Co-funded by the European Union

P4ELECS
Platform for Electrification Skills & Competences

www.p4elecs.com

P4ELECS

Basics of a Smart Grid

Annick Dexters - Patricia Boogaard - Mozaher Patwary
21/09/2026

KU LEUVEN
HAN_UNIVERSITY OF APPLIED SCIENCES
Technology Arts Sciences TH Köln

COURSE DESCRIPTION

BACKGROUND – RELEVANCE

The climate and zero CO_2 emission goals have to be achieved till 2050, an unprecedent challenge. Renewables and electrification of heat production and transport are the most important technologies used to realise this. All these components will be connected to the same electrical grid and grid operators must under all circumstances guarantee a good power quality and stability of the system. In the past only generators and the grid were controlled, now also loads must be part of the control to keep the balance. Storage is key to cope with the difference between the production and consumption of electrical energy. The electricity system is a system of systems that requires a concise coordination. It is important for engineers and electricians to have a basic knowledge of the complexity of this system and to understand the reasoning behind the rules grid users have to comply with when connecting to the electricity grid.

ABSTRACT

This basic course explains the structure and operation of the different parts of the electricity grid and subsequently the cooperation and coordination of all these elements to keep the grid stable and control the voltage. The impact of the energy transition on the grid will be illustrated and solutions addressed.

In an immersive lab of 5 days the behavior of the most important components in the energy system will be explored and how to control their interaction with the grid. After familiarization with these components a complete smart grid will be assembled by interconnecting and integrating (renewable) power generation, power transmission, power storage and loads. Voltage control and balancing will be performed real time for several situations. The lab sessions use the Lucas Nuelle set up for smart grids.
https://www.lucas-nuelle.us/2755/apg/1168/Products/Power-Engineering-%7C-Smart-Grid-%7C-Micro-Grid.htm

KEYWORDS - HASTAGS

Synchronous generator, doubly fed induction generator, smart grid, balancing, voltage control, basics

AUTHOR
[Annick Dexters – ESAT – ELECTA Diepenbeek
Annick Dexters@kuleuven.be
KU Leuven

AUTHOR
Patricia Boogaard – SEECE
Patricia.boogaard@han.nl
HAN

AUTHOR
Mozaher Patwary – IET
mozaher.patwary@th-koeln.de
TH Koln

FOCUS ON …	Knowledge	Application		Implementation	
CDIO		Conceive	Design	Implement	Operate
DIFFICULTY LEVEL	Basic	Intermediate		Advanced	
EQF LEVEL	6	**CREDITS**	4	**LANGUAGE**	English

LEARNING OUTCOMES

The student can …

VIRTUAL PART

1. Can explain the structure and operation of the different components in the grid and substations.
2. Explain the relevant parameters, structure, operation and control of different generators (SG, DFIG, convertor) and batteries to connect them to the grid and support grid stability and voltage control.
3. Apply this knowledge in exercises and control algorithms.
4. Explain the functionalities of the control packages (EMS, DMS, DA) integrated in the SCADA systems of the TSO and DSO.
5. Explain what the goal is of different ancillary/flex services, how they are purchased on the different energy markets
6. Explain the impact of the integration of RES and the integration of heat pumps/electrical vehicles/batteries on the performance (stability, voltage control) of the grid and the protection and possible solutions.
7. Explain the responsibilities of the different actors in the energy system (TSO, DSO, producers, flex providers or aggregators, balancing responsible parties, suppliers, energy service providers (ESCOs) and their information exchanges.

PRACTICAL PART

POWER GENERATION AND STORAGE

1. Control a synchronous generator in island, grid connected mode and perform the synchronization
2. Control a doubly fed induction generator, a PV convertor in grid connected mode for maximum yield and grid support
3. Operate a battery management system.

POWER TRANSMISSION – BUSBAR SYSTEMS

4. Execute the correct switching sequencies in double busbar changes of a bay.
5. Apply voltage control in HV and medium voltage systems

SMART GRID INTEGRATION

6. Assemble and control (balance, load distribution, voltage control) a complete smart grid by interconnecting power generation, power transmission, power storage and loads and configure SCADA Power-LAB to monitor and control all subsystems in real-time.

PRIOR KNOWLEDGE REQUIRED

1. Calculation of AC systems (RLC) using phasor techniques
2. Calculation of symmetrical three phase systems
3. Measurement Skills: operate multimeters, oscilloscopes, and power supplies safely, following the respective protocols

PRACTICAL ORGANISATION		
	Virtual Part	**Physical Part**
ORGANISER	K**U Leuven**	K**U Leuven**
ERASMUS CODE	xxx	
WHEN	Start AJ till 31/12/2025	1/12/2025 – 5/12/2025
WHERE	Online	Thor Park – T2 Campus in Genk (BE) https://t2-campus.be/faciliteit/smart-grid-labo/
TEACHER(s) INSTRUCTOR(s)	Patricia Boogaard Annick Dexters Mozaher Patwary	Patricia Boogaard Annick Dexters Mozaher Patwary
COURSE MATERIAL	available end of August in www.Xdemia.com	available end of August in www.Xdemia.com
SOFTWARE USED	xxx	xxx
OTHER MATERIAL		
MAX ATTENDEES	8	8
REGISTRATION		Registration Form BIP - Basics of a Smart Grid - Formulier invullen
CONTACT PERSON	annick.dexters@kuleuven.be +32 496 69 23 53	annick.dexters@kuleuven.be +32 496 69 23 53
EXAM	Oral exam	Lab report

COURSE PROGRAM			
	DATE/TIME	**LOCATION**	**TOPIC**
W1	W21/9/26	1 x 2h online	Intro Architecture of the (EU) public grid – voltage levels and characteristics
W2	W28/9/26	1 x 2h online	Architecture of the public grid Structure and operation of different components of the HV grid.
W3	W5/10/26	1 x 2h online	(Smart) Substations Busbar systems – transformers – measurement devices - protection devices – switches – control systems, automation and infrastructure
W4	W12/10/26	1 x 2h online	TSO and DSO control systems EMS – DMS – DA - Scada in LN lab
W5	W19/10/26	1 x 2h online	Synchronous generators – Structure, operation and control
W6	W26/10/26	1 x 2h online	Asynchronous generators – Structure, operation and control
W7	W2/11/26	1 x 2h online	Lines Structure, operation, voltage control, power flow
W8	W9/11/25	1 x 2h online	Frequency control balancing, FCR, aFRR, mFRR, RR, energy market
W9	W16/11/26	1 x 2h online	Impact of RES on the operation of the grid - protection, balancing, voltage problems etc.
W10	W23/11/26	1 x 2h online	Flexibility and the energy transition Paradigm shift – EMS – flexibility market
	WEEK 1 till 5/12/25	EnergyVille (BE)	Physical part – DAY1-4: Investigating the operation of different generators/HV lines /batteries of a smart grid DAY 5: Building and operating a small smart grid Presentation end of the week 4/12/2026 Survey first impressions course Report lab sessions 11/12/2026