Approved in 36th BoA Meeting

Course number: EE 582
Course Name: Nonlinear Analysis and Control of Power Electronic Converters
Credit: L-T-P-C: 3-0-0-3
Prerequisite: Control Systems (EE301) & Power Electronics (EE 309)
Intended for: UG/PG
Elective/Core: Elective

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1. **Preamble:** Power electronic converters exhibit a variety of nonlinear phenomena due to the presence of switching elements, control loop, etc. This course deals with different mathematical tools to analyze those phenomena. Also, a few nonlinear control techniques are covered in this course to improve the transient performance compared to the linear controllers.

2. Course Modules with quantitative lecture hours:

Module 1: Introduction **[6 hours]**
Introduction to nonlinear models, nonlinear phenomena, common nonlinearities, qualitative behavior of linear systems, phase portraits, limit cycle oscillation, Jacobi linearization, direct method and indirect method of Lyapunov

Module 2: Sources of Nonlinearities in Power Electronic Converters **[3 hours]**
Nonlinearity due to switch and reactive components, nonlinearity introduced by the closed loop control, nonlinear phenomena observed in power electronic converters

Module 3: Control techniques for power electronic converters:
Voltage mode control, current mode control, PWM of type 1 and type 2, hysteresis control, sliding mode control, digital control, time optimal control **[7 hours]**

Module 4: Dynamic Modeling Techniques **[4 hours]**
Average modelling of PWM converters, limitations of average model, Discrete-time 1-D and 2-D models

Module 5: Stability Analysis **[7 hours]**
Basics of bifurcation theory and chaos, bifurcation of smooth and piecewise-smooth maps, nonstandard bifurcation in discontinuous maps, techniques of experimental investigations

Module: 6 Describing Function Analysis of Power Electronic Converters **[7 hours]**
Basics of describing function, describing function of different nonlinearities, stability analysis of limit cycle using Nyquist criteria

Module: 7 Simulation Study **[7 hours]**
Matlab based project work on i) Analysis of instability introduced by the different nonlinear components, ii) Nonlinear controller design to improve transient performance and stability boundary.

3. **Text books:**

S. Banerjee and G. C. Verghese, Eds., *Nonlinear Phenomena in Power Electronics: Attractors, Bifurcations, Chaos, and Nonlinear Control*. New York: IEEE Press, 2001.

4. **References:**

I. H. K. Khalil, *Nonlinear Control*, Pearson Education, 2015

II. C. K. Tse, *Complex Behavior of Switching Power Converters*. New York: CRC, 2003.

III. N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics Converters, Applications, and Design*, 3rd ed., Wiley India, 2008

IV. R. W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*, 2nd ed. Dordrecht, The Netherlands: Kluwer, 2001.

V. L. Corradini, R. Zane, D. Maksimović, P. Mattavelli, *Digital Control of High-Frequency Switched-Mode Power Converters*, John Wiley & Sons, 2015

5. **Similarity content declaration with existing courses:** less than 17% (module 1 and some portion of module 4)
   (i) Switch Mode Power Conversion (EE504)
   (ii) Nonlinear systems: stability and control (EE 515)

6. Justification of new course proposal if cumulative similarity content is >30%: NA

Approvals:

Other Faculty interested in teaching this course: -

Proposed by: Dr. Amit Kumar Singha School: SCEE

Signature: Date:

Recommended/Not Recommended, with Comments:

_____ Date:_____

Chairman, CPC

Approved / Not Approved

_____ Date:_____

Chairman, Senate