Arizona State University

Curriculum Based Reinforcement Learning to Avert Cascading Failures in the Electric Grid

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The Power Grid Enables Climate Change Mitigation

- Increasing *renewables* in the power grid & *electrification* of transportation and gas are necessary for climate change mitigation

- The secure operation of the power grid is key for a reliable grid – disruption to this critical infrastructure incurs high societal and commercial cost

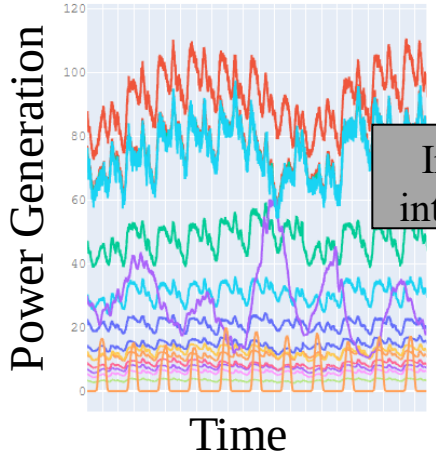
- Cascading failures occur when line flows exceed limits due to unexpected load & generation – more frequent with renewables

2003 North East Blackout: ~$5 Billion
Blackout due to cascading failure

Cascading Example on an IEEE 14-bus System

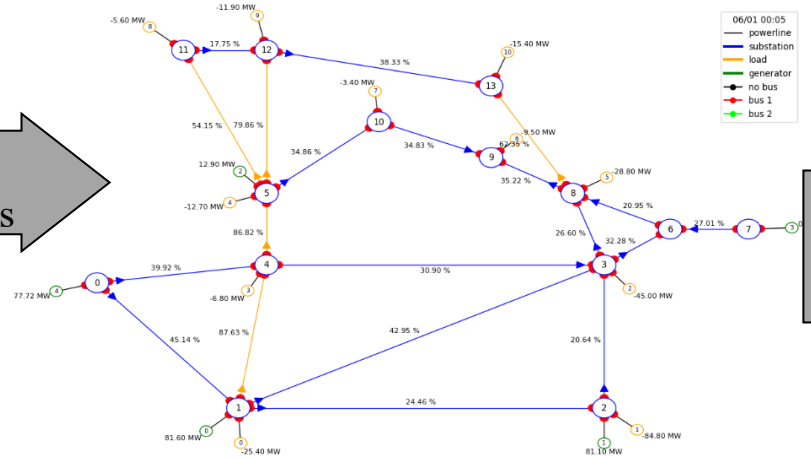
- A transmission line disconnects after 3 **continuous** time steps above its limit
- Immediate disconnection if flow exceeds 1.5x limit

Wind gen has sharp rise

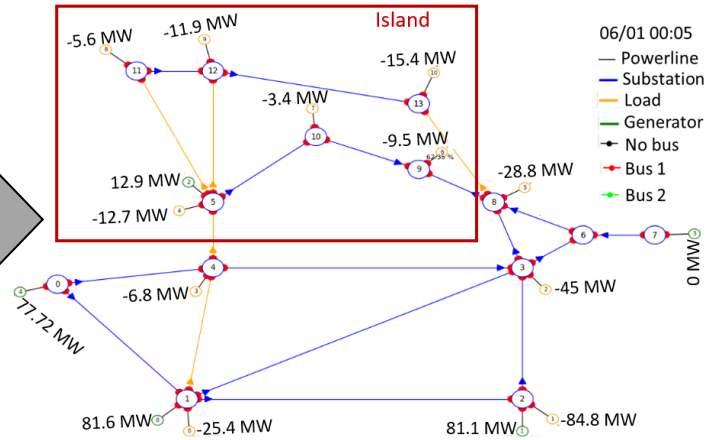


Injected into Nodes

Line Overloads

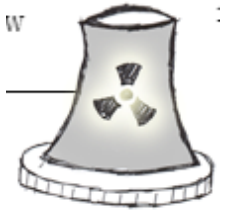


After 6 time-steps



Conventional Approaches to Mitigate Line Overload

Change Generation and Load



Redispatching

Many over the grid & $$$

Load shedding

Many over the grid & $$$$$

Flow Control Devices

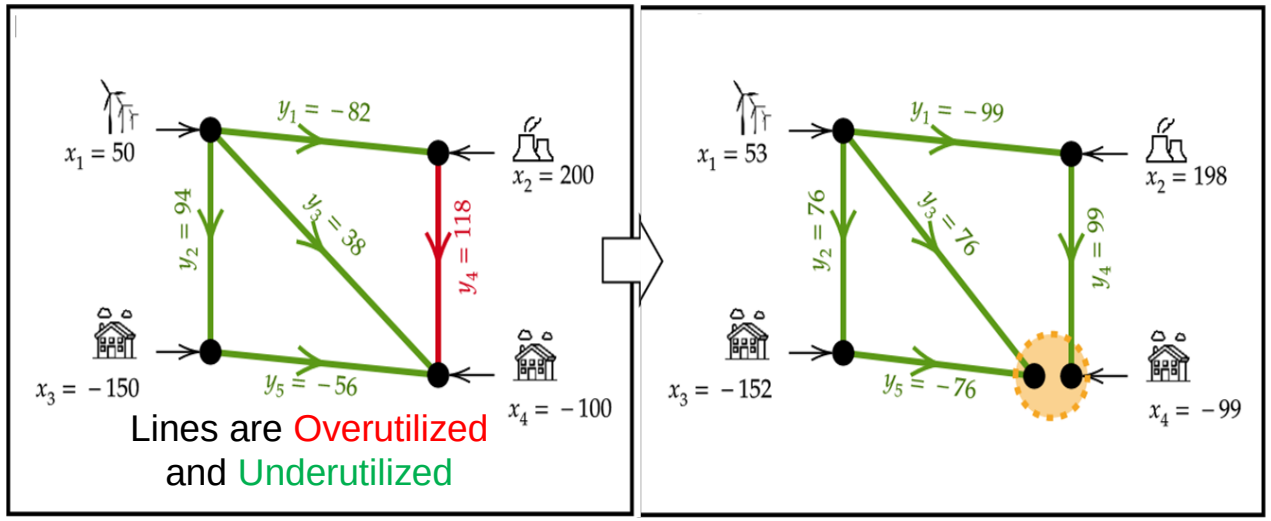
Power devices:

- Transformers
- Phase shifter
- HVDC
- …

Few & local & 0$

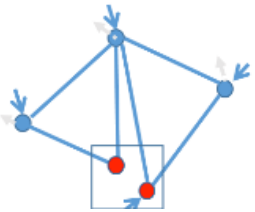
Our Approach to Mitigate Line Overload & Cascading

Change Topology Locally via Node Splitting



Topology:

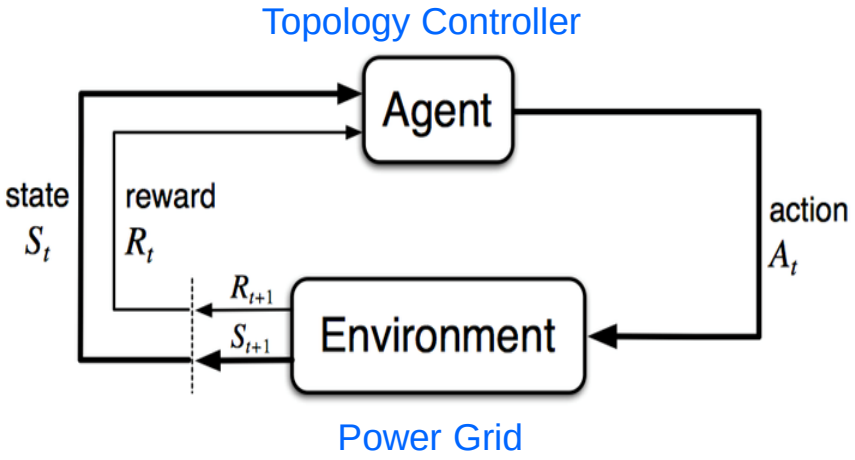
- Branch switching
- Node merging/splitting

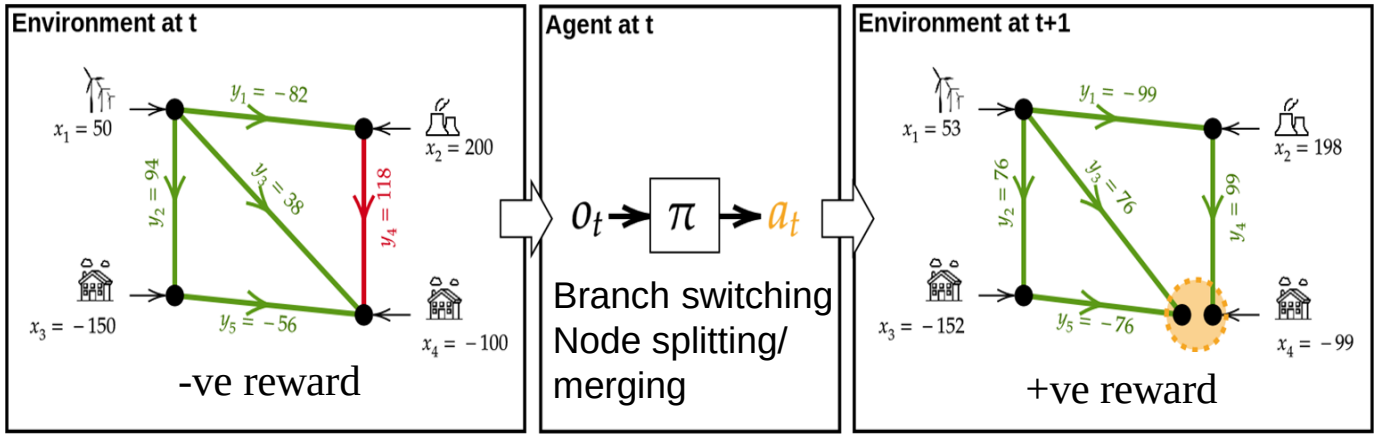


All over the grid & 0$!

Hard problem due to combinatorial nature

Modelled as a sequential decision-making problem: RL can be used

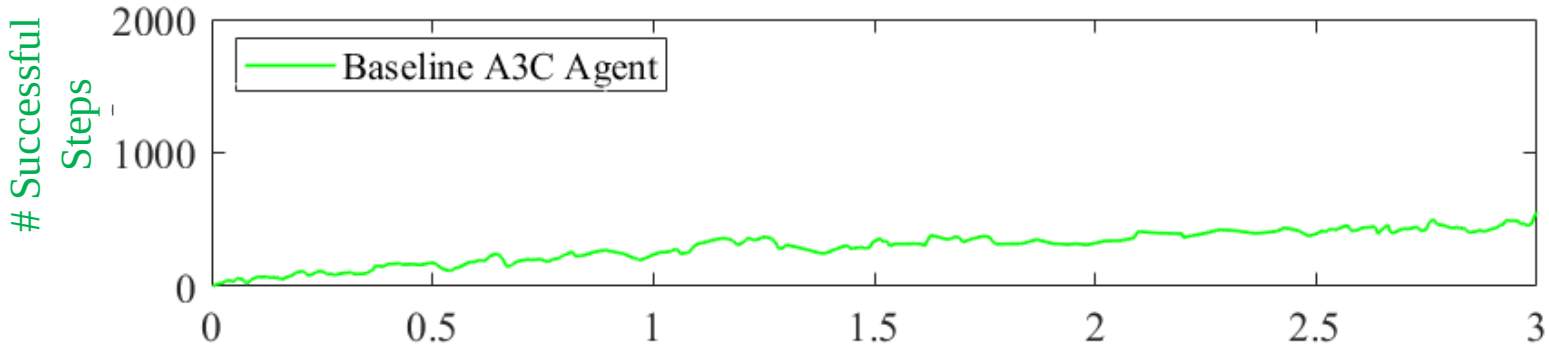




B. Donnot, "Grid2op- A testbed platform to model sequential decision making in power systems." https://GitHub.com/rte-france/grid2op, 2020

Curriculum Approach Leveraging Grid Physics

- The IEEE 14-node system is used as a case study to learn topology controllers
- Domain knowledge of grid operation is used to **reduce the action space** and **derive an appropriate reward** function to capture cascading – RL agents still failed



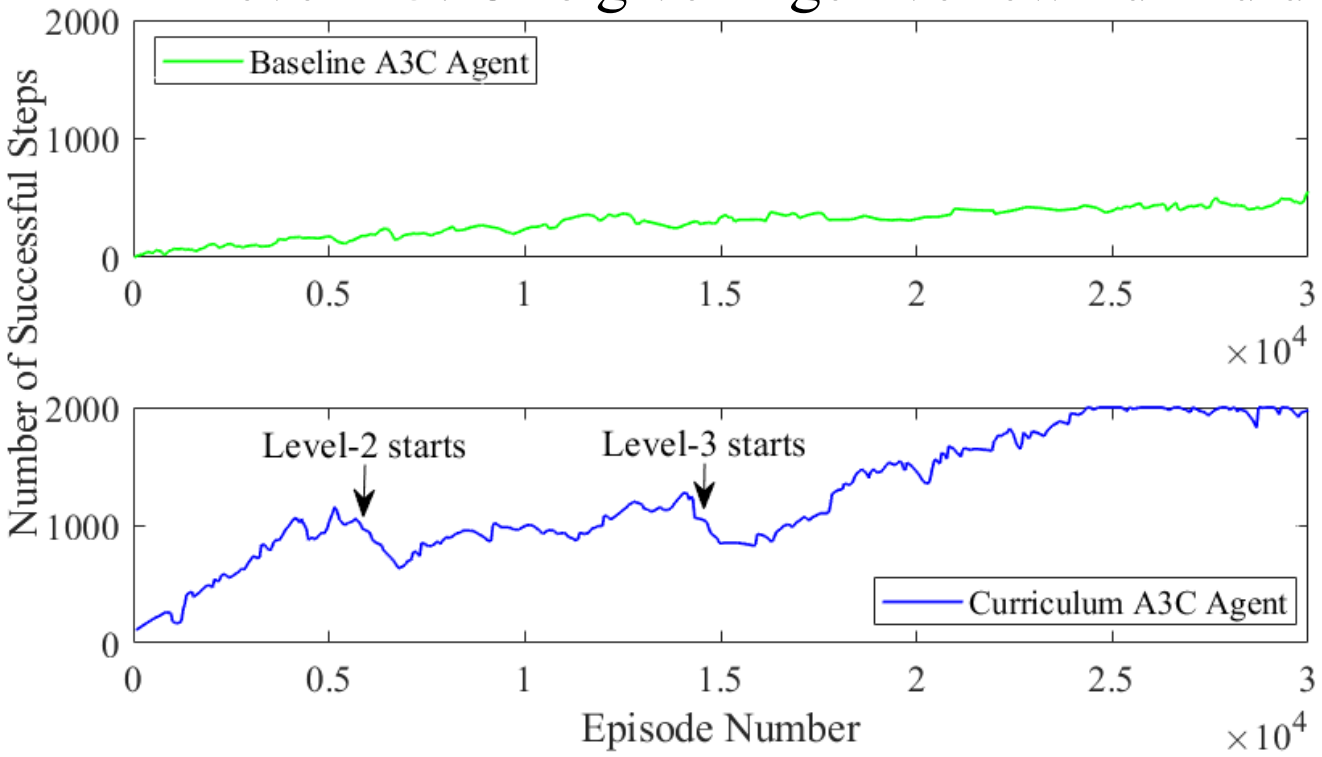
2000 successful steps implies no cascading

- **The problem is too hard** –use grid physics to simplify the problem and learn
- Motivated by how students learn a simpler concept and transfer their learning to learn a complex concept – This is referred to as curriculum learning
- Once simplified problem is mitigated to a sufficient degree, increase problem level

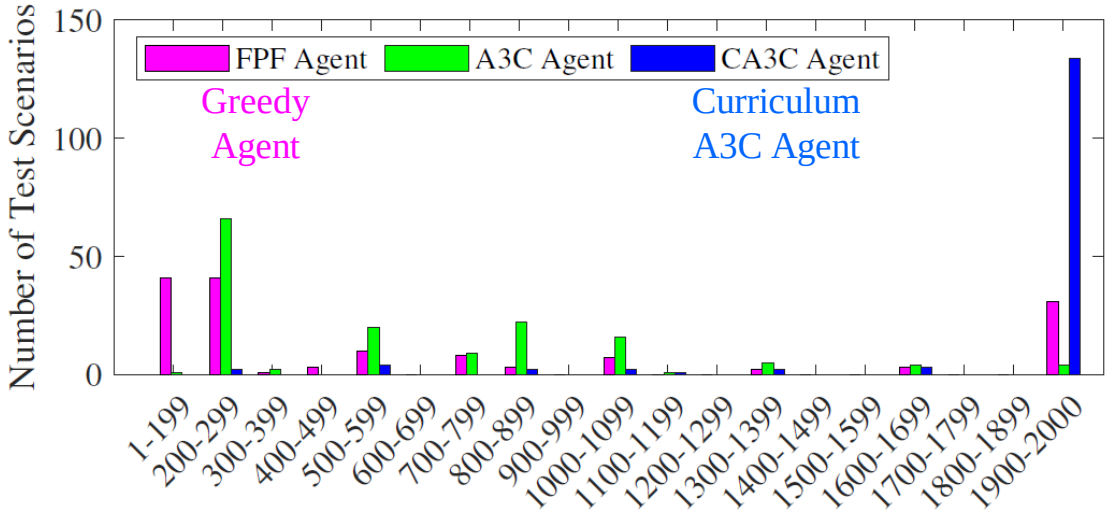
"Gamifying the grid" – Not trivial as poor choice can impede learning

Results Demonstrating Successful Learning To Mitigate Cascading

- Level – 1: Overload lines (OLs) give small –ve reward but never disconnect
- Level – 2: OLs give medium –ve reward and disconnect with high delay
- Level – 3: OLs give large –ve reward and disconnect with small delay



Trained on 50 Scenarios & tested on 150 Scenarios



Physics Inspired Curriculum Agents Successfully Mitigates Cascading

This Agent Placed 2nd in RTE's L2RPN Global Challenge

Thank you !
See you in the Poster Session

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Code: https://github.com/amar-iastate/L2RPN-using-A3C

Journal Paper: A. R. R. Matavalam, K. P. Guddanti, Y. Weng and V. Ajjarapu, "Curriculum Based Reinforcement Learning of Grid Topology Controllers to Prevent Thermal Cascading," in IEEE Transactions on Power Systems, 2022, doi: 10.1109/TPWRS.2022.3213487.