ACADEMIC MASTER HARMONIZED

National Program

Updated 2022

Detailed Program by Subject for Semester S1

Semester: 1

Fundamental Unit Code: UEF 1.1.1

Subject: Electrical Energy Transmission and Distribution Networks

VHS: 45h (Lecture: 1h30, Tutorial: 1h30)

Credits: 4

Coefficient: 2

Teaching Objectives:

The objective of this course is twofold: first, to expand the knowledge acquired during the "Electrical Networks" course in the undergraduate program, and second, to introduce the necessary knowledge for the management and operation of electrical networks.

Recommended Prerequisites:

Fundamental laws of electrical engineering (Ohm's law, Kirchhoff's laws, etc.), analysis of alternating current electrical circuits, complex calculations, and modeling of electrical lines (undergraduate electrical networks course).

Subject Content:

Chapter 1: Architectures of Electrical Substations (2 weeks)

Overall architecture of the electrical network, equipment, and substation architectures (bus-coupled substations, circuit breaker-coupled substations), topologies of transmission and distribution networks.

Chapter 2: Organization of Electrical Energy Transmission

2.1. Transmission Lines (3 weeks)

Calculation of transmission lines: Conductor cross-section selection, insulation, mechanical calculation of lines, operation of transmission lines in steady-state and transient regimes. High-voltage direct current (HVDC) transmission.

2.2. Distribution Networks (2 weeks)

Introduction to electrical energy distribution, primary distribution, secondary distribution, distribution transformers, reactive power compensation in distribution networks, distribution reliability.

Chapter 3: Operation of Medium and Low Voltage Electrical Networks (3 weeks)

Protection of HV/MV substations against overcurrents and overvoltages. Modeling of electrical network components. Voltage regulation, voltage regulation devices, reactive power control in an electrical network.

Chapter 4: Neutral Grounding Systems (2 weeks)

Neutral grounding systems (isolated, grounded, impedance-grounded), artificial neutral.

Chapter 5: Voltage Regulation (3 weeks)

Voltage drop in electrical networks, voltage regulation methods (automatic voltage regulation at generator terminals, AVR, reactive power compensation using conventional and modern means, voltage regulation by autotransformer), introduction to voltage stability.

Assessment Method:

Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. *F. Kiessling et al, 'Overhead Power Lines, Planning, Design, Construction'. Springer, 2003.*
2. *T. Gonen et al, 'Power Distribution', book chapter in Electrical Engineering Handbook. Elsevier Academic Press, London, 2004.*
3. *E. Acha and V.G. Agelidis, 'Power Electronic Control in Power Systems', Newnes, London 2002.*
4. *Turan Gönen: Electric Power Distribution System Engineering. McGraw-Hill, 1986.*
5. *Turän Gonen: Electric Power Transmission System Engineering. Analysis and Design. John Wiley & Sons, 1988.*

Semester: 1

Fundamental Unit Code: UEF 1.1.1

Subject: Advanced Power Electronics

VHS: 45h (Lecture: 1h30, Tutorial: 1h30)

Credits: 4

Coefficient: 2

Teaching Objectives:

To provide the electrical circuit concepts behind the different operating modes of inverters for a deep understanding of their operation. To equip students with the necessary skills to design power converters for UPS, drives, etc. To develop the ability to analyze and understand the different operating modes of various power converter configurations. To design single-phase and three-phase inverters.

Recommended Prerequisites:

Power components, basic power electronics.

Subject Content:

Chapter 1: Modeling and Simulation Methods for Power Semiconductors (2 weeks)

Idealized characteristics of different types of semiconductors, logical equations of semiconductors, simulation methods for static converters.

Chapter 2: Commutation Mechanisms in Static Converters (3 weeks)

Principle of natural commutation, principle of forced commutation, calculation of commutation losses.

Chapter 3: Design Methods for Naturally Commutated Static Converters (2 weeks)

Commutation rules, definition of the commutation cell, different types of sources, power exchange rules, direct and indirect converters (e.g., study of a cycloconverter).

Chapter 4: Design Methods for Forced Commutation Static Converters (3 weeks)

- PWM Inverter
- Sinusoidal Absorption Rectifier
- PWM AC Voltage Controller
- Switching Power Supplies

Chapter 5: Multilevel Inverter (3 weeks)

Multilevel concept, topologies, comparison of multilevel inverters. PWM control techniques for single-phase and three-phase impedance source inverters.

Chapter 6: Power Quality of Static Converters (3 weeks)

- Harmonic pollution due to static converters (case study: rectifier, AC voltage controller).
- Harmonic study in voltage inverters.
- Introduction to mitigation techniques.

Assessment Method:

Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. *Power Electronics, from the Commutation Cell to Industrial Applications. Course and Exercises, A. Cunière, G. Feld, M. Lavabre, Casteilla Editions, 544 p. 2012.*
2. *Technical Encyclopedia "Engineering Techniques," Treatise on Electrical Engineering, Vol. D4, Articles D3000 to D3300.*

Semester: 1

Fundamental Unit Code: UEF 1.1.1

Subject: Microprocessors and Microcontrollers

VHS: 22h30 (Lecture: 1h30)

Credits: 2

Coefficient: 1

Teaching Objectives:

To understand the structure of a microprocessor and its utility. To differentiate between a microprocessor, microcontroller, and a computer. To understand memory organization. To learn assembly programming. To understand the use of I/O interfaces and interrupts. To use microcontrollers (programming, system control).

Recommended Prerequisites:

Combinational and sequential logic, industrial automation.

Subject Content:

Chapter 1: Architecture and Operation of a Microprocessor (3 weeks)

Structure of a computer, information flow in a computer, hardware description of a microprocessor, operation of a microprocessor, memories. Example: Intel 8086 microprocessor.

Chapter 2: Assembly Programming (2 weeks)

General principles, instruction set, programming methods.

Chapter 3: Interrupts and I/O Interfaces (3 weeks)

Definition of an interrupt, interrupt handling by the microprocessor, addressing of interrupt subroutines, addressing of I/O ports, I/O port management.

Chapter 4: Architecture and Operation of a Microcontroller (3 weeks)

Hardware description of a microcontroller and its operation. Microcontroller programming. Example: PIC microcontroller.

Chapter 5: Applications of Microprocessors and Microcontrollers (4 weeks)

LCD interface - Keyboard interface - Signal generation for ports - Motor control - DC/AC device control - Frequency measurement - Data acquisition system.

Assessment Method:

Exam: 100%.

Bibliographic References:

1. *R. Zaks et A. Wolfe. From Component to System -- Introduction to Microprocessors. Sybex, Paris, 1988.*
2. *M. Tischer et B. Jennrich. The PC Bible -- System Programming. Micro Application, Paris, 1997.*

3. *R. Tourki. The PC Computer -- Architecture and Programming -- Course and Exercises. University Publication Center, Tunis, 2002.*
4. *H. Schakel. Programming in Assembly on PC. Micro Application, Paris, 1995.*
5. *E. Pissaloux. Practical Assembly I80x86 -- Course and Exercises. Hermès, Paris, 1994.*

Semester: 1

Fundamental Unit Code: UEF 1.1.2

Subject: Advanced Electrical Machines

VHS: 45h (Lecture: 1h30, Tutorial: 1h30)

Credits: 4

Coefficient: 2

Teaching Objectives:

By the end of this course, the student will be able to establish the general equations of electromechanical energy conversion applied to synchronous, asynchronous, and DC machines and determine their characteristics in static or variable regimes. This will enable the consideration of machine associations with static converters.

Recommended Prerequisites:

Three-phase electrical circuits, alternating currents, power. Magnetic circuits, single-phase and three-phase transformers, DC and AC electrical machines (motor and generator operation).

Subject Content:

Chapter 1: General Principles (3 weeks)

Principle of electromechanical energy conversion. Principle of stator/rotor coupling: the primitive machine. Windings of electrical machines. Calculation of magnetomotive forces. Mechanical equation.

Chapter 2: Synchronous Machines (4 weeks)

General principles and equations of the smooth-pole synchronous machine. Study of synchronous machine operation. Different excitation systems. Armature reactions. Elements on salient-pole synchronous machines with and without dampers. Potier diagrams, two-reactance diagram, and Blondel diagram. Elements on permanent magnet machines. Alternators and parallel coupling. Synchronous motors, starting...

Chapter 3: Asynchronous Machines (4 weeks)

General principles. Equations. Equivalent circuits. Torque of the asynchronous machine. Characteristics and diagram of the asynchronous machine. Motor/generator operation, starting, braking. Deep-bar and double-cage motors, single-phase asynchronous motors.

Chapter 4: DC Machines (4 weeks)

Structure of DC machines. Equations of DC machines. Starting, braking, and speed regulation modes of DC motors. Commutation phenomena. Saturation and armature reaction. Auxiliary commutation poles. Motor/generator operation.

Assessment Method:

Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. *J.-P. Caron, J.P. Hautier: Modeling and Control of the Asynchronous Machine, Technip, 1995.*
2. *G. Grellet, G. Clerc: Electrical Actuators, Principles, Models, Controls, Eyrolles, 1996.*
3. *J. Lesenne, F. Notelet, G. Séguier: Introduction to Advanced Electrical Engineering, Technical and Documentation, 1981.*
4. *Paul C. Krause, Oleg Wasyzczuk, Scott S. Sudhoff, "Analysis of Electric Machinery and Drive Systems", John Wiley, Second Edition, 2010.*
5. *P.S. Bimbhra, "Generalized Theory of Electrical Machines", Khanna Publishers, 2008.*
6. *A.E. Fitzgerald, Charles Kingsley, Jr, and Stephan D. Umans, "Electric Machinery", Tata McGraw Hill, 5th Edition, 1992.*

Semester: 1

Fundamental Unit Code: UEF 1.1.2

Subject: Applied Numerical Methods and Optimization

VHS: 45h (Lecture: 1h30, Tutorial: 1h30)

Credits: 4

Coefficient: 2

Teaching Objectives:

The objective of this course is to present the necessary tools for numerical analysis and optimization, with or without constraints, of physical systems in the field of engineering.

Recommended Prerequisites:

Mathematics, programming, proficiency in MATLAB environment.

Subject Content:

Chapter I: Review of Some Numerical Methods (3 weeks)

- Resolution of nonlinear equation systems by iterative methods.
- Numerical integration and differentiation.
- Methods for solving ordinary differential equations (ODE): Euler methods; Runge-Kutta methods; Adams method.
- Resolution of ODE systems.

Chapter II: Partial Differential Equations (PDE) (6 weeks)

- Introduction and classification of partial differential problems and boundary conditions.
- Methods for solving PDEs: Finite Difference Method (FDM); Finite Volume Method (FVM); Finite Element Method (FEM).

Chapter III: Optimization Techniques (6 weeks)

- Definition and formulation of an optimization problem.
- Single and multiple optimization with or without constraints.
- Unconstrained optimization algorithms (Deterministic methods, Stochastic methods).
- Constraint handling (Transformation methods, Direct methods).

Assessment Method:

Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. *G. Allaire, Numerical Analysis and Optimization, Edition of the Polytechnic School, 2012.*
2. *S.S. Rao, 'Optimization -- Theory and Applications', Wiley-Eastern Limited, 1984.*
3. *A. Fortin, Numerical Analysis for Engineers, International Polytechnic Press, 2011.*
4. *J. Bastien, J. N. Martin, Introduction to Numerical Analysis: Applications under Matlab, Dunod, 2003.*
5. *A. Quarteroni, F. Saleri, P. Gervasio, Scientific Computing, Springer, 2008.*
6. *T. A. Miloud, Numerical Methods: Finite Difference Method, Integral and Variational Methods, University Publications Office, 2013.*
7. *J. P. Pelletier, Numerical Techniques Applied to Scientific Computing, Masson, 1982.*
8. *F. Jedrzejewski, Introduction to Numerical Methods, Springer, 2001.*
9. *P. Faurre, Numerical Analysis, Optimization Notes, Polytechnic School, 1988.*
10. *Fortin. Numerical Analysis for Engineers, International Polytechnic Press, 2011.*
11. *J. Bastien, J.N. Martin. Introduction to Numerical Analysis: Applications under Matlab, Dunod, 2003.*
12. *Quarteroni, F. Saleri, P. Gervasio. Scientific Computing, Springer, 2008.*

Semester 1

Methodological Unit Code: UEM 1.1

Subject: Lab: Microprocessors and Microcontrollers

VHS: 15h (Lab: 1h)

Credits: 1

Coefficient: 1

Teaching Objectives:

To learn assembly programming. To understand the principle and execution steps of each instruction. To understand the use of I/O interfaces and interrupts. To use microcontrollers (programming, system control).

Recommended Prerequisites:

Combinational and sequential logic, industrial automation, algorithms.

Subject Content:

Lab 1: Getting Started with a Microprocessor Programming Environment (1 week)
Lab 2: Programming Arithmetic and Logical Operations in a Microprocessor (1 week)
Lab 3: Using Video Memory in a Microprocessor (1 week)
Lab 4: Microprocessor Memory Management (2 weeks)
Lab 5: Stepper Motor Control by a Microprocessor (2 weeks)
Lab 6: Screen Management (1 week)
Lab 7: PIC Microcontroller Programming (2 weeks)
Lab 8: Stepper Motor Control by a PIC Microcontroller (2 weeks)

Assessment Method:

Continuous assessment: 100%.

Bibliographic References:

1. *R. Zaks et A. Wolfe. From Component to System -- Introduction to Microprocessors. Sybex, Paris, 1988.*
2. *M. Tischer et B. Jennrich. The PC Bible -- System Programming. Micro Application, Paris, 1997.*
3. *R. Tourki. The PC Computer -- Architecture and Programming -- Course and Exercises. University Publication Center, Tunis, 2002.*
4. *H. Schakel. Programming in Assembly on PC. Micro Application, Paris, 1995.*
5. *E. Pissaloux. Practical Assembly I80x86 -- Course and Exercises. Hermès, Paris, 1994.*
6. *P. Mayeux. Learning Mid-Range PIC Programming through Experimentation and Simulation. Dunod, 2010.*
7. *A. Reboux. Introduction to PIC Programming in Basic and Assembly. Dunod, 2002.*

Semester: 1

Methodological Unit Code: UEM 1.1

Subject: Lab: Electrical Energy Transmission and Distribution Networks

VHS: 22h30 (Lab: 1h30)

Credits: 2

Coefficient: 1

Teaching Objectives:

To provide students with all the necessary tools to manage, design, and operate electro-energetic systems, particularly electrical networks.

Recommended Prerequisites:

General knowledge of electrical transmission and distribution networks.

Subject Content:

Lab 1: Voltage Regulation by Synchronous Motor
Lab 2: Power Distribution and Voltage Drop Calculation
Lab 3: Voltage Regulation by Reactive Power Compensation
Lab 4: Neutral Grounding System
Lab 5: Interconnected Networks

Assessment Method:

Continuous assessment: 100%.

Bibliographic References:

1. *Sabonnadière, Jean Claude, Electrical Lines and Networks, Vol. 1, Electrical Power Lines, 2007.*
2. *Sabonnadière, Jean Claude, Electrical Lines and Networks, Vol. 2, Methods of Network Analysis, 2007.*
3. *Lasne, Luc, Electrical Engineering Exercises and Problems: Basic Concepts, Networks and Electrical Machines, 2011.*
4. *J. Grainger, Power System Analysis, McGraw Hill, 2003.*
5. *W.D. Stevenson, Elements of Power System Analysis, McGraw Hill, 1998.*

Semester: 1

Methodological Unit Code: UEM 1.1

Subject: Lab: Advanced Power Electronics

VHS: 22h30 (Lab: 1h30)

Credits: 2

Coefficient: 1

Teaching Objectives:

To enable students to understand the operating principles of new power converter structures.

Recommended Prerequisites:

Basic principles of power electronics.

Subject Content:

Lab 1: New Converter Structures
Lab 2: Power Factor Improvement
Lab 3: Harmonic Elimination
Lab 4: Static Reactive Power Compensators

Assessment Method:

Continuous assessment: 100%.

Bibliographic References:

1. *Guy Séguier and Francis Labrique, "Converters in Power Electronics - Volumes 1 to 4", Lavoisier Tec et Documentation, available in the library.*

2. *Valérie Léger, Alain Jameau, Energy Conversion, Electrical Engineering, Power Electronics. Course Summary, Problems and Solutions, Ellipses Marketing.*

Semester: 1

Methodological Unit Code: UEM 1.1

Subject: Lab: Applied Numerical Methods and Optimization

VHS: 22h30 (Lab: 1h30)

Credits: 2

Coefficient: 1

Teaching Objectives:

To program numerical resolution methods and associate them with optimization problems.

Recommended Prerequisites:

Algorithms and programming.

Subject Content:

- Introduction to MATLAB environment (Introduction, Basic aspects, Comments, Vectors and matrices, M-Files or scripts, Functions, Loops and control, Graphics, etc.). (1 week)
- Writing a program to:
    - Calculate the integral using the following methods: Trapezoidal, Simpson, and general methods. (1 week)
    - Solve ordinary differential equations and systems by Euler, Runge-Kutta 2nd and 4th order methods. (2 weeks)
    - Solve linear and nonlinear equation systems: Jacobi; Gauss-Seidel; Newton-Raphson. (1 week)
    - Solve PDEs by FDM and FEM for the three types of equations (Elliptic, Parabolic, and Hyperbolic). (6 weeks)

- o Minimize a multivariable function without constraints. (2 weeks)
- o Minimize a multivariable function with constraints (inequalities and equalities). (2 weeks)

Assessment Method:

Continuous assessment: 100%.

Bibliographic References:

1. *G. Allaire, Numerical Analysis and Optimization, Edition of the Polytechnic School, 2012.*
2. *Computational Methods in Optimization, Polak, Academic Press, 1971.*
3. *Optimization Theory with Applications, Pierre D.A., Wiley Publications, 1969.*
4. *Taha, H. A., Operations Research: An Introduction, Seventh Edition, Pearson Education Edition, Asia, New Delhi, 2002.*
5. *S.S. Rao, "Optimization -- Theory and Applications", Wiley-Eastern Limited, 1984.*

Semester: 1

Methodological Unit Code: UEM 1.1

Subject: Lab: Advanced Electrical Machines

VHS: 22h30 (Lab: 1h30)

Credits: 2

Coefficient: 1

Teaching Objectives:

To complement, consolidate, and verify the knowledge already acquired in the course.

Recommended Prerequisites:

Proficiency in computer tools and MATLAB-SIMULINK software.

Subject Content:

1. Electromechanical characteristics of the asynchronous machine.
2. Circle diagram.
3. Autonomous operation of an asynchronous generator.
4. Coupling an alternator to the network and its operation as a synchronous motor.
5. Determination of synchronous machine parameters.

Assessment Method:

Continuous assessment: 100%.

Bibliographic References:

1. *Th. Wildi, G. Sybille "Electrical Engineering", 2005.*
2. *J. Lesenne, F. Noielet, G. Seguier, "Introduction to Advanced Electrical Engineering" Univ. Lille. 1981.*
3. *M. Retif "Vector Control of Asynchronous and Synchronous Machines" INSA, Pedg. Course. 2008.*
4. *R. Abdessemed "Modeling and Simulation of Electrical Machines" ellipses, 2011.*

Semester: 1

Discovery Unit Code: UED 1.1

Subject: Subject 1 (Elective)

VHS: 22h30 (Lecture: 1h30)

Credits: 1

Coefficient: 1

Semester: 1

Discovery Unit Code: UED 1.1

Subject: Subject 2 (Elective)

VHS: 22h30 (Lecture: 1h30)

Credits: 1

Coefficient: 1

[Note]{.underline}:
The specialization team is free to choose the two elective subjects proposed in the curriculum or select other elective subjects based on the needs and interests of the program.

Semester: 1

Transversal Unit Code: UET 1.1

Subject: Technical English and Terminology

VHS: 22h30 (Lecture: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

To introduce students to technical vocabulary. To strengthen their language skills. To help them understand and summarize technical documents. To enable them to follow scientific conversations in English.

Recommended Prerequisites:

Basic English vocabulary and grammar.

Subject Content:

- Written comprehension: Reading and analyzing texts related to the specialization.
- Oral comprehension: Note-taking, summarizing, and presenting authentic scientific videos.
- Oral expression: Presentation of a scientific or technical topic, elaboration and exchange of oral messages (ideas and data), telephone communication, gestural expression.
- Written expression: Extracting ideas from a scientific document, writing a scientific message, exchanging information in writing, CV writing, internship or job application letters.

Recommendation:
It is strongly recommended that the instructor presents and explains, at the end of each session (at most), ten technical terms of the specialization in three languages (if possible): English, French, and Arabic.

Assessment Method:

Exam: 100%.

Bibliographic References:

1. *P.T. Danison, Practical Guide to Writing in English: Usage and Rules, Practical Advice, Editions d'Organisation 2007.*
2. *A. Chamberlain, R. Steele, Practical Communication Guide: English, Didier 1992.*
3. *R. Ernst, Dictionary of Applied Techniques and Sciences: French-English, Dunod 2002.*
4. *J. Comfort, S. Hick, and A. Savage, Basic Technical English, Oxford University Press, 1980.*
5. *E. H. Glendinning and N. Glendinning, Oxford English for Electrical and Mechanical Engineering, Oxford University Press 1995.*
6. *T. N. Huckin, and A. L. Olsen, Technical Writing and Professional Communication for Nonnative Speakers of English, McGraw-Hill 1991.*
7. *J. Orasanu, Reading Comprehension from Research to Practice, Erlbaum Associates 1986.*

IV - Detailed Program by Subject for Semester S2

Semester: 2

Fundamental Unit Code: UEF 1.2.1

Subject: Modeling and Identification of Electrical Systems

VHS: 45h (Lecture: 1h30, Tutorial: 1h30)

Credits: 4

Coefficient: 2

Teaching Objectives:

To acquire and master fundamental concepts and basic methods for developing input-output representation models describing system behavior from experimental measurements and techniques for identifying a process to be controlled for the development of high-performance regulation systems.

Recommended Prerequisites:

Mathematical basics and control systems.

Subject Content:

Chapter 1: Systems and Experiments (1 week)
General principles, types of models, models and simulation, how to obtain a model.

Chapter 2: Mathematical Model (2 weeks)
Block diagram of a system, characteristic variables, internal and external representations of a system.

Chapter 3: Modeling of Electrical Systems (2 weeks)
Modeling of passive and active components and basic electrical circuits, application examples.

Chapter 4: Modeling Tools (2 weeks)
Bond graph (BG) or Causal Information Graph (CIG) (Application to electrical circuits).

Chapter 5: Generalities on Identification (2 weeks)

- Definitions, steps, generation of Pseudo-Random Binary Sequence (PRBS), choice of model structure (AR, ARMA, ARMAX...).
- Review of basic methods in Automation: Time response of a system, Frequency approach, Direct identification from time and frequency responses of 1st and 2nd order systems, instrumental variable method.
- Model adjustment principle: Linear model with respect to parameters, Minimization of the adjustment criterion and calculation of the optimal solution.

Chapter 6: Graphical Identification Methods (2 weeks)
Strejc method, Broïda method...

Chapter 7: Numerical Identification Methods (2 weeks)
Recursive methods, non-recursive methods.

Chapter 8: Estimation and Observation (2 weeks)

- Estimation of electrical systems (example: Gopinath estimator).
- Deterministic observation (Luenberger observer).
- Non-deterministic or stochastic observers (Kalman filter).

Assessment Method:
Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. I.D. Landau, "System Identification", Hermès, 1998.

2. E. Duflos, Ph. Vanheeghe, "Estimation Prediction", Technip, 2000.
3. T. Soderstrom, P. Stoica, "System Identification", Prentice Hall, 1989.
4. R. Hanus, "Identification in Automation", DE Boeck, 2001.
5. L. Lennart, "System Identification: Theory for the User", Second edition, Prentice Hall 1999.
6. P. Borne, Geneviève Dauphin-Tanguy, Jean-Pierre Richard, "Modeling and Identification of Industrial Processes", Technip, 1992.
7. R. Ben Abdenour, P. Borne, M. Ksouri, M. Sahli, "Identification and Digital Control of Industrial Processes", Technip, 2001.
8. E. Walter, L. Pronzato, "Identification of Parametric Models from Experimental Data", Springer, 1997.

Semester: 2

Fundamental Unit Code: UEF 1.2.1

Subject: Techniques of Electrical Control

VHS: 67h30 (Lecture: 3h00, Tutorial: 1h30)

Credits: 6

Coefficient: 3

Teaching Objectives:

- To acquire fundamental knowledge enabling the design of a motorization chain (motor and power electronics) for a variable speed drive, meeting predefined specifications, based on DC or AC machines.
- To dimension the necessary PID controllers for the control of electrical machines, according to specifications, using an appropriate method.
- To evaluate and compare the performances of different control strategies.

Recommended Prerequisites:
Mathematics, basic knowledge of electrical machines, power electronics converters, and control theory.

Subject Content:

Chapter 1: Variable Speed Electrical Drives (1 week)
Architecture of a drive system, the interest of variable speed, their structures, comparison of different drives.

Chapter 2: Modeling of Asynchronous and Synchronous Machines for Control (4 weeks)
Different three-phase to two-phase transformations, dynamic models of asynchronous and synchronous machines in the biphasic Park reference frame, functional diagrams.

Chapter 3: Control Strategies for Asynchronous Machines (5 weeks)

- Review of scalar control.
- Vector control: Principle of vector control, choice of reference frame and control strategy, rotor flux-oriented vector control, stator flux-oriented vector control.
- Direct torque control (DTC) of the asynchronous motor: Control strategies, torque control, power control.

Chapter 4: Control Strategies for Synchronous Machines (5 weeks)
Starting problem of synchronous machines, machine-converter association, synchronous motor in variable speed, self-control, vector control, torque control of the synchronous machine, DPC of synchronous machines.

Assessment Method:
Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. *Modeling and Control of the Asynchronous Machine, J.P. Caron and J.P. Hautier, Technip, 1995.*
2. *Control of Electrical Drives, W. Leonard, Springer-Verlag, 1996.*
3. *Vector Control of AC Machines, Peter Vas, Oxford University Press, 1990.*
4. *Control Methods of Electrical Machines, R. Husson, Hermès.*
5. *Power Electronics and AC Drives, Prentice-Hall, B.K. Bose, 1986.*
6. *Modern Power Electronics and AC Drives, B-K. Bose, Prentice-Hall International Edition, 2001.*
7. *Electrical Actuators, Guy Grellet and Guy Clerc, Eyrolles, 1997.*
8. *Control of Asynchronous Motors, Modeling, Vector Control and DTC, Volume 1, C. Canudas De Wit, Hermès Sciences Editions, Lavoisier, Paris 2004.*

Semester: 2

Fundamental Unit Code: UEF 1.2.2

Subject: Sampled Control and Digital Regulation

VHS: 45h00 (Lecture: 1h30, Tutorial: 1h30)

Credits: 4

Coefficient: 2

Teaching Objectives:
To understand sampling, the difference between continuous, sampled, and discrete systems. To know and master the mathematical tool "Z-transform". To know discrete models. To analyze sampled (discrete) systems and synthesize digital (discrete) controllers (PID, RST, and state feedback). To implement digital (discrete) controllers.

Recommended Prerequisites:
Knowledge of sampling, the difference between continuous, sampled, and discrete systems. Mastery of the mathematical tool "Z-transform". Knowledge of discrete models.

Subject Content:

Chapter 1: Structure of a Digital Control System (1 week)
History. Advantages and disadvantages of digital control. General structure of a digital control system. A/D and D/A conversions. Samplers/holders.

Chapter 2: Sampling and Reconstruction (1 week)
Sampling. Shannon sampling theorem. Practical considerations. Signal reconstruction.

Chapter 3: Z-Transform: Properties and Applications (2 weeks)
Definitions. Properties of the Z-transform. Z-transform of some signals. Inverse Z-transform. Application examples.

Chapter 4: Sampled (Discrete) Systems (2 weeks)
Definitions. Representation by difference equations. Advance/delay operators. Representation by impulse response. Representation by discrete transfer function (Z-transfer). Representation in state space. Block diagram algebra (simplification of blocks/diagrams).

Chapter 5: Analysis of Sampled Systems (3 weeks)
Introduction. Stability, accuracy, stability-accuracy dilemma. Time analysis (impulse response, step response, effects of poles and zeros). Frequency analysis. Stability criteria (Schur-Cohn, Jury, Routh-Hurwitz, discrete Nyquist, discrete Evans locus).

Chapter 6: Control by Digital PID Controller (2 weeks)
Continuous PID, discretization of the continuous PID. Synthesis in the Z-plane. Practical implementation of PID controllers.

Chapter 7: RST Digital Control (2 weeks)
Synthesis in the continuous case. Synthesis in the discrete (sampled) case. Practical implementation of RST controllers.

Chapter 8: Digital Control by State Feedback (2 weeks)
Synthesis in the continuous case. Synthesis in the discrete (sampled) case. Practical implementation of state feedback controllers.

Assessment Method:
Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. *J.R. Ragazzini, G. F. Franklin, "Sampled-Data Control Systems", Dunod, 1962.*

2. *D. Viault, Y. Quenec'hdu, "Sampled Control Systems", ESE, 1977.*

3. *C. Sueur, P. Vanheeeghe, P. Borne, "Automation of Sampled Systems: Course Elements and Solved Exercises", Technip, December 5, 2000.*

4. *P. Borne. G.D. Tanguy. J. P. Richard. F. Rotella, I. Zambetalcis, "Analysis and Regulation of Industrial Processes-Digital Regulation", Volume 2-Technip Editions, 1993.*

5. *Emmanuel Godoy, Eric Ostertag, "Digital Control of Systems: Frequency and Polynomial Approaches", Ellipses Marketing, 2004.*
6. *H. Buhler, "Sampled Controls", Volume 1, Dunod Edition.*
7. *Dorf & Bishop, "Modern Control Systems", Addison-Wesley, 1995.*
8. *J. L. Abatut, "Linear and Sampled Control Systems", Dunod Edition.*
9. *T.J. Katsuhiko, "Modern Control Engineering", 5th Edition, Prentice Hall.*
10. *R. Longchamps, "Digital Control of Dynamic Systems", Polytechnic Press, 2006.*

Semester: 2

Fundamental Unit Code: UEF 1.2.2

Subject: Fault Diagnosis in Control Systems

VHS: 45h00 (Lecture: 1h30, Tutorial: 1h30)

Credits: 4

Coefficient: 2

Teaching Objectives:
Industrial fault diagnosis is based on the knowledge of symptom(s) to determine the cause(s). This subject enables students to acquire essential knowledge to avoid failures, ensuring reliability and continuity of service in an electrical control system.

Recommended Prerequisites:
Electrical machines, electrical circuits, signal theory, numerical analysis.

Subject Content:

Chapter 1: Introduction to Fault Diagnosis Techniques (3 weeks)
Definitions: Purpose of diagnosis, normal operation, fault and defect*, failure, disturbance, residual, detection, fault localization, fault identification, signature, monitoring, supervision.

Methodology of diagnosis: How to perform a diagnosis? Logical steps of fault search, localization of the defective element under power and without power, diagnosis and search for the cause.

Intervention methodology: permanent monitoring, inspection, replacement of the defective element and verifications, intervention report, fault classification: location, modeling, temporal characteristics, monitoring using models: physical (hardware) redundancy, analytical redundancy, fault detection and isolation (FDI), principle of diagnosis: diagnosis architecture, residual generation based on models: obtaining signature tables, model-based diagnosis methods, state observer-based approaches.

Chapter 2: Tools for Fault Diagnosis (2 weeks)
Sensors, signal visualization, signal processing, spectral analysis: tools and techniques.

Chapter 3: Inspections, Directives, Interventions (3 weeks)
Specificity of industrial installations in terms of inspections, diagnosis of control and power equipment, exploitation of manufacturer data and reference values, mastery of the degradation curve and exploitation threshold situations.

Chapter 4: Preventive Maintenance of Equipment (2 weeks)
Reading electrical diagrams composed of power, control, and/or remote control circuits. Periodic verification of connector tightening, conductor condition, overheating. Control of leakage currents, nominal intensity, voltage.

Chapter 5: Case Studies of Various Practical Cases (3 weeks)
Motor, conveyor, control system.

Chapter 6: Introduction to Diagnosis Using Intelligent Methods (2 weeks)
Expert systems, state graphs, fuzzy logic, neural networks, genetic algorithms, ...

Assessment Method:
Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. J. Montmain, J. Ragot, D. Sauter, Supervision of Complex Processes, Lavoisier, 2007.
2. L. Ljung, Systems Identification: Theory for the User. Prentice-Hall, 2nd edition, 1999.
3. P.S.R. Murty, Power System Analysis, BS Publications, 2007.
4. D. Brown, D. Harrold, R. Hope, Control System Power and Grounding Better Practice, Elsevier, 2004.
5. G. Cullman, Elements of Information Calculation, Library of the Electrical-Mechanical Engineer. Ed. Albin Michel.
6. J.D. Glover, M.S. Sama, T.J. Overbye, "Power Systems Analysis and Design", 4th Edition, Thompson-Engineering.

Semester: 2

Teaching Unit: UED 1.2

Course: Elective Course 3

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Weighting: 1

Semester: 2

Teaching Unit: UED 1.2

Course: Elective Course 4

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Weighting: 1

[Note]{.underline}:

The specialty team may freely choose the two discovery courses proposed in the curriculum or select other discovery courses from those offered, depending on the needs and interests of the program.

Semester: 2

Teaching Unit: UET 1.2

Course: Compliance with Ethical and Integrity Standards

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Weighting: 1

Teaching Objectives:

To raise students' awareness of ethical principles and the rules governing university life and the workplace. To sensitize them to the respect and valorization of intellectual property. To explain the risks of moral issues such as corruption and how to combat them, and to alert them to the ethical challenges posed by new technologies and sustainable development.

Recommended Prerequisites:

Ethics and professional conduct (fundamentals).

Course Content:

A. Respect for Ethical and Integrity Rules

1. **Review of the MESRS Charter of Ethics and Professional Conduct:** Integrity and honesty. Academic freedom. Mutual respect. Demand for scientific truth. Objectivity and critical thinking. Equity. Rights and obligations of students, teachers, and administrative and technical staff.
2. **Integrity and Responsible Research**
    - Respect for ethical principles in teaching and research.
    - Responsibilities in teamwork: Equal professional treatment. Anti-discrimination conduct. Pursuit of the common good. Inappropriate behaviors in collective work.
    - Adopting responsible conduct and combating misconduct: Responsible research practices. Scientific fraud. Anti-fraud measures. Plagiarism (definition, forms, procedures to avoid unintentional plagiarism, detection, sanctions, etc.). Data falsification and fabrication.
3. **Ethics and Professional Conduct in the Workplace**
    - Legal confidentiality in companies. Loyalty to the company. Workplace responsibilities. Conflicts of interest. Integrity (corruption in the workplace, its forms, consequences, methods of combating it, and sanctions).

B. Intellectual Property

I. Fundamentals of Intellectual Property

1. Industrial property. Literary and artistic property.
2. Rules for citing references (books, scientific articles, conference papers, theses, dissertations, etc.).

II. Copyright

1. **Copyright in the Digital Environment**
    - Introduction. Copyright for databases and software. Special case of open-source software.
2. **Copyright on the Internet and E-Commerce**
    - Domain name rights. Intellectual property on the internet. E-commerce site rights. Intellectual property and social networks.

3. **Patents**

    - Definition. Rights in a patent. Utility of a patent. Patentability. Patent applications in Algeria and worldwide.

III. Protection and Valorization of Intellectual Property

- How to protect intellectual property. Violations and legal tools. Valorization of intellectual property. Protection of intellectual property in Algeria.

C. Ethics, Sustainable Development, and New Technologies

- Link between ethics and sustainable development. Energy conservation. Bioethics and new technologies (artificial intelligence, scientific progress, humanoids, robots, drones, etc.).

Assessment Method:
Exam: 100%

Bibliographic References:

1. Charter of University Ethics and Professional Conduct, link
2. Order No. 933 of July 28, 2016, on rules for preventing and combating plagiarism.
3. ABC of Copyright, United Nations Educational, Scientific and Cultural Organization (UNESCO).
4. E. Prairat, *De la déontologie enseignante*, Paris, PUF, 2009.
5. Racine L., Legault G. A., Bégin, L., *Éthique et ingénierie*, Montréal, McGraw Hill, 1991.
6. Siroux, D., *Déontologie: Dictionnaire d'éthique et de philosophie morale*, Paris, Quadrige, 2004, p. 474-477.
7. Medina Y., *La déontologie, ce qui va changer dans l'entreprise*, éditions d'Organisation, 2003.
8. Didier Ch., *Penser l'éthique des ingénieurs*, Presses Universitaires de France, 2008.
9. Gavarini L. et Ottavi D., *Éditorial. de l'éthique professionnelle en formation et en recherche*, Recherche et formation, 52 | 2006, 5-11.
10. Caré C., *Morale, éthique, déontologie*, Administration et éducation, 2nd quarter 2002, No. 94.
11. Jacquet-Francillon, François. *Notion : déontologie professionnelle*, Le télémaque, May 2000, No. 17.
12. Carr, D., *Professionalism and Ethics in Teaching*, New York, NY: Routledge, 2000.
13. Galloux, J.C., *Droit de la propriété industrielle*, Dalloz, 2003.
14. Wagret F. et J-M., *Brevet d'invention, marques et propriété industrielle*, PUF, 2001.
15. Dekermadec, Y., *Innover grâce au brevet: une révolution avec internet*, Insep, 1999.
16. AEUTBM, *L'ingénieur au cœur de l'innovation*, Université de technologie Belfort-Montbéliard.
17. Fanny Rinck and Lédia Mansour, *Littératie à l'ère du numérique : le copier-coller chez les étudiants*, Université Grenoble 3 and Université Paris-Ouest Nanterre la Défense, France.
18. Didier Duguest IEMN, *Citer ses sources*, IAE Nantes, 2008.

19. *Les logiciels de détection de similitudes : une solution au plagiat électronique?* Report of the Working Group on Electronic Plagiarism presented to the CREPUQ Pedagogy and ICT Subcommittee.

20. Emanuela Chiriac, Monique Filiatrault, and André Régimbald, *Guide de l'étudiant: l'intégrité intellectuelle plagiat, tricherie et fraude... les éviter et, surtout, comment bien citer ses sources*, 2014.

21. Université de Montréal Publication, *Stratégies de prévention du plagiat, Intégrité, fraude et plagiat*, 2010.

22. Pierrick Malissard, *La propriété intellectuelle : origine et évolution*, 2010.

23. World Intellectual Property Organization website: www.wipo.int

24. http://www.app.asso.fr/

Semester: 3

Fundamental Teaching Unit Code: UEF 2.1.1

Course: Nonlinear and Advanced Control

Total Hours: 67h30 (Lectures: 3h, Tutorials: 1h30)

Credits: 6

Weighting: 3

Teaching Objectives:

To familiarize students with different approaches for modeling and regulating nonlinear systems. To understand the principles of optimal, adaptive, sliding mode control, and how they differ from other control methods. To synthesize optimal, adaptive, and sliding mode controls and learn the conditions for their application. To apply these controls to industrial processes requiring such methods.

Recommended Prerequisites:

- Control of continuous linear systems.
- State-space modeling and control.
- Mathematical tools (ordinary differential equations, Lie derivative and bracket).
- System regulation and optimization.

Course Content:

Chapter 1: Basics of Nonlinear Systems (3 weeks)
1.1. Overview of nonlinear systems, common nonlinearities, and state-space modeling.
1.2. Complex interconnected nonlinear systems, singular perturbations.
1.3. Piecewise linear systems and multi-models.

Chapter 2: Stability and Control of Nonlinear Systems (3 weeks)
2.1. Stability, Lyapunov stability.

2.2. Regulation by state feedback linearization. Input-state linearization.
2.3. Regulation by state feedback linearization. Input-output linearization.

Chapter 3: Optimal Control (3 weeks)
3.1. Problem formulation.
3.2. Optimal control of systems without inequality constraints:

- Optimal control of nonlinear, non-stationary systems.
- Optimal control of linear, non-stationary systems with quadratic criteria.
- Optimal control of linear, stationary systems with quadratic criteria (LQ).
- Optimal control of linear, stationary systems with quadratic criteria (LQG).

Chapter 4: Adaptive Control (3 weeks)
4.1. Principle of adaptive control.
4.2. Different adaptive control techniques.
4.3. Synthesis of adaptive control laws:

- Direct adaptive control with reference model.
- Indirect adaptive self-tuning control.
- Self-tuning adaptive control with predictor reparameterization.

Chapter 5: Advanced Control Techniques (3 weeks)
5.1. Sliding mode control.
5.2. Backstepping control.
5.3. Passivity-based control.

Assessment Method:
Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. M. Vidyasagar, *Nonlinear System Analysis*, Prentice Hall.
2. A. Isidori, *Nonlinear Control Systems (I and II)*, Springer-Verlag.
3. H. K. Khalil, *Nonlinear Systems*, Prentice Hall.
4. H. Nijmeijer, *Nonlinear Dynamical Control Systems*.
5. D. Alazar, *Robustesse et commande optimale*, Masson, 1990.
6. R. Boudarel et al., *Commande optimale des processus*, Masson, 1989.
7. J-P. Babary and W. Pelczewski, *Commande optimale des systèmes continus déterministes*, Masson, 1985.
8. S. N. Desineni, *Optimal Control System*, CRC Press, 2003.
9. R. Lozano and D. Taoutaou, *Commande adaptative et applications*, Paris: Hermès Science Publications, 2001.
10. P. Naslin, *Théorie de la commande et conduite optimale*, Dunod, 1969.

11. J-P. Babary and W. Pelczewski, *Commande optimale des systèmes continus déterministes*, Masson, 1985.

12. K. Astrom and B. Wittenmark, *Adaptive Control*, Lund Institute of Technology, Addison-Wesley, 1989.

13. Grellet, *Actionneurs électriques*, Eyrolles, 1999.

14. J. Levine, *Introduction à la commande non linéaire*, Centre Automatique et Systèmes, École des Mines de Paris.

15. J. Levine, *Analyse et commande des Systèmes non Linéaires*, Centre Automatique et Systèmes, École des Mines de Paris.

16. Nadjib Bennis, *Représentation d'état des systèmes linéaires continus, commande par placement des pôles*.

17. www.specialautom.net

Semester: 3

Fundamental Teaching Unit Code: UEF 2.1.1

Course: Programmable Logic Controllers (PLCs)

Total Hours: 22h30 (Lectures: 1h30)

Credits: 2

Weighting: 1

Teaching Objectives:

To acquire the necessary skills to design (hardware and software) an automation solution based on a PLC, and to deepen knowledge to design and implement digital regulation (e.g., speed control of a motor). To address industrial applications and consider more or less complex forms of GRAFCET, and to introduce industrial networks.

Recommended Prerequisites:
Combinatorial and sequential logic, programming, microprocessors.

Course Content:

Chapter 1: General Architecture of a PLC, Hardware Description of Simatic S7 (e.g., S7-200/CPU216) (I/O, cycle concept, data types, addressing modes, etc.).

Chapter 2: Basic Instruction Set (STEP 7 Language) (Logic stack, Boolean instructions, transfer instructions, arithmetic and logic instructions).

Chapter 3: Timers (Identification and programming).

Chapter 4: Interrupts (Program organization in STEP 7, Simatic S7 events, handling an interrupt event, programming).

Chapter 5: Analog I/O (Identification and programming).

Chapter 6: PID Control Loop (Identification and programming).

Chapter 7: Industrial Networks (General architecture, communication protocols, applications).

Assessment Method:
Exam: 100%.

Bibliographic References:

1. *Micro System SIMATIC S7-200 One Hour Primer*, Siemens AG, 1999.
2. *Micro System SIMATIC S7-200 Two Hour Primer*, Siemens AG, 2000.
3. *SIMATIC S7-200 Programmable Controller System Manual*, Siemens AG, 1998.
4. E. Godoy, *Régulation industrielle: Outils de modélisation, méthodes et architectures de commande*, 2nd ed., Paris: Dunod, 2014.
5. K. Kamel and E. Kamel, *Programmable Logic Controllers: Industrial Control*, New York: McGraw-Hill Professional, 2013.
6. W. Bolton, *Les automates programmables industriels*, Paris: Dunod, 2010.
7. J. Stenerson, *Programmable Logic Controllers with Controllogix*, International Edition, Clifton Park, NY: Broadman & Holman Publishers, 2009.
8. S. Moreno and E. Peulot, *Le Grafcet: Conception-Implantation dans les automates programmables industriels*, Saint-Quentin-en-Yvelines: Casteilla, 2009.
9. F. P. Miller, A. F. Vandome, and J. McBrewster, *Automate Programmable Industriel: Programmation informatique, Automatique, Industrie, Programme (informatique), Interrupteur, Automaticien*, Alphascript Publishing, 2010.

Semester: 3

Fundamental Teaching Unit Code: UEF 2.1.2

Course: Artificial Intelligence Techniques

Total Hours: 45h (Lectures: 1h30, Tutorials: 1h30)

Credits: 4

Weighting: 2

Teaching Objectives:

To familiarize students with artificial intelligence techniques applied to system control and optimization.

Recommended Prerequisites:
Dynamic systems, mathematical analysis, optimization basics, probability basics.

Course Content:

Chapter 1: Fuzzy Logic (2 weeks)

- Basics. Fuzzy sets. Linguistic variables. Membership functions. Fuzzy logic operators. General structure of a fuzzy controller. Fuzzification. Inference engine. Inference methods. Defuzzification.

Chapter 2: Neural Networks (3 weeks)

- Topology of neural networks. Layered networks. Static networks. Dynamic neural networks. Learning methods: Supervised and unsupervised.

Chapter 3: Neuro-Fuzzy Networks (2 weeks)

Chapter 4: Genetic Algorithms (2 weeks)

Chapter 5: Particle Swarm Optimization (2 weeks)

Chapter 6: Expert Systems (2 weeks)

Chapter 7: Probability and Probabilistic Reasoning (2 weeks)

Assessment Method:
Continuous assessment: 40%; Exam: 60%.

Bibliographic References:

1. P. A. Bisgambiglia, *La logique floue et ses applications*, Hermès-science.
2. H. Buhler, *Commande par logique floue*, PPR.
3. Heikki Koivo, *Soft Computing*.
4. D. R. Hush & B. G. Horne, *Progress in Supervised Learning Neural Networks*, IEEE Signal Processing Magazine, Vol. 10, No. 1, pp. 8–39, Jan. 1993.
5. B. Kosko, *Neural Networks and Fuzzy Systems: A Dynamical Systems Approach to Machine Intelligence*, Englewood Cliffs, NJ: Prentice-Hall, 1992.
6. L. X. Wang, *Adaptive Fuzzy Systems & Control: Design & Stability Analysis*, Prentice-Hall, 1994.
7. David E. Goldberg, *Algorithmes Génétiques*, Addison Wesley, 1994.
8. Hansruedi Bühler, *Réglage par logique floue*.
9. Pierre-yves Glorennec, *Algorithmes d'apprentissage pour systèmes d'inférence floue*.
10. P. Borne, J. Rozinoer, J.-Y. Dieulot, L. Dubois, *Introduction à la commande floue*.
11. Bernadette Bouchon-Meunier, Laurent Foulloy, Mohammed Ramdani, *Logique floue. Exercices corrigés et exemples d'applications*.
12. Bernadette Bouchon-Meunier, *La logique floue et ses applications*.
13. Hung T. Nguyen, Nadipuram R. Prasad, Carol L. Walker, Elbert A. Walker, *A First Course in Fuzzy and Neural Control*.
14. Fakhr Eddine O. Karray, Clarence de Silva, *Soft Computing and Intelligent Systems Design. Theory, Tools and Applications*.
15. Pierre Borne, Mohamed Benrejeb, Joseph Haggège, *Les réseaux de neurones. Présentation et applications*.

16. Beghdadi Hadj Ali, Senouci Mohamed, *Réseaux de neurones: Théorie et pratique*.
17. G. Dreyfus, J.-M. Martinez, M. Samuelides, M. B. Gordon, F. Badran, S. Thiria, L. Hérault, *Réseaux de neurones. Méthodologie et applications*.
18. Léon Personnaz, Isabelle Rivals, *Réseaux de neurones formels pour la modélisation, la commande et la classification*.
19. Christine Solnon, *Optimisation par colonies de fourmis*.
20. Nicolas Monmarché, Frédéric Guinand, Patrick Siarry, *Fourmis artificielles 1. Des bases de l'optimisation aux applications industrielles*.
21. Stuart Russell, Peter Norvig, *Intelligence artificielle, avec plus de 500 exercices*.
22. Johann Dréo, Alain Pétrowski, Patrick Siarry, Éric Taillard, *Métaheuristiques pour l'optimisation difficile: Recuit simulé, recherche avec tabous, algorithmes évolutionnaires et algorithmes génétiques, colonies de fourmis...*
23. Patrick Siarry et al., *Métaheuristiques: Recuit simulé, recherche avec tabous, recherche à voisinages variables, méthodes GRASP, algorithmes évolutionnaires, fourmis artificielles, essaims particulaires et autres méthodes d'optimisation*.

Semester: 3

Fundamental Teaching Unit Code: UEF 2.1.2

Course: Electrical Control of Industrial Mechanisms

Total Hours: 67h30 (Lectures: 3h, Tutorials: 1h30)

Credits: 6

Weighting: 3

Teaching Objectives:

To prepare students for better integration into industry by presenting various industrial mechanisms and appropriate control techniques.

Recommended Prerequisites:
Basic principles of control, electromechanical systems.

Course Content:

Chapter 1: Criteria for Choosing an Electric Motor in an Industrial Environment (2 weeks)
1.1. Electric motors: Motors for cranes, specially constructed motors, use of standard electric machines.
1.2. Motor selection: Based on power, operating regime.

Chapter 2: Electrical Control and Automation of Pumps, Fans, and Compressors (3 weeks)
General principles, shaft power, starting mechanisms with fan torque, electrical control of fans, general recommendations for choosing electrical control for pumps, fans, and compressors.

Chapter 3: Power Supply and Automation of Elevators and Extractors (2 weeks)
General principles, parking accuracy in lifting systems, requirements for elevator control systems, typical control schemes for elevators, automation of elevator speed control.

Chapter 4: Automation of Overhead Cranes (2 weeks)
General principles, motor loads in crane mechanisms, electromagnetic lifting systems, electrical control systems for cranes, requirements for mechanical characteristics of crane electrical controls, automation of cranes using thyristor converters, equipment for large cranes, remote control of cranes, power supply for cranes.

Chapter 5: Power Supply and Automation of Continuous Transport Mechanisms (3 weeks)
General principles, conveyor control selection, synchronization of multiple motors on a conveyor, electrical control of transport systems, automation of cable cars, passenger transport machines (traction): escalators, multi-cabin elevators, rotary excavators.

Chapter 6: Mini-Projects (3 weeks)
Case studies (excavators, rolling mills, electric furnaces, welding equipment, metal electrolysis and coating, metallurgical plants, oil drilling stations, paper and pulp industry, cement industry, glass industry, metal industry, etc.).

Assessment Method:
Continuous assessment: 40%; Exam: 60%.

Semester: 3

Methodological Teaching Unit Code: UEM 2.1

Course: Practical Work on Nonlinear and Advanced Control

Total Hours: 22h30 (Practical Work: 3h)

Credits: 4

Weighting: 2

Teaching Objectives:

To provide students with the necessary tools to program, simulate, validate, and implement various approaches for modeling and regulating nonlinear systems, as well as validating optimal, adaptive, and other advanced control techniques such as sliding mode, backstepping, or passivity through simulation. Then, implementation on test benches equipped with a DsPACE control card and acquisition cards.

Recommended Prerequisites:
System regulation and optimization. Programming and ability to use dynamic system simulation and programming software (Matlab).

Course Content:

Practical Work 1: Usual nonlinear systems, complex interconnected systems, singular perturbations. (2 weeks)

Practical Work 2: Regulation by state feedback linearization. Input-output linearization. (2 weeks)

Practical Work 3: Validation by simulation with Matlab of an optimal control without constraints for a DC motor, then validation on a DsPACE-equipped test bench. (2 weeks)

Practical Work 4: Validation by simulation with Matlab of a direct adaptive control with reference model for a DC motor, as well as validation on a DsPACE-equipped test bench. (2 weeks)

Practical Work 5: Validation by simulation with Matlab of a sliding mode control for a DC motor, as well as validation on a DsPACE-equipped test bench. (2 weeks)

Practical Work 6: Validation by simulation with Matlab of a backstepping control. (2 weeks)

Practical Work 7: Validation by simulation with Matlab of a passivity-based control. (2 weeks)

Assessment Method:
Continuous assessment: 100%.

Bibliographic References:

1. R. Lozano and D. Taoutaou, *Commande adaptative et applications*, Paris: Hermès Science Publications, 2001.
2. D. Alazar, *Robustesse et commande optimale*, Masson, 1990.
3. R. Boudarel et al., *Commande optimale des processus*, Masson, 1989.
4. J-P. Babary and W. Pelczewski, *Commande optimale des systèmes continus déterministes*, Masson, 1985.
5. S. N. Desineni, *Optimal Control System*, CRC Press, 2003.
6. V.I. Utkin, *Sliding Mode and Their Application in Variable Structure Systems*, Mir, Moscow, 1978.
7. H. Buhler, *Réglage par mode de glissement*, Presses polytechniques romandes, Lausanne, 1983.
8. M. Vidyasagar, *Nonlinear System Analysis*, Prentice Hall.
9. A. Isidori, *Nonlinear Control Systems (I and II)*, Springer-Verlag.
10. H. K. Khalil, *Nonlinear Systems*, Prentice Hall.
11. H. Nijmeijer, *Nonlinear Dynamical Control Systems*.
12. J. Levine, *Analysis and Control of Nonlinear Systems*.

Semester: 3

Methodological Teaching Unit Code: UEM 2.1

Course: Practical Work on Artificial Intelligence Techniques / Implementation of Real-Time Digital Control

Total Hours: 22h30 (Practical Work: 1h30)

Credits: 2

Weighting: 1

Teaching Objectives:

To program and simulate control laws based on artificial intelligence techniques. To learn how to implement real-time digital control.

Recommended Prerequisites:
Simulation and programming software. Dynamic systems. Optimization. Logic. Probabilities.

Course Content:

[Practical Work on Artificial Intelligence Techniques]

Practical Work 1: Introduction to fuzzy logic. (1 week)

Practical Work 2: Artificial neural networks. (1 week)

Practical Work 3: Adaptive networks and neuro-fuzzy networks. (1 week)

Practical Work 4: Genetic algorithms. (2 weeks)

Practical Work 5: Particle Swarm Optimization (PSO). (1 week)

Practical Work 6: Expert systems and probabilistic reasoning. (2 weeks)

[Practical Work on Implementation of Real-Time Digital Control]

Practical Work 1: Modeling and implementation of an Analog-to-Digital Converter (ADC) in Matlab. (1 week)

Practical Work 2: Modeling and implementation of a Digital-to-Analog Converter (DAC) in Matlab. (1 week)

Practical Work 3: Speed regulation of a DC motor using a digital PID. (1 week)

Practical Work 4: Implementation of PWM techniques on a digital processor. (2 weeks)

Practical Work 5: Computer-controlled electric motor. (2 weeks)

Assessment Method:
Continuous assessment: 100%.

Bibliographic References:

1. P. A. Bisgambiglia, *La logique floue et ses applications*, Hermès-science.
2. H. Buhler, *Commande par logique floue*, PPR.
3. Heikki Koivo, *Soft Computing*.
4. D. R. Hush & B. G. Horne, *Progress in Supervised Learning Neural Networks*, IEEE Signal Processing Magazine, Vol. 10, No. 1, pp. 8–39, Jan. 1993.
5. B. Kosko, *Neural Networks and Fuzzy Systems: A Dynamical Systems Approach to Machine Intelligence*, Prentice-Hall, 1992.
6. L. X. Wang, *Adaptive Fuzzy Systems & Control: Design & Stability Analysis*, Prentice-Hall, 1994.
7. David E. Goldberg, *Algorithmes Génétiques*, Addison Wesley, 1994.

Semester: 3

Methodological Teaching Unit Code: UEM 2.1

Course: Practical Work on Electrical Control of Industrial Mechanisms

Total Hours: 22h30 (Practical Work: 1h30)

Credits: 2

Weighting: 1

Teaching Objectives:

To familiarize students with real control examples.

Recommended Prerequisites:
Control techniques, electromechanical systems.

Course Content:

Practical Work 1: Automatic barrier. (2 weeks)

Practical Work 2: Drilling. (2 weeks)

Practical Work 3: Soap marking. (2 weeks)

Practical Work 4: Door system. (3 weeks)

Practical Work 5: Goods lift. (3 weeks)

Practical Work 6: Brick sorting. (3 weeks)

Assessment Method:
Continuous assessment: 100%.

Bibliographic References:
TP brochures.

Semester: 3

Methodological Teaching Unit Code: UEM 2.1

Course: Practical Work on Programmable Logic Controllers (PLCs)

Total Hours: 15h (Practical Work: 1h)

Credits: 1

Weighting: 1

Teaching Objectives:

To teach students how to install, program, and use a PLC. To introduce them to mastering program editing and debugging tasks, as well as correcting detected errors.

Synthesis, simulation, and implementation of PLC-based systems (logical automation, regulation, and industrial networks).

Recommended Prerequisites:
Combinatorial and sequential logic, PLCs, GRAFCET, STEP 7, Simatic S7.

Course Content:

Practical Work 1: Logical automation: Pneumatic cylinder system.

Practical Work 2: Logical automation: System with various logical processes: motors, cylinders, etc.; direct or timed actions; emergency events (interrupt handling).

Practical Work 3: Regulation: Implementation and simulation and/or realization of a control for an electric motor.

Practical Work 4: Industrial network: Implementation and operation of an industrial network.

[Note]{.underline}:

The above practical works can be performed on the TIA Portal software platform or on an experimental test bench based on a Simatic S7 (e.g., S7-200) with scaled-down processes (small motors, small cylinders), displays, tachometers, buttons, etc.

Assessment Method:
Continuous assessment: 100%.

Bibliographic References:

1. *Micro System SIMATIC S7-200 One Hour Primer*, Siemens AG, 1999.
2. *Micro System SIMATIC S7-200 Two Hour Primer*, Siemens AG, 2000.
3. *SIMATIC S7-200 Programmable Controller System Manual*, Siemens AG, 1998.
4. J. A. Rehg and G. J. Sartori, *Programmable Logic Controllers*, 2nd ed., Upper Saddle River, NJ: Prentice Hall, 2008.
5. E. P. Adrover, *Introduction to PLCs: A Beginner's Guide to Programmable Logic Controllers*, San Bernardino, CA: Elvin Perez Adrover, 2012.
6. J. R. Hackworth and F. D. H. Jr, *Programmable Logic Controllers: Programming Methods and Applications*, 1st ed., Upper Saddle River, NJ: Prentice Hall, 2003.
7. G. Barton, *Programmable Logic Controller 139 Success Secrets - 139 Most Asked Questions On Programmable Logic Controller - What You Need To Know*, Emereo Publishing, 2014.
8. R. J. Tocci, N. Widmer, and G. Moss, *Digital Systems: Principles and Applications: International Edition*, 11th ed., Boston, Mass.: Pearson, 2010.

Semester: 3

Discovery Teaching Unit Code: UED 2.1

Course: Elective Course 5

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Weighting: 1

Semester: 2

Discovery Teaching Unit Code: UED 2.1

Course: Elective Course 6

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Weighting: 1

[Note]{.underline}:

The specialty team may freely choose the two discovery courses proposed in the curriculum or select other discovery courses from those offered, depending on the needs and interests of the program.

Semester: 3

Transversal Teaching Unit Code: UET 2.1

Course 1: Document Research and Thesis Design

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Weighting: 1

Teaching Objectives:

To provide students with the necessary tools to search for useful information and effectively utilize it in their final year project. To guide them through the various steps leading to the writing of a scientific document. To emphasize the importance of communication and teach them how to rigorously and pedagogically present their work.

Recommended Prerequisites:
Methodology of writing and presentation.

Course Content:

Part I: Document Research

Chapter I-1: Topic Definition (2 weeks)

- Topic title.
- List of keywords related to the topic.
- Gather basic information (acquisition of specialized vocabulary, meaning of terms, linguistic definition).

- Information sought.
- Assess one's knowledge in the field.

Chapter I-2: Selecting Information Sources (2 weeks)

- Types of documents (books, theses, dissertations, journal articles, conference proceedings, audiovisual materials, etc.).
- Types of resources (libraries, internet, etc.).
- Evaluate the quality and relevance of information sources.

Chapter I-3: Locating Documents (1 week)

- Search techniques.
- Search operators.

Chapter I-4: Processing Information (2 weeks)

- Work organization.
- Initial questions.
- Synthesis of selected documents.
- Links between different sections.
- Final plan of the document research.

Chapter I-5: Presenting the Bibliography (1 week)

- Systems for presenting a bibliography (Harvard system, Vancouver system, mixed system, etc.).
- Document presentation.
- Source citation.

Part II: Thesis Design

Chapter II-1: Thesis Plan and Steps (2 weeks)

- Define and delimit the topic (abstract).
- Problem statement and thesis objectives.
- Other useful sections (acknowledgments, list of abbreviations, etc.).
- Introduction (*written last*).
- Literature review.
- Hypothesis formulation.
- Methodology.
- Results.
- Discussion.

- Recommendations.
- Conclusion and perspectives.
- Table of contents.
- Bibliography.
- Appendices.

Chapter II-2: Writing Techniques and Standards (2 weeks)

- Formatting. Chapter, figure, and table numbering.
- Cover page.
- Typography and punctuation.
- Writing. Scientific language: style, grammar, syntax.
- Spelling. Improving general linguistic competence in comprehension and expression.
- Saving, securing, and archiving data.

Chapter II-3: Workshop: Critical Study of a Manuscript (1 week)

Chapter II-4: Oral Presentations and Defenses (1 week)

- How to present a poster.
- How to deliver an oral presentation.
- Thesis defense.

Chapter II-5: How to Avoid Plagiarism? (1 week)
(Formulas, sentences, illustrations, graphs, data, statistics, etc.)

- Citation.
- Paraphrasing.
- Providing complete bibliographic references.

Assessment Method:
Exam: 100%.

Bibliographic References:

1. M. Griselin et al., *Guide de la communication écrite*, 2nd ed., Dunod, 1999.
2. J.L. Lebrun, *Guide pratique de rédaction scientifique: comment écrire pour le lecteur scientifique international*, Les Ulis, EDP Sciences, 2007.
3. A. Mallender Tanner, *ABC de la rédaction technique: modes d'emploi, notices d'utilisation, aides en ligne*, Dunod, 2002.
4. M. Greuter, *Bien rédiger son mémoire ou son rapport de stage*, L'Etudiant, 2007.
5. M. Boeglin, *Lire et rédiger à la fac. Du chaos des idées au texte structuré*, L'Etudiant, 2005.

6. M. Beaud, *L'art de la thèse*, Editions Casbah, 1999.

7. M. Beaud, *L'art de la thèse*, La découverte, 2003.

8. M. Kalika, *Le mémoire de Master*, Dunod, 2005.

Proposed Discovery Courses

Semester: ..

Discovery Teaching Unit Code: UED ..

Course: Electrical Power Quality

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Weighting: 1

Teaching Objectives:

- Study the main phenomena that degrade electrical power quality (EPQ), their origins, and their effects on equipment through voltage and/or current degradation and network disturbances.
- Understand the role of nonlinear loads in degrading power quality and learn about the main solutions to improve it by addressing disturbances, eliminating or mitigating them when unavoidable.

Recommended Prerequisites:
Electrical networks, harmonics, filters, fundamental electrical engineering, power electronics.

Course Content:

Chapter 1: Introduction to Electrical Power Quality (EPQ) (3 weeks)
Context, definition, and terminology of power quality. Objectives of EPQ measurement.

Chapter 2: Degradation of Power Quality (5 weeks)
Most common power quality issues and their effects on loads and processes:

- Voltage sags and interruptions: Causes of sags and surges. Effects on receivers. Flicker concepts.
- Harmonics and interharmonics: Causes of harmonics. Nonlinear loads. Impacts of harmonics on the network and receivers.
- Voltage variations and fluctuations: Internal/external causes of interruptions. Effects on production and equipment.
- Transient phenomena: EMC concepts. Lightning impacts. Equipotentiality. Protective conductor (PE).
- Imbalances.

Chapter 3: Power Quality Standards (3 weeks)
Voltage characteristics. Terminology. Measurement strategies for voltage parameters. Standards. Network analyzers.

Chapter 4: Solutions to Improve Power Quality (4 weeks)
Reducing the number of voltage sags and interruptions. Reducing the duration and depth of voltage sags. Making installations less sensitive. Use of static uninterruptible power supplies (UPS).
Reducing generated harmonic currents: Modifying the installation. Passive filtering. Active filtering. Hybrid filtering.
Remedies for protection against temporary overvoltages, switching surges (shock coils, static compensators), atmospheric overvoltages (lightning).
Voltage fluctuations: Changing lighting modes, modifying motor starting methods, adjusting the network.
Imbalances: Balancing single-phase loads across three phases. Increasing transformer power and cable sections upstream of imbalance generators. Machine protection. Use of LC loads (Steinmetz connection).

Assessment Method:
Exam: 100%.

Bibliographic References:

1. *Guide to Quality of Electrical Supply for Industrial Installations Part 2: Voltage Dips and Short Interruptions*, Working Group UIE Power Quality, 1996.
2. G.J. Wakileh, *Power System Harmonics-Fundamental Analysis and Filter Design*, Springer-Verlag, 2001.
3. A. Kusko, M-T. Thompson, *Power Quality in Electrical Systems*, McGraw Hill, 2007.
4. F. Ewald Fuchs, M.A.S. Masoum, *Power Quality in Power Systems and Electrical Machines*, Elsevier Academic Press, 2008.
5. R.C. Dugan, Mark F. Granaghan, *Electrical Power System Quality*, McGraw Hill, 2001.
6. Schneider Technical Guides No. CT199, CT152, CT159, CT160, and CT1.
7. A. Robert, *Supply Quality Issues at the Interphase between Power System and Industrial Consumers*, PQA 1998.
8. *Qualité de l'énergie*, Course by Delphine RIU, INP Grenoble

Semester: ..

Discovery Unit Code: UED ..

Subject: Industrial Informatics

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

This subject allows students in this master's program to familiarize themselves with the field of industrial informatics. They will acquire knowledge of communication protocols.

Recommended Prerequisites:

Combinatorial and sequential logic, microprocessors and microcontrollers, informatics.

Subject Content:

Chapter 1: Introduction to industrial informatics; **(02 weeks)**

Chapter 2: Hardware connection to a µP; **(02 weeks)**

Chapter 3: Peripherals and interfaces (Ports, Timers, etc.); **(04 weeks)**

Chapter 4: Serial communication buses (RS-232, DHCP, MODBUS, I2C); **(05 weeks)**

Chapter 5: Data acquisition: CAN and CNA peripherals; **(02 weeks)**

Assessment Method:

Exam: 100%

Bibliographic References:

1. Baudoin, Geneviève & Virolleau, Férial, "The DSP family, TMS 320C54X [printed text]: application development," Paris: Francis Lefebvre, 2000, ISBN: 2100046462.
2. Pinard, Michel, "The DSP family, ADSP218x [printed text]: principles and applications," Paris: Francis Lefebvre, 2000, ISBN: 2100043439;
3. Tavernier, Ch., "PIC microcontrollers: applications," Paris: Francis Lefebvre, 2000, ISBN: 2100059572;
4. Tavernier, Ch., "PIC microcontrollers: description and implementation," Paris: Francis Lefebvre, 2004, ISBN: 2100067222;
5. Cazaubon, Christian, "HC11 microcontrollers and their programming," Paris: Masson, [n.d.], ISBN: 2225855277;
6. Tavernier, Christian, "AVR microcontrollers: description and implementation," Paris: Francis Lefebvre, 2001, ISBN: 2100055798;
7. Dumas, Patrick, "Industrial informatics: 28 practical problems with course reminders," Paris: Francis Lefebvre, **2004**.

Semester: ..

Discovery Unit Code: UED ...

Subject: Industrial Ecology and Sustainable Development

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

To raise awareness of sustainable development, industrial ecology, and recycling.

Recommended Prerequisites:

None

Subject Content:

Chapter 1: Birth and evolution of the concept of industrial ecology **(02 weeks)**

Chapter 2: Definition and principles of industrial ecology **(02 weeks)**

Chapter 3: Industrial ecology experiences in Algeria and worldwide **(02 weeks)**

Chapter 4: Industrial symbiosis (eco-industrial parks/networks) **(03 weeks)**

Chapter 5: Gaseous, liquid, and solid waste **(03 weeks)**

Chapter 6: Recycling **(03 weeks)**

Assessment Method:

Exam: 100%.

Bibliographic References:

1. *Industrial and Territorial Ecology, COLEIT 2012*, by Junqua Guillaume and Brullot Sabrina.
2. *Towards Industrial Ecology: How to Implement Sustainable Development in a Hyper-Industrial Society*, Suren Erkman, 2004.
3. *Energy and Its Management. Montpellier Cedex 2: CRDP of Languedoc-Roussillon, 2004. ISBN 2-86626-190-9.*
4. *Appropriations of Sustainable Development: Emergences, Diffusions, Translations*, B. Villalba, 2009.

Semester: ..

Discovery Unit Code: UED ...

Subject: Renewable Energies

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

To equip students with the scientific foundations enabling them to join the research community in the field of renewable energies, batteries, and associated sensors for engineering applications.

Recommended Prerequisites:

Energy conversion devices and technologies.

Subject Content:

Chapter 1: Introduction to renewable energies (Sources of renewable energies: deposits and materials) **(04 weeks)**

Chapter 2: Solar energy (photovoltaic and thermal) **(04 weeks)**

Chapter 3: Wind energy **(03 weeks)**

Chapter 4: Other renewable sources: hydraulic, geothermal, biomass, etc. **(02 weeks)**

Chapter 5: Storage, fuel cells, and hydrogen **(02 weeks)**

Assessment Method:

Exam: 100%.

Bibliographic References:

1. Sabonnadière, Jean Claude. *New Energy Technologies 1: Renewable Energies*, Ed. Hermès.
2. Gide, Paul. *The Comprehensive Book of Wind Energy*, Ed. Moniteur.
3. Labouret, A. *Photovoltaic Solar Energy*, Ed. Dunod.

4. Viollet, Pierre Louis. *History of Hydraulic Energy*, Ed. Press ENP Chaussée.
5. Peser, Felix A. *Thermal Solar Installations: Design and Implementation*, Ed. Moniteur.

Semester: ..

Discovery Unit Code: UED ..

Subject: Materials in Electrotechnics

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

The objective of this course is to provide the basic knowledge necessary to understand the physical phenomena occurring in materials and to make appropriate choices for the design of electrical components and systems. The fundamental characteristics of different types of materials, as well as their behavior in the presence of electric and magnetic fields, are addressed.

Recommended Prerequisites:

Fundamental physics and applied mathematics.

Subject Content:

Chapter 1: Understanding the operation, structure, technology, and specifications of electrical equipment used in electrical networks. **(03 weeks)**

Chapter 2: Magnetic materials: properties, losses, types, thermal and mechanical properties, characterization, magnets. **(04 weeks)**

Chapter 3: Conductive materials: properties, losses, insulation, tests, and applications. **(04 weeks)**

Chapter 4: Dielectric materials: properties, losses, breakdown and performance, constraints, tests. **(04 weeks)**

Assessment Method:

Exam: 100%.

Bibliographic References:

1. A.C. Rose-Innes and E.H. Rhoderick, *Introduction to Superconductivity*, Pergamon Press.
2. P. Tixador, *Superconductors*, Editions Hermès, Materials Collection, 1995.
3. P. Brissonneau, *Magnetism and Magnetic Materials*, Editions Hermès.
4. P. Robert, *Electrotechnical Materials, Volume II*, Treatise on Electricity, Electronics, and Electrotechnics of the Swiss Federal Institute of Technology, Dunod Edition.
5. *Techniques of the Engineer*.

6. R. Coelho and B. Aladenize, *Dielectrics*, Treatise on New Technologies, Materials Series, Editions Hermès, 1993.
7. M. Aguet and M. Ianoz, *High Voltage, Volume XXII*, Treatise on Electricity, Electronics, and Electrotechnics of the Swiss Federal Institute of Technology, Dunod Edition.
8. C. Gary et al., *Dielectric Properties of Air and Very High Voltages*, Collection of the Studies and Research Directorate of Electricité de France, Eyrolles Edition, 1984.
9. *Dielectric Materials for Electrical Engineering, Volumes 1 & 2*, HERMES LAVOISIER, **2007**.

Semester: ..

Discovery Unit Code: UED ..

Subject: Maintenance and Operational Safety

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

Recommended Prerequisites:

Subject Content:

Chapter 1: History, context, and definitions of operational safety **(02 weeks)**

Chapter 2: Analysis of systems with independent components **(02 weeks)**

Modeling of failure logic using fault trees, qualitative and quantitative Boolean analysis, method limitations.

Chapter 3: Analysis of systems accounting for certain dependencies **(03 weeks)**

System modeling using Markov state graphs, quantitative exploitation of the model, method limitations.

Chapter 4: Analysis of systems accounting for generalized dependencies **(03 weeks)**

Modeling using Petri nets (PN), quantitative exploitation of the model: stochastic PN.

Chapter 5: Application of operational safety methodologies **(03 weeks)**

Reliability, maintainability, availability, safety.

Chapter 6: Reliability prediction methodologies **(02 weeks)**

Reliability calculations, failure mode analysis, fault diagnosis and maintenance techniques.

Assessment Method:

Exam: 100%.

Bibliographic References:

1. Patrick Lyonnet, *Reliability Engineering*, Edition TEC & DOC, Lavoisier, 2006.
2. Roger Serra, *Reliability and Industrial Maintenance*, Course, École de Technologie Supérieure ETS, Université de Québec, 2013.
3. David Smith, *Reliability, Maintenance, and Risk*, DUNOD, Paris **2006**.

Semester: ..

Discovery Unit Code: UED...

Subject: Implementation of Real-Time Digital Control

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

This unit addresses the digital control of converter-machine sets using programmable components (microcontrollers, DSPs, ARMs, FPGAs).

Recommended Prerequisites:

Microprocessors and microcontrollers, informatics, control, electrical machines, power converters.

Subject Content:

Chapter 1: Description of real-time systems; **(03 weeks)**

Chapter 2: Digital control of systems; **(04 weeks)**

Chapter 3: Study of PWM technique implementation on a digital processor; **(04 weeks)**

Chapter 4: Examples of machine control implementations: DC machines, asynchronous machines, synchronous machines. **(04 weeks)**

Assessment Method:

Exam: 100%.

Bibliographic References:

1. B. Bouchez, *Digital Audio Applications of DSPs: Theory and Practice of Digital Processing*, Elektor, 2003.
2. Baudoin, Geneviève & Virolleau, Férial, "The DSP family, TMS 320C54X [printed text]: application development," Paris: Francis Lefebvre, 2000, ISBN: 2100046462.
3. Pinard, Michel, "The DSP family, ADSP218x [printed text]: principles and applications," Paris: Francis Lefebvre, 2000, ISBN: 2100043439;
4. Tavernier, Ch., "PIC microcontrollers: applications," Paris: Francis Lefebvre, **2000**.

Semester: ..

Discovery Unit Code: UED...

Subject: Special Machines

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

Upon completion of this course, students will enhance their training by acquiring new skills due to the evolution of the field in which they already have a foundation, enriching their knowledge of different types of electrical machines.

Recommended Prerequisites:

Electrical machines, construction of electrical machines, electromagnetic conversion.

Subject Content:

Chapter 1: Introduction to special machines **(01 week)**

Chapter 2: Asynchronous machines **(04 weeks)**

- Single-phase motor
- Linear motor

Chapter 3: Synchronous machines **(05 weeks)**

- Synchronous machines
- Variable reluctance machines
- Permanent magnet motors
- Stepper motors
- Superconducting machines

Chapter 4: Micromachines **(05 weeks)**

- Synchros (Selsynes)
- Hysteresis synchronous motors
- Tachometric DC generators
- Resolvers

Assessment Method:

Exam: 100%.

Bibliographic References:

1. M. Kostenko and L. Piotrovski, *Electrical Machines*.

2. Réal-Paul Bouchard and Guy Olivier, *Design of Asynchronous Motors*.
3. B. Saint-Jean, *Electrotechnics and Electrical Machines*.

Semester: ..

Master: Electrical Control

Discovery Unit Code: UED

Subject: Transient Regimes in Electrical Systems

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

To design protection devices for electrical systems, the study of transient regimes is essential. This course therefore focuses on the study of transient regimes in electrical machines. The dynamic behaviors of electrical machines are addressed in both linear and non-linear regimes (where the concept of extending linear models to saturated regimes is introduced).

Recommended Prerequisites:

Electrical circuits, electrical machines, machine modeling, power electronics.

Subject Content:

I. Dynamic Model of the Asynchronous Machine (6 weeks)

- Review of relative and symmetrical components
- Analysis of transient regimes in asynchronous machines
- Motor operation
- Generator operation
- Dynamic performance during three-phase faults in asynchronous machines

II. Dynamic Model of the Synchronous Machine (5 weeks)

- Analysis of transient regimes in synchronous machines
- Alternator operation
- Motor operation
- Dynamic performance during three-phase faults in asynchronous machines

III. Dynamic Model of the DC Machine (4 weeks)

- Analysis of transient regimes in the machine
- Generator operation

- Motor operation

Assessment Method:

Exam: 100%.

Semester: ..

Master: Electrical Control

Discovery Unit Code: UED

Subject: Industrial Automation

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

- Understand, in terms of control-command, industrial automated systems.
- Learn the methodology for studying automated systems.
- Develop specifications.
- Perform programming and configuration of programmable logic controllers (PLCs).
- Be able to implement industrial systems designed around industrial PLCs.

Recommended Prerequisites:

Combinatorial and sequential logic, electrical diagrams and equipment, industrial technologies.

Subject Content:

Chapter I: Programmable Logic Controllers (PLCs) (4 weeks)

Basic concepts, global function of an automated system, production system, automation, structure of an automated production system (APS), hardware architecture of PLCs, criteria for selecting a PLC, synthesis of sequential systems, methods for analyzing the operation of automated systems.

Chapter II: Grafcet Tool (6 weeks)

Fundamental concepts, basic principles, evolution rules, basic structures, sequence notion, particular structures, advanced notions, hierarchical structures of a Grafcet, forcing and freezing of situations, equation formulation of a Grafcet.

Chapter III: PLC Programming Languages (5 weeks)

Common objects, different types of languages, SFC language, LD language, IL language, FBD language, ST language, LADDER (LD) language, LADDER symbolism, implementation of automation systems based on PLCs.

Assessment Method:

Exam: 100%.

Semester: ..

Master: Electrical Control

Discovery Unit Code: UED

Subject: Automation and Industrial Informatics

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

To understand the functioning and architecture of automated systems and the contribution of industrial informatics to these systems.

Recommended Prerequisites:

Algorithmics, programming, electrical circuits and systems.

Subject Content:

[Part 1]

1. Structure of an automated system: relational part; command part; operative part.
2. Examples of automated systems: Heating box; Lighting box; Domotics model, etc.
3. Modbus communication protocol: Transfer via Ethernet; Modbus frames, Example of exchange between master and slave.
4. Programming languages for automation applications:
    - Textual languages: IL "instruction list" (e.g., ASSEMBLER); ST "structured text" (e.g., Matlab).
    - Graphical languages: FBD "function block diagram" (e.g., Crouzet Millenium 3); LD "ladder diagram": Boolean equation programming (true/false); SFC "sequential function chart": e.g., GRAFCET, and all sequential processes.

[Part 2]

1. Presentation of industrial informatics and micro-programmed systems.
2. Architecture of microcontrollers.
3. Presentation of the different elements of a microcontroller, selection criteria.
4. Review of binary numbers and different encodings.
5. Instructions.
6. Review of combinatorial and sequential logic.

7. Study of the operation of a microcontroller: the PIC 18F4520.
8. Programming in Assembly – Review of flowcharts.
9. Presentation of interrupts.
10. Study of an Assembly program with interrupt management.
11. Presentation of integrated functions in the microcontroller (timer, PWM, etc.).
12. Presentation of the C language for the microcontroller / specifics for the PIC 18F4520.

Assessment Method:

Exam: 100%.

Bibliographic References:

1. Michel Lauzier, Gérard Colombari, *Automation and Industrial Informatics. Volume 1, Description Tools*, 96p, Foucher, 1994.
2. Michel Lauzier, Gérard Colombari, *Automation and Industrial Informatics. Volume 2, System Design*, 128p, Foucher, 1995.
3. Jean Perrin, Francis Binet, J. J. Dumery, Christian Merlaud, J. P. Trichard, *Automation and Industrial Informatics: Theoretical, Methodological, and Technical Foundations*, 336p, NATHAN (November 12, 2004).
4. Jean-Louis Fanchon, J.M. Bleux, *Industrial Automation*, 128p, NATHAN, 2001.
5. D. Blin, J. Danic, R. Le Garrec, F. Trolez, J.C. Seite, *Automation and Industrial Informatics*, Educalivre, August 1, **1999**.

Semester: ..

Master: Electrical Control

Discovery Unit Code: UED

Subject: Control of Future Energy Systems

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

[Subject Program]

1. Review of New and Renewable Energy Systems: General concepts, Non-renewable electrical energy, Renewable electrical energy, Microgrids, Control and monitoring of electrical energy systems, Necessity of intelligent electrical systems: Smart House, Smart City, Smart Grid, Smart electrical meters, Communication technology for intelligent networks (ZigBee, Winmax, other types of communications).
2. Artificial Intelligence in future energy systems: AI for domestic networks (Smart Home); AI for microgrid balance (Smart City); AI for global supply-demand balance (Smart Grids); AI for

marketplaces and collaborative platforms; AI for predictive maintenance and operations; AI for digital workforces.

3. How AI redefines energy challenges: For suppliers (producers), customers (consumers), and intermediaries or facilitators? What will it fundamentally transform in this ecosystem?
4. Artificial Intelligence as a robust optimization tool for energy production and consumption.
5. Notions on Big Data platforms and IoT (Internet of Things) for real-time aggregation of heterogeneous data.

Assessment Method:

Exam: 100%.

Bibliographic References:

1. C. Sabonnadière and N. Hadjsaid, *Smart Grids: Intelligent Electrical Networks*, HERMES, 2012.
2. N. Hadjsaid, *Electrical Distribution Networks: From Decentralized Production to Smart Grids*, HERMES, 2010.
3. Bouckaert Stéphanie, "Contribution of Smart Grids to the Energy Transition: Evaluation in Long-Term Scenarios." PhD Thesis, École Nationale Supérieure des Mines de Paris. 2013.
4. L. Freris and D. Infield, *Renewable Energy for Electricity Production*, DUNOD, Paris, 2009.
5. Burton T., Sharpe D., Jenkins N., Bossanyi E., Hassan G., *Wind Energy Handbook*, England, 2001.
6. Riolet E., *Solar and Photovoltaic Energy for Individuals*, Eyrolles, 2010.
7. Bryans L., Flynn D., Fox B. et al, *Wind Electrical Energy*, Dunod, 2015.
8. Damien A., *Biomass Energy*, Dunod, 2013.
9. Ginocchio R., Viollet P.-L., *Hydraulic Energy*, Lavoisier, 2012.
10. "The Smart Grid Market Value Chain," www.items.fr, 2012.
11. Smart Grids-cre, Dossier "Advanced Meters," http://www.smartgridscre.fr/index.php.
12. ZigBee homepage, http://www.zigbee.org.
13. SmartGrids – CRE, "Smart Grid City: Local Management of Supply and Consumption Sources," 2011, available at: http://www.smartgrids-cre.fr/index.php?p=smartcities-smart-grid-city.
14. Chambolle.T, Meaux.F, "Report on New Energy Technologies," Paris, 2004.
15. Frédéric Scibetta, Yvon Moysan, Eric Dosquet, Frédéric Dosquet, *The Internet of Things and Data: Artificial Intelligence as a Strategic Breakthrough*, DUNOD, 2018.

Semester: ..

Discovery Unit Code: UED ..

Subject: Electrical Machines in Dynamic Regime

Total Hours: 22h30 (Lectures: 1h30)

Credits: 1

Coefficient: 1

Teaching Objectives:

To enable students to acquire knowledge concerning the modeling of synchronous and asynchronous machines in dynamic regimes.

Recommended Prerequisites:

Mathematics, operation of electrical machines in steady-state regimes.

Subject Content:

Chapter 1: Model of the Synchronous Machine in Dynamic Regime

- Construction of the synchronous machine and phenomena involved in its operation – simplifying assumptions.
- Voltage equations for stator and rotor in the real axis (salient pole machine).
- Flux equations – Inductance calculations – case of smooth pole machines – Mechanical equation and calculation of electromagnetic torque – problems related to system resolution.
- Axis transformation – Concordia – Park.
- Model of the machine in the Park reference frame – expression of electromagnetic torque – advantages of the Park model – state model.
- Limitations of the obtained model.

Chapter 2: Model of the Asynchronous Machine in Dynamic Regime

- Construction of the asynchronous machine and phenomena involved in its operation – simplifying assumptions.
- Voltage equations for stator and rotor in the real axis (wound rotor machine).
- Flux equations – Inductance calculations – case of cage rotor machines – Mechanical equation and expression of electromagnetic torque.
- Model of the machine in the Park reference frame – Different types of reference frame positions – expression of electromagnetic torque – state model.
- Limitations of the obtained model.

Assessment Method:

Exam: 100%.

Bibliographic References:

1. *Modeling and Control of the Asynchronous Machine*, J.P. Caron and J.P. Hautier, Technip, 1995.
2. *Control of Electrical Drives*, W. Leonard, Springer-Verlag, 1996.

3. *Vector Control of AC Machines*, Peter Vas, Oxford University Press, 1990.
4. *Control Methods for Electrical Machines*, R. Husson, Hermès.
5. *Power Electronics and AC Drives*, Prentice-Hall, B.K. Bose, 1986.
6. *Modern Power Electronics and AC Drives*, B-K. Bose, Prentice-Hall International Edition, 2001.
7. *Electrical Actuators*, Guy Grellet and Guy Clerc, Eyrolles, 1997.
8. *Control of Asynchronous Motors: Modeling, Vector Control, and DTC, Volume 1*, C. Canudas De Wit, Edition Hermès Sciences, Lavoisier, Paris **2004**.