Doctorat (PhD) Project Proposal

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Field: Electrical Engineering

Title*:* **Microgrid Control Enhancement using Micro-Phasor Measurement Unit Based Energy Management System**

Abstract/Summary
The proposed PhD research focuses on optimizing and controlling smart microgrids through the integration of Micro-Phasor Measurement Units (µPMUs) and Energy Management System (EMS). Smart microgrids, which incorporate renewable energy sources and energy storage systems, present challenges in ensuring efficient and reliable power distribution. This study aims to leverage EMS based on µPMUs for real-time monitoring and data acquisition, enabling advanced optimization and control strategies. The research will develop algorithms to enhance energy management, minimize reliance on backup sources, and improve grid stability. The proposed framework can be validated through simulations and hardware-in-the-loop testing, with the goal of contributing to more efficient, resilient, and sustainable microgrid systems. This proposal provides a detailed plan for pursuing a PhD in the area of smart microgrids using µPMUs and EMS. The project has the potential to make significant contributions to both academia and industry by advancing the state of the art in smart grid optimization and control.

Index Terms: Smart microgrids, µPMUs, Energy Management System (EMS) and Optimization techniques.

1. Introduction and Background

The increasing integration of renewable energy sources into power grids has led to the emergence of smart microgrids. These microgrids are small-scale versions of the traditional power grid, can operate onto two modes; islanded mode or connected to the main grid. Smart microgrids are equipped with advanced communication, control, and optimization technologies that enhance their efficiency, reliability, and sustainability. One of the key components enabling the advanced control and monitoring of these microgrids is EMS the Micro-Phasor Measurement Unit (µPMU)[1-4].

Micro-PMUs provide high-resolution, time-synchronized measurements of electrical quantities such as voltage, current, and frequency across the microgrid [5-8]. These measurements are critical for real-time monitoring, fault detection, and optimization of power flow within the microgrid. The integration of µPMUs into smart microgrids offers significant potential for improving system performance, enhancing grid stability, and ensuring efficient energy management [9-12].

2. Objectives of this Doctorat research proposal

The research work is mainly concerned with:

1) To design and implement an Energy Management System based on µPMU for real-time data acquisition in smart microgrids.
2) To develop optimization algorithms that leverage EMS based on µPMU data to improve the efficiency and reliability of energy distribution within the microgrid.
3) To analyze the impact of µPMU-enabled control strategies on the stability and resilience of smart microgrids during normal and fault conditions.
4) To validate the proposed framework through simulation and experimental studies using a hardware-in-the-loop (HIL) testbed.

3. Literature Review

The literature review will explore the following areas:

- Smart Microgrids integrating EMS: A comprehensive review of existing smart microgrid architectures, focusing on the integration of renewable energy sources, energy storage systems, and power electronic devices as well as its energy management system [1-3].
- Phasor Measurement Units (PMUs): An overview of the evolution of PMUs, with a focus on the development of µPMUs and their applications in distribution networks and microgrids [5-8].
- Optimization Techniques: An analysis of state-of-the-art optimization algorithms for energy management in smart microgrids, including model predictive control (MPC), machine learning-based approaches, and heuristic optimization methods [13-15].
- Challenges and Opportunities: Identification of the key challenges in implementing EMS based on µPMUs in smart microgrids and potential research opportunities in this field.

4. Methodology Steps

The research methodology can be divided into four (4) phases:

(A) System Design and Simulation

- Design a smart microgrid model integrating various renewable energy sources, energy storage systems, and controllable loads.
- Develop a simulation environment using tools such as MATLAB/Simulink other software tools such as DIgSILENT PowerFactory to model the microgrid with its EMS and simulate its operation under different scenarios.

(B) μPMU Integration and Data Acquisition

- Integrate μPMUs into the microgrid model to enable high-resolution, time-synchronized data acquisition.
- Develop algorithms for real-time data processing, fault detection, and state estimation using μPMU measurements.

(C) Optimization and Control

- Develop optimization algorithms that utilize μPMU data to enhance energy management, optimize power flow, and improve the overall efficiency of the microgrid.
- Implement control strategies to ensure the stability and resilience of the microgrid, particularly during fault conditions and peak demand periods.

(D) Validation and Testing

- Validate the proposed framework through simulation studies, focusing on different operational scenarios such as islanded mode, grid-connected mode, and fault conditions.
- Conduct experimental validation using a hardware-in-the-loop (HIL) testbed to assess the performance of the μPMU-based EMS with optimization strategies in real-time (It is preferred the experiment will be conducted presently or at least remotely).

5. Expected Benefits

The expected outcomes of this research include:

- A comprehensive understanding of the role of μPMUs in enhancing the performance of smart microgrids.
- Development of a robust optimization framework that leverages μPMU data to improve energy efficiency, reliability, and stability in smart microgrids.
- Validation of the proposed control strategies through simulation and experimental studies, demonstrating their effectiveness in real-world applications.

6. Potential Contributions

This research has the potential to contribute to the following areas:

- **Academic Contributions:** The development of novel algorithms and control strategies for smart microgrids, contributing to the academic knowledge base in the field of power systems engineering.
- **Industrial Contributions:** Providing practical solutions for the optimization and control of smart microgrids, which can be implemented by utilities and energy companies to enhance the efficiency and reliability of their networks.
- **Societal Contributions:** Supporting the transition to sustainable energy systems by improving the integration of renewable energy sources into smart microgrids, thereby reducing greenhouse gas emissions and promoting energy independence.

7. Timeline

The research is expected to be completed over a period of four years, with the following timetable:

Year	Task to be performed
Year 1	Literature review, system design, and simulation,
Year 2	µPMU integration, data acquisition, and algorithm development,
Year 3	Optimization and control, simulation studies, and initial validation,
Year 4	Experimental validation, final analysis, and thesis writing.

8. Research Plan

- **Monthly Meetings:** A monthly meeting (either face-to-face or virtual) will be held to present research progress and facilitate discussions.
- **Progress Reports:** A detailed progress report will be submitted every six months.
- **Publication Requirement:** The candidate will be expected to publish at least one technical paper in an indexed journal (Scopus or WoS).

9. References

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