Smart Control and Operation of Inverters for Distributed Energy Resources

YASIR MANZOOR	Bhagwant University, ajmer
ADITYA SHARMA	Bhagwant University, ajmer
GAURAV MATHUR	Bhagwant University, ajmer
GULZAR AHMAD DAR	Bhagwant University, ajmer

Abstract

This research aims to explore how smart inverters and voltage source converters (VSCs) can effectively control and operate distributed energy resources (DERs) like solar panels, batteries, and plug-in hybrid electric vehicles (PHEVs). The focus is on addressing challenges in smart grids by optimizing the functions of VSCs and smart inverters and enhancing microgrid operations. Specifically, the study concentrates on the potential of smart inverters for future microgrids, examining their applications in both grid-tied and autonomous modes.

In grid-tied mode, smart inverters and VSCs are utilized to integrate DERs such as solar panels and batteries, ensuring the system receives appropriate power through control of real and reactive power output. In autonomous mode, smart inverters play a crucial role in maintaining voltage and frequency levels, managing load fluctuations, and distributing power evenly among connected devices. However, operational control of microgrids remains a significant challenge

Keywords: VSCs, microgrid, single smart inverter, multiple smart inverters, DER, PHEVs

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1. INTRODUCTION

1.1 Background

The integration of distributed energy resources (DERs) such as solar panels, batteries, and plug-in hybrid electric vehicles (PHEVs) into the electrical grid has revolutionized the energy landscape. The increasing penetration of these resources necessitates advanced control systems to ensure grid stability, reliability, and efficiency. Smart inverters and voltage source converters (VSCs) have emerged as critical components in managing these DERs within smart grids and micro grids.

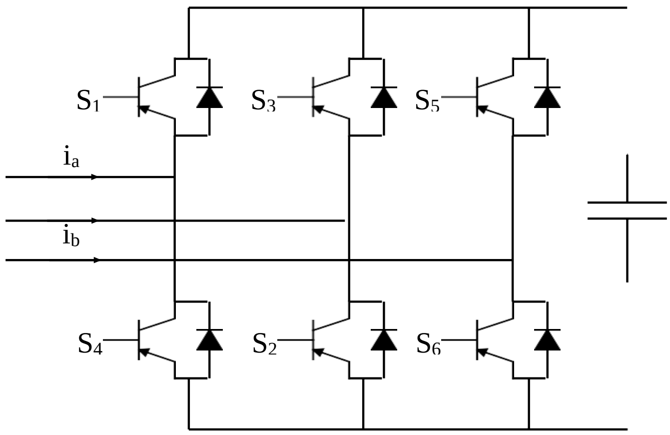


Figure 1.1 Configuration of a three-phase bidirectional VSC converter

1.2 Problem Statement

Traditional grid systems face numerous challenges when integrating DERs, including issues related to voltage and frequency regulation, load balancing, and power quality. Smart inverters and VSCs offer solutions, but their effective control and operation require sophisticated strategies. This research addresses the need for optimized control techniques for smart inverters and VSCs, particularly in micro grid environments, to enhance their functionality in both grid-tied and autonomous modes.

1.3 Objectives

The primary objectives of this research are:

- To investigate the low-level control mechanisms of single smart inverters.
- To develop and propose novel control techniques to improve micro grid operations and address challenges such as circulating current and unequal power sharing.

2. LITERATURE REVIEW

2.1 Smart Inverters and VSC Technology

Smart inverters and VSCs are pivotal in the conversion and control of electrical power from DERs. These devices regulate the flow of real and reactive power, ensuring the stability and efficiency of the power system. Recent advancements in smart inverter technology have introduced features such as dynamic voltage and frequency support, fault ride-through capabilities, and advanced grid support functions.

2.2 Micro Grid Operations

Micro grids, which can operate in both grid-tied and autonomous modes, provide localized energy solutions. Effective micro grid operation requires managing multiple DERs to maintain voltage and frequency stability, manage load fluctuations, and ensure reliable power distribution. Research highlights the need for robust control strategies to handle these complexities.

2.3 Challenges in DER Integration

Integrating DERs into existing grid infrastructure poses challenges such as voltage instability, frequency deviations, and power quality issues. Smart inverters and VSCs must be capable of addressing these challenges through advanced control algorithms that enable seamless operation in both grid-tied and autonomous modes.

3. METHODOLOGY

3.1 Low-Level Control of Single Smart Inverter

The first phase of the research focuses on the low-level control of a single smart inverter. This involves:

Designing control algorithms for real and reactive power management.

Implementing voltage and frequency regulation techniques.

Evaluating the performance of smart inverters compared to conventional VSCs.

3.2 High-Level Control of Micro Grid

The second phase addresses the high-level control of the micro grid by integrating multiple smart inverters. This includes:

Developing communication protocols between smart inverters and the main operator.

Implementing control strategies to manage circulating current and power sharing.

Testing and validating the proposed control techniques in a simulated micro grid environment.

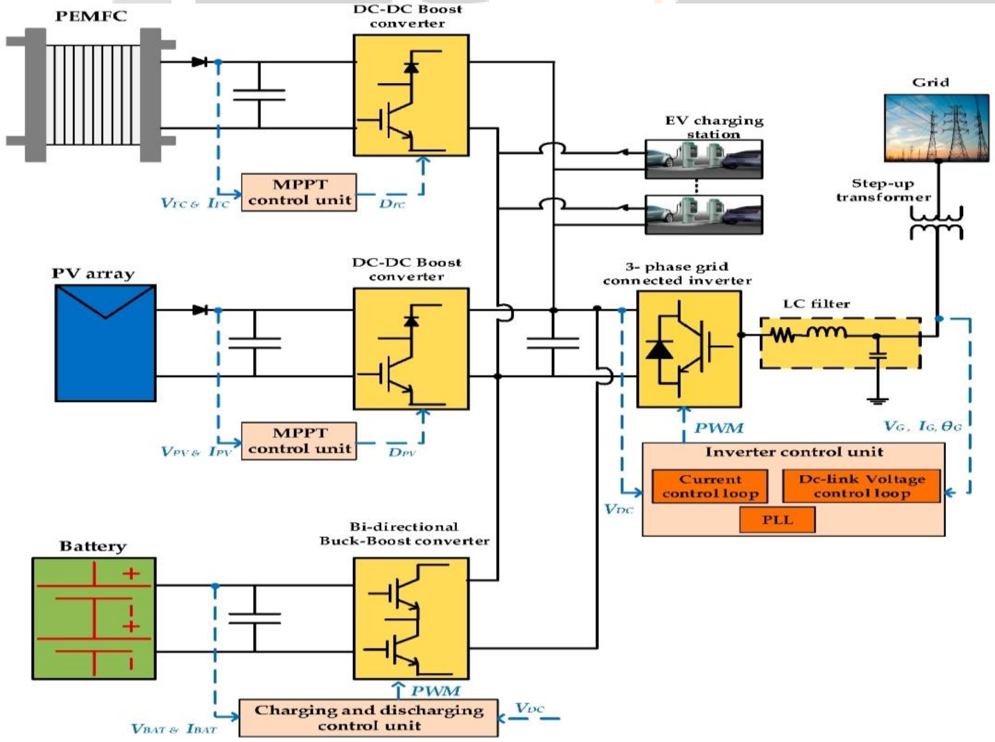
4. RESULTS AND DISCUSSION

4.1 Performance of Single Smart Inverter

The results from the low-level control experiments demonstrate the enhanced capabilities of smart inverters in managing real and reactive power. Smart inverters exhibit superior performance in voltage and frequency regulation compared to conventional VSCs.

4.2 Micro Grid Optimization

The high-level control strategies for the micro grid show significant improvements in operational efficiency. The proposed communication and control techniques effectively reduce circulating current and ensure equitable power distribution among DER units.



4.3 Comparative Analysis

A comparative analysis of smart inverters and VSCs highlights the advantages of smart inverters in terms of flexibility, reliability, and advanced grid support functions. The integration of smart inverters in micro grids offers a promising solution to the challenges posed by DERs.

5. CONCLUSION

This research highlights the critical role of smart inverters and VSCs in the future of microgrids. By addressing both low-level and high-level control challenges, this study provides a comprehensive framework for optimizing the operation of DERs in smart grids. Future work will focus on further refining control strategies and exploring advanced communication techniques to enhance microgrid resilience and efficiency.

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