T.R.
SAKARYA UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DESIGN OF HYBRID SOLAR WIND SYSTEM FOR SUSTAINABLE ENERGY STORAGE: A CASE STUDY RUTBA CITY

MSc THESIS

Ahmed Basem Mohammd ALDULAEMI

Electrical and Electronics Engineering Department

JUNE 2023

T.R.
SAKARYA UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DESIGN OF HYBRID SOLAR WIND SYSTEM FOR SUSTAINABLE ENERGY STORAGE: A CASE STUDY RUTBA CITY

MSc THESIS

Ahmed Basem Mohammd ALDULAEMI

Electrical and Electronics Engineering Department

Thesis Advisor: Prof.Dr. Cenk YAVUZ

JUNE 2023

The thesis work titled "DESIGN OF HYBRID SOLAR WIND SYSTEM FOR SUSTAINABLE ENERGY STORAGE: A CASE STUDY RUTBA CITY" prepared by Ahmed BASEM MOHAMMED was accepted by the following jury on 26/06/2023 by unanimously/~~majority~~ of votes as a MSc THESIS in Sakarya University Graduate School of Natural and Applied Sciences, electrical engineering department.

Thesis Jury

Head of Jury :	**Prof. Dr. Cenk YAVUZ** (Advisor) Sakarya University	....
Jury Member :	**Assoc. Prof. Dr. Ceyda AKSOY TIRMIKÇI** Sakarya University	....
Jury Member :	**Assist. Prof. Dr. Nur SARMA** Düzce University	....

STATEMENT OF COMPLIANCE WITH THE ETHICAL PRINCIPLES AND RULES

I declare that the thesis work titled " DESIGN OF HYBRID SOLAR WIND SYSTEM FOR SUSTAINABLE ENERGY STORAGE: A CASE STUDY RUTBA CITY", which I have prepared in accordance with Sakarya University Graduate School of Natural and Applied Sciences regulations and Higher Education Institutions Scientific Research and Publication Ethics Directive, belongs to me, is an original work, I have acted in accordance with the regulations and directives mentioned above at all stages of my study, I did not get the innovations and results contained in the thesis from anywhere else, I duly cited the references for the works I used in my thesis, I did not submit this thesis to another scientific committee for academic purposes and to obtain a title, in accordance with the articles 9/2 and 22/2 of the Sakarya University Graduate Education and Training Regulation published in the Official Gazette dated 20.04.2016, a report was received in accordance with the criteria determined by the graduate school using the plagiarism software program to which Sakarya University is a subscriber, I accept all kinds of legal responsibility that may arise in case of a situation contrary to this statement.

17/05/2023

Ahmed Basem Mohammd ALDULAEMI

I dedicate this research to God and the individuals for whom I have always sought their fulfilment more than that of others: my mother and my late father, who will always hold a special place in my heart; may Allah have mercy on him.

To my honourable professor Dr. Cenk YAVUZ, who gave me all the credit for the accomplishment I am enjoying today and who believed in me, supported, and helped me,

To you, Dr. Saif, my family, brothers, and friends. With all of their ups and downs, Dr. Ibraheem, the stunning and brilliant ruhmaa, and friend of all days,

To devoted close friends, my dear brother-in-law Mr. Firas, attorney Ahmed, and engineer Badran, who have never stopped offering assistance, support.

ACKNOWLEDGMENTS

It was really lovely to have you by my side on my special day. You made my graduation more special.

Mom and Dad, you both are the priceless blessing in my life. I wouldn’t know where today I am without your inspiration and support. Thank you for all your guidance!

Thank you for taking the time out and wishing me a good graduation. Your kind words are priceless. Love you.

Without your contribution, this would never be possible. Thank you, dear teacher.

Thanks for your generosity and special thanks for the graduation card. I appreciate you every day.

Receiving your wish has made my graduation seem even more joyous! Thank you for all the love and blessings.

Ahmed Basem Mohammd ALDULAEMI

TABLE OF CONTENTS

Sayfa

ABBREVIATIONS

CC	: Cycle Charging
COE	: Cost of Energy
CO_2	: Carbon Dioxide
CRF	: Capital Recovery Factor
HES	: Hybrid Energy System
HOMER	: Hybrid Optimization of Multiple Energy Resources
LF	: Load Following
NASA	: National Aeronautics and Space Administration
NOx	: Nitrogen Oxide
NPC	: Net Present Cost
O and M	: Operation And Maintenance
PV	: PhotoVoltaic
RES	: Renewable Energy Source
SO_2	: Sulfur Dioxide

SYMBOLS

a, β, and γ	: Smoothing Constants
$C_{ann,total}$	: Total Yearly Cost
$C_{batt,energy}$	: Battery Energy Cost
$C_{batt,w}$	: Battery Wear Cost
$C_{cc,i}$	: Cycle Charging Cost In Time Step i
C_{disch}	: Battery Discharging Cost
C_T	: Temperature Coefficient Of Power
D_{PV}	: Derating Factor
$E_{cc,i}$	: Value Of Stored Energy In The Battery In Time Step i
E_{served}	: Yearly Electrical Energy That Is Used To Supply The Load
$F_{t+\tau}$	: Forecast For τ Periods Ahead
i	: Yearly Real Interest Rate
L_t	: Level Components
m_t	: Trend Component
N_{batt}	: Number Of Batteries In The Storage Bank
s	: Length Of Seasonality
S_t	: Seasonal Component
P_{in}	: Input Power Of Converter
P_L	: Load Demand
P_{out}	: Output Power Of Converter
P_{PV}	: PV Output Power
$P_{PV,STC}$	: PV Array Rated Power
Q_{life}	: Throughput Of A Single Battery
R_S	: Amount Of Solar Radiation Striking The PV Array
$R_{S,STC}$	: Standard Radiation
T_C	: PV Cell Temperature
T_p	: Project Lifetime
T_{STC}	: PV Cell Temperature Under Standard Test Condition
Y_t	: Actual Observed Value
η_{inv}	: Inverter Efficiency

η_{rect} : Rectifier Efficiency

η_{rt} : Battery Round-Trip Efficiency

LIST OF TABLES

Page

LIST OF FIGURES

Page

DESIGN OF HYBRID SOLAR WIND SYSTEM FOR SUSTAINABLE ENERGY STORAGE: A CASE STUDY RUTBA CITY

SUMMARY

In today's world, generating power from renewable sources is an alternative. The environment and human ecology are being severely impacted by power generating using conventional energy. There is an abundance of renewable energy across the cosmos. Clean, environmentally friendly, efficient, and dependable energy comes from renewable sources. In the modern world, solar and wind power are becoming increasingly important. The project's goal is to use Matlab/Simulink to create a grid-connected hybrid power generation system that uses both solar and wind energy.

The available solar irradiance, sunshine hours, temperature, wind speed, wind direction, and topography are taken into consideration when designing the model. Using the data, a model that combines the energy from solar and wind resources can be created. Over areas of Iraq, there is an average solar irradiation of 5.68 KW/m2/day and a wind speed of 12.9 mph. Since Iraq is between the Tropic of Cancer and the Equator, its average annual temperature is 28°C. Additionally, standalone PV and wind models are simulated. Solar panels, (P&O) MPPT, a boost converter, an inverter, a wind turbine, and a PMSG generator are all components of the hybrid model and are all connected to the grid. The PV model is simulated with various irradiance and temperature conditions, and output is assessed. Simulated hybrid model results from Matlab are examine.

The increasing demand for sustainable and renewable energy sources has led to the exploration of hybrid systems that combine solar and wind power. This study focuses on the design of a hybrid solar wind system for sustainable energy storage, using Rutba City as a case study. The objective is to propose an optimal configuration that maximizes energy generation and storage capacity while minimizing costs and environmental impacts.

The research methodology involves a comprehensive analysis of the local climatic conditions, solar radiation data, wind speed patterns, and energy consumption patterns in Rutba City. The design process includes selecting appropriate solar panels, wind turbines, batteries, and inverters based on their technical specifications and compatibility with the hybrid system.

The sizing and optimization of the hybrid system are performed using mathematical models and simulation tools. Different scenarios are considered, including variations in solar and wind resources, energy demand, and system configurations. The performance of the hybrid system is evaluated based on key parameters such as energy generation, storage capacity, reliability, and cost-effectiveness.

The results indicate that the hybrid solar wind system offers significant advantages over standalone solar or wind systems. By utilizing both solar and wind resources, the system achieves a higher overall energy generation capacity and improved reliability, as the availability of one resource compensates for the intermittent of the other. The

energy storage component plays a crucial role in balancing energy supply and demand, ensuring a continuous power supply during periods of low solar or wind availability.

Furthermore, the economic analysis reveals that the hybrid system presents a favorable return on investment compared to standalone systems. The cost savings are achieved through efficient utilization of resources and optimized system sizing. Additionally, the environmental impact assessment demonstrates a substantial reduction in greenhouse gas emissions and a decrease in reliance on fossil fuel-based power generation.

This study contributes to the field of sustainable energy systems by providing insights into the design and optimization of hybrid solar wind systems. The findings from the Rutba City case study can serve as a valuable reference for similar regions with similar climatic conditions. The proposed hybrid system offers a reliable, cost-effective, and environmentally friendly solution for sustainable energy storage, promoting the transition towards a greener energy future.

The paper begins with an overview of the current energy scenario in Rutba City and the challenges associated with conventional energy sources. It emphasizes the importance of transitioning to renewable energy for meeting the growing energy demands sustainably. next, the researchers delve into the design and integration of a hybrid solar-wind system. The system aims to harness both solar and wind energy to ensure continuous power generation regardless of weather conditions. The paper provides details about the sizing, installation, and configuration of solar panels, wind turbines, and energy storage devices.

The researchers conducted a feasibility study to evaluate the economic viability and environmental impact of the proposed system. They considered factors such as initial setup costs, operational expenses, maintenance requirements, and potential energy savings over the system's lifespan. Moreover, the paper discusses the implementation process and the technical challenges faced during the installation. It also highlights the performance of the hybrid system under various weather conditions and how it copes with the intermittent of solar and wind resources.

A crucial aspect of renewable energy systems is energy storage. The researchers explore various energy storage technologies suitable for the hybrid solar-wind system. Battery storage, pumped hydro storage, and compressed air energy storage are among the options evaluated for their feasibility, cost-effectiveness, and environmental impact.

The study also addresses the issue of grid integration. The researchers analyze the compatibility of the hybrid system with the existing power grid infrastructure in Rutba City. Strategies for managing grid stability, power quality, and grid-tie inverters are explored to facilitate seamless energy injection into the grid.

Furthermore, the paper outlines the regulatory and policy frameworks governing renewable energy adoption in Rutba City and the broader region. It highlights the importance of supportive government policies, feed-in tariffs, and incentives to encourage investments in renewable energy projects.

To assess the environmental impact of the proposed system, a comprehensive life cycle assessment (LCA) is conducted. The LCA evaluates the system's greenhouse gas emissions, energy payback time, and overall sustainability in comparison to conventional energy sources.

The research also considers the socio-economic impacts of implementing the hybrid solar-wind system. Job creation, skill development, and potential socioeconomic benefits for the local community are analyzed to understand the project's broader implications.

In conclusion, the study showcases the successful integration of a hybrid solar-wind system in Rutba City, demonstrating its potential as a sustainable energy solution for other regions facing similar energy challenges. The research emphasizes the importance of adopting renewable energy technologies to reduce greenhouse gas emissions, combat climate change, and promote a greener future.

SÜRDÜRÜLEBİLİR ENERJİ DEPOLAMASI İÇİN HİBRİT GÜNEŞ RÜZGAR SİSTEMİNİN TASARIMI: RUTBA ŞEHİRİ ÖRNEK ÇALIŞMASI

ÖZET

Bugünün dünyasında, yenilenebilir kaynaklardan güç üretmek bir alternatiftir. Çevre ve insan ekolojisi, geleneksel enerji kullanarak güç üretimi tarafından ciddi şekilde etkilenmektedir. Kozmosun her tarafında bol miktarda yenilenebilir enerji bulunmaktadır. Temiz, çevre dostu, verimli ve güvenilir enerji, yenilenebilir kaynaklardan gelir. Günümüz dünyasında, güneş ve rüzgar enerjisi giderek daha önemli hale gelmektedir. Bu proje, hem güneş hem de rüzgar enerjisini kullanan bir şebekeye bağlı hibrit enerji üretim sistemi oluşturmak için Matlab/Simulink kullanmayı amaçlamaktadır.

Model tasarımında, mevcut güneş ışınımı, güneş saatleri, sıcaklık, rüzgar hızı, rüzgar yönü ve topografya dikkate alınır. Veriler kullanılarak güneş ve rüzgar kaynaklarından enerjiyi birleştiren bir model oluşturulabilir. Irak'ın bazı bölgelerinde ortalama güneş ışınımı 5.68 KW/m2/gün ve rüzgar hızı 12.9 mil/saat olarak ölçülmüştür. Irak, Dönencesel Tropik ve Ekvator arasında bulunduğu için ortalama yıllık sıcaklığı 28°C'dir. Ayrıca, bağımsız PV ve rüzgar modelleri de simüle edilmiştir. Güneş panelleri, (P&O) MPPT, yükseltici dönüştürücü, invertör, rüzgar türbini ve PMSG jeneratörü, hibrit modelin bileşenleri olup hepsi şebekeye bağlıdır. PV modeli, çeşitli ışınım ve sıcaklık koşullarıyla simüle edilir ve çıkışı değerlendirilir. Matlab ile simüle edilen hibrit modelin sonuçları incelenir.

Sürdürülebilir ve yenilenebilir enerji kaynaklarına olan artan talep, güneş ve rüzgar enerjisini birleştiren hibrit sistemlerin araştırılmasına yol açmıştır. Bu çalışma, Rutba Şehri'nde sürdürülebilir enerji depolama için bir hibrit güneş rüzgar sistemi tasarımına odaklanmaktadır. Amaç, enerji üretimini ve depolama kapasitesini maksimize ederken maliyetleri ve çevresel etkileri minimize eden en uygun yapılandırmayı önermektir.

Araştırma metodolojisi, Rutba Şehri'nin yerel iklim koşullarının, güneş ışınımı verilerinin, rüzgar hızı desenlerinin ve enerji tüketimi desenlerinin kapsamlı bir analizini içermektedir. Tasarım süreci, teknik özelliklerine ve hibrit sisteme uyumluluklarına dayanarak uygun güneş panelleri, rüzgar türbinleri, piller ve invertörlerin seçimini içerir.

Hibrit sistemlerin boyutlandırılması ve optimize edilmesi matematiksel modeller ve simülasyon araçları kullanılarak gerçekleştirilir. Farklı senaryolar, güneş ve rüzgar kaynaklarındaki değişiklikler, enerji talebi ve sistem yapılandırmaları göz önünde bulundurulur. Hibrit sistemin performansı, enerji üretimi, depolama kapasitesi, güvenilirlik ve maliyet-etkinlik gibi temel parametrelere dayanarak değerlendirilir.

Sonuçlar, hibrit güneş rüzgar sisteminin tek başına güneş veya rüzgar sistemlerine kıyasla önemli avantajlar sunduğunu göstermektedir. Hem güneş hem de rüzgar kaynaklarını kullanarak sistem, daha yüksek toplam enerji üretim kapasitesine ve geliştirilmiş güvenilirliğe ulaşır, çünkü bir kaynağın aralıklı olduğu durumlarda diğeri bulunabilirliğini karşılar. Enerji depolama bileşeni, enerji arzı ve talebini dengelemede

önemli bir rol oynar, böylece düşük güneş veya rüzgar bulunabilirliği dönemlerinde sürekli bir güç sağlanır.

Ayrıca, ekonomik analiz, hibrit sistemin tek başına sistemlere kıyasla olumlu bir yatırım getirisi sunduğunu göstermektedir. Maliyet tasarrufu, kaynakların verimli kullanımı ve optimize edilmiş sistem boyutlandırmasıyla elde edilir. Ek olarak, çevresel etki değerlendirmesi, sera gazı emisyonlarında önemli bir azalma ve fosil yakıt temelli güç üretimine olan bağımlılığın azalmasını göstermektedir.

Bu çalışma, hibrit güneş rüzgar sistemlerinin tasarımı ve optimize edilmesine ilişkin görüşler sunarak sürdürülebilir enerji sistemleri alanına katkıda bulunmaktadır. Rutba Şehri örneğiyle elde edilen bulgular, benzer iklim koşullarına sahip diğer bölgeler için değerli bir referans olabilir. Önerilen hibrit sistem, sürdürülebilir enerji depolama için güvenilir, maliyet-etkin ve çevre dostu bir çözüm sunarak daha yeşil bir enerji geleceğine yönelik geçişi teşvik eder.

Makale, Rutba Şehri'ndeki mevcut enerji durumunun genel bir açıklamasıyla başlar ve geleneksel enerji kaynaklarıyla ilişkili zorluklara vurgu yapar. Büyüyen enerji talebini sürdürülebilir bir şekilde karşılamak için yenilenebilir enerjiye geçişin önemine vurgu yapar. Ardından, araştırmacılar hibrit güneş rüzgar sisteminin tasarımına ve entegrasyonuna derinlemesine girer. Sistem, hava koşullarından bağımsız olarak sürekli güç üretmeyi sağlamak amacıyla hem güneş hem de rüzgar enerjisini kullanmayı hedefler. Makale, güneş panelleri, rüzgar türbinleri ve enerji depolama cihazlarının boyutlandırılması, kurulumu ve yapılandırması hakkında detaylar sağlar.

Araştırmacılar, önerilen sistemin ekonomik sağlamlığını ve çevresel etkisini değerlendirmek için bir fizibilite çalışması yaparlar. Sistem kurulumu maliyeti, işletme giderleri, bakım gereksinimleri ve sistemin ömrü boyunca potansiyel enerji tasarrufları gibi faktörler göz önünde bulundurulur. Ayrıca, makale, kurulum sırasında karşılaşılan teknik zorlukları vurgular. Ayrıca, hibrit sistemin farklı hava koşullarında performansı ve güneş ile rüzgar kaynaklarının aralıklı olduğu durumlarla nasıl başa çıktığına dair bilgiler sunar.Yenilenebilir enerji sistemlerinin önemli bir yönü enerji depolamadır. Araştırmacılar, hibrit güneş rüzgar sistemi için uygun çeşitli enerji depolama teknolojilerini araştırır. Pil depolama, su pompalı hidro depolama ve sıkıştırılmış hava enerjisi depolama, uygulanabilirlikleri, maliyet-etkinlikleri ve çevresel etkileri açısından değerlendirilen seçenekler arasındadır. Çalışma ayrıca şebeke entegrasyonu konusuna da değinir. Araştırmacılar, hibrit sistemin, Rutba Şehri'ndeki mevcut güç şebekesi altyapısıyla uyumluluğunu analiz ederler. Şebeke kararlılığını yönetmek, güç kalitesini sağlamak ve şebekeye bağlı invertörleri kullanarak enerji enjeksiyonunu kolaylaştırmak için stratejiler incelenir. Ayrıca, makale, Rutba Şehri ve daha geniş bir bölgede yenilenebilir enerji benimsemesini düzenleyen yasal ve politika çerçevelerini de açıklar. Hükümet politikalarının, besleme tarifelerinin ve teşviklerin yenilenebilir enerji projelerine yatırım yapmayı teşvik etmek açısından önemini vurgular.

Önerilen sistemin çevresel etkisini değerlendirmek için kapsamlı bir yaşam döngüsü değerlendirmesi (LCA) yapılır. LCA, sistemdeki sera gazı emisyonlarını, enerji geri ödeme süresini ve genel sürdürülebilirliği geleneksel enerji kaynaklarıyla karşılaştırarak değerlendirir. Araştırma ayrıca hibrit güneş rüzgar sisteminin sosyo-ekonomik etkilerini ele alır. İş yaratma, beceri geliştirme ve yerel toplum için potansiyel sosyo-ekonomik faydaları analiz ederek projein genişlemiş etkilerini anlamak için çalışır. Sonuç olarak, çalışma, Rutba Şehri'nde hibrit güneş rüzgar sisteminin başarılı entegrasyonunu sergileyerek benzer enerji zorluklarıyla karşı karşıya olan diğer bölgeler için sürdürülebilir bir enerji çözümü olarak potansiyelini göstermektedir. Araştırma, sera gazı emisyonlarını azaltma, iklim değişikliğiyle mücadele etme ve daha yeşil bir geleceği teşvik etme konusundaki önemi vurgulamaktadır.

1. INTRODUCTION

The ability to acquire energy is a key factor in any country's ability to grow. It is essential to the growth and economics of the country. For us, the main energy-producing sources are coal, oil, and natural gas. It is well known that energy is needed for industrial, agricultural, commercial, and domestic applications. The world's demand for energy is growing every day. There are numerous ways to produce energy from coal, fossil fuels, oil, and other gases. [3]. However, there are limitations on how and when each of these sources may be used because they are all harmful to the environment. Because of environmental pollution and global warming, we require clean energy sources. Eco-green energy, or the production of energy without harming the environment, is the key focus in today's globe. Then, we can select from a variety of renewable energy sources, such as solar, wind, small hydro, biomass, and biofuel. The use of renewable energy to meet energy demand has a lot of promise. However, employing these energy sources has some serious downsides, and numerous experiments are being done to improve their efficiency. Systems for preventing global warming and carbon emissions should be implemented since protecting natural resources should be the top priority. The country will save money by transitioning to renewable sources rather than coal or other fossil fuels to produce electricity. Using this renewable resource to generate power is expected to reduce CO2 emissions [9]. As was already said, there are a variety of renewable energy sources, but wind and solar energy are the most prevalent. When we talk about renewable energy sources, the first things that come to mind are wind and sun because they are well-known energy sources and are everywhere. Single sources of energy like wind and PV are not totally reliable due to climate change, nighttime sunshine, the rainy season, and changes in wind speed [1]. Before deciding whether or not it is suitable for use in a solar application, it must first establish the amount of solar radiation that is accessible in a country. As a result, "insolation" refers to the quantity of solar radiation energy that is received on a certain region of the surface over a particular period of time [2]. Irradiance is often measured in terms of (W/m^2) or ($kWh/(m^2 \cdot day)$) or (hours/day). According to Figure

1.1, Iraq is one of the nations in this area with the highest levels of solar radiation, indicating that it is an appropriate location for implementing solar technologies.

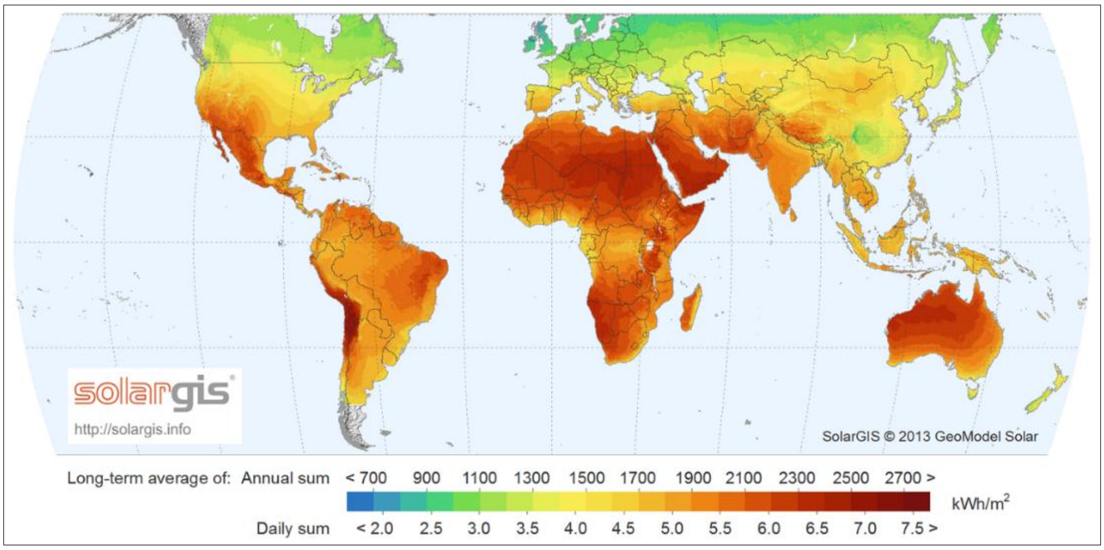


Figure 1.1. Solar irradiation map *[3]*.

1.1. Hybrid Wind-Solar Power System

Solar energy and wind energy have been integrated in this system in order to generate power from both of the aforementioned sources. Hybrid systems provide a number of benefits over systems that simply use a single source of energy in their operation. Academics have a highly challenging task when tasked with optimising the system's total energy output while simultaneously minimising both expenses and reliability [8]. Photovoltaic panels, a charge controller, and battery storage are the elements that make up the components of a conventional wind-solar hybrid power system. The kinetic energy of the wind is captured by wind turbines and transformed into mechanical energy, which can later be transformed into electrical energy. Regardless of the kind of electrical energy that was being produced, it is unreliable and inconsistent. Inverters are regulating devices that are required in multiples so that the flow of energy may be made continuous and stored in a battery. This energy is put to use in a wide variety of domestic activities. A photovoltaic array is a collection of solar panels that may either be linked in series or in parallel to generate electrical energy from the sun's kinetic energy. The controller pulls this DC energy from the battery, depending on the load's requirements, and uses it to power either DC or AC takimata sanctus est Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed loads. This system has a number of advantages, such as a high daily power producing capacity, low manufacturing costs, low maintenance needs, and others [13].

1.1.1. Requirements of wind-solar hybrid power system

Mathematical and modeling computations are required to create this system and examine performance. In the literature, several hybrid system models have been discussed. The elements from the review of the literature were just as follows:

- Meteorological information: An analysis of the site's meteorology is necessary for the optimisation process. For maximising the utilisation of solar and wind energy, it is essential. The main input for the hybrid system is data on the measurement of the solar and wind resources. that all data must be collected hourly, daily, and in response to environmental changes.
- Load Demand : This system component has to be designed and examined. Making a decision about how to calculate the precise load demand is difficult and difficult. Systems must be designed for near to or greater than the load demand since seasonal load variations are unpredictable and must be taken into account.
- System Configurations: The right equipment selection must be decided after careful consideration of all relevant data, including wind speed, load demand, and sun radiation. However, system sizing would depend on the surrounding circumstances. Since the area that has been chosen will determine how much electricity is produced by solar and wind.Secondary purpose of the thesis (Third level title: Only first letter capital)

1.2. Problem Statement

One noteworthy aspect of the situation in Iraq is the growing need for electrical energy [4]. Most of this energy is required for the electrical machinery and appliances used in homes and factories and for electric propulsion [5]. Due to Iraq's large population, the country's need for power continues to rise. The significance of ore sit et dolore magna. Stet clita kasd gub rgren, no sea takimata sanctus est. having access to electricity in Iraq's day-to-day living has reached the point where it is necessary to take precautions against damage to the power grid in the event of faults and to guarantee the greatest possible level of uninterrupted power supply [6]. The power infrastructure in Iraq is struggling with several issues, leading to an inadequate amount of energy being generated. The issues include a low output of energy compared to the actual demand, a dysfunctional power infrastructure, an absence of natural resources necessary for the creation of electricity, and other similar issues.

Solar and wind energy have often been employed independently to create electricity, however both have some losses. These systems were impacted by climate change in the same way that our environment is altered daily. Solar radiation and wind speed variations influence the system's functionality. Any installation costs that would have been necessary for a single system would have been somewhat reduced with this combined hybrid system.

In contrast to using a single system, combining these two will help each other overcome losses. similar to how power is produced by a solar PV system and used by a wind turbine system during daylight hours. The solar system will act as a backup to generate electricity when wind conditions are insufficient to do so. Many scientists have used different combinations to make the hybrid wind-solar system more reliable and comfortable. They utilised hybrid diesel/PV, wind/diesel, and diesel/wind/PV systems to combine wind and solar energy with other sources [12].

1.3. Objectives of The Thesis

Designing and evaluating the performance of a wind-solar hybrids system for power production at a selected site in Rutba City is the major goal of the thesis. Specific Goals:

1. Conduct an in-depth analysis of the energy market in Rutba City, including its current energy sources, consumption patterns, and demand projections. This will involve reviewing existing literature and data sources, as well as conducting interviews with key stakeholders such as energy companies, regulators, and consumers.
2. Identify and discuss the major issues facing the energy sector in Rutba City, including environmental concerns, energy security, and affordability. This will involve synthesizing information from various sources, analyzing trends and patterns, and considering the perspectives of different stakeholders.

3. Evaluate the wind and solar potential in various areas of Rutba City, using a range of data sources and methods. This will include analyzing meteorological data, conducting site visits and surveys, and using geographic information systems (GIS) to map the wind and solar resources.
4. Design a hybrid wind-solar system for a suitable site in Rutba City, based on the results of the previous objectives. This will involve selecting appropriate equipment and technologies, optimizing the system design, and ensuring compatibility with existing infrastructure and regulatory frameworks.
5. Conduct an economic analysis of the wind-solar hybrid power production system, to evaluate its financial viability and potential impact on the energy market in Rutba City. This will involve estimating the costs and benefits of the system over its lifespan, considering factors such as capital and operating costs, revenue streams, and environmental and social externalities.
6. Develop recommendations for policymakers, energy companies, and other stakeholders based on the findings of the thesis, to promote the adoption of renewable energy sources and support the transition to a sustainable and resilient energy system in Rutba City.

1.4. Thesis's General Structure

This thesis is divided into five chapters:

- Chapter 1 broad summary of the thesis "Design Of Hybrid Solar Wind System For Sustainable Energy Storage: A Case Study Rutba City." The rationale, issue description, and study objectives are also mentioned.
- The introduction to solar energy industry and its difficulties are covered in Chapter 2 of the literature review.
- Chapter 3 presents estimates of the wind and solar resources in Rutba City as well as some fundamental background theory on these energy sources. covers the specifics of the wind-solar hybrid power production system's design.
- Chapter 4 analyzes data on available solar and wind resources in localized areas.

- Eventually, Chapter 5 summarizes the findings of the thesis, draws inferences, and offers suggestions.

2. BACKGROUND OF RENWABLE ENERGY

2.1. Background

Energy is used in endless and laborious ways throughout the entire earth. The amount of energy utilized is rising along with the pace at which different development activities are taking place throughout the globe. As a consequence, traditional energy supplies are quickly running out, and even hydrel reserves are proving unable to meet the rising energy demand. As a consequence, customers everywhere must bear the weight of rising power outages and energy prices. Therefore, electricity independence is quickly turning into a crucial demand for the future. As a result, the design concept develops a system that offers internally produced energy for households and also incorporates a sub system within the home to remove reliance on the power board.

The current chapter will describe the solar energy as well as the wind energy in details along with the hybrid of system requirement.

2.2. The Energy of Resource

The primary of energy source that sustains all living activities on Earth, including plant photosynthesis, the Earth's temperature comfort, the entire biogeochemical process, seems to be the sun. When the electromagnetic radiation from the sun reaches the earth's surface, it would be transformed into different forms of energy and utilized for a variety of things [7].

Photoelectricity production and thermal conversion are the two main applications of solar energy for humans. These applications represent an important development in the effort to end the world's energy dilemma. Given that the global energy demand is predicted to be between 25 and 30 TW in 2050, it is obvious that only solar energy will be able to satisfy the need and eliminate the need for fossil fuels. As an example, it was found that approximately TW of the 1.76x1015 TW of raw solar energy hitting the Earth could be converted into electricity affordably [8].

Figure 2.1. Solar panel field.

2.2.1. Thermal conversion

The processes used to convert solar energy into heat rely on the black body surface's ability to absorb radiant energy. Depending on the kind of absorbent material, this might be a difficult task. Includes electron acceleration, diffusion photon absorption, and many collisions, but the end result was heating, or the conversion of all radiant energy into heating that is symbolized by the rise in temperature. For instance, solar energy may be collected using collector to create heat that can either be consumed directly or transformed to power using thermomechanical operations like a steam power plant cycle [9].

2.2.2. Photoelectric conversion

Once light that has a specific frequency shines on a transparent metallic surface, this basic photoelectric conversion involves the departure of electron (electrical current) from that surface [10].

2.2.3. The photovoltaic system

A PV system, which consists of all the necessary hardware to convert solar photons directly into energy (AC), is made up of solar panels, charge/discharge regulators, storage, and inverters (where necessary to convert direct currents (DC) to alternate current) [11]. Sometimes storage is not required, based on the goal (for example, connection to the grid). Solar cells are a PV system's most important component. The photoelectric effect, which is the process by which some materials produce electricity when exposed to light, is the basis for this element's ability to convert solar energy into electricity.

The silicon solar cell (SC) was first discovered by French physicist Edmond Becquerel in 1839. The Becquerel tests demonstrated that when subjected to light, certain substances generate a little quantity of electricity. This phenomenon was first investigated in metals like silicon, whose performance was around 2 percent. The study continued, and in 1954 Chapin, Fuller, and Pearson announced the development of a Si solar cells with an effectiveness of roughly 6 percent [12]. In terms of usage, the SCs were initially employed in 1958 to recharge the batteries of the America Satellite (U.S. Vanguard) [9,13].

The SCs have been originally mainly utilized for space, military, and academic research owing to their exorbitant cost. Nevertheless, interest in creating SCs for civilian use arose leades to the energy crisis that started in the 1970s [8].

2.2.4. Solar cell architecture

Various semiconductor substances, including cadmium telluride (CdTe), gallium arsenide (GaAs), indium phosphide (InP), germanium (Ge), silicon (Si) and others could be used to make SCs, nonetheless, some of these resources,like Si is most frequently utilised in commercial applications because Si and Ge are more abundant on Earth and less expensive when compared to InP and GaAs[14]. Due to the Ge's decreased efficiency, as illustrated in figure 2.1 below, it is rarely often employed.

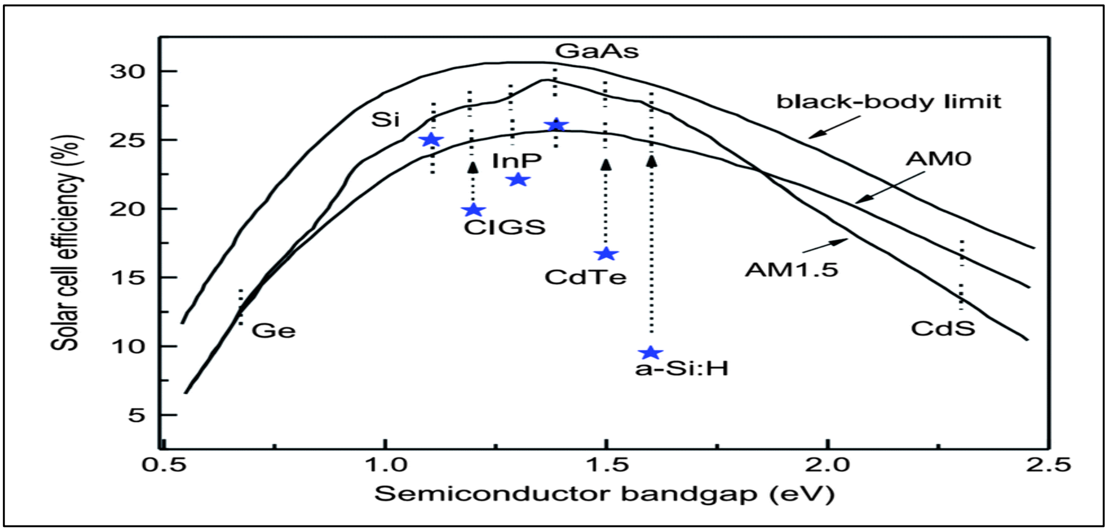


Figure 2.2. Efficacy potential of some semiconductor substances *[14]*.

2.2.5. Operations of silicon cells

The SC seems to be a junction of two different semiconductor material kinds, namely the n and p kinds. Once they are combined, open holes from the p-kind substance travel to the n-kind substance and vice versa, mimicking the passage of electrical charges and resulting in the so-called diffusion current (JD) [8].

2.3. Photovoltaic Principles

The photo-voltaic impact may be seen in nature in a number of materials, although as mentioned above, semiconductors exhibit the optimum performance in sunshine. It need an electrical field to encourage free electrons with greater energies than those first formed once photons from the sunlight were captured in a semiconductor to flow through the semiconductor and do meaningful work. The electrical fields for most solar cells is created by a substances junction with various electrical characteristics.

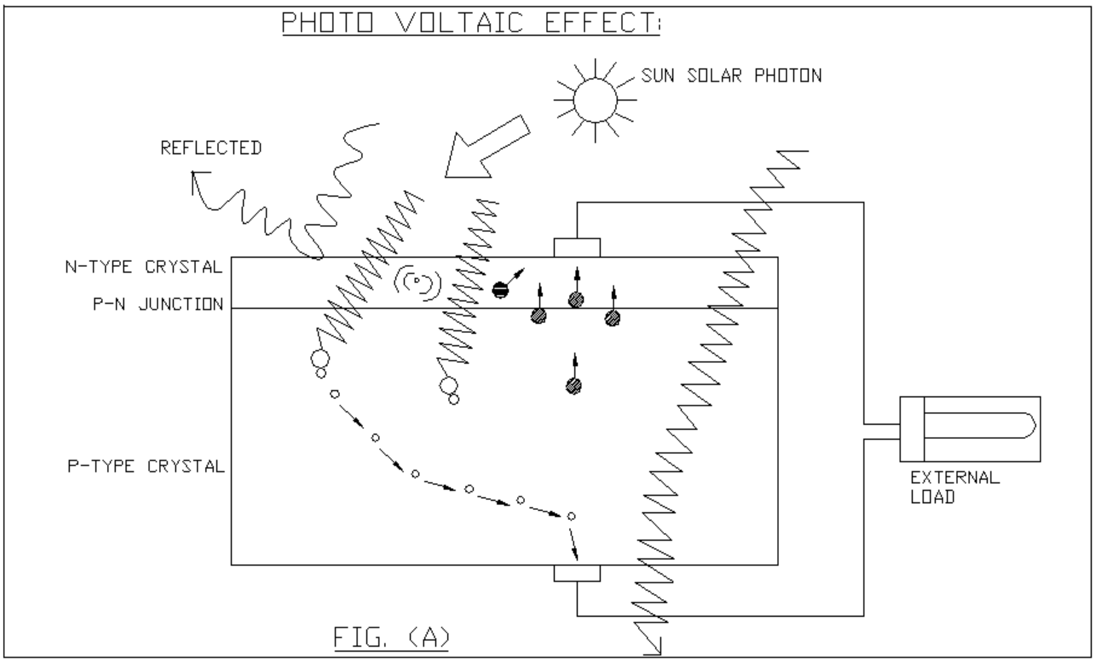


Figure 2.3. Voltaic effect process *[16]*.

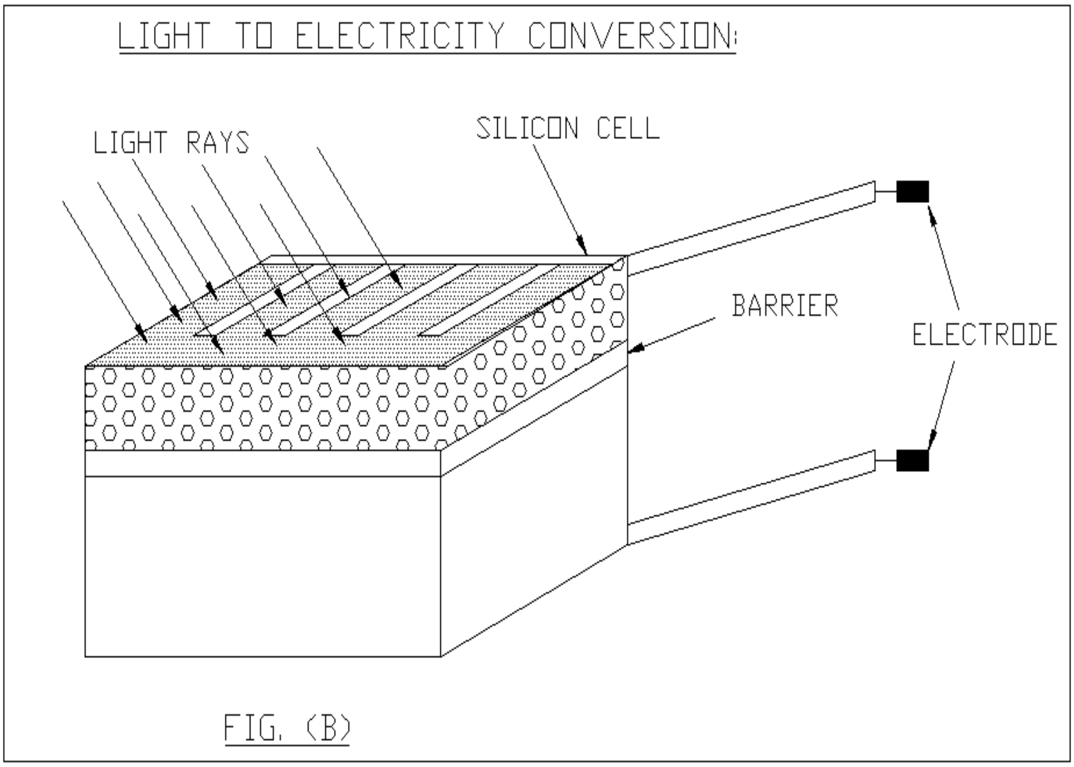


Figure 2.4. Converting the light to electricity *[17]*.

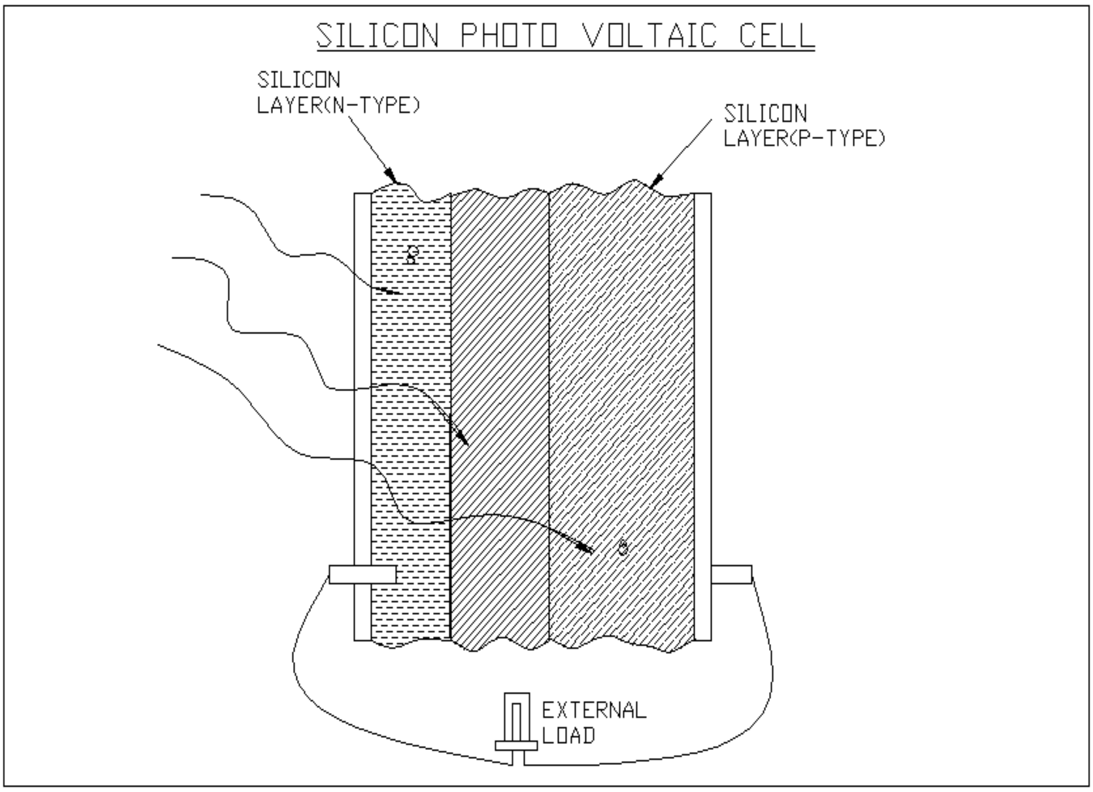


Figure 2.5. Silicon Voltaic cell *[18]*.

Three steps are necessary for photons interactions in a semiconductor to produce an usable output power.

- The photon must be captured in the substance's active region in order to excite electrons to a greater energy potential.
- It is necessary to physically separate and transfer the hole - electron charge carriers produced by the absorbing to the cell's edge.
- Before the charging carriers lose their additional potential, they should be taken out of the cell and given to the usable load.

A solar cell is made up of:

- A semiconductor in which hole - electron pairs were formed by the capture of incoming solar energy.
- A drift field-containing region for charge separation.
- Front and rear electrodes for charge collection.

P-n junctions in semiconductors are excellent candidates for explanations of the photovoltaic phenomenon. There seem to be no free electrons at absolute zero in an Table captions should be written using a line spacing with before 12 pt and after 6 pt, inherent semiconductor like silicon because every single four valence electrons of the substance atom is bound by a chemical bond. A portion of such a substance would have an excess of electrons within this side and turn into an n-kind semi-conductor if it is doped with a five valence electron substance, like arsenic or phosphorus, on one side. In the semiconductor lattice, the extra electrons would have had nearly unrestricted movement. An electron shortage would result in a p-kind semiconductor when a material with three valence electrons, like boron, dopes the opposite side of the same piece. The excess of holes in the lattice that are open to movement is how this insufficiency is reflected. The term "p-n junction" refers to a semiconductor component having one side of the p-kind and the other of the n-kind. In order to make up for their respective deficits, the free electrons of the n-side of this junction will tend to flow to the p-side and the holes of the p-side will prefer to flow to the n-region. An electrical field would be created by this diffusion from the n-area to the p-area. As the total of the diffusion possibilities for holes and electrons, V, approaches, this field will grow until it achieves equilibrium.

Charge carriers cannot flow across a junction that forms inside an electric potential because of the electric field that has built up there. Nevertheless, after being stimulated by an external source, it is crucial to guide the charge carriers once they enter the depletion region (for example, thermal or sunlight excitation).

Two key findings from the theory of light indicate that photons are a collective unit in addition to electromagnetic waves. Therefore, depending on the energy of those photons relative to the semiconductor bandgap energy, various events, including the formation and recombination of electron-hole pairs, may occur as soon as they enter the p-n junction (Eg).

The photon could jump into the conduction bands after attempting to transfer its energy to the electrons if its energy appears to be equal to or greater than Eg when it enters the p-n junction. The electrons might then be led to an n-kind substance and the hole to a p-kind substance thanks to the electrical dipole in the depletion area [19].

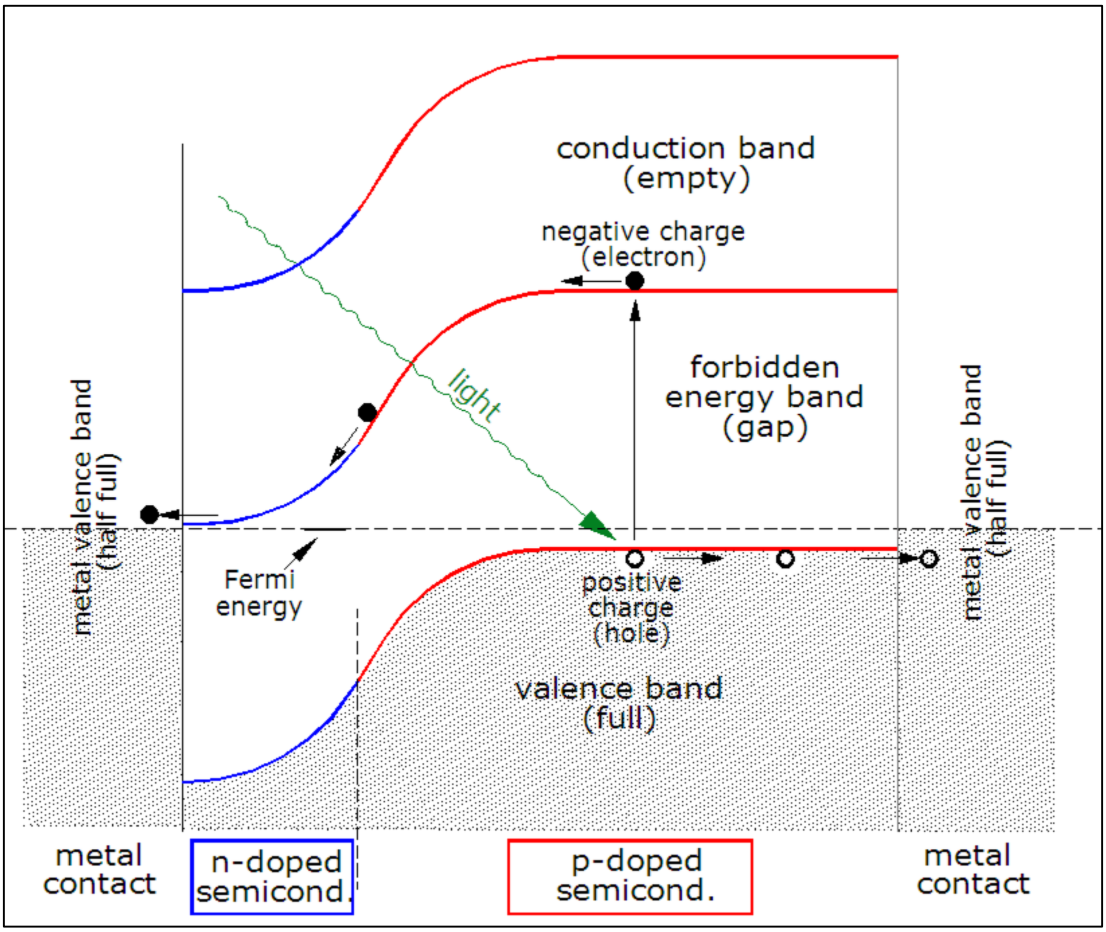


Figure 2.6. Graph of a Si solar cells, under illumination *[20]*.

Two models—the first coupled to a single diode model and the second to a two diode model—can be used to examine how the SC operates. However, we are changing the single diode model because the second involves more work and is only required to fully understand the behaviour of SCs during the following phases [21].

2.3.1. Advantages of solar energy

2.3.1.1. Renewable energy source

One of the most significant advantages of solar power was the fact that it used a source of energy that was entirely sustainable. This may be used at any time and from any location in the world, since it is accessible around the clock. In contrast to other potential sources of energy, solar energy can never be depleted. According to the findings of scientists, SE would remain accessible throughout the whole of the sun's existence; hence, After the sun's destruction, humans would still have access to it for at least 5 billion years.

2.3.1.2. Decreases the bills of electricity

Since the solar system would be capable of generating enough power to satisfy a part of the building's energy requirements, the monthly costs for the building's energy consumption would decrease. The size of the solar system and the amount of power or heating that it consumes were factors that determined the percentage of money that was saved on the bill. If users operate a company that uses commercial solar cells, for instance, making the transition might save a significant amount of money since the big size of the system may cover a significant portion of the company's energy expenses. In addition to having the potential to reduce the amount spend on the monthly power bill, there is also the possibility that you might be eligible for compensation via the Smarter Exporter Guaranteed programme for any surplus energy that was sent back to the grid (SEG). When the amount of energy produced exceeds the amount of energy used, there is a surplus (considering that SP system is connected to the grid).

2.3.1.3. Diverse applications

SE may be used in a diverse selection of contexts. Photovoltaics have the potential to be exploited in the generation of both power and heat (solar thermal). SE might be used to power spacecraft, distil water in locations with a dearth of clean water, and create electricity in places without access to the grid. It is possible that SE will be utilised in the building supplies. Sharp has recently started producing transparent SE windows.

Figure 2.7. Solar energy.

2.3.1.4. Low maintenance costs

In general, there is not a lot of maintenance is required for SE systems. Simply keeping them clean consistently is all required, so washing them a few times per year should be plenty. Even while it is unlikely, it might still depend on professional cleaning services, the hourly rate for which ranges between $25 and $35. The warranties offered by the vast majority of reputable SP manufacturers range from 20 to 25 years. It would seem that there is no wear and tear since there are no mechanical mechanisms present. Because it is responsible for converting solar energy into usable forms of electricity and heat, the inverter is often the sole component that requires replacement every 5–10 years (thermal solar against PV solar). In addition to the inverter, the cables in the solar power system need to be maintained so that they may function at their highest efficiency. As a consequence of this, after it has paid for the solar system, it may anticipate spending a relatively small amount on repairs and upkeep.

2.3.1.5. Developments in technology

The technologies in the solar powers business has always improved, and this tendency would continue for the foreseeable future. Quantum physics and nanomaterials breakthroughs have the ability to increase solar cell efficacy and quadruple, if not triple, SE system electrical input .

2.3.2. Disadvantages of solar energy

2.3.2.1. Cost

At first glance, it may seem that acquiring a solar power system would need significant financial investment. This cost takes into account the installation of solar electricity as well as inverters, batteries, and wiring. On the other hand, given that advancements in solar technology are always being made, it is realistic to anticipate that costs will continue to fall in the years to come.

2.3.2.2. Depending on weathers

Even though SE may potentially be gathered even on cloudy and wet days, the efficiency of the solar system would be reduced. It is necessary to expose SPs to sunshine in order to get SE. Because of this, even a short stretch of overcast and rainy weather might have a significant impact on the energy system. It is also important to keep in mind that SE could not be gathered during the nighttime hours. On the other hand, thermodynamics panels seem to be a workable alternative if the heating water systems are needed to run throughout the night or throughout the winter.

2.3.2.3. Se storage is expensive

Energy from the sun could be utilized right once or stored in large batteries. Solar batteries, which are utilized in off-grid solar powers systems, might well be charged during the day and then utilized at night. This is a great way to use SE during the day, but it's also quite expensive. In most cases, utilizing energy from the sun during the day and drawing electricity from the grid at night is more cost effective (that can just do this once your system is connected to the grid). Luckily, the energy needs seem to be higher during the day, therefore SE might provide the bulk of them.

2.3.3. Factors that influence the operation of a solar module

The performance of solar cells may be impacted by five main aspects, specifically:

1. The cell substance: Various lighting conversion efficiencies of solar cells can be attained based on the material and manufacturing process employed. For example, the efficiency of amorphous silicon ranges from 5 to 7 percent, that of polycrystalline silicon does not exceed 12 percent, and that of

monocrystalline silicon is greater than 12 percent but does not exceed 18 percent [22,23].

2. The output current was proportional to the solar radiation; when light intensity rises, the output current rises as well, but the voltage would not significantly change at the I-V curve above [21].

3. The impact of heat on module output: As a module's temp rises, its output voltage is impacted. The voltage drastically drops down as the temp rises, while the current hardly changes. Depending on Haberlin, [21], the formula equation below may be used to describe how a solar module's operating temp changes:

$$T_s - T_a = (NNNT - 20)\frac{G}{800} \tag{2.1}$$

Whereas G seems to be the solar irradiation [W/m2], Tc and Ta have become the cell's and the environment's respective temps, "NOCT" is the term for the standard operational cell temp, which for a standard module varies between 44 and 54 degree centigrade under the following circumstances at open circuit: Solar radiation GNOCT=800W/m2, temperature Ta=200 C, air mass 1.5, and wind speed 1 m/s.

4. The module output's shading impact: A module or portion of a module (cell) that is shaded may only partly or not at all generate electricity. If this occurs, it may also result in hot spots heating. Nevertheless, inserting bypass diodes might lessen the impact of this phenomenon [24].

2.3.4. Solar panel orientation angles

The best location for placing a solar panel depends on the site's latitude; on the north side of the equator, where the sun is often in the south, the panel should be pointed south; and on the south side, where it should be pointed north. The solar altitude angle (γ) differs from 0-90o and the greatest capturing of solar radiation on a panel takes place once the remarkable angle is 900. Considering these factors, tilting the panel toward this Sun, — in other words at an angle ß comparative to the horizontal plane, could indeed enhance energy yield. Typically, for fixed panels, this angle ought to be equivalent to the site latitude plus 100 degrees (Figure 2.7) [24].

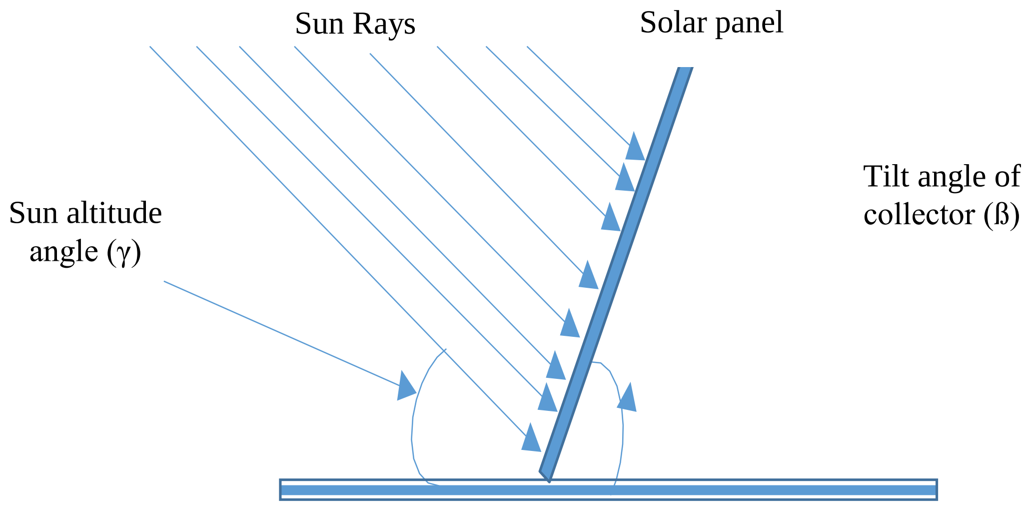


Figure 2.8. The geometry of installation of solar panel *[25]*.

2.3.5. Solar panel circuit connections

Based on the requires, the solar PV panels may be linked either in in series or parallel. When two devices are connected in series, the voltage rises but the current stays the same, however when they are connected in parallel, the voltage stays the same but the current rises [26]. However, as seen in figure 2.8, these linkages may be integrated into a single series-parallel circuit.

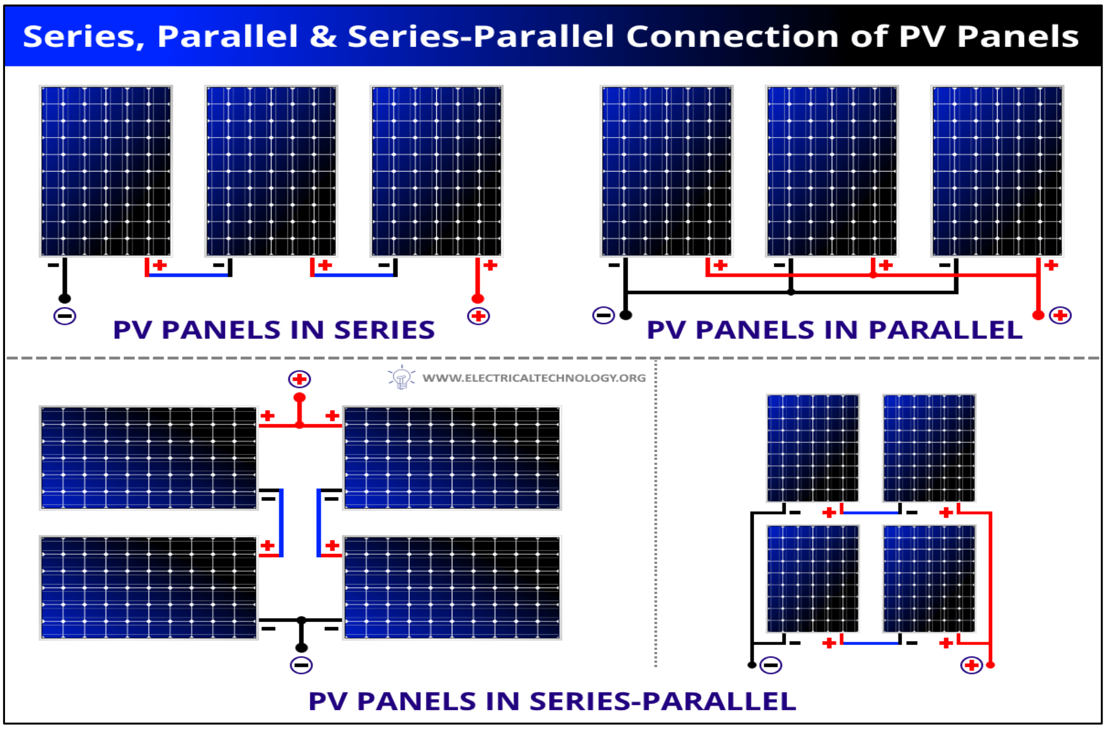


Figure 2.9. PV Panels connections type *[27]*.

2.3.6. The effect of weathers on solar energy

The quantity of powers produced by a solar system is affected by weathering conditions, although not in the manner may imagine. Of course, the ideal circumstances for creating SE involve a bright sunny day. Solar Panels, like most electronics, seem to be more efficient in cold weathers than in hot weathers. The panel may generate more powers in the same period of time as a result of this. The panel creates less voltage and generates less powers as the temp increases [28].

Solar Panels seem to be more efficient in cold weathers, however they don't always generate more powers in the winter than they do in the summer. During the summers, the weathers are usually brighter. Aside from less clouds, the sun is generally out for a longer period of time. Therefore, even if your panels are less efficient in hot weathers, they will almost certainly generate more powers in the summer than in the winter.

2.4. The Wind Energy Resource

Air in motion causes wind. An increase in pressure causes the movement of air. Convective circulation is one of the main global forcing mechanisms driving surface winds from the poles toward the equator. The air near the equator is heated by solar radiation, and this low density heated air is hoisted aloft. Cooler, denser, higher-pressure air traveling from the poles displaces it at the surface. As a result, air tends to flow away from the equator and back toward the poles in the upper atmosphere close to the equator. Overall, the northern hemisphere has a worldwide convective circulation with surface wins from north to south. The frictional effects of the boundary layer between the flowing air and the uneven surface of the ground add another degree of complexity. The movement of air along stream lines is impeded by mountains, trees, structures, and other impediments. As altitude increases close to the surface, turbulence develops and the wind velocity in a horizontal direction sharply increases. Two processes are responsible for local winds. The differential heat of land and water is the first. Daytime solar radiation is easily converted to useful energy by the land surface, but it is also partially absorbed in layers under the water's surface and partially consumed by water evaporation. The air over the land warms up and becomes warmer than the air above the sea as a result of the land mass being hotter than the water. The colder, heavier air over the ocean replaces the warmer, lighter air above the land as it rises. This is how shore winds operate. Because the land mass cools to the sky more quickly than the ocean, if there is a sky, the direction of the winds at night is reversed. Hills and mountain sides are the primary source of the second mechanism of local winds. More quickly than the air over low lands, the air above slopes warms up throughout the day and cools down at night. Due to this, hot air rises up the slopes during the day and comparatively chilly, heavy air descends at night. Wind energy is easily turned into electrical energy by coupling a wind turbine to an electric generator, which creates rotating motion. The term "aero generator" is sometimes used to describe the generator and wind turbine combo. The comparatively slow speed of the wind rotor must typically be matched to the faster speed of an electric generator using a step-up transmission.

In the late 1950s and early 1960s, interest in windmills began to grow in India. Other than bringing in a few from outside, fresh designs were also created, however they were not maintained. Development work has just recently started to take place at several institutions. The fact that wind is very weak and varies significantly with the seasons in India must be a significant factor in the lack of interest in wind energy. According to data cited by various experts, the wind speed in India ranges from 5 to 15-20 km/h. These weak, cyclical winds indicate a significant expense of wind energy extraction. A unit of energy derived from a windmill would be least multiple times greater than energy develop the required from electricity distribution divisions at the standard rates, assuming such electrical energy would be even remotely accessible at the windmill site, according to estimations depending on the performance of a classic windmill. For a number of reasons, the aforementioned justification may not entirely apply in rural locations. Because of the high cost of generating and delivery to sparsely populated small consumers, first electric power does not seem to be and will not be accessible in many of these regions. Second, with the right design, it may be possible to lower the price of the windmills. Last but not least, on modest scales, the total upfront cost for meeting a perceived demand and minimal maintenance expenses matter more than the energy unit cost. The last argument is clearly shown by the fact that dry cells are widely used in both urban and rural regions despite supplying electricity at an absurdly high cost of roughly Rs. 300 per kWh. Additional alternative for pumping and producing electricity is provided by wind energy. India ranks among the most promising nations for using this source, with a potential for power production of about 20,000 MW. In many regions of our nation, particularly those close to the coastlines, the price of energy production from wind farms now has fallen below that of diesel power and is equivalent to that of thermal power. In various regions of the nation, wind power projects totaling 8 MW in capacity were built, including 7 wind farms with a combined capacity of 6.85 MW, of which DNES completed 3 MW in 1989. Over 150 lakes unit of electricity have already been sent to the corresponding state networks by wind farms, which are now running satisfactorily. More than 25 MW of new wind power capacity is now being implemented. Up to February 1989, 271 wind pumps were erected as part of the demonstration program. 60 tiny wind battery charges with capacities ranging from 300 watts to 4 kW are now being installed. Similar to standalone wind power generators, which range in size from 10 to 25 kW.

2.4.1. Types of wind turbines

Wind turbines may be divided into two categories: those with horizontal axes and those with vertical axes. The significant proportion of wind generators have only a horizontal axis, consisting of a propeller-like structure with rotating blades. The wind strikes the blades of horizontal axis turbines either upwind or downwind (before the tower) (the winds hits the tower firstly and then the blades). A yaw drive and motors are also a part of upwind turbines; they turn the nacelle to maintain the rotor towards the winds once the wind changes direction.

Although there are a number of producers of vertical-axis wind turbines, their market penetration is not as great as that of horizontal access turbines in the utility size market (100 kW and bigger). There are two basic designs for vertical axis turbines:

- Savonius or drag-based turbines typically feature solid-vaned rotors that revolve along a vertical axis.
- Lift-based turbines, also known as Darrieus turbines, feature tall, vertical airfoils (some appear to have an eggbeater shape). An experimental lift-based turbine called the Windspire has been tested impartially at the Renewable Energy Lab.

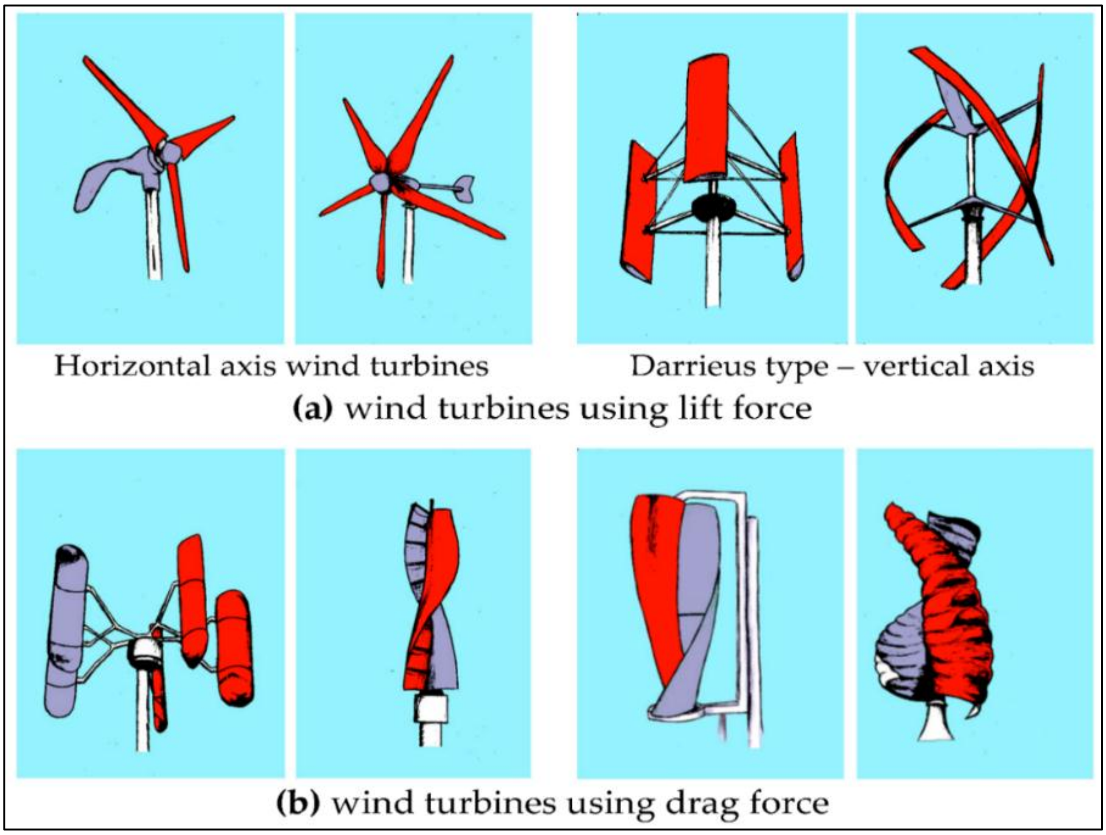


Figure 2.10. Wind turbine kinds.

2.4.2. Wind turbine applications

Wind turbines have a variety of uses, from catching offshore winds sources to generating electricity for a single home:

- Large wind turbines that utilities most typically use to power a grid, have power outputs that vary from 100 kilowatts to many megawatts. These utility-scale turbines are frequently grouped together in wind farms to produce substantial amounts of electricity.
- Up to 100 kilowatts of electricity generated by tiny wind turbines are frequently utilized locally, such as next to residences, communication towers, or water pumping stations. Wind farms, which might also consist of a few or hundreds of turbines, might power tens of thousands of homes. Sometimes, small turbines might well be connected to diesel engines, solar panels, and batteries.
- Many countries use offshore wind turbines to harness the power of reliable, powerful winds that blow along coastlines.

- These systems, sometimes known as hybrid wind systems, have often been employed in remote, off-grid locations without access to a utility grid. Wind resources over U.S. coastal oceans may provide more than 4,000 gigawatts of electricity, or about four times the producing capacity of the current electrical power grid. Even if not all of these resources would be used, there is a good likelihood that coastal areas might be supplied with power. In order to take advantage of America's abundant offshore wind resources, the Department is supporting three offshore wind demonstration projects with the aim of establishing offshore winds systems in federal and state waters by 2017.

2.5. The Main Parts of a Wind Turbine

A wind turbine is made up of a total of ten different components, including five major parts and five secondary parts. The basic components are the foundation, the tower, the nacelle, the generator, and the rotors and hubs, each of which has three blades. Throughout this installation process, each of these elements calls for a unique form of wind turbine gear.

2.5.1. Wind turbine foundation

Onshore turbines have a base on the ground, but the soil covering it makes it unnoticeable. It is a sizable, weighty concrete structural block that should sustain the whole turbine as well as the forces pushing on it. The base of offshore wind turbines are submerged and hidden. The base of offshore turbines located far from the water floats but has sufficient bulk to support and withstand the turbine weight and any applied forces.

Figure 2.11. Wind turbine foundation.

2.5.2. Wind energy tower

The towers of the vast majority of modern turbines are made of steel tubes in the shape of cylinders. The optimal height of a turbine tower is one that is proportional to the diameter of the circle that is created by the rotating the turbine's blades. The higher up the turbine is located, the greater the likelihood that it may be damaged by gusts of wind. owing to the fact that the wind grows more powerful the more away researchers are from the earth (the wind does not have the same speed at different heights).

2.5.3. The rotor of wind turbine and hub

The element of the wind turbine that does the actual spinning is called the rotor, and it consists of three blades as well as a hub which is located in the centre. Regardless of the fact that three blades are the most common configuration for a turbine, this number is not always present. The three-bladed rotor, on the other hand, offers advantages such as increased efficiency. The blades appear to be hollow and to be made of a composite material which is both light and robust, despite the fact that they are not very powerful. They are becoming bigger (to accommodate more power), lighter (to save weight), and more robust all the time. For reasons related to aerodynamics, the blades were designed in the form of an airfoil, much like the wings of an aeroplane. In addition to this, they do not have a flat surface and instead have a twist that runs between their roots and tips. The axis of the blade might rotate up to ninety degrees. This kind of movement was referred to as a pitch. The hub's responsibility is to provide support for the blades and to enable rotation with regard to the remaining portion of the turbine body.

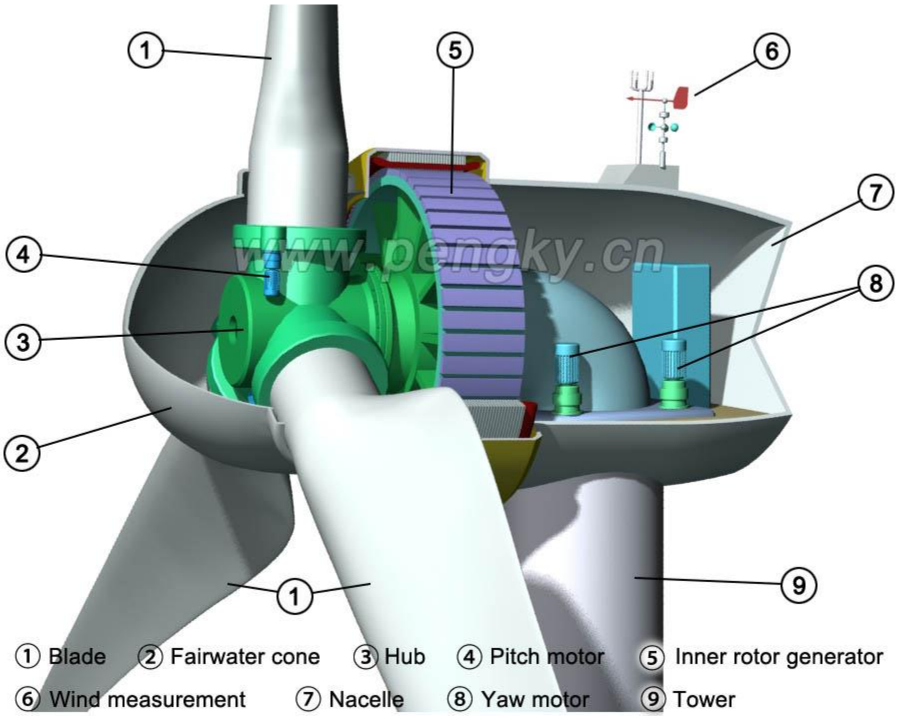


Figure 2.12. wind turbine parts.

2.5.4. Wind turbine nacelle

The nacelle of a wind turbine seems to be an elaborate electromechanical system that consists of a number of complex pieces that all perform their functions in a precise and exact manner. It would seem that the generator as well as the turbine shaft, that employs a gearbox to convey renewable power to the generators, are significant components of the turbine. The gearbox that is part of the wind turbine and is housed on the cable car, is an extremely important components. Because the rotor of the turbine needs to follow the wind and adjust its direction to correspond with the direction of the wind, this must spin in respect to the tower. The term "yaw movement" refers to this motion, which takes place as the nacelle and rotor rotate around the tower's axis.

2.5.5. Wind energy generator

The mechanical energy which was created by the winds was transferred to the rotor by a mechanism called a generator, which then converts it into electrical energy. The generator might be constructed in a manner similar to that of an electric motor.

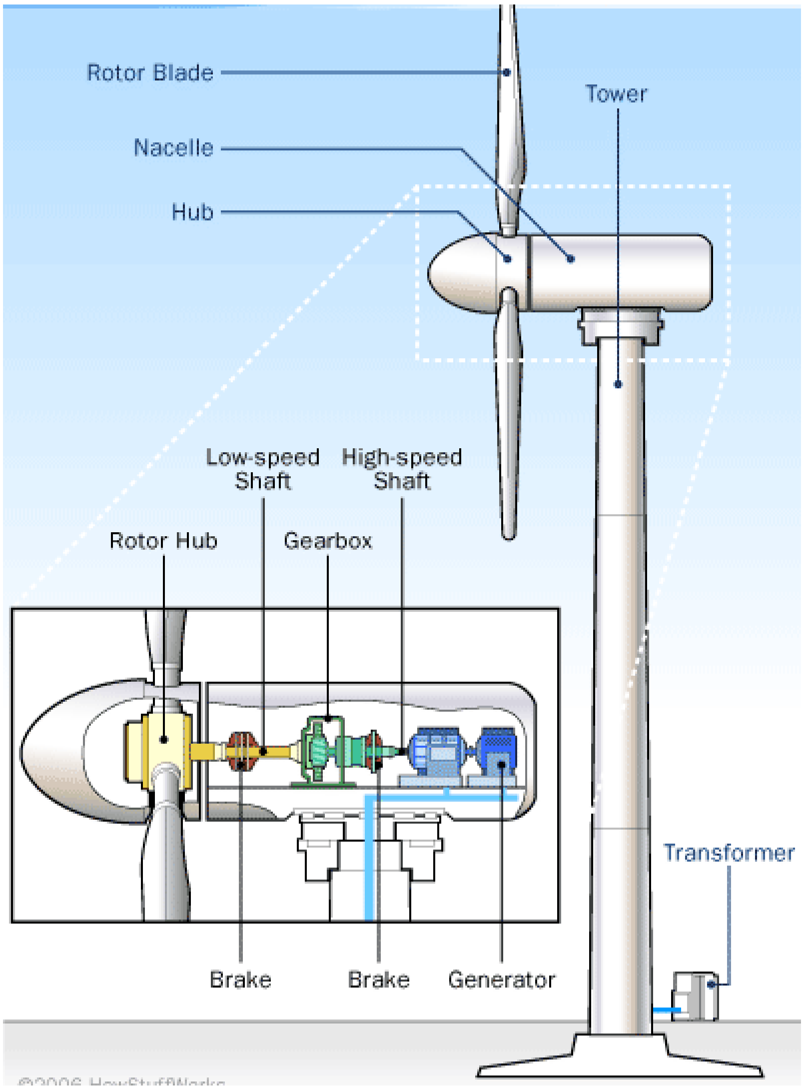


Figure 2.13. wind turbine.

2.6. Wind Turbines: Working Principles

The moment the wind blows across the rotor blades, they start spinning rapidly. The rotor of the turbine is equipped with a gearbox that may reach very high speeds.

Through the use of a gearbox, the rotational speed of the rotor may be altered from slow to fast. Because of the connection between the high-speed shaft of the gearbox and the rotor of the generator, the rotational speed of the electrical generator is increased. An exciter is needed in order for the magnetic coil that is part of the producing field system to be able to provide the requisite amount of power and excitation . The voltage, which is generated at the output terminals of the alternator is impacted both by the field flux and the speed of the alternator. The power of the wind, which cannot be controlled, is what dictates the speed. As a result, regulation of the excitation should take place in line with the availability of renewable wind energy so as to guarantee that the output power from the alternator was consistent. The exciter current is managed by a controller for the turbine that measures the speed of the wind. The voltage that is produced by the alternator is then transmitted to a rectifier that alters it so that it produces direct current (DC). Before being sent to a transmission grid or an electrical transmission network, the rectified DC output is first converted into stabilised AC output by a line converter unit utilising a step-up transformer. After this, the output is then provided to the transmission grid. Internal Supply Units are supplementary units that give power to the internal auxiliary components of a wind turbine. These components include the motors, the batteries, and a variety of others.

A contemporary large wind turbine has another two control systems linked to it.

- Managing the turbine blade's orientation.
- Regulating the turbine face's orientation.

The turbine blade base hub is responsible for controlling the blade's orientation. The blades were secured to the centre hub by the use of a rotating arrangement that is comprised of gears, a miniature electrical motor, or a hydraulic system that rotates in a circular motion. It is possible that the system will be operated mechanically or electrically, depending on how it was developed. It is possible for the blades to spin depending on the speed of the wind. This technique is referred to as pitch control. In order to extract the most amount of energy from the wind, the turbine blades are oriented in such a way that they make the most efficient use of the available space.

It is possible for the nacelle or the entire structure of the turbine to be positioned to follow the direction of changeable winds in order to maximise the amount of mechanical energy that can be gathered from the winds. An anemometer, which is a device that automatically measures the wind's speed, is attached to the top of the nacelle's back so that it can determine both the wind's direction and its speed. The signals are then relayed back to a computerised microprocessor-based regulating system, which uses the yaw motor as its governor to rotate the entire nacelle utilizing gearing in order to face the wind turbine in the direction that the wind is blowing.

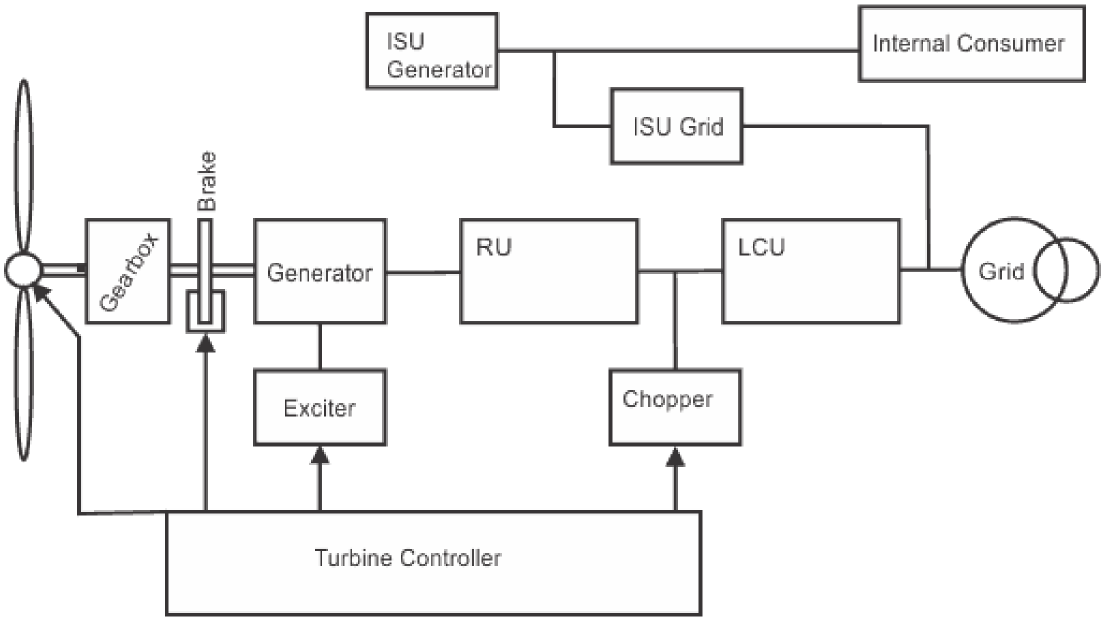


Figure 2.14. A Block plan of a wind turbine.

2.6.1. Wind energy conversion

In the Middle Ages, conventional windmills are widely utilized for cow watering, land draining, and grain milling. In certain regions of the globe, winds energy converters were always utilized for similar reasons today, although the major concentration is now on their usage to produce electricity. Although there is increasing interest in using winds energy to heating homes, buildings, and glasshouses, the potential market would be far lower than that for electricity production. Although it is barely used, the word "wind mill" is nevertheless often used to designate wind energy conversion technologies. It is more suitable to refer to advanced energy conversion systems as WECS, aerogenerations, wind turbine generators, or simply "wind turbines." For certain uses, like pumping water for land drainage, the fact that the wind is a variable and intermittent source of energy is irrelevant - provided, of course, that there is a wide match between the energy supplied throughout any key time and the energy needed. The task is completed if the wind blows; else, it must wait. Nevertheless, the interruption of supplies might be extremely inconvenient for a variety of applications for which electricity is used. Operators or consumers of wind turbines must make sure that they have backup plan in place to address times when there is not enough (or too much) wind. Backup options for small producers include:

- Battery storage,
- A connection to the local electrical distribution system

A medium and large-sized wind turbines may need to be integrated into utilities' distribution networks, which might result in the need for extra equipment that could react swiftly to changing demands.

2.6.2. Advantages of wind energy

1. Wind energy was easily accessible and a clean energy source, therefore it does not have negative environmental effects.
2. Fuel supply and transportation are avoided by wind energy systems.
3. Up to a few KW systems are less expensive on a small scale. On a big scale, costs may be comparable to those of traditional power, and mass manufacturing may result in reduced costs.
4. It may be helpful in delivering electricity to isolated places when other energy sources are hard to get by and has minimal running costs.

2.6.3. Disadvantages of wind energy

- The nature of the wind energy accessible is diluted and erratic.
- In contrast to water energy, winds energy requires storage space due to its erratic nature. • The functioning of winds energy systems are loud; a large unit may be heard from miles away.
- The wind energy system is extremely large total weight since it involves the building of tall towers with gear boxes, generators, couplings, etc.
- Propellers with a diameter of one to 3 meters have often been required for large regions.
- Current systems were hardly operationally dependable nor maintenance-free.
- Only in broad, open spaces with ideal wind conditions are wind power plants allowed to be placed. These areas are often far from load canters.
- At the moment, it only produces one to a few MW, which is insufficient to fulfill the energy demands of major cities and businesses.

2.7. Energy Storage (Battery types and Operation)

Regardless of the fact that power generation and demand change during the day, one of the challenges that the sector of power generation from alternative energy sources has is maintaining a fixed or consistent quantity of electricity generated over a particular period of time. Energy storage technologies is employed to solve this issue. These systems collect additional energy throughout times of low demand, store it in alternative forms, and then transform it back into the original form when the need calls for it.

Rechargeable batteries, also recognized as accumulators, are utilized to store energy produced by solar and wind energy. Batteries were electrochemical devices that utilizing ions as electrical charges to transform electric energy into storage capacity. The ideal battery would meet the demands at night, on rainy and cloudy days, or throughout periods of lesser winds speed, in the event of electrification in distant places utilizing solar or wind energy. These machines were crucial for stabilizing the significant voltage fluctuations caused by solar panels and wind turbines [11].

2.8. Types of Batteries

For those being utilized commercially and on small sizes, rechargeable batteries may be of the lead-acid, nickel-cadmium, nickel metal hydride, or lithium ion types. Owing to its appropriateness, availability, and affordability compared to the other varieties, that are primarily utilised tiny electric gadgets like radios and mobile phones, lead acid batteries are the most popular for solar/wind power systems [29].

Lead Acid Batteries: The fundamental working concept of lead-acid batteries would be depending on the interaction between lead plates (positive plates) linked to the negative connector (Pb) and lead plates (negative plates) covered with PbO_2 that have been attached to the positive connector (Pb). As illustrated in the reaction equation below, the assembly is put in the battery compartment and submerged in an aqueous solution of sulphuric acid (H_2SO_2) after being separated by a cardboard, plastic, or some kind of microporous paper separator [11].

$$Pb + PbO_2 + 2\ H_2SO_4 \leftrightarrow 2\ PbSO_4 + 2\ H_2O \qquad (2.2)$$

Hankins [11] states that lead-acid batteries may be divided into two groups: deep discharge (deep cycle) batteries and automotive batteries (start-up batteries).

Automobile batteries have been created to provide strong current bursts for brief intervals, which results in a shallow depth of discharge that is typically just 20percent of the charge capacity. Given that the starter of a vehicle's engine uses a lot of power for a short period of time while beginning, these sort of batteries are often utilized for engine starting. Peak current batteries have more plates but are thinner than stationary deep-cycle batteries [29].

Deep discharge (deep cycle) batteries, such as absorbed glass mat (AGM), captive electrolyte gel, and tubular plates batteries/OPZS or OPZV (wet or gel Cells) batteries, were designed to survive discharges of up to 80percent of their capacity.

Figure 2.15. Various kinds of deep discharge batteries, a) AGM; b) captive electrolyte gel; c) tubular plate batteries/OPZV or OPZS *[30]*.

The life cycles, market prices, and architecture of the different deep-cycle battery enhancements vary; nevertheless, the tubular plate kinds, which was the last one in Figure 2.15, is the most advantageous since its enormously long lifetime (900-1200 cycles), especially in comparison to any other lead-acid battery kind [29,31].

2.8.1.1. Battery voltage (V)

The nominal voltage of a lead-acid battery is 2.0 V per cell; however, this voltage varies significantly during charging and discharging depending on the current supplied or withdrawn, the amount of time since unloading or loading, the temperature, and the constructive properties of the battery. If the battery is towards the end of its usable life or is undergoing rapid charging, the voltage may increase to 2.5 V per cell. During deep discharge, the voltage may drop to 1.6 V per cell, which is frequently regarded as a destructively low level.

2.8.1.2. Battery power (C)

The quantity of power that a battery can produce under certain circumstances, such as with a specified discharge current up to a specific voltage level at a specific temperature, is often measured in ampere-hours (Ah). Based on the estimation below, the C20 and C100 batteries seem to be the most helpful for stand-alone processes, so the battery capacity and discharge current are frequently indicated along with a subscript for discharge duration in hrs, — for example, C10 means battery capacity C for a discharge time time of 10 h. This is how batteries were also typically designated to represent their nominal capacities.

Definition of nominal capacity roughly:

$$C10: C10 \sim 0.85 \times C20 \sim 0.7 \times C100 \quad (2.3)$$

2.8.1.3. Battery charge and discharge limit

When a battery is connected to a load, its voltage begins to drop; nevertheless, if the battery's nominal voltage drops to between 1.7 and 1.85 V, it must be unplugged from appliances to preserve its long life and avoid a damaging depth of discharge (DoD). To avoid increased gas generation (gassing), the battery must be unplugged if it is being charged and the voltage rises over around 2.4 V [21].

2.8.1.4. Life cycle versus depth of discharge

Battery kind and DoD are the main determinants of a battery's life cycle, which refers to the cycles number this could withstand before losing 80 percent of its nominal capacity. All kinds of batteries have reduced life spans the greater the DoD. It is suggested against routinely discharging even deep cycle batteries below 60percent DoD (40 percent state of charge) [21].

Additionally, all battery types operate more effectively during both charge and discharge at low currents as opposed to high ones. Any battery may last longer thanks to slow charge/discharge cycles, which also enable a maintained high capacity level throughout the battery's life. Any kind of electrochemical battery may readily suffer from poor performance and a shorter lifespan when charged and discharged quickly, drawing large currents.

2.9. Controllers Charge and Inverters

The usage of inverters allows for the conversion of AC electrical current from DC electrical current. Depending on their waveform, inverters may be divided into three categories: sine wave, modified square wave, and square wave [29]. Despite having the lowest prices on the market, square wave inverters are not suited for domestic usage since they have a very low control output voltages and a severe harmonic distortion. In order to lessen the harmonic distortion caused by the first kind, modified square waves inverters are connected to certain electronic components (field effect transistors, or FETs, or silicon controlled rectifiers, or SCRs). However, this sort of inverter also prohibits the use of several household appliances. The most sophisticated and suitable for household electricity are sine wave inverters, which give forth output signals with less harmonic distortion. This enables them to provide energy to any machine, especially delicate ones [29].

2.10. Need of Hybrid Power Plant

The burning of fundamental fuels including coal, natural gas, gasoline, etc. is an example of a traditional combustion kind power production technique. Mechanical power was created by a steam generator, which converts thermal energy from the fuel combustion into rotational energy. The majority of thermal power plants generate steam; hence, they are often referred to as steam power plants. The second rule of thermodynamics states that not all heat energy could be converted into mechanical power. As a result, heat is constantly wasted to the surroundings. As an alternative, there are nuclear power plants where the mechanical energy needed to turn a turbine was produced by boiling water into great energy (KE or PE) steam. We employ nuclear reactions for the purposes of heating. The water that is kept in a container is heated using the heat that nuclear reactors release. But the danger element is where this technology differs most from nuclear power plants. These nuclear power facilities might leak, which would be very harmful to both abiotic and biotic elements in the area. Additionally, both of them suffer from the drawback of air contamination.

2.11. Disadvantages of Conventional Combustion Generators

- Utilizing sustainable energy sources represents the most agreeable solution. A green source of energy refers to one that produces energy with little environmental impact. These sources involve the fuel cells, waves, sun, wind, and others. But electricity has to be produced just when it's needed. This need is not met by wind or sunlight.
- In order to avoid power shortages and utilize all available wind and solar energy, a new type of power plant should be built.
- There are at least two methods to reach this objective:
- The storage of electrical energy.
- A producing station with an additional management systems and two (or more) major sources.
- Owing to all of these problems, the use of hybrids power system was necessary.

2.11.1. Solution

The most palatable answer is to use sustainable energy sources. A clean energy source is one that generates energy without significantly affecting the environment. These sources include fuel cells, the sun, the wind, the waves, and others. However, power must be generated precisely when it is required. Wind and sun do not satisfy this condition. Therefore, a new kind of power station must be constructed to prevent power shortages and to make use of all accessible solar and wind energy.

At least two strategies exist to accomplish this goal:

- A generating station with an extra control system and two (or more) main sources.
- The storing of electrical energy.

The utilization of a hybrid power system is required due to all of these issues.

2.12. Hybrid Power Systems

A hybrid power system is simply one that generates electrical energy from many sources. In contrast to the current system, where outputs from various producing stations were hooked together, here the various energy sources are combined at the point of production, employing two or more fuels for the same devices that, once combined, overcome the shortcomings of each fuel separately.

The following were examples of the many hybrid power systems which are frequently employed:

- A wind-fuel cells hybrid systems;
- A solid oxide fuel cell coupled with a micro turbine or gas turbine.
- A hybrid wave-wind system.
- DC hybrid systems with micro grid; wind generator with battery storage and diesel backup generators.

Furthermore renewable sources of electricity like solar, wind, or hydropower systems, a hybrid power system has to have a controllable source like a generator driven by a gasoline or diesel engine. This is due to energy generated by renewable energy sources, including wind or solar energy, fluctuates and can't always effectively match the need for load. Once the first fails to function, the diesel engine generator maintains electricity generation. A backup battery is always included in hybrid systems. Its primary purpose is to provide a steady flow of energy once the other two sources aren't producing any. Additionally, it aids in reducing the production of a renewable power source's jarring oscillations. We used a solar-wind hybrid powers station as an instance in this presentation.

2.13. Literature Study of The Hybrid Solar-Wind System

Utilizing energy that is a combination of solar and wind sources is necessary for the growth of the nation. Numerous studies have been carried out in order to develop and evaluate the overall performance of the solar and wind hybrid system. According to Ramli et al. [32]. research study model for the hybrid solar and wind systems on the techno-economic energy analysis for Saudi Arabia, hybrid wind and solar systems systems are becoming increasingly popular. Once conducting an investigation into the economic manufacture of electric vehicles using a hybrid system, the numerous criteria that need to be satisfied are taken into consideration.

Khare et al [33] provided for the HRES. In the study that was given, the primary emphasis was placed on a wide range of issues pertaining to HRES, including appropriate size, feasibility analysis, modelling, control considerations, and dependability. The authors of this paper, Bhandari et al. [34], differentiate between the electricity produced by wind turbines and photovoltaic (pv) panels based on the weather conditions. They came to the conclusion that the system might be improved and made more functional by utilising storage systems as a form of backup..

They then build component specifications for the hybrid system using a variety of optimization strategies. Once again, they concentrate on the current environmental crisis situation. This research, by Sharma et al. [35], focuses mostly on rural development in India utilizing a unique hybrid methodology. They research several hybrid power generation system combinations. The load was separated into phases based on the estimated load demand for rural areas, and additional analysis is then performed.

Bekele et al. [36] created a hybrid solar and wind power producing system for a rural part of Ethiopia. The system is created based on research investigations' essential requirements for electricity. Data for the research was gathered from a national organization. Using the HOMER program, the simulation of that hybrid system is examined. The study's findings showed that the system was functioning well and that up to 20percent of the lack of energy had been filled.

The innovative methods for producing hybrid electricity were asserted in Perlis, Malaysia by Irwan et al [37]. The PV module is cooled using electricity produced by wind. PV modules are utilized with the Savinious and Darrieus combo. Performance may be enhanced using the new hybrid system design methodology. According to Gwani et al., this device combines a vertical axis wind turbine with omnidirectional guiding vanes to generate energy utilizing a blend of solar and wind power (ODGV) [38]. The ODGV was created by the author to maximize the power production from wind energy, which uses the venturi effect. They were able to increase the hybrid system's power output by adopting this combination. This system's electricity is utilized to power appliances like streetlights and other electrical devices. The most effective methods for generating hybrid wind and solar electricity in distant places were developed by Prabhakant et al. [39] to reduce the creation of carbon and coal while producing electricity. Bouzelata et al. investigated the best configuration for a hybrid wind and solar energy system [40]. The WECS is used to generate power using a double fed induction generator. According to the study's findings, the power quality was enhanced by the usage of power electronics in energy production.

Jain and Abhishek [41], The fundamentals of small size VAWT for blade pitching throughout varying amplitude were discussed. The many design concerns were examined, and it was determined that a broad variety of wind speeds and tip speed ratios, as well as variations in the magnitude of blade pitching caused the turbine to operate at its optimum efficiency. The Western Himalayas region's potential for installing a micro winds and Solar hybrid system was outlined by Sunanda Sinha et al. [42]. On the basis of data from NASA and ANN predictions, measured data for Hamirpur, and estimated data for eleven places in Himachal Pradesh, the hybrid system's analysis is conducted.

In the last two decades, there has been an increased focus on renewable resources as a result of the continuing need for energy, the decline in the availability of fossil fuel resources, and the negative impact of fossil fuels on the environment. The amount of electricity that is produced in Iraq is insufficient to satisfy the requirements of the country's industrial and residential sectors. Dihrab and Sopian presented a renewable resource of power production for grid-connected applications in three cities in Iraq [43]. This resource would be solar energy. MATLAB solver was used to do a simulation of the proposed system. The climatological data for the various sites that were being considered as well as the dimensions of the PV and wind turbines were used as input variables for the solution. According to the findings, it is feasible for Iraq to employ wind and solar energy to create sufficient amounts of electricity to supply the needs of certain desert or rural communities. Throughout this period when the system is completely shut down, it is also feasible to use such a system as just a black start power source. According to the findings, Basra is the optimal location for this system in terms of both wind and solar energy. Both the use of fossil fuels and the release of greenhouse gases may be significantly cut down with the aid of hybrid energy systems, often known as HESs. These systems combine both traditional and renewable forms of energy. An appropriate control strategy is necessary for the optimum design of HESs since it is necessary to meet the environmental, economic, technological, and design goals. Aziz et al. conducted research to determine the optimal design for a grid-connected PV/battery HES that is capable of meeting the load needs of a residential dwelling in Iraq. In order to design a novel dispatch strategy that forecasts future solar output and demand for power, the MATLAB Link that is included in the HOMER programme was used. In HOMER, a comparison is made between the changed approach and the default methods, such as load following and cycle charging. This comparison is made by taking into consideration the technological, economic, and environmental viewpoints. According to optimization studies, the improved approach results in the highest performance while incurring the least amount of net present cost (USD 33,747), unmet load (87 kWh/year), grid purchases (6188 kWh/year), and CO2 emission (3913 kg/year). In the end, the sensitivity analysis was carried out on a variety of essential factors, which had an effect on the optimal findings over a range of scales. Taking into account the recent advocacy efforts aimed at achieving the sustainable development targets, the models that were proposed in this paper can be used for a similar system design and operation planning that allows for a shift to more efficient dispatch strategies of HESs. This was accomplished by taking into consideration the recent efforts that were made.

The findings of a research project on a combined wind and photovoltaic system that might be used in the energy sector of the Republic of Iraq were provided by Abd et al. [45]. The hybrid system that has been given here is an idea for supplying electricity to utility users in Iraq and for the country's energy industry. The chronic lack of power that Iraqi customers are facing may be helped by the solution that has been presented, which is for wind and solar systems to work together to jointly generate energy. The authors demonstrate that the overall efficacy of the mini-energy complex is improved as a result of the combined production of electric energy by converting the solar radiation and the wind flow into usable forms of energy. The purpose of this research is to investigate and develop a small-scale hybrid wind–solar.

3. ENERGY SYSTEMS

3.1. Introduction

Matlab and Simulink were the programmes that were used to carry out the research study. The pv-wind hybrid system that was built is constructed with the use of the Simulink library's Matlab/Simulink blocks. The hybrid power generation system's structure involves the application of mathematical equations, which are then subjected to analysis. Matlab is an advanced programming language that could communicate with programmes, pictures, and environmental numerical computing. Its name comes from the Matrix Laboratory, which was established by Math Works. Matlab is a high-level programming language. In addition to this, it assists in the creation of models by making use of the physical blocks contained within the built-in Matlab/Simulink library, it is capable of doing mathematical formulas, and it can connect with programmes written in additional computer languages to analyse data. The programming language Matlab is utilised extensively in the fields of both science and engineering. In addition to that, it comes with a comprehensive library of mathematical operations, including integration and differentiation of numerical formulas, linear algebra, statics, and Fourier analysis. The method used to build a hybrid power generation system that uses wind and solar energy is tied to the electrical grid for the goal of transmitting power in order to meet the needs. In order to achieve optimum efficiency and power regulation, the hybrid system combines the utilisation of solar energy and wind energy obtained from the resources that are available. With the help of this technology, power may be sent to loads as well as the grid, and it does so based on the weather and the availability of solar and wind energy. Solar energy is widely available, and the Perturb and Observe method, an MPPT methodology, can be used to track its production. The temperature and the amount of voltage that is available in the solar cells both affect how much solar energy is generated. Through the use of DC-DC boost converters, solar energy is increased and then given to a DC-AC inverter circuit where it can be used to power a load. For a wind energy system, permanent magnet synchronous machines capture the speed of the wind turbines' rotors. The output wind energy was then linked with the turbines to be transformed into electrical energy [44]. For the purpose of send the output to the load, inverters transform the output from direct current to alternating current.. The system functions properly at temperatures and radiation levels that are considered normal, as well as wind speeds that are considered normal. It is possible to construct a hybrid system by combining several techniques, including converters, inverters, transformers, and regulating systems, including PI and PWM, for the system's internal operations. Matlab block sets were utilised in the process of developing and modelling this hybrid system, which takes place in the software Matlab/Simulink.

The accessibility of alternative energy sources across area is the most important piece of data that must be gathered before designing a hybrid power generation system that makes use of renewable energy. Along with the temperature, the irradiance and the maximum number of hours of sunshine are essential pieces of information for solar energy. Radiation from the sun and its temp are the primary factors that have an effect on the production of solar energy. However, in order to harness the power of the wind, one must have an understanding of both the wind velocity and the topographical factors that influence it. In order to compute a mean total production of energy that can be produced in the area, a comprehensive examination of the solar radiation and the speed of the wind is necessary. The data from Iraq are used as a reference to demonstrate that the location is suitable for the installation of a hybrid power generation unit that uses solar power for energy and the wind. The power of Sun and wind are both readily available in Iraq; therefore, combining these two resources would result in the highest possible amount of electricity production.

3.2. Pv Energy System

Solar energy is the name given to the energy that is obtained from the sun's rays. It is easily available all over the surface of the planet and has a widespread distribution. The energy that comes from the sun is a clean, highly effective, and very inexpensive source of energy. Solar energy may be converted into usable power via the use of PV panels. Solar-material panels act as the medium through which solar energy is converted into either heat or electricity. Materials that are semiconductors are used to build the solar panels. Silicon is a kind of semiconducting material that is utilized in solar cells. This material is located on the surface of the cell, which is where the sunlight hits and is absorbed. In their most basic form, solar cells perform the same function as a diode thanks to the PN junction that is produced in the material. When sunlight strikes a material's surface, some of the light's energy is absorbed, making it possible for electrons to flow around unimpeded. The production of electric current is a direct consequence of the passage of electrons. The photoelectric impact is the name given to the fundamental process that allows solar energy to be converted into usable forms of electricity [46,47].

Combining individual PV cells results in the formation of solar panels. PV cells are linked together to create a PV module, which is then followed by PV modules being connected to one another to create the necessary PV panels or arrays. In a PV module, the number of PV cells will typically vary anywhere between 36 and 96 cells. The load requirements decide whether to connect the cells in series or parallel. The modules would be connected either in series or in parallel combinations, similar to how the cells are set up. Photovoltaic cells are frequently arranged in series for high output voltage, whereas they are typically stacked in parallel for high output current. In order to build a solar panel, the cells are first connected in series to get the necessary voltage, and the strings that result are then connected in parallel to achieve the requisite current [46,47].

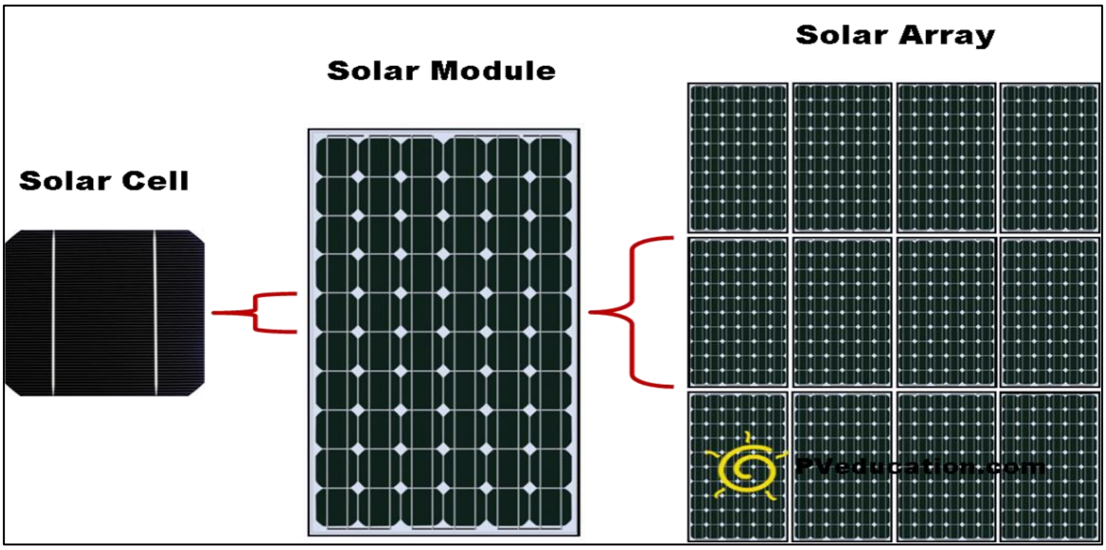


Figure 3.1. PV cell, PV module, PV panel, and finally, PV array.

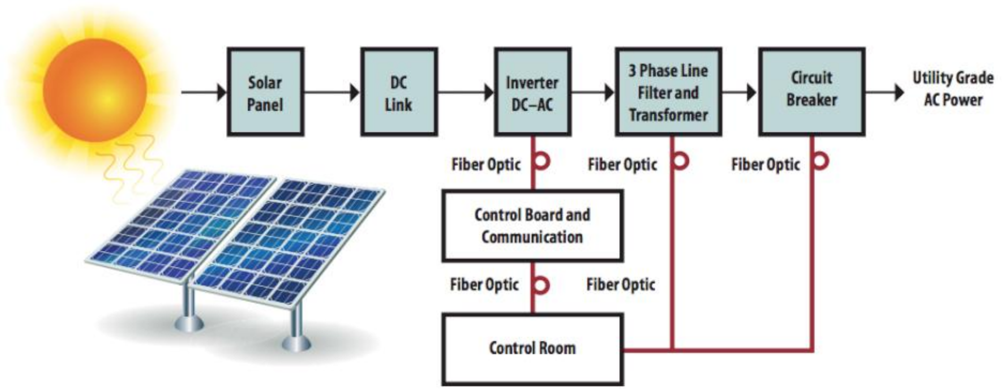


Figure 3.2. Diagrammatic presentation of solar energy.

The fundamental outline of the circuitry involved in the creation of solar energy is seen in figure 3.2. In the illustration, the solar panels are positioned such that they receive sunlight from the sun. These photovoltaic solar panels use photovoltaic silicon semi-conductors as its primary material component. PV cells take use of the photoelectric impact, which allows the sun's energy to be turned directly into electricity. The converters get their DC power from the solar panel's output panels, which is supplied into them. The point of max power In order to monitor the greatest amount of solar energy, tracking methods are utilised alongside the system, and the resulting pulses are then provided to the converter. Converters, which are used to produce regulated DC output, are necessary to convert the voltage from one level to another. After obtaining the input voltage from the solar panels, the converter produces a controlled DC output. In order to create the alternating current (AC) output that will be provided to the load or the grid, the converters' regulated direct current output is fed into the inverter's input. Figure depicts a solar energy generating system in block diagram form. İn fig(3.3).

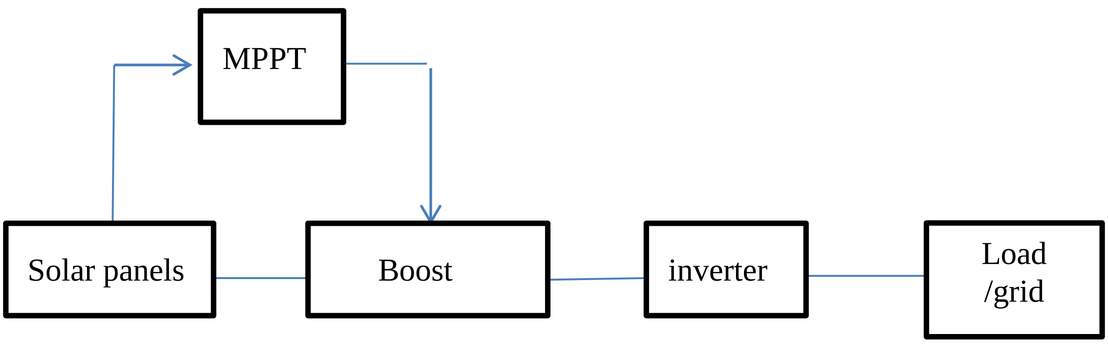


Figure 3.3. Diagram of the solar energy system.

3.2.1. Solar panel moduling

The photovoltaic (PV) cells are the most fundamental component of a solar panel. When designing the solar panels, the fundamental equivalent circuit model and the formulas that describe a PV cell were taken into consideration. Formulas were utilised to simulate the behaviour of the solar panel.

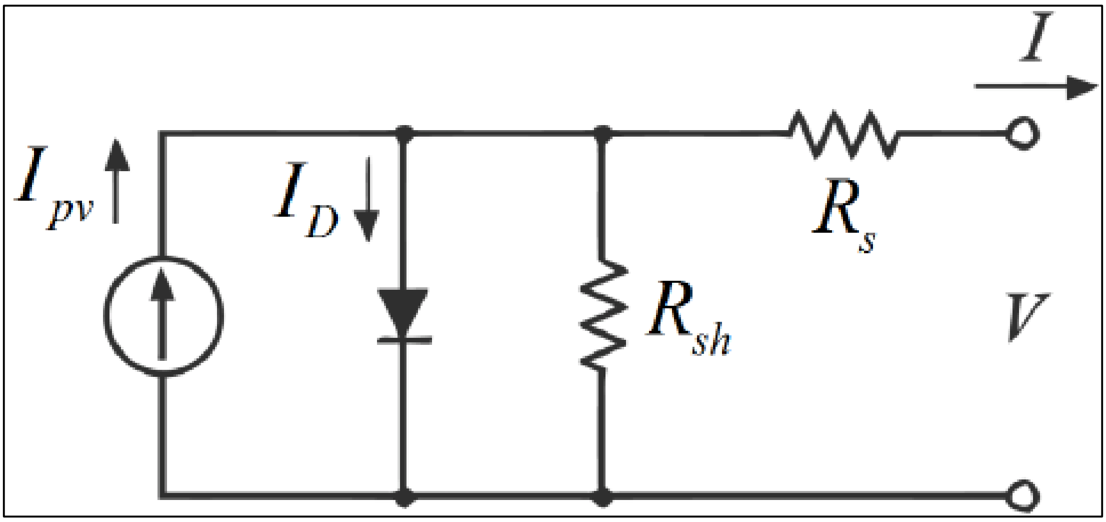


Figure 3.4. PV Cell equivalent circuit model with resistances [48].

Figure 3.4 shows the simple diode equivalent circuit configuration for a solar cell with resistors linked in series and parallel. The following equation can be used to express the produced current from a solar cell:

$$I_{PV\ Cell=} I_D + I_{Sh} + I \tag{3.2}$$

$$I = I_{PV\ Cell} - I_D - I_{Sh} \tag{3.2}$$

The current through the diode in a solar cell is represented as:

$$I_D = I_{0\ Cell}[e^{\frac{v+IR_S}{aV_{th}}} - 1] \tag{3.3}$$

$$I_{sh} = \frac{V + IR_S}{R_P} \tag{3.4}$$

It may be expressed as by substituting equations 3.2 and 3.3 in formula 3.2:

$$I = I_{PV\ Cell} - I_{0\ cell}[e^{\frac{v+IR_S}{aV_{th}}} - 1] - \frac{V+IR_S}{R_P} \tag{3.5}$$

$$I = I_{PV\ Cell} - I_{0\ cell}[e^{\frac{q(v+IR_S)}{akT}} - 1] - \frac{V+IR_S}{R_P} \tag{3.6}$$

$$I = I_{PV\ Cell} - I_{0\ cell}[e^{\frac{q(v+IR_S)}{akT}} - 1] \tag{3.7}$$

In a PV module, several cells are connected to the circuit in both series (N_s) and parallel (N_p), configurations, together with the shunt and series resistance.

$$I = N_P I_{PV\ Cell} - N_p I_{0\ Cell}[e^{\frac{q(v+IR_S)}{akT}} - 1] - \frac{V+IR_S}{R_P} \tag{3.8}$$

Both the temperature and the solar radiation have a significant impact on the photon current that is incident on the solar cell. This could also be said as:

$$I_{PV\ cell} = [I_{sc} + K_i(T - 298)] * \frac{G}{1000} \tag{3.9}$$

The diode current always takes the saturation current in the opposite direction, regardless of temperature, and appears to be a function of both the current and voltage. As a result, the reverse saturation current can be computed as follows:

$$I_{ocelln} = \frac{I_{scn}}{exp^{\left(\frac{V_{OCN}}{aNV_{th}}\right)-1}} \tag{3.10}$$

$$I_{cell} = I_{cell}(\frac{T}{T_{ref}})^3 \exp[\frac{qE_g}{ak}(\frac{1}{T} - \frac{1}{T_{ref}})] \tag{3.11}$$

Irradiance and temp of the cell are the primary factors that determine the I-V and P-V properties, respectively. The output of the features varies in response to changes in both the temp and the amount of solar radiation. These mathematical formulas are used in the process of designing a photovoltaic panel [49,50].

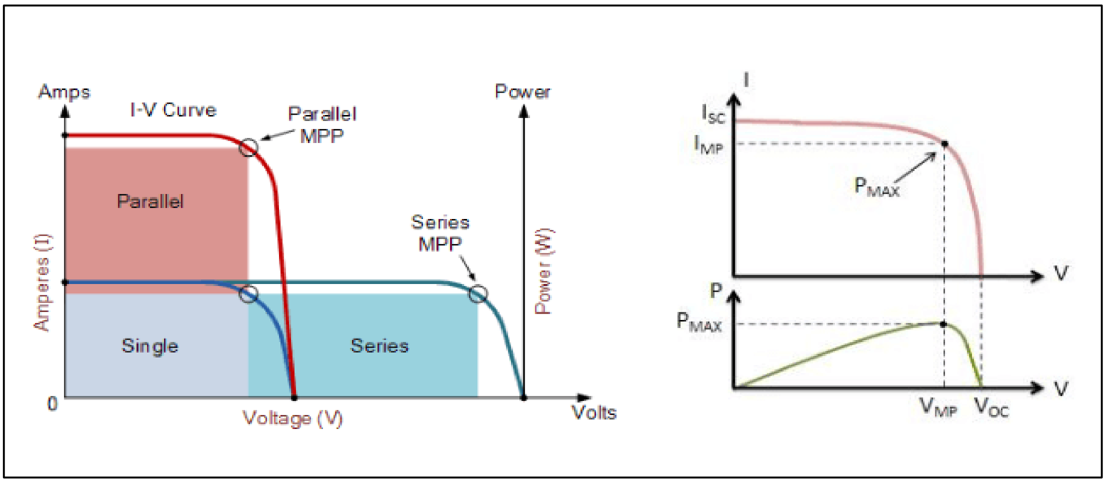


Figure 3.5. Solar cell properties P-V and I-V [50].

3.3. Tracking Maximum Power Point

An electronic gadget called the Max Power Point Recording system keeps track of the most readily available energy source, which improves the output performance and effectiveness of solar PV panels. This is accomplished by tracking the max power point at which the resource is accessible. The output seems to have a nonlinear nature and is subject to frequent fluctuations as a result of variations in the weather conditions. This gadget assists in tracking the available power in the environment and operating at the greatest power point, both of which contribute to an increase in efficacy. The voltage where a photovoltaic panel produces its highest amount of electricity is referred to as the max power point [48,51].

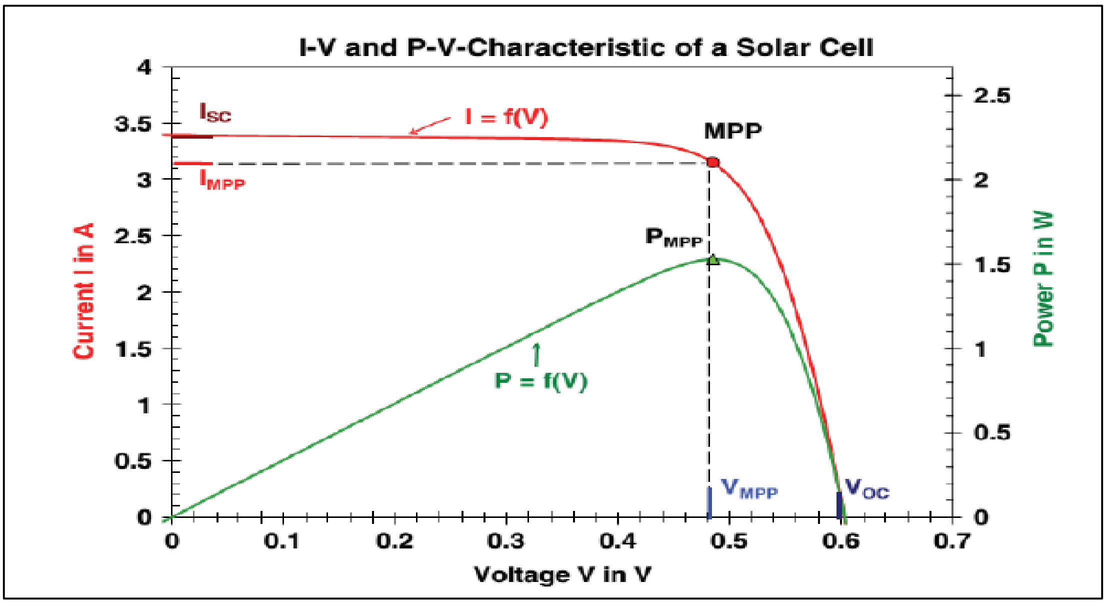


Figure 3.6. Power properties curve for P-V and I-V *[51]*.

The MPP shifts in response to changes in both the amount of solar irradiation and the ambient temperature. Both the voltage source area and the current source region are considered to be properties of a PV cell. At the current source area of the solar cell, the internal impedance of the solar cell would be high, but at the voltage source region of the solar cell, the internal impedance of the solar cell will be low. The greatest amount of power will be delivered to the load once the internal impedance is equal to the impedances of the load. The max power point (MPP) monitors the power output of the PV cells in relation to the load. Despite the fact that the temp and irradiance of the environment have an effect on the efficacy of the panel, because of the fluctuating weather conditions, the MPP is intended to have a quick reaction time, dependable performance, and reduced fluctuation. Owing to balance concerns, this control system could be linked directly to load. Instead, it is connected through a DC-DC converter so that it may regulate the load. A converter is a device that matches the impedances of the source and the load in order to send the greatest amount of power from the PV cell to the load. Step up or step down DC-DC converters are typically employed in most applications [51,52]. There are many distinct methods that can be utilised for MPPT, but the ones that are utilised most frequently in PV generation include the incremental conductance technique, the perturb and observe technique, the constant voltage and current method, fuzzy logic, the curve fitting technique, the open circuit voltage technique, the short circuit current technique, and many others. The Perturb and Observe approach and the Incremental Conductance method are the two strategies that are utilized the most often among them. Less time is needed for tracking using these methods, and their implementation is straightforward [51,52].

3.3.1. Perturb and observe

A alternative name for the Perturb and Observe strategy is the hill climbing approach. The ease of usage and wide range of potential applications make this approach the one that is most often chosen. The operation of this system in a PV module was determined by the fluctuations in output power that are caused by an increase or reduction in the voltage. The algorithm of the system takes into account the solar cell's PV curve. In this case, the voltage of the photovoltaic panel is changed such that it varies with voltage (dv), which also causes a concomitant change in output power (dp). Both of the different alternatives have to go in the same general direction. In the event that the functioning of the solar panel deviates from the MPP point and the voltage is upset with even a tiny variation, then a change in power would be seen. When any operating point is shifted closer to the MPP, there is a positive change in power, and the voltage would also experience perturbations in the same direction. When the operational point goes further away from the MPP, there will be a negative change in power, which would cause a perturbation of voltage in the opposite direction [53,54].

The most power is determined via the P&O method, which oscillates around the MPP. When the sun irradiance and temperature conditions change, the P&O MPPT approach is advantageous. These changes can be managed by lowering the disturbance and slowing the tracking speed. The P&O MPPT system responds to changes in the panel's voltage as well as comparisons with the power magnitude produced by the PV system during the cycle before [53].

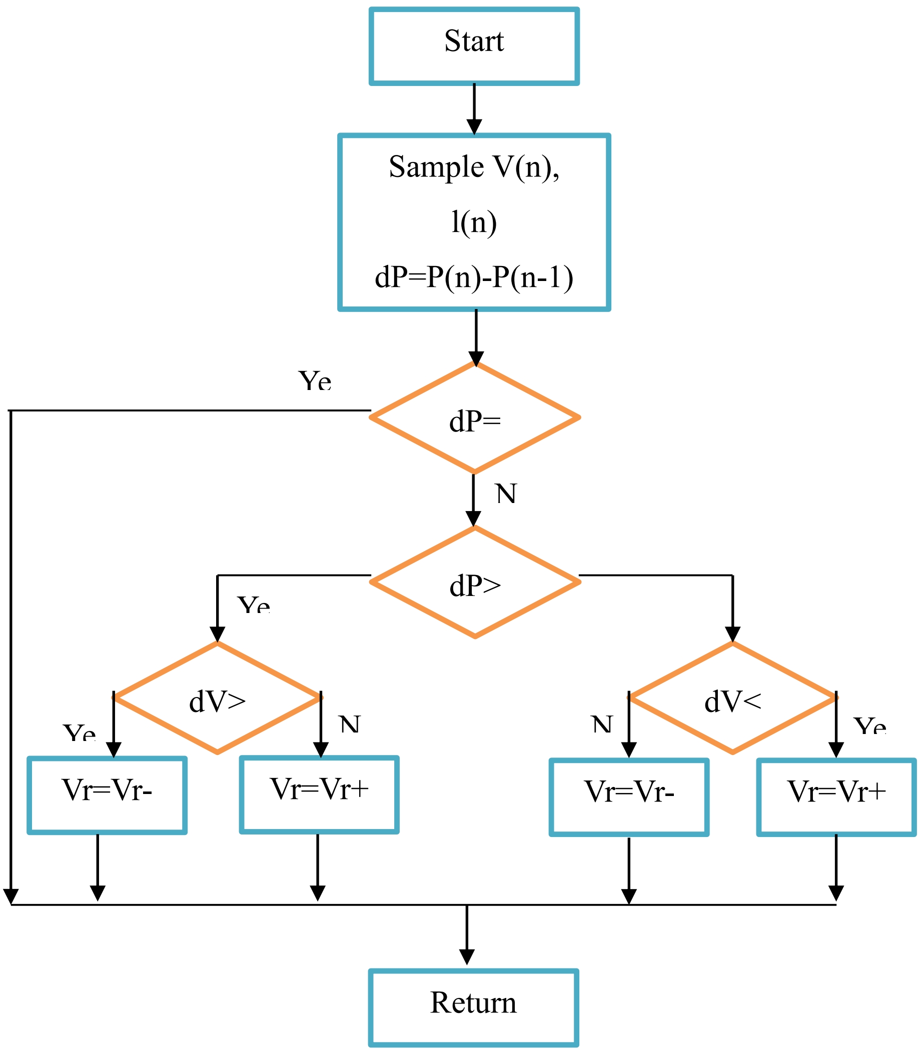


Figure 3.7. Flowchart for algorithm P&O MPPT [52].

3.3.2. Incremental conductance method

A different approach to solving the problem that the MPPT technique presents is the incremental conductance technique. This is a differential approach, and it works by calculating the PV power in relation to the voltage. When the power is differentiated in relation to the voltage, the output should go toward zero, and the PV voltage should either grow or reduce depending on whether there are positive or negative fluctuations in the ratio of the change in power to the voltage change (dP/dV). The incremental conductance approach is reliable for accurately tracking power despite variations in the environmental circumstances [52].

The algorithm for the incremental conductance approach distinguishes between shifts in power and shifts in voltage.

$$\frac{dP}{dV} = \frac{d(dVI)}{dV} = \frac{IdV}{dV} + \frac{VdI}{dV} \tag{3.12}$$

$$I + \frac{VdI}{dV} = 0 \tag{3.13}$$

$$the\ \frac{dP}{dV} = 0\ at\ MMP \text{ Therefore }, \frac{-I}{V} = \frac{dI}{dV} \tag{3.14}$$

The instantaneous conductance was denoted by the symbol -I/V in formula 3.14, while the incremental conductance was denoted by the symbol dI/dV. On the basis of the operational point, a series of iterations are carried out utilising this derivation, and each of these iterations would result in a value of zero at the MPP [55]. When choosing MPP as a tracking method, the technology utilised to analyse data has to be one that is effective, precise, and cost-effective. P&O and the incremental conductance technique are the two MPP approaches that are utilized for monitoring the most often. The reason for this is because not only are they easy to deploy in terms of their structure, but they also need relatively little monitoring time. In situations when it is not essential to tune the parameters, the approaches of "Perturb & Observe" and "Incremental Conductance technique" seem to be more likely to be utilised. The implementation of these systems is quite expensive, hence they are often reserved for usage in large-scale rather than in small-scale applications. The P&O approach is used in situations in which there is a fluctuation in climatic circumstances, most significantly shifting sun's radiation, as well as for instances in which there are rapid changes in the characteristics of the environment. However, due to the fact that this approach sometimes finalises the adjustments based on MPP rather than radiation from the sun, the computations end up being inaccurate. The incremental conductance approach is used in order to resolve this problem. This approach may be used in a digital setting and yields superior outcomes in settings when the weather is unpredictable and constantly changing. Within the range of the max power point, this system is able to achieve reduced oscillations. The sole disadvantage of using this strategy is its intricate structure. As a result, this technology is utilised mostly for endeavours operating on a massive scale, including satellite applications [51,55].

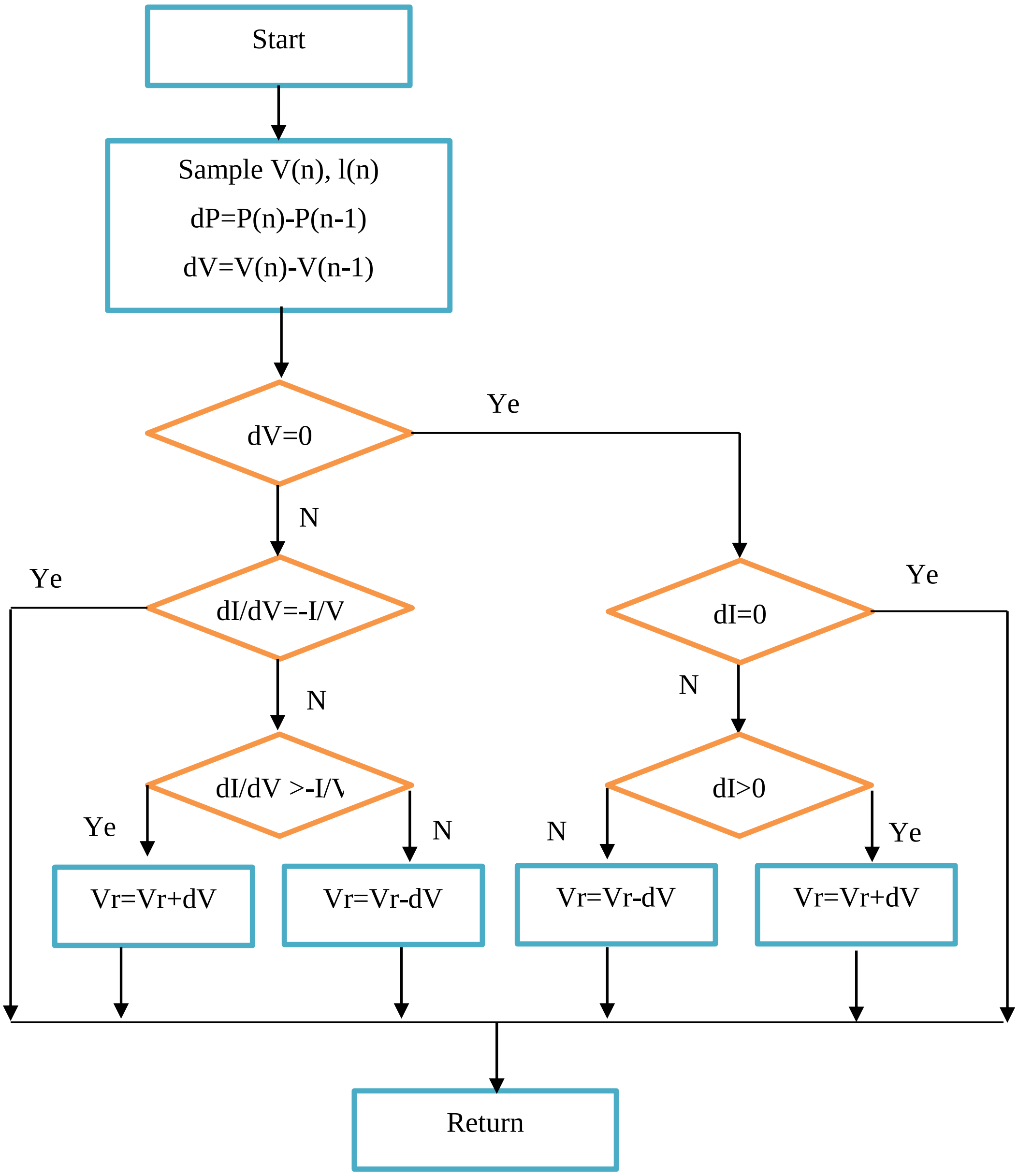


Figure 3.8. Flowchart for conductance technique [52].

3.4. Wind Energy System

Wind power is one of the most promising forms of renewable energy for meeting the ever-increasing requirements of the global economy. It is a clean and green kind of energy that does not harm the environment. Wind is the movement of air in the atmosphere. Through the use of wind turbines, the kinetic energy that is gained from the wind may be turned into mechanical energy. Generators are then used in order to complete the transformation of this mechanical energy into electrical energy. Wind energy may be generated by a variety of generators, the most popular of which being induction generators and permanent magnet synchronous generators, abbreviated as PMSGs (IG). In permanent magnet synchronous generators, the field of excitation was supplied not by excitation coils but rather by permanent magnets. The production of energy is by far the most widespread commercial utilization of this technology. These kind of generators were referred to as synchronous generators since the speed of the rotor always coincides with the frequency of the supply. Permanent synchronous generators have become the most common kind of generator utilized in high-power uses since of their cheap cost and ease of maintenance, as well as their high efficacy and independence from a DC supply [56,57].

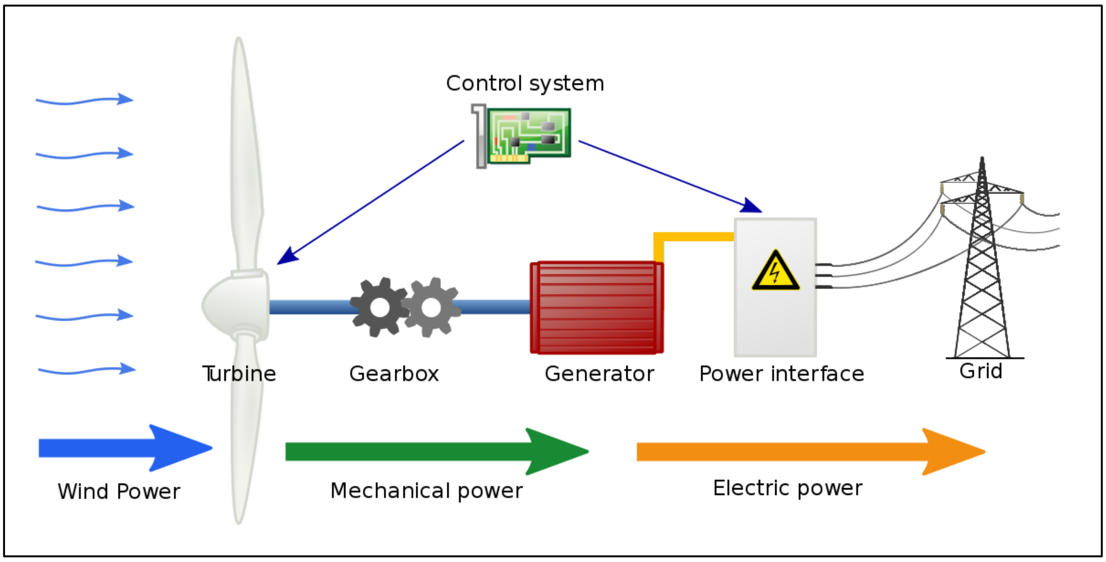


Figure 3.9. Illustration of wind energy.

The flowchart for the generation of wind energy is shown in figure 3.10 below. The wind turbine consists of a variety of parts, including a tower, generator, nacelle, gearbox, blades, and rotor, among others. The nacelle of the turbine is where the gearbox and generator are located. This is the most important component of the turbine. The wind turbine tower is home to both the rotors and the nacelle of the machine. Kinetic energy is transferred from the wind as it passes over the rotor blades and into the rotor hub. It is the job of the gearbox to bring the rotating speed shafts up to a higher level, and it is the generator's job to transform the mechanical energy of the revolving shaft into electrical energy. The outputs from the generator was sent into the inverter, which then produces the needed amount of AC output at the grid so that it may be distributed. In figure 3.10 below, a schematic diagram for a wind energy system is shown. [58].

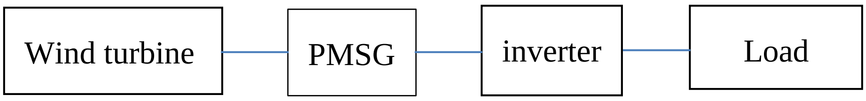


Figure 3.10. Wind Energy Schematic Diagram.

3.4.1. Wind turbine modelling

The air density (ρ) kg/m2, the power coefficient (Cp), the wind turbine swept area (A) m2, and the wind speed (V) m/s are the variables that determine the aerodynamic power properties of a wind turbine. The power coefficient is a function that takes into account both the blade pitch angle (β) and the tip speed proportion (λ). One way to write the formula for power (Pw) is as follows:

$$P_w = 0.5\rho A V^3 C_\rho(\beta, \lambda) \tag{3.15}$$

The tip speed proportion (λ) has been described as the proportion of the wind turbine's rotational speed (w) and blade radius (R) to the wind velocity (v)

$$\lambda = \frac{WR}{V} \tag{3.16}$$

The highest possible magnitude for the power coefficient (Cp) may be calculated to be 0.59 on a theoretical basis. The Cp seems to be a portion of the upstream wind power that is caught by the rotor blades of the wind turbines, while the remaining power is released to the downstream direction. Always maintaining the blade pitch angle (β) at zero ensures that the wind turbines produce their greatest possible torque [50,52].

3.5. Generators Powered by Wind

The power prodused from wind is a type of green energy that can satisfy the world's growing demand for power without compromising the availability of fossil fuels to fulfill foreseeable future requirements. The natural world provides an ample supply of the pure kind of energy. The generators that are utilized in the process of creating electrical energy form the foundation of wind energy conversion systems. There are two types of wind turbines: those that have a different wind speed and those that have a constant wind speed. Wind turbines with variable speeds were capable of achieving optimum efficacy throughout a broad range of wind speeds, in contrast to wind turbines with fixed speeds, which only achieve max efficacy when the wind speed is constant. The directly operated permanent magnet synchronous generator seems to be the technique that is utilized the most often for the conversion of wind energy as a result of its high level of efficacy and dependability.

3.5.1. A synchronous permanent magnet generator

The wind turbine produces mechanical power, which is then converted into electrical power by the generators with permanent magnets. In the end, these power electronic equipment are used to feed this power into a load or the grid as showen in fig 3.11.

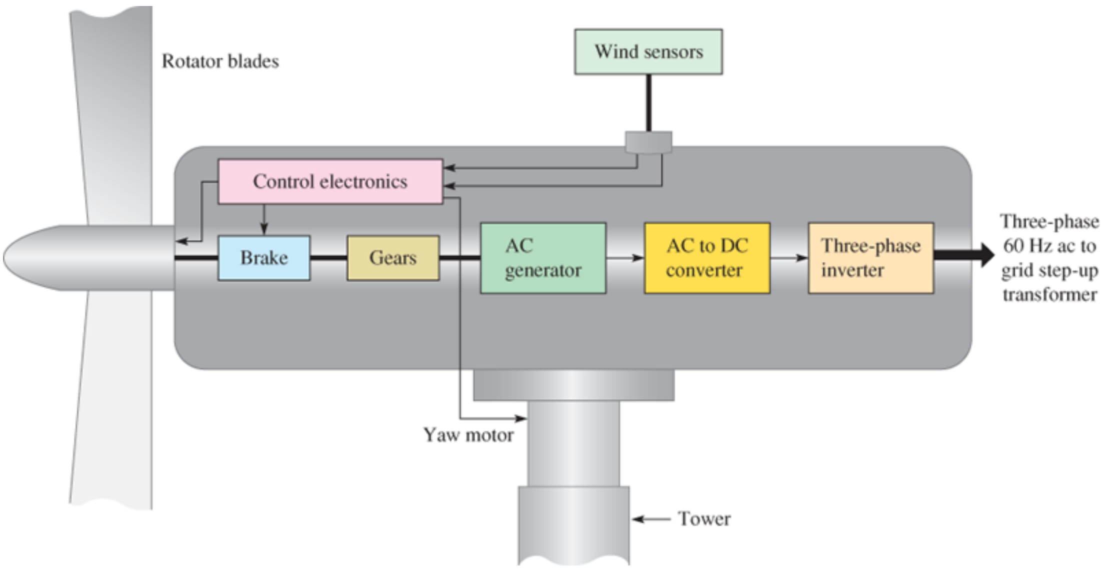


Figure 3.11. Simple wind energy conversion system illustration.

The creation of a dynamic model in a PMSG involves two steps. The q-axis is 90 degrees in front of the d-axis in terms of rotation direction. In a d-q reference frame spinning synchronously, the mathematical model can be written as follows:

$$\frac{di_d}{dt} = \frac{1}{L_{ds} + L_{Is}}(-R_s I_d + w_e(L_{qs} + L_{ls})i_q + u_d) \tag{3.17}$$

$$\frac{di_q}{dt} = \frac{1}{L_{qs} + L_{Is}}(-R_s I_q + w_e[(L_{ds} + L_{ls})i_d + \psi_f] + u_d) \tag{3.18}$$

Lq and Ld seem to be the d and q axis inductances in generators, while Llq and Lld seem to be the q and d represent the Generator axis leakage inductance. ψf is the persistent magnetic field flux, and e is the generator's electrical motor speed. The notation d and q refers to the d-q frame of reference. The formula for the torque produced by a PMSG.

The generator's d and q axis inductances appear to be Lq and Ld, whereas the leakage inductances of the generator's q and d axes, Llq and Lld, are Llq and Lld. e denotes the generator's electrical rotation speed, while ψf denotes the permanent magnetic flux. Referring to the d-q reference frame is indicated by the notation d a- q. formula for the torque a PMSG produces.

$$\tau_e = 1.5P((L_{ds} - L_{ls})i_d i_q + i_q \psi_{f)} \tag{3.19}$$

p refers to the poles' number in a generator [52].

3.5.2. Induction generator

The generator is the component of the wind energy producing system that is the most difficult to understand. Before it can begin producing electricity, the induction generator has to wait for the excitation capacitor to first self-excite. Since of their cheap cost, their resilience, and the absence of any cogging torque, IG are suitable for use in low power wind turbines. Due to the high rotational speed of the IG, its use in tiny wind turbines necessitates the addition of a gearbox. The electromagnetic state variables, as well as the stator, rotor, and electromagnetic transients, are all included in IGs. The rotor slip proportion may be calculated using:

$$S = \frac{w_s - w_g}{w_s} \tag{3.20}$$

The generator power and the electrical torque are both supplied by.

$$T_e = \Psi_{qr} I_{dr} - \Psi_{dr} I_{qr} \tag{3.21}$$

$$P = V_{ds} I_{ds} + V_{qs} I_{qs} \tag{3.22}$$

The complexity of the model is reduced because to the application of Park's Transformation approach, which takes into account the fact that the inductances of both the stator and the rotor shift with time. The slip output would be positive when operating in the monitoring mode, but would be negative when operating in the generating mode. The magnetic flow is denoted by the symbol in formula 3.21 . In formula (3.22), V_{qs} and V_{ds} represent the voltages of the quadrature axis and stator direct axis of an induction generator found in a wind turbine. The induction generator's current along the quadrature axis and the current along the stator direct axis are denoted by I_{ds} and I_{qs}, respectively.[59,60].

3.6. Hybrid Energy System

In order to satisfy the ever-increasing requirements of the future, hybrid power production systems are the finest answer that is now available. The term "hybrid energy systems" refers to the generation of electricity via the integration of two or more distinct energy sources. The climatic conditions have a significant role in the production of renewable energy. When the sun's radiation is greater, the temperature will generally be higher as well, which is sufficient for the generation of solar energy; however, during this time the wind energy will be weak. In a similar vein, when there is a lot of wind, the sky will be overcast, and there is a good likelihood that it will rain. Additionally, visibility will be poor, and there will be very little sunshine. As a result, it is not prudent to derive all of one's energy requirements from a single supply in order to maintain continuous power production. Energy derived from the sun is only accessible during the day, but wind may be harnessed at any time of the day or night. Despite this, the gustiness of the wind tends to be at its peak throughout the night, and as a result, either one of the two sources of power would be accessible at all times. The energy that comes from the sun is most advantageous throughout this summer months, when the weather is warmer and sunnier, while the energy that comes from the wind is most useful during the winter months, when the weather is colder and windier. Consequently, the integration of renewable sources of energy offers higher levels of performance and output reliability than do standalone systems throughout each and every cycle of the power production system [61].

The goal of the hybrid energy systems is to maximise the amount of electricity generated by combining renewable sources of energy like solar and wind with grid-connected control mechanisms. The advantage of having a power generating unit that is tied to the grid is that in the event that there is a disruption in the generation of electricity derived from solar or wind sources, the grid may function as a source or as a backup system. The grid is used to store any extra energy that is produced by renewable resources, and this energy is then used to satisfy any load demand that may arise. Hybrid power production is going to be the greatest option in the near future since seasonal changes for the wind and sun could be overcome by combining the energy, and output performance could be enhanced. This will make hybrid power generation the optimum answer in the approaching future [61].

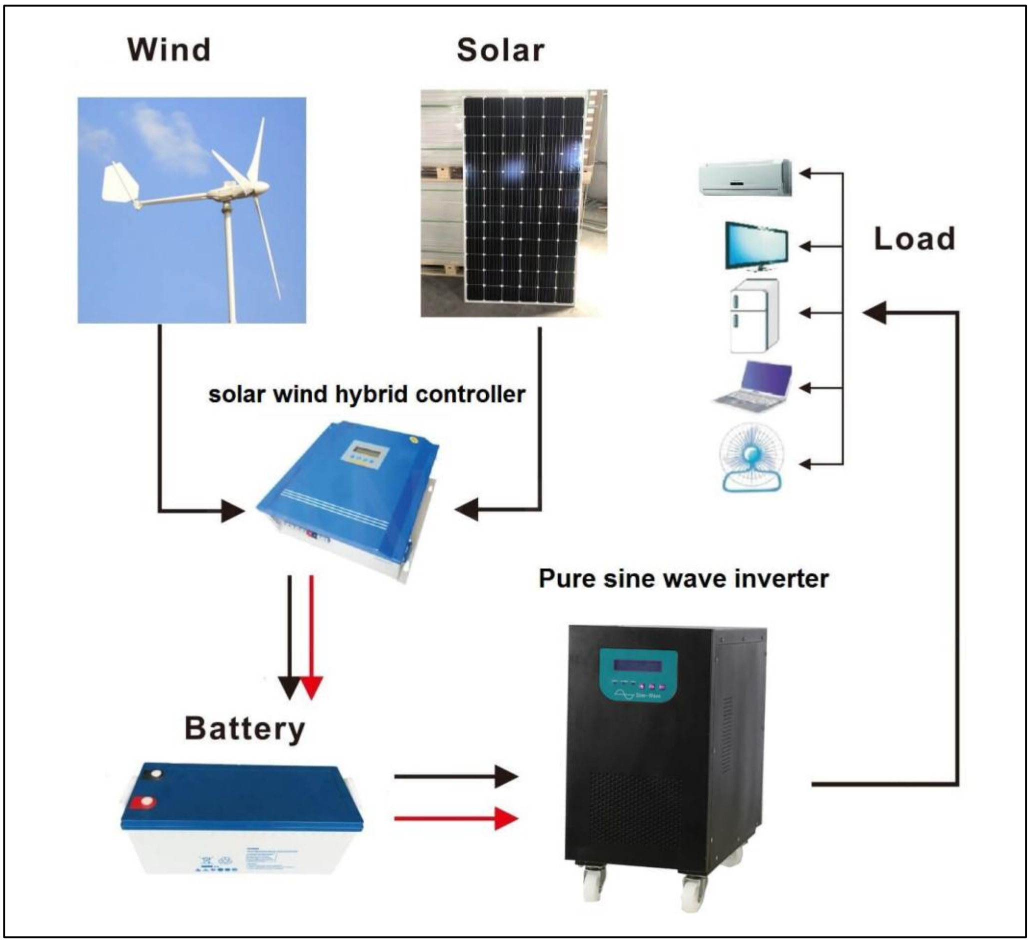


Figure 3.12. Hybrid solar and wind energy sources represented diagrammatically.

Figure 3.11 shows the concept for a hybrid power generating system that uses both solar and wind energy. Before either the grid or the load can be powered, the two different sources of energy are merged using various control mechanisms. The solar energy that would be captured from the sun is routed through a converter with the use of MPPT technology to produce a controlled DC output. After that, an inverter converts this output into an AC output. The generator then takes the mechanical energy that was created by the turbine of wind and converts it into electrical power, which is then sent into the inverter. The output from both generators is blended before being sent to the AC grid. Since the changing patterns of the sun and the wind throughout the year, and because continuous power production requires the use of wind and solar power, hybrid systems have an important function [62].

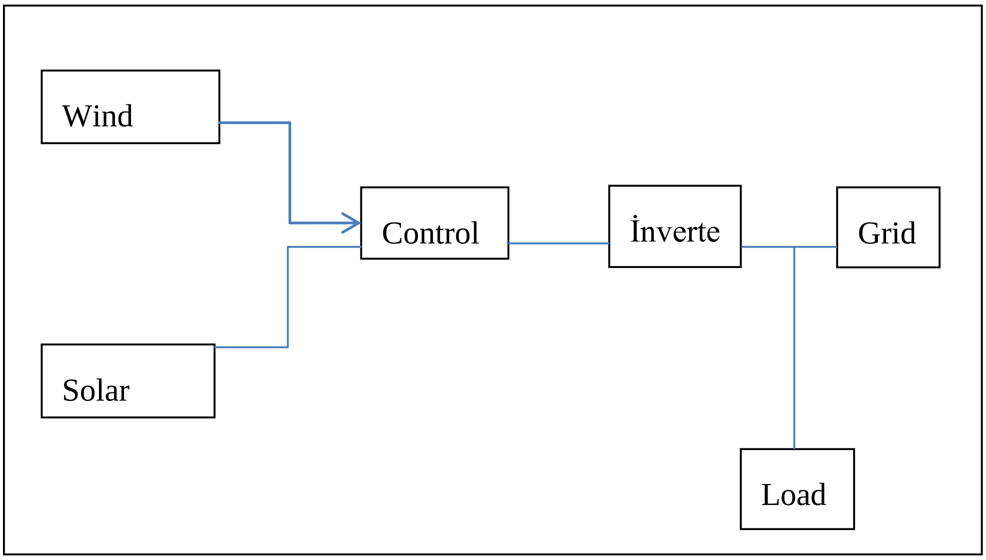


Figure 3.13. Block diagram of hybrid energy system.

A hybrid energy generating system that makes use of solar and wind power is seen in the block diagram that can be found above in figure 3.12. The illustration provides a general sense of how the hybrid system works. That tracking approach is utilised to use the greatest possible amount of power from the energy resource, and the energy from the sun is caught and converted for the purpose of creating power for that method. Perturb and Observe seems to be the technique of tracking that is utilised (P&O). The electricity that is used is routed via a boost converter, which increases the amount of power that the output of dc power supplies to the inverter. The inverter changes the direct current to alternating current. The input is converted to Alternatve Curent (AC) using a three phase inverter so that it may be sent to the grid and utilised to satisfy the requirement for energy. In a similar fashion, the energy that is derived from the wind may be converted into a form that is usable by using a wind turbine, which measures the rotational speed of the wind and converts it into mechanical energy. The generator takes the kinetic energy from the wind and converts it into electrical energy. A synchronous permanent magnet generator is employed in the generation process. The electricity that is produced is fed into the grid in order to satisfy demand.

3.7. Study Area

Rutba is an Iraqi city located in western Iraq within the administrative Al-Anbar Governorate. The city has a population of about 41,000 people, 645 meters above sea level. It is the center of Rutba district. Administratively, it has two sub-districts: Al-Walid and Al-Nakhaib, which is a link between Al-Anbar and the Kingdom of Saudi Arabia and jorden respectively. Many of its residents migrated to the Saudi city of Arar. The city is characterized by a mild climate in summer with light rains. Its mild climate is due to its location in a high area and exposure to northern winds, which had a reason to soften its climate in the summer. It also passes through two valleys, Hauran and Al-Massad. And there are minerals such as iron, aluminum, zircon, glass, kaolin, and bentonite in its land. It is 310 km away from the center of the province, and it is the nearest city to it, and 320 km from the city of Al-Qaim. Rutba borders three countries: the Kingdom of Saudi Arabia, the Hashemite Kingdom of Jordan, and the Syrian Arab Republic. Rutba was the Iraqi border post for those traveling to Jordan and Syria. Before the establishment of the Karama Borders Center in Trebil, it was mentioned in the book (Geography of Iraq and the Arab Countries) printed in 1947 AD that Rutba was “the first Iraqi village that was established as a result of finding a number of fresh wells. Both the Iraqi border with Jordan and the Iraqi border with Saudi Arabia are around 110 kilometres apart from Rutba as shown in figure 3.13 [41].

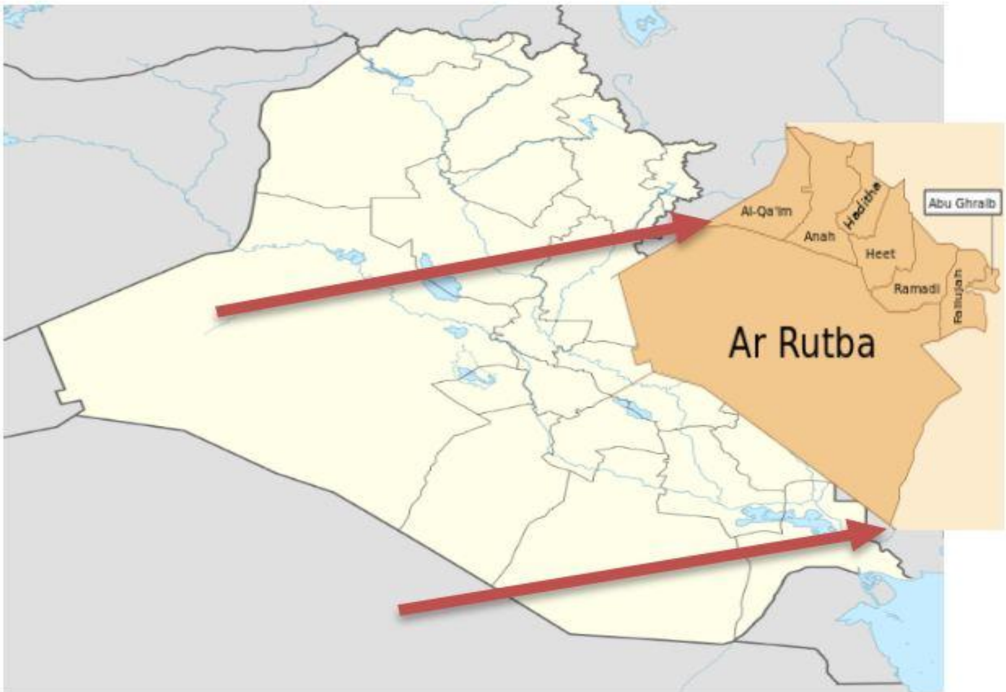


Figure 3.14. The location of the study area.

Rutba is one of remotest sub-district in the west of Iraq province . it is located at 8° 44'43" south latitude and 115° 32'21" east longitude on the astronomical map. As indicated in figure (3.13), this region receives an average light intensity of 5.34 kWh/m2/day, with an average wind speed of 4.4 m/s, an average air temperature of 27.2° C, and an average humidity of 79.5 percent. As a result, the region's wind and solar energy potential deserves to be classified as a source of renewable energy power plants.

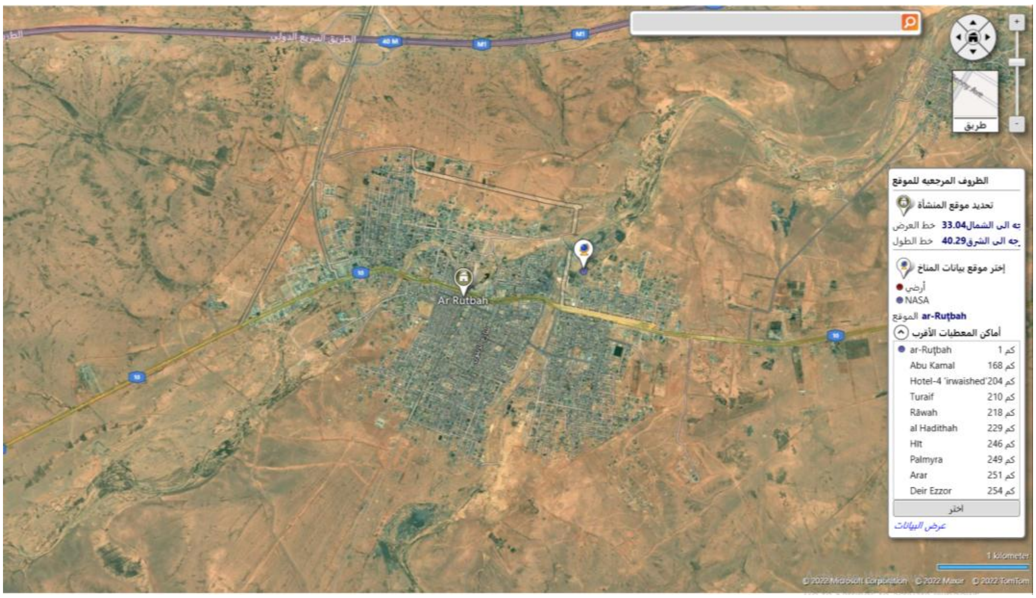


Figure 3.15. Location of rutba city

The usage of a solar and wind hybrid system will be more efficient than using the two systems separately. Both of these energy sources will be complimentary, with the solar system dominating in the dry season and wind power playing a larger role in the rainy season .

Implementation of solar and wind power generation is carried out in line with the anbar government project to achieve the 'anbar go green, go clean' which is one of the projects submitted by Iraq on Climate Change .

3.7.1. Rutba city's generating system

The power system consist of Rutba are diesel generators. This system has 15 diesel generating units (10 units Cummins diesel engine and 5 unit cater paler diesel engine). The interconnection of generation system in Rutba is shown in Figure (3.15).

Rutba is one of iraqi’s most remote islands, located off the coast of anbar. This area's electrical grid is separate from Anbar's grid , which is supplied by a 20 kV interconnection of hybrid solar-wind-diesel power stations. The average solar radiation is 5,34 kWh/m2/day, with an average wind speed of 4,4 m/s. This circumstance might be used to construct a renewable energy power plant in this location. Anbar is one of Iraqi's provinces, having a land area of 5636.66 km2, or 0.29 percent of the country's total area. The tourism sector is the backbone of the Anbar economy, and it requires a reliable electrical power supply. The energy of Rutba infrastructure is supported by 15 major diesel generators with a combined capacity of 1 MW per generator , which are connected to general network through Iraq .

Figure 3.16. The power system plant in Rutba city.

At the beginning of the operation, this power plant system is running well. Until this time and the total energy generated by this units reached 110 MWh per day in total. The energy produced is equivalent to 25,000 liters of diesel per day. Taking into account the price of diesel fuel 4$/ liter at the time and 2$/liter of lubricate engine .in addition to this, the cost of repair is also too expensive in comparing with the other source of energy . besides ,the pollution result from the engine. It can be produce one million of diesel fuel produce 2.5 ton of co_2.it is leads to increase pollution to environment.

3.8. Full-Model Architecture

In this chapter we will explain the implementation of one MW hybrid wind-solar system in the west of iraq by using matlab program and the data that have received from retscreen program with energy storage is the system under discussion. A 400 kW grid-connected turbine of wind that employs a battery bank that is coupled to a bidirectional DC-DC converter for energy storage after a PMSG with a generator- and grid-side controller and converter architecture is connected to a bidirectional boost-buck converter. The suggested system architecture is shown in Figure 3.16, which also shows a 600 kW PV array that is coupled to a boost DC-DC converter and is controlled by a Perturb and Observe (P&O) algorithm block for power point tracking.

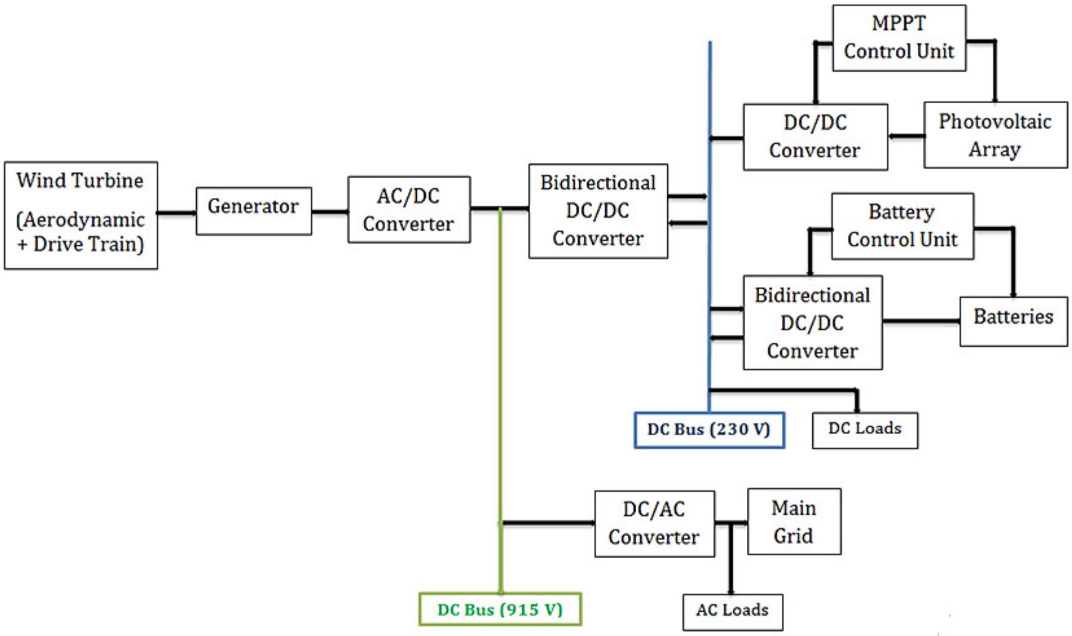


Figure 3.17. Hybrid power generator of wind solar system architecture.

In figure 3.18 shows the Simulink model of hybrid solar-wind power in matlab program.

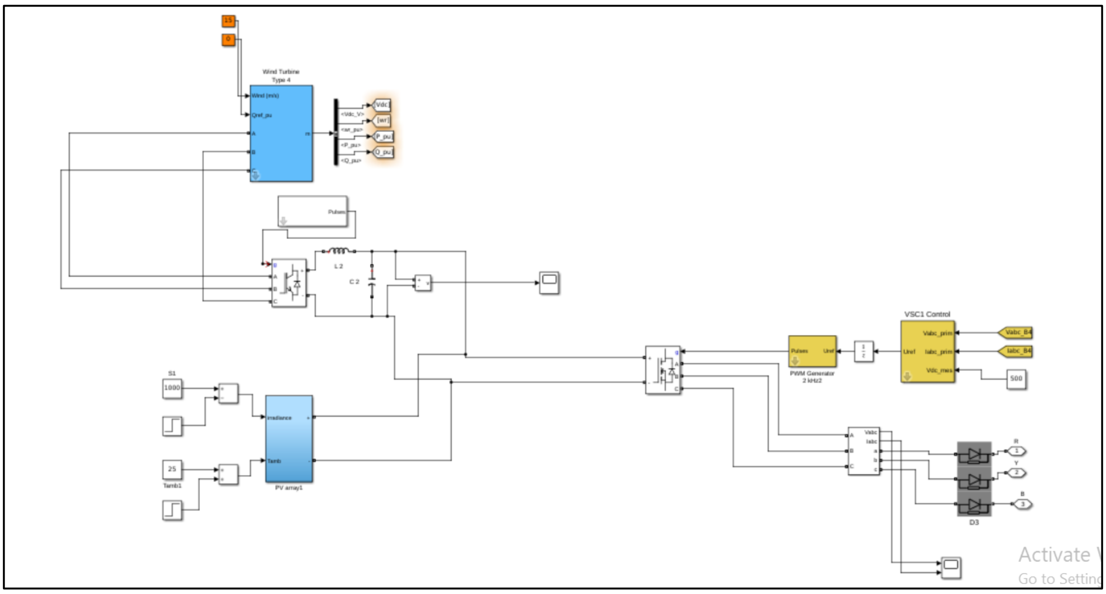


Figure 3.18. Simulink of hybrid power of wind-solar system in matlab.

3.9. Conditions Of The Hybrid System Location

3.9.1. Retscreen expert

The platform that is RETScreen® Clean Energy Management Software makes it possible to prepare for and execute low-carbon strategies, as well as monitor and report on their progress. Management software for environmentally friendly energy sources [1]. A complete software platform that allows experts and decision-makers to quickly assess and verify the actual and ongoing energy performance of buildings, industries, and power plants located all over the globe in an intelligent and easy-to-use manner. In addition to this, it helps them to rapidly discover and evaluate the profitability of proposed initiatives including energy efficacy, sustainable sources, and cogeneration.

3.10. Instlation Of Solar-Wind In Rutba City

Natural and environmental elements, such as solar radiation, temperature, rainy days, air pressure, humidity, wind speed, and others have a significant impact on the use of renewable energy. The environment must be taken into account in order to maximize the contribution of hybrid plants, particularly wind speed and solar radiation, which are key contributors to the production of electrical energy.by the using data of retscreen program ,the weather condition of Rutba city are more efficient to build the hybrid of solar-wind station as shown in Figure (3.19.)

	Unit	Climate data location	Facility location	Source
Latitude		33.0	33.0	
Longitude		40.3	40.3	
Climate zone		2B - Hot - Dry		NASA
Elevation	m	637	621	NASA – Map
Heating design temperature	°C	1.7		NASA
Cooling design temperature	°C	36.3		NASA
Earth temperature amplitude	°C	26.1		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	6.1	61.0%	11.47	2.66	94.4	4.0	5.7	369	0
February	7.9	54.8%	11.48	3.60	94.3	4.4	7.9	283	0
March	12.2	43.4%	8.06	4.84	94.1	4.3	12.8	180	68
April	18.4	32.8%	6.60	5.97	93.9	4.3	19.6	0	252
May	24.1	25.9%	2.48	7.25	93.8	4.2	26.1	0	437
June	28.2	21.2%	0.30	8.35	93.6	4.6	30.6	0	546
July	30.5	21.3%	0.00	7.93	93.3	4.8	32.8	0	636
August	30.4	21.8%	0.62	7.23	93.4	4.1	32.5	0	632
September	26.9	23.6%	0.30	6.03	93.8	3.5	28.4	0	507
October	21.4	32.3%	5.58	4.24	94.2	3.5	22.0	0	353
November	13.2	48.1%	12.60	2.93	94.4	3.6	13.1	144	96
December	7.6	59.6%	9.30	2.23	94.5	3.8	7.2	322	0
Annual	**19.0**	**37.1%**	**68.79**	**5.28**	**94.0**	**4.1**	**20.0**	**1,298**	**3,528**
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA
Measured at					m	10	0		

Figure 3.19. Weather condition in Rutba city.

3.11. Climate

Rutba is a city located in the Al-Anbar Governorate of western Iraq. The city has a hot desert climate, also known as a BWh climate under the Köppen climate classification system. This type of climate is characterized by extremely hot summers and mild winters, with very low precipitation throughout the year.

In Rutba, summers are long, hot, and dry, with average high temperatures reaching up to 43°C (109°F) in July and August. Nighttime temperatures in the summer months are relatively cooler, dropping down to around 24°C (75°F). Winter temperatures in Rutba are mild, with average high temperatures in the range of 17-21°C (63-70°F) and average low temperatures around 5-8°C (41-46°F).

Precipitation in Rutba is extremely low, with an average annual rainfall of only around 72 mm (2.8 inches). Most of the rainfall occurs during the winter months, from December to March, with little or no rain falling during the summer months.

The city is also prone to sandstorms, which can occur throughout the year but are more common during the summer months when hot, dry winds blow over the desert. These sandstorms can cause visibility issues and respiratory problems for the residents of Rutba.

Overall, the climate of Rutba is characterized by hot and dry summers, mild winters, and very low precipitation throughout the year, which is typical of the desert regions in western Iraq.

Table 3.1. Climate data for rutba.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	12.8 (55.0)	15.6 (60.1)	19.8 (67.6)	25.4 (77.7)	31.5 (88.7)	36.0 (96.8)	38.2 (100.8)	37.8 (100.0)	36.1 (97.0)	29.8 (85.6)	21.5 (70.7)	14.4 (57.9)	26.6 (79.8)
Average low °C (°F)	1.1 (34.0)	2.2 (36.0)	3.3 (37.9)	10.2 (50.4)	15.2 (59.4)	18.5 (65.3)	21.1 (70.0)	21.1 (70.0)	17.3 (63.1)	12.8 (55.0)	7.2 (45.0)	2.7 (36.9)	11.1 (51.9)
Average precipitation mm	16 (0.6)	13 (0.5)	17 (0.7)	19 (0.7)	10 (0.4)	0 (0)	0 (0)	0 (0)	1 (0.0)	6 (0.2)	16 (0.6)	19 (0.7)	117 (4.6)

4. RESULT AND DISCUSSION

4.1. Estimation Of Real Condition

It is vital to measure the daily solar radiation intensity and wind speed to ascertain how much weather fluctuations affect the production of solar and wind power stations,it can be clearly seen from data in figure 4.1 that the solar radiation increased gradually with air temperature from 5 c^0in January until reach to the peak point at July 27.2c^0 after that is has been decrees to 7c^0 at December.

Figure 4.1 shows the climate data values based on relationship between Air temperature and daily solar radiation-horizontal (kWh/m^2/d), June month records the highest solar radiation, while months July and August record highest wind speeds due to increase the wind speed with reduce the air humidity.

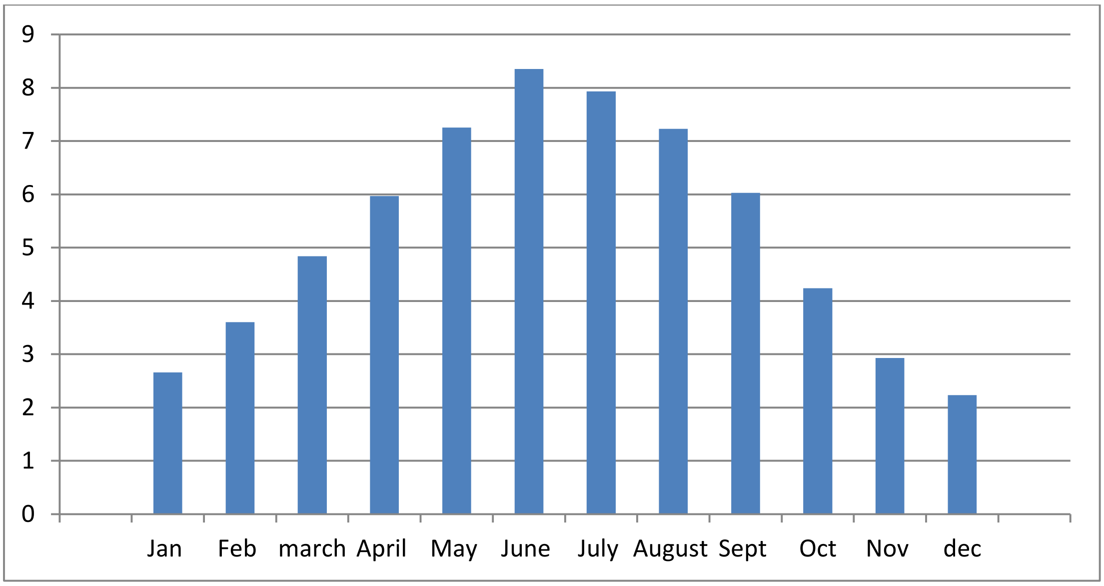


Figure 4.1. Daily of solar radiation per month.

In figure 4.2 illustrates the wind speed and the air temperature from January to December. Figure 4.2 shows the climate data values based on relationship between Air temperature and wind speed, July month records the highest solar radiation, while months July and August record highest wind speeds due to increase the wind speed with reduce the air humidity.

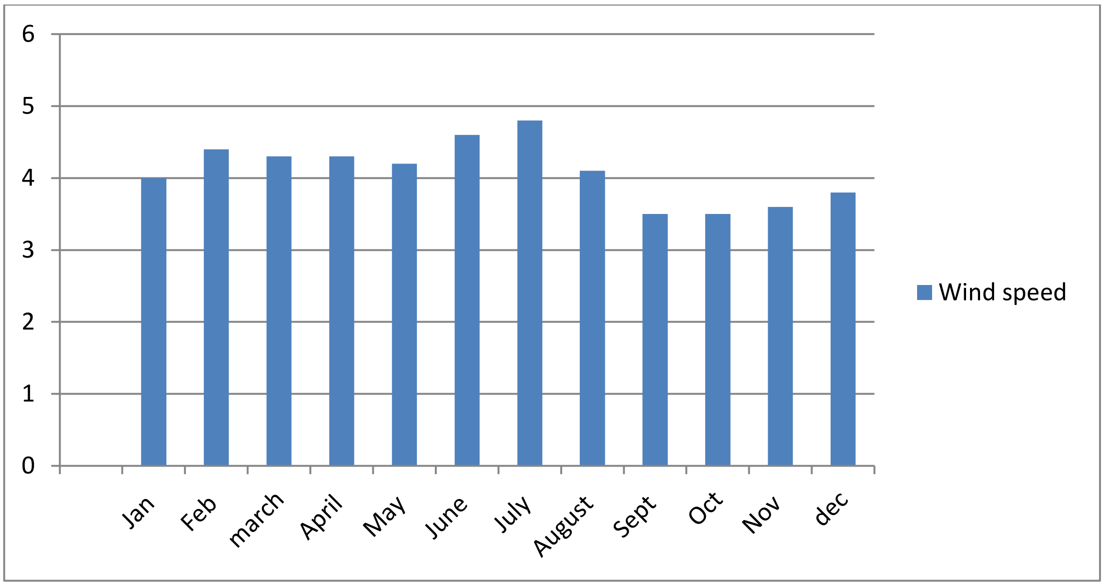


Figure 4.2. daily of wind speed per month.

4.2. Matlab Model of Hybrid Solar-Wind

4.2.1. PV simulink model

Simulink was used to build the Simulink model of the PV cell depicted in Figure 4.3 using circuit components from the SimPowerSystems package.

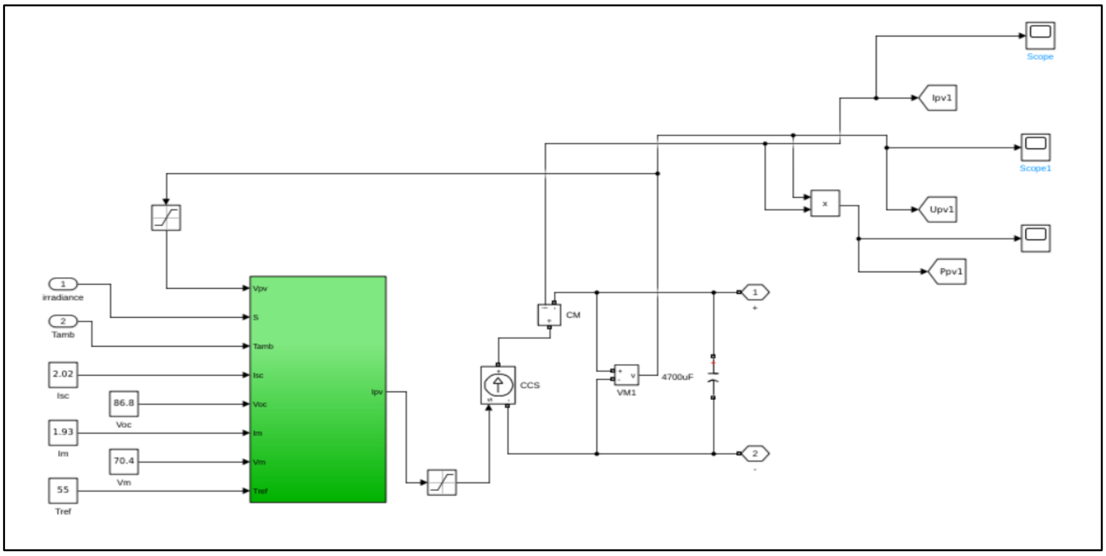


Figure 4.3. Using circuit components in matlab simulink.

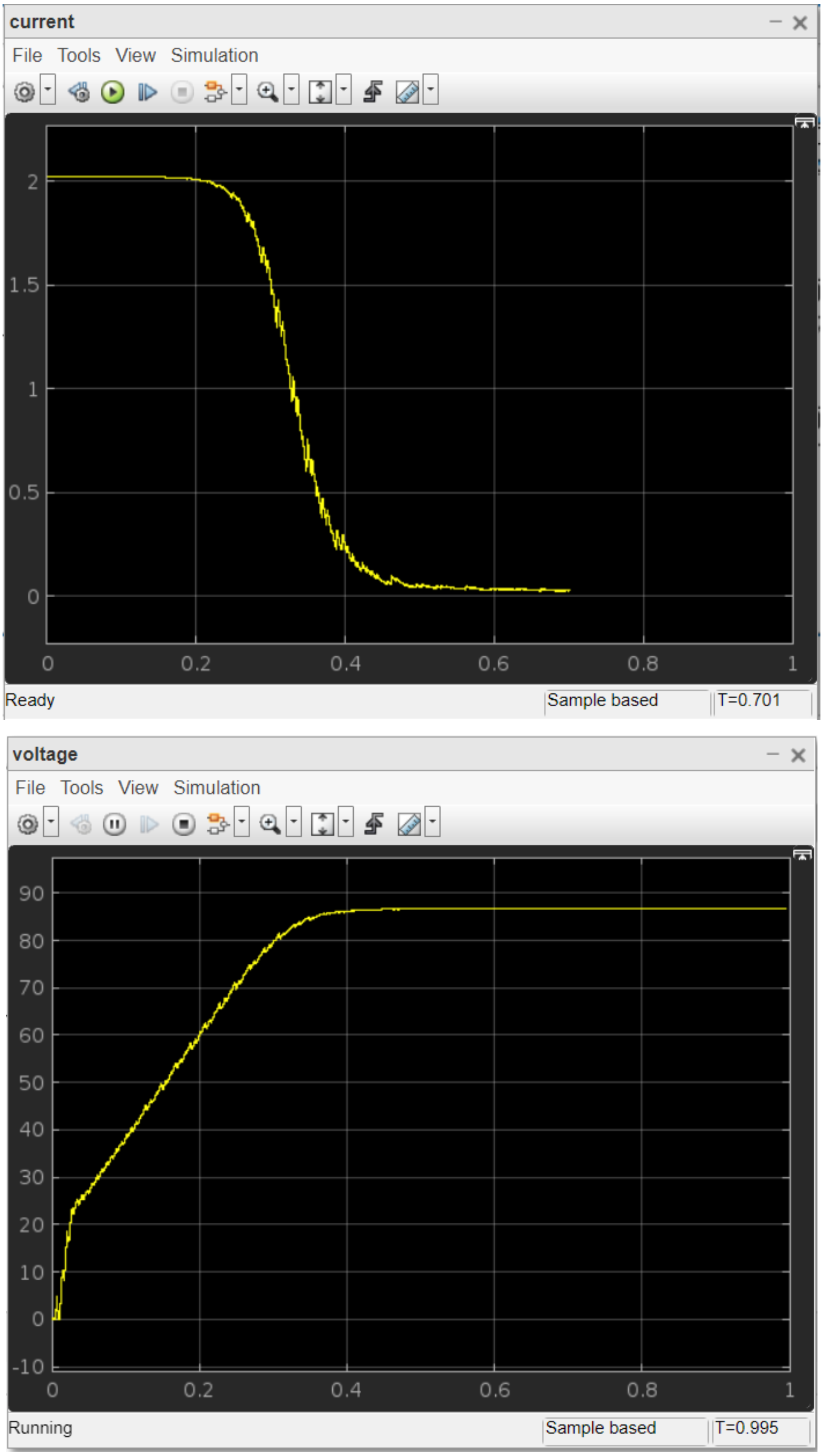


Figure 4.4. DC current and voltage of pv solar cell.

The photovoltaic power of solar cell is calculating by using equation 4.1:

$$P_{PV} = I_{PV} * V_{PV} \tag{4.1}$$

Due to the direct relationship between the PV voltage and its output power, as the photocurrent increases, the output power likewise varies as a result of voltage fluctuations, as depicted in Figure 4.5.

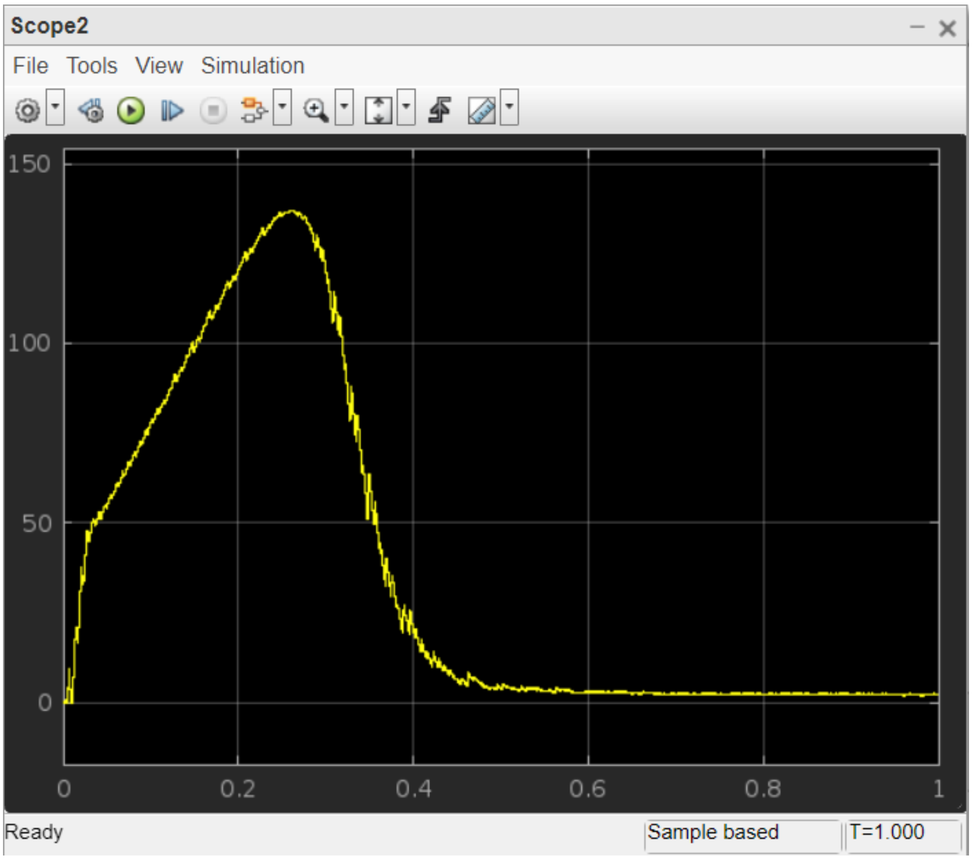


Figure 4.5. Power of pv solar cell .

4.2.2. Simulink model of a complete grid-connected wind turbine

The system of wind turbine was built as shown in Figure (4.6) and then masked into a block in Simulink as shown in Figure (4.7) once the components had been expanded with the appropriate equations and graphics. Figures illustrate how the full model was simulated. The system was simulated under standard circumstances, with the wind speed set at 10 m/s.

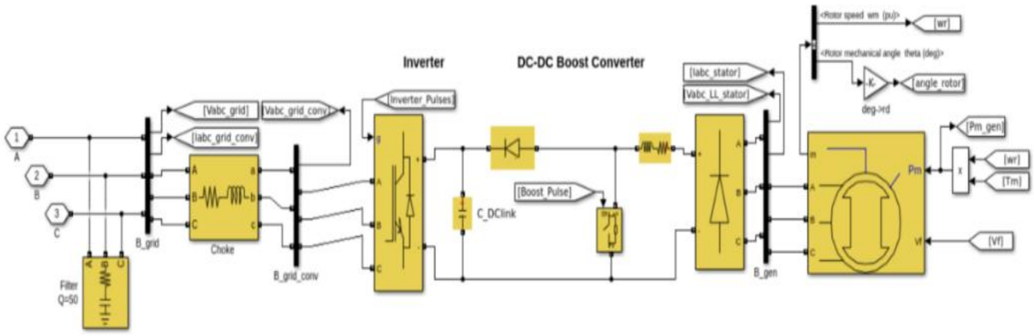


Figure 4.6. Wind turbine system.

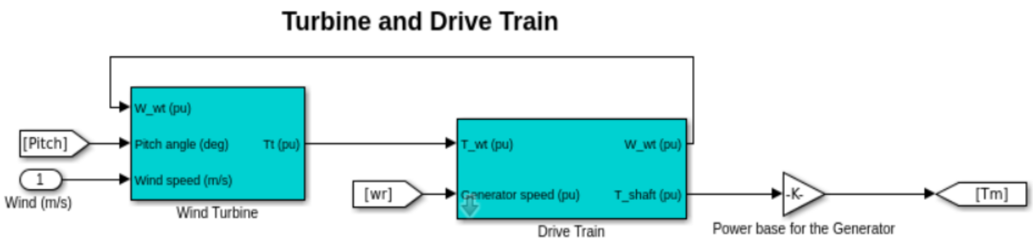


Figure 4.7. Turbine drive.

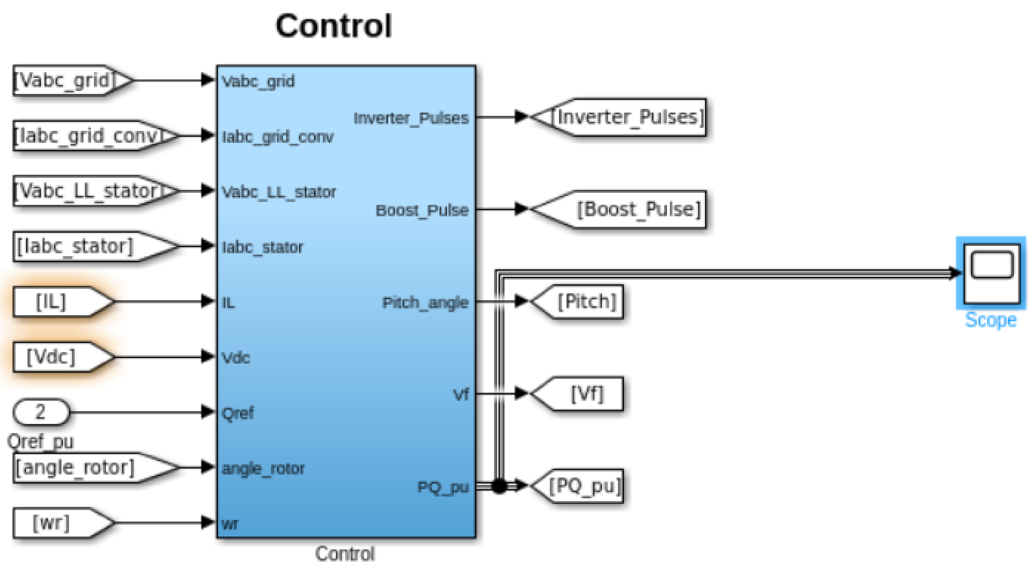


Figure 4.8. Control of wind turbine.

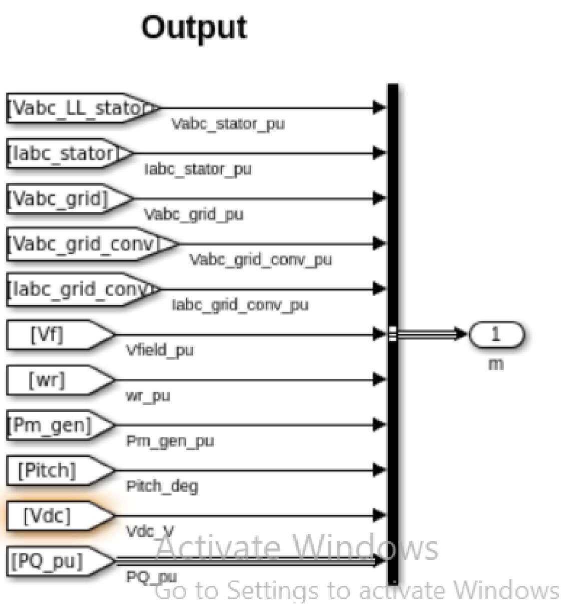


Figure 4.9. Output of wind turbine system.

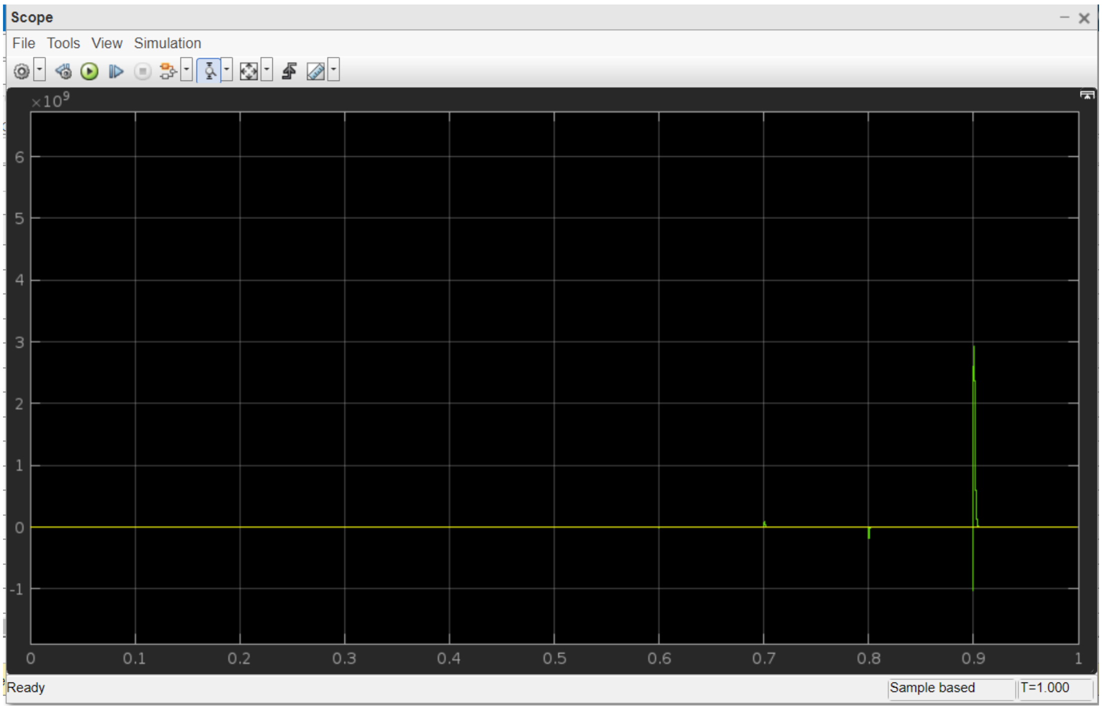


Figure 4.10. DC bus voltage from the wind turbine.

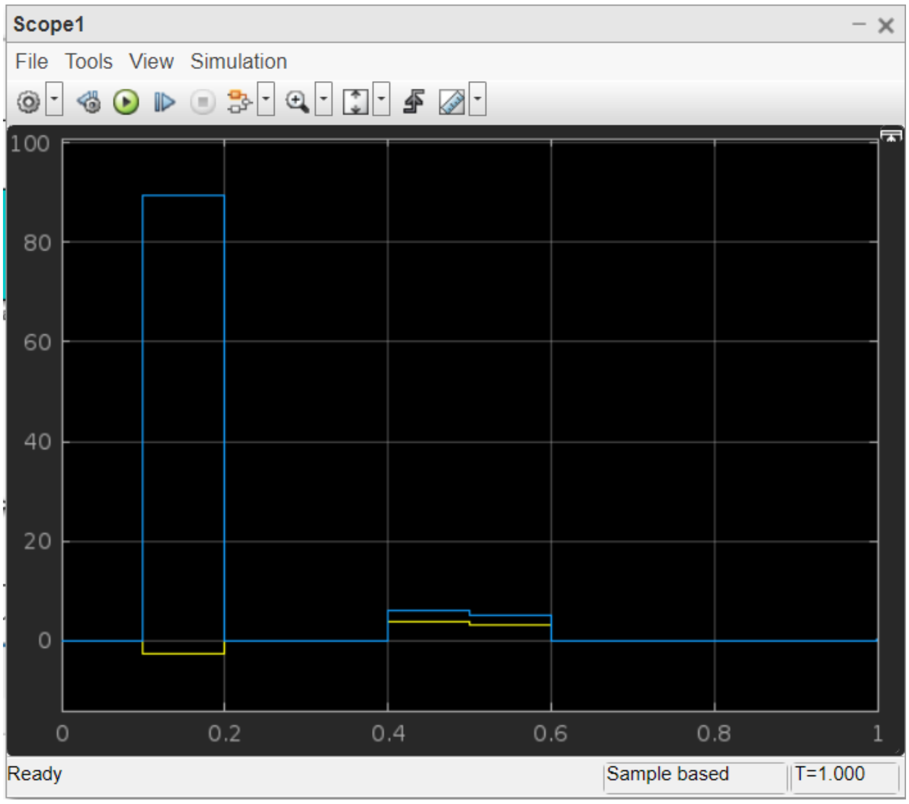


Figure 4.11. Pulse of real and reactive power.

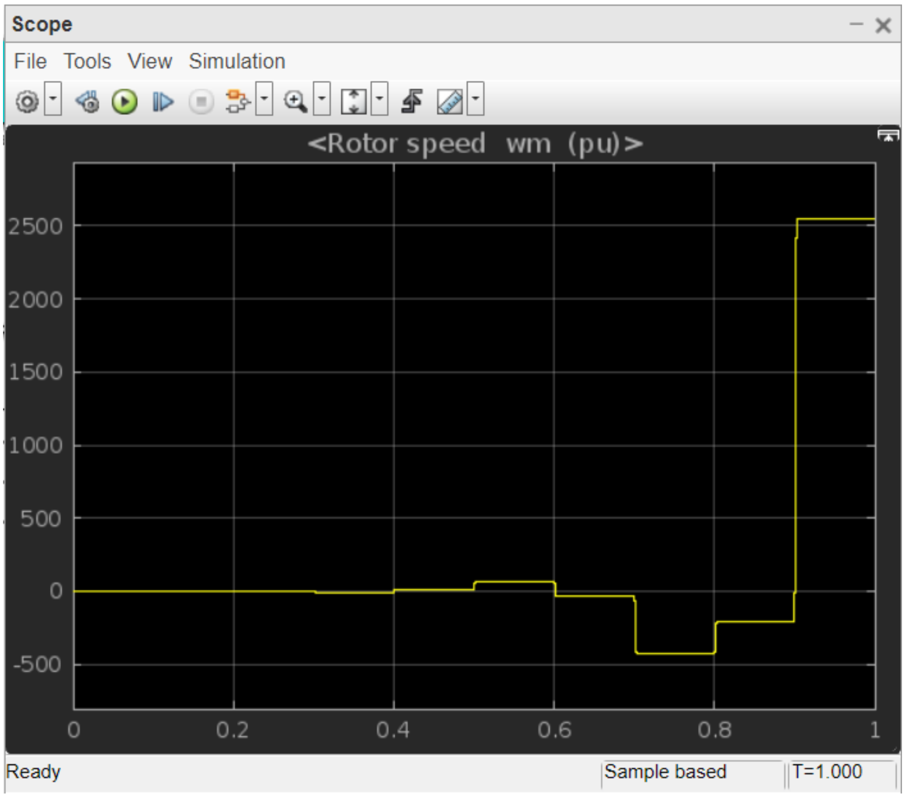


Figure 4.12. Rotor speed of wind turbine.

4.2.3. Hybrid of solar model in matlab simulink

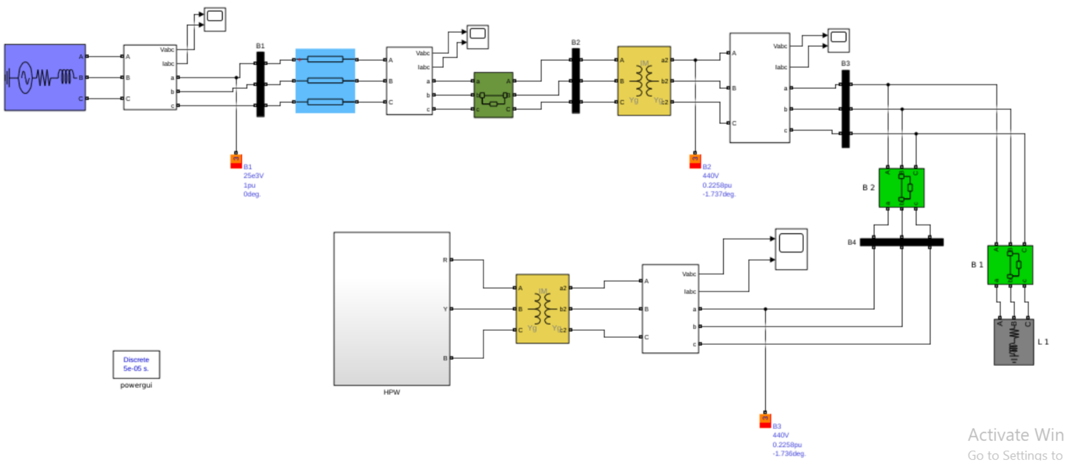


Figure 4.13. Hybrid system.

The short circuit types created by three-phase fault block cause the most common type of faults such as balanced three-phase (3Φ) fault, line-to-line (LL), single line-to-ground (SLG), and double line-to-ground (DLG) faults. Fault was launched in between 0.08 - 0.1 second in convenient to the analysis of the power system. The use of fault blocks enables the selection of the appropriate relay and the circuit-breaker and also the suitable relay coordination with respect to the consisted short-circuit currents.

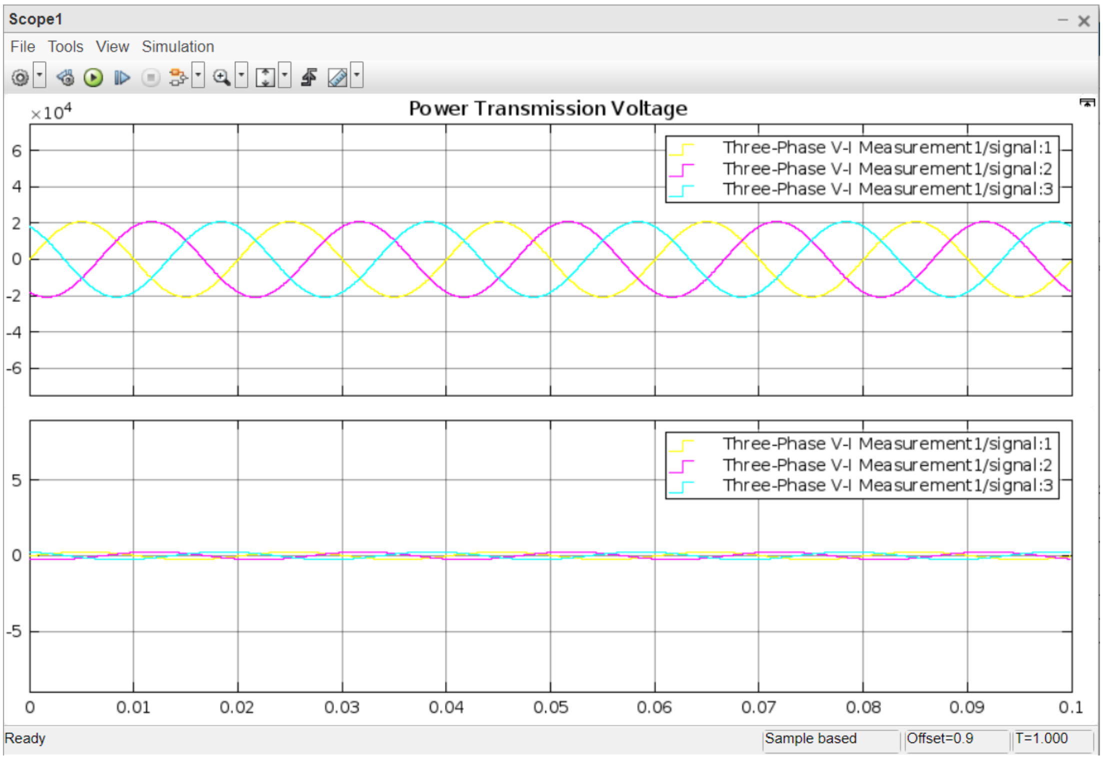


Figure 4.14. Power transmission voltage for scope 1.

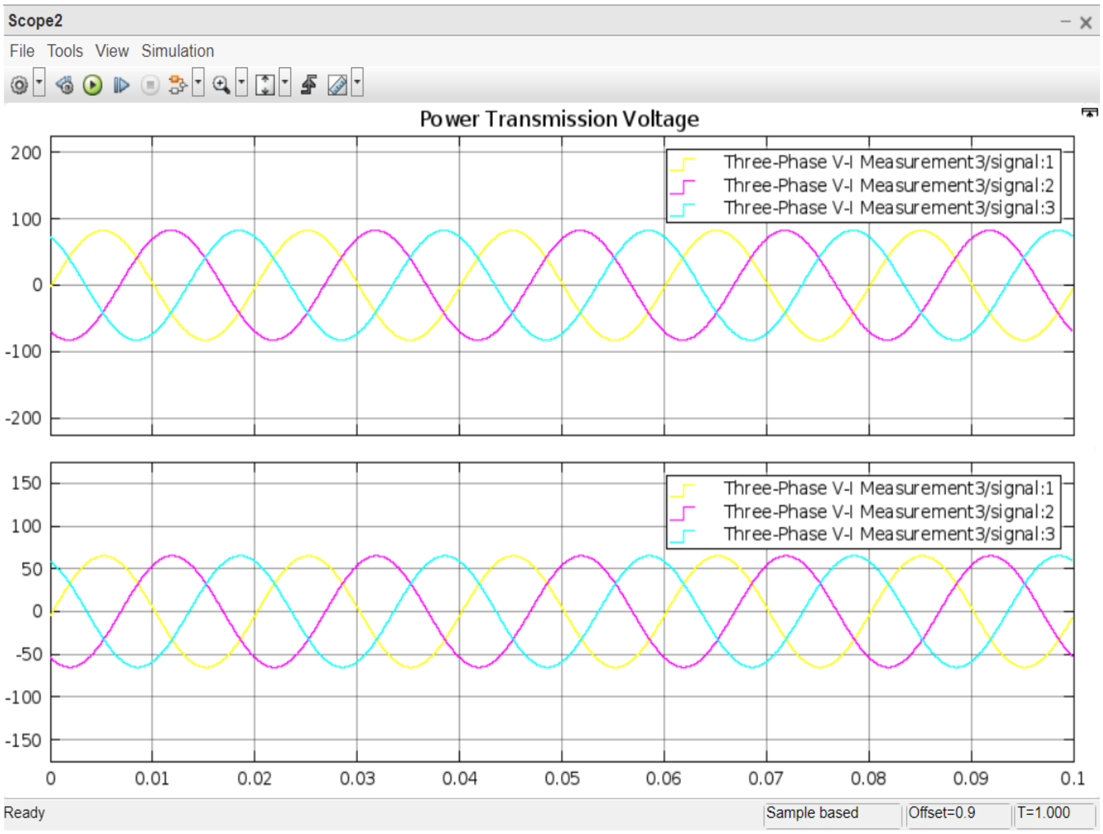


Figure 4.15. power transmission voltage for scope 2.

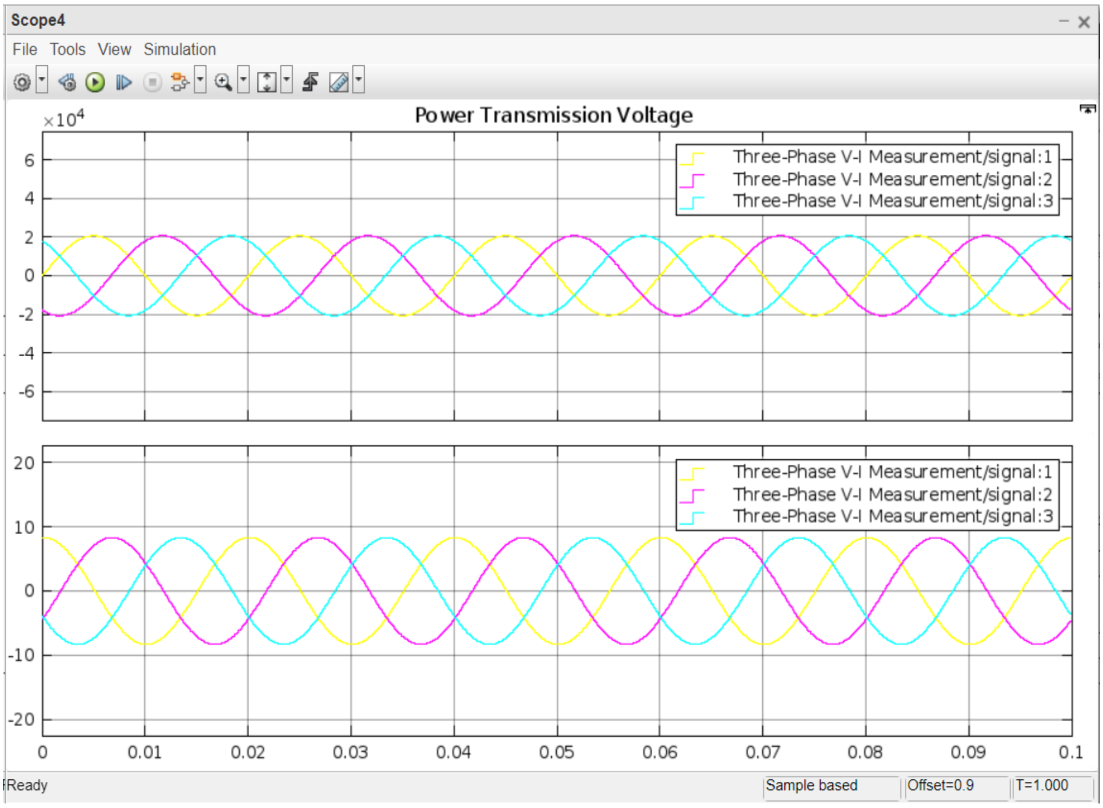


Figure 4.16. Power transmission voltage for scope 3.

4.3. System Performance And Cost Analysis

4.3.1. System performance in practice

For the years 2018 to 2021, the monthly average sunshine and daylight hours for Rutba were collected online and shown in Figure (4.17) .

The average numbers were relatively comparable over the session of the four years, therefore it was assumed that the values displayed were accurate for the most recent period (namely December 2020).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Sunlight Hours/ Day	06:11	07:13	07:56	08:32	09:40	11:36	11:13	11:25	10:32	08:48	07:06	06:15	08:52
Average Daylight Hours & Minutes/ Day	10:12	10:56	11:55	12:58	13:51	14:18	14:06	13:20	12:19	11:16	10:24	09:58	12:00
Sunny & (Cloudy) Daylight Hours (%)	62 (38)	67 (33)	67 (33)	67 (33)	71 (29)	82 (18)	80 (20)	86 (14)	86 (14)	79 (21)	69 (31)	64 (36)	74 (26)
Sun altitude at solar noon on the 21st day (°).	36.8	46.1	57	68.7	76.9	80.2	77.1	68.8	57.4	45.9	36.8	33.4	57.1

Figure 4.17. Monthly average sunshine and daylight hours online [2].

The average monthly solar irradiation was required to simulate and monitor the quantity of power generated by the suggested PV system, and it was acquired from internet sources [3]. Rutba's average monthly irradition levels are displayed in Figure (4.18). The solar panel's placement was hypothetically changed to maximize the amount of sunlight. Figure (4.18) illustrates how much higher the sun irradiation is in comparison between month , the summer from May to August have a hight rate from other months. Since the irradition values were consistent over the session of the previous four years, it was thought that they would be accurate in 2020.

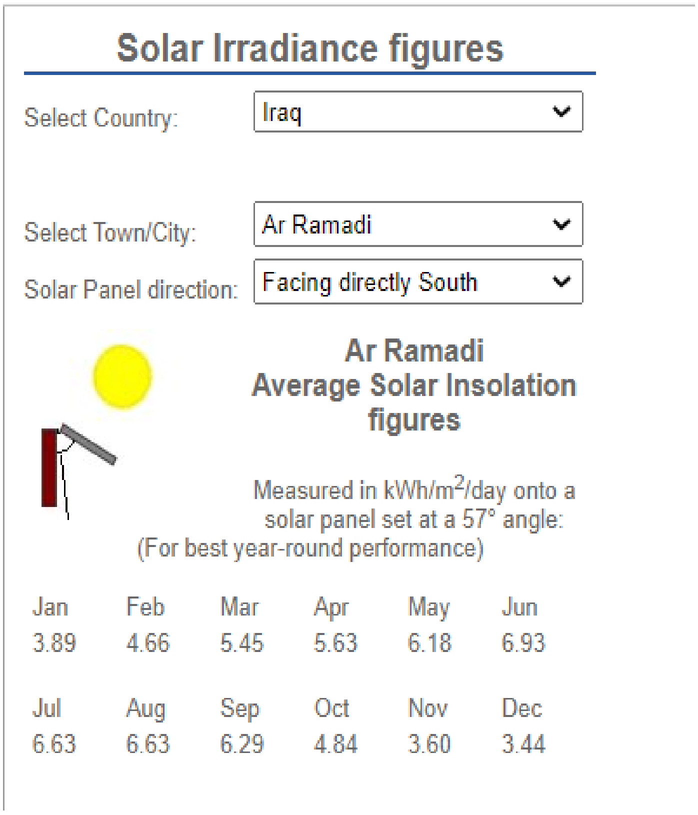


Figure 4.18. Solar radiation received on average each day of each month of the year.

The following equation was used to compute the PV system's hourly energy output:

$$kwh = P_{pv}(kw) \times numberof\ hours\ of\ day\ light\ (h) \quad (4.2)$$

The power generated by the PV system was calculated by modelling it for various average monthly solar irradiation values shown in Figure 4.18 for the PV system shown in Figure 4.16. The insolation numbers shown in Figure 4.18 were in kWh/m2, therefore they needed to be converted to W/m2, and the formula below was used to do so:

$$solar\ irradiation\ \frac{W}{m^2} = solar\ irradition\ \left(\frac{Kwh}{m^2}\right) * \frac{1000}{number\ of\ hour\ of\ day\ light} \quad (4.3)$$

The number of kWh produced by the PV system was then computed using equation 4.2, and the results were noted in Table 4.1.

Table 4.1. Average monthly kwh that a PV system produces.

Month	Hours of daylight on average	Average dayly kwh that a pv system produces Kwh	Average monthly solar radiation Kwh/ m^2	Average yearly kwh that a pv system produces Kwh
Jan	10.12	3.89	348.38	987,120
Feb	10.56	4.66	441.2	1,071,360
Mar	11.55	5.45	471.8	1,118,880
Apr	12.58	5.63	447.5	1,380,240
May	13.51	6.18	457.4	1,447,200
Jun	14.18	6.93	457.43	1,524,960
Jul	14.06	6.63	471.5	1,501,200
Aug	13.20	6.63	502.2	1,518,480
Sep	12.19	6.29	516	1,421,280
Oct	11.16	4.84	433.7	1,276,560
Nov	10.24	3.6	351.56	1,103,760
Dec	09.58	3.44	359	965,520

Next, the online data for Rutba monthly average wind speeds from 2018 to 2021 is shown in Table 4.2. Online meteorological databases show that compared to other months, Rutba's spring season (February to April) has generally higher wind speeds.

This demonstrates unequivocally that a technology for generating wind energy would generate more energy in the spring than in other seasons. The data also reveals that The same month's monthly average wind speed may occasionally change dramatically from year to year. These variances are evidence that there will be significant changes in the wind generator's monthly energy output component of the wind-solar hybrid system.

Table 4.2., Average monthly wind speed in Ratba, Iraq from 2018 to 2021

Month	2018	2019	2020	2021
Jan	4.5	4.4	4	4.2
Feb	4.7	4.8	4.3	4.5
Mar	4.2	4.9	3.8	4.8
Apr	4.0	4.2	3.6	3.7
May	5.1	4.7	4.2	4.9
Jun	4.1	5.2	4.5	5.2
Jul	3.8	4.7	4.3	4.8
Aug	3.9	4.6	4.9	4.3
Sep	4.3	4.2	5.1	5.3
Oct	4.8	4.4	4.8	4.8
Nov	5.0	5.5	5.8	5.3
Dec	5.2	5.7	6.1	6.3

After obtaining the fluctuations in Rutba's average monthly wind speeds, Table 4.3. entry for the output power of the wind generator system throughout 2018 can be found in Figure 4.12.

Table 4.3. Average monthly wind energy produced in mw.

Month	Monthly average wind speed (m/sec)	Average monthly wind energy produced mw in each turbine
Jan	4.2	100.6
Feb	4.5	140
Mar	4.8	170
Apr	3.7	45
May	4.9	175
Jun	5.2	195
Jul	4.8	170
Aug	4.3	125
Sep	5.3	195
Oct	4.8	170
Nov	5.3	205
Dec	6.3	290

It was determined that the total MWh generated by wind turbines that are dependent on varying wind speeds is equivalent to the kW of power generated per hour (because, unlike solar irradiation, wind is never completely absent during the day).Thus, the overall kWh generated by the wind-solar hybrid system was calculated.

The estimated data that have been aqcuired from minstry of electricityfor one generator of Rutba, average monthly consumption data were acquired to figure out how much this entire amount of kWh can add to the overall amount of MWh consumed by one suburb in Rutba City. The data was collated in Table 4.4, and it was from this that the amount of energy (MWh) used by the wind-solar system was calculated.

Table 4.4. Contribution of monthly MWh production from solar and wind energy.

Month	Average monthly production of mwh from the wind and solar system	Wind (mw)	Solar (mw)	Rutba city's average monthly mwh consumption for each suburb per unit	Percentage of Wind –solar contribution %
Jan	182.8	100.6	82.2	720	12.59
Feb	229.2	140	89.2	700	14
Mar	263.2	170	93.2	680	15
Apr	160	45	115	713	17
May	295	175	120	800	16.16
Jun	322	195	127	815	17
Jul	295	170	125	789	17
Aug	251	125	126	770	17.4
Sep	313	195	118	782	16.4
Oct	276	170	106	792	14.5
Nov	296	205	91	805	12.5
Dec	370.4	290	80.4	900	10.3

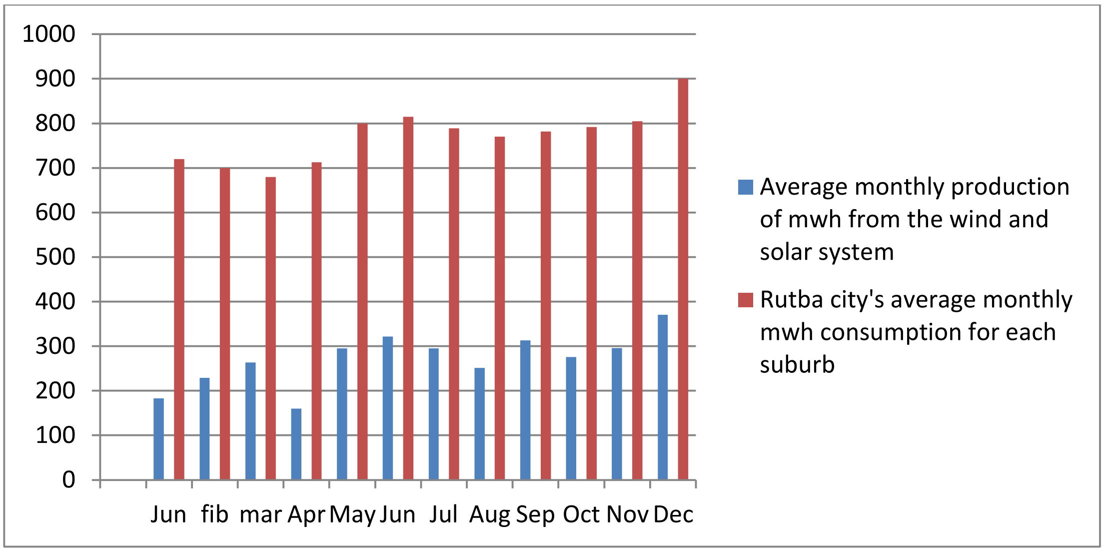


Figure 4.19. Contribution of monthly MWh production from solar and wind energy.

A column chart is used in Figure 4.19 to compare the total monthly MWh produced by the wind-solar hybrid system with the total MWh consumed by the suburbs in Rutba city.it is cleary seen from data that production of solar wind energy fluctuated during a year.the peak value recorded in December while the minimum in April.

4.4. A Wind-Solar Hybrid System Cost Analysis

One question that is frequently asked prior to RES installation is "How much does wind-solar electricity cost?" Here, there are essentially two questions that require distinct responses:

1. How much does installing solar power cost up front? In other words, how much does it cost to establish a system that provides a certain peak power and a certain amount of energy storage today?
2. How much does solar energy cost during its lifetime per kilowatt-hour? In other words, how do the costs of grid power and wind energy compare?

The questions were addressed using the following strategy:

1) The cost of each significant component must first be determined in terms of user-specified variables. The main parts are batteries, inverters, wind turbines, and solar panels.

The cost of the entire system will be in the thousands of euros. The following user-specified factors will be taken into consideration: a day's total energy production and consumption, the typical number of hours of sunshine, and the average wind speed.

2) After determining the component prices, they should be totaled together to generate straightforward equations or formulas that can be used to determine the answers to each of the questions above.

The results should be seen as upper bound estimates because the numbers given below are quite cautious and include installation charges. To make the calculations simpler, simple numbers have also been rounded up to the nearest simple number.

4.5. Cost of PV Panels in Relation to Energy Consumption

The kind and quantity of solar panels one uses affects the peak electricity they can produce:

$$P_{peak\ panels} = number\ of\ penal * power\ per\ penal \quad (4.4)$$

Although the solar panels will undoubtedly provide the energy used by the appliances, it is not necessary for their peak output to match the peak power consumed:

$$P_{peak,usge}: not\ necerairy\ equal\ to: P_{peak\ panel} \quad (4.5)$$

Instead, the entire quantity of energy that must be produced each day must be used to calculate the peak power of the solar panels and, consequently, the number of solar panels.

By designating the energy generated by the PV system as E produce , this value needs to match the daily energy consumption of the PV system in order to:

$$E_{prodused} = E_{used} \quad (4.6)$$

Equation 4.1 is used to specify the energy in kWh.

By using Table 4.4, the projected PV system's average daily objective for E_{used} is 800kWh. iraq's system charges about 15 cents per kilowatt-hour for electricity. It is important to know the average amount of sunlight hours per day every month, which is T_{sun}, in order to calculate the daily electrical expenditures, where:

$$T_{sun} = average\ hours\ of\ sunshine \tag{4.7}$$

8.25 hours per day on average was discovered to be the value of (Table 4.1). Therefore, if the grid consumes 500 kilowatt-hours per day and the cost of electricity is approximately 14 cents per kilowatt-hour, one's PV electrical expenditures would be about 57,750,000 $ per day, or almost 1,732,500,000$ per month.

It is possible to express the above in writing by using the power and energy formula:

$$P_{peak,panel} = \frac{E_{used}}{T_{sun}} \tag{4.8}$$

A study of recent market prices revealed that the price of buying and installing a PV panel in iraq is roughly 1.20$/W. As a result, the solar panels' initial cost per kW is 800$. So, depending on energy consumption, the price of the solar panels will be:

$$cost_{panel} = \left(\frac{E_{used}}{T_{sun}}\right) * \frac{800\$}{kw} \tag{4.9}$$

As a result, the cost of the PV panels for the proposed PV power generation system will be roughly:

$$cost_{panel} = \left(\frac{600kwh}{8.25h}\right) * \frac{800\$}{kw} \approx 58181\$ \tag{4.10}$$

4.6. Cost of Wind Turbines in Relation to Energy Consumption

A study of recent market prices revealed that the price per kW to buy and install a wind turbine ranges from roughly 1500$ to 2000$. is almost equal to 2000$ if the cost of a wind turbine is believed to be the average of the previously indicated figures. Now, if it is assumed that the wind turbine has an operating power of 600 kW (based on Table 4.4), it can be said that:

$$cost_{panel} = \left(P_{avg,wind}\right) * cost_{wt} \tag{4.11}$$

Cost wt will therefore roughly be:

$$cost_{wt} = (400kw) * \frac{1500\$}{kw} = 600000\$ \qquad (4.12)$$

4.7. Cost of an Inverter in Relation to Required Peak Power

When constructing a solar system, one must be aware of two different types of power requirements: the peak power given to the load and the peak power produced by the solar panels by the system. The total maximum power level that can be anticipated to be used by appliances in a home is represented by the peak power delivered to the load.

The size of the system's inverter truly determines how much peak power it can produce:

$$P_{peak,usage} = P_{peak,inverter} \qquad (4.13)$$

As a result, the cost of the inverter depends on the peak power used and is as follows:

$$cost_{inverter} = P_{peak,usage} * \frac{400}{kw} \qquad (4.14)$$

Therefore, the cost of the inverter will be around 400,000 $ if it is anticipated that one uses the entire 1000 kW peak output from the inverter systems of the proposed wind system.

4.8. Battery Costs in Relation to Energy Use

The quantity of energy (stored in batteries) that may be used after dark, especially when there is little wind, depends on the amount of energy stored. Depending on how many and what kind of batteries are used in the system, a certain amount of kWh can be stored:

$$E_{stored} = Energy\ battery * number\ of\ batteries \qquad (4.15)$$

Deep cycle batteries often only last 3 to 10 years, depending on how well they are maintained (overcharging, overdrawing, etc. must be avoided, for example). Currently, batteries cost around 500$ per kWh of storage.

$$cost_{batteries} = \frac{500\$}{kwh} \tag{4.16}$$

Therefore, the price of batteries as a function of energy used is

$$cost_{batteries} = E_{used} * \frac{500\$}{kwh} \tag{4.17}$$

Assuming that the lead-acid battery used in the photovoltaic system has a maximum output of 5000h x 100 = 5000000 h, or 500kWh, the batteries will cost roughly:

$$cost_{batteries} = 500kwh * \frac{500\$}{kwh} \approx 250000\$ \tag{4.18}$$

4.9. Cost Calculation Up Front

The cost of the PV panels, wind turbine, inverter, and batteries when added together is as follows:

$$\begin{aligned} cost_{upfront} &= cost_{panels} + cost_{wt} + cost_{inverter} + cost_{batteries} \\ &\approx 58181\$ + 600{,}000\$ + 400{,}000\$ + 250{,}000\$ \approx 1{,}308{,}181\$ \end{aligned} \tag{4.19}$$

4.10. Return Period

The total average MWh produced monthly by the hybrid wind-solar power system was calculated using the information from Table 4.4 and was discovered that the average of mwh per month around 573 MWh aproximatly . This information was used to determine the approximate time it takes for the investment to pay for government it self . As a result, the daily average kWh generated by the wind-solar system will be 573mw ÷12 =47.787Mw per day. The cost of the wind-solar system's total daily of 47.787MW will be =47.787Mw*15$=716 $ or 261,636.2 $ for a year of use. This is because energy costs approximately 0.15$/kWh in iraq.

$$Payback\ period = \frac{1{,}308{,}181,\$}{261{,}636.2} \approx 5\ years \tag{4.20}$$

4.11. Comparing Result With PVSYST Software

PVsyst is a software program widely used in the solar energy industry for the analysis, design, and optimization of photovoltaic (PV) systems. It is a comprehensive tool that helps engineers, researchers, and solar professionals evaluate the performance and financial viability of solar power projects.

For the design and estimate of the cost parameters of the solar PV power plant, one of the most often used softwares is PVSyst.This software offers outcomes that are almost closer to those predicted by theory because to its many options and built-in capabilities.By camparnig the result mesurment with the rusult of pv syst .

After entering the system's data, including system size, geographic location, and the type of devices utilized, into the pvsyst program , the same theoretical results appeared as depicted in the diagram below figures (4.20-4.24).

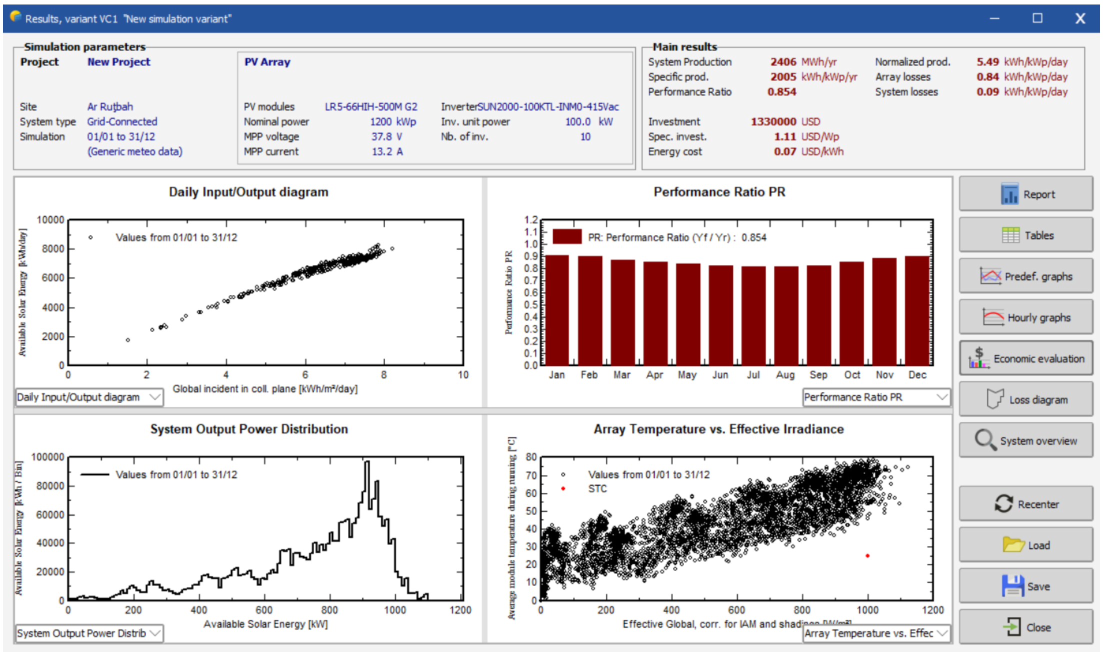


Figure 4.20. Result of PVSYST program in rutba city.

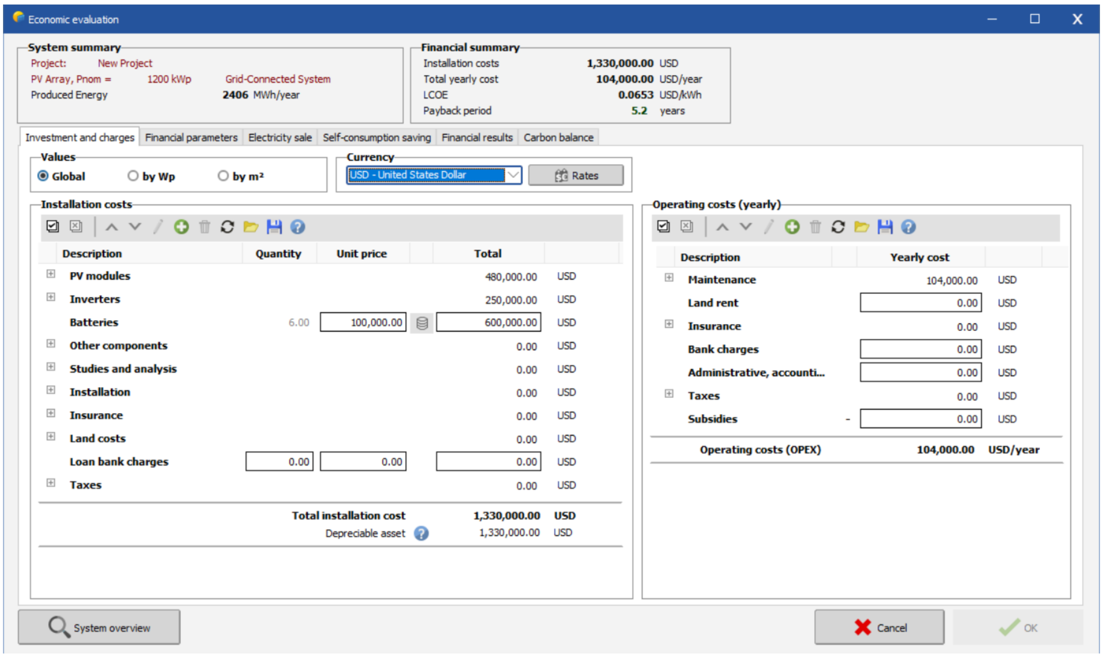


Figure 4.21. Total cost of solar system.

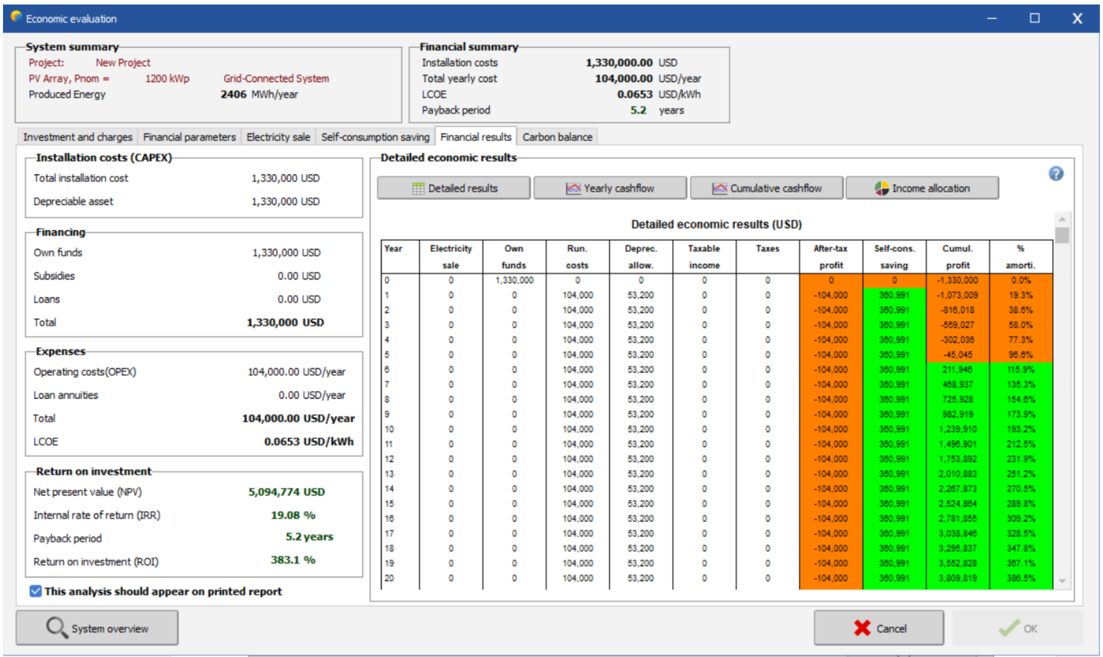


Figure 4.22. Payback cost of solar system over 25 years.

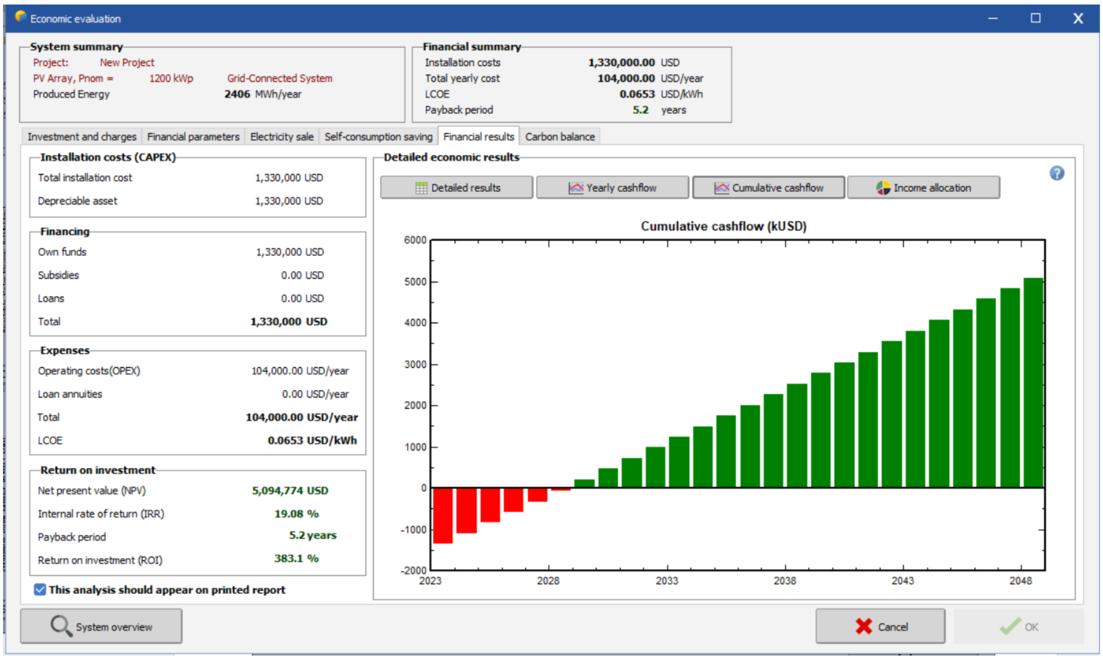
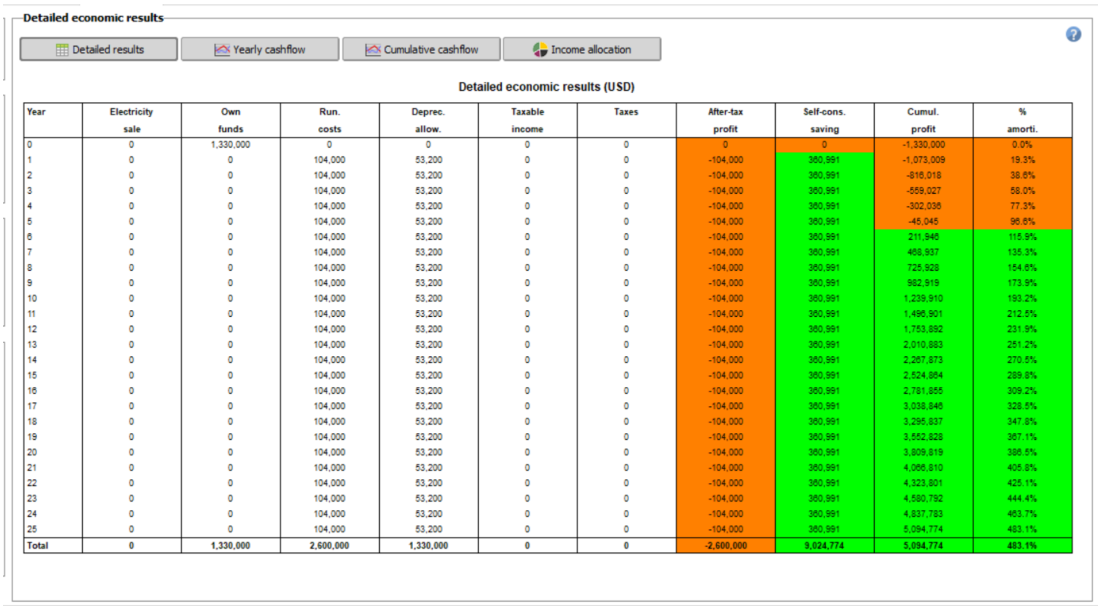


Figure 4.23. Cumulative cashflow in PVSYST.



Detailed economic results

Detailed results | Yearly cashflow | Cumulative cashflow | Income allocation

Detailed economic results (USD)

Year	Electricity sale	Own funds	Run. costs	Deprec. allow.	Taxable income	Taxes	After-tax profit	Self-cons. saving	Cumul. profit	% amorti.
0	0	1,330,000	0	0	0	0	0	0	-1,330,000	0.0%
1	0	0	104,000	53,200	0	0	-104,000	360,991	-1,073,009	19.3%
2	0	0	104,000	53,200	0	0	-104,000	360,991	-816,018	38.6%
3	0	0	104,000	53,200	0	0	-104,000	360,991	-559,027	58.0%
4	0	0	104,000	53,200	0	0	-104,000	360,991	-302,036	77.3%
5	0	0	104,000	53,200	0	0	-104,000	360,991	-45,045	96.6%
6	0	0	104,000	53,200	0	0	-104,000	360,991	211,946	115.9%
7	0	0	104,000	53,200	0	0	-104,000	360,991	468,937	135.3%
8	0	0	104,000	53,200	0	0	-104,000	360,991	725,928	154.6%
9	0	0	104,000	53,200	0	0	-104,000	360,991	982,919	173.9%
10	0	0	104,000	53,200	0	0	-104,000	360,991	1,239,910	193.2%
11	0	0	104,000	53,200	0	0	-104,000	360,991	1,496,901	212.5%
12	0	0	104,000	53,200	0	0	-104,000	360,991	1,753,892	231.9%
13	0	0	104,000	53,200	0	0	-104,000	360,991	2,010,883	251.2%
14	0	0	104,000	53,200	0	0	-104,000	360,991	2,267,873	270.5%
15	0	0	104,000	53,200	0	0	-104,000	360,991	2,524,864	289.8%
16	0	0	104,000	53,200	0	0	-104,000	360,991	2,781,855	309.2%
17	0	0	104,000	53,200	0	0	-104,000	360,991	3,038,846	328.5%
18	0	0	104,000	53,200	0	0	-104,000	360,991	3,295,837	347.8%
19	0	0	104,000	53,200	0	0	-104,000	360,991	3,552,828	367.1%
20	0	0	104,000	53,200	0	0	-104,000	360,991	3,809,819	386.5%
21	0	0	104,000	53,200	0	0	-104,000	360,991	4,066,810	405.8%
22	0	0	104,000	53,200	0	0	-104,000	360,991	4,323,801	425.1%
23	0	0	104,000	53,200	0	0	-104,000	360,991	4,580,792	444.4%
24	0	0	104,000	53,200	0	0	-104,000	360,991	4,837,783	463.7%
25	0	0	104,000	53,200	0	0	-104,000	360,991	5,094,774	483.1%
Total	0	1,330,000	2,600,000	1,330,000	0	0	-2,600,000	9,024,774	5,094,774	483.1%

Figure 4.24. Economic result of solar system.

4.12. Co2 Emessions With PVSYST Program

By installing the hybrid solar-wind system instead of diesel generator, it means that we can saved 52244.869 metric tonnes of CO2 and supply the grid with 2406.9 MWh for 30 years as showen in figure (4-25).

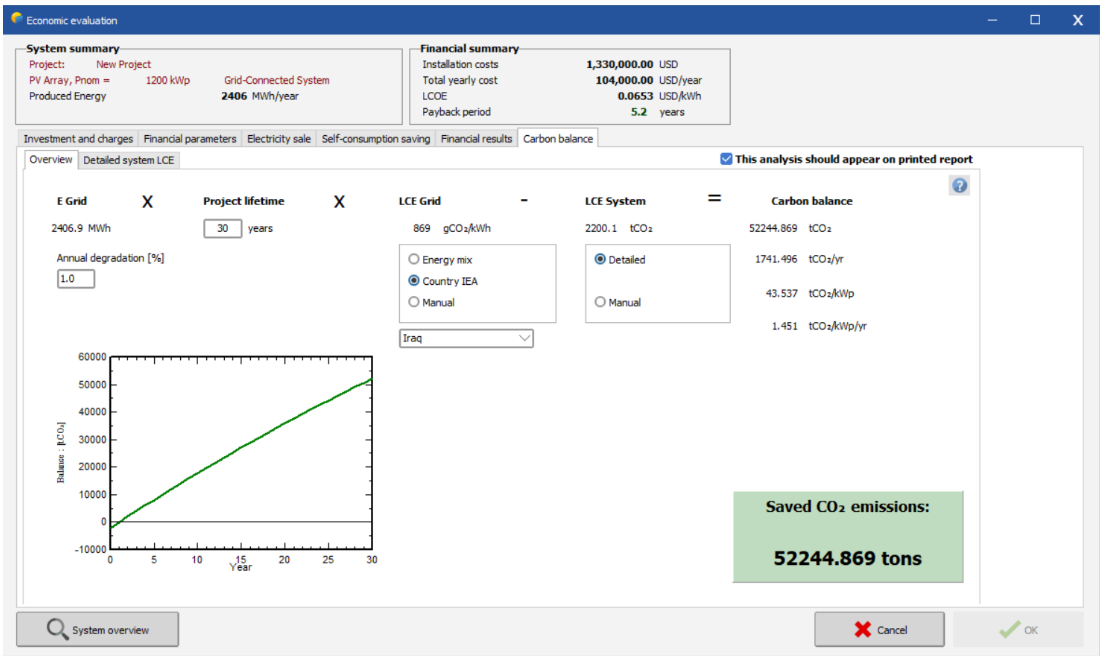


Figure 4.25. Saved CO2 emission.

5. CONCLUSION

Matlab/Simulink is going to be the primary tool that will be used in the investigation of a hybrid photovoltaic/wind power generating system that will be used in a grid-connected application. The estimation of the solar irradiance and wind speed data in the areas of Rutba was done as a reference to establish the feasibility, and with the availability of energy, it is feasible to propose and construct a model. This was done in the process of proving that it is possible. A solar irradiation of 5.68 kWh/m2 /day is typical for the areas of Rutba, which also have an average temperature of 28 degrees Celsius. On average, Rutba receives roughly 8 hours of sunlight every day, which contributes to the state's high level of solar exposure. According to a research, the regions of Rutba have a rich reservoir of wind energy, with a mean wind speed of 12.9 mph, which may be used to generate electricity. Both the terrain and the wind direction have a significant impact on the wind speed. The generation of power from a single source of renewable energy is not sufficient to meet the load demands; consequently, a hybrid PV-wind model has been proposed as a means of compensating for the impacts of environmental factors and climate changes of the resources that impact the continuous the operation of electricity generation. The Observe and Perturb Maximum Power Point Tracking (P&O MPPT) approach is utilised for efficient tracking of solar energy, and a boost converter is employed to decrease fluctuations at the inverter that converts DC power to AC power. Sinusoidal alternating current electricity is produced by wind energy systems that use permanent magnet synchronous generators. To achieve the requirements, a combination of these two energy sources is used to power the grid. Matlab/Simulink was used to create a model of the hybrid system, and the output has been checked. The findings indicate that the output of the system is affected by both the temperature and the amount of solar radiation. Although a rise in temp causes a fall in the magnitude of voltage, which in turn leads to a reduction in power, an increase in solar irradiation results in an increase the magnitude of current, which concurrently results in an increase in output power. Wind speed and wind direction are two of the most important parameters that influence the output, and the findings reveal that sinusoidal AC power is generated with only very tiny changes as a consequence of variations in wind speed. The output of the hybrid system is around 1.5 megawatts when taken as a whole. The production of clean energy results from the combination of these two renewable sources for the creation of electricity in order to satisfy the needs.

5.1. Future Scope of The Thesis

However, there are concerns with the power quality, which affects the operation of the entire systems. The thesis is effective for the continuous production of electricity. Power quality problems typically involve voltage sag, voltage swell, harmonics, and transients, all of which primarily work to lower the quality of electricity generated by solar and wind energy. The use of electronic gadgets that consume more power also has an influence on the energy production, which may lead to swings. It is advised that several strategies be used in order to address the power quality difficulties. Some of these techniques include incorporating static compensators, series type LC filters, and UPQC. DSTATCOM contributes to the reduction of harmonics, the correction of the power factor, and the balancing of the load. STATCOM is utilised because maintaining stability is important. Recording the data from the sun and the wind requires the employment of more sophisticated technologies in order to be able to get an estimate of the power required for a constant energy supply. There is a variety of MPPT technology available for use in the monitoring of the resources.

REFERENCES

A.A.; Alwazzan, M.J.; Alrubaie, A.J.K. Design and Optimization of a Grid-Connected Solar Energy System: Study in Iraq. *Sustainability* **2022**, *14*, 8121.

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. *Appl Sol Energy* **2020**, *56*, 284–290.

Abid, Z.; Wahad, F.; Gulzar, S.; Ashiq, M.F.; Aslam, M.S.; Shahid, M.; Altaf, M.; Ashraf, R.S. Solar Cell Efficiency Energy Materials. *Fundam Sol Cell Des* **2021**, 271–315.

Agrawal, B.; Tiwari, G.N. Return on Capital and Earned Carbon Credit by Hybrid Solar Photovoltaic—Wind Turbine Generators. *Appl Sol Energy* **2010**, *46*, 33–45.

Aissou, S.; Rekioua, D.; Mezzai, N.; Rekioua, T.; Bacha, S. Modeling and Control of Hybrid Photovoltaic Wind Power System with Battery Storage. *Energy Convers Manag* **2015**, *89*, 615–625.

Alex, Z.; Clark, A.; Cheung, W.; Zou, L.; Kleissl, J. Minimizing the Lead-Acid Battery Bank Capacity through a Solar PV-Wind Turbine Hybrid System for a High-Altitude Village in the Nepal Himalayas. *Energy Procedia* **2014**, *57*, 1516–1525.

Amelia, A.R.; Irwan, Y.M.; Leow, W.Z.; Irwanto, M.; Safwati, I.; Zhafarina, M. Investigation of the Effect Temperature on Photovoltaic (PV) Panel Output Performance. *Int J Adv Sci Eng Inf Technol* **2016**, *6*, 682–688.

Anurag, A.; Bal, S.; Sourav, S.; Nanda, M. A Review of Maximum Power-Point Tracking Techniques for Photovoltaic Systems. *Int J Sustain Energy* **2016**, *35*, 478–501.

Atiq, J.; Soori, P.K. Modelling of a Grid Connected Solar PV System Using MATLAB/Simulink. *Int J Simul Syst Sci Technol* **2017**, *17*, 41–45.

Badescu, V. Modeling Solar Radiation at the Earth’s Surface. *SpringerVerlag, Berlin/heidelb* **2008**.

Baranoff, E.; Yum, J.-H.; Graetzel, M.; Nazeeruddin, M.K. Cyclometallated Iridium Complexes for Conversion of Light into Electricity and Electricity into Light. *J Organomet Chem* **2009**, *694*, 2661–2670.

Bekele, G.; Boneya, G. Design of a Photovoltaic-Wind Hybrid Power Generation System for Ethiopian Remote Area. *energy Procedia* **2012**, *14*, 1760–1765.

Bertrand, P.; Legendre, L. The Atmosphere: Connections with the Earth’s Mass and Distance from the Sun. In *Earth, Our Living Planet*; Springer, 2021; pp. 49–87.

Bhandari, B.; Lee, K.-T.; Lee, G.-Y.; Cho, Y.-M.; Ahn, S.-H. Optimization of Hybrid Renewable Energy Power Systems: A Review. *Int J Precis Eng Manuf Technol* **2015**, *2*, 99–112.

Bouzelata, Y.; Altin, N.; Chenni, R.; Kurt, E. Exploration of Optimal Design and Performance of a Hybrid Wind-Solar Energy System. *Int J Hydrogen Energy* **2016**, *41*, 12497–12511.

Brabec, C.J. Organic Photovoltaics: Technology and Market. *Sol energy Mater Sol cells* **2004**, *83*, 273–292.

Chen, C.J. *Physics of Solar Energy*; John Wiley & Sons, 2011; ISBN 0470647809.

Dihrab, S.S.; Sopian, K. Electricity Generation of Hybrid PV/Wind Systems in Iraq. *Renew Energy* **2010**, *35*, 1303–1307.

Djurišić, A.B.; Leung, Y.H.; Ng, A.M.C. Strategies for Improving the Efficiency of Semiconductor Metal Oxide Photocatalysis. *Mater Horizons* **2014**, *1*, 400–410.

Ellsworth, D.; Lu, L.; Lan, J.; Chang, H.; Li, P.; Wang, Z.; Hu, J.; Johnson, B.; Bian, Y.; Xiao, J. Photo-Spin-Voltaic Effect. *Nat Phys* **2016**, *12*, 861–866.

Gerbinet, S.; Belboom, S.; Léonard, A. Life Cycle Analysis (LCA) of Photovoltaic Panels: A Review. *Renew Sustain Energy Rev* **2014**, *38*, 747–753.

Gorbatsevich, A.A.; Danilin, A.B.; Korneev, V.I.; Magomedbekov, E.P.; Molin, A.A. Analysis (Simulation) of Ni-63 Beta-Voltaic Cells Based on Silicon Solar Cells. *Tech Phys* **2016**, *61*, 1053–1059.

Gowtham, D.; Royrichard, T. Hybrid Distributed Power Generation System Using PV and Wind Energy. *Int J Comput Appl* **2014**, *975*, 15.

Gwani, M. Urban Eco-Greenergy Hybrid Wind-Solar Photovoltaic Energy System & Its Applications, ISSN 2234-7593. *Int J Precis Eng Manuf* **2014**, *16*.

Häberlin, H. *Photovoltaics: System Design and Practice*; John Wiley & Sons, 2012; ISBN 1119978386.

Hamid, M.R.; Rahimi, J.; Chowdhury, S.; Sunny, T.M.M. Design and Development of a Maximum Power Point Tracking (MPPT) Charge Controller for Photo-Voltaic (PV) Power Generation System. *Am J Eng Res* **2016**, *5*, 15–22.

Hankins, M. *Stand-Alone Solar Electric Systems: The Earthscan Expert Handbook for Planning, Design and Installation*; Routledge, 2010; ISBN 1849776504.

Hontoria, L.; Riesco, J.; Aguilera, J.; Zufiria, P. Application of Neural Networks in the Solar Irradiation Field: Obtainment of Solar Irradiation Maps. In Proceedings of the Sixteenth European Photovoltaic Solar Energy Conference; Routledge, 2020; pp. 2539–2542.

Ingole, A.S.; Rakhonde, B.S. Hybrid Power Generation System Using Wind Energy and Solar Energy. *Int J Sci Res Publ* **2015**, *5*, 1–4.

International, S.E. *Photovoltaics: Design and Installation Manual*; New society publishers, 2004; ISBN 1550924044.

Irwan, Y.M.; Daut, I.; Safwati, I.; Irwanto, M.; Gomesh, N.; Fitra, M. A New Technique of Photovoltaic/Wind Hybrid System in Perlis. *Energy Procedia* **2013**, *36*, 492–501.

Jain, P.; Abhishek, A. Performance Prediction and Fundamental Understanding of Small Scale Vertical Axis Wind Turbine with Variable Amplitude Blade Pitching. *Renew Energy* **2016**, *97*, 97–113.

Kabalci, E. Design and Analysis of a Hybrid Renewable Energy Plant with Solar and Wind Power. *Energy Convers Manag* **2013**, *72*, 51–59.

Kalogirou, S.A. *Solar Energy Engineering: Processes and Systems*; Academic press, 2013; ISBN 0123972566.

Khare, V.; Nema, S.; Baredar, P. Solar–Wind Hybrid Renewable Energy System: A Review. *Renew Sustain Energy Rev* **2016**, *58*, 23–33.

Kumar, Y.; Ringenberg, J.; Depuru, S.S.; Devabhaktuni, V.K.; Lee, J.W.; Nikolaidis, E.; Andersen, B.; Afjeh, A. Wind Energy: Trends and Enabling Technologies. *Renew Sustain Energy Rev* **2016**, *53*, 209–224.

Maini, A.K.; Agrawal, V. *Satellite Technology: Principles and Applications*; John Wiley & Sons, 2011; ISBN 1119957273.

Mani, M.; Pillai, R. Impact of Dust on Solar Photovoltaic (PV) Performance: Research Status, Challenges and Recommendations. *Renew Sustain energy Rev* **2010**, *14*, 3124–3131.

McClure, E.; Gaddy, E. Analysis of Record Photovoltaic Efficiencies from 1954 to 2009. In Proceedings of the 2010 35th IEEE Photovoltaic Specialists Conference; IEEE, 2010; pp. 2569–2573.

Melo, C.L.A.; Moura, M.G.L.; Pinto, M.F.; Zachi, A.R.L.; Melo, A.G.; Moraes, C.A. Controle de Um Painel Solar Para Rastreamento de Orientações de Máxima Geração de Potência. In Proceedings of the Congresso Brasileiro de Automática-CBA; 2020; Vol. 2.

Nath, S.; Rana, S. The Modeling and Simulation of Wind Energy Based Power System Using MATLAB. *Int J Power Syst Oper Energy Manag* **2011**, *1*, 12–17.

Nye Jr, J.S. US Power and Strategy after Iraq. *Foreign Aff* **2003**, *82*, 60.

Özçelik, M.A.; Yilmaz, A.S. Effect of Maximum Power Point Tracking in Photovoltaic Systems and Its Improving and Its Application of Wireless Energy Transmission. *J Clean Energy Technol* **2015**, *3*, 416–441.

Peter, Y.U.; Cardona, M. *Fundamentals of Semiconductors: Physics and Materials Properties*; Springer Science & Business Media, 2010; ISBN 3642007104.

Ramli, M.A.M.; Hiendro, A.; Al-Turki, Y.A. Techno-Economic Energy Analysis of Wind/Solar Hybrid System: Case Study for Western Coastal Area of Saudi Arabia. *Renew energy* **2016**, *91*, 374–385.

Reddy, K.P.; Rao, M.V.G. Modelling and Simulation of Hybrid Wind Solar Energy System Using MPPT. *Indian J Sci Technol* **2015**, *8*, 1.

Ruiz, Y.P.M.; Acevedo, E.M. NANOTECHNOLOGY APPLIED TO SOLAR CELLS FOR ENERGY SOLUTIONS. *Nanotechnol Res J* **2014**, *7*, 179.

Saidi, A.; Chellali, B. Simulation and Control of Solar Wind Hybrid Renewable Power System. In Proceedings of the 2017 6th International Conference on Systems and Control (ICSC); IEEE, 2017; pp. 51–56.

Sargent, E.H. Infrared Photovoltaics Made by Solution Processing. *Nat Photonics* **2009**, *3*, 325–331.

Sarkar, M.R.; Julai, S.; Tong, C.W.; Chao, O.Z.; Rahman, M. Mathematical Modelling and Simulation of Induction Generator Based Wind Turbine in MATLAB/SIMULINK. *power* **2006**, *2*, 7.

Seraphim, O.J.; Siqueira, J.A.C.; Fiorentino, J. de J.; Araujo, J.A.B. de Energy Efficiency of Photovoltaic Modules Mono and Polycrystalline in Function of Global Solar Radiation; Eficiencia Energetica de Modulos Fotovoltaicos Mono e Poli-Cristalinos Em Funcao Da Radiacao Solar Global. **2004**.

Sharma, C.; Jain, A. Maximum Power Point Tracking Techniques: A Review. *Int J Recent Res Electr Electron Eng* **2018**, *1*, 25–33.

Sharma, R.; Goel, S. Stand-Alone Hybrid Energy System for Sustainable Development in Rural India. *Environ Dev Sustain* **2016**, *18*, 1601–1614.

Shen, D.; Izadian, A.; Liao, P. A Hybrid Wind-Solar-Storage Energy Generation System Configuration and Control. In Proceedings of the 2014 IEEE Energy Conversion Congress and Exposition (ECCE); IEEE, 2014; pp. 436–442.

Siddiqi, A.; Anadon, L.D. The Water–Energy Nexus in Middle East and North Africa. *Energy Policy* **2011**, *39*, 4529–4540.

Sinha, S.; Chandel, S.S. Prospects of Solar Photovoltaic–Micro-Wind Based Hybrid Power Systems in Western Himalayan State of Himachal Pradesh in India. *Energy Convers Manag* **2015**, *105*, 1340–1351.

Sinha, S.; Chandel, S.S. Review of Recent Trends in Optimization Techniques for Solar Photovoltaic–Wind Based Hybrid Energy Systems. *Renew Sustain Energy Rev* **2015**, *50*, 755–769.

Sivaramakrishna, N.; Reddy, C.K.R. Hybrid Power Generation through Combined Solar–Wind Power and Modified Solar Panel. *Int J Eng Trends Technol* **2013**, *4*, 1414–1417.

Stapleton, G.; Neill, S. *Grid-Connected Solar Electric Systems: The Earthscan Expert Handbook for Planning, Design and Installation*; Routledge, 2012; ISBN 0203588622.

Tripathi, S.M.; Tiwari, A.N.; Singh, D. Grid-Integrated Permanent Magnet Synchronous Generator Based Wind Energy Conversion Systems: A Technology Review. *Renew Sustain Energy Rev* **2015**, *51*, 1288–1305.

Velasco-Quesada, G.; Guinjoan-Gispert, F.; Piqué-López, R.; Román-Lumbreras, M.; Conesa-Roca, A. Electrical PV Array Reconfiguration Strategy for Energy Extraction Improvement in Grid-Connected PV Systems. *IEEE Trans Ind Electron* **2009**, *56*, 4319–4331.

Zamanabadi, A.N. Optimal Allocation of Central Storage in Segmented Rural Distribution Networks Considering Operational Costs and Reliability. *Power Eng Sch Electr Eng Comput Sci* 2017, *Doctor of*.

CURRICULUM VITAE

Name Surname : Ahmed Basem Mohammd ALDULAEMI

EDUCATION:

- **Undergraduate** : 2013, Anbar University / Department of Electrical and Electronic Engineering
- **Graduate** : 2023, Sakarya University / Institute of Natural Sciences / Department of Electrical and Electronics Engineering

PROFESSIONAL EXPERIENCE AND AWARDS:

- 2018 – Date Electrial Mimistry of İraq Engineer

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- Ahmed B. Mohammed, Cenk Yavuz, "Economy Of Hybrid Solar Wind System: A Case Study Rutba City", pp. 178-184, 1st. *International Conference on Frontiers in Academic Research*, ICEANS 2023, February 18-21, 2023, Konya, Turkey.