Project funded by the EU Lifelong Learning Programme
Project Reference No. 527877-LLP-1-2012-1-UK-ERASMUS-ENW

**Higher Education Technical Challenges:**
**Renewable Energies Bachelor Programme (180 Credits)**

# Semester 1 - 4: 120 ECTS

## Compulsory Modules:

1. Mathematics (fundamental)*
2. Programme applied mathematics with physics*
3. Programme applied Physics*
4. Computer Science (basic programming, mathematical programming, databases, networking, operating systems)*
5. Circuit Theory (DC, AC, 3-phase systems)*
6. Basic Analogue and Digital Electronics with projects*
7. Basics of Control Engineering*
8. Fundamentals of power systems*
9. Applied electromagnetics & Electrical machines*
10. Basics of entrepreneurship, project management*
11. Communication and Engineering Methodology (soft skills, written and oral presentation, ethics)*

## Optional Modules:

1. Technological Awareness (e.g. short seminars with industry experts)*
2. English language (basic, technical): country specific*

**** Indicates modules that are general for many curricula, they do not require special definition***


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# Semester 5: 30 ECTS
# (3 compulsory + 2 optional modules)

| | |
|---|---|
| | Power electronics* |
| RE1B | Foundations of renewable energy (wind, solar, biomass, hydro) |
| RE2B | Transmission and distribution systems |
| | Control engineering II* |
| RE3B | Fabrications technologies |
| RE4B | Protection in power systems |

# Semester 6: 30 ECTS

# Internship and/or Bachelor project

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# Module Specification

**Module name:** **RE1B -Foundations of Renewable Energy**

**Programme (Energy/ICT):** Energy
ECTS: 6
**Type:** Bachelor/MSc Bachelor
**Module name:** *Foundations of Renewable Energy*
**Scope and form:**

- Lectures and group work
- Load Flow simulations. Group projects, in which students model realistic micro grid.

**Duration (weeks; Hours/week):** 13 weeks (total workload of 180 hours)
Type of assessment: Written examination, project work.
Qualified Prerequisites: Basic knowledge within AC-circuits and main AC components, mathematics
**General module objectives:**

To give basic understanding of current power system practices and issues in future electrical power systems incorporating renewable energy sources. The students achieve knowledge about the power grid and the main components involved under production, transmission and distribution of electrical energy. The main principles and analytical tools for modeling grid systems and of frequently used grid parameters are discussed, giving the students student some experience and confidence in with practical problems arising in grid technology involving renewable energy sources. The course forms the basis for further education within electrical power engineering and dealing with special problems related to renewable energy. The course is however generally useful for all students aiming at some specialization within electrical energy systems.

**Topics and short description:**
- Power grid
- AC circuits, 3-phase systems, power considerations
- Components in the grid like transmission lines, cables, transformers, generators and more.
- Power flows and tools for simulation
- Symmetry faults
- Renewable energy basics

The topics from the text book can be supported by related topics like wind turbine technology, photovoltaics etc..

In the project, a realistic problem has to be solved by means of the numerical simulation program PowerFactory (load flow) with graphical user interface.

**Learning outcomes:**

| Knowledge | Skills | Competences |
|---|---|---|
| About the essential components power grids and their interactions | Calculate various parameters of interest in power grids | Construct and apply these concepts in equivalent circuits with various electrical components |
| Model the grid with appropriate equivalent circuits and analyse the grid performance under different loads | Use load flow programs like *PowerFactory* for grid simulations | Analyse results from laboratory work and evaluate fault situations and identify them |
| Interaction of renewable energy sources in power grids | Definition, resources and exploitation, generators and power conversion, conversion of wind energy, solar energy conversion, energy management in decentralized systems. | The student demonstrates understanding working operation of these diverse systems and learn to implement new solutions and operate practical systems |

Recommended literature:

1. J.D. Glover, M.S. Sarma and T.Overbye, "*Power System, Analysis and Design*", Cengage Learning; 4 edition (May 18, 2007), pp.768; ISBN-10: 0534548849; ISBN-13: 978-0534548841.
2. H. Saadat, "*Power System Analysis*", PSA Publishing LLC; 3rd edition (2011), pp.772, ISBN-10: 0984543864; ISBN-13: 978-0984543861.
3. G. Boyle, "*Renewable Energy: Power for a Sustainable Future*", Oxford University Press; Third Edition edition (November 8, 2012), pp.584, ISBN-10: 0199545332, ISBN-13: 978-0199545339.
4. J. Shere, "*Renewable: The World-Changing Power of Alternative Energy*", St. Martin's Press; 1St Edition edition (November 26, 2013), pp.304, ISBN-10: 0312643756, ISBN-13: 978-0312643751.
5. Marine Renewable Energy Handbook - Bernard Multon, ISTE Ltd. (2011), ISBN-10: 1848213328.

6. Power Conversion and Control of Wind Energy Systems, Bin Wu, ISBN: 978-0-470-59365-3, Wiley -IEEE Press (2011)
7. Electric Power Principles: Sources, Conversion, Distribution and Use by James L. Kirtley, ISBN-13: 978-0470686362, Wiley (2010)
Remarks: As this course involves evolving technologies, course content will be tuned to handle new developments using suitable webpages of developers of new technologies.

**Special Considerations:** Generically none for this module but should be commented on by the institution delivering the module.

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# Module Specification

University/Department -
**Module name: RE2B - Transmission and distribution systems**
Programme (Energy/ICT): Energy
ECTS: 6
Type Bachelor/Msc: Bachelor
Course name: Transmission and distribution systems
Scope and form: Compulsory
Duration (weeks; Hours/week): 15 weeks; 4 hours/week; 90 hours of self-study time
Type of assessment:
Diagnostic tests, independent homework, achievement tests, seminar papers
Qualified Prerequisites:

- Competences and skills acquired upon the completion of "Electrical networks" course

General course objectives:

- Understanding of the fundamental laws, principles and phenomena in Transmission and distribution systems
- Analysis of Transmission and distribution systems
- Application of acquired knowledge and skills in distribution network planning, designing and building.

Topics and short description:

Role of distribution network in power system. Structure and configurations of distribution networks. Load characteristic and modelling. Faults in distribution network. Current and voltage calculations in distribution network. Low-voltage distribution networks – load planning, voltage drop and current calculation, conductor sizing, transformer selection, protection measures, selecting and settings of protection devices. Grounding of distribution networks. Power and energy losses calculation. Reactive power compensation. Electric energy quality. Voltage regulation in distribution network. Distribution network control and management, SCADA systems. Ripple control system and load management. Tariff system. Operation and maintenance of distribution network. Distribution network planning, design and building.

Learning outcomes:

| Knowledge | Skills | Competences |
|---|---|---|
| Specify the components of the transmission and distribution system and their properties | Apply the appropriate software tools for design and analysis of transmission and distributionsystem | Apply technical knowledge and skills to solve engineering problems as part ofthe project team |
| Describe the working | Implement an economic | Access the literature on |

| | | |
|---|---|---|
| principles and application of systems for transmission and distribution of electricity | analysis of the transmission and distribution system | transmission and distribution systems and write reports on their development |
| Recommend solutions based on model systems, simulation and measurement of relevant quantities | Implement solutions to problems in distribution network | Appreciate an industrial perspective of technology development |

Course recommended literature:

1. E. Lakaervi, E.J. Holmes: *Electricity Distribution Network Design*, Peter Peregrinus Ltd. 1989.
2. C. R. Baylis, B. J. Hardy: *Transmission and Distribution Electrical Engineering*, Elsevier, 2007.
3. L.M. Faulkenberry, W. Coffer, *Electrical Power Distribution and Transmission,* Prentice Hall, 1996.
4. L.L. Grigsby, *Electric Power Generation, Transmission and Distribution*. CRC Press, 2012.

Remarks: -

**Special Considerations:** Generically none for this module but should be commented on by the institution delivering the module.

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# Module Specification

**Module name: RE3B - Fabrication Technologies**

**Programme (Energy/ICT)**: Energy
**ECTS:** 6
**Type** Bachelor/Msc : Bachelor
**Module name** : **Fabrication of fuel and solar cells and batteries for electric cars.**
**Scope and form:**
The Fabrication Technologies module enables students to acquire high-performance knowledge and skills needed to help boost the productivity, innovation, and competitiveness of manufacturers in different hardware areas of renewable energy. Students gain fabricating skills in fuel and solar cells and car batteries.
**Duration (weeks; Hours/week):** 15 weeks; 4hours/week'
**Type of assessment:** Distributed evaluation with final exam.
**Qualified Prerequisites:** Fundaments of mathematics and physics (bachelor); Basic Analogue and Digital Electronics with projects; Applied electromagnetics & Electrical machines.
**General module objectives:** The objective of the module is the acquisition of knowledge regarding the fabric of special hardware to renewable energy production, namely fuel and solar cells and batteries for electric cars. A project for small systems using solar and fuel cells is required as application.
**Topics and short Introduction:**

1. Introduction to the fabric technologies; economics aspects of different fabric technologies

2. Fuel Cells, Different types of fuel cells: Alkaline Fuel Cells (AFC), Phosphoric Acid Fuel Cells (PAFC), Solid Oxide Fuel Cells (SOFC), Proton Exchange Membrane Fuel Cells (PEMFC); design; Technologies of the different types of fuel cells. Comparison of fuel cell types, Efficiency of leading fuel cell types, Fuel cells Applications (Power, Cogeneration, Fuel cell electric vehicles (FCEVs)), Fueling stations

3. Solar cells, or photovoltaic cells, Cells, modules, panels and systems, Declining costs and exponential growth, Solar cells Materials , Solar cells Manufacture, Solar cells efficiency; Comparison solar cells types, Applications of solar cells

4. Electric vehicle batteries (EVB), Batteries types: lead-acid batteries, lithium-ion batteries, Nickel cadmium batteries; Technologies of the different types of batteries, Batteries costs, Batteries charging, Charging station, Comparison between different types of batteries

Learning outcomes:

| Knowledge | Skills | Competences |
|---|---|---|
| Fuel Cells | Capacity to understand the importance of fuel cells | Comprehend the fundamentals of fuel cells |
| Fundamentals of fuel cells | Understand the physical principle of fuel cells | To introduce the use of fuel cells to energy conservation |
| Solar Cells | Understand the physical principle of a solar cells | To introduce the use of solar cells to energy conservation |
| Solar Cells | To project a solar cells system for a house | To increase the use of solar cells for energy efficiency of a family house |
| Electric vehicle batteries (EVB) | Capacity to understand the physics of different vehicle batteries | To compare the different technologies of electric vehicle batteries |

**Module recommended literature:**

1. Fuel Cell Fundamentals , Ryan O'Hayre and Suk-Won Cha, John Wiley & Sons; 2nd Edition 2009, ISBN-10: 0470258438.
2. Fuel Processing: for Fuel Cells, Gunther Kolb, Wiley VCH; 1 edition (26 Mar. 2008), ISBN-10: 3527315810.
3. Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet, Peter Hoffmann and Byron Dorgan , MIT Press; Revised and expanded 2nd edition, 2012,ISBN-10: 0262516950.
4. Physics of Solar Cells: From Basic Principles to Advanced Concepts,Peter Würfel, 2009, ISBN-10: 3527408576.
5. Solar Cells: Materials, Manufacture and Operation, Second Edition 2012, ISBN-10: 0123869641
   by Augustin McEvoy and L. Castaner.
6. The Electric Car: Development and Future of Battery, Hybrid and Fuel-Cell Cars (Iee Power & Energy Series, 38) , Michael Westbrook, December 1, 2001.

7. Bottled Lightning: Superbatteries, Electric Cars, and the New Lithium Economy, Seth Fletcher 2011, ISBN-10: 0809030535.

**Special Considerations:** Generically none for this module but should be commented on by the institution delivering the module.

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# Module Specification

**Module name: RE4B Protection in Power Systems**

Programme (Energy/ICT): Energy

ECTS: 6

Type Bachelor/MSc: Bachelor

Scope and form: Lectures and group exercises in connection with the lectures

Duration (weeks; Hours/week): 15 weeks; 2 hours lecture, 1 hour group exercise/week (150 hours of workload)

Type of assessment: Written examination and project

Qualified Prerequisites: Basic knowledge of DC and AC circuits and main AC components

General course objectives:
To give basic understanding of protection power systems and power components. Students will be expected to demonstrate knowledge of the fundamentals of electrical power protection and applications, to recognise the different fault types, perform simple fault and design calculations, understand protection system components, to choose appropriate protective devices for different equipment.

Topics and short description:
The goal of this course is to help students develop an in-depth understanding of analytical techniques for faults that occur on a power system and the corresponding protection schemes that are designed to minimize the impact.

- Protection Principles and Components,
- Limitations of Traditional Overcurrent Protection
- The Role of Protection,
- Fault Calculation,
- Overcurrent Protection,
- Transient Overvoltage Protection,
- Protection and Monitoring of Generators, Transformers, Generator-Transformer Units
- Busbar Protection
- Transmission Line Protection
- Protection of Motors, Reactors, Boosters and Capacitors
- Protective Transformers, Fuses, Relays, Protection Signalling


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- Application of protection systems to renewable energy system
- Modern Solutions for Distribution System Protection, Automation, and Monitoring
- Power System Communications, information Processing, information Security.

Learning outcomes:

| Knowledge | Skills | Competences |
|---|---|---|
| This course will include fundamentals on protection, relay design and protection schemes for transmission lines, transformers, reactors, generator and bus | Able to recognise basic overcurrent and overvoltage problems in power systems. | Ability to use diagnostic skills to identify overcurrent and overvoltage problems in power systems, both in educational settings and at work |
| The course will include measurement and modelling techniques to identify power quality problems. | Able to select protection: relay design and protection schemes for transmission lines, transformers, reactors, generator and bus.Able to perform simple fault and design calculations.<br>Able to choose appropriate protective devices for different items of equipment. | Ability to exercise personal autonomy and to take responsibility for identifying overcurrent and overvoltage problems, performing calculations and selecting appropriate protection |

Course recommended literature:

- **Modern Solutions for Protection, Control and Monitoring of Electric Power Systems**, by Hector J. Altuve Ferrer and Edmund O. Schweitzer III, 2010
- **Protective Relaying: Principles and Applications, Third Edition (Power Engineering),**by J. Lewis Blackburn, Thomas J. Domin, 2006
- **Monitoring, Control and Protection of Interconnected Power Systems**, Ulf Häger, Christian Rehtanz, Nikolai Voropai
- **Power System Relaying**, S. Horowitz and A. G. Phadke, 2009.
- **Fundamentals of Power System Protection**, by Y.G. Paithankar, S.R. Bhide , 2013
- **Practical Power System Protection (Practical Professional Books)**, by Leslie Hewitson and Mark Brown BAppSc(Phty) MHSc(Sport Phty) MBA FASMF, 2005

- **Power System Protection**, by Paul M. Anderson, 1998

**Special Considerations:** Generically none for this module but should be commented on by the institution delivering the module.