ICRERA 2024 Tutorial Proposal

1. Title of the Tutorial

Grid-Integration and Beyond for Solar Photovoltaic Systems

2. Instructor Team

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3. Abstract

Recently, power electronics, as an efficient power interface, is benefiting the development of renewable energy resources (RESs). Meanwhile, driven by the continuous decrease in the levelized cost of energy (LCoE), photovoltaic systems (PVSs) are widely integrated into the power grid for carbon neutrality. However, the high penetration level of PVSs raises concerns about grid instability due to intermittent power fluctuations, such as the frequency stability induced by the deficient mechanical inertia in power electronics interfacing RES systems. Accordingly, various attempts have been made to ensure grid-friendliness with a sharp proportion of PV integration to guarantee utility resilience and energy harvesting. Beyond conventional passive integration, recent PVSs are required to act as active power sources, becoming primary sources in the system, particularly, mitigating the adverse effects and simultaneously providing intelligent controllability and flexibility. In this tutorial, we will walk through the current technological challenges for grid-integration of solar PV energy as well as potential solutions. This tutorial provides a comprehensive approach to designing grid-friendly PVSs, covering the details from modelling to advanced controls. The goal is to improve the functionality and manageability of grid-connected PVSs by advanced controls to ensure the sustainability, compatibility with the power grid, efficiency, and reliability of PVSs that adhere to grid regulations and help to reduce the LCoE. The tutorial is organized for intermediate and advanced audiences, engineers, and researchers seeking practical solutions for grid-friendly power electronics for extending integration to resilience enhancement, particularly PV power conversion systems. The prerequisite is basic power electronics and control.

4. Tutorial Outline

The tutorial will be divided into two parts: Design for Grid-Friendliness and Control for Grid-Friendliness, with focuses on efficiency, reliability, and grid-supportive schemes. The outline and time schedule of the tutorial are as follows:

Part I – Design for Grid-Friendliness in Solar PV Systems

- Grid Forming Demands on PV Systems
- General Design for PV Systems as Primary Sources
  - PV systems modelling, monitoring, and diagnosis
    - Panel modelling and diagnosis
    - Power converter system modelling
    - Panel safety issues, monitoring, and protection
  - Energy harvesting optimization and design
  - General power feed-in control design
  - Grid synchronization techniques
  - Application examples

Coffee Break (10 minutes)

Part II – Grid-Integration Control for Active PV Systems

- Advanced Control to Enhance "**Passive**" Integration
  - Practical incidents exemplification and analysis
  - High-precision and harmonic-free control of grid currents
  - Advanced control and operation under voltage faults
    - Single-phase PV systems
    - Three-phase PV systems
  - Application examples
- Flexible Control for PV Systems Enabling "**Active**" Integration
  - Low inertia system and background
  - Flexible power point tracking strategies
  - Virtual inertia provision by PV systems
  - Grid-forming control and flexibility framework
  - Application examples
- Summary and Outlook
  - Tutorial summary
  - Future trends

Final Q&A and wrap up (15 minutes)

5. Lecture Style and Requirements

The tutorial is in traditional lecture format (using PowerPoint presentation) with a discussion section, and it would be more convenience if a laptop and a projector are available. This tutorial is organized for intermediate and advanced audiences, engineers, and researchers seeking practical solutions for grid-friendly power electronics, particularly PV power conversion systems. Also, researchers and engineers seeking the basic knowledge of PV technology and system integration are welcomed. The prerequisite is basic power electronics and control.