VOLTAGE REGULATION OF DC LINK FOR MICROGRID STABILITY AND OPERATION

NUR'AIN SYAKIRAH BINTI KASMAT AIDI

BACHELOR OF ELECTRICAL ENGINEERING (POWER SYSTEM)

UNIVERSITI MALAYSIA PAHANG

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DR. ABU ZAHARIN BIN AHMAD
ASSOCIATE PROFESSOR
FACULTY ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITI MALAYSIA PAHANG
26600 PEKAN
PAHANG DARUL MAKMUR
TEL : 09-424 6002 FAX : 09-424 6111

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ID Number : EC18053

Date : 22/06/2022

VOLTAGE REGULATION OF DC LINK FOR MICROGRID STABILITY AND OPERATION

NUR'AIN SYAKIRAH BINTI KASMAT AIDI

Thesis submitted in fulfillment of the requirements
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ABSTRAK

Penyongsang penarafan kuasa yang sama yang beroperasi pada titik set kuasa berbeza dalam mod terpencil atau bersambung grid boleh mengakibatkan kuasa edaran antara unit akibat daripada ketidakpadanan yang ketara antara penjanaan kuasa dan permintaan semasa kontinjensi rangkaian (kesalahan pada bahagian beban berat atau pulau yang tidak disengajakan). Kuasa edaran ini mungkin melebihi had voltan pautan dc, mencetuskan skema perlindungan dan mengurangkan kebolehpercayaan microgrid. Artikel ini mencadangkan pengawal selia untuk mengawal voltan pautan dc penyongsang semasa tempoh kuasa edaran. Ia terdiri daripada perintang nyahcas yang disambungkan secara bersiri dengan suis merentasi kapasitor pautan dc yang diaktifkan oleh algoritma kawalan apabila voltan pautan dc melebihi had yang telah ditetapkan. Kami menjalankan kajian kes penyongsang bersambung selari dan menilai kestabilannya menggunakan analisis isyarat kecil. Selain itu, mikrogrid realistik dibina dan diuji sebagai rangkaian voltan rendah (LV) untuk mengesahkan konsep dan tindakan kawal selia yang dibentangkan. Keputusan simulasi mengesahkan keberkesanan pengawal selia yang dicadangkan dengan kehadiran kontingensi rangkaian.

ABSTRACT

Equal power-rating at different power set points in an isolated or grid-connected mode may result in inter-unit circulating power due to a significant mismatch between power generation and demand during network contingencies. This mismatch can occur when there is a substantial imbalance between power generation and demand (faults on the heavy load side of unintentional islanding). Because of this circulating power, the dc-link voltage limit might be exceeded, which would set off the protection mechanism and make the microgrid less reliable. When circulating power is present, the article suggests using a regulator to keep the voltage on the converter dc-link under control. It comprises a discharge resistor with a switch placed across the dc-link capacitor. This switch is actuated by a control algorithm when the voltage across the dc-link exceeds an established limit. The case studies of dc-link connected in parallel input energy sources is investigated. In addition, a realistic microgrid is built and put through its paces as a low-voltage (LV) network test to confirm the concept and the regulatory actions described. The findings of the simulation provide evidence that the suggested regulator is successful even in the presence of unforeseen network conditions.

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LIST OF SYMBOLS

W	Watt
Kw	Kilowatt
Hz	Hertz
I	Inductor
F	Capacitor
R	Resistor
V	Voltage
C	Current
P	Active
Q	Reactive

LIST OF ABBREVIATIONS

LV	Low-Voltage
PCC	Point of Common Coupling
DG	Distributed Generators
MPPT	Maximum Power Point Tracking
PV	Photovoltaic
VSI	Voltage Source Inverter
ISS	International Space Station
MG	Micro Grid
DERs	Distributed Energy Resources
LB	Lithium Battery
VSGs	Virtual Synchronous Generators
RERs	Renewable Energy Resources
HCIC	Hybrid Coupled Interlinking Converter
SVC	Static VAR Compensator
BESS	Battery Energy Storage Systems
DC	Direct current
PBC	Passivity-based control
FC	Fuel Cells
SOC	State of Charge
GUI	Graphical User Interface
SSM	Simulate The Detailed Model
AC	Alternating Current
DC	Direct current

CHAPTER 1

INTRODUCTION

1.1 Microgrid

A microgrid is a self-contained energy organism that provides power to a condensed region, such as the grounds of an educational institution, a medical facility, a central business district, or a neighborhood. Microgrids can be powered by various decentralized energy sources (solar panels, wind turbines, mutual heat and power, generators). The microgrid may be connected to the larger grid or operate independently. Whenever a fault occurs, the RAS is often applied to the microgrids, and the microgrid transitions into a functional model referred to as islanded or isolated. When operating in grid-connected mode, the host grid is responsible for regulating both the frequency and the voltage.

1.1.1 Modes of operation

Microgrid Isolated operation or connection to a larger grid are the two primary modes of operation for microgrids. The latter can be further subclassified, keen on power-matched or mismatched operation using the point of common coupling (PCC) (Fig. 1.1). Mutually active (P) and reactive (Q) electricity only flow through the PCC, suggesting that power altercation between the distribution network and the microgrid occurs through the PCC link. In general, the distribution network and the microgrid are connected through the PCC.

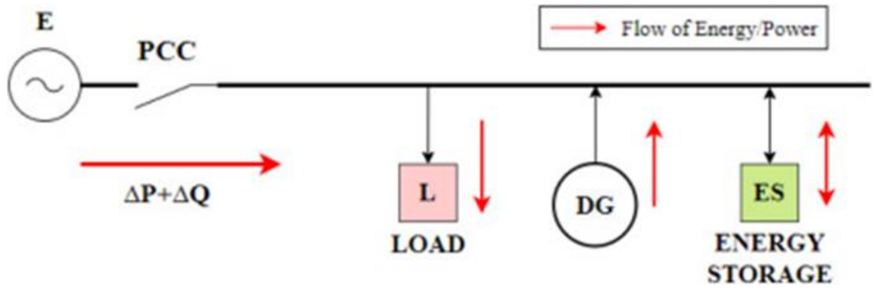


Figure 1.1 Different modes of operation via PCC link. PCC, Point of common coupling

The amount of transferred power, also known as the difference in active and reactive power, is represented by dint of the letters P and Q, correspondingly. When both P and Q are 0 (P=0 and Q=0), the power flow through the PCC is 0; this indicates that the DG output has been synchronised with the load demand, and no power is being traded (or transferred) through the PCC. This mode of operation, which is referred to as power-matched operation, is the one that saves the most money over time. On the other hand, in contrast to the case before, if either P or Q is not 0 (P0 or Q0), there is a charge flow via the PCC link, which indicates that power was traded flanked by the microgrid and the distribution network. Power-mismatched operation is the name given to this mode of operation, and it can be broken down into the following categories:

Case I : $\Delta P (or \Delta Q) < 0$

Suppose the amount of active (or reactive) power exchanged is less than zero, also known as P (or Q) 0. In that case, the amount of power generated by DGs is excessive, and the microgrid has added power into the distribution network after fulfilling the load demand.

Case II: $\Delta P (or \Delta Q) > 0$

If the amount of active (or reactive) power exchanged is greater than zero, also known as P (or Q)>0, the amount of power generated by DGs is insufficient for satisfying the load demand. As a result, additional power must be conveyed from the distribution network to the microgrid to meet the demand.

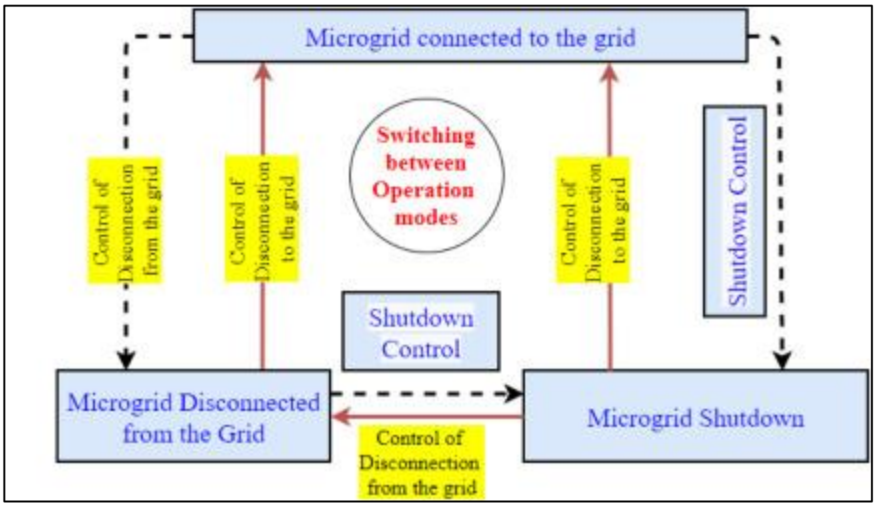


Figure 1.2 Several switching (or transfers) between different modes of operation of microgrid

1.1.2 DC microgrid

Going from an AC microgrid to a DC microgrid for islanded mode operations in rural hilly locations is a possible alternative. However, because the frequency is not present throughout the grid, DC microgrid implementation is more complicated than AC microgrid implementation.

Existing power frequency droop features, common in AC systems but cannot be directly incorporated into a DC grid, are similarly challenging to deploy. These features are common in AC systems since DC grids do not have frequency. When a DC microgrid is connected to an AC grid, the steadiness between the DC microgrid and the AC grid must be sustained by exchanging energy from the DC microgrid to the AC grid and from the AC grid to the DC microgrid. This is done to keep the DC microgrid and the AC grid in a state of dynamic equilibrium. While exchanging energy, the photovoltaic and wind generators connected to the DC microgrid make an effort to function in maximum power point tracking (MPPT) mode. This allows the maximum amount of energy to be extracted from the DC grid, which is then distributed to the local load, and any excess energy enters the AC grid.

Correspondingly, when the load on the DC microgrid increases, electricity may be drawn from the AC grid to satisfy the demand imposed by the DC load. Now, if the DC microgrid is operating in an islanded mode of operation, the local energy for the microgrid must be balanced without the assistance of the grid. Under these conditions, a method for energy storage is a prerequisite because, when surplus energy is available, the storage may be charged, the battery can be discharged, and vice versa. This allows the storage to be used both effectively and efficiently.

1.2 Project Background

Alternating current was used as an energy source in the early days of electricity. As a result of modernization, the number of consumer items has increased, as has the power demand. Recent advancements in semiconductor technology have made it feasible to generate electricity by utilising solar energy as the source of energy. Because the vast majority of electronic loads call for a DC supply, the AC current generated within the device must be converted to DC before it can give power to the load. Before recharging, the DC power from the solar panel is converted to AC and then back to DC. PV is a DC power generation system. A tremendous amount of energy is wasted by adding converters that reduce the device's output. There is an easier way to draw power directly from the source. DC Micro-grid is then used. With this method, higher performance and reliability can be achieved. When the power from the solar system is not enough, the micro-grid can get power from the batteries. Using controls for the microgrid, the region and the grid can be supplied with power that has the desired voltage, frequency, and quality. Always operating in MPPT mode should be your default setting if you want to make the most of the available renewable energy sources. There are a variety of algorithms that have been proposed for controlling the flow of electricity in grid-connected systems. In autonomous systems, it is critical to preserve the voltage profile at the expense of the maximum power point tracking (MPPT) mode. Within this undertaking, the DC connections voltage is managed using the battery charge/discharge circuit, all while making the most use possible of renewable energy sources. The developed power flow management algorithm may set the operation mode based on the availability of solar and wind energy while also considering the battery voltage and demand. This helps ensure that the load receives a consistent and stable supply of electricity. A photovoltaic solar array, a battery bank, and power converters coupled to the DC bus are the components that make up the DC microgrid being suggested.

Within the confines of the DC microgrid, there is the potential for operation in both grid-connected and islanding modes. The power distribution network utilised by the

International Space Station is an example of a direct current (DC) microgrid (ISS). This system runs in an isolated mode and uses solar arrays and batteries to regulate the flow of electricity throughout the spacecraft. The DC-DC converters perform essential control operations such as regulating and converting voltages for their respective applications. During this investigation, a controller is suggested to manage the DC-Link voltage via microgrid inverters during periods of circulating power. Class of direct current (DC) microgrids with photovoltaic (PV) solar generation and battery storage operate in islanding mode. These microgrids require efficient control algorithms to achieve currents and voltages while supporting solar PV solar energy's maximum power point tracking (MPPT). In this investigation, the DC microgrid is modelled as a nonlinear system. This modelling considers the nonlinear dynamics of the PV generators (a non-constant power source with nonlinear response characteristics), the DC/DC converters, and the constant power loads.

1.3 Problem Statement

Microgrids comprise various distributed generation (DGs), energy stored and loads. The plug-and-pay nature of microgrid could change the configuration. Thus, this is the problem statement:

1. The need for electrical power is always growing. (To strike a balance between the expanding needs, to continue expanding, and to find the most effective technique to create energy at distribution areas)

2. Equal power-rating of inverters operating with different power set-points in an islanded or grid-connected microgrid mode may lead to inter-unit circulating power caused by a large mismatch between power generation and demand during network contingencies. (microgrids have two operating modes, grid-connected and islanded grid. When it is connected to grid, the control strategy should be able to make inverters pump the set value of active and reactive powers. It has two, voltage collapse or drops, that’s why we make voltage control to minimize the voltage)

3. voltage control throughout the microgrid in the configuration is limited (in microgrid operation, not many studies on voltage control are caused by microgrid operation mode.)

4. The socializing power may violate the dc-link voltage limit (if there is an operation mode in the microgrid and any change in energy and loads. Circulation current/power in the microgrid system can violate the whole system, so we have to control for any circulation current/power properly)

1.4 Objective

The primary purpose of this research project is to investigate the feasibility of presenting a regulator for managing the DC-link voltage through a microgrid converter while the power is circulating. Thus, the objectives of this thesis as in the following,

I. To study the grid and non-grid (islanded) microgrid behavior to see the power circulating issue.

II. To propose a regulator for controlling the dc-link voltage through the microgrid's converters to compensate during the period of circulating current/power.

III. To verify and analyze the proposed work through a simulation environment using Matlab/Simulink

1.5 Scope of Project

The part titled "design research" is where you will find an in-depth explanation of the design system. In conclusion, the following is a list of the scopes of the research:

I. Design and develop the small-scale grid and islanded microgrid consisting of PV, battery energy storage and load variations.

II. Tool: Matlab/Simulink

Voltage regulator using M-file integrated to Simulink – The droop or adaptive droop control is preferred to adopt for a voltage regulator

1.6 Project Limitation

I. The operation of the microgrid is limited to short-term operation

II. The irradiation is set to a single value due to wanting to focus the viability of PV power

1.7 Thesis Organization

This thesis is organized into 5 chapter and appendices section, which are as included as follows:

Chapter 1 describes the background of the project in general, statement of the problem, the project objective, and thesis organization.

Chapter 2 are presenting the literature review, which explains the voltage regulation and the relationship between the DC link for microgrid. There is also literature review on few analyses for renewable energy field of study.

Chapter 3 provides the research methodology that is being used in this project, and the software that is being used is MATLAB/Simulink for analyzing the results.

Chapter 4 presents the results of the case study load flow and the effect of adding the converter and inverter to the microgrid system. The results will show the output of the PV and Battery to the capacitive and inductive load.

Chapter 5 summarizes the research work performed. It will draw a clear view of this study in the form of a conclusion and recommendations to understand the optimization of the case study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review or also known as narrative analysis, is a sort of research article. A research article that examines current material, such as empirical observations and theoretical and analytical techniques on a particular issue, is another way to understand a literature review. This type of article is known as a research article. Literature articles are secondary sources that do not mention any fresh or initial scientific research. This chapter shall present details about the grid and non-grid (islanded) microgrid by using boost-converter and inverter.

2.2 Voltage Regulation of DC-Microgrid with PV and Battery

When DC microgrids have the potential to offer considerable benefits over traditional AC power systems when they are used in buildings, data centers, airplanes, and other special mission applications. These microgrids integrate local DC generators and loads and are powered by DC. The following is a list of the primary benefits: If the majority of a power system's generation sources and loads are DC, then 1) the efficiency of the power system improves, necessitating the use of fewer DC/AC or AC/DC converters; 2) the reliability of the power system improves, as the decreased number of converters reduces the likelihood of failure; 3) the number of power electronic components decreases, leading to lower capital costs; and 4) the complexity of the control system decreases, leading to increased survivability in the event of disturbance Both grid-connected and island modes are possible for the deployment of a direct current (DC) microgrid. The power system on board the International Space Station (ISS), which runs in an islanded mode and uses solar arrays and batteries to generate power for the entire spacecraft, serves as a model for DC-microgrid technology. This technology was developed in response to the ISS power system. On a DC power source, the DC-DC converters are responsible for performing important control activities such as converting the voltage and regulating it. The DC-microgrid is modeled as a nonlinear system, which takes into consideration the nonlinear dynamics of the PV generators (which are a non-constant current source with a nonlinear response), the DC/DC converters, and the constant power loads. Controlling the microgrid is made more difficult by the fact that the system's dynamics are nonlinear, and its structure is non-affine. Two of the problems that are known to exist are 1) issues in voltage regulation and power-sharing and 2) the potential for the system to become unstable as a result of the continual power loads.

The microgrid is challenging to govern since its nonlinear dynamics and non-affine structure makes it a nonlinear system. The following are examples of known challenges: 1) issues in voltage management and power-sharing; and 2) the possibility for the system to become unstable as a result of the constant power loads. In most cases, these difficulties arise while attempting to operate DC microgrids that use renewable energy sources, energy storage, and nonlinear loads.

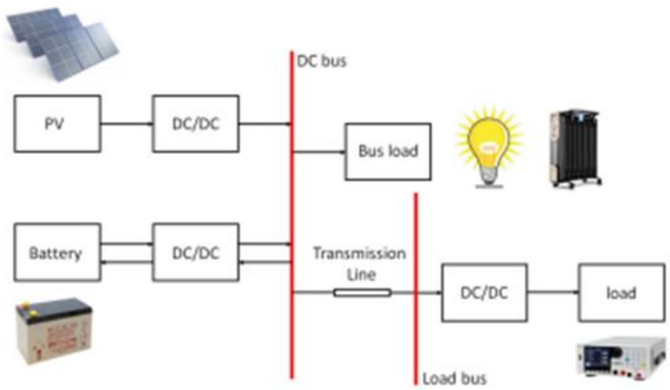


Figure 2.1 The DC-microgrid system configuration

2.2.1 DC-Microgrid and System Configuration

The DC-microgrid system that we are going to look at is depicted in figure 2.1. It is made up of a solar photovoltaic production source, a battery energy storage unit, a number of DC/DC converters, and two loads that have variable voltages. A DC/DC boost converter is utilized in the connection between the PV array and the DC bus in order to achieve maximum power output from the PV system. Over the use of a bidirectional DC/DC boost converter, the battery is brought into connection with the DC bus so that the voltage on the DC bus can be controlled. The other load is associated with the load bus over a DC/DC boost converter, in contrast to the first load, which is connected to the DC bus through a direct connection. Because of the rapid depletion of conventional energy sources as well as the continuously rising need for energy in the modern world, extensive research into the development of new power plants that are greener, more efficient, and equipped with cutting-edge technology has been carried out.

2.3 Control Strategy for Inverter-Based Microgrid

The demand for electricity is increasing all the time. Distributed generation (DG) helps to a large extent in balancing the increasing demands. Micro-grids (MC), which are primarily inverter-based, are gaining in popularity as a result of their ability to provide accommodations for various types of distributed generation (DG) and their superior power quality. An MC can be used in two modes: connected to the grid and islanded. Each mode has its own set of controls that are unique to it. It is proposed in this paper that a control strategy for inverter-based MG be implemented in order to ensure stability and proper power-sharing among inverters when operating in the islanded mode When it comes to inverter load sharing, the output impedance of an inverter can have a significant impact, according to Loan MG. The proposed control scheme makes use of a second-order general integrator in conjunction with indirect operation of the droop method in order to improve the stability and power-sharing of the MG system.

It's possible to think of an MG as a low-voltage network of distributed energy resources (DERs) and local loads in the area. Either a centralized controller or an individual controller is responsible for regulating the power output of the DERs. Moreover. The total installed capacities of MGs typically range from a few hundred kilowatts to a few megawatts. MGs are typically small-scale power supply networks. The primary objective of MG is to provide supremacy to a remote location or a community by making use of the local resources that are available in locations where there is no grid connection. Additionally, MG can be designed to supply uninterruptible power of high quality to sensitive loads in a specific location. MG is a one-of-a-kind power system due to the fact that, although it can be run in parallel with the grid, it can also be automatically switched over to islanded mode. This is the feature that distinguishes MG from other power systems when its control system detects a fault or disturbance in the power quality coming from the grid. Whenever its control system detects a fault, the MG will be able to be resynchronized with the main network as soon as the fault has been repaired or the disruption has been eliminated. The rise in the number of MCs not only eases the burden on traditional power generation plants but also contributes to reducing carbon footprints left on the planet.

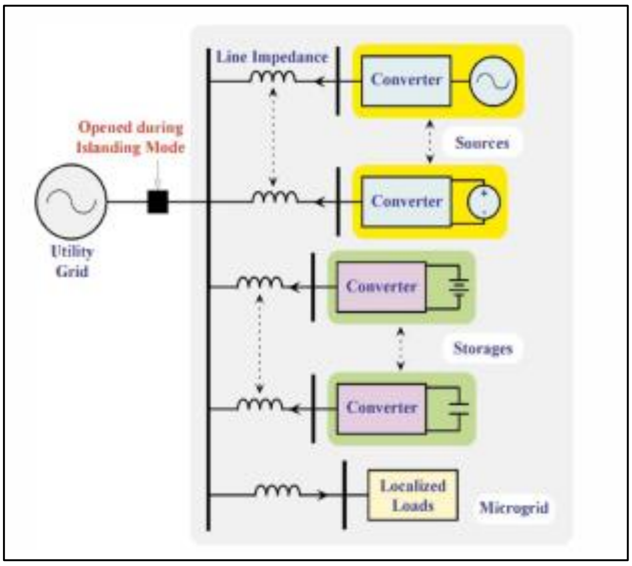


Figure 2.2 The Structure of Microgrid

The use of inverter-based MG is critical in improving the reliability of the system and allowing it to be more integrated with various types of DERs. Access to micro resources can be provided plug and play by an MG that has a proper control strategy in place (MS). Figure 2.2 depicts a block diagram of an inverter-based motor-generator. An important parameter that needs to be regulated in an MG is the active power dispatch of various micro sources. Other important parameters that need to be regulated in an MG include the voltage and frequency of the system, the power-sharing among the inverters, and the active power dispatch of various micro sources. MG can function in two different modes: the first mode keeps it connected to the grid, while the second mode disconnects it from the grid. The control strategy should be able to direct inverters to pump the predefined values of active and reactive powers when the system is linked to the grid. PQ Control and Constant Current Control are two methods that can be utilised in this scenario to accomplish this objective. In the islanded mode, in addition to the active and reactive powers, the voltage and frequency of the MG can also be regulated using the P and Q-V droop methods. This allows for a greater degree of control over the MG's output. Because of the inductive nature of high-voltage and medium-voltage grids, this droop approach is most suited for using these grids.

2.3.1 Review of Various Droop Control Techniques

2.3.1.1 Conventional droop method

The basic equation that governs the transfer of power in a conventional power system is given by:

$$P=\frac{Vs\ X\ Vr}{X}\sin\delta \ (1)$$

$$Q=\frac{Vs^2}{X}-\frac{VsVr}{X}\cos\delta \ (2)$$

Reactive power is determined by the system's voltage profile, while real power is determined by the phase angle delta or frequency, as shown in the equation. This is true in networks dominated by inductance. Wireless control strategies for inverters that are used in islanded operation now use the various droop methods derived from Equations 1 and 2.

2.4 DC-Link Voltage Stability-Based Control Strategy for Grid-Connected Hybrid AC/DC Microgrid

An integrated grid-connected hybrid DC/AC microgrid is controlled by proposing various linear compensators embedded in the inner dynamics of the power converters being utilized. This microgrid consists of a PV-based DC/DC converter, a bidirectional Lithium Battery (LB)-based DC/DC converter, and a grid-connected DC/AC converter. All DC-link voltage fluctuations are instantaneously merged with the other components of closed-loop systems by using the relevant compensators as a result of the design of the suggested control techniques for power converters. The employment of appropriate compensators accomplishes this. This is performed by determining the natural frequencies and amplitudes of transfer functions realized from the proposed control techniques-based closed-loop systems to obtain the highest level of performance possible for the compensators' parts. The performance of the suggested control strategy is evaluated through the presentation of relative simulation results generated in MATLAB/SIMULINK. To check the intended DC link voltage, the applicable regulation of DC/DC power converter output currents, the stability of the AC grid, and the correctness of the AC power-sharing system, the results of the test are employed

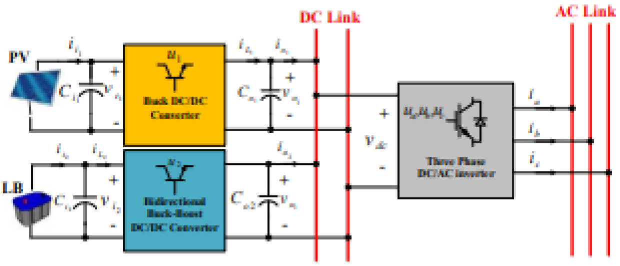


Figure 2.3 Studied AC/DC hybrid microgrid

Power electronic converters have always been an integral part of the relevant process for control system design, as well as the generation of both direct current (DC) and alternating current (AC). These power electronic converters have been researched for use in various industrial applications, including direct high-voltage current (HVDC) systems, microgrids, virtual synchronous generators (VSGs), and plenty of other uses. Both alternating current (AC) and direct current (DC) microgrids can deliver considerable benefits to a wide range of AC and DC loads when renewable energy resources (RERs) are present. These benefits include supplying the necessary power and achieving a steady DC-link voltage. This is the case when looking at the equation from both the supply and the demand side. Because of these variables, hybrid AC/DC microgrids, including all of the independent characteristics of both AC and DC microgrids, are better suited for industrial applications. AC and DC microgrids each have their own set of characteristics that make them unique.

DC Grid-connected and islanding DC/DC and AC/DC converters have historically been the most frequent components used in hybrid microgrids. For instance, in recent years, power electronic converters that have been used in an application involving a hybrid microgrid have included multi-port interlinking DC/DC converters, modular multilevel converters, and interleaved multilevel boost converters, and bidirectional solid-state transformers. Another big obstacle presents itself when hybrid microgrids are used, and that is the design of the controls. It is possible to coordinate a hybrid microgrid by employing an active and reactive power decoupling technique in conjunction with maximum power point tracking (MPPT). The active and reactive power flow in a hybrid AC/DC microgrid was controlled by using the P- and Q-P, V- droop curves developed for the hybrid-linked interlinking converter (HCIC). Several optimal power distribution algorithms and interconnected power distribution networks were discussed as potential uniform control strategies for hybrid microgrids. This was done as an alternative to using the P-Q- droop curve to control the static VAR compensator (SVC) of the HCIC.

2.4.1 Hybrid Ac/Dc Microgrid and Proposed Control Technique

Fig.2.4 The DC/AC hybrid microgrid being investigated may be seen in Fig.2.4. This microgrid uses photovoltaic cells (PV) and lithium batteries (LB) as DC power sources. The PV cells and the LB are connected to the DC grid, with the PV cells doing so through a buck DC/DC converter and the LB using a bidirectional Buck-Boost DC/DC converter. The connection between the AC and DC grids is made by a three-phase AC/DC converter, which can also function as an inverter or rectifier. In figure 2.4, the specific settings of the employed converter are shown in further detail. The AC and DC grids have their voltages adjusted to meet the demands placed on them by their respective loads. In situations in which the output power of the DC sources is higher than that of the DC loads, the bidirectional buck-boost DC/DC converter will inject additional power into the LB in the opposite direction.

2.5 Hybrid AC/DC microgrid test system simulation: grid-connected mode

Renewable The term "renewable energy systems" (RES) refers to a potentially more environmentally friendly technology that can satisfy the ever-increasing electrical needs of both connected and unconnected societies. The scientific community's interest in MGs has increased in recent years, and they also represent a potentially helpful answer for developing future conventional energy systems. MGs are currently being investigated as a feasible technological option for integrating variable renewable energy systems into existing grids. MGs not only enable a dependable and clean connection of distributed generation to the main grid, but they also give a high level of reliability in their capacity to function despite the presence of natural phenomena and active distribution grids. Because of this, fewer energy losses during transmission and distribution and shorter construction and investment times. In addition, the capacity of MGs to function despite the presence of active Distribution Grids provides a high level of reliability. An MG is a low-voltage distribution power system capable of supplying load demand and to which remote modular generating systems, such as distributed generators, intermediate storage units, and renewable energy sources, are coupled. An MG also can satisfy load demand. The utility grid can categorize this power system as either a regulated load or a generator. Even though MG formations might be completely DC, AC, or a combination of the two technologies, most research efforts are concentrated on AC MG. This is because it is compatible with the Main Grid and may work in conjunction with it. It is common knowledge that each has unique benefits, which is why the HMG benchmark is an essential part of this inquiry.

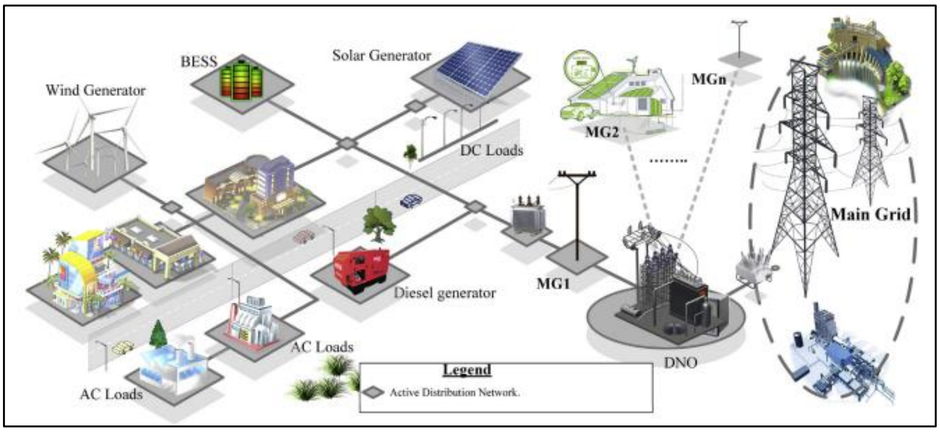


Figure 2.4 Studied AC/DC hybrid microgrid

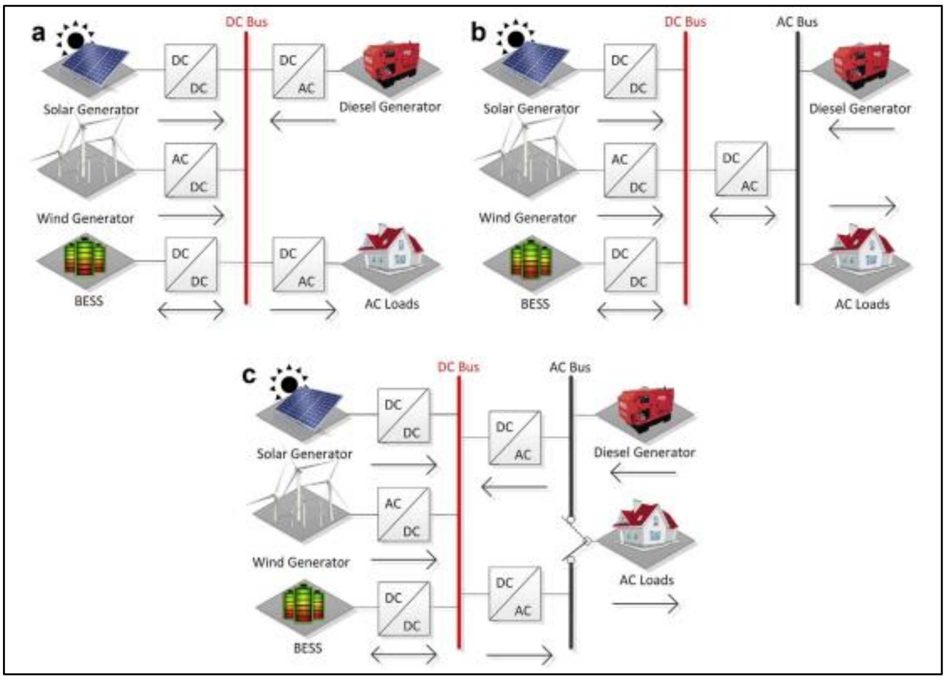


Figure 2.5 AC/DC MG configurations.

2.5.1 Electric microgrids

Even on a smaller scale, MGs are one of the most exciting alternatives researchers might consider. MGs can boost power flow in distribution grids through DG connectivity, renewable energy sources (RES), battery energy storage systems (BESS), and load management. Additionally, MGs can reduce the amount of electricity lost in transmission lines. Several reviews can be found in the published research that point readers to various control tactics. These control strategies include test beds, optimization methodologies, and available software tools. Even though MGs are thought to be relatively modest, the technological complexity involved in modeling and simulating them is significantly higher than that of the traditional energy system. As a result, models that provide dynamic analysis are essential in ensuring that future MGs will operate reliably.

2.5.2 Microgrid architectures

Figure 2.4 presents the many systems and subsystems that make up MGs. These systems and subsystems include distributed generation, energy storage, as well as a variety of different sorts of loads. The MGs have the capability of operating in three distinct modes: parallel with the Main Grid with no power exchange; isolated mode with power sources that are independent of the Main Grid; and interconnected mode with the set points of the Main Grid assumed.

AC/DC MGs are commonly implemented in series, switched, parallel, or some mix of these three configurations, as shown in Figure 2.6. In the MG series architecture (Fig. 2.5a), a DC bus connects all of the generation systems and loads via their respective converters. This bus is part of the MG series. The generation systems and loads in the parallel design (Fig. 2.5b) are directly connected through an AC bus. Inverters or bidirectional voltage source converters (VSC) connect the DC devices to the AC bus. Alternatively, a DC bus coupled to the AC bus via an inverter can also be used.

Last but not least, in the switched design (Fig. 2.5c), the load may be supplied by a DG source or the Distribution Grid (but never by both at the same time), and two inverters connect the DC and AC MGs. This configuration is the most efficient. In AC, the most frequent setup to use is the MG. Despite this, DC MGs have recently garnered a lot of interest due to the benefits they offer, such as the absence of reactive power and harmonics, among other things. In addition, there is no requirement to synchronize DC generation because it has low power losses, and there are no modifications to the DC bus after a blackout. Despite all of these positive aspects, there are a few negative aspects as well, the most significant of which is the absence of zero-crossing points and the increased complexity of the protective systems at high voltage levels.

2.6 Voltage Regulation of an Isolated DC Microgrid with a Constant Power Load

In addition to the conventional electrical power system, direct current (DC) microgrids (MGs) are becoming an increasingly popular alternative. Additionally, MGs are deployed as standalone systems in various applications, including airplanes and ships. Determining the amount of power each source must deliver is often the starting point for controlling an MG.

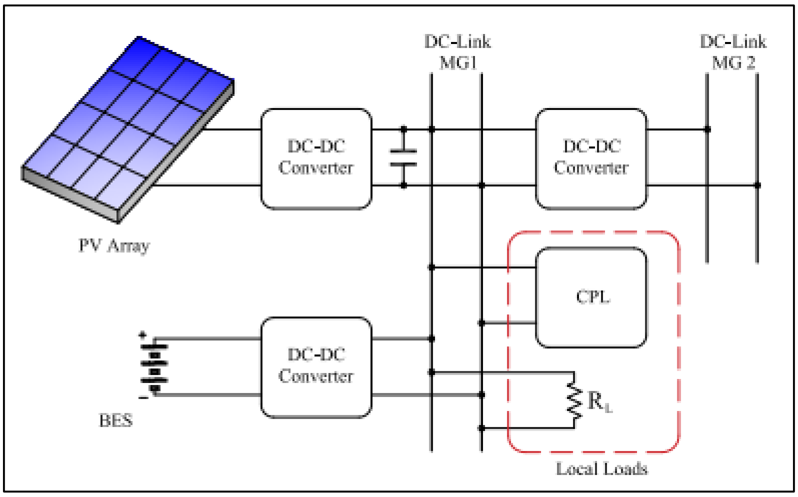


Figure 2.6 AC/DC MG configurations.

On the DC link, specific loads might generate a negative impedance effect, which can cause the system to become unstable and cause the regulator on the feeder system to stop working correctly. Another method for exercising control over power converters is passivity-based control, or PBC for short. The IDA-most PBC's impressive qualities are the consistency of its results and the ease with which it may be used to tailor the model's parameters.

2.7 Control strategy for distributed integration of photovoltaic and energy storage systems in DC micro-grids

The use of photovoltaic (PV) systems, fuel cells (FC), and battery energy storage systems are examples of DC output type sources that have seen a significant increase in interest in DC microgrids as a means of connecting more efficiently with DC output type sources (BESS). In addition, if DC powers the loads in the system, the conversion losses between the sources and the loads are lower than in a microgrid that operates on AC. In this study, we offer various operation and control solutions for integrating PV and BESS in a DC microgrid. The control that has been suggested makes it possible to make the most use of renewable energy in any of the modes in which the micro-operating grid can operate, whether it be grid-connected, islanded, or transitioning between these two modes, all while taking into account DC voltage control and DC-load supply. When the system is linked to the grid and functioning normally, the AC grid converter will adjust the active power necessary to maintain a steady DC voltage. It has been proposed to carry out system operation while islanding circumstances are present by utilising a coordinated strategy for the BESS, PV, and load management. This technique will consider the charge state of the batteries and include load shedding (SoC). The control methods that have been suggested ensure a smooth transition for the PV converter control between maximum power point tracking (MPPT) and voltage control modes, as well as for the battery converter between charging and discharging, and for the grid side converter between rectification and inversion, for a variety of grid operation modes. The voltage level on the DC bus is measured and used as an information carrier to discriminate between modes and decide when to switch modes. The robust operation performance of the proposed control system is validated and demonstrated by simulations in MATLAB/SIMULINK. These simulations are run under a variety of different operating situations.

2.7.1 System configuration and operation

2.7.1.1 DC micro-grid structure and circuit configuration

The layout of the explored DC microgrid can be seen in Figure 11. The system comprises a photovoltaic source connected via a DC/DC boost converter and an energy storage battery connected via a bi-directional buck-boost DC/DC converter. In islanding mode, the BESS is used to balance the power difference between the power supply from the PV system and the power demand from the load. Connecting the DC bus to the AC primary grid also requires using a bi-directional DC/AC converter that goes by the name GS-VSC. This allows for power flow in both directions. Since PV and BESS are located in different parts of the system, a decentralized control strategy based on MDBS is being investigated for coordinating PV and BESS within the system. The PV system is the primary source of power generation for the DC microgrid, and it is controlled to operate at the maximum power point tracking setting (MPPT). The battery satisfies the requirement of the sensitive load to maintain a constant power supply if there are fluctuations in the primary grid or while the system is operating in islanding mode.

2.7.1.2 Grid operating modes

Both grid-connected and islanding states should be possible for a DC microgrid to operate in.

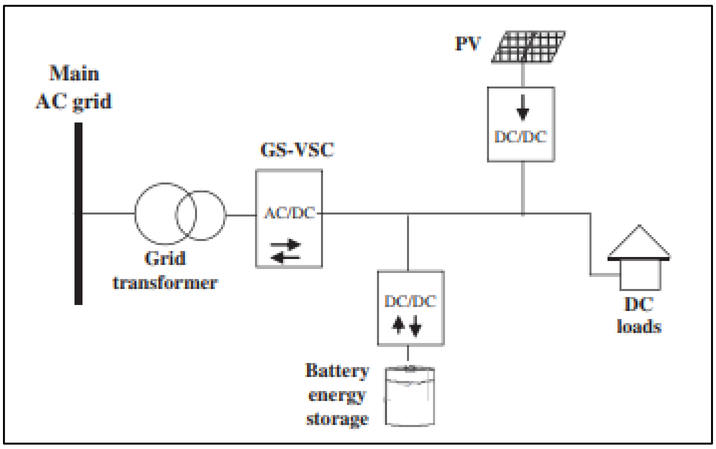


Figure 2.7 The layout of the studied DC micro-grid for the integration of PV and BESS.

Mode	Micro-grid state	PV state	BESS state	GS-VSC
I	Grid connected	MPPT	Charging/off	Inverting mode
II	Grid connected	MPPT	Charging/off	Rectifying mode
III	Islanding	MPPT	Discharging/off	Disconnected
IV	Islanding	MPPT	Charging/off	Disconnected
V	Islanding	Off-MPPT	Off	Disconnected
VI	Islanding	MPPT	Limited	Disconnected

Figure 2.7 DC micro-grid operating modes

The DC control and management system, as well as the operating modes, should be responsible for managing the DC bus voltage. Several modes of operation for the DC microgrid are being examined, with a summary of these modes being presented in figure 2.8. The DC microgrid has been successfully linked to the grid and is now functioning in Mode I with a light load. While the PV runs in MPPT and BESS modes, either charging or not charging, the GS-VSC controls the voltage on the DC bus, and any excess power generated by the PV is sent to the primary grid. Operating Mode II is typically activated when there is a significant load. The statuses of the PV and BESS are the same as in Mode I; however, the GS-VSC is the one supplying the insufficient power. Modes III and IV correspond to the situation in which the microgrid is islanding. In these modes, the PV operates in MPPT, and the microgrid's battery energy storage system (BESS) is discharging and charging to maintain a balanced supply of electricity. In each of these modes, the voltage regulation is the storage system's responsibility. When the BESS has been fully charged in the isolated microgrid, and the amount of electricity that is needed is over the maximum amount of power that the PV system can generate, the system is operating in Mode V. In this scenario, the PV should be able to manage the output power and maintain a constant DC voltage even when the maximum power point tracking mode is not active. This will prevent the battery from being overcharged. The microgrid is also in an islanding condition when Mode VI is active, and the necessary power is more than the maximum power that can be provided by the PV and BESS combined. As a direct consequence of this, load shedding is essential to preserve the system's integrity.

2.8 Control Strategies of a DC Microgrid for Grid Connected and Islanded Operations

2.8.1 An algorithm for generation scheduling and control of the DGs

In this paper, we propose an algorithm for the coordinated control of distributed generators in a direct current microgrid (DCMG) in islanding and grid operation. The DCMG that has been proposed connects several non-conventional energy sources, storage systems, the DC grid, as well as three-phase and single-phase AC loads. To integrate the three-phase load and the utility grid into the DCMG under various operational circumstances, a control approach for three-phase voltage source inverters has also been presented. The proposed control approach uses feedback and feedforward control loops to achieve optimal results.

Besides that, two proportional-integral controllers for AC voltage control and internal current control in two rotating synchronous reference frames with common and quadrature axes have been proposed to control the respective operative and block components. These controllers are used to control the AC voltage and internal current. Simulations are run to test the robustness of the proposed algorithm and control method under various operating settings, including failure scenarios, and to determine how effective they are in preserving the microgrid's dc voltage.

Integrated with the DCMG and given in this work is a method for preserving power balance in multiple operating scenarios, including island and grid operations. A control strategy for three-phase VSI was developed. It involved combining the signals from the FB and FF control loops to generate the positive- and negative-sequence reference currents for internal current controllers. It also involved using dual PI controllers for AC voltage and internal current control.

2.9 Point of common coupling (PCC) voltage control of a grid-connected solar photovoltaic (PV) system

In Voltage regulation may become an essential duty in future low-voltage networks with multiple inverters connected to the network. Inverter-coupled power sources can regulate the voltage at the point of standard coupling (PCC) of the respective inverter-coupled power sources. This is achievable. Dynamically managing the amount of reactive power each system injects into the power distribution network allows for the possibility of achieving PCC voltage regulation with inverter-coupled sources. Within the scope of the present investigation, a closed-loop control strategy for regulating the PCC voltage of a solar photovoltaic system coupled to a single-phase power distribution network has been developed (with a ratio of R to X more significant than 1). When developing the system model for the PCC voltage regulator for the PV system, it is necessary to consider the reactance and resistance of the grid to which the PV system is linked. To discover an appropriate compensator for the PCC voltage regulator and to regulate the PCC voltage at a specific reference voltage, three different compensators are tested and compared against one another. The theoretical method used to develop the controlled system model of the PCC voltage controller is correct through a series of simulation studies, and experimental verification has shown that the controller design procedure is reliable. The controller design approaches provided in this research lead to a PCC voltage control system with satisfactory dynamic and steady-state performances.

By managing the amount of reactive power injected into the grid by the PV system, the proposed controller for a PV system linked to the distribution grid can maintain the voltage at the point of standard coupling (PCC) of the PV system at a given reference voltage. A suitable compensation is recommended to be incorporated into the controller to provide accurate control of the PCC voltage at the stated reference.

Among The scaled integrator was the most suitable compensator out of the three different compensators tested and evaluated for the study. It was found to be most suitable for controlling the PCC voltage of the PV system at a given reference voltage, which resulted in a steady-state error of zero.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter that is discussing on how to undergo the method of experiment. The explanation of the method and techniques will be discussed in this chapter, including the computer-aided software used for this project, the MATLAB/Simulink software—the method used to be boost-converter and inverter. As stated in chapter 1, the objective of this project is to study the grid and non-grid (islanded) microgrid behavior to see the power circulating issue and to propose a regulator for controlling the dc-link voltage through the microgrid's converters/inverter to compensate during a period of circulating current/power. The flow chart used for this project is very clear and easier to understand. This flow chart will briefly discuss the overall process of making the whole system. We designed a DC microgrid with PV and an integrated battery. The load is a constant DC voltage, and a controller provides smooth switching between sources. Three sources are available, namely grid and solar PV. All these sources charge the battery, and when unavailable, the battery powers the load. All the work is done in MATLAB SIMULINK.

3.2 General Flowchart

The flowchart below is the benchmark to follow the work stages. It also drives to do complete project since early until the end of project which starts with understanding about microgrid comprising various distributed generation (DGs) energy storage and loads. The plug-and-play nature of microgrid could change the microgrid configuration. Thus, the voltage throughout the microgrid must be regulated within the acceptable configuration. In addition, the mismatched power due to fault and input voltage collapse between input power generation from DGs and demand loads in islanded mode may lead to the inter circulating power. The circulating power may violate the DC-link voltage limit, and how to eliminate it by doing literature review related journals, thesis, IEEE papers, and scholars. It is important in order to understand more about the project as well to get more ideas and concepts of how the project works.

At the beginning of this project, first, have to develop grid-connected/islanded micro grid/load in MATLAB/Simulink then convert PV and battery to DC-DC Boost Converter. Grid-connected using a three-phase source at 11kV is then stepped down using a three-phase step-down transformer to 220V. Buck-boost connected was used in this PV connection because it has ability to increase or decrease the operating voltage, and the total maximum power of this subsystem is approximately 12Kw. The energy storage uses bidirectional converter. It converts a commercial power supply (AC) and internal DC current in both directions and exchanges energy. Lead-acid batteries are used in this simulation because lead-acid batteries have a low energy density a long lifetime and low costs compared to other battery types. Next insert parameter of impedances. After that run the simulation, after running the simulation V_Grid shows the connection if NO, PV array OFF if YES battery, current, voltage and loads are active. However, at t=1.5s V_Grid OFF then PV array ON, if NO battery ON and if YES, battery, current, voltage and loads are functional, lastly make analyses and make comparison on voltage regulation.

3.2.1 Flowchart Project

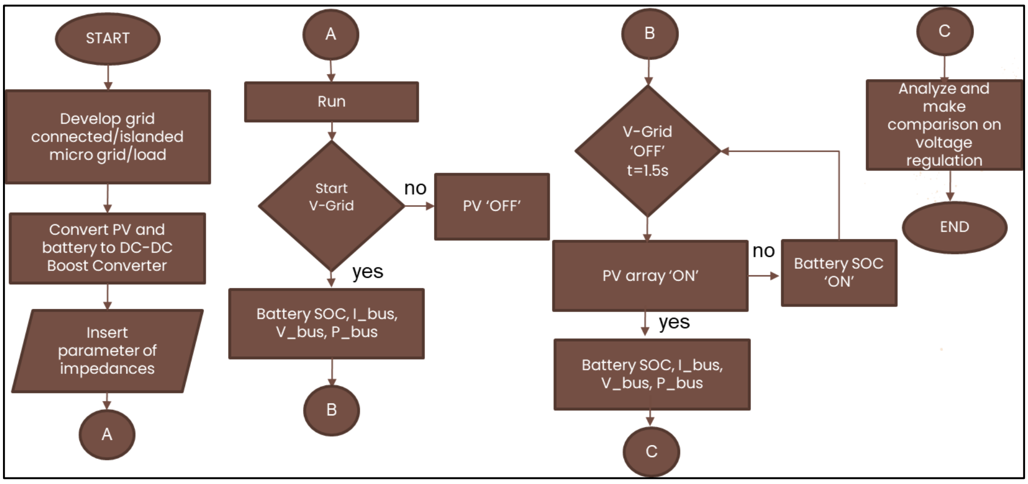


Figure 3.1 Flowchart of the system

3.3 MATLAB/Simulink Software

MATLAB's add-on product Simulink offers a user-friendly, graphic environment for modeling, simulating, and evaluating dynamic systems. This environment can be accessed through an interactive interface. It allows for the efficient production of virtual prototypes, which may be used to investigate design concepts at any level of detail and with little effort. The graphical user interface (GUI) that Simulink offers for modeling allows users to construct models in the form of block diagrams. It comes with an extensive library of prefabricated blocks that may be dragged and dropped with the mouse to create graphical representations of different kinds of systems. The user can create an "up-and-running" model, which is an advantage over the traditional method of building models in a laboratory setting, which might take several hours. It can model linear and nonlinear systems in continuous time, sampled time, or a hybrid form combining the two. Because students learn most effectively when they receive regular feedback, the interactive nature of Simulink encourages users to experiment with the program's features. Users can make changes to the program's parameters "on the fly" and view the results immediately, allowing for "what if" exploration. Last but not least, Simulink is integrated with MATLAB, which means that users of either application can send data back and forth between them.

3.4 Develop microgrid system

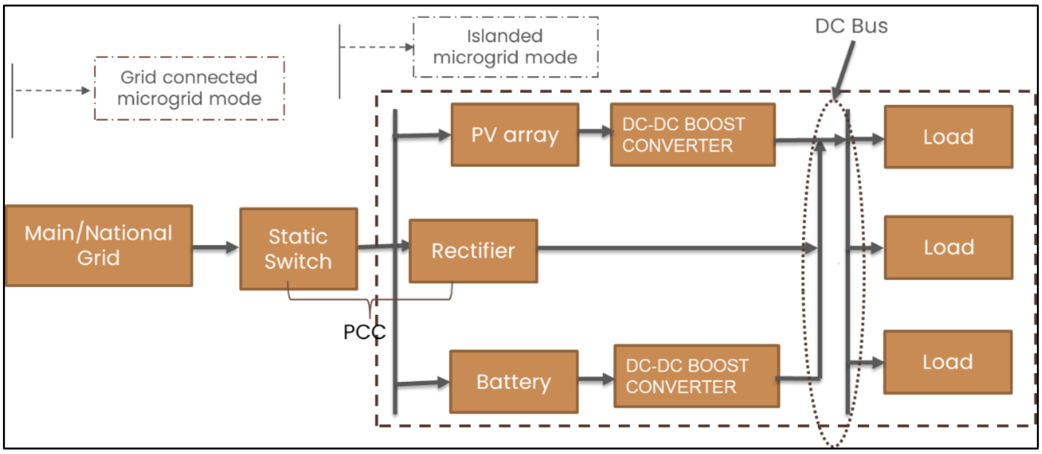
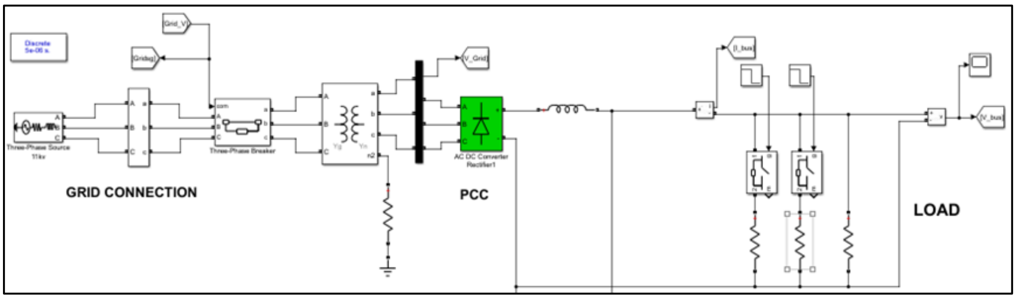


Figure 3.2 Block diagram of the DC microgrid

A block diagram represents a system in which the primary parts or functions of the system are each represented by a block, and the blocks are connected by lines that depict the connections between the blocks and the system. They find widespread application in engineering, particularly in the design of hardware, software, and electronic and process flow diagrams. In the first place, we have a main or national grid, a static switch, and a rectifier known as PCC (Point Couple Coupling). The switch engages to become grid-connected mode if an islanded microgrid cannot supply power to the loads or if any malfunction of energy sources. Then there is the island mode, which consists of a photovoltaic array and a battery, which employs a DC-DC converter and DC bus voltage to give power to the loads.

3.5 Design Simulink Circuit and Control Block of Dc Bus Voltage Circuit



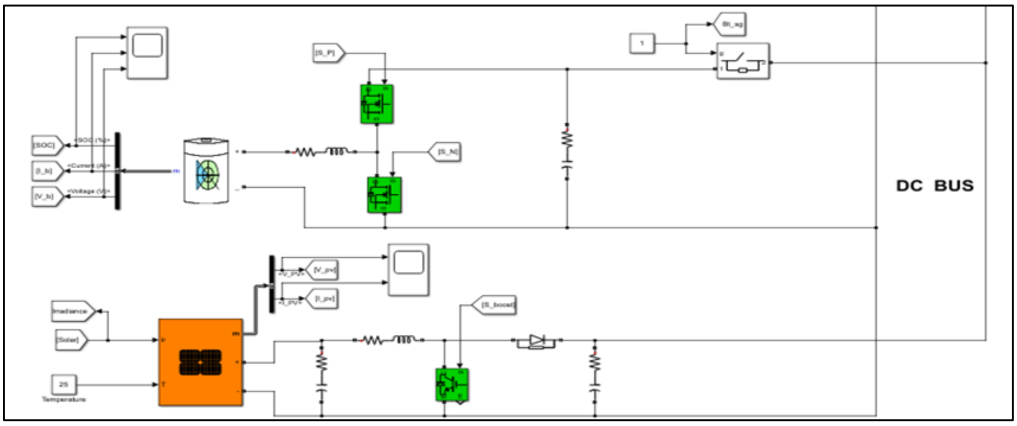


Figure 3.3 Design Simulink Circuit

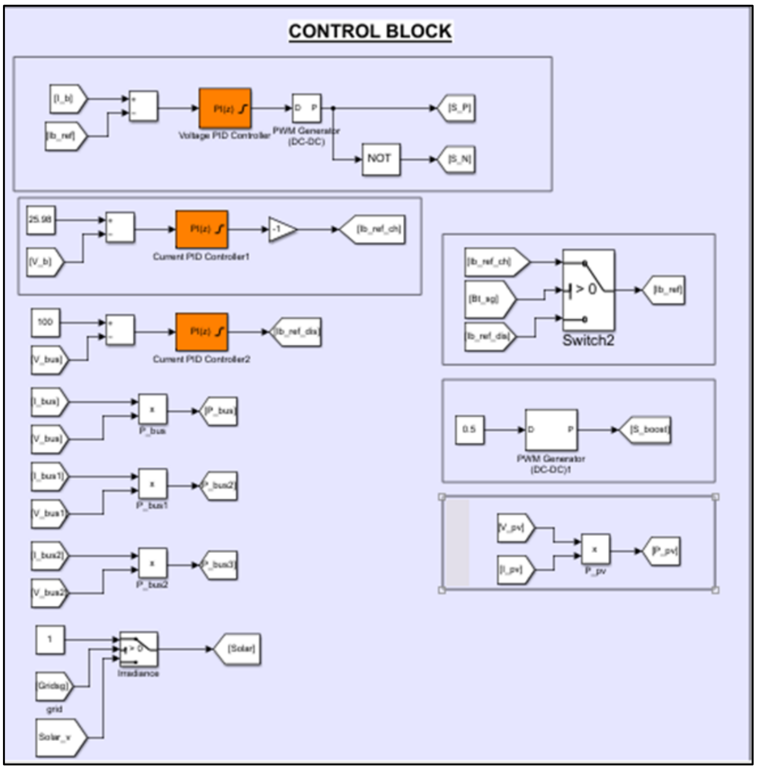


Figure 3.4 Control Block

3.6 Purpose of The Dc Micro Grid System

3.6.1 Following three terms are briefly summarized purposes of the DC micro grid system.

I. Increase the number of PV units that are scattered around the country.

II. By integrating the junction between a commercial grid and a DC bus, which connects PV units and accumulators, one can reduce the amount of energy lost and the costs associated with the facility as a result of AC/DC conversion.

III. Even when the commercial grids are out of service, power should still be supplied to loads through their regular distribution lines and not through special emergency lines.

This system delivers power to a community that may consist of dozens or even hundreds of families and uses a DC bus as its backbone. The community is located in a residential neighborhood. In typical AC distribution systems, a bidirectional AC/DC converter is used to link a 250-V DC bus that has been installed in place of lines operating at 200/100 volts. This bus is then connected to a commercial high-voltage grid. Through DC/DC converters, every PV system in the neighborhood is wired into the community's DC bus. These converters will always operate by the maximum power point of the DC power sources, which shifts depending on the amount of solar radiation present. If an inverter capable of converting direct current (DC) electricity to two hundred and one hundred volts of alternating current (AC) is placed in each home, conventional home appliances can continue to be used. However, once secure and compact devices such as breakers and sockets are standardized in the future, DC feeding will become more popular due to the high efficiency it offers. The DC bus also has connections for the storage batteries located around the town. Because the PV equipment and the battery DC are interconnected, the distribution system based on DC can reduce the equipment costs and energy losses associated with AC/DC conversion. Additionally, the majority of the energy-saving devices currently available are powered by DC due to advancements in inverter technology.

3.7 System Architecture

3.7.1 Generation system

DER to DC microgrid solutions include solar photovoltaic, battery storage systems, and other DC utility systems. An independent PV system is wired up with a DC-DC converter so that it may communicate with the DC bus system. Electricity is flowing in only one way in this instance. Similarly, a wind turbine is equipped with an AC-DC converter connected to the DC bus to ensure the effective flow of power. Under certain constraints imposed by the grid, distributed energy resources can operate in a degraded mode.

3.7.2 Battery

Regardless of whether the equipment uses lead-acid or lithium-ion batteries, the energy storage device is connected to the rail DC through bidirectional converters. In the mode where the batteries are connected to the grid, charging occurs whenever the demand is lower than the generation. Utilizing a generator allows for the load to be provided independently. The battery is an example of an efficient energy storage device that acts in both directions to get the best possible results.

3.7.3 DC Load

DC Bus is wired up and connected to the correct DC load at the rated voltage. With an existing AC network, a bidirectional converter is utilized to create a multilevel DC system.

3.7.4 Grid-connected converter

A bidirectional converter with a transformer and circuit breakers is utilized to link the AC grid system. Power grid systems affect various other factors, including the costs of maintenance, the resilience and durability of the system, the hierarchy of equipment management, efficiency, quality, resource consumption, and market flexibility. When determining the configuration of the grid, several essential factors should be considered. These factors include the impact on the environment, the capacity accessible at various stages, the most efficient use of energy, and the possibility for scalability. In the research that has been done, many different topologies have been documented, and it has been found that six different types of structures can cover practically all architectures.

3.8 Modes of Operation

The DCMG is wired up to a bidirectional converter so that the power flow on both the grid and the load sides can be maintained in equilibrium. If the converter experiences a malfunction, it must be able to detach itself from the supply side. During this time, the battery storage system will contribute to ensuring that the load continues to get electricity. This type of operation is known as "off-grid." The converter should maintain the voltage level at all times, and the converter's switching should be done orderly and smoothly. The load should be reconnected to the main power supply once the supply problem has been resolved, and the battery will be charged in preparation for the subsequent discharge period. In a nutshell, every microgrid may be broken down into one of two primary modes of functioning. The grid-connected mode and the isolated mode are the two that are available. Further subcategorization of the grid-connected mode includes the grid-controlled mode and the uncontrolled mode. This is mostly dependent on the management of electricity as well as the regulation of voltage.

I. Grid connected mode

In the DCMG mode of operation, the power converter's responsibility is to maintain control between the load and the DC link voltage. When the overall amount of storage in the gadget is greater than what is needed, the device's extra charge is sent out into the power system. The energy management system will divide the balance amongst the various storage devices when operating in this mode. Because of this, DCMG can function perfectly with very little loss.

II. Isolated mode

The DCMG is disconnected from the electric grid and has the capability of functioning in island mode. These inverters are connected in parallel to the DC bus operating in an isolated mode. The converters connected to the grid do not run while this process is taking place, but the converters that are part of the microgrid do, which allows for the control of the grid to be maintained. Because the inverters are not connected to the DC bus so that they may regulate it, the storage parts of the inverter are only responsible for maintaining the voltage of the DC link. Therefore, the battery is the primary component responsible for keeping the DC voltage stable, and the supercapacitor, one of the storage parts, plays the role of an energy supply during periods of fluctuating demand.

3.9 Operational Structure of Dc Microgrid

There are typically six distinct configurations to choose from when designing the architecture of a DC microgrid. In this section, a comprehensive discussion of the various topologies, as well as a comparative analysis of them, are presented.

I. Single Bus DCMG Structure

This A DC microgrid can be constructed most straightforwardly using an arrangement similar to this one. In this configuration, there is essentially just one primary bus. Other devices, such as a wind turbine, a photovoltaic system, and a battery bank, are connected to it as a source. Because the battery bank is connected to the main bus, it is now possible to send and receive electrical power in both directions. This increases the system's degree of steadiness. DC is joined to the utility grid to act as a load. A radial arrangement is another name for this particular type of arrangement. It is essential to correctly position the interface devices, which may include power electronic converters, to guarantee the system's stability and resilience. Since there is only one line, the issue of single point failure occurs whenever the battery state of charge is not achieved perfectly. The regulation of the battery's tension will rise as the number of batteries increases. The use of this kind of structure is better suited for applications that involve low voltage. Two distinct direct current methods to alternating current conversion can achieve improved stability.

II. Multi bus DCMG Structure

This kind of building amalgamates several separate bus systems on their respective floors. The current structure gives off the impression of being more solid and trustworthy thanks to the consistent use of the same pattern. This arrangement is suitable for usage in naval ships because it features redundancy. As a result of the voltage range's adaptable character, it is possible to vary it on up to three distinct levels. This makes it possible for data to be conveyed to the adjacent bus and reduces the amount of repetition. Although it has a few flaws, it is an excellent method for keeping communications private. Because there are several different voltage sources, choosing an appropriate voltage range is necessary to improve the system's effectiveness, quality, and viability. This kind of technology is capable of functioning at low as well as medium voltages.

3.10 Power Transmission

DC Electricity is transmitted by underground cables or overhead lines, which consist of conductors, insulators, and supporting structures. Aluminium is often used as a conductor because it has low resistance, low cost, good weight-to-strength ratio, and is widely available. The resistance of a DC cable can be calculated using Equation below. The aluminium is usually reinforced with steel to make it stronger. Aluminium conductor, steel reinforced (ACSR) is made in strands to simplify manufacturing. Overhead lines are not covered with an insulator to help dissipate heat. In transmission AC, insulating washers are usually used to separate the cable bundles. The higher the voltage used, the more insulating material is needed. Support structures are used to suspend the cables at a safe distance from the public in height and can be made of wood or metal.

$$R_{\mathrm{DC}} = \frac{\rho l}{A}$$

Where ρ is the resistivity of the conductor at a specific temperature, l is the conductor length and A is the cross sectional area of the conductor.

3.11 Power Quality

Power quality could be a degree of the unwavering quality and stability of a control source in terms of the voltage, recurrence and waveform. The reason why DC frameworks display higher control quality than AC frameworks is since the recurrence is zero for DC systems in this manner it is much less demanding to attain a flag that's inside determinations. A microgrid should be able to supply control to the loads without harming them, which may be a more prominent concern with the increment in advanced hardware. The term control quality is utilized but the estimation is really the quality of the voltage. The DC control can be calculated by Condition underneath. DC frameworks have no stage point between the voltage and current hence show no responsive control expanding the control quality. Moreover, since the recurrence is zero of a DC waveform there's no consonant mutilation. Sounds show up in products of the control supply recurrence. Voltage stability is the most centre in DC frameworks and control electronic converters and batteries can be utilized in arrange to preserve DC voltage stability.

$$P = VI = \frac{V^2}{R} = I^2 R$$

3.11.1 Modelling

The operation of the individual components of the microgrid will be analyzed utilizing MATLAB/Simulink. Simulink has an environment called Simcape which can be utilized to demonstrate dynamical frameworks. Simulink, an add-on item to MATLAB, gives an intelligently graphical environment for modeling, mimicking, and analyzing energetic frameworks. It empowers the fast development of virtual models to investigate plan concepts at any level of detail with negligible exertion. For modeling, Simulink gives a graphical client interface (GUI) for building models as square graphs. It incorporates a comprehensive library of pre-defined squares to be utilized to develop graphical models of frameworks utilizing drag-and-drop mouse operations. The customer can generate an "up-and-running" demonstration, which is something that would otherwise require many hours to construct within the environment of the research centre. It supports linear and nonlinear frameworks that can be described as continuous-time, tested time, or a hybrid of the two. Since students learn most effectively with visit input, the intelligent nature of Simulink encourages you to try things out; you'll be able to change parameters "on the fly" and quickly see what happens for a "what if" investigation. Since students learn most effectively with visit input, the intelligent nature of Simulink encourages you to try things out. In conclusion, it should not be in the least bit surprising to learn that Simulink is coordinating with MATLAB so that data may be easily transferred between the two applications.

3.12 Dc-Dc Converters

DC-DC converters will be utilized in conjunction with components of the microgrid to assist stabilize the voltage and create maximum control. Three DC-DC converter sorts will be examined:

I. Buck converter
II. Boost converter
III. Buck-Boost converter

For these DC-DC converters to function, a switch must be intermittently opened and closed—both the buck converter and the boost converter work to reduce the input voltage. However, the boost converter works to increase the input voltage. Because the output voltage is higher than the input voltage, this converter is referred to as a boost converter. The buck-boost converter can either increase or decrease the input voltage, but it does so by inverting the polarity of the voltage.

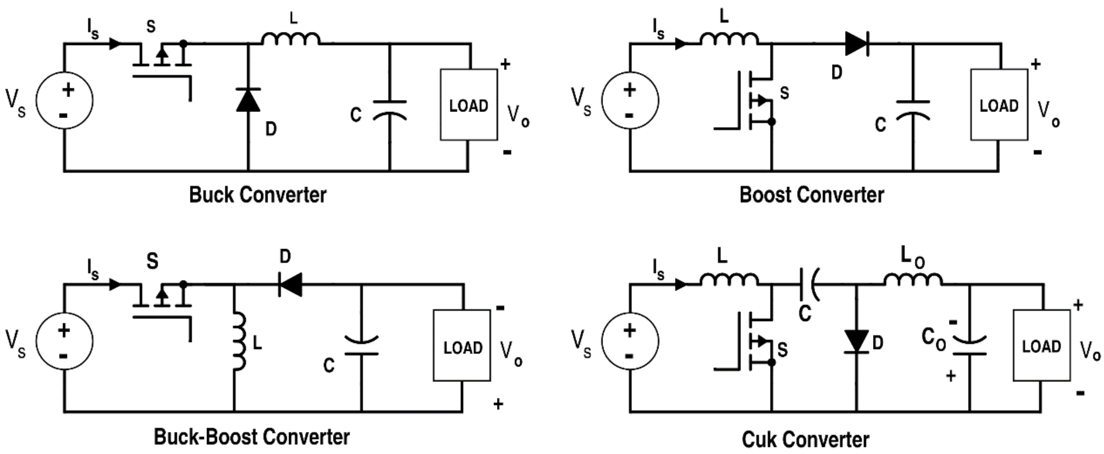


Figure 3.5 Types converter

The converters contain a low pass filter after the switch at the output in arrange to get a simply DC output. The output voltage is changed by shifting the obligation cycle. The output of the buck, boost and buck-boost converters are calculated by Conditions separately with the reactions plotted.

$$Vo = VsD$$

$$Vo = \frac{Vs}{1 - D}$$

$$Vo = -Vs\frac{D}{1 - D}$$

3.13 The Bidirectional Converter

It is necessary to have a converter to transfer power from and to the microgrid's batteries. In early iterations of buck and boost converters, bidirectional power flow was not a viable option. This is because each one has diodes, which prevent the flow of electricity in the opposite direction when they are present. Create a bidirectional converter by combining the features of buck and boost converters and replacing the diodes in those converters with switches. This will allow the converter to work in either direction. The switch on top acts as a buck converter, sending electricity from the high voltage side to the low voltage side. The switch on the bottom, on the other hand, acts as a boost converter, which means it sends power from the low voltage side to the high voltage side. To perform the simulation of the design, Simulink was utilized. The bidirectional converter will be controlled by a charge controller, determining whether energy needs to be delivered to or from the battery. Except for the inductor value, the bidirectional converter employed the same values as the buck converter design. This will help smooth out the fluctuations caused by using renewable energy sources and ensure that the voltage is maintained. It was found that a large value for the inductor impedes the system's voltage stability; hence, a value with a lower magnitude was selected. Because of the reduced ripple, the batteries will be charged and discharged more effectively, which will result in a longer lifespan for the batteries.

3.14 Photovoltaic Cell

Within PV cells, photoelectric activity converts the light from the sun into a voltage so that the cell can be used to generate electricity. A load connected across an array of photovoltaic cells will draw current from the array while also drawing electricity from the array itself. To cause a flow of current in an external circuit, the photovoltaic array being produced utilises both n-type and p-type materials. When light is thrown onto a photovoltaic (PV) cell, a photon is absorbed by the cell, and a pair of electrons and holes are created as a by-product. Since an external circuit connects the n-type and p-type materials, an electron will move from the n-type material to the p-type material, which will cause the current to flow. To boost the voltage and current, many cells are linked in series and parallel. This is essential because a single cell can only provide 0.5–0.8 V of voltage, which is insufficient to provide sufficient power to the load. By using a current source, it is possible to replicate the operation of a solar cell. The Simulink block representing the photovoltaic cell is designed with a two-diode model. The array data tab provides information regarding the number of parallel and series strings available for use in modifying the PV array's voltage and current settings. On the Module data tab, you may view the one-of-a-kind operating information that pertains to the PV array. You can select from several different manufacturers or enter the information by hand. The one-of-a-kind parameters of the PV array are then displayed under the tab labeled Model Parameters.

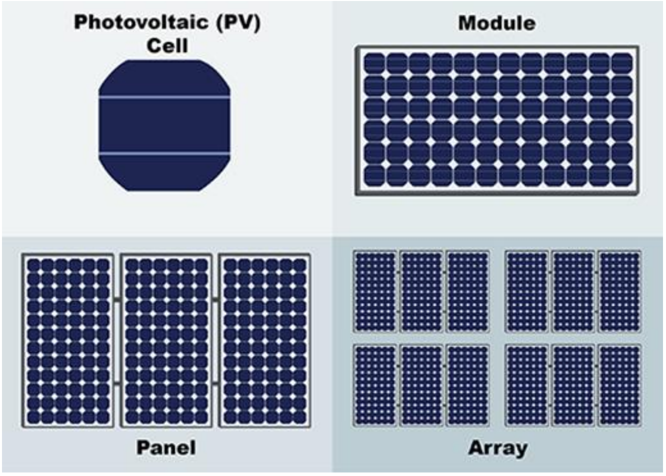


Figure 3.6 PV array

3.14.1 Solar Panel

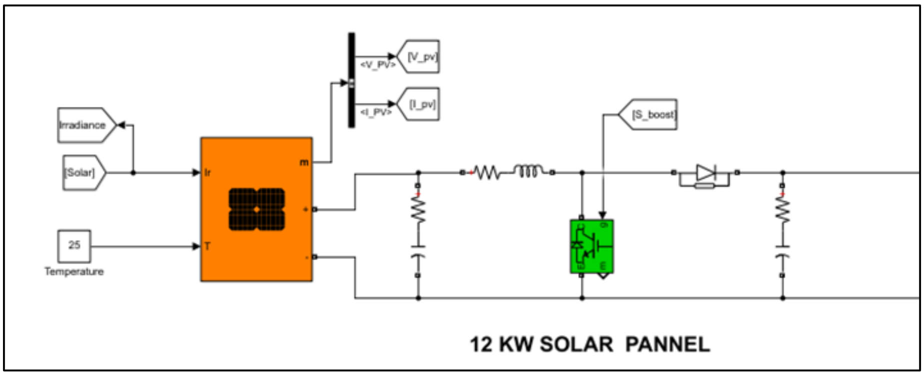
Within PV cells, photoelectric activity converts the light from the sun into a voltage so that the cell can be used to generate electricity. A load connected across an array of photovoltaic cells will draw current from the array while also drawing electricity from the array itself. To cause a flow of current in an external circuit, the photovoltaic array being produced utilises both n-type and p-type materials. When light is thrown onto a photovoltaic (PV) cell, a photon is absorbed by the cell, and an electron-hole pair is created as a by-product resulting from this process. Since an external circuit connects the n-type and p-type materials, an electron will move from the n-type material to the p-type material, which will cause the current to flow. To boost the voltage and current, many cells are linked in series and parallel. This is essential because a single cell can only provide 0.5–0.8 V of voltage, which is insufficient to provide sufficient power to the load. It is possible to simulate a solar cell by using a current source. The Simulink block representing the photovoltaic cell is designed with a two-diode model. The array data tab provides information regarding the number of parallel and series strings available for use in modifying the PV array's voltage and current settings. On the Module data tab, you may view the one-of-a-kind operating information that pertains to the PV array. You can select from several different manufacturers or enter the information by hand. The one-of-a-kind parameters of the PV array are then displayed under the tab labeled Model Parameters.

Aside from the fact that solar panels make it possible to live off-grid, perhaps the most significant advantage you would derive from using solar power is that it is both a clean and renewable source of energy. You would not have to worry about running out of power if you used solar power. As a result of the onset of climate change worldwide, it is now more imperative than ever before that we do everything in our power to lessen the strain that the release of greenhouse gases places on our atmosphere. Solar panels are low maintenance and have no moving parts, so they are a great option. They are of sturdy construction and, assuming they are cared for, can last for decades.

Last but not least, once a system has compensated for its installation's initial expenses, the electricity it produces for the balance of its lifespan, which may be as long as fifteen to twenty years depending on the system's quality, is free of charge! The moment a solar power system connected to the grid gets turned on. The owner may start to enjoy the benefits, which may include a reduction in the amount of money they spend each month on electricity or, even better, an increase in the amount of money they receive from their electric supplier. How? Suppose you can create more electricity from your solar energy system than you require. In that case, you may be able to make money by selling the excess energy to the utility company that serves your area. A great number of additional applications and benefits come with using solar panels to meet your home's electrical requirements, all of which would be impossible to discuss here. As you navigate our website, you will obtain a crystal clear grasp of how adaptive and practical solar power may be.

3.15 PV Connected Buck-Boost Converter

In this scenario with a buck-boost connected the power is increased in each scenario because the buck-boost converter has the ability to increase or decrease the operating voltage. In real applications a boost converter is sufficient because most loads are much higher than this simulated case



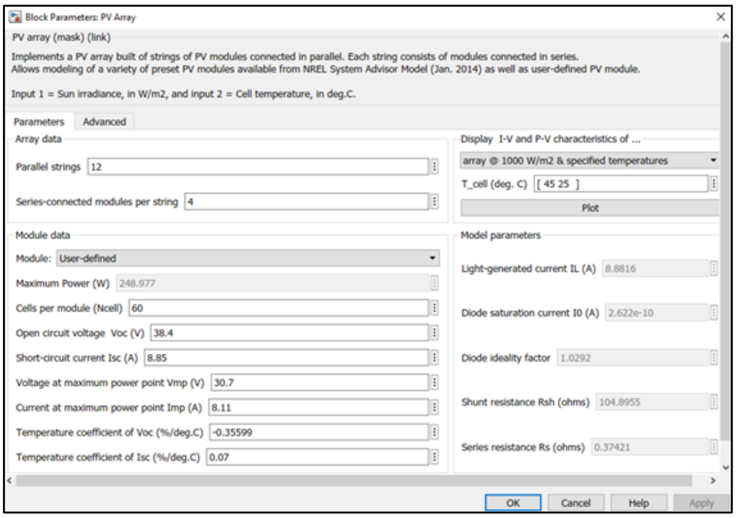


Figure 3.7 Simulink of PV array

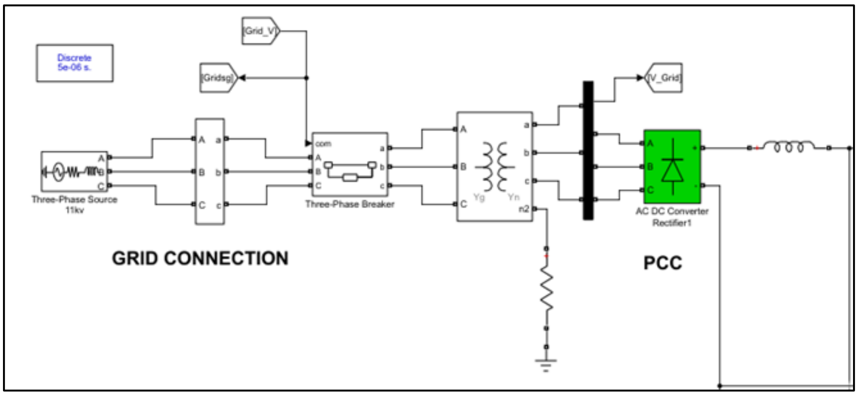


Figure 3.8 Simulink of Grid connected

Grid is also modelled in Simulink using by a three phase source at 11kV and then it is stepped down using a three phase step down transformer to 220V.

3.16 Energy Storage

The ability to store energy is essential to any microgrid that functions off of renewable power sources. The storage of energy will help maintain voltage stability and smooth out the variations caused by the output of renewable energy. Batteries, which use a chemical reaction that can be reversed to store energy and transform chemical energy into electrical energy, will serve as the microgrid's element for the storage of energy in this DC version of the grid. Batteries are not as quick to respond as super capacitors, but they can store more energy, which is an essential factor to consider when designing microgrids. Because the electrical energy may be stored directly in super capacitors rather than going through a chemical process first, the response time is significantly reduced.

Because we don't have to worry about frequency control in a DC microgrid, the response time isn't as crucial as in other types of grids. Because batteries might be harmed by going through a full discharge cycle, the amount of charge they can hold should be kept within a suitable range.

It is possible to describe a battery as a non-linear voltage source, in which the output voltage is contingent not only on the current but also on the battery's level of charge (SOC). The SOC is a function that is not linear in terms of both the current and the time. The state of charge of the battery affects the battery's internal resistance and voltage. The state of charge (SOC) can be defined as the ratio of the total ampere-hours of the battery to the number of ampere-hours that are still available in the battery. When the state of charge reaches 90 percent, a battery's internal resistance is virtually constant; after that point, it begins to climb exponentially. Because of the difference in concentration of the various chemical species found inside a battery, a diffusion capacitance will eventually develop. Because of the behavior of the electrolytes as a dielectric, there is a capacitance effect referred to as diffusion capacitance. This effect is caused by the two diffusion layers having opposite charges. Side reactions can occur whenever a battery is charged at a rate higher than the chemical process's capacity that converts energy. This results in the heating of the battery, which in turn triggers a process known as gassing, in which hydrogen and oxygen gases are created.

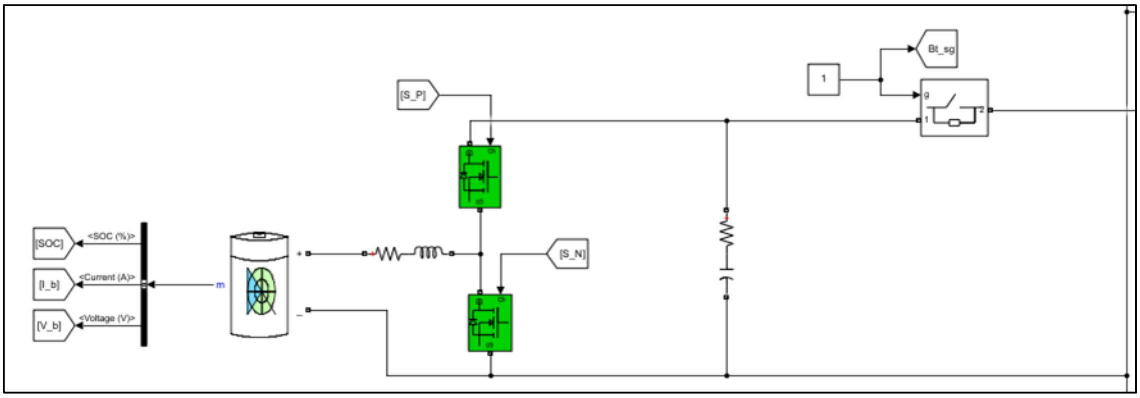


Figure 3.9 150V 50AH Battery Bank

3.16.1 Charge Controllers

Charge controllers in a microgrid are responsible for regulating the flow of current into and out of the batteries. They are essential components for the proper operation of the DC bus voltage regulation as well as the safety of the batteries. As part of this DC microgrid project, a charge controller will be used to regulate a bidirectional converter. This will allow the PV output voltage to be brought down to the level required by the batteries. When the output from the PV array reaches zero, the charge controller will kick in and activate the bidirectional converter. This will cause the electricity stored in the batteries to be transferred to the microgrid. The diagram illustrates the proposed logic for a charge controller to be used in a DC microgrid. Most battery packs are designed to operate anywhere from 30 to 90 percent of their capacity.

As a consequence, the controller's logic will check to see if the batteries have a charge level of between 30 and 90 percent. If they do, the batteries will either charge or discharge themselves according to the power balance between the generation and the load. If the SOC is below 30 percent and the power generated is more than the required load, the batteries will be charged; however, load shedding should be considered to safeguard the batteries if the load is larger than the power generated. The final possible outcome occurs when the batteries have a high state-of-charge (SOC) of greater than 90 percent. Suppose the microgrid produces an excessive amount of electricity. In that case, the current will be redirected to a dump load to prevent the batteries from being overcharged and a rise in the DC bus voltage.

In photovoltaic systems, the type of battery utilized most frequently is known as a lead-acid battery. Although lead-acid batteries have a low energy density, modest efficiency, and significant maintenance requirements, they have a long lifetime and inexpensive costs compared to other types of batteries. Lead-acid batteries also have a low cost per charge compared to other battery types. One of the primary benefits of lead-acid batteries is that they are the type of battery utilized in most rechargeable battery applications (for instance, in the ignition system of automobile engines). Consequently, they possess a technological base that is not only well-developed but also established and mature. A negative electrode that is made of lead and is porous or spongy is what makes up a lead-acid battery. This electrode is located on the positive side of the battery. Its porous structure contributes to the production of lead and its subsequent disintegration. Positive electrodes often consist of lead oxide in their construction. After that, both electrodes are put into an electrolytic solution that consists of sulphuric acid and water. This solution is the next step in the process. A chemically permeable and electrically insulating membrane separates the two electrodes in the battery if the two electrodes come into contact with each other as a result of the physical movement of the battery or variations in the thickness of the electrodes. This barrier not only keeps an electrical short from happening, but it also keeps the electrolyte safe. The next diagram illustrates a chemical system that is capable of working in reverse and storing energy in lead-acid batteries. The overall chemical reaction is:

$$PbO2 + Pb + 2H2SO4 \leftrightarrow 2PbSO4 + 2H2O$$

The depth of discharge, in conjunction with the battery capacity, is an essential component when designing a battery bank for a photovoltaic system. This is since the amount of energy that can be recovered from the battery is obtained by multiplying the battery capacity by the depth of discharge. This is because the amount of energy that can be reclaimed from the battery is calculated by multiplying its capacity by the amount that it has been discharged. Deep-cycle and shallow-cycle batteries are the two primary classifications of batteries available. A deep-cycle battery can have a depth of discharge of up to 80 per cent, which is larger than the standard 50 per cent mark. This proportion has the potential to reach one hundred per cent. A bank of shallow-cycle batteries will need to have a higher capacity than a bank of deep-cycle batteries to get the same usable capacity.

3.17 PI Controller

A microgrid can be controlled by voltage-based droop control or communication-based control. In this project we will use the communication-based control method based on a proportional Integral (PI) controller. A PI controller will be used as the control mechanism for the charge controller. A block diagram of a PI controller is shown in Figure. This is a commonly used control mechanism which calculates the error e(t) between the output y(t) and the desired set point Ref. A proportional and integral correction is made to the error signal and the combination of these corrections forms the control variable u(t). This control variable is used to reduce the error in the system and the process is continued to decrease the error. In the DC microgrid design the reference will be the desired DC voltage of 250 V and the monitored output y(t) will be the DC bus voltage. The control variable u(t) will operate the bidirectional converter which will control the flow of power between the microgrid and battery in order to stabilize the DC bus voltage. The proportional term generates a proportional response relative to the error. If there was no error signal in a proportional only controller the bidirectional converter would not be activated, and the DC voltage would deviate once a zero steady state error is reached due to inertia in the system. Therefore, we also use an integral response which adds a control based on the past errors. A P controller will exhibit a faster response, but a PI controller has a better power regulation and zero steady-state error.

3.17.1 PI Controller Design

The Simulink objects were used to implement the PI controller. The integral block was set to 3 while the proportional block was set to 0.02. The terms were added together, and a restriction of 0.95 to -0.95 was set since the output will run a bidirectional converter with a maximum duty ratio of 1, but infinite at 1 causes complications, therefore 0.95 was chosen for the limitations. The error is sent back into the import u, and the output is sent to the out port y. Depending on whether the DC voltage needs to be increased or decreased, the output y will be positive or negative.

Table 3.1 Table of Simulink Block

Three phase sources	Current measurement	IGBT/DIODE
Three phase breaker	Battery	Diode
Three phase transformer	Series RLC Branch	Step
Three phase VI measurement	MOSFET	PID Controller
Universal bridge	Ideal switch	Add
Filter	Permanent magnet synchronous machine	Multiply
Load resistive	Ideal switch	Add
Voltage measurement	PV array	Switch

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The outcomes of the simulation and technique by using MATLAB/Simulink and simulation will be exhibited and discussed in this chapter. The chapter is titled "Simulation and Methodology Using MATLAB/Simulink.". Simulation results show DC Bus voltage = 250v DC Bus current = 80A, Load (resistive) = 10kW

The figure below shows the result in the grid-connected mode, and the microgrid sources will be controlled to give constant real and reactive power injection. The microgrid sources will be controlled in the islanded mode to offer constant real and reactive power injection. The sources will be regulated in the grid-connected mode to provide continuous voltage and frequency operation.

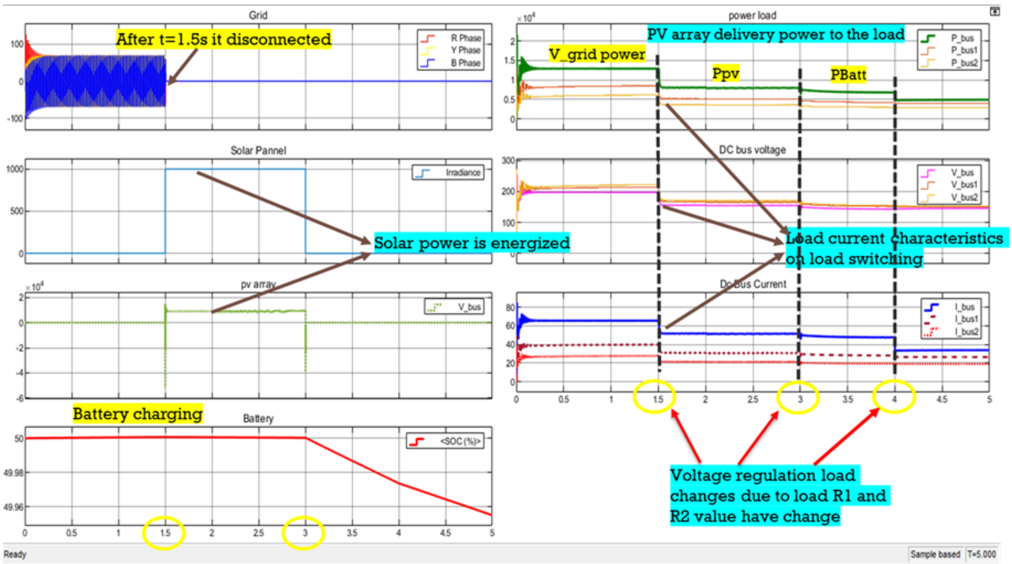


Figure 4.1 Grid connected mode

The result show for the first graph show the grid connected microgrid operation that getting supply from the grid system. Battery is set initially in 50%SoC. in this condition the load is powering from the grid. Next, when grid connected at t=1.5s grid was OFF, the PV array was take over to supply the current to the load. It makes that all 3 of loads started gradually decreasing and PV power tracks the decreasing loads with less fluctuation. When reaching t=3s, the irradiances drop to 0 and makes PV also drop. However, both DC bus and power load, still have supply due to the battery that take over the charge. This is because the output from the DC-DC boost converter is connected to microgrid where the loads are connected. So that, the charging and discharging of the battery is done by bidirectional buck-boost converter which it also regulates the dc link voltage.

The simulations have confirmed that the proposed voltage regulator can manage to regulate dynamic DC bus voltage. The DC bus voltage is mainly controlled by the battery converter that uses linear feedback to regulate the DC bus voltage.

4.2 Analysis Data

Table 4.1 Load Data Analysis

P(kW)/Time(s)	0	1.5	3	4	6
L1	13.28K	12.92K	8.056K	6.782K	7.863K
L2	8.146K	8.533K	5.158K	4.252K	8.135K
L3	5.706K	6.167K	3.668K	3.003	8.266K

Table 4.2 Dc Bus Current

Vbus(V)/Time(s)	**0**	**1.5**	**3**	**4**	**6**
L1	196.9V	196.9V	155.5V	142.6V	153.5V
L2	211V	214.1V	166.5V	151.1V	156.2V
L3	217.4V	221.9V	171.1V	154.8	157.4V

Table 4.3 Dc Bus Voltage

I(A)/Time(s)	**0**	**1.5**	**3**	**4**	**6**
L1	65.62A	65.62A	51.82A	47.54A	51.21A
L2	39.28A	39.86A	30.99A	28.14A	52.09A
L3	27.22A	27.79A	21.43A	19.39A	52.51A

For the analysis data the value of load. In my project, I use different value of resistances to determine the load changes. From my observation, I can see that the output power will start to stabilize and constant due to the regulator that installed in the circuit. This regulator can prevent from mismatch power due to load changes and input voltage collapse between input power generation and demand loads in islanded mode may lead to the inter circulating power. From this table we can see that when higher resistances were applied to the load more stability were archive.

CHAPTER 5

CONCLUSION

5.1 Introduction

In conclusion, this project is to propose a voltage regulator for controlling the voltage regulation due to the circulating current in the microgrid system. Even the microgrid can provide in less cost for long term operation, nonetheless the impact of the energy sources fluctuation, load variations, grid and non-grid connection has created a high possibility to the circulating problem in the microgrid network. Thus, compensating the voltage deviation could improve the stability of the microgrid operation. overall all the objectives were achieved.

For future work, the voltage regulation from grid-connected to islanded microgrid can be further investigated using the real irradiation value to the solar PV. The fault can be added (to see the extreme voltage changes) in order to investigate and propose the robustness controller to the regulation voltage in a microgrid. Besides that, adaptive droop control also can be adopted for efficient voltage regulation compensation.

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APPENDIX A

Gant chart PSM 1

No	Task	TASK DESCRIPTION	EFFORT ALLOCATED (Hour)	ASSIGNED PERSON	PLAN START (Week No.)	PLAN DURATION (Week)	ACTUAL START (Week No.)	ACTUAL DURATION (Week)	PERCENT COMPLETE	WEEKS													
										1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Information Gathering	Briefing PSM1	1	Dr. Huda	1	1	1	1	100%	■													
2	Logbook Progress	Logbook report for every week	2	Ain	2	14	2		86%	■	■	■	■	■	■	■	■	■	■	■	■	■	
3	Research	Find the journal paper or article	3		2	5	2	6	87%			■	■	■									
4		Identify and develop the topic	2	Ain	2	2	2	5	80%			■											
5		Search for the information	3		2	2	2	2	75%			■	■	■	■	■							
6		Expected Result	2		5	3	7	4	65%					■	■								
7		Calculation for the input and output																					
8		Design for the simulation in Matlab																					
9		Connection of DC link for microgrid stability and operation																					
10	Progress Presentation	Slide preparation for project progress presentation	2	Ain	8	2	10	2	100%										■	■	■	■	
11	Simulation	Build a design for to simulate the project																					
12		Try to simulate																					
14	Final Project Presentation	Slide preparation for project presentation																					
15	Report	Introduction	2	Ain	5	3	6		72%						■	■	■						
16		Problem Statement	1	Ain	5	3	6		72%						■	■	■						
17		Chapter 2																					
18		Chapter 3																					
19																							

Gant chart PSM 2

No	Task	TASK DESCRIPTION	EFFORT ALLOCATED (Hour)	PLAN START (Week No.)	PLAN DURATION (Week)	ACTUAL START (Week No.)	ACTUAL DURATION (Week)	PERCENT COMPLETE	WEEKS													
									1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Information Gathering	Briefing PSM2	1	1	1	1	1	100%	■													
2	Logbook Progress	Logbook report for every week	2	2	14	2	14	50%	■	■	■	■	■	■	■							
3	Research	Find the journal paper or article	3	2	5	2	6	100%			■	■	■									
4		Identify and develop the topic	2	2	2	2	5	80%			■											
5		Search for the information	2	2	2	2	2	75%			■	■	■	■	■							
6		Expected Result	2	2	3	3	7	100%					■	■					■	■	■	■
7		Calculation for the input and output	2	2	3	5	7	20%					■	■	■							
8		Design for the simulation in Matlab	3	2	3	2	7	100%			■	■	■	■	■							
9		Connection of DC link for microgrid stability and operation	2	2	8	5	7	100%						■	■							
10	Progress Presentation	Slide preparation for project progress presentation	2	8	2	10	2	60%											■	■	■	
11	Simulation	Build a design for to simulate the project	2	3	7	2	7	100%		■	■	■	■	■	■				■	■	■	■
12		Try to simulate	2	3	7	5	7	40%		■	■	■	■	■	■				■	■	■	■
14	Final Project Presentation	Slide preparation for project presentation	1	9	3	7	13	100%												■	■	■
15	Report	Report	2	5	14	5	14	90%												■	■	■
16		Result	2	4	11	2	11	100%										■	■	■	■	■

APPENDIX B
SAMPLE APPENDIX 2

For Appendices Heading, use TITLE AT ROMAN PAGES style.