FUTURE DC RAILWAY ELECTRIFICATION SYSTEM
Go for 9kV
Observation: In France, 6000 km of overhead-line supplied by 1.5 kV DC system need to be renovated:

- The same electrification system or converted to 25 kV AC.
- New MVDC electrification system.
Why looking to a MVDC Railway Electrification System?

To mix advantages of the existing electrification systems
- Power sharing between substations.
- Three-phase power supply from public grid.
- Simple locomotive on-board power converter.
- Light overhead line and no inductive voltage drop.

Power electronics is mature enough
- HVDC power converters.
- Solid State DC Circuit Breakers.
- MV drives for industrial motors are commercially available.
- SiC power semi-conductors enable the realization of compact MV traction converters.

A real breakthrough for the future of rail transportation
- A solution for countries not yet electrified.
- A solution for DC lines renewal (copper savings, energy efficiency increase).
- Easier integration of MVDC smart grid concept.
INTRODUCTION

New Medium-Voltage DC Railway Electrification

Determining substations distance and overhead-line cross-section

- Railroad traffic
- Train power
- Voltage range

Computational Algorithm

Line parameters

- Overhead-line cross-section versus substation spacing

Electrical and thermal constraints

Computation Results

\( P = 3 \text{MW} \)
\( v = 80 \text{km/h} \)
\( \text{Tim.} = 5 \text{min.} \)

\( P = 12 \text{MW} \)
\( v = 280 \text{km/h} \)
\( \text{Tim.} = 5 \text{min.} \)


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Electrification Conversion Strategy (from 1.5 kV DC to 9 kV DC)

Case Study (Bordeaux-Hendaye line)

Conclusion and future work
Existing solution: 1.5 kV DC Railway Electrification System

- Low substation distance.
- Heavy overhead line, cross-sections up to 1000 mm$^2$.
- System originally developed for low power rolling stocks.
First step: Three-wire supply system 9 kV -1.5 kV

- 9kV transformer-rectifier groups and feed-wires are added.
- Intermediate 1.5kV transformer-rectifier groups are replaced by DC-DC PETs.

PET : Power electronics transformer.
Final step: 9 kV DC Railway Electrification System

- Overhead-line supplied by 9kV substations.
- 1.5 kV DC transformer-rectifier groups and PETs completely removed.
- DC-DC PETs or/and MVDC converter embedded in the traction-unit.
- The overhead-line cross-section is reduced.
- The number of substations is reduced.
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Conclusion and future work
CASE STUDY: Bordeaux-Hendaye line

Railroad traffic
- Trains from St. Paul to Lamothe
- Trains from Lamothe to St. Paul

Absorbed Power by trains

Average overhead line cross-section = 850mm²
- 6 substations

Original power supply 1.5 kV

LAMOTHE
- km 47
- km 67
- km 89
- km 108
- km 126
- St PAUL
- km 147

Feed-wire(s)
- Messenger wires
- Contact wires

Pantograph voltages
- ∆V = 30%

Traction Power derating Under 1300 V

Railroad traffic

Future DC Railway Electrification System – Go for 9kV
CASE STUDY: Bordeaux-Hendaye line

Three-wire supply system 9 kV/1.5 kV

- Average overhead line section 850 mm² per track.
- 2 substations and 4 PETs.
- Feed-Wires: 2 x 150 mm².
CASE STUDY: Bordeaux-Hendaye line

9 kV DC

- Overhead line cross-section per track: 266 mm²
- Substations distance: 100 km

Power supplied by substations 9kV DC

Pantograph voltages

\[ \Delta V = 12\% \]
CASE STUDY: Bordeaux-Hendaye line

Comparison between 9 kV and 1.5 kV system

Specifications

![Graph of railroad traffic for half day](image)

- Red: Trains from St. Paul to Lamothe
- Blue: Trains from Lamothe to St. Paul

![Graph of absorbed power by trains](image)

- Absorbed Power by trains

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CASE STUDY: Bordeaux-Hendaye line

Comparison between 9 kV and 1.5 kV system

Equivalent overhead-line cross-section

\[
\frac{A_{9kV}}{<A_{1.5kV}>} \approx 0.3
\]

\[
< A_{1.5kV} > = 850 \text{ mm}^2
\]

\[
A_{9kV} = 266 \text{ mm}^2
\]

Overhead-line efficiency

\[
\eta_{9kV} = 0.95
\]

\[
\eta_{1.5kV} = 0.89
\]

Total Energy supplied by substations

\[
2.5 \text{ MWh per half day}
\]

Maximum Power supplied by substations

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CONCLUSIONS and FUTURE WORK

Moving to 9kV allows:

• Reducing the copper of the overhead line (70% of the cross-section that is about 20 M€ saved for 100 km).
• Reducing the number of substations compared to 1.5kV DC (about 60% less installed power).
• Increasing efficiency (about 6%).
• Saving 2 GWh per year for 100 km (about 150 k€ per year).

Outlook:

• Very attractive for countries that need to develop an electrified railway network.
• A DC system towards which European railway companies can converge within a long-term.

Work in progress:

• Development of a Power Electronics Transformer based on SiC MOSFETs.
Thank you for your attention

The research team

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