

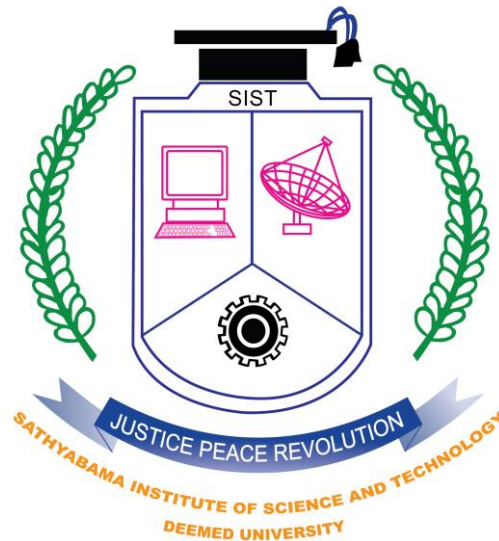
HYBRID ENERGY SOURCE BASED LANDSMAN CONVERTER FOR AC/DC MICRO GRID

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering Degree in
Electrical and Electronics Engineering

by

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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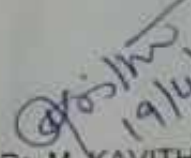
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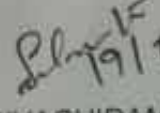
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of GUNAL N (Reg. No. 39140015) and LOGESHWARAN J (Reg. No. 39140026) who carried out the project entitled "HYBRID ENERGY SOURCE BASED LANDSMAN CONVERTER FOR AC/DC MICRO GRID" under our supervision from November 2022 to April 2023.


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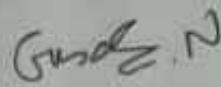
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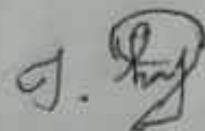
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DECLARATION

We GUNAL N (Reg. No. 39140015) and LOGESHWARAN J (Reg. No. 39140026) hereby declare that the Project Report entitled "HYBRID ENERGY SOURCE BASED LANDSMAN CONVERTER FOR AC/DC MICRO GRID" done by us under the guidance of Dr. M. KAVITHA is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electrical and Electronics Engineering.

1. 

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DATE: 19/04/2023

PLACE: Chennai

SIGNATURE OF THE CANDIDATES

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ABSTRACT

This project presents a hybrid energy source-based Landsman converter for AC/DC micro-grid systems. The proposed converter is designed to integrate renewable energy sources with traditional power sources to increase efficiency, reduce energy costs, and improve power quality. The converter operates in a closed-loop control system, which allows for stable and reliable operation of the micro-grid. The hybrid energy system consists of photovoltaic panels, wind energy generation system, and battery storage systems. The Landsman converter is responsible for converting the DC voltage generated by the hybrid energy system into DC voltage with better performance, which can be used by the micro-grid. Simulation results demonstrate the effectiveness of the proposed Landsman converter for micro-grid systems, including better output voltage, less voltage ripple, high voltage gain. The proposed system has the potential to implement in various micro-grid applications, including rural electrification, remote area power supply, and emergency backup power systems

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	-	Alternating Current
DC	-	Direct Current
MOSFET	-	Metal oxide semiconductor field effect transistor
L	-	Inductor
C	-	Capacitor
D	-	Diode
V_{in}	-	Input Voltage
V_{out}	-	output Voltage
V	-	Voltage

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The increasing demand for electricity and the growing concern for the environment have led to the development of various renewable energy sources, including solar, wind, and hydro power. These sources have the potential to provide sustainable and clean energy, but their intermittent nature poses challenges for their integration into power grids. To address these challenges, hybrid energy systems that combine multiple renewable energy sources and energy storage devices have emerged as a promising solution. Hybrid energy systems are becoming increasingly popular as a way to generate electricity using a combination of energy storage devices and renewable energy sources. This approach provides a stable and reliable power supply by combining the strengths of different energy sources, while also addressing the limitations of individual sources. It offers several benefits, including increased efficiency, improved energy security, and reduced dependence on fossil fuels. They can also help to reduce the greenhouse gas emission and mitigate the impacts of climate change. With advances in technology and decreasing costs, hybrid energy systems are becoming an increasingly viable option for meeting the growing demand for clean, reliable, and sustainable energy.

The Landsman converter is a power electronics topology that can be used for various energy conversion applications. One of its key advantages is its ability to combine the benefits of a boost converter and a buck-boost converter in a single circuit. This makes it an attractive option for applications that require a boost operation, such as battery charging or renewable energy systems. In a boost operation, the output voltage of the converter is higher than the input voltage. The Landsman converter achieves this by using a combination of capacitors, inductors, and switches to convert the input voltage to a higher output voltage. By using a unique control scheme, the Landsman converter

can achieve high efficiency and low ripple in the output voltage, making it an effective solution for boost applications.

An AC/DC microgrid is a localized power distribution system that can operate independently or in parallel with the main grid. It is typically composed of distributed energy resources, energy storage devices, and power electronics converters that enable the system to manage power flow and voltage regulation. The main advantage of an AC/DC microgrid is its ability to operate autonomously during power outages or grid disturbances. It can also help improve the overall efficiency and reliability of the power system by reducing transmission losses and increasing local generation. In addition, it can incorporate renewable energy sources such as solar and wind power, which can contribute to the reduction of greenhouse gas emissions and promote sustainable energy development

1.2 MOTIVATION FOR SELECTION OF THIS PROBLEM

To enable effective integration of renewable energy sources into microgrids, there is a need for efficient and flexible power conversion technologies that can manage power flow and voltage regulation. The Landsman converter is a promising solution due to its ability to perform both boost and buck-boost operations, and its potential for integrating multiple energy sources and storage devices. However, while the Landsman converter has been studied extensively in recent years, there is still a need for further research on its performance in microgrid applications. This project aims to address this gap by designing and implementing a hybrid energy source based Landsman converter for AC/DC microgrid applications. The goal is to evaluate the converter's performance in terms of efficiency, power quality, and stability, and to assess its impact on the overall performance of the microgrid.

Overall, the motivation for this project is to contribute to the development of more efficient and sustainable energy systems by exploring the potential of the Landsman converter for microgrid applications.

1.3 OVERVIEW

In this work, the design and implementation of a hybrid energy source-based Landsman converter for AC/DC microgrid is carried out. The proposed converter can effectively integrate different renewable energy sources and energy storage devices into a microgrid, providing a stable and reliable power supply. The Landsman converter is a topology that combines the advantages of a boost converter and a buck-boost converter, making it suitable for various energy conversion applications. The primary objective of this project is to investigate the performance of the proposed hybrid energy source-based Landsman converter in a microgrid. It has to be conduct simulation and experimental studies to evaluate the converter's efficiency, power quality, and stability. Additionally, it should analyze the converter's impact on the microgrid's overall performance, including its ability to support grid-connected and islanded operations.

Overall, this project aims to contribute to the development of efficient and reliable hybrid energy systems for microgrid applications. The findings of this study can be used to inform future research and development in the field of renewable energy and power electronics.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

A literature survey on "Hybrid Energy Source Based Landsman Converter for AC/DC Micro Grid" would involve a critical analysis of scholarly literature on the design and performance of hybrid energy sources in the context of AC/DC microgrid systems. The Landsman converter is a key component in these systems, and its design plays a critical role in the performance of the overall system. The literature survey would explore the existing research and theoretical frameworks related to hybrid energy sources, Landsman converter design, and microgrid system integration. The survey would also identify gaps in the existing literature and areas for further research in this field. Some of the key areas that would be covered in this survey could include the use of renewable energy sources such as solar, wind, and hydroelectric power, energy storage technologies, power electronics, and control systems. By conducting a comprehensive literature survey, researchers can develop a better understanding of the current state of knowledge in this field, identify key trends and debates, and establish a foundation for their own research on hybrid energy source-based Landsman converters for AC/DC microgrids

2.2 MAJOR FINDINGS FROM LITERATURE SURVEY

Saima Ishaq et al., (2022) proposed that because of their greater operational efficiencies and low emission levels, distributed generating systems are becoming more and more popular. Distributed generators operate using a variety of micro sources, including fuel cells, micro turbines, batteries, and solar cells. DGs provide peak generation during peak load hours, when energy costs are high, and standby generation during system disruptions. Clusters of loads and concurrent distributed generating systems are combined to create microgrids in a specific local region. Microgrids can meet the demands for both power quality and system dependability

since they have a large power capacity and additional control flexibility. Voltage regulation and high-performance power control must be used for microgrid operation.

Adriel M. Rizzato Lede et al., (2017) discussed a system approach, or microgrid, is suggested in order to exploit the rising potential of distributed generation, which views generating and related loads as a subsystem. This strategy eliminates the need for central dispatch by involving local control over dispersed generation. Local reliability in a microgrid can be higher than the overall reliability of the power system during disturbances caused by islanding generation and loads. This program doubles the system's effectiveness. The present microgrid approach combines sources with loads, approves deliberate islanding, and utilizes readily available waste heat from power producing systems.

Shobha. S Kumbar et al., (2012) described According to the micro grid theory, a group of loads and micro sources work together to form a single, programmable system that supplies localized areas with both power and heat. This idea provides a cutting-edge foundation for describing how distributed generation works. The micro grid could be viewed as a managed power system cell by the utility. The micro grid can be tailored to the specific requirements of the customer, taking into account requirements for things like increased local reliability, decreased feeder losses, support for local voltages, increased efficiency through the use of waste heat, voltage sag correction, or features for an uninterruptible power supply, among other things. Low voltage (LV) distribution systems known as micro grids (PV arrays, etc.) combine energy storage with distributed energy resources (DERs) such microturbines, fuel cells, and solar panels. These systems are connected to the medium voltage (MV) distribution network, even though they have the ability to operate independently from the main grid in the event of issues with the upstream network. From the consumer's point of view, micro grids satisfy both electrical and thermal needs while also increasing local dependability, reducing emissions, enhancing power quality by sustaining voltage and reducing voltage dips, and possibly lowering energy supply prices. From the perspective of the power system, a controlled component is referred to be a "micro grid" if it can be operated as a single aggregated load or generator and, with sufficient compensation, as a modest supply of

power or ancillary services supporting the network. Therefore DERs and DR work together as closely as feasible to benefit both customers and grids in a micro grid. A microgrid uses a single, manageable system to supply local residents with both power and heat. This concept offers a novel prototype for the operation of distributed generating. Think of the utility microgrid as a power system cell that can be controlled. In the event of a microgrid fault, the main utility needs to be cut off from the distribution section soon away to protect loads. The client load on the microgrid affects the isolation. In certain circumstances, it may be necessary to protect the important loads using both sag compensation and isolation from the distribution system.

Adam Hirsch et al., (2018) analyzed the microgrid idea brings down the price and raises the dependability of small distributed generators. This idea's main objective is to accelerate awareness of the advantages offered by small distributed generators, such as their ability to generate waste heat when necessary. From a grid standpoint, microgrid is a preferable alternative since it accepts that the nation's distribution system is extensive, old, and will change gradually. Without the need to modify the distribution system, this concept allows for significant distribution generation penetration. The cost of solar photovoltaic generation and battery storage is dropping steadily, and they are swiftly closing in on conventional electricity sources in terms of affordability. Therefore, these technologies might become more widely used shortly. By balancing supply and demand locally and assuring liability and resilience against what look to be growing natural and man-made calamities, microgrids are perfectly adapted to handle this transition.

Baseem Khan et al., (2018) proposed the integration of significant amounts of microgeneration without disrupting the operation of the utility network is addressed by the microgrid concept. The distribution network subsystem or microgrid will disrupt the utility network less than conventional microgeneration if microgeneration and loads are effectively and intelligently coordinated. The microgrid may be able to separate from the main network and continue operating independently when there are problems, which helps to increase the user's experience with electricity quality. Hybrid energy systems are becoming more desirable for supplying electricity to rural areas in

all categories, including dependability, sustainability, environmental concerns, and developments in renewable energy technology. The ideal choice is to develop renewable energy sources like solar and wind energy to provide a dependable power supply with enhanced system efficiency and significant cost reduction. This is particularly true for people living in rural locations where grid extension is difficult. The ideal choice is to develop renewable energy sources like solar and wind energy to provide a dependable power supply with enhanced system efficiency and significant cost reduction. This is particularly true for populations living in distant locations where grid extension is problematic. The challenges of integrating renewables into the current conventional system are fascinating, and there is also an increasing need for renewable energy sources in large cities. Local loads are close to distributed generators; therefore, grid integration of renewable distributed generators must be steady and reliable in the future. While the majority of existing power plants have centralized management systems and remote power producing locations, renewable energy sources are typically distributed and connected to low- or medium-voltage networks close to the customer. Renewable energy sources can be used to generate dependable, sustainable power because energy shortages and outages increase along with increased power demand. The chapter will provide a comprehensive overview of the microgrid system, as well as how it functions and is managed.

Zeeshan Ahmad Arfeen et al., (2019) introduced A variety of important power conditioning interfaces and their related controls have been created with the development of DGs and microgrids for connecting various micro sources to the microgrid and eventually connecting the microgrids to conventional power systems. This connectivity significantly improves the autonomy of a microgrid in a grid-connected or islanded condition. Each micro source has the ability to generate current, supplying the grid with the most power in the first scenario. Without a robust grid and a steady system voltage, when the main grid is not correspondingly bigger or is simply disconnected due to the occurrence of a fault, the islanded mode of operation with additional supply-demand balancing requirements would be activated. To avoid overstretching any one entity, the distribution should ideally be proportional to their power ratings. For the installation of a microgrid, effective and efficient grid parameter

control approaches are required. Reverse power, or an imbalance between power generation and nonlinear load, is a concern with the use of distributed generating. The advantages and disadvantages of the current controllers are the main topics of this article. Additionally, the most recent developments in the regional power grid are reviewed, with a focus on energy storage technologies and renewable energy sources. The dependability and stability of the power flow between sources and consumers are also taken into account when utilizing a voltage source inverter.. The concept of a growing microgrid in islanding and grid-connected modes is shown using a number of controllers and a soft computing approach. Through this document, the reader immediately understands the application and context of the controller.

Jaime Prieto Thomas et al., (2016) discussed technical research in two key areas is required for the installation of distributed generators. The first is addressing the effects of distributed generators without significantly altering the conventional distribution system's control technique, and the second is coming up with a novel idea for using distributed generators. The latter strategy is what the microgrid concept is based on. A microgrid's installation has a lot of advantages. Microgrids are effective at integrating loads and dispersed energy resources. The operation policy of the distribution grid does not need to be altered because the micro grid is recognized as a "grid friendly entity" and has no detrimental effects on the connected distribution network. In the event of a problem, it can also operate independently. Due to the lack of a large central generator in a microgrid, supply and demand may become imbalanced in the event of significant interruptions. Microgrid also uses a variety of DERs. Despite maintaining energy balance, unwanted oscillation continues. In many nations, distributed generation (DG) is a top policy priority, and its future seems promising. The centralized electricity networks of today do not always easily accommodate DG, despite the fact that it can have a number of benefits. In order to integrate DG, this chapter examines electrical networks and the function of network regulation. The claim that DG can lower network costs is frequently made. However, networks frequently need to adjust to DG, which adds to the expense Even if the overall advantages of DG are favorable, higher network costs act as a deterrent for network operators from connecting DG. The chapter covers a range of regulatory measures for

removing this barrier and enhancing communication between network and plant operators. Even if DG has overall good effects, higher network costs act as a deterrent to network operators from connecting DG. The chapter explores a range of regulatory approaches to address this deterrent and enhance communication between network and plant operators.

Bing wang et al., (2022) described Mentoring and connector models are utilized for each microgrid component to increase system resilience. Peer-to-peer technology ensures that the microgrid can keep running even if a generator or component fails. Plug-and-play functionality means that a unit can be installed anywhere on the electrical system without requiring the controls to be re-engineered, which reduces the possibility of engineering errors. In order to reduce the effects of grid islanding and grid-connected mode switching on both large and microgrids, this essay will present a smart microgrid method. In this study, artificial intelligence (AI) and the droop control approach are used to construct an intelligent synchronous grid-connected control mechanism. Due to the frequency coefficient fluctuating simultaneously with the variation in the voltage drop coefficient, which lowers the volatility of DC voltage throughout the power regulation process, the conventional droop control technique has a lesser change in power reference value. The function of smooth switching of the minimum item in islanding and item is realized by the electrical amplitude error, stage view error, and the frequently used error between the two in accordance with the output voltage of the strength item and the minimal item. The online simulation platform has ultimately been used to create this micro grid operation control model. According to the results of a simulation, the suggested intelligent technique could provide dual-mode smooth switching and steady-state operation while also reducing the amplitude error, often error, and stage orientation error by, respectively, 61%, 78%, and 64%.

Octavian Bass et al., (2018) describes that A nation's economy is largely dependent on its access to reliable, high-quality electric electricity. Distributed energy supply satisfies the customers' need for electricity quality and supply. The majority of the distribution system's components, which are often situated near to the customer's

premises, are modest power generating and storage devices. The advantages of DERs include higher reliability, better power quality, and high energy efficiency due to the use of waste heat. As there is less pollution generation, it is a desirable alternative in terms of environmental issues. By reducing grid congestion, the need for new transmission and production, and the demand for services like voltage support and demand response, it also benefits the electric utility. A microgrid is an all-encompassing system. The DERs linked to the microgrid must be integrated. Furthermore, there are problems with grouping, controlling, and controlling DERs consistently and effectively. A distribution network's energy efficiency can be significantly increased by deploying energy storage systems (ESSs), and their appropriate siting, sizing, and use can enhance overall network performance. related to the expansion of the distribution network. The positioning, sizing, and use of the optimum ESS are summarized in this paper. It takes into account different grid scenarios, desired performance goals, practical tactics, different ESS kinds, and the benefits and drawbacks of the suggested systems and techniques. Flywheel energy storage (FES) also merits attention under particular distribution network conditions, despite the fact that batteries are often utilized as ESSs in a variety of applications, according to a systematic comparison analysis of ESS technological features. This study offers suggestions for relevant requirements or practices, appropriate ESS selection, intelligent ESS charging and discharging, ESS sizing, placement, and operation, and power quality issues. Additionally, this study identifies topics for further investigation into issues with establishing and implementing ESS installation plans, effective procedures, societal implications, and energy security.

E Dintwa et al., (2019) analyzed Grid instability results from integrating solar and wind turbine systems. One solution to this problem is the installation of a microgrid. Despite the fact that running a microgrid has several advantages, there are significant transmission line losses. A microgrid contains a number of units that can be employed in a house or a country. Home DC buses are connected to energy storage and renewable energy systems utilizing a variety of converter topologies to supply power to DC loads. Inverters are used to transmit power between AC and DC buses. On the AC bus, various coupling points are used to connect common and delicate

loads. The microgrid operates in island mode when there is a problem with the utility grid. The demand for various energy production techniques has been greatly enforced by the world's energy needs. By converting solar energy into non-renewable sources, integrated systems, often referred to as photovoltaic systems, are at the vanguard of this revolution. This is significant because it lowers the rates of consuming non-renewable resources and lessens reliance on fossil fuels. Due to the current energy demand, the depletion of fossil fuel reserves, and environmental consequences, researchers and specialists are growing more interested in integrating renewable energy from this source into networks. In this overview, the benefits of solar-grid integration are highlighted along with information on the outcomes and difficulties of integration, as well as the features of the solar system that make it suitable for integration. Both the utility side and the solar system side of the integration and compatibility issues between the two systems (solar and grid generations) are addressed. This review will help future projects incorporate solar-grid integration without encountering the same obvious challenges that currently present, and it will also provide information to researcher and scientists on the viability of solar-grid integration.

Ahmed Zayed AL Shaqsi et al., (2020) introduced Microgrids include renewable energy sources to cut down on fuel consumption and CO₂ emissions. The utilization of renewable resources is a challenging task due to their unpredictable nature, leading to a need for more controllable and adaptable renewable energy generators. Energy systems are constantly evolving due to technological advancements, alternative energy sources, demand, costs, and environmental effects. Fossil fuels have been the traditional energy source, but the focus has shifted towards modern technologies like wind and solar power. Although prices are rising, demand for renewable energy is increasing due to population growth, economic development, per capita consumption, and availability in remote areas. Energy storage can provide flexible electricity generation and delivery to meet consumer demand. By 2030, the energy storage capacity required is expected to quadruple, necessitating the use of specialized equipment and systems. This review study compares and evaluates current and future energy storage systems and technologies, such as flow batteries, super

capacitors, SMES, FES, PHS, TES, CAES, and HES. The aim is to help practitioners and decision-makers select the most advanced energy storage technologies for their grids and related uses. This study may be particularly useful for various stakeholders in the energy sector.

Bonu Ramesh Naidu et al., (2019) An AC/DC converter converts an AC voltage into DC power to power DC loads using typical AC power systems. Industrial drives also employ AC/DC/AC converters to regulate motor speed. Renewable resources are connected as distributed generators or ac microgrids to address the environmental problems with traditional power plants. In order to save energy and lower carbon dioxide (CO₂) emissions, more and more DC loads, such LED lights and electric vehicles, are being connected to AC power systems. When power can be generated locally utilizing renewable energy sources, long-distance high-voltage transmission is no longer required. Using DC/AC inverters, AC sources in a DC system must be converted to DC, and vice versa for AC loads connected to the DC grid.

Salomonsson et al., (2007) discussed the topic of using a DC power system to power delicate electronic loads is covered. The report includes measurement data from a lab setup and examines the difficulties in constructing DC power systems. The study demonstrates that fragile electronic loads can be powered via an AC/DC interface while still maintaining communication during grid transients. Less power conversion stages are required when using a DC power system to serve delicate electronic loads, which results in reduced losses than with a conventional AC uninterruptible power supply. Power electronic converters are used by DC systems to transform AC sources into DC, which is subsequently distributed using DC lines. DC distribution becomes a more desirable alternative in industrial parks that include both large motor-controlled loads and delicate electronic equipment. These power electronic converters' rapid response times allow for effective noise filtering and a dependable power supply. Two significant concerns with DC systems are also addressed by the employment of power electronic-based converters: dependable conversion from AC/DC/AC and the interruption of DC current under normal and fault conditions.

Barone et al., (2014) proposed that it is now impossible to add distributed generation in the traditional "fit and forget" fashion to existing passive distribution networks without having an influence on the network's stability and performance. It will be necessary for distribution networks to switch from a passive to an active mode of operation. In this context, the paper's authors propose a power management control approach with grid-ancillary services for a novel microgrid configuration they call a "Smart User Network," which is composed of several micro-source and storage system types connected by a common DC bus. A Smart User Network model created in the MATLAB/Simulink environment displays the most important numerical results.

F. D. Kanellos et al., (2019) proposed Modern mobile power sources known as distributed generations (DG) are utilized most frequently for small-scale power requirements and are situated close to the client. Utilizing embedded or local generation reserves has many benefits that guarantee universal access to electricity. Microgrid is the collective term for the load, local generation reserves, and other auxiliary units. The parallel network, which includes both local generation facilities and conventional power generation methods, is part of the energy management system and works in harmony with it. The idea of local generation as a whole eliminates routine AC to DC conversion between source and load. For local load requirements, renewable energy sources are used. In order to control load effectively and dynamically, non-conventional energy centers are interfaced with the grid using new power electronic technology-based converters. The hybrid AC/DC microgrid is discussed in this work in terms of grid linked operation, and a thorough analysis is done about the viability of the suggested system in real-time. Solar power modules, wind energy conversion systems, and batteries used for storage are examples of renewable energy sources.

Dasari Sekhar Babu et al., (2019) proposes the hybrid micro grids, which combine fuel cells and other power-smoothing technology with a variety of producing sources, including solar and wind, for practical utilities. As is common knowledge, ac power sources and dc loads are currently connected via ac grids and dc grids, respectively. Currently, we can see that both AC and DC are connected via lengthy

transmission lines, which have a variety of existing losses and other difficulties. Coming to these kinds of micro power grids allows for the optimization of transmission length and losses as well as the ability to run the micro grid autonomously in grid tidal position by employing the appropriate algorithms, we can synchronize the power sources and converters. According on the loading generations and load conditions, the coordination between the AC DC Grids fluctuates. Wind speed, sun irradiation level, temperature, and load irregularities are also taken into account. A tiny grid and hybrid microgrids have been proposed and modelled. The simulation findings demonstrate that, when the grid is run under the suggested circumstances, the system can continue to work steadily.

2.3 PROBLEM STATEMENTS

- The existing system has a single ac or dc grid with many dc-ac-dc or ac-dc-ac conversions. In order to simplify the processes of several reverse conversions in a single ac or dc grid and to make it simpler to connect various renewable ac and dc sources and loads to a power system, it is advised to employ a hybrid ac/dc microgrid.
- The integration of different types of energy sources such as wind, solar, and battery storage systems in microgrids can cause power quality issues like voltage fluctuations, harmonic distortions, and flicker. These problems may risk safety as well as the functionality of delicate microgrid equipment.
- The capacity of energy storage systems is one of the most critical factors in hybrid energy source based microgrids. The storage capacity should be able to meet the energy demands of the microgrid during peak hours and also during periods when renewable sources are not available.

2.4 EXISTING BLOCK DIAGRAM AND EXPLANATION

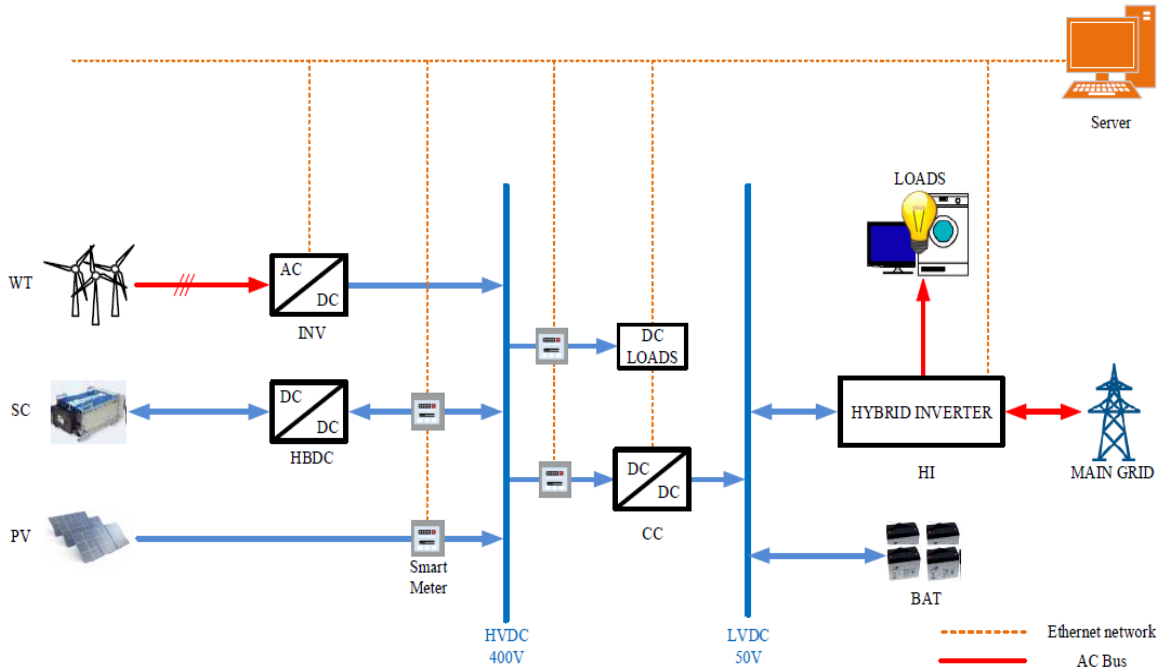


Fig 2.1 Existing Block diagram

The fig 2.1 shows an individual ac or dc grid's multiple dc-ac-dc or ac-dc-ac conversions using a hybrid ac/dc micro grid's block diagram. A multidirectional converter connects the ac and dc networks that make up the hybrid grid. In contrast to dc sources and loads, which are related to the dc network, AC sources and loads are connected to the ac network. Both dc and ac links can be used to connect energy storage systems. The proposed hybrid grid has two operational modes: grid-tied and independent. For efficient power transfer between dc and ac links and for reliable system operation under a variety of generating and load scenarios, coordination control algorithms are presented. System control and operation also take into account the erratic and intermittent nature of speed of the wind, irradiation level of solar, ambient temperature and load

2.5 DISADVANTAGE OF EXISTING SYSTEM

- High switching losses.
- THD is high.
- No of solar panels are high.
- Higher order ripple contents in the voltage.

2.6 STANDARD

The IEEE Standard adapted for this project are IEEE 1547 – 2018 and IEEE 936-1987.

IEEE 1547 – 2018: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces:

IEEE 936 - 1987: IEEE Guide for Self-Commutated Converters.

2.6.1 TERMINOLOGY

IEEE 1547-2018 is a standard developed by the Institute of Electrical and Electronics Engineers (IEEE) for interconnecting distributed energy resources (DERs) with electric power systems. This standard specifies the technical requirements for interconnection and interoperability of DERs, including renewable energy sources such as solar and wind, with the electric power grid. The standard also addresses safety, power quality, and grid support functions of DERs. IEEE 1547-2018 provides a framework for utilities, regulators, and manufacturers to ensure that DERs can be integrated safely and reliably into the electric power system, which is crucial for the ongoing growth of renewable energy and the transition towards a more sustainable energy future

IEEE 936-1987 is a guide for self-commutated electronic power converters. It provides guidance on the design, testing, and operation of these converters, which use components within the converter to accomplish commutation. The standard was

published by the IEEE in 1987 and is available for download from various libraries and online resources. This tutorial is intended for self-commutated electronic power converters, or converters whose internal components do commutation. In converters using turn-off-capable switching elements like transistors or gate-turn-off thyristors.

2.7 CONSTARINTS AND TRADE – OFF

CONSTARINTS:

1. **Cost:** The cost of the hybrid energy source-based Landsman converter system can be a significant constraint. It involves multiple components such as solar panels, wind turbines, batteries, inverters, and controllers. The cost of these components can be high, especially for high-capacity systems.
2. **Space:** The space required for installing the hybrid energy source system can also be a constraint. The system involves multiple components, and these components require adequate space for installation.
3. **Scalability:** The hybrid energy source-based Landsman converter system should be scalable, which means it should be able to accommodate additional components and energy sources as the energy demand increases. The design should be flexible enough to integrate new components into the existing system.
4. **Efficiency:** The efficiency of the system is another constraint. The system should be designed to maximize energy conversion efficiency and minimize energy loss

TRADE - OFFS:

1. **Reliability vs. Cost:** The reliability of the hybrid energy source-based Landsman converter system can be improved by using high-quality components, redundant systems, and backup power sources. However, these measures can increase the cost of the system.
2. **Energy Storage vs. Efficiency:** The system can be designed to store excess energy in batteries for use during periods of low energy production. However, energy storage can reduce the overall efficiency of the system due to energy conversion losses.
3. **Energy Source Diversity vs. Complexity:** The Landsman converter system can be created to use hydro, wind, and solar energy sources, among others. However, using several energy sources might make the system more complex and increase installation and maintenance expenses.
4. **AC/DC Conversion vs. Energy Loss:** The hybrid energy source-based Landsman converter system involves the conversion of energy from AC to DC and vice versa. The conversion process can lead to energy losses, which can reduce the overall efficiency of the system. However, the conversion process is necessary to integrate the different energy sources into the microgrid

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 INTRODUCTION

The aim of the present investigation is to develop a hybrid energy source-based Landsman converter for AC/DC grid. With the increasing demand for renewable energy sources, there is a need to develop efficient and reliable power converters that can integrate multiple energy sources into the power grid. The scope of this investigation is to design, simulate, and develop a prototype of a hybrid energy source-based Landsman converter for AC/DC grid. The hybrid energy source-based converter will be able to handle multiple energy sources such as solar and wind, and integrate them into the power grid seamlessly. The investigation will also aim to optimize the converter's design to improve its performance, efficiency, and reliability

3.2 OBJECTIVE

The objectives of the proposed work are as follows

- To give an efficient DC-DC conversion using LANDSMAN converter
- To provide quickly and effectively supply reactive power to ensure power system voltage stability in the micro grid.
- To improve power quality at the customer side
- To maintain voltage stability at grid.

3.3 SCOPE OF THE PROJECT

This work suggests a hybrid energy source-based landsman converter. To maintain a stable system under varying loads and resource conditions as well as the control mechanism, models are constructed for all converters. The hybrid grid can offer consumers dependable, superior-quality, and more effective power. For small, isolated industrial facilities that use wind turbine generators and PV systems as their primary power sources, the hybrid grid may be practical

3.4 METHODOLOGY

- The solar panel and wind energy conversion system (WECS) are the input sources.
- The wind energy conversion systems (WECS) and solar panel having Landsman converter are connected to the input DC line.
- A battery connected to the DC bus through a bidirectional DC/DC converter serves as energy storage.
- The Landsman converter is responsible for boost the voltage received from the input sources
- While solar and wind energy are available, the battery is charged through the use of a bidirectional converter, which operates as a buck converter.
- In the absence of input sources, the battery is discharged and the bidirectional converter functions as a boost converter
- The Digital Signal Processing and Controller (DS PIC microcontroller) is used to giving the gate pulse to the landsman converter, bidirectional converter and three-phase voltage source inverter.
- The three-phase voltage source inverter is used to convert the DC-AC supply to the load. The grid synchronization is achieved using hysteresis current controller

- To resemble different loads, a variable DC and AC load is connected to their DC and AC buses..

3.5 PROPOSED BLOCK DIAGRAM AND EXPLANATION

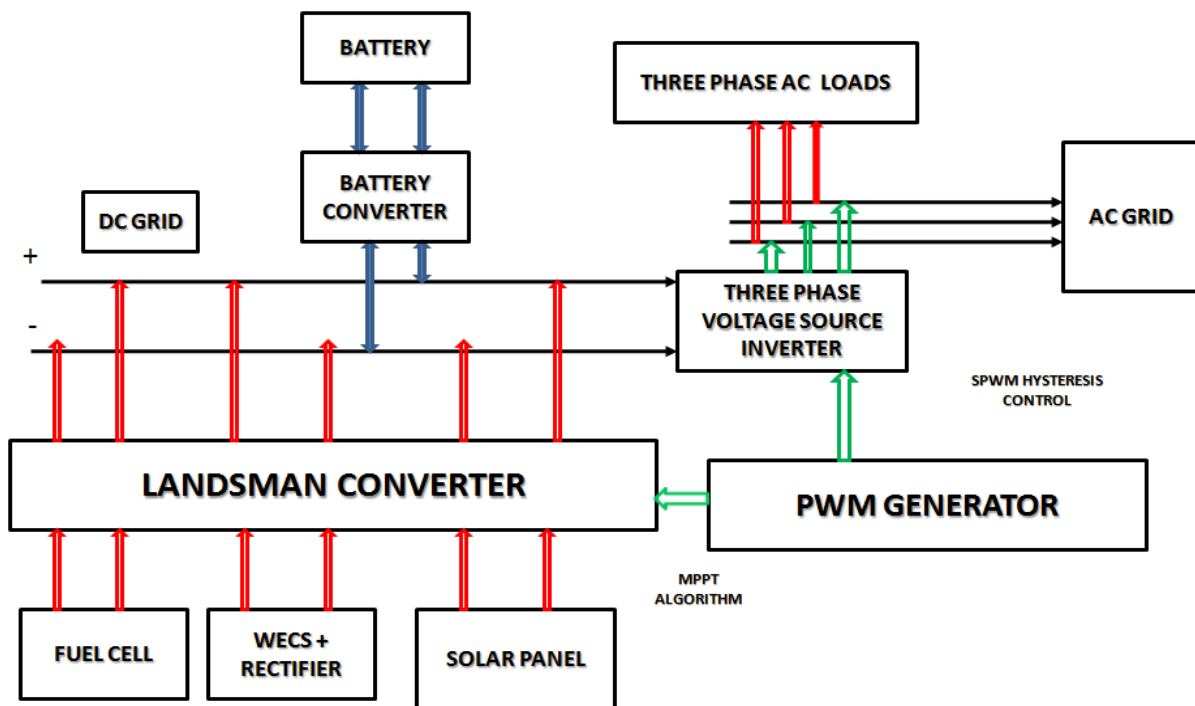


Fig 3.1 proposed Block diagram

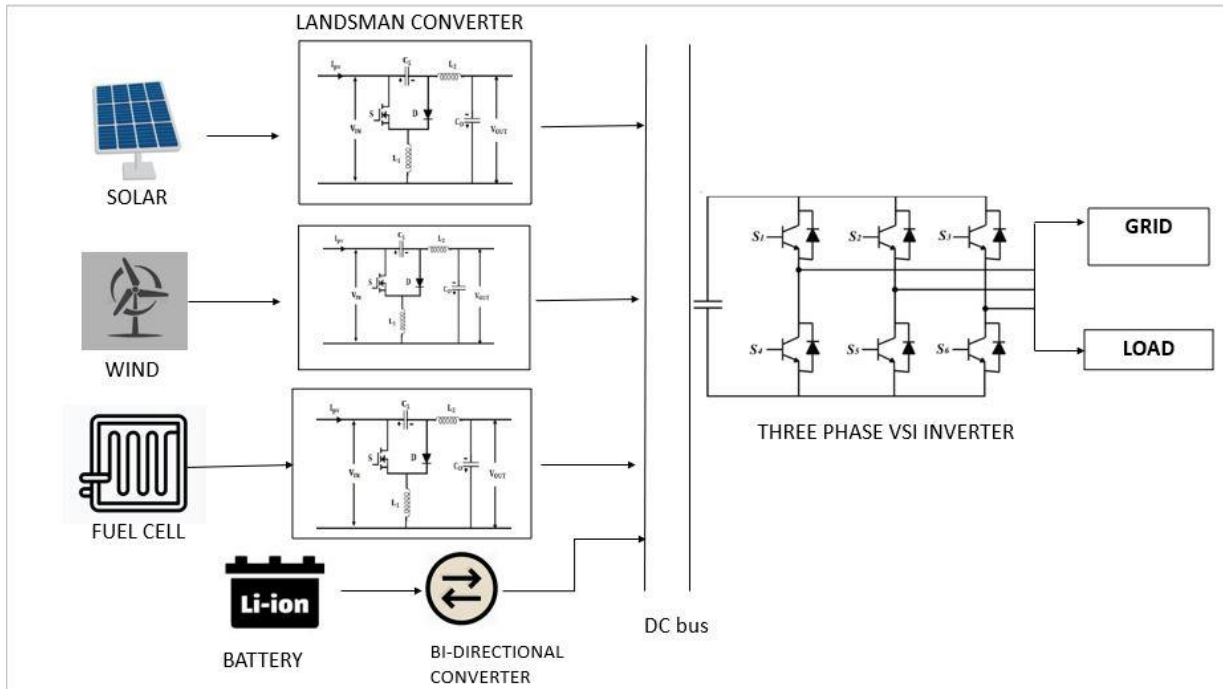


Fig 3.2 proposed circuit diagram

The proposed system involves connecting PV arrays to the DC bus via a boost converter to imitate DC sources. An AC bus is used to connect a DFIG wind generation system in order to simulate AC sources. Energy storage is achieved by linking a bidirectional DC/DC converter battery to the DC bus. Finally, a variable DC and AC load are connected to their respective DC and AC buses to imitate various loads as shown in Figure 3.1 and Figure 3.2

3.5.1 Solar Panel

Both series and parallel wiring is used to connect the solar panels. The power output of the panels varies due to variations in solar radiation and the surrounding temperature. A capacitor with the designation C is added at the PV terminal in order to reduce high frequency variations in the output voltage.



Fig 3.3 solar panel

3.5.2 wind generation system

The doubly fed induction generator (DFIG) is a type of induction motor that has a wound rotor and is powered by an electrical source at both the rotor and stator, hence the name. A DFIG is used in conjunction with an AC bus, a back-to-back AC/DC/AC PWM converter that is coupled to the rotor through slip rings, and a wind generation system.



Fig 3.4 wind energy system

3.5.3 DESIGN OF LANDSMAN CONVERTER

To reduce the strain on the power semiconductor device's current and voltage, the Landsman converter is designed to operate continuously in conduction mode (CCM) Figure 4.3 shows the Landsman DC-DC Converter's circuit diagram. By considering the two modes shown, its operation can be analyzed.

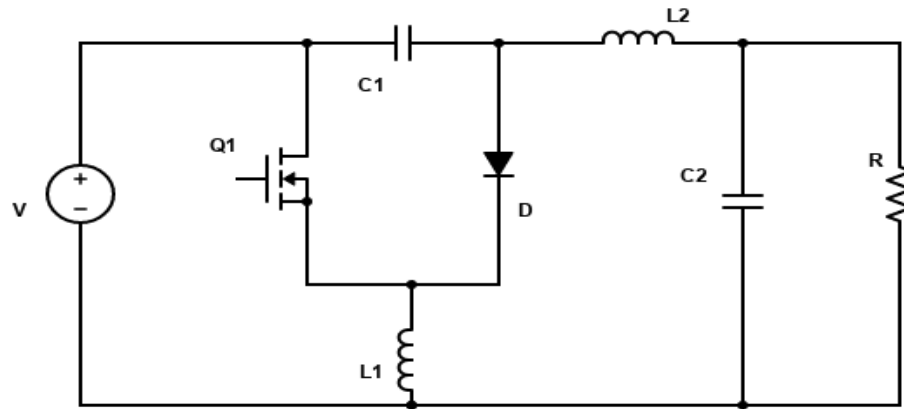


Fig 3.5 circuit diagram of landsman converter

i. Mode 1- when switch is ON

The circuit shown in Figure 4.4 is built around the voltage across the intermediate capacitor C_1 , which, when the switch is turned on, causes the diode to be reverse biased, resulting in V_{C1} . V_{C1} discharges through the switch, transferring energy to the inductor L and the output when the output voltage V_o is greater than the inductor current I_L flowing through the closed switch. Energy is sent to inductor L_1 by the input as V_{C1} falls, I_L rises.

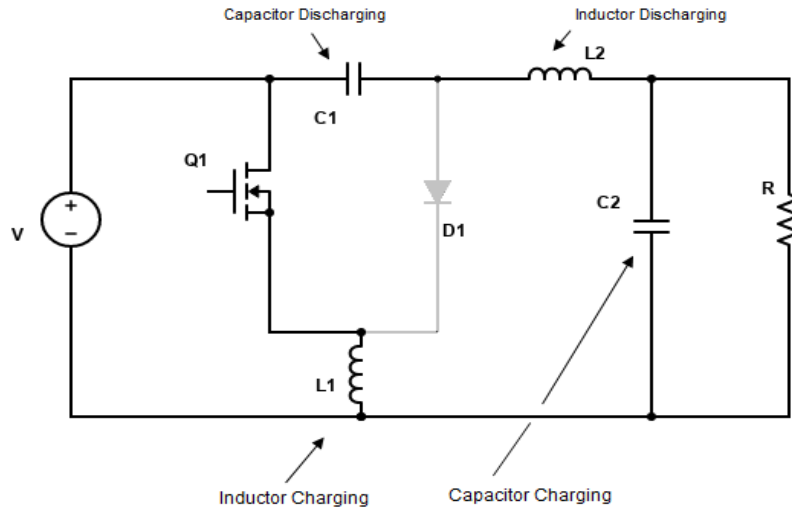


Fig 3.6 Mode I operation of Landsman Converter

ii. Mode 2- when switch is OFF

The circuit diagram in Figure 3 results from the diode conducting when the switch is in the "OFF" position because it becomes forward biased. Since the inductor current I_L now passes via the diode, the energy stored in Mode I is transferred to the output through the diode. Energy from the input and $L1$ is used simultaneously to charge $C1$ through the diode.

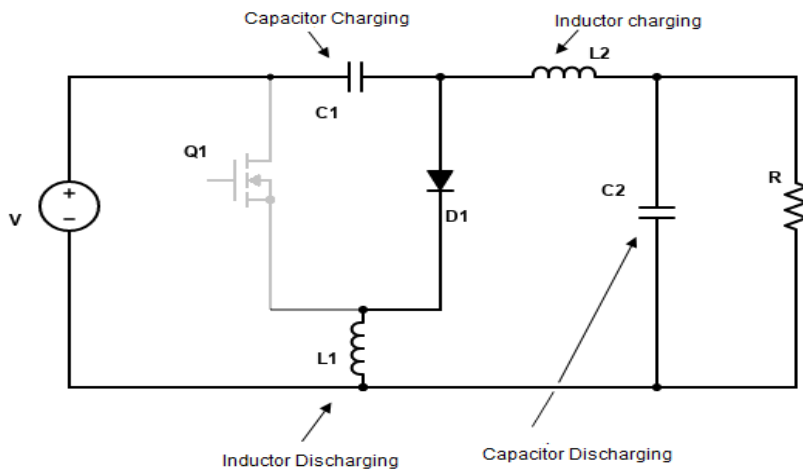


Fig 3.7 Mode II operation of Landsman Converter

3.5.4 Bidirectional Converter

When the system is operating autonomously, the bidirectional DC/DC converter is intended to maintain the steady DC bus voltage by charging or discharging the battery. Both power balancing and voltage stability depend heavily on the battery. The bidirectional converter is another name for the battery converter.

3.6 ADVANTAGE OF PROPOSED SYSTEM

- Reduced total harmonics distortion.
- Increased voltage stability.
- Quick response irrespective of the load.
- Voltage collapse prevention.

3.7 APPLICATION

- Power system application: STATCOM, UPFC, power quality, power conditioners, reactive power compensators, grid connected systems etc.
- AC and DC Motor drive applications

CHAPTER 4

SIMULATION RESULTS

4.1 MATLAB DESCRIPTION

Users can build user interfaces, handle matrices, plot functions and data, perform algorithms, and link their work with software developed in other programming languages including C, C++, Java, and Fortran using MATLAB. The fourth-generation programming language and environment for numerical computing, MATLAB, was created by MATHWORKS. Although MATLAB's primary purpose is for numerical computing, users can leverage symbolic computing skills by using the MUPAD symbolic engine, which is provided as an additional toolbox. The software package SIMULINK also enhances MATLAB's capabilities by providing users with graphical multi-domain simulation and Model-Based Design for dynamic and control systems.

4.2 SIMULINK

Simulink is a piece of software that facilitates multi-domain simulation and model-based design in a block diagram setting. It is equipped with the tools required to manage simulation, continuous testing, automatic code generation, embedded system verification, and system-level design. Simulink has a number of features, including a graphical editor, customizable block libraries, and solvers for modelling and simulating dynamic systems. The seamless integration of Simulink and MATLAB enables users to import MATLAB techniques into their models and export simulation results to MATLAB for further analysis.

4.3 OPEN LOOP ANALYSIS OF THE CONVERTERS

The open loop analysis for both the LANDSMAN and SEPIC converters is being conducted with the common input parameters shown in TABLE 4.1. This is being done in the MATLAB/Simulink platform, and the results are being compared to determine why the LANDSMAN converter outperforms the SEPIC converter in certain parameters, as outlined in this paper

TABLE 4.1 SPECIFICATIONS OF LANDSMAN AND SEPIC CONVERTER

Parameters	Value
Input Voltage	12V
Duty Ratio	0.6
Switching Frequency	25kHz
Load Resistance	100 ohms

4.3.1 Open loop analysis of SEPIC Converter

The open loop analysis for the SEPIC converter has been carried out as shown in Figure 4.1, and the results of the simulation have been presented in Figure 4.2 and Figure 4.3. These results will be used to compare the performance of the SEPIC converter with that of the LANDSMAN converter. With a duty cycle of 0.6 and a switching frequency of 25 kHz, a 12V input voltage is converted to an output voltage of 34V, exhibiting a voltage ripple of 1.00V and a voltage gain of 2.8

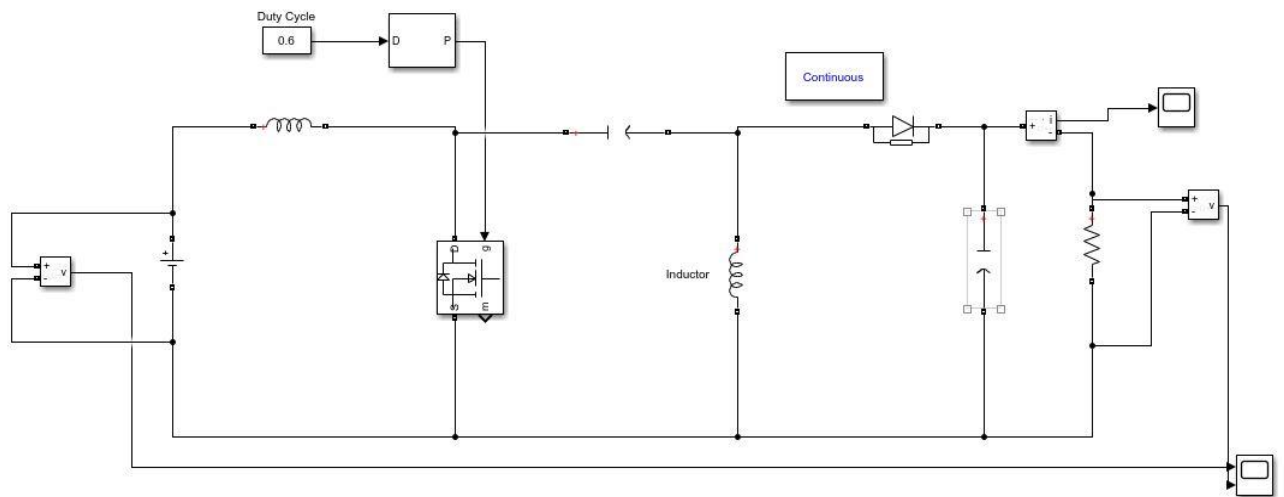


Fig 4.1 Simulink Model of SEPIC Converter

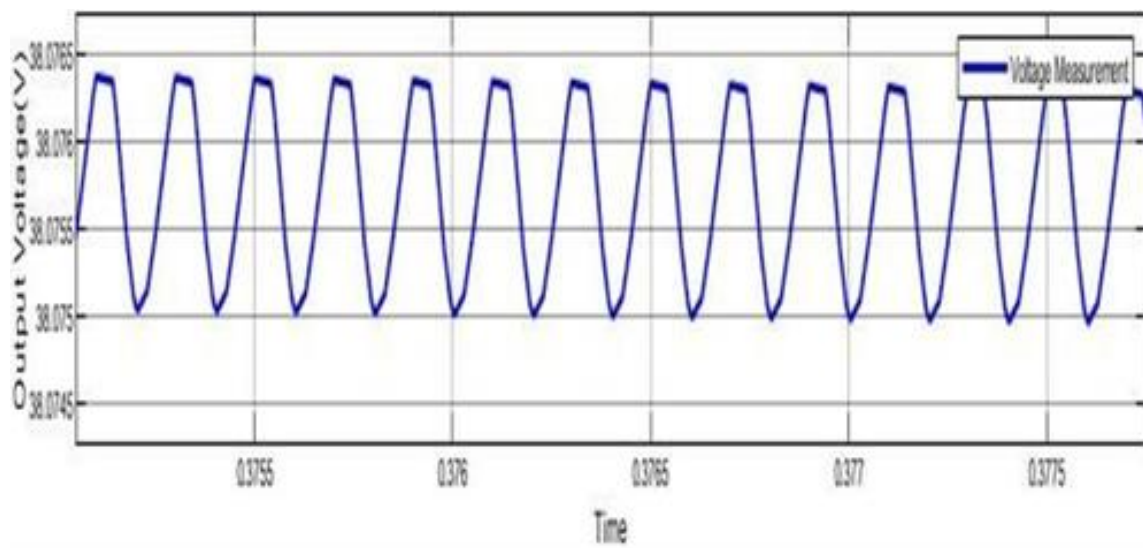


Fig 4.2 Voltage ripple waveform of SEPIC Converter

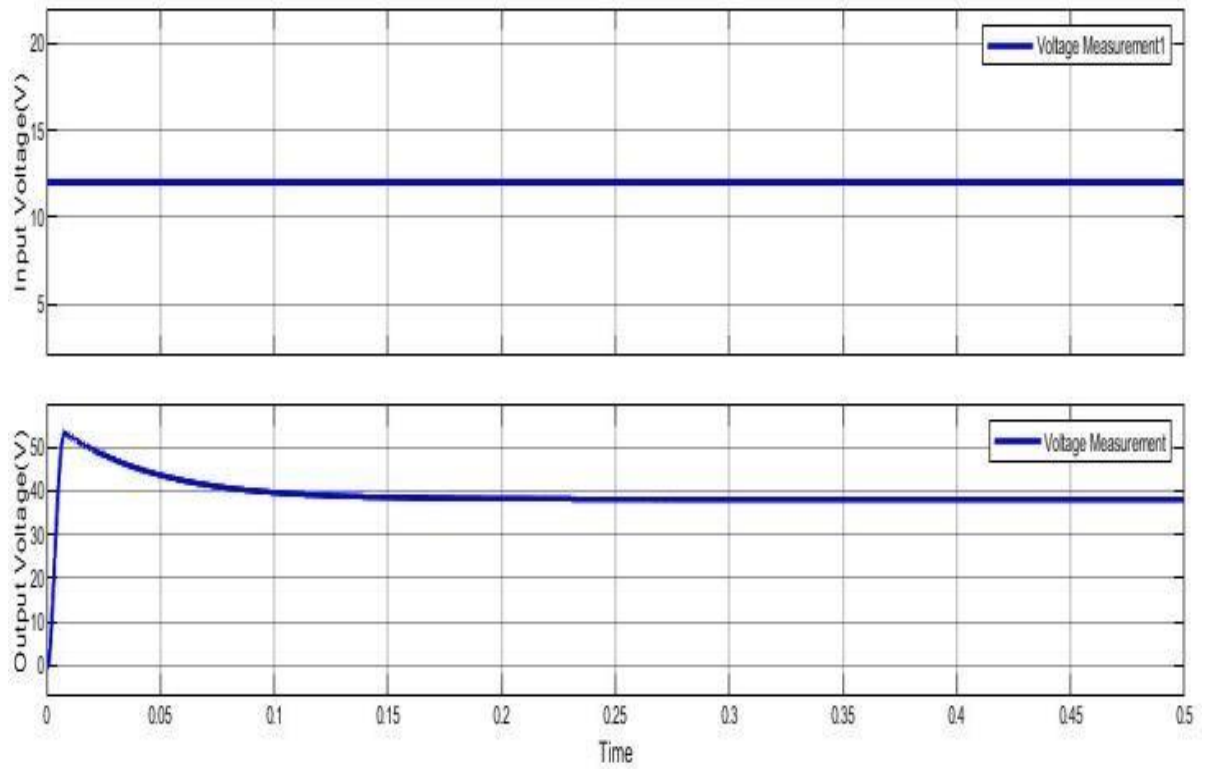


Fig 4.3 Input and output voltage waveform of SEPIC CONVERTER

4.3.2 Open loop analysis of LANDSMAN Converter

The Landsman converter's open loop analysis was conducted using the same specifications that were applied to the SEPIC converter are shown in Figure 4.4, and the resulting data is displayed in Figures 4.5 and 4.6. By operating at a switching frequency of 25 kHz and a duty cycle of 0.6, the system converts a 12V input voltage into an output voltage of 38V, resulting in a voltage ripple of only 0.01V and a voltage gain of 3.1

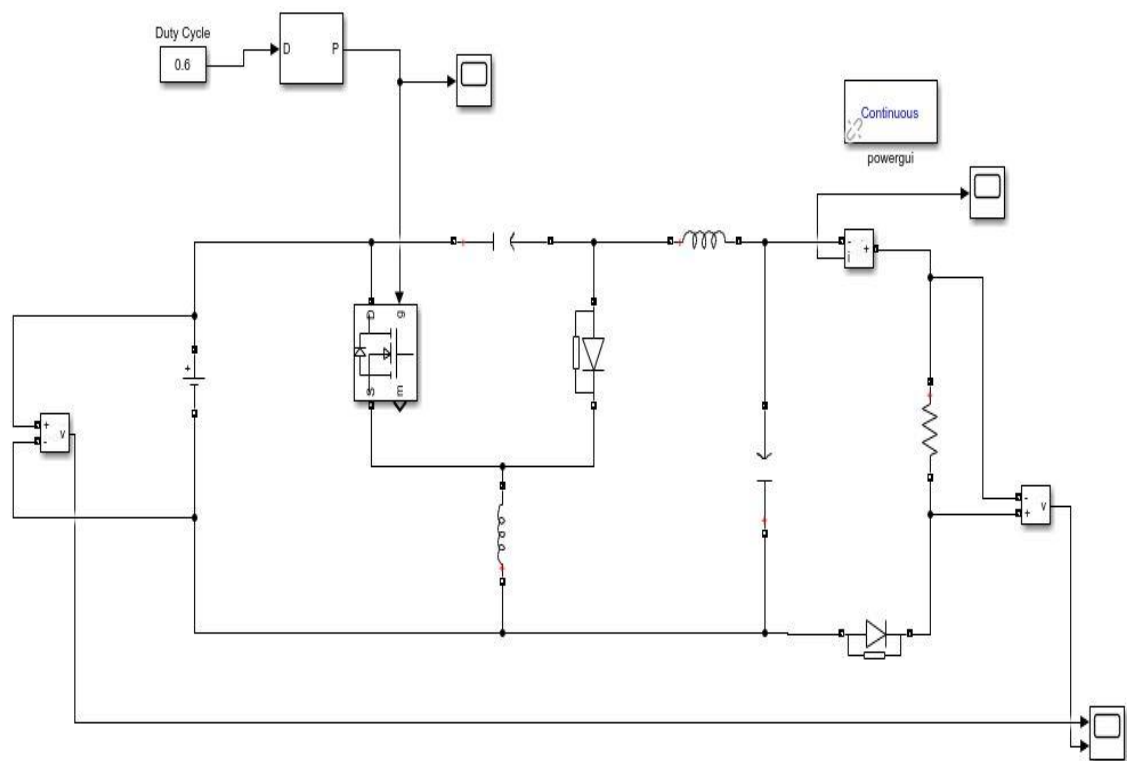


Fig 4.4 Simulink model of landsman converter

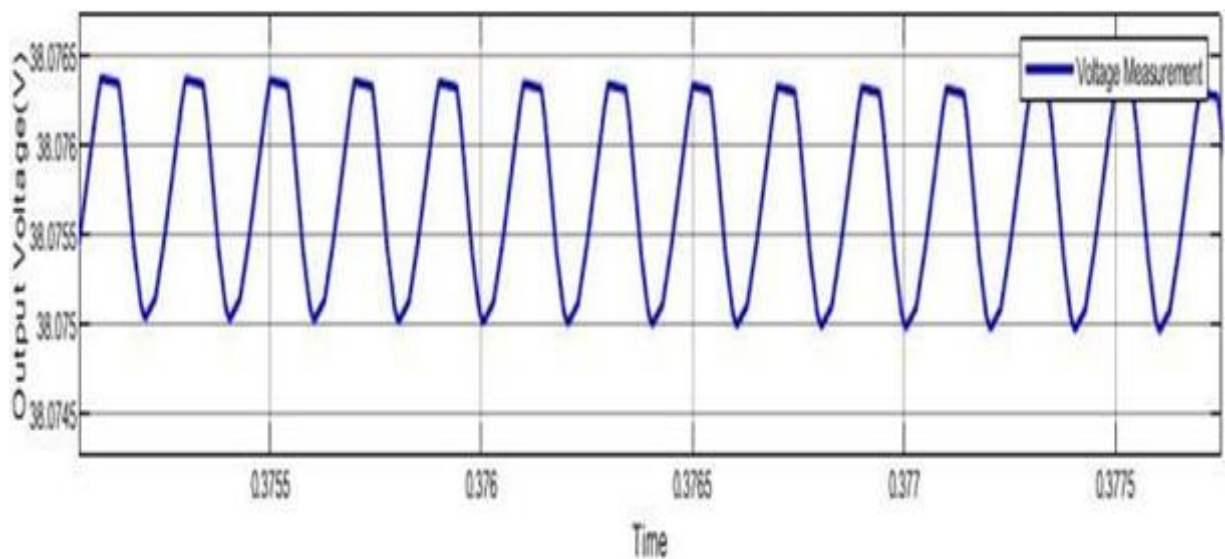


Fig 4.5 Voltage ripple of landsman converter

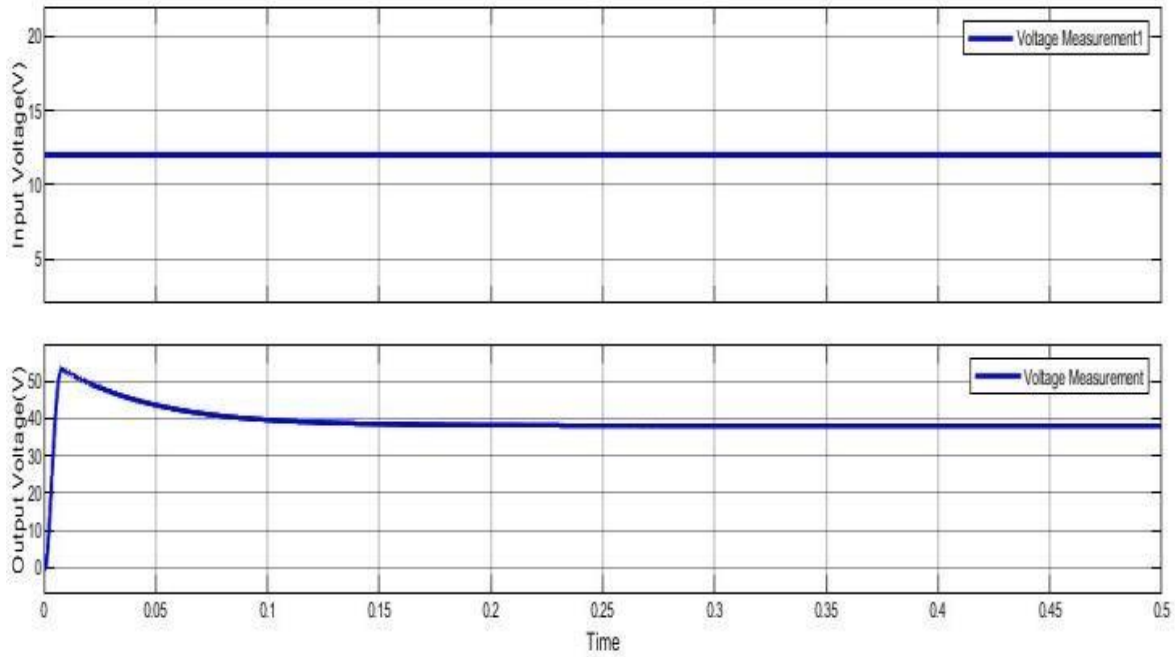


Fig 4.6 Input and Output Voltage waveforms of landsman converter

By conducting MATLAB/Simulink simulations for both the Landsman and SEPIC converters, the results were compared, and the enhancements accomplished through the utilization of the Landsman converter were summarized in Table 4.2.

TABLE 4.2. PERFORMANCE COMPARISON OF TWO CONVERTERS

Converters	Input (V_{in})	Output (V_o) $V_o = (1+D)/(1-D) \cdot V_{in}$	Voltage ripple(V)	Voltage gain(V)
Landsman converter	12	38	0.01	3.1
SEPIC converter	12	34	1.00	2.8

Moreover, the comparison carried out enables the identification of the areas where the Landsman converter surpasses the SEPIC converter. Hence, closed-loop analysis of the Landsman converter will be conducted, with and without the inclusion of a PI controller

4.4 CLOSED LOOP ANALYSIS OF LANDSMAN CONVERTER

The Landsman converter undergoes testing using a DC voltage source input set at approximately 12V, with gradual increments in the input value over time, while simultaneously monitoring the output variations with and without the application of a PI controller.

4.4.1 WITHOUT PI CONTROLLER

Initially, a MATLAB simulation of the Landsman converter was performed without utilizing a PI controller, which is shown in Figure 4.7

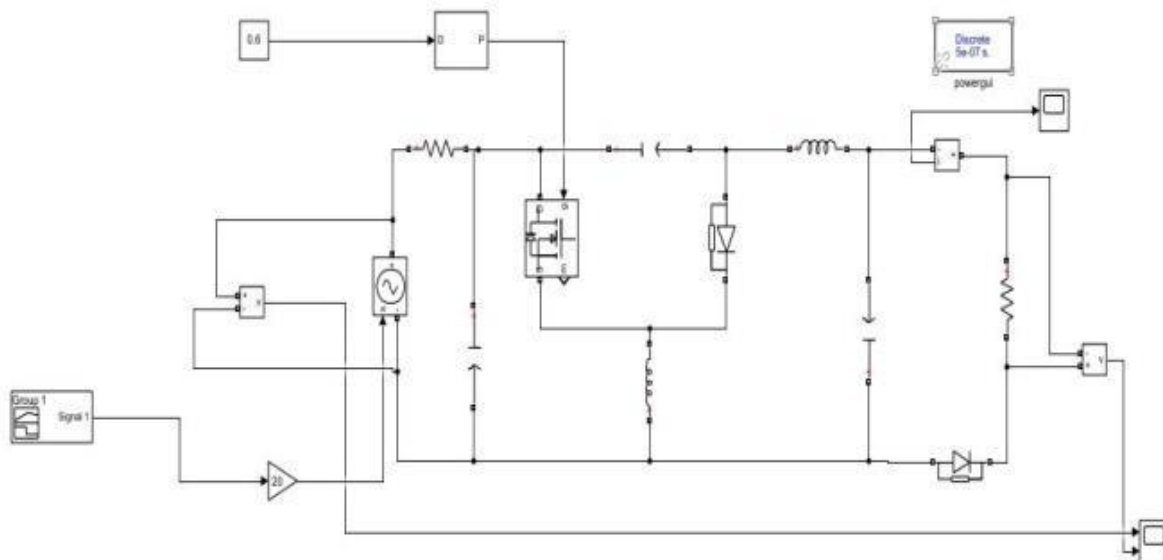


Fig 4.7 Simulink model of landsman converter without PI controller

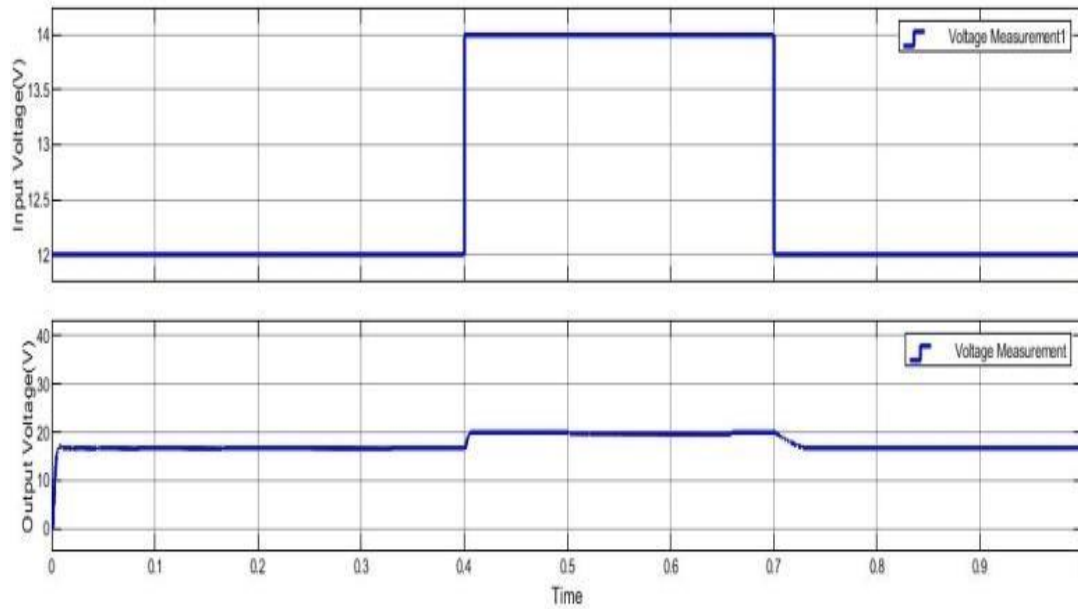


Fig 4.8 Input and output voltage waveform without PI controller

During the time period between $t=0.4$ and 0.7 , the input voltage of the Landsman converter was increased from 12V to 14V, which resulted in the output voltage rising from 16V to 20V, as shown in Figure 4.8. This change in input voltage caused the observed variation in output voltage.

4.4.2 WITH PI CONTROLLER

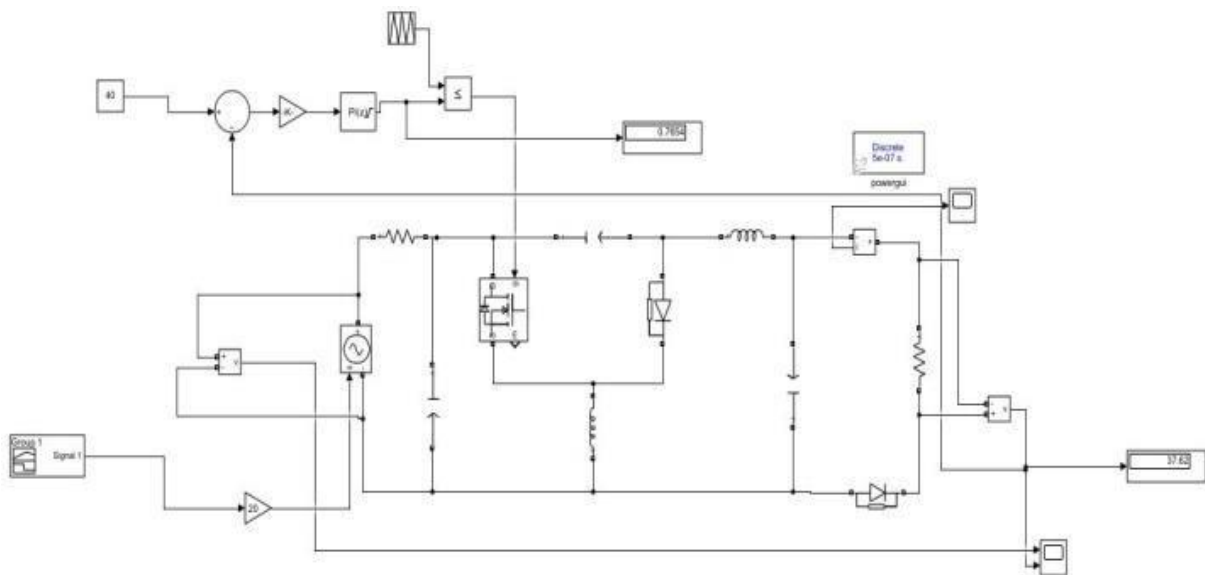


Fig 4.9 Simulink model of landsman converter with PI controller

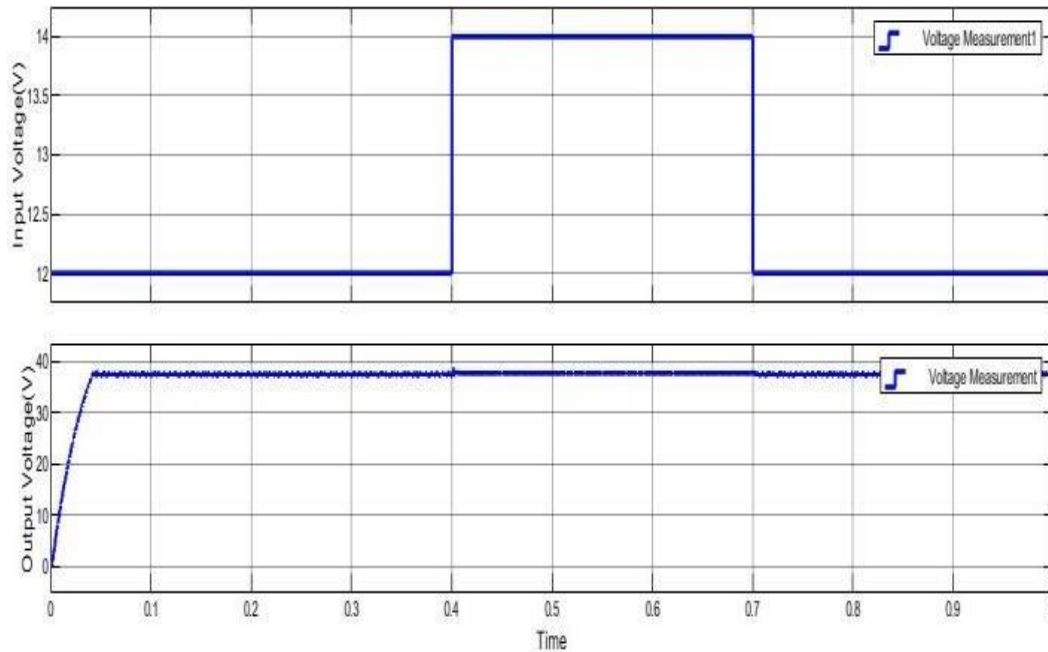


Fig 4.10 Input and output voltage waveform with PI controller

The Landsman converter was simulated with closed-loop control using PI controller in MATLAB Simulink, as depicted in Figure 4.9. The input voltage was raised from 12V to 14V during the time period between $t=0.4$ and 0.7 . With the utilization of a PI controller with $P = 32$, $I = 0.1$, and a gain of $1/100$, the output voltage exhibited no variation and remained constant throughout the increase in input voltage, as illustrated in Figure 4.10

CHAPTER 5

HARDWARE IMPLEMENTATION AND RESULTS

5.1 INTRODUCTION

The hardware implementation of a hybrid energy source-based Landsman converter involves the use of power electronics components, such as switches, capacitors, and inductors. The converter works by controlling the flow of energy between the energy sources and the load, thereby ensuring a consistent and stable power supply. This implementation involves various design considerations, such as the selection of appropriate power electronics components, control strategies, and the optimization of the converter's efficiency. These systems can provide a reliable and stable source of power while reducing the reliance on fossil fuels, thereby helping to meet the world's growing energy demand sustainably

Furthermore, the hardware implementation can also help to improve grid stability by reducing the impact of intermittent renewable energy sources on the grid. This is achieved through the converter's ability to control the power flow and maintain a stable grid voltage and frequency. Overall, the implementation of a hybrid energy source-based Landsman converter for AC/DC grids has the potential to play a significant role in the integration of renewable energy sources into the grid, thereby contributing to a more sustainable and reliable energy future

5.2 HARDWARE COMPONENTS

The hardware components of modern electronic systems are made up of a variety of intricate components that work together to perform a specific task. These components include the landsman converter, bidirectional converters, inverters circuit, and PIC microcontroller circuits, which are all constructed using inductors, capacitors, diodes and power electronic switching devices like MOSFETs. These devices are responsible for the efficient transfer and conversion of electrical energy within the system, enabling it to perform its intended function. The interplay of these hardware components is a

complex process that requires careful design and implementation to ensure optimal system performance

5.2.1 Digital Signal Peripheral Interface Controller

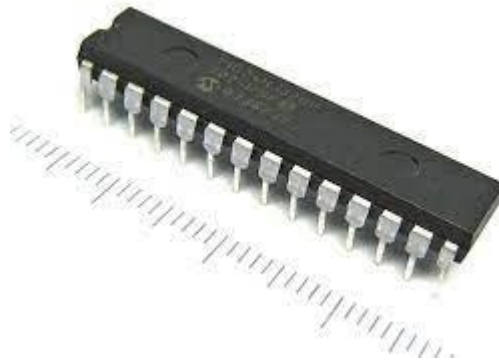


Fig 5.1 PIC microcontroller

DS PIC microcontrollers are commonly used for generating gate pulses in power electronic applications. The high-speed digital signal processing capabilities of the DS PIC microcontrollers make them ideal for controlling the timing and frequency of gate pulses. These microcontrollers can be programmed to generate pulse width modulation (PWM) signals, which are commonly used to control the power output of DC-DC converters, inverters, and other power electronic circuits. The DS PIC microcontrollers can also be programmed to generate various types of gate drive signals, including complementary, push-pull, and floating signals, depending on the specific application requirements. The ability of the DS PIC microcontrollers to generate precise and accurate gate pulses is essential for achieving optimal performance and efficiency in power electronic systems.

5.2.2 LANDSMAN CONVERTER

The Landsman converter is a type of DC-DC converter that operates by using a capacitor to transfer energy from the input voltage source to the output load as shown in figure 5.2. The parameters of the Landsman converter circuit include the input voltage (V_{in}), output voltage (V_{out}), switching frequency (f_s), duty cycle (D), output current (I_{out}), and capacitor value (C). The input voltage is the voltage applied to the input of the converter, while the output voltage is the voltage delivered to the load. The switching frequency is the rate at which the converter switches between the on and off states, while the duty cycle is the percentage of time the switch is on during one switching cycle. The output current is the current delivered to the load, and the capacitor value determines the amount of energy that can be stored and transferred between the input and output stages. The values of these parameters are crucial for designing and optimizing the performance of the Landsman converter circuit

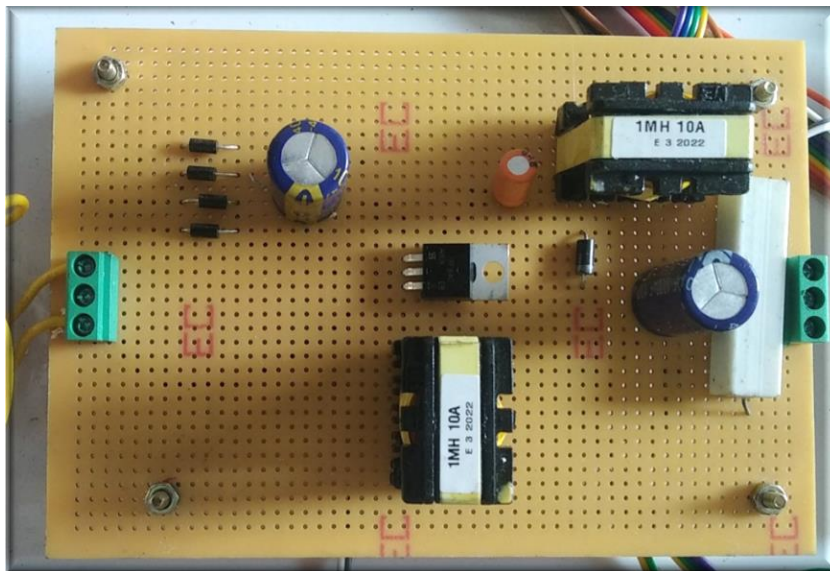


Fig 5.2 Hardware Circuit of Landsman Converter

5.2.3 BI-DIRECTIONAL CONVERTER

A bidirectional converter circuit with two MOSFETs, one capacitor, and one inductor is a type of DC-DC converter as shown in figure 5.3 that allows energy to flow in both directions between the input and output stages. This circuit is commonly used in applications such as battery charging, energy storage systems, and renewable energy systems. The circuit consists of two MOSFETs (Q1 and Q2), one inductor (L), one capacitor (C), and two diodes (D1 and D2). The arrangement of MOSFETs is such that they face each other, with Q1's source connected to the positive input voltage, and Q2's source connected to the negative input voltage. The inductor is positioned between the two MOSFETs' drains, while the capacitor is connected across the output load. When Q1 is activated, current flows through Q1, the inductor, and the output load, with the capacitor charging. Once Q1 is deactivated, the energy stored in the inductor flows through D2 and the capacitor to the output load. Similarly, when Q2 is activated, the energy stored in the capacitor flows through D1 and the inductor to the output load, and when Q2 is deactivated, the energy stored in the inductor flows back into the capacitor through D1.

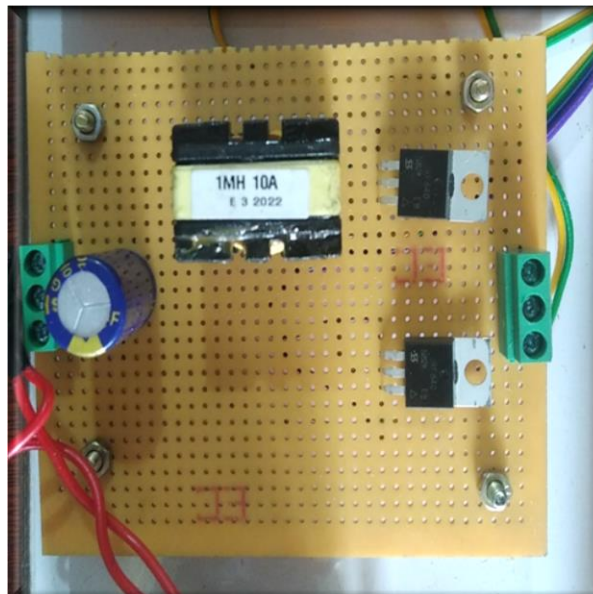


Fig 5.3 Hardware Circuit of Bidirectional Converter

5.2.4 SINGLE PHASE INVERTER

The circuit uses four MOSFETs (M1 through M4) to create a single-phase inverter which is shown in figure 5.4. The inductor (L1) is used to smooth out the output voltage and reduce harmonic distortion.

The LM324 op-amp is used as a comparator to generate the PWM signal that controls the MOSFETs. The op-amp compares a triangle wave generated by the oscillator circuit (composed of R1, R2, C1, and C2) with a variable DC voltage level, which is set by the potentiometer (RV1). The output of the op-amp is fed into the gate of each MOSFET to turn them on and off.

this is a simplified circuit, and in practice, additional components may be required for proper operation, such as snubber circuits to suppress voltage spikes, gate drive circuits to boost the gate voltage of the MOSFETs, and feedback circuits to regulate the output voltage. Additionally, proper precautions must be taken for thermal management and safe operation of high voltage and current circuits

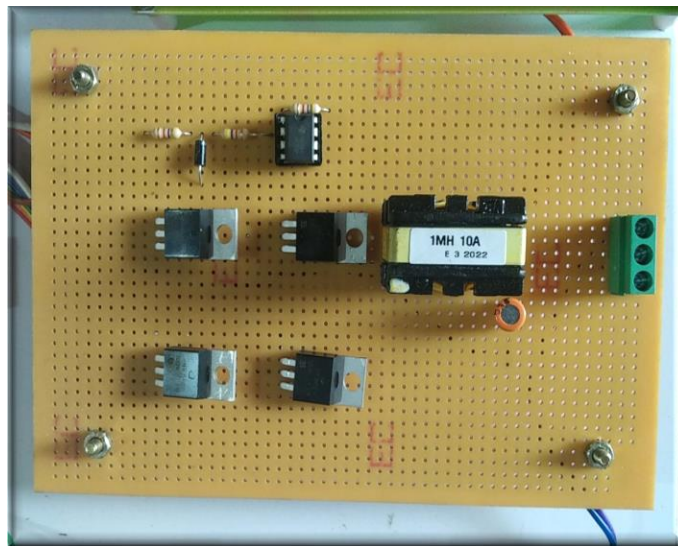


Fig 5.4 Hardware Circuit of Single-Phase Inverter with LM324 op-amp

5.3 HARDWARE KIT AND EXPLANATION



Fig 5.5 Hardware kit

The hardware implementation of a Landsman converter that utilizes a hybrid energy source for an AC/DC grid is shown in figure 5.5. In this system, solar panels and wind energy conversion systems (WECS) serve as input sources as based on **IEEE 1547 – 2018: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces** and are each accompanied by a distinct Landsman converter as per IEEE Standard of **IEEE 936 - 1987: IEEE Guide for Self-Commutated Converters**. A bidirectional DC/DC converter and battery are connected to the DC bus in order to store energy. The "Digital

Signal Processing and Controller" microcontroller is utilized to produce gate pulses for the converters, which are then transmitted to the switches of the Landsman converter, bi-directional converter, and single-phase voltage source inverter. The Landsman converter is responsible for amplifying the voltage received from the input sources. When solar and wind energy are accessible, the battery is charged through the use of a bidirectional converter, which operates as a buck converter. Conversely, in the absence of input sources, the battery is discharged and the bidirectional converter functions as a boost converter. The DC voltage is transmitted to the single-phase inverter, which is equipped with an LC filter. The single-phase voltage source inverter then transforms the DC supply into AC and dispenses it to the load. To simulate different loads, grid synchronization is carried out while connecting variable DC and AC loads to their respective DC and AC buses

5.4 HARDWARE RESULTS

Hardware results can be obtained by analyzing the input and output signals of various components of a hardware kit, such as converters and inverters. The input signal represents the electrical input that is fed into the component, while the output signal represents the electrical output that is generated by the component. By analyzing the waveform, frequency, voltage level, and other characteristics of the input and output signals, engineers can evaluate the performance of the component and identify any potential issues or areas for improvement. These results are essential for optimizing the design and performance of hardware systems and ensuring their reliability and efficiency.

The input and output voltage for Landsman has been measured and is displayed in both Figure 5.6 and Figure 5.7 and output voltage of single-phase inverter is measured as shown in Figure 5.8



Fig 5.6 Input voltage of Landsman converter



Fig 5.7 Output voltage of Landsman converter

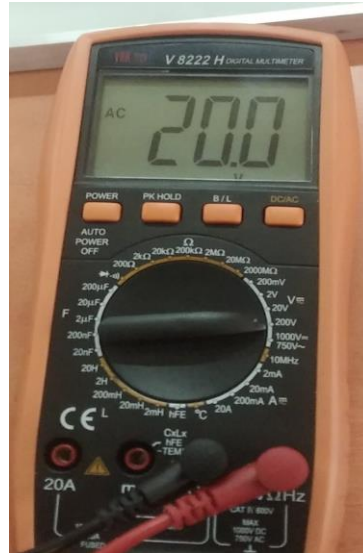


Fig 5.8 Output voltage of Single-phase Inverter

After the hardware is implemented, the output measurements are obtained. Figure 5.9 illustrates the waveform input voltage of 12V supplied to the Landsman converter from the energy source

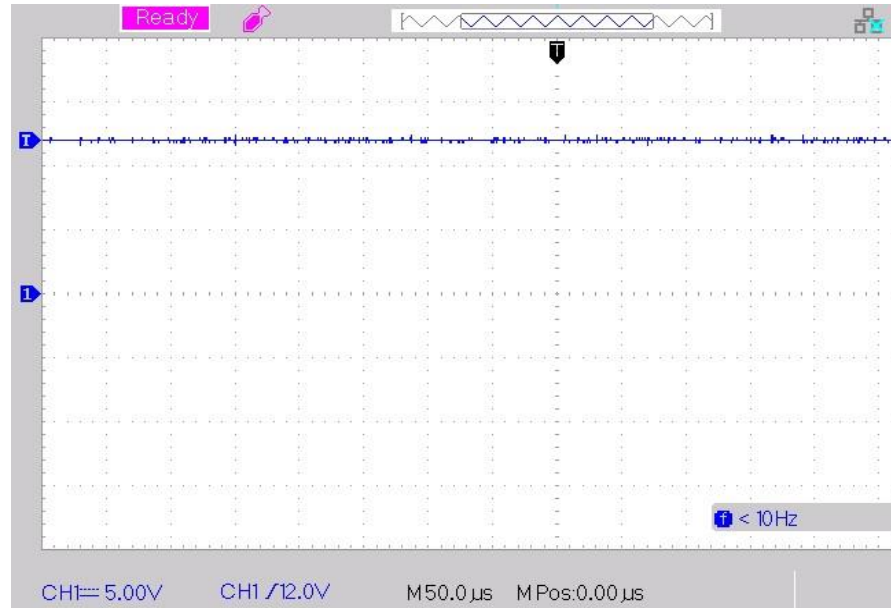


Fig 5.9 waveform of landsman converter input voltage

The voltage waveform of around 32V is obtained at the output terminal of the Landsman converter is shown in Figure 5.10

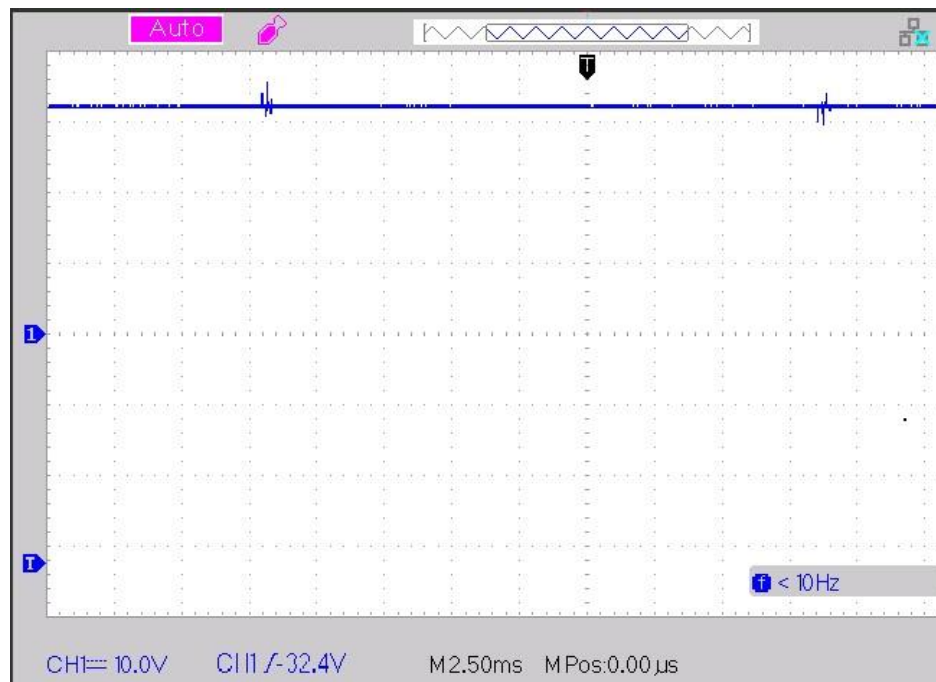


Fig 5.10 Waveform of Landsman Converter Output Voltage

The AC voltage waveform of 20V output is taken from the single-phase inverter is shown in figure 5.11.

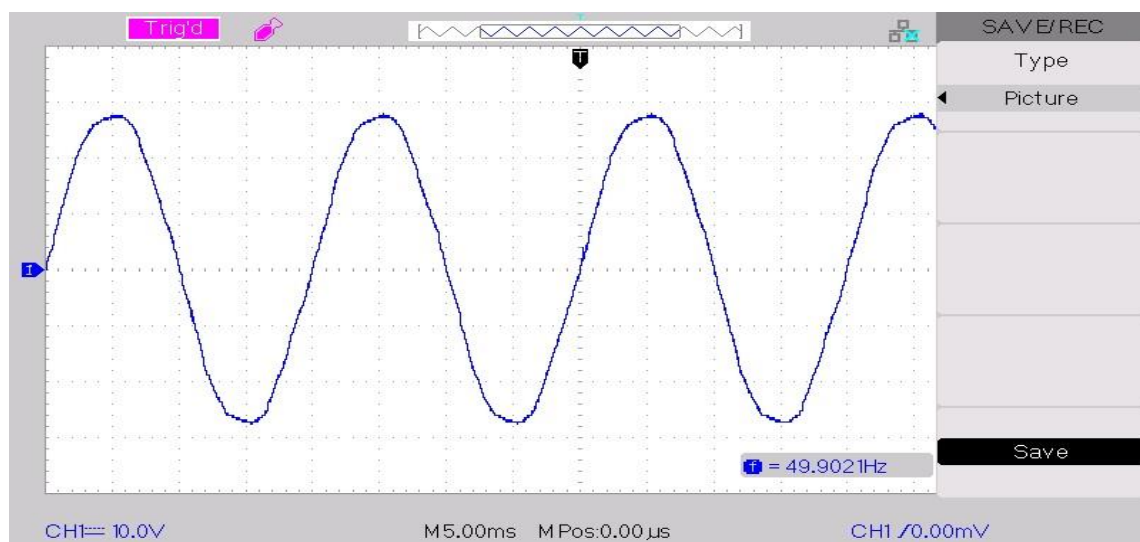


Fig 5.11 Waveform of Single-Phase Inverter Output Voltage

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

In this project, performance analysis of proposed converter is carried out by comparing the Landsman converter with the existing SEPIC converter using MATLAB/SIMULINK. The converters are provided with a 12V input voltage and operate with a duty cycle of 0.6 and a switching frequency of 25 kHz. Upon comparing the results, it was observed that the Landsman Converter produced an output voltage of 38V with a voltage ripple of only 0.01V and a voltage gain ratio of 3.1, while the SEPIC Converter provided an output voltage of 34V with a voltage ripple of 1.00V and a voltage gain ratio of 2.8. These findings enabled the identification of the areas where the Landsman converter outperforms the SEPIC converter. In addition, a closed-loop analysis was conducted to compare the performance of the Landsman converter with and without a PI controller. Initially, a MATLAB simulation of the Landsman converter was performed without utilizing a PI controller. During the time period between $t=0.4$ and 0.7 , the input voltage of the Landsman converter was increased from 12V to 14V, which resulted in the output voltage rising from 16V to 20V. Then Landsman converter was simulated with closed-loop control using PI controller Where the input voltage was raised from 12V to 14V during the time period between $t=0.4$ and 0.7 . With the utilization of a PI controller with $P = 32$, $I = 0.1$, and a gain of $1/100$, the output voltage exhibited no variation and remained constant throughout the increase in input voltage.

Further, the hardware implementation is carried out. After the hardware is implemented, the output measurements are obtained the input voltage of 12V supplied to the Landsman converter from the energy source and got a voltage of around 32V is measured at the output terminal of the Landsman converter and this DC output is given to the inverter circuit and AC voltage output of around 32V is taken from the single-phase inverter. Overall, the implementation of this project has the potential to

significantly contribute to the development of sustainable and efficient microgrids for power distribution in remote and off-grid areas.

6.2 SCOPE FOR FUTURE WORK

- **Performance optimization:** There is a scope for further optimization of the converter's control algorithm to improve the microgrid's performance in terms of energy efficiency, power quality, and stability.
- **Integration of more renewable energy sources:** The converter can be extended to accommodate more renewable energy sources like biomass, geothermal, and tidal energy, increasing the microgrid's renewable energy penetration.
- **Investigation of the environmental benefits:** Additional investigation into the ecological advantages of the Landsman converter, which relies on a combination of energy sources, can be performed. This could include exploring its capacity to decrease the amount of greenhouse gas emissions and its role in helping to alleviate the impact of climate change

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