Performance Analysis of DC Primary Power Protection in Railway Cars using EMTP-RV

Event: EMTP-RV User Group meeting

Location: New Orleans

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Title: Jr. Eng., M.A.Sc. candidate

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Performance Analysis of DC Primary Power Protection in Railway Cars using EMTP-RV

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Further details will be provided in the following reference:

M. Berger, C. Lavertu, I. Kocar, J. Mahseredjian, « Performance Analysis of DC Primary Power Protection in Railway Cars using a Transient Analysis Tool », Vehicle Power and Propulsion Conference (VPPC), 2015 IEEE, Oct. 2015 [Digest Accepted]

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Agenda

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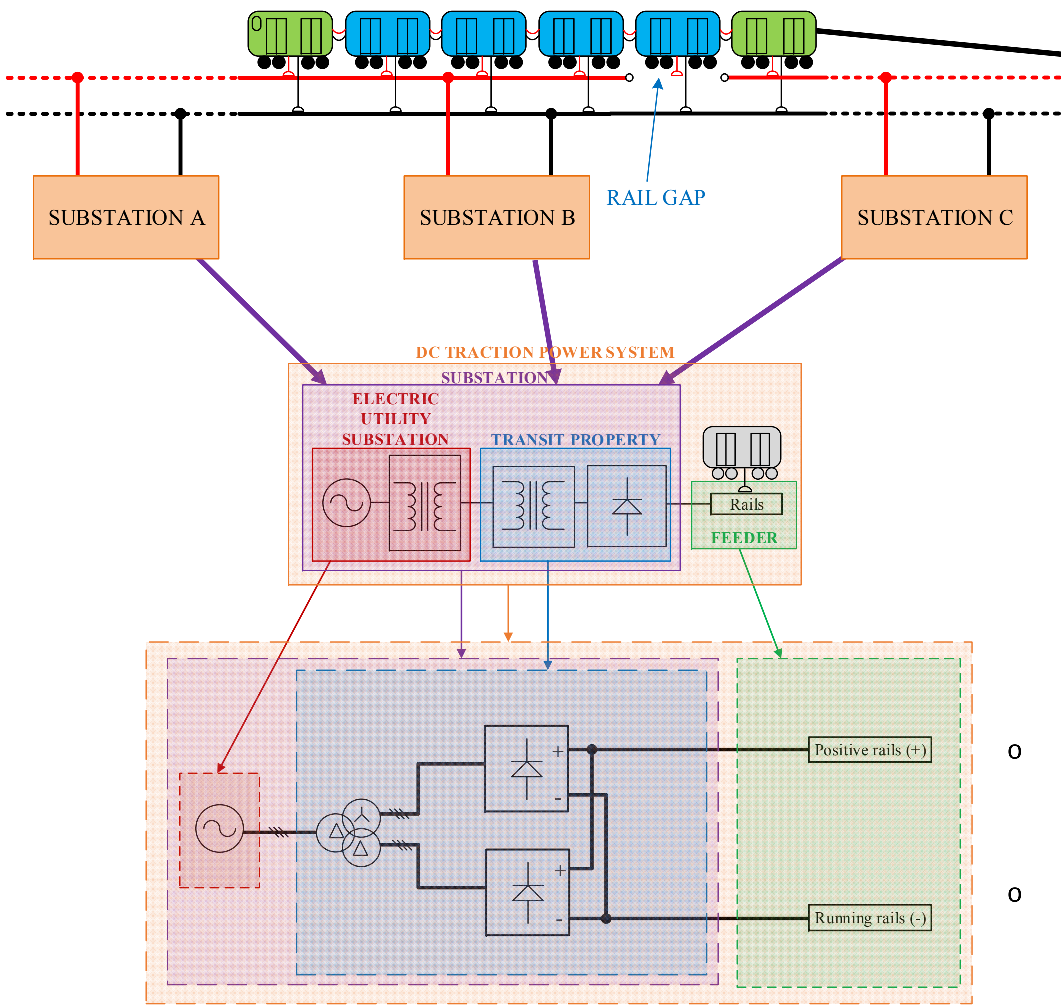
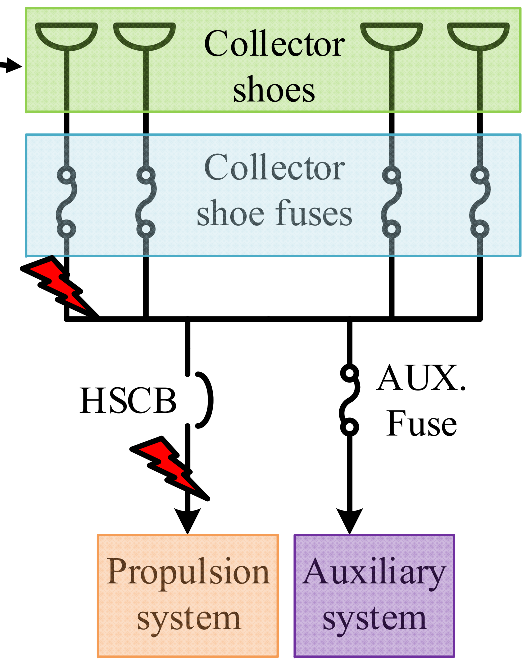
Introduction
Context





- Primary DC Voltage: 600 V, 750 V, 1 kV, 1.5 kV
- Average Rated Power: 2 MW - 5 MW (some even bigger)

General Objectives:

- Equipment and cables protection
- Limit high thermal and magnetic energy (typically undercar)

Specific Objectives:

- Determine available fault level
- Define Ratings and Settings of the protective devices
- Evaluate fault duration
- Assess selectivity of protective devices
- Determine protection performance under different scenarios

Progress

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Why using a transient analysis tool ?

A transient analysis tool is used since:

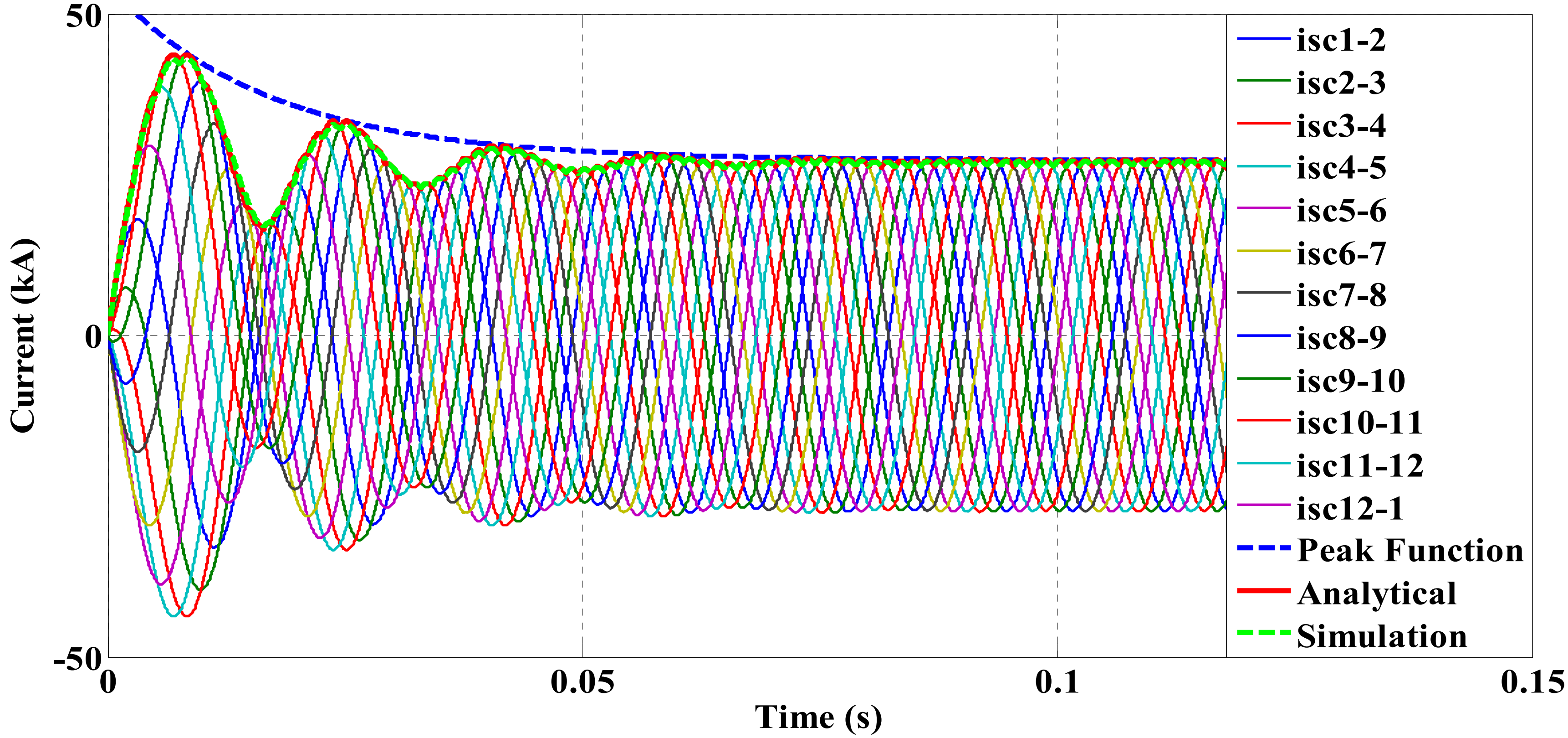
- Traditional AC RMS Time-Current Curves (TCCs) are of a limited use in DC.

- AC Let-Through Curves are also of limited use and may not be always available in DC.

We will see why…

Why using a transient analysis tool ?
Short Circuit Current Waveform

- Short-circuit current waveform depends on the substation rectifiers transient response: It is neither AC nor DC [8].



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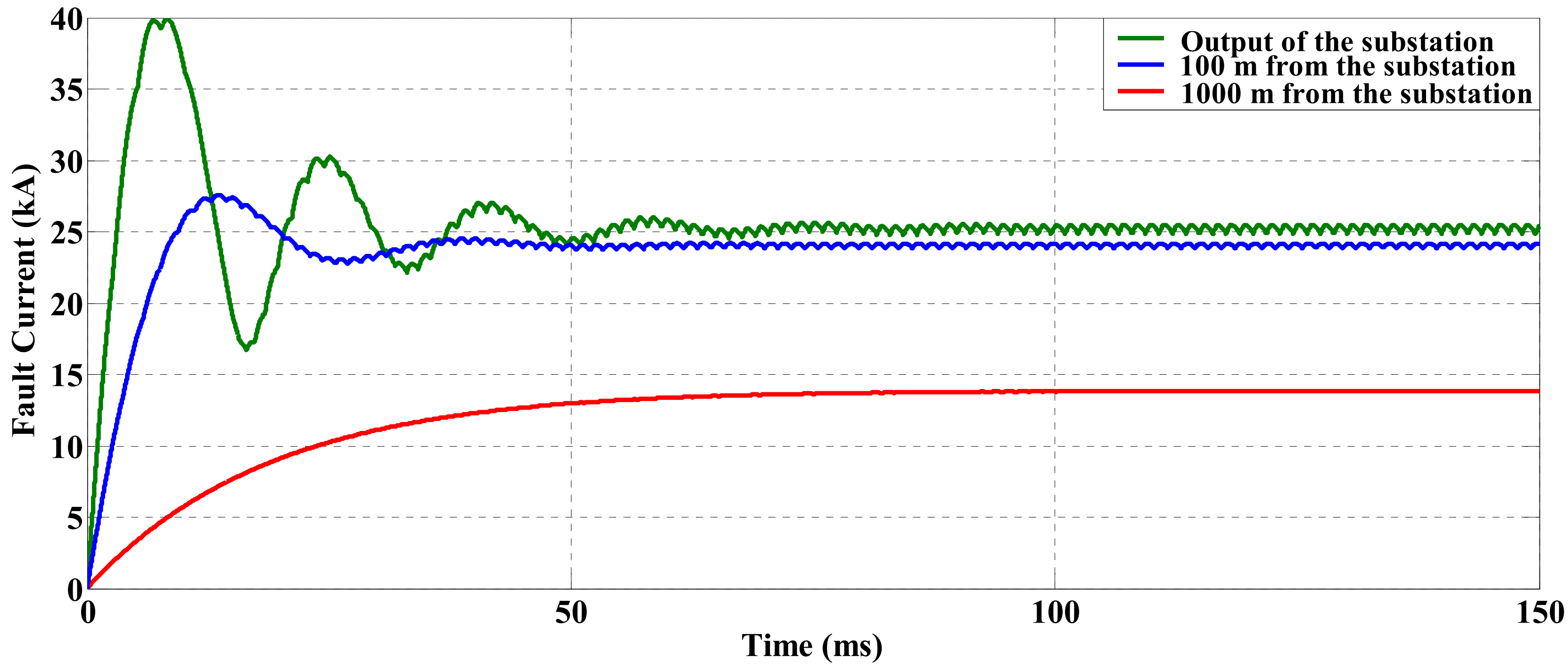
Why using a transient analysis tool ?
Fault Level

- ❑ Fault level depends on the location of the train throughout the DC traction system due to the track parameters – (Close, Max. Energy, Remote)



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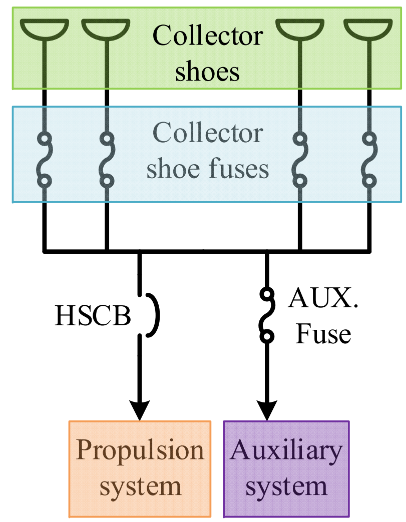
Why using a transient analysis tool ?
Current-Limiting Fuses vs High Speed Circuit Breaker

- Current-Limiting Fuses (CLF) and High Speed Circuit Breaker (HSCB) :
  - Different detection mechanisms:
    - HSCB: Magnetic
    - CLF: Thermal
  - Sophisticated arcing mechanism.
  - MOST IMPORTANT: Likely to break transient current.
  - Downstream HSCB energy limitation have an impact on the energy seen by the upstream fuses.



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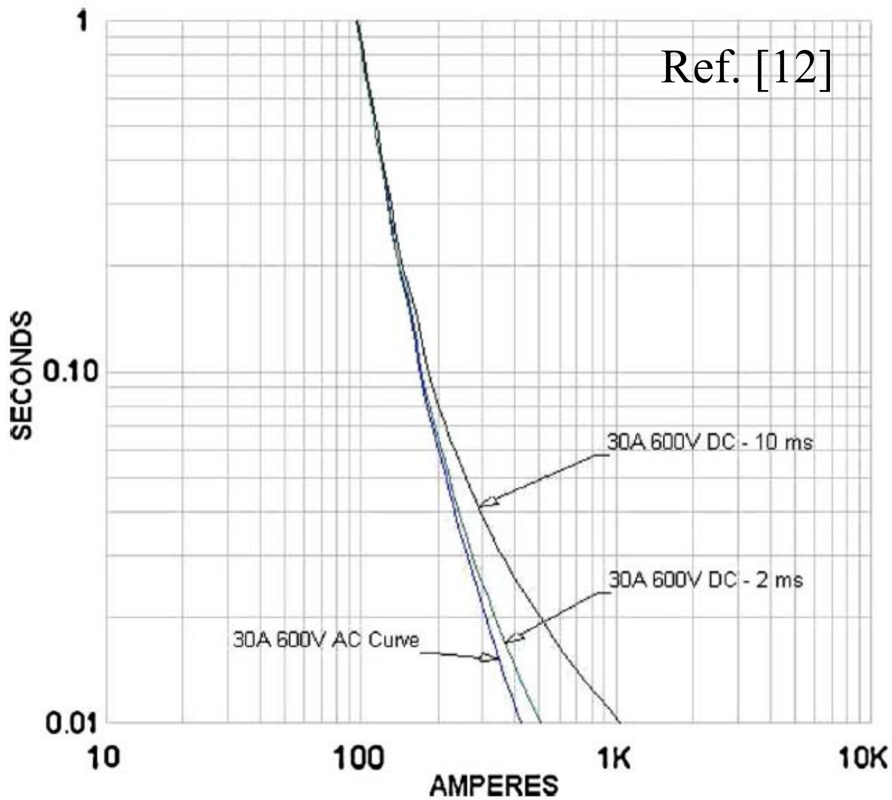
Why using a transient analysis tool ?
CLF vs HSCB – Detection mechanism

- Effect of the fault circuit L/R ratio on fuse Time-Current Curve (TCC)



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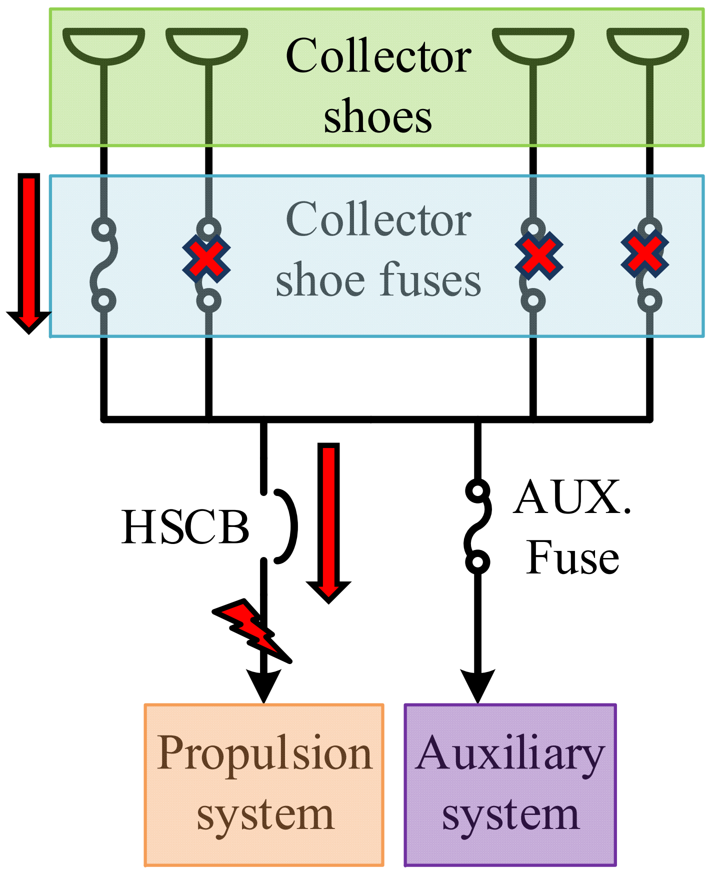
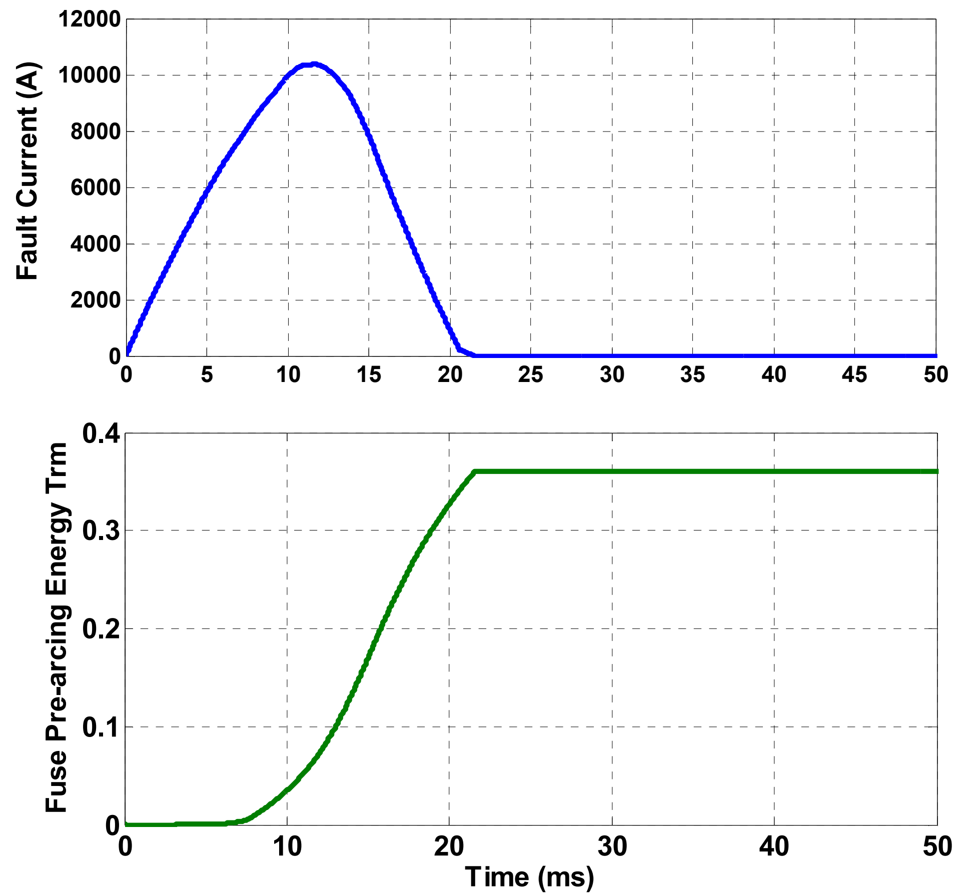
Why using a transient analysis tool ?
CLF vs HSCB – HSCB Energy Limitation Impact on the CLFs

Case with the HSCB breaking the fault current (with I_d= 2000A):





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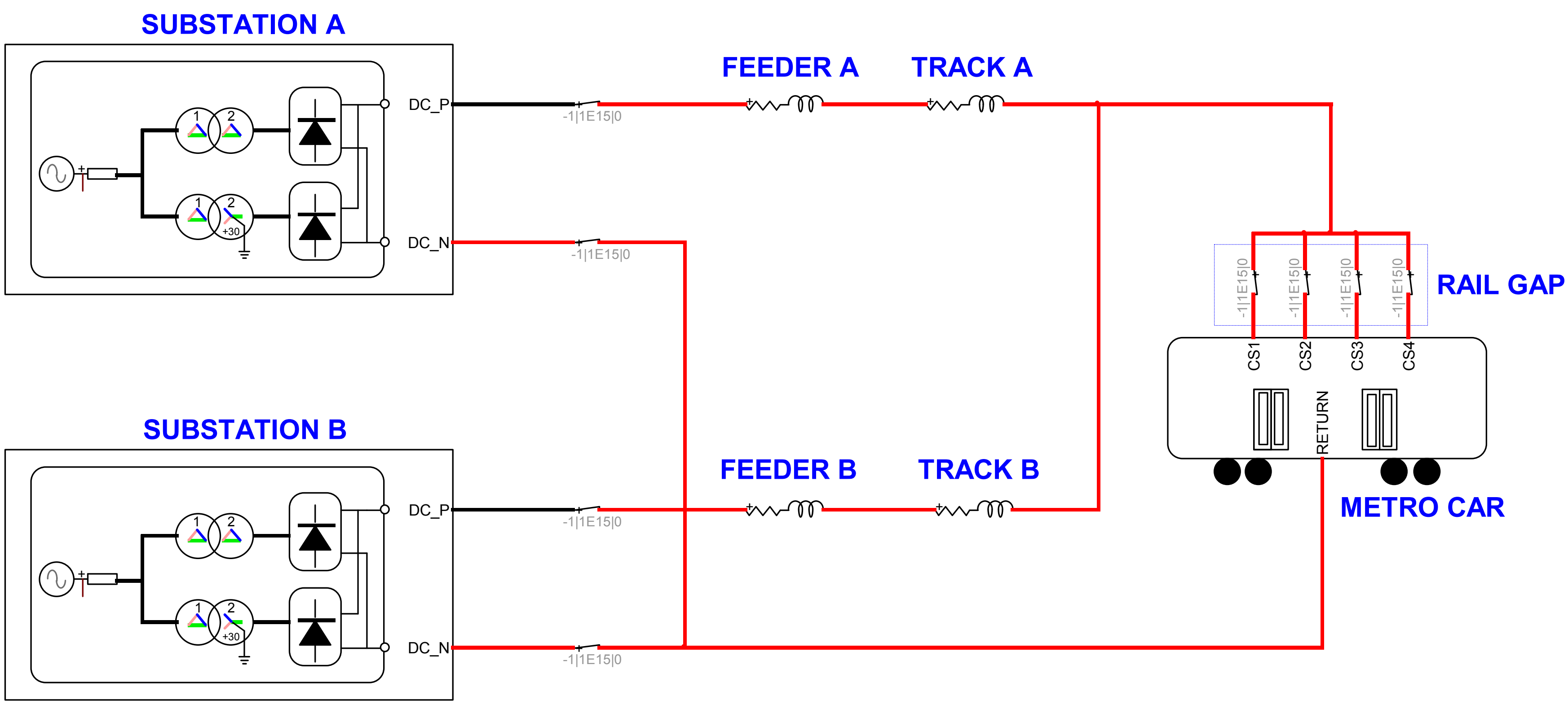
Progress

Building the model
DC Traction System Model



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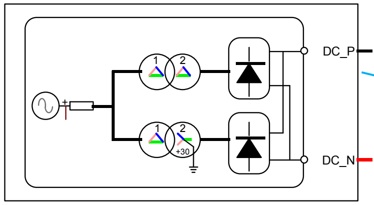
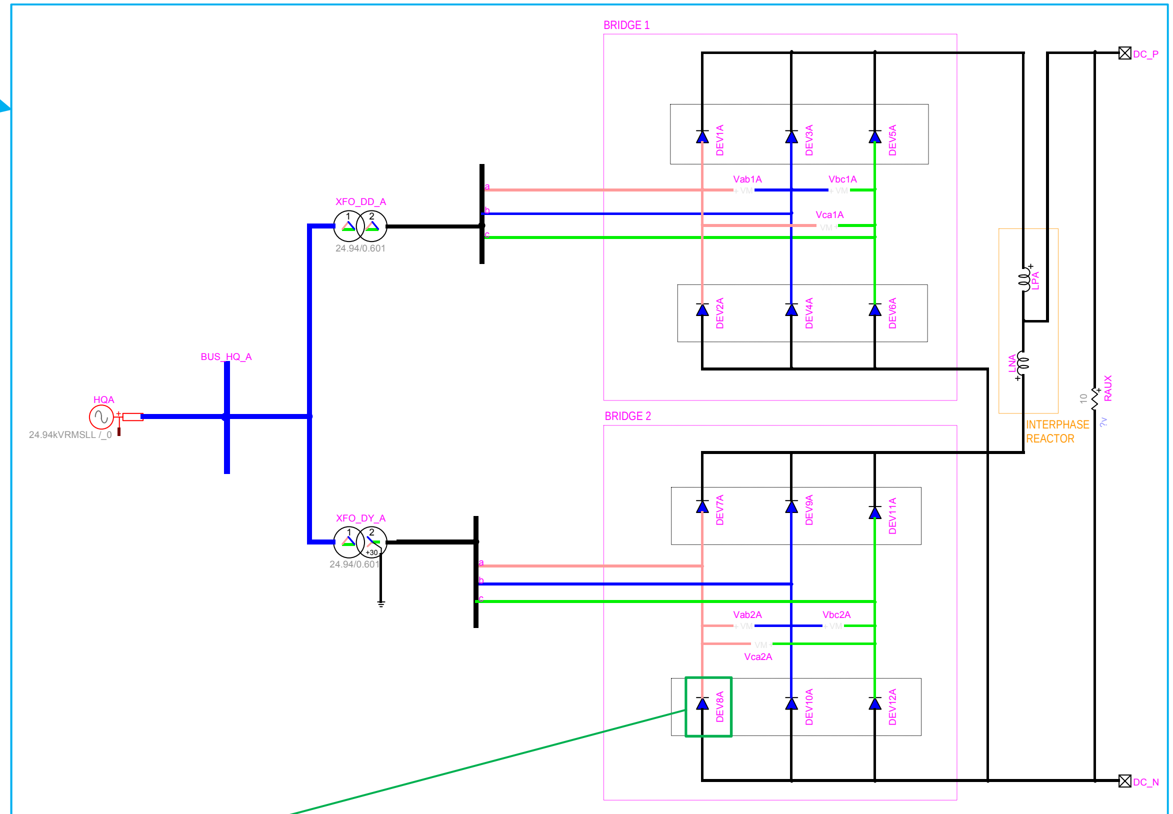
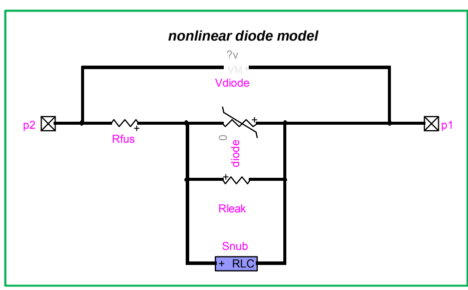
Building the model
Substation Model

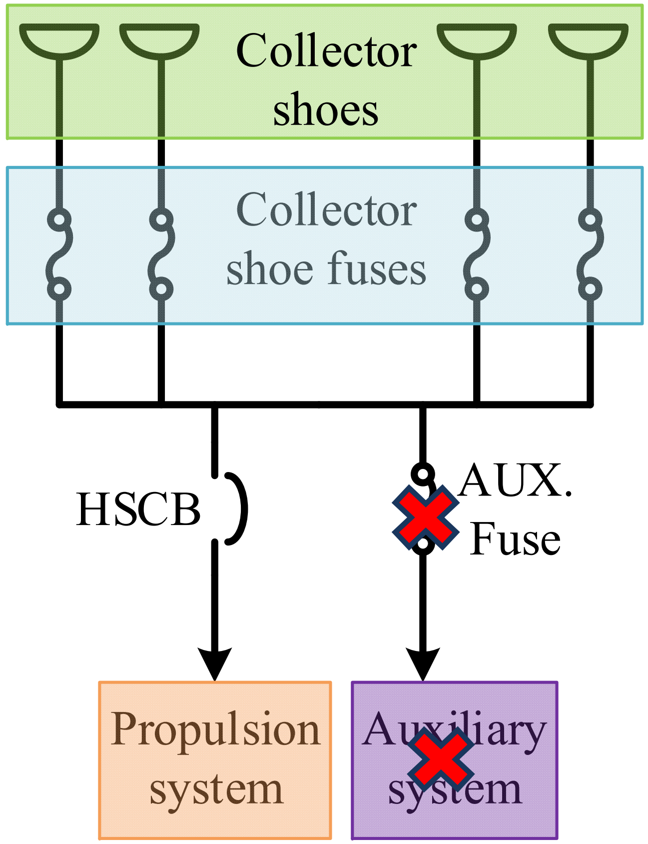


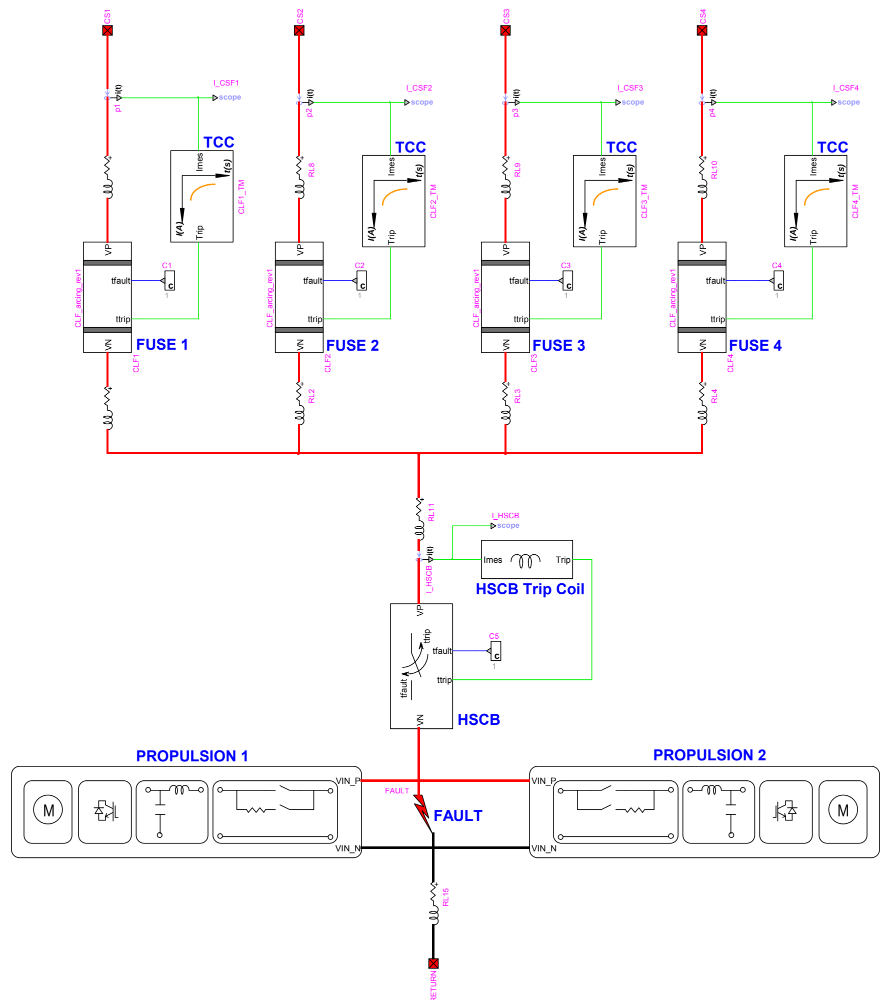




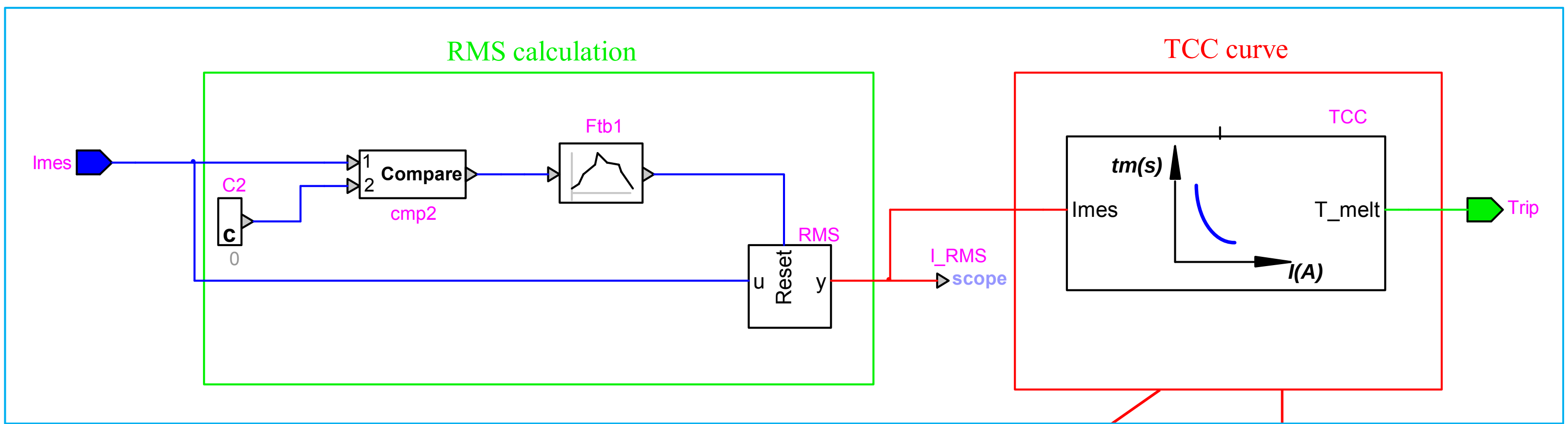
Mainly based on « Société de Transport de Montréal (STM) » 2.5 MW, 750 Vdc, 12-pulse parallel rectifier data [11].

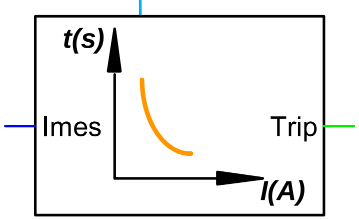
Building the model
Car Model

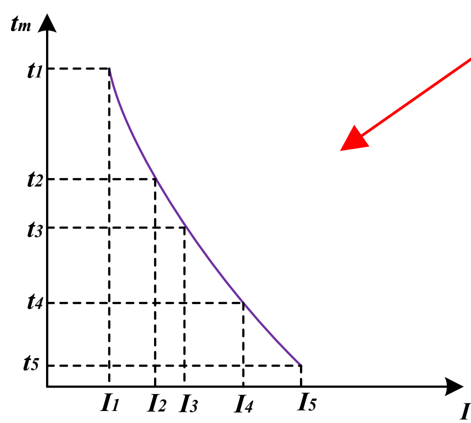




Fuse Time-Current Curve (TCC) Model (Melting Time):







$$Tr_m = \int \left(1 / t_m(t)\right) dt$$

Fuse melting energy reached when Tr_m=1

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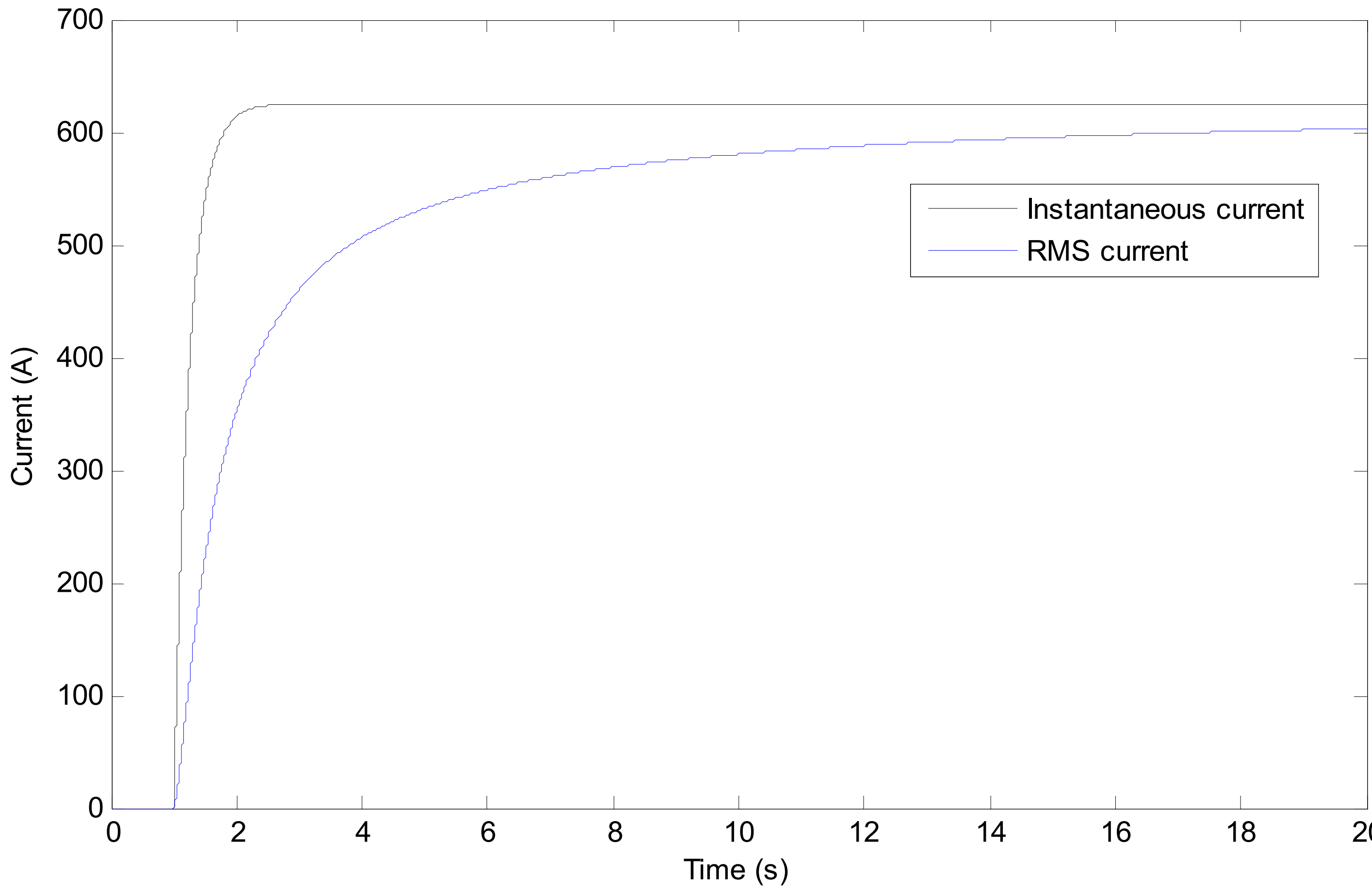
Building the model
Current-Limiting Fuse (CLF)

- ❑ What is the RMS current in transient DC? [3]



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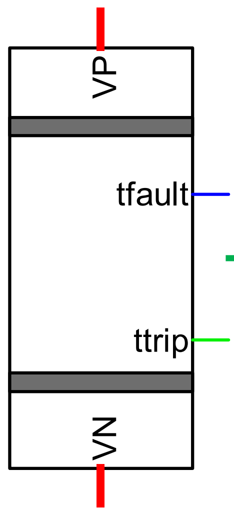
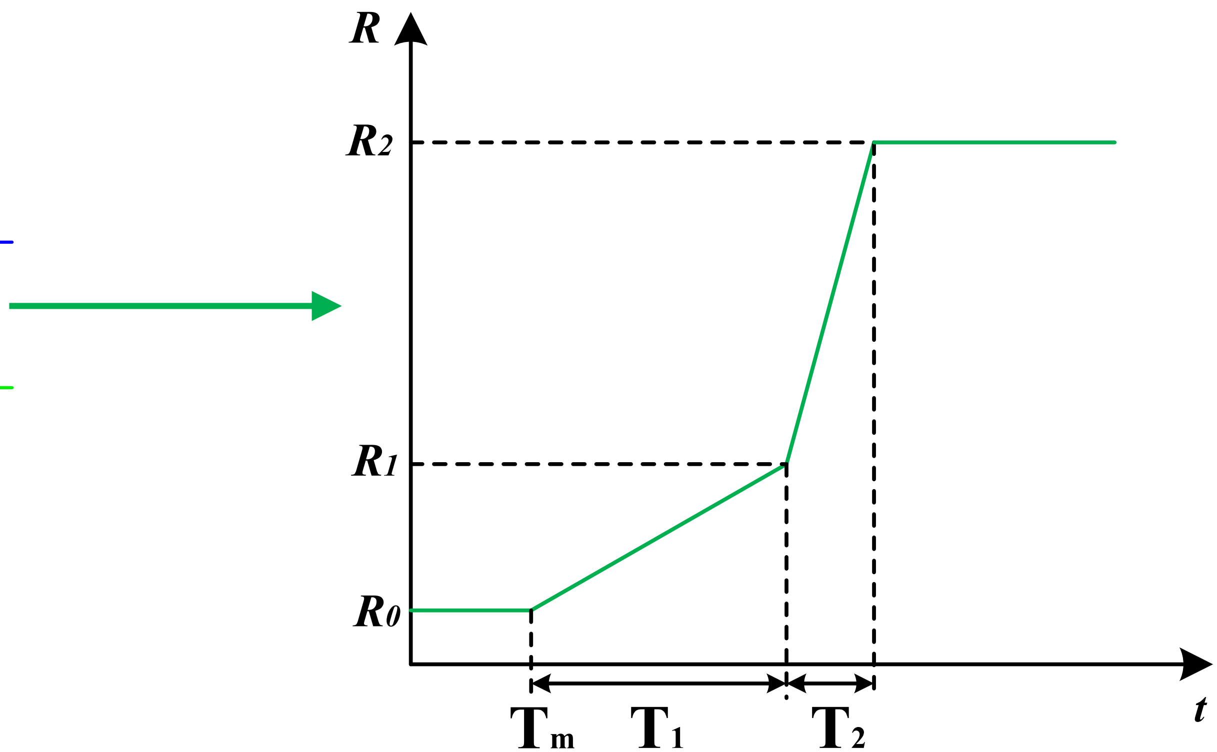
Building the model
Current-Limiting Fuse (CLF)

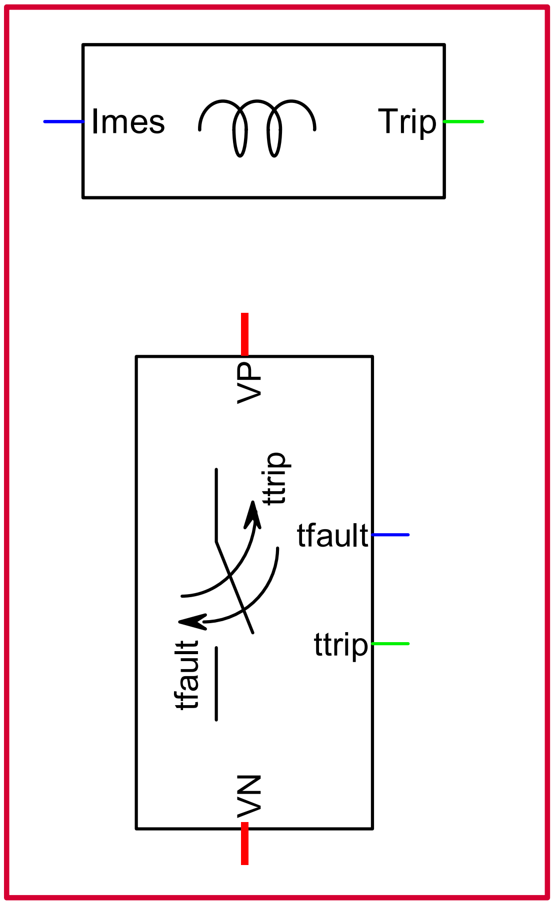
Fuse arcing model (Piecewise linear increasing resistance):

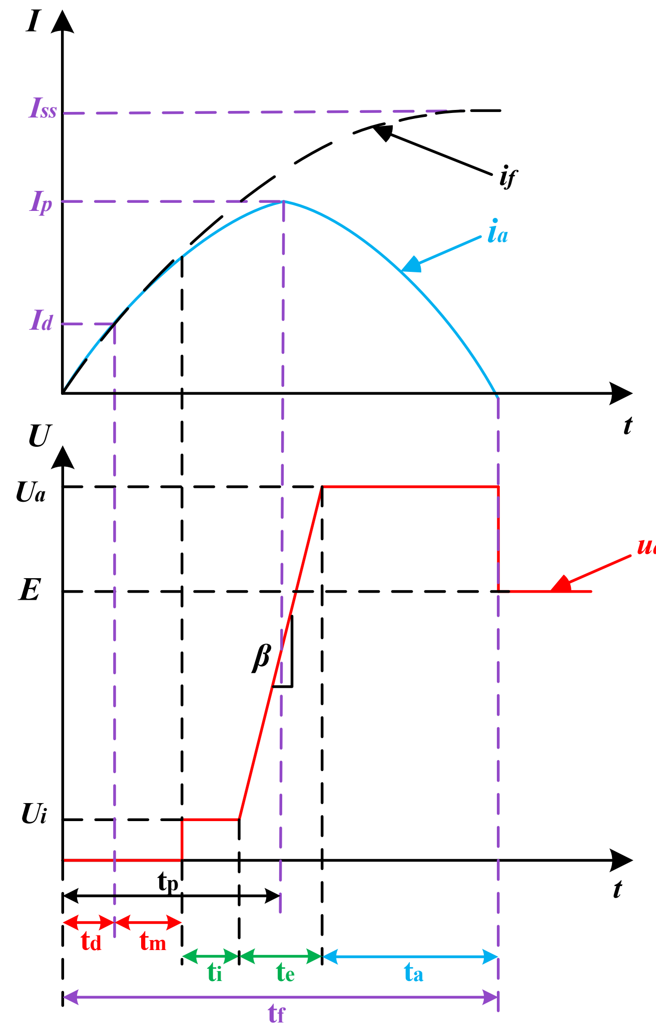




Building the model
High Speed Circuit Breaker (HSCB)

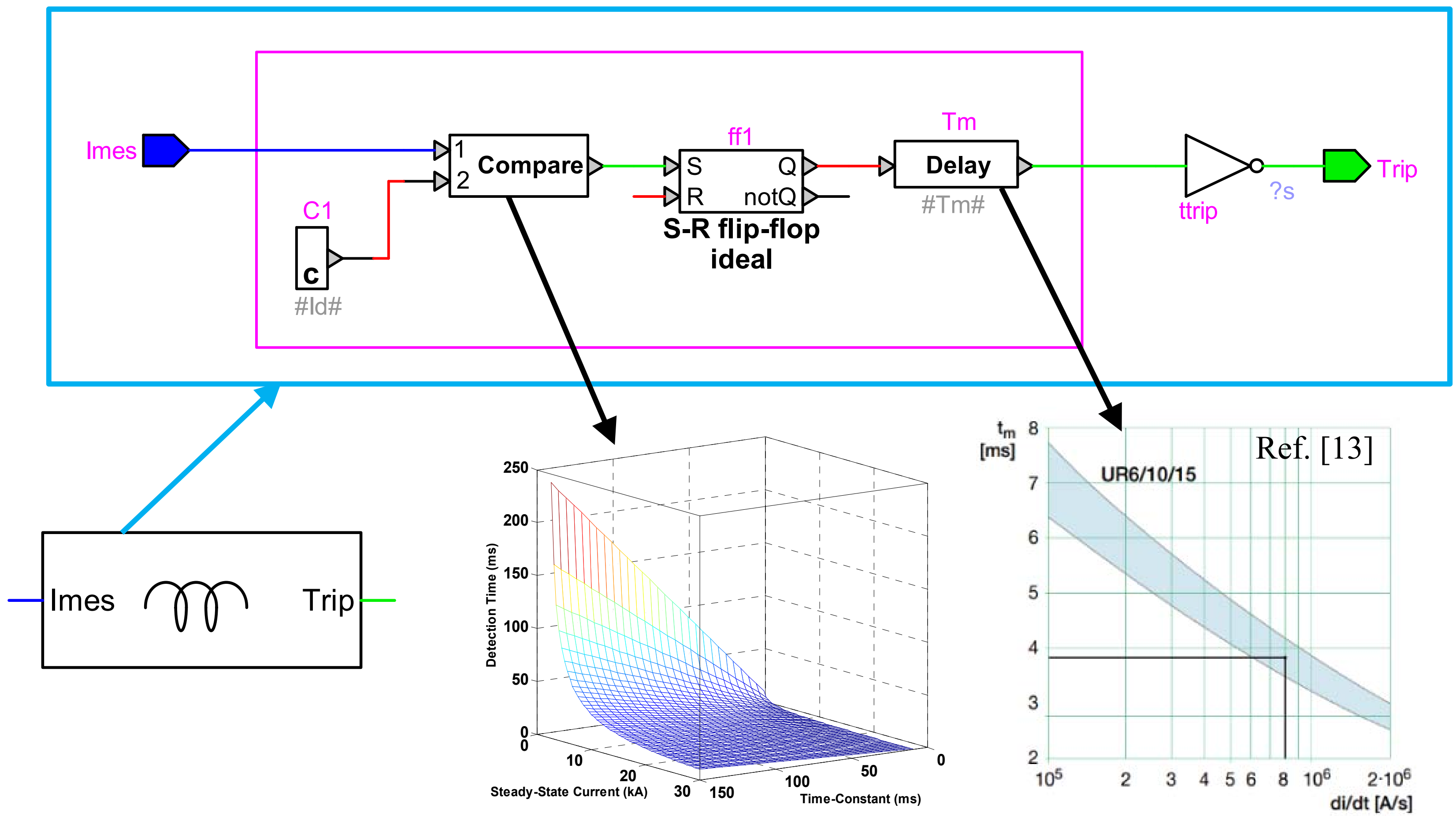
HSCB Detection and Opening:





Building the model
High Speed Circuit Breaker (HSCB)

HSCB Detection (trip coil):



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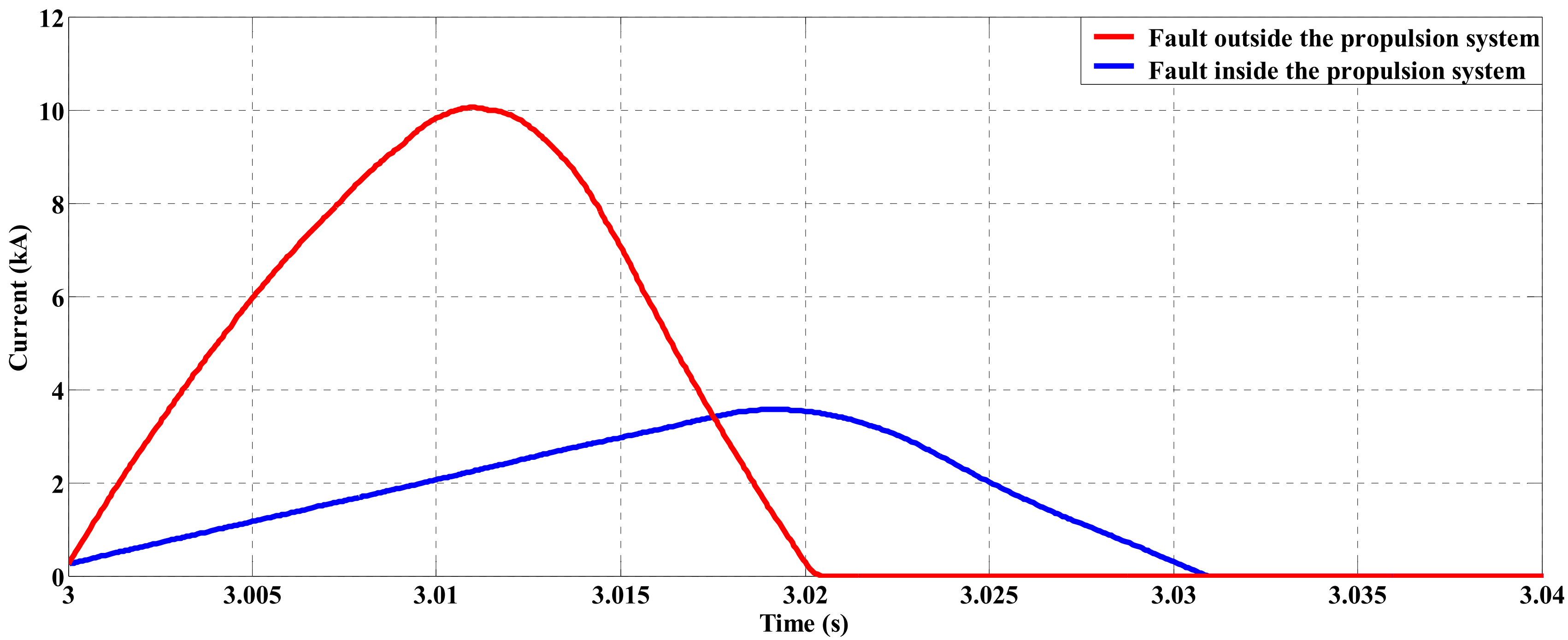
Progress

Case Study
Case #1 – Fault inside vs outside the propulsion system

- In both case, the HSCB clears the fault.
- Extra damping of the filter inductors increases the fault clearing time.



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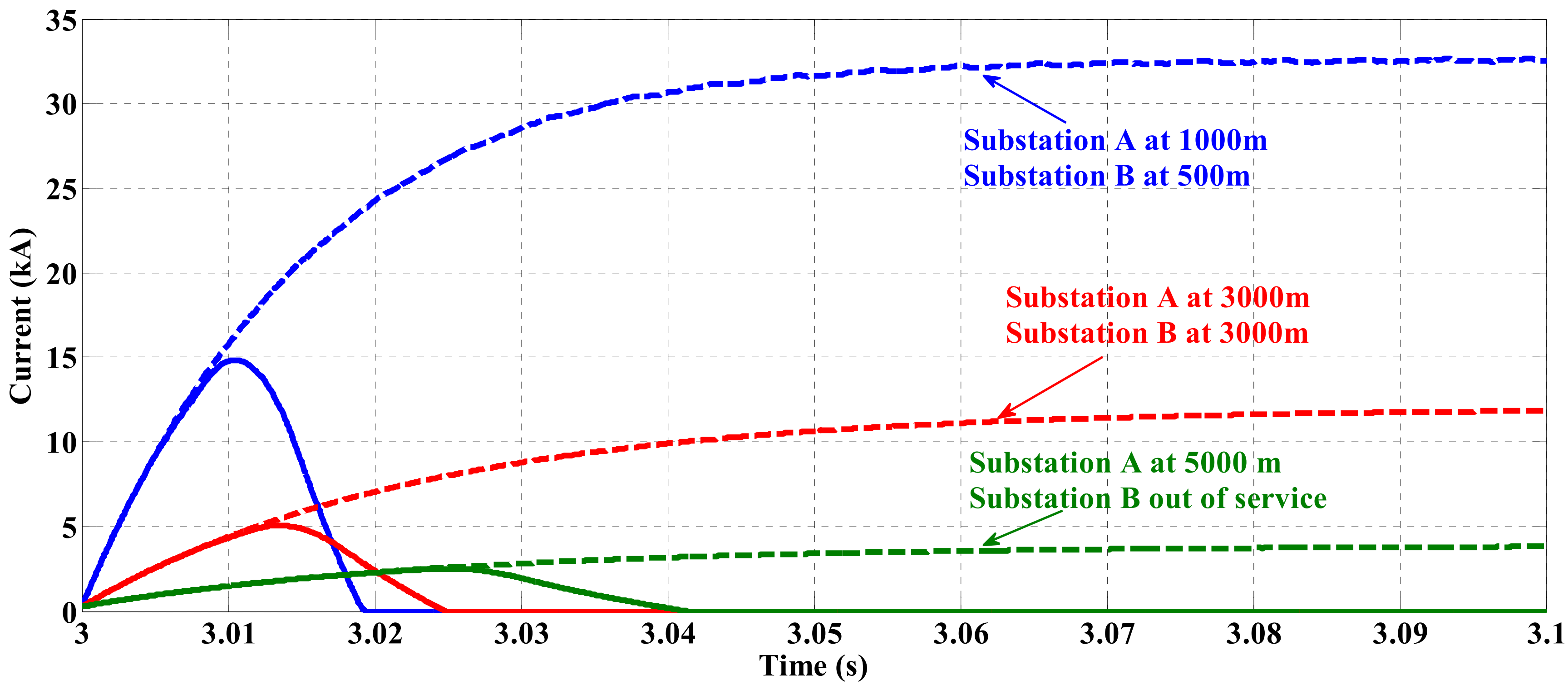
Case Study
Case #2 – Fault current and HSCB operating time (different location)

- In all cases, the HSCB clears the fault.
- Track inductance increases the fault clearing time.



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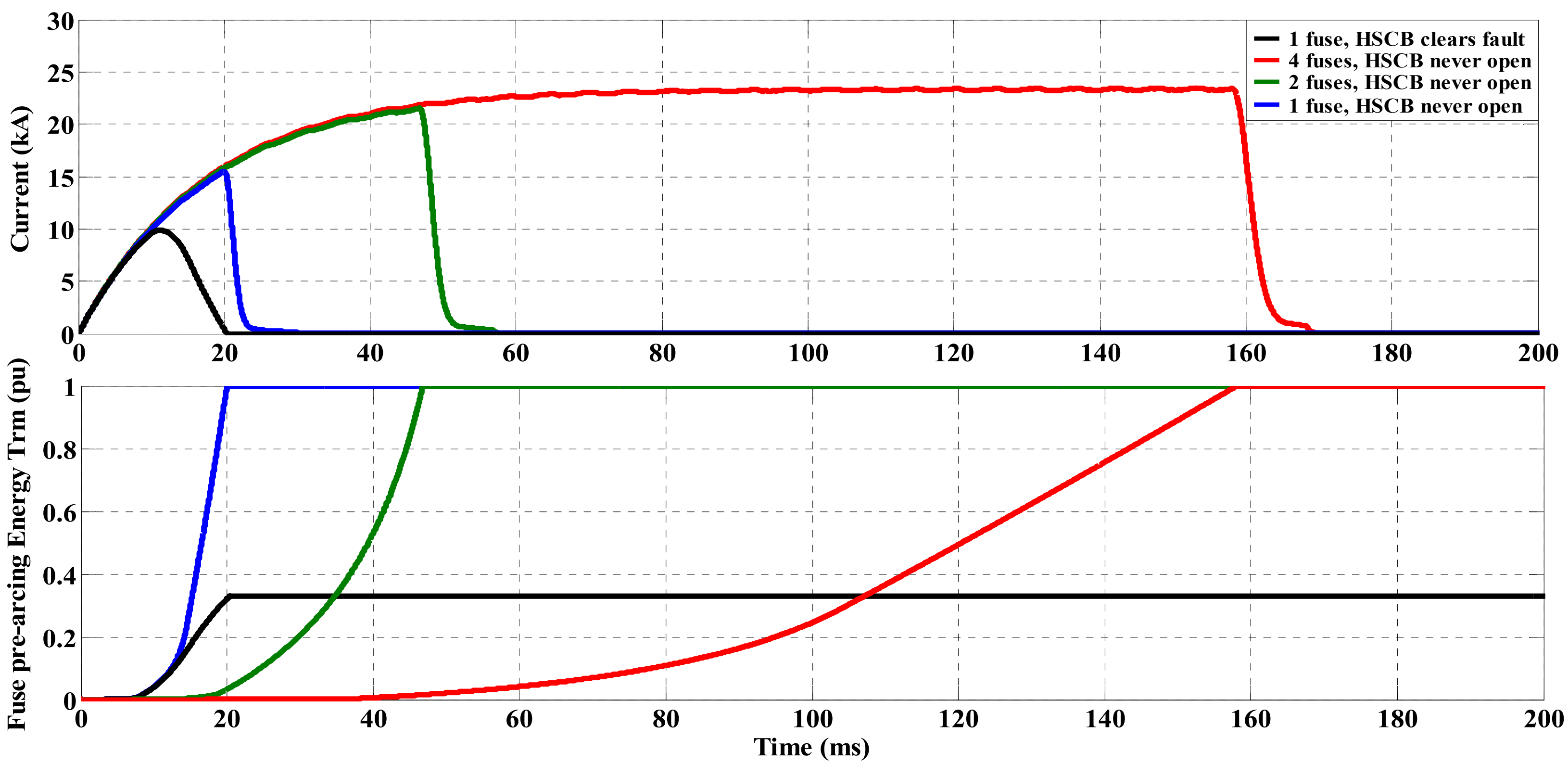
Case Study
Case #3 – Different car configurations and operating conditions

- **Black**: Selectivity of a single fuse in series with the HSCB
- **Red**, **Green**, **Blue**: (4), (2) or (1) fuse sharing the current



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Conclusion

- By working closely with transit authority, fuse and HSCB manufacturers, the proposed tool could be used by railcar design engineers to study the performance of primary power protection.

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Q&A

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