# Selectivity Analysis in Medium Voltage Distribution Networks

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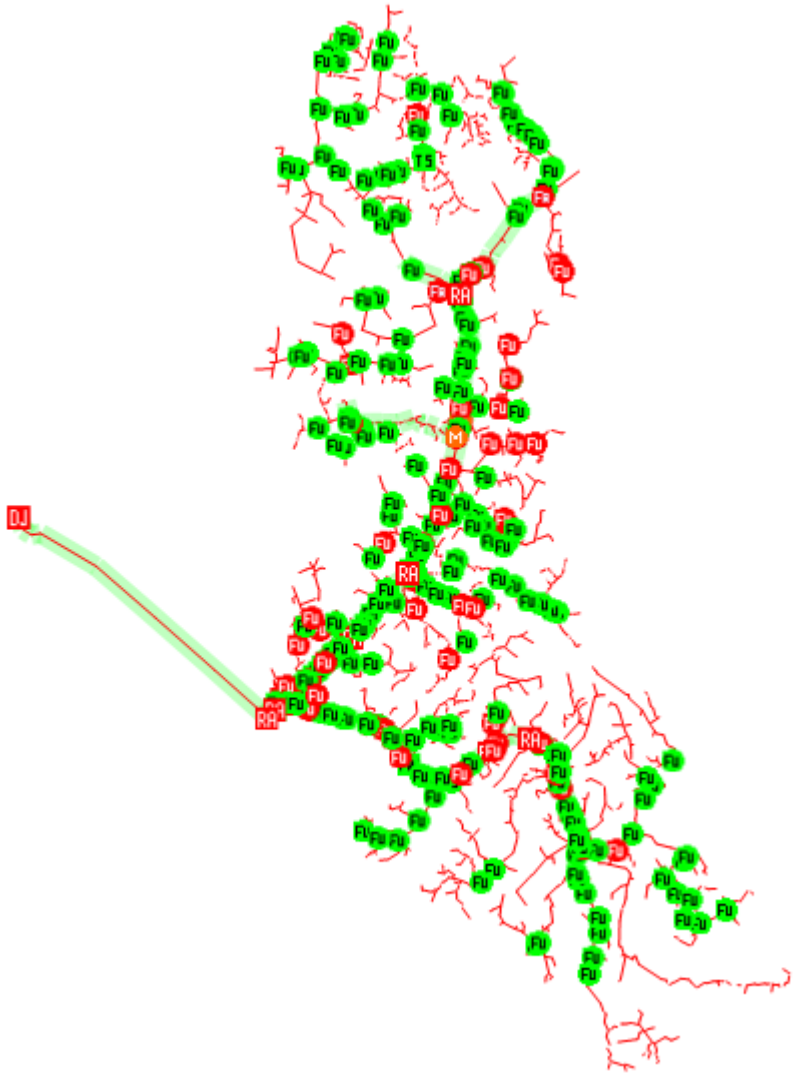
# Introduction

General information about distribution company:

- Gross revenue: BRL 15B (~ USD 2.69B)
- Number of clients: 3 290 731
- Number of feeders: 1 400
- State area: 340 086 $km^2$

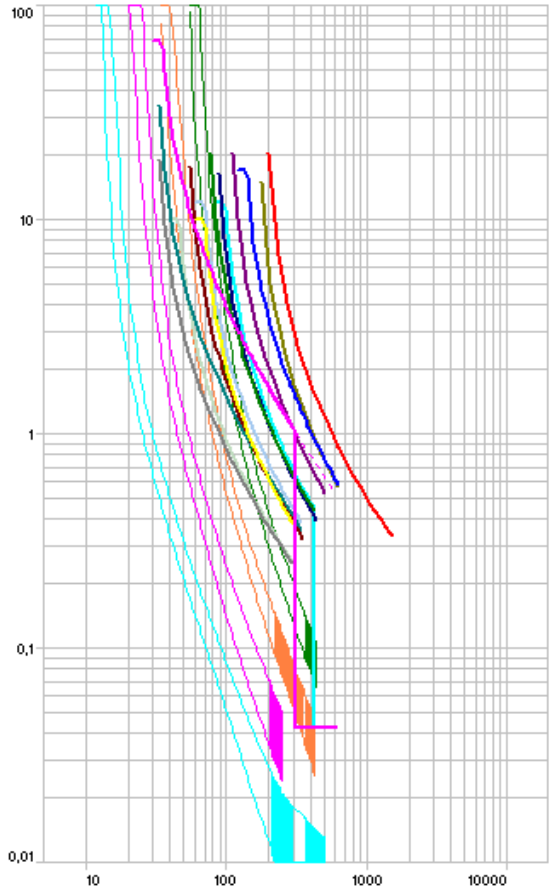
# Introduction




- 16 reclosers
- 451 fuses

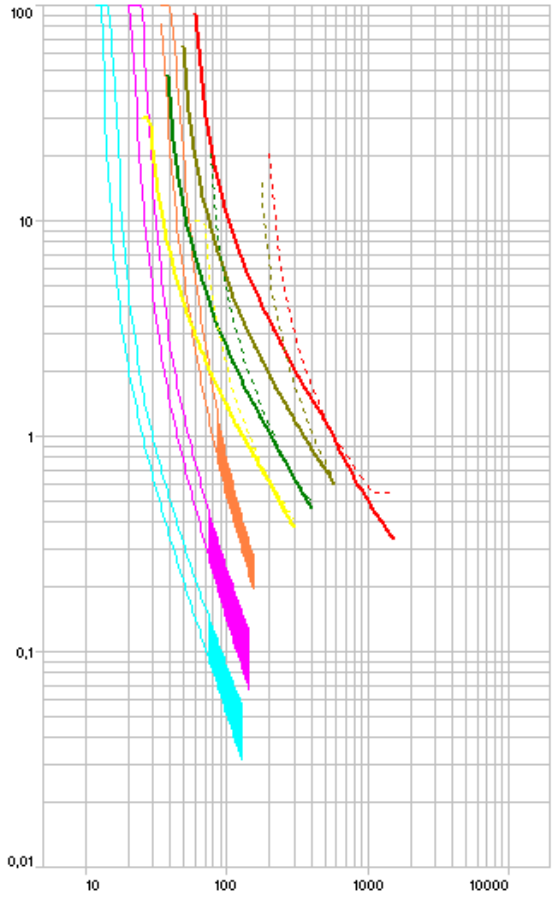
# Introduction

Source -> Load




Hard to analyze

Load -> Source




Laborious to keep track

# Introduction

New protection studies are done when:

- A new recloser is installed;
- An incident happens.

...but could be done based on:

- Increase/decrease of short-circuit levels (due to the installation of new generation facilities and/or transmission lines);
- Violation of company knowledge (maximum number of fuses in series, load from which a recloser is indicated etc.);
- Loss of system selectivity (may occur due to feeder growth and/or network maneuvers).

# Methodology

This project proposes a tool for a broad analysis on system selectivity.

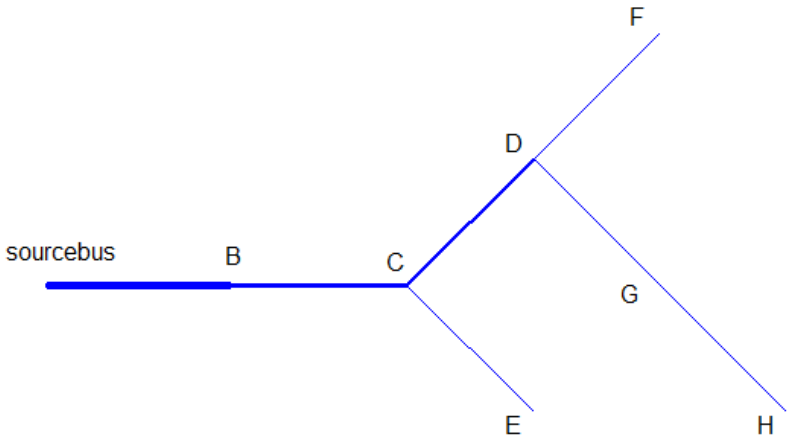
The analysis is conducted from the evaluation of the time responses from the protection devices (fuses, reclosers).

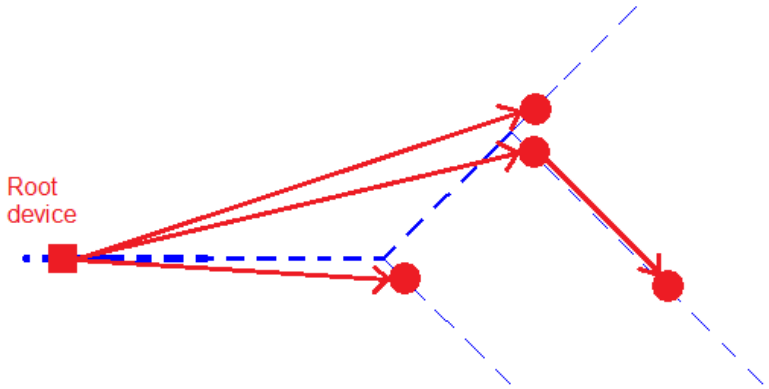
Algorithm:

- Build “protection graph” (P);
- For each device in P:
  - Short circuit associated bus;
  - Compute all time responses from current device up to “root” device;
  - Display message when time difference is lower than a predefined threshold.

# Methodology

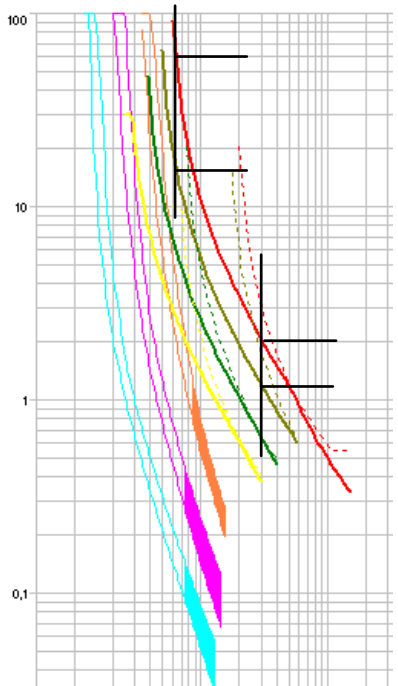
Protection graph: directed, unweighted graph, showing the relationship between upstream and downstream protection devices.



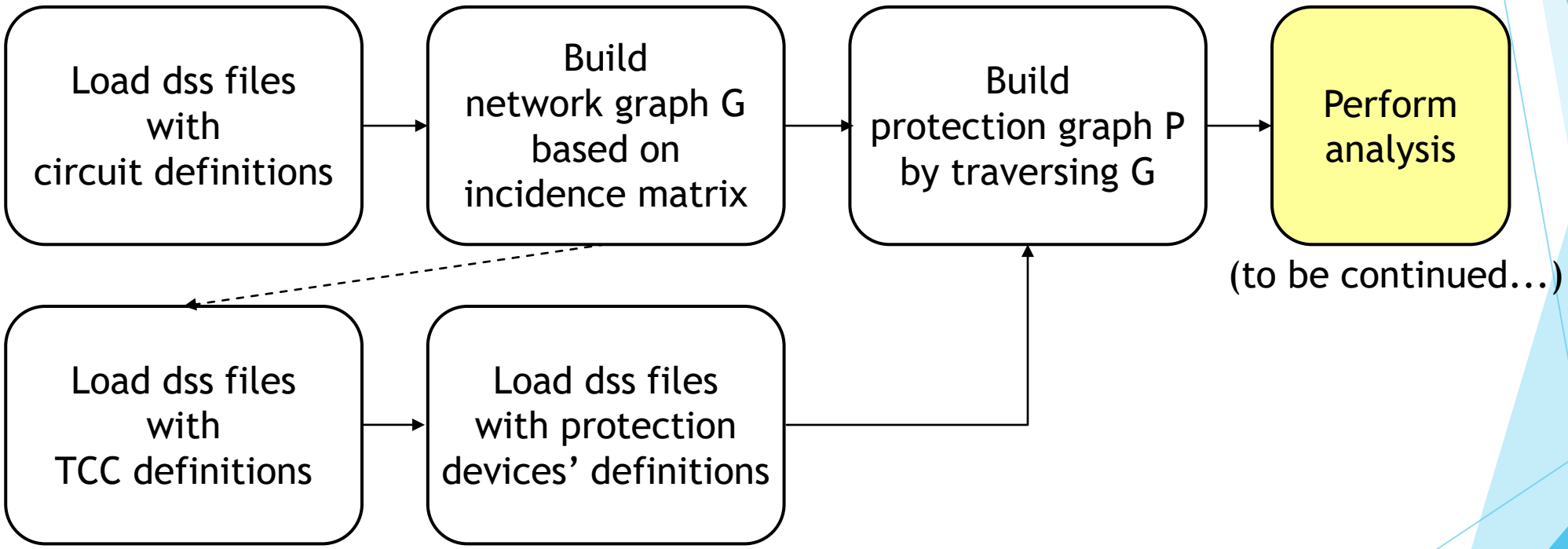



# Methodology

Hypothesis: for each pair of connected devices in P, their time-current curves (TCC) are closer for higher currents. Therefore, a zero-impedance short-circuit on the downstream bus of the monitored line will be a good estimate of the highest current the device might be subjected to. An evaluation of the entire curve is encouraged, though.



# Methodology



# Methodology

Analysis algorithm:

For each device in P:

--Short circuit downstream bus of monitored line (SLG)

--Get path from current device up to root device

--Define empty list relative to current path

--For each device in current path:

----Get currents through monitored line

----Compute time response

----Append triad (device, current, response time) to list

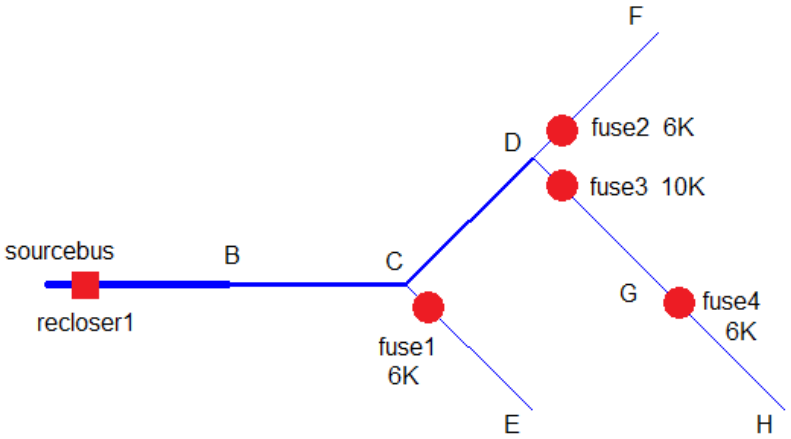
--For each triad in list:

----Calculate (upstream device response time) – (current device response time)

----Show message if time delta lower than threshold

# Results

## Case 1



# Results

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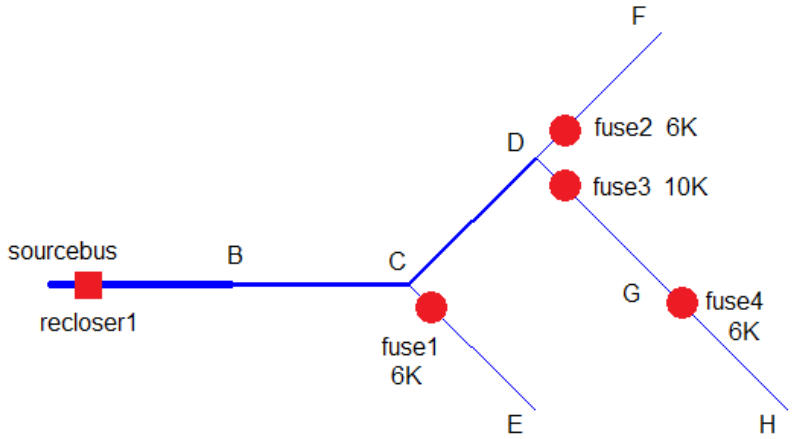
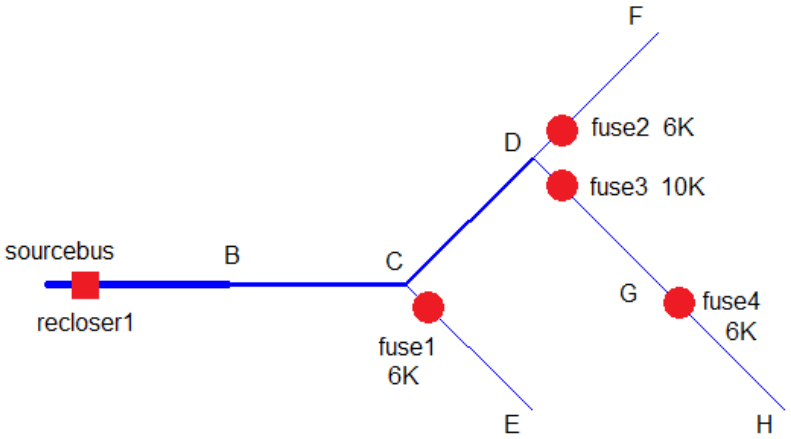
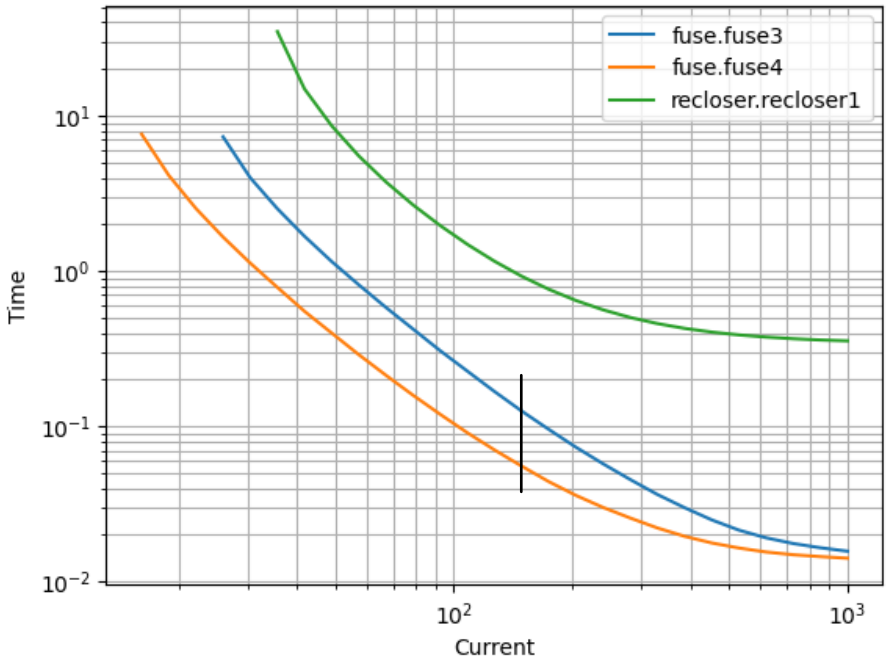



```
'SLG fault on bus h:'
'• fuse.fuse4 is not selective with upstream fuse.fuse3'
'• fuse.fuse4 -> current: 156.6649, time: 0.051258 | fuse.fuse3 -> current: 156.6649, time: 0.114439'
'• Time delta = 0.063181'
```

# Results

## Case 1

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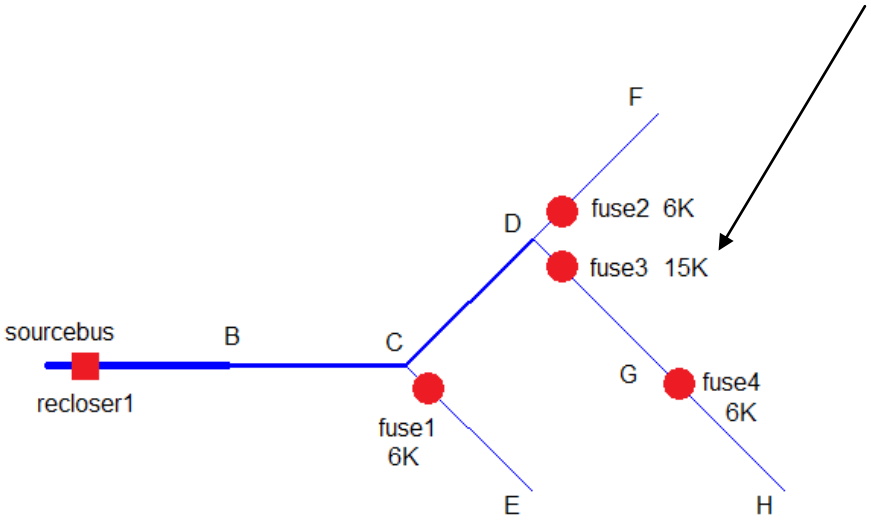
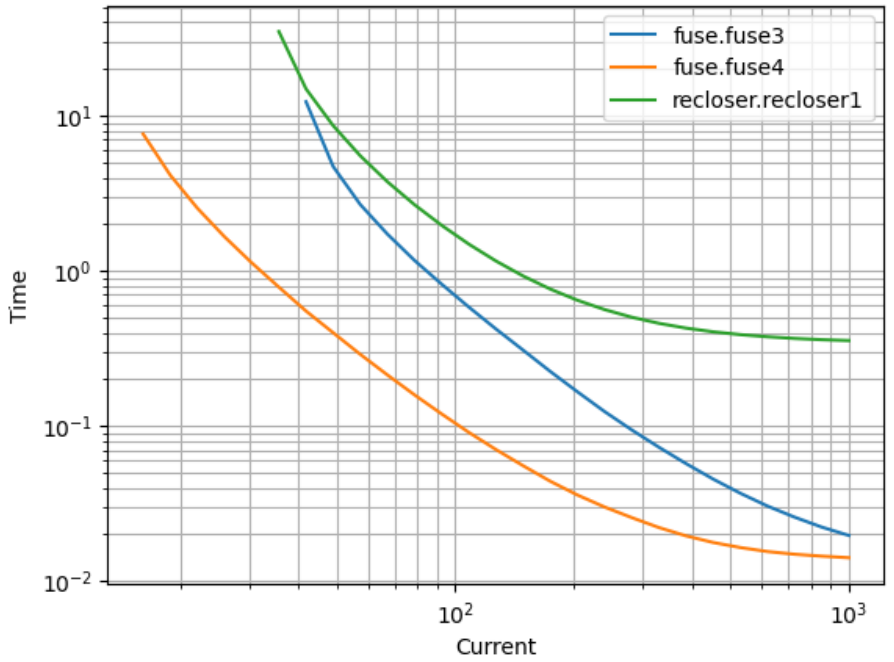
# Results

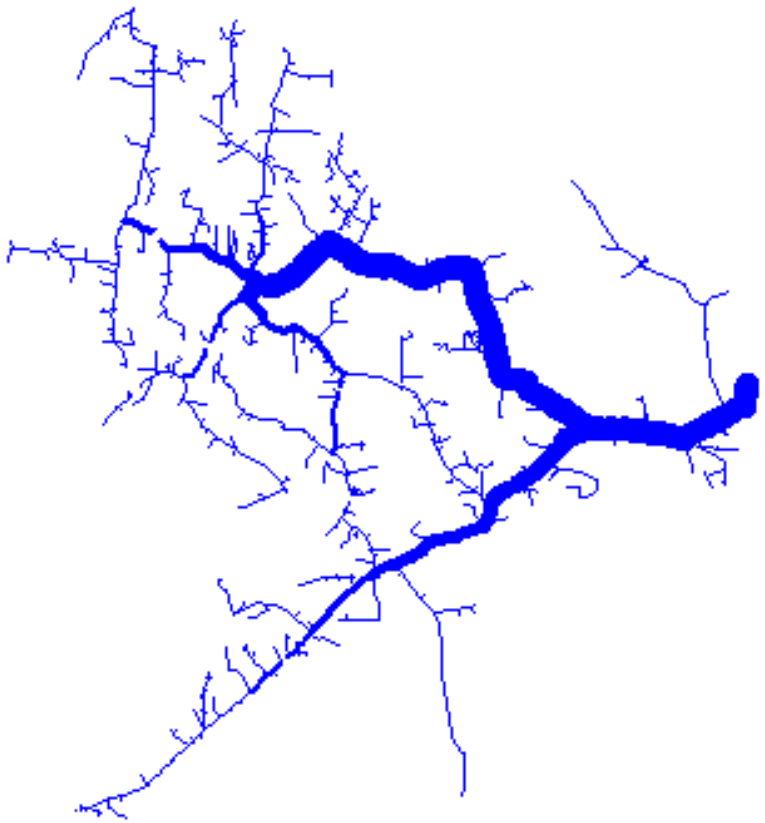
## Case 2



# Results

Case 3 – IEEE 8500-Node (modified)



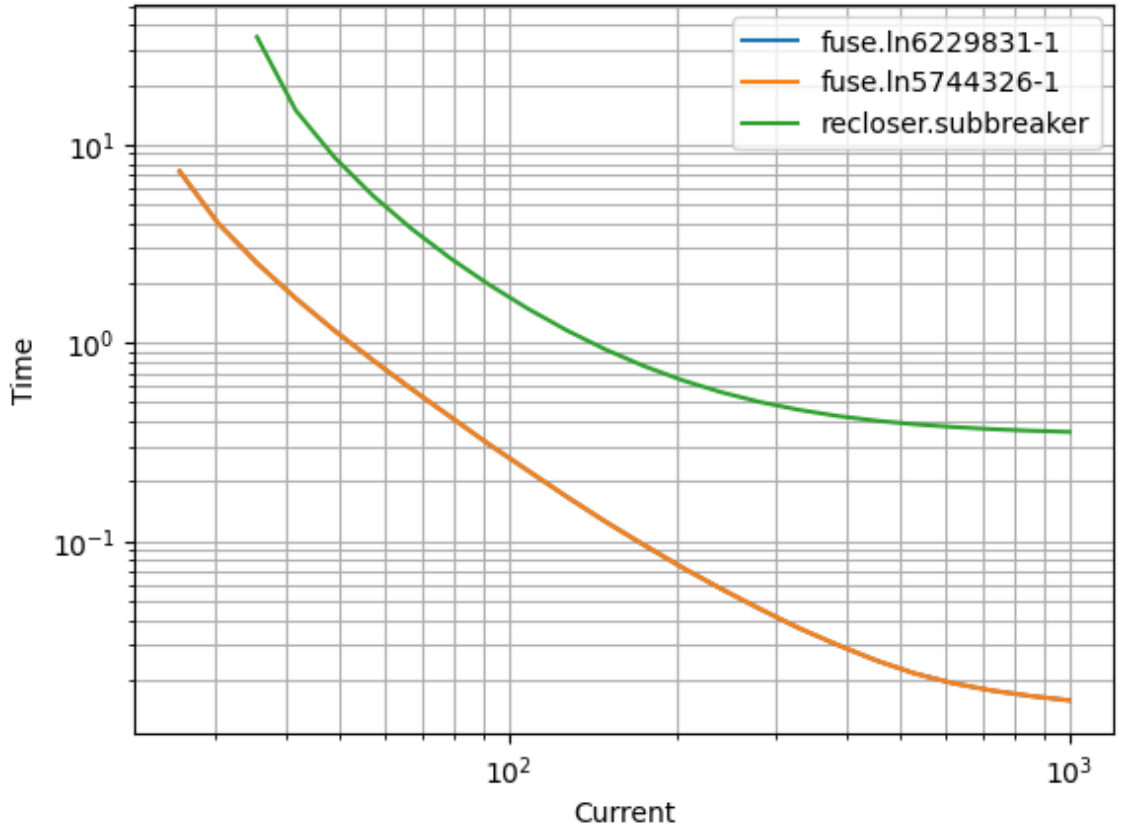
# Results

## Case 3 – IEEE 8500-Node (modified)

```
'SLG fault on bus l2973171:'
'• fuse.ln5895802-1 is not selective with upstream fuse.ln5985355-3'
'• fuse.ln5895802-1 -> current: 895.4292, time: 0.016249 | fuse.ln5985355-3 -> current: 895.4501, time: 0.016248'
'• Time delta = -0.000000'
'SLG fault on bus m1010017:'
'• fuse.ln6106583-5 is not selective with upstream fuse.ln5712587-2'
'• fuse.ln6106583-5 -> current: 438.5343, time: 0.025761 | fuse.ln5712587-2 -> current: 438.5456, time: 0.025760'
'• Time delta = -0.000001'
'SLG fault on bus m1009838:'
'• fuse.ln5744326-1 is not selective with upstream fuse.ln6229831-1'
'• fuse.ln5744326-1 -> current: 552.6719, time: 0.020737 | fuse.ln6229831-1 -> current: 552.6805, time: 0.020737'
'• Time delta = -0.000000'
'SLG fault on bus l2897765:'
'• fuse.ln5986923-1 is not selective with upstream fuse.ln5898058-2'
'• fuse.ln5986923-1 -> current: 529.4731, time: 0.021452 | fuse.ln5898058-2 -> current: 529.4918, time: 0.021452'
'• Time delta = -0.000001'
'SLG fault on bus m1089113:'
'• fuse.ln6409873-1 is not selective with upstream fuse.ln5955074-2'
'• fuse.ln6409873-1 -> current: 1014.8363, time: 0.015619 | fuse.ln5955074-2 -> current: 1014.8363, time: 0.015619'
'• Time delta = 0.000000'
'SLG fault on bus m1069456:'
'• fuse.ln5562961-1 is not selective with upstream fuse.ln6141147-1'
'• fuse.ln5562961-1 -> current: 765.5898, time: 0.017198 | fuse.ln6141147-1 -> current: 765.7530, time: 0.017197'
'• Time delta = -0.000002'
'SLG fault on bus l2935551:'
'• fuse.ln5532741-1 is not selective with upstream fuse.ln6141147-1'
'• fuse.ln5532741-1 -> current: 891.5556, time: 0.016272 | fuse.ln6141147-1 -> current: 891.6648, time: 0.016271'
'• Time delta = -0.000001'
```

# Results

## Case 3 – IEEE 8500-Node (modified)



# Conclusion

The project developed is promising, and could be put in production as it is.

However, there is a bunch of improvements that can be added to it's roadmap development, such as:

- Selectivity analysis throughout the curve, not only maximum current;
- Selectivity analysis for other types of short-circuits, not only SLG;
- Algorithm for proposing fuse substitution and recloser adjustments;
- Implementation of company rules, such as a warning for an excessive number of fuses in series;
- Impact of distributed generation in protection coordination;
- Implementation of manufacturers' peculiarities;
- Improvements in visualization, such as the plot of the protection graph;
- Improvements in user interface in general.

# Thank you!