Abstract:

The global transition toward clean and sustainable energy has significantly increased the number of renewable energy sources such as solar panels, wind turbines, and battery storage systems. These systems rely on power electronic converters to transfer energy efficiently between the source and the power grid. Ensuring these converters operate safely, reliably, and with high performance—even in the face of grid fluctuations—is one of the key challenges in modern energy systems.

This project focuses on developing an intelligent and cost-effective control strategy for a special type of power converter known as a grid-connected converter with an LCL filter. The LCL filter helps improve the quality of the electricity fed into the grid but also introduces complex dynamics that make the system difficult to control, especially when the filter inductances are asymmetrical—a common situation in weak or rural grids. Furthermore, these systems can exhibit non-minimum phase (NMP) behavior, meaning the converter initially reacts in the opposite direction of what is expected, complicating the design of stable controllers.

To address these challenges, we propose a novel method based on model predictive control (MPC)—a technique that predicts the future behavior of the system and adjusts the control signals accordingly. A key innovation introduced in this project is the use of a currents common measurement scheme, where a single sensor is used to monitor both converter-side and grid-side currents simultaneously. This simplification not only reduces cost and hardware complexity but also enables more robust control under varying grid conditions.

The research will proceed in two main phases. First, the converter and filter system will be modeled using advanced techniques in MATLAB/Simulink, and its behavior will be verified through simulations and experiments. Next, the predictive control algorithm will be developed and tested in both inverter (sending energy to the grid) and rectifier (receiving energy from the grid) modes.

Expected results include:

- Improved dynamic response and stability of the converter under realistic operating conditions.
- A low-computation, real-time control solution that is compatible with inexpensive microcontrollers.
- Enhanced ability to integrate renewable energy sources into the grid with higher reliability and lower cost.

This project combines advanced control theory with practical engineering implementation and has the potential to contribute significantly to the development of future smart grids, distributed energy systems, and home energy solutions.