and 24 hours a day on the vertical axis from the left side.

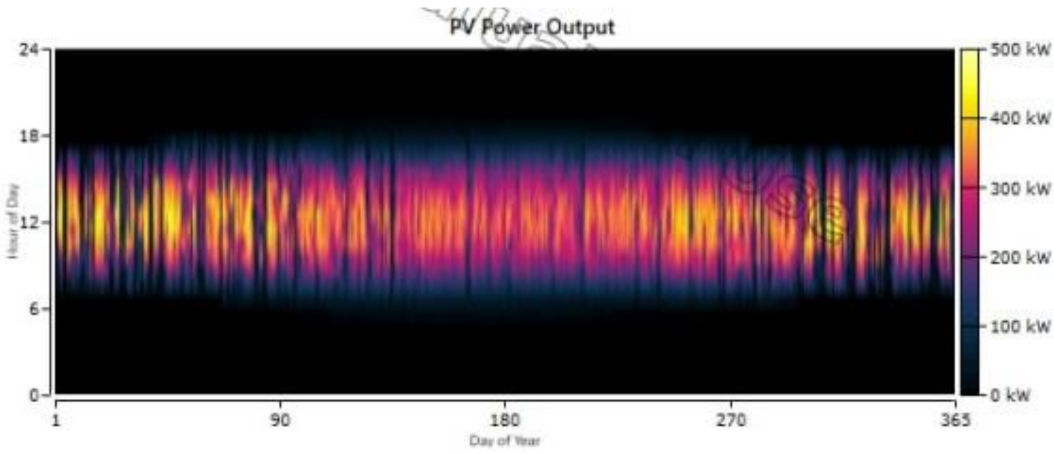


Figure 5.7. PV power output for Altun Kupri.

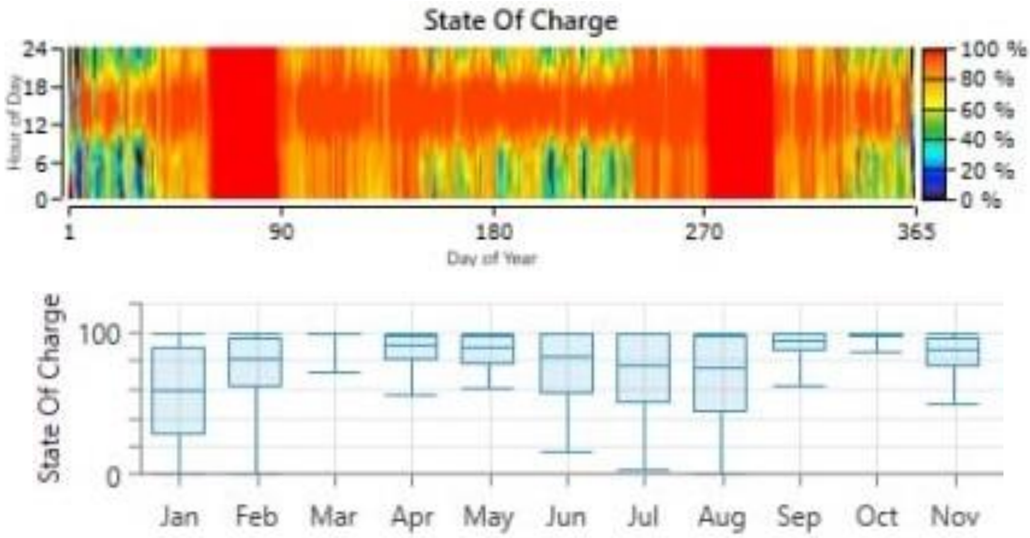


Figure 5.8. State of charge for the battery for Altun Kupri.

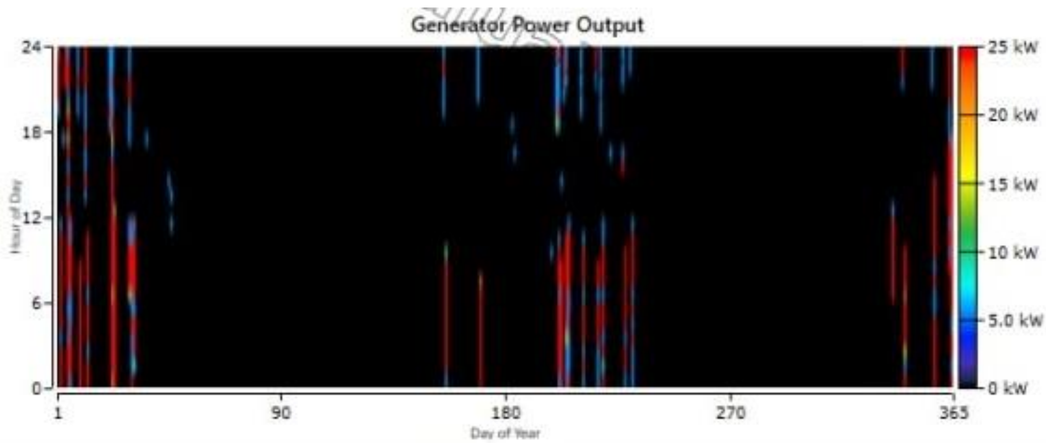


Figure 5.9. Generator power output for Altun Kupri.

The case-wise comparison of yearly emissions is given in Table 5.2. The quantities of carbon monoxide, particulate matter emissions, and unburned hydrocarbons are stable in some cases and they equal zero in other cases. On the other hand, a difference was found in the amounts of Carbon Dioxide, Nitrogen Oxide, and Sulfur Dioxide from one system to another.

Table 5.2. Case-wise comparison of yearly emissions for Altun Kupri.

Emissions (kg/year)						
Quantity(kg/yr)	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
Carbon Dioxide	688237	676339	67584	698456	778274	725017
Carbon Monoxide	39	36.4	0	0	76.1	0
Unburned Hydrocarbons	1.72	1.6	0	0	3.35	0
Particulate Matter	0.234	0.218	0	0	0.457	0
Sulfur Dioxide	2972	2921	293	3028	3351	3143
Nitrogen Oxides	1483	1456	1433	1481	1696	1537

5.3. TECHNO-ECONOMIC ANALYSIS OF KHANAQIN

5.3.1. The Simulation by HOMER PRO

There are many proposals for different systems with different components and costs, so HOMER showed all the possible solutions. As a result, six cases of low-cost hybrid systems appeared, these cases are:

1. The hybrid PV/diesel generator/battery/converter/and grid system.
2. The hybrid PV/wind turbine/diesel generator/battery/converter/and grid system.
3. The hybrid PV/battery/converter/and grid system.
4. The hybrid PV/wind turbine/battery/converter/and grid system.
5. The hybrid wind/battery/converter/and grid system.
6. The hybrid wind/diesel generator/battery/converter/and grid system.

5.3.2. The Optimization Results

After the simulations for suggested systems are completed, HOMER organizes the results into a list based on their COE, initial capital cost ($), NPC, and operating cost ($/yr), as shown in Figure 5.10.

Export...

Optimization Results

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

Architecture							Cost				System	
LR6-60BK (kW)	G10	Gen25 (kW)	HAD-100AH-16S	Grid (kW)	Leon300 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
424		25.0	57	200	177	CC	$992,949	$0.0473	$25,337	$665,398	30.2	2,768
419	1	25.0	57	200	179	CC	$1.01M	$0.0482	$25,627	$680,581	30.8	2,783
490			62	200	254	CC	$1.09M	$0.0521	$25,466	$765,059	34.5	0
453	1		65	200	399	CC	$1.26M	$0.0601	$31,064	$860,931	33.8	0
	38		196	200	243	CC	$2.39M	$0.114	$47,711	$1.77M	27.7	0
	50	25.0	140	200	392	CC	$2.47M	$0.118	$52,029	$1.80M	32.3	1,502

Figure 5.10. The optimization resalt for Khanaqin.

HOMER-provided optimization results for six scenarios as follows:

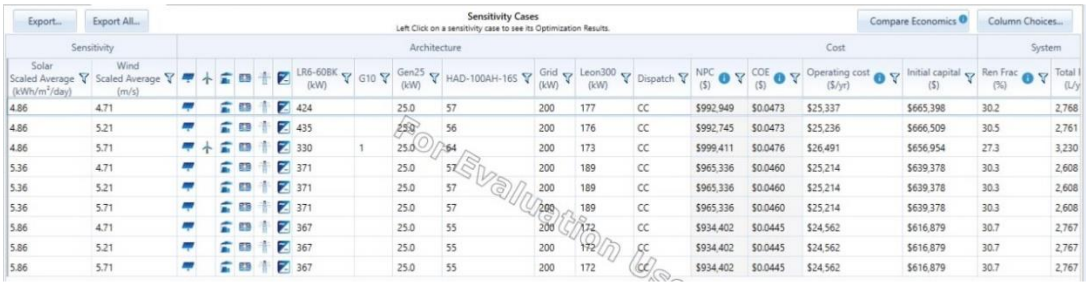
1. In the first scenario, the hybrid system comprises a PV system, a diesel generator, a battery, a converter, and a grid. It has 424 kW solar panels, a 25 kW diesel generator, 57 batteries, 177 kW converter, and (COE) of 0.0473 dollars per kWh, (NPC) of 9,992,949 dollars, an initial capital price of 665,398 dollars, an operating cost of 25,337 dollars yearly, and a 30.2% renewable fraction.
2. In the second scenario, the hybrid system comprises a PV system, a wind turbine, a diesel generator, a battery, a converter, and a grid. It has 419 kW solar panels, one wind turbine, 25 kW diesel generator, 57 batteries, 179 kW converter, with (COE) of 0.0482 dollars per kWh, (NPC) of 1.01M dollars, an initial capital cost of 680,581 dollars, an operating price 25,627 dollars per year, and a 30.8% renewable fraction.
3. In the third scenario, the hybrid system comprises a PV system, a battery, a converter, and a grid. It has 490 kW solar panels, 62 batteries, 254 kW converter, with (COE) of 0.0521 dollars per kWh, (NPC) of 1.09M dollars, an initial capital cost of 765,059 dollars, an operating price of 25,466 dollars per year, and a 34.5% renewable fraction.
4. In the fourth scenario, the hybrid system comprises a PV system, a wind turbine, a battery, a converter, and a grid. It has 453 kW solar panels, one wind turbine,

65 batteries, 399 kW converter, with (COE) of 0.0601 dollars per kWh (NPC) of 1.26M dollars, an initial capital cost of 860,931 dollars, an operating price of 31,064 dollars per year, and a 24.3% renewable fraction.

5. In the fifth scenario, the hybrid system comprises a wind turbine, a battery, a converter, and a grid. It has 38 wind turbines, 196 batteries, 243 kW converter, with (COE) of 0.114 dollars per kWh, (NPC) of 2.39M dollars, an initial capital cost of 1.77M dollars, an operating price of 47,711 dollars per year, and a 27.7% renewable fraction.
6. In the sixth scenario, the hybrid system comprises a wind turbine, a diesel generator, a battery, a converter, and a grid. It has 50 wind turbines, 25 kW diesel generator, 140 batteries, 392 kW converter, with (COE) of 0.118 dollars per kWh, (NPC) of 2.47M dollars, an initial capital cost of 1.8M dollars, an operating price of 52,029 dollars per year, and a 32.3% renewable fraction

5.3.3. The Sensitivity of the System

The sensitivity parameter for solar radiation was set as (5.36, 5.86, 4.86) and the sensitivity parameter for wind speed was set as (5.21,5.71,4.71) with an increase of 0.5 and a decrease of 0.5 on the solar radiation and wind speed value to study the input of the system and the extent of the economic impact on the system whether increased or decreased. The modular can specify one variable or more than one for sensitivity for every input, and analysis for sensitivity can be one or more dimensional, regardless of the number of sensitivity variables. HOMER evaluates the effects of changes or unregulated parameters during this process. Eventually, a table is presented that contains list of different hybrid system designs, with the total COE, NPC, and operating price of every structure ranked from the least to the top value as shown in Figure 5.11.



Sensitivity Cases
Left Click on a sensitivity case to see its Optimization Results.

Solar Scaled Average (kWh/m²/day)	Wind Scaled Average (m/s)	LR6-60BK (kW)	G10	Gen25 (kW)	HAD-100AH-16S	Grid (kW)	Leon300 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total I (L/y
4.86	4.71	424		25.0	57	200	177	CC	$992,949	$0.0473	$25,337	$665,398	30.2	2,768
4.86	5.21	435		25.0	56	200	176	CC	$992,745	$0.0473	$25,236	$666,509	30.5	2,761
4.86	5.71	330	1	25.0	64	200	173	CC	$999,411	$0.0476	$26,491	$656,954	27.3	3,230
5.36	4.71	371		25.0	57	200	189	CC	$965,336	$0.0460	$25,214	$639,378	30.3	2,608
5.36	5.21	371		25.0	57	200	189	CC	$965,336	$0.0460	$25,214	$639,378	30.3	2,608
5.36	5.71	371		25.0	57	200	189	CC	$965,336	$0.0460	$25,214	$639,378	30.3	2,608
5.86	4.71	367		25.0	55	200	172	CC	$934,402	$0.0445	$24,562	$616,879	30.7	2,767
5.86	5.21	367		25.0	55	200	172	CC	$934,402	$0.0445	$24,562	$616,879	30.7	2,767
5.86	5.71	367		25.0	55	200	172	CC	$934,402	$0.0445	$24,562	$616,879	30.7	2,767

Figure 5.11. Sensitivity cases for Khanaqin.

5.3.4. Results and Discussions for Khanaqin

HOMER performs optimization and sensitivity analysis then presenting results in table form for various hybrid system configurations, as shown in Figure 5.10, and Figure 5.11. The compared optimization results of the base case with six systems designs are presented in Table 5.3.

Table 5.3. Comparison between systems in terms of cost and percentage of the renewable fraction for Khanaqin.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
NPC ($)	965336	1.08M	1.16M	1.28M	2.55M	2.71M
COE($/KWh)	0.046	0.0515	0.0551	0.061	0.121	0.129
Operating Cost ($/yr)	25,214	23,841	30,309	32,675	61,811	6,273
Initial Capital ($)	639,378	773,428	765,515	857,749	1.75M	1.90M
Ren. Frac. (%)	30.3	37.4	31.7	32.6	33.7	36.1

The previous outcomes show that the hybrid PV panels/battery/ Converter/diesel/generator / and grid system, which is the first case, has the lowest COE of the six systems, which is the best system to choose. The first system is the best. Figure 5.12 shows the comparison of NPC between the base case which is in the grey line and the lowest cost system which is in the blue line.

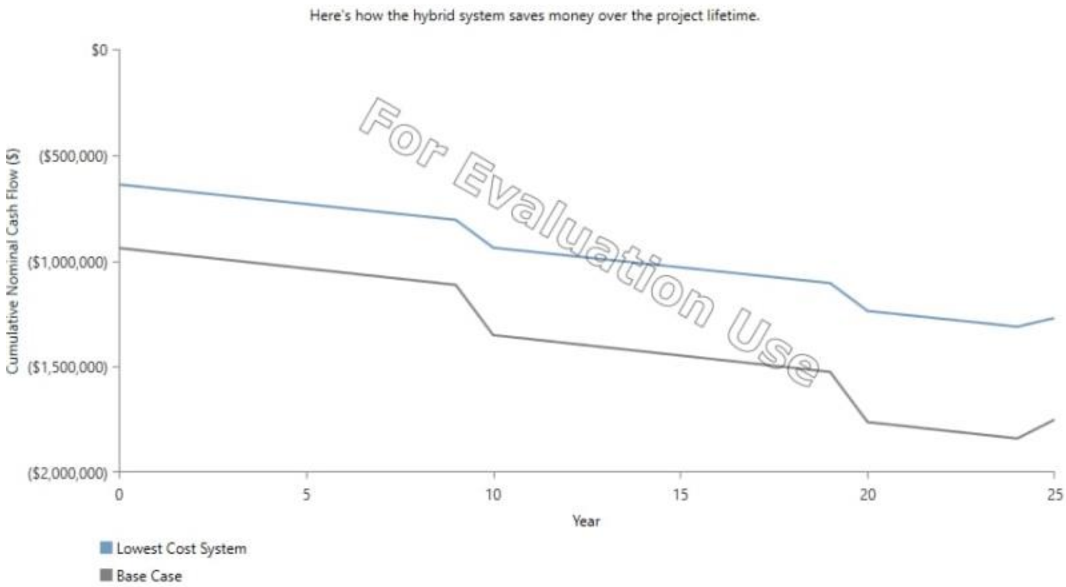


Figure 5.12. Comparison of NPC between lowest cost system and base case system in Khanaqin.

The annual produced electricity and consumption summary for the first system (case1) are shown in Figure 5.13 which illustrates the monthly average value of produced electricity for case 1 that contains PV panels / battery / converter / diesel generator and the grid. Because the grid-generated electricity cannot fully meet the system electricity demand, PV systems and diesel generator are mainly and continually used throughout the day during the year [43-48]

For the first system, if there is any energy that is more than the area's demands, it will be charged to the batteries because the total production is 1,728,877 kWh/yr and the total consumption equals 1,624,148 kWh/yr. The PV system produces 34.5% of the total energy, and 0.472 % from diesel generation, while the grid makes 65%. The cost summary is shown in Figure 5.14.

Production	kWh/yr	%
LONGi Solar LR6-60BK	614,686	35
Generic 25kW Fixed Capacity Genset	8,645	0.4
Grid Purchases	1,124,443	64
Total	1,747,773	10

Consumption	kWh/yr	%
AC Primary Load	1,624,128	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	1,624,128	100

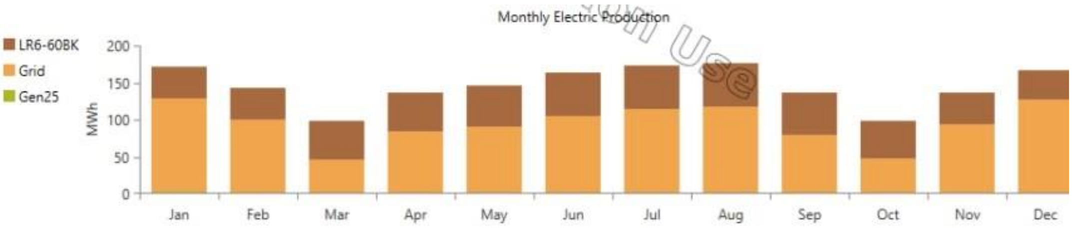
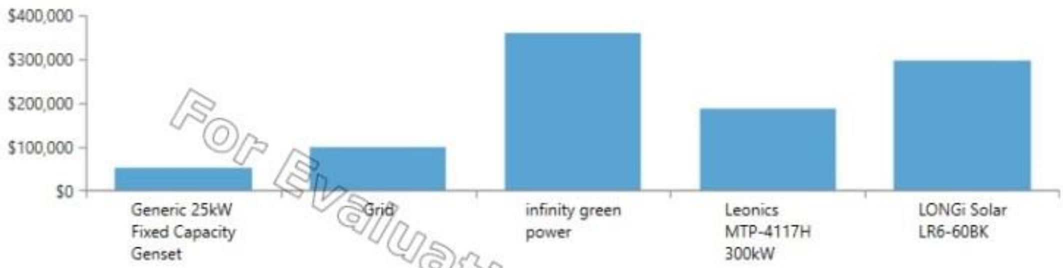


Figure 5.13. Electric production and consumption for Khanaqin.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic 25kW Fixed Capacity Genset	$12,500.00	$0.00	$4,799.34	$35,787.87	($524.03)	$52,563.18
Grid	$0.00	$0.00	$98,846.55	$0.00	$0.00	$98,846.55
infinity green power	$285,000.00	$0.00	$73,686.84	$0.00	$0.00	$358,686.84
Leonics MTP-4117H 300kW	$106,235.67	$93,852.59	$0.00	$0.00	($12,724.79)	$187,363.46
LONGi Solar LR6-60BK	$261,662.65	$0.00	$33,826.48	$0.00	$0.00	$295,489.13
System	$665,398.32	$93,852.59	$211,159.22	$35,787.87	($13,248.83)	$992,949.17

Figure 5.14. The cost summary for Khanaqin.

For the first hybrid system, the annual PV power output for one year, battery's state of charge, and generator power output are illustrated in Figures 5.15, 5.16, and 5.17 respectively. All information was shown by colors based on 360 days a year on the horizontal axis and 24 hours a day on the vertical axis from the left side.

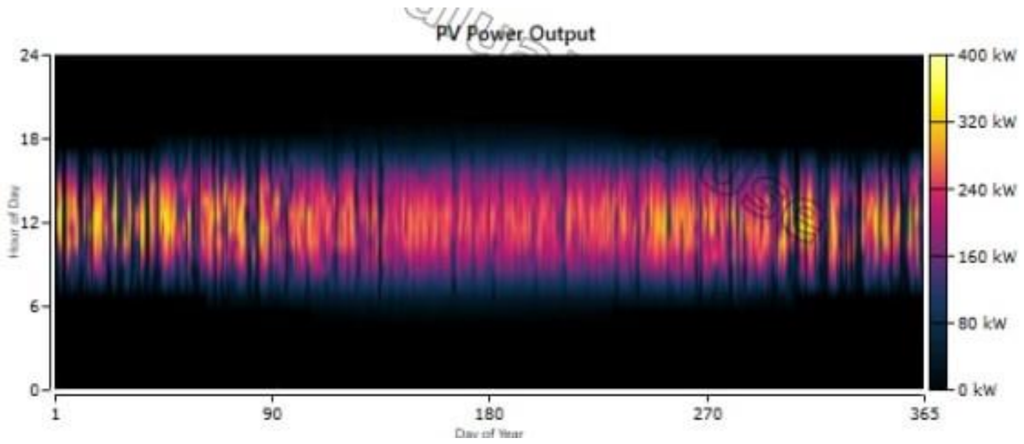


Figure 5.15. PV power output for Khanaqin.

Figure 5.16. State of charge for the battery for Khanaqin.

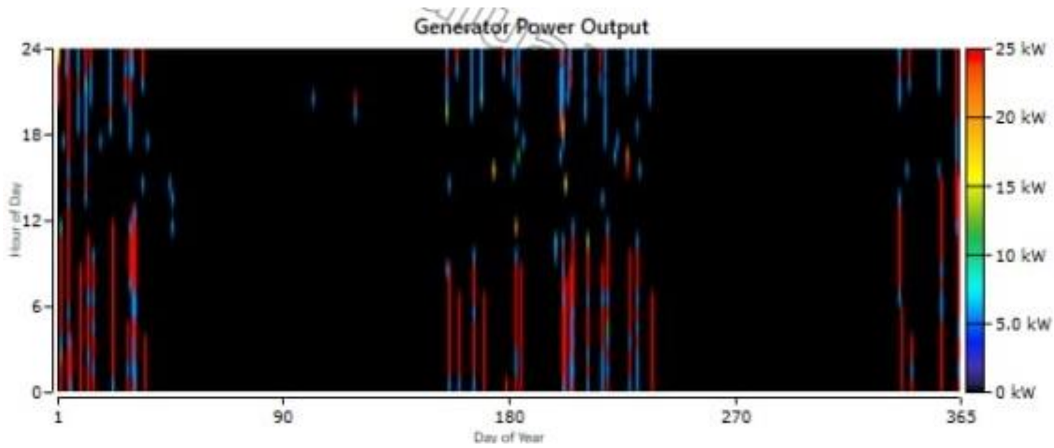


Figure 5.17. Generator power output for Khanaqin.

The case-wise comparison of yearly emissions is given in Table 5.4. The quantities of carbon monoxide, particulate matter emissions, and unburned hydrocarbons are stable for some cases and they equal zero in other cases. But the difference was found in the amounts of Carbon Dioxide, Nitrogen Oxide, and Sulfur Dioxide from one system to another.

Table 5.4. Case-wise comparison of yearly emissions for Khanaqin.

Emissions (kg/year)						
Quantity(kg/yr)	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
Carbon Dioxide	717,302	644,232	702,209	692,276	681,111	655,477
Carbon Monoxide	342.6	0	23.1	0	19.9	0
Unburned Hydrocarbons	1.88	0	1.02	0	0.879	0
Particulate Matter	0.256	0	0.138	0	0.120	0
Sulfur Dioxide	3,097	2,785	3,037	3,001	2,947	2,842
Nitrogen Oxides	1,546	1,362	1,503	1,468	1,456	1,390

5.4. TECHNO-ECONOMIC ANALYSIS OF FALLUJAH

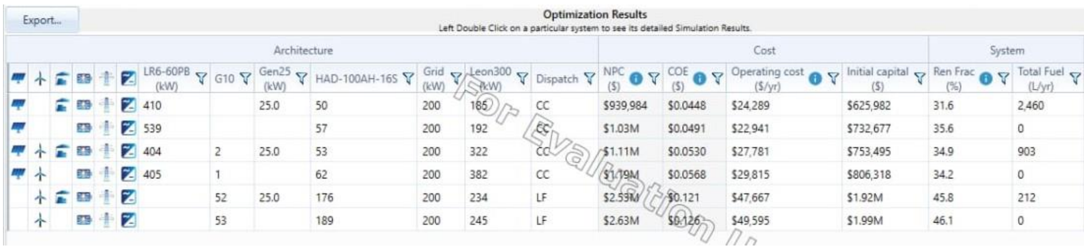
5.4.1. The Simulation by HOMER PRO

For Fallujah, six scenarios of low-cost hybrid systems appeared, these cases are as follows:

1. The hybrid PV/diesel generator/battery/converter/and grid system.
2. The hybrid PV/battery/converter/and grid system.
3. The hybrid PV/wind turbine/diesel generator/battery/converter/and grid system.
4. The hybrid PV/wind turbine/battery/converter/and grid system.
5. The hybrid wind turbine/diesel generator/battery/converter/and grid system.
6. The hybrid wind turbine/battery/converter/and grid system.

5.4.2. The Optimization Results

Figure 5.18 was shown the results for six scenarios



Optimization Results

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

LR6-60PB (kW)	G10	Gen25 (kW)	HAD-100AH-16S	Grid (kW)	Leon300 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
410		25.0	50	200	185	CC	$939,984	$0.0448	$24,289	$625,982	31.6	2,460
539			57	200	192	CC	$1.03M	$0.0491	$22,941	$732,677	35.6	0
404	2	25.0	53	200	322	CC	$1.11M	$0.0530	$27,781	$753,495	34.9	903
405	1		62	200	382	CC	$1.19M	$0.0568	$29,815	$806,318	34.2	0
	52	25.0	176	200	234	LF	$2.53M	$0.121	$47,667	$1.92M	45.8	212
	53		189	200	245	LF	$2.63M	$0.126	$49,595	$1.99M	46.1	0

Figure 5.18. Optimization result for Fallujah.

1. In the first scenario, the hybrid system comprises a PV system, a wind turbine, a converter, and a grid. It has 289 kW solar panels, one wind turbine, a 152 kW converter, and a (COE) of 0. 0448 dollars per kWh, (NPC) of 939,984 dollars, an initial capital price of 625,982 dollars, an operating price of 24,289 dollars for every year, and a 31.6% renewable fraction.
2. In the second scenario, the hybrid system comprises a PV system, a battery, a converter, and a grid. It has 282 kW solar panels, one battery, 144 kW converter, with (COE) of 0.07491 dollars per kWh (NPC) of 1.03M dollars, an initial capital price of 732,677 dollars, an operating price of 22,941 dollars per year, and a 35.6% renewable fraction.
3. In the third scenario, the hybrid system comprises a PV system, wind turbine, diesel generator, converter, and grid. It has 289 kW solar panels, one wind turbine, 25 kW diesel generator, 152 kW converter, with (COE) of 0.053 dollars per kWh, (NPC) of 1.11M dollars, an initial capital cost of 753,495 dollars, an operating price 27,781 dollars per year, and a 34.9% renewable fraction.
4. In the fourth scenario, the hybrid system comprises a PV system, diesel generator, battery, converter, and grid. It has 282 kW solar panels, 25 kW diesel generator, one battery, 144 kW converter, with (COE) of 0.0568 dollars per kWh (NPC) of 1.19M dollars, an initial capital cost of 806,318 dollars, an operating price of 29,815 dollars per year, and a 34.2% renewable fraction.
5. In the fifth scenario, the hybrid system comprises a PV system, wind turbine, battery, converter, and grid. It has 281 kW solar panels, one wind turbine, 11

batteries, 122 kW converter, with (COE) of 0.121 dollars per kWh, (NPC) of 2.53M dollars, an initial capital cost of 1.92M dollars, an operating price of 47,667 dollars per year, and a 45.8% renewable fraction.

6. In the sixth scenario, the hybrid system comprises a PV system, wind turbine, diesel generator, battery, converter, and grid. It has 281 kW solar panels, one wind turbine, 25 kW diesel generator, 11 batteries, 122 kW converter, with (COE) of 0.126 dollars per kWh, (NPC) of 2.63M dollars, an initial capital cost of 1.99M dollars, an operating price 49,595 dollars per year, and a 46.1% renewable fraction.

5.4.3. The Sensitivity of the System

The sensitivity parameter for solar radiation was set as (5.4, 5.9, 4.9) and for wind speed was set as (5.58,6.08,5.08) with an increase of 0.5 and a decrease of 0.5 on the solar radiation and wind speed value to study the input of the system and the extent of the economic impact on the system whether increased or decreased [13]. HOMER showed in Figure 5.19 the optimal design for the system with the least total COE, NPC, and operating price.

Export... Export All...

Sensitivity Cases
Left Click on a sensitivity case to see its Optimization Results.

Compare Economics Column Choices...

Sensitivity		Architecture							Cost				System	
Solar Scaled Average (kWh/m²/day)	Wind Scaled Average (m/s)	LR6-60PB (kW)	G10	Gen25 (kW)	HAD-100AH-16S	Grid (kW)	Leon300 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total (L/y
4.90	5.08	367		25.0	57	200	184	CC	$963,981	$0.0460	$25,476	$634,638	28.4	2,817
4.90	5.58	367		25.0	57	200	184	CC	$963,981	$0.0460	$25,476	$634,638	28.4	2,817
4.90	6.08	367		25.0	57	200	184	CC	$963,981	$0.0460	$25,476	$634,638	28.4	2,817
5.40	5.08	410		25.0	50	200	185	CC	$939,984	$0.0448	$24,289	$625,982	31.6	2,460
5.40	5.58	410		25.0	50	200	185	CC	$939,984	$0.0448	$24,289	$625,982	31.6	2,460
5.40	6.08	410		25.0	50	200	185	CC	$939,984	$0.0448	$24,289	$625,982	31.6	2,460
5.90	5.08	399		25.0	49	200	210	CC	$937,303	$0.0447	$23,776	$629,938	33.6	1,593
5.90	5.58	404		25.0	47	200	191	CC	$921,229	$0.0439	$23,973	$611,312	32.9	2,395
5.90	6.08	392		25.0	48	200	189	CC	$918,006	$0.0438	$23,993	$607,839	32.4	2,412

Figure 5.19. Sensitivity cases for Fallujah.

5.4.4. Results and Discussions for Fallujah

The optimization results for different system components are shown in Figure 5.18, and sensitivity analysis for various hybrid system configurations is shown in Figure 5.19. The compared optimization results of the base case with six systems designs are presented in Table 5.5.

Table 5.5. Comparison between systems in terms of cost and percentage of renewable fraction for Fallujah.

	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
NPC ($)	939,984	1.03M	1.11M	1.19M	2.53M	2.63M
COE($/KWh)	0.0448	0.0491	0.0530	0.0568	0.121	0.126
Operating Cost ($/yr)	24,289	22,941	27,781	29,815	47,667	49,595
Initial Capital ($)	625,982	732,677	753,495	806,318	1.92M	1.99M
Ren. Frac. (%)	31.6	35.6	34.9	34.2	45.8	46.1

The previous results showed the hybrid system that consists of PV panels/battery/converter/diesel generator and grid, which is the first case, has the least COE by comparing with the other systems, which is the best system to choose. Figure 5.20 shows the comparison of NPC between the base case which is in the grey line and the lowest cost system which is in the blue line [48].

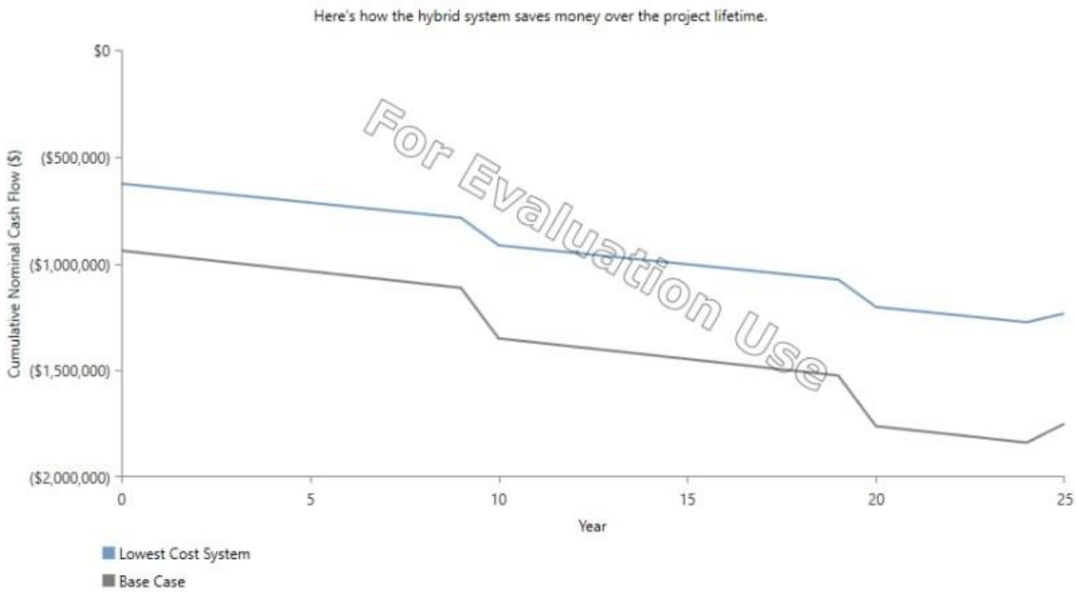


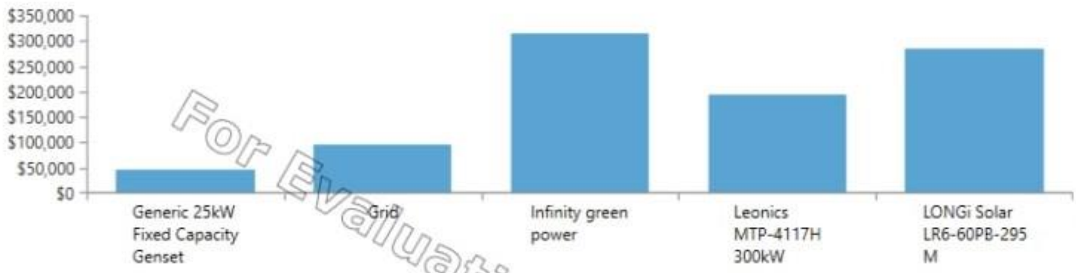
Figure 5.20. Comparison of NPC between lowest cost system and base case systemin Fallujah.

The annual produced electricity and consumption summary for the first system (case1) are shown in Figure 5.21 which illustrates the monthly average electricity production share for case 1 (PV / diesel generator/battery/converter and grid). For the first system, if there is any energy that is more than the area's demands, it will be charged to the batteries because the total production is 1,773,025 kWh/yr and the total consumption equals 1,622,636 kWh/yr. The PV system produces 37.4% of the total energy, 0.433 % from diesel generation, while the grid makes 62.2%. Figure 5.22 shows the cost summary.

Production	kWh/yr	%
LONGi Solar LR6-60PB-295M	663,256	37
Generic 25kW Fixed Capacity Genset	7,686	0.4
Grid Purchases	1,102,084	62
Total	1,773,025	10

Consumption	kWh/yr	%
AC Primary Load	1,622,636	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	1,622,636	100

Figure 5.21. Electric production and consumptionfor Fallujah.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic 25kW Fixed Capacity Genset	$12,500.00	$0.00	$4,246.69	$31,796.12	($808.51)	$47,734.30
Grid	$0.00	$0.00	$96,881.02	$0.00	$0.00	$96,881.02
Infinity green power	$250,000.00	$0.00	$64,637.58	$0.00	$0.00	$314,637.58
Leonics MTP-4117H 300kW	$110,753.01	$97,843.38	$0.00	$0.00	($13,265.88)	$195,330.52
LONGi Solar LR6-60PB-295M	$252,729.13	$0.00	$32,671.60	$0.00	$0.00	$285,400.73
System	$625,982.14	$97,843.38	$198,436.89	$31,796.12	($14,074.38)	$939,984.15

Figure 5.22. Cost summary for Fallujah.

For the first hybrid system, the annual PV power output for one year, battery’s state of charge, and generator power output are illustrated in Figures 5.23, 5.24, and 5.25

respectively. All information was showed by colors based on 360 days a year on the horizontal axis and 24 hours a day on the vertical axis from the left side.

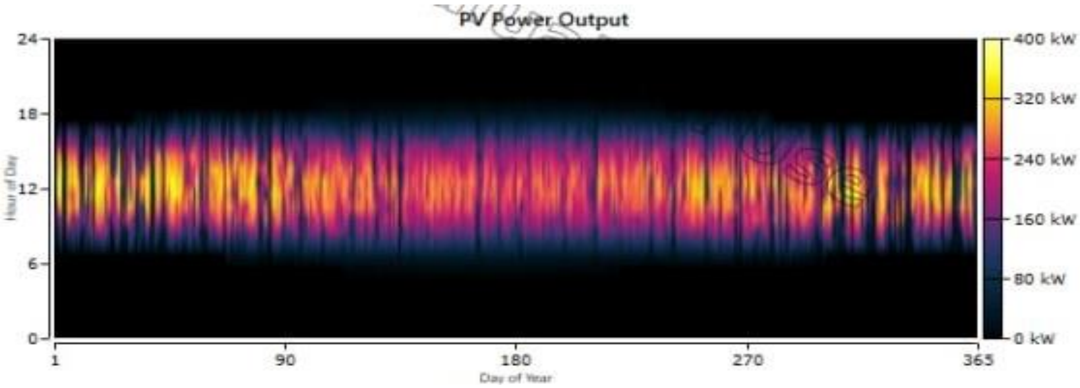


Figure 5.23. PV power output for Fallujah.

Figure 5.24. Charge of the battery for Fallujah.

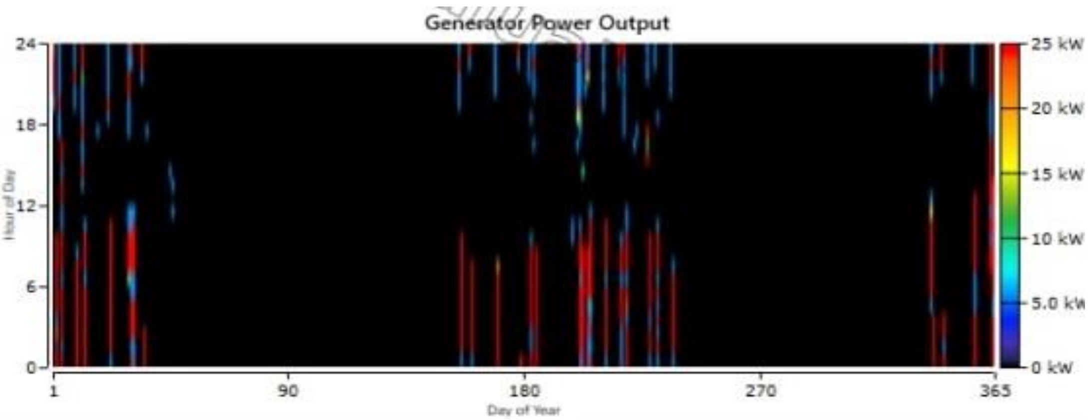


Figure 5.25. Generator output for a year for Fallujah.

The case-wise comparison of yearly emissions is given in Table 5.6. The quantities of carbon monoxide, particulate matter emissions, and unburned hydrocarbons have stable values for some cases and they equal zero in other cases. On the other hand, the difference was found in the amounts of Carbon Dioxide, Nitrogen Oxide, and Sulfur Dioxide from one system to another. The cost comparative analyzing between three regions as shown in Table 5.7

Table 5.6. Case-wise comparison of yearly emissions for Fallujah.

Emissions (kg/year)						
Quantity(kg/yr)	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
Carbon Dioxide	702,956	660,390	667,953	674,777	555,958	552,602
Carbon Monoxide	40.2	0	14.7	0	3.46	0
Unburned Hydrocarbons	1.77	0	0.650	0	0.152	0
Particulate Matter	0.241	0	0.0885	0	0.0207	0
Sulfur Dioxide	3,035	2,863	2,891	2,925	2,409	2,396
Nitrogen Oxides	1,515	1,400	1,425	1,431	1,181	1,172

Table 5.7. Economic comparison between the three regions.

	Altun kupri	**Khanaqin**	**Fallujah**
COE ($/kWh)	0.0507	0.0473	0.448
NPC ($)	1.09M	9992949	939984
Initial Cost ($)	749639	6665398	625982
Operating Cost($/yr)	26458	25337	24289

PART 6

CONCLUSION AND SUGGESTIONS

6.1. CONCLUSION

This thesis discussed the hybrid system that consists of photovoltaic panels, a wind turbine, a diesel generator, and a battery that was proposed to support the national grid, which suffers from a lack of electricity generation, for three residential complexes in three different regions in Iraq that are Altun Kupri, Khanaqin, and Fallujah. The research was carried out by utilizing a trial version of (HOMER) software. Yearly load data for the three regions were obtained from the directorates of the Iraqi ministry of electricity for the year 2021. The databases for solar radiation, wind speed, and temperatures were obtained directly from the official NASA website for the period of 1-1-2010 to 31-12-2021 according to the latitude and longitude for each area. The components of the system were selected in a very professional way, and the prices for each component were determined based on the reality of the local market at the time of the study.

HOMER suggested 6 systems for each region, techno-economic and environmental analyses were accomplished, and a comparative study was conducted of all the systems proposed by HOMER. The simulation and optimization results showed that the best system for the three regions is the first system which is the hybrid photovoltaic, diesel generator, converter, battery, and grid system. It is the most reliable, bridges the gap between generation and demand, and at the same time, it is the lowest-cost system in terms of the net present cost (NPC), the initial capital cost, and the cost of energy (COE). The optimal system differs from one region to another in the size of its components and cost. Through our findings in part five, Fallujah’s system was the least expensive among the rest regions, because it is characterized by high solar irradiation and high value of wind speed compared to Altun Kupri and Khanaqin.

In Fallujah, the first system was consisting of 410 kW solar panels, 25 kW diesel generator, a grid supply of 200 kW, 50 batteries (each battery providing 16.8 kWh, 51.2 V, and 328 Ah), 185 kW converter, with (NPC) of 939,984 dollars, and (COE) of 0.0448 dollars per kW, operating cost 24,289 dollars per year, initial capital cost 625,982 dollars, and 31.6% renewable fraction. The first system provided the required energy, but any energy that is more than the area's demands will be charged to the batteries because the total production is 1,773,025 kWh/year and the total consumption equals 1,622,636 kWh/yr. The PV system produces 37.4% of the total energy, 0.433 % from a diesel generator, while the grid makes 62.2%.

A sensitivity test for two parameters of solar radiation and wind speed was done. An attempt was made to invest in wind energy in the study areas and small wind turbines that match the wind speed were used, but it turned out that it is not feasible to utilize them because of their high cost and low energy generation, on the other hand, the monsoon wind speed is low in the selected areas.

6.2. SUGGESTIONS

- The study only considered three places in Iraq; thus, it may be useful to use the results and compare them with other regions in Iraq by considering the feature of energy selling to the national grid.
- The research may be also carried out by getting the actual data of solar irradiation and wind speed in a given place and comparing the findings with values obtained from NASA.
- It is possible to study the feasibility of the hybrid system in supplying other electrical loads such as governmental, industrial, commercial, and agricultural loads.
- Sensitivity testing can be used for more parameters such as fuel prices and other parameters.

REFERENCES

1. Khare, V., Nema, S., & Baredar, P., "Solar–wind hybrid renewable energy system: A review", ***Renewable and Sustainable Energy Reviews,*** 5(8): 23-33 (2016).

2. Deshmukh, M. K., & Deshmukh, S. S., "Modeling of hybrid renewable energy systems", ***Renewable and Sustainable Energy Reviews,*** 12(1): 235-249 (2008).

3. Albaba, M., "Theoretical simulation and optimization of the hybrid renewable energy systems", ***Doctoral dissertation, Yıldırım Beyazıt Üniversitesi Fen Bilimleri Enstitüsü***, Ankara, 12-18 (2019).

4. Internet: "Energy supply in Iraq", **iea.org/countries/iraq** (2012).

5. Bahta, S. T., "Design and analyzing of an off-grid hybrid renewable energy system to supply electricity for rural areas: case study: Atsbi district", ***North Ethiopia,*** Ethiopia, 12-19 (2013).

6. U.S. Energy Information Administration, "Country analysis executive summary: Iraq", ***Joint Oil Data Initative,*** Iraq, 43-46 (2021).

7. Vakhshouri, A. K., "Iraq's energy security strategy: A path to diversity and energy independence the other side of the crisis: energy dependence", ***Issue Brief,*** 19-28 (2020).

8. Rashid, S., "Electricity problem in Iraq related papers", ***Ministry of Electctricity Report,*** 12-19 (2012).

9. Al-Khafaji, H., "Electricity generation in Iraq Problems and solutions", ***Al-Bayan Center for Planning and Studies***, Iraq, 1-12 (2018).

10. Mahmood, N. S., Ajmi, A. A., Sarip, S. B., Kaidi, H. M., Jamaludin, K. R., & Talib, H. H. A., "Modeling the sustainable integration of quality and energy management in power plants", ***Sustainability,*** 14(4): 24-60 (2022).

11. Internet: "Data and statistics", **https://www.iea.org/data-and-statistics/data-browser?country=WORLD&fuel=Energyconsumption&indicator=CO2 Industry/** (2021).

12. Internet: "Civil generators illuminate Iraqi homes", **https://www.independ entarabia.com/node/264976/**(2021).

13. Ismael, A. I., "Off-grid electricity generation with hybrid renewable energy technologies in Iraq: an application of homer: electrical", ***Diyala Journal of Engineering Sciences,*** 8(4): 277-286 (2015).

14. Internet: "NASA", **https://power.larc.nasa.gov/data-access-viewer**/(2021).

15. Udayakanthi, G., "Design of a Wind-Solar Hybrid Power Generation System in Sri Lanka", ***Master of Science Thesis, KTH School of Industrial Engineering and Management,*** Sri Lanka, 23-31 (2015).

16. Muh, E., & Tabet, F., "Comparative analysis of hybrid renewable energy systems for off-grid applications in Southern Cameroons", ***Renewable Energy,*** 13(5): 41-54 (2019).

17. Al-Shammari, Z. W., Azizan, M. M., Rahman, A. S. F., & Hasikin, K., "Analysis on renewable energy sources for electricity generation in remote area of Iraq by using HOMER: A case study", ***In AIP Conference Proceedings***, 23(39): 2-7 (2021).

18. Abdelmjid, S. A. K. A., "Techno-economic Assessement of Hybrid Energy System for a Stand-alone Load in Morocco", ***International Journal of Renewable Energy Research (IJRER),*** 10(4): 1774-1782 (2020).

19. Al-Sarraj, A. T., Salloom, H. K., Mohammad, K., & Ghareeb, M. M., "Simulation Design of hybrid System (Grid/PV/Wind Turbine/battery/diesel) with applying HOMER: A case study in Baghdad Iraq", ***International Journal of Electronics and Communication Engineering,*** *7*(5): 10-18 (2020).

20. Ibrahim, M. H. & Ibrahim, M. A., "Solar-wind hybrid power system analysis using homer for Duhok, Iraq", ***Prz. Elektrotechniczny,*** 9(2):139–143 (2021).

21. Budes, F. A. B., Ochoa, G. V., Obregon, L. G., Arango-Manrique, A., & Álvarez, J. R. N., "Energy, Economic, and Environmental Evaluation of a Proposed Solar-Wind Power On-grid System Using HOMER Pro®: A Case Study in Colombia", ***Energies,*** 13(7): 1-19 (2020).

22. Aziz, A. S., Tajuddin, M. F. N., Adzman, M. R., Mohammed, M. F., & Ramli, M. A., "Feasibility analysis of grid-connected and islanded operation of a solar PV microgrid system: A case study of Iraq", ***Energy,*** 19(1): 116-591 (2020).

23. Niyonteze, J. D. D., Zou, F., Asemota, G. N. O., Bimenyimana, S., & Shyirambere, G., "Key technology development needs and applicability analysis of renewable energy hybrid technologies in off-grid areas for the Rwanda power sector", ***Heliyon,*** 6(1): 3-30 (2020).

24. Aziz, N. G., "Design of A Grid-Tied Solar Plant Using Homer Pro and an Optimal Home Energy Management System", ***Nagarjuna College of Engineering and Technology, Institute of Electrical and Electronics Engineers. Bangalore Section,*** India, 12-19 (2020).

25. Aziz, A. S., Tajuddin, M. F. N. B., & Adzman, M. R., "Feasibility analysis of PV/wind/battery hybrid power generation: a case study", ***International Journal of Renewable Energy Research,*** 8(2): 661-671 (2018).

26. Khalil, L., Bhatti, K. L., Awan, M. A. I., Riaz, M., Khalil, K., & Alwaz, N., "Optimization and designing of hybrid power system using HOMER pro", ***Materials Today: Proceedings,*** 4(7): 110-115 (2021).

27. Abada, H. H., Al-Shamani, A. N., & Faisal, M. D., "A grid connected PV system for a rural resident in Al-Najaf, Iraq", ***In AIP Conference Proceedings,*** 22(90): 5056 (2020).

28. Al-Hamdani, A. H., Dawood, A. F., Abdullah, K. N., & Mousaui, S. M., "Optimal sizing of photovoltaic systems using HOMER for Baghdad", ***International Journal of Computation and Applied Sciences,*** 1(2): 1-6 (2016).

29. Hassan, Q., Jaszczur, M., & Abdulateef, J., "Optimization of PV/wind/diesel hybrid power system in homer for rural electrification", ***In Journal of Physics: Conference Series,*** 745(3): 32-60 (2016).

30. Jeyanathan, A., Chew, S., Stevenson, D., & Cipcigan, L., "Whole life costing of off-grid power supplies for rail level crossing safety systems", ***In 2021 56th International Universities Power Engineering Conference,*** Middlesbrough, United Kingdom, 1-6 (2021).

31. Khasawneh, H. J., Mustafa, M. B., Al-Salaymeh, A., & Saidan, M., "Techno-economic evaluation of on-grid battery energy storage system in Jordan using Homer Pro", ***In 2019 AEIT International Annual Conference (AEIT),*** Florence, Italy 1-6 (2019).

32. Siddique, M. N., Ahmad, A., Nawaz, M. K., & Bukhari, S. B. A., "Optimal integration of hybrid (wind--solar) system with diesel power plant\newline using HOMER", ***Turkish Journal of Electrical Engineering & Computer Sciences,*** 23(6): 1547-1557 (2015).

33. Al-Hafidh, M. S. M. and Ibrahem, M. H., "Hybrid power system for residential load", ***in 2013 International Conference on Electrical, Communication, Computer, Power, and Control Engineering,*** Iraq, 70–75 (2014).

34. Al-Hardanee, T., "Design and improvement of an intelligent control system to solve the dam ground water problem", ***Ankara Yildirim Beyazit University Graduate School of Natural And Applied Sciences,*** Ankara, 34-45 (2019).

35. Sumathi, S., Kumar, L. and Surekha, P., "Solar PV and wind energy conversion systems", ***Springer,*** Germany, 34-56 (2015).

36. Tzanakis, I., "Combining Wind and Solar Energy to Meet Demands in the Built Environment", ***University of Strathclyde, Master Thesis,*** United Kingdom, 12-19 (2006).

37. Alshamri, H. A. H., "Optimal sizing of hybrid renewable systems to improve electricity supply reliability in Iraqi domestic dwellings", ***Doctoral Dissertation, University of Leeds,*** United Kingdom, 23-45 (2019).

38. Internet: "Renewable and nonrenewable energy", **https://sciencelecturer.com/ renewable-and-nonrenewable-resources/** (2022).

39. Saffar, A. W., "Battery charge control for standalone PV system by using Matlab/Simulink", ***Master Thesis, Karabuk University,*** Turkey, 12-19 (2021).

40. Hilal, A., Raulet, M. A., Martin, C., & Sixdenier, F., "Power Loss Prediction and Precise Modeling of Magnetic Components in DC-DC Power Converter Application", ***Lyon University,*** France, 1-13(2019)

41. Internet: "Buck", **https://www.electronics-lab.com/analysis-buck-converter-efficiency**/(2021).

42. Internet: "Single phase and three phase", **https://www.watelectrical.com/ what-is-an-inverter-working-principle-classification-applications/**(2021).

43. Jäger, K. D., Isabella, O., Smets, A. H., van Swaaij, R. A., & Zeman, M., "Solar energy: fundamentals, technology and systems", ***UIT Cambridge,*** United Kingdom, 37–40 (2016).

44. Internet: "Advantages and disadvantages of Solar Photovoltaic", **https://www.renewableenergyworld.com/storage/advantages-and disadvant a ges -of-solar-photovoltaic-quick-pros-and-cons-of-solar-pv/#gref** (2022).

45. Abad, G., & Iwanski, G., "Properties and control of a doubly fed induction machine", ***Power electronics for renewable energy systems, transportation and industrial applications,*** 1(8): 270-318 (2014).

46. Apata, O., & Oyedokun, D. T. O., "An overview of control techniques for wind turbine systems", ***Scientific African,*** *10(2):* 4-13 (2020).

47. Abad, G., Lopez, J., Rodriguez, M., Marroyo, L., & Iwanski, G., "Doubly fed induction machine: modeling and control for wind energy generation", ***John Wiley & Sons,*** USA, 35-48 (2011).

48. Yusupov, Ş. U. Z., "Techno-economic analysis of KBU MG_Sigma_Revised-2", 39(4): 23-33 (2021).

49. Internet: "homer pro manual net present cost (NPC)", **https://www.home renergy .com/products/pro/docs/latest/net_present_cost.html** (2022).

50. Internet: "Homer pro manual cost of energy (COE)", **https://www.homeren ergy.com/products/pro/docs/latest/levelized_cost_of_energy.html** (2022).

51. Abd Ali, L. M., Al-Rufaee, F. M., Kuvshinov, V. V., Krit, B. L., Al-Antaki, A. M., & Morozova, N. V., "Study of hybrid wind–solar systems for the Iraq energy complex", ***Applied Solar Energy,*** 56(4): 284-290 (2020).

52. Basheer, A. G. M. F. S., & AL-khuwaylidee, I. K. R., "The Climate Assessment of Iraq Region", ***J Nat Sci Res,*** 6(20): 66-70 (2016).

53. Internet: "Geography", **http://www.iraqiembassy.us/page/geograph y**/(2021).

54. Basheer, A. G. M. F. S., & AL-khuwaylidee, I. K. R., "The climate assessment of iraq region", ***J Nat Sci Res,*** *6*(20): 66-70 (2016).

55. Internet: "Global horizontal irradiation", **https://solargis.com/maps-and-gis-data/download/iraq** (2021).

56. Internet: "Altun kupri", **http://www.maplandia.com/iraq/arbil/altun-kupri/** (2021).

57. Internet: Khanaqin, "Bagdad, Baghdād, Madīnat al-Salām, the Round City", **https://www.britannica.com/place/Khanaqin** (2021).

58. Internet: Fallujah, "Al-Fallūjah, Falluja", **https://www.britannica.com /place/Fallujah** (2021).

59. Basheer, M. J., "Solar energy applications in Iraq: a review", ***Int. J. Sci. Eng. Sci,*** *1*(9): 30-39 (2017).

60. Mishaal, A. K., Abd Ali, A. M., & Khamees, A. B., "Wind Distribution Map of Iraq-A Comparative Study", ***In IOP Conference Series: Materials Science and Engineering***, 928(2):22-44) (2020).

61. Marty, P. F., "Design of a hybrid power PV–Genset–Battery storage system for a remote off-grid application in Malaysia", ***School of Industrial Engineering and Management (ITM), Energy Technology, Heat and Power Technology***, Malaysia, 12-23 (2016).

62. Internet: Longi A. "SOLAR-Alibaba.com”, **https://www.alibaba.com/ product-detail/solar-panels-Certificate-LONGi-single550_62024991161.ht ml ?spm =a2700. shop _plgr. 41413.28.459c1a7cIfxFv9** (2022).

63. Jenkins, P., Elmnifi, M., Younis, A., & Emhamed, A., "Hybrid power generation by using solar and wind energy: case study", ***World Journal of Mechanics,*** 9(4): 81-93 (2019).

RESUME

Eman Mohammad Sami Ali AL-JANABY was born in Iraq in 1981 and she graduated first and elementary education in Diyala governorate. She holds a bachelor’s degree in electronic engineering from the University of Diyala, College of Engineering which she graduated in 2003, after that, she started to complete her M. Sc. education, and she moved to Karabük University