Optimizing fault search in power grid outages through Reinforcement Learning

Master’s degree in *Data Science and Scientific Computing*

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Aim of the project

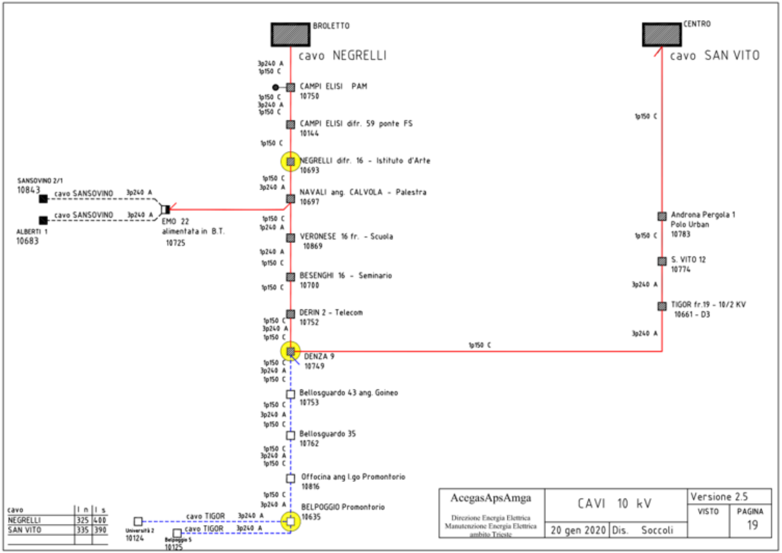
We want to optimize the fault search in power grid outages through Reinforcement learning.

Why?

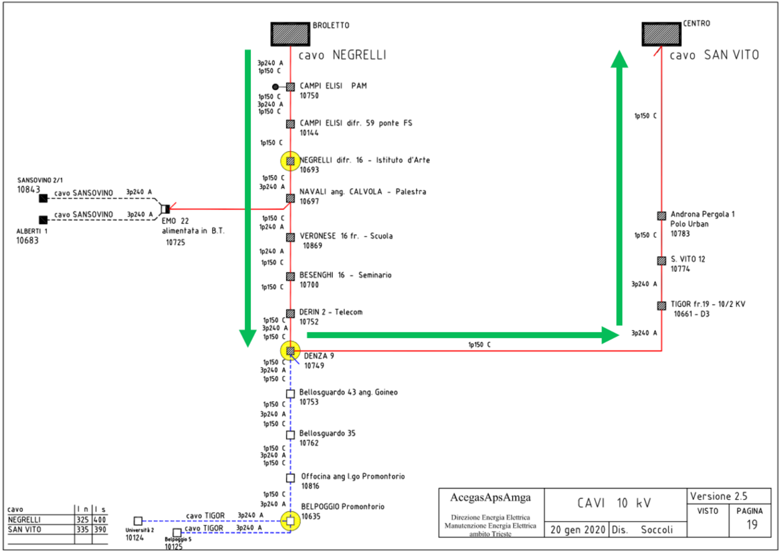
- The restoration process is done by the technicians using only their experience.
- We want to exploit the data on the power grid that we have at our disposal.

The restoration process

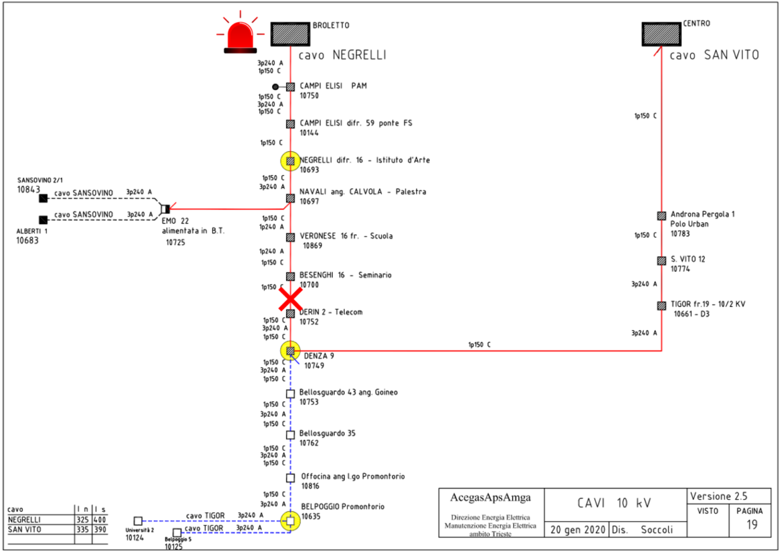
Example of a power line in medium voltage



The energy flow in the standard set-up

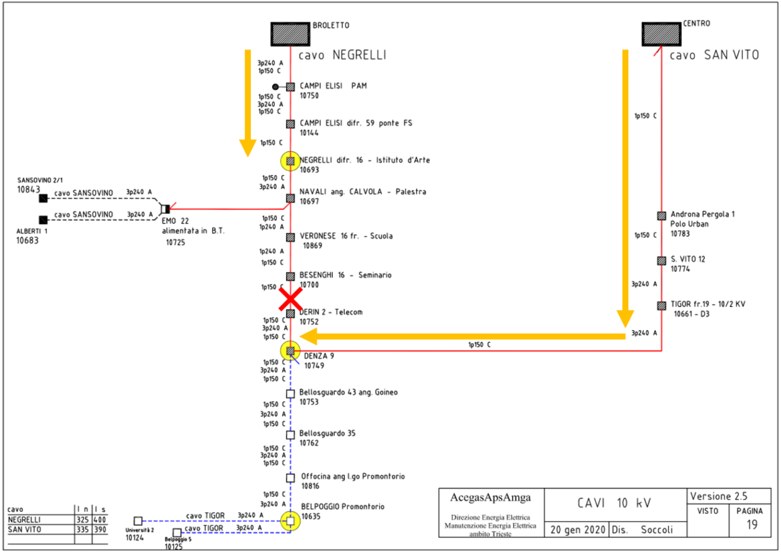


Failure scenario



cavo	I n	I s
NEGRELLI	325	400
SAN VITO	335	390

Failure scenario



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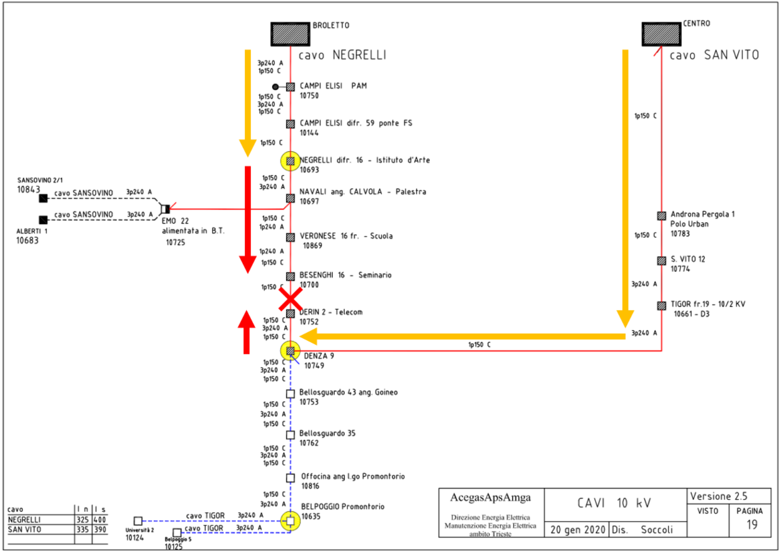
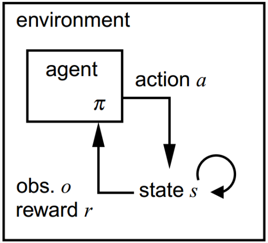
Failure scenario



The mathematical model

At the beginning, we are given a set of disconnected substations, $\mathcal{C}$, between two remotely controlled substations.

To model the problem, we used a partially observable Markov decision process (POMDP), since we don't know where the fault is. In this model, we have an agent in an environment, and the former has to take actions according to a policy π to minimize the expected cost J.



In our specific problem, the action is the choice of the specific substation the technician will visit as the next step.

Instead, the expected cost is the time (*in seconds*) of going to a certain substation multiplied by the number of disconnected users.

Our algorithms

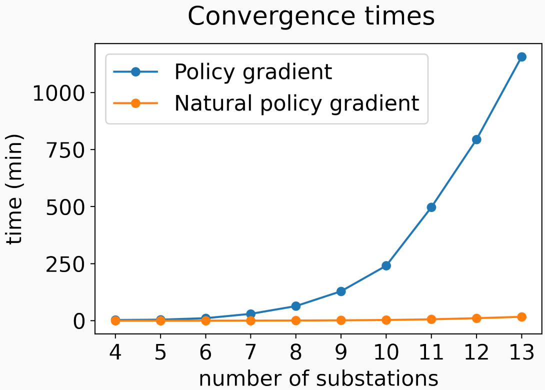
We use the Policy Gradient (PG) algorithm, in which we **parametrize the policy** and we try to find the best policy in order to optimize the POMDP.

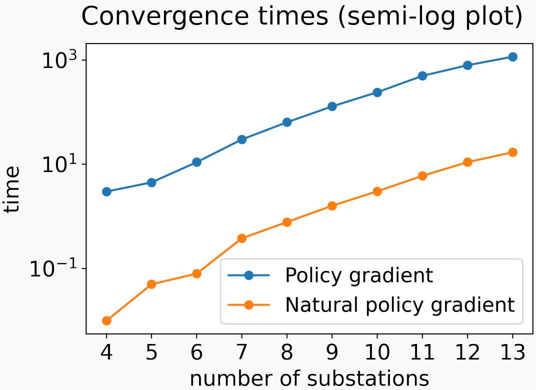
How do we do it? **We start from a certain policy**, for example the *random policy*, in which all actions have an equal probability of being selected. Then we **perform gradient descent on the parameters of the policy**.

This algorithm has a **very slow convergence**, so we also implemented the Natural Policy Gradient (NPG) algorithm, which only changes the formula of the gradient to speed up convergence.

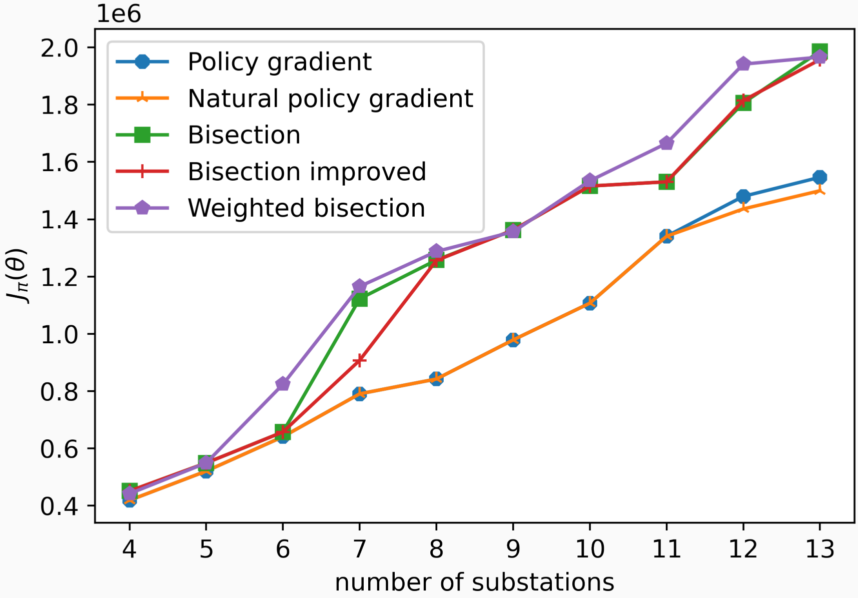
Results

Convergence times of PG and NPG





Performance comparison



Recap

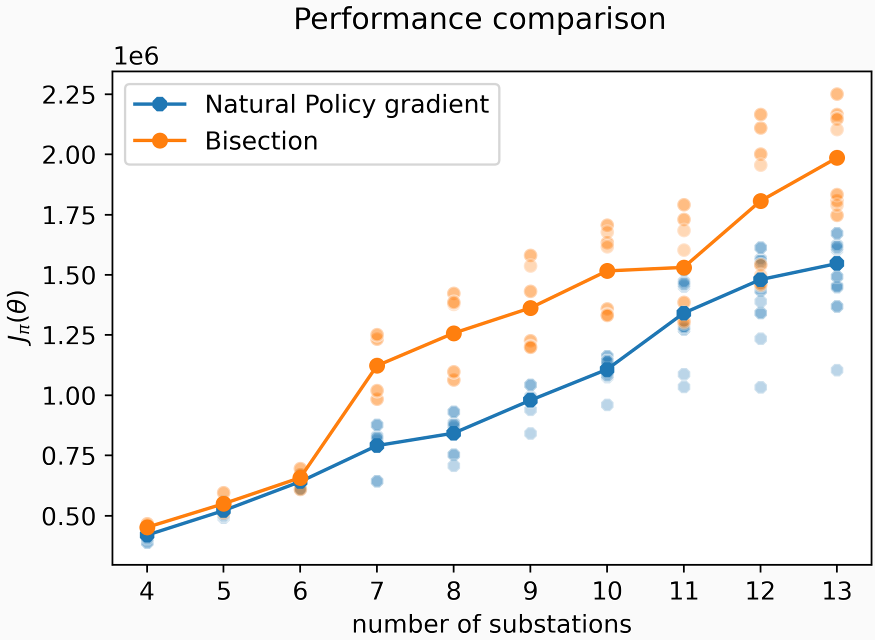
Thus, we optimized the fault search in power grid outages:

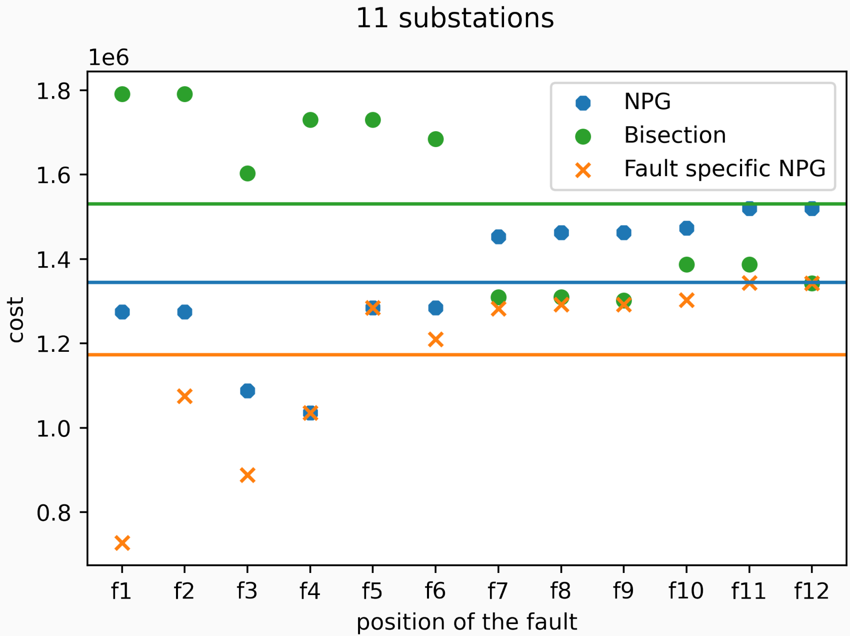
- We modeled Trieste's power grid using graphs.
- We modeled the current method used by the technicians to find the fault during the restoration process: the bisection algorithm.
- We developed a new algorithm that was able to exploit the data that we have on the substations and to improve the restoration process: the (natural) policy gradient algorithm.

Thank you for your attention!

☺

Backup slides


Performance comparison
1e6
Natural Policy gradient
Bisection
$J_\pi(\theta)$
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
4
5
6
7
8
9
10
11
12
13
number of substations


11 substations
1e6
1.8
1.6
1.4
1.2
1.0
0.8
cost
NPG
Bisection
Fault specific NPG
f1
f2
f3
f4
f5
f6
f7
f8
f9
f10
f11
f12
position of the fault


Via dei Soncini
Via Manlio Vulsone
Via Marco Praga
Via Marco Praga
Via dei Soncini
Via Soncini
(angolo
Via Giacometti)
Scuola
Primaria
e dell'Infanzia
Statale
Biagio
Marin
20 m
50 ft
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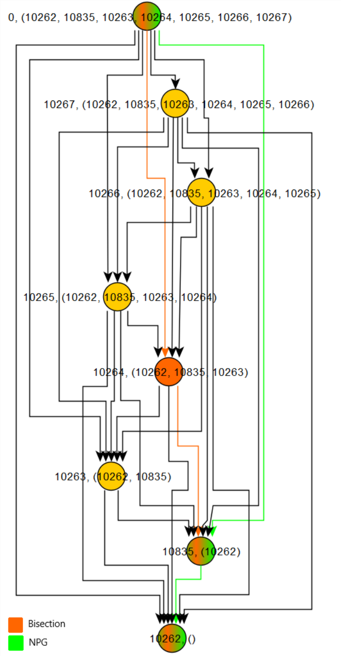

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10835, (10262)
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Bisection
NPG