SIMULATION ON OFF GRID HYBRID PV-BATTERY SYSTEM

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DEDICATION

My Beloved Parents Specially My Mother and Father

As well as Brothers and Sister

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ABSTRACT

With the growing usage of renewable energy sources (RES), solar photovoltaic (PV) systems have seen a considerable increase in their use over the last three decades, moving from freestanding to utility-connected PV systems. Off-grid is a type of power distribution system that makes use of renewable energy and is powered by a hybrid PV battery system. In this project the simulation on off grid hybrid PV battery system have been discussed. The system is modelled and simulate in MATLAB Simulink where a PV array with MPPT is connected to the DC bus with a battery storage system of 720 kWh, the performance of the PV system results shows an efficient MPPT where the modules output power at solar irradiance and ambient temperature of 1000 and 1500 W/m2 and 25 C temperature maintained at 2750 W which shows the MPPT efficiency is 98%.

ABSTRAK

Penggunaan sumber tenaga boleh diperbaharui (RES) dilihat semakin hari semakin meningkat. Bidang sistem fotovoltaik suria (PV) telah menyaksikan pengembangan yang besar dalam penggunaannya yang luas dari sistem PV yang berdiri sendiri hingga yang berkaitan dengan utiliti selama tiga dekad terakhir. Sambungan tanpa grid adalah sejenis sistem pengagihan kuasa yang bergantung kepada tenaga yang boleh diperbaharui melalui sistem bateri PV hibrid. Dalam projek ini, simulasi sistem bateri PV hibrid tanpa sambunga grid telah dibincangkan. Sistem ini dimodelkan dan disimulasikan dalam MATLAB Simulink di mana array PV dengan MPPT disambungkan ke bus DC dengan sistem penyimpanan bateri 720 kWh. Hasil akhir sistem PV menunjukkan MPPT yang cekap di mana modul mengeluarkan tenaga pada pancaran matahari dan suhu persekitaran 1000 W/m2 dan 1500 W/m2 dengan suhu 25°C dikekalkan pada 2750 W. Ini menunjukkan kecekapan MPPT adalah 98%.

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LIST OF SMBOLS AND ABBREVIATIONS

RES	–	Renewable Energy Source
MPPT	–	Maximum Power Point Tracker
PV	–	Photovoltaic
DRES	–	Distributed Renewable Energy Source
ESS	–	Energy Storage System
PTS	–	Power Transformation System
HRES	–	Hybrid Renewable Energy Source
AC	–	Alternating Current
DC	–	Direct current
CDCS	–	Charge Discharge Control System
TEG	–	Thermoelectrically Generation
PQ	–	Power Quality
CSP	–	Concentrated Solar Power
VSC	–	Voltage Source Converter

CHAPTER 1

INTRODUCTION

1.1 Introduction

The traditional electrical system is changing into a new paradigm that entails moving away from a huge generator with a lot of power (centralised generation) and toward a distributed generation with low-power parts. In addition, the complete electrical system is out of the ordinary. In every part of the globe, there exist various configurations due to various human demands (islands, remote areas without public grid access, rural areas, and it is at this point that isolated electrical systems must be considered). The isolated system's fundamental problem is its instability. They don't have a lot of grid support, therefore even small changes in the system can have a big influence on the factors that can cause grid collapse.[1].

As a result, greater stability control and monitoring are required in this type of application. In recent years, rising energy demand has been met by increasing centralised supply in large generators, resulting in an overburdened electricity transmission grid. Thus, in order to make better use of distributed resources, it can be viewed as a collection of microgeneration and loads, referred to as a subsystem or microgrid.

Microgrids are made up of renewable and conventional generation systems, storage, and distributed loads that operate under system control and can be operated in grid connected or islanded mode. Diesel generators, microturbines, small wind turbines, and photovoltaic systems are the main power generation technologies used in remote areas today[2]. These renewable generation systems, on the other hand, can be linked (hybridised) with diesel generators to improve reliability and lower diesel costs. For example, in photovoltaic hybridization, where the photovoltaic (PV) + diesel combination is one of the most common today, with or without storage, different configurations could be considered. As a result, it is critical to understand the islanded mode installation behaviour in order to ensure reliability and supply security in the event of a grid outage.

As a result, and in light of the current hybrid system trend, it was thought interesting to focus on a microgrid consisting of photovoltaic, diesel, and storage systems. As a result, and in light of the current hybrid system trend, it was thought interesting to focus on a microgrid consisting of photovoltaic, diesel, and storage systems.

There are currently several techniques available for implementing proper voltage and frequency control during islanded operation mode. It should be noted that microgrids are controlled by electronic converters. As a result, a critical component of microgrid management is the development of proper controlling techniques in converters. There are two possible operating modes for the operation converter, depending on its purpose. On the one hand, a converter can operate as a current source in PQ control mode, controlling the active and reactive power[3]. On the other hand, a converter can work as a voltage source (Vf control), establishing the grid (voltage and frequency references).

As a result, some microgrids use the Single Master Operation as their islanded mode control technique (SMO). Only one converter operates as the installation's master under Vf control, creating voltage and frequency references, while the rest of the equipment operates under PQ control. When a microgrid is used in this manner, the associated control method is active load sharing, specifically master-slave islanded mode control (classic or with storage system). Master-slave control techniques are distinguished by accurate current/power sharing among parallel converters and good output voltage regulation. On the contrary, critical communication lines are required, which reduces the system's robustness and expandability. A variation of the previous method is master-slave control with storage. As previously stated, its goal is to eliminate the critical communications requirement for current/power distribution. This is accomplished by incorporating a converter associated with a storage system that serves as a master.

In general, the power quality concept and its requirements ensure that the voltage, current, and frequency remain within acceptable operating limits. As a result, determining the power quality supplied by each piece of equipment capable of generating the grid when the microgrid is in islanded mode has been deemed critical. Furthermore, a system's ability to generate the grid is proportional to its stability. A stable system is one that can maintain frequency and voltage within established ranges despite being subjected to disturbances[4]. As a result, the converter power quality and stability of lead-acid batteries were investigated, and a similar study was conducted with the diesel generator to compare both performances.

Hence, this project is focused on off grid system. The output of a photovoltaic (PV) system is affected by environmental factors like solar irradiance. Electricity generation is the primary goal of photovoltaic panels. The current work's goal is to examine the PV output as solar radiation changes.

1.2 Problem Statement

The concept of microgrid arose as a result of the increasing demand for dependable, flexible, and high-quality power while also being environmentally conscious. When a microgrid is islanded, whether by accident or design, it creates a slew of control issues in terms of stability, power quality, and harmonics. The penetration of a large number of intermittent Distributed Renewable Energy Sources (DRES) such as wind and solar makes controlling an islanded microgrid even more difficult.

Due to grid-side faults, frequent power outages, voltage drops, or power fluctuations are possible in remote locations such as villages, islands, and hilly areas. For such remote locations, to meet local critical load requirements during grid-side breakdowns, grid-connected renewable energy systems or micro-grid systems are desirable. Solar photovoltaic (PV) power systems are available in renewable energy systems, Energy storage systems (ESS) or hybrid PV-battery systems are more adapted to supplying uninterruptible power to local essential loads during grid-side faults[5].

Solar radiation received on the earth's surface varies constantly due to a variety of factors such as the appearance of cloud paths, the accumulation of water droplets and dust particles in a specific section of the atmosphere, changes in air density with temperature and humidity, and so on. The appearance of a cloud in a specific section of the earth's surface is the most significant factor influencing the output of the solar panel. During certain seasons of the year, the appearance and disappearance of cloud patches is so frequent that solar PV output and, consequently, inverter output connected to a grid-tied system experience large fluctuations in voltage and currents[5].

1.3 Objectives

The objective of these research are the follows:

(i) To model the hybrid PV battery components in MATLAB software.

(ii) To simulate an off-grid hybrid unit of PV battery system.

(iii) To analyse the output of PV battery system when the solar irradiance varies.

1.4 Scope of Project

The scope of study tends to look at the following:

- ✓ Model will influence PV, inverter, dc load, dc/dc convert and battery system.
- ✓ Use MATLAB software for Simulink the off-grid hybrid PV battery system.
- ✓ Analysis is on power, voltage and current output with change on PV system solar irradiance of 1000 and 1500 W/m^2.

1.5 Report Outline

This thesis is divided into the following 4 chapters namely:

Chapter 1: Introduction

The backdrop of the microgrid's solar system, as well as the concept of power quality, are discussed in this chapter. In addition, the Problem Statement is found in this chapter. This chapter does, however, include the purpose and scope of the works.

Chapter 2: Literature Review

Renewable energy challenges for the solar system's basic energy will be examined in this chapter. This includes the solar system's fundamental operation.

Chapter 3: Methodology

The purpose of methodology is to outline the strategies or methods that will be used to complete this Final Project. Discuss the project's overall scope as well as the Simulink software.

Chapter 4: Result and Discussion

The results and discussion of this project are presented in this chapter.

Chapter 5: conclusion and recommendation

This chapter summarises the project's findings and makes recommendations for the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Micro grid technology based on renewable energy and a distributed power generation system combined with a power electronic system is currently being developed as a concept for future network technologies. One of the new trends in power electronic technologies is the integration of renewable energy sources and energy storage systems. The main benefits of Off-Grid development are that it provides a good solution for supplying power in the event of an emergency or a power outage due to a power outage in the main grid. Off-grid systems include a low-voltage distribution system, as well as distributed energy resources like photovoltaic power systems and wind turbines, as well as a storage device[7].

Photovoltaic generators are currently designed to provide the most power to the grid. Due to the stochastic nature of PV power output, large scale developments of grid-connected PV systems result in significant swings in the grid's frequency, power, and voltage. PV generation, on the other hand, is sporadic and weather-dependent. Thus, the MPPT causes the PV system to provide its maximum power, and the energy storage element is required to help get stable and reliable power from the PV system for both loads and the utility grid, improving both the steady and dynamic behaviour of the entire generation system[7]. The battery can be integrated into a more stable and reliable PV generation system due to its low cost and high efficiency.

2.2 Renewable Energy Resource

Renewable energy is defined as energy derived from natural renewable resources that is both sustainable and abundant when compared to human lifespan. Solar energy, for example, can be gathered by converting solar irradiance into either heat or electricity, depending on the method utilized. Renewable resources include wind, hydropower, tide, biomass, and geothermal. Due to a variety of concerns and factors, renewable energy has enormous global potential. They emit less pollution than fossil fuels, are found almost everywhere, and may have higher total efficiency as energy harvesting and conversion technologies improve. Furthermore, global demand growth and the rise of the smart grid concept place greater emphasis on choosing those sources over traditional ones. Because solar and wind energy resources were chosen as components of the studied hybrid renewable energy system model, they will be the focus of this Section[8].

Solar and wind were chosen because they are almost everywhere on the planet, as opposed to other renewable resources such as hydropower and geothermal, which occur in some parts of the world but not others due to geographical features. Also, for off-grid system applications, portable, easy-to-transport, easy-to-install, and compact systems, such as solar photovoltaic panels and wind turbines, are preferable. In addition, wind power generation overtook hydropower as the second largest renewable energy source in 2016, with a capacity of 487 GW compared to 433 GW in 2015.

Whereas solar PV ranked third with a power capacity of 303 GW in 2016, an increase of 32.9% over solar PV capacity in 2015. Furthermore, new installed solar PV in 2016 accounts for 47% of new installed renewable energy in 2016. There are numerous other reasons to use solar and wind energy to ensure a sustainable future generation's life, such as reducing greenhouse emissions such as nitrogen oxides (NO, NO2 & N2O), Sulphur oxides (SO2 & SO3), and carbon oxides (CO & CO2) and diversifying energy sources. The average CO2 emissions from solar PV are 49.91 g, with a low estimate of 1 g and a high estimate of 218 g per kWh, while wind CO2 emissions are 34.11 g, with a low estimate of 0.4 g and a high estimate of 364.8 g per kWh.[9].

2.3 Solar Energy

The sun is the primary source of most of the world's energies. Every day, it rises to the sky, carrying a great deal of energy with it to heat and light the earth's surface. It is the only star in our solar system and the closest one to us that can provide a massive amount of energy to our planet[10]. It accounts for nearly 99.85% of the solar system's total mass. The average distance between the sun and the earth is 150 million kilometers, and it takes sunlight eight minutes and twenty seconds to reach the earth. In theory, the sun has 89,300 TW of power over the earth's surface. The Sun is powered by nuclear fusion of hydrogen atoms, and its surface temperature can reach 5,800 degrees Celsius, while its core temperature can reach 15.7 million degrees Celsius[11].

When the sun rises, the sunlight energy is either reflected or absorbed. Around 51% is absorbed by land and ocean and 16% by the atmosphere which heats up earth and makes it suitable for all living species. On the other side, 20% is reflected by clouds, 6% by the atmosphere and others[12]. Plants are the oldest solar harvester which harvests the sunlight and convert it into chemical energy in the form of sugar and produce oxygen because of a process called photosynthesis. For a long time, people looked at the sun as a great source of energy and they started thinking how to convert that energy into useful forms. One of the trivial methods started by concentrating solar power into a focal point to cook food and the first reported solar cooker was in India in 1878 by Adams. Heating water up, distilling water or purring water using solar power can be added to the list. In late 20th century, with the increase of fossil fuel price fluctuation, the rise of global warming and the need for energy security, many governments, industrial holders, scientists and 12 engineers took in consideration developing new technologies and methods to harvest solar energy resource and generate electricity as a renewable, clean, and sustainable power source.

Technologies went in different directions as some scientists and engineers focused on converting sunlight into heat and then into electricity while others prefer direct conversion. One big achievement in today’s solar energy field is the photovoltaic cell that is a semiconductor material which converts light into electricity based on a physical principle named photoelectric effect. Other semiconductor materials can convert solar heat into electricity where this process is called thermoelectrically generation (TEG)[13]. However, it is still in its early ages since some scientists work to increase their efficiency and decrease their production cost.

Both power conversion cells are solid state and direct energy converters that's account for quiet operation with no moving parts and less maintenance. On the other hand, solar thermal power takes a much longer process and requires more various parts to achieve electric power generation.

2.3.1 Sun Energy Form

Sun energy comes to earth in the form of electromagnetic radiations with different wavelengths [14]. It follows this distribution: 6.6% ultraviolet, 44.7% visible light and 48.7% infrared as shown in the Figure: 2.1.

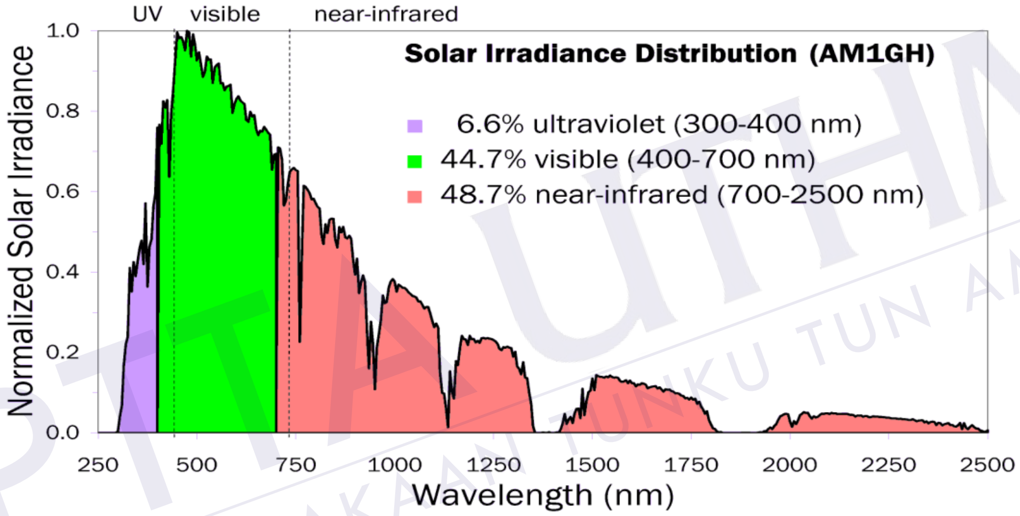

Figure: 2.1 solar energy distribution [14]

2.3.1.1 Sun Energy Harvesting Techniques

There are many techniques nowadays to harvest solar energy and convert it into useful power or electrical power specifically. For electrical power application, solar energy can be harvested using photovoltaic or solar thermal technologies and in this thesis work, photovoltaic technology is selected because such technology plays an important role in the renewable energy industry, solar type[15]. It is nominated to be the first choice for investors compared to concentrated solar power (CSP) and other technologies due to its cost competitive, low maintenance, easy installation, compatibility, noiseless and direct energy conversion. In 2016, China alone accounts for 85% of the total Solar PV installation worldwide. The Figure: 2.2 classifies different solar technologies according to their working principle.

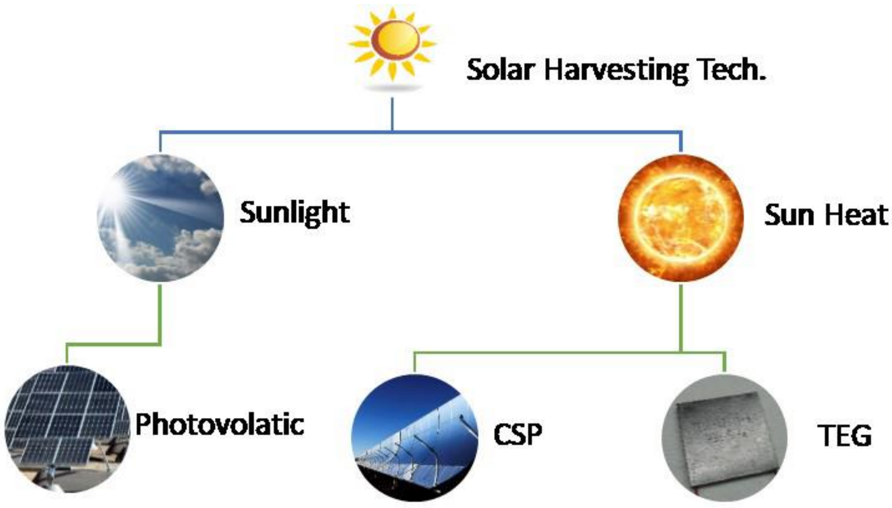

Figure: 2.2 Solar Harvesting techniques [14].

2.3.1.2 Photovoltaic

A photovoltaic cell is a semiconductor material that converts light directly to electricity based on the principle of photoelectric effect. The first photoelectric effect discovered by French physicist Edmund Becquerel in 1839 where he observed it in Selenium. Photovoltaic cells consist of two or more layers to create a permeant electric field. When light strikes the cell, electrons get excited and make their way to the conducting part of the cell to the load[16].

The solar irradiance and ambient temperature are the PV cell's inputs whereas electrical current and voltage are the cell's outputs. The commercial PV cell has very low conversion efficiency with an average around 12-17%, and where a super-mono cell has an efficiency of 21% as shown in the Figure: 2.3. Since those cells have lower efficiencies yet and they are weather dependent and have nonlinear output power, extracting the maximum possible power is an essential aim for a powerful PV system.

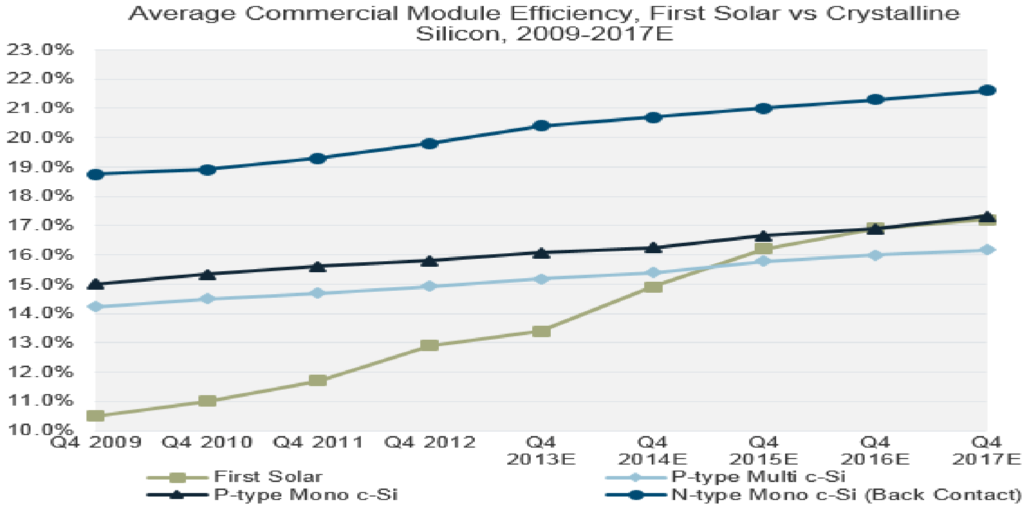

Figure: 2.3 Average Commercial PV Efficiency [16].

The Figure: 2.4 describes the characteristic of a PV current and voltage. Thus, the cell current is proportional to solar irradiance while its voltage is inversely proportional to ambient temperature.

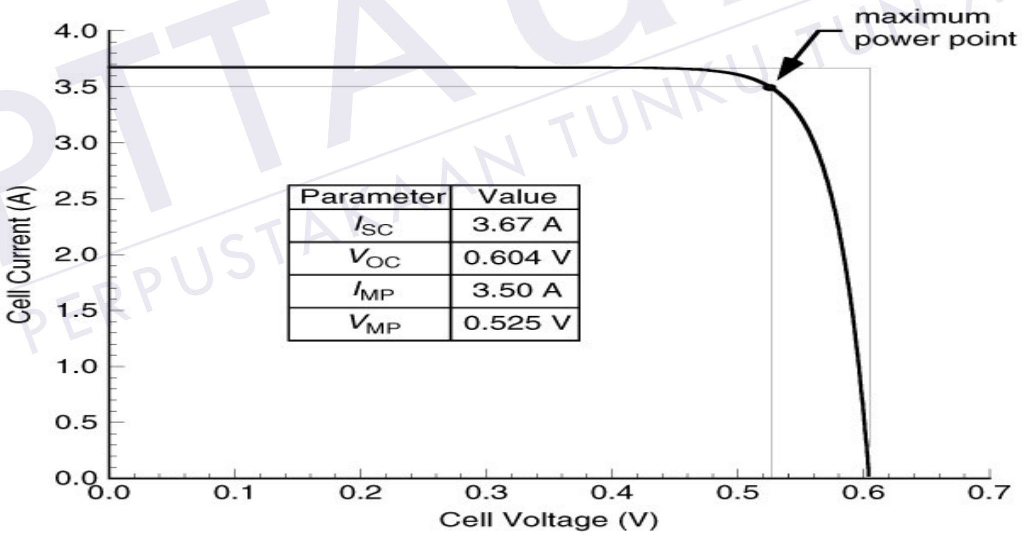

Figure: 2.4 Current-Voltage characteristic for PV cell [16].

When a PV cell is coupled to a load, it converts light of various wavelengths into current at the PN junction, resulting in electricity being produced directly from the cell. The PV cell correlates to and produces open circuit voltage and closed circuit current based on the solar irradiation and ambient temperature, which are two critical physical parameters in PV technology[16].

Extracting the maximum available power can be done by monitoring the maximum power point on the PV curve under varying operating conditions such as irradiance changes (partial shading), temperature changes and load changes. This monitoring mechanism determines the best system's voltage value and it is done using maximum power point tracker MPPT. The MPPT is the medium between PV arrays and the rest of the power system. It consists of a dc-dc power converter and a control that observe PV current and voltage and based on certain algorithm adjust the duty cycle of the dc-dc power converter. Researchers have been developed different approaches and techniques to design this algorithm. Some of those algorithms in those papers[17].

The generic Solar PV system consists of solar arrays, MPPT controller, and a DC-DC power converter as shown in the Figure: 2.5

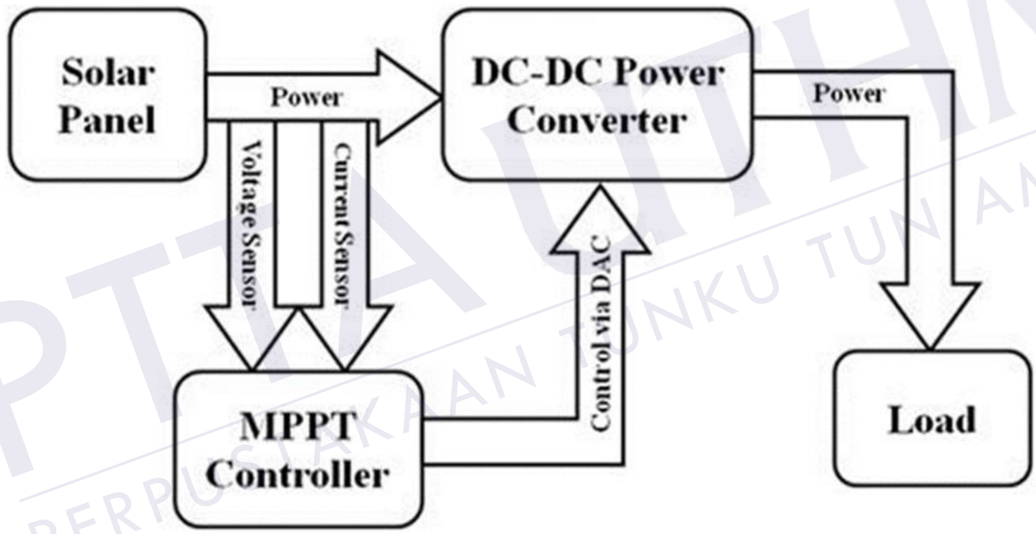

Figure: 2.5 Solar PV System Components [17].

2.4 Energy Storage System

Supply is most of the time not matching the demand and it is worse in the case of renewable power generation since power generation as a supply is nonlinear and time variant all the time because the power availability is reliant on weather conditions. As a result, power intermittency and power shaving occur and cause challenges to the system which affect power quality, reliability, and robustness. As a result, when the supply power is higher than demand, the extra power is lost unless there is a way to store and vice-versa scenario when demand is higher than supply power extra power needed to be in the system otherwise the system will shut down and cause a blackout. Therefore, having a storage system as a medium to store extra surplus power and release it when needed and smoothing output power is vital in modern renewable power system design. However, there are diverse ways of storing energy in different forms. Those forms are mechanical, electrical, chemical, thermal and electrochemical. The following table illustrates those diverse types with some examples [18]:

Table 2.1: Electrical Energy Storage Types

Mechanical	**Electrical**	**Chemical**	**Thermal**	**Electrochemical**
Pumped Hydro Compressed Air Flywheel	Double-layer Capacitor Superconducting magnetic coil	Hydrogen Fuel	Sensible heat Storage as molten salt	Secondary batteries Flow batteries

Most electrical storage system has three essential components as power transformation system (PTS), central storage and charge-discharge control system (CDCS). Different types of electrical storage systems have different power and energy ratings as shown in next Figure 2.6.

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