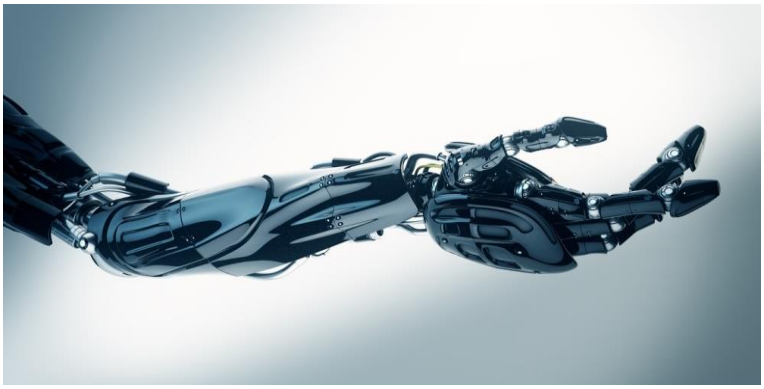
LEBANESE UNIVERSITY
FACULTY OF TECHNOLOGY



Curriculum
Master of
Mechatronics and Energy Engineering

2019

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Summary

Page

General Presentation and Objectives

The objective is to train technical graduates as well as R&D project managers in the fields of mechatronic product design, instrumentation of electromechanical production systems, and energy management.

The skills acquired must enable the registered students to improve their scientific and technological approach helping them to establish or optimize multi-criteria and multiphase specifications of mechatronics and energy products on one hand; and proceed in their design and optimization on the other hand.

This path is oriented towards both a research and a professional purpose: students will be able to go to industry or pursue their doctoral studies.

LEBANESE UNIVERSITY	Program Course	الجامعة اللبنانية
Faculty of Technology	Master	كلية التكنولوجيا
	Mechatronics and Energy Engineering	

	Semester 1				Semester 2			
	Code	Course	ECTS	CM+TD+TP	Code	Course	Crédits	CM+TD+TP
M1	MS1ACEL	Electric Actuators	4	30	MS2COEL	Electromechanical Converter	4	30
	MS1ANSC	Scientific English	3	30	MS2ENRA	Advanced renewable Energy	4	30
	MS1AUSU	Automation and Supervision	4	30	MS2GQEE	Electrical Energy Quality and Management	4	30
	MS1ELAV	Advanced Electronics	4	30	MS2MARK	Marketing	3	30
	MS1GEPR	Project Management	3	30	MS2MICE	Embedded Micro-Controllers	4	30
	MS1MOSM	Modeling of Mechanical System	4	30	MS2REBI	Bibliographic Research	4	45
	MS1PRSY	Programmation System	4	30	MS2ELFS	Finite Element and Simulation *	4	30
	MS1TRSI	Signal Processing	4	30	MS2INCA	Instrumentation and Sensors *	4	30
					MS2RETR	Electric Network and Transformers *	4	30
					MS2SYEE	Energy Systems and Environment *	4	30
	Total	8	30	240	Total	8	31	255

	Semester 3				Semester 4			
	Code	Course	Crédits	CM+TD+TP	Code	Course	Crédits	CM+TD+TP
M2	MS3AQEC	Quality Assurance and Eco-Design	4	30	MS4SEMI	seminars	8	60
	MS3COAV	Advanced Automation	5	45	MS4STPR	Internship - Project (≈250h/student - project)	22	250
	MS3COMP	Accounting	3	30				
	MS3ECEI	Business and Industrial Economics	4	30				
	MS3OPEN	Optimization and Energy	5	45				
	MS3EENC	Electronics for non-conventional energies *	4	30				
	MS3ENBA	Energy in Buildings *	4	30				
	MS3MEFM	Flexible Mechanics and Materials *	4	30				
	MS3SYTM	Thermal and Multiphysics Systems *	4	30				
	Total	7	29	240	Total	2	30	310

* : Elective Courses - ECTS : European Credit Transfert and accumulation System - CM : Lecture - TD : Exercises - TP : LAB Sessions

Total ECTS:	120
Total Hours:	1045

Semester 1

Code	Course	ECTS	CM+TD+TP
MS1ACEL	Electric Actuators	4	30
MS1ANSC	Scientific English	3	30
MS1AUSU	Automation and Supervision	4	30
MS1ELAV	Advanced Electronics	4	30
MS1GEPR	Project Management	3	30
MS1MOSM	Modeling of Mechanical System	4	30
MS1PRSY	Programmation System	4	30
MS1TRSI	Signal Processing	4	30
Total	8	30	240

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS1ACEL	Electric Actuators	1	4				30

Objectives:

In this course, the general concepts of electromechanical conversion of energy will be presented and extended to other types of actuators. This course also deals with the dynamic modeling of electrical machines. The aim is to describe the transient conditions of the machines coupled to the network and the converter-machine coupled in the context of the auto-piloting of the torque of the AC machines. Thus, the modeling of the alternative machines will be achieved by the use of adequate transformations. Finally, taking into account the saturation of the magnetic circuits will be discussed.

Contents:

Electromagnetic actuators
• General concepts on the electromagnetic conversion of energy
• Variable reluctance machines
• Modeling of the asynchronous machine in transient regime
• Scalar control of the torque
• Application of Park transformation to machine torque control
• Synchronous machine with salient poles
• Auto-piloting of the torque of an asynchronous machine
• Actuators in an unbalanced state
• Simulation study of a converter-machine association

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS1ANSC	Scientific English	1	3				30

Objectives:

Communication is one of the most important, yet least appreciated, aspects of engineering. You can do the best work in the world, but if you cannot communicate it to anyone, then what is the point? The purpose of this class is to teach you how to communicate your technical work. We primarily emphasize written communication, but we also discuss oral communication. Communication, like any other skill, requires time and practice. If you want to become a good communicator, then read, write, and speak. If you want to become an excellent communicator, then read, write, and speak even more.

Contents:

1. Multicultures
2. Audience
3. References and Citations
4. How to Read
5. State Your Thesis
6. The Writing Process, Effective Writing, and Peer Review
7. Writing Structure and Style
8. Ethics in Communication
9. Graphics and Tables
10. Oral Presentations
11. Proposals
12. Letters, Memos, and Emails
13. Job Applications, Writing a Résumé; The Basics; and Chronological and Analytical approaches.

Lab Sessions:

1. plan technical communication based on analysis of context
2. design a document effectively, choosing the appropriate format, layout, visuals, ...
3. synthesize technical information from a variety of resources and references and present this information in the form of a research report following proper documentation procedures
4. produce descriptive, informative and evaluative summaries of technical material
5. write and edit various business memoranda, letters, and technical reports
6. prepare for a job interview
7. deliver formal, informative oral presentations
8. collaborate with other team members to plan and produce/deliver written/oral communication

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS1AUSU	Automation and supervision	1	4				30

Objectives:

From a functional analysis, how to choose and dimension the components of an automated system (control, sensors, actuators, pre-actuators) and, once the specified architecture, know how to decompose the application with method and program the PLC. Understand the need for the supervisory function in industrial processes and know the technologies implemented for supervision.

Contents:

-The architecture of automated systems.
-Some typical applications of automated systems (BMS, industry, energy production).
-The architecture of an industrial programmable equipment (PLC, embedded PC, SNCC ...)
-The mode of operation of an API: cyclic tasks, periodic tasks …
-I/O technologies (PNP, NPN…).
-The operation of pneumatic actuators and pre-actuators.
-The integration of the PLC into a wiring diagram.
-The use of a method to structure his program (UML or other).
-The description of a sequential problem using a state machine or a grafcet.
-Programming languages of PLCs according to standard IEC 113.
-A method of describing and programming GEMMA based approach.
-Technical and IT architecture for supervision
-Role and services offered by supervision: alarm, remote maintenance, etc.
-Establishment of the communication between the supervision software and the PLC (s).

Lab Sessions:
The practical work and the study projects will lead the student to:

- Master a professional automation development environment.
- Implement multidisciplinary industrial components (sensors, actuators ...)
- Realize a project, using functions and functional blocks and carry out the associated tests.

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS1ELAV	Advanced Electronics	1	4				30

Objectives:

This couse focuses on the design of electronic systems with a high level of abstraction, starting from the architecture of a wireless transceiver to explore the main functionalities of digital and analog circuits and the challenges in their design. The interface between the analog and digital domains is introduced and through a study on the design of Sigma-delta modulators the fundamental notions are reviewed. Digital filter design is covered to highlight the main considerations of real time implementations of digital circuits. The choice criteria of digital hardware and the design of complex digital systems is then presented, along with a comparison of current digital processors. In the last part of this course, the current and future trends in the industry of digital electronic systems and leading applications are explored.

Contents:

Wireless transmission of information. Main analog and digital building blocks in a wireless transceiver. Nonlinearity of analog components and design challenges. Baseband units.

Analog to digital and digital to analog converters. Design considerations of Sigma-delta modulators.

Analog vs digital filtering. Design and fixed-point implementation of digital filters.

Challenges in the design of digital electronic systems. system-on-chip (SoC). Embedded systems. Different kinds of digital processors existing on the market today and their architectures.

Understand the current and future trends in the industry of electronic systems. Internet-of-things, micro and nanotechnology, cognitive radio, Radio over Fiber (RoF). Most important applications.

Lab Sessions:
Analysis of circuits nonlinearity using behavioral models in Matlab.
Design and analysis of fixed-point implementation of digital filters using Matlab.

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS1GEPR	Project Management	1	3				30

Objectives:

This course explores technical and managerial challenges of project management in general. The topics addressed in this course range from project selection techniques, project planning, budgeting, risk analysis, resource management to project monitoring and termination. The goal is to understand how project management decisions are reached, what trade-offs are made, and why some projects succeed and some not.

Contents:

After completing this course you will be able to

- Understand why some projects succeed and some not
- Understand the main issues and techniques in project planning and controlling
- Conduct project planning activities that accurately forecast project costs, timelines, and quality
- Implement processes for successful resource, communication, quality and risk management

I. Introduction to project management

a) What is a project? What is Project Management?
b) Project Management processes
c) Project Organization
d) Project Stakeholders
e) Project Success

II. Project Selection & Scope Management

a) Definition of objectives
b) Work Breakdown Structure
c) Concept development
d) Selecting from Options
e) Project Charter

III. Project Planning & Scheduling

a) PERT charts & Gantt diagram
b) Critical Path Method (CPM)
c) Planning the resources
d) Schedule development & control

IV. Risk Analysis

a) Identifying risks
b) Reacting to the risks
c) Risk monitoring

V. Cost Management

a) Estimates
b) ROI (Return On Investment) calculation
c) Cost Control

VI. Quality Management

a) Quality Planning
b) Quality reviews
c) Quality Control

VII. Progress Control

a) Work packages

b) Milestones
c) Schedule Control
d) Managing changes

VIII. The Project Team

a) Building the team
b) Team development
c) Responsibility chart
d) Communication/ Weekly Meetings

IX. Project Closing

a) Project acceptance
b) Final report
c) Lessons learned

Lab Sessions:

Project Management Simulation: Simultrain
Project Management software: Primavera

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS1MOSM	Modeling of Mechanical System	1	4				30

Objectives:

This course aims to help the students designing a mechanical system, studying the failure and fatigue of any component in this mechanical design and to integrating this knowledge in the design of task-specific power transmission systems

Contents:

1. Familiarize students with the fundamental concepts of fatigue theories of mechanical components under static and cyclic loads
2. Introduce students to the philosophy of certain codes, theories, and important standards used in the industry
3. being able to model any mechanical system subjected to any load (shaft, gears, and bearings)

Lab Sessions:

Matlab applications (Harmonic analysis, spectral analysis, signal synthesis, digitization, filtering)

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS1PRSY	Programmation System	1	4				30

Objectives:

This course introduces the concepts of system programming on the Linux/Unix platform with application. Topics include shell programming, system calls, file access, dynamic memory allocation, POSIX threads, multiprocessors, inter-process communication.

Contents:

1- Linux Installation, shell, text editor and debugger tools.
2- Advance C tutorial
3- Streams, buffers, pipes and other I/O operations
4- System calls, signals, sockets, shared memory
5- Libraries (the C standard library, the Curses library and the X library)
6- Scripting languages

Lab Sessions: At the end of this course, student will be able to:

1- install and configure Linux systems
2- use basic shell commands and utilities under Linux
3- understand system programming tools and resources
4- enhance their programming skills through the development, testing and debugging of C programs under Unix using standard and customized libraries
5- use basic operating system to create and manage multithreaded and multiprocessing applications
6- appreciate the importance of linux and how they can make use of it in both industry and academia
7- recognize some relevant open source and free tools in the area of mechatronic that are developed to be run under linux

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS1TRSI	Signal Processing	1	4				30

Objectives:

Acquire the basic tools needed for the analysis and processing of continuous and discrete signals.

Contents:

1. An introduction to signals and systems: Definitions, Classification, Energy, Power, Common models
2. Harmonic analysis of periodic signals : Decomposition principle, Amplitude and phase spectra, Harmonic synthesis
3. Spectral analysis of non-periodic signals : Properties of the Fourier Transform, Amplitude and phase spectra, Fourier Transform of some common signals
4. Convolution and linear filtering: Physical interpretation, Convolution/filtering relationship, Convolution properties, Amplitude and phase response, Linear filters
5. Digitization of signals: Sampling, Quantification, Shannon, Anti-recovery filter, Signal reconstruction
6. Spectral analysis of digital signals : Discrete Fourier Transform (DFT), Spectral resolution, Windowing, Fast Fourier Transform (FFT)
7. Digital filtering : Classification, Structures, z-Transfer function, Stability, Properties of FIR and IIR filters, Frequency response of digital filters

Lab Sessions:

Matlab applications (Harmonic analysis, spectral analysis, signal synthesis, digitization, filtering)

Semester 2

Code	Course	Crédits	CM+TD+TP
MS2COEL	Electromechanical Converter	4	30
MS2ENRA	Advanced renewable Energy	4	30
MS2GQEE	Electrical Energy Quality and Management	4	30
MS2MARK	Marketing	3	30
MS2MICE	Embedded Micro-Controllers	4	30
MS2REBI	Bibliographic Research	4	45
MS2ELFS	Finite Element and Simulation *	4	30
MS2INCA	Instrumentation and Sensors *	4	30
MS2RETR	Electric Network and Transformers *	4	30
MS2SYEE	Energy Systems and Environment *	4	30
Total	8	31	255

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS2COEL	Electromechanical Converter	2	4				30

Objectives:

This module deals with the analysis and synthesis of the main structures of non-isolated static converters of the power electronics. This involves understanding the operation, analyzing the waveforms and sizing basic converters such as three-phase controlled rectifiers, AC/AC converters, choppers and inverters. The converter-machine combination will be also discussed. This module is part of the continuation of Power Electronics module elaborated in license degree.

Contents:

Sources of electrical energy.
Roles and classification of converters.
Power components + classification.
Power switching components, quasi-resonant switches.
Operating principle of the rectifiers, choppers (series, parallel, reversible: 2 quadrants and 4 quadrants, interlaced), AC/AC converters (phase angle, train wave) and inverters (single phase and three phase).
Converter-machine combination (Chopper-DC Machines, Inverter-ASM or SM, AC/AC converter-ASM).
Flyback alimentation in full or incomplete demagnetization and forward alimentation.
Dynamic modeling and control of static converters: Width control (pulse width modulation), amplitude control (hysteresis).

LAB Sessions:

Executing simulations (CAD) of several examples discussed during this course.

Code	Entitled	Semester	Crédits	CM	TD	TP	Total
MS2ENRA	Advanced Renewable Energy	2	4				30

Pre-requisites: Electric Power, Machine and Electric actuators, Production and Distribution of electrical energy, renewable energy.

Objectives:

The course provides students the fundamentals of solar and wind energy conversion and system design for energy sources.

Contents:

- **Photovoltaic solar energy:** characteristics and performance by technology – silicon cells: mono and poly-crystalline, amorphous – thin mineral layer cells: Silicon, Cd In Si, Cd In Ge Si – Organic thin-layer cells, – Estimation of user's energy requirements. Sizing equations. Selection criteria of the photovoltaic system. System sizing. Installation of photovoltaic fields. Estimation of investment, operation and maintenance costs. Environmental impact, Maintenance, recycling of components.

- **Wind power**: Wind: Measurement, modeling, resource valuation – wind Turbines: definitions and basic principles. – Technological characteristics of wind turbines: horizontal axis Wind Turbine: Geometric description, modelling, performance – Vertical axis wind turbine (other types of wind turbines: Darrieus, Savonius,). – Sizing and physical characteristics of wind turbines – Description of the various components of wind power generation.

- **Energy storage**: Evolution of electricity, electromechanical machines and energy. Opportunities offered by renewable energies.
  1. Mechanical or thermal electrical Conversion
  2. Electric generators.
  3. Static Conversion of electrical energy.
  4. Storage systems: Batteries, accumulators, super capacitors. Modeling and control.
  5. Numerical simulations

- **Energy efficiency**: A case study on the evaluation of energy building codes. Different types of building codes.

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS2GQEE	Electrical Energy Quality and Management	2	4				30

Objectives:

Electrical energy systems are designed to operate ideally with three-phase balanced loads at the fundamental frequency. The deviation from ideal conditions has a considerable impact on the power efficiency of the whole system. This is due to the excessive losses, heating of electric machines, transformers and appliances. The comprehension of these imperfections in the electric network, which become more and more complex, is essential to the quantification of distortions and to provide solutions to improve the quality of distributed energy. Energy management systems propose a continuous control of the electric network using the latest technological innovations. A network of measurement instruments, installed at different levels of the electric network and connected to database and analysis centres, is used to evaluate in real-time the health of the network. This monitoring system has also a significant economic impact. In this course, we will analyse different types of distortions for a better understanding of imperfections, in particular nonlinearities, and the quantification parameters used. Different aspects of energy management systems and power efficiency improvement techniques are addressed.

Contents:

Structure of the electric network: Generation, transmission and distribution of electric energy, conventional and non-conventional sources, structure of the energy management system, communication standards, and Demand Side Management (DSM)

Power quality: Definitions, problems classification of power quality, the different causes of perturbations (harmonic distortion, frequency variation, voltage fluctuation and flicker), measure of the power quality.

The different types of distortions related to nonlinearity and imbalance: Power computation in presence of harmonics, power factor and displacement power factor, active filters, compensation of unbalanced loads.
Energy management systems: The needs and the importance of these systems, different aspects of the smart grid, PDCA (Plan-Do-Check-Act) approach, ISO-50001, real-time control.

Lab Sessions:

Simulations under Matlab : Analysis of nonlinearities in the electric network, voltage source nonlinearities and current nonlinearities due to the presence of active components in loads. Quantification parameters. Frequency analysis (FFT).

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS2MARK	Marketing	2	3				30

Objectives:

This course provides an introduction to basic marketing concepts. Topics include the marketing mix, new product development, consumer behavior, customer relationship management, strategic planning and e-commerce. Students will develop a comprehensive marketing plan and apply course concepts to real or imaginary products.

Contents:

Target market identification; Market segmentation; Competitive advantage; Competitive analysis; Positioning strategies; SWOT analysis; 4P's; Environmental scanning; Market research; New product development; Pricing strategies; Consumer behavior; E-commerce; Global marketing.

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS2MICE	Embedded Micro-Controllers	2	4				30

Pre-requisites: Logic circuit and Programmable circuits.

Objectives:
Study and implementation of basic systems and Microsystems adapted to the requirements of embedded systems and control systems. Give the necessary basic knowledge and methodology to achieve correctly the conception of programmable logic device (FPGA, CPLD, ...) in VHDL. In order to know how to implement the VHDL language, for the modeling, design and synthesis of digital circuits system with the certainty of achieving a product that meets the specifications that interfere with the electronics.

Contents:
Introduction, Design flow (Presentation of the FPGA, interest, evolution, field of application - Explanation of the FPGA and CPLD architecture, the distribution of the elements and the possibilities of exploitation of these different elements. Logic, embedded memory, clock blocks, DSP blocks, PLL, routing structure etc. Design methodology, tools ... The VHDL language and structures: Introduction to the VHDL language - IEEE libraries - Basic functions - Modular design - Modular decomposition (instantiation) [Data typing (Std_logic_vector) - Design units (entity, architecture, package, configuration) - Signals and ports, processes of a signal, variables vs. signals] - Concurrent and sequential instructions - Structural and behavioral description- GENERATE statement - Functions and procedure - State machine (synchronous and asynchronous) - Memory - Complex sequential systems (VHDL model for a simple microprocessor).

LAB Sessions:
The programmable device - FPGA (Altera DE2).
Practical work and programming VHDL- Getting started with a simulation tool and a synthesis tool VHDL- Programming the FPGA module with the software (Quartus).
Objectives: Realize the synthesis of logical functions in VHDL, Simulate the behavior of the system and to validate the realization on the module (DE2 of Altera) - Programming of an SRAM FPGA module. Examples covered: Multiplexers, Decoders, Segment Display 7, Counters, State Machine, traffic Light Controller, Model for a simple microprocessor, Memory, UART ... Study case : A pair work (each pair work has a different subject) with a part of specifications analysis, a part of functional analysis, the synthesis of the functions using a VHDL description, global simulation then realization on the model for testing and validation. (Proposed subjects: control of a remote system, realization of a high-frequency function generator, sound analysis, telemeter US, sigma-delta converter, sensor and display I2C...

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS2REBI	Bibliographic Research	2	4				45

Objectives:

To provide an in-depth reflection on a subject, it is essential to read the facts and opinions attached to it. In other words, it is to acquire and / or modify ideas, in contact with those of others. Reading is the preferred means of communicating thought. As part of a methodical search, learning is equivalent to reading concepts contained in documents written by others.

It is important to give some pointers and some tips that are sometimes lacking for students at the beginning of their work. Where to find the necessary references and how not to overlook the most important ones? How to feed their bibliography, how to build and classify it?

Four privileged sources of bibliographic information are distinguished, which the student will always be interested in referring to during the course of research: bibliographies of books, periodical articles, and library attendance and computer resources.

Contents:

1. Being a Researcher today, what is it?
2. The landscape of Scientific and Technical Information (STI) today and the place of the researcher
3. Seek and exploit its sources
4. Produce and publish

Lab Sessions:

Projects on different topics to do a thorough bibliographic search

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS2INCA	Instrumentation and Sensors	2	4				30

Pre-requisites: Basics of analog and digital electronics.

Objectives:

This course explains and illustrates the functioning of a variety of sensors and transducers used in industrial electronics and professional control applications. The course provides the basic physical principles of operation of sensors, it describes the conversion to and from electrical signals and focuses particularly on signal conditioning and data acquisition chain. Many industrial application are covered in this course with the analysis of benefits and limitations of different types of sensors.

Contents:

A student who successfully fulfills the course requirements will have demonstrated an ability to:

- Explain the principles of operation of the main types of sensors
- Utilise the merits of various types of sensors for a wide range of applications
- Understand the limitations in the performance of instrumentation systems
- Being able to connect a sensor to an electronic circuit while preserving the integrity of the measured signal.
- Understand the main characteristics of sensors
- Analyse the specifications of various types of sensors
- Select appropriate sensors for a given application and design simple electronic sensor interface system

Topics covered:

1- Different types of sensors: strain, pressure, force, load, weight, position, direction, distance, motion, flow, acoustic sensor, etc….

2- Main components of a data acquisition system.

3- Sensor signal conditioning: filters, amplifiers, ADCs…

4- Sensors fundamentals and characteristics.

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS2SYEE	Energy Systems and Environment	2	4				30

Contents:

1. Introduction and basic concepts
    a. Introduction
    b. Energy, energy transfer, and general energy analysis
    c. Properties of pure substances
    d. Energy analysis of closed systems
    e. Mass and energy analysis of control volumes
2. The second law of thermodynamics
    a. Thermal energy reservoirs
    b. Heat engines
    c. Refrigerators and heat pumps
    d. Reversible and irreversible processes
    e. The Carnot cycle: Carnot refrigerators and heat pumps
    f. Case-study: Household refrigerators
3. Entropy
    a. What is Entropy
    b. The increase of Entropy principle
    c. Entropy change of pure substances: solids, liquids and ideal gases
    d. Minimizing the compressor work
    e. Entropy balance
    f. Case-study: Reducing cost of compressed air
4. Exergy
    a. Exergy: work potential of energy
    b. Exergy transfer by heat, work, and mass
    c. The decrease of exergy principle and exergy destruction
    d. Exergy balance: closed systems and control volumes
5. Refrigeration cycles
    a. Refrigerators and heat pumps
    b. Ideal vapor-compression refrigeration cycle
    c. Actual vapor-compression refrigeration cycle
    d. Second-law analysis of vapor-compression refrigeration cycle
    e. Selecting the right refrigerant
    f. Heat pump systems
    g. Innovation vapor-compression refrigeration systems
    h. Gas refrigeration cycles
    i. Absorption Refrigeration systems
    j. Case study: Thermoelectric power generation and refrigeration systems
6. Energy and Environment
    a. Ozone and smog
    b. Acid rain
    c. The greenhouse effect
    d. Global warming and climate change
    e. Carbon foot-print calculator: household use and travel outside work

    f. Methods of calculating "Total Equivalent Warming Impact" (TEWI)
7. Economic tools for energy systems
    a. The time value of money
    b. Economic analysis of energy systems
    c. Equations for relating present, annual, and future values
8. 4-E evaluation criteria for energy systems
    a. Energy
    b. Exergy
    c. Environment
    d. Economic

Semester 3

Code	Course	Crédits	CM+TD+TP
MS3AQEC	Quality Assurance and Eco-Design	4	30
MS3COAV	Advanced Automation	5	45
MS3COMP	Accounting	3	30
MS3ECEI	Business and Industrial Economics	4	30
MS3OPEN	Optimization and Energy	5	45
MS3EENC	Electronics for non-conventional energies *	4	30
MS3ENBA	Energy in Buildings *	4	30
MS3MEFM	Flexible Mechanics and Materials *	4	30
MS3SYTM	Thermal and Multiphysics Systems *	4	30
Total	7	29	240

Code	Title	Semester	ECTS	Lecture	Exercises	Total
MS3COAV	Advanced Automation	3				45

Pre-requisites: Control Systems, Calculus II.

Objectives:

- Functional analysis and modeling of a control system.
- Black Box Identification of control system
- State space analysis
- Implementation and adjustment of PID (*proportional–integral–derivative*).

Contents:

1. Learn the different identification methods in order to obtain a control system model.
   - Direct identification, Broïda method, Strejc method, closed loop identification.
2. State space modeling for SISO and MIMO systems.
   - Obtain the transfer function from the state space model and vice versa
   - Obtain the state space canonical form: controllability and observability.
3. Stability of linear control system :
   - Routh criterion, geometrical criterion (Bode, Nyquist, Black), Phase margin and gain margin.
4. Design by the Root Locus Method
   - Different steps for root locus plot
   - Designing of P, PI, PID Controller, Lead and Lag compensators.
5. Solving the time-invariant state equation
   - Time response, transition matrix.
6. Control Systems Design in State Space
   - Pole placement, solving pole placement with Matlab,

LAB Sessions:

- Data acquisition and identification of control systems.
- Time and frequency analysis for control systems.
- Temperature and level control for a real system.
- Speed and position control for DC motor.

References:

- ***Course Automatique, K. GASSO, INSA Rouen***
- ***Course-Asservissements Linéaires Continus, M-K. Fellah, Université Djillali Liabès.***
- ***Modern Control Engineering, K. Ogata, 5th Edition.***
- ***AUTOMATIQUE: Systèmes linéaires, non linéaires, à temps continu, à temps discret, représentation d'état. Y. Granjon, DUNOD.***
- ***Course: Techniques de Commande Avancée, H. Merabet Boulouiha, Centre universitaire de Rélizane Ahmed Zabana.***
- ***Course automatique, T. Château., Polytech' Clermont Ferrand.***

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS3AQEC	Quality Assurance and Eco-Design	3	4				30

Pre-requisites: Knowledge in Electrical Engineering.

Aim: know the basics of the ISO 50001 standard and its implementation.

Objectives: To allow the students in Master to apprehend a Modern Management System, Integration with other management systems.

Contents:
The ISO 50001 standard, "Energy Management System", The 2011 version that remains applicable until 2021 will serve as a basis, The new 2018 version will also be addressed.

LAB Sessions: Case Studies will be treated.

References: Essentially the standards

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS3COMP	Accounting	3	3				30

Objectives:
To introduce the concept of chart of accounts and business transactions to students and to become familiar with the accounting transactions, adjusting the accounts and financial statements.
Contents:
Introduction to principles of accounting – Recording business transactions – Purchases and other expenses – Sales and other revenues - VAT – Depreciations

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS3ECEI	Business and Industrial Economics	3	4				30

Objectives:

This course introduces economic concepts that are fundamental to understanding many of the issues faced by business firms by integrating the theoretical and conceptual contributions of the management in order to understand the operation of the industrial company. The goal of this course is to develop the skills necessary to make optimal managerial decisions given different situations, environments, and information which involves analytical work. The theoretical knowledge presented can be applied to concrete situations, allow a confrontation between theory and practice and offer the possibility of perceiving the management interest of industrial companies.

Business Economics provides a broad overview of the economics of organization and business decision-making. It starts to present the basics of the business economy, to know the functioning of the company and in particular the industrial enterprise, and to examine the internal structure of firms, then moves on to the action of entrepreneurship, Finally, how these can be used in a business environment to help decision making. The emphasis will be throughout on understanding how the theoretical tools can be used to analyze real world issues.

Contents:

- What's an enterprise? Action of entrepreneurship, diversity of organization structure, size, strategy, classification, management, information in the company ... The main functions of the industrial enterprise (the function of management, production and stock inventory, commercial, human resources, financial,..)
- The company and its environment.
- Strategic management, project and risk management.
- Case studies, exercises and projects, dissertations, relevant examples, group discussions.

References:

- BRESSY G., KONKYUT C., Economie d'entreprise, coll. « Aide Mémoire », Ed. Sirey, nouvelle édition en 2006
- Gilles Bressy, Christian Konkuyt, économie D'entreprise, 7e édition, 2004, campus Dalloz
- LONGUATTE J. et MULLER J., Economie d'entreprise, coll. Express, 2004, Dunod
- MENARD C., Les théories de la firme, Collection « Repères », Ed. La Découverte
- MANKIW G.N., Principes de l'Economie, Economica
- Olivier Bouba-Olga, l'économie de l'entreprise 2003, amazon
- PASTRE Olivier, économie d'entreprise, 2011, édition économica
- Rudolf Brennemann, Sabine Sépari, économie d'entreprise, Dunod, Paris, 2001

- **Introduction to Principles of Accounting**

  - What is accounting?
  - Users of accounting?
  - Stakeholders
  - Chart of accounts and accounts

- **Recording business transactions**
    - The principle of the double-entry system
    - Application of the double-entry system
    - Journal, general ledger, trial balance, income statement and balance sheet
- **Purchases and other expenses**
    - Operating expenses (purchases, trade discounts, financial discounts, purchase returns, discounts granted after billing, other operating expenses and incidental purchase expenses)
    - Financial expenses
    - Non-operating expenses
- **Sales and other revenues**
    - Operating revenues (sales, incidental expenses on sales and other operating revenues)
    - Financial revenues
    - Non-operating revenues
- **VAT**
- **Depreciations**

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS3OPEN	Optimization and Energy	3	5				45

Objectives:
Acquire the necessary knowledge of optimization techniques and apply them in the field of optimization of multi-source energy.

Contents:

- Generality on the theoretical bases: Definition of Optimization problem, Solution, Differentiability, Classification of optimization problems, Optimization techniques.
- Traditional optimization techniques: Single variable optimization, Multiple variable optimization without constraints, Multiple variable optimization with equality constraint, Multiple variable optimization with inequality constraints
- Modern optimization methods: Genetic Algorithms, Simulated Annealing, Optimization of Particle Swarms, Ant Colony System, Fuzzy System Optimization, Neural Network Optimization.
- Optimization of multi-source systems of electricity production there renewable energies: multi-source energy system, optimization of the local distribution of renewable energy systems.

Lab Sessions:

1. Graphs and optimization in Matlab: Graph of a scalar function, graph of a function of 2 variables, contour lines and gradient field, functions and descriptors, optimization without constraints, optimization under constraints.
   Algorithms of optimization in Matlab

2. Optimizing the location of power plants in a multi-source energy system.

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS3EENC	Electronics for non-conventional energies	3	4				30

Pre-requisites: Electric machines, Power electronics, Basics in renewable energy systems.

Objectives:
Power electronics technologies are widely used nowadays in different areas of the electric systems. Their applications are among the fastest growing engineering field today and they have witnessed an increased use in the renewable energy systems, transportation sector and various industrial applications. This course is intended to provide an introduction to power electronics converters and how they are used in renewable energy systems. Basics about different types of machines and the associated power converters used in the wind and solar energy systems are presented in order to study the power exchanged with the grid. Each of these systems is simulated under MATLAB/SIMULINK environment. Obtained curves and results are commented and analyzed.

Contents: -
- Describe the input/output characteristics of photovoltaic and wind energy systems;
- Recognize the importance of power electronics in the operation of RE systems;
- Discuss different types of machines and power converters used in the RE industry;
- Analyze the performance of a 2-MW doubly fed induction generator for wind turbines application;
- Discuss some grid integration related issues;
- Interpret standards and codes such as NEC2104, IEC61400-12-1(2017), IEC61400-21. Application for a 10-kW PV residential system;
- List the grid-tie inverter provisions as per IEEE1547 (UL1741).
- Implement some models under MATLAB/SIMULINK;
- Analyze and comment on the obtained results.

References:

- H. Abu-Rub, *"Power electronics for renewable energy systems, transportation and industrial applications"*, 2014, Wiley.
- A. Gonzalo, *"Doubly fed induction machines. Modeling and control for wind energy applications"*, 2011, Wiley.
- E. Acha, *"FACTS, modeling and simulation in power networks"*, 2004, Wiley.
- Q. Zhong, *"Control of power inverters in renewable energy and smart grid integration"*, 2013, IEEE press.
- G.B. Gharehpetian, *"Distributed generation systems. Design, operation and grid integration"*, 2017, Elsevier.
- B. Zha, *"Grid integrated and standalone photovoltaic distributed generation systems",* 2017, Wiley.

Code	Title	Semester	ECTS	Lecture	Exercises	LAB	Total
MS3ENBA	Energy in Buildings	3	4				30

Objectives:

1. Demonstrate the significant energy consumption in buildings
2. Introduce the concept of "net-zero energy buildings"
3. Identify the energy flows in a building
4. Evaluate the energy savings in buildings for each improvement
5. Optimize the building envelop using passive energy solutions
6. Estimate the cost of an energy system of the building
7. Study the economic feasibility of any energy retrofit project in the building using LCC, NPV, PBP…
8. Estimate the environment impact of an energy system of the building

Contents:

1. Introduction and basic concepts
    a. Why studying energy in buildings?
        i. Energy price
        ii. Energy availability
        iii. Climate warming
    b. Pollution
    c. Population growth and Urbanization
    d. Building energy-loads
    e. Solution steps
        i. Passive
        ii. Energy efficient systems
        iii. Renewable energy
        iv. Reach nzeb
        v. Designing priorities (economic, availability…)
    f. Climatic protecting protocols
    g. Norms and standards
    h. Residential building rating systems and indices
2. Economic analysis for building energy systems
    a. Basic Concepts - Time Value of Money
        i. Interest Rate
        ii. Inflation Rate
        iii. Tax Rate
        iv. Cash Flows
    b. Compounding Factors
        i. Single Payment
        ii. Uniform-Series Payment
    c. Economic Evaluation Methods among Alternatives
        i. Net Present Worth
        ii. Rate of Return
        iii. Benefit–Cost Ratio
        iv. levelized cost of energy
        v. Payback Period
    d. Life-Cycle Cost Analysis Method

e. General Procedure for an Economic Evaluation
f. Financing Options

3. Building Envelope
    a. Basic Heat Transfer Concepts
        i. Heat Transfer from Walls and Roofs
        ii. Infiltration Heat Loss/Gain
        iii. Variable Base Degree-Days Method
    b. Simplified Calculation Tools for Building Envelope
        i. Estimation of the Energy Use Savings
        ii. Estimation of the BLC for the Building
        iii. Estimation of the Degree Days
        iv. Foundation Heat Transfer Calculations - examples
    c. Selected Retrofits for Building Envelope
        i. Insulation of Poorly Insulated Building Envelope Components
        ii. Window Improvements
        iii. Reduction of Air Infiltration
4. Energy Analysis Tools for Buildings
    a. Ratio-Based Methods
        i. Types of Ratios
        ii. Examples of Energy Ratios
    b. Inverse Modeling Methods
        i. Steady-State Inverse Models
            1. ANAGRAM Method
            2. PRISM Method
        ii. Dynamic Models
    c. Forward Modeling Methods
        i. Steady-State Methods
        ii. Degree-Day Methods
        iii. Bin Methods
        iv. Dynamic Methods
5. Methods for Estimating Energy Savings in Buildings
    a. General Procedure
    b. Energy Savings Estimation Models
        i. Simplified Engineering Methods
        ii. Regression Analysis Models
            1. Single-Variable Regression Analysis Models
            2. Multivariable Regression Analysis Models
        iii. Dynamic Models
        iv. Computer Simulation Models
    c. Applications
    d. Uncertainty Analysis
6. Energy Auditing in Buildings
    a. Types of Energy Audits
        i. Walk-Through Audit
        ii. Utility Cost Analysis
        iii. Standard Energy Audit
        iv. Detailed Energy Audit
    b. General Procedure for a Detailed Energy Audit

i. Step 1: Building and Utility Data Analysis
ii. Step 2: Walk-Through Survey
iii. Step 3: Baseline for Building Energy Use
iv. Step 4: Evaluation of Energy Savings Measures

c. Common Energy Conservation Measures
i. Building Envelope
ii. Electrical Systems
iii. HVAC Systems
iv. Compressed Air Systems
v. Energy Management Controls
vi. Indoor Water Management
vii. New Technologies

d. Case Study
e. Verification Methods of Energy Savings

7. Case Studies
a. Building Description
i. Building Envelope
ii. Building Infiltration
iii. HVAC System
iv. Water Management
v. Appliances
vi. Thermal Comfort

b. Energy Efficiency Measures
i. Building Envelope
ii. Water Management
iii. Appliances

c. Economic Analysis
d. Recommendations**rences:**

[1] McQuiston FC, Parker JD, Spitler JD. Heating, ventilating, and air conditioning: analysis and design. 6. ed., intern. ed. Hoboken, N.J: Wiley; 2005.
[2] Kuehn TH, Ramsey JW, Threlkeld JL. Thermal environmental engineering. vol. 188. Prentice Hall Upper Saddle River, NJ; 1998.
[3] Harkouss F, Fardoun F, Biwole PH. Optimization approaches and climates investigations in NZEB—A review. Build Simul 2018. doi:10.1007/s12273-018-0448-6.
[4] Krarti M. Energy audit of building systems: an engineering approach. 2nd ed. Boca Raton, FL: CRC Press; 2011.
[5] Shukla A, Sharma A, editors. Sustainability through energy-efficient buildings. Boca Raton: Taylor & Francis, CRC Press; 2018.
[6] Krarti M. Energy-Efficient Electrical Systems for Buildings. CRC Press; 2017.
[7] Jaluria Y. Design and optimization of thermal systems. 2nd ed. Boca Raton: CRC Press; 2008.
[8] Jayamaha L. Energy-efficient building systems: green strategies for operation and maintenance. New York: McGraw-Hill; 2007.

Semester 4

Code	Course	Crédits	CM+TD+TP
MS4SEMI	seminars	8	60
MS4STPR	Internship - Project (≈250h/student - project)	22	250
Total	2	30	310