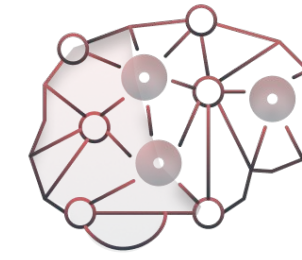




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State and Action Factorization in Power Grids

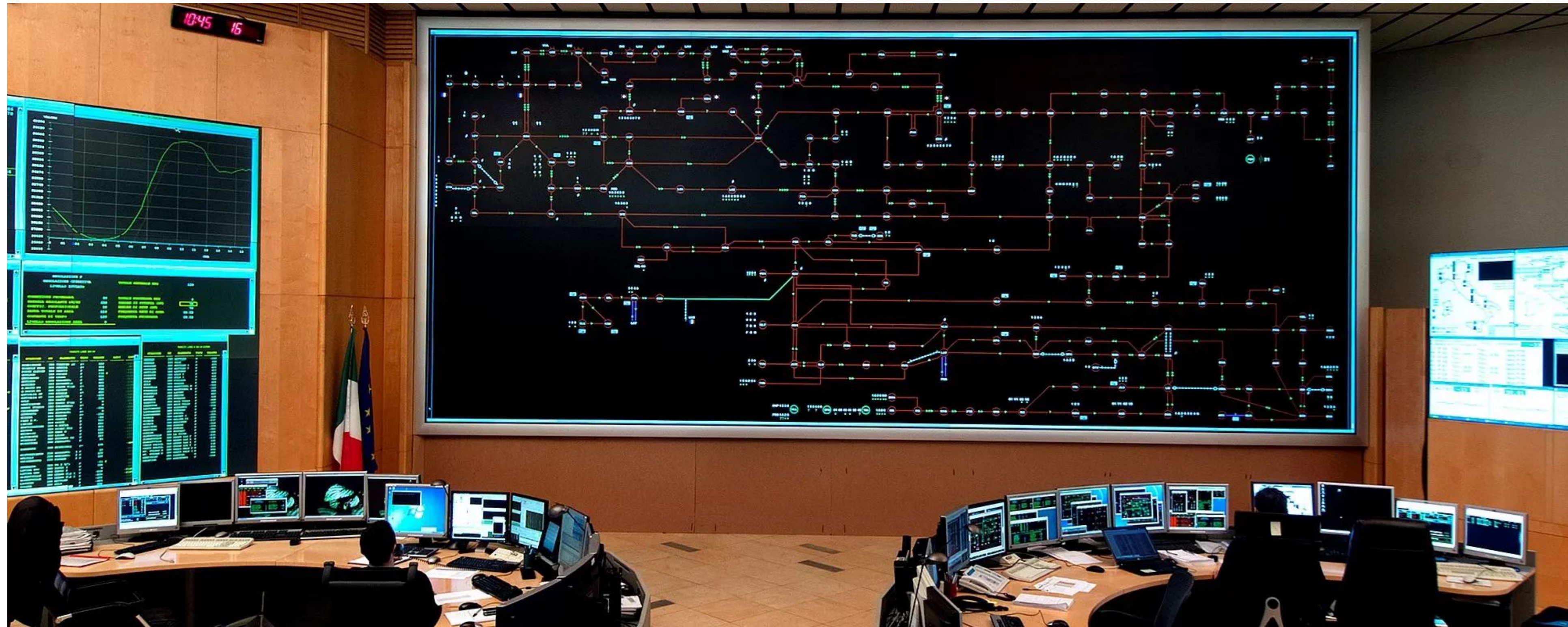
Losapio G · Beretta D · Mussi M · Metelli AM · Restelli M

ECML 2024

Machine Learning for Sustainable Power Systems Workshop

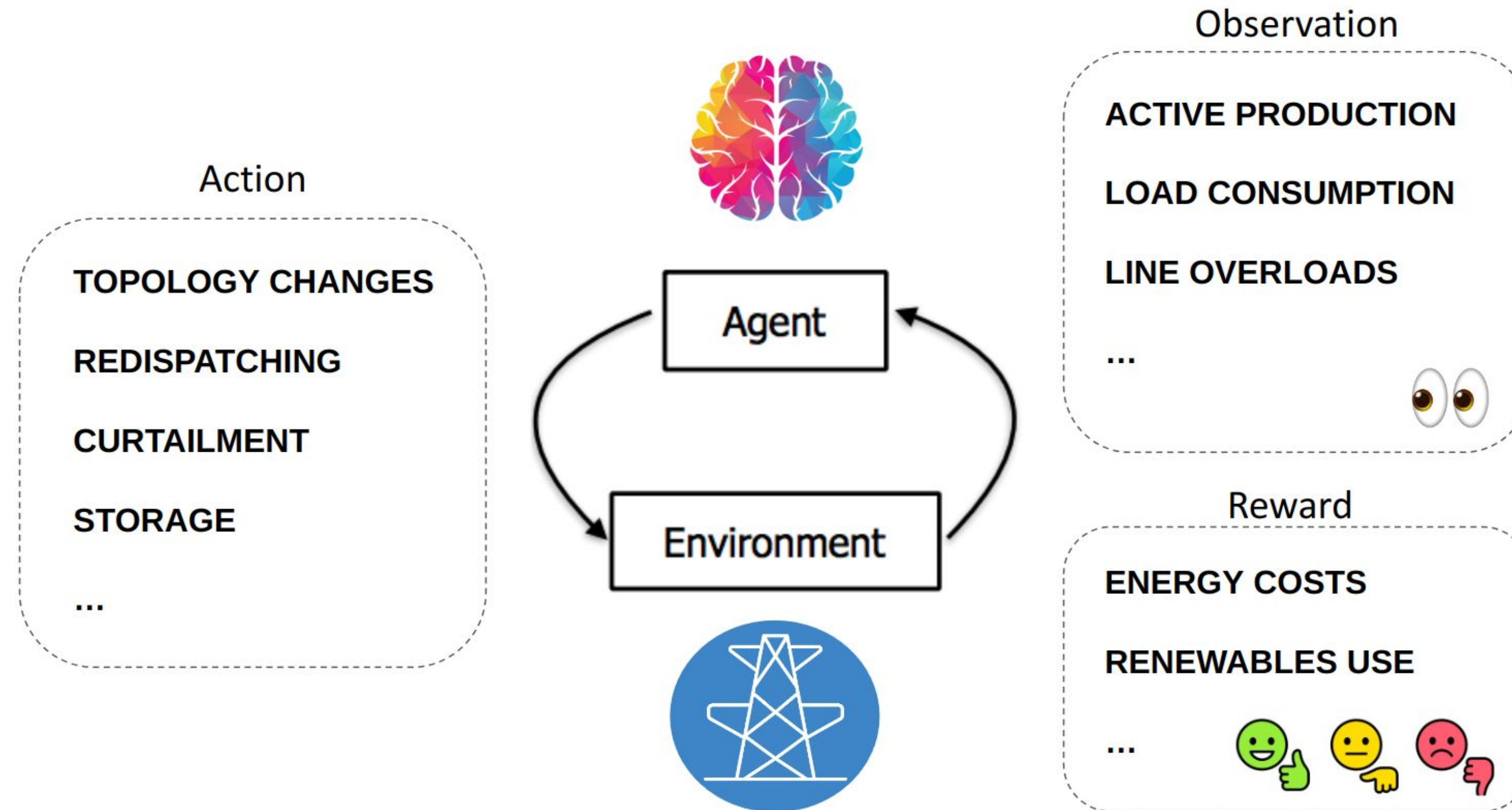
Vilnius - September 9th, 2024

AI to support control room operators



Increasingly complex towards carbon neutrality!

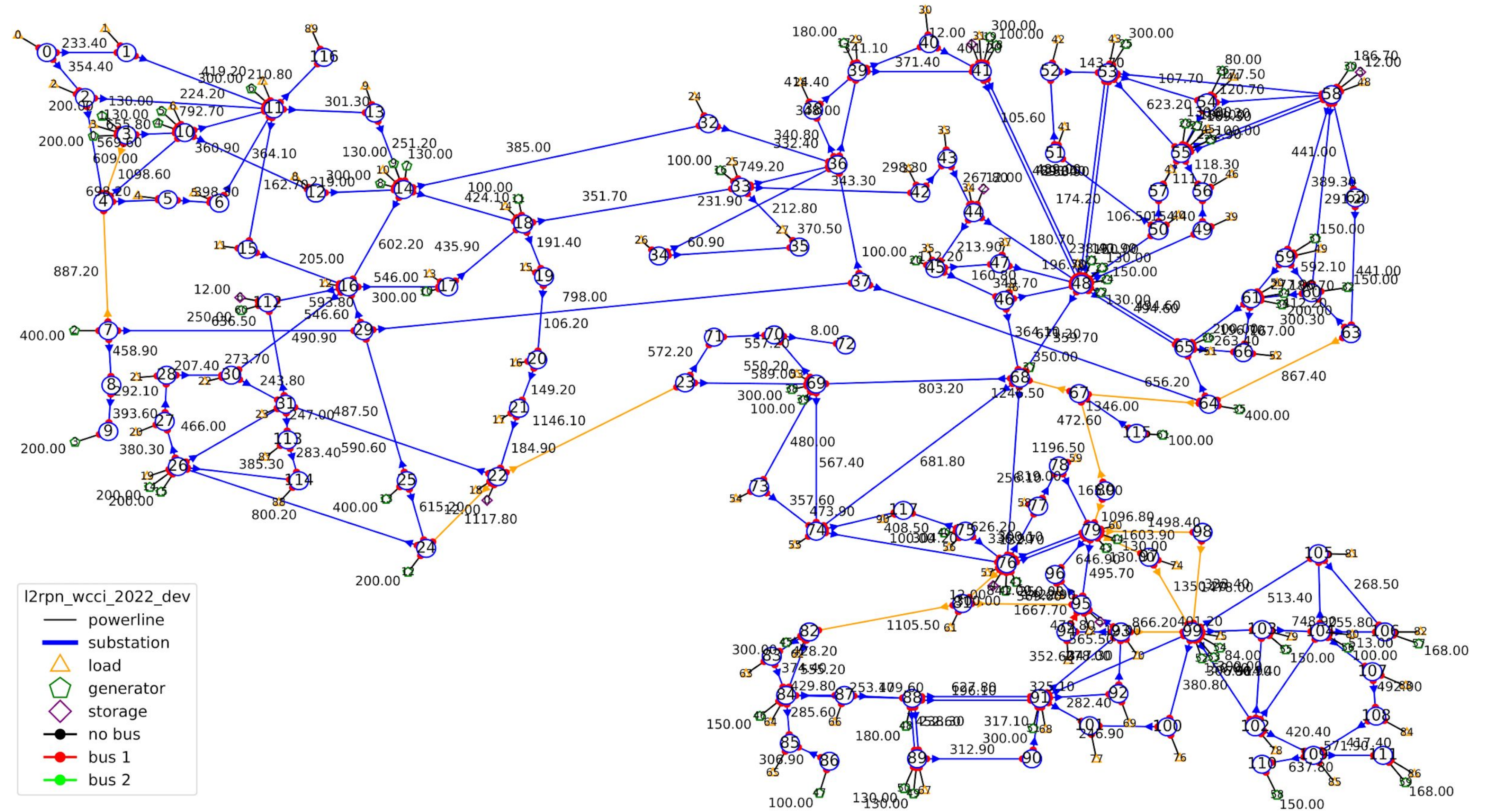
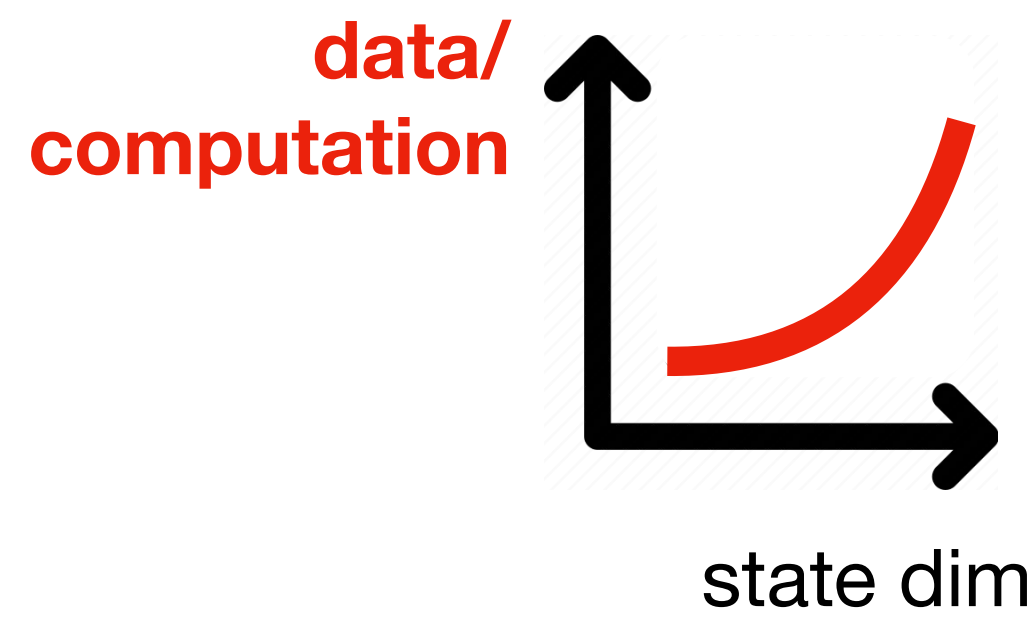
Reinforcement learning for power grids



GOAL: "Find remedial actions that human operators are unaware of or unaccustomed to"

Lots of papers in the last few years (mainly after the L2RPN competition series)

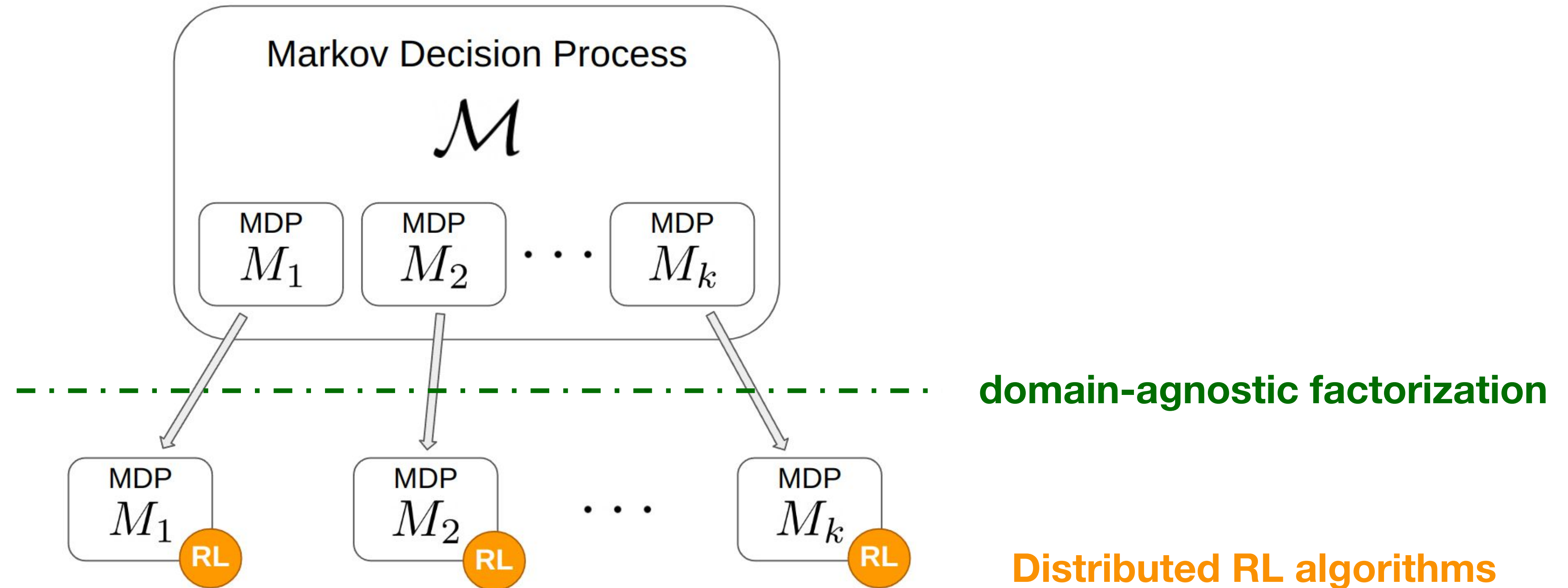
The curse of dimensionality



Solution: power grid segmentation

Original contribution

- **Algorithm** for data-driven factorization of the state and action space in power grids



- **Validation** on a power grid benchmark (open-source simulator Grid2Op)

Algorithm

1. Collect a dataset of transitions from the original MDP $\rightarrow \mathcal{D} = \{(\mathbf{s}, \mathbf{a}, \mathbf{s}')_t\}_{t=1}^T$

2. Compute the matrix of Mutual Information (MI)

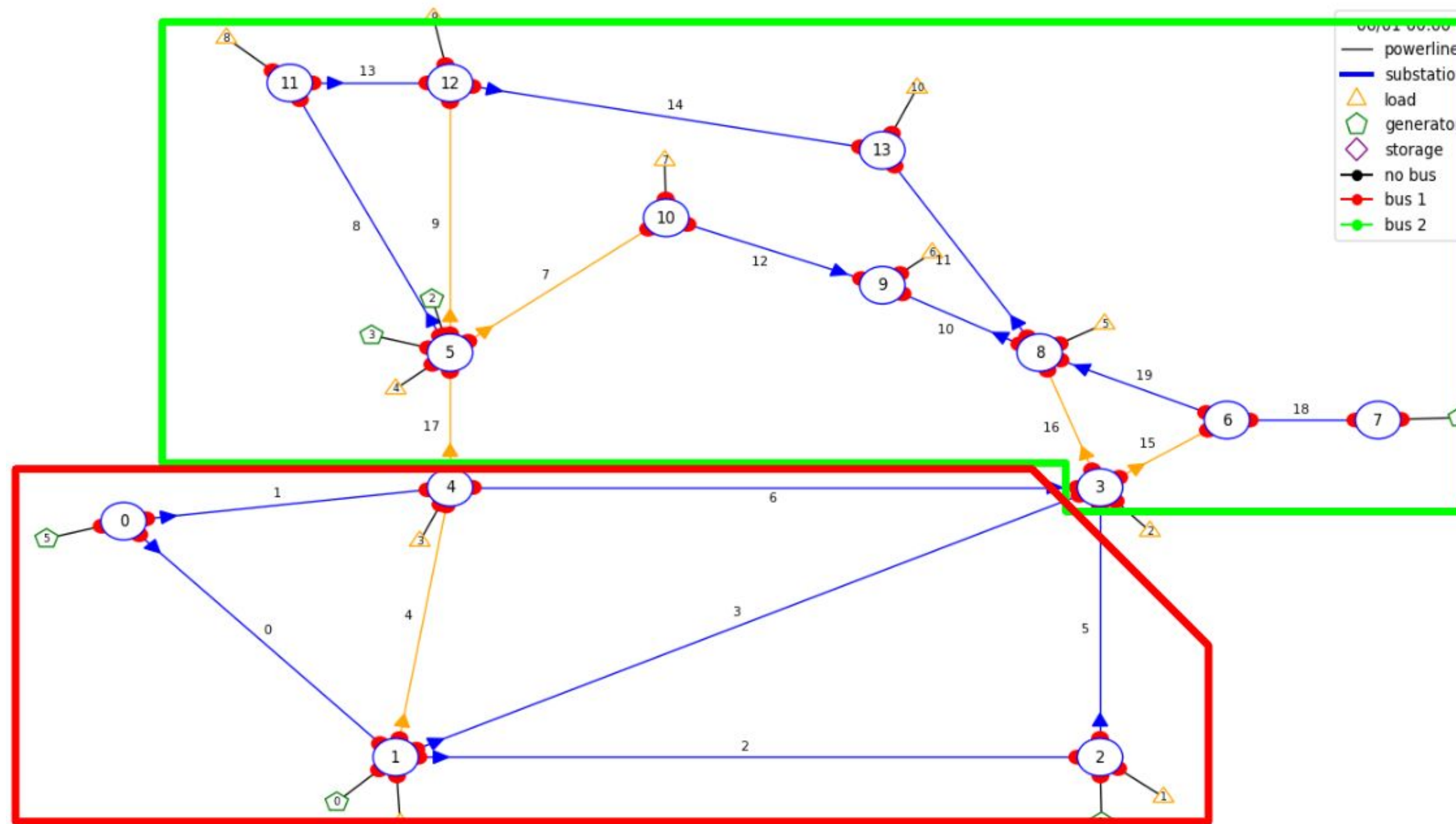
$$\begin{array}{c} s_1 \quad s_2 \quad s_3 \quad s_4 \quad s_5 \quad a_1 \quad a_2 \quad a_3 \\ \left[\begin{array}{cccccccc} s'_1 & & & & & & & \\ s'_2 & & \square & & & & & \\ s'_3 & & & & & & & \\ s'_4 & & & & & & & \\ s'_5 & & & & & & & \end{array} \right] \end{array}$$

$\square = \text{MI}(s'_2, s_3)$
(estimated on the dataset \mathcal{D})

3. Transform it into a pseudo block-diagonal matrix (after applying a threshold) \rightarrow block = MDP

Experiment

IEEE case14 benchmark
 (Grid2Op open-source simulator)
 4 substations · 20 lines · 6 generators · 11 loads



s0	1	1	1	0	0	0	0
s1	1	1	0	0	0	0	0
s2	1	1	1	1	0	0	0
s3	1	1	1	0	0	0	0
s4	1	1	1	0	0	0	0
s5	0	0	1	0	0	0	0
s6	1	1	1	1	0	1	0
s12	0	0	0	1	1	0	0
s7	0	0	0	0	1	0	0
s8	0	0	0	0	1	1	1
s9	0	0	0	0	1	1	0
s15	0	0	0	1	0	1	0
s17	0	0	0	0	0	1	0
s18	0	0	0	1	0	1	1
s11	0	0	0	0	1	0	1
s13	0	0	0	0	0	0	1
s14	0	0	0	1	1	0	1
s19	0	0	0	0	0	0	1
s10	0	0	0	0	0	0	0
s16	0	0	0	0	0	0	0
	sub1	sub4	sub2	sub3	sub12	sub5	sub8

Performance: $\left\| I_G - \hat{I}_G \right\|_F^2$ approx. by similarity to domain-expert analysis*

*Marot et al. "Guided machine learning for power grid segmentation" (2018)

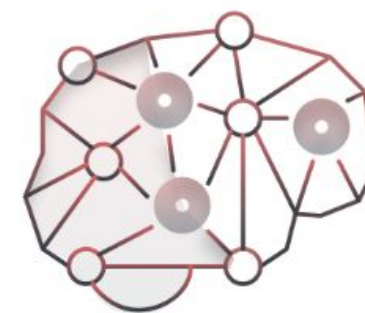
Conclusion

- Scaling RL solutions to large power grids can be challenging (**curse of dimensionality**, ...)
- We introduced a **domain-agnostic algorithm** for the factorization of state and action spaces in power grids
- Each state/action subset is an MDP that can be solved with **distributed RL algorithms**
- **Promising results** on a power grid benchmark (in line with domain-expert analysis)

Future work = { larger grids, hyperparams, correlation metrics, clustering, ... }



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