



# Education and Training Methods and Tools – Achievements and Lessons Learnt

*Virtual ERIGrid Final Conference  
April 1<sup>st</sup> 2020*

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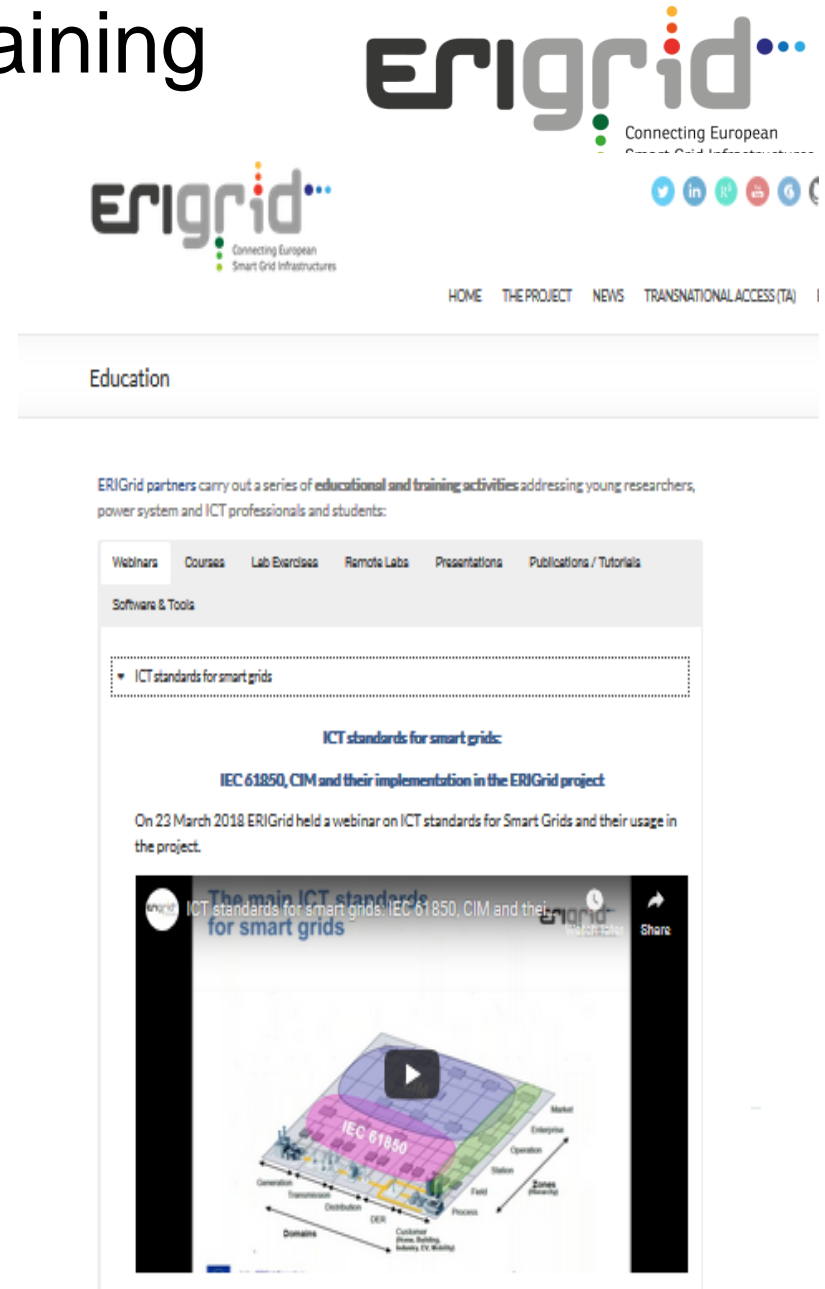
# New educational/training needs in a complex environment

- Need for new skills and expertise to foster the energy transition
- Increased complexity of intelligent energy systems
- A broad understanding of topics of different domains is necessary, i.e. electric power, heat, markets and definitely **ICT** → a holistic understanding is needed
- Interdisciplinary approach, understanding of interactions
- The need for new educational approaches: lectures combined with simulations, e-learning, laboratories etc. Application of learner centered educational methods

*P. Kotsampopoulos, N. Hatziargyriou, T. I. Strasser, C. Moyo, et al, Chapter: “Validating Intelligent Power and Energy Systems – A Discussion of Educational Needs” in “Industrial Applications of Holonic and Multi-Agent Systems”, Springer, 2017*

# At a glance: ERIGrid project educational/training activities

- 6 Webinars: **300 participants** (2000+ views on Youtube)
- 5 Summer Schools at ERIGrid partner universities
- 12 Workshops and 3 Tutorials: more than **450 participants**.
- 7 Educational tools: virtual/remote labs, interactive notebooks, co-simulation tools etc
- Advanced laboratory exercises
- **450+ students** have benefited from ERIGrid exercises, tools and other resources in their Bachelor, Master or PhD studies



The screenshot displays the ERIGrid project website. At the top, the ERIGrid logo is shown with the tagline "Connecting European Smart Grid Infrastructures". Below the logo, there are social media icons for Twitter, LinkedIn, Facebook, YouTube, and Instagram. A navigation bar includes links for HOME, THE PROJECT, NEWS, and TRANSNATIONAL ACCESS (TA). The main content area is titled "Education" and features a sub-header: "ERIGrid partners carry out a series of educational and training activities addressing young researchers, power system and ICT professionals and students:". Below this, there is a menu with options: Webinars, Courses, Lab Exercises, Remote Labs, Presentations, and Publications / Tutorials. A section titled "Software & Tools" is visible, with a dropdown menu showing "ICT standards for smart grids". The main content area displays a video player with the title "ICT standards for smart grids: IEC 61850, CIM and their implementation in the ERIGrid project". The video description states: "On 23 March 2018 ERIGrid held a webinar on ICT standards for Smart Grids and their usage in the project." Below the video player, there is a diagram titled "The main ICT standards for smart grids" showing a 3D grid structure with various components labeled: Generation, Transmission, Distribution, DER, Customer (Homes, Buildings, Industry, IT, etc.), Process, Field, Station, Operation, Enterprise, and Market. The diagram also includes labels for "Zones planning" and "Process".



# Online resource center at the ERIGrid website

<https://erigrd.eu/education-training/>



- Co-simulation
- Real-time simulation
- Smart grid validation
- Remote/ICT labs

ERIGrid  
Connecting European Smart Grid Infrastructures

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Education You are here: ERIGrid > Education

**Co-simulation** Real-time simulation Smart grid validation Remote/ICT labs

- + Courses
- + Lab Exercises
- + Presentations
- + Publications
- + Remote Labs
- + Software
- + Webinars

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1 April 2020

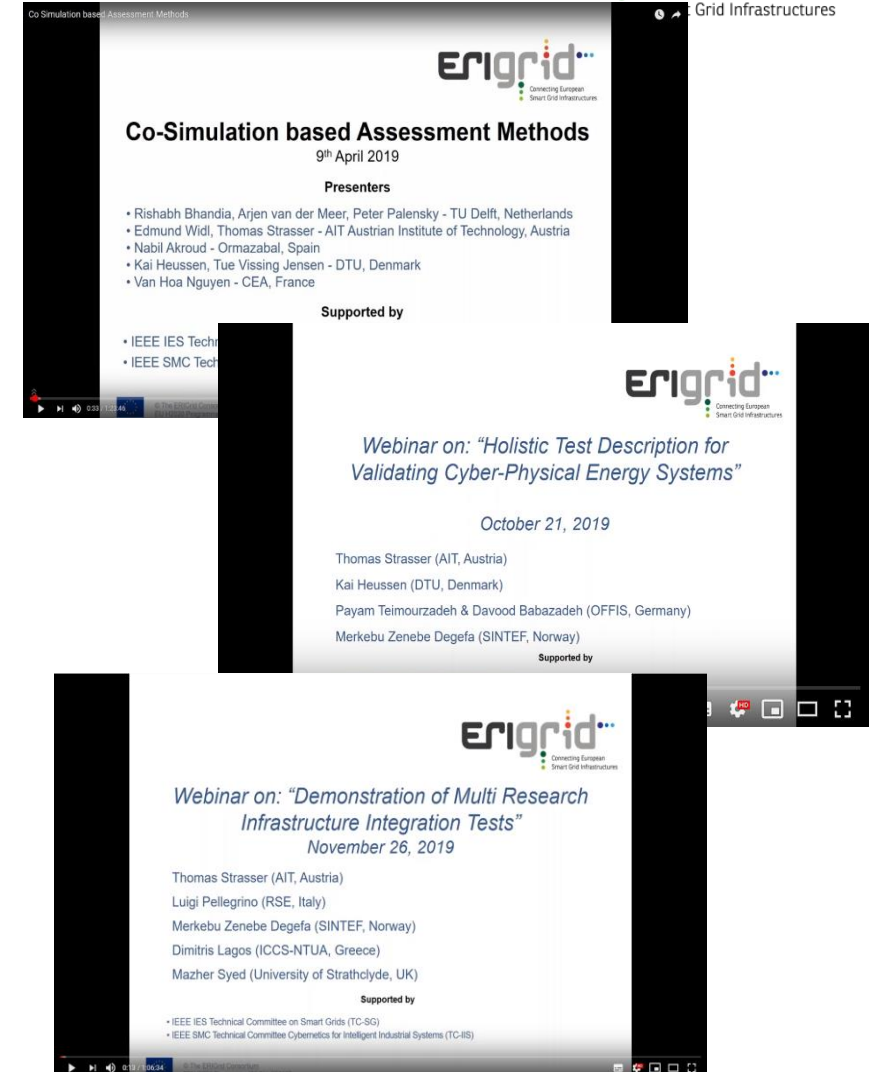
Coming to an end in April 2020, the ERIGrid project is organising its Virtual Final Conference dedicated to presenting the ...

Read More



# Training/Education material – Webinars

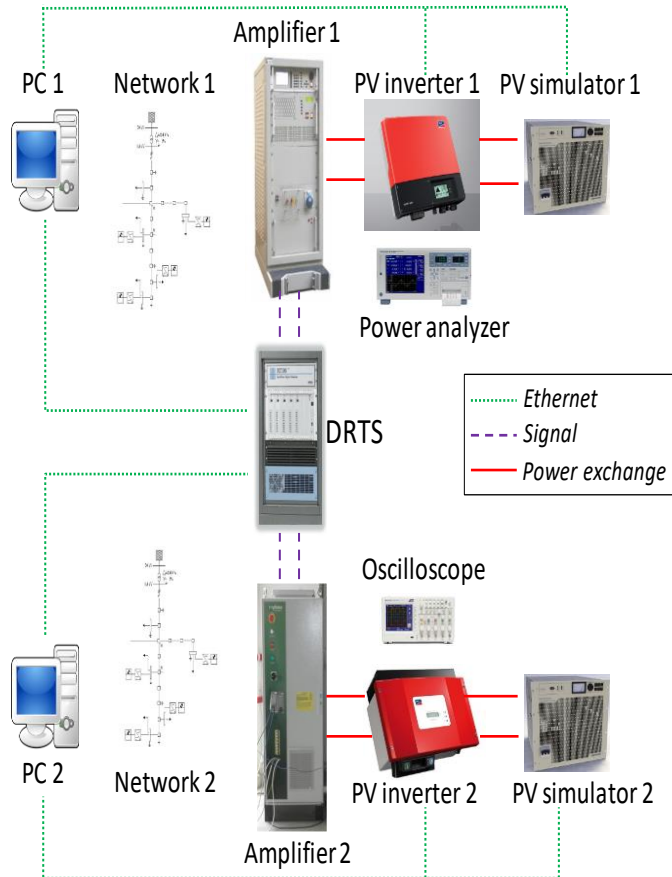
No.	Webinar Name	No. of Attended Persons	No. of Project External Persons	Views on YouTube
1	<b>Co-simulation</b> with real-time simulation using <u>OpSim</u>	32	1	-
2	<b>PHIL simulation</b> for DER and smart grids: best practices and experiences from the <u>ERIGrid</u> project	59	33	620
3	ICT standards for smart grids: <b>IEC 61850, CIM</b> and their implementation in the <u>ERIGrid</u> project	76	45	1075
4	<b>Co-Simulation</b> based Assessment Methods	51	41	227
5	<b>Holistic Test Description</b> for Validating Cyber-Physical Energy Systems	41	27	131
6	<b>Demonstration of Multi Research Infrastructure</b> Integration Tests	36	25	50
<b>Sum</b>		<b>295</b>	<b>172</b>	<b>2103</b>



The image shows three overlapping webinar slides from the ERIGrid project. The top slide is titled "Co-Simulation based Assessment Methods" dated 9th April 2019, with presenters Rishabh Bhandia, Arjen van der Meer, Peter Palensky, Edmund Widl, Thomas Strasser, Nabil Akroud, Kai Heussen, Tue Vissing Jensen, and Van Hoa Nguyen. The middle slide is titled "Webinar on: 'Holistic Test Description for Validating Cyber-Physical Energy Systems'" dated October 21, 2019, with presenters Thomas Strasser, Kai Heussen, Payam Teimourzadeh, Davood Babazadeh, and Merkebu Zenebe Degefa. The bottom slide is titled "Webinar on: 'Demonstration of Multi Research Infrastructure Integration Tests'" dated November 26, 2019, with presenters Thomas Strasser, Luigi Pellegrino, Merkebu Zenebe Degefa, Dimitris Lagos, and Mazher Syed.

# Training/Education material – Laboratory education

a) **PHIL simulation:** used for educational purposes in a systematic way for the first time



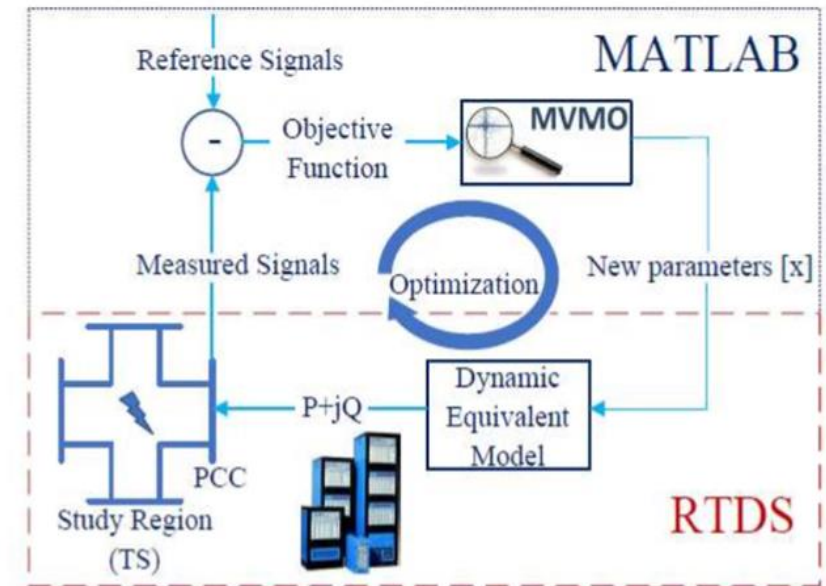
Double PHIL  
setup

Experiential  
learning

b) **Real time simulation exercises for master level students\***

- Small Time-step, PMUs, MMC, HVDC, scripting etc

*\*Source files are available on the ERIGrid website*



P. Kotsampopoulos, V. Kleftakis, N. Hatzargyriou, "Laboratory Education of Modern Power Systems using PHIL Simulation", IEEE Transactions on Power Systems, December 2016



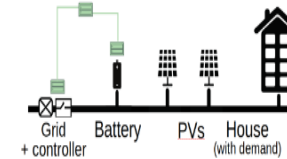
## 7 Educational software tools

### Jupyter (interactive) Notebooks

- A merge between a standard text book and what real programming looks like
- Contains explanatory text and figures, while running on an IPython kernel allowing the student to execute python code
- Provides a way to narrow the gap between theoretical concepts and application by setting up code examples
- Minimizes the need for programming skills
- Used at Summer Schools etc.

#### 3. Initiate "world"

Now we initiate a new world (world\_3) the same way as before, but adding the extra entity corresponding to a battery and making sure to save the output from the collector in a different file (datastore\_grid\_demand\_PV\_batt):



```
In [19]: world_3 = mosaik.World(SIM_CONFIG)
filename_3 = 'grid_demand_PV_batt_output'
sim_dict, entity_dict = init_entities(world_3, filename=data_path+filename_3)
sim_dict, entity_dict = add_entities_1(world_3, sim_dict, entity_dict)
sim_dict, entity_dict = add_entities_2(world_3, sim_dict, entity_dict)
```

```
Starting "DemandModel" as "DemandModel-0" ...
Starting "SimpleGridModel" as "SimpleGridModel-0" ...
Starting "CollectorSim" as "CollectorSim-0" ...
Starting "PVModel" as "PVModel-0" ...
Starting "PVModel" as "PVModel-1" ...
Starting "BatteryModel" as "BatteryModel-0" ...
Starting "ControlModel" as "ControlModel-0" ...
```

#### 4. Connect components

The controller is connected to the grid and to the battery. The keyword argument "time\_shifted" is added in order to have a loop in the network, something that is otherwise not allowed in mosaik.

```
In [20]: # Connect units to grid busbar
world_3.connect(entity_dict['demand1'], entity_dict['grid1'], ('P', 'P'))
world_3.connect(entity_dict['pv1'], entity_dict['grid1'], ('P', 'P'))
world_3.connect(entity_dict['batt1'], entity_dict['grid1'], ('P', 'P'))
world_3.connect(entity_dict['pv2'], entity_dict['grid1'], ('P', 'P'))
```

# Training/Education material – Virtual Labs and Remote Labs

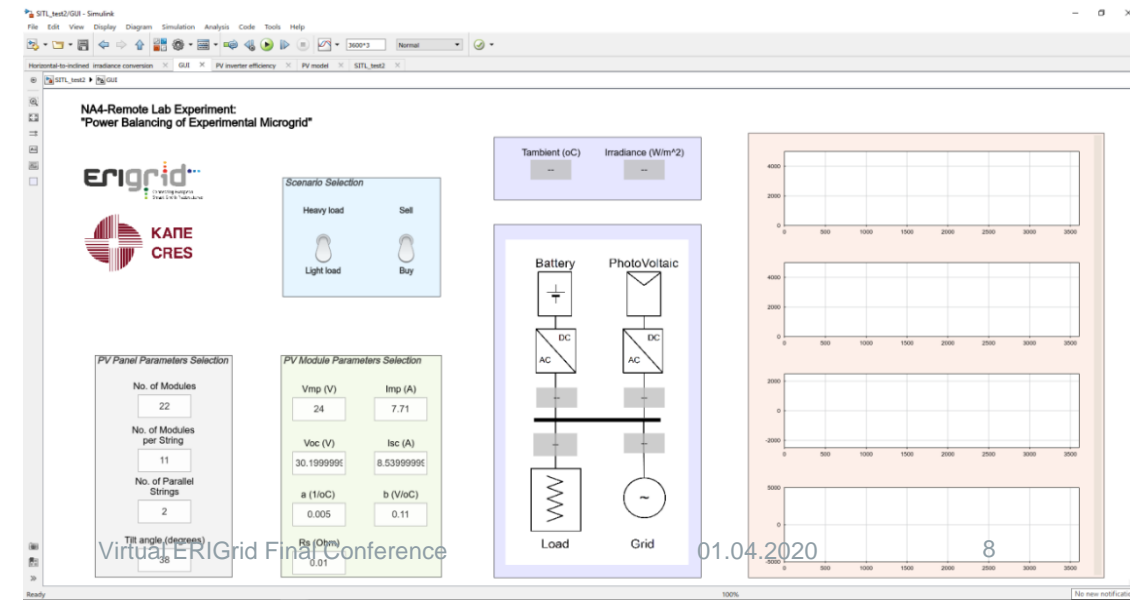
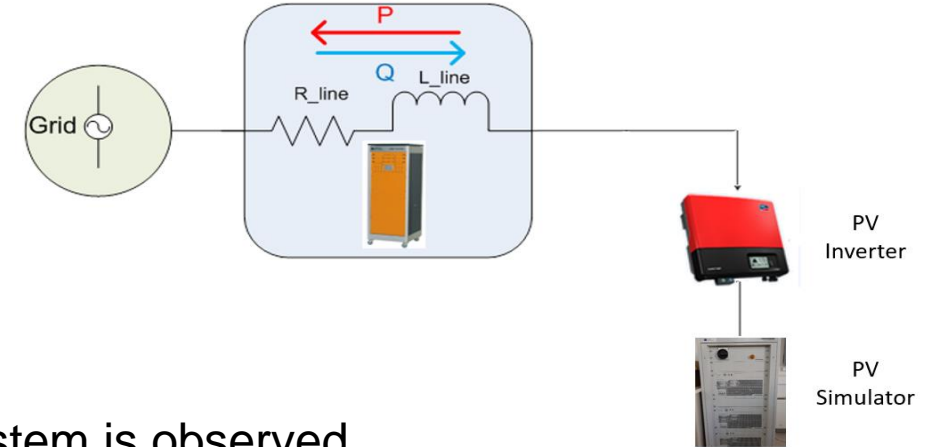
- **Remote Lab:** Measurement and control of actual equipment
- **Virtual Lab:** Simulation of the lab operation
- 3 Virtual/Remote Labs were developed

## Advantages of the Remote Lab:

- More realistic than the Virtual Lab as the operation of the real system is observed, providing a more meaningful experience to the user. Also video can be used
- Noise, equipment inaccuracies, communication delays, etc are taken into account

## Disadvantages of the Remote Lab:

- Only 1 user can typically have access at a time → more difficult to offer to a wide audience.
- Safety reasons: laboratory staff monitors the process of the experiment and if necessary communicates with the user.





# Experiences from the ERIGrid Summer Schools



- 5 Summer Schools
- 71 participants in total
- **Lectures, hands-on laboratory work, visits to cutting-edge installations and industry insights**

## Laboratory work

- **Individual work:** e.g. use software to execute real-time simulations
- **Team work:** e.g. HIL experiments of inverter controls: fine tune control parameters
- **Live demonstrations:** e.g. several HIL experiments

# Workshops, Seminars and Tutorials



Co-simulation  
workshops

- **15** Workshops, Seminars and Tutorials in total
- **More than 450** participants

Real-time  
simulation  
workshops



- ✓ Co-simulation tools/frameworks
- ✓ Resilience and security in digitalized energy systems
- ✓ Methods and tools for validating cyber-physical energy systems



DSO training  
+  
Education  
trends sessions

- ✓ Power system protection, control & security with real-time simulation
- ✓ Power system testing using HIL simulation
- ✓ Laboratory-based services for smart grids

- ✓ Workshop for DSO professionals
- ✓ Sessions on trends in laboratory education



# Additional educational activities

- Educational activities at high schools



- European Researchers Night (Vienna)



# Conclusions

- A need for new skills and competences. New technical tools but also educational methodologies.
- The role of laboratory education/training is important in the new complex era
- Webinars, hands-on practice, coding and software tools are beneficial
- PHIL simulation proved to be an efficient educational tool
- Remote/virtual labs can support the educational process. Remote Lab offers important advantages, but its actual implementation is more challenging.
- ERIGrid approaches and methodologies are supporting education/training on Smart Grids
- Stay tuned for ERIGrid 2.0 activities



# Thank you for your attention!

- Panos Kotsampopoulos, ICCS-NTUA, Smart RUE

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