Sinergy
Capacity building in Smart and Innovative eNERGY management

WP3
Learning Material, Training Courses and Joint Proposal Preparation

D3.2
Training Courses and Learning Material on Smart Grid Technologies (v2)

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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.

This report (Deliverable 3.2) 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 June 2023. It also serves as an update to Deliverable 3.1 where an overview was provided for the first period of the project.

During this reporting period a total of 12 lectures by 10 different AIT lecturers have been performed (either online or on AIT or IMP premises) which is in line with the project proposal (3 to 6 per year). One training was added with respect to previous reports to provide access to the AIT SimLab environment, which is a virtual laboratory for Smart Energy simulation tasks. Towards the end of the project, 4 more training lectures will be conducted to finalize the AIT training efforts within the Sinergy projects.

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

SINERGY repository of lectures is accessible at this link https://project-sinergy.org/Lectures.

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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 (D3.1 and this report – D3.2)
- Task 3.2: Preparation of training courses on Energy Efficient Building Operation (D3.3 and D3.4)
- Task 3.3: Joint project proposals preparation and management skills upgrade (D3.5)

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.

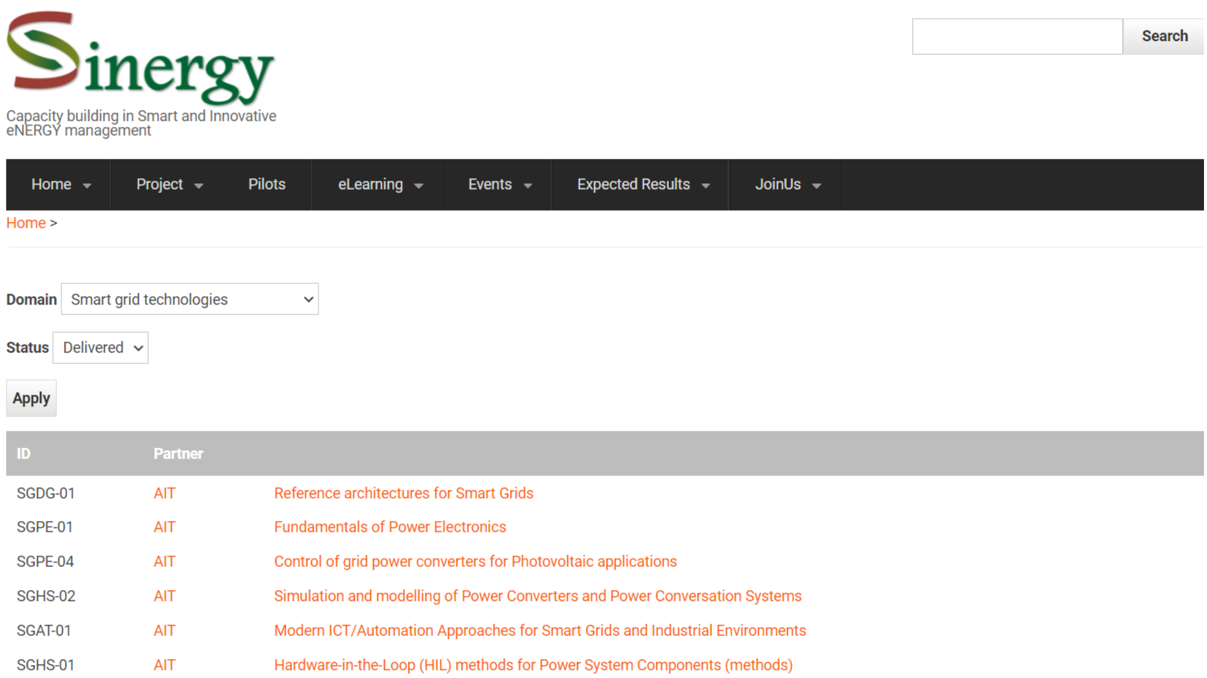


Figure 1. AIT Lectures in SINERGY repository (example)

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

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

- D3.1 Training Courses and Learning Material on Smart Grid Technologies (v1)
- D3.3 Training courses and learning materials on Energy Efficient Building Operation (v1)
- D3.4 Training courses and learning materials on Energy Efficient Building Operation (v2)
- 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
- D5.3 The Third SINERGY Workshop – Belgrade's Smart Energy Management laboratory
- 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 as seen in Figure 1. The courses are listed including AIT staff in charge to provide the training and the actual status in the project timeline (Table 1). Courses which have been performed are indicated with "done" while upcoming courses show "pending" with the proposed year of execution in brackets.

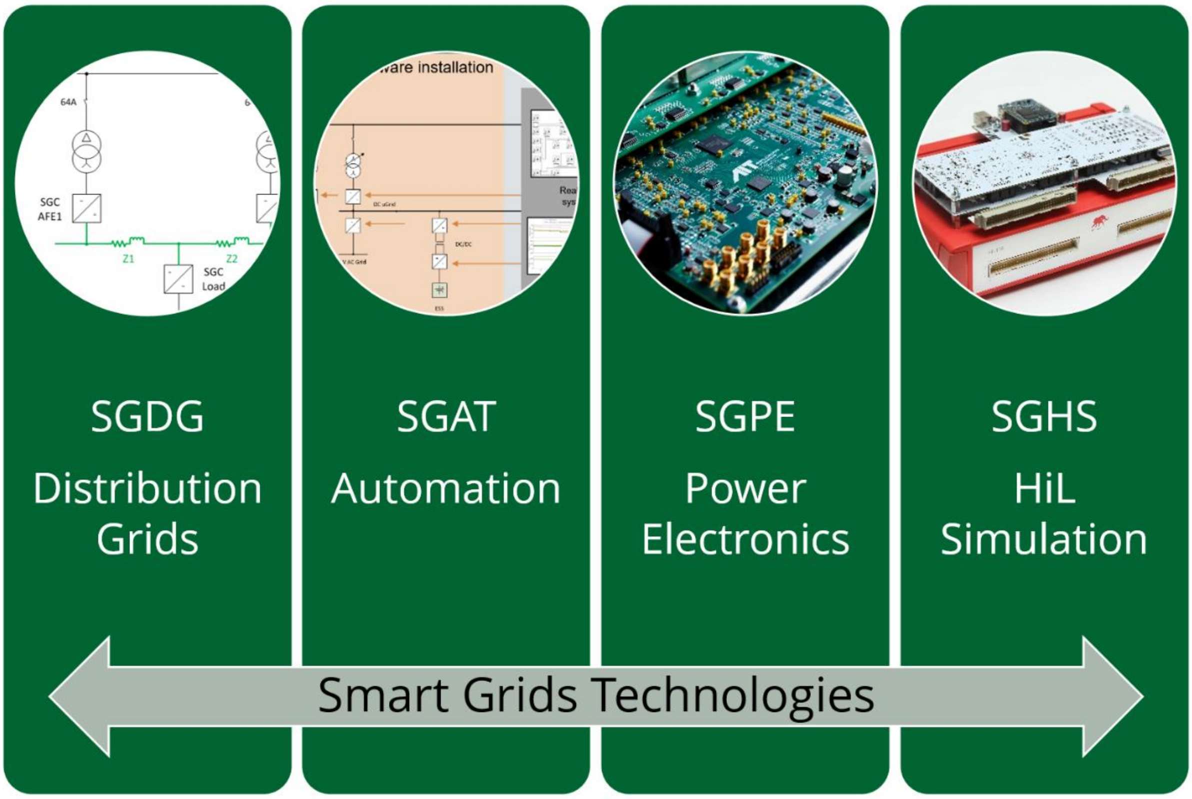


Figure 2. - Structure of core topics

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)](project-sinergy.org).

Table 1. Smart Grid Technologies Lectures (delivered by M30)

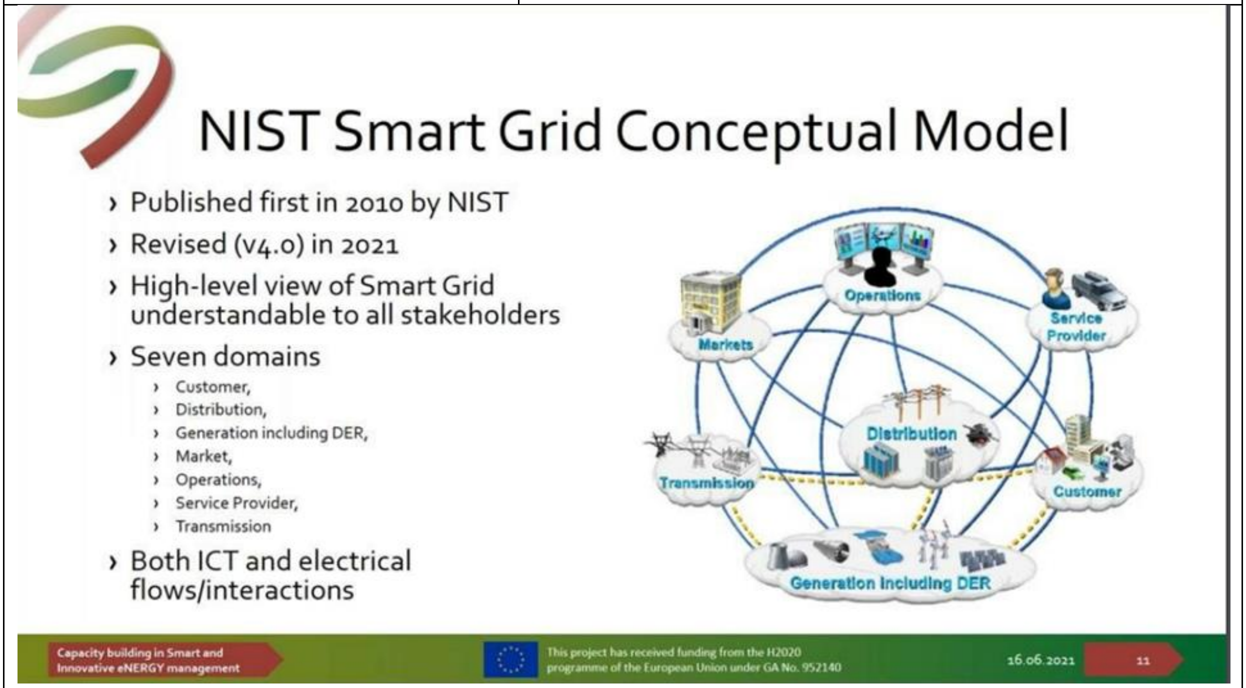
	Smart Grid Technologies		
ID	Module Title (version 1)	Delivered by:	Status:
SGDG-01	Reference architectures for Smart Grids	Friederich Kupzog	done
SGDG-03	Network planning for DC, and ACDC-Hybrid-Grids	Gerhard Jambrich	done
SGAT-01	Modern ICT/Automation Approaches for Smart Grids and Industrial Environments	Thomas Strasser	done
SGAT-02	Grid Interconnection Codes and Requirements - Review of Todays codes and requirements and future trends	Roland Bründlinger	done
SGAT-04	Electric Energy Storages	Christian Messner	done
SGAT-05	SmartEST SimLab Demonstration	Edmund Widl, Thomas Strasser	done
SGPE-01	Fundamentals of Power Electronics	Markus Makoschitz	done
SGPE-02	Grid power converters, architecture, and design considerations	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
SGHS-03	Rapid Controls Development for the Grid Connected/Forming Power Converters	Zoran Miletic, Andres Tarraso-Martinez	done

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

	Smart Grid Technologies		
ID	**Module Title (version 2)**	**Delivered by:**	**Status:**
SGDG-02	Enhancement of the hosting capacity of distribution grids	Barbara Herndler	pending (Q3/2023)
SGDG-04	Integrating DER in Smart Grids and High penetration of PV in Electricity Grids	Roland Bründlinger	pending (Q4/2023)
SGAT-03	Standards for integrating PV in Electricity Grids	Roland Bründlinger	pending (Q4/2023)
SGPE-03	Emerging Technologies for Power Electronics Systems in Smart Grids	Markus Makoschitz	pending (Q3/2023)

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

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

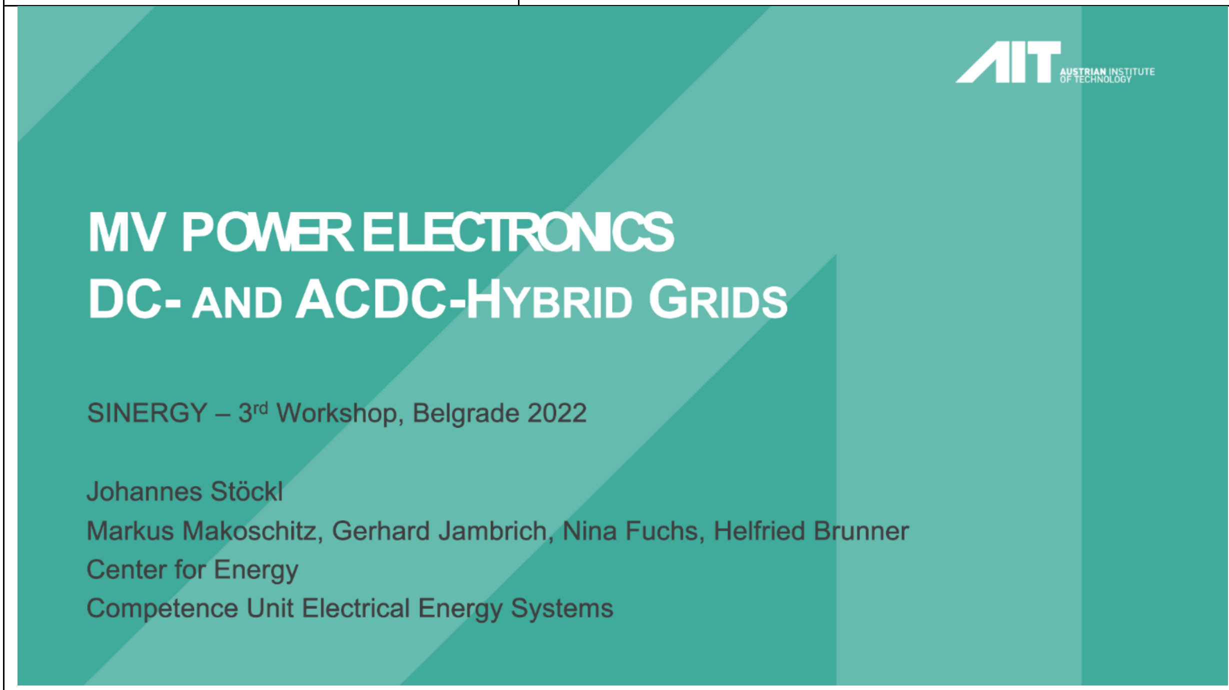


[Reference architectures for Smart Grids | Project Sinergy (project-sinergy.org)]

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, Technologieplatform 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	

SGDG-03 – Network planning for DC, and ACDC-Hybrid-Grids	
Delivered by:	**Keywords**
Gerhard Jambrich	Smart Grid



Duration	120 minutes
Summary	Due to the increasing share of power electronics which contribute to a stable electricity grid the area of DC- and ACDC-hybrid grids becomes more interesting for the distribution system. The training starts with the motivation of DC infrastructures and the potential benefits in terms of volume, weight, and costs. With a brief introduction of enabling technologies (MF-transformers and WBG power semiconductors) relevant use cases are discussed. This includes localized infrastructures for MW-charging as well as distribution lines which provide low loss power flow for single communities in rural areas in Finland. Beyond that the vision of distribution grid installations as proposed in the H2020 project "Hyperride" (GA No. 957788) with coupling to MVDC backbones or MV-distribution is discussed. Further, enabling technologies from DC circuit breakers until grid design and development tools for DC grid planning and load flow analysis are shown. For the specific use case of electric energy for industrial processes projects are presented where DC production lines benefit from extension with DC lines to efficiently integrate renewables and storage technologies. The field of laboratory infrastructures for test and validation of relevant DC technologies is presented with the use case of AIT SmartEST laboratory and

	AIT High Current DC laboratory where respective test procedures are developed.
Reference Material	
• N. Fuchs, G. Jambrich and H. Brunner, "SIMULATION TOOL FOR TECHNO-ECONOMIC ANALYSIS OF HYBRID AC/DC LOW VOLTAGE DISTRIBUTION GRIDS," CIRED 2021 - The 26th International Conference and Exhibition on Electricity Distribution, Online Conference, 2021, pp. 2549-2553, doi: 10.1049/icp.2021.2122.	
• G. Jambrich, J. Stöckl and M. Makoschitz, "MVDC ring-cable approach for new DC distribution and restructured AC grids," 2019 IEEE Third International Conference on DC Microgrids (ICDCM), Matsue, Japan, 2019, pp. 1-5, doi: 10.1109/ICDCM45535.2019.9232731.	
• Kupzog, F., Jambrich, G. & Brunner, H. DC-Technologien. Elektrotech. Inftech. 139, 413–414 (2022). https://doi.org/10.1007/s00502-022-01042-z	
• Jambrich, G., & Fuchs, N. (2021). CIRED WG 2019-1 DC distribution networks - Final Report. DC DISTRIBUTION NETWORKS - WG 2019-1.	
• Jambrich, Gerhard, Stöckl, Johannes, Strasser, Thomas I., Munoz-Cruzado Alba, Jesus, & Sanchez, Breogan. (2021, November 30). Towards Resilient hybrid Medium and Low Voltage AC-DC Power Grids – A European Perspective. 3rd CIGRE SEERC Conference Vienna 2021 (CIGRE SEERC Vienna 2021), Online.	
• HYPERRIDE: HYbrid Provision of Energy based on Reliability and Resiliency via Integration of DC Equipment https://hyperride.eu/	
• Tigon Project: https://tigon-project.eu/	

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>
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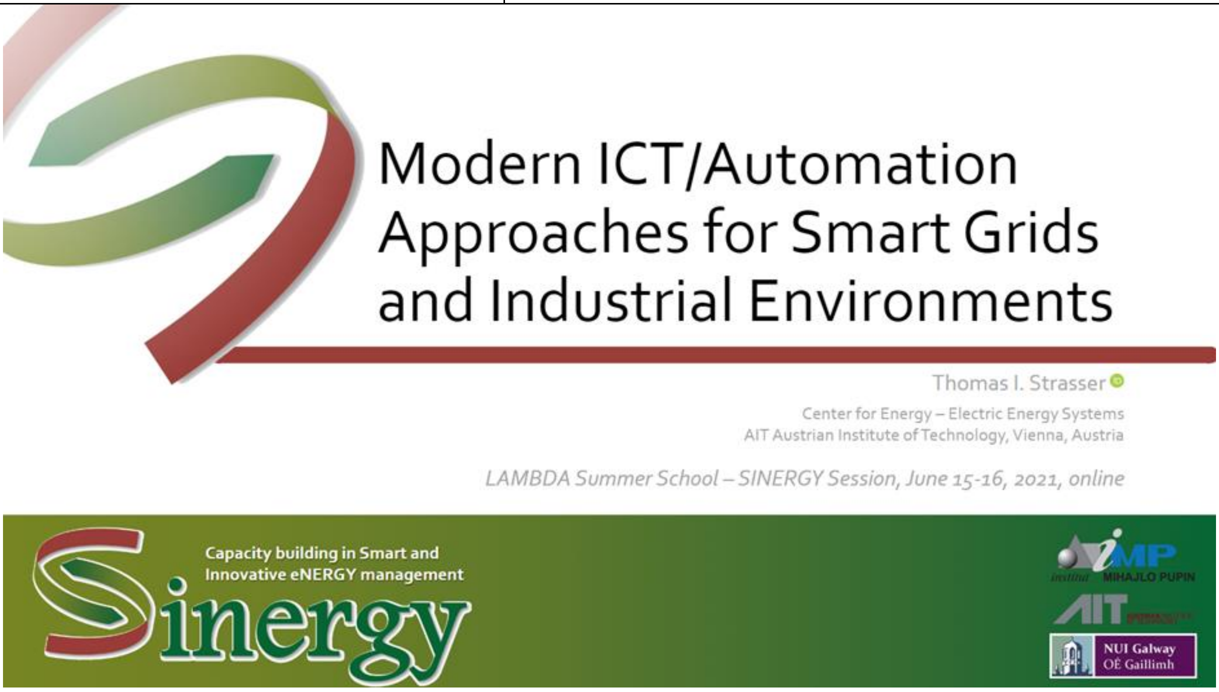


https://doi.org/10.5281/zenodo.6088671

[Modern ICT/Automation Approaches for Smart Grids and Industrial Environments | Project Sinergy (project-sinergy.org)]

Duration	40 minutes
Summary	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 CO_2 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

	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.

SGAT-02 - Grid Interconnection Codes and Requirements - Review of Todays codes and requirements and future trends

Delivered by:	Keywords
Roland Bründlinger	Automation, ICT, Grid Codes, Smart Grid, Power System, Lecture

Country Requirements – LV connected, Type A PPMs

Country Update 12/2021	NC RfG*	EN 50549-1 (Type A)	Germany	Italy	Austria	France	Spain	Denmark (Type A)	UK*
Type A power limit (MW)	≤1	≤1	≤0.135	≤0.011	≤0.25	≤1	≤0.1	≤0.125	≤1
Function	2016	2019	2018	2019	2019	2019	2019	2019	2018/2018
Frequency range	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/Yes
ROCOF withstand cap.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/Yes
P(f) at over freq.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/Yes
P(f) at under freq.	N/S	Yes	Yes	Yes	No	No	No	No	No/No
Q/cosφ range	N/S	Yes	Yes (cosφ)	Yes (all)	Yes	No	No	Yes	No/No
Cosφ(P)	N/S	Yes	Yes (all)	Yes (all)	Yes	No	No	Yes	No/No
Q(U)	N/S	Yes	>4.6 kVA	>11.08 kW*	Yes	No	No	No	No/No
P(U)	N/S	Optional	Allowed*	Optional	Yes	No	No	No	No/No
Ramp rate limits	N/S	No	Yes	No	No	No	No	No	No/No
Remote control of P	N/S	Yes	>30kW	>11.08 kW	No	No	No	No	No/No
Remote control of Q	N/S	Optional	No	>11.08 kW	No	No	No	No	No/No
Remote off	Yes	Yes	Yes	Yes (all)	Yes	No	No	Yes	Yes/Yes
LVRT (UVRT)	No	Yes	Yes*	>11.08 kW	Yes	No	No	No	No/Optional
HVRT (OVRT)	No	Yes	Yes*	No	No	No	No	No	No/No
Fast reactive current		No	No	No	No/Yes*	No	No	No	No/No
Reference	(EU) 2016/631 (NC RfG)	EN 50549-1:2019	VDE AR N 4105: 2018-11	CEI 0-21:2019	TOR Erzeuger Type A:2019-07	Arrêté du 23 avril 2008 Enedis-NOI-RES_13E V 7 2018	Propuesta OM Códigos de Red Norma Tecnica Supervision V1.0	Dansk Energi Guide for connection of power-generating plants to the low-voltage grid Type A and B V1.1	ENA_EREC_G98_Issue_1_Ammendment_1_2018 ENA_EREC_G99_Issue_1_Ammendment_1_2018
Remarks	* non exhaustive requirements subject to implementation in national codes		* Not required	* Additional lock-in/-out function	* On request of DSO		*Draft proposals only		* Type A ≤16 A/>16 A

https://erigrid2.eu/smartest-sim-lab/

Duration	40 minutes
Summary	The training given on December 15, 2022 highlighted latest trends in grid code developments for the connection of distributed and renewable generation, focusing on the experiences from Europe. As an introduction, an overview on the role of Solar PV and Wind generation in the European electricity system was provided, also giving an outlook on the expected future development based on the latest European strategy documents. In the second part of the training course, the European Network Code “Requirements for generators” (NC RfG) was presented in detail, explaining the basic approach, requirements and their application to different types of generating systems. As the detailed implementation requirements are specified on the European national levels, an overview on the differences related to the requirements was provided for selected European markets. In the third part of the training course, the new EN 50549-X series of European standards was introduced, which expand the definitions of the European Network Code RfG to cover all requirements relevant for the connection of generating systems to the Low-Voltage and Medium-Voltage distribution systems.

	The fourth part of the training course was dedicated to latest experiences with testing of distributed resources (DER), which were made by AIT in research and demonstration projects. In this part, the application of innovative approaches for testing of DER was presented, highlighting opportunities as well as limitations of the different concepts.
Reference Material	
• Global Market Outlook For Solar Power 2022-2026; https://www.solarpowereurope.org/insights/market-outlooks/global-market-outlook-for-solar-power-2022	
• https://www.entsoe.eu/major-projects/network-code-development/requirements-for-generators/	
• EN 50549 SERIES CENELEC TC8X WG03: Advanced grid support requirements for inverter based generating plants ("Power Park Modules")	

SGAT-04 – Electric Energy Storages	
Delivered by:	**Keywords**
Christian Messner	Electric Energy Storage, Battery Storage, Automation, ICT, Digitalisation, Smart Grid, Power System, Training

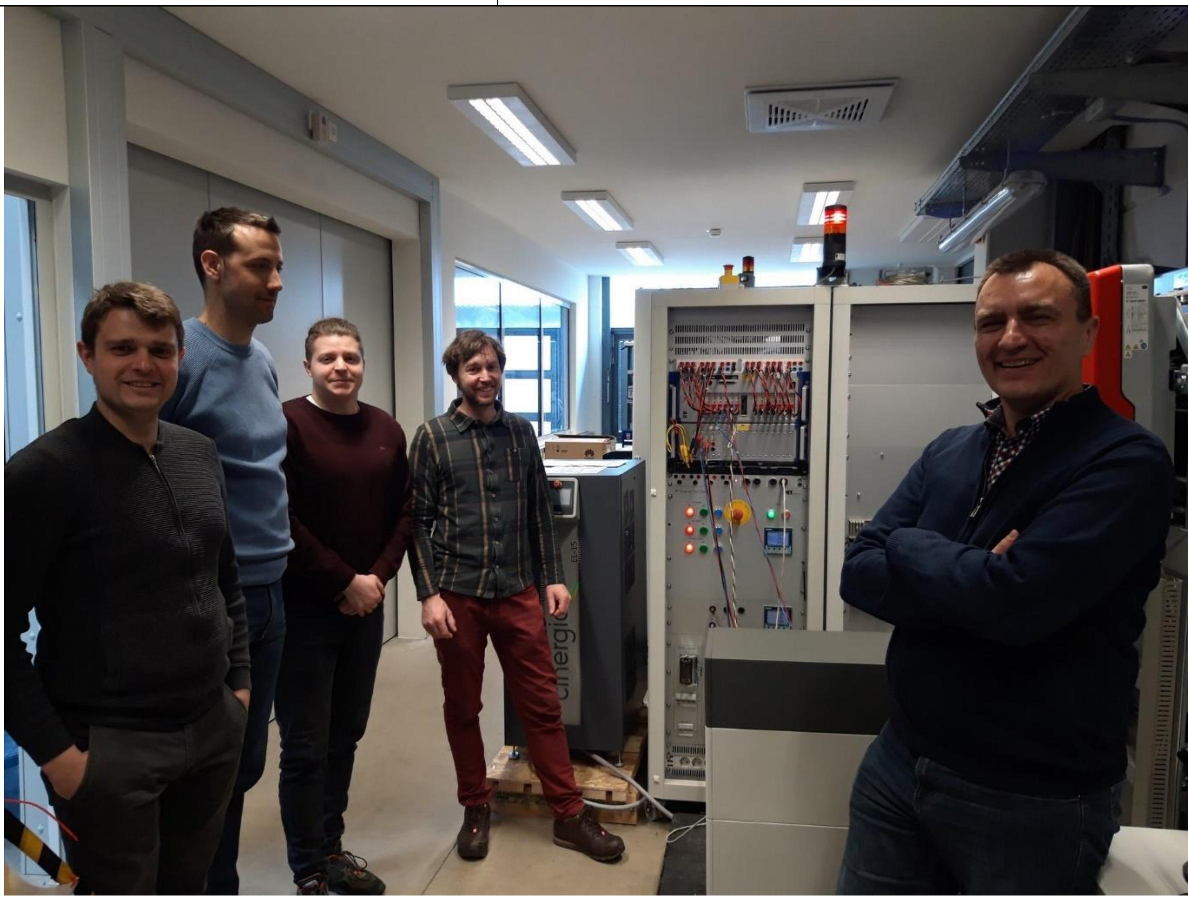
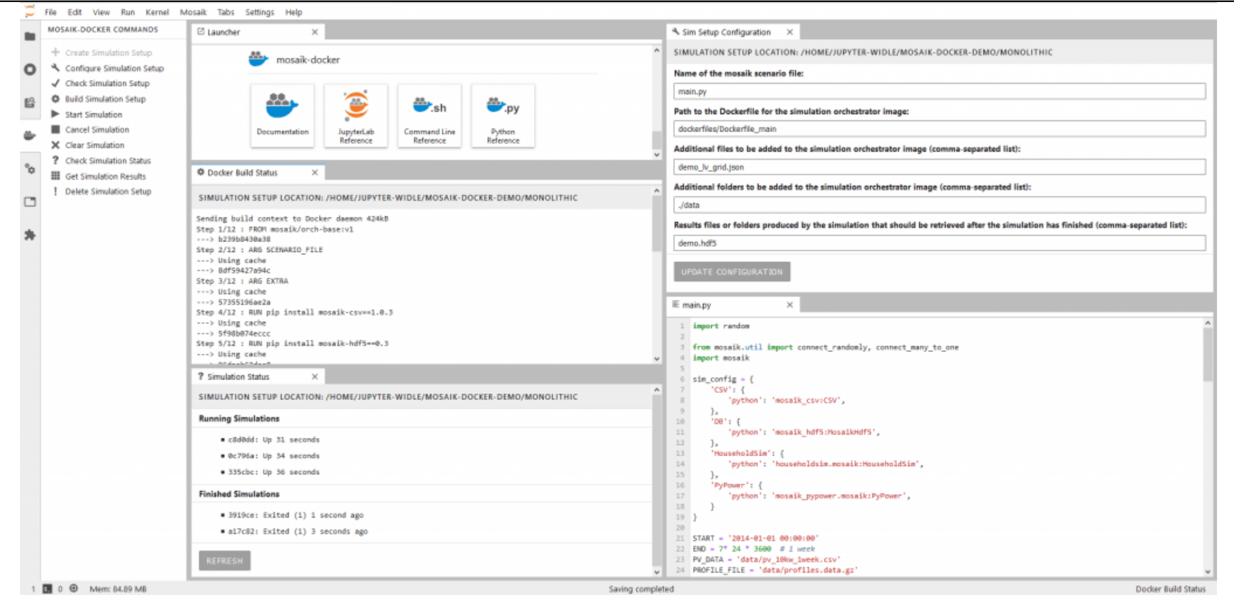


Figure 3. Example of training at AIT premises

Duration	1 day
Summary	Battery electric energy storage systems started to become consumer products about 10 years ago starting with limited data sheet requirements. Hence, the available products were not easily comparable and normally not tested according to comparable procedures. Consequently, EU research institutes and test laboratories aligned to develop a proper guideline on the test procedures presented as a guideline of best practice. Such tests involve e.g. round trip efficiency (cycles of charging and discharging) or set point accuracies. AIT as a presenter of this course was involved from the beginning and is able to conduct the most relevant tests of storage performance in its Smart Grids Laboratory "SmartEST"

	The course started with an introductory presentation on PV Home Storage Systems. Later, the operation of the "Sunny Boy" 10kVA single-phase inverter with DC sources emulating PV panels and 3kWh battery storage was also shown, where basic operations and auxiliary functions for supporting the grid were demonstrated. The training course provides an overview of performance test and validation of battery electric energy storage systems. The training was conducted during a staff exchange event at AIT premises.
Reference Material	
• Rosewater, David; Johnson, Jay; Verga, Maurizio; Lazzari, Riccardo; Messner, Christian; Bründlinger, Roland; Kathan, Johannes; Hashimoto, Jun; Otani, Kenji. (2015). International development of energy storage interoperability test protocols for renewable energy integration.	
• Tjaden, Tjarko; Weniger, Johannes; Messner, Christian; Knoop, Michael; Littwin, Matthias; Kairies, Kai-Philipp; Haberschusz, David; Loges, Hauke; Quaschning, Volker. (2017). Offenes Simulationsmodell für netzgekoppelte PV-Batteriesysteme.	
• Kulkarni, Siddhi Shrikant & Büchle, Felix & Munzke, Nina & Heckmann, Wolfram & Giesen, Niklas & Messner, Christian. "Effizienzleitfaden für PV-Speichersysteme: Wiederholbarkeit und Einfluss von Mess- und Auswerteparametern / Efficiency Guideline for PV Storage Systems: Repeatability and impact of measurement and evaluation parameters.", 2022	
• N. Ninad et al., "PV Inverter Grid Support Function Assessment using Open-Source IEEE P1547.1 Test Package," 2020 47th IEEE Photovoltaic Specialists Conference (PVSC), Calgary, AB, Canada, 2020, pp. 1138-1144, doi: 10.1109/PVSC45281.2020.9300372.	
• C. Seitl, C. Messner, H. Popp and J. Kathan, "Emulation of a high voltage home storage battery system using a power hardware-in-the-loop approach," IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society, Florence, Italy, 2016, pp. 6705-6710, doi: 10.1109/IECON.2016.7794104.	

SGAT-05– SmartEST SimLab Demonstration	
Delivered by:	**Keywords**
Edmund Widl, Thomas Strasser	Virtual Lab, Simulation



https://zenodo.org/record/6810644

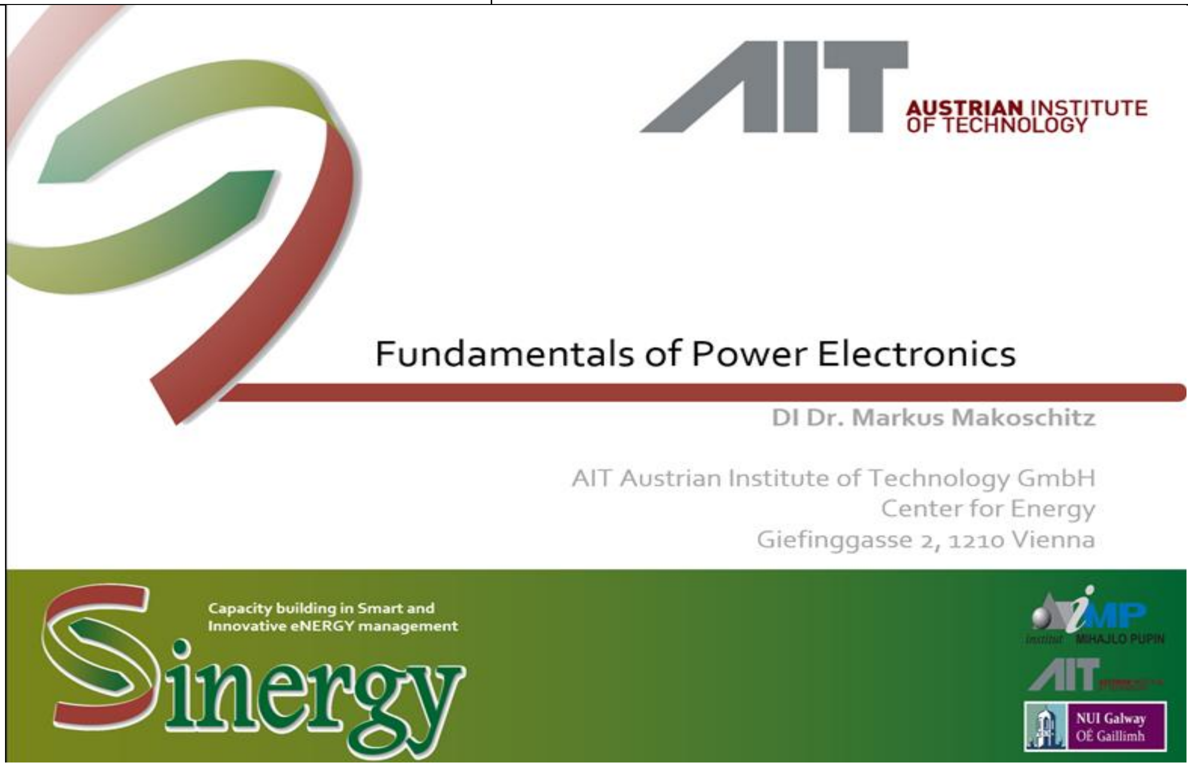
Duration	120 minutes
Summary	This course serves as an introduction to working with the SmartEST Sim Lab platform. The virtual environment has been created as part of the EU project “EriGRID 2.0” and has been opened to the Sinergy consortium for free use. This lecture was provided to help new users from Pupin and Galway to learn about the user interfaces and the capabilities. An overview is provided on the prerequisite packages Jupyter, Mosaik, Docker and how those interact to set-up the environment.

Reference Material

- Access-point: https://smartest-sim-lab.erigrid2.eu/hub/about
- Prerequisite package MOSAIK: https://mosaik.offis.de/
- Prerequisite package DOCKER: https://docs.docker.com/
- Prerequisite package JupyterLab: https://jupyter.org/

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: "SINERGY Presentation_PEFundamentals.pptx" or "SINERGY Presentation_PEFundamentals.pptx.pdf"**

SGPE-02 - Grid power converters, architecture, and design considerations

Delivered by:	Keywords
Markus Makoschitz	Power Electronics, Applications, DC/DC Converters

Figure 4. Example of online training with Markus Makoschitz

Duration	240 minutes
Prerequisites	Basics on electric engineering
Software	Power Point, Repaper, Plexim - Plecs Software
Summary	In this workshop, attendees will get initial insights in the PLECs power electronics simulation tool for modelling and simulating power electronics converters. Furthermore, knowledge on analysis and simulation from lecture 1 will be extended AC/DC multi-phase systems including also state-of-the-art three-phase power electronic circuits for renewable energy systems. Also, single phase AC/DC inverters for PV-applications will be discussed. Moreover, input and output filter design issues will be addressed. Again, participants get the chance to practice their skills and can work on selected design examples (AC/DC).

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

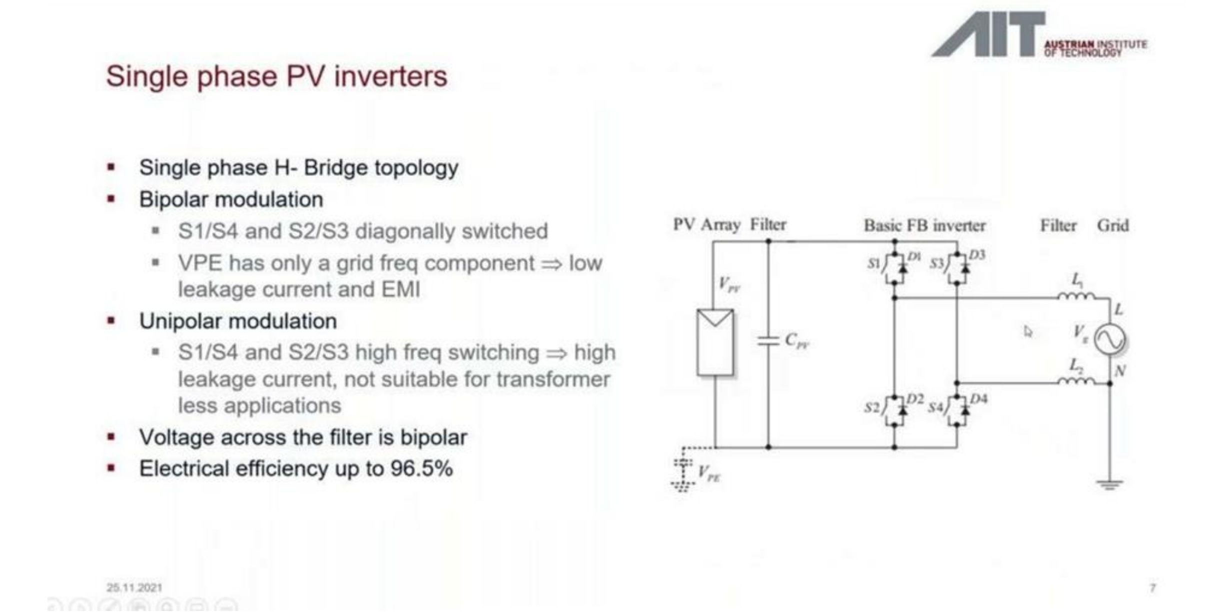
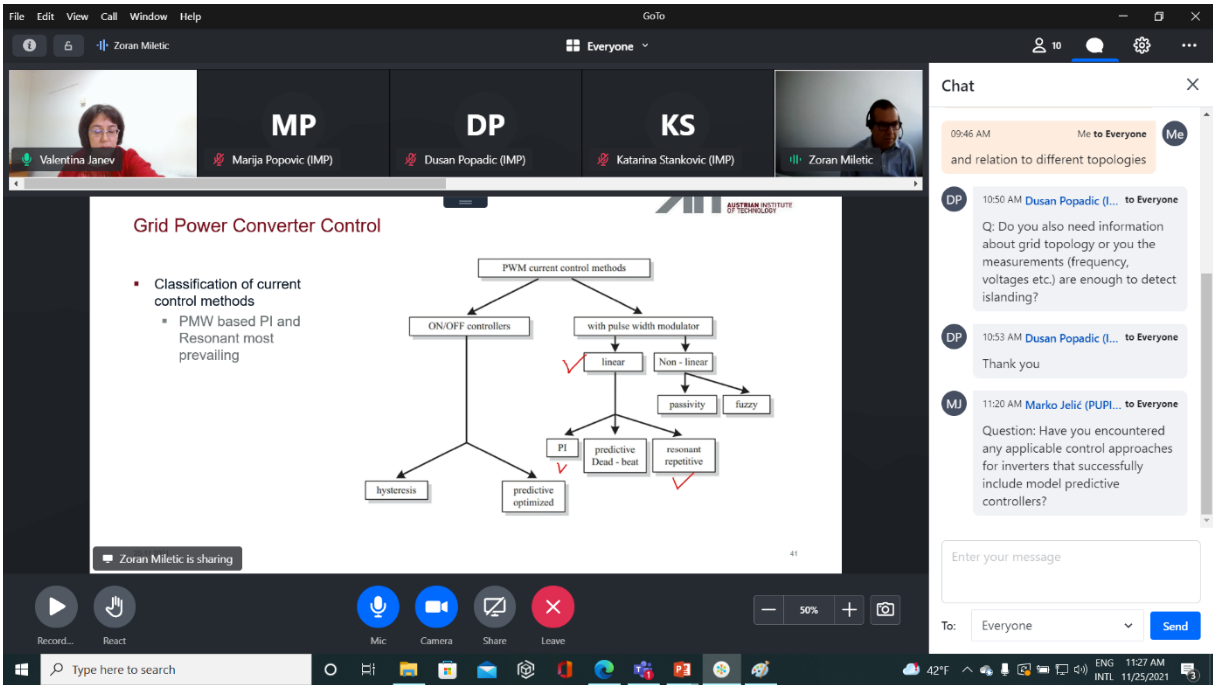


Figure 5. Example of online training with Zoran Miletic



[Control of grid power converters for Photovoltaic applications | Project Sinergy (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

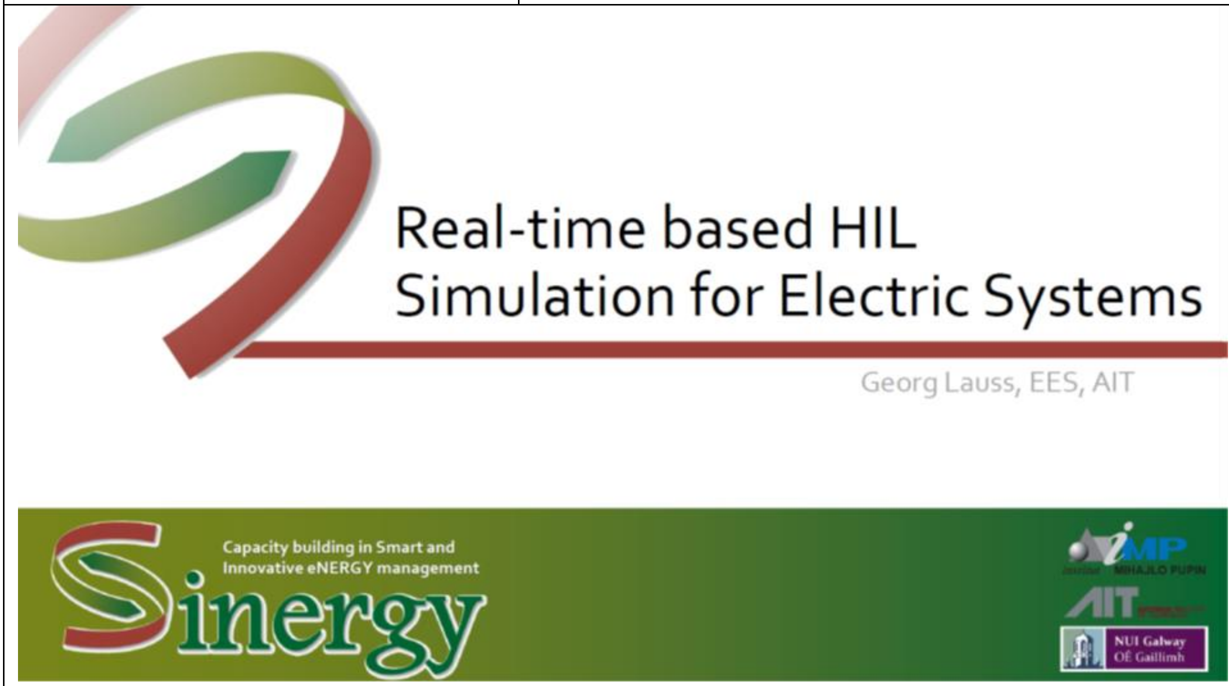
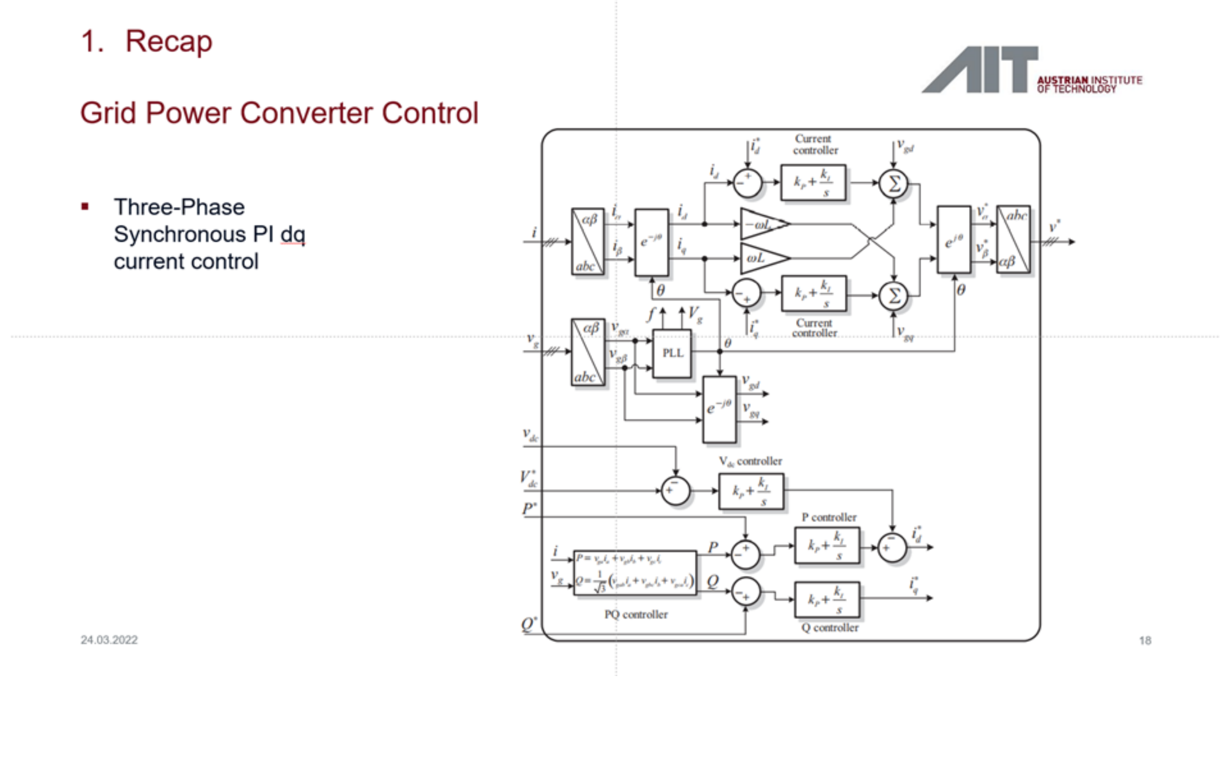


Figure 6. Example of online training with Georg Lauss

[Hardware-in-the-Loop (HIL) methods for Power System Components (methods) | Project Sinergy (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

SGHS-03 - Rapid Controls Development for the Grid Connected/Forming Power Converters

Delivered by:	Keywords
Zoran Miletic; Andres Tarraso-Martinez	Power electronics, Photovoltaics, Converters

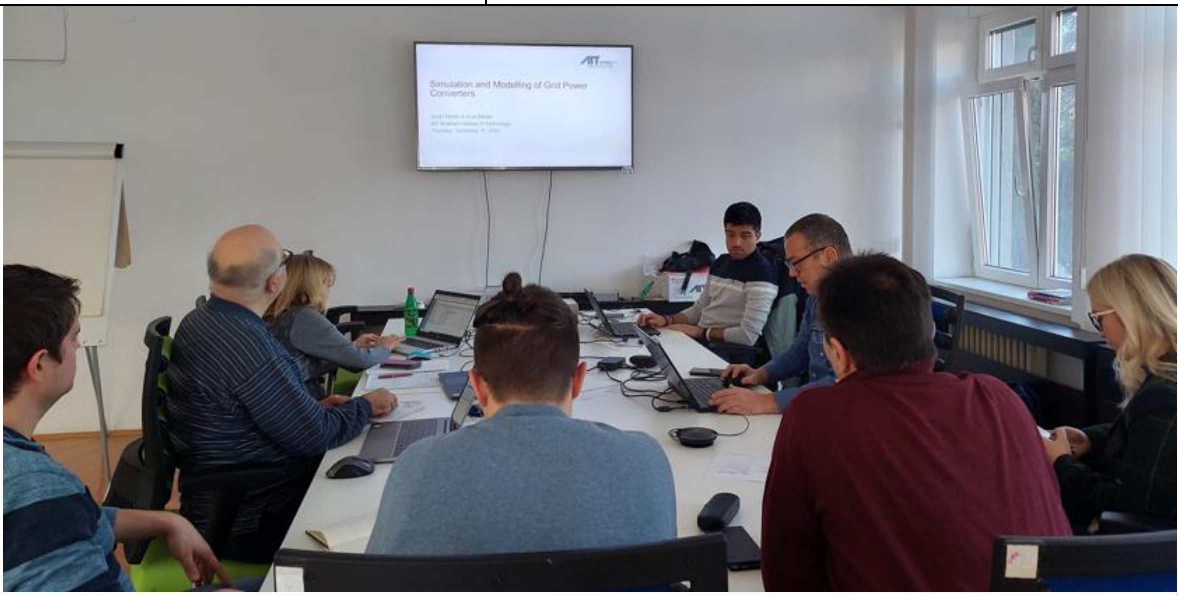


Figure 7. Example of training with Zoran Miletic at IMP premises

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

Duration	120 min
Prerequisites	Control of grid power converters for Photovoltaic applications, Simulation and modelling of Power Converters and Power Conversation Systems
Software	Typhoon-HIL
Summary	This presentation is 3rd part of lectures on the Control of Grid Connected Power Converters with emphasis of actual implementation of the controls on AIT's Rapid Controls Development Platform with live demonstrations on Typhoon C-HIL Real Time simulator.

Reference Material

- S. Bhattacharya et al., "Photovoltaic grid-forming control strategy investigation using hardware-in-the-loop experiments," 13th Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion (MEDPOWER 2022), Hybrid Conference, Valletta, Malta, 2022, pp. 420-424, doi: 10.1049/icp.2023.0029.
- Entry point for HIL models and documentation: https://www.typhoon-hil.com/ait/

6. Conclusion

Within the 30 months project duration 12 trainings have been organized by AIT for IMP staff in the field of Smart Grid Technologies. The progress can be considered in line with the project plan by flexible adaptation to changes in the pandemic situation although 4 further trainings are planned to be delivered towards the end of the project. One training (SmartEST Virtual Lab) was added to the list of planned trainings in addition to the proposal. This access in collaboration with the project “EriGRID 2.0” is available for all partners within Sinergy and the Sinergy target area of Serbia.

Though the early courses were held online in a webinar setting, the 2022 and 2023 meetings were located on site at AIT (March 2022) and IMP premises (March 2022, June 2022, November 2022, December 2022), as committed in V1 of this report (D3.1).