Indian Institute of Technology, Kanpur

Proposal for a New Course

1. Course No: **EE 66XXX**

2. Course Title: Operation and Control of the Power System with Inverter-Based Resources

3. Per Week Lectures:3(L), Tutorial: _(T), Laboratory: __(P), Additional Hours[0-2]: ___(A),
   Credits (3*L+2*T+P+A): 9
   Duration of Course: **Full Semester**

4. Proposing Department/IDP: **Electrical Engineering Department**
   Other Departments/IDPs which may be interested in the proposed course: **Department of Sustainable Energy Engineering**
   Other faculty members interested in teaching the proposed course:
5. Proposing Instructor(s): **Dr Ebin Cherian Mathew**
   Level of the Course: PG

6. Course Description:

This course will provide an overview of operating the power system with Inverter-Based Resources (IBRs). It will explore the challenges associated with the increased penetration of IBRs by analyzing grid events in the renewable energy (RE) complex within the Indian power system.

Key topics in the course will include the operation of grid-following and grid-forming converters, as well as the control of various IBR types, such as solar, wind, and battery energy storage systems (BESS). The course will also investigate power transmission strategies for reliably evacuating energy from renewable energy (RE) plants and will introduce recent advancements in power electronics that can enhance the stability of a grid with high IBR penetration.

By the end of the course, students will acquire the knowledge necessary to navigate the evolving landscape of power systems in the context of increasing RE integration.

A) Objectives:

- To understand the challenges of operating power systems with Inverter Based Resources (IBRs).
- To analyse various schemes for integrating IBRs into the grid.
- To understand the control and operation of different types of Inverter Based Resources.
- To analyse power transmission schemes for evacuating power from RE plants.
- To investigate recent trends in power electronics aimed at enhancing stability in IBR-penetrated grid.

B) Contents (*preferably in the form of 5 to 10 broad titles)*:

S. No	Broad Title	Topics	No. of Lectures(hrs)
1.	Inverter Based Resources	• Basics of Power Electronic Converters • Grid Integration of Inverters-Grid Forming vs Grid following controls	8
2.	Power System Operation with inverter-based resources	• Power System Operation with Conventional generation/IBR • Analysis of Grid events in IBR penetrated area-Oscillation / Grid events studies • Stability issues with increased RE penetration • Issues with declining system inertia and low short circuit strength.	5
3.	Operation and Control of Inverter Based Resources	• Solar • Wind • BESS systems	8
4.	Analysis of evacuation schemes (generation side) for RE integration	• MVAC Transmission • MVDC Transmission	2
5.	Analysis of transmission schemes for power evacuation from large RE complex	• AC Transmission • HVDC Transmission-VSC vs LCC	4
6.	Recent Developments in Power Electronics to Improve Stability in IBR-Penetrated Grids	• Virtual Synchronous Machine. • E-STATCOM. • Grid forming Control of HVDC systems. • HVDC with energy storage.	8

Total: 35 hrs.

C) Pre-requisites, if any: **EE360 (Power electronics) ,EE 330(Power System) or equivalent**

D) Short summary for including in the Courses of Study Booklet: Grid-Following and Grid-Forming Inverters, Challenges in Power System Operations with Inverter-Based Resources, Control and Operation of Inverter-Based Resources, Power Transmission Schemes for Inverter-Based Resources, Virtual Synchronous Machines, E-STATCOM, Grid-Forming Control for HVDC Systems, HVDC Systems with Energy Storage.

7. Recommended books:
   Textbooks:
   -
   - Mohan, Ned, Tore M. Undeland, and William P. Robbins. *Power electronics: converters, applications, and design*. John Wiley & Sons, 2003.
   - Reference Bo Burton, T., Jenkins, N., Sharpe, D., & Bossanyi, E. (2011). Wind energy handbook. John Wiley & Sons.oks:
   - A.Huque and D. Ramasubramanian, EPRI Tutorial (2023), Grid Forming Inverters

- D. B. Rathnayake *et al*., "Grid Forming Inverter Modeling, Control, and Applications," in *IEEE Access*, vol. 9, pp. 114781-114807, 2021, doi: 10.1109/ACCESS.2021.3104617.
- Feasibility study and application of electric energy storage systems embedded in HVDC and STATCOM systems, CIGRE Technical Brochure 935.2024
- "IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems," in *IEEE Std 2800-2022* , vol., no., pp.1-180, 22 April 2022
- Jovcic, Dragan. *High voltage direct current transmission: converters, systems and DC grids*. John Wiley & Sons, 2019.
- Kundur, Prabha. "Power system stability." *Power system stability and control* 10 (2007): 7-1.

8. Any other remarks:N/A

Dated:24-09-2024 Proposer: Ebin Cherian Mathew

Dated:_____ DUGC/DPGC Convener:_____

The course is approved / not approved

Chairman, SUGC/SPGC

Dated:_____