

PhD research proposal

Divine Okeke, 2023

Proposed supervisor: **Federico Martin Ibanez**

Title: Distributed Control Strategies for Smart Distribution Grids with High Penetration of Renewable Energy

Overview

The integration of renewable energy sources into distribution grids is accelerating the transition towards a sustainable energy future. However, this integration poses significant challenges in terms of grid stability, power quality, and efficient resource utilization. To address these challenges, this research proposal aims to investigate distributed control strategies for smart distribution grids with a high penetration of renewable energy. The objective is to develop innovative control methodologies that enable effective integration, operation, and management of distributed energy resources, ensuring grid stability, reliability, and optimal resource utilization.

Introduction

The shift towards renewable energy sources necessitates their seamless integration into distribution grids to meet increasing electricity demand. However, the intermittent nature of renewable generation and the bidirectional power flow create operational complexities[1]. To overcome these challenges, distributed control strategies offer a promising solution. By enabling autonomous decision-making and coordination among distributed energy resources, these strategies ensure grid stability, efficient operation, and optimal resource utilization.

The Problem

As the penetration of renewable energy sources increases, several challenges emerge within smart distribution grids:

Grid Stability: Fluctuations in renewable generation and bidirectional power flow can lead to voltage and frequency deviations, compromising grid stability[2]. Therefore, effective control strategies are needed to regulate voltage and frequency and maintain grid equilibrium.

Power Quality: Variability in renewable energy generation can impact power quality, resulting in voltage sags, harmonic distortion, and flicker[3]. It is crucial to develop control methodologies that mitigate these power quality issues and ensure reliable electricity supply.

Resource Utilization: Efficient utilization of distributed energy resources, including renewable generation, energy storage systems, and demand response, is essential for optimizing grid operation and minimizing energy costs[4]. Advanced control strategies are required to manage these resources effectively.

Communication and Coordination: Seamless communication and coordination among distributed energy resources are vital for ensuring their successful integration and optimal grid performance[5]. Therefore, robust communication architectures and coordination mechanisms need to be developed.

Research Plan

To address the challenges outlined in the problem statement, the following research plan will be implemented:

1. **Literature Review:** A comprehensive review of existing literature on distributed control strategies, smart grids, and renewable energy integration in distribution grids will be conducted. This review will identify research gaps and challenges related to grid stability, power quality, and optimal resource utilization.
2. **Development of Distributed Control Algorithms:** Building upon the literature review, innovative distributed control algorithms will be developed. These algorithms will enable autonomous decision-making and coordination among distributed energy resources. Specifically, they will address voltage and frequency regulation, load balancing, and reactive power control. By leveraging decentralized optimization algorithms, efficient resource allocation and management will be achieved.
3. **Integration of Renewable Energy Sources:** Control strategies for the effective integration of renewable energy sources will be investigated. The research will focus on addressing the intermittent nature and power variability of renewables. Algorithms will be developed to predict and forecast renewable energy generation, enabling enhanced control performance and grid stability. Additionally, real-time monitoring and control techniques will be explored for distributed generation units, such as solar panels and wind turbines.
4. **Power Quality Improvement:** The research will delve into control strategies aimed at mitigating power quality issues arising from the integration of renewable energy sources. Algorithms will be developed for voltage regulation, harmonics compensation, and flicker mitigation in smart distribution grids. The impact of these control strategies on power quality indicators, including voltage stability and waveform distortion, will be analyzed to ensure reliable electricity supply.
5. **Communication and Coordination:** Robust communication architectures and protocols will be designed to facilitate seamless communication among distributed energy resources. The research will investigate coordination mechanisms to enable effective cooperation and information sharing among distributed control agents. The performance and scalability of these communication and coordination strategies will be evaluated, particularly in large-scale smart distribution grids.

By systematically implementing this research plan, the study aims to contribute to the field of advanced power systems control. The proposed research will provide insights into distributed control strategies for smart distribution grids with a high penetration of renewable energy. The outcomes of this research will offer valuable guidance for achieving grid stability, power quality improvement, efficient resource utilization, and seamless communication in future energy systems.

References

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