

# Machine Learning Applications in Active Electric Distribution Grids

## Challenges

- Increasing integration of Distributed Energy Resources (DERs) leads to higher utilization of grid assets and possibly grid congestion
- Active operational control and monitoring** of the grid state is needed
- Optimization-based methods suffer from **scalability** and the need of full **observability** of the grid's state
- Deep Reinforcement Learning (DRL)** can offer a promising alternative for controlling DERs

## Introduction

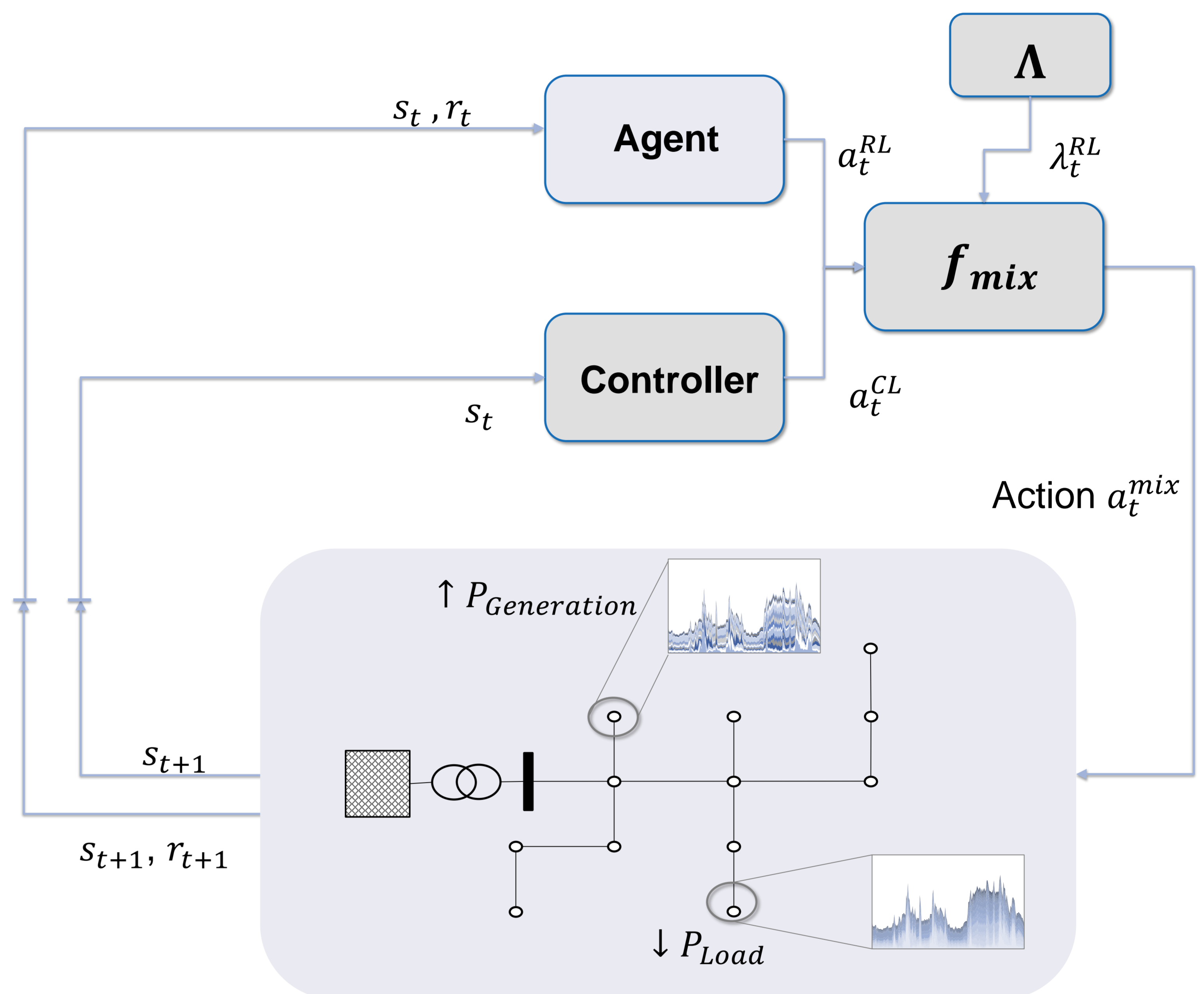
- DRL-based methods can be applied to control DERs e.g. to ensure voltage regulation
- DRL offers a scalable solution, which can also handle partial observability in distribution grids
- DRL however suffers from different limitations:
  - Data-inefficiency and long trainings
  - Unsafe behavior

➤ **How can we develop a safe and scalable DRL framework for voltage control?**

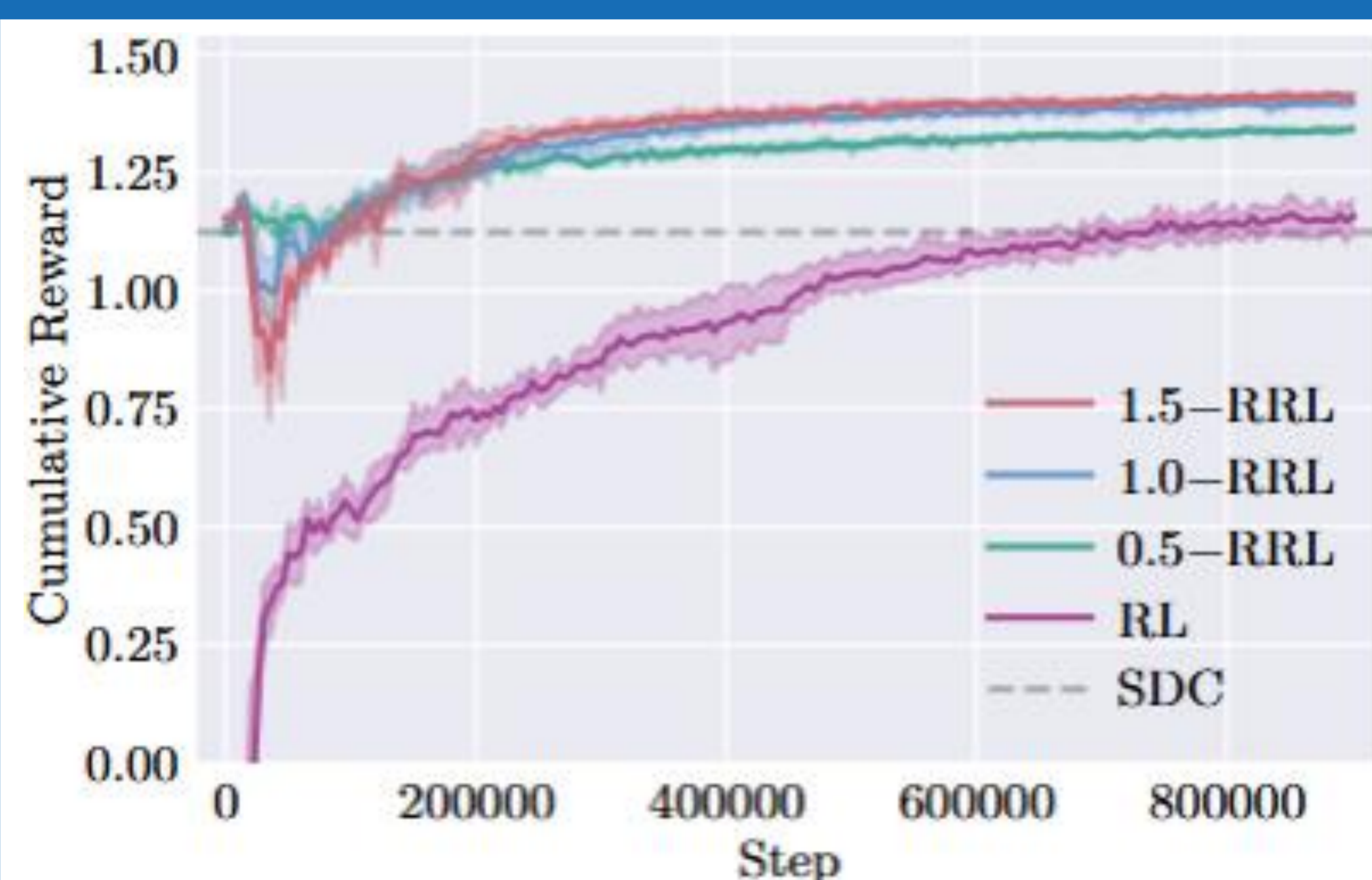
## Method

- The DRL agent learns by interacting with an environment and gets a tailored **reward**  $r_t$  for the task at hand:
  - Minimizing voltage violations and active power curtailment
- In order to ensure the DRL agent learns safe actions, a prior controller could be used and act as a **guiding prior** → **Residual Reinforcement Learning (RRL)**
- Actions of the RL agent and control prior are combined according to a **fixed weight**  $\lambda_t^{RL}$  and using a **mixing function**  $f_{mix}$ :

$$a_t^{mix} = \lambda_t^{RL} \cdot a_t^{RL} + (1 - \lambda_t^{RL}) \cdot a_t^{CT}$$



## Results

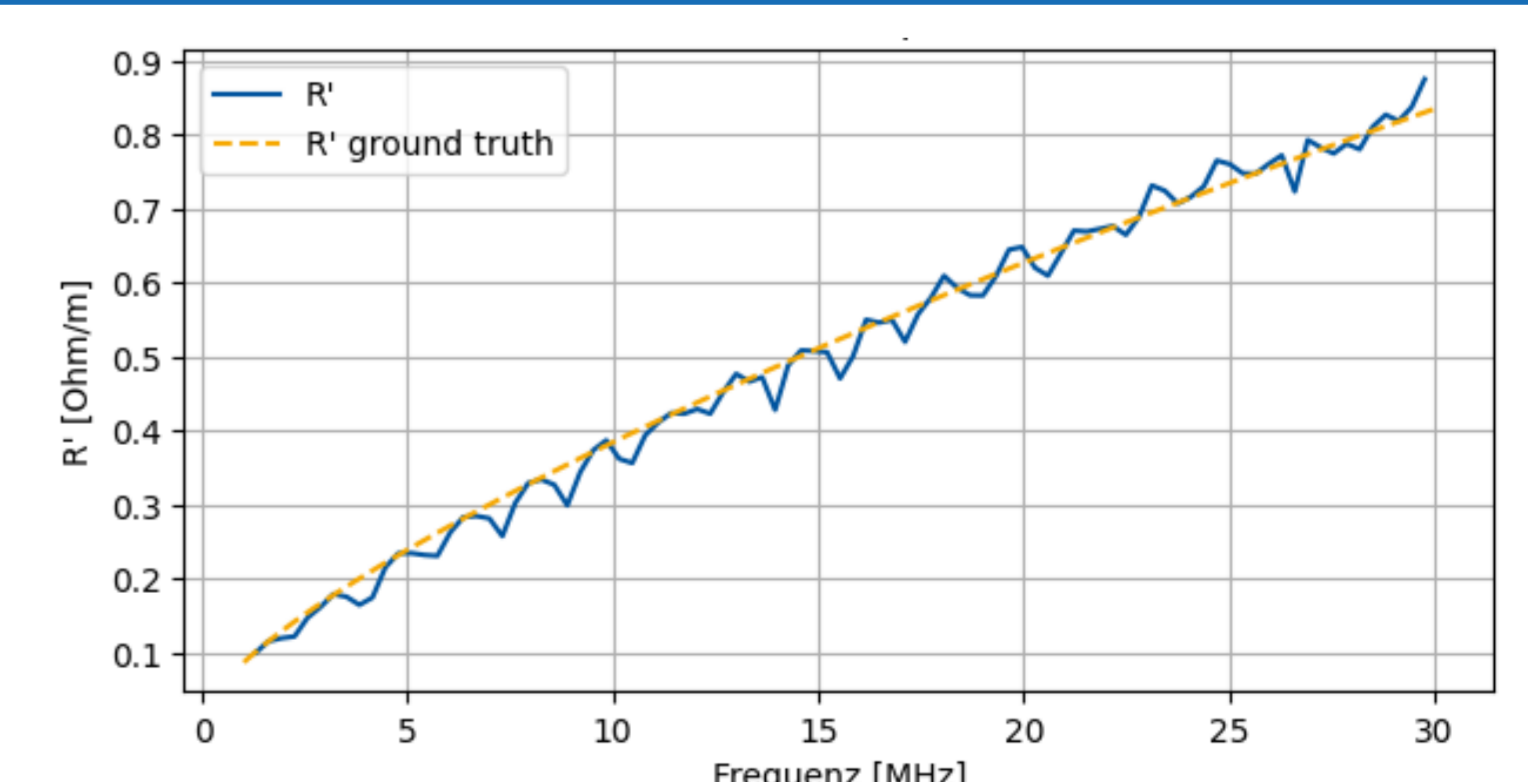


- The comparison of the learning curves includes the RRL approach with different weighting coefficients (1.5, 1.0, and 0.5), a vanilla RL approach, and the SDC control prior
- The pure RL model exhibits the slowest convergence, reaching the cumulative reward level of the baseline SDC controller only after approximately 700,000 training steps
- All RRL-based models surpass the SDC controller's performance within the first 100,000 training steps

➤ **Accelerated convergence and enhanced exploration efficiency**

## Further Applications of ML in Distribution Grids

- ML methods offer a wide range of applications in distribution grids beyond control schemes
- One major challenge is predictive maintenance and anomaly detection, particularly for distribution cables
- This can be addressed by leveraging measurements, such as those from PLC (Power Line Communication) devices, to predict and monitor cable parameters → significant deviations in these parameters may indicate potential anomalies
- Project Goal: Develop an adaptive system to monitor low-voltage cable aging and utilization**



**Next STEP**  
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