Trustworthy AI for Power Systems

All slides available:
http://www.chatziva.com/pscc2024.html

Online Feedback
during Tutorial
Join at menti.com
Use Code: **1858 6971**

Tutorial Lecturers:
Baosen Zhang, Univ. of Washington
Pascal van Hentenryck, GeorgiaTech
Priya Donti, MIT
Sam Chevalier, Univ. of Vermont
Spyros Chatzivasileiadis, DTU *(Tutorial Chair)*

Trustworthy AI for Power Systems

Spyros Chatzivasileiadis
Professor
Head of Section Power Systems
Technical University of Denmark (DTU)

All slides available online!

- Except for the conclusion ;)
- And links with coding examples added (and more material might come later)

http://www.chatziva.com/pscc2024.html

What are your main takeaways from the Tutorial ?

- Add your keywords as we go!
- **What do you want to remember after Friday?** Submit it as phrase or keyword! It might be important for others too!

Note your Takeaways as we go!

Join at menti.com

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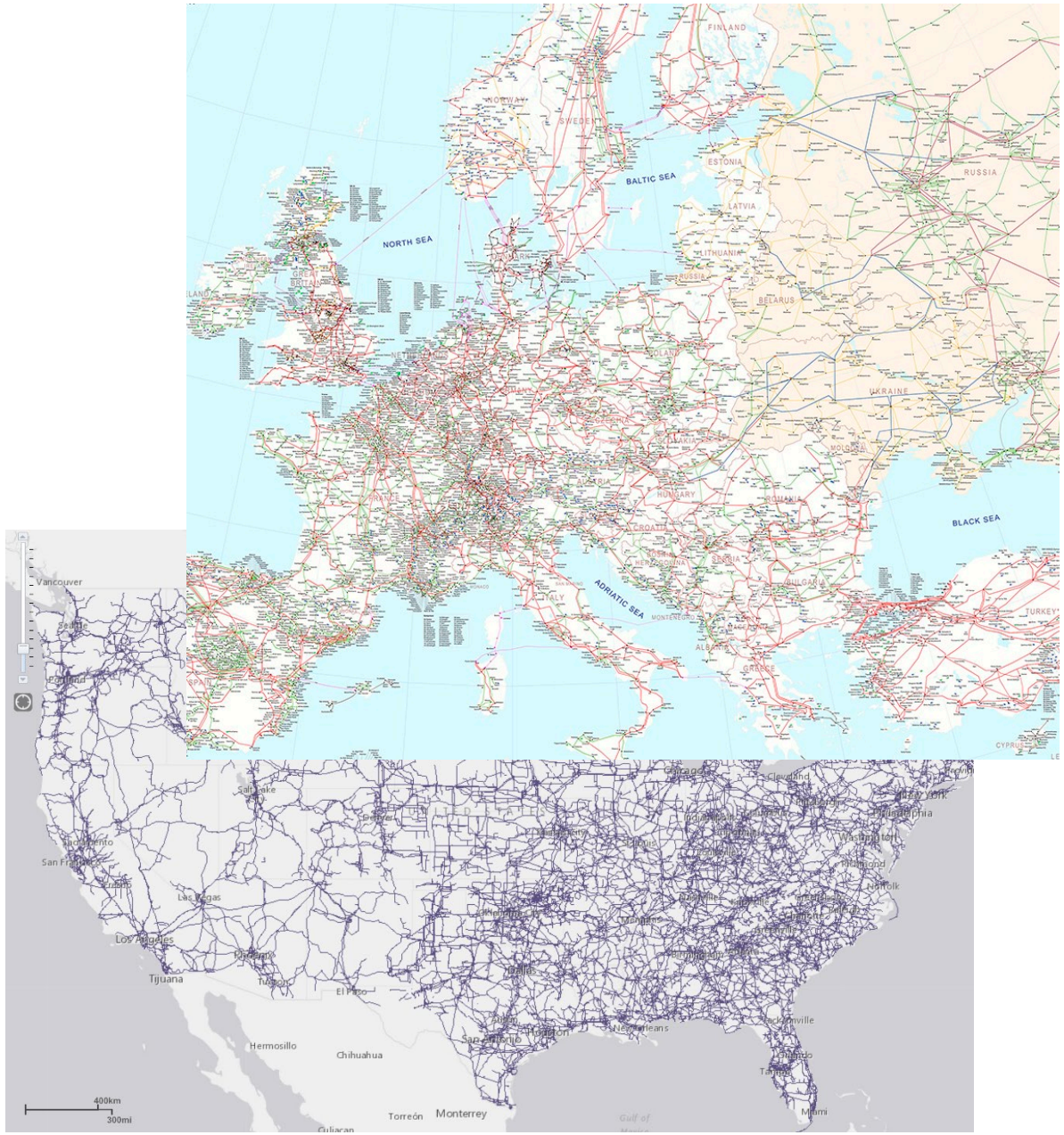
The electric power grid: Probably, the largest machine humans ever built

- Millions of loads
- Thousands of generators
- Very large machines
  - Human lives can be in danger
- All interconnected
  - If a fault happens in Portugal, it can affect lives in Sweden
- Extreme economic value
  - A blackout for a day means billions of Euros in economic loss



Power Systems Computations have always been very complex

1. Make sure that **everyone always has electricity**
   (e.g. whenever & wherever you plug your smartphone)
2. Make sure that **nothing, never goes wrong**
3. You cannot really store any electricity (yet)

How?

1. We need to **run millions of scenarios**, to make sure we are prepared for anything going wrong
2. We need to take **good decisions fast** (real-time)

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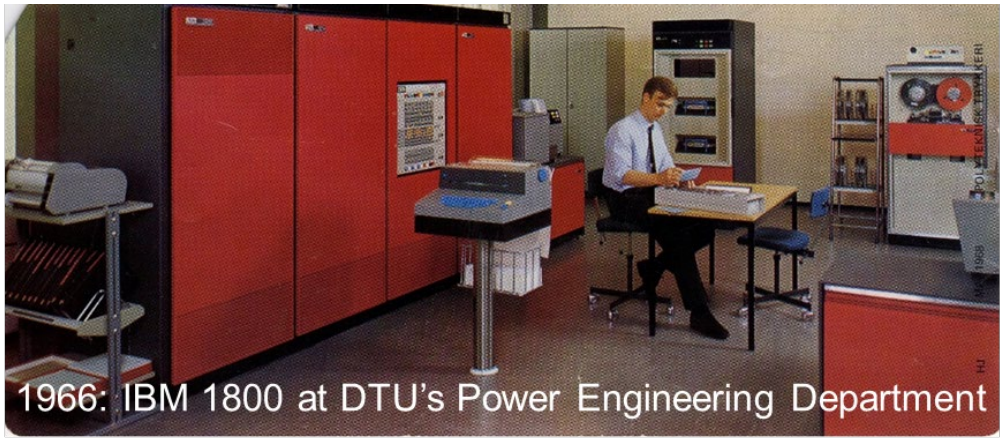
1966: IBM 1800 at DTU's Power Engineering Department

How?

1. We need to **run millions of scenarios**, to make sure we are prepared for anything going wrong
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Towards the Green Transition

What is the challenge?

1. We need to run a grid on (ideally) 100% Renewable Energy Sources

2. We need to electrify carbon intensive sectors, e.g. transportation, heating in buildings, etc.

What does this mean?

1. Millions of new injection points
2. Orders of magnitude higher complexity (due to power electronic converters)
3. A lot of uncertainty (e.g. wind, solar, electric vehicles)

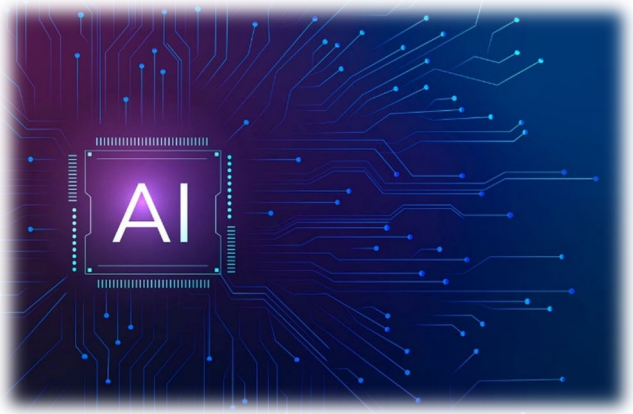
Towards the Green Transition

Towards the Green Transition

Current Computational Tools are no longer sufficient

We need tools that are 10x-100x-1'000x faster to capture much higher complexity and thousands of more scenarios

Could AI help?



AI and Energy:
two of the Sectors with the highest growth potential

AI is already creating value in Energy Systems

- Load Forecasting
- Weather Forecasting
- Predictive Maintenance
- Energy Trading (forecasting of prices or quantities)

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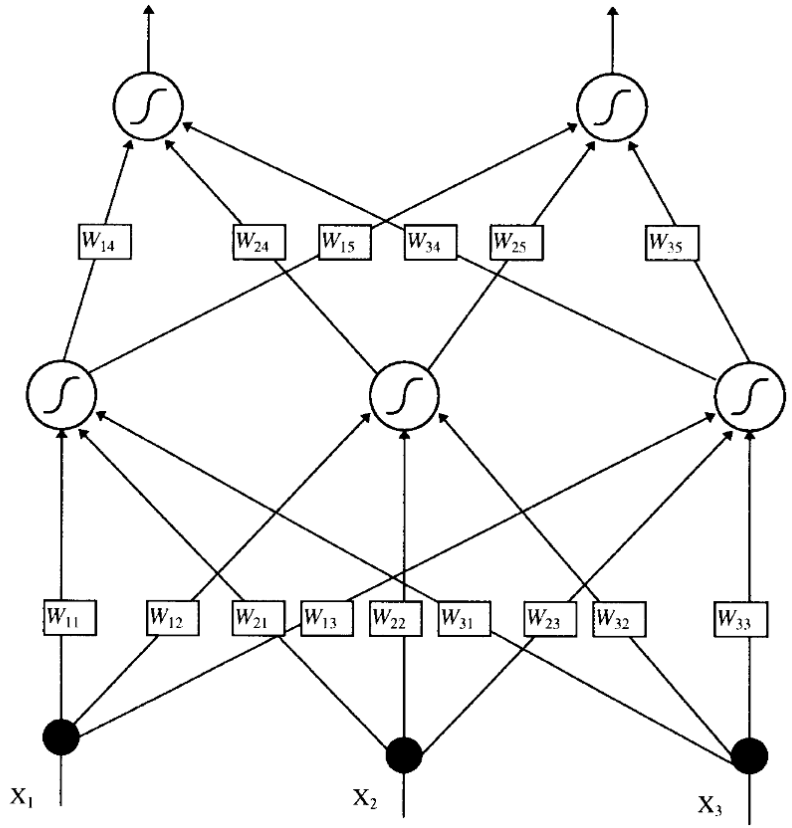

- **ANNSTLF**: Probably the **first tool based on Machine Learning** in Power Systems
- Developed by EPRI (Electric Power Research Institute) in the US
- First deployed in 1992 in Texas. Deployed to 32 utilities by 1997

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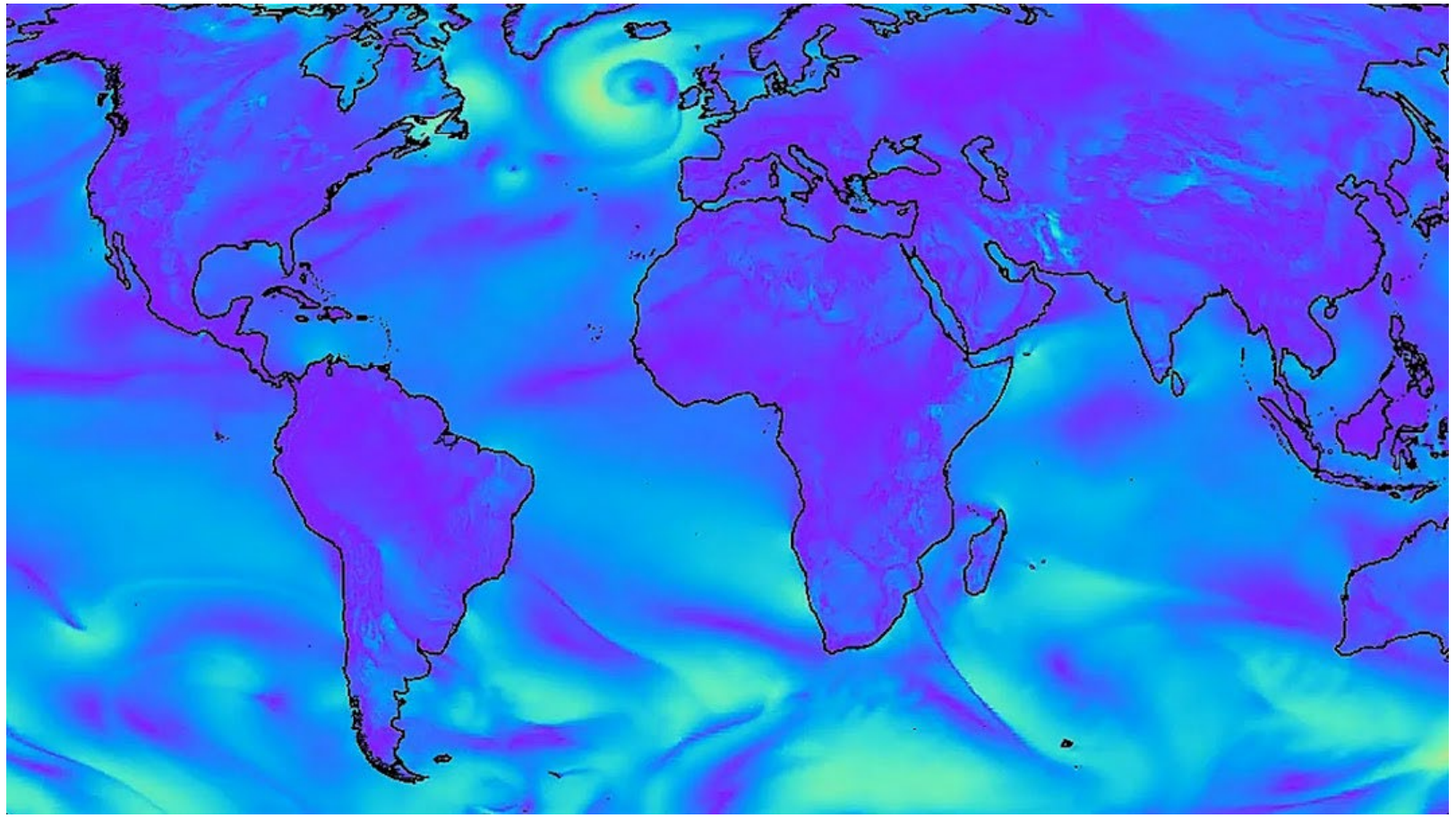

Google Graphcast: AI is already better than physical models for global weather forecasting

But AI can do a lot more things

1. Virtual assistant
2. Live interpreter/translator
3. Creative writing
4. Support for decision making

And many more

Costs of training Generative AI models (e.g. ChatGPT) 2017-2023

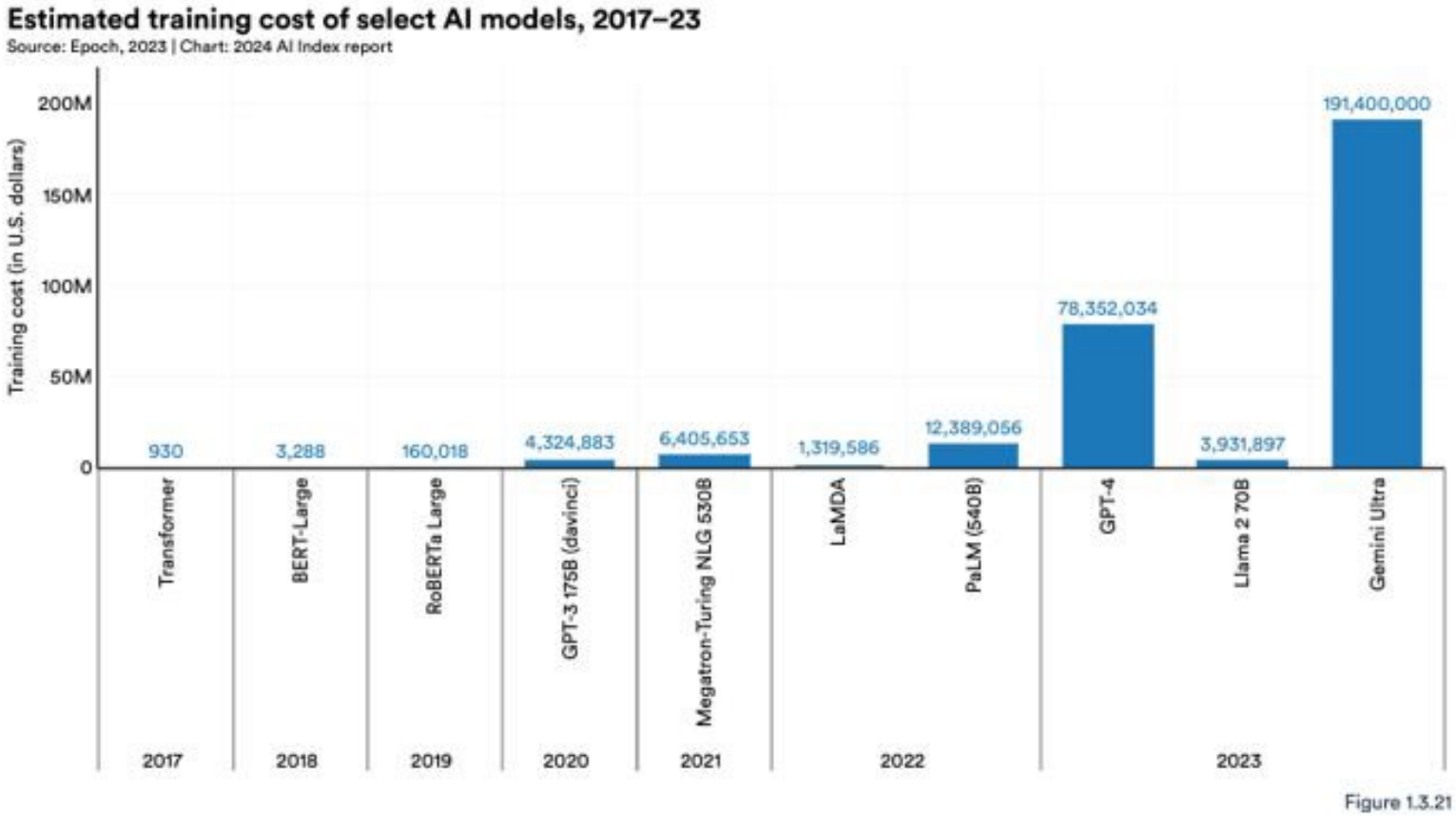

Figure 1.3.21

But: Would you ever trust AI to run your electricity network?

Well, somebody already trusted AI to fly a fighter jet…

- If AI can fly a plane, it can probably run a power grid in the future

- Trustworthy AI absolutely necessary to have a fighter plane fly and enter a dogfight

And new questions arise:

- ”Can AI be trusted to pull a trigger?”

Same questions arise for the use of AI in safety-critical operations of power systems!

Necessary:

Responsible and Trustworthy Use of AI

First AI-piloted fighter jet in the US on 2nd May 2024

https://taskandpurpose.com/news/ai-pilot-f-16/

A lot of recent developments for trustworthy AI

- **April 2021:** The EU is promoting rules for Trustworthy AI
- **December 2023**: EU AI Act

- Ms. Margrethe Vestager, EU Commissioner of Competition, Executive Vice President of "A Europe Fit for the Digital Age"
  - In April 2021, Ms. Vestager proposed new rules and actions aiming to turn Europe into the global hub for trustworthy Artificial Intelligence

Visit of Ms. Margrethe Vestager at DTU

A lot of recent developments for trustworthy AI

- World-leading optimization tool: Starting with Gurobi 10.0, Gurobi supports Neural Network verification since 2023

Gurobi Optimizer

Gurobi 10.0 also includes the following advances in the underlying algorithmic framework:

- **New network simplex algorithm** – Greatly speeds up solving LPs with network structure.
- **New heuristic for QUBO models, which can arise in quantum optimization** – Improves Gurobi's ability to quickly find good feasible solutions for quadratic unconstrained Boolean optimization problems.
- **Significant performance gains on MIPs that contain machine learning models** – Results in a more than 10x improvement on certain models that contain embedded neural networks with ReLU activation functions.

A lot of recent developments for trustworthy AI

5th International Verification of Neural Networks Competition (VNN-COMP'24)

- Tailored MILP solvers for NN Verification
  - Alpha-beta-crown is the winning algorithm
  - Over 100x speedup
- Focus is mostly on Image Classification/ Image Recognition
  - Key for medical applications such as recognition of MRI images, for self-driving car applications, and others
- **There is an effort to submit models related to power systems, so that participants can test and develop verification algorithms with focus on power systems** (we also tried to submit some power system models, but we did not manage to complete our effort)

A team of great (award-winning) speakers!

Pascal van Hentenryck
Professor
GeorgiaTech

Sam Chevalier
Assistant Professor
Univ. of Vermont

Spyros Chatzivasileiadis
Professor
DTU

Baosen Zhang
Associate Professor
Univ. of Washington

Priya Donti
Assistant Professor
MIT

Trustworthy AI is essential for safety-critical operations

What is a power system safety critical operation?

1. **Optimization**
   - E.g .optimal power setpoints that do not violate constraints

2. (Dynamic) **Security Assessment**
   - Also, state estimation, and others

3. **Control**
   - E.g. frequency control, and many others

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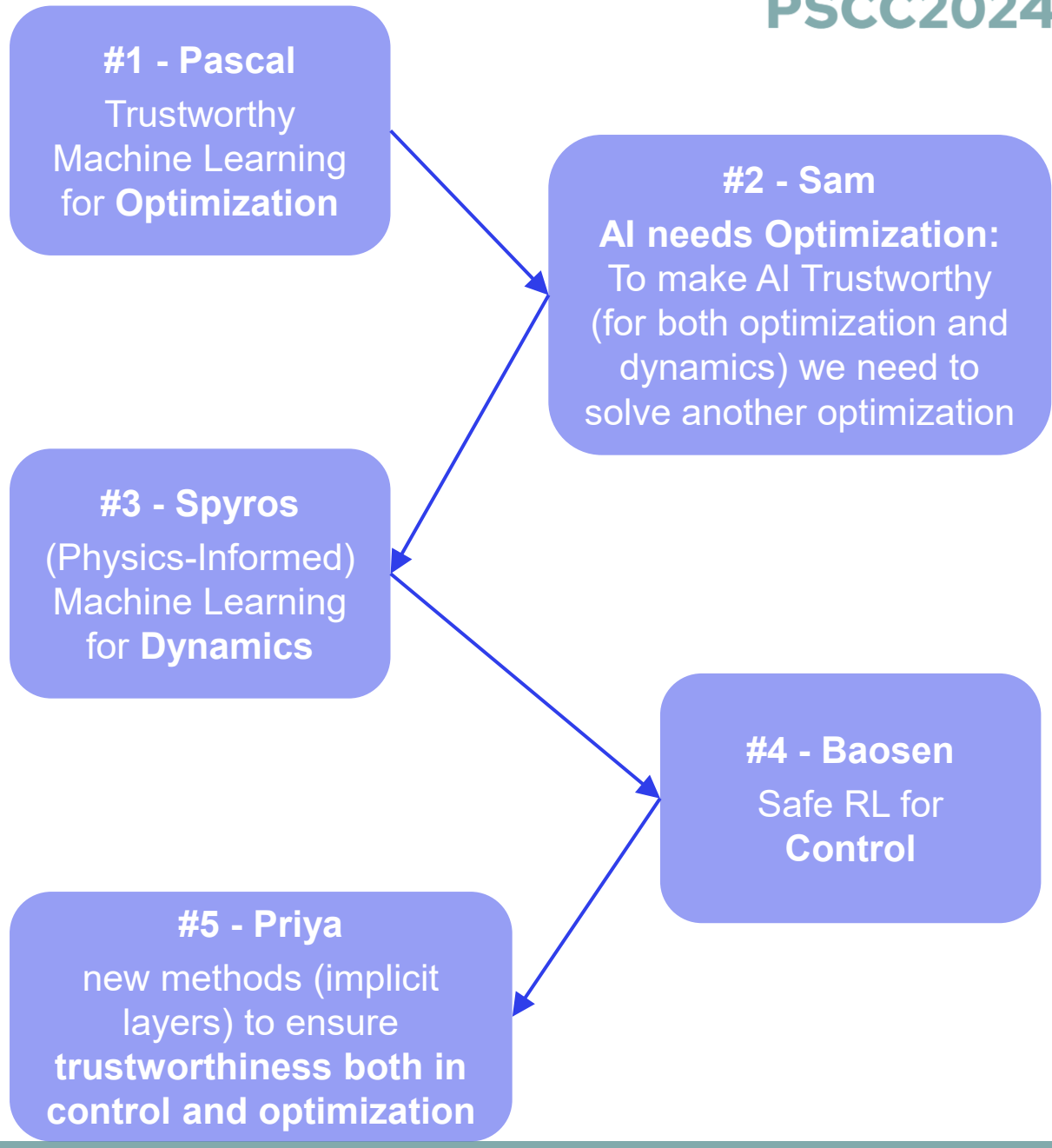

9.00-9.20	**Introduction** – Spyros Chatzivasileiadis, DTU
9.20-10.20	**Trustworthy AI for Optimization** Pascal van Hentenryck, GeorgiaTech
10.20-10.30	Break
10.30-11.30	**Trustworthy AI and Machine Learning Verification for Power Systems** Sam Chevalier, Univ. of Vermont
11.30-11.45	Break
11.45-12.45	**Physics-Informed Neural Networks for Power System Dynamics** Spyros Chatzivasileiadis, DTU
12.45-14.00	Break
14.00-15.00	**Safe Reinforcement Learning for Power Systems** Baosen Zhang, Univ. of Washington
15.00-15.15	Break
15.15-16.15	**Implicit Layers: A Toolkit for AI in Power Systems** Priya Donti, MIT
16.15-16.30	**Conclusion** – Spyros Chatzivasileiadis, DTU
17.00-18.30	Panel Session on Equality, Diversion and Inclusion

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Equality, diversity and inclusion (EDI) in the power systems community

Britta Buchholz
Hitachi Energy

Marco Reggiani
University of Strathclyde

Gabriela Hug
ETH Zurich

Keith Bell
University of Strathclyde

The roundtable will bring together Academic and Industri… Equality, Diversity, and Inclusion (EDI) within the power… a broad spectrum, including gender… erts will share their personal journe… hlight ongoing EDI initiatives. Atte… ions, and present their own EDI experiences and… isations.

And do not forget! Right after this Tutorial we have an exciting Panel Session on Equality, Diversity, and Inlcusion! Starting at 17.00!

Moderated by:

Biljana Stojkovska
BP

Agusti Egea-Alvarez
University of Strathclyde

Appendix

AI is already creating value in Energy Systems

- Load Forecasting
- Weather Forecasting
- **Predictive Maintenance**
- Energy Trading (forecasting of prices or quantities)

- Combination of images with other sensor data to predict failures
- IEA: digitalization can help lower maintenance costs of electricity grids by 5% = **80 billion EUR**

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