WP3

Learning Material, Training Courses and Joint Proposal Preparation

D3.1
Training Courses and Learning Material on Smart Grid Technologies (v1)

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Executive Summary

The main objective of SINERGY work package 3 is to establish collaboration with strategic partners, i.e. AIT and NUIG, and enable expertise and "know-how" exchange in the area of smart grids, distributed energy resources, building optimization and building information modelling.

Task 3.1 focuses on the preparation of training courses on Smart Grid Technologies as mainly provided by the partner AIT Austrian Institute of Technology. The course structure is designed to cover all system levels from the grid and its operation down to the individual components (mostly power electronics converters) and the connecting control structures.

The report (Deliverable 3.1) summarizes the proposed training courses in the field of Smart Grid Technologies, the advances of the training based on the courses performed from January 2021 to March 2022. During the first reporting period a total of 6 lectures by 5 different AIT lecturers have been performed which is in line with the project proposal (3 to 6 per year).

The individual courses which have been performed are presented with respect to content, sources, references and training material.

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Abbreviations and Acronyms

SGAT	Smart Grid “Automation”
SGDG	Smart Grid “Distribution Grids”
SGHS	Smart Grid “HIL-Simulation”
SGPE	Smart Grid “Power Electronics”

1. Introduction

The courses in this deliverable focus on the field of Smart Grid Technologies which are performed by AIT Austrian Institute of Technology.

1.1 Scope

The main scope of work package 3 (Learning Material, Training Courses and Joint Project Proposals Preparation) can be summarized as:

- Task 3.1: Preparation of training courses on Smart Grid technologies (this report)
- Task 3.2: Preparation of training courses on Energy Efficient Building Operation (D3.2)
- Task 3.3: Joint project proposals preparation and management skills upgrade (D3.3)

This report lists the proposed lectures (see for instance Figure 1, a screenshot from the SINERGY repository)[1] with an update on personnel with respect to the project proposal. Further, it provides an overview on the already performed trainings and insight on the pending activities for the upcoming project duration. Respective training materials and webinar recordings are listed in the subsequent sections.

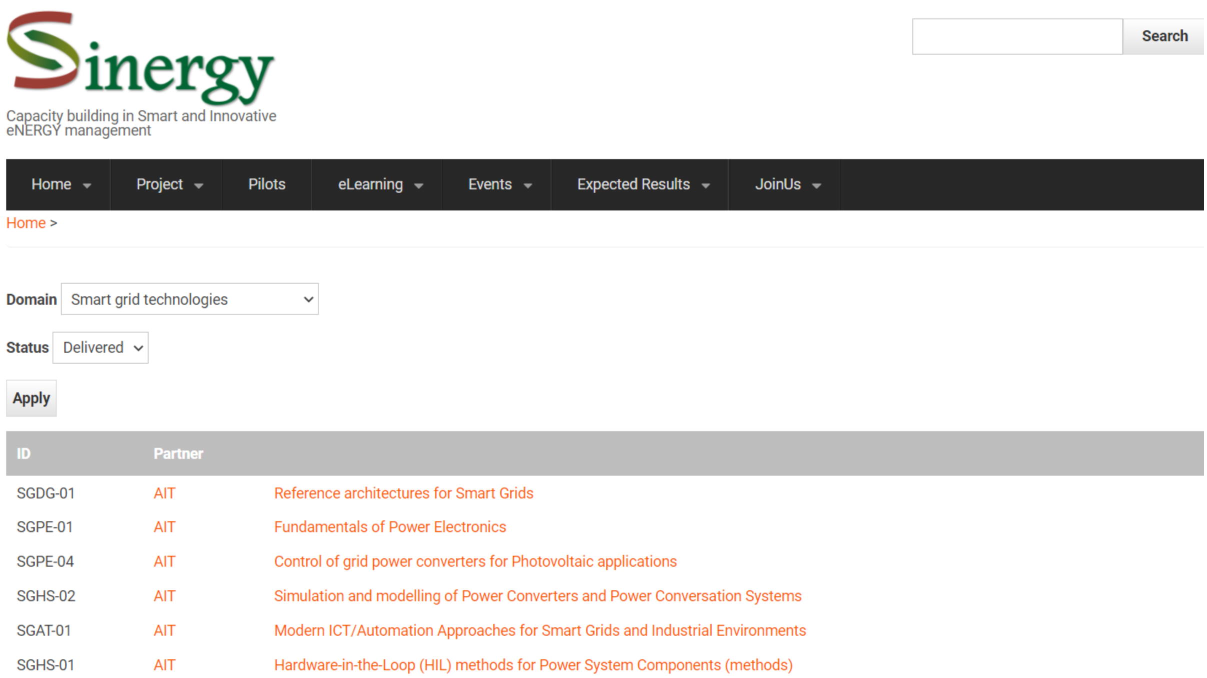


Figure 1. AIT Lectures in SINERGY repository (example)

1.2 Relation to other deliverables

The deliverable is linked to the following deliverables:

- D1.1 Project Work Plan
- D2.1 Scientific and Technological Landscape of Smart Energy Management and SWOT analysis
- D3.2 Training courses and learning materials on Energy Efficient Building Operation

[1] SINERGY Lectures | Project Sinergy (project-sinergy.org)

- D4.1 Report on Mutual Exchange of Personnel and Training Activities
- D4.2 Report on early stage researcher engagement and mentoring
- D5.1 The first Sinergy Workshop - Smart Grid Technologies
- D6.2 Sinergy web portal and communication material

1.3 Structure of Modules

As training activities in the field of Smart Grid Technologies a set of lectures have been defined during the proposal preparation phase. The order is based on the system level with respect to the grid from distribution grids in general towards, operation and digitalization toward power electronics topics at the end of the table. The courses are further attached with the AIT staff in charge to provide the training and the actual status in the project timeline. Courses which have been performed are indicated with "done" while upcoming courses show "pending" with the proposed year of execution in brackets.

The respective information for already performed trainings can be found in the subsequent chapters. The description of the lectures can be retrieved via this link SINERGY Lectures | Project Sinergy (project-sinergy.org).

Table 1. Smart Grid Technologies Lectures (delivered by M15)

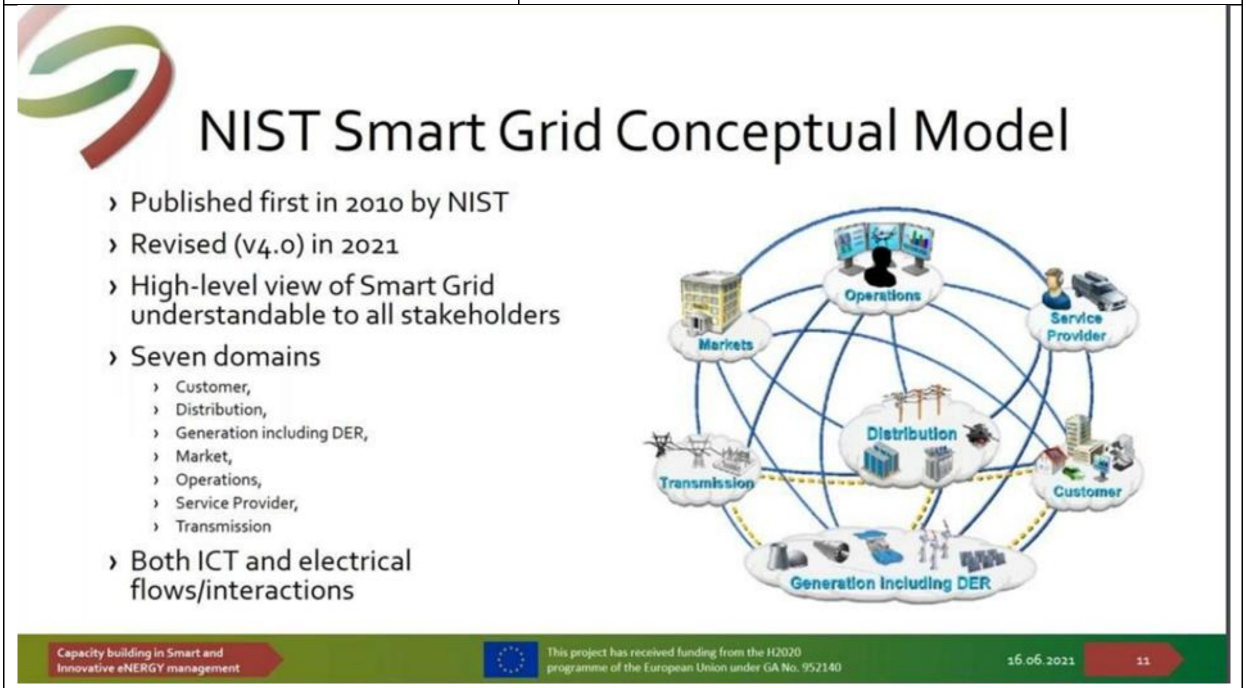
	Smart Grid Technologies		
ID	**Module Title (version 1)**	**Delivered by:**	**Status:**
SGDG-01	Reference architectures for Smart Grids	Friederich Kupzog	done
SGAT-01	Modern ICT/Automation Approaches for Smart Grids and Industrial Environments	Thomas Strasser	done
SGPE-01	Fundamentals of Power Electronics	Markus Makoschitz	done
SGPE-04	Control of grid power converters for Photovoltaic applications	Zoran Miletic	done
SGHS-01	Hardware-in-the-Loop (HIL) methods for Power System Components (methods)	Georg Lauss	done
SGHS-02	Simulation and modelling of Power Converters and Power Conversation Systems	Zoran Miletic	done

Table 2. Smart Grid Technologies Lectures (to be delivered by M30)

	Smart Grid Technologies		
ID	Module Title (version 2)	Delivered by:	Status:
SGDG-02	Enhancement of the hosting capacity of distribution grids	Antony Zegers, Wolfgang Hribernik	pending (2023)
SGDG-03	Network planning and Resonance Mitigation for Smart Grids	Gerhard Jambrich	pending (2022)
SGDG-04	Integrating DER in Smart Grids and High penetration of PV in Electricity Grids	Roland Bründlinger	pending (2023)
SGAT-02	Grid forming DERs, connection and parallelization of DER	Zoran Miletic, Roland Bründlinger	pending (2023)
SGAT-03	Standards for integrating PV in Electricity Grids	Roland Bründlinger	pending (2022)
SGAT-04	Electric Energy Storages	Christian Messner	pending (2022)
SGPE-02	Grid power converters, architecture and design considerations	Markus Makoschitz	pending (2022)
SGPE-03	Emerging Technologies for Power Electronics Systems in Smart Grids	Markus Makoschitz	pending (2023)
SGHS-03	Rapid prototyping of inverter-based DER devices	Zoran Miletic	pending (2022)

2. Lecture Materials – Module “Distribution Grids” (SGDG)

SGDG-01 - Reference architectures for Smart Grids	
Delivered by:	**Keywords**
Friederich Kuzog, Jawad Kazmi	Smart Grid

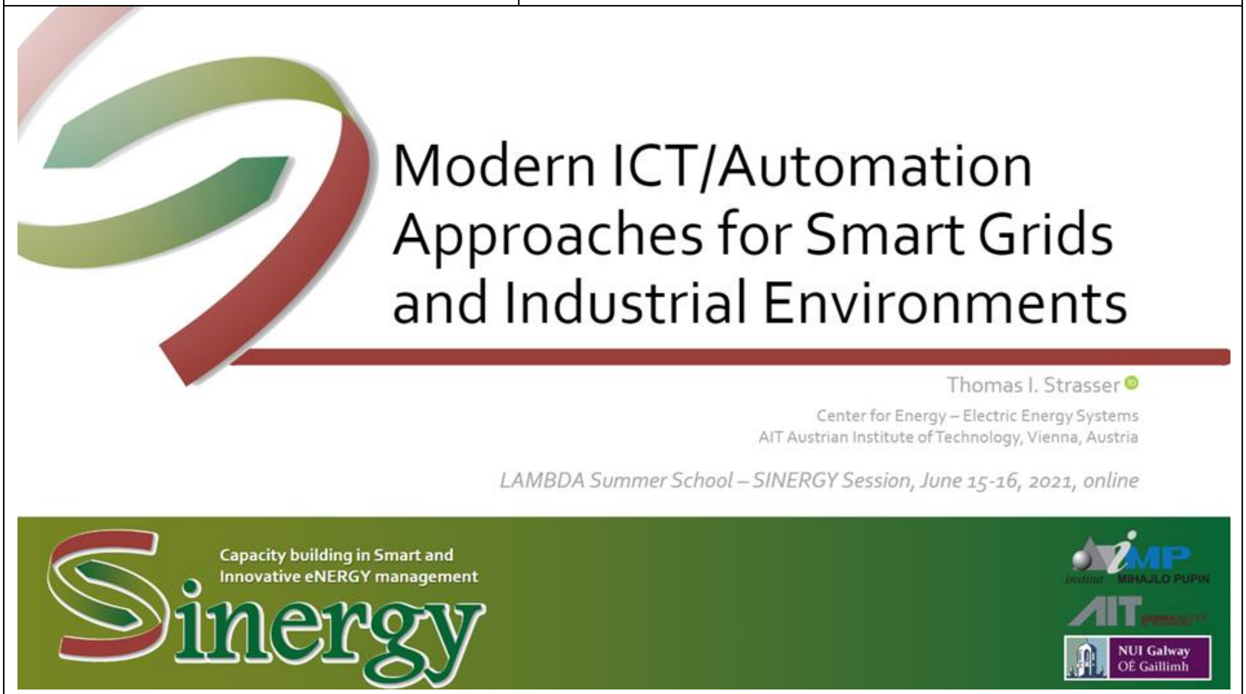


[Reference architectures for Smart Grids | Project Sinergy (project-sinergy.org)](project-sinergy.org)

Duration	40 minutes
Summary	Due to the advancing digitalization, which also affects the energy systems, an unprecedented level of information technology networking is being achieved step by step. This leads to two main challenges for the system design: on the one hand, interoperability between different (sub)systems and components must be ensured, on the other hand, effective security and data protection measures are required to protect this critical infrastructure from cyber-attacks and to increase consumer acceptance. A high security of supply can only be guaranteed in the long term if both challenges of technological development are taken into account when designing future smart grids. The workshop dealt with the main two reference architectures for smart grids relevant in an European context. Such a reference architecture aims to support in planning of future systems and migrating from existing legacy architectures to a new smart grid architecture. Especially the requirements for safety and security bring additional complexity into the system. As one if the main origins of the European Smart Grid Architectural Model (SGAM) as developed in the EU Mandate M/470 by CEN, CENELEC and ETSI,

	the US American Smart Grid Conceptual Model was introduced. This model, published by the US National Institute of Standards and Technology (NIST), also referred to as "NIST-Model", introduces the main scope of the reference architecture and has a strong focus on interoperability. Subsequently, the European SGAM Model was discussed, and example applications were modeled in SGAM to illustrate the benefits of using a unified modeling approach to describe smart grid use cases. Best practices and learnings around the usage of SGAM were discussed.
Reference Material	
• Technologieplattform Smart Grids Austria (TPSGA): Technologieroadmap Smart Grids Austria - Die Umsetzungsschritte zum Wandel des Stromsystems bis 2020. Technical report, Technologieplattform Smart Grids Austria, April 2015. http://www.smartgrids.at/index.php?download=372.pdf	
• Smart Grid Coordination Group: Smart grid reference architecture. Technical report, CEN-CENELEC-ETSI, November 2012. http://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx	
• GridWise Architecture Council Interoperability Framework Team: Interoperability Context-Setting Framework. Technical report, GridWise Architecture Council, July 2007. http://www.caba.org/resources/Documents/IS-2008-30.pdf	
• Kreutzmann, H., Vollmer, S.: Protection profile for the gateway of a smart metering system (smart meter gateway pp). Technical report BSI-CC-PP-0073, Bundesamt für Sicherheit in der Informationstechnik (BSI) Federal Office for Information Security, Germany, March 2014. https://www.bsi.bund.de/DE/Themen/SmartMeter/Schutzprofil_Gateway/schutzprofil_smart_meter_gateway_node.html	
• Federal Office for Information Security Germany: Protection profile for the security module of a smart meter gateway (security module pp). Technical report BSI-CC-PP-0077-V2, Bundesamt für Sicherheit in der Informationstechnik (BSI), December 2014. https://www.bsi.bund.de/DE/Themen/SmartMeter/Schutzprofil_Security/security_module_node.html	
• Smart Grid and Cyber-Physical Systems Program Office and Energy and Environment Division, Engineering Laboratory, Physical Measurement Laboratory, Information Technology Laboratory: NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 3.0. Technical report SP 1108R3, NIST, February 2014. http://www.nist.gov/smartgrid/upload/NISTDraftFrameworkOct_2013.pdf	
• Smart Grid Interoperability Panel: Guidelines for smart grid cyber security. Technical report 7628, Cyber Security Working Group, (NIST), September 2010. http://www.nist.gov/smartgrid/upload/nistir-7628_total.pdf	

3. Lecture Materials – Module “Automation” (SGAT)

<table>
<tr><th colspan="2">SGAT-01 - Modern ICT/Automation Approaches for Smart Grids and Industrial Environments</th></tr>
<tr><td>Delivered by:</td><td>Keywords</td></tr>
<tr><td>Thomas Strasser</td><td>Automation, ICT, Digitalisation, Smart Grid, Power System, Lecture, Summer School, European Union (EU), Project, H2020, SINERGY, GA 952140 (according to https://doi.org/10.5281/zenodo.6088671)</td></tr>
<tr><td colspan="2">
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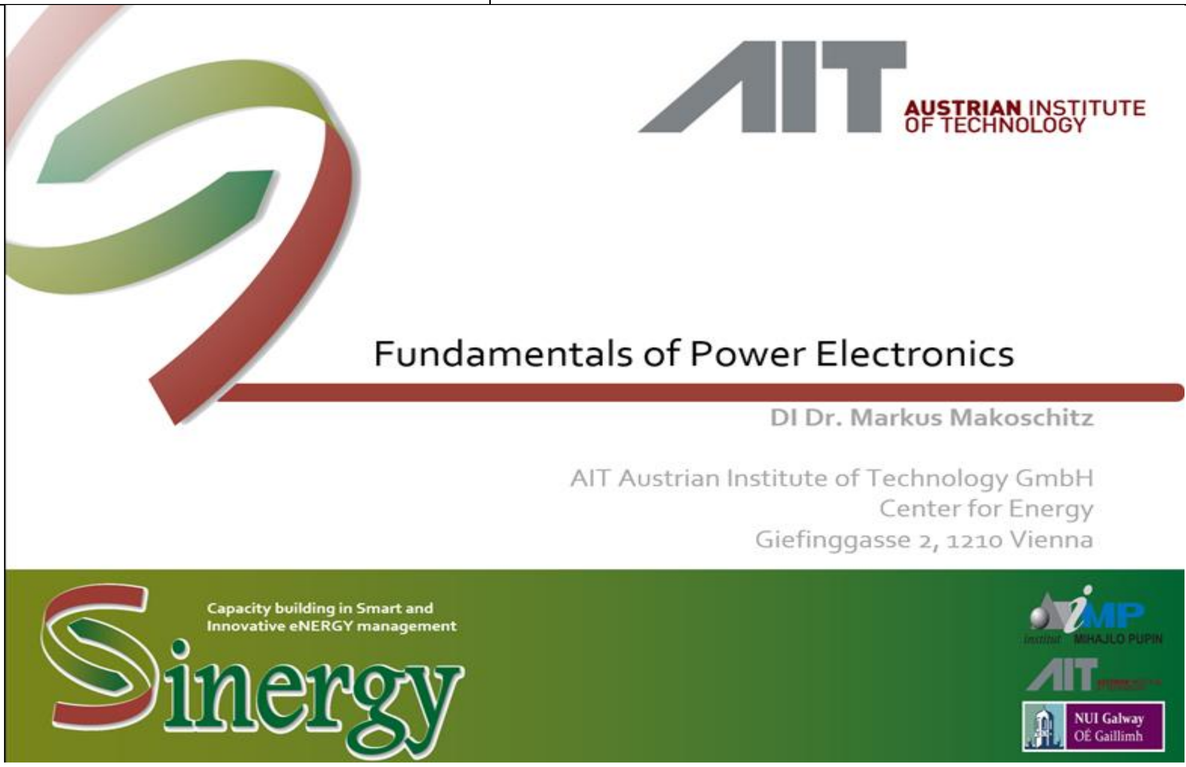
<tr><td colspan="2">https://doi.org/10.5281/zenodo.6088671

[Modern ICT/Automation Approaches for Smart Grids and Industrial Environments | Project Sinergy (project-sinergy.org)]</td></tr>
<tr><td>Duration</td><td>40 minutes</td></tr>
<tr><td>Summary</td><td>There is a continuously growing demand for electricity, which must be satisfied by the electric energy systems worldwide. At the same time, a stable supply must be guaranteed. The current situation with CO2 emissions and global warming has created an obvious trend towards a sustainable electric energy system. The integration of Renewable Energy Sources (RES) is an important requirement. Such renewable sources, but also energy storage systems and flexible loads provide enhanced possibilities but power system operators and utilities have to cope with their fluctuating nature, limited storage capabilities and the typically higher complexity of the whole infrastructure. Additionally, due to changing framework conditions, like the liberalization of the energy markets and new regulatory rules, as well as technology developments (e.g., new components), approaches for design, planning, and operation of the future</td></tr>
</table>

	electric energy system have to be restructured. Sophisticated component design methods, intelligent Information and Communication Technology (ICT) architectures, automation and control concepts as well as proper standards are necessary in order to manage the higher complexity of intelligent power systems (i.e., smart grids). Therefore, this training course provides an overview of ICT and automation-based approaches, concepts, methods and related standards which are important for the realization of smart grid systems.
Reference Material	
• T. Strasser, F. Andren, J. Kathan, C. Cecati, C. Buccella, P Siano, P Leitao, G. Zhabelova, V. Vyatkin, P Vrba, V. Marik: "A Review of Architectures and Concepts for Intelligence in Future Electric Energy Systems"; IEEE Transactions on Industrial Electronics, Volume 62 (2015), Issue 4; 2424 - 2438.	
• F. Andren, R. Bründlinger, T. Strasser: "IEC 61850/61499 Control of Distributed Energy Resources: Concept, Guidelines, and Implementation"; IEEE Transactions on Energy Conversion, Volume 29 (2014), Issue 4; 1008 - 1017.	
• F. Pröstl Andren, T. Strasser, W Kastner: "Engineering Smart Grids: Applying Model-Driven Development from Use Case Design to Deployment"; Energies, 10 (2017).	
• T. Strasser, F. Andren, F. Lehfuss, M. Stifter, P. Palensky: "Online Reconfigurable Control Software for IEDs"; IEEE Transactions on Industrial Informatics, Vol. 9, August 2013 (2013), No. 3; 1455 - 1465.	
• M. Faschang, S. Cejka, M. Stefan, A. Frischenschlager, A. Einfalt, K Diwold, F. Pröstl Andren, T. Strasser, F. Kupzog: "Provisioning, deployment, and operation of smart grid applications on substation level: Bringing future smart grid functionality to power distribution grids"; Computer Science - Research and Development, Special Issue Paper (2016), 1 - 14.	
• J. Resch, B. Schuiki, S. Schöndorfer, C. Brandauer, G Panholzer, F. Pröstl Andren, T. Strasser: "Engineering and validation support framework for power system automation and control applications"; e & i Elektrotechnik und Informationstechnik, issue 8 (2020), Volume 137; 470 - 475.	

4. Lecture Materials – Module "Power Electronics" (SGPE)

SGPE-01 - Fundamentals of Power Electronics	
Delivered by:	**Keywords**
Markus Makoschitz	Power Electronics, Applications, DC/DC Converters



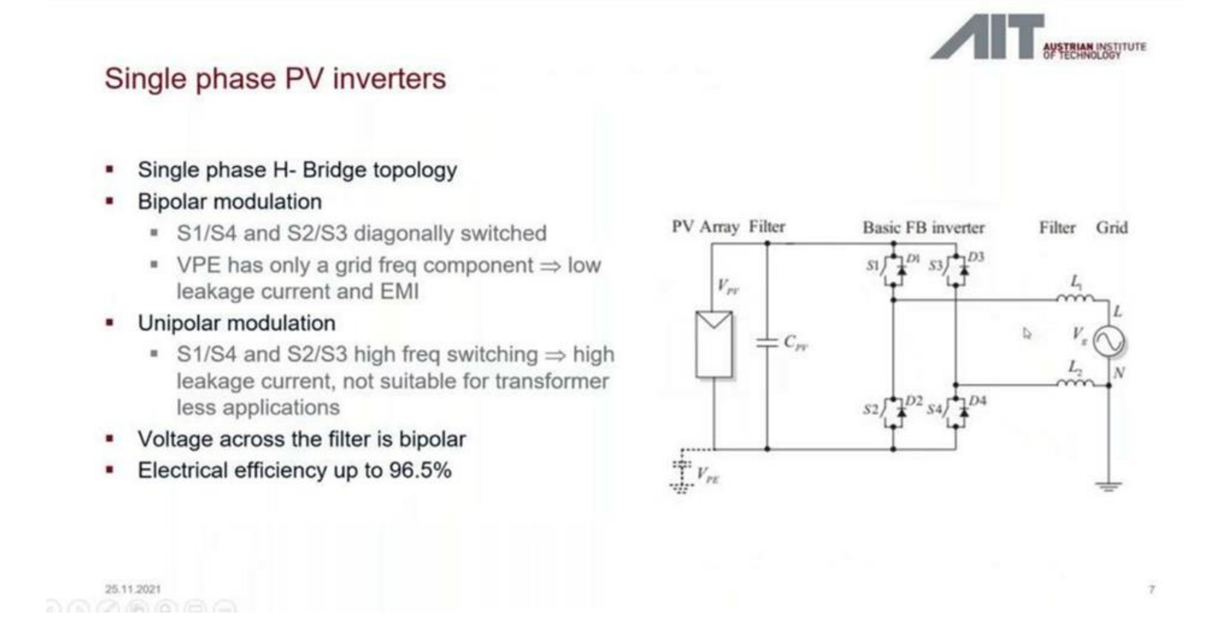
[Fundamentals of Power Electronics | Project Sinergy (project-sinergy.org)](project-sinergy.org)

Duration	240 minutes
Prerequisites	Basics on electric engineering
Software	Power Point, Repaper, Plexim - Plecs Software
Summary	In this lecture, participants were introduced into state-of-the-art DC/DC power electronic converters. A general overview highlighted the relevance of power electronics in our modern society. Furthermore, upcoming challenges based on running national and international funded projects and roadmaps have been discussed. Additionally, most relevant power electronics applications, the Austrian road to 100% renewables (#mission2030) and the current situation in Austria and the impact on power electronics has been reviewed based on APG data and an electricity map (both online accessible). In the second part of the lecture, an in-depth evaluation of DC/DC converter architectures and operating modes as well as mathematical tools to derive fundamental converter parameters was covered.

Reference Material

• Presentation: "SYNERGY Presentation_PEFundamentals.pptx" or "SYNERGY Presentation_PEFundamentals.pptx.pdf"

SGPE-04 - Control of grid power converters for Photovoltaic applications	
Delivered by:	Keywords
Zoran Miletic	Power electronics, Photovoltaics, Converters



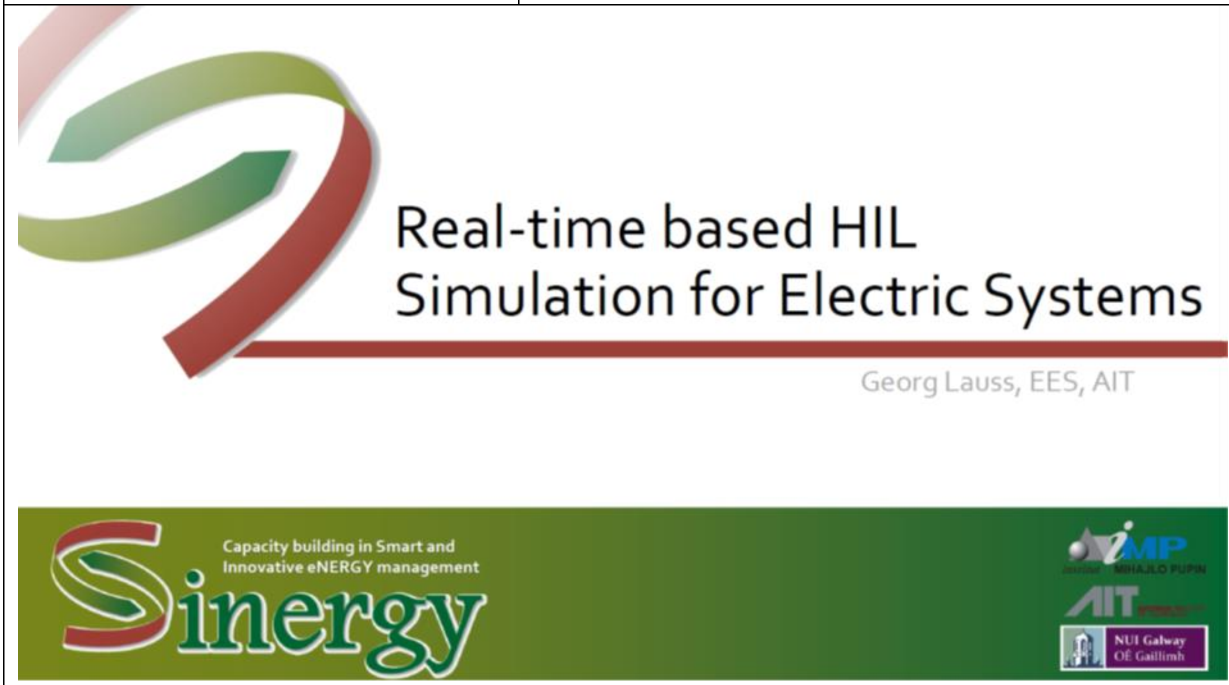
[Control of grid power converters for Photovoltaic applications | Project Sinergy (project-sinergy.org)](project-sinergy.org)

Duration	80 min
Summary	Converters for photovoltaic applications have been used in the electricity grid for several years. The integration of these systems requires base functionalities which are discussed in this lecture. Due to the AC-nature of the electricity grid the synchronization with the power system 50 Hz fundamental frequency is mandatory for single phase and 3-phase operation. Starting from this point the continuous operation by regulating the power delivery is discussed. Finally, various methods of islanding detection, the coordinated shut down during grid outage, as a safety function are presented. The course builds a foundation for subsequent lectures in the SINERGY project.

Reference Material
• "Grid Converters for Photovoltaic and Wind Power Systems"; R. Teodorescu, M. Liserre and P. Rodriguez, 2011, John Wiley & Sons, Ltd.; ISBN: 987-0-470-05751-3
• "Pulse Width Modulation for Power Converters, Principles and Practice"; D. G. Holmes and T. Lipo; 2003; IEEE Press, New York

5. Lecture Materials – Module "HIL-Simulation" (SGHS)

SGHS-01 - Real-time based HIL Simulation for Electric Systems	
Delivered by:	**Keywords**
Georg Lauss	Real-time simulation, HIL systems, electric power systems, advanced laboratory testing

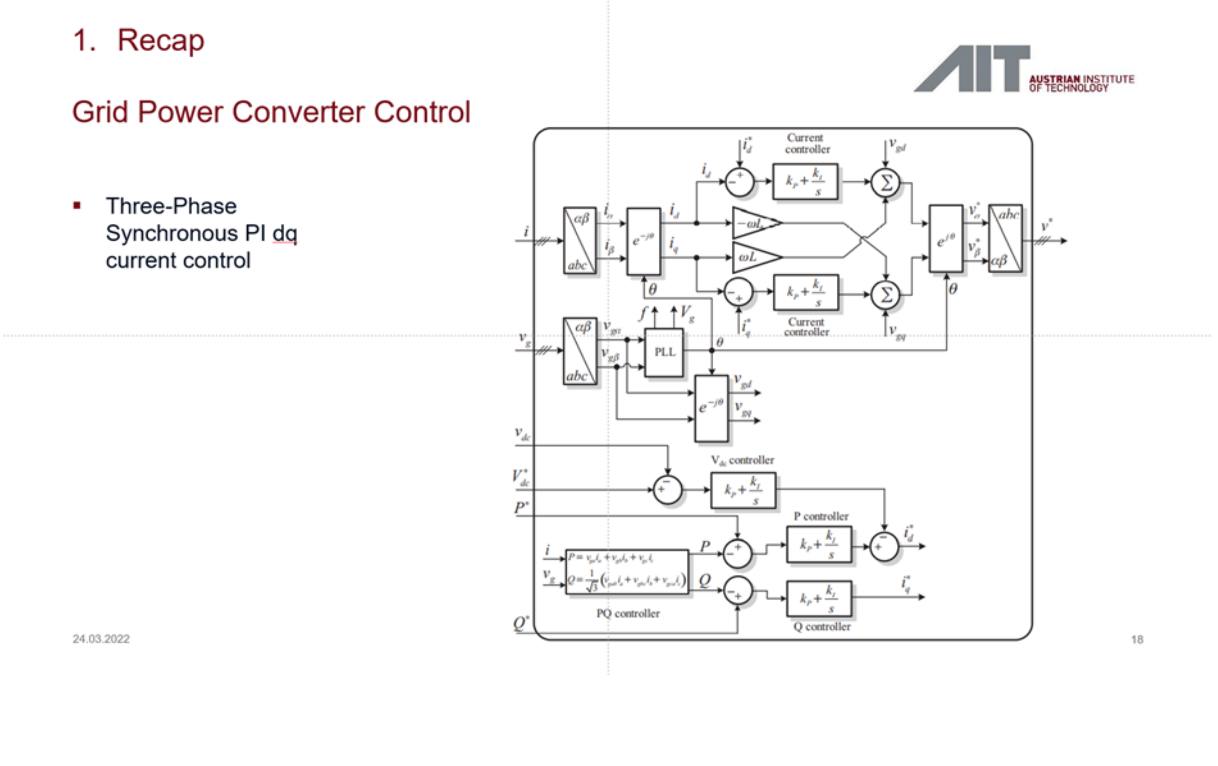


[Hardware-in-the-Loop (HIL) methods for Power System Components (methods) | Project Sinergy (project-sinergy.org)](https://project-sinergy.org)

Duration	180 minutes
Prerequisites	Basics on electric engineering and simulation techniques
Software	None (applied software such as RT-Lab has been presented)
Summary	Test/simulation approaches are expanded and optimized due to the latest technologies such as real time systems, power electronics, analogous/digital measurement devices. Novel simulation techniques gain increasing importance in research and for manufacturers and for international standardisation groups. It is the intention of this course to create a detailed insight on real-time simulation techniques, real-time simulation system topologies and their common application fields such as rapid prototyping and manufacturing, standardized testing procedures, or establishing novel research areas in the electrical domain. Use cases for Controller Hardware-in-the Loop (CHIL) and Power Hardware-in-the-Loop (PHIL) have been introduced, explained, and results have been highlighted.
Reference Material	

• G. De Carne et al., "On Modeling Depths of Power Electronic Circuits for Real-Time Simulation – A Comparative Analysis for Power Systems," in IEEE Open Access Journal of Power and Energy, vol. 9, pp. 76-87, 2022, doi: 10.1109/OAJPE.2022.3148777.
• G. Lauss and K. Strunz, "Accurate and Stable Hardware-in-the-Loop (HIL) Real-Time Simulation of Integrated Power Electronics and Power Systems," in IEEE Transactions on Power Electronics, vol. 36, no. 9, pp. 10920-10932, Sept. 2021, doi: 10.1109/TPEL.2020.3040071.
• C. Gavriluta, G. Lauss, T. I. Strasser, J. Montoya, R. Brandl and P. Kotsampopoulos, "Asynchronous Integration of Real-Time Simulators for HIL-based Validation of Smart Grids," IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society, 2019, pp. 6425-6431, doi: 10.1109/IECON.2019.8927131.

SGHS-02 - Simulation and Modelling of Grid Power Converters	
Delivered by:	**Keywords**
Zoran Miletic; Anja Banjac	Power electronics, Photovoltaics, Converters



[Simulation and modelling of Power Converters and Power Conversation Systems | Project Sinergy (project-sinergy.org)](project-sinergy.org)

Duration	1 day
Prerequisites	Control of grid power converters for Photovoltaic applications
Software	Typhoon-HIL
Summary	Starting with a recap of "Control of grid power converters for Photovoltaic applications" the course provides insight in real-time simulation of power

	converters and implementation of algorithms which have been discussed in theory. Topics covered are methods to develop grid synchronization algorithms based on phase locked loop (PLL) and frequency locked loop (FLL) methods with special treatment of DSOGI (double second order generalized integrator). Futher, typcial grid functions such as Volt-Var, Frequency-Var and Frequency-Watt are presented. A methodological basis for the lecture is use of hardware-in-the-loop systems with AIT demonstrator hardware (AIT HIL Controller, and AIT Vindobona power electronics development kit). The development platform is also presented in detail for further use in subsequent courses and staff exchange.
Reference Material	
• https://www.ait.ac.at/fileadmin//mc/energy/Business_Cases/3_Power_System_Technologies/Smart_Grid_Converter_3.pdf	
• "Grid Converters for Photovoltaic and Wind Power Systems"; R. Teodorescu, M. Liserre and P. Rodriguez, 2011, John Wiley & Sons, Ltd.; ISBN: 987-0-470-05751-3	
• "Pulse Width Modulation for Power Converters, Principles and Practice"; D. G. Holmes and T. Lipo; 2003; IEEE Press, New York	

6. Conclusion

Within the first reporting period six trainings have been held by AIT in the field of Smart Grid Technologies. This number (40 %) is in line with the linear project timeline (42 %). The progress can be considered in line with the project plan by flexible adaptation to changes in the pandemic situation.

Though the early courses were held online in a webinar scheme, the 2022 meetings were located on site at AIT and IMP premises.

In the upcoming period a shift to physical presence is expected. A further intensification of knowledge exchange is aimed for. For already performed courses follow ups are considered to overcome potential shortcomings of a webinar setup.