BOMBARDIER
TRANSPORTATION

Propulsion System Configurations in Rail Passenger Transportation Applications

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Bombardier Transportation Americas

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Agenda

1. Introduction to Bombardier Transportation
2. Electric Trains – Typical Configurations
3. Power Equipment Configurations
4. Application of Power Inverters to Propulsion & Dynamic Braking
5. Q&A

BOMBARDIER
Overview

Bombardier is the world's largest manufacturer of both planes and trains, with a worldwide workforce of **70,900**(1) (2) people.

Bombardier is headquartered in Montréal, Canada. Our shares are traded on the Toronto Stock Exchange (BBD) and we are listed on the Dow Jones Sustainability World and North America indexes.

In the fiscal year ended December 31, 2015, we posted revenues of **18.2 billion USD.**

(1) As at December 31, 2015, including contractual and inactive employees. Subsequent to the end of the fiscal year, we decided to take steps to optimize our workforce with a combination of manpower reduction and strategic hiring. These figures do not reflect the planned changes.

(2) 3,950 product development engineering, Corporate office and other employees are not allocated to a reportable segment.

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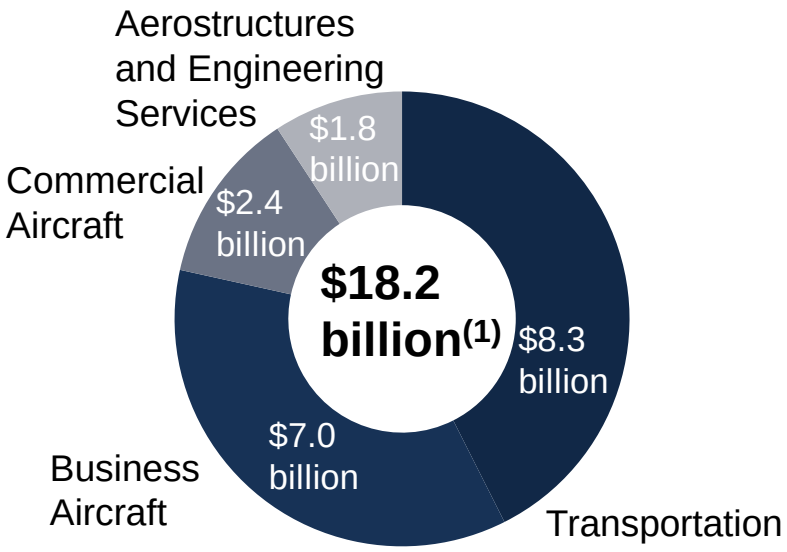
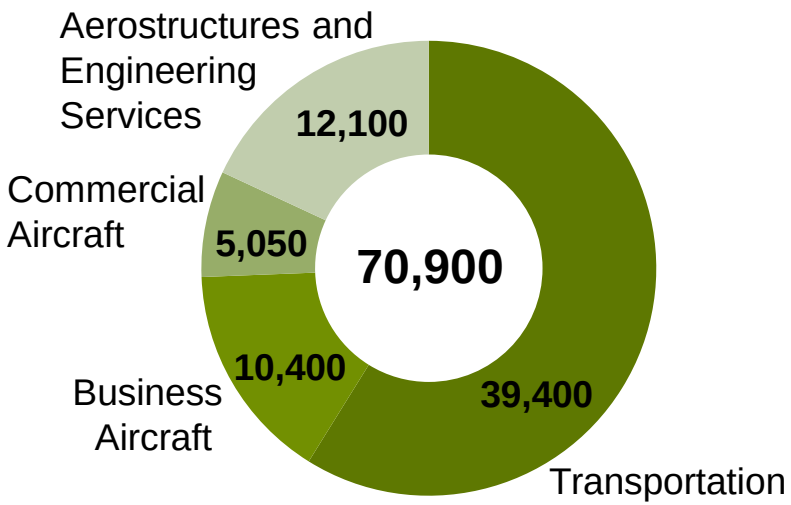
A diversified company

Breakdown by revenues(1)



Breakdown by workforce(2) (3)



(1) For fiscal year ended December 31, 2015. Consolidated revenues $ 18,2 billion.
(2) As at December 31, 2015, including contractual and inactive employees. Subsequent to the end of the fiscal year, we decided to take steps to optimize our workforce with a combination of manpower reduction and strategic hiring. These figures do not reflect the planned changes.
(3) 3,950 product development engineering, Corporate office and other employees are not allocated to a reportable segment.

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BOMBARDIER TRANSPORTATION
A global player with a European base

Revenues 2015(1): $8.3 billion **Employees(2): 39,400**

Global Headquarters

Production Sites

(1) As at December 31, 2015

(2) As at December 31, 2015, including contractual and inactive employees. Subsequent to the end of the fiscal year, we decided to take steps to optimize our workforce with a combination of manpower reduction and strategic hiring. These figures do not reflect the planned changes.

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Bombardier Transportation is a global leader - we have secured strategic orders worldwide against key competitors

156 *FLEXITY* for Vienna & 24 years *FlexCare* $480M **(2015)**

180 *AVENTRA* cars and 35 years of maintenance for Transport for London, $558M **(2015)**

15 CRH380D for China Railways $381M **(2015)**[1]

30 years maintenance on *FLEXITY* for Toronto $308 M **(2015)**

19 *Francilien* trains for STIF and SNCF $141 M **(2015)**

80 high speed sleeper trains for China Railway Corp. $165 M **(2015)**

INTERFLO 450 signalling for V/HS lines of ADIF $185 M **(2015)**[3]

62 *FLEXITY* LRVs for Rheinbahn AG ($135 M) and KVB ($ 68 M) **(2015)**

162 *MOVIA* metro cars for India's Delhi Metro $228 M **(2015)**

INNOVIA APM for Chicago O'Hare International Airport $180 M **(2015)**

62 *TRAXX* Locomotives for Israel Railways $262 M **(2015)**

1,362 Double Deck trains for SNCB $3.6 B **(2015)**[2]

Option for 47 *FLEXITY* LRVs for Berlin Transport Authority $190 M **(2015)**

Option for 40 *FLEXITY LRVs* for Ghent & Antwerp $107 M **(2015)**

1. Bombardier Sifang Transportation, a Chinese entity in which Bombardier holds a 50 % interest, has been awarded a contract with China Railway Corp. (CRC) to supply 15 CRH380D very high-speed trains valued at $381 million
2. BT share valued at $2.3 billion
3. BT share valued at $86 million

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OUR PRODUCTS AND SERVICES
The broadest portfolio in the rail industry

Rail Vehicles

- Light rail vehicles
- Metros
- Commuter trains
- Regional trains
- Intercity trains
- High speed trains
- Locomotives

Transportation Systems

- Driverless Systems: Monorails, Metros, People Movers
- Light rail systems
- Metro Systems
- Intercity Systems
- E-mobility Solutions
- Operations and Maintenance

Services

- Fleet Management
- Asset Life Management
- Material Solutions
- Component re-engineering and overhaul

Rail Control Solutions

- Integrated control systems
- Automatic train protection and operation
- Interlocking systems
- Wayside equipment
- Services

Propulsion & Controls

- Traction converters
- Auxiliary converters
- Traction drives
- Control and communication

Bogies

- Portfolio to match entire range of rail vehicles
- Full scope of service over the lifetime of a bogie

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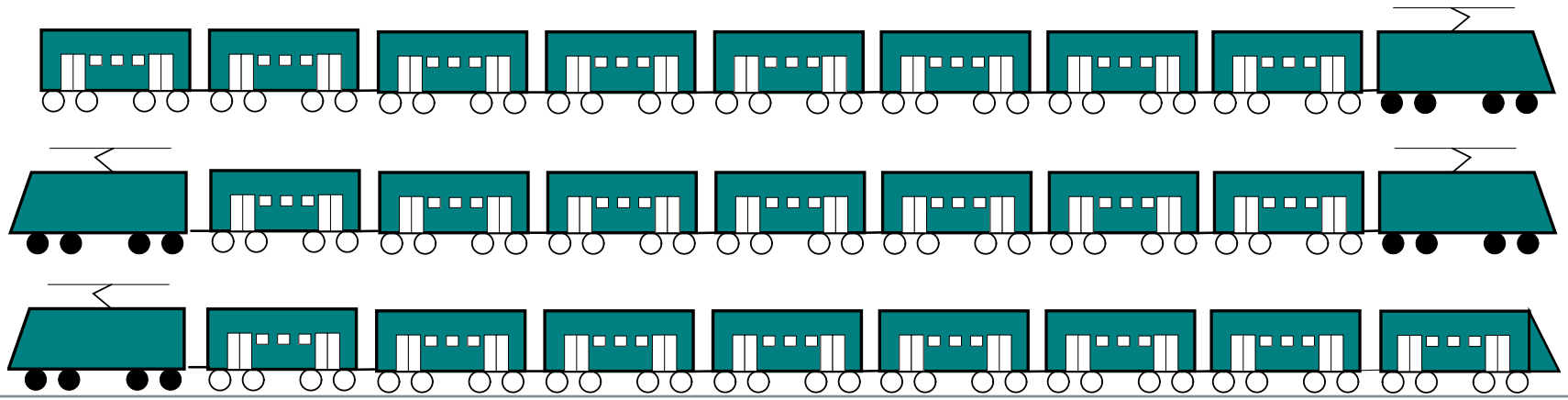
Typical Propulsion Configurations

Mainline trains with electric locomotives


New-Jersey Transit
ALP-46A & ML cars

AMTRAK
Acela



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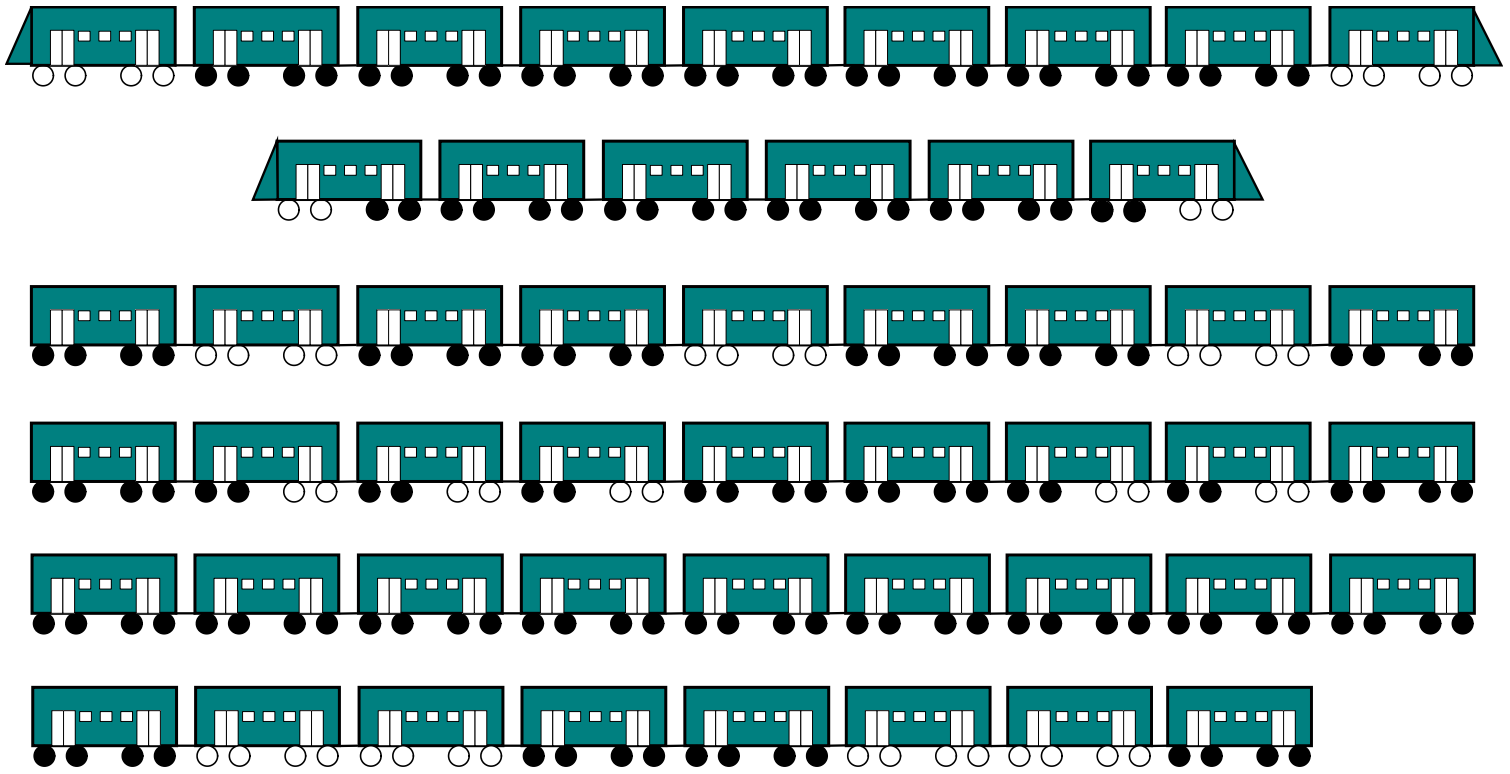
Typical Propulsion Configurations

Metro cars or
Electric Multiple Unit



Montréal
AZUR

Toronto
TTC-Rocket

Montréal
MR-73

New-York
R-142

New-York
M-7

Montréal
MR-90

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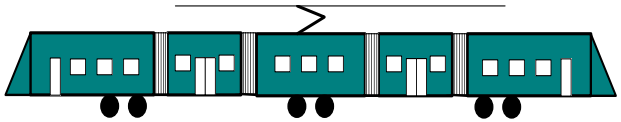
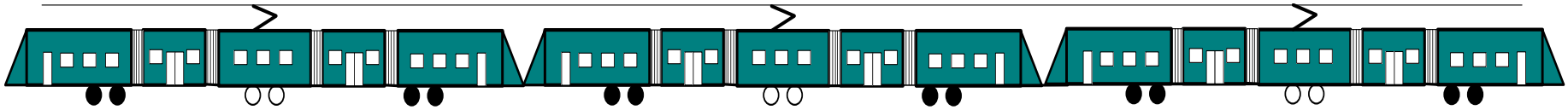
Typical Propulsion Configurations

Tramways and Light Rail Vehicles

TTC Streetcar



Toronto TTC Streetcars



Toronto Metrolinx LRV

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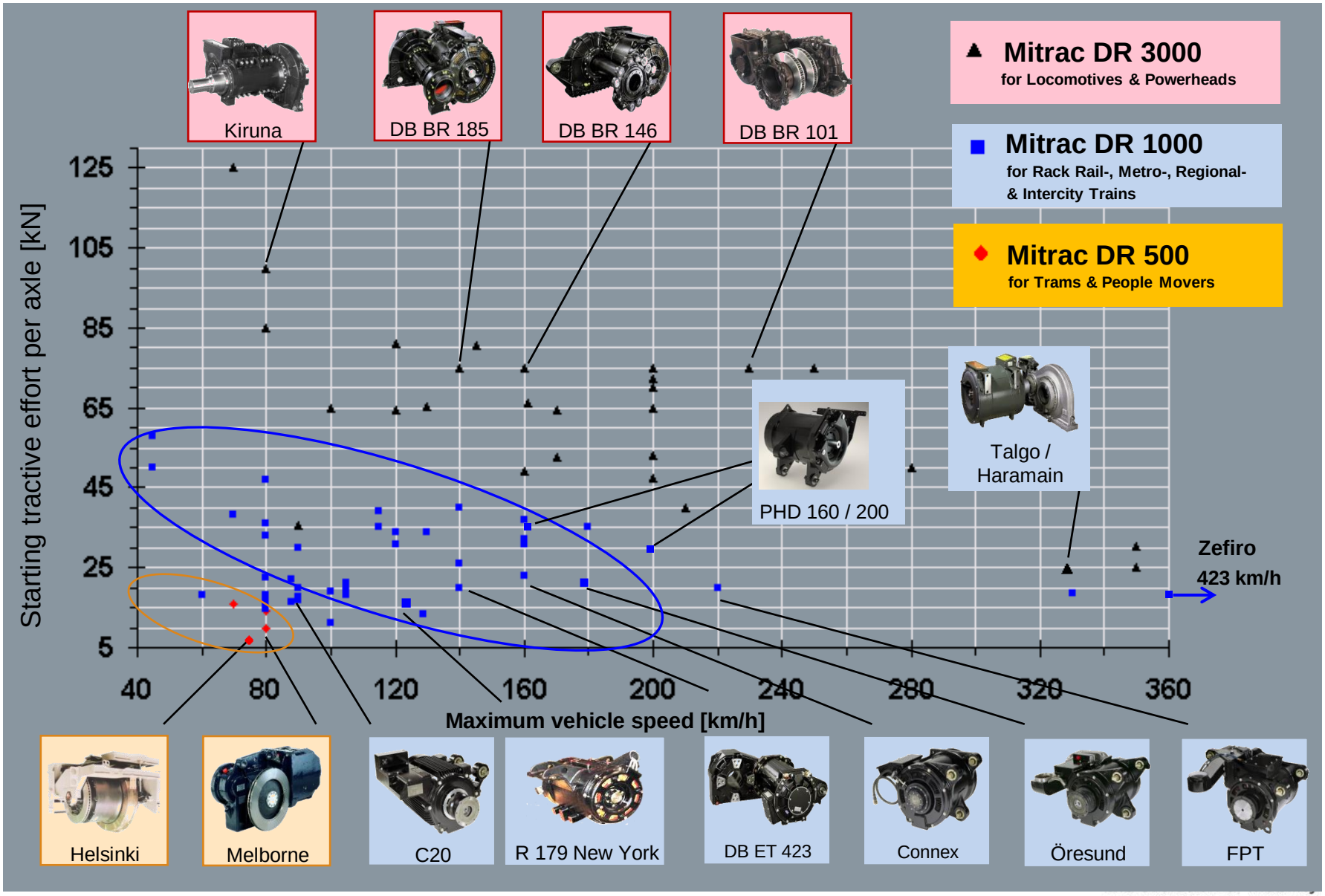
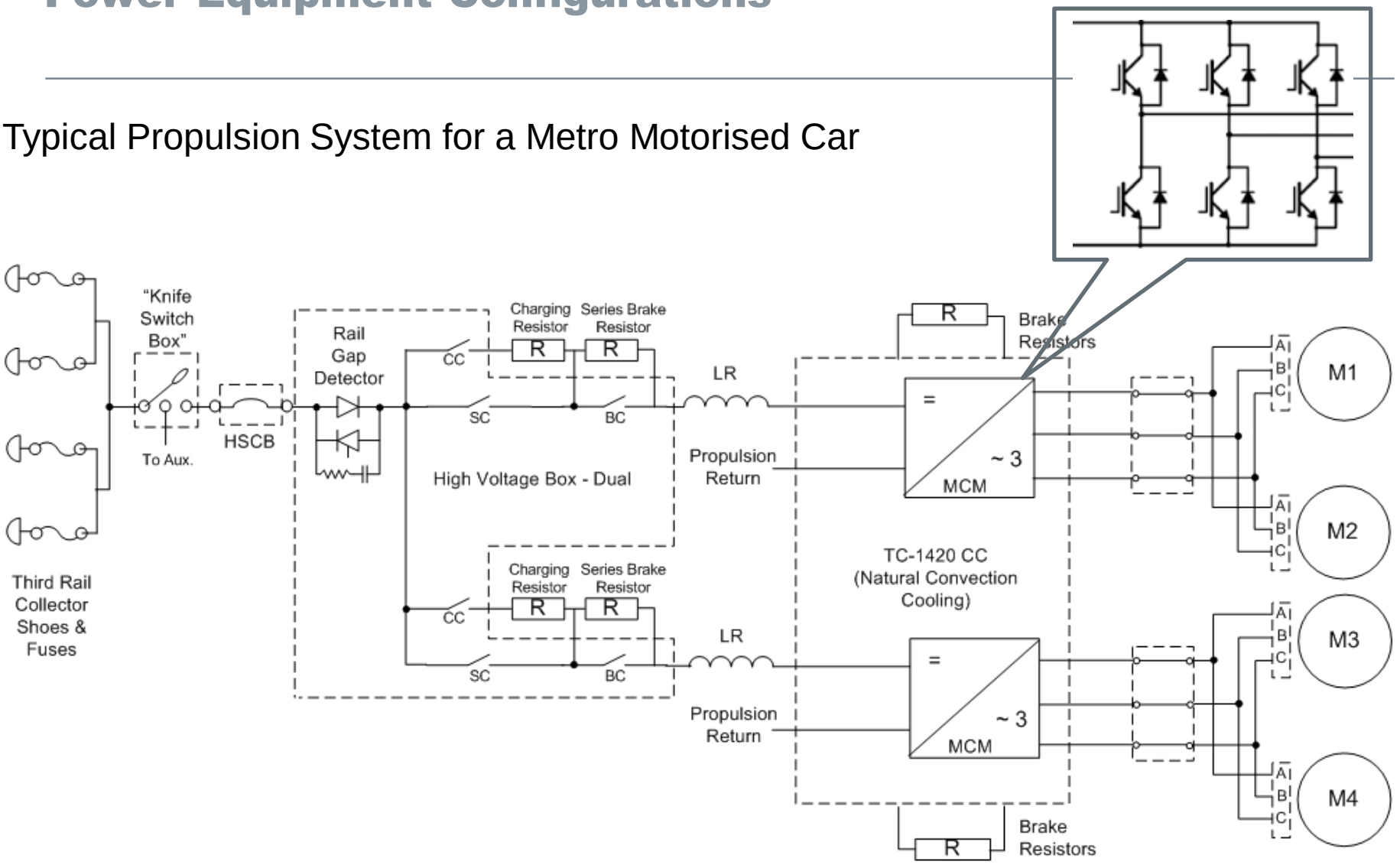
MITRAC Drive Products

Functional Segmentation of Drive Products



Power Equipment Configurations

Typical Propulsion System for a Metro Motorised Car



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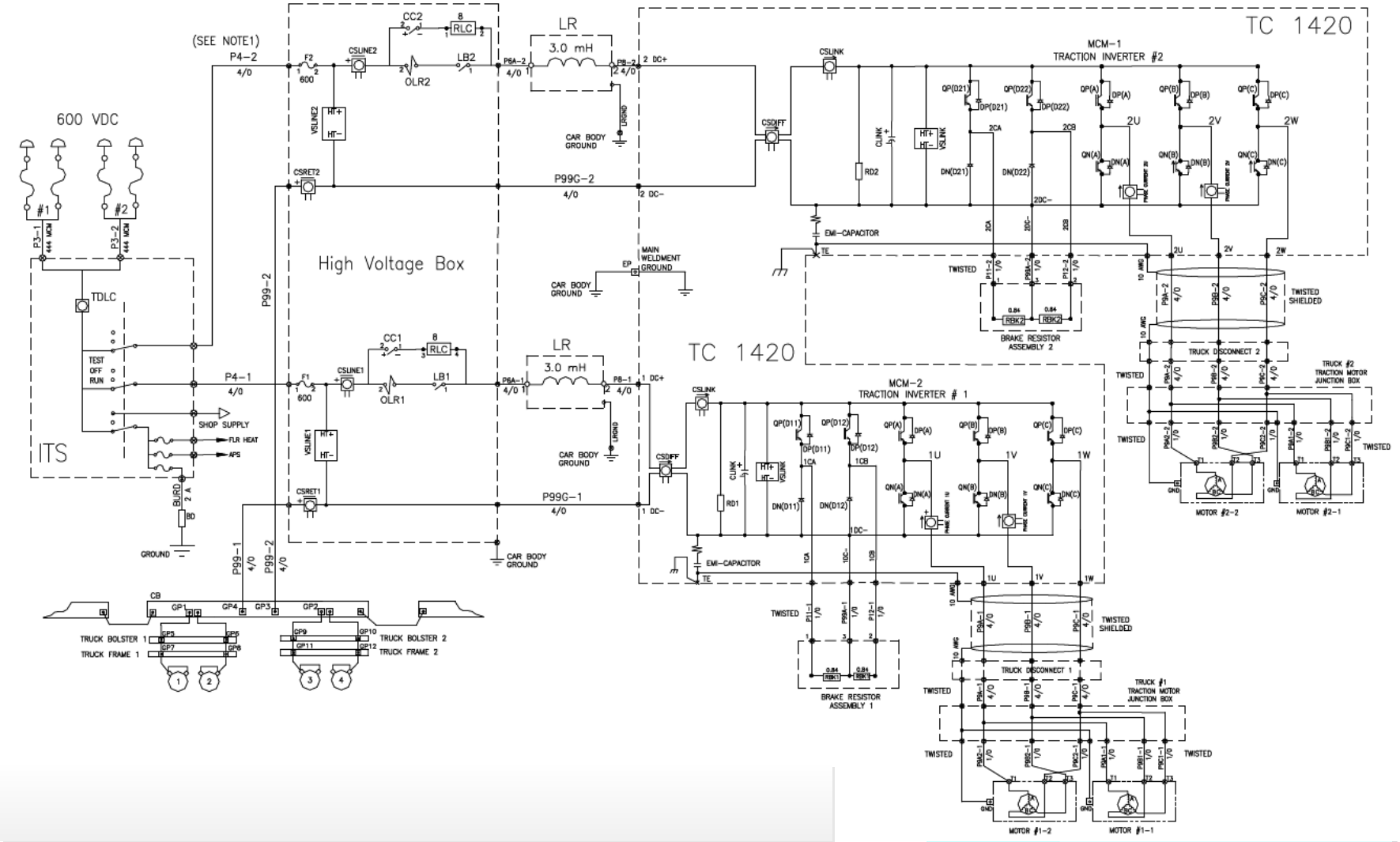
Power Equipment Configurations
Bombardier – TTC Rocket Subway Cars



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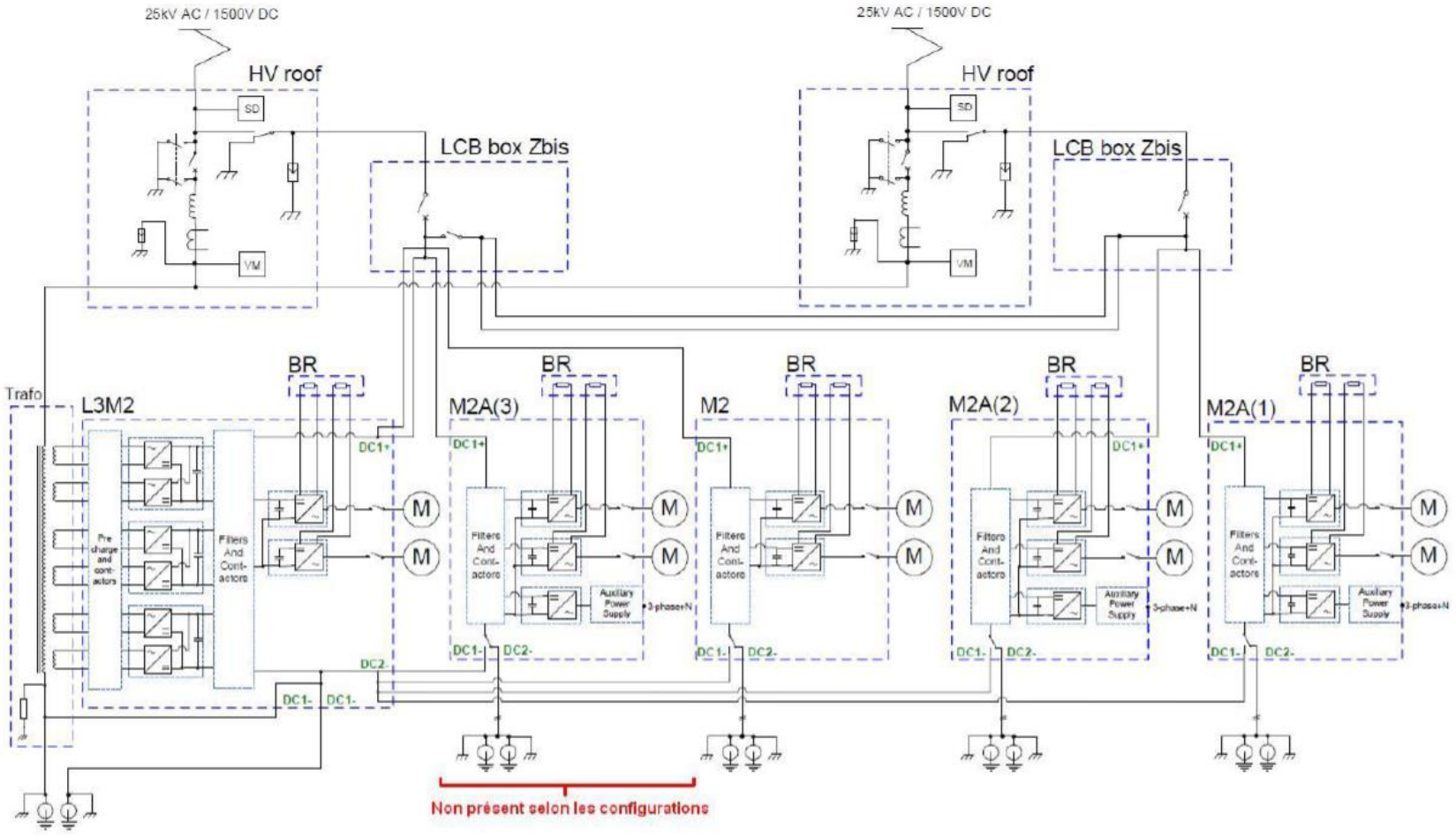
Power Equipment Configurations
Bombardier – Region2N (OMNEO)



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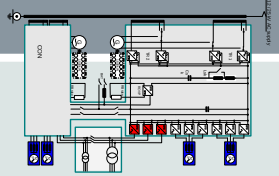
MITRAC Propulsion and Controls
ALP-45 Dual-Power (NAFTA)

Most important facts at a glance:
- 3 System AC application and diesel-electric propulsion
- 1-phase auxiliary and 1176kW Head end power (HEP)
- Very compact design due to limited space
- Optimized for high availability and reliability

Traction converter 3360 DP V01

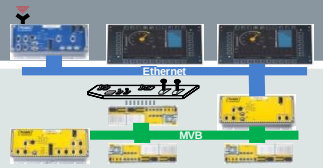


Technical information
Units/vehicle: 1 center unit, 4x1x2m
Type of modules: 4.5 kV HVIM, water-cooled
Line voltages: 12 kV 25 Hz, 25 kV 60 Hz, 12.5 kV 60Hz and/or DIESEL
DC links (quantity, voltage): 2, 2.8 kV regulated. Can be separated into 2 links in case of failure
Tractive effort and max. speed: 316 kN; 200km/h and Diesel up to 160km/h
Auxiliary/trains supply: Integrated 1-phase auxiliary outputs 140kVA and 1176kW HEP 1-phase

Drive 3700F

Technical information
Units/vehicle: 4
Technology: Asynchronous Motor
Type of suspension:
Fully suspended TM 3700F V01 and GB 3700I V02 (ALP-46: 160km/h or ALP-46A: 200km/h)
Motor housing: Thin sheet housing
Insulation Class: H
Temp. Range: -30 to 40°C

TCMS (Safe and regular control)



Technical information
TCMS: Regular and Safe Control function in integrated system
UIC 556 5th edition: Interoperability, Safe inauguration
Vehicle Communication: Safe and regular communication WTB, ETH, MVB Train to Wayside Communication: Wi-Fi, 2G, 3G, 4G
Safe Data Visualization: Safe Display areas
Homologation: Homologated base functionality, Independent safe processing

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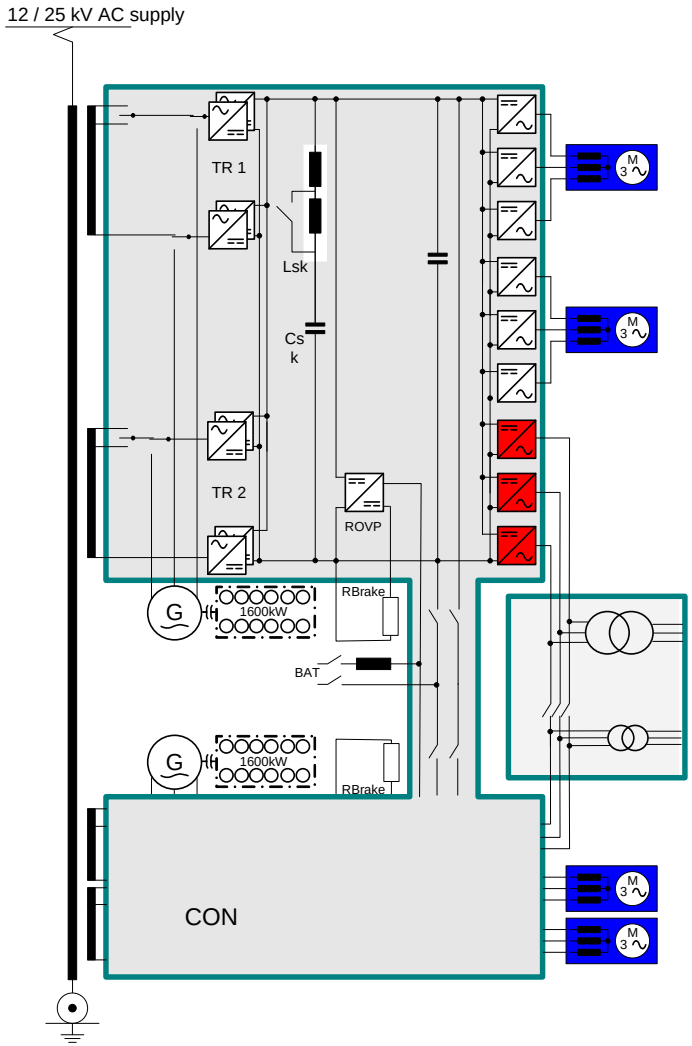
Power Equipment Configurations
Bombardier ALP-45DP Dual Mode Locomotive



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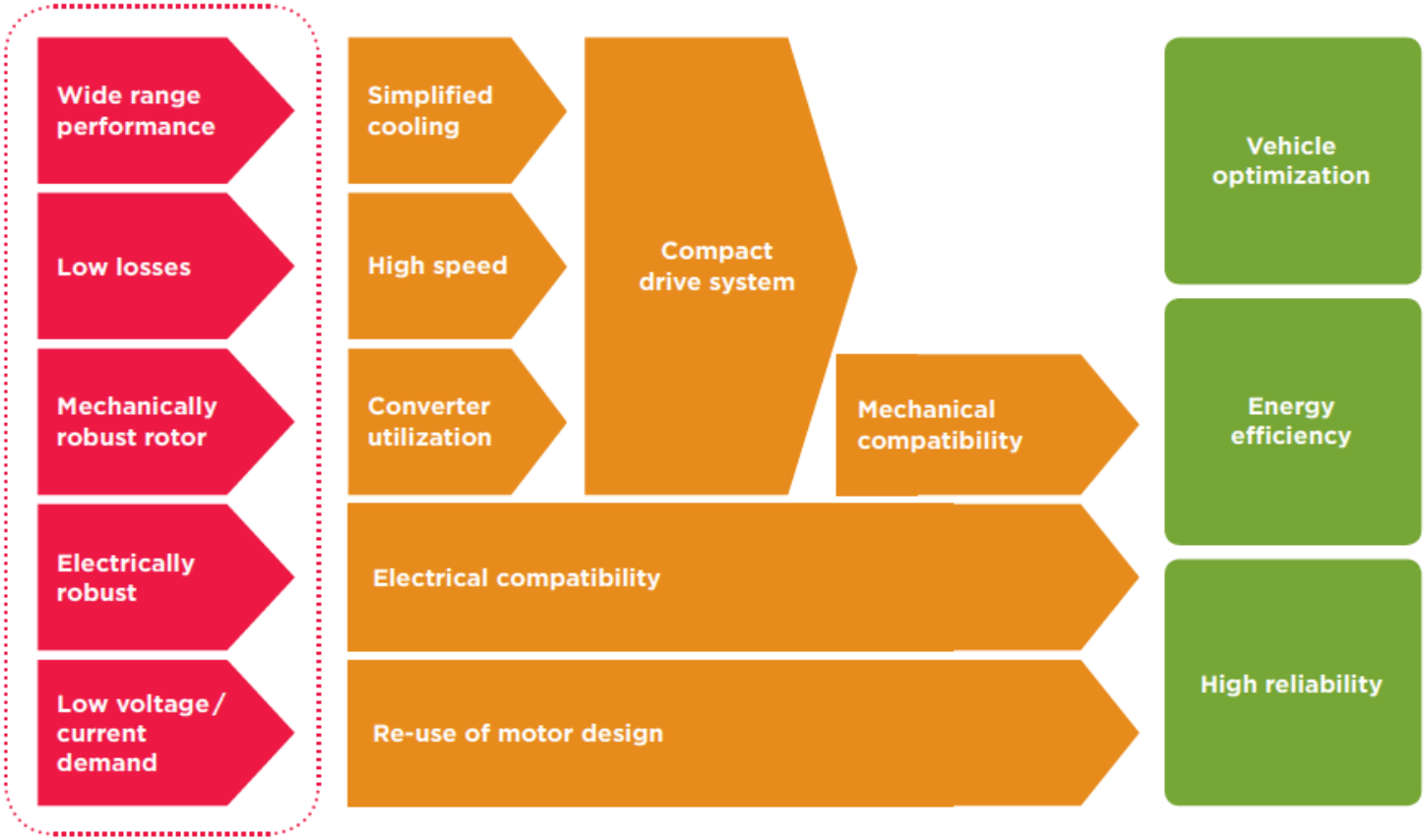
MITRAC Permanent Magnet Motor
Advantages at a Glance



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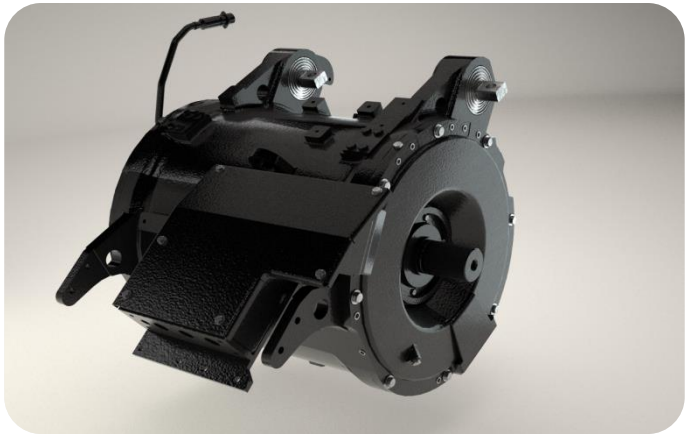
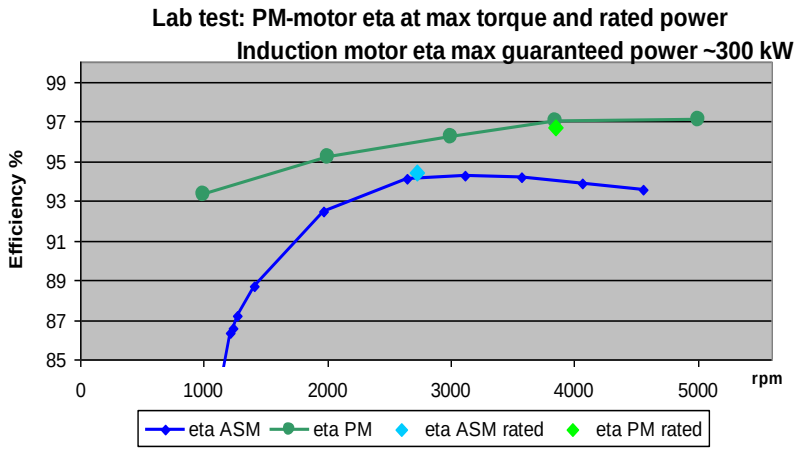
MITRAC Permanent Magnet Motor

MITRAC TM1810PW permanent magnet motor for *TWINDEXX*





Characteristics

- Rotor must not be magnetised in service
- No rotor losses
- Better weight / torque relations compared to inductions motors

Advantages

- Compact motor design gives space in the bogie
- Higher efficiency: 2.6% better than inductions motors

Disadvantage

- 15 to 25% higher initial costs
- Single converter necessary (every motor needs a converter for control)
- Maintenance workshop has to be trained (slipping in a rotor => forces up to 1t)

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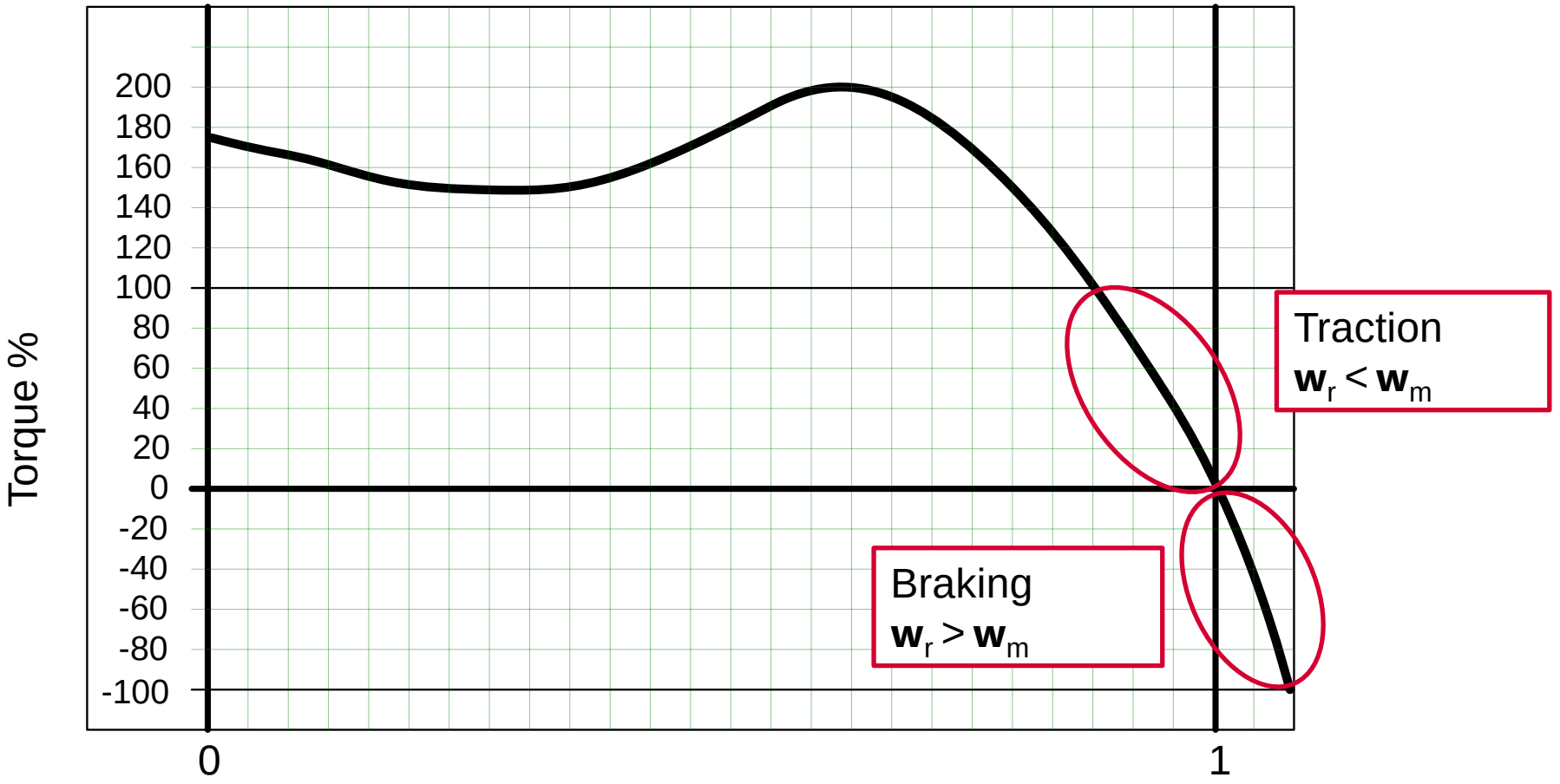
Power Equipment Configurations

Application of a VVVF inverter to an asynchronous traction motor



The switching of the VVVF inverter allows the use of the induction motor in propulsion or in dynamic braking.
Mechanical rotation of the motor versus the frequency switching (rotating field) allows this control.

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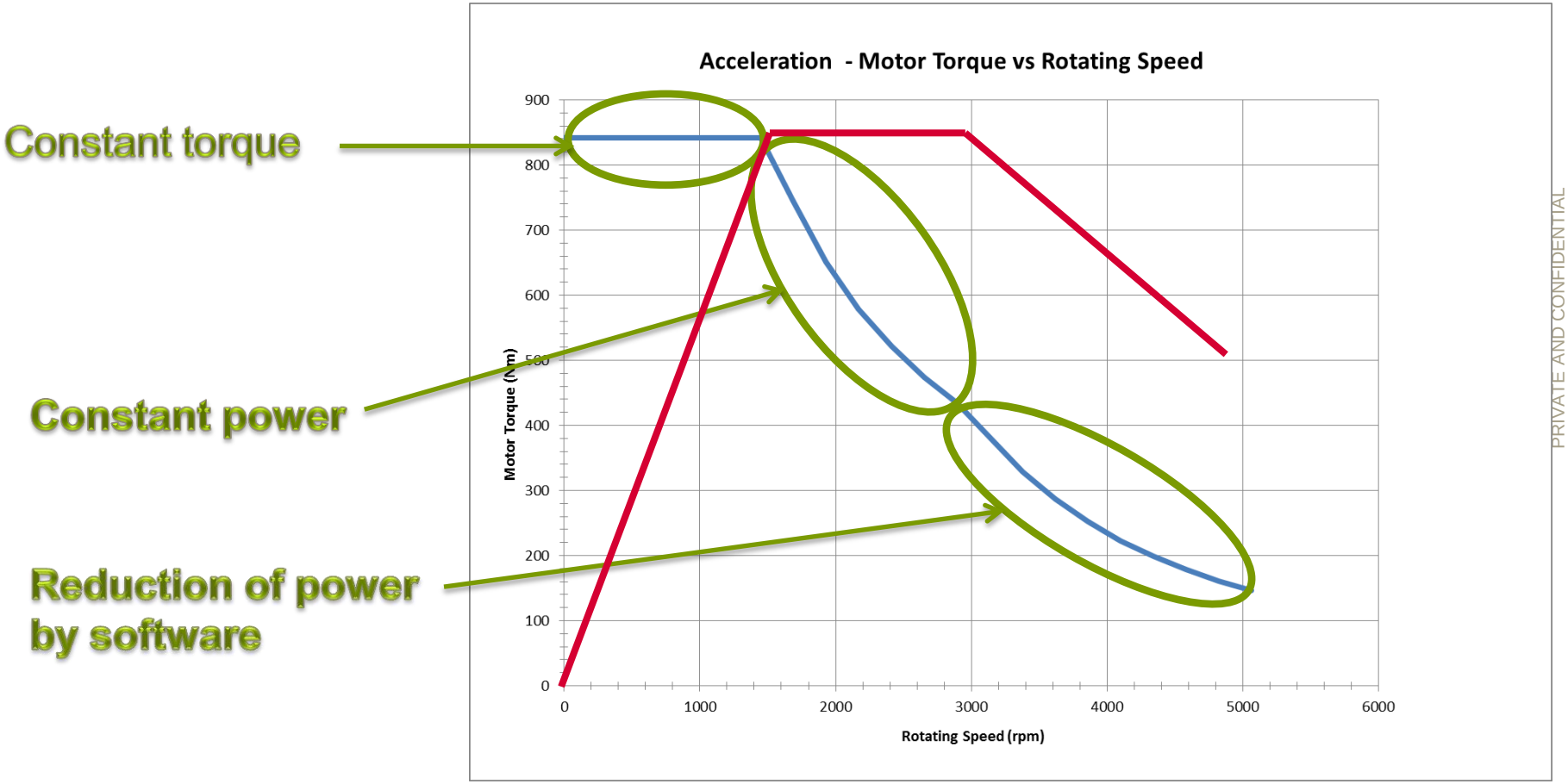
Application of Power Inverters to Propulsion & Dynamic Braking

Typical traction torque curve of a propulsion system using a VVVF inverter combined with asynchronous traction motors



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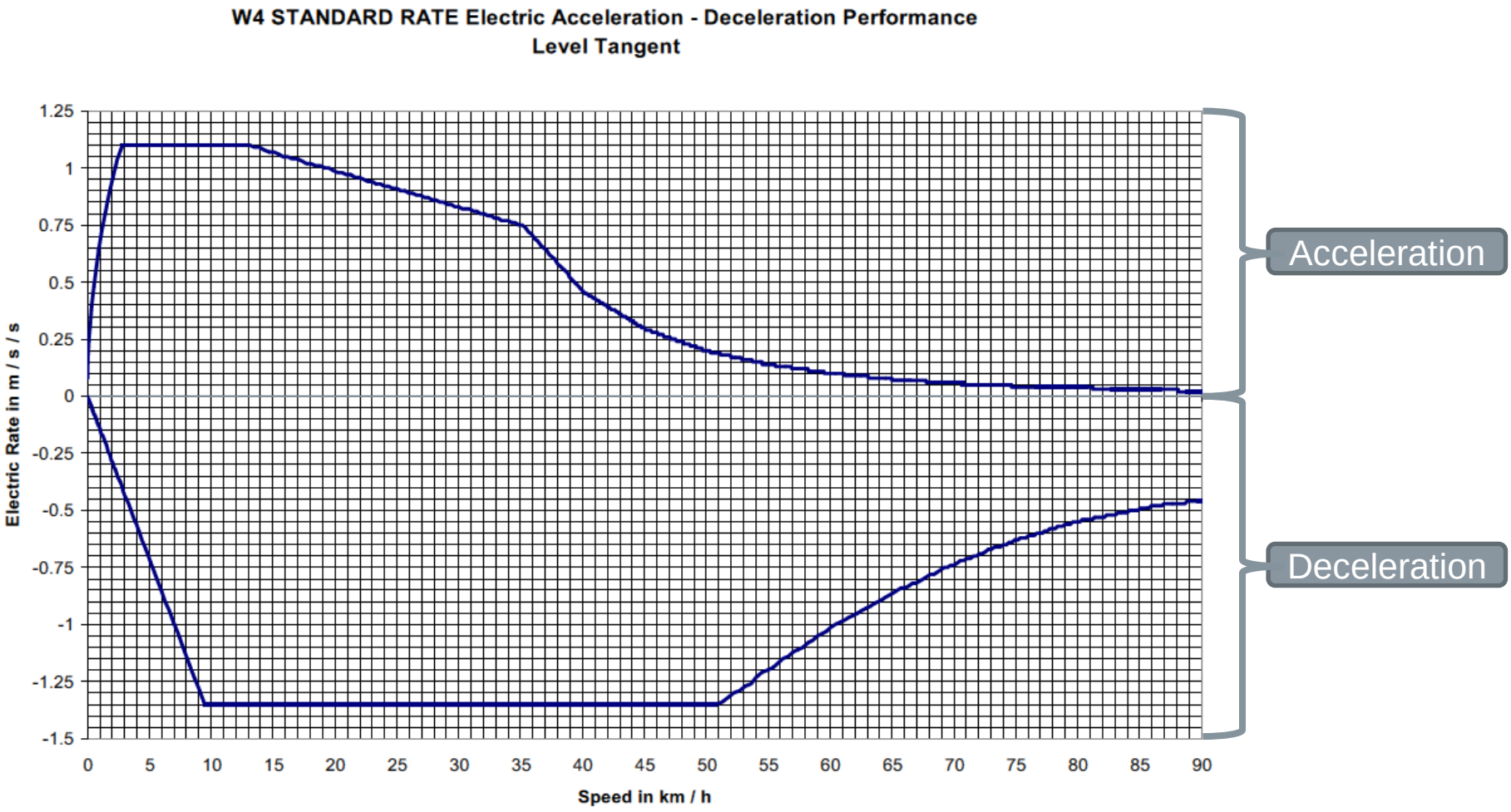
Power Equipment Configurations
Example one: TTC Rocket Subway Car



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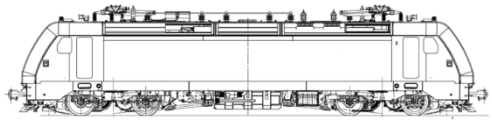
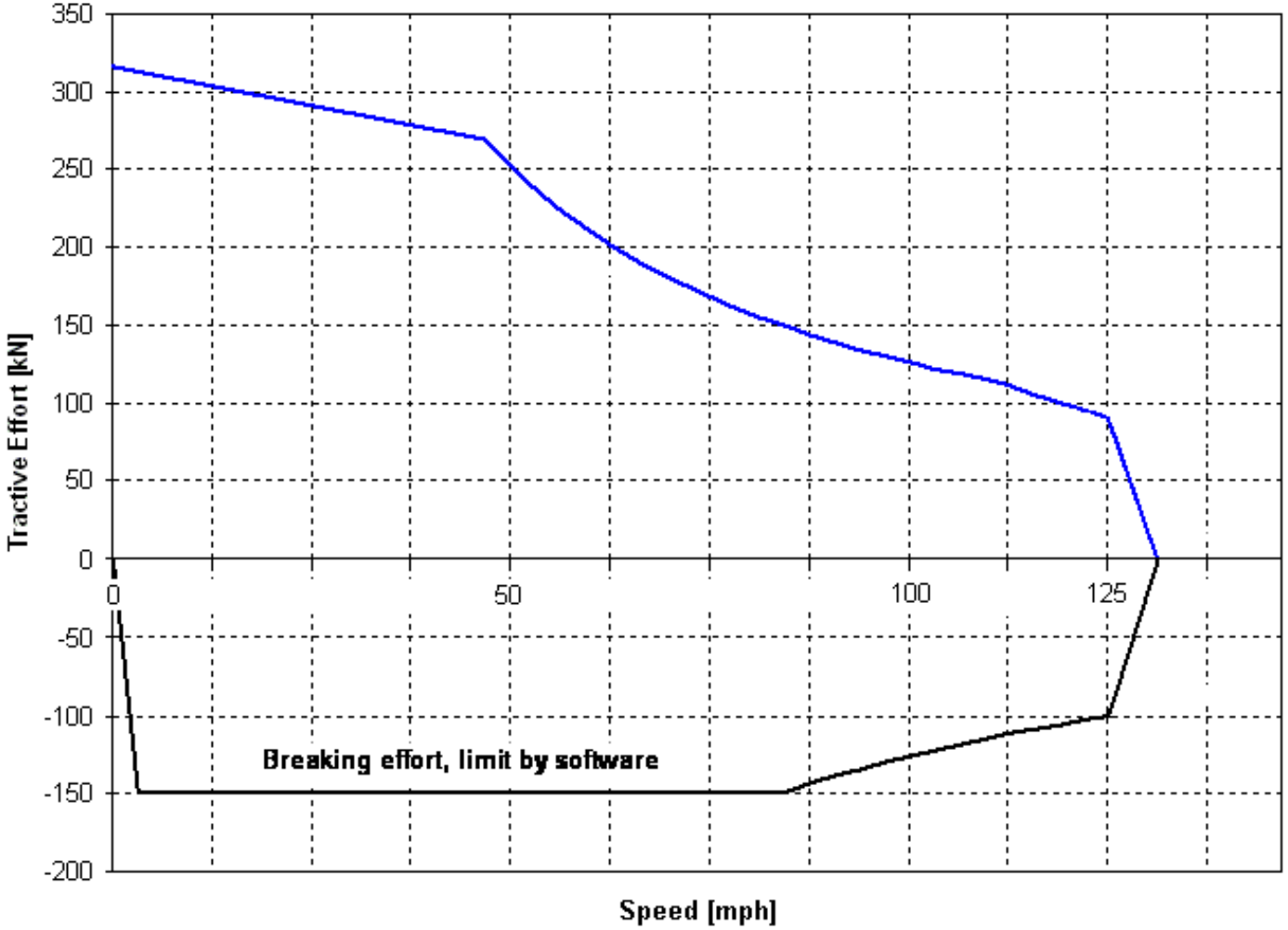
Power Equipment Configurations
Example two: ALP-46A Locomotive





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