CENTRALE NANTES

MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

2023-2024

YEAR 1

CONTROL AND ROBOTICS

DYNAMICS OF RENEWABLES-BASED POWER SYSTEMS (DREAM)

PROGRAMME SUPERVISOR(S):
Bogdan MARINESCU

YEAR 1 - Autumn Semester

CORE COURSES

Course code	Title	ECTS Credits
CONF	Conferences	-
CROSS	Control of electrical drive systems	4
DYCOS	Dynamic components of power systems	6
MIAMI	Mathematical modeling and identification	5
NASH	Nonlinear and switching dynamics	4
OPTIM	Optimization	5
POWER	Power systems dynamics	4

Master Programme - Control and Robotics - Dynamics of renewables-based power systems (DREAM)
YEAR 1 - Autumn Semester

Conferences [CONF]

LEAD PROFESSOR(S): Bogdan MARINESCU

Objectives

Acquire the bases of the dynamic operation of power grids. After completing this module, students will be able to:
- Understand and analyze the main dynamic phenomena of interconnected power systems
- Know the basic and classic regulations of power grids
- Use grid dedicated simulation softwares
- knowledge of the electricity sector (fields of activity of companies like RTE, EDF or equipment manufacturer such as, for example, Alstom, Siemens, ABB)

Course contents

- Electricity production and grid management (general notions)
- Load flow
- Basic dynamics (frequency/voltage) of a power grid; generation/consumption balance
- Stability (voltage, frequency/transient, small-signal/oscillatory)
- Primary/secondary/tertiary regulations;
- Voltage & frequency system services
- Zoom on the French and European grids

Course material

P. Kundur, Power System Stability and Control, McGraw-Hill, 1994.
G. Rogers, Power System Oscillations, Kluwer Academic, 2000.
M. Ilic, J. Zaborsky, Dynamics and Control of Large Electric Power Systems, Wiley, 2000.
P.W. Sauer, M.A. Pai, Power Systems Dynamics and Stability, Prentice Hall, 1998.

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	-	20 hrs	0 hrs	0 hrs	0 hrs	0 hrs

Master Programme - Control and Robotics - Dynamics of renewables-based power systems (DREAM)

YEAR 1 - Autumn Semester

Control of electrical drive systems [CROSS]

LEAD PROFESSOR(S): Bogdan MARINESCU

Objectives

- Know how to analyse stability and structural properties of a large-scale power system
- Acquire bases for robust control for different grid objectives (control of generators, damping of grid power oscillations, ...)

Course contents

- Performances & robustness of large-scale systems ; loop-shaping and basic principles
- Multi-input/multi output systems
    - o State-space form & DAE representations
    - o Structural properties & model reduction
- Robust control techniques
    - o Methodologies (internal model principle, H2/H infinity, ...)
    - o Power systems study cases: control for mixed local and grid objectives

Course material

1. T. Kailath, Linear Systems, Prentice-Hall, 1980.
2. J. Doyle, B. Francis, A. Tannenbaum, Feedback Control Theory, MacMillan 1990. www.e-booksdirectory.com
3. M. Ilic, J. Zaborsky, Dynamics and Controls of Large Electric Power Systems, Willey 2000.

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	20 hrs	6 hrs	4 hrs	0 hrs	2 hrs

Master Programme - Control and Robotics - Dynamics of renewables-based power systems (DREAM)

YEAR 1 - Autumn Semester

Dynamic components of power systems [DYCOS]

LEAD PROFESSOR(S): Vinu THOMAS

Objectives

▪ To apply the knowledge gained on mathematical modelling of power system components and to utilize simulation software tools to develop simulation models of power system components in order to analyse the dynamic behavior of the power systems

▪ To develop the fundamental skills required to carry out research work on power system dynamics

Course contents

The students do the project in groups of 3 to 5 members. A project topic is assigned to each group. An introductory session on the topic shall be provided by the instructor and there will be interactive sessions of the group with the instructor every few weeks. The students shall be assigned specific tasks related to the project topic, to be completed before the next interactive session. During the interactive sessions, additional tasks are assigned to enable the students to complete the objectives of the project topic.

Towards the end of the semester, the students are supposed to complete all the tasks and develop a mathematical simulation model as per the topic and carry out case studies. Project assessment is done based on a final written report and oral presentations made by group members during the interactive sessions.

Course material

Perelmuter, Viktor, Renewable Energy Systems: Simulation with Simulink® and SimPowerSystems. CRC Press, 2016.

Kunjumuhammed, Linash, Stefanie Kuenzel, and Bikash C. Pal, Simulation of Power System with Renewables. Academic Press, 2019.

Kundur, P. S., Power system stability and control. McGraw-Hill Education, 1994

Yazdani, A., & Iravani, R., Voltage-sourced converters in power systems: modeling, control, and applications. John Wiley & Sons, 2010

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	6	10 hrs	20 hrs	0 hrs	0 hrs	0 hrs

Master Programme - Control and Robotics - Dynamics of renewables-based power systems (DREAM)
YEAR 1 - Autumn Semester

Mathematical modeling and identification [MIAMI]

LEAD PROFESSOR(S): Eric LE CARPENTIER

Objectives

· To mathematically model power system components.
· To take into account the model uncertainty using a probabilistic approach.
· To develop system identification and state tracking methods using a probabilistic approach.

Course contents

Part 1

· Mathematical modelling – Types of modelling, Need for modelling
· Mathematical description of a synchronous machine, review of magnetic circuit equations and basic equations of a synchronous machine, dq transformation, per unit representation, representation of magnetic saturation
· AC Transmission: transmission line, characteristics and performance equations, two winding and three winding transformer representation, load modelling – static and dynamic, modelling of induction motors, representation in stability studies, synchronous motor models- acquisition of load model parameters
· Modelling of excitation systems: modelling of excitation components and complete excitation systems, Prime movers and electricity supply systems –hydraulic, steam, thermal and wind turbines and governing systems
· Voltage source converter modelling – averaged model, model in beta and dq frame

Part 2
· Probability theory: random vectors, density, mean, variance.
· Time analysis, frequency analysis: random signals, autocorrelation, power spectral density.
· Classical estimation Theory, Bayesian estimation: maximum likelihood (ML) estimation, minimum mean square error (MMSE) estimator, maximum a posteriori (MAP) estimator, linear minimum mean square error (LMMSE).
· Markov chains, Markov processes, Statistical filtering: Kalman

Course material

Lecture notes at Centrale Nantes (provided document)
Kundur, P. S., Power system stability and control. McGraw-Hill Education, 1994
Yazdani, A., & Iravani, R., Voltage-sourced converters in power systems: modeling, control, and applications. John Wiley & Sons, 2010

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	5	18 hrs	4 hrs	8 hrs	0 hrs	2 hrs

CENTRALE NANTES

Master Programme - Control and Robotics - Dynamics of renewables-based power systems (DREAM)
YEAR 1 - Autumn Semester

Nonlinear and switching dynamics [NASH]

LEAD PROFESSOR(S): Bogdan MARINESCU

Objectives

- Have an introduction to nonlinear systems
- How to analyze the stability and performance properties of nonlinear systems
- Have an introduction to hybrid and switched systems and familiarize with their main behaviors
- Acquire the main tools to analyze the stability of switched systems and provide main tools for their stabilization.
- The obtained skills will be based on both extensions of linear tools as well as electrical applications and power converters.

Course contents

- Introduction to nonlinear dynamics and associated definitions
- Stability of nonlinear systems with Lyapunov function theory
- Introduction to a specific class of nonlinear systems: hybrid and switched systems.
- Stability of switched systems.
- Control design for switched systems.

Course material

1. R. Goebel, R. G. Sanfelice, A. R. Teel. Hybrid Dynamical Systems: Modeling, Stability and Robustness. Princeton University Press.
2. H. K. Khalil. Nonlinear Systems. Second Edition. Prentice Hall, Upper Saddle River. 1996.
3. D. Liberzon. Switching in Systems and Control. Birkhäuser, 2003.
4. Z. Sun, S. S. Ge. Stability Theory of Switched Dynamical Systems. Springer London. 2011.
5. M. Vidyasagar. Nonlinear Systems Analysis. Second Edition. Prentice-Hall International Editions. 1993.

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	14 hrs	4 hrs	12 hrs	0 hrs	2 hrs

Master Programme - Control and Robotics - Dynamics of renewables-based power systems (DREAM)
YEAR 1 - Autumn Semester

Optimization [OPTIM]

LEAD PROFESSOR(S): Ina TARALOVA

Objectives

Optimisation is transversal to all engineering fields, and beyond.
The aim of the course is to get acquainted with iterative optimization methods in one dimensional and multidimensional case, linear or nonlinear, with or without constraints.

Students will be given further analytical tools for the formulation and solution of PF and OPF problems, with numerical applications to benchmark problems in power systems such as congestion management in RTE.

Course contents

1. Introduction to optimization problems : Examples, definitions. Convex sets and convex functions.
2. Unconstrained optimization. Definition of convergence rate, complexity of the algorithm
2.0. Unconstraint optimization. Linear problem, Simplex method
2.1. Unidimensional problems
2.1.1 Derivative-based optimization methods (DBO) : Newton's method, Secant method
2.1.2. Derivative-free optimization methods (DFO) : Mini-Max problems, Dichotomy, Fibonacci, Golden section, Brent's method, "Economic" methods
2.2. Multidimensional problems
2.2.1 Direct search heuristic methods : Hooke and Jeeves, Nelder – Mead simplex method
2.2.2 Gradient-based method: Gradient, steepest descent, conjugate gradients, quasi-newton
3. Constrained optimization. Examples of constrains in Control.
3.1. Dual methods : Lagrange multipliers
3.2. Primary methods: Interior and exterior points

Second part taught by RTE lecturers

4.1Optimisation in power systems
4.2 Optimisation in electrical grids based on linear models (N-1 rule, Security Constrained Optimal Power Flow)
4.3 ACOPF : Alternative Current Optimal Power Flow
4.4 Real-time optimization for congestion management in RTE

Course material

1. (2016), D.Bertsekas, Nonlinear Programming, Athena Scientific.
2. (2004) S.Boyd, L. Vandenberghe, Convex Optimization, Cambridge University Press,

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	5	20 hrs	2 hrs	8 hrs	0 hrs	2 hrs

Master Programme - Control and Robotics - Dynamics of renewables-based power systems (DREAM)

YEAR 1 - Autumn Semester

Power systems dynamics [POWER]

LEAD PROFESSOR(S): Bogdan MARINESCU

Objectives

Acquire the bases of the dynamic operation of power grids. After completing this module, students will be able to:
- Understand and analyze the main dynamic phenomena of interconnected power systems
- Know the basic and classic regulations of power grids
- Use grid dedicated simulation softwares
- knowledge of the electricity sector (fields of activity of companies like RTE, EDF or equipment manufacturer such as, for example, Alstom, Siemens, ABB)

Course contents

- Electricity production and grid management (general notions)
- Load flow
- Basic dynamics (frequency/voltage) of a power grid; generation/consumption balance
- Stability (voltage, frequency/transient, small-signal/oscillatory)
- Primary/secondary/tertiary regulations;
- Voltage & frequency system services
- Zoom on the French and European grids

Course material

P. Kundur, Power System Stability and Control, McGraw-Hill, 1994.
G. Rogers, Power System Oscillations, Kluwer Academic, 2000.
M. Ilic, J. Zaborsky, Dynamics and Control of Large Electric Power Systems, Wiley, 2000.
P.W. Sauer, M.A. Pai, Power Systems Dynamics and Stability, Prentice Hall, 1998.

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	18 hrs	4 hrs	8 hrs	0 hrs	2 hrs