Distribution grid management with graph neural networks

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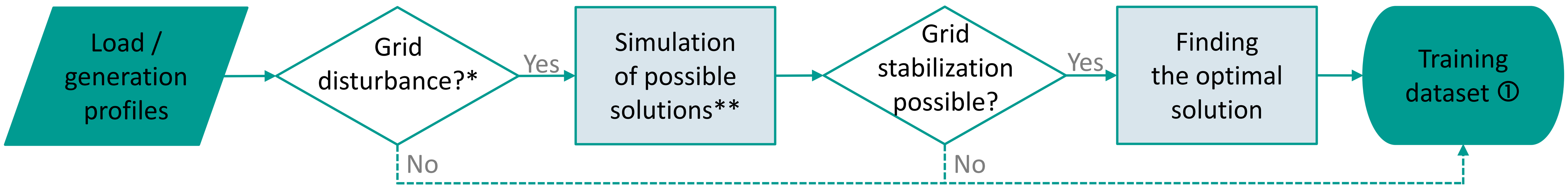
INTRO

The expansion of renewable energies leads to a need for active grid operation management in the distribution grid. Conventional methods are too slow to react to short term disturbances.

OUR IDEA: A grid optimization tool based on graph neural networks (GNNs) to support distribution system operators.

GOAL: Reduction of grid expansion and avoidance of supply bottlenecks through intelligent use of the existing grid infrastructure.

TRAINING DATA



* **Disturbances:** Overloads of lines and transformer stations and voltage deviations above 3%

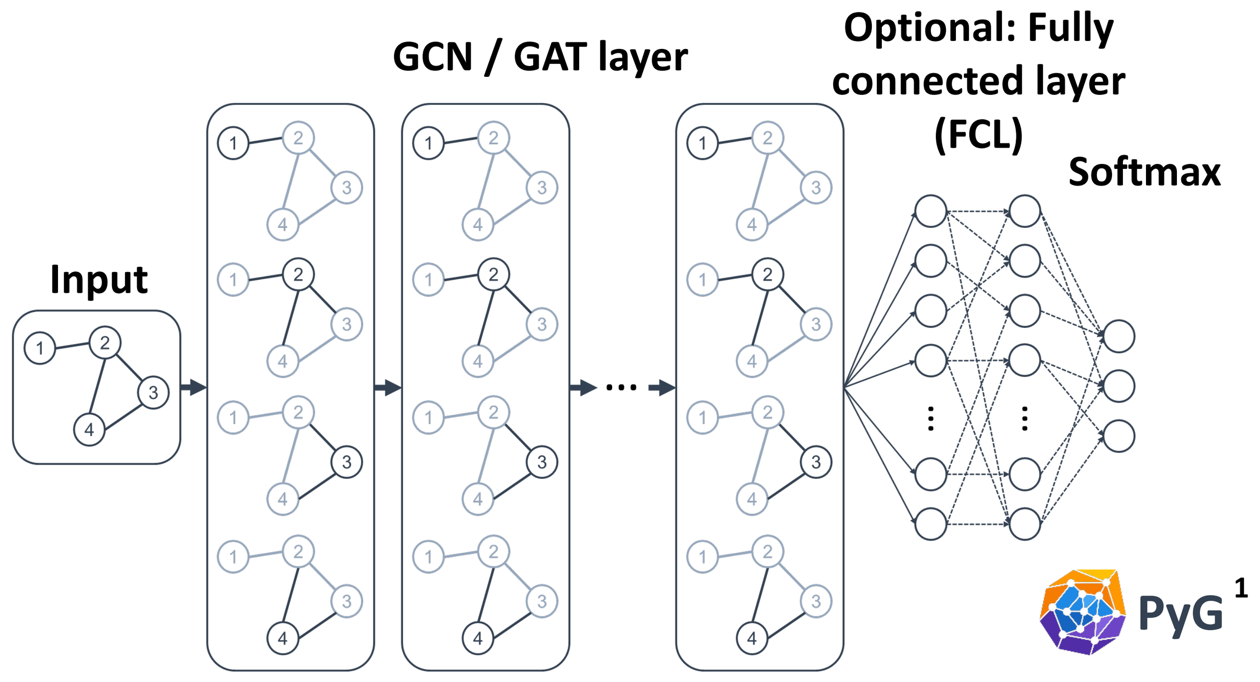
** **Possible Solutions:** Different grid states with varying positions of the transformer tap changers and remote-controlled line switches

GNN-MODEL & INPUT

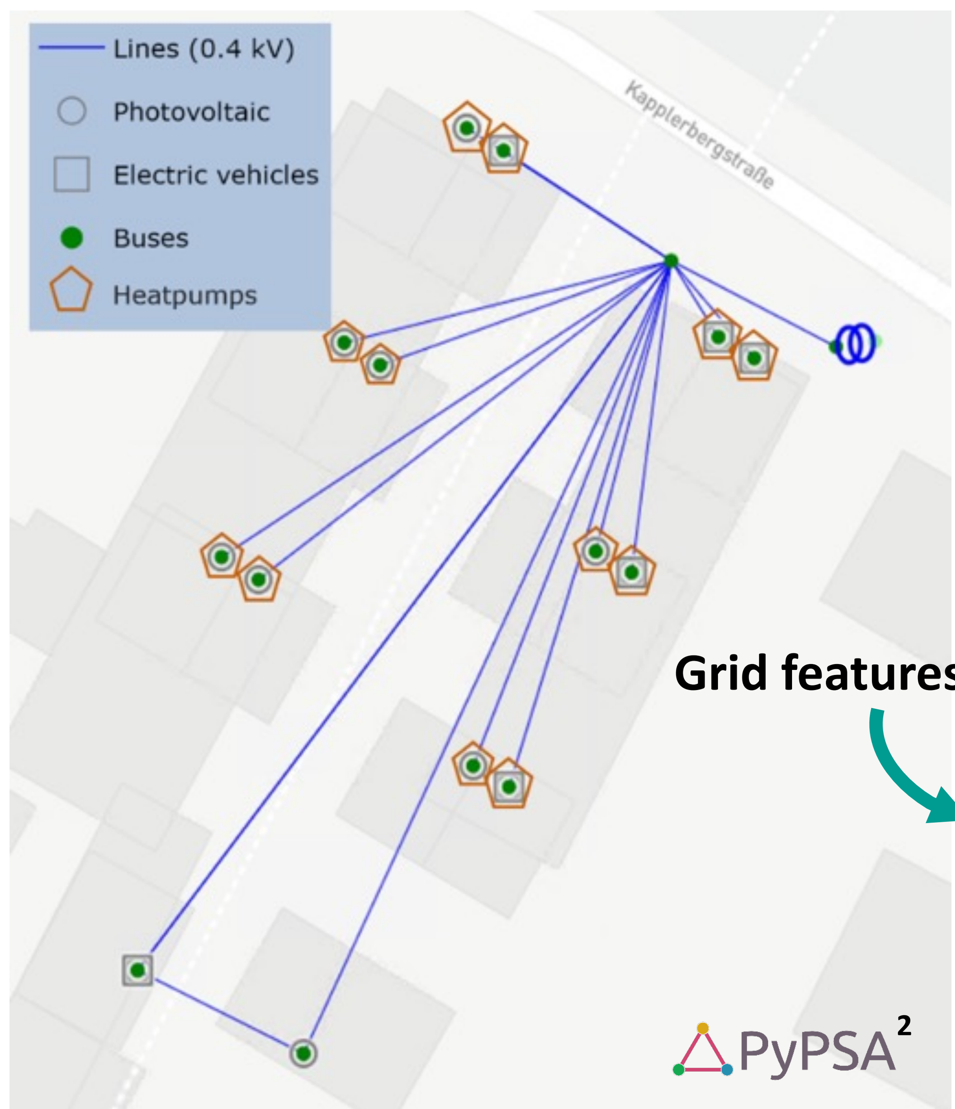
Graph Convolutional Network (GCN) & Graph Attention Network (GAT)

- Model architecture is independent of the size of the input grid and permutation invariant
- Topology of the network is used for training
- Trained GNN can also be applied to new topologies

Model Architecture



Input: training dataset ① and grid features ②



Grid features ②

Training dataset ①	
Node features	Loads [MW]
	Generations [MW]
	Storage units [MW]
Targets	Solution vector

Edge index: Adjacency matrix

0	1	...	1
1	0	...	0
...	...	...	...
1	0	...	0

Edge features
Line length [km]
Primary line constants (x, r, g, b)
Ratio of per unit voltages at each bus for tap changed (tap ratio)

RESULTS & CONCLUSION

Model	Training Loss	Validation Loss	Test Accuracy
GCN	0.191	0.152	92.2 %
GAT	0.099	**0.079**	**94.4 %**
GCN-FCL	0.238	0.164	93.0 %
GAT-FCL	**0.097**	0.108	93.6 %

Best overall performance!

Klassen	F1 Score 0	1	2
GCN	0.895	0.947	0.928
GAT	**0.923**	0.961	0.951
GAT-FCL	0.912	0.938	**0.961**
GCN-FCL	0.905	**0.965**	0.923

CONCLUSION

GNNs are well-suited for controlling a distribution grid and enable optimal use of existing grid infrastructure

OUTLOOK

- Integrating the curtailment of generation and consumption
- Test at the Digital Grid Lab (Fraunhofer ISE)

REFERENCES

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ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contributions of Mohamad Ali Rajeh, who contributed to the results of this work as part of his bachelor thesis.

This work has been funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety due to a decision of the German Federal Parliament (Project Number: 67KI2012A).

Supported by: Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

based on a decision of the German Bundestag