Education and Training Methods and Tools – Achievements and Lessons Learnt

Virtual ERIGrid Final Conference
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Panos Kotsampopoulos, Alkistis Kontou, Nikos Hatziargyriou

Smart RUE, ICCS-NTUA

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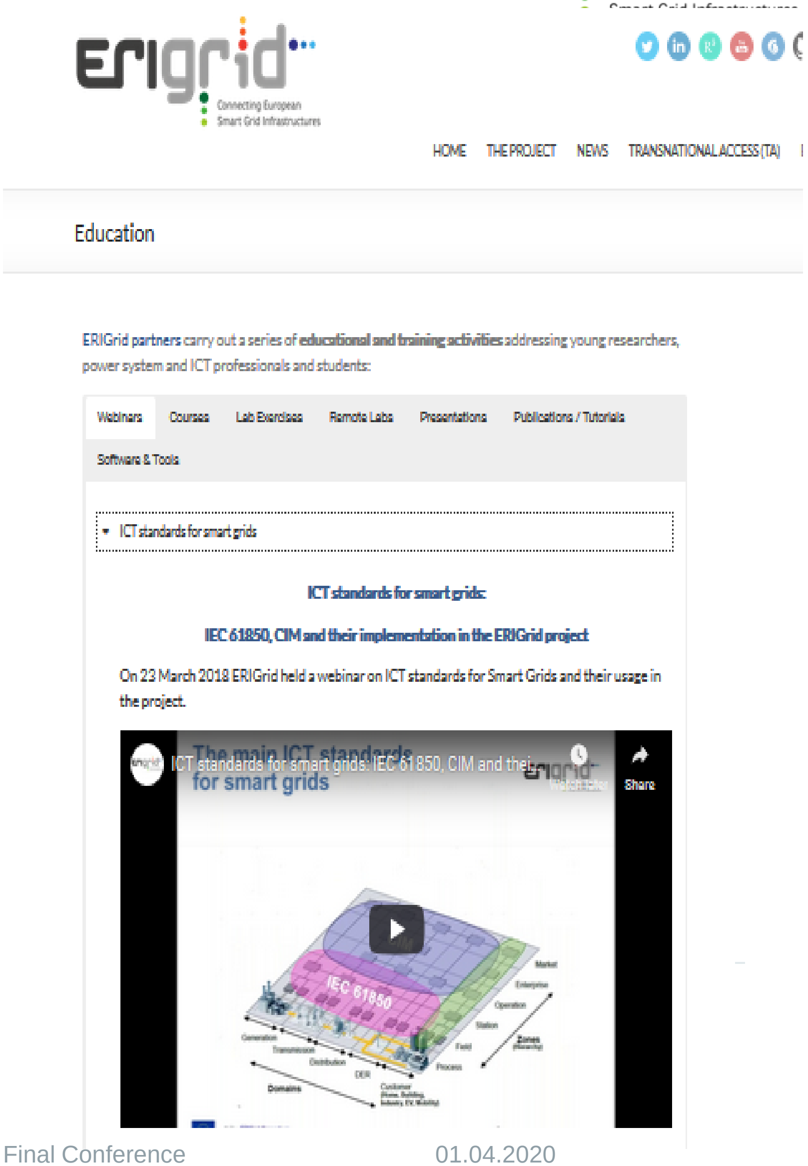
New educational/training needs in a complex environment

- 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

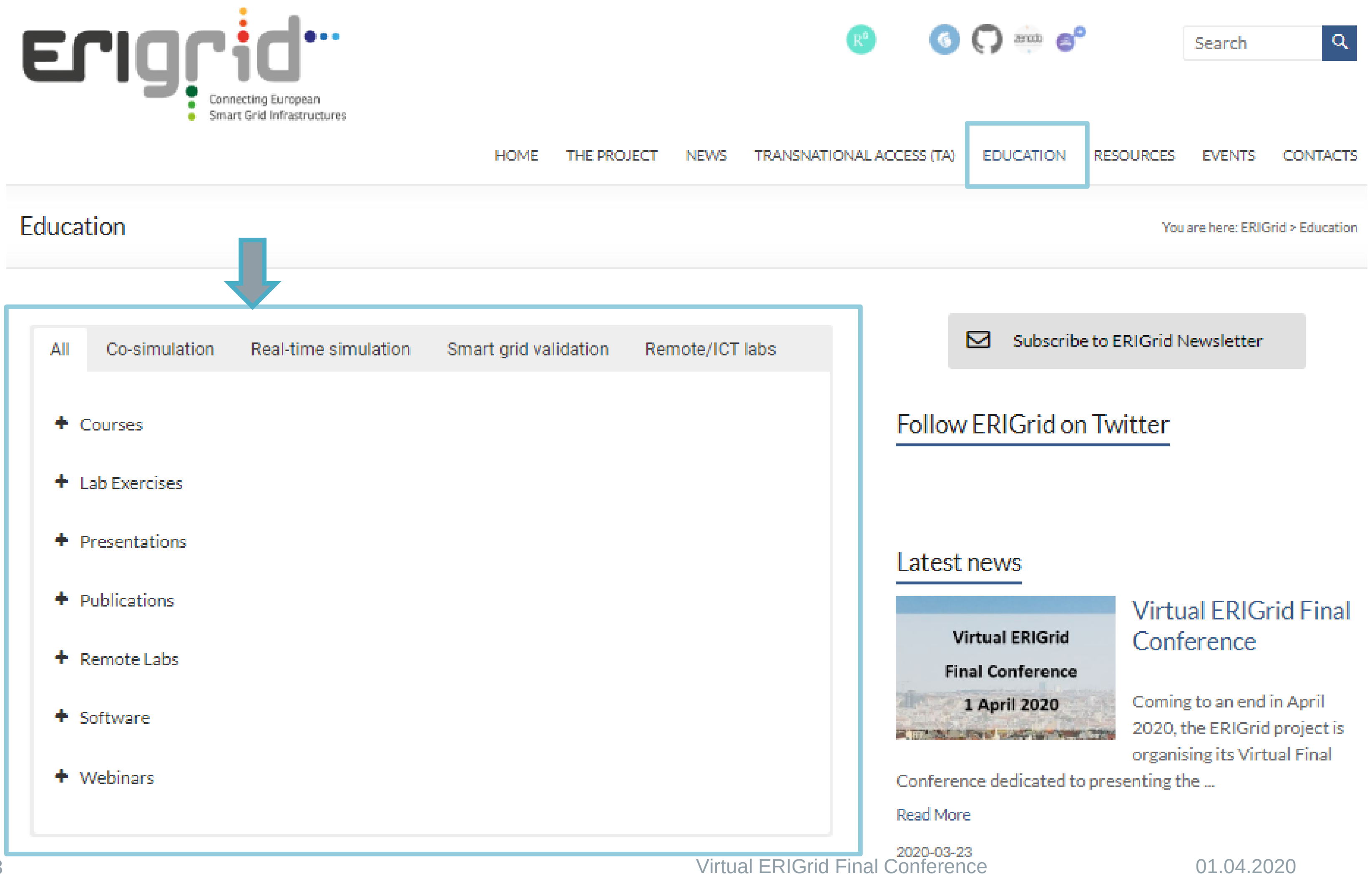
- 6 Webinars: **300 participants** (2000+ views on Youtube)
- 5 Summer Schools at ERIGrid partner universities
- 12 Workshops and 3 Tutorials**:** more than **450 participants**.
- 7 Educational tools: virtual/remote labs, interactive notebooks, co-simulation tools etc
- Advanced laboratory exercises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



Online resource center at the ERIGrid website

https://erigrid.eu/education-training/

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

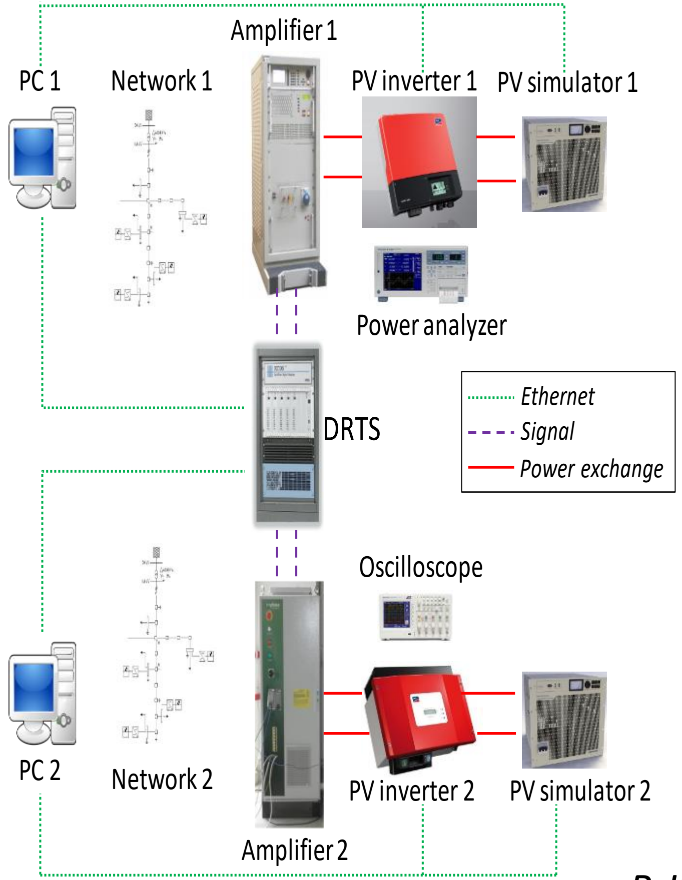


Training/Education material – **Webinars**

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

Training/Education material – **Laboratory education**

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



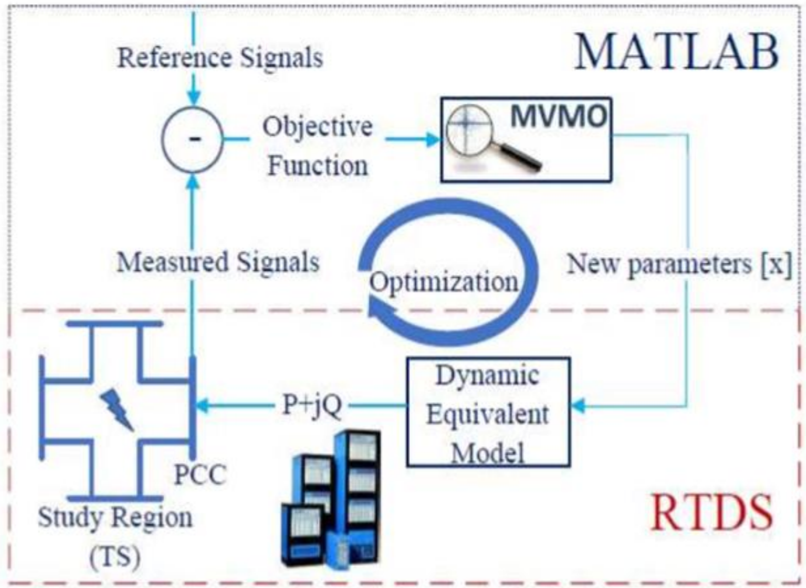
Double PHIL setup

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. Hatziargyriou, "Laboratory Education of Modern Power Systems using PHIL Simulation", IEEE Transactions on Power Systems, December 2016

Training/Education material – **Software Tools**

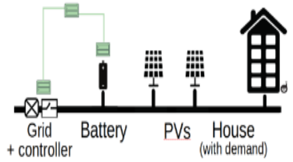
7 Educational software tools

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'))
```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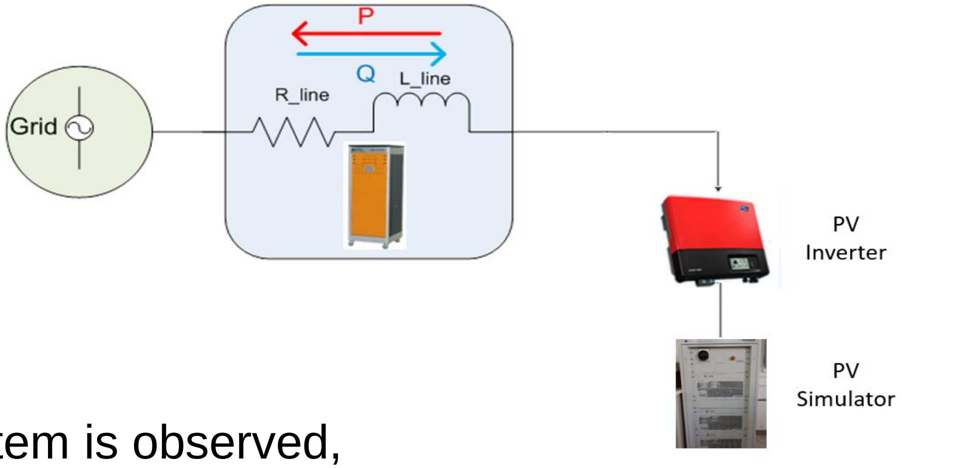
Training/Education material – **Virtual Labs and Remote Labs**

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

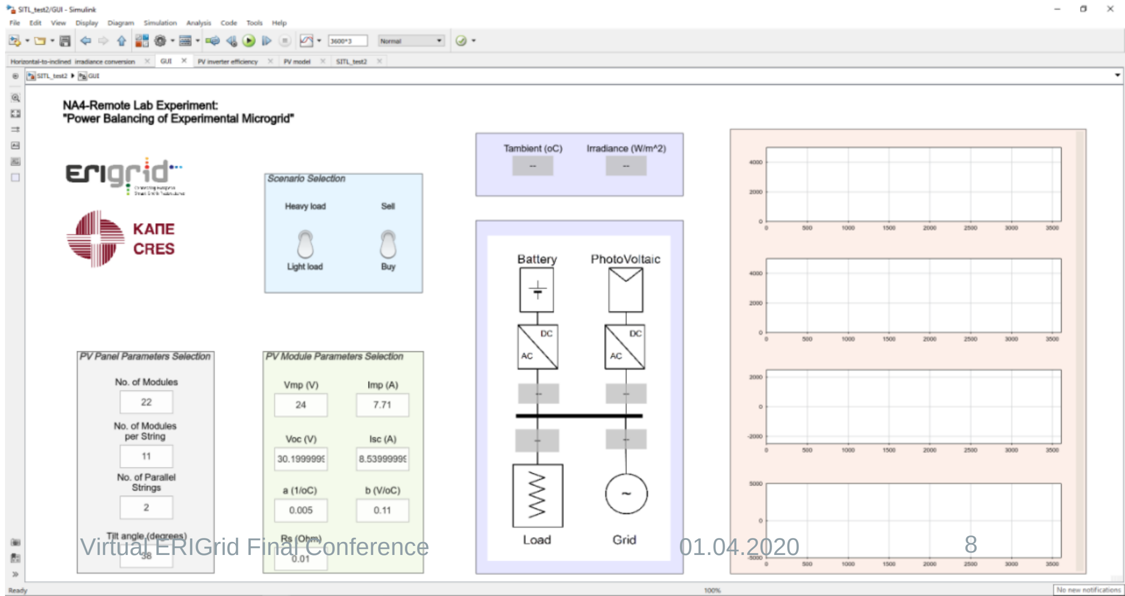


<u>Advantages</u> of the Remote Lab:

- 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

<u>Disadvantages</u> 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

Real-time simulation workshops

DSO training + Education trends sessions

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

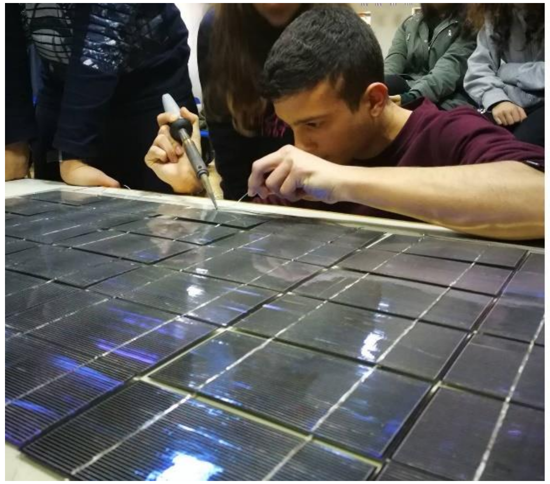
✓ Co-simulation tools/frameworks
✓ Resilience and security in digitalized energy systems
✓ Methods and tools for validating cyber-physical energy systems

✓ 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)**

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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

ICCS-NTUA

Thank you for your attention!

- Panos Kotsampopoulos, ICCS-NTUA, Smart RUE

kotsa@power.ece.ntua.gr *+30 2107721499*

www.smartrue.gr