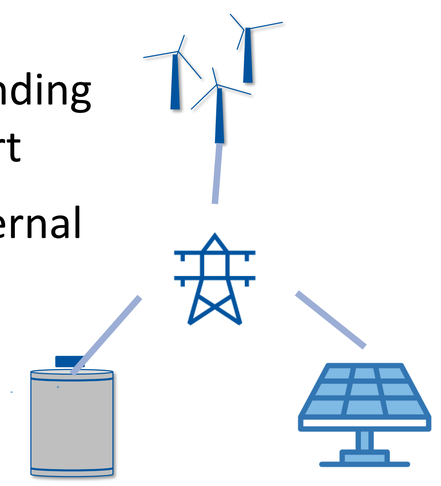
A Trustworthy Physics-Informed Neural Networks Approach for Dynamic Modelling of Converters

Challenges

- The rise of inverter-based resources leads to fast dynamics, nonlinearities, and uncertainties, demanding detailed EMT models and high computational effort
- EMT models also require the full knowledge of internal parameters
- Machine leaning neural networks need large and diverse dataset to generalize which are hard to generate



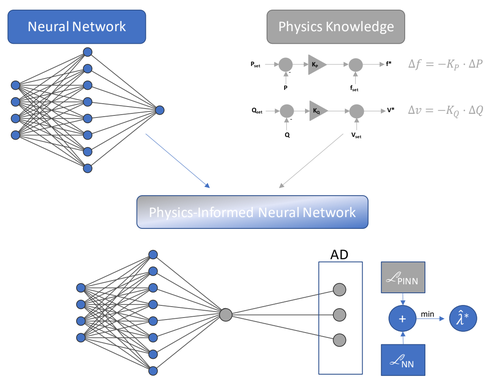
Research Questions

- How to design a generalized Physics-Informed Neural Network (PINNs) for system identification and dynamic state modeling?
- How to ensure the interpretability and robustness of the developed models?
- How can PINNs be experimentally validated in a laboratory setup?

Goal

Develop, Implement and Validate trustworthy physics-informed neural network models to capture the dynamic behavior of grid-forming and grid-following converters

Methodology

PINN Models	Interpretability	Laboratory Validation
		
▪ Generate the required datasets ▪ Add the physical equations ▪ Define the requirements and aspects of the models ▪ Train and validate the PINN models ▪ Augment training data with laboratory measurments to enhance model validity $\min \mathcal{L} = \lambda_{NN}\mathcal{L}_{NN} + \lambda_{dp}\mathcal{L}_{data}^{physics} + \lambda_{cp}\mathcal{L}_{collo}^{physics} + \lambda_{ic}\mathcal{L}_{collo}^{ic}$	▪ Conduct feature analysis to evaluate and understand the influence and relevance of each input variable ▪ Apply formal verification techniques and analyze the impact of missing inputs to assess and improve the model robustness	▪ Validate the developed PINN models in a laboratory environment ▪ Analyze the model behavior under realistic grid scenarios to assess the performance in practical applications ▪ Identify opportunities for models' enhancement by evaluating limitations and analyzing performance gaps

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Project Presentation: PICNIC

Decentralized and Centralized Control Concepts for PQ Improvement:

- Decentralized and Centralized control concepts associated with inverter-based resources to enhance the PQ
- Demonstration of the developed concepts in a laboratory environment to bridge the gap between research and real-world challenges

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