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PERFORMANCE OF STUDY FOR HYBRID RENEWABLE ENERGY IN DIFFERENT CLIMATE

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BY

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By Ismail Taha Ismail AL-KUBAISI

August 2022

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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ABSTRACT

PERFORMANCE OF STUDY FOR HYBRID RENEWABLE ENERGY IN DIFFERENT CLIMATE

Ismail Taha Ismail AL-KUBAISI

Master of Science in Electrical and Electronics Engineering

Advisor: Asst. Prof. Dr. Göksu GÖREL

August 2022

One of the most promising sources for meeting the rising demand for electricity is renewable energy resources. Using diesel generators and battery energy storage systems can raise the dependability and quality of the entire system. This research analyzes the viability of a stand-alone hybrid energy system consisting of PV panels with MPPT boost converters., Wind turbine, battery bank with bidirectional converter, and diesel generator in areas of unstable climate. To meet out power quality requirements for 100kW liner and non-liner loads connected through close loop inverter. Operating priority for different sources is assigned by controller depends on state of charged SOC for the battery bank. Total harmonics distortion THD was 1.2% with liner load and 3.2% with non-liner load, voltage amplitude was bigger than 0.95PU.

2022, 70 pages

Keywords: Energy storage system, Hybrid renewable energy, Solar photovoltaic system, Wind systems

ÖZET

HİBRİT YENİLENEBİLİR ENERJİ İÇİN FARKLI İKLİMLERDE ÇALIŞMA PERFORMANSI

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Ağustos 2022

Artan elektrik talebini karşılamak için en verimli kaynaklardan biri yenilenebilir enerji kaynaklarıdır. Dizel jeneratörlerin ve akü enerji depolama sistemlerinin kullanılması, tüm sistemin güvenilirliğini ve kalitesini yükseltebilir. Bu araştırma, MPPT yükseltici dönüştürücülere sahip PV panellerinden oluşan bağımsız bir hibrit enerji sisteminin uygulanabilirliğini analiz etmektedir. Rüzgâr türbini, çift yönlü dönüştürücülü akü birimi ve dengesiz iklim bölgelerini enerji ihtiyacını karşılamak için dizel jeneratör kullanılmıştır. Kapalı çevrim invertör aracılığıyla bağlanan 100 kW doğrusal ve doğrusal olmayan yükler için güç kalitesi gereksinimlerini karşılanmıştır. Farklı kaynaklar için çalışma önceliği, kontrolör tarafından belirlenir ve akü birimi için şarj durumu SOC'nin kontrolüne bağlıdır. Toplam harmonik bozulma THD, doğrusal yükü ile 1.2% ve doğrusal olmayan yük ile 3.2% ve gerilim genliği 0.95 PU'dan büyük olacak şekilde elde edilmiştir.

2022, 70 sayfa

Anahtar Kelimeler: Enerji depolama sistemi, Hibrit yenilenebilir enerji, Solar fotovoltaik sistem, Rüzgâr sistemleri

PREFACE AND ACKNOWLEDGEMENTS

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Ismail Taha Ismail AL-KUBAISI
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CONTENTS

LIST OF SYMBOLS

$\Delta i_{L_{1,2}}$	Change between estimated ripple current for inductor 1, 2
$\Delta v_{C_{1,2}}$	Change between voltage capacities 1, 2
$\mathrm{E_{go}}$	The excitation energy for the semiconductor, and for silicon, is $\mathrm{E_{go}} = 1.1(\mathrm{ev})$
$\mathrm{G_n}$	Reference solar radiation value
$\mathrm{I_0}$	The saturation current varies according to the temperature
$\mathrm{I_{pv,n}}$	The current produced when sunlight directly strikes an array of solar cells while the temperature and solar radiation are present
$\mathrm{I_{pv}}$	The solar cell array's current is produced when light strikes it directly.
$\mathrm{I_{sc,n}}$	Nominal short current
$\mathrm{K_i}$	The coefficient of increasing the shortening current due to the increase in temperature
$\mathrm{K_v}$	The coefficient of change of the work effort over a vacuum due to the change in temperature
$\mathrm{N_s}$	The number of serially connected solar cells
$\mathrm{T_r}$	Reference solar cell array temperature
$\mathrm{V_{oc,n}}$	The working voltage in a vacuum at the reference temperature and solar radiation
C_{min}	The minimum value of the capacitance required to reduce the oscillation the output voltage's value
D_{max}	Maximum duty cycle
I_{Omax}	Maximum output current of the application
I_i	Input current.
I_o	Output current
L_{min}	Minimum inductive value required to operate in CCM mode
$M_{V\ \ DC}$	Transfer function of DC voltage
N_p	Number of parallel solar cells in a solar cell array
R_{Lmax}	Maximum inductor resistor
V_{Cpp}	Mean V_i.
V_i	Input voltage.
V_o	Output voltage.
f_s	Minimum switching frequency of the converter.
Δi_{Lmax}	Maximum estimated inductor ripple current.
a	The ideal condition parameter
G	Intensity of solar radiation.
I	The output current of the solar cell array.
K	Boltzmann constant K=1.3805*10^{-23} J/K

Q	Electron charge q= $1.6*10^{-19}$ c
T	The temperature of the solar cell array in Kelvin
V	The output voltage of the solar cell array
D	Duty cycle
f	Frequency

LIST OF ABBREVIATIONS

AC	Alternative current
DC	Direct current
FLC	Fuzzy logic controller
MPPT	Maximum power point tracking
PID	Proportional integral derivative
PSO	Particle swarm optimization
PV	Photovoltaics
THD	Total harmonic distortion

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1 INTRODUCTION

Due to the rapidly approaching fossil fuel runout supplies both the constant rise considering the increase in energy consumption, renewable energy sources like those that wind and solar are increasingly being used to provide electricity needs in urban and remote locations. Clearly, the ever-present, renewable energy sources have environmentally favorable and endless characteristics.

Their intermittent/stochastic nature balances them out. Furthermore, the potential mismatchbetween the energy generation profiles and the load demand requirements energy storage technologies' inclusion into energy system designs in in order to employ renewable energy sources as much as possible available in a given area a certain area despite the tremendous scientific advances made The aforementioned technologies have recently been developed, although they are still viewed as being quite capital intensive., highlighting the need for comprehensive and ongoing to reach economies of scale, that field of study needs to be expanded.

For electric rural consumers, hybrid renewable energy systems (HRES) are one of the most flexible and secure solutions to the main power grid, as they help to protect climate and reduce fossil fuel use. These systems have major advantages comparing with single-energy-source-based systems, as following:

- Excellent dependability
- Reduce the need for energy storage volume, especially if a hybrid energy system makes use of RES that have complementary qualities, like solar and wind energy.
- Modularity.
- Increased efficiency.

A poorly structured and unorganized HRES project development can result in a higher estimated investment cost. As a result, a variety of modeling approaches and simulation tools have been implemented to benefit HRES stakeholders' research, planning, and development efforts.

Solving numerical formulas that outline the mathematical models for the function of the relevant HRES components is a part of HRES simulation. The system behavior will be illuminated, and the project decision-making process will be aided. It is worth mentioning that the simulation algorithms produce non-identical combinations of renewable energy systems based on the user-supplied input parameters.

1.1 Problem Statement

Despite the huge number of renewable sources of energy, most villages still lack access to electricity, whether from the utility grid or through self-generated renewable energy.

The provision of power to the populace is difficult for two reasons. To begin with, there is insufficient power generation to meet present demand. Second, even if there is ample power generation, due to their geographical positions and cost constraints, installing a grid system in each community is difficult. Extending transmission lines from the utility grid to these rural settlements to electrify these remote places is labor and time expensive, as well as capital costly. Electricity, water supply, communication, and transportation are some of the basic amenities that should be supplied to a community. As a result, dependable electricity is required to provide all of these services. To meet the country's growing demand, the electricity-generating infrastructure must expand to include renewable energy sources. Rural remote places may be able to generate electricity using hybrid sources of renewable energy. The provision of low- electricity price generated mostly from renewable resources has a direct link to poverty reduction in the country. Based on the available renewable energy resources, it is a pressing need for rural residents to have consistent electrical access in their daily activities, as well as to improve industrialized farming, small and micro businesses. As a result, energy has become the backbone of the country's economic prosperity.

1.2 Research Objectives

The aim objective of this research as following:

1) Simulating and improving a hybrid system with solar panels, wind turbines, and a diesel generator, battery storage, and converters.
2) Using and counting methods of Maximum power point tracker MPPT algorithm.
3) Using permanent magnet synchronized generator and wind turbine.
4) Dependent on Hybrid Renewable Power Systems (HRES) to preserve the environment and reducing the use of fossil fuels.
5) Using several energy sources to get electricity permanently regardless of climatic conditions.
6) Utilizing renewable energy is mostly done to further economic growth and increase energy security in areas with uncertain climates., and provide access to the finest renewable energy sources in areas experiencing climate change.

1.3 Significance of the Study

First, solar and wind resources vary greatly between locations. The power percentage of wind, solar, and diesel in a hybrid energy system impacts the system's reliability and economy. It is vital to optimize and simulate a solar-wind-diesel hybrid system in order to design one that can provide reliable power at a low cost. Second, the research informs the government and investors about the feasibility, quality of power supply, and operation cost of hybrid renewable power systems in climate-vulnerable locations, allowing them to make investment decisions.

1.4 Scope of the Study

Renewable energy can have a significant impact on the security of energy supply in industrialized and non-fossil fuel regions and in reducing greenhouse gas emissions.

Using renewable energy can limit the use of fossil fuels and energy imports; in addition, it reduces the largest source of carbon dioxide emissions, and improve efficiency in climate-changing regions.

In situations where a system is not directly connected to electrical distribution or the power grid, a hybrid wind-solar-diesel energy system is the ideal solution. as a source of electrical backup, a diesel producing plant fueled by non-conventional fuels is used. In the HRES program, a diesel producing plant is used to ensure that the electricity supply remains stable. The system becomes more sophisticated when an engine generator is added to the HRES framework. Modern controllers, on the other hand, can run these systems on their own. Furthermore, the system's power electronic converter can be made smaller with the help of the engine generator.

Furthermorewhen the demand for energy exceeds the capacity of renewable sources of energy, The battery can be used to store extra energy. As a result, it aids in the cost reduction of hybrid systems.

1.5 Report of the Thesis

The five chapters that make up this thesis are as follows:

- An overview of the issue and the research rationale for this work is presented in Chapter one, which comprises a complete introduction to the subject, a statement of the problem, the search objectives, the study's significance, and the study's parameters.
- Chapter two of the review of literature.
- Chapter three provides a summary of all the parts that make up the hybrid power system. solar power panels, wind turbine, diesel generator and batteries. We also talked about the types of converter and the algorithm of MPPT and relied on artificial intelligence in this algorithm and how to use neural networks with it.

- Chapter four, the installation proposed method and simulation for the system components.
- Chapter five, simulation results for the HRES under different operating conditions and climate changes.

2 LITERATURE REVIEW

Hybrid energy systems are spreading widely because of fossil fuel exhaustion. A hybrid energy system includes both conventional and modern power supply elements, such wind power, fuel cells, PV, and biofuel generator. In addition, a standalone In addition to combining conventional and renewable energy sources, a hybrid energy system needed an energy storage system to reduce wasteful electricity, especially in uncertain climates.

The output variability power with variations The most common drawback of solar PV systems is their sensitivity to temperature and sun radiation. Maximum Power Point Tracking (MPPT) technique is a proceeding of finding automatically the current IMPP or voltage VMPP, way a photovoltaic project must operate to generate the MPPP's maximum power at a specified temperature and amount of sunlight (Agdam *et al.* 2021). The installation of a DC-DC converter is necessary for MPPT techniques, boost converter or step up converter are using to move transferring the largest amount of power possible from the solar panel to the load side (Verma *et al.* 2022).

There are many MPPT technics can operate with boost converter similar as the P&O method (perturbation and observation), which since the DC-DC converters are the most crucial component, is based on an altered converter design. in renewable energy circuit sources. The design of DC-DC converters using in MPPT scheme as an essential part (Zhu *et al.* 2021). There is many utilizations of conventional DC-DC boost converters, buck converters, novel converters, buck-boost converters, and multilevel inverters are also submitted in the literature for MPPT functioning. P&O can be used with boost converter to ensure that MPPT tracking works effectively and that the boost chip is completely integrated while also being as simple to implement on the hardware as possible. (Hussein *et al.* 2021). In order to apply MPPT algorithms in challenging circumstances, such as broad fluctuations in temperature, irradiance, and load, a DC-DC boost converter is typically required. From the PVG to the load, the boost converter can guarantee a steady power flow. (Sun 2021).

Battery is essential component for the standalone renewable energy system. Bidirectional converter is the interface between storage battery and hybrid system (Roy *et al.* 2022). It is recommended in to use a bidirectional DC-DC converter with a high transition ratio. (Mohammed *et al.* 2017). to for two-way power transfer and used for battery charging. Besides, in order to correct the frequently low voltage input from renewable energy sources.

A hybrid sources of renewable energy (HRES) combines two or more renewable energy sources to produce energy more reliably and efficiently. Examples of such sources include solar systems and wind turbines. (Kavadias and Triantafyllou 2021). In a thorough analysis of electronic power converter topologies in wind-solar HRES, design optimization algorithms, mathematical modeling, and power architectures. Also, Several hybrid energy storage coupling solutions were presented, highlighting the key benefits and drawbacks of each.

Design and dispatch for hybrid system can be done by many software tools, such as LEAP (Long Range Energy Alternatives Planning), IHOGA's hybrid energy simulation mode is called HYSIM. (Improved Hybrid Optimization by Genetic Algorithms), RAPSIM (Remote Area Power Supply Simulator), and HOMER (Hybrid Optimization Model for Electric Renewables) which program is most frequently used. The National Renewable Energies Laboratory designed it. (USA) (Chen *et al.* 2022).

Hybrid standalone system with battery was presented in (Joshi *et al.* 2021), a PMSG is connected directly to the wind turbine without applying gear box. The balance of power between the load and generated output is conducted by the battery storage system (BSS). To reach maximum power from hybrid system optimal torque based MPPT controller for wind turbine and the boost converter for solar PV system. The output power produced by PMSG corrected by 3-D bridge rectifier circuit and convert in to DC voltage. The main idea for HRES system in this paper is the same.

(Bates *et al.* 2009) In this paper, controlled a solar-wind hibrid-battery system, and designed a storage battery control system to feed a load at 4 kW, giving the system good results but at higher load settlements the controller could not control the effectiveness of the ability.

(Baumann *et al.* 2010) built a hybrid system model in matlab and a useful experimental model. (Micro CHP - Fuel Cell – PV – Micro Wind Turbine) with two battery storage systems and hydrogen tank, the objective of the research is study the creation of an efficient energy-management system for the usage of hybrid systems in residential applications, including the energy flow between the hybrid system's components. 10.8 KW of load power was measured, Battery capacity used 10 KWH, deep discharge does not exceed 50%. Power of hydrogen tanks are 18m^3, researchers designed a control system to manage energy demand to ensure no discontinuance of feeding from pregnancy, the system gave positive results regarding the quality of electric feeding provided to the load, but at peak hours the system showed weakness in responding to rapid load changes resulting in some loads going out.

(Liu *et al.* 2011) from Australia studied the feasibility of a hybrid system (solar-wind-biomass-batteries) to supply electricity to a residential area in Australia. The housing load was 200KWh/day; the environmental and economic aspects of such a hybrid system have been studied according to the data of the tropical site. Simulation it at the program HOMER, researchers have found that this system is an effective way to reduce environmentally harmful emissions.

(Hoque *et al.* 2012) studied a hybrid power plant that combines a diesel generator, wind turbines, and solar panels, Homer used to analyze system performance. Research results indicated the previous system's ability to effectively meet load variables in order to adjust its power 10KW, but emissions from the diesel generator reduced the system's environmental viability.

(Chaib *et al.* 2016) developed a hybrid system model Control of a hybrid solar/wind energy system (Solar Biomass Fuel Cell). They studied the housing construction situation in the area MANIT Bhopal in India, using the program HOMER. The maximum load was 5KW, and daily energy consumption is 101KWh. Modeling results were that the optimal size of renewable energy sources is 5 kW biomass, 5 Kilowatt solar cells, 5 Kilowatt Fuel Cells. Modelling Results indicated that the system could handle payload changes throughout the year without any power interruptions and with an actual surplus capacity of approximately 36 kWh per year.

(Lagorse *et al.* 2009) studied a street lighting system based on a hybrid power source in an area far from the equator, where a conventional system consisting of geothermal cells and batteries cannot operate efficiently. analysis of the economy selection of components of a system made up elements geothermal cells, batteries, fuel cells and hydrogen tank, using genetic algorithm technology once and using a technique called simple analysis again. The analysis' findings demonstrated that the hybrid model is the most cost-effective choice, also in terms of performance; a simple analysis technique can be adopted and gives acceptable results.

(Ekren and Ekren 2010) used a technique response methodology surface (RSM) to choose the size of components a hybrid energy system with wind turbines, photovoltaic cells and batteries. (RSM) is based on a range using surface response examples as the foundation for statistical and mathematical techniques for design variables. In this study, the surface of the response was Hybrid system expenses are used to measure output performance, and the solar module's size is one of the design parameters. Wind turbine power and battery power, the researcher used the program ARENA 10.0 as a modeling tool in his research to make sure the electrical feeding of a cell broadcasting station is secured. (Ekren and Ekren 2010) then conducted an economic analysis using the net present value approach NPV to make the economic comparison between securing electrical feeding through the hybrid power system adopted in his previous study and securing nutrition from the public grid by extending an electrical grid. The result of the work determined the length of the electrical grid, after which the use of a hybrid feeding system would be better than the laying of an electrical grid.

3 HYBRID POWER SYSTEM AND THE COMPONENTS USED

3.1 Introduction

In contrast to a system that relies on a single source, hybrid energy systems (HESs) combine several generating, storage, and consumption technologies into a single system, increasing overall benefits. Initial plans called for combining traditional, nonrenewable generation (e.g., diesel generators) Their concept has now been expanded to include battery storage systems (BESSs) that are solely fueled by renewable energy sources. [e.g., solar photovoltaics (PV) and wind], beside systems that combine different energy storage systems (e.g., BESSs, fuel cells, and supercapacitors). The capacity of HESs has also increased, shifting from modest, off-grid systems of a few kilowatts that are typically made for low voltage DC and AC, to bigger me admits the main reasons that determine the requirement for the power electronics converters used in HESs are the specific use cases for HESs, resources, electricity, and voltage levels, and grid connectivity. This chapter will look at a several of power electronics converters (Figure 3.1) that can be used in HESs, including topologies and typical layouts for combining combining two or more energy sources in one converter. systems that can now connect to the grid at medium voltage in GA watts. two or more energy resources into a single converter.

3.2 PV Panel

PV panels, better known as solar panels, transform the energy acquired from the sun into electricity this electricity is used to run electrical appliances at homes and huge equipment in factories.

The single component of PV is called a cell, which is small and produces 1 to 2 watts of electric power.

The basic materials that make up these cells are semiconductors. We encapsulated the cells in a mix of glass or plastic to protect it from environment for many years.

We connect pv cells with each other to enhance their production in chains to form larger units called panels where we can use panels individually or as a matrix to produce the largest amount of electrical power.

The matrix of the panels is placed on composite structures where the panels' direction is towards the sun.

When the sun is shining above the cells, these cells create an electric field. Electricity production increases, as the sun is brighter and stronger. But cells can produce electric power on a cloudy day that is; they do not need direct sunlight to work.

Solar panel system shown in Figure 3.1 has two models: the first model connected to the national electrical grid, which is the best model because when the dark comes, solar panels do not work so we can use electricity from the electrical grid.

While the second model is independent and not connected to the grid here, we can add solar batteries to the system to get electricity at night. This model is suitable in remote areas, which the electrical grid is not connected.

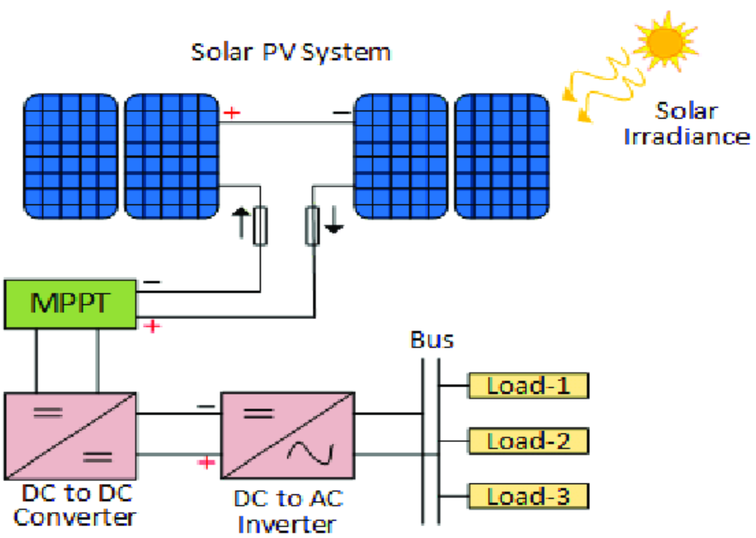

Figure 3.1 PV panel system

3.2.1 The current generated from solar cell

Figure 3.2 depicts the solar cell's equivalent circuit , where the source of current I_{pv} is pointing to the current its generated photons.

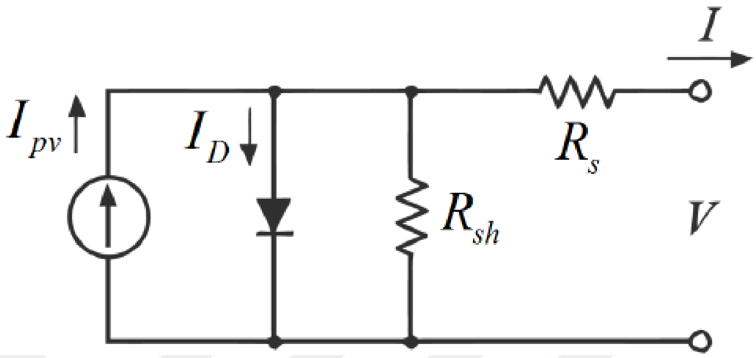

Figure 3.2 Circuit of the solar cell

When we link the solar cells in parallel and series to create solar panels, The solar panel is explained by the Equation (3.1), Equation (3.2) and Equation (3.3):

$$I_{pv} = \left[I_{pv,n} + K_i(T - T_r)\right] * \frac{G}{G_n} \tag{3.1}$$

- I_{pv}: The current produced directly by the light by falling on the solar cell array.
- $I_{pv,n}$: The direct current produced by the light by falling on the solar cell array at temperature and Solar radiation references.
- K_i: The coefficient of increasing the shortening current as a result of temperature increase.
- T: The temperature of the solar cell array in Kelvin.
- T_r: Reference array of solar cells temperature.
- G: intensity that of solar radiation.
- G_n: Reference solar radiation value.

$$I_0 = \frac{I_{sc,n} + K_i\,(T - T_r)}{exp\left(q * \frac{V_{oc,n} + K_v(T - T_r)}{a.N_S.K.T}\right) - 1} \tag{3.2}$$

- $V_{oc,n}$: The working voltage in a vacuum at the reference temperature and solar radiation.
- I_0: The saturation current varies according to the temperature.
- $I_{sc,n}$: nominal short current
- Q: Electron charge q= 1.6*10^{-19} c.
- N_s: The number of serially connected solar cells.
- K: Boltzmann constant K=1.3805*10^{-23} J/K
- K_v: The coefficient of change of the work effort over a vacuum due to the change in temperature.
- E_{go}: The excitation energy for the semiconductor, and for silicon, is $E_{go} = 1.1(ev)$
- a: The ideal condition parameter.

$$I = I_{pv} - I_0\left[\exp\left(\frac{q*(V+IR_s)}{a.N_s.K.T}\right)\right] - \frac{V+IR_s}{R_p} \qquad (3.3)$$

- I: The array of solar cells' output current.
- V: The solar cell array's output voltage.
- N_p: In a solar cell array, the number of parallel solar cells.

3.2.2 Benefits of using solar panels

- Creating alternative energy for fossil fuel energy.
- Eco-friendly in their use.
- Source to make money by exporting surplus capacity to the grid and selling it.
- Excellent electrical source for remote and isolated areas.

3.2.3 Disadvantages of using solar panels

- Cost of installing power panels.
- The cost of batteries that need to be changed from time to time.

3.3 Wind Turbine

Kinetic wind energy is converted into electrical energy using wind turbines. We use small wind turbines to charge batteries or run some small devices while large wind turbines generate huge electric power and if we want more electric power for a particular area, we head to wind farms.

Turbines convert wind power into electricity using the aerodynamic power of rotary blades, which acts as a helicopter blade.

The air pressure decreases on one side of the blade when the wind flows through this blade.

Differing air pressure across both sides of the blade leads to lifting and pulling. As the lifting force is stronger than the pull, the rotor rotates.

The generator connects to a rotor directly either when the turbine is directly driven or through a shaft and gearbox, that accelerates the rotation.

3.3.1 Wind turbine study

Wind power with m mass moving at v speed can be expressed by relationship Equation (3.4):

$$E = \frac{1}{2} m v^2 \tag{3.4}$$

Taking the area of the circular cross section (A=π.r2) crossed by air mass at v speed, we get the volume of air flowing through a certain area and within a specified time, which is called the size of the flow V shown in the Equation (3.5):

$$V = v.A \tag{3.5}$$

Flowing air mass Equation (3.6):

$$m = \rho.v.A \tag{3.6}$$

hen the total kinetic energy of the wind can be obtained from the relationship Equation (3.7):

$$E = \frac{1}{2}\rho A v^3 \tag{3.7}$$

This relationship is fully possible in the air mass as the mechanical capacity extracted from the air relates to the difference between the speed of the air in and out of the turf when the value of the flowing air mass is fixed, as the greater the difference is the capacity extracted.

To find mathematical relationships expressing the value of mechanical ability according to Betz's theory of air movement.

Let our v1 wind flow speed in the turf income, and v2 wind flow speed in the turf output. From which we can find the value of mechanical power derived Equation (3.8):

$$P = \frac{1}{2}.\rho.v_1{}^3.A_1 - \frac{1}{2}.\rho.v_2{}^3.A_2 = \frac{1}{2}.\rho.(v_1{}^3.A_1 - v_2{}^3.A_2) \tag{3.8}$$

The constant of the flowing air mass Equation (3.9) and Equation (3.10):

$$\rho.v_1.A_1 = \rho.v_2.A_2 \tag{3.9}$$

$$P = \frac{1}{2}.\rho.v_1.A_1.(v_1{}^2 - v_2{}^2) = \frac{1}{2}.m.(v_1{}^2 - v_2{}^2) \tag{3.10}$$

Great mechanical power is obtained when v2 = 0, but physically this is not possible, because then the airflow will not continue.

So in order to get a supermassive mechanical power, we have to find the ratio (v2/v1) between the two speeds in income v1 and exit v2 that achieve the greatest mechanical power derived from the turbine, and for that we need a new equation that describes the force applied to the turbine by the wind and this Equation (3.11) is:

$$F = m.(v_1 - v_2) \tag{3.11}$$

The turbine will respond to the force of the wind that is applied to it with an equal and opposite force in accordance with the action and reaction principle. That is, pushing the air at the speed of v 'air, which requires the power of its amount this Equation (3.12):

$$P = F.v = m.(v_1 - v_2)v' \tag{3.12}$$

Therefore, mechanical power derived can be created by finding the difference between wind flow power and the reaction required of the turbine we find Equation (3.13):

$$\frac{1}{2}.m.(v_1{}^2 - v_2{}^2) = m.(v_1 - v_2).v \tag{3.13}$$

Therefore, the speed of flow through the turbine is Equation (3.14):

$$v' = \frac{v_1 - v_2}{2} \tag{3.14}$$

The flow mass is Equation (3.15):

$$m = \rho.v'.A = \frac{1}{2}.\rho.A.(v_1 + v_2) \tag{3.15}$$

Therefore, the mechanical power derived from the wind is Equation (3.16):

$$P = \frac{1}{4}.\rho.A.(v12 - v22).(v1 + v2) \quad (3.16)$$

This mechanical power was attributed to the power to flow air through the same cross section but without being extracted from it, without any barrier to wind flow Equation (3.17):

$$P_O = \frac{1}{2}.\rho.A.v_1{}^3 \quad (3.17)$$

The mechanical power produced by a wind turbine may thus be stated using the following relationshipEquation (3.18):

$$\mathrm{P_m} = \frac{1}{2}\mathrm{C_P}(\lambda, \beta)\rho \mathrm{A}\mathrm{v}^3 \quad (3.18)$$

$\mathrm{C_P}$The rotor power yield of the turbine has to do with the terminal velocity boundary λ and the angle of inclination of the blades β, the relationship of boundary speed Equation (3.19):

$$\mathrm{TCR}(\lambda) = \frac{\mathrm{w_m R}}{\mathrm{v}} \quad (3.19)$$

$\mathrm{w_m}$: Rotor angular speed, R: radius

Mechanical torque resulting from the turbine applied to the synchronous generator is Equation (3.20):

$$T_m = \frac{P_m}{w} \quad (3.20)$$

3.4 Synchronous Generator

Faraday's law governs the operation of synchronous generators. Unlike a DC generator that generates a single, direct-current output, From its fixed coils, the generator produces a three-phase AC output voltage. a little wind turbine systems for synchronous generators can use single-phase Synchronous generators.

An electromechanical device called a synchronous generator creates a magnetic field on the rotating rotor. Permanent magnets, either installed directly the magnetic field system is produced either directly on the rotor or when the rotating field windings are activated electrical by an outside DC current.

The terminology used to describe machine parts for the "synchronous generator" is the inverse of that used to describe the DC generator.

The major magnetic field is produced by the field coils, which are the rotor coils for a In a synchronous generator, the coils that carry the primary voltage are known as the armature coils.

In other words, In a synchronous generator, the stator coils are the induced coils, while the rotor coils are the field coils.

In diverse ways, variable speed generators are employed in wind turbines. The PMSG has various benefits that are similar to the reference. (Chen *et al.* 2012, Binder and Schneider 2005) , despite the fact that permanent magnetic synchronous generators (PMSG) are being used more frequently, doubly fed induction generators (DFIG).

Specifically, PMSG features direct drive and a moderate rotation speed, can be used without a gearbox, and has no rotor current. The minimum maintenance and high efficiency will reduce investment costs, which is the most important factor. On the other hand, PMSG has a number of flaws. An electromagnetic field with a flexible structure is necessary, which leads to high requirements for operation and production. In addition, the generator's varying speed must be known to the power inverter.

3.4.1 Structure of pmsg wind turbine

The basic structure of the PMSG wind turbine is depicted in Figure 3.3 is given as Wind power provides thrust in the wind turbine(Sarir *et al.* 2021) . The torque is delivered to the generator rotor via the generator shaft. Depending on the ratio of the mechanical torque generated by the wind turbine to the electrical torque generated by the generator, the mechanical system either accelerates, decelerates, or maintains a constant speed.

The generator is connected to a three-phase inverter, which corrects the current and charges a DC-link Udc capacitor. (Yuan *et al.* 2009). The DC-link Udc feeds a second three-phase inverter, which is connected to the grid through a transformer. The control system accepts wind speed, pitch angle, rotor RPM, and inverter output for comparison with grid-side data. Therefore, by using a digital signal processing system to provide the appropriate signal for controlling these components, this information is resolved. Connecting to the electric grid and supplying it with power is the main goal.

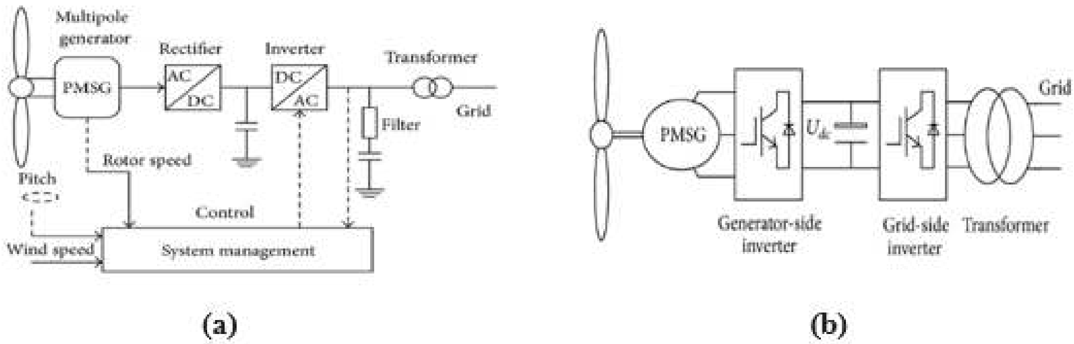

Figure 3.3 General wind turbine PMSG system with control schemes

3.4.2 Wind plant

Multiple turbines in one location create electricity in wind power stations. Wind conditions, adjacent lands, access to electrical transmission, and other site considerations all influence the location of a wind farm. Every wind farm shown in Figure 3.4 in a utility-scale wind farm produces electricity that is sent to a substation, then to the grid, and then to our towns.

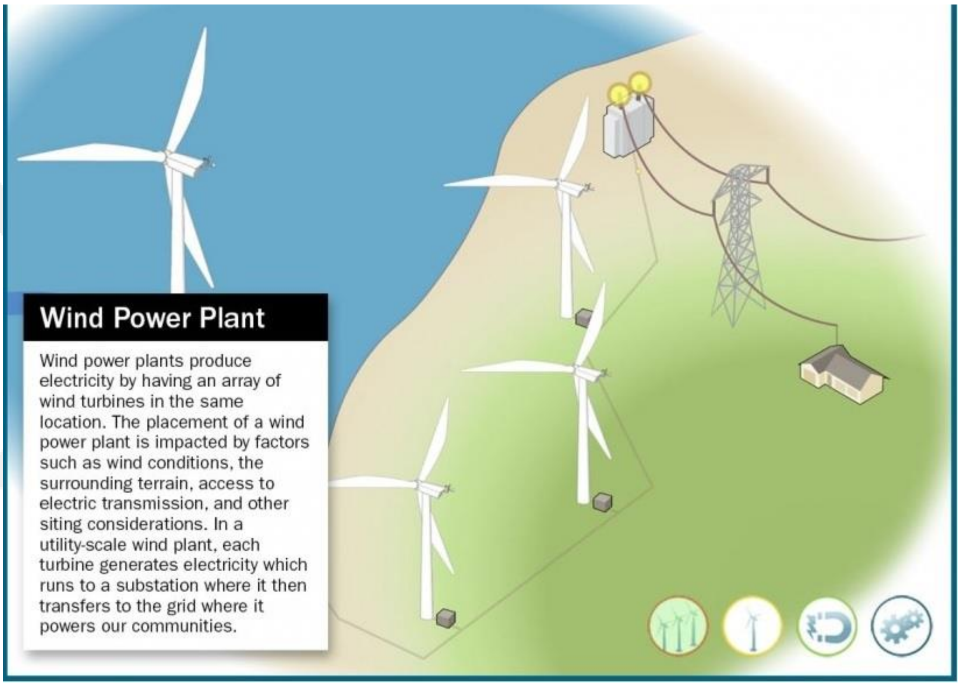

Figure 3.4 Wind power plant

Bidirectional converter

So because output of a renewable energy system fluctuates due to changes in weather conditions, a bidirectional dc-to-dc converter is used as a crucial component to interface storage devices between source and load in a renewable energy system for continuous power flow.

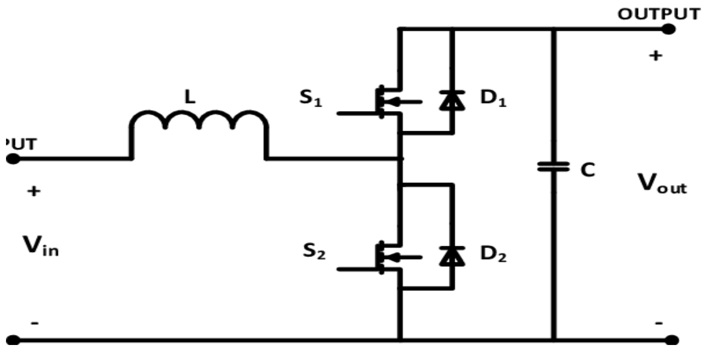

Figure 3.5 Circuit of the bidirectional converter

Advantages bidirectional converter

- Insulated DC-DC converters, depending on the kind, have a high voltage insulation of several hundred to thousands of volts.
- For different equipment, the output can be set to be positive, negative, or buoyant.
- They offer a high noise capacity and interference blocking capability, allowing for a cleaner direct current source, which is required by many sensitive loads.

Dis advantages bidirectional converter

- Size is large.
- Core saturation problem.
- Switching losses.
- Less efficient than the uninsulated bi-directional DC-DC converter.
- The transformer is used to increase the voltage, which creates more leakage losses because of the inductance in the winding.

Depending on the type of standard, isolated DC-DC converters offer high voltage isolation ranging from several hundreds to thousands of volts.

For various equipment, the output can be set to be positive, negative, or floating ground.

They offer a high level of noise and interference blocking capacity, resulting in a cleaner DC source for the load, which is required by many sensitive loads.

Bidirectional converter uses

When we need to convert DC electricity from one voltage level to the next, we can utilize DC converters. These converters are required because, unlike the AC power source, the DC boost can be easily increased or decreased. A DC transformer is also known as a DC-to-DC converter.

3.5 Boost Converter

A DC-to-DC converter known as a boost converter generates an output voltage that is higher than the input voltage. A boost converter is also referred to as a step-up converter since it "steps up" the source voltage. Due to the need to preserve power, the output current is lower than the source current; the circuit is shown in Figure 3.6.

Necessary Parameters:

- $M_{V\ \ DC}$: Transfer function of DC voltage.
- V_o: Output voltage.
- V_i : Input voltage.
- I_i: Input current.
- I_o: Output current.
- D: Duty Cycle.
- L_{min}: Minimum inductive value required to operate in CCM mode.
- f_s: Minimum switching frequency of the converter.
- R_{Lmax}: Maximum inductor resistor.
- C_{min}: The minimum value of the capacitance required to reduce the oscillation value of the output voltage.
- I_{Omax}: Maximum output current of the application.
- D_{max}: Maximum duty cycle.
- V_{Cpp}: Mean V_i.
- Δi_{Lmax}: Maximum estimated inductor ripple current.

- L: selected inductor value.
- $\Delta v_{c_{1,2}}$: Change between voltage capacities 1, 2.
- $\Delta i_{L_{1,2}}$: Change between estimated ripple current for inductor 1, 2.
- f: Frequency.

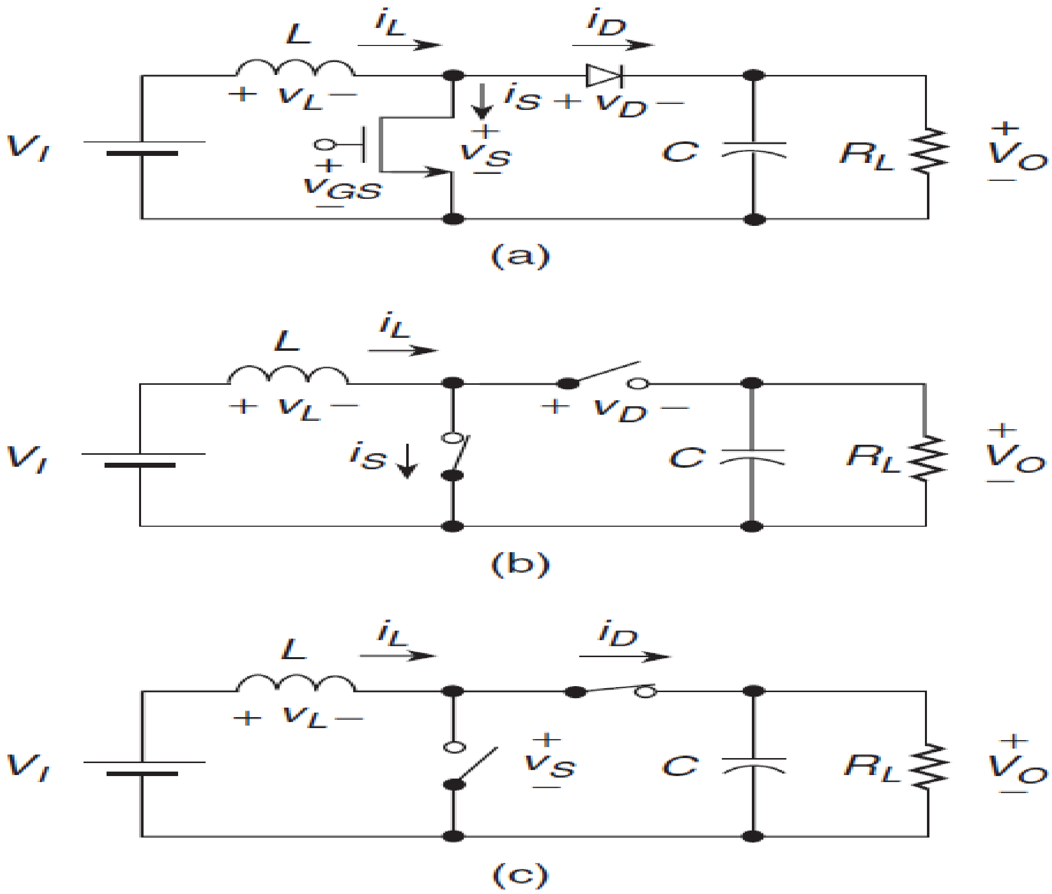

Figure 3.6 Circuit of the boost converter

Transfer function of DC voltage Equation (3.21):

$$M_{V\ DC} = \frac{V_o}{V_i} = \frac{I_i}{I_o} = \frac{1}{1-D} \tag{3.21}$$

Duty Cycle Equation (3.22):

$$D = 1 - \frac{1}{M_{V\ DC}} = \frac{M_{V\ DC} - 1}{M_{V\ DC}} \tag{3.22}$$

Minimum inductive value required to operate in CCM mode Equation (3.23):

$$L_{min} = \frac{2}{27} \frac{V_o}{f_s . I_{oBmax}} = \frac{2}{27} \frac{R_{Lmax}}{f_s} \tag{3.23}$$

The minimum value of the capacitance required to reduce the oscillation value of the output voltage Equation (3.24):

$$C_{min} = \frac{I_{Omax} . D_{max}}{f_s . V_{Cpp}} = \frac{D_{max} . V_O}{f_s . R_{Lmin} . V_{Cpp}} \tag{3.24}$$

3.5.1 Advantages boost converter

- It uses minimum components to raise or drop the voltage.
- The operating duty cycle is reduced.
- It has a large range of input and output voltages and great efficiency.
- It is less expensive than the majority of converters.

3.5.2 Disadvantages boost converter

The traditional boost converter has a number of drawbacks. It has no influence on the stream flowing into it. At a high duty cycle, it draws a significant quantity of input current from the source. A large quantity of current can cause major problems for the DC-DC converter's components.

3.5.3 Boost converters uses

Boost converters are one of the varieties of dc voltage converters in which, depending on the operating cycle, output is always greater than income. They are frequently utilized in white LED power supplies and battery packs for electric vehicles , and many other applications.

3.6 Buck Converter

The voltage from the input (power supply) to the output (load) is bucked by a buck converter (reduces the average current). This is a type of switch mode power supply (SMPS), that typically consists of at least two semiconductors (diodes and transistors) Figure 3.7 shows it, while contemporary buck converters swap the diode with a second transistor for synchronous rectification. , Capacitors, inductance, or a combination of both) and has at least one energy storage element. The output (load side filter) and input (supply side filter) of such converters are commonly composed of capacitors (periodically in combined with inductors) to reduce voltage ripple. The voltage across the inductor "reverses" or opposes the supply voltage, resulting in a back converter.

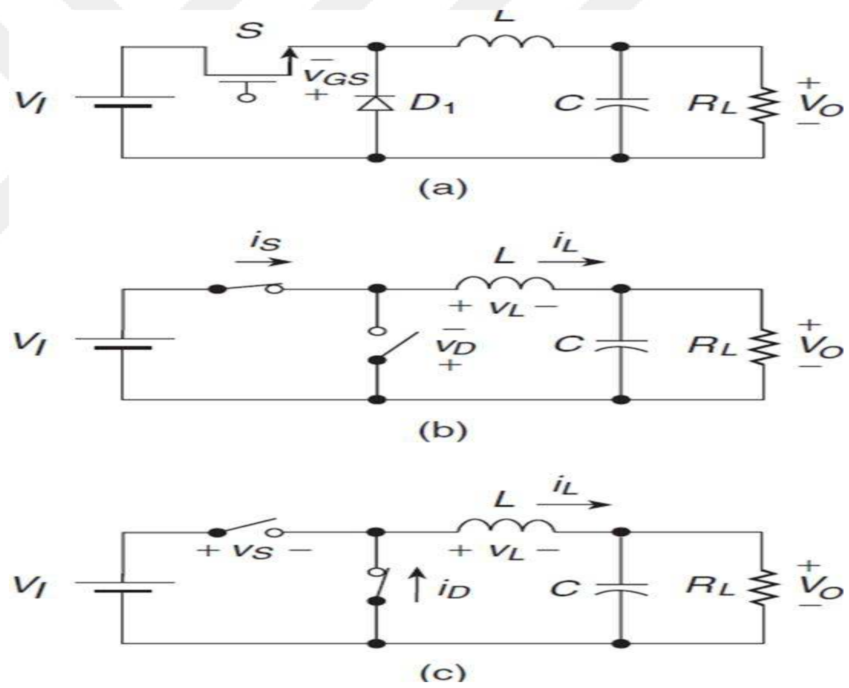

Figure 3.7 Circuit of the buck converter

Duty Cycle Equation (3.25):

$$M_{V\ DC} = \frac{V_0}{V_1} = \frac{I_1}{I_0} = D \tag{3.25}$$

The minimum inductive value required to operate in CCM mode Equation (3.26):

$$L_{min} = \frac{V_o(1-D_{min})}{2f_s.I_{Omin}} = \frac{R_{Lmax}(1-D_{min})}{2f_s} = \frac{D_{min}(V_{Imax}-V_o)}{2f_s.I_{Omin}} \tag{3.26}$$

The minimum value of the capacitance required to lessen the variation in the output voltage Equation (3.27):

$$C_{min} = \frac{\Delta i_{Lmax}}{8f_s.V_{Cpp}} = \frac{(1-D_{min})V_o}{8f_s^2.L.V_{Cpp}} \tag{3.27}$$

3.7 Buck–Boost Converter

A buck-boost converter's output voltage is greater than or equal to its input voltage. In this flyback converter, a single inductor is employed in place of a transformer. Buck-boost converters can have two distinct topologies. Both can deliver a voltage output that is substantially greater (in absolute digits) than the input voltage and close to zero. The output voltage has the opposite polarity as the input voltage in an inverting topology. It is a switching power supply using a boost converter or buck converter circuit architecture. To alter the output voltage, the duty cycle of the switching transistor can be changed. There is no ground connection on the switch on this converter, which could be a disadvantage. This makes the driving circuit more complicated. However, if the power source is isolated from the load circuit, this disadvantage is negated because the polarities of the power supply and diode can simply be reversed. The switch can be grounded or supplied if they can be reversed; Circuit is shown in Figure 3.8.

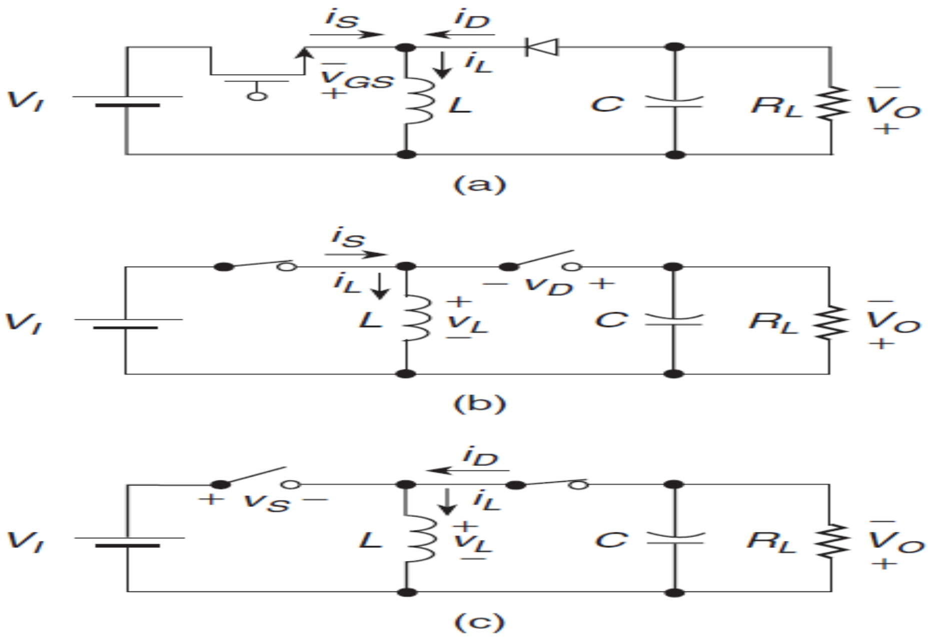

Figure 3.8 Circuit of the buck boost converter

Transfer function of DC voltage Equation (3.28):

$$M_{V\ DC} = \frac{V_o}{V_i} = \frac{I_i}{I_o} = \frac{D}{1-D} \tag{3.28}$$

Duty Cycle Equation (3.29):

$$D = \frac{M_{V\ DC}}{M_{V\ DC}+1} \tag{3.29}$$

Minimum inductive value required to operate in CCM mode Equation (3.30):

$$L_{min} = \frac{V_o(1-D_{min})^2}{2f_s.I_{OB}} = \frac{R_{Lmax}(1-D_{min})^2}{2f_s} \tag{3.30}$$

The minimum value of the capacitance required to reduce the oscillation value of the output voltage Equation (3.31):

$$C_{min} = \frac{I_{Omax} \cdot D_{max}}{f_S \cdot V_{Cpp}} = \frac{D_{max} \cdot V_O}{f_S \cdot R_{Lmin} \cdot V_{Cpp}} \quad (3.31)$$

3.8 Cuk Converter

Cuk converters are buck-boost converters that have a low ripple current. The Cuk converter can be thought of as a boost and back converter combined with a switching mechanism for energy binding and a common capacitor.

Non-isolated Cuk converters' output voltage is usually inverted and can have a low or high value with respect similar to buck-boost converters with an inverting topology to the input voltage. In DC-DC converters, inductance is commonly used as the principal energy storage component. The capacitor is the major energy storage component of the cuk converter. Slobodan Chuk of the California Institute of Technology was the one who first proposed the design; Fig. 3.9 depicts the circuit.

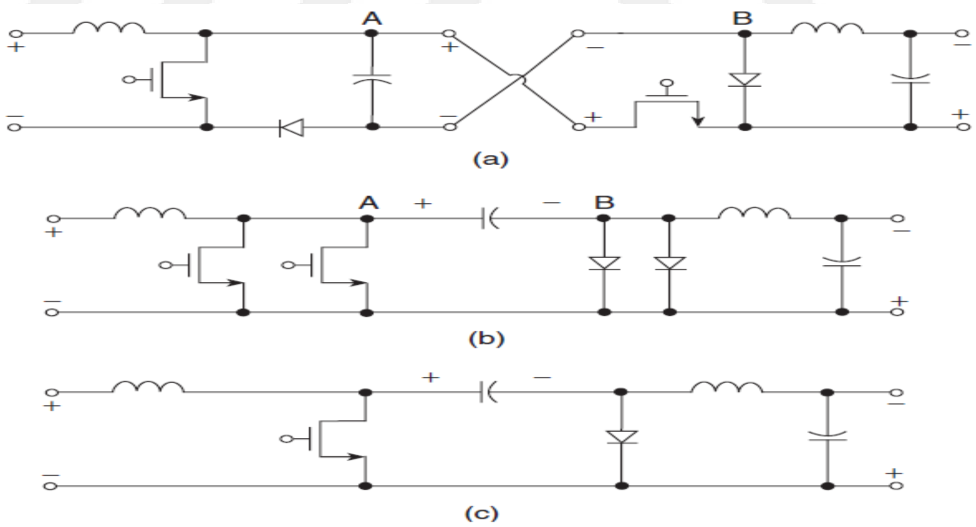

Figure 3.9 Circuit of the cuk converter

Transfer function of DC voltage Equation (3.32):

$$M_{V\ DC} = \frac{V_o}{V_i} = \left(\frac{1}{1-D}\right)(-1)(D) \quad (3.32)$$

Duty Cycle Equation (3.33):

$$V_O = V_i \frac{-\delta}{1-\delta} = D \tag{3.33}$$

Minimum inductive value required to operate in CCM mode Equation (3.34):

$$L_{1,2} = \frac{V_I D}{f \Delta i_{L_{1,2}}} \tag{3.34}$$

The minimum value of the capacitance required to reduce the oscillation value of the output voltage Equation (3.35):

$$C_1 = \frac{V_o D}{R f \Delta v_{C_{1,2}}} \qquad C_2 = \frac{1-D}{8 r f^2 L_2} \tag{3.35}$$

3.9 Sepic Converter

The output potential (voltage) the input potential of a single-ended primary inductor converter (SEPIC) may be higher or lower (voltage). The duty cycle of the control switch regulates the SEPIC's output (S1) Figure 3.10 shows it.

Because it is SEPIC is similar to a regular boost converter in that it is essentially a boost converter followed by an inverted boost converter, but it has the advantage of having a non-inverting output (the output has the same voltage polarity as the input) (the output has the same voltage polarity as the input)and uses series. Capacitors that can combine input-to-output power (and so react more elegantly to output short circuits) and perform an actual shutdown: the output (V0) goes to 0V when switch S1 is sufficiently off. It will fall. A fairly active transient loss of command.

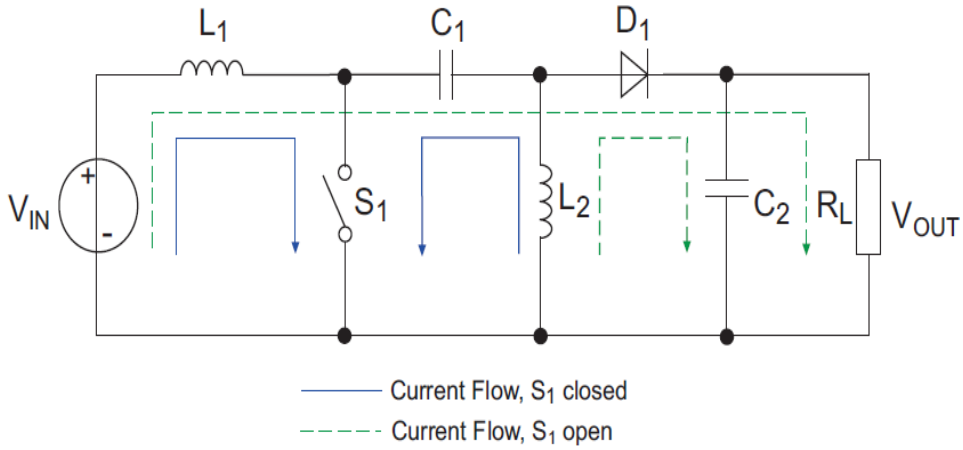

Figure 3.10 Circuit of the spec converter

Transfer function of DC voltage Equation (3.36):

$$\frac{V_O}{V_i} = \frac{\delta}{1-\delta} \tag{3.36}$$

Duty Cycle Equation (3.37):

$$D = \frac{V_o}{V_o + V_s} \tag{3.37}$$

Minimum inductive value required to operate in CCM mode Equation (3.38):

$$L_{1,2} = \frac{V_I D}{f \Delta i_{L_{1,2}}} \tag{3.38}$$

The minimum value of the capacitance required to reduce the oscillation value of the output voltage Equation (3.39):

$$C_{1,2} = \frac{V_o D}{R f \Delta v_{c_{1,2}}} \tag{3.39}$$

3.10 Diesel Generator

A diesel (DG) generator produces electrical power by combining an electric generator and a diesel engine (typically an alternator). This motor-generator is unique. Although most compression-ignition diesel engines are made to operate on diesel fuel, several models can also run on alternate natural gas or liquid fuels.

Diesel generators are used for complex applications including peak loading, grid support, & grid export as well as in areas without electricity or as a backup power source in the event of a grid failure.

The diesel generators must be suitably dimensioned to prevent lack of power or low load. The peculiarities of recent electronics, especially non-linear loadings, make dimensioning difficult. Although a diesel engine system with a size range of around 50 MW or more is significantly more powerful at full load and much more compact than an open-cycle gas turbine, open-cycle gas turbines are occasionally favored over diesel grids for routine partial charge due to their higher efficiency.

3.10.1 Advantages

Diesel engines are more fuel-efficient than gasoline engines because they do not use as much fuel to produce the same amount of power. Diesel engines are also heavier than gasoline engines to cope with the additional stress imposed by higher compression ratios.

3.10.2 Disadvantages

The following are the primary drawbacks of diesel generators: Because of regulation, the price of diesel will continue to rise. To ensure generator operation, regular maintenance is required. The fuel injection system and other components are more likely to fail, resulting in a lack of dependability and expensive replacement costs.

3.10.3 Energy storage

The doubt of renewable resources can be greatly reduced by adding the ESS into wind-solar HRES designs, where renewable energies cause many supply quality problems such as voltage fluctuation and harmonic reduction as these problems are solved by the ESS. Among the several varieties of ESS on the market, batteries and super capacitors (SC) are the most commonly used components.

Rechargeable batteries come in a variety of types, comprising lithium ion, lead acid, nickel, cadmium, and lithium polymer. It is used as an energy storage element where the determination of its types relates to applications used such as operating temperature during charging and discharging, cost, size and weight limits.

3.11 Maximum Power Point Tracker

PV can operate at its greatest power thanks to an electrical technology called MPPT (Maximum Power Point Tracking). It is a shifting point on the P-V curve that is influenced by temperature and light intensity. The rented power from sources must be as great as possible, as there is electrical tracking in electro-solar systems as there is mechanical pursuit of solar radiation.

The O&P method measures voltage and current at the moment and then calculates current capacity and compares it to the previous moment, and using the comparative outcome, the transformer's operating cycle increases to change voltage (Kalogirou 2003) . Current (I) and voltage (V) are used to calculate photovoltaic power (V). By modifying the duty cycle of the PWM, the P&O method is applied on buck-boost. The duty cycle will be raised until the MPP is found if the most recent power is higher than the most recent. This approach has the disadvantage of introducing an swing in the steady state and a large voltage variation. This approach also requires a long overseeing time and responds slowly to changes in irradiance and temperature.

3.11.1 Perturbation and observation

Because of their simple structure and the few measurable parameters that are necessary, P&O algorithms are commonly utilized in MPPT. Duty cycle leads to a change in effort, which is called Perturbation, and compares the ability between the current and the previous moment. If the increase in effort increases capacity, the perturbation will proceed in the same manner.. If that increase in effort causes a decrease in power, then the next effort must be reduced, so the sampling time must be very small to ensure the speed of response.

Power Perturbation around the MPPT is the main disadvantage of this method, and therefore the value of the disorder must be reduced.

This method is simply implemented and does not need to be trained as in AI methods, as well as because it is not about the type of board or size of the system.

This difficulty can be handled by modifying the P&O algorithm's logic to compare the when the P&O is attained and avoid the perturbation step by using the parameters of two previous cycles. Another option to limit power loss around the P&O is to remove the perturbation step; however, the algorithm will be slow to follow the P&O as atmospheric conditions change, resulting in increased power loss.

Compare instantaneous values of and Vpv rather than average values, as well as peak current control, which shows one-cycle speed of response for slight variations in the reference current, to boost the system's performance. The suggested MPPT system makes advantage of peak current control. The switch is turned on by a clock signal and is shut off when the reference current is reached. As a result, the reference current can be changed (increased or decreased) during each switching cycle, indicating that the perturbation cycle or refresh rate is equal to the switching cycle. (Masood *et al.* 2014).

P & O algorithms shown in Figure 3.11 are commonly used in MPPT due to their simple structure and the few Required measurement parameters They work by perturbing (raising or reducing) a voltage array on a regular basis and comparing the PV output power to the preceding perturbation cycle's output. The disturbances continue in the same way in the next cycle as the power increases. Otherwise, the perturbation direction is reversed. This means that every MPPT cycle, the array's terminal voltage is disrupted. As a result, when P & O is attained, the P & O algorithm oscillates around it, resulting in PV performance degradation, particularly in constant or slowly changing atmospheric circumstances. By enhancing the logic of the P & O algorithm, comparing the parameters of the previous two cycles, ensuring that the P & O has been reached, and avoiding the failure level, this problem can be handled. Reduce the disturbance steps to reduce power loss near the P & O; however, the algorithm will gradually follow the P & O when air conditions change and more power is lost. To implement the existing (I) P & O type MPPT with an improved update rate, two things must be done. First, the P & O algorithm must function at high sampling rates, with voltage and current samples reflecting the output power trend as the MPPT power converter reference signal rises or fallsSecond, the MPPT power converter's response time should be very short while the switching loss (frequency) is kept low. This can be accomplished by comparing the immediate value of Vpv with the peak current control, which indicates the response speed of one cycle to tiny fluctuations in the reference current, rather than the average value of Vpv. Peak current control is used in the proposed MPPT system. The clock signal activates the switch, which is then shut off when the real current reaches the reference current. As a result, with each switching cycle, the reference current can fluctuate (increase or decrease). The perturbation cycle, or refresh rate, is therefore equal to the switching cycle (Masood *et al.* 2014).

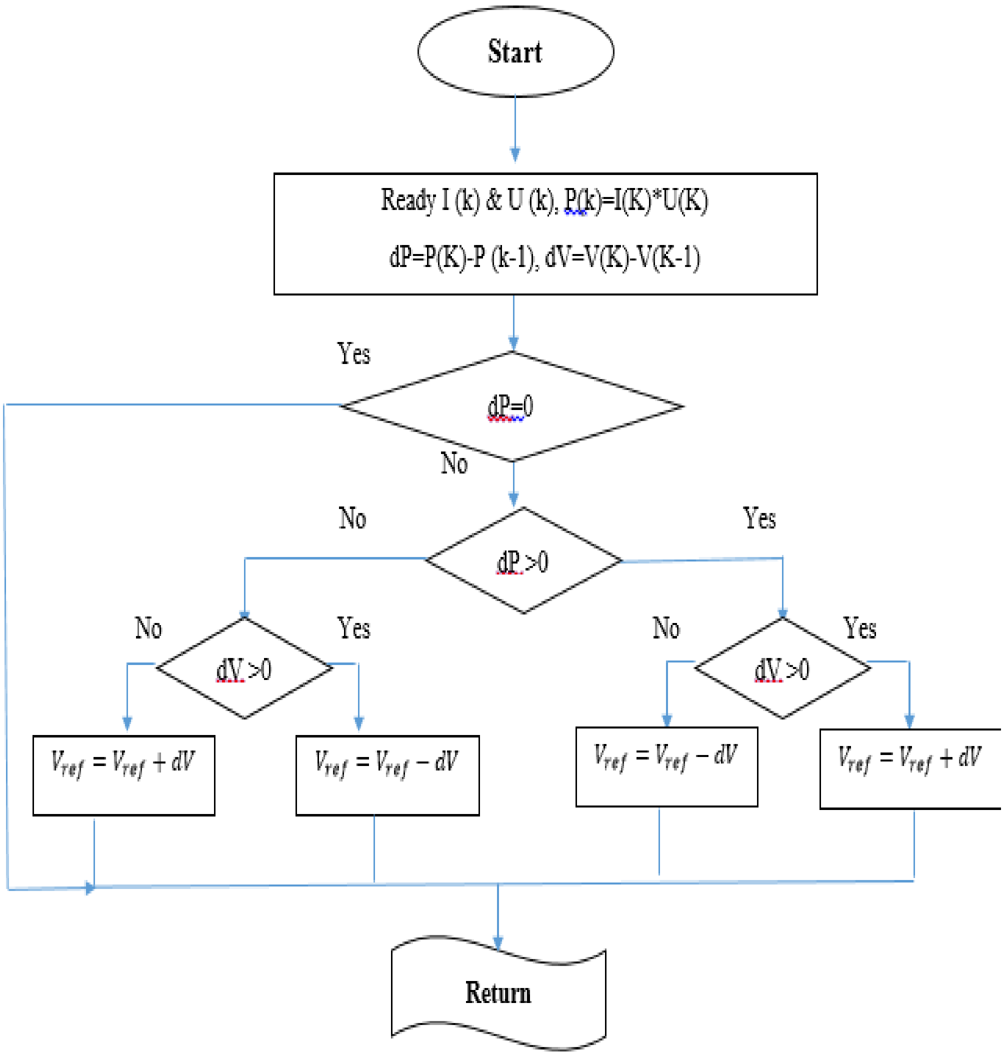

Figure 3.11 Algorithms of P&O

3.11.2 Incremental conductance method

Based on observing the P-V characteristic curve, Incremental Conductance was developed. This method was created in 1993 to address some of the P&O algorithm's shortcomings. On a broad irradiation changes environment, IC attempts to improve the tracking time and create more energy. The MPPT can be calculated using the dI/dV and -I/V relationship.

MPPT is on the right side of recent position if dP/dV is negative and on the left side if MPPT is positive.

3.11.3 Fractional short circuit current

The FSCC method of tracking the MPPT is simple but effective. This MPPT technique requires the value of FSCC by isolating the PV array to track the power. This approach does not work on genuine MPPT since the MPPT calculated using this methodology is based on Eq., which is an approximation. Nonetheless, the technique's simplicity makes it suited for use in low-cost small-scale applications. This method can be applied in either analog or digital mode. The current at MPP (Impp) is closely positioned near the short circuit current Isc, according to the basic outline of this approach. As a result, multiplying Isc by the factor k as follows yields the operational point: Isc =k Impp The constant "k" is simply computed from the PV module specifications and is always smaller than one. Because the constant k has a fixed value, it can be used in the algorithm as a fixed entity. Because FSCC MPPT just requires a current sensor and is therefore less expensive and simple to build, the value of k is often between 0.85 and 0.95.4. The periodic loss of power when monitoring the short circuit current is a disadvantage.

3.11.4 Artificial neural networks in mppt algorithms

Artificial neural networks, or ANNs, are a type of data processing system powered by biological neurons. They attempted to depict a fundamental neuron in 1943 using electrical circuits, but the available technology was limited. Since then, ANN has advanced significantly. It is excellent at drawing conclusions from vast amounts of data. In data that is too sophisticated for classification by a machine or a human, it can also find patterns and modes. A skilled ANN can analyze the given data and deliver predictions and solutions to the challenges that follow. ANN approaches problem resolution differently than traditional forecasting algorithms. Which are like the brains of human beings, and they adjust to situations that do not have obvious algorithmic solutions and are able of handling indefinite data. Besides using in many applications that have insignificant data, such as signal processing, robotics, financial applications, and pattern recognition. As a result, they can succeed where traditional computers frequently fail thanks to this advantage. ANN are recognized as efficient computational models that may be applied to a variety of challenging problems. ANN is useful for difficulties related to classification, prediction, complex system prediction and control (CPM), and regression (Kalogirou 2003).

3.11.5 Fuzzy logic

One of Lotfi Zadeh's most well-known expert system techniques is fuzzy logic.

This logic works by graduating the element's membership of the set, i.e. the element has a gradual affiliation and can be linked between linguistic variables (voltage and current) and mathematical relationships.

Work in fuzzy logic goes through three phases: in the first phase the linguistic variables are released to the elements, and then the fuzzy rules between income and exit are established in the second phase. Finally, in the third phase the results are reflected after the link between income and exit through the rules and determination of the graduation affiliation according to the degree of income affiliation.

3.11.5.1 The mppt based fuzzy logic controller

Fuzzy Logic controllers offer a huge range of uses in renewable energy resources (FLC). Because of its simplicity, the demand for FLC has surged over the previous decade. FLC also handles erroneous input, which does not necessitate a precise mathematical model for the controller. For maximum power from PV Modules, FLC can easily manage nonlinearity circumstances. It can function in any weather situation, as well as changes in temperature or irradiance level (Larbes *et al.* 2009).

There are three types of fuzzy logic controller processes:

- Fuzzification
- Rule Evaluation
- Defuzzification.

In the first phase the verbal variables are released to the elements, and then the fuzzy rules between income and exit are established in the second phase. Finally, in the third phase the results are reflected after the link between income and exit through the rules and determination of the graduation affiliation according to the degree of income affiliation (Larbes *et al.* 2009, Tavares *et al.* 2009).

The Fuzzy logic controller is employed in the MPPT controller connected to the P&O algorithm in this project. FLC involvement in MPPT boosts output voltage, and designing a Fuzzy Logic Controller is straightforward and does not require significant knowledge of the model's particular requirements. It only takes assigning the rule to each set of the membership function (Larbes *et al.* 2009).

3.11.6 Particle swarm

A computational technique called particle swarm optimization (PSO) aims to improve a candidate solution iteratively in terms of a specific quality metric. By creating a population of potential answers, or "particles," and moving them around the search area according to a straightforward mathematical formula based on their position and velocity, it can solve problems. Each particle moves in accordance with its local best-known position, which is updated as other particles find better positions. However, each particle also moves in the direction of the best-known positions in the search space. As a result, it is anticipated that the swarm would go toward the best possibilities.

(Eberhart *et al.* 2001) are given credit for developing PSO. It was developed to replicate social behavior by stylizing the movement of organisms in a bird flock or fish school

(Kennedy 1997). After the algorithm was made simpler, it was found to be optimizing. There are numerous philosophical discussions of PSO and swarm intelligence in (Eberhart *et al.* 2001)'s book. Poli conducts a thorough examination of PSO applications. Bonyadi and Michalewicz recently released a comprehensive survey of theoretical and experimental efforts on PSO.

3.11.7 Particle swarm for mppt

PSOs are metaheuristics in that they cancel expectations about the problem to be solved or make them little and can search for a very big number of applicant solutions. PSO also ignores the gradient of the problem to be solved. That is, unlike traditional optimization methods like gradient descent and quasi-Newton, the PSO does not need to be able to discriminate the optimization issue. Metaheuristics such as PSO, on the other hand, do not ensure that you will find the optimal answer. The objective is to improve the algorithm by introducing additional programs and methods to improve the system's post-optimization capacity and hasten its exit from local minima in late particle swarm iterations. Combine natural selection with the conventional particle swarm MPPT algorithm, whose main idea is to retain the best solution from each particle's historical memory while replacing the half of the particles with lower fitness values with the other half with higher fitness values in each iterative process. Thus, in the MPPT process, the particle population goes through constant evolution and replacement, which significantly lowers the possibility of early convergence while improving the search speed and quality of the particle populations (Figure 3.12)

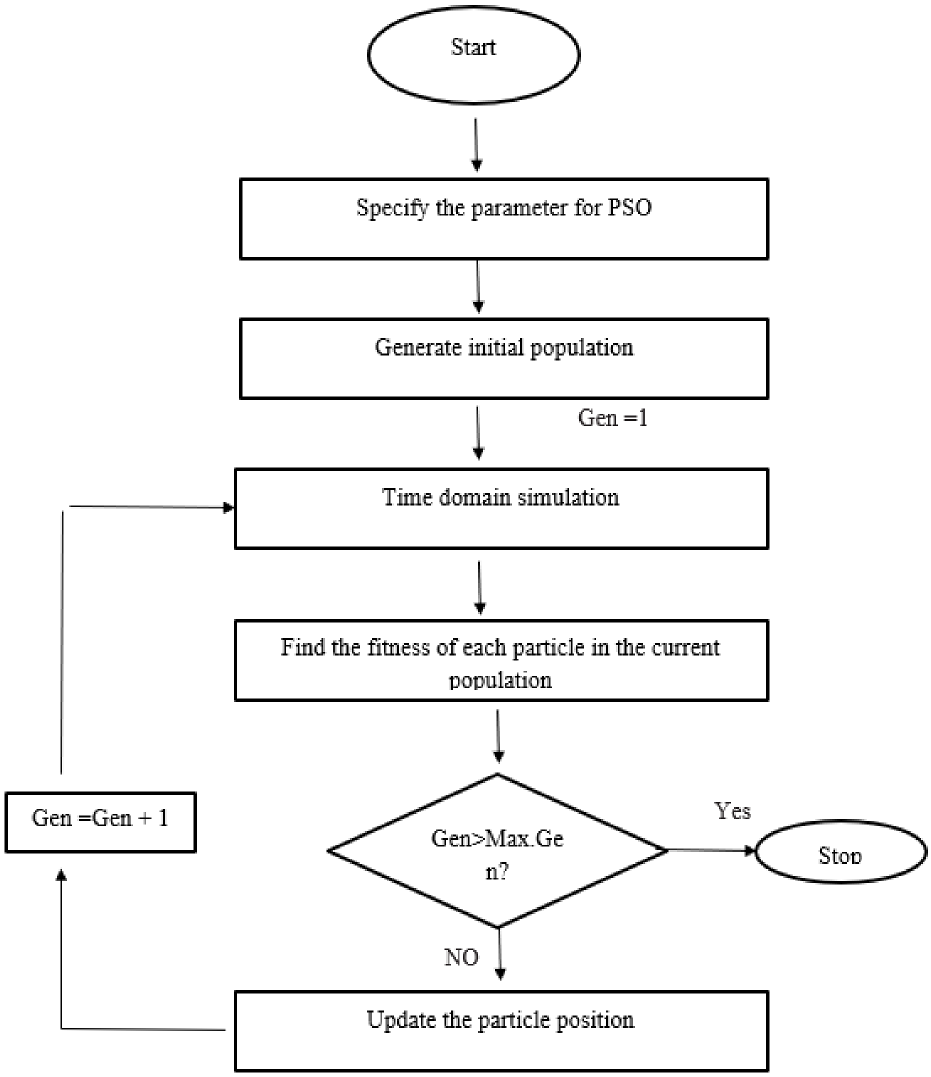

Figure 3.12 Flow chart of PSO

4 PROPOSED METHOD

4.1 Introduction

Renewable energies resources are between the most potential sources to bout the increasing demand for electrical power. Solar and wind hybrid systems give feasible solution for standalone application, as both have complimentary nature, using diesel generators and battery energy storage system can increase the reliability and quality of overall system, this paper investigates the feasibility of a stand-alone hybrid energy system consists of PV panel with MPPT boost converter, Wind turbine, battery bank with bidirectional converter, and diesel generator in areas of unstable climate. There are many structures can be used to install hybrid system, Figure 4.1 show the purposed structure in this research.

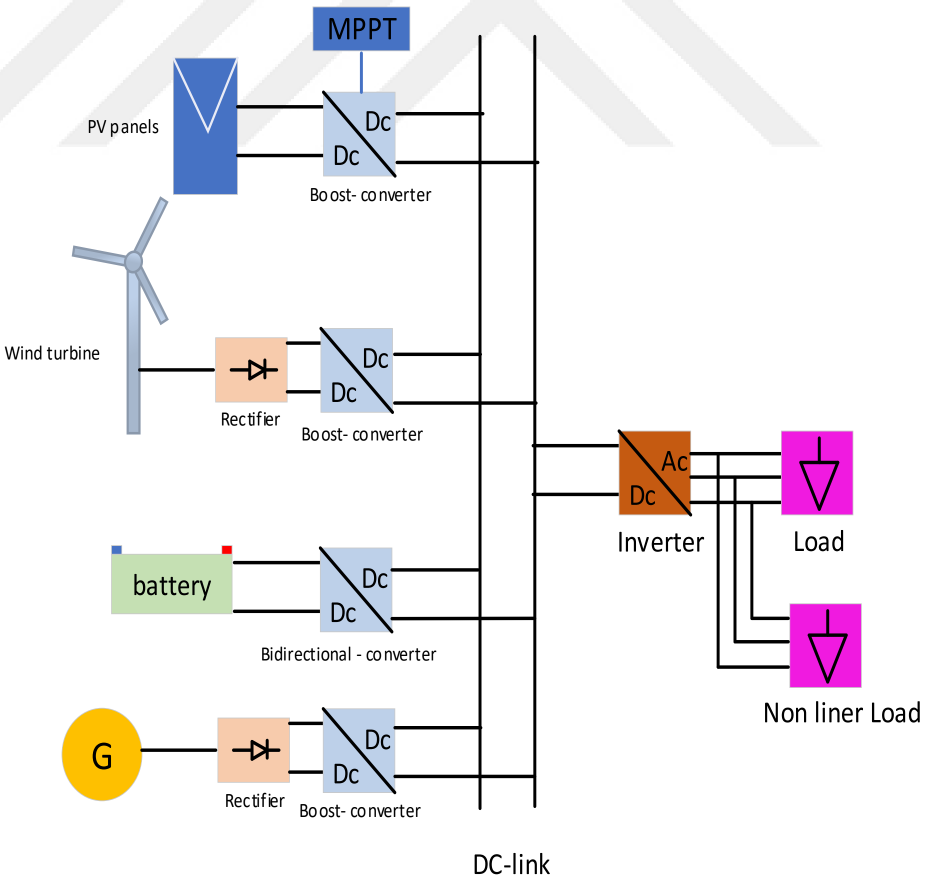

Figure 4.1 The purposed structure for hybrid system

We can see that the proposed installation has many components; in this chapter, we are going to discuss the system components.

4.2 Perturb and Observation with Boost Converter

4.2.1 Boost converter

The output voltage for boost converter is always higher that input voltage as the following Equation (4.1):

$$V_{out} = \frac{1}{1-D} V_{in} \tag{4.1}$$

Where D: Is duty cycle for the converter and the equivalent circuit is given is Figure 4.2

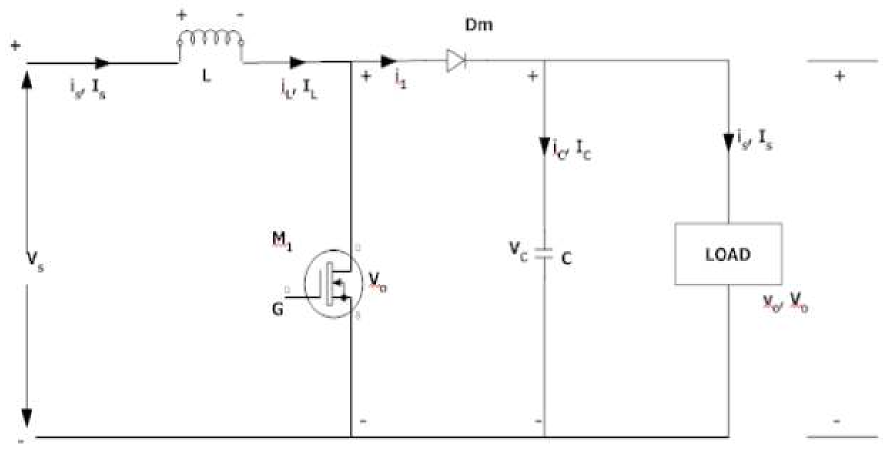

Figure 4.2 Equivalent circuit for boost converter

Figure 4.3 shows the simulation for Dc-Dc- boost converter

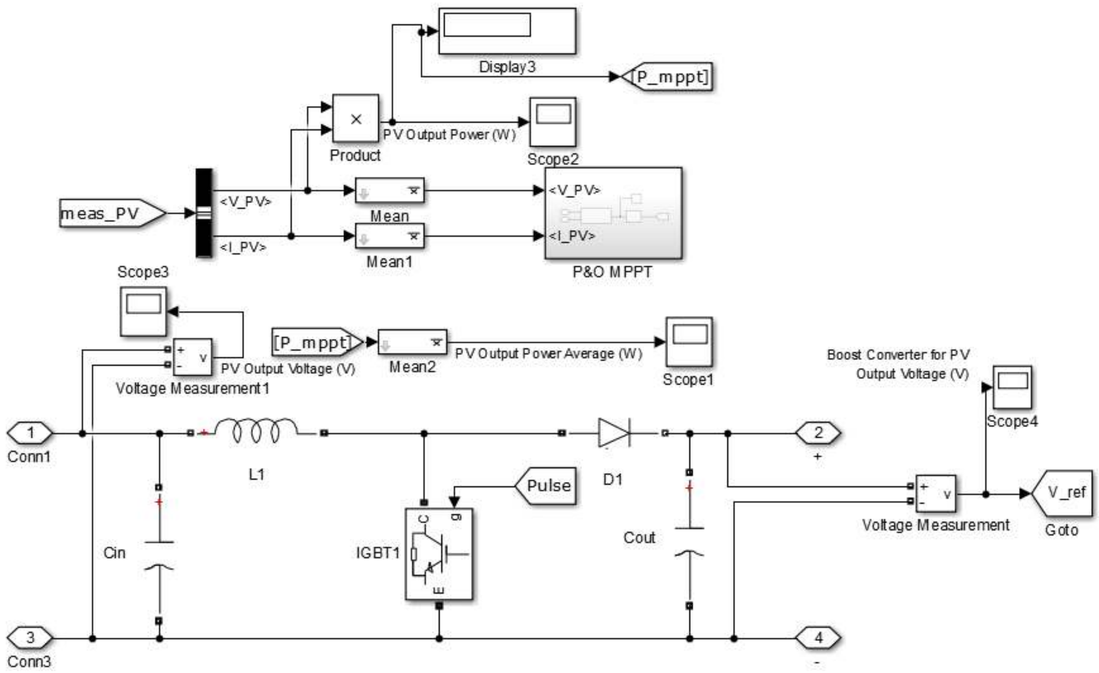

Figure 4.3 DC-DC boost converter of pv model

4.2.2 Perturb and observation p&o

P&O is the most common maximum power point tracking algorithm in solar PV systems, it measures the output parameters for PV panel (current and voltage) then calculates the power and compare it with output power in pervious time step, and then it will increase or decrease it according for the comparison. Figure 4.4 shows the flowchart for this algorithm

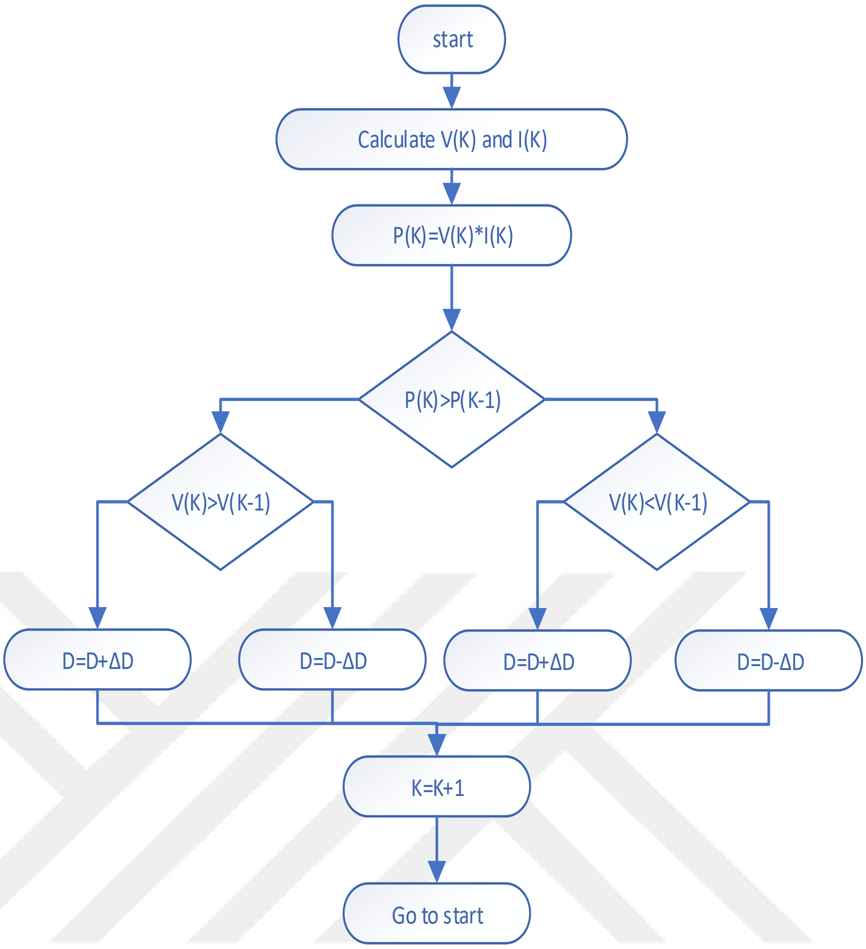

Figure 4.4 P&O algorithm

Figure 4.5 shows the simulation of P&O algorithm

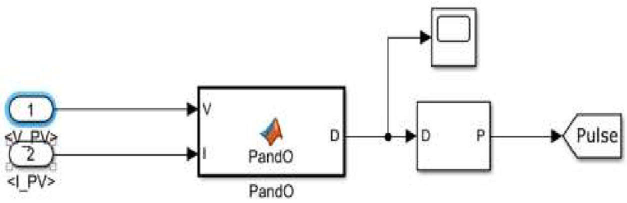

Figure 4. 5 Simulation of P&O algorithm

4.2.3 Simulation for p&o and boost converter

We are going to use two PV panels, the first use MMPT algorithm and the second is ordinary PV panel with the same load for both of them, Figure (4.6) shows the simulation for the case study (Figure 4.6).

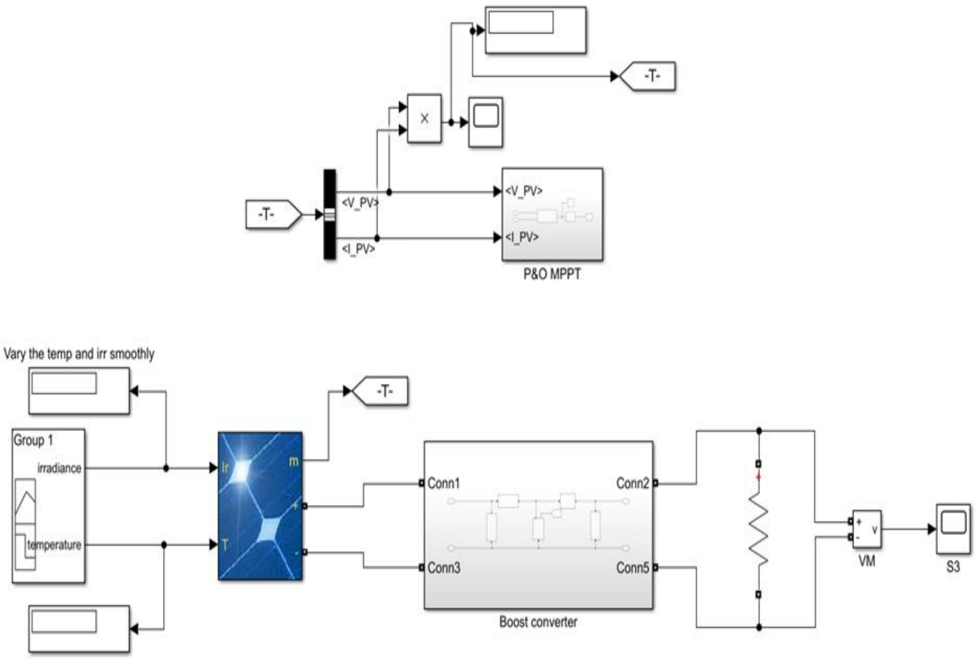

Figure 4.6 Shows the simulation of MPPT boost converter and PV panel

Simulation and testing the algorithm will be under different operating conditions (irradiance and temperature).Table 4.1 show the characteristics of the used PV panel in this study

Table 4.1 Characteristics of the PV panel

Variable	value
Maximum Power (W)	305
Open circuit voltage Voc (V)	96
Short-circuit current Isc (A)	5.96
Voltage at maximum power point Vmp (V)	54.7
Current at maximum power point Imp (A)	5.58

4.3 Wind Turbine with Boost Converter

In this model a 100kVA synchronous generator with wind turbine is used to feed load under different values of wind speed, the output voltage for the of the generator will have unstable amplitude and frequency, so we are going to use three phase rectifier and boost converter to regulate the voltage then half bridge three phase inverter with LCL filter to feed the AC load.

4.3.1 Wind turbine model

The wind turbine model consists of two main parts, the aerodynamic equations which are used to converter the wind speed into mechanical power for the generator, and the synchronous generators. Table 4.2 show the characteristics of wind turbine

Table 4.2 Wind turbine characteristics

Variable	Value
Nomainal mechanical output power (W)	100e3
Base power of the electrical generator (VA)	100e3/0.9
Base wind speed (m/s)	6
Base rotational speed (p.u of base generator speed)	0

Table 4.3 show the characteristics of synchronous generator.

Table 4.3 Synchronous generator characteristics

Variable	Value
Rated power (KVA)	100
Frequency (Hz)	60
Rotor Speed (RPM)	1800

And the full combination for this system is illustrated in Figure 4.7

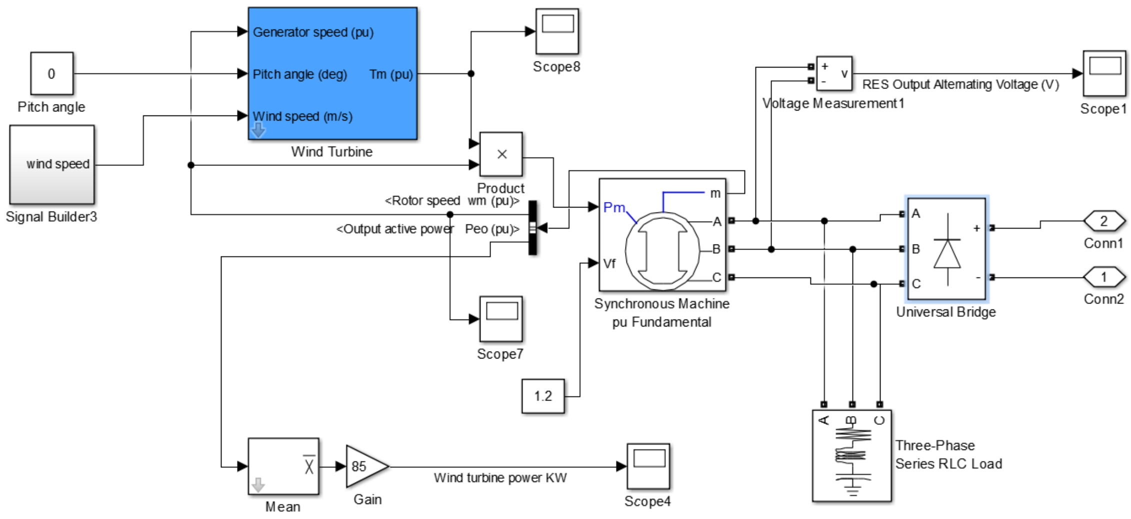

Figure 4.7 Modeling of wind turbine, generator, and rectifier

4.4 Boost Converter with PID

After rectifying the AC voltage from synchronous generator, boost converter with PID controller is used to regulate DC voltage for the desired value. PID controller gives the appropriate duty cycle for the transistor in the converter. Figure 4.8 shows the simulation for boost converter with PID.

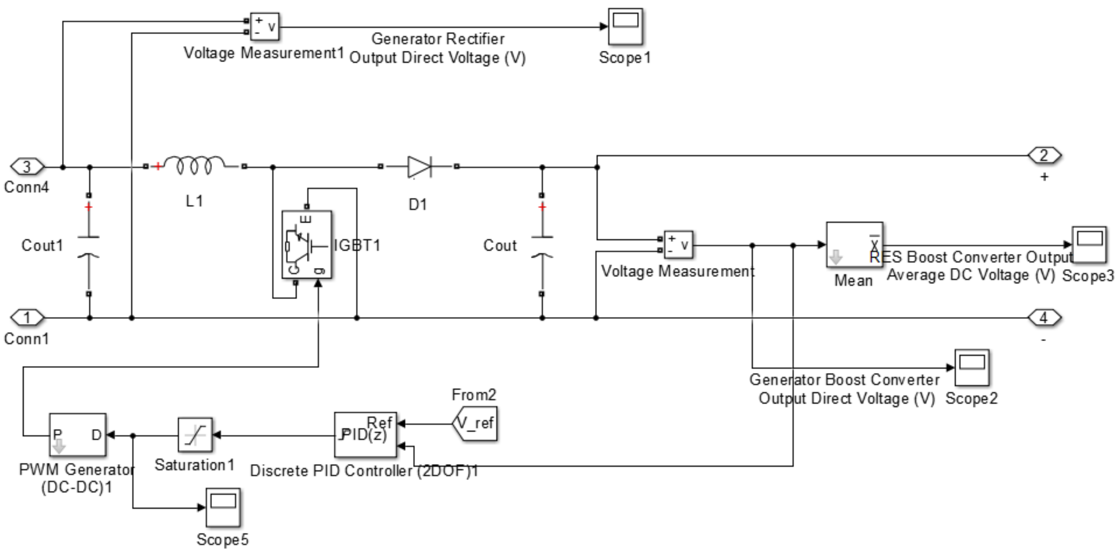

Figure 4.8 Boost converter with PID

Ziglar-Nicole method is used for tuning the PID controller, Table 4.4 shows the PID parameters.

Table 4.4 PID parameters

Proportional	Integrator	Derivative
0.0025	5	1.0907e-06

4.5 Half Bridge Three Phase Inverter

After regulating DC voltage, we use inverter to feed the load with AC voltage, the inverter operates with PWM technics for pulsing transistors, the output voltage for this inverter is full with harmonics, so we have to use passive filters to mitigate it. Total harmonics distortion THD is used to measured the amounts of harmonics in the output wave form. Figure 4.9 shows half bridge inverter in series with LCL filter.

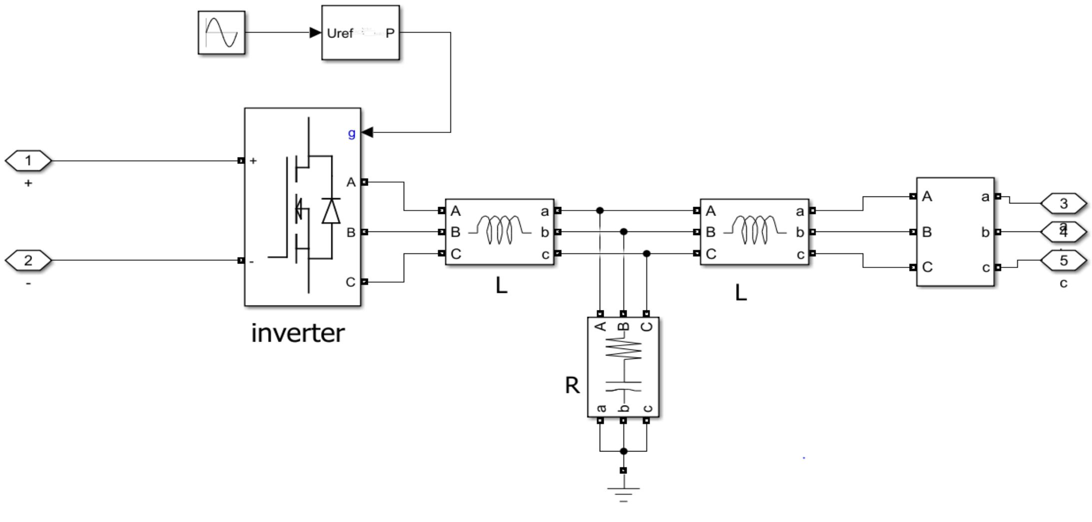

Figure 4.9 Half bridge inverter and LCL filter

In this model we are going to make sure that the electrical load is getting fed with high quality power in spite of wind turbine changes, after that we are going to connect this system with PV panels and MPPT boost converter for feeding the loads. Figure 4.10 shows the full model for the pervious components.

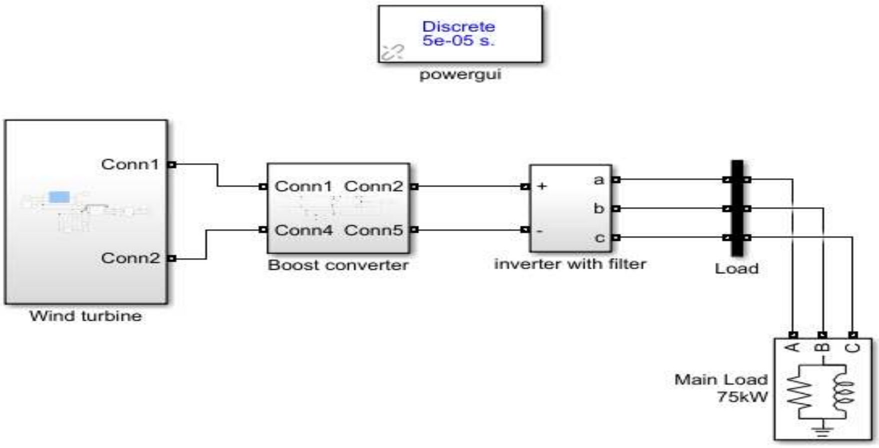

Figure 4.10 Wind turbine, boost converter, and inverter

4.6 Bidirectional Converter with Battery

As we are going to use DC link for our hybrid power systems, bidirectional converter is usually used for charging and dis charging the batteries from DC source. In this section we are going to model battery bank with bidirectional converter, in future work we will combine all the hybrid components together.

4.7 Battery

Our Dc link voltage is about 630 (380* $\sqrt{2}$ +filter losses) so we are going to use 480 Volte battery bank, the battery will be charged and discharged by the converter. We will get the maximum current for both cases from the simulation model for lithium- ion battery in MATLAB/Simulink according to the chosen voltage and current. Table 4.5 shows battery parameters.

Table 4.5 The parameters of battery

Variable	Value
Type	Lithium-Ion
Nominal voltage (V)	480
Rated capacity (Ah)	200

4.8 Bidirectional Converter

This converter has to control system and power circuit, the power circuit consist of two transistors each one work in the opposite with the other. Figure 4.11 shows the converter circuit modeling in MATALB.

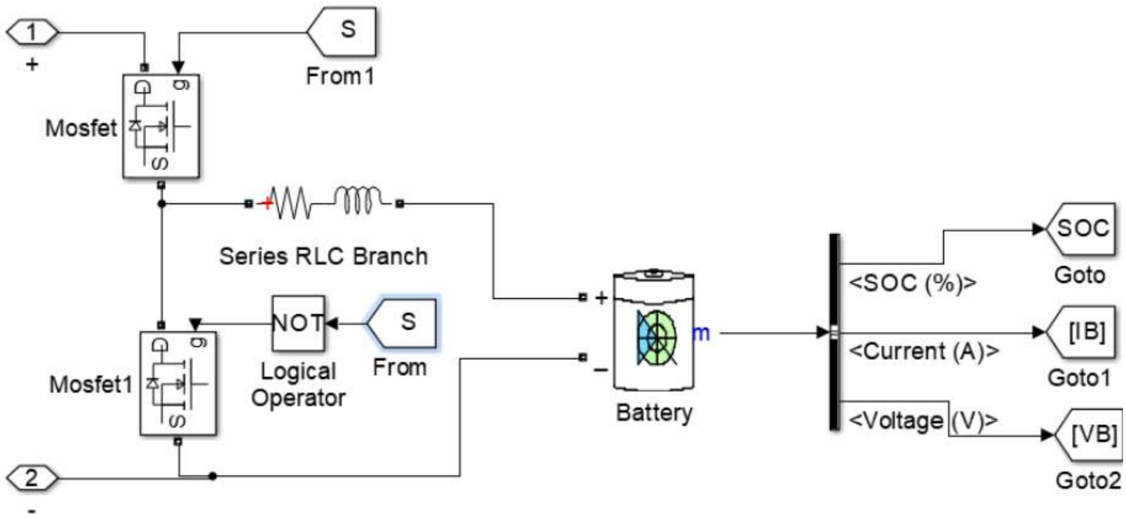

Figure 4.11 Bidirectional converter of battery

As this converter works in two states (charge and discharge) the controller should have two parts as following

Charging mode:

In this case the output voltage will be used with open circuit voltage at 90% of the battery to determine charging current, Figure 4.12 shows the modeling for this case controller.

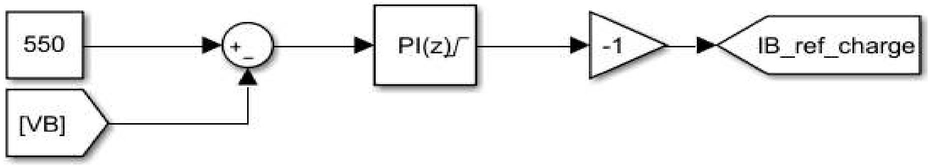

Figure 4.12 Charging controller

Where: 550 volts is obtained from battery bank characteristics from MATLAB. And using -1 gain to represent the current direction

Discharge mode:

In this case we use normal operating current as maximum value for the discharge, the reference voltage is the desired load voltage, Figure 4.13 shows the controller simulation of battery.

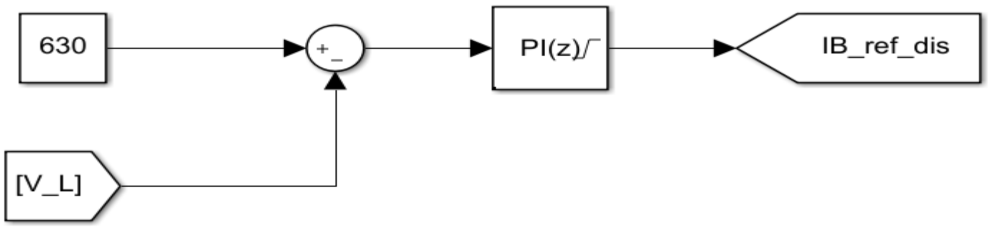

Figure 4.13 Controller simulation of battery

To determine the operating state, we are going to use switch with controller to set the operating case. Figure 4.14 shows the case and transistors controller for battery.

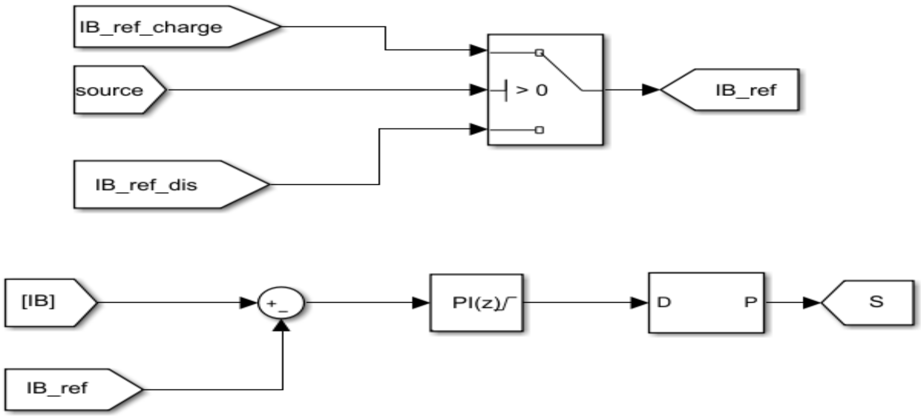

Figure 4.14 The case and transistors controller of battery

4.9 Simulation for Bidirectional Converter with Battery

Charging mode

In this case the battery will be charged to 45% and the control state on charging mode, so in this case the reference current will be negative and SOC% will increase, and load voltage should be constant, Figure 4.15 shows charge present, load and battery voltage and battery current with reference value from the PI controller.

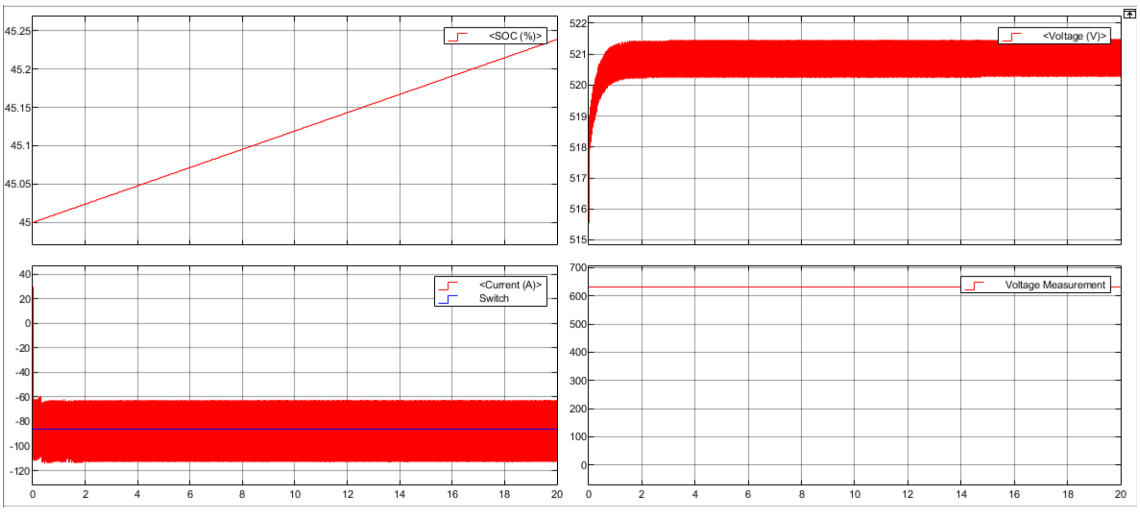

Figure 4.15 Battery parameters during charging

Charging mode

In this case the battery will be charged to 80% and the control state on charging mode, so in this case the reference current will be positive (discharging) and SOC% will decrease, and load voltage should be constant, Figure 4.16 shows charge present, load and battery voltage and battery current with reference value from the PI controller.

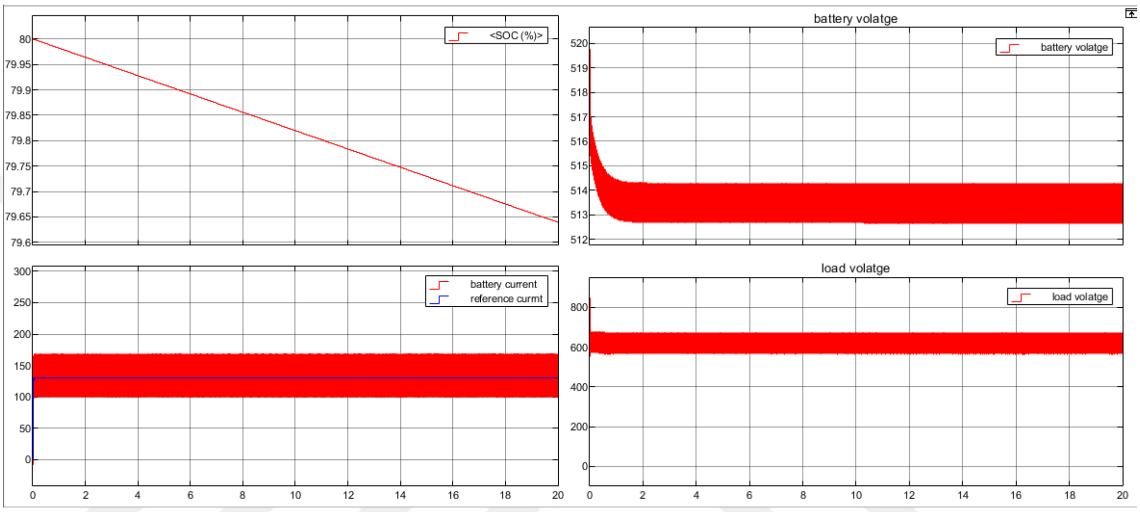

Figure 4.16 Battery parameters during discharging

We can see that the bidirectional converter is working in proper way to during charging and discharging the battery, and keep the load voltage constant in both cases.

4.10 Batteries State Controller

Batteries are used for supporting the voltage for the load, when the V-rms for the ac voltage on load side is lower than 1PU the batteries should be on discharge modem otherwise when the voltage on the load side is equal to 1 or more the batteries should be on charging mode, Figure 4.17 shows the simulation for the battery bank with state control system.

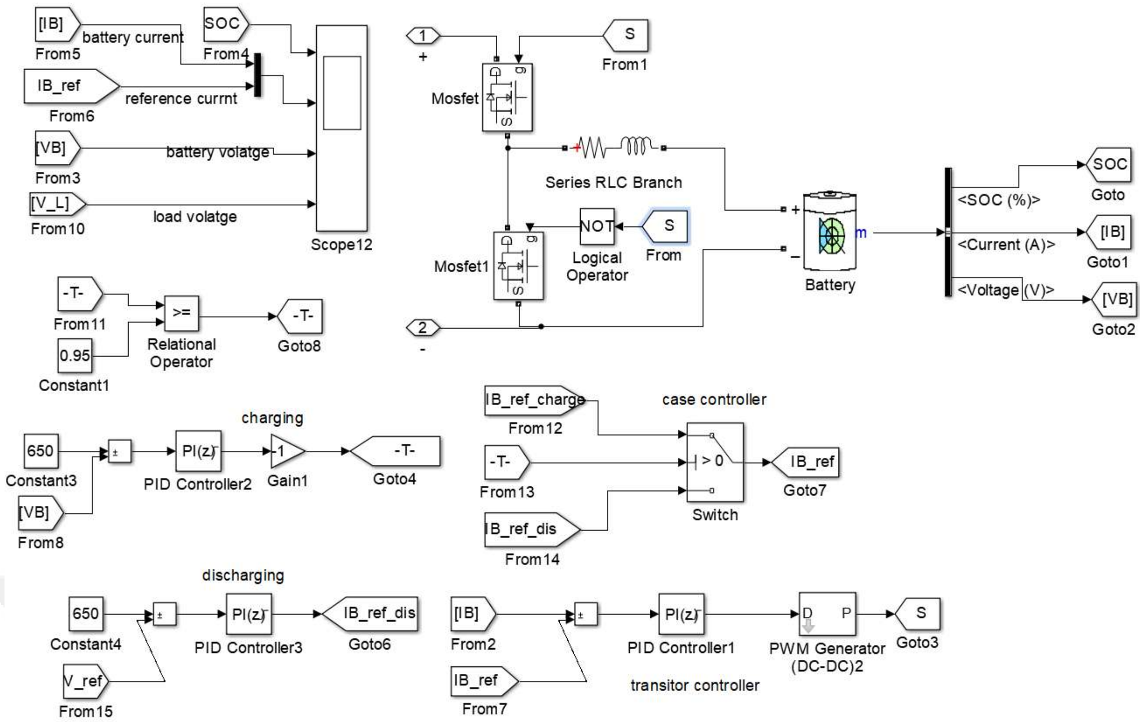

Figure 4.17 Simulation for battery bank with state control system

4.11 Diesel Generator with Operating Controller

In this part we are going to talk about generator the last power source in our study, as we know all the previous components are connect to DC ling we are going to rectify and adjust the output voltage of the generator so we can charge the batteries for the Dc link through bidirectional converter. once the generator is started it will feed the loads and charge the battery till it reaches 80% as operating algorithm, we will talk about it later.

4.11.1 Modeling the generator

Three phase voltage source with limited power (to feed the load and charge batteries) will be used as the last choice for feeding the loads, controlled breaker is used to put in or out the generator from the hybrid system according to battery state-of-charge SOC. The output voltage for this generator will be regulated by DC-Dc boost converter and connected it with DC link, as Figure 4.18 shows.

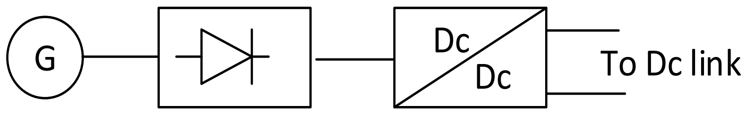

Figure 4.18 Generator connection to system diagram

Figure 4.19 shows the simulation for the components in MATLAB/Simulink

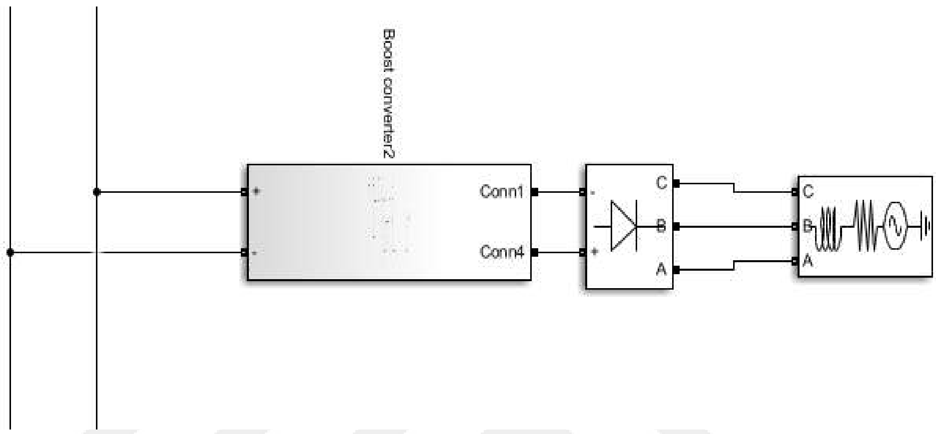

Figure 4. 19 Generator connection to system simulation

4.12 Operating Algorithm

The main challenge for the diesel generator is to decide when to turn it on or off, the proposed method depends on state of charge SOC for the battery, because when the generated power from the PV and wind turbine is not enough, the battery will discharge, and by assuming the depth of discharge for the battery is 70% the generator will be on when SOC is equal or less 40%. An important thing here is when the SOC is 31% it's not right to shut down the generator, so the suggested algorithm will start the generator on 30% SOC but won't shut down until the battery is charged to 75%. Figure 4.20 shows the algorithm for operating the generator.

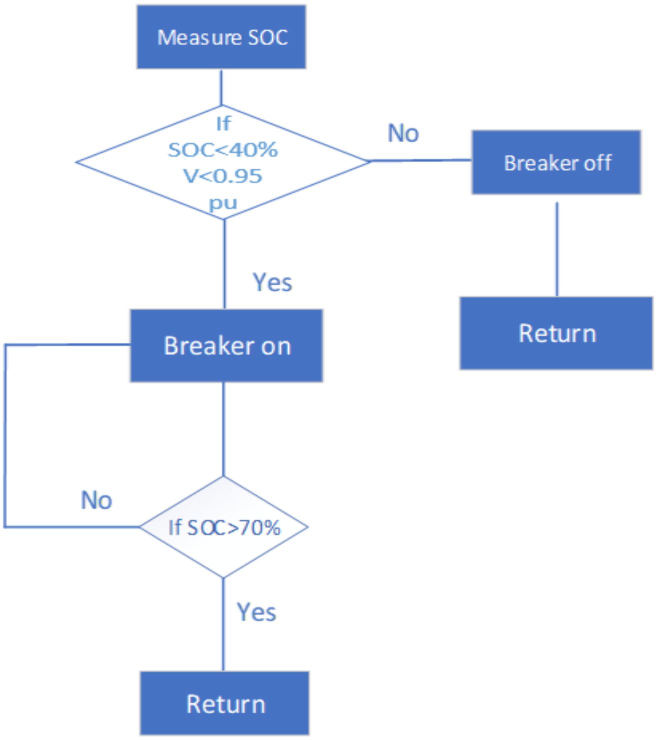

Figure 4.20 Algorithm of generator operating algorithm

Figure 4.21 show the simulation for the controller with breakers on the output of the regulation converter.

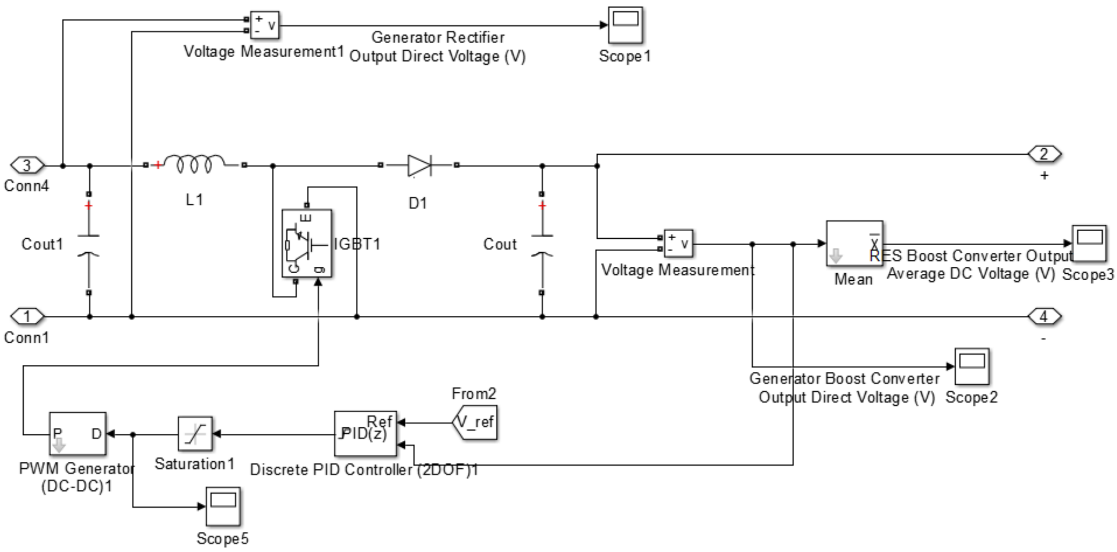

Figure 4.21 Simulation for the controller with breakers

4.13 Close Loop Standalone Inverter

The inverter is used to feed the AC load from DC link, as we know boost converter can't mitigate the amplitude of DC voltage, so we will use close loop inverter to adjust the AC voltage for load, we can use modeled wave (in PWM) to control the frequency and amplitude for the output voltage, Figure 4.22 shows the control scheme for close loop inverter

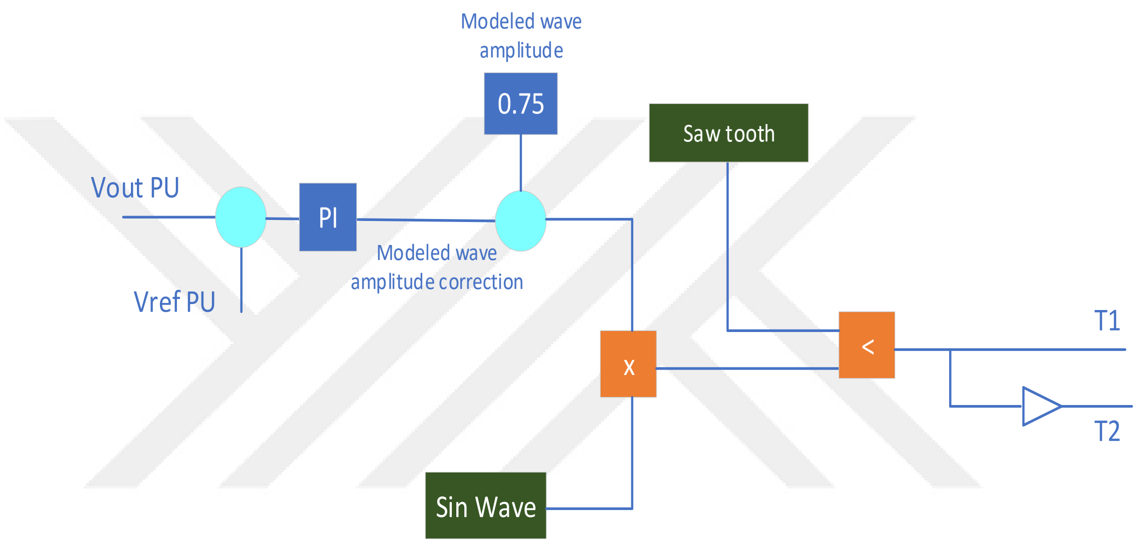

Figure 4.22 The control scheme for close loop inverter

Figure 4.23 shows the simulation for close loop standalone inverter.

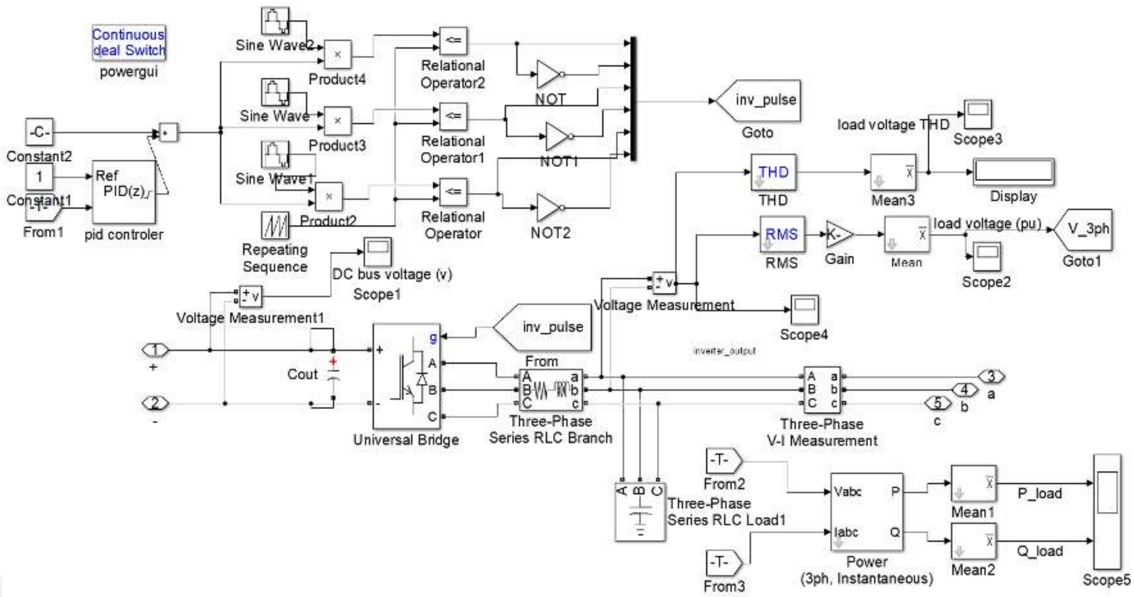

Figure 4.23 Simulation for close loop standalone inverter

In the next chapter we are going to see the full system simulation and its response under different operating conditions.

5 SIMULATION RESULTS

5.1 Introduction

In this chapter we are going to connect all the previous components to install the hybrid generating system, then we will study the system response under different environmental conditions for wind speed, temperature, and solar irradiance. The main goal for this study is to keep the electrical power for the load form the different sources with THD less than 5% and stable amplitude, and to put the generator on service on the right time, All these sources are feeding a 150kW 10kVAR load Figure 5.1 shows the simulation for the full system. PV panels capacity is 100kW and 100KVA wind turbine.

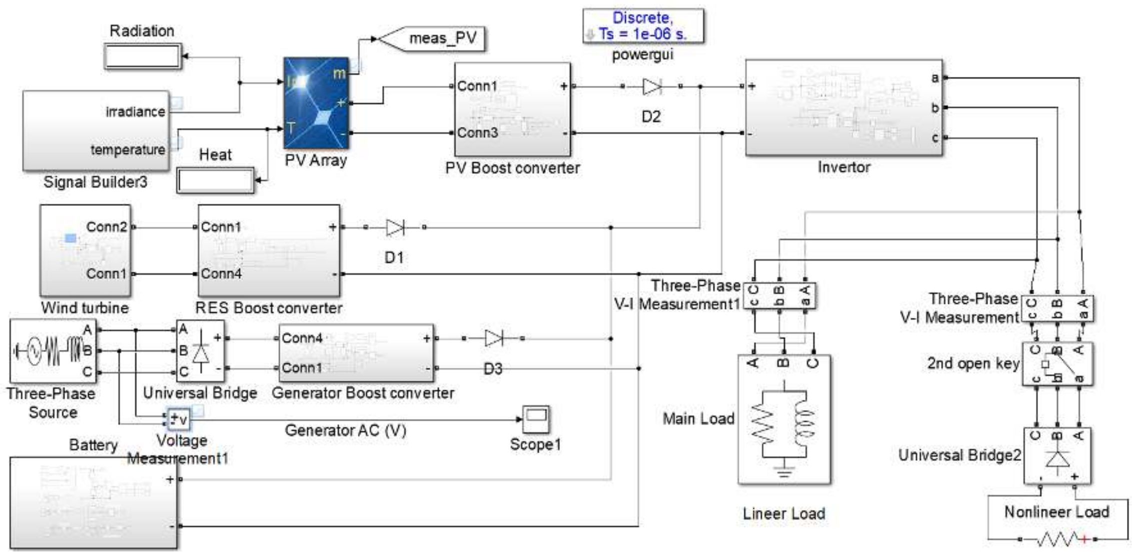

Figure 5.1 Hybrid system simulation

This work will discuss the operating for hybrid system in three main cases, the first is when the battery is discharge and there is there is flections in the generating power so the battery will support the DC link voltage. The second is the batteries aren't charged and the generated power isn't enough to feed the load so the generator will be put in service to charge the batteries and feed the load. The third is feeding a non-liner load from the hybrid system after two second. The Dc-Ac inverter will regulate load voltage amplitude, and the LC filter will illuminate the harmonics from the voltage.

5.2 Simulation Results with Liner and Non Liner Load

İn the beginning the hybird system is going to feed liner load, after while non-liner load will be added to load bus, and in the same time, in the fisrt case the batteries are charged and will help the HRES to feed the load.

The environmental status will change during simulation, which will cause changes in generated power from the wind turbine and the solar panel, Figure 5.2 shows wind speed, solar irradiance, and temperature during simulation.

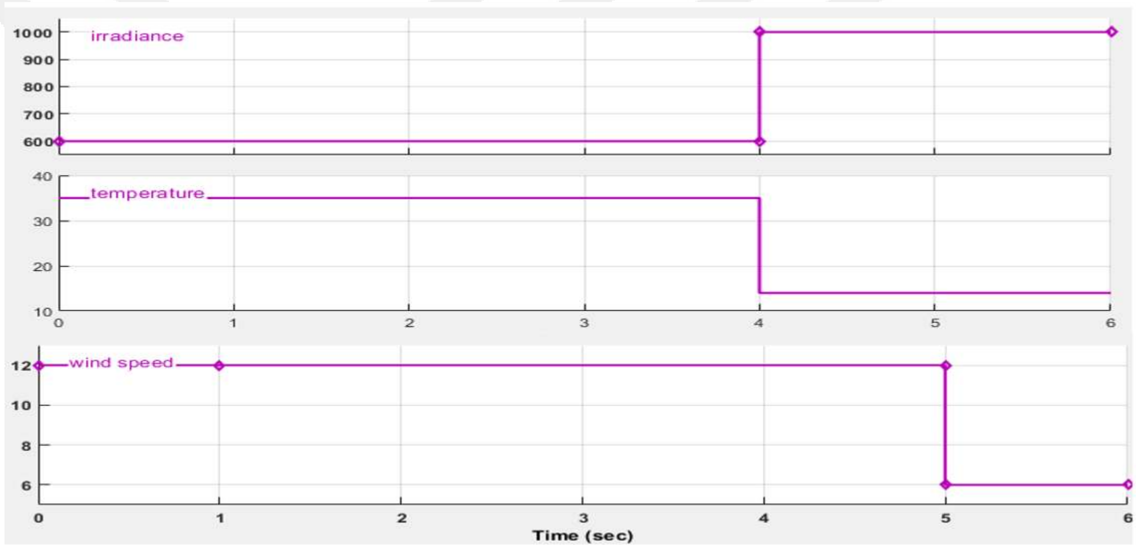

Figure 5.2 Wind speed, solar irradiance, and temperature during simulation

Figure 5.3 shows the output power for PV panel during simulation.

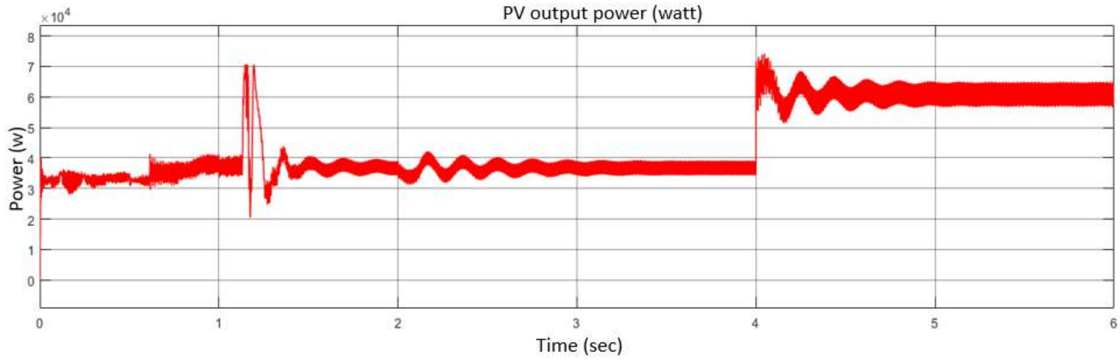

Figure 5.3 Output power for PV panel during simulation

It is clear there are changes in output power due to changes in solar irradiance and temperature,we can see the power is increse after four seconds when the irradiance increse and the temperature decrese. Figure 5.4 shows the output power for wind turbine in kw during simulation

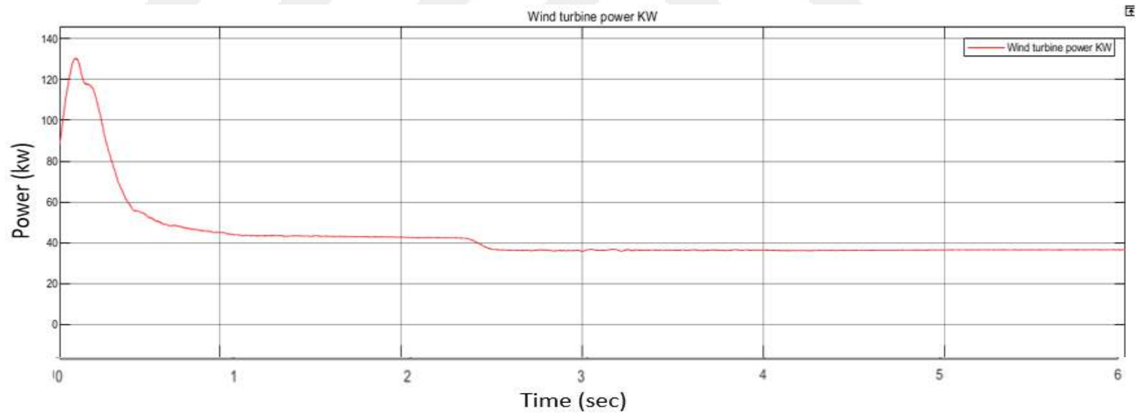

Figure 5.4 Output power for wind turbine during simulation

We can see the changes in output power due to changes in speed of wind..So it is clear in the bigninning the batteries are discharged. Figure 5.5 shows the signal of diesel generator and as we see the disesl genetrator conectting to the system after 0.6 second nearly.

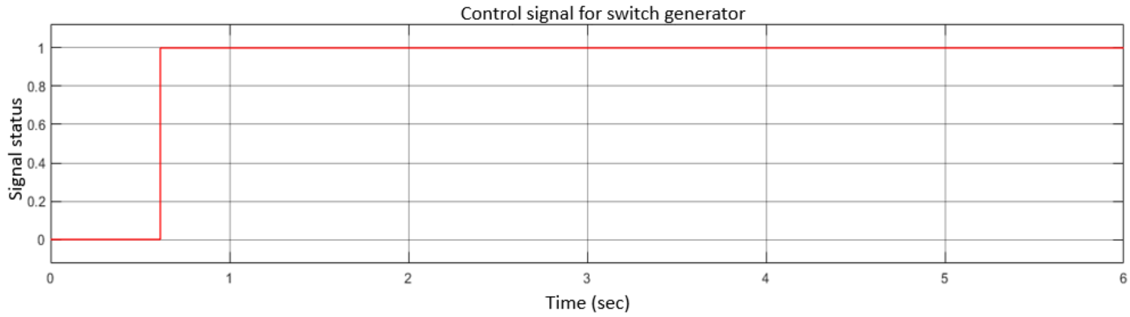

Figure 5.5 Control signal for switch generator

Figure 5.6 shows voltage waveform of generator.

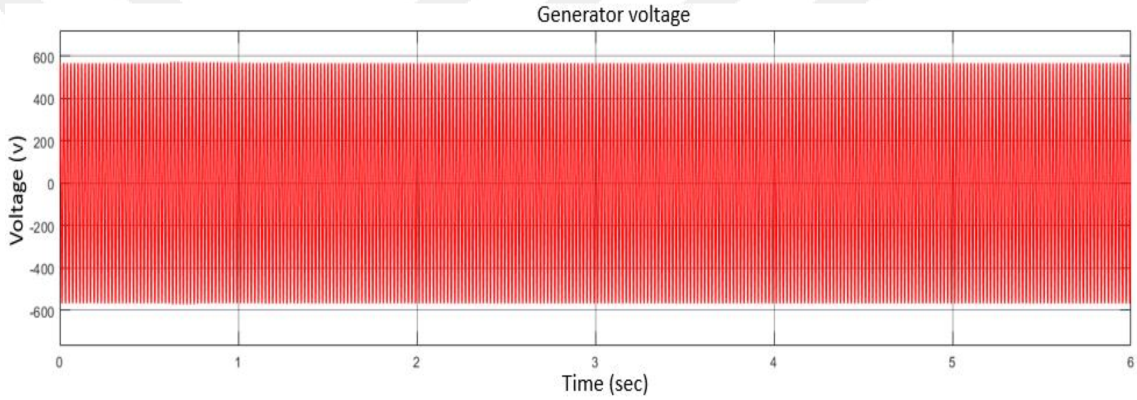

Figure 5.6 Voltage waveform of generator

Figure 5.7 shows load power during simulation, the power flow for the load is stable in spite of climate changes.

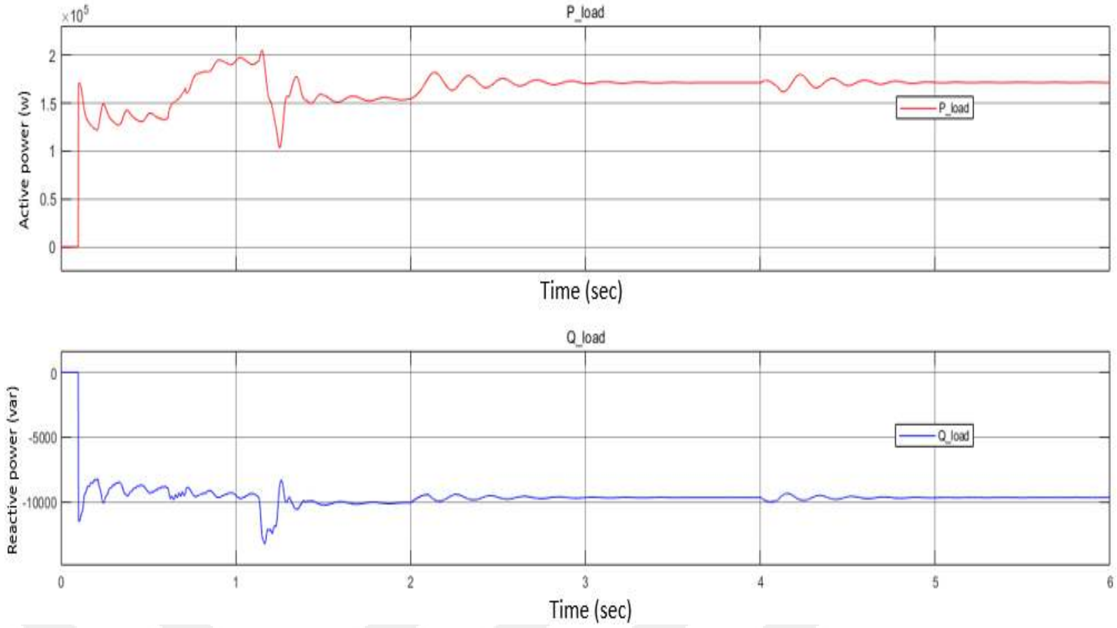

Figure 5.7 Load power during simulation

Figure 5.8 shows the load voltage amplitude in PU during simulation

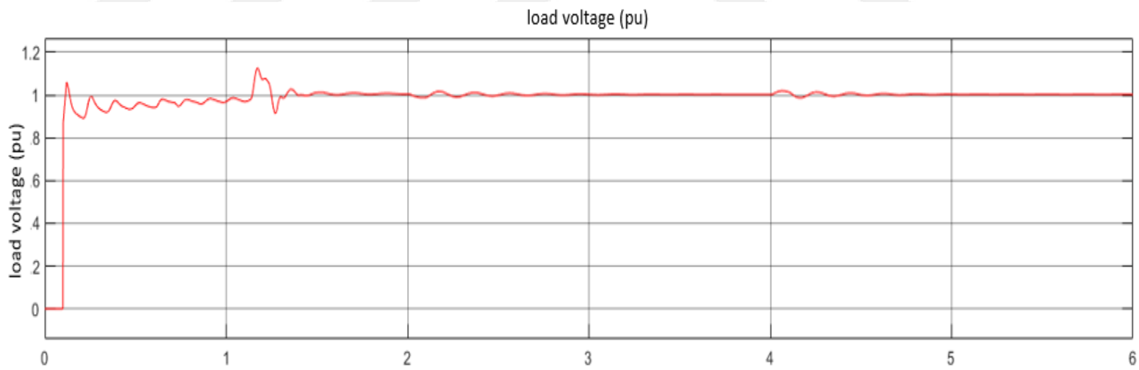

Figure 5.8 Load voltage amplitude in PU during simulation of load

Voltage amplitude in PU is between (0.95-1) in different operating conditions. Figure 5.9 shows THD in load voltage during simulation.

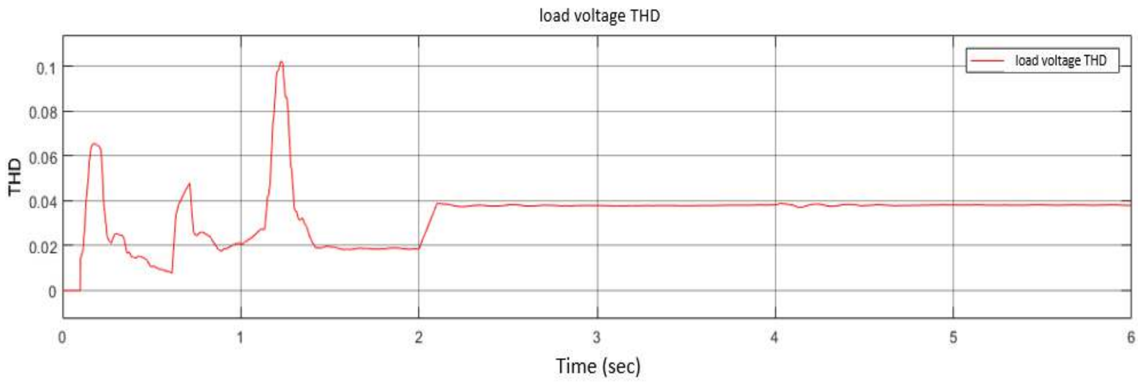

Figure 5.9 THD in load voltage during simulation

THD is less than 3% in all operating conditions, which is very low value. Figure 5.10 shows batteries SOC and Voltage of battery and load

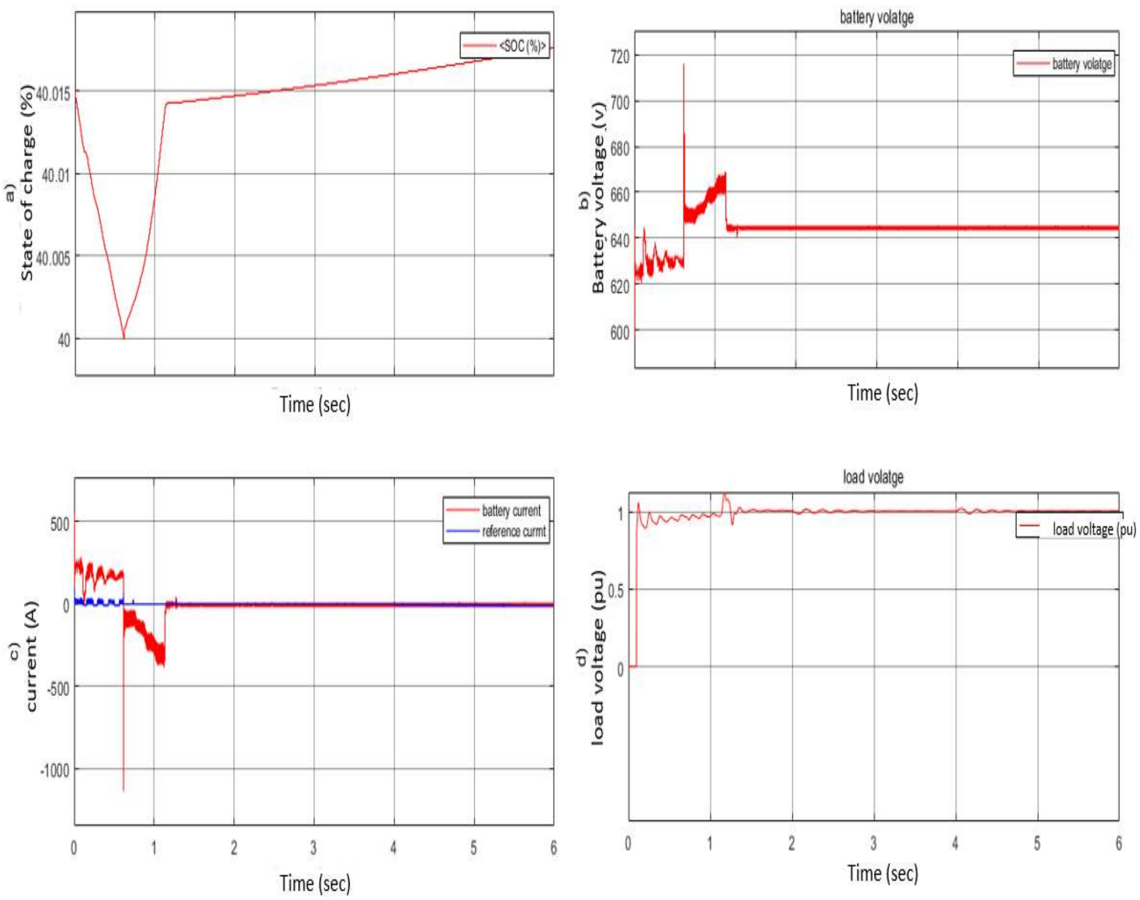

Figure 5.10 Batteries SOC and voltage battery and load

Here we should notice that the generated power is enough to feed loads and charge the batteries and on other times, the battery discharged to support the voltage. The batteries are less 40% charged. The environmental status will change during simulation, which will cause changes in generated power from the wind turbine and the solar panel; in this case the generator will feed the load and recharge the battery.

From the simulation results, we can see the following:

- Proposed system was able to feed the load with high quality voltage in spite of the environmental changes in wind speed, solar irradiance, and temperature.
- Voltage amplitude was bigger than 0.95 PU with THD < 1.8%.
- We can increase the amplitude by lowering the filtering cappelletti
- Using DC-link is very effective to connect multi sources but it has to use a large number of batteries.

5.3 Conclusions and Recommendation

In this research, we proposed an installation method for hybrid power systems consists of solar PV panels, wind turbine, diesel generator, and battery bank. The PV panels operate with maximum power point tracking boost converter, perturb and observation MPPT algorithm has been chosen and tested under different values for solar irradiance and temperature. Bidirectional converter is used to charge and discharge the battery bank, the load was connected with close loop standalone inverter which was able to regulate the voltage on the load side. A proposed controller which base on battery state of charge was used to decide to put the diesel generator on the service and recharge the batteries through Dc-link. All these components were tested under unstable climate conditions and the results was as illustrated on Table 5.1

Table 5.1 The results and comparing between linear and non linear load

Parameter	**Linear and non linear Load**	
Battery state	**Discharge**	**Charging**
Voltage amplitude	>0.95	0.97-1.03
Voltage THD	3%	1.8%
Current THD	2.05%	3.5%
DC-Linke power exchange	Effective	Effective

In the proposed installation we were able to connect many electrical source with different voltage values and nature, and regulate the voltage load with high power quality and reliability.

5.4 Future Works

- Using grid connected renewable energy system to feed loads.
- Using C2000 real-time microcontrollers device.
- Improving maximum power point tracking method or using artificial intelligence technics for MPPT.
- Using isolated DC-DC converter for its high design power and low power losses.
- Finding optimal dispatch for multi-electrical power resources
- Using load forecasting for determining the load demand which will be covered with renewable energy sources.

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