

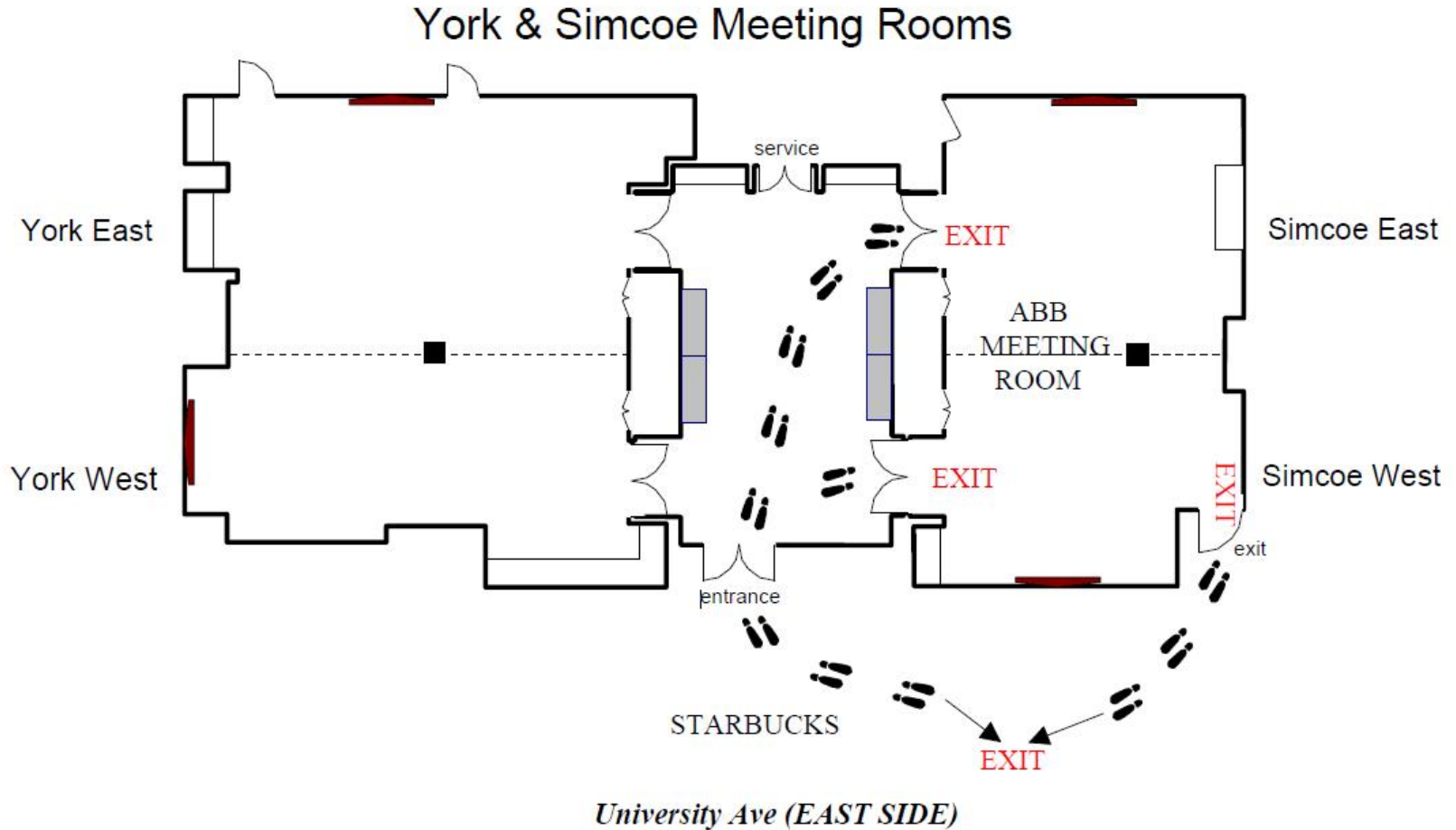


Toronto: October 18, 2016

Rail and Transportation Expert Day

Sustainable choices that improve operations and eliminate downtime

Rail and Transportation Day Safety



Agenda

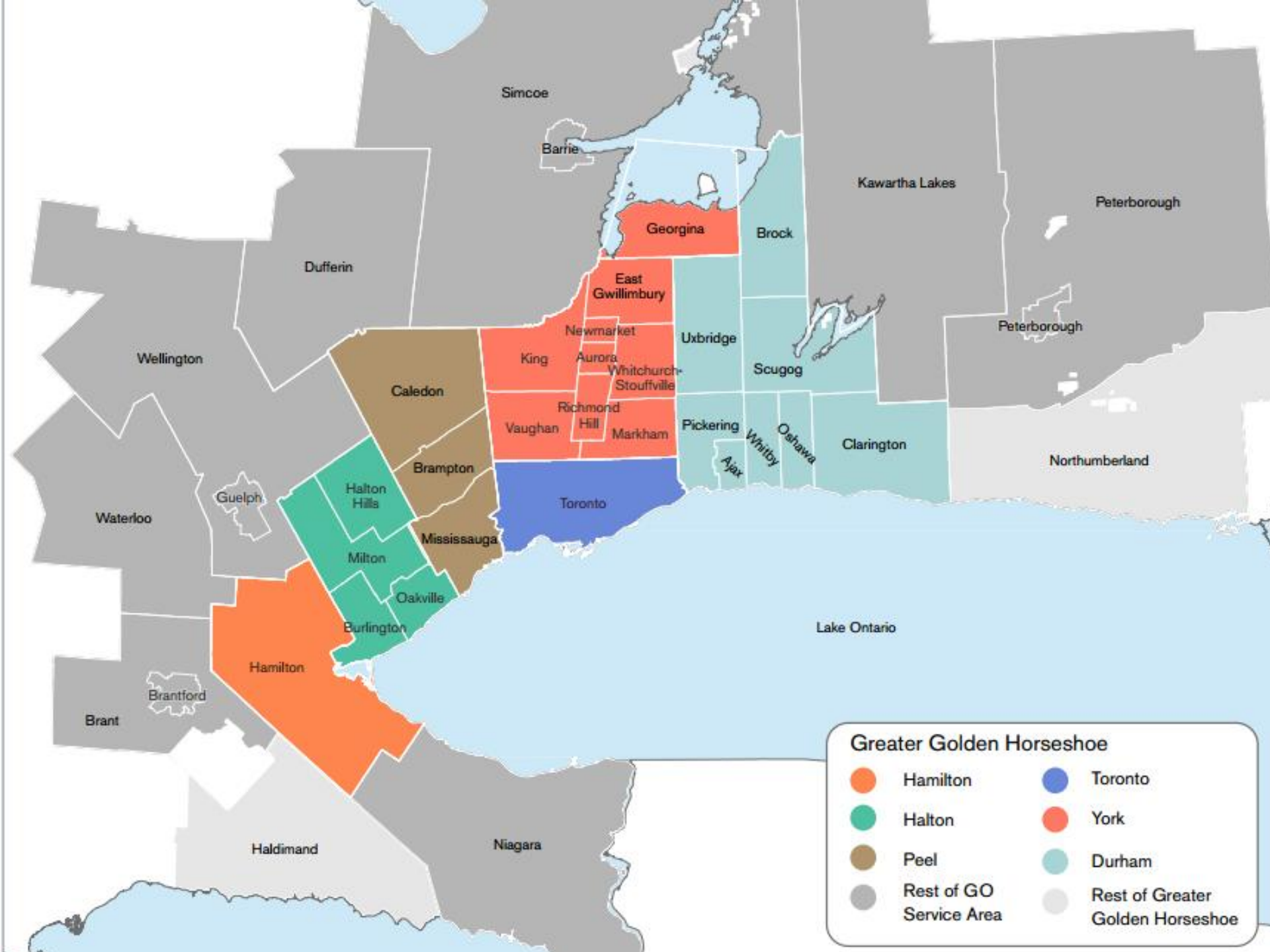
| | |
|-------------|---|
| 9:30-9:45 | Welcome |
| 9:45-10:15 | Keynote: Metrolinx – Transforming the way we move |
| 10:30-11:45 | Session 1: Moving more people and products with fewer resources: Innovative solutions to improve efficiency in rail |
| 11:45-12:30 | Lunch |
| 12:30-2:45 | Session 2: Design considerations for safe and reliable operations in mass transportation |
| 2:45-3:00 | Break |
| 3:00-4:45 | Session 3: Electrification of transportation in response to environmental concerns and urban population growth |
| 4:45-5:15 | Summary and Q&A |

ENTRANCE TO TRAINS

Metrolinx: Transforming the Way We Move

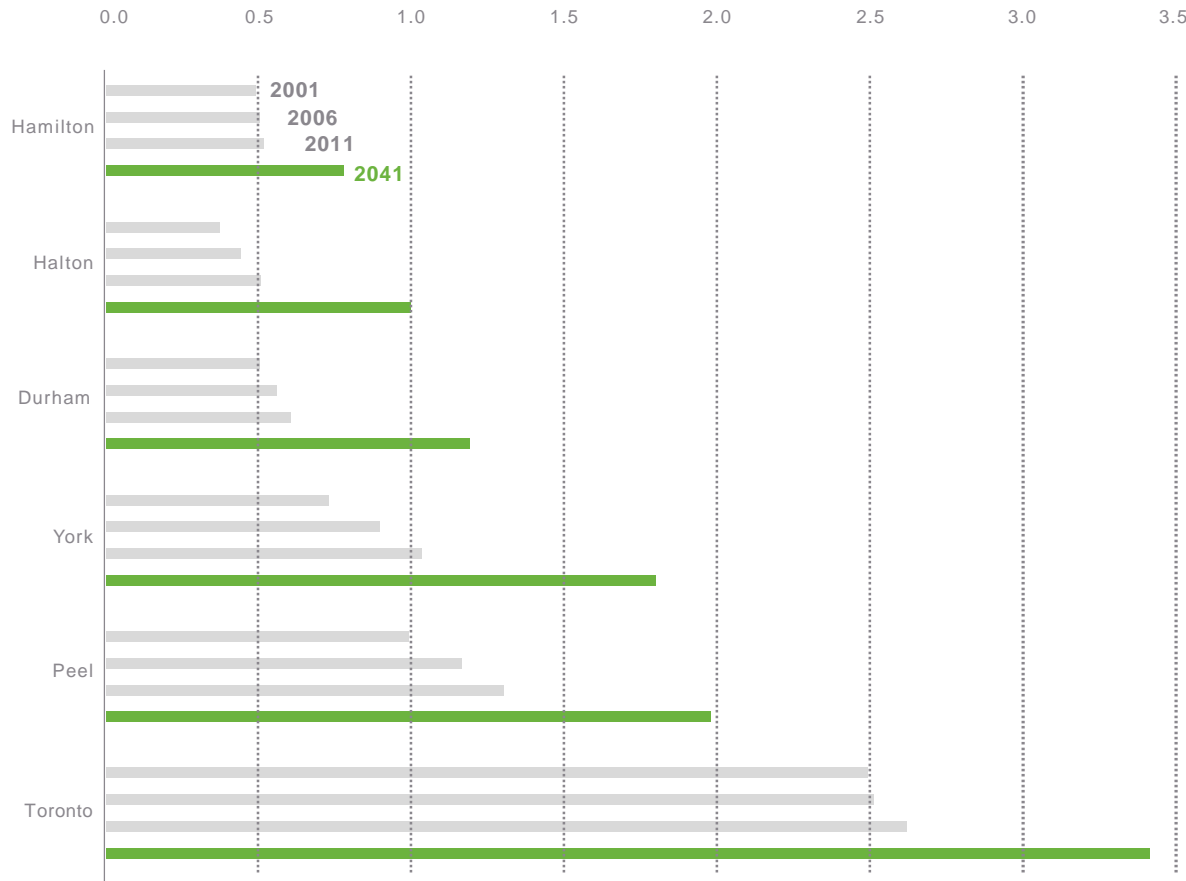
Peter Paz, Manager, Regional Partnerships, Metrolinx

October 18, 2016



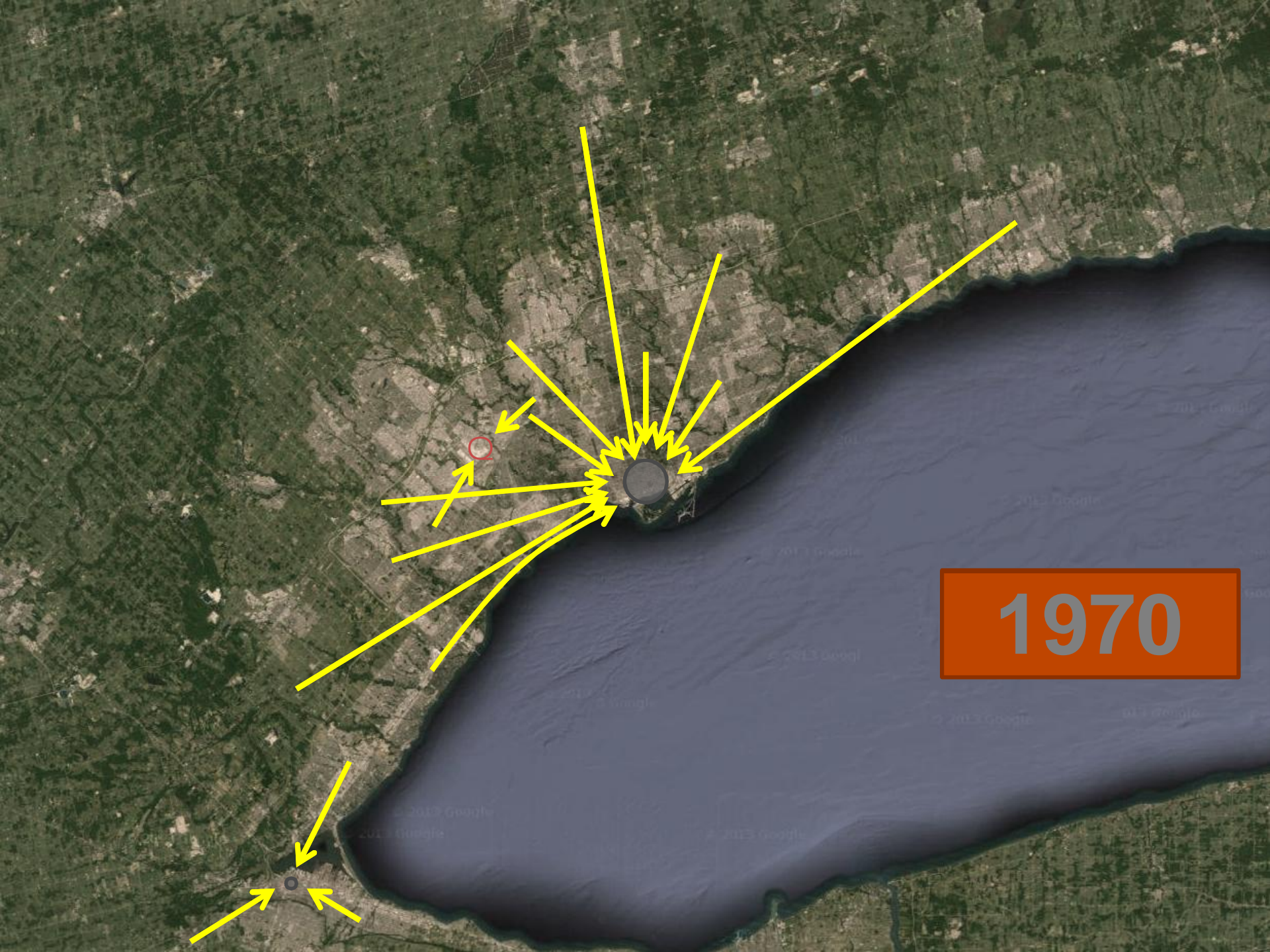
Total Population in the GTHA

Total Population 2001 - 2041

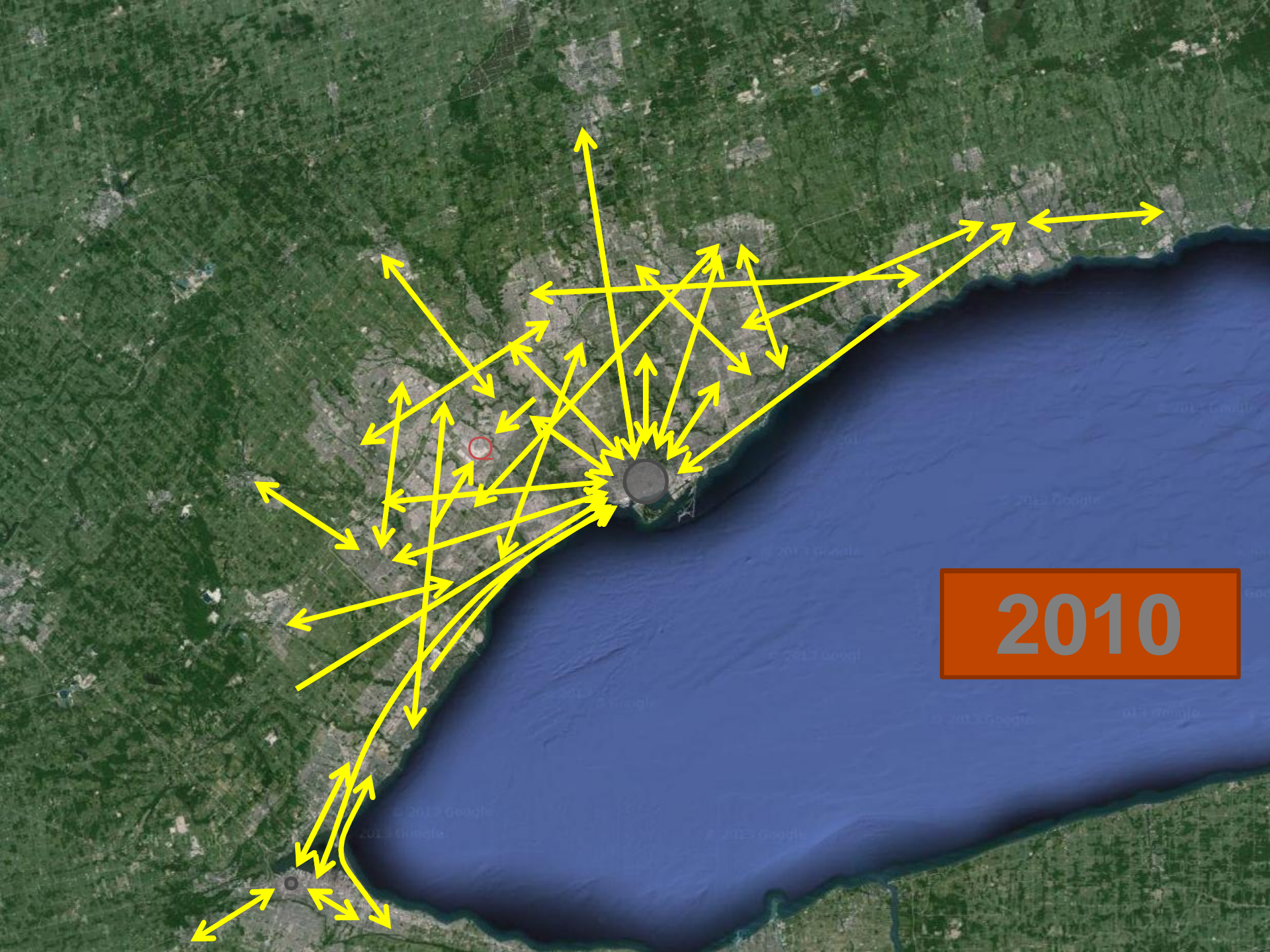


Population Growth 2011-2041

| | |
|-----------------|------------|
| Hamilton | 50% |
| Halton | 99% |
| Durham | 96% |
| York | 73% |
| Peel | 52% |
| Toronto | 30% |



1970



2010



Future



Vaughan

Markham

THORNHILL

SCARBOROUGH

Toronto

NORTH YORK

WOODBRIDGE

Rouge Park

427

401

407

407

3

68

72

71

57

407

400

401

401

401

409

427

427

401

403

A Region under Pressure



Average Commute:
82 minutes



Economic Costs:
\$6 billion



Pollution:
500,000 tonnes

The Issue with Transportation

- § Over 1/3 of GHG emissions
- § Insufficient coordination with land use
- § Casualties and injuries
- § Inequalities
- § Hidden but real costs for governments and households
- § Inefficiency:
 - § For example...





95%

70%



Who is Metrolinx?

Metrolinx was created in 2006 by the Province of Ontario as the **first Regional Transportation Agency** for the Greater Toronto and Hamilton Area.



MINISTRY OF TRANSPORTATION

Mission:

Champion, develop and implement an integrated transportation system for our region that enhances prosperity, sustainability and quality of life



Metrolinx Mandate

Plan



Build



Operate



The Big Move

A **25-year** transportation blueprint
100 priority actions and policies



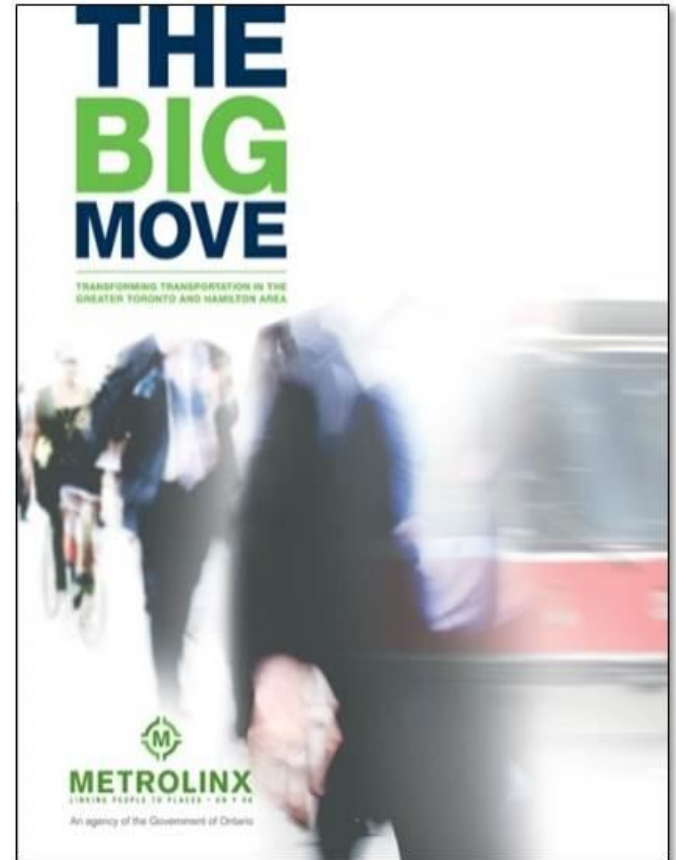
**A high quality
of life.**



**A competitive
economy.**



**A sustainable
environment.**



10 Key Strategies

1. Build a Comprehensive Regional Rapid Transit Network
2. Enhance and Expand Active Transportation
3. Improve the Efficiency of the Road and Highway Network
4. Create an Ambitious Transportation Demand Management Program
5. Create a Customer First Transportation System
6. Implement an Integrated Transit Fare System
7. Build Communities that are Pedestrian, Cycling and Transit Supportive
8. Plan for Universal Access
9. Improve Goods Movement Within the GTHA and With Adjacent Regions
10. Commit to Continuous Improvement

BUILDING THE RAPID TRANSIT NETWORK



EXPANDING GO TRAIN SERVICE

More service on all lines

- Electric trains, **every 15 minutes or better** in both directions, for most GO customers

76 KM of NEW LIGHT RAIL TRANSIT

Under construction:

- **Eglinton Crosstown**

In design / planning:

- **Finch West**
- **Sheppard East**
- **Hurontario**
- **Hamilton**

52 KM of NEW BUS RAPID TRANSIT

Partially in-service, with remainder under construction:

- **Viva** in York Region
- **Mississauga Transitway**

UP Express

Express air-rail link from Union Station to Pearson airport

- Started service **June 6, 2015**

Union Station

Expanding and revitalizing the heart of the regional network

PRESTO

One fare card that connects the region

- Deployed on:
- GO Transit
 - Seven 905 transit systems
 - Ottawa
 - TTC by end of 2016

RER Program Overview

The Project

- Regional Express Rail (RER) is a **\$13.5 Billion 10-year capital program**
- The RER program is scalable. RER can be further expanded upon with new stations, and other regional (and potentially national) rail investment
- RER leverages and improves the performance of most other rapid transit investments

A major feature of the program is the phasing in of electric trains, namely electrical multiple units (EMU's) to provide fast, frequent service within the network. These vehicles will be acquired as part of the capital program



GO RER will reduce travel times and give people more ways to get where they want to go with:

Trains up to every 15 minutes



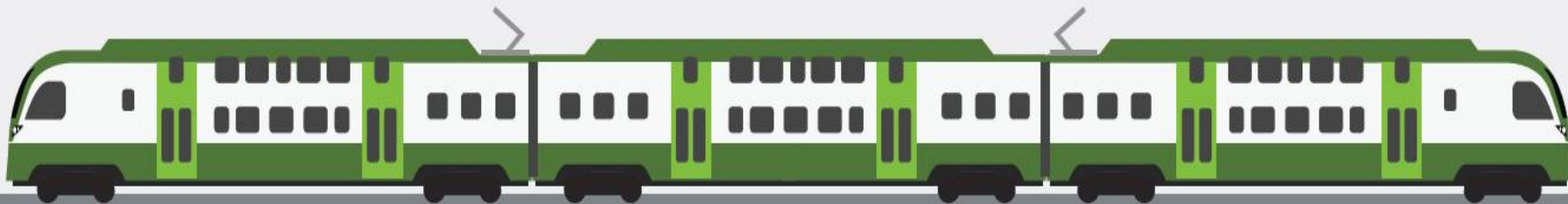
Service in both directions



More all-day service



Faster electric trains

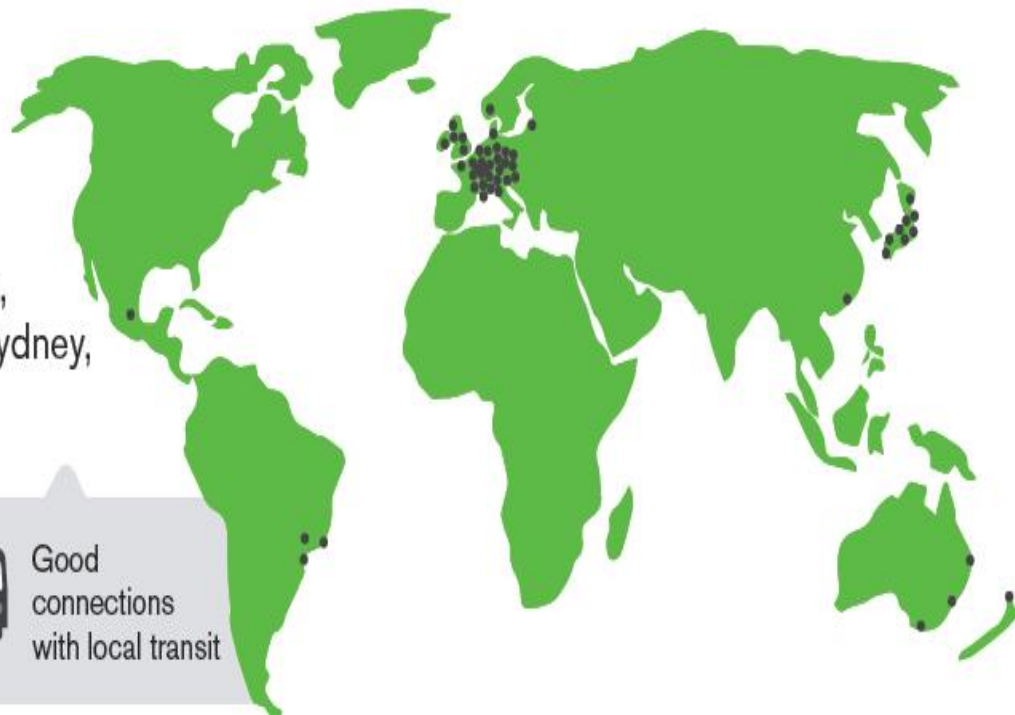


More than

50

large cities across the world use Regional Express Rail systems.

Whether it's the Réseau Express Régional in Paris, the Overground in London, or NSW TrainLink in Sydney, each RER system has these basic traits:



Frequent all-day service



Uses electric trains



Runs on surface rail lines



Good connections with local transit

Major Components of the Workplan

- 1) **Service Concept**, in order to define the frequency and type of service on each corridor
- 2) **Infrastructure Needs**, in order to identify the infrastructure and equipment that will be needed to deliver on the Service Concept
- 3) **Phasing Plan**, to identify the optimal sequencing of infrastructure and service
- 4) **Engagement Plan**, to identify the work necessary to engage stakeholders that include the public, municipalities, and elected officials

RER Service Concept: Weekday Rush Hour (Peak Direction)

EXISTING



RER Service Concept: Weekday Rush Hour (Peak Direction)

GO RER



RER Service Concept: Mid-Day, Evening & Weekend

EXISTING



RER Service Concept: Mid-Day, Evening & Weekend

GO RER



Further service expansion

The following GO rail extensions (in addition to RER) were announced in June 2016 :

- § Two-way all-day rail service to Kitchener
- § Rail service extension from the future Confederation GO Station to Niagara Falls
- § Rail service extension from Oshawa to Bowmanville



Infrastructure Needs

- Delivering RER will require many infrastructure improvements
 - New track and signal enhancements, including enhanced train control
 - Bridge expansions, grade separations and pedestrian crossings
 - Station platform, tunnel and parking expansions
 - Electrification infrastructure (traction power, substations, catenary etc.)
 - Property acquisition and utility relocation
- A number of environmental assessments (EAs), tenders, and construction projects are already underway to deliver the RER program



Rapid Transit - Eglinton Crosstown LRT

- § 19 km long: 10 km underground and remainder running on surface in dedicated lanes
- § Up to 60% faster than current bus service
- § Over 100,000 homes and businesses within 750 metres
- § Coordinated planning along corridor to ensure transit-supportive land use:
 - § “Eglinton Connects” and mobility hub planning
 - § Joint development initiatives in partnership with private sector
- § Tunnelling is complete; station construction now underway



Rapid Transit - Finch & Sheppard LRT

- Funded by \$8.7 billion commitment to Toronto projects from 2010
- Metrolinx to own and TTC to operate

Finch West LRT

- 11 km, connecting Humber College to new Finch West station on Spadina subway extension
- Now in market, three pre-qualified private consortia are responding to an RFP to design, build, finance and maintain
- Construction anticipated from 2017 to 2021

Sheppard East LRT

- 13 km, extending eastwards from existing TTC subway line at Don Mills
- To be constructed following the completion of the Finch West LRT



Rapid Transit - Hurontario & Hamilton LRT

- Funded by *Moving Ontario Forward* GTHA transit fund

Hurontario LRT

- Extending from Port Credit GO to Steeles Ave.
- Includes 22 stops, including connections to two GO Transit lines, Brampton Züm, and the Mississauga Transitway
- Environmental Assessment completed in 2014; anticipated construction start in 2018 and in-service in 2022



Hamilton LRT

- East-west LRT from McMaster to Queenston Circle
- Connections with GO service
- Preliminary design completed in 2013; anticipated construction start in 2019 and in-service in 2024



Rapid Transit - Bus Rapid Transit

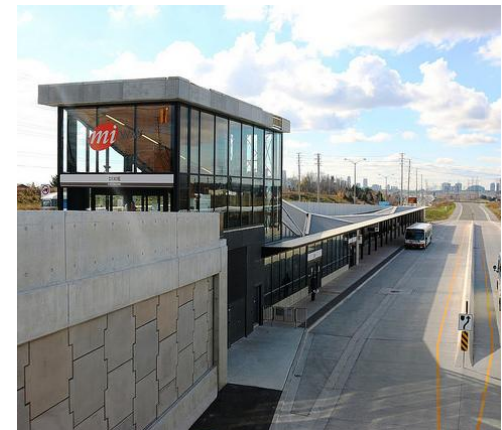
York Viva BRT

- Rapidways — dedicated lanes in the centre of the road — that will allow buses to move out of congested traffic
- Connections with all three GO lines in York Region
- First phase opened August 2013; further segments opening incrementally to 2019



Mississauga Transitway

- New bus-only roadway for MiWay Bus Rapid Transit routes as well as through GO buses
- 18 km east-west corridor spanning Mississauga, with buses travelling uninterrupted beyond the transitway to Pearson Airport and TTC subway
- First phase opened November 2014; further segments opening incrementally to 2017



Planning Future Projects



YONGE RELIEF NETWORK STUDY

- Short, medium and long term solutions to crowding on the TTC Yonge line
- Network-wide review of GO service, new LRT and subway options

YONGE NORTH

- Expansion of Yonge North corridor to Richmond Hill



DURHAM-SCARBOROUGH BUS RAPID TRANSIT

- 36 km route connecting Scarborough, Pickering, Ajax, Whitby and Oshawa



DUNDAS STREET BUS RAPID TRANSIT

- 37 km integrated route from Kipling TTC station to the 407 in Burlington



BRAMPTON QUEEN STREET RAPID TRANSIT

- Review of bus and light rail rapid transit between Downtown Brampton and Vaughan

We continue to work with municipal and regional partners on developing the detailed planning, design and engineering work plans in preparation for future funding commitments.

Significant Progress Has Been Made

- Since *The Big Move*, Metrolinx and its partners have been working at a rapid pace to deliver improvements to public transit, active transportation and road networks
- Most projects are complete or in progress

See Appendix for breakdown by RTP Strategy

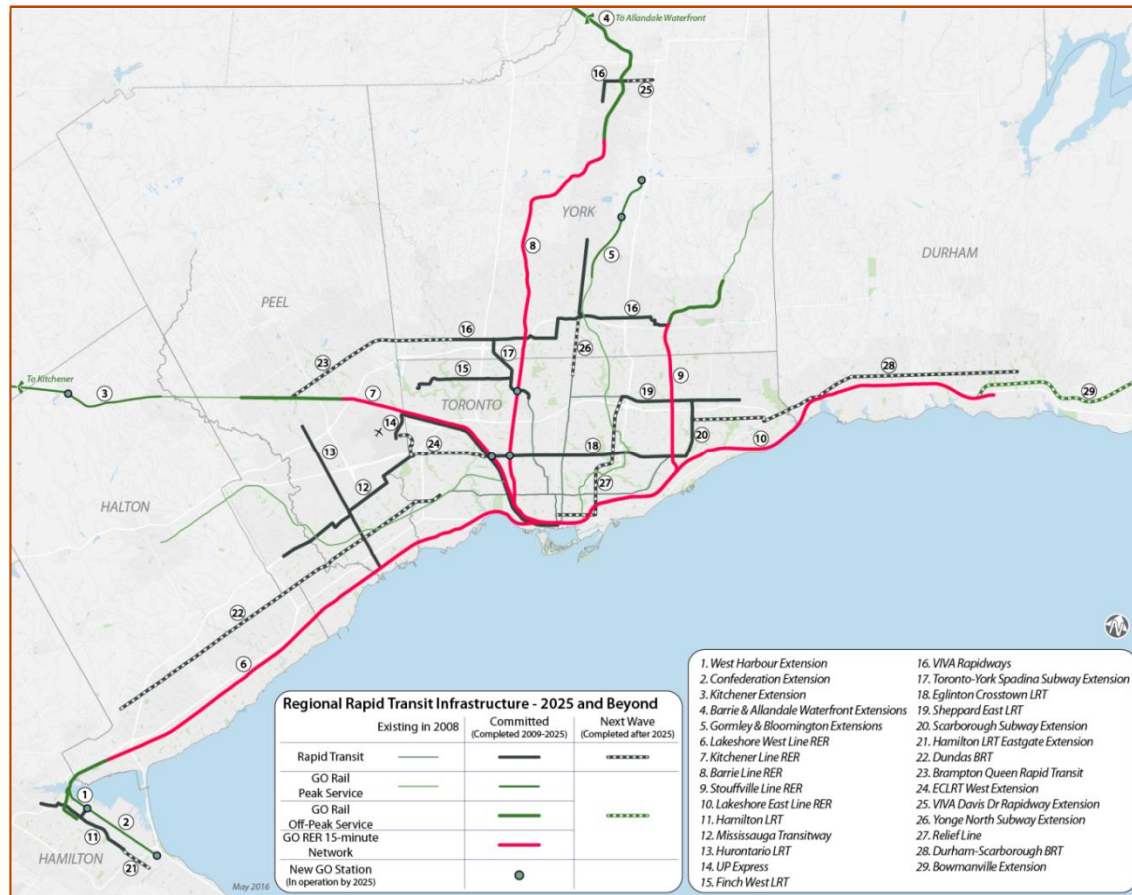
STATUS* OF THE BIG MOVE'S 92 ACTIONS AND POLICIES

Complete ● 2%

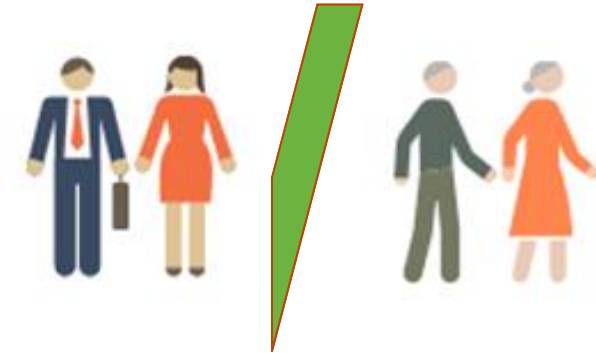
In Progress ● 89%

To be Initiated ● 9%

* Based on *The Big Move Baseline Monitoring Report, Appendix B: Inventory of Initiatives, 2013 (with updates)*



What We Have Learned



Review of The Regional Transportation Plan

Metrolinx is required to review the GTHA multimodal regional transportation plan under the *Metrolinx Act (2006)* at least every ten years, in alignment with Ontario's Growth Plan for the Greater Golden Horseshoe.

A review of *The Big Move* at this time allows Metrolinx to:

- Evaluate and incorporate evidence-based research, new analysis and innovative approaches
- Assess progress, change and the impacts of committed provincial investments on the region's transportation system
- Continue to strengthen our relationships with stakeholders by advancing and aligning the provincial, regional and local priorities that together can achieve the shared vision for the GTHA's transportation system.

The Corporation shall, at least every 10 years after subsection (1) comes into force, complete a review of the transportation plan required by clause (1) (a) and make any necessary changes to the transportation plan to ensure that it complies with the prescribed provincial plans and policies in accordance with clause (2) (d). 2006, c. 16, s. 6 (4).



**CHALLENGES
AHEAD**

Addressing the evolving mobility needs of Youth, Millennials and Seniors

PROPORTION IN 2018 PROPORTION IN 2041 GROWTH 2018 – 2041

Youth
(age 3-19)



22%

21%

31%

Young Adults
(age 20-34)



22%

19%

20%

Seniors (65+)

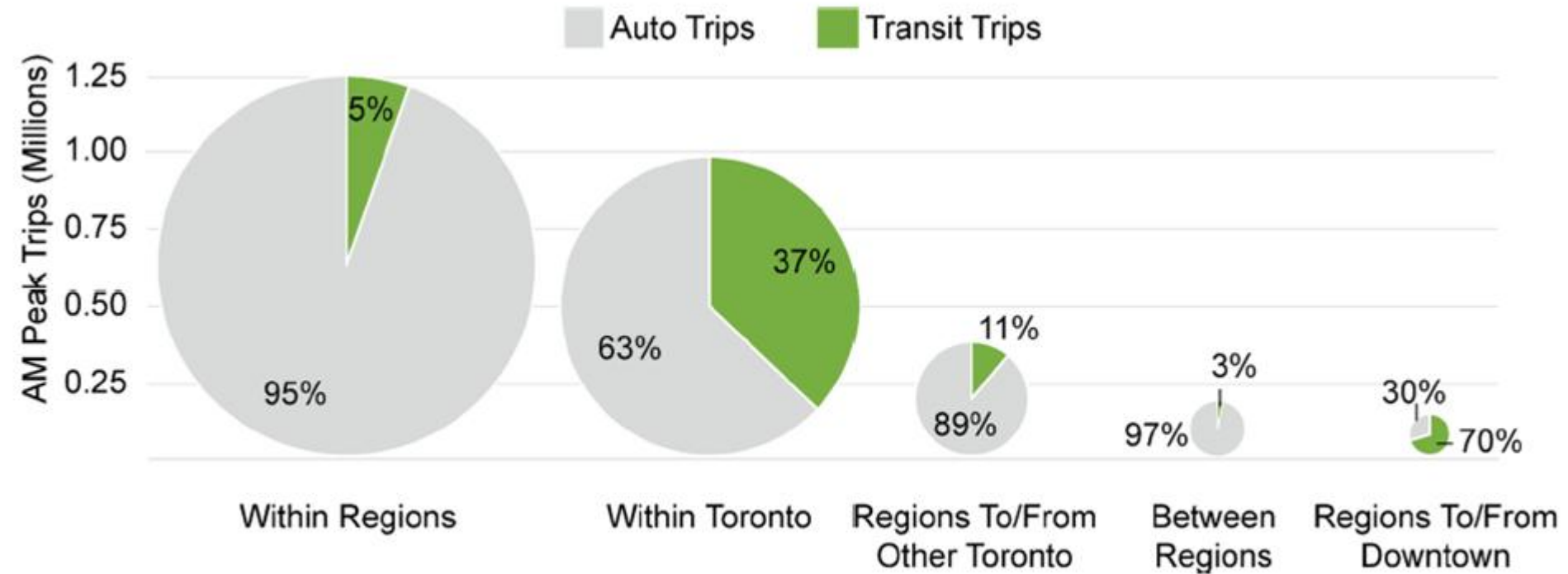


14%

23%

121%

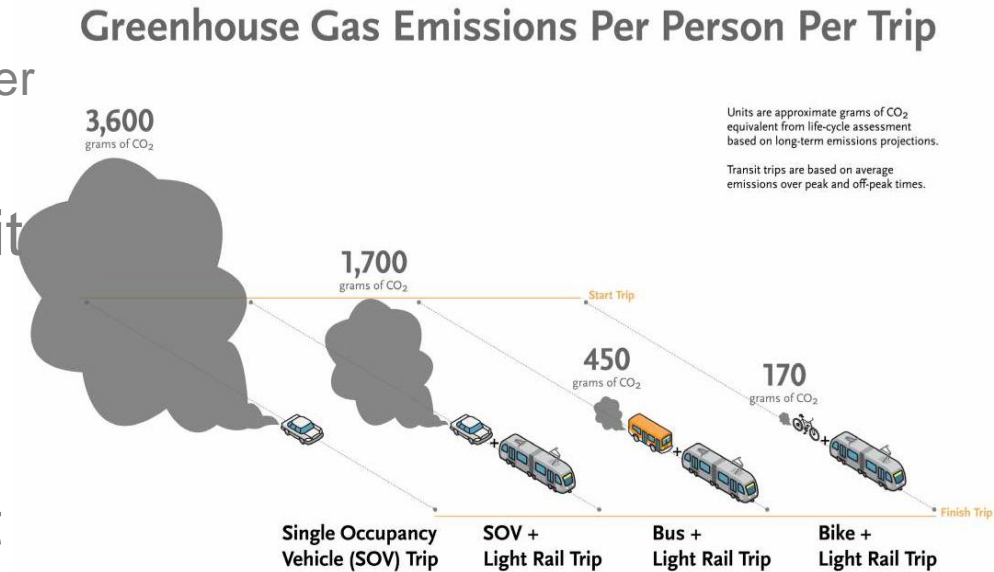
The magnitude of the challenge



Source: Transportation Tomorrow Survey 2011

To achieve real emission reductions

- § Shorten distances:
 - § bring origins and destinations closer together
- § Make walking, cycling, transit viable for more trips
- § Enhance infrastructure
- § Make vehicles more efficient
- § Switch fuels
- § Think about moving people, not vehicles

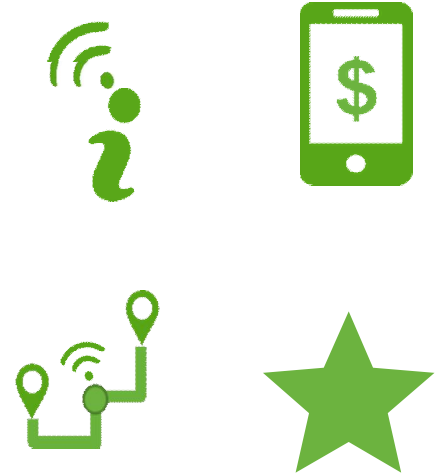


Mikhail Chester et al, "Infrastructure and Automobile Shifts: Positioning Transit to Reduce Life-Cycle Environmental Impacts for Urban Sustainability Goals", *Environmental Research Letters* 8, no.1 (2013). doi:10.1088/1748-9326/8/1/015041

Integrating new technologies and services into our transportation system

The Smartphone Revolution

- § Always connected
- § On-demand, location-based services
- § Seamless payment



New Services

- § A constellation of new on-demand services
 - § Competitors or complements?
- § Mobility as a Service (MaaS): Bundling of services to address all needs; Single method of payment; E.g. Transit + Bikesharing + Carsharing + Ridesourcing

Traditional Services

- uberHOP
- uberSUV
- uberX
- uberSELECT
- uberBLACK
- uberTAXI
- uberASSIST
- uberWAV
- uberEATS

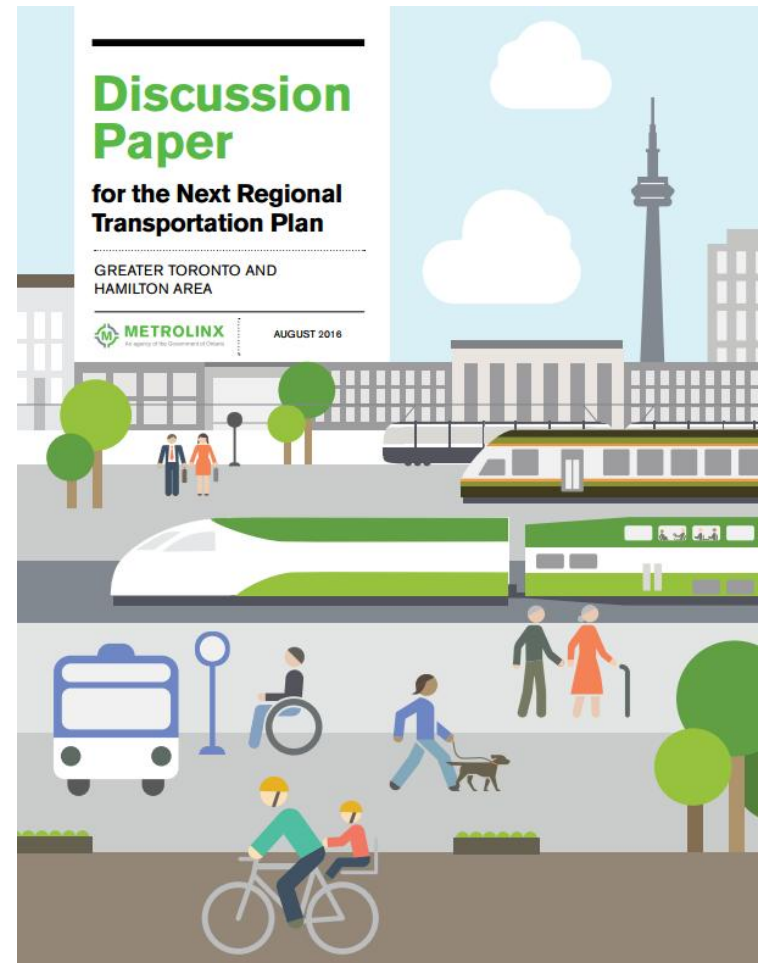


- Bus Route
- TAXI
- Private Driver
- Carpool
- Paratransit
- Food Delivery
- Parking
- Bikeshare
- Carshare



The Discussion Paper

The Discussion Paper is informed by extensive technical analysis and background research, as well as consideration of lessons learned and stakeholder feedback



Join the Conversation!

FEEDBACK AND INPUT



www.MetrolinxEngage.com

Deadline to comment on the Discussion Paper has
been extended to **November 30, 2016**



Break: Resume at 10:30

Moving more people & products with fewer resources

Innovative solutions to improve efficiency in rail

10:30– 11:00 Next generation of AC traction equipment



Steven Ojalvo, Mass Transit, ABB

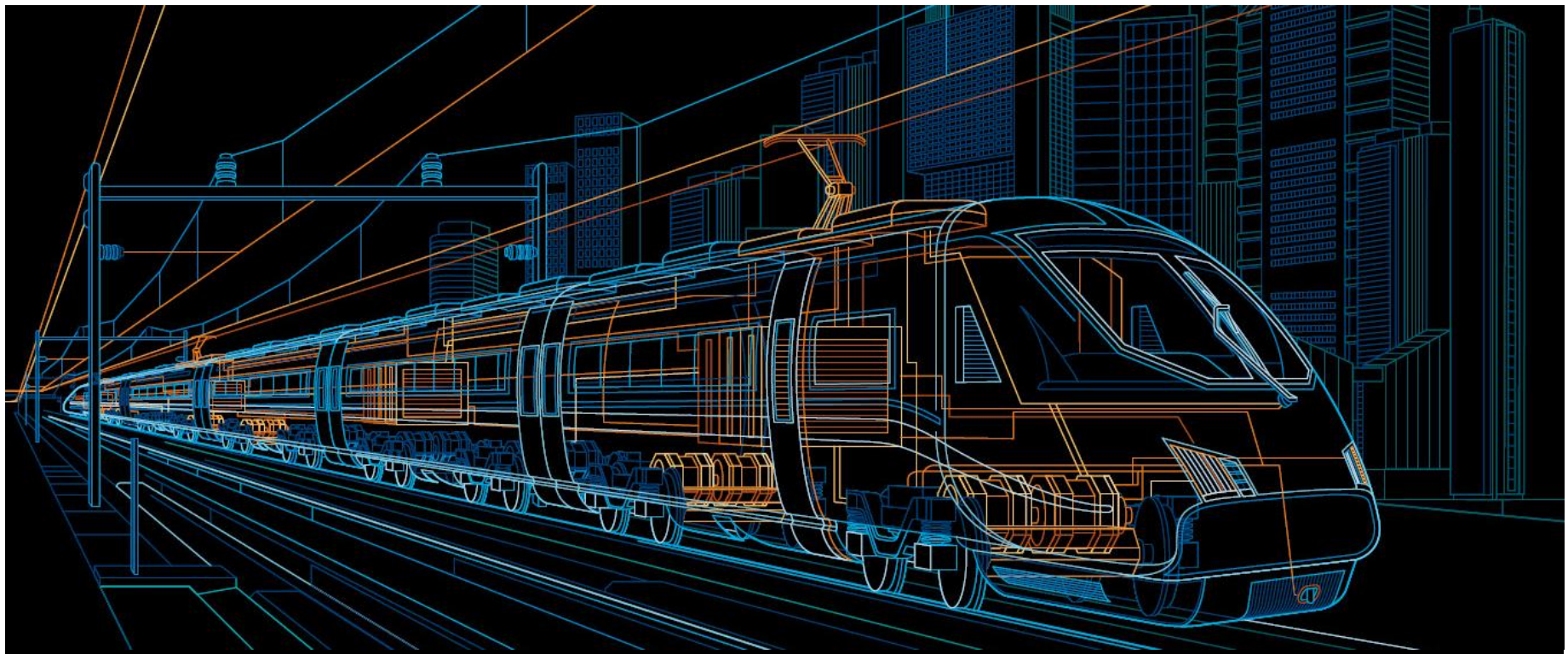


Liam Martin, Traction, ABB

11:00– 11:45 Wayside energy storage system



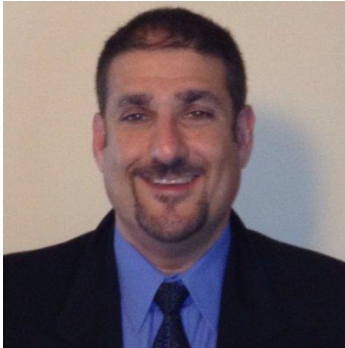
Patrick Savoie, DC Wayside, ABB



Steven Ojalvo & Liam Martin

Next generation of AC traction equipment

Next generation of AC traction equipment



Steven Ojalvo

§ Account Manager,
Mass Transit applications
North America

§ Email: steven.ojalvo@ca.abb.com

§ Mobile: 514 952 6374



Liam Martin

§ Product Expert,
Traction Chain & Converters

§ Email: liam.martin@us.abb.com

§ Mobile: 804 236 3318

Operator Objectives



REQUIREMENT

- § On-Time Service
- § Minimize Down-Time
- § Easy to maintain equipment
- § Manage Life Cycle Cost
- § Increase passenger count
- § Energy Efficiency
- § Superior Ride quality

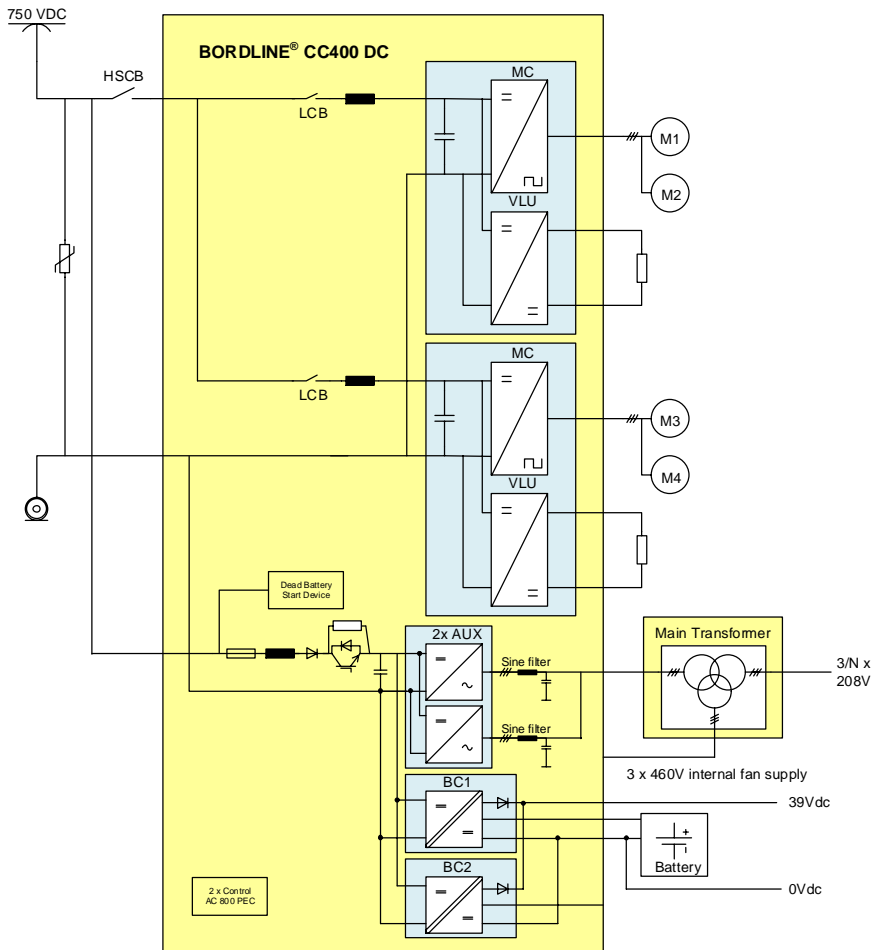
) **Reliability**

) **Maintainability**

) **Efficiency**

) **Performance**

Reliability - Based on Experience & Knowhow

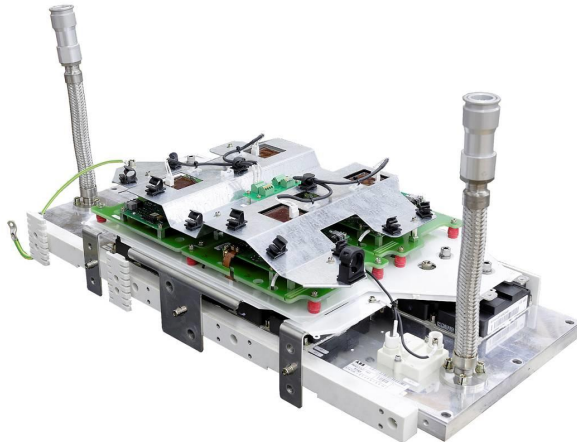


Fully Redundant Traction Converter (example)

- Internal redundancy
 - Failure of one power module will not impede operation of the converter
 - Separated line filters for each motor power module (line inductor failure will not stop the operation of the converter)
 - Per-bank control topology
 - Redundant braking chopper
 - Redundant APS and LVPS
- Integrated solution
 - Integrated APS and LVPS (significant advantages in terms of weight, dimensions, service and energy efficiency)
- Forced air cooling with integrated blower
- Possibility to integrate Dead Battery Device
- Braking energy management

Field Service Proven Design

Maintainability - Modular Design



- § Building block topology
- § Compact, robust and lightweight
- § Low thermal resistance
- § Optimized for load cycling
- § Highly advanced IGBT gate drivers
- § High energy efficiency and environmentally friendly
- § Low lifecycle cost
 - § Designed for easy maintenance
 - § Low preventive and corrective maintenance cost
 - § Availability of spare parts
 - § Reliability and robustness

Maintainability

Predictive Failure Analysis with Intelligent Diagnostic Software

Key Considerations for Diagnostic Tools

- User Friendly for maintenance workers
- Two and more level access, with or w/o password (as required)
- Event Data downloading, snap shot viewing, with required data (car number, date ..)
- Recording of events created by user defined triggers
- Real time viewing & recording / Chart recording, saving
- Preventive Maintenance - Defined Line Replaceable Units

Watchdog Approach

Customized Interface / GUI based on Individual & Operational Needs

Example of Intelligent Diagnostic Software

The screenshot displays a diagnostic software interface with a table of events and a sidebar of active alarms. The table columns include Event Type, Device, Date, Time, Source, ID, and Event Name. The sidebar lists various system alerts such as 'Traction Safe Maxing', 'Pump circuit breaker is open', and 'Water Level too low'.

| Event Type | Device | Date | Time | Source | ID | Event Name |
|-------------|------------------|------------|------------------|--------|-------|--------------------------------------|
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:39.5746552 | MS | 20516 | Coolant flow sensor failed |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:38.9647510 | MS | 20402 | PEC-PEC link error |
| Error | M1200 MPI HEP... | 2014-07-08 | 16:05:38.8647284 | MS | 20401 | PEC-PEC link error |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:38.5547526 | MS | 20007 | P2P_Link_Rx_error_on_PEC |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:38.4364652 | MS | 20310 | Constant flow sensor failed |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:33.4347296 | MS | 20307 | Water Level too low |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:33.4347258 | MS | 20306 | Pump circuit breaker is open |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:33.4347214 | MS | 20304 | Internal fan circuit breaker is c... |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:33.4347146 | MS | 20314 | Water Temperature Sensor fail... |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:33.4347116 | MS | 20315 | Channel 1 air temperature sen... |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:33.4347070 | MS | 20312 | Control Air Temperature Senc... |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:29.5652524 | MS | 20408 | J1939 Communication Failed |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:29.5520070 | MS | 20403 | Display Communication F failed |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:29.5648210 | MS | 20504 | PEC CPU watchdog error |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:29.5648164 | MS | 20502 | PEC Power fail +3.3V |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:29.5648110 | MS | 20515 | Battery overvoltage detected at... |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5648014 | MS | 20007 | P2P_Link_Rx_error_on_PEC |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5647978 | MS | 20006 | GD D852 2 to PEC Link error |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5647412 | MS | 20005 | GD D852 1 to PEC Link error |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5548456 | MS | 20003 | PEC CPU watchdog error |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5548428 | MS | 20504 | PEC Power fail -15V |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5548306 | MS | 20002 | PEC Power fail +15V |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5548370 | MS | 20502 | PEC Power fail +3.3V |
| Information | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5548316 | MS | 20515 | Battery overvoltage detected at... |
| Warning | M1200 MPI HEP... | 2014-07-08 | 16:05:28.5548222 | MS | 20501 | PEC Power fail |

Active alarms
Shows active alarms at the primary controller

Active faults
Shows active faults at the primary controller

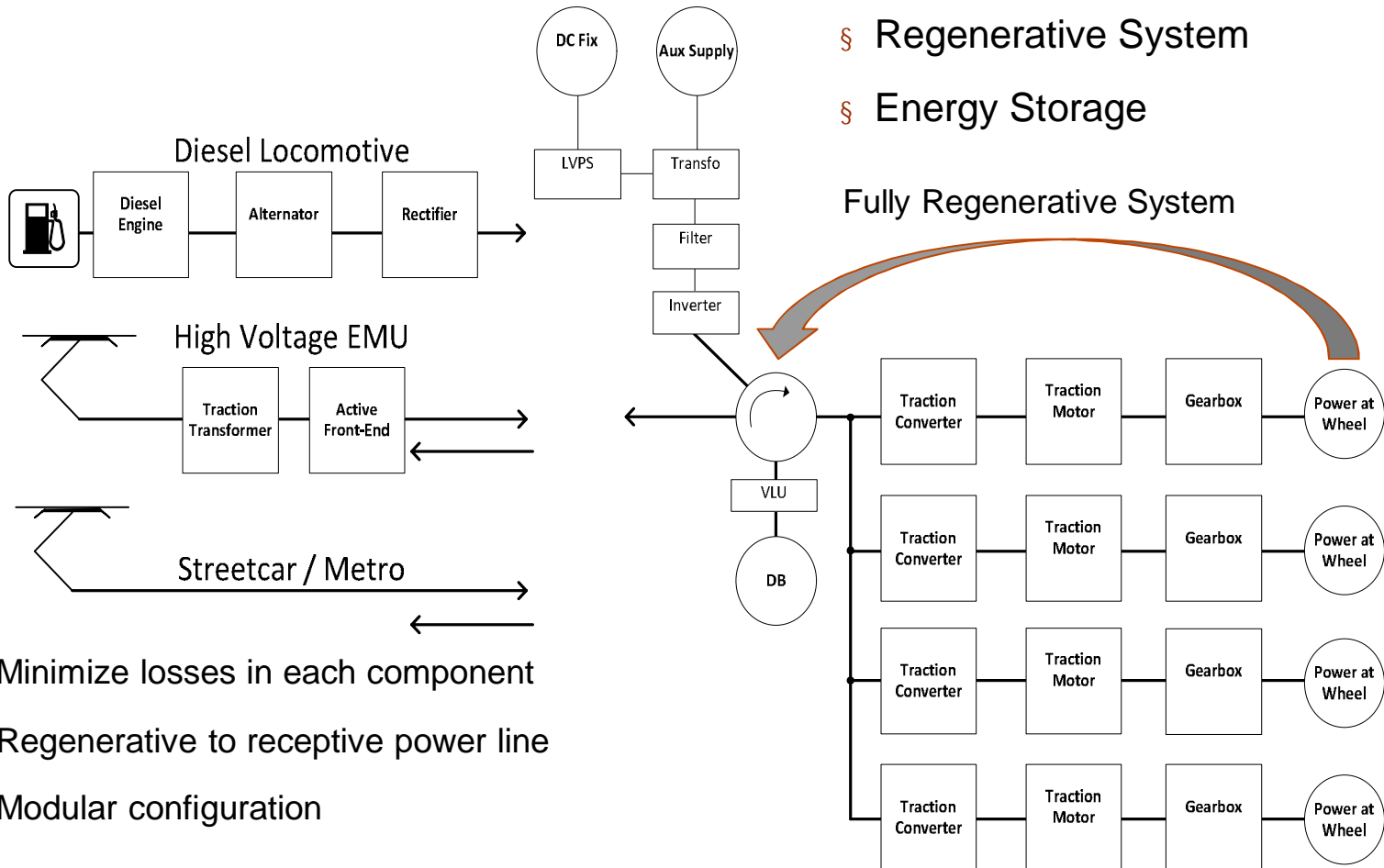
Resolved events

Active events

Efficiency

System efficiency dependent on module topology

- § Low loss componentry
- § Regenerative System
- § Energy Storage



- § Minimize losses in each component
- § Regenerative to receptive power line
- § Modular configuration

Performance Traction Converter Technology – Keys for Performance



- Advanced control hardware
- Fast and smooth slip slide control
- Modern and predictive diagnostic
- Adhesion optimized: “Best weather performance”
- Bogie-friendly vibration suppression
- Single Axle Control, one converter for one motor
- One converter failure equals one motor out, still more than 75% of the performance
- Fault current monitoring
- Advanced modification in pulse pattern to reduce losses in motors
- Compact & Light weight design considering Liquid Cooled Technology

Advanced technologies for rolling stock applications

Key power components



Traction Converters



Motors and Generators



Auxiliary Converters



Traction Transformers

- § AC grid voltage applications (15 kV / 16.7Hz or 25 kV / 50Hz)
- § DC grid voltage applications (600/750V_{DC}, 1.5 kV_{DC}, 3kV_{DC})
- § Diesel generator applications
- § Multi-system and hybrid applications

- § Modular traction motors
 - § LRV to HST range
 - § 30-900 kW
 - § Induction
- § Frameless traction motors
 - § Locomotive and VHST range
 - § 600-1800 kW
 - § Induction
 - § U-Tube Mounted
- § Gearbox and coupling

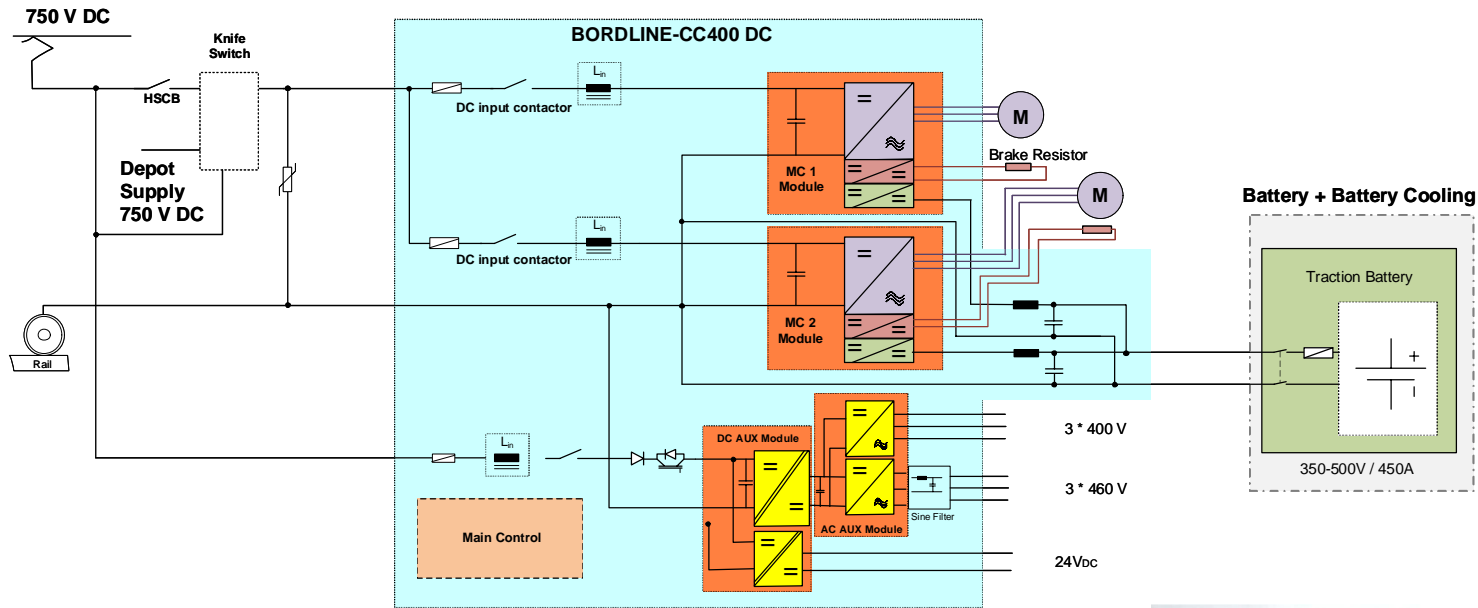
- § Auxiliary Converters and Battery Chargers for all kind of in- and output voltages in AC and DC applications
- § Output power range between 1 and 1'200 kW
- § Roof, under floor or machine room mounting possible
- § Air-cooled and completely sealed

- § Single to multiphase systems (AC only, AC/DC, diesel/AC, 16.7 Hz, 25 Hz, 50 Hz, 60 Hz)

All products with cross-industry synergies, optimized and adapted for railway application

BORDLINE® CC400 – Project Examples

Example: DART Platform with BEC

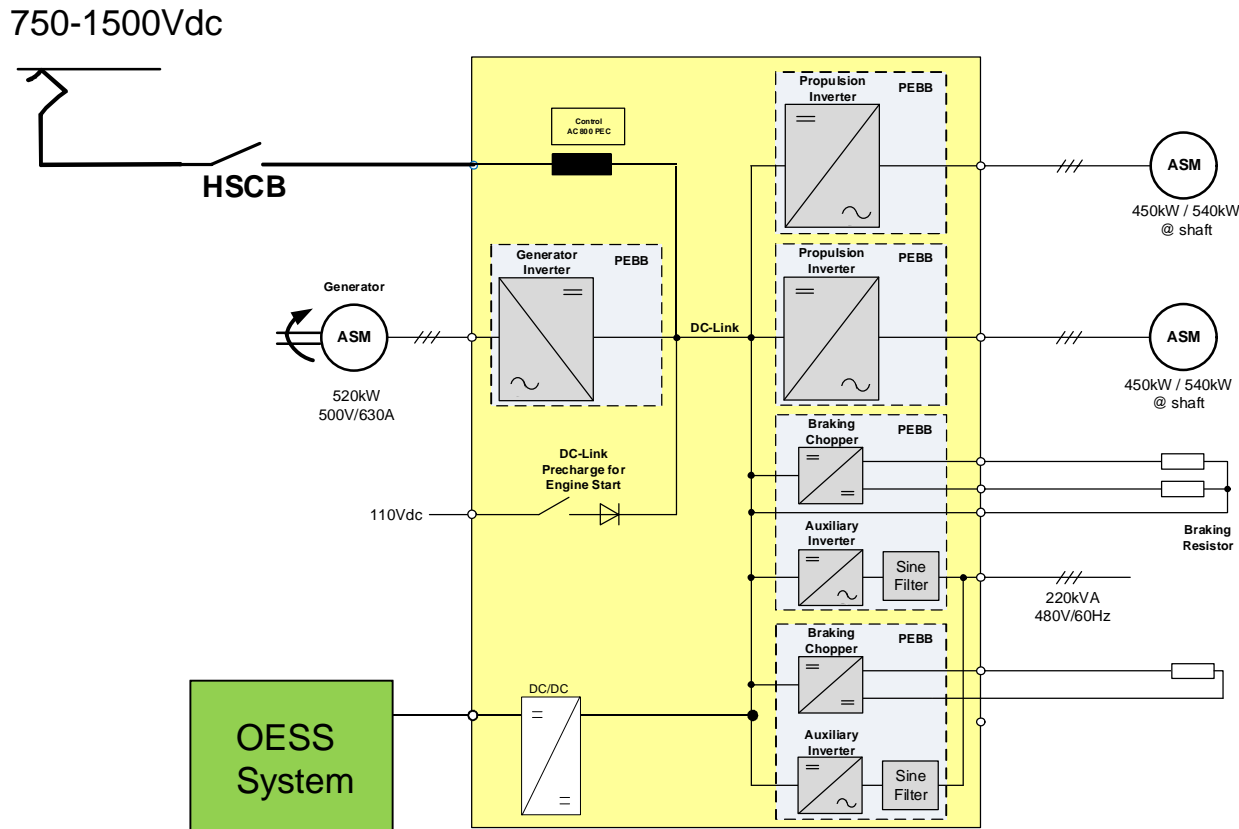


- § New & Overhaul LRV / HRVs
- § Fully integrated AC and DC/LVPS auxiliaries, FF & VV/VF AUX available
- § Redundant control and auxiliary systems available



BORDLINE® CC750 – Project Examples

Example: DC+DMU w/OESS

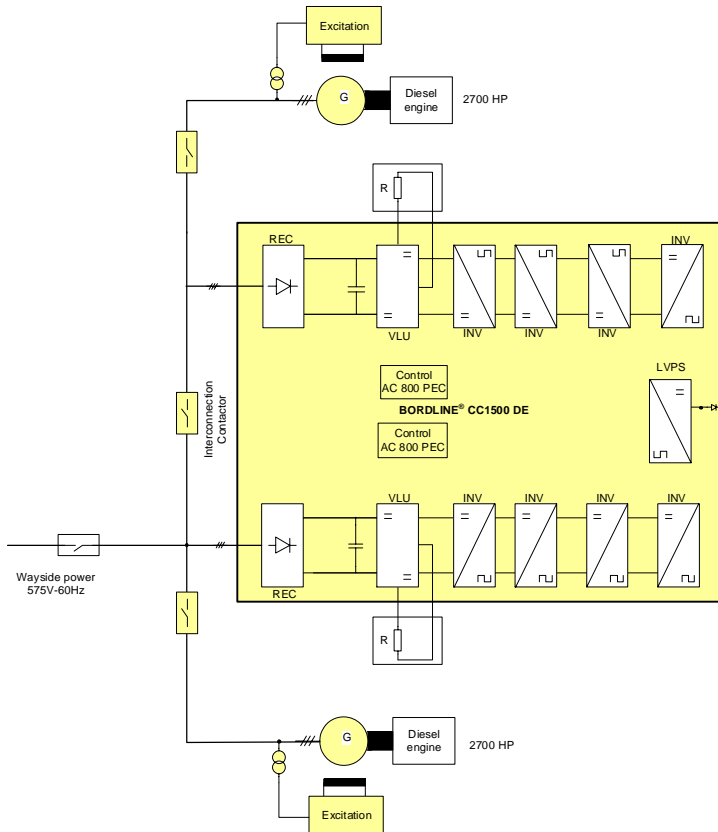


- § Commuter E/DMUs
- § Fully integrated AC auxiliaries
- § Variable effort dynamic brake
- § Expandable (Additional LC/MCs/AUX PEBBs etc)
- § Catenary Free/'Burst' mode operation possible with OESS

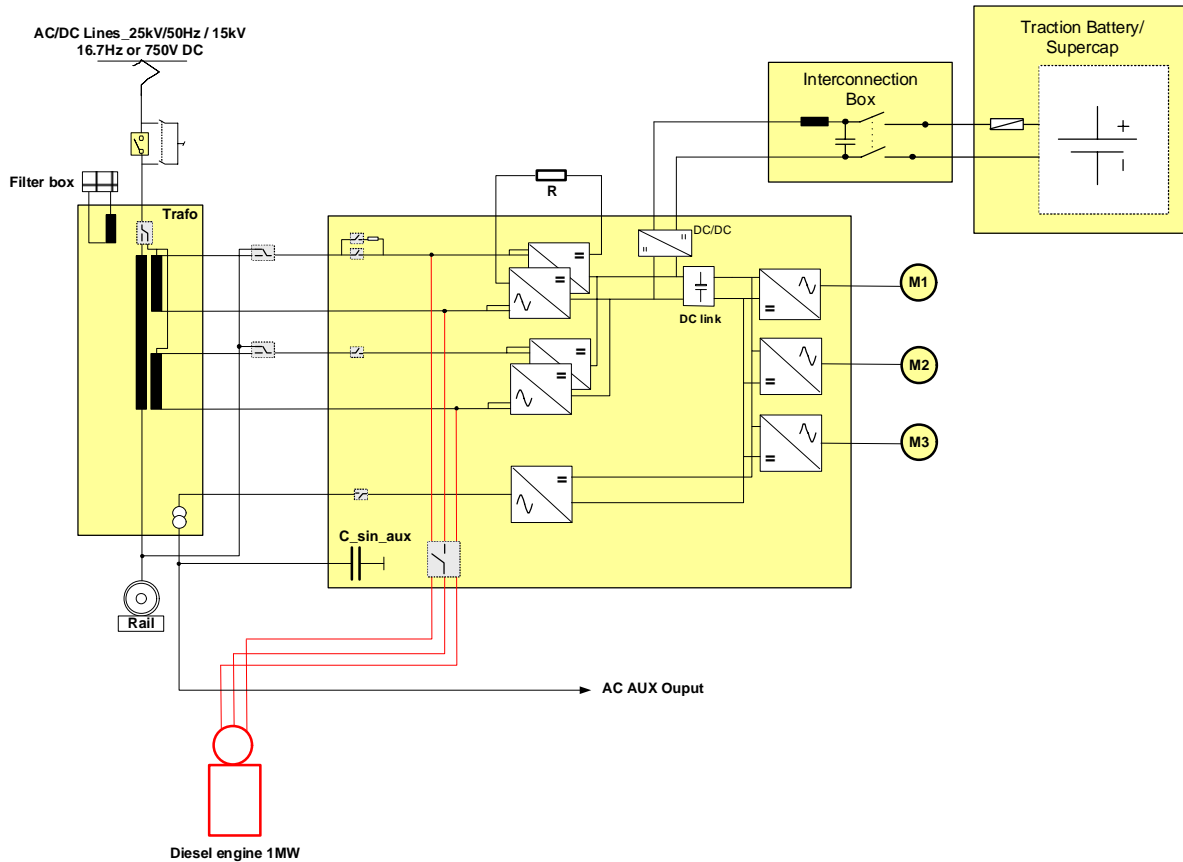
BORDLINE® CC1500 – Project Examples

Example: MPI54AC / GO Transit Tier 4 Platform

- § Commuter/Freight Locomotives
- § 160kW Constant tractive effort
- § 2MW Continuous braking effort
- § 1MW HEP, VV/VF AUX
- § Switchable Input/Output – single and dual engine operation possible
- § Easily expandable to CoCo with additional MC modules



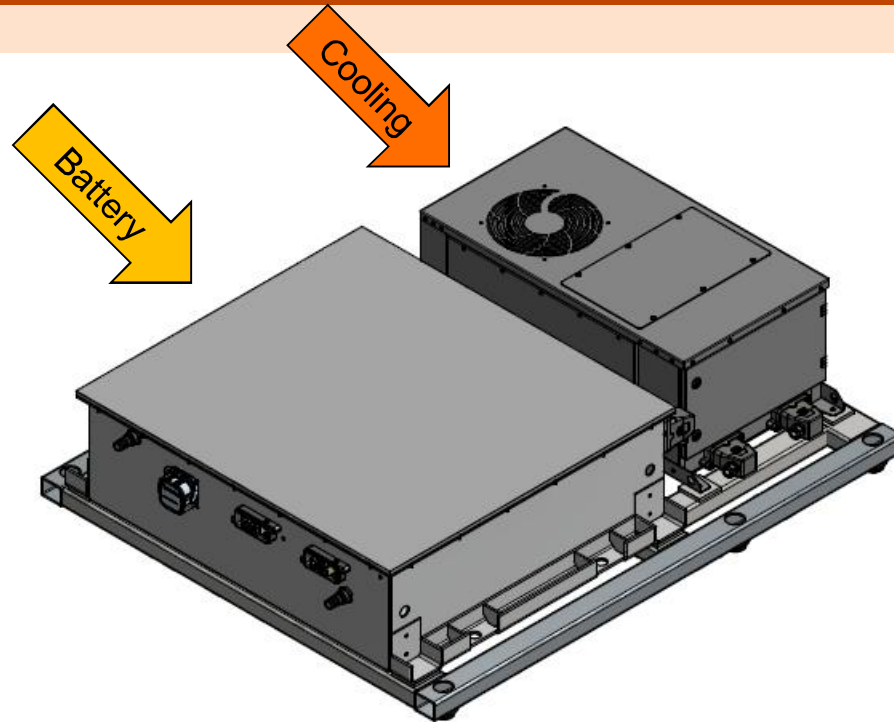
Modular Traction Converters : AC+DC+Diesel-Electric w/OESS Hybrid



- § Truly multi-system – Compatible with un-electrified RoW, tunnels, electrified routes at multiple voltages
- § Catenary free operation without engine if required ('quiet' areas/late night use)
- § Regenerative braking to recharge OESS/feed back to receptive line
- § Multiple levels of redundancy
- § Fleet simplification

Energy Storage in Mass Transit OESS Implementation

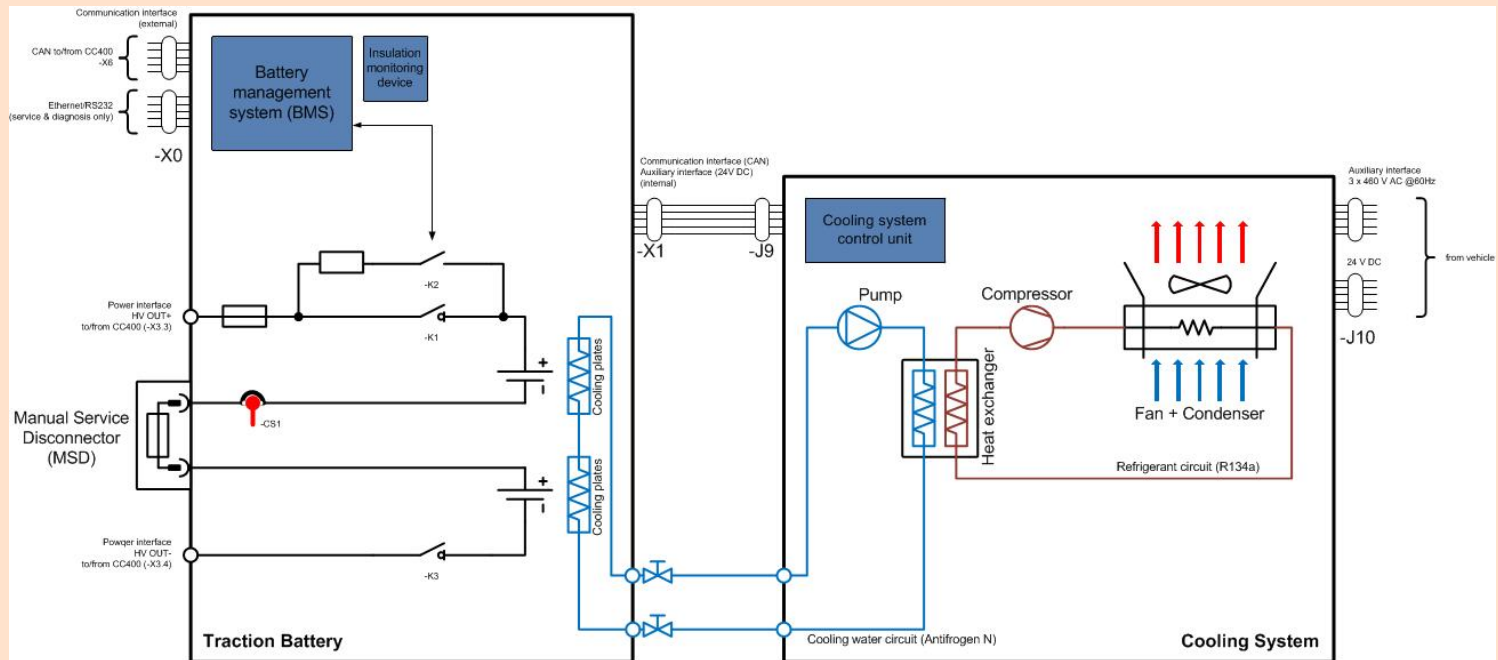
OESS Module - Battery



Images courtesy of Maxwell & ABB

Energy Storage in Mass Transit OESS Implementation

OESS Module Internal View



Images courtesy of Maxwell & ABB

Future Outlook –Areas of Interest Semiconductors

SiC Overview

Current tech is maxing out capabilities

Higher power density, lower loss

May allow for smaller converter footprint, cooling considerations

Faster switching/smaller passives

Challenges:

Cost (early adopters), availability, optimization of current equipment families

SiC – Future Adoption in Railway

Market <1000V well established with SiC MOSFETs & BJTs widely available in small, low-power packages

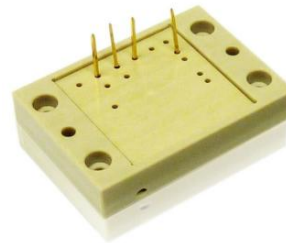
SiC technology already used in auxiliary converters

1200V FET Modules available, 1700V Si-IGBT +SiC BD available for traction and finding limited use

Possibility to shift 750V traction power electronics toward SiC/Hybrid technologies to gain efficiency



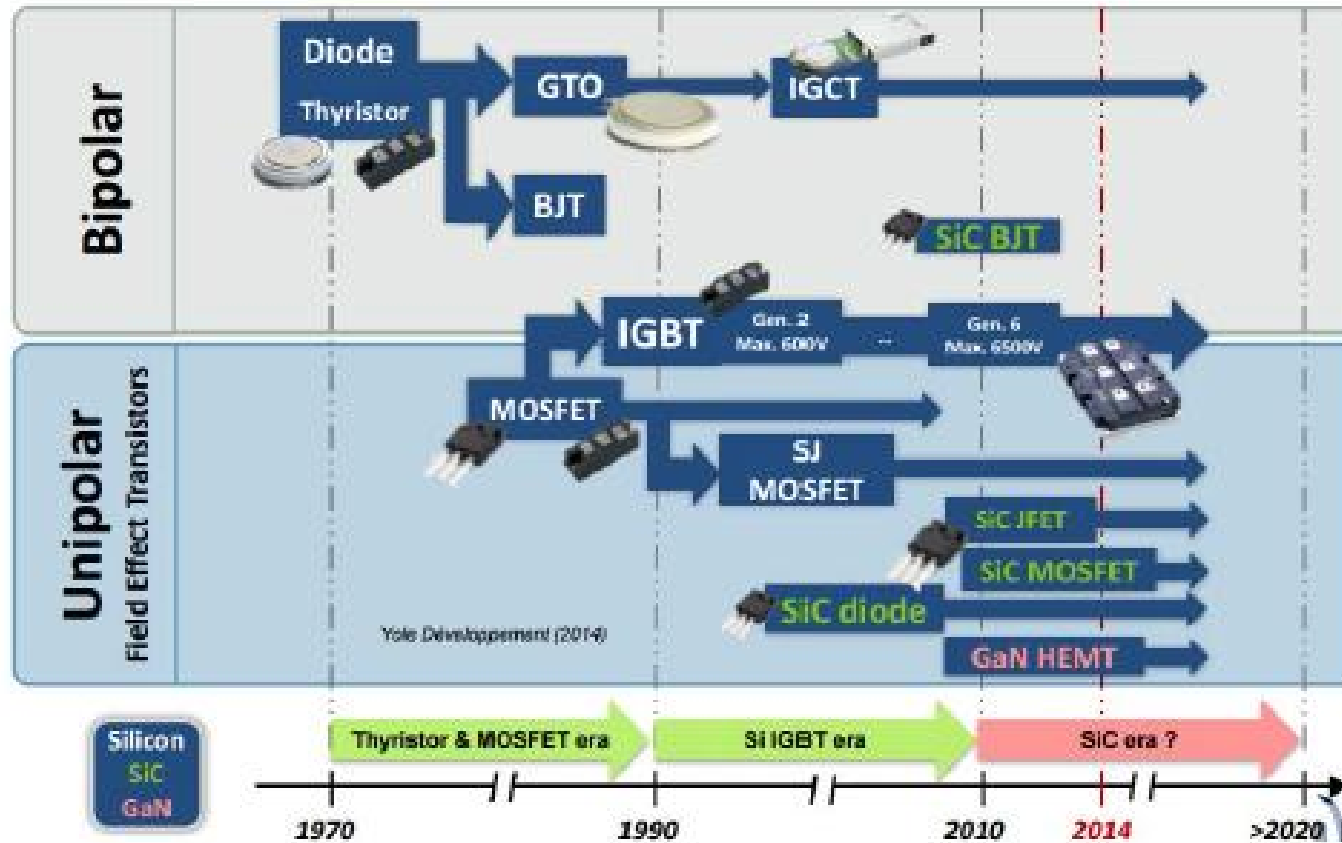
(a) 4 inch 1,700 volt SiC Junction Barrier Schottky diodes wafer (16x5 mm² chips), (b) 4 inch 4,500 volt SiC pin-diode (2.5x2.5 mm² chips) wafer. Both developed at ABB Corporate Research.



Images courtesy of Maxwell & ABB

Overview of the Future in Power Electronics

A new generation every ~20 years...



Silicone Carbide (SiC) Power SemiConductor



Patrick Savoie - Business Development Manager, ABB Inc.

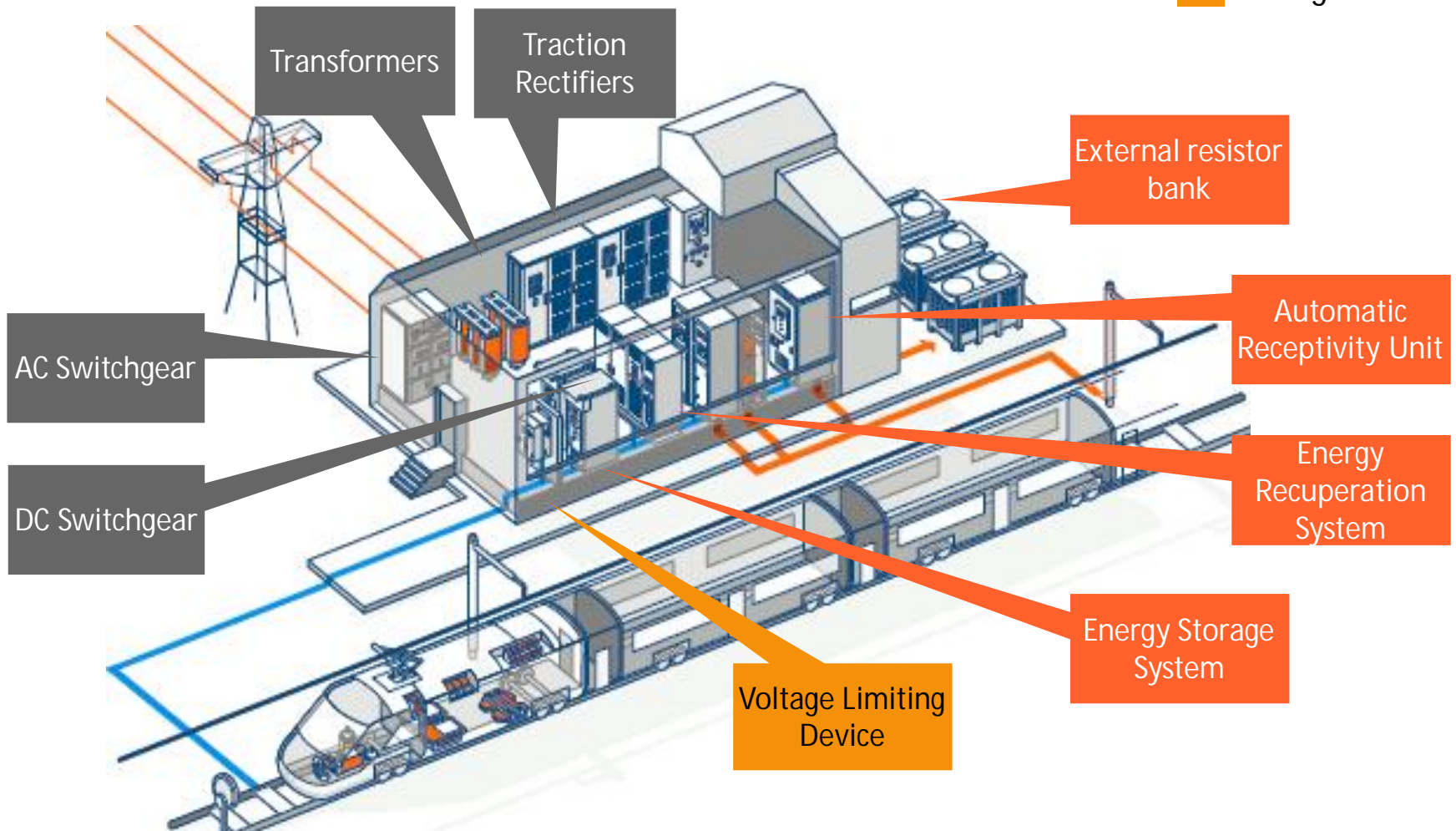
Oct 18th 2016

2016 ABB Rail Expert Day

Wayside Energy Storage System

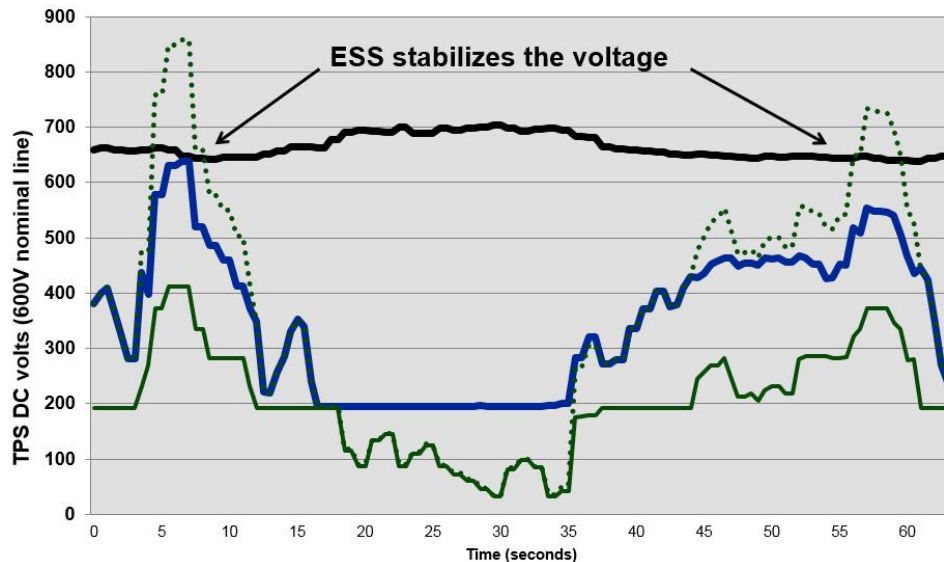
ENVILINE™ Traction Power and Wayside Energy Management Solutions

- Traction Power
- Energy Management
- Voltage Protection



ENVILINE Energy Storage System (ESS) Infrastructure Asset for Transit Authorities

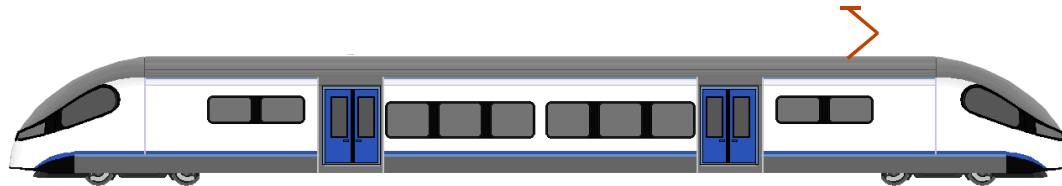
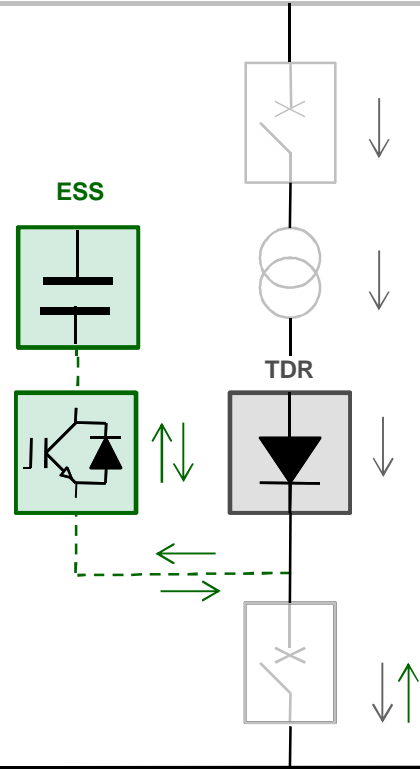
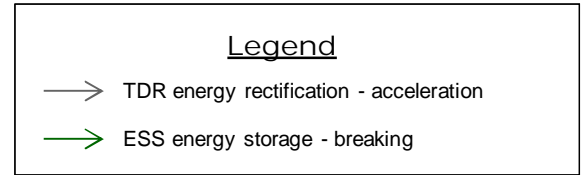
1. Recovers surplus regen braking energy
2. Reduces peak power demand
3. Provides Voltage stabilization
4. Smart Grid services (Behind the meter)



ENVILINE Energy Storage System (ESS) Energy Management on the DC side

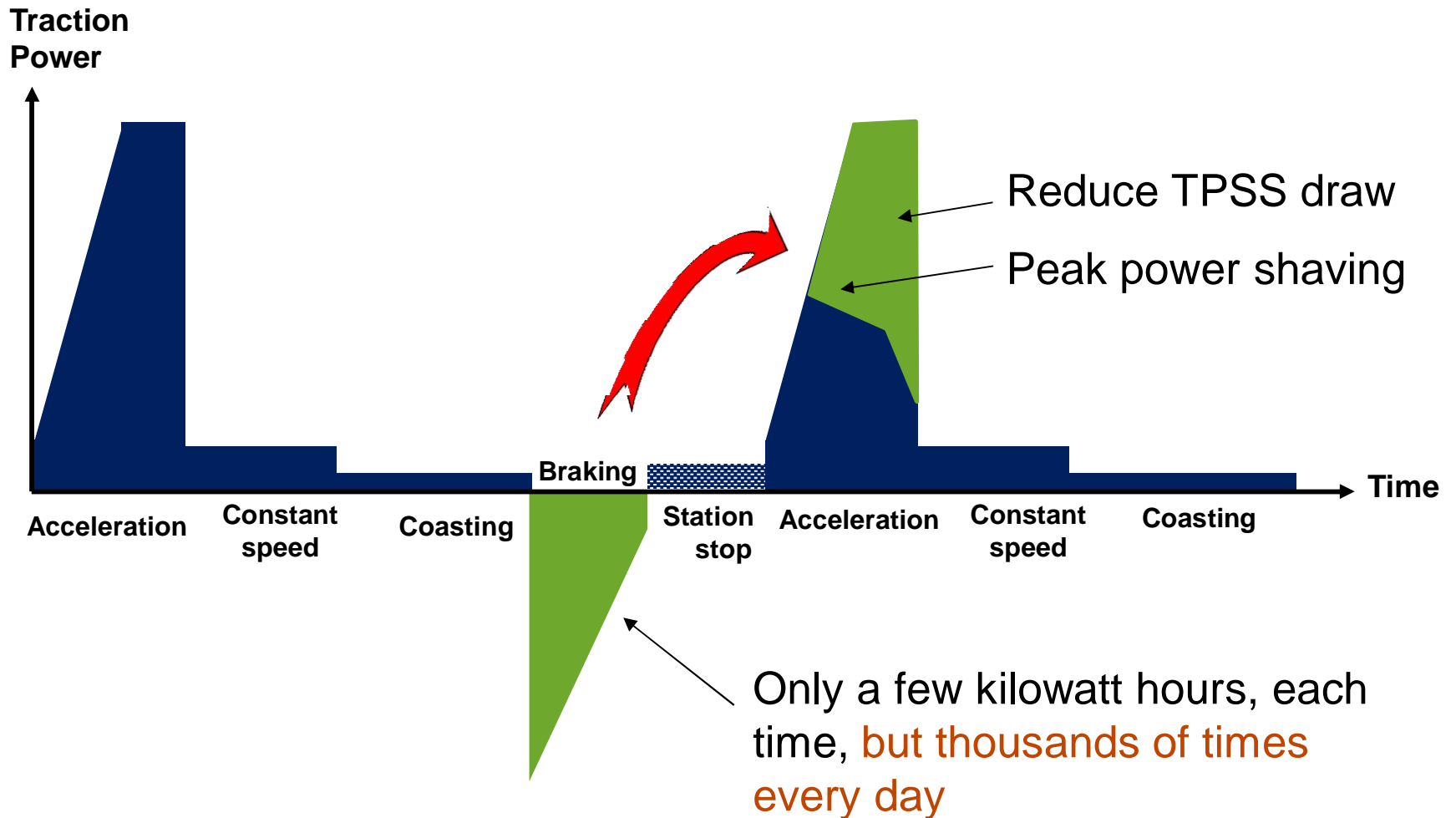
MV/HV Network

AC ~



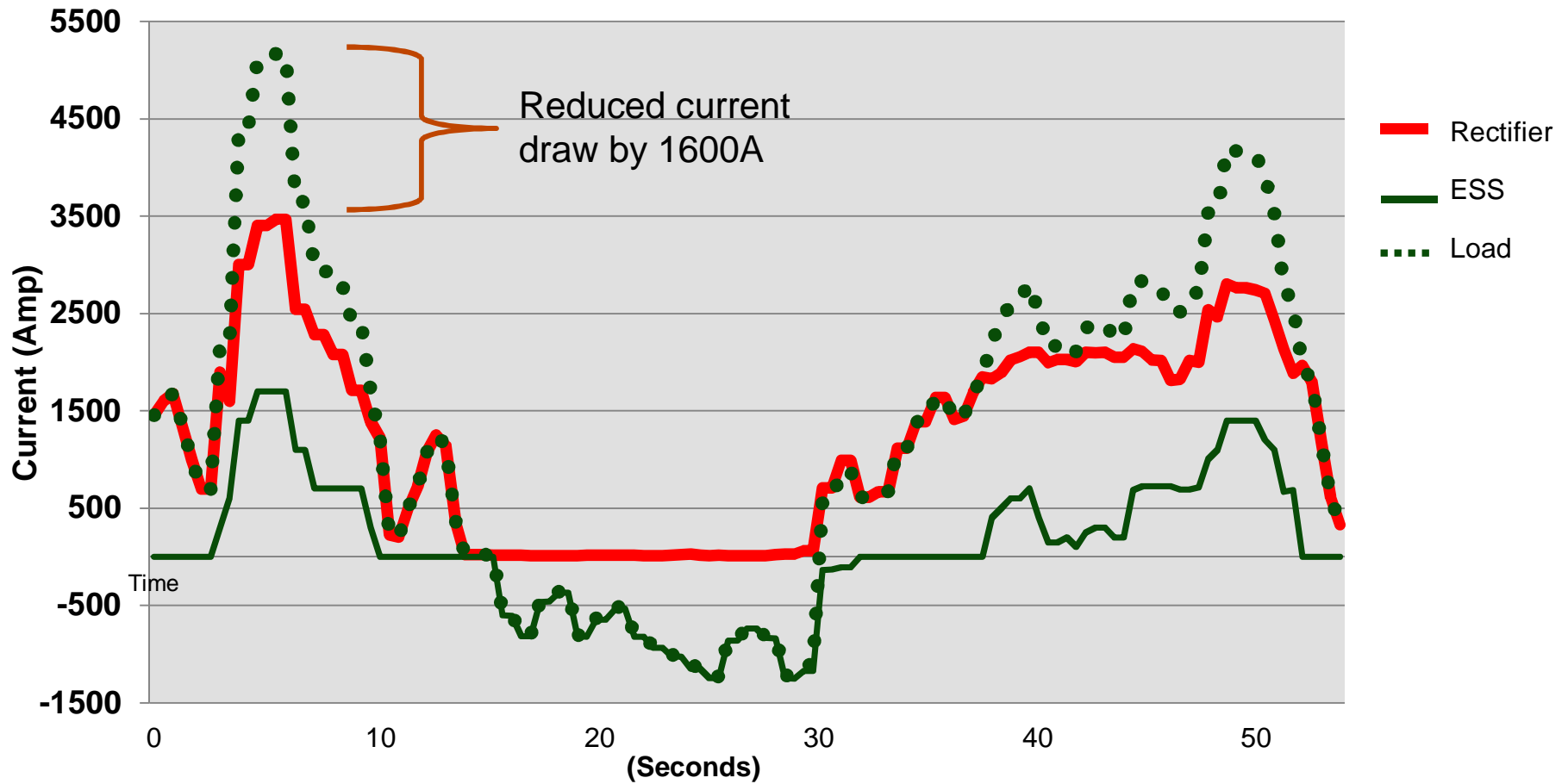
ENVILINE ESS

Recovers Braking Energy

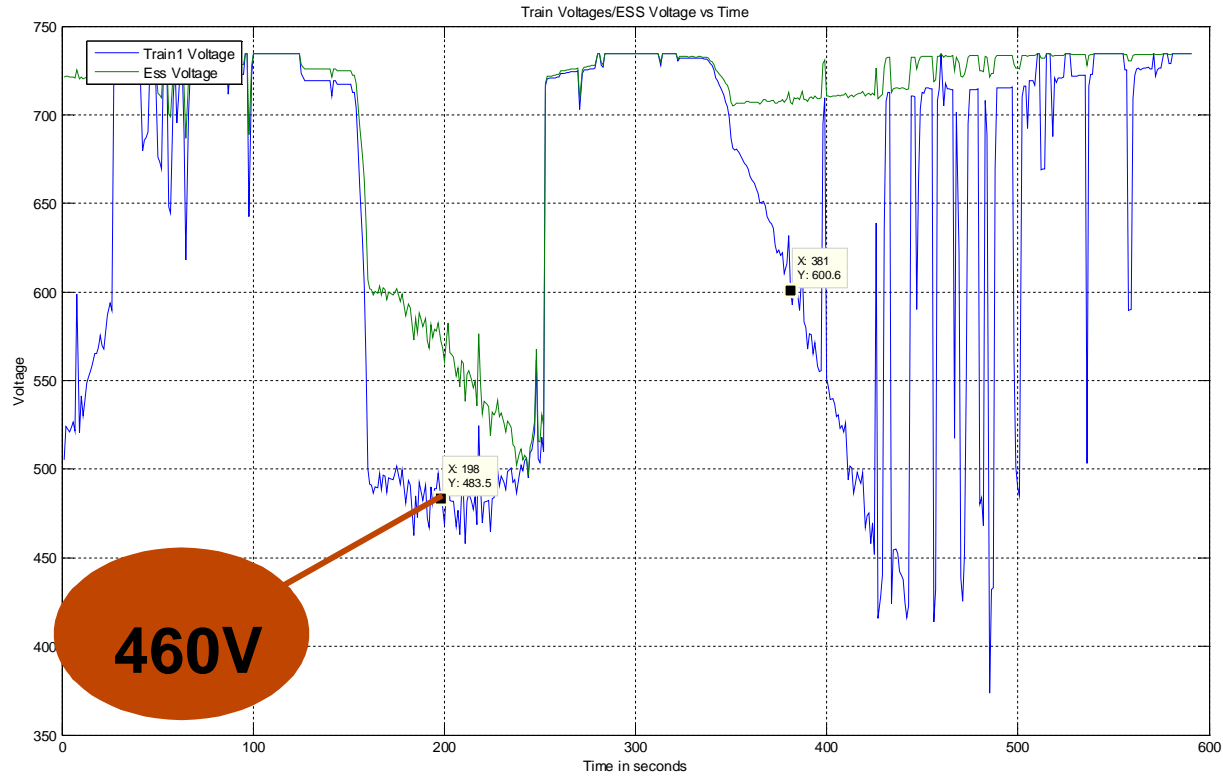


ENVILINE ESS

Peak shaving

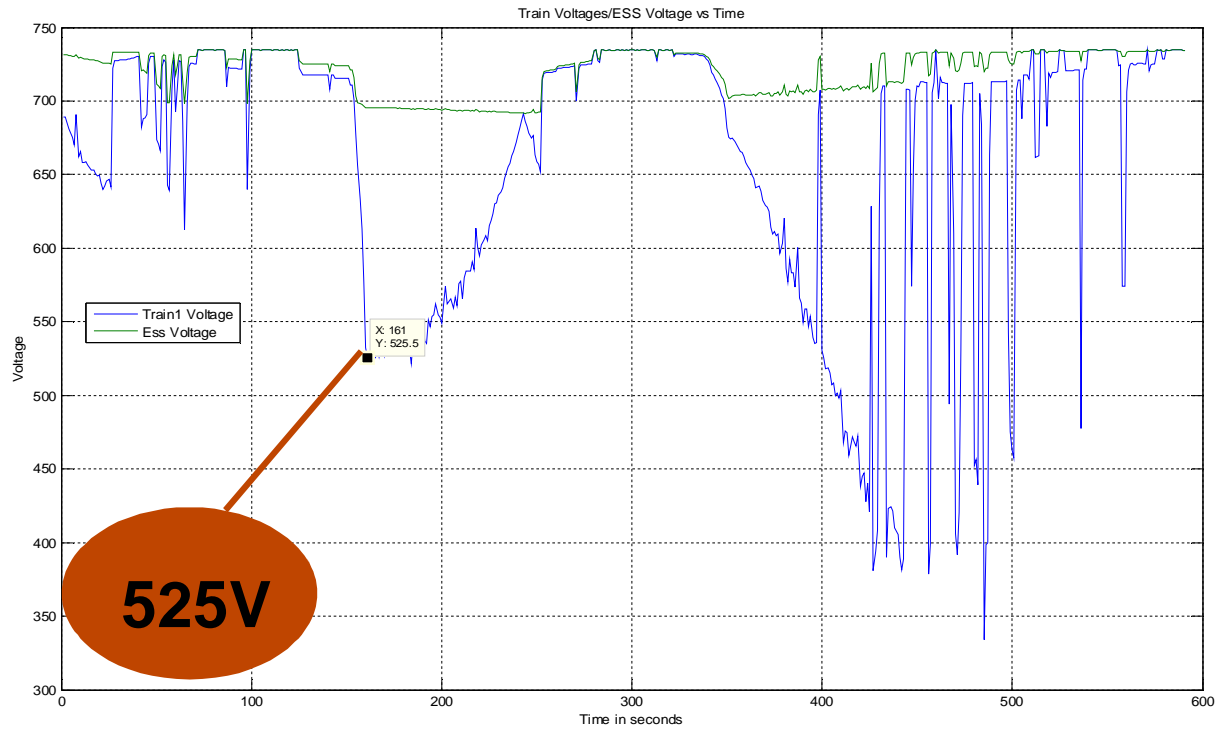


ENVILINE ESS Voltage Stabilization



Before

ENVILINE ESS Voltage Stabilization

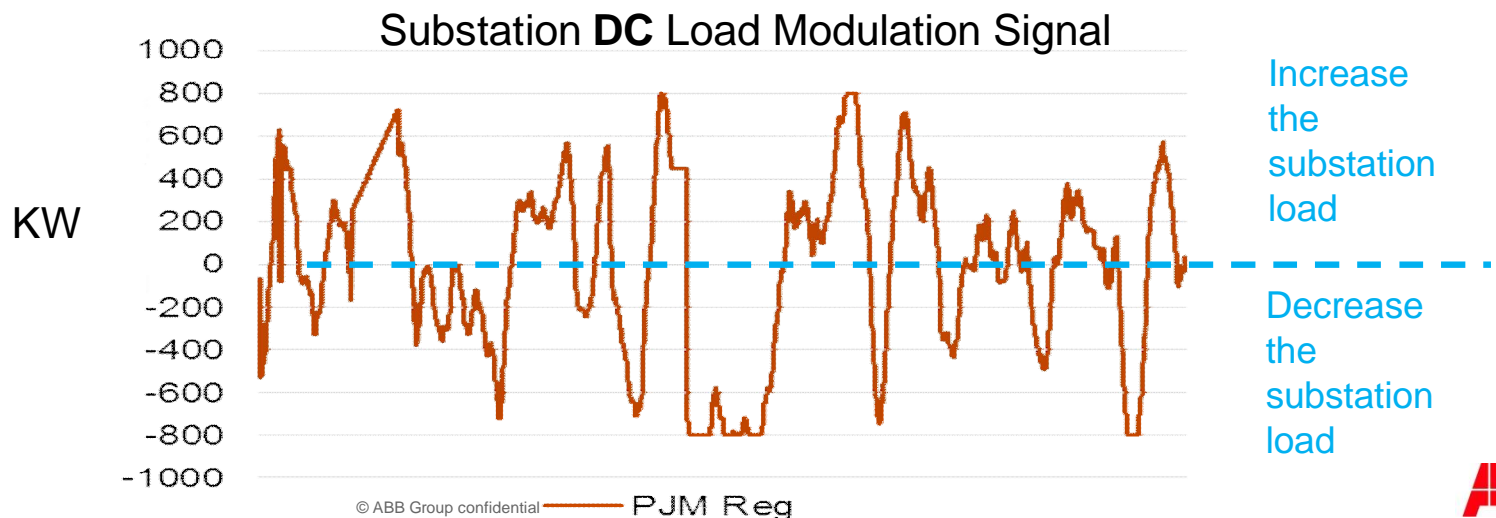


After

ENVILINE ESS

Smart Grid Application

1. Load Levelling
2. Peak Power Shaving
3. Demand Response Services
4. Frequency adjustment
5. Global adjustment charge reduction



Examples of applications

ENVILINE ESS

Braking Energy Recovery - Poland



- § Captures braking and gravitational energy
- § 3MW power capability
- § $\approx 10\text{kWh}$ of useable storage capacity
- § Currently recuperates $\geq 3\text{MWh/day!}$

ENVILINE ESS

Poland Data 2016-09-27

wtorek, 27 września 2016 10:59:27 CEST

Sumatory energii Warszawa - Dworzec Stadion C14



Aktualnie **present**

power

Poziom mocy -226.03 kW



Odzysk energii-krótki termin **energy savings - short term**

today

Dzisiaj 373 kWh 1343 MJ

this week

Ten tydzień 1943 kWh 6994 MJ



Odzysk energii-długi termin **energy savings - long term**

this month

Aktualny miesiąc 91 MWh 327 GJ

this year

Aktualny rok 668 MWh 2405 GJ

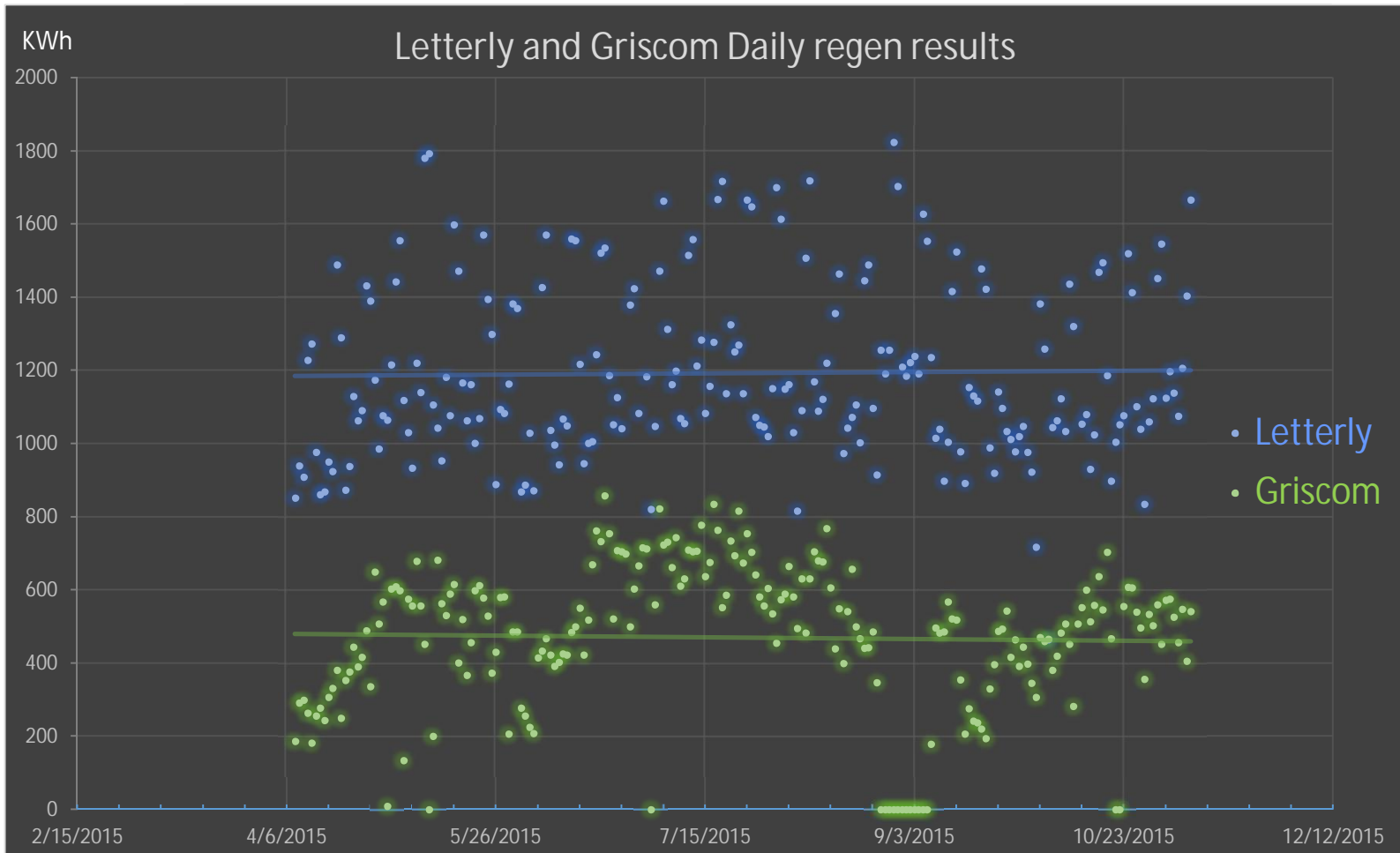
life cycle

Cykl życia 919 MWh 3309 GJ



ENVILINE ESS

Daily regen at SEPTA



ENVILINE ESS

Reduces demand power: How much?

05/29/2014 – 06/26/2014

Rate Schedule: E20P Service to Custs with Max Demands of 1000 kW or More

| | | | |
|---|--------------------------------|---------------------|-----|
| Customer Charge | 29 days @ \$49.28131 | \$1,429.16 | |
| Demand Charge ¹ | | | |
| Max Peak | 5,186.000000 kW @ \$16.86000 | 87,435.96 | 42% |
| Max Part Peak | 4,919.000000 kW @ \$3.49000 | 17,167.31 | |
| Max Demand | 5,186.000000 kW @ \$9.97000 | 51,704.42 | |
| Energy Charges | | | |
| Peak | 537,270.000000 kWh @ \$0.14791 | 79,467.61 | 57% |
| Part Peak | 573,790.000000 kWh @ \$0.10421 | 59,794.66 | |
| Off Peak | 907,891.000000 kWh @ \$0.07865 | 71,405.63 | |
| Power Factor Adjustment (@ 97.00% Power Factor) | | -1,211.37 | |
| Energy Commission Tax | | 585.50 | |
| Total Electric Charges | | \$367,778.88 | |

Peak demand reduction range of 80-250kW
per billing period = \$16K – \$48K / year

ENVILINE ESS

Voltage Stabilization Experience

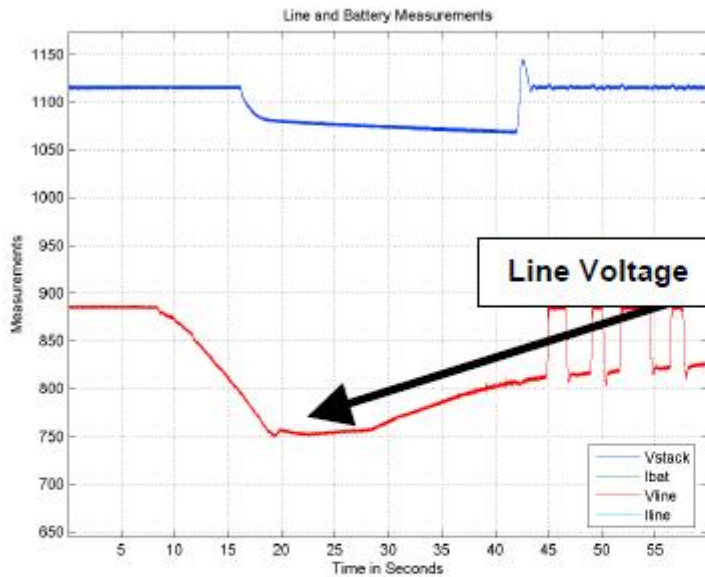


Figure 4a – Without BASS
- Line voltage collapses to 750Vdc

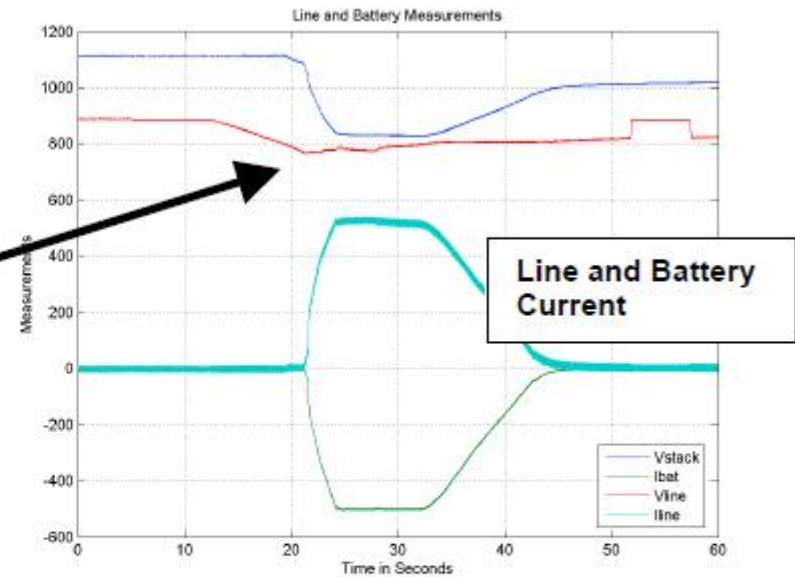
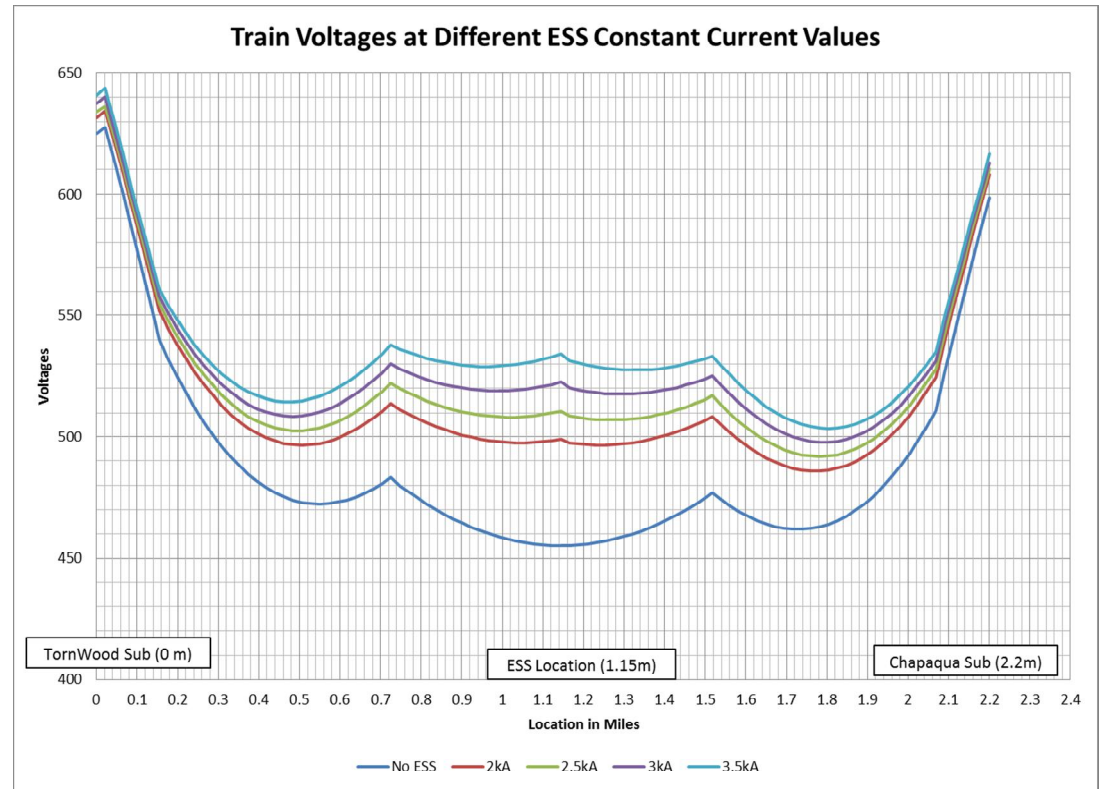


Figure 4b- With BASS
- Line voltage is maintained at 800Vdc
- Battery provides current to sustain energy demand

ENVILINE ESS

Voltage Stabilization Experience

- § Deferred capital expenditure range from 40-70% of standard TPSS
- § Operates as an off-grid TPSS
- § Provides emergency power
- § Avoids penalties from loss of services and reduced performance



ENVILINE ESS

Regen and Smart Grid



Letterly Substation - 2012



Griscom substation - 2014

Site locations & sequence



Network Deployment - 2016

- § ABB ENVILINE™ ESS
- § Saft (420 kWh, 1600A (1.1MW) regen / 800kW FR market)
- § Viridity Energy
24/7 operations via Vpower™ Curtailment System
- § Single storage medium for regen energy and FR

- § ABB ENVILINE™ ESS
- § Saft (580 kWh, 1100A / 1MW FR market)
- § Maxwell Supercapacitors(SC)
1.5MW, 3.3kWh regen
- § Viridity Energy
24/7 operations via Vpower™ Curtailment System
- § Battery for FR, SC for regen

- § ABB ENVILINE™ ESS
Conditional regen
- § Saft (3.3 MWh, / 8.75MW FR market)
- § Viridity Energy
24/7 operations via Vpower™ Curtailment System
- § Single storage medium for conditional regen and FR

ENVILINE ESS

Regen and Smart Grid



- § PJM revenues \$100-125K / MW / year
- § Captures braking Energy (\$40+25K/year)
- § Large load enables high bidding possibility
- § Use of existing infrastructure and Real Estate
- § No out-of-pocket costs for the Transit Authority
- § Lower cost VS AC grid regulation connection

Lunch: Resume at 12:30

Design considerations for safe and reliable operations in mass transportation

12:30– 1:00

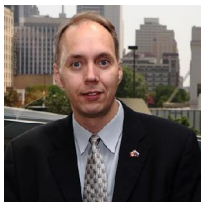


Over voltage protection for equipment and people
Chris Spudic, High Voltage, ABB



Andrew Wilkins, DC Wayside, ABB

1:00– 1:45



Safety and reliability by design
Oleg Goureev, Low Voltage, ABB



Marc Chevalier, Low Voltage, ABB

Design considerations for safe and reliable operations in mass transportation

1:45– 2:15



Avoiding transformer failures with predictive maintenance

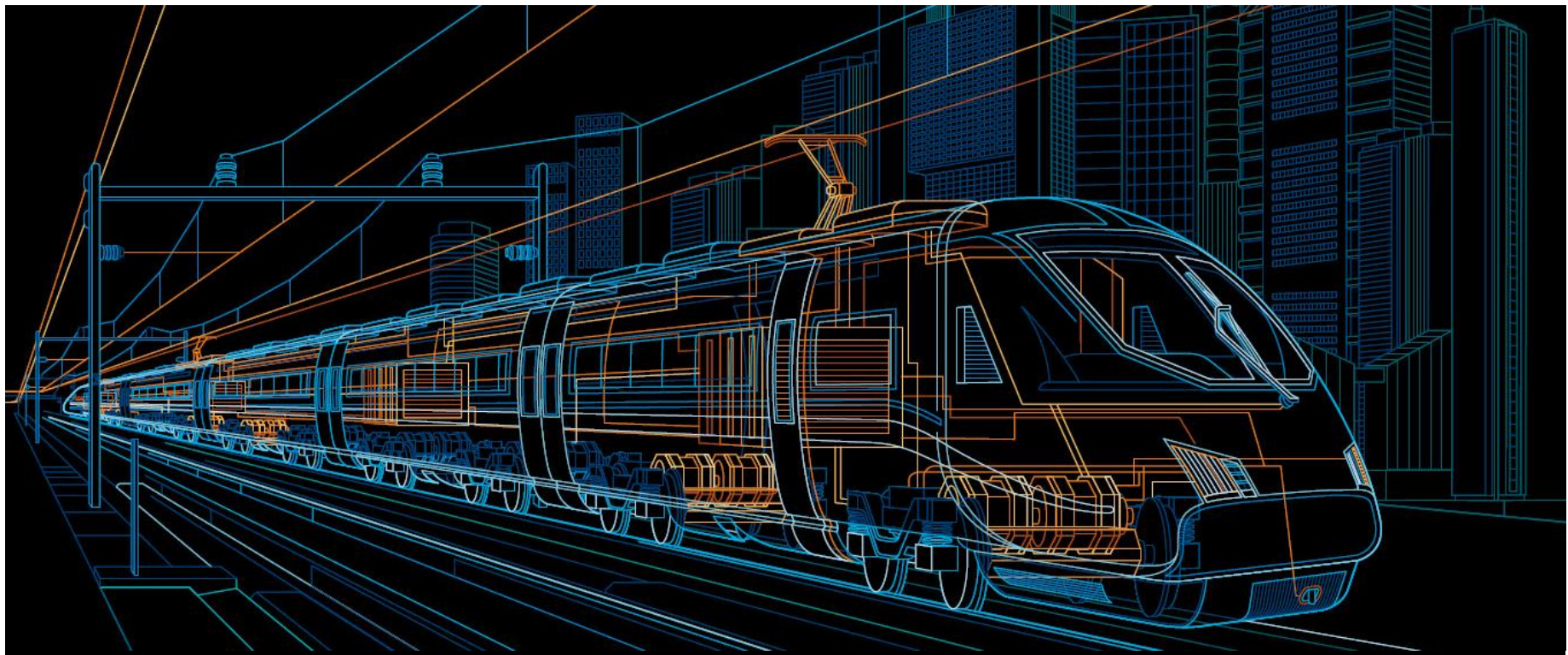
Brett Todd, Transformer Services, ABB

2:15– 2:45



Condition monitoring and asset health management

David Clark, Enterprise Software, ABB

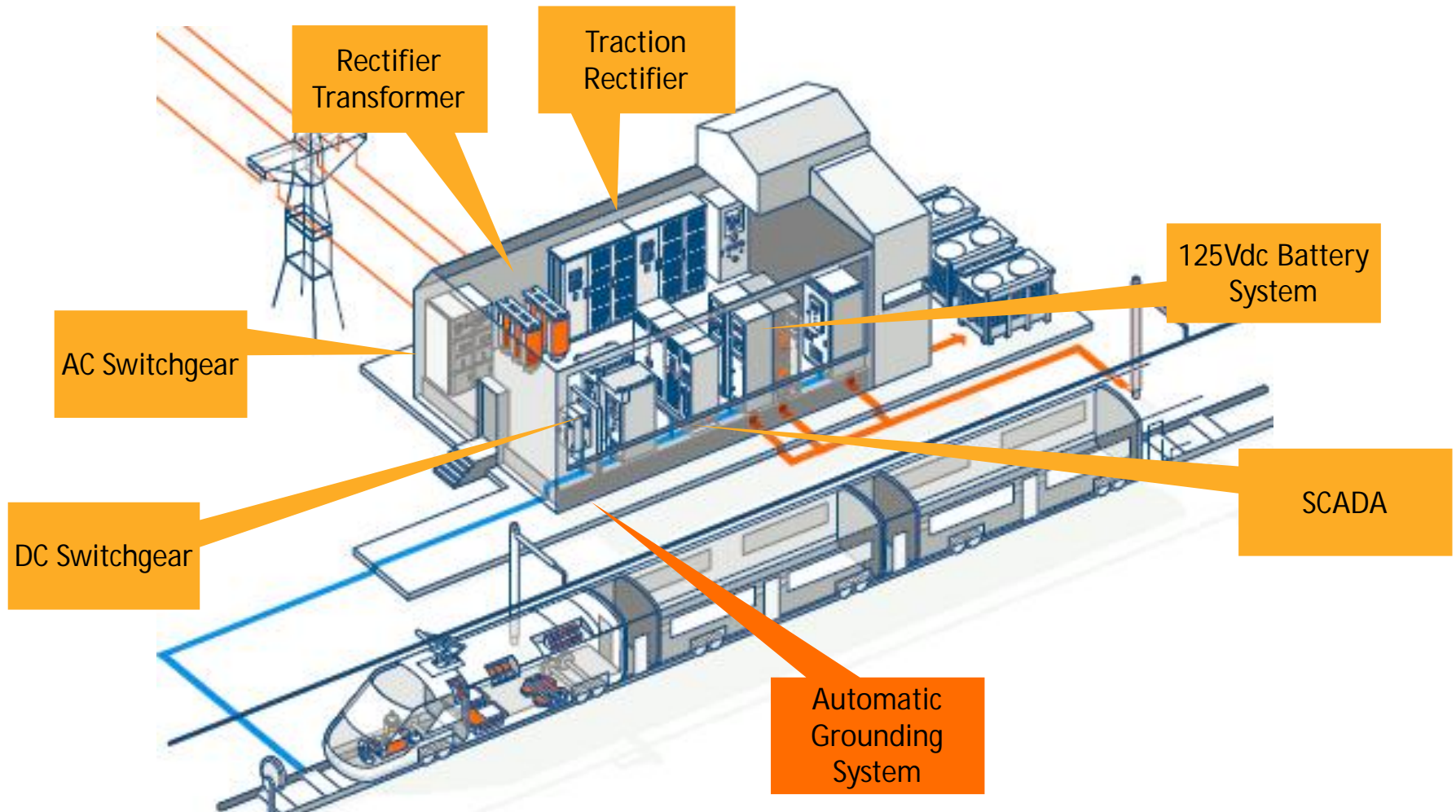


Andrew Wilkins, Business Development Manager, DC Wayside Power

Overvoltage Protection for Equipment and People

Wayside Automatic Grounding Systems

DC Traction Power – Main Equipment



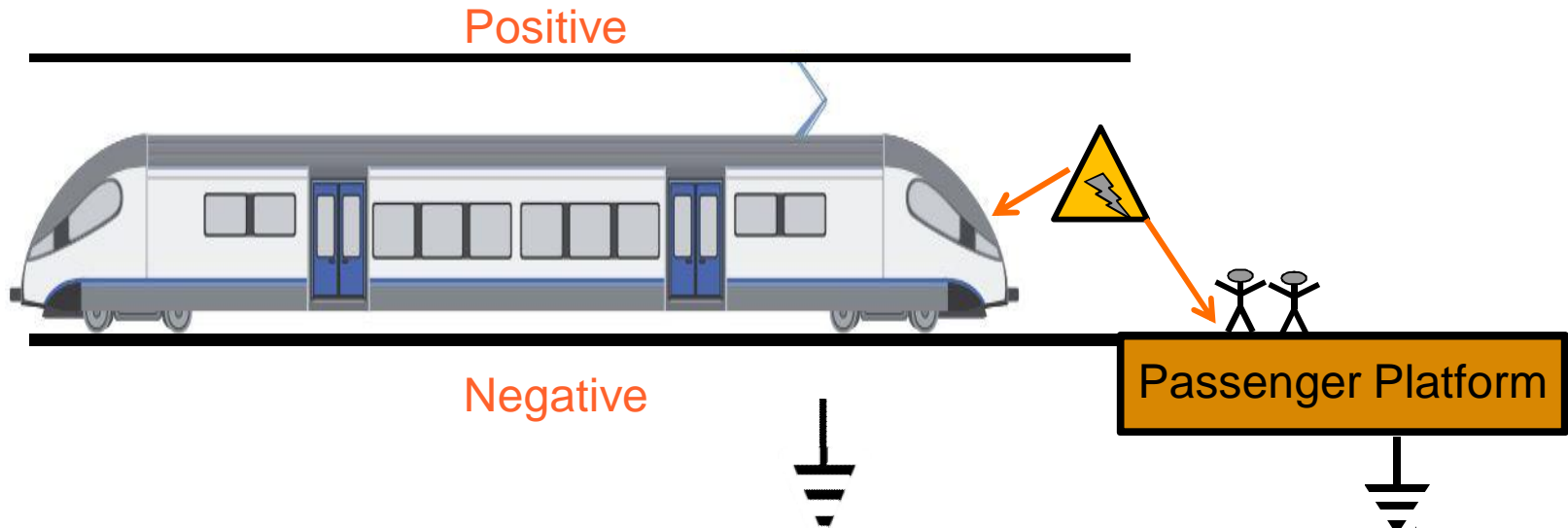
Automatic Grounding Systems

- § Most modern DC rail networks operate on a floating negative rail system
- § Why a floating system? To minimize stray current which can damage underground infrastructure.
- § AGS are also known as:
 - § *Negative Grounding Device (NGD)*
 - § *Floating Negative Automatic Grounding System (FNAGS)*
 - § *Rail Grounding Switch (RGS)*
 - § *Rail to Ground (R2G) Switch*
 - § *Voltage Limiting Device (VLD)*

Consequence of a Floating Negative Rail System

Potential exposure to unsafe voltages

- Even though the Negative is floating (ungrounded), high traction currents and rail resistance (debris) cause a potential across the Negative and Ground over time.
- AGS constantly monitors Negative vs Ground, and clears the unsafe voltage condition (programmed 30 – 200VDC) when it occurs.



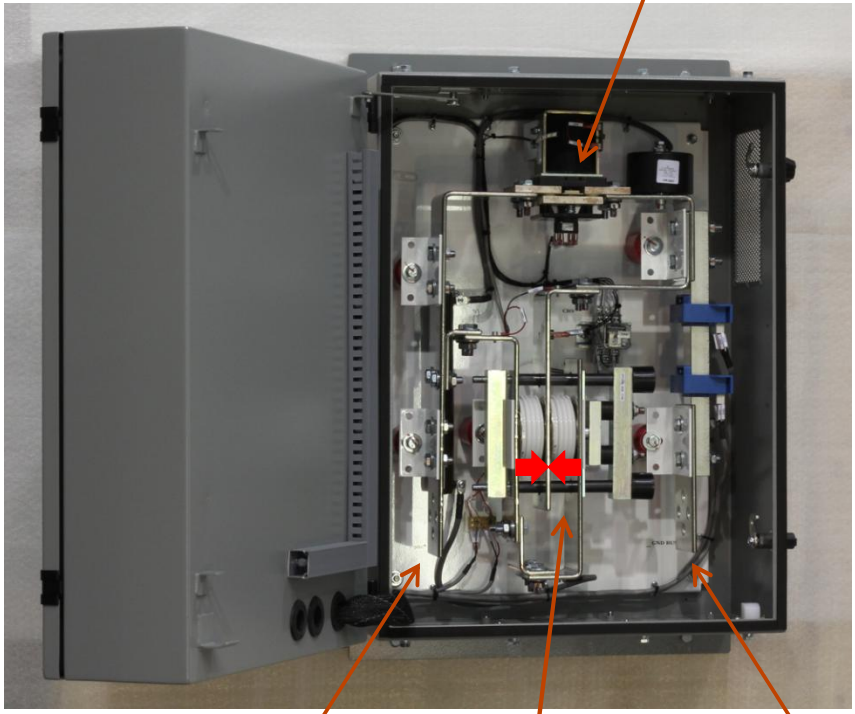
AGS – Wall Mount or Freestanding Enclosure

Separate Control and Power Compartments

§ Control compartment



§ Power compartment



§ Contactor

§ Negative (running) rail connection

§ SCRs (thyristors)

§ Earth connection

Meeting the EN50122-1 Touchsafe Voltage Standard

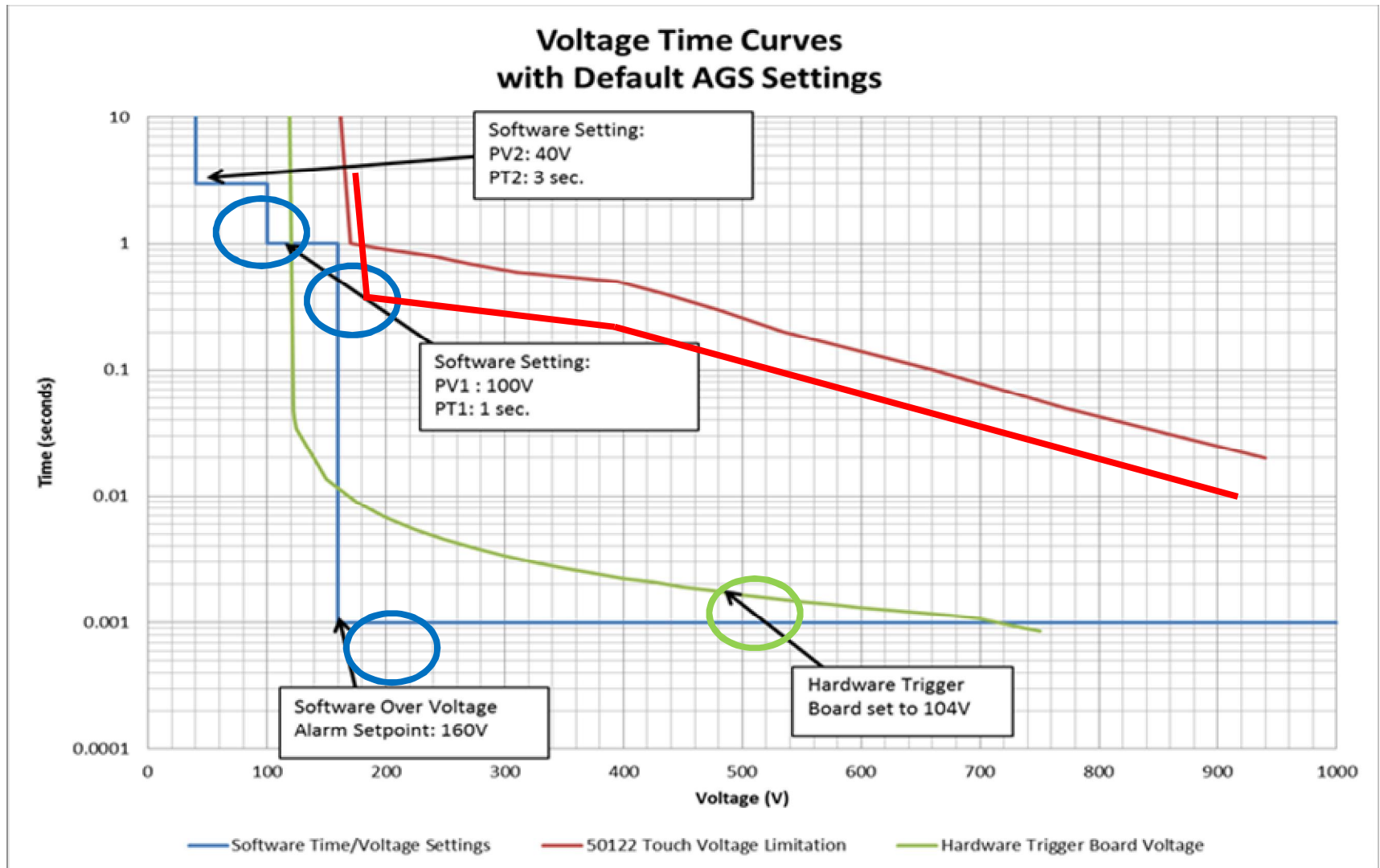
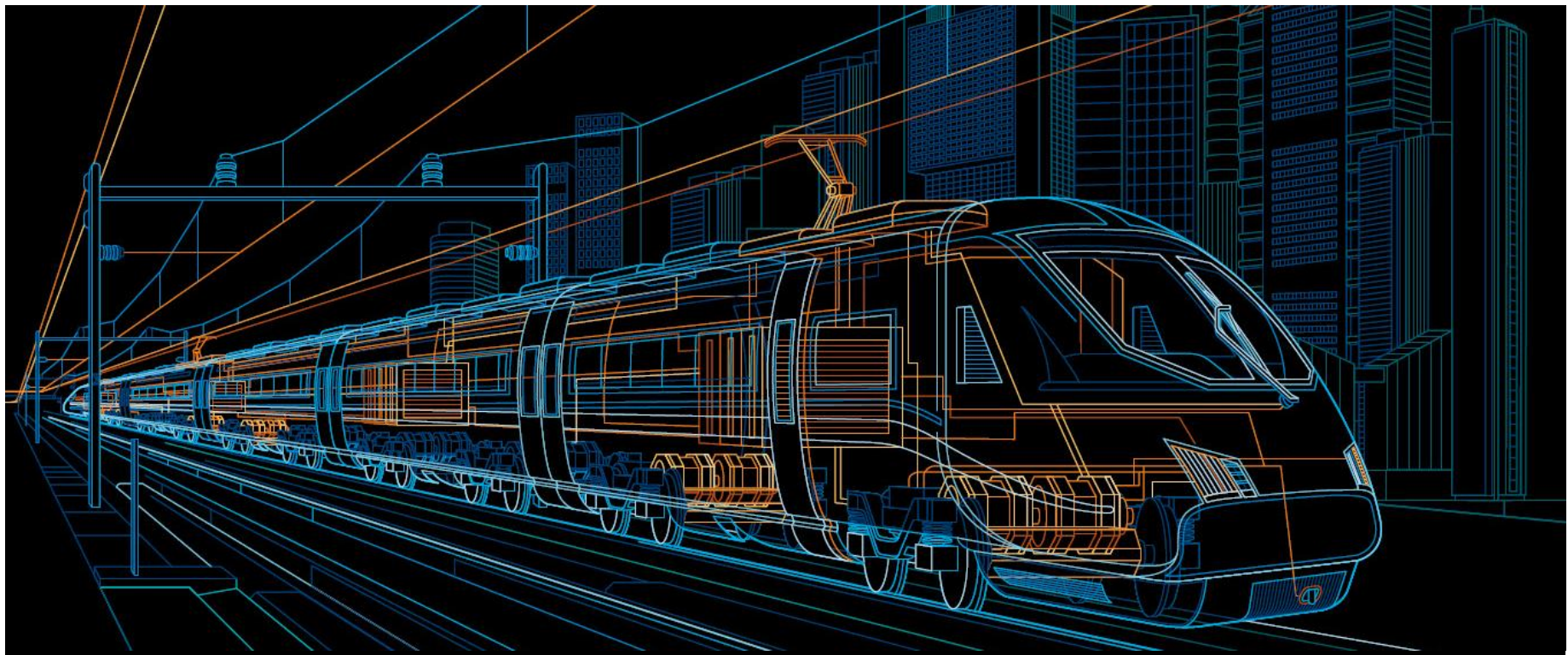


ABB AGS Facts

- § Proven safety and lifecycle design of 25+ years, > 100 units in field.
- § The only wall mounted version available, saving precious TPSS floorspace.
- § Bidirectional: Some competitors offer unidirectional only.
- § Contactor / Thyristor design offers more flexibility.
- § Meets EN50122-1 Touchsafe Voltage Standard.
- § Enviline Website: www.abb.com/enviline



Christopher M. Spudic, AC/DC Surge Arrester Specialist, Andrew Wilkins, BDM, DC Wayside Power

Overvoltage protection System reliability and safety

Agenda



§ What is a Surge Arrester



§ How does an Arrester Function



§ Considerations when Selecting Surge Arresters



§ Implications and Applications on Traction Systems



§ Success Story

Surge Arrester Portfolio

Surge arresters for HV and MV



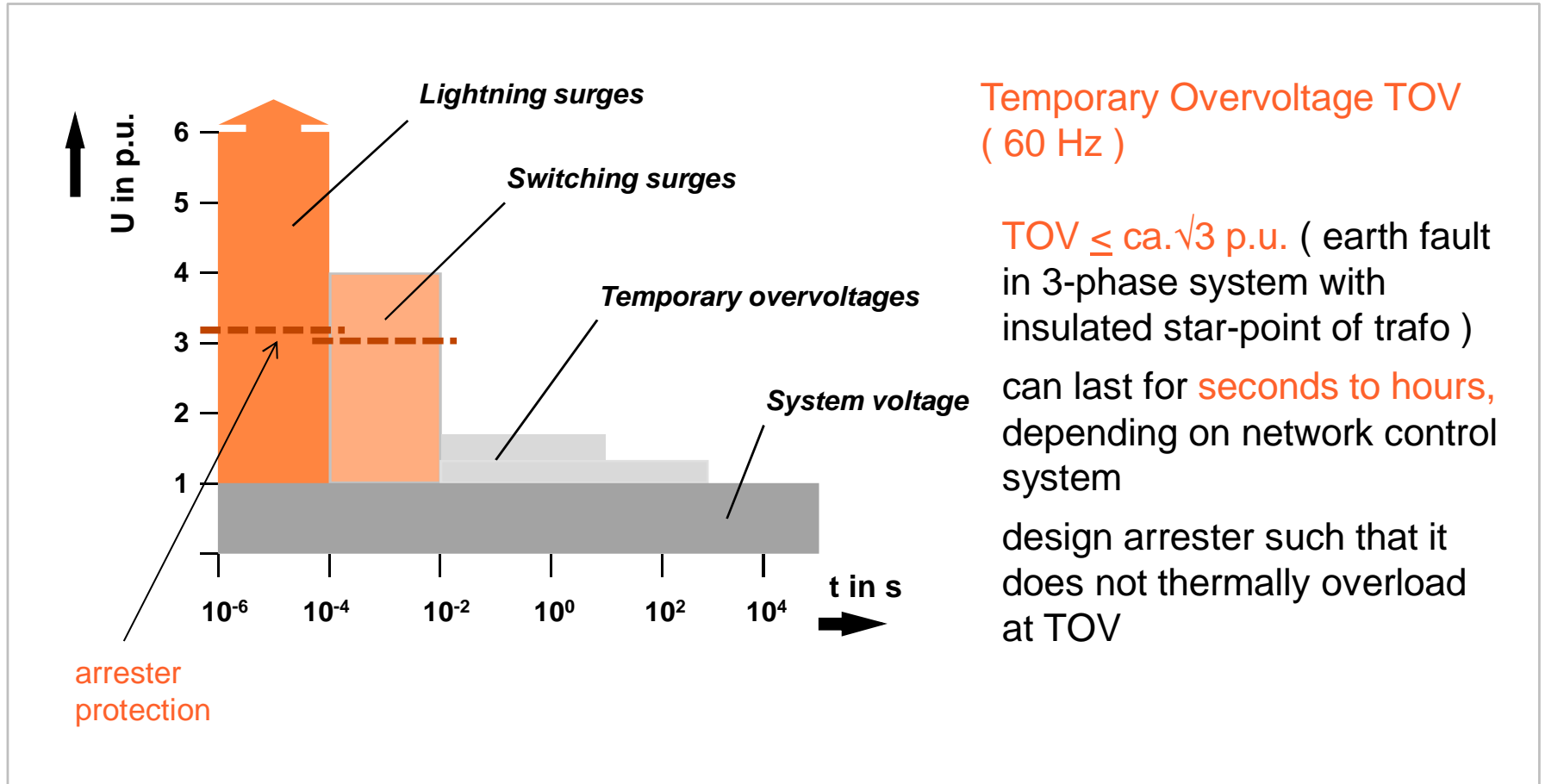
What is a Surge Arrester?

A surge arrester is a device comprised of Metal Oxide Varistors used to protect electrical equipment from over-voltage transients caused by external (lightning) or internal (switching) events

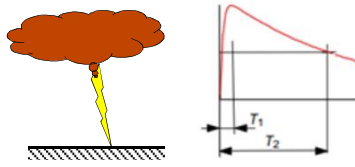
ABB's Portfolio specializes in AC and DC solutions and arresters for traction systems that consider regenerative braking and the potential for TOVs.

What Do Arresters Do

Overvoltage Stresses in MV Systems



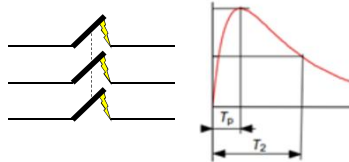
What Should Be Considered Sources of Overvoltages



$$T_1 = 1,2 \mu\text{s}$$
$$T_2 = 50 \mu\text{s}$$

Lightning overvoltages

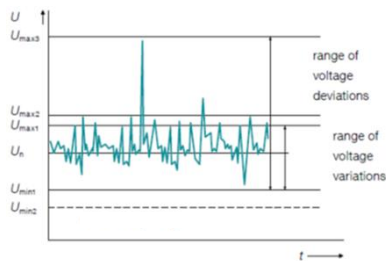
- Direct and indirect lightning (back flash)
- Induced voltages



$$T_p = 250 \mu\text{s}$$
$$T_2 = 2\,500 \mu\text{s}$$

Switching overvoltage

- Breakers
- Re-strikes
- Fuses
- Line discharges



Temporary overvoltage

- § Low impedance phenomena (voltage variations on primary network)

Lightning and switching overvoltages have high amplitudes (several 100 kV up to MV).

They are transients overvoltages and occur only for short times (in the range of μs to ms)

They can seriously damage all kind of equipment.

The most effective protection against these overvoltages is the use of MO surge arresters close to the electrical equipment.

Temporary overvoltage have low amplitudes but occur for much longer times (some 1s up to hours). In general these overvoltages are not a problem for most of the equipment but **can be dangerous for the MO surge arresters due to the high amount of energy**. This must be considered during selection of surge arrester

Performance Curve

Voltage-current characteristic of a MO-varistor

A operating point, continuous operating voltage MCOV

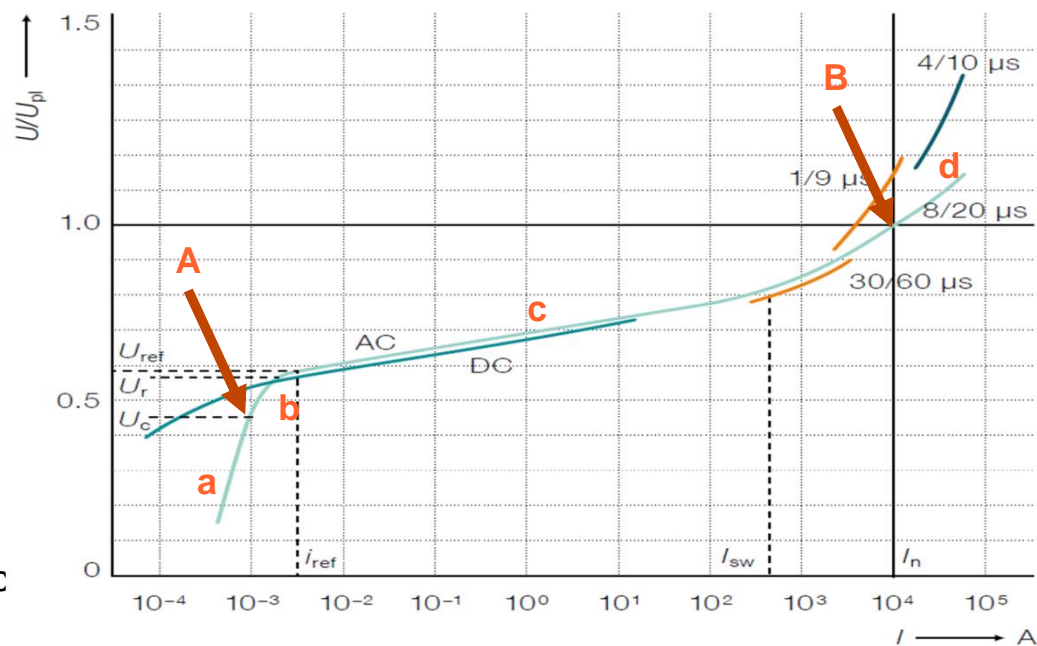
B protective region, residual voltage Duty Cycle

a linear region, capacitive characteristic

b knee point

c extremely non-linear region

d linear region, ohmic characteristic



Surge Arresters

MV arresters direct mold silicone rubber

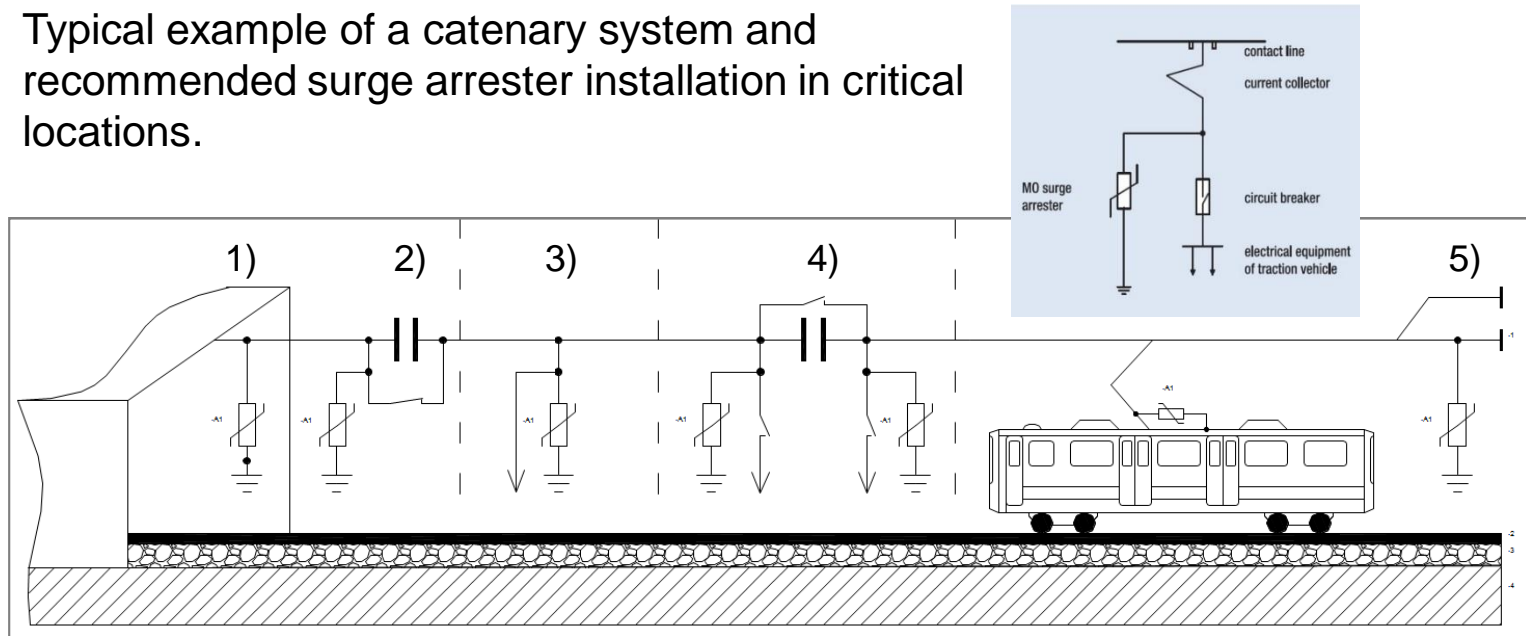
- § ABB direct mold silicone rubber design introduced since 1985
- § The MO blocks are clamped between metal end fittings with pre-stressed rods, high mechanical stability
- § **Completely sealed**, no moisture ingress in the arrester and between MOs' preventing internal discharges
- § High environmental robustness; **high UV and ozone stability**
- § Silicone is **naturally hydrophobic** due to low molecular weight silicone oils
- § Hydrophobic even heavily polluted
- § For operating temperatures from -60°C to $+80^{\circ}\text{C}$



What To Look For

Selection of arrester voltage

Typical example of a catenary system and recommended surge arrester installation in critical locations.



- 1) Underpass entrance
- 2) section separation
- 3) current tap, e.g. switch heater

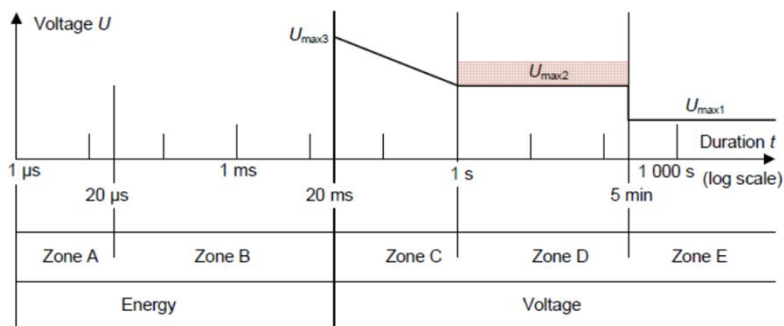
- 4) feeder from substation
- 5) line end

What To Look For

Selection of arrester voltage

IEC 62497-2 or EN 50163

Railway applications – Insulation coordination
Part 2: Overvoltages and related protection



IEC 042/10

Table A.1 – Overvoltages

| Nominal voltage U_n V | 750 | 1 500 | 3 000 | 15 000 | 25 000 |
|----------------------------|---------|---------|---------|---------|---------|
| Coefficient k | 0,061 1 | 0,067 6 | 0,067 3 | 0,076 7 | 0,074 1 |
| U_{max1} (V) | 900 | 1 800 | 3 600 | 17 250 | 27 500 |
| U_{max2} (V) | 1 000 | 1 950 | 3 900 | 18 000 | 29 000 |
| U_{max3} (V) | 1 270 | 2 540 | 5 075 | 24 300 | 38 750 |

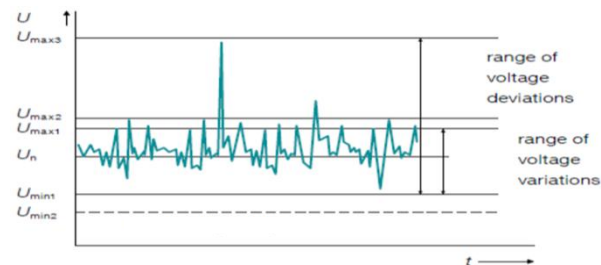
Zone A: Lightning overvoltages

Zone B: Switching overvoltages, due to high impedance phenomena (currents switched off inductive circuits)

Zone C: Temporary overvoltages, due to low impedance phenomena (voltage variations on primary network)

Zone D: Highest non-permanent voltage U_{max2}

Zone E: Highest permanent voltage U_{max1}



Threat of Atmospheric Discharge

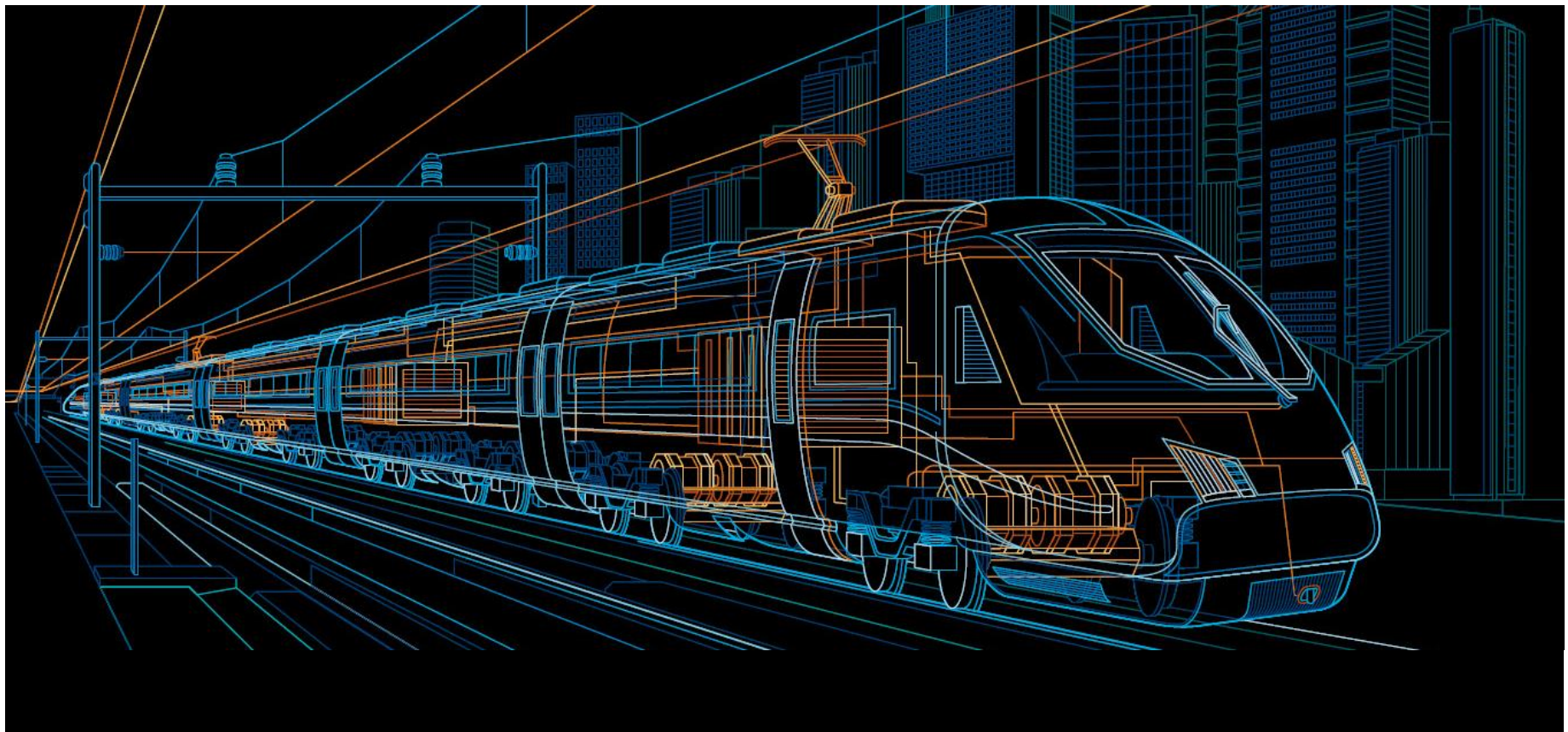
- The majority of lightning-related fatalities and injuries in Canada occur in Ontario
- Toronto sees ~28 thunderstorms a year
- Toronto experiences ~200 lightning strikes a year



Determining Lightning Strike Probability

§ “Lightning Protection of Light Rail Transit DC Overhead Contact System” – DEV Paul P.E. Senior Member IEEE

- Determine likely lightning is to strike your system
- $Ng=0.04(Td^{1.25})$
 - Ng = Flash Density (Provides some likelihood of number of times lightning will strike the ground.)
 - $Ng=0.4(60^{1.25})$
 - $Ng=6.68$
- $Nocs=WLNg$
 - W = Width of the track Km (0.015)
 - L = Length of track Km (161)
 - Ng = Determined above (6.68)
 - $Nocs=0.015(161)(6.68)$
 - $Nocs=16$
 - 16 strokes can be expected to strike either directly or near RTD Catenary systems.



Oleg Goureev, Railway product & systems manager, Low Voltage

Safety and reliability by design

ABB Low Voltage Products division



Oleg Goureev

- Railway Products and Systems manager, Low Voltage Products
- Over 18 years in railway business

Low Voltage Products

What does it mean low voltage components?

- § Below 1500V (third-rail and OCS included)
- § Relays, contactors and motor starters
- § Circuit breakers and switches
- § Timers and monitoring relays
- § Pilot Devices
- § Connectivity (terminal blocks and PMA)



Low Voltage Products

Applications and where used in the car

- § 50-150 breakers per car
- § 50-250 relays and contactors per car
- § Protections (main breakers, branch circuits)
- § Motor/heater power controls
- § Train line relays, lighting, doors, breaks etc



Low Voltage Components in the car Design, considerations and misconception



- § Low voltage components mainly considered as non-critical path during car design
- § Often commodities and major systems are following through different procurement channels
- § Components selection usually occurs after design advance of major car systems
- § Time constrains and main system design/integration leave less time for component selection
- § Safety and reliability assessment is done by system supplier based on its scope of supply



Design approach

Reliability



- § Reliability – probability of the system to operate properly for a specific period of time (design life) at the specific design conditions without failure.
- § Reliability of a system is equal to probability that at least one of the minimal path sets works.
- § For a minimal path set to work, each component in the set must work. Failure at least one component in the set leads to the failure of the entire system.

Design approach

Reliability

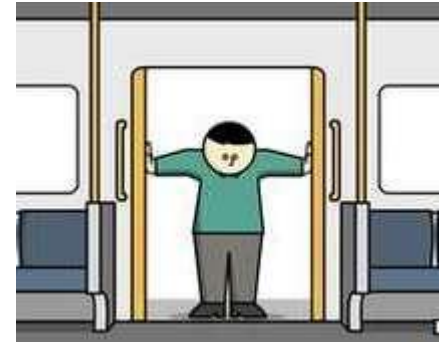
- § Example, door system.
- § Good reliability was predicted by door system supplier.
- § Car builder implemented door system trainline control and monitoring relay
- § Resulted path set becomes:



Driver console



trainline relay



door operator

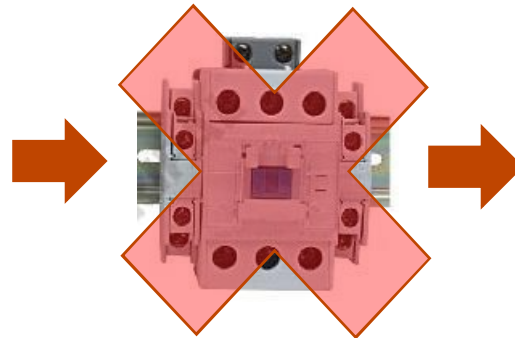
Design approach

Reliability

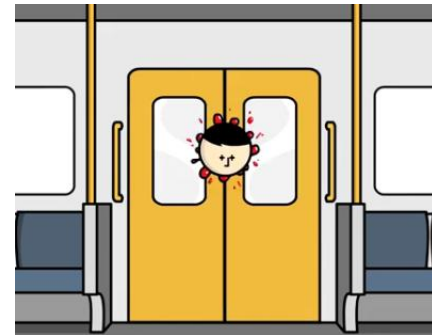
- § Adding more components will reduce door system reliability that was provided by door supplier.
- § Additional component selection may lead to significant deterioration of system reliability.



Driver console



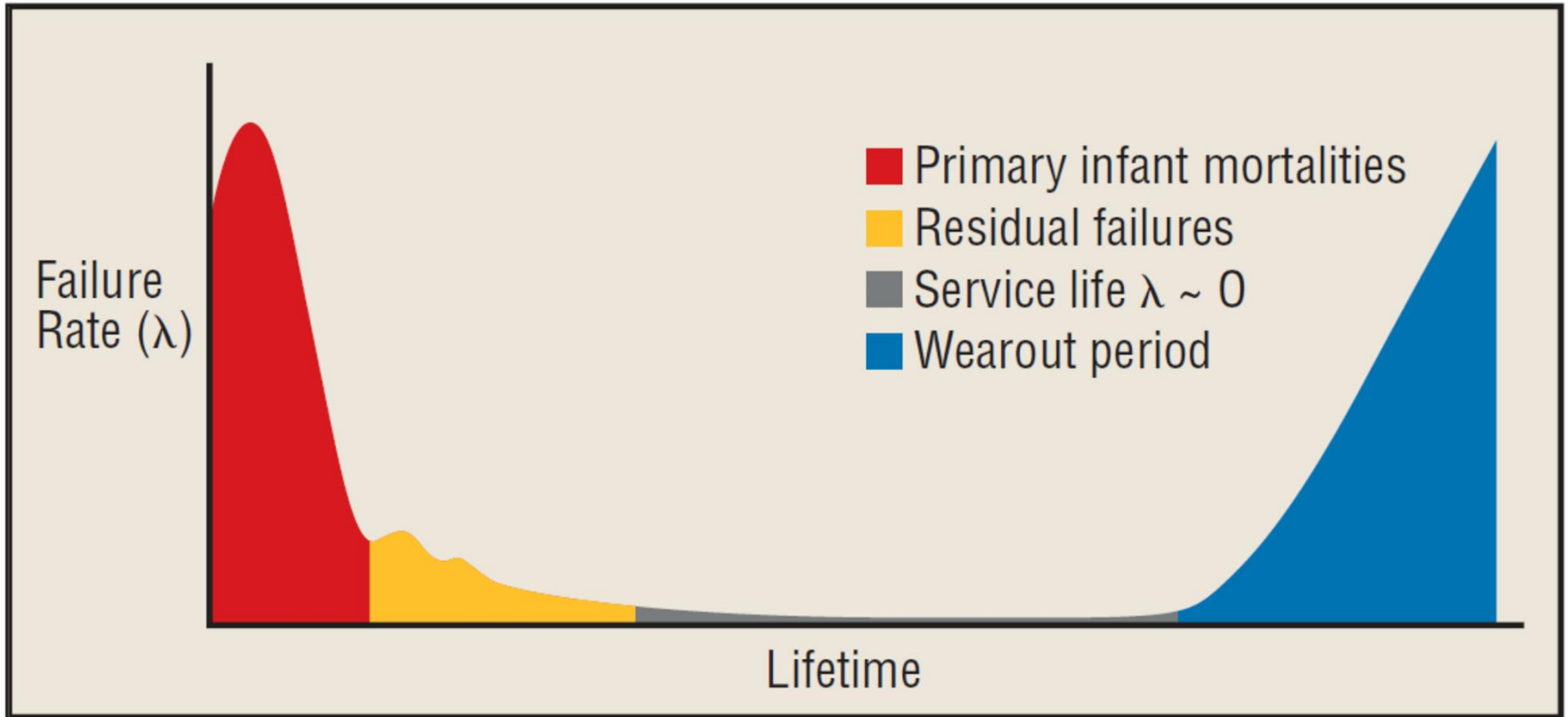
trainline relay
failure



door operator

Design approach

Failure rate



§ Typical “bathtub curve”

§ Failure rate: $\lambda = \sum_{i=0}^n (\lambda_{mode})_i$ - sum of all failure rates of all components in all modes

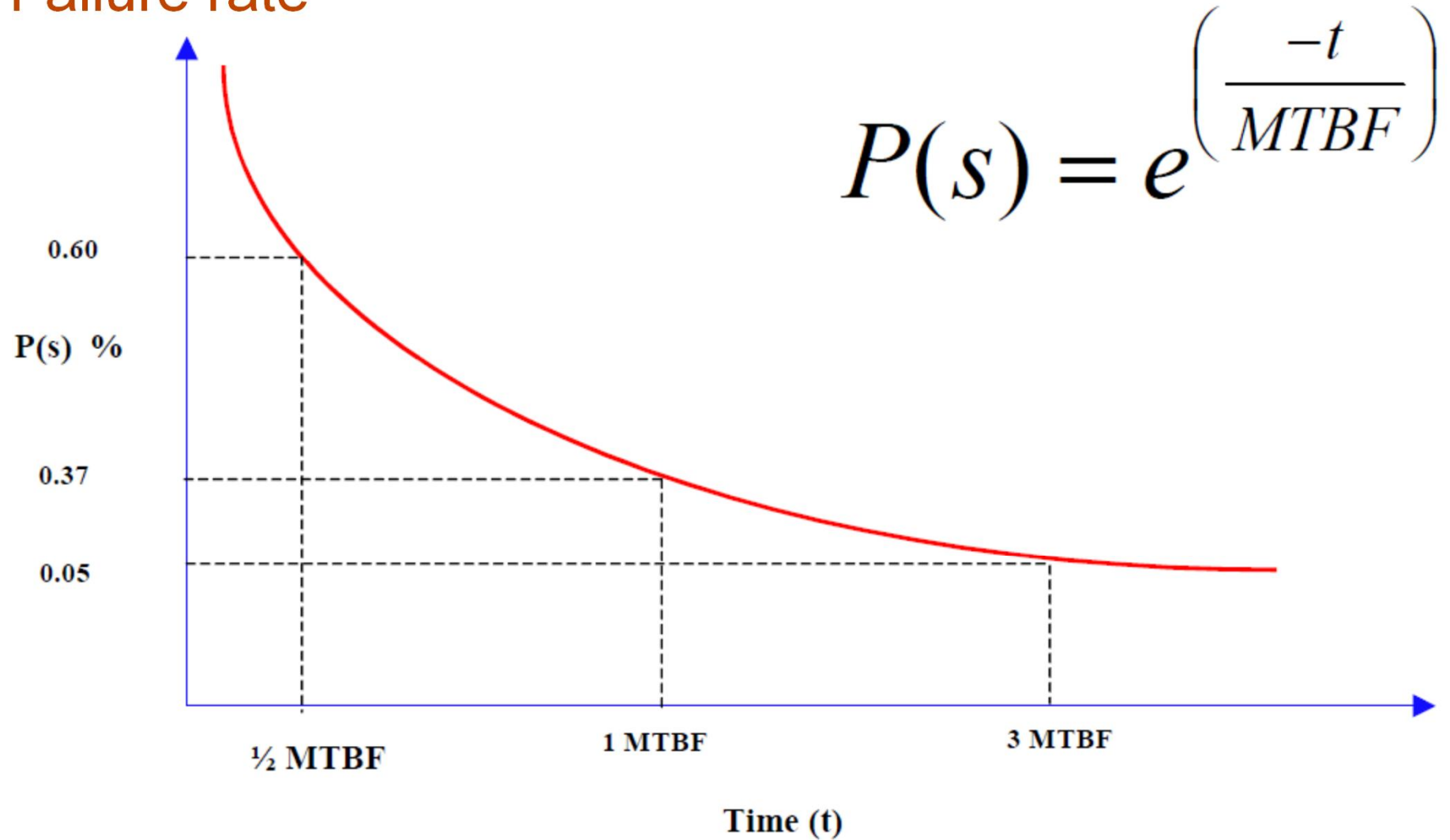
Design approach

System Reliability

- § Reliability measure: Mean Time Between Failures (MTBF) or Mean Time To Failure (MTTF).
- § MTBF – avg time between successful failures (repairable units)
- § MTTF – average time until failure occurs (non-repairable)
- § Reliability Function: $P(s) = e^{-\frac{t}{MTBF}}$
- § At the moment $t=MTBF$ the probability that the system will still work: $P(s) = e^{-1} = 1 / 2.718 = 0.37 = \underline{\underline{37\% - confidence level}}$
- § For previous example, if Door system MTBF = 500,000 hrs, the confidence level that door will still operate as intended in 500,000 hrs is 37%
- § MTTR – Mean Time To Repair. Average time to repair repairable system (down time for rail system).

Design approach

Failure rate



$$P(s) = e^{\left(\frac{-t}{MTBF}\right)}$$

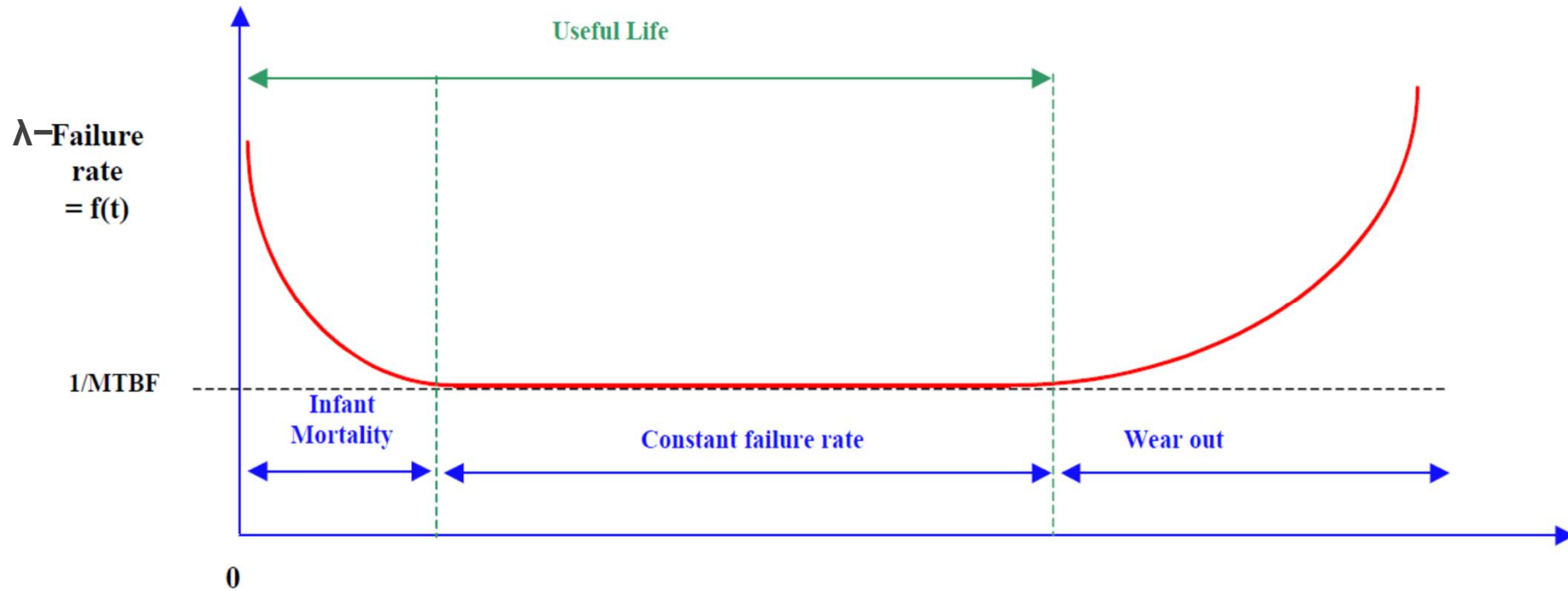
Design approach

System Reliability

- § $MTBF = 1 / \lambda$
- § For component having 20 failures in 1M hrs ($\lambda = 20 * 10^{-6}$):
 $MTBF = 1 / 20 * 10^{-6} = 50,000$ hrs
- § For door operator with $MTBF = 500,000$: $\lambda = 1 / 500,000 = 2 * 10^{-6}$
- § Let's say control relay reliability: $\lambda_{\text{relay}} = 20 * 10^{-6}$. Total system reliability will become: $\lambda_{\text{TOT}} = \lambda_{\text{door}} + \lambda_{\text{relay}} = 2 * 10^{-6} + 20 * 10^{-6} = 22 * 10^{-6}$
- § Resulting total MTBF will pass from 500,000 to $1 / 22 * 10^{-6} = 45,455$ hrs (-91% !!!)
- § ABB commercial relay reliability data: $100 * 10^{-9}$ ($0.1 * 10^{-6}$). MTBF with ABB relay: $1 / 0.1 * 10^{-6} = 10,000,000$ hrs (-5%). Railway applications are different from commercial and industrial applications. **MTBF is much lower for railway applications.**

Design approach

Failure rate



Design approach

System Availability

- § Availability – another measure of reliability. It is a probability of the system to provide its functions when needed.
- § $\text{Availability} = \text{UpTime} / (\text{UpTime} + \text{DownTime}) = \text{Uptime} / \text{TotalTime}$
- § Availability is traceable by monitoring system performance fleet-wise over time period (month, quarter, year).
- § MUT – Mean Up Time = MTBF
- § MDT – Mean Down Time = MTTR (Mean Time To Repair)
- § Example. At the end of 3-month period for 100-car fleet: cumulative revenue hours for door system reported at 600,000. Cumulative time reported by repair shop for door system: 1,440
 $\text{Availability} = 600,000 / (600,000 + 1,440) = 99.8\%$
- § Sometimes it is easier to monitor car mileage than time. In this case MTBF replaced by MDBF (Mean Distance Between Failures)

Design approach

Failure rate calculation

$$\S \lambda_p = \lambda_b * \pi_T * \pi_A * \pi_R * \pi_S * \pi_C * \pi_Q * \pi_E \text{ (MIL-HDBK-217F)}$$

| | |
|-------------|--|
| λ_p | Part failure rate per million hours (1/10 ⁶ hrs) |
| λ_b | Base failure rate usually expressed by a model relating the influence of electrical and temperature stresses on the part |
| π_E | Environmental factor (for railroad the π_E shall be used based on G _M - mobile ground) |
| π_Q | Quality factor |
| π_L | Learning factor |
| π_T | Temperature sensitivity |
| π_L | Load Stress Factor |
| π_C | Contact Form Factor |
| π_{CYC} | Cycling Factor |
| π_F | Application and Construction factor |

Design approach

Failure rate calculation

- § ABB TNL relay example (max current: 16A, 4 poles)
- § Operating conditions: +50°C, 10 cycles per hour, Load – 10A resistive
- § 1) Industrial application (+25°C, fixed ground)

$$\lambda_p = 2.06 \cdot 10^{-6}, \text{ MTTF} = 1 / \lambda_p = 485,000 \text{ hrs}$$

- § 2) Railway application (+50°C, mobile ground)

$$\lambda_p = 21.85 \cdot 10^{-6}, \text{ MTTF} = 1 / \lambda_p = 46,000 \text{ hrs}$$

- § Solution: Select different component (TAL40):

$\lambda_p = 14.12 \cdot 10^{-6}, \text{ MTTF} = 1 / \lambda_p = 71,000 \text{ hrs}$ or work on the environmental conditions – lower operating temperature to +40°C:

$$\lambda_p = 12.76 \cdot 10^{-6}, \text{ MTTF} = 1 / \lambda_p = 78,000 \text{ hrs}$$

- § Another way ABB improves reliability – factory type test at railway-specific conditions (IEC61373 shock and vibration, temp test etc).

Design approach

At the end....

- § It is important to understand the meaning of reliability prediction – it is a confidence level that system will work for certain period.
- § MTBF is not a magical number that guaranties the life of the system
- § MIL-HDBK-217F is over-conservative, field-data monitoring gives more accurate results based on volume.
- § Example of system scheduled to be used for 2 years
($2 \cdot 365 \cdot 24 = 17,520$ hrs of non-stop operation during 2 years)

| MTBF | P(s), % |
|---------|---------|
| 100,000 | 84% |
| 200,000 | 92% |
| 500,000 | 97% |

Safety by design

Fire, Smoke and Toxicity (FST)

- § Historically engineering used FRA regulations (originally issued in 1984, then revised in 1989). 49CFR Part 238 used as a guideline.
- § Objective to estimate fire hazard by analyzing:
 - HRR – Heat Release Rate
 - Smoke opacity
- § Not directly called by FRA, toxicity is added in fire hazard analysis
- § Main objective - let passenger enough time to evacuate. Select materials that will not create hot temperature at upper layer and keep exit door visible.

Safety by design

Fire, Smoke and Toxicity (FST)

- § Attempt to limit fire propagation and limiting smoke toxicity
- § Safety testing split for small and big parts
- § Later NFPA-130 becomes widely used for FST requirements and testing
- § NFPA-130 requirements:
 - Small parts ($< 16\text{in}^2/103\text{cm}^2$): no testing required if not contribute to the fire growth in end use configuration. Otherwise small parts can be tested as per ASTM E1354 and meet the following performance criteria:
 - ü Avg. heat release rate (180s): $\leq 100 \text{ kW/m}^2$
 - ü Avg. specific extinction area (180s): $\leq 500 \text{ m}^2/\text{kg}$

Safety by design

Fire, Smoke and Toxicity (FST)

- Big parts ($\geq 16\text{in}^2/103\text{cm}^2$): shall be tested as per ASTM E 162 (Surface Flammability) and ASTM E 662 (Specific Optical Density of Smoke) with following performance criteria:

ü ASTM E 162: $I_s \leq 35$

ü ASTM E 662: $D_s(1.5) \leq 100$ and $D_s(4.0) \leq 200$

§ Toxicity to be tested according with SMP-800C / BSS 7239 with performance criteria (note that now 9 gases shall be tested instead of 7 required in the past):

| Gas | Carbon Monoxide CO | Carbon Dioxide CO ₂ | Nitrogen Oxides NO/NO ₂ | Sulfur Dioxide SO ₂ | Hydrogen Chloride HCl | Hydrogen Fluoride HF | Hydrogen Bromide HBr | Hydrogen Cyanide HCN |
|-------------------------------------|-----------------------|-----------------------------------|---------------------------------------|-----------------------------------|--------------------------|-------------------------|-------------------------|-------------------------|
| Critical Concentration (ppm) | 3 500 | 90 000 | 100 | 100 | 500 | 100 | 100 | 100 |
| BSS-7239 | X | | X | X | X | X | | X |
| SMP-800C | X | X | X (NO ₂) | X | X | X | X | X |

Requirements on railway product in NAM

Fire, Smoke and Toxicity (FST)

| Standard | Output | Attempts to limit |
|---------------------|---|---|
| ASTM-E162 | Flame Spread Index, Is and flame drips | Flame propagation |
| ASTM-E662 | Smoke developed at 1.5m and 4 min | Smoke optical density (opacity). Not a toxicity |
| ASTM-E1534 | Heat Release – peak and average at 3min (180 sec) | Flame propagation and flashover |
| BSS-7239 / SMP-800C | Concentration of toxic gases | Smoke toxicity |

Requirements on railway product in NAM

Fire, Smoke and Toxicity (FST)

- § FST test report are required. Declaration of conformity doesn't work anymore
- § Test reports shall be not older than 3 years or up to 5 year max if company provides a letter certifying that no materials or production was tolerated (changed) since last time it was tested. This requirements means plastic shall be re-tested every 3 years.

ABB Low Voltage Products and Systems

Customer support service



- § ABB Canada (Montreal) – Railway Center of Excellence in NAM
- § Rail market focus
- § Components selection, railway industry support
- § Standards compliance for railway-graded selected products
- § Testing and approval process for railway products (on-car testing, engineering evaluation etc.)
- § Customer support with on-site troubleshooting and problem solving
- § Extensive failure analysis tailored for customer application (includes schematics and operation analysis, component operation mode analysis, failure analysis in the specific circuit etc.)



Marc Chevalier, Rail Day Toronto, October 2016

Flexible Non-Metallic Cable Protection Conduits, Fittings and Accessories

Flexible Non-Metallic Cable Protection Systems

Potential Hazards for Cables

Cables are an essential part of most electronic systems, providing power and making signal connections for monitoring and control functions.

They are often exposed to environmental and mechanical hazards which can be potentially damaging and may ultimately cause the electronic system to malfunction or even fail completely.

Mechanical Effects



Impact



Tension



Rodents



Pressure



Abrasion

Atmospheric Effects



Water



UV-radiation



Dust



Weathering
(snow, ice, rain)

Chemicals



Oils, fats, bases, acids

Flexible Non-Metallic Cable Protection Systems

Cable Protection Systems can help



The ideal cable protection system provides.....

- Protection against the Mechanical Stresses which prevail in the application

Compression, Impact, Abrasion, Tension (Including conduit retention in fitting)

- Flexibility - If the cables are required to move with the machine. (Resistance to fatigue)
- Resistance to the sorts of chemicals which the system is exposed to in the application e.g. Oil, grease, cleaning agents etc.
- A sealed system excluding ingress of liquids and dust



Flexible Non-Metallic Cable Protection Systems

Cable Protection Systems can help



The ideal cable protection system provides.....

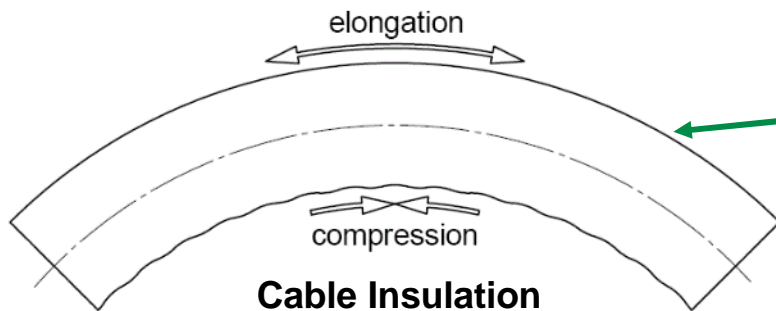
- Good resistance to weathering for external applications. Including UV resistance
- Resistance to attack by rodents if installed on the ground in external applications
- Ease of installation – Saving time and cost
- A wide operating temperature range



Polyamide Corrugated Conduits

Flexibility without loss of Strength

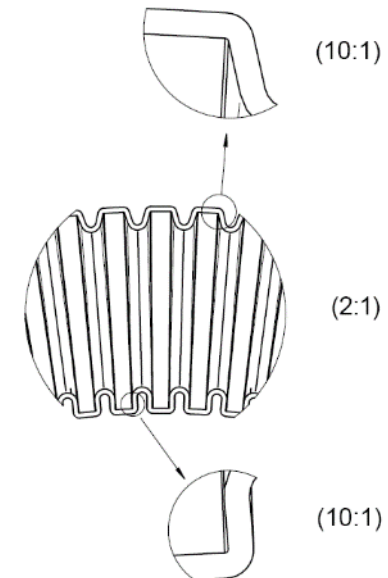
- Flexibility and pure mechanical strength are difficult to achieve at the same time
- Elastic materials such as those used for cable insulation are generally less robust and vulnerable to damage
- The Flexibility of Corrugated Conduits is provided by their geometry so that tougher, more robust materials can be used with excellent mechanical stability



Soft, elastic materials are necessary to provide flexibility

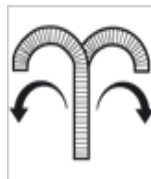
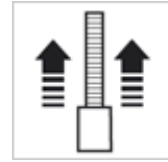
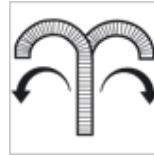
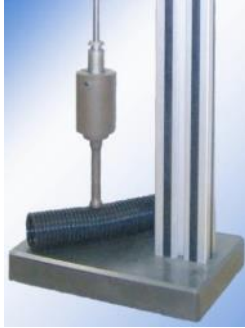


Flexibility is provided by the geometry (corrugations) strong hard, materials can be used



Polyamide Corrugated Conduits

Flexibility without loss of Strength



Flexible Non-Metallic Cable Protection Systems

Polyamide Corrugated Cable Protection Systems

Advantages of Polyamide Corrugated Cable Protection Systems

- Ease of Installation saving time and money.
Polyamide corrugated conduits can be cut to length using simple tools without the creation of sharp edges which could cut fingers or damage cable insulation. They can be connected to fittings in seconds.
- Simple configuration to suit system requirements. Wide range of Fittings and Accessories
- Since there is no metal content there is no danger of corrosion or of a short circuit which could potentially make the conduit itself live and require an earth connection. Polyamide corrugated conduits provide additional insulation



Flexible Non-Metallic Cable Protection Systems

Polyamide Corrugated Cable Protections Systems

Advantages of Polyamide Corrugated Cable Protection Systems

- High Impact and compression resistance. There is a common perception that metal is stronger than plastic. Polyamide corrugated conduits are crush resistant, providing very high impact resistance and compression strength. They recover in contrast to metals which remain permanently deformed
- High resistance to continuous bending cycles. Can be used in robotic applications where frequent high speed bending is involved
- Excellent resistance to UV and other forms of weathering in outdoor applications particularly for PA12



Flexible Non-Metallic Cable Protection Systems

Polyamide Corrugated Cable Protection Systems

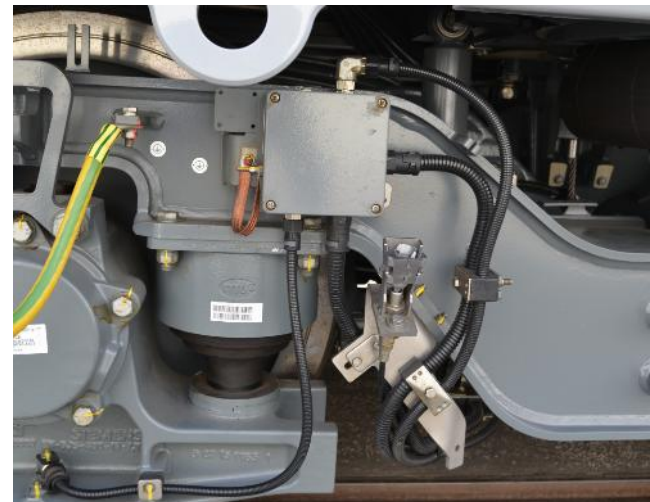
Advantages of Polyamide Corrugated Cable Protection Systems

- Excellent fire safety characteristics. Low flammability, smoke emission and toxicity allowing use in fire safety sensitive areas such as tunnels
- Polyamide (Nylon) is a very benign “Green” material complying with both the REACH and RoHS directives.
- There is no release of environmentally damaging chemicals during its production and with the addition of suitable additives it can comply with the most stringent fire safety standards for use in public installations such as railway carriages (Even underground)
- In Europe and Asia Polyamide Corrugated Cable Protection Systems are widely established. In North America their acceptance has been slowed by restrictive standards and the local metal conduit manufacturing base. However the technical advantages are convincing and widespread use will undoubtedly come with time.

Flexible Non-Metallic Cable Protection Systems Worldwide Rail Vehicle Applications

The combination of mechanical strength, flexibility, resistance to UV/weathering and sealing performance make polyamide corrugated conduits and fitting systems ideal for rail vehicle applications

- General cable protection
- Couplings
- On carriage roof
- On bogies
- In the passenger zone
- Junctions between railway carriages
- Special connections



Flexible Non-Metallic Cable Protection Systems Trackside and Infrastructure Applications



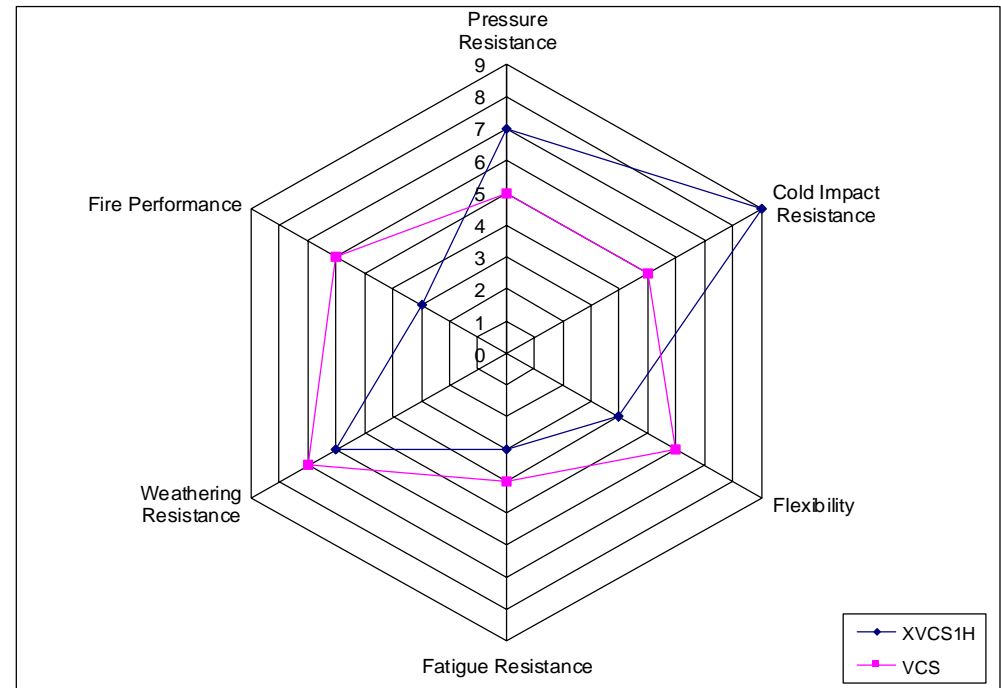
- § Track monitoring systems
- § Signalling
- § Sensor assemblies
- § Track points heating systems
- § Control cabinets

Flexible Non-Metallic Cable Protection Systems

Materials Technology - Additives

Basic polyamide PA12 and PA6 raw material characteristics can be modified to suit various applications with the addition of carefully selected additives. Extensive research and development is invested in the materials science since the addition of some modifiers has a negative effect upon other characteristics

- Antioxidants, UV- and heat stabilizers
- Flame retardants
- Antistatic additives (ESD)
- Impact modifiers
- Softeners
- Processing additives
- Fillers and reinforcements
- Pigments



Flexible Non-Metallic Cable Protection Systems

Materials Technology - Additives

| Additive | Improvement | Negative Effect Upon |
|------------------|---|---|
| Stabilizers | Temperature resistance UV-resistance | |
| Flame retardants | Flammability | Impact resistance Dynamic characteristics |
| Impact modifiers | Impact resistance Cold impact resistance | Fire safety properties |
| Softeners | Flexibility Reversed bending resistance | All mechanical strength characteristics Flame properties |
| Antistatic / ESD | Conductivity | Impact resistance Reversed bending resistance |

Flexible Non-Metallic Cable Protection Systems

Operating Temperature Range

Maximum Operating Temperature

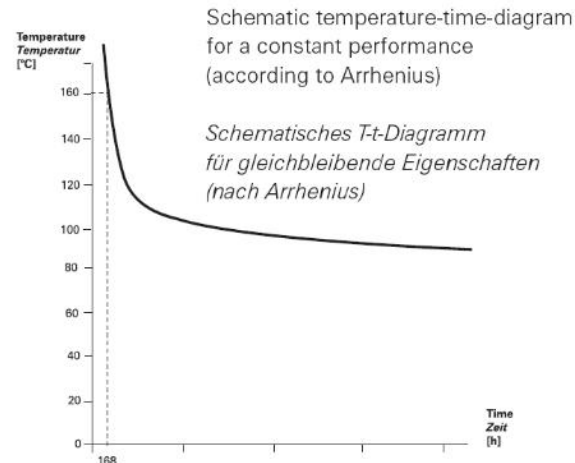
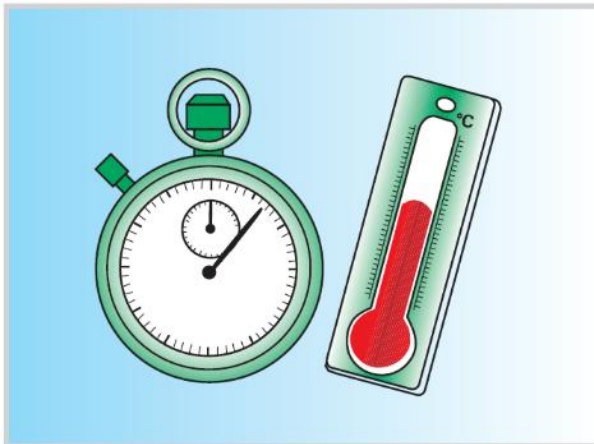
The Arrhenius curve below shows the relationship between temperature and material characteristics

For short periods of time exposure to higher temperatures may not be damaging

However if the temperature - time product rises above the curve permanent change may occur to the material composition affecting the product characteristics

| | | | |
|---------------|-------|-------|--------------------------------------|
| PMA specifies | PA6 | PA12 | |
| | 105°C | 95°C | max continuous operating temperature |
| | 120°C | 110°C | 20,000 hrs |
| | 160°C | 150°C | short term 168 hours. |

Special material products for high temperature applications PSX (200°C), TEC (250°C).



Sealing Performance

Flexible Non-Metallic Cable Protection Systems







Ingress Protection Levels EN 60529 / DIN 40050

IP(xy) x = Protection against Dust ingress
 y = Protection against Water ingress

- § IP66 strong water jet from any angle
- § IP67 immersion to a depth of 1m for 30 min
- § IP68 immersion, increase in depth or time to customer requirement
- § IP69K high pressure water jets from any angle. Simulation of cleaning jets.

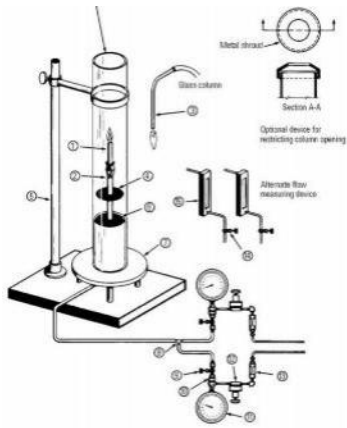
Achieving good sealing characteristics for a static system is relatively easy
for a system in continuous motion it is significantly more difficult



| | | |
|--|--------------|---|
|  | IPx4 | Splash water from all directions <i>Spritzwasser aus allen Richtungen</i> |
|  | IPx5 | Jet water at any angle <i>Strahlwasser (Düse) aus allen Richtungen</i> |
|  | IPx6 | Powerful jet water from any angle <i>Starkes Strahlwasser aus allen Richtungen</i> |
|  | IPx7 | Submersion (1m, 30 min.) <i>Untertauchen (1m, 30 min.)</i> |
|  | IPx8 | Submersion at time and pressure > IPx7 <i>Untertauchen mit Dauer und Druck > IPx7</i> |
|  | IPx9K | High pressure (up to 80 bar) water from any angle <i>Wasser aus allen Richtungen unter starkem Druck (bis zu 80 bar)</i> |

Flexible Non-Metallic Cable Protection Systems

Fire Safety Performance



§ **Flame Propagation or Retardance**

Ability to prevent a fire or limit its development if one does start.

§ **Smoke Emission**







In the event of a fire to enable personnel to see their way to escape.

§ **Toxicity**

In the event of a fire to ensure personnel are not overcome during their escape.

Flexible Non-Metallic Cable Protection Systems

Country Specific Rail Fire Safety Standards

| | NF F 16-101 NF F 16-102  | BS 6853 Fire Safety Categories  | DIN 5510-2:2009  | CEI 11173-3 Fire Risk Level  | NFPA 130  | EN45545-2  |
|--|---|--|---|---|---|---|
| Flame Propagation, Flammability | Glow Wire Test NF T 51-071 Limited Oxygen Index NF C 20-455 I(x) | Temperature Index BS ISO 4589-3 or Limited Oxygen Index BS ISO 4589-2 | Gas Burner Method DIN 54837 S(x) Flammability ST(x) Dripping | Direct flame EN ISO 11925-2 | Radiated Heat Method ASTM E 162 Limited Oxygen Index ASTM D 2863 | ISO 5658-2 ISO 11925-2 LOI: ISO 4589-2 |
| Smoke Emission, Smoke Density | NF X 10-702 F(x) | BS6853 D.8.3 (A_o max) | DIN 54837 SR(x) | NF X 10-702 F(x) | Optical Density of Smoke ASTM E 662 | ISO 5659-2 |
| Toxicity | NF X 70-100 F(x) | NF X 70-100 R value | ISO 5659-2 | NF X 70-100 F(x) | | NF X 70-100 |
| Thermal Capacity | | | | | ASTM E 1354-02a | ISO 5660-1 Cone Calor. |

Flexible Non-Metallic Cable Protection Systems

New Multilayer Conduit Technology

Multilayer Conduits for improved Performance Characteristics

Our new innovative railway engineering multilayer conduits launched at the 2016 InnoTrans Rail trade show in Berlin provide protection and safety for cables on inter-carriage jumper connections, bogies, roof installations and under-carriage installations.

The new multilayer technology allows combinations of materials for optimal product characteristics in rail applications. An innovative manufacturing technology creates a corrugated conduit with two layers of material. The combination of different materials significantly improves the overall performance of the conduits.

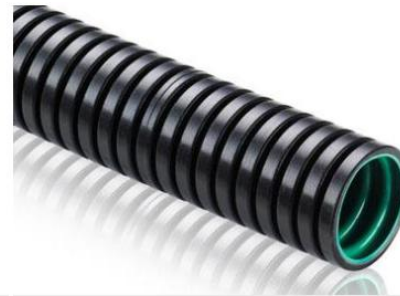
ABB now offers two multilayer solutions for the rail industry:



[Multilayer brochure](#)
Download the PDF of the brochure for more information



XPCSF Multilayer conduit
XPCSF conduit with orange inner layer for highly dynamic external installations in railway vehicles



XPCS Multilayer conduit
XPCS conduit with green inner layer for external applications

Flexible Non-Metallic Cable Protection Systems

New ABB Multilayer Technology

The XPCSF conduit with orange inner layer for highly dynamic external installations in railway vehicles.

The XPCS conduit with green inner layer for static and less dynamic external applications

A new standard in comprehensive end-to-end cable protection solutions
Together with PMA's tried and tested product range of fittings and accessories in various sizes, the XPCSF and XPCS conduits with new state-of-the-art multilayer technology offer a comprehensive and sustainable end-to-end cable protection solution for the rail industry.

The key benefits:

- Excellent dynamic characteristics
- Improved fire safety with EN 45545-2 HL3 classification
- Outstanding ageing characteristics

InnoTrans | 20 - 23 September 2016 | Berlin
Germany

You can view this page in: [EN](#) [DE](#)



Flexible Non-Metallic Cable Protection Systems Fire Barrier Solutions



- Fire barriers are an important part of the fire safety concept for many applications whether it be on a train, on a ship or in a public building. Fire barriers can limit the affected area and prevent heat and smoke spreading winning time for evacuation.
- It is not difficult to understand that positions where cables are fed through a firewall could represent weak points where fire, heat, smoke and gases could break through.



PMA adapter solution



PMA Strain relief fitting



PMA solution with Roxtec



EN45545 Railway applications

Flexible Non-Metallic Cable Protection Systems

PMA EMC Solutions

PMA EMC Product Line

The PMA EMC System offers one additional function over and above the standard mechanical and environmental protection of cables. Shielding of Electromagnet Signals. Small signal sensor cables can be shielded from external interference. Noisy power cables can be prevented from disturbing other neighbouring electronic systems



EMC Connectors + adapters



EMC Connectors with strain relief, metal threads



EMC Screening braids



EMC Hexagonal lock nuts, metal



Brett Todd, Sales & Marketing Manager - Canada, ABB Transformer Services

Avoiding Transformer Failures with Predictive Maintenance

Transformer Maintenance Best Practices

Intelligence Based Transformer Services

- § Maintenance Actions Should be Driven by Transformer Condition
- § Basic Message: Time is a Factor, but by far not the only Factor

Today We Will Cover:

- § Transformer Lifecycle Support
 - § How Transformers Break
 - § Options When Everything is not Okay
 - § Maintenance Actions to Extend Transformer Life

Why Should You Be Concerned? Aging Transformers and Accessories

Doble Statistics on Transformer Failures

- § 43% winding insulation
- § 16% load tap changers
- § 19% bushings

In 1999, Hartford Steam Boiler Insurance projected:

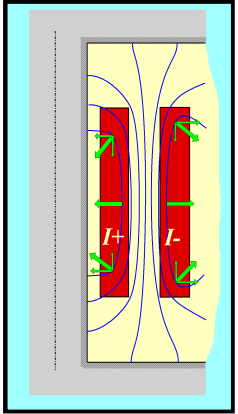
- § 2% annual failure rate of existing installed base of transformers by the end of 2008
- § **5% failures by the year 2013**

**How many failures are caused by:
poor maintenance?
short circuits?
overloading?**



Stresses Acting on Power Transformers

Understanding These Allows Development of an Effective Maintenance Plan for Your Transformer



Mechanical Stresses

- § Forces between conductors, leads and windings due to overcurrents or fault currents caused by short circuits and inrush currents

Thermal Stresses

- § Due to local overheating, overload currents and leakage fluxes when loading above nameplate ratings; malfunction of cooling equipment



Dielectric Stresses

- § Due to system overvoltages, transient impulse conditions or internal resonance of windings



Risk: Short Circuit Forces & Stress Failures

Through faults often Initiate Transformer Failures

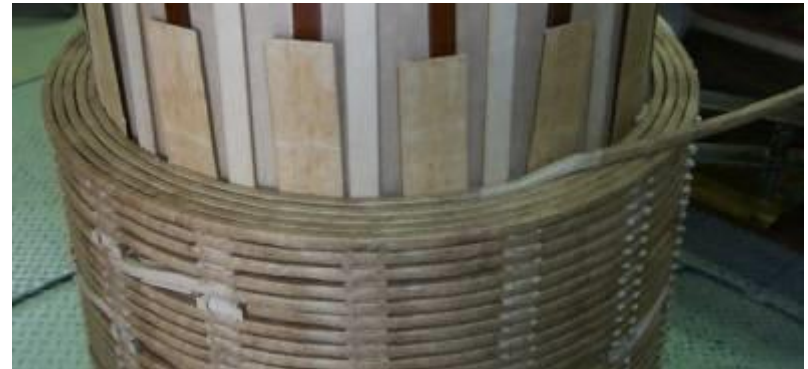
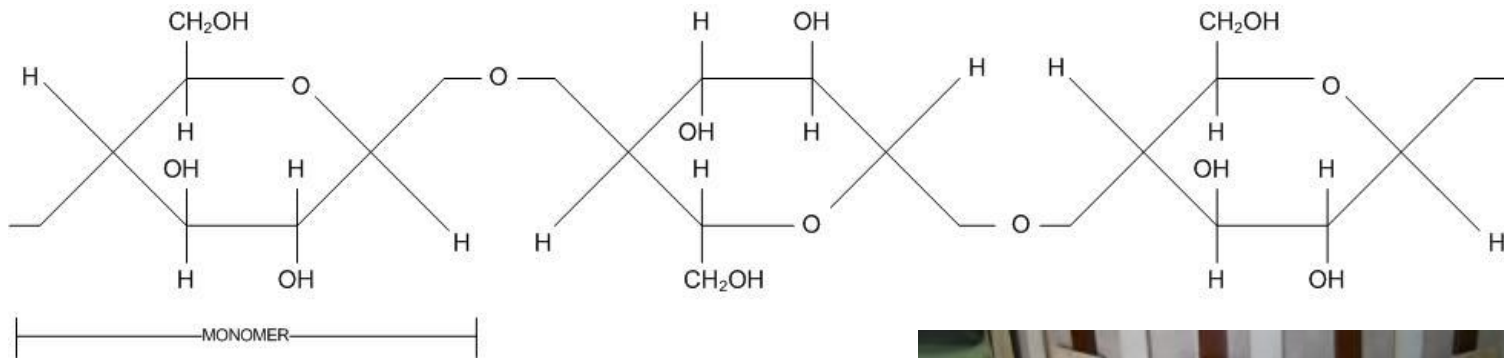


- § Many older designs have insufficient margin for today's fault currents
- § Loose coils due to aging can cause failures
- § Normal aging results in brittle insulation and increased failures
- § Even brief overloading may cause significant aging
- § Oxygen in the oil can double the aging rate
- § Moisture in the insulation increases aging rate 2-5 times depending on the amount of moisture

Degree of Polymerization – DP Measures Insulating Paper Strength

Degree of polymerization is a measure of the number of intact chains in a cellulose fiber. It provides an indication of the ability of the transformer insulation to withstand mechanical force (due to through-faults, etc).

Cellulose Fiber Chain



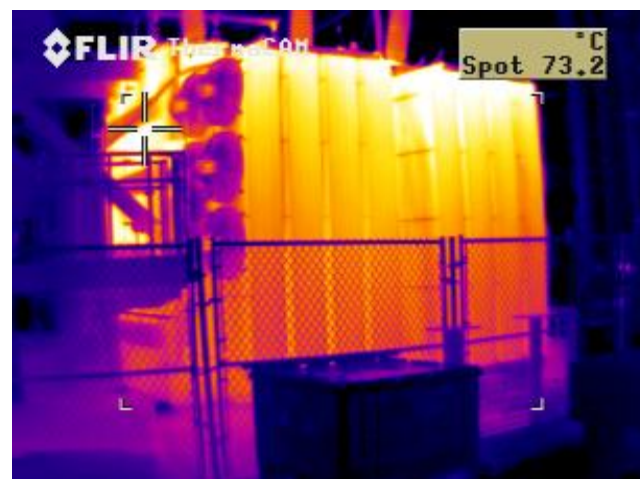
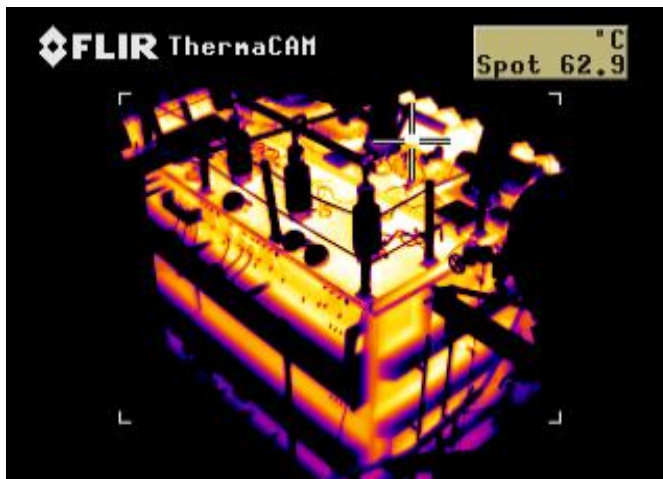
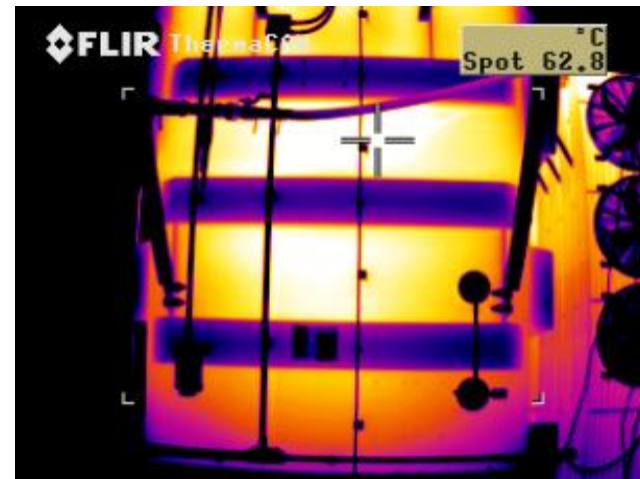
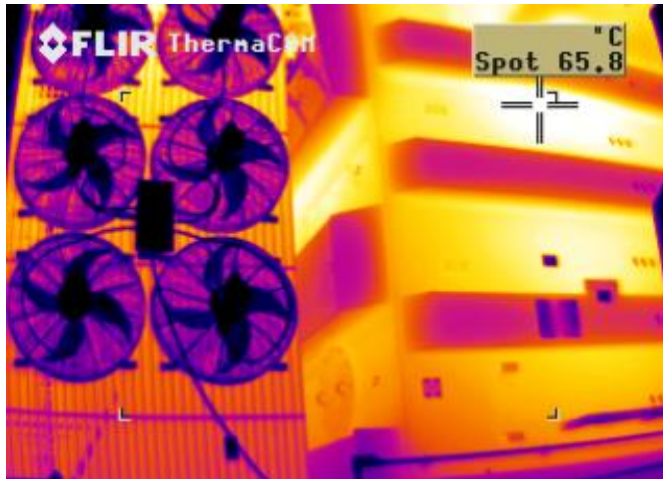
Degree of Polymerization – DP

Factors affecting DP and Measurement Method

- § The DP of the insulation is affected by the following conditions:
 - § Moisture content
 - § Acidity of the oil
 - § Oxygen content
 - § Temperature
- § The DP is measured by viscosity measurements according an ASTM method after dissolving the paper samples in cupriethylene diamine solvent.
 - § Paper samples must be taken from enough different areas in a transformer in order to get a profile of deterioration of the cellulose
 - § When combined with detailed design knowledge, measurements in one area of the transformer can give information on the condition of paper in inaccessible areas of the windings.

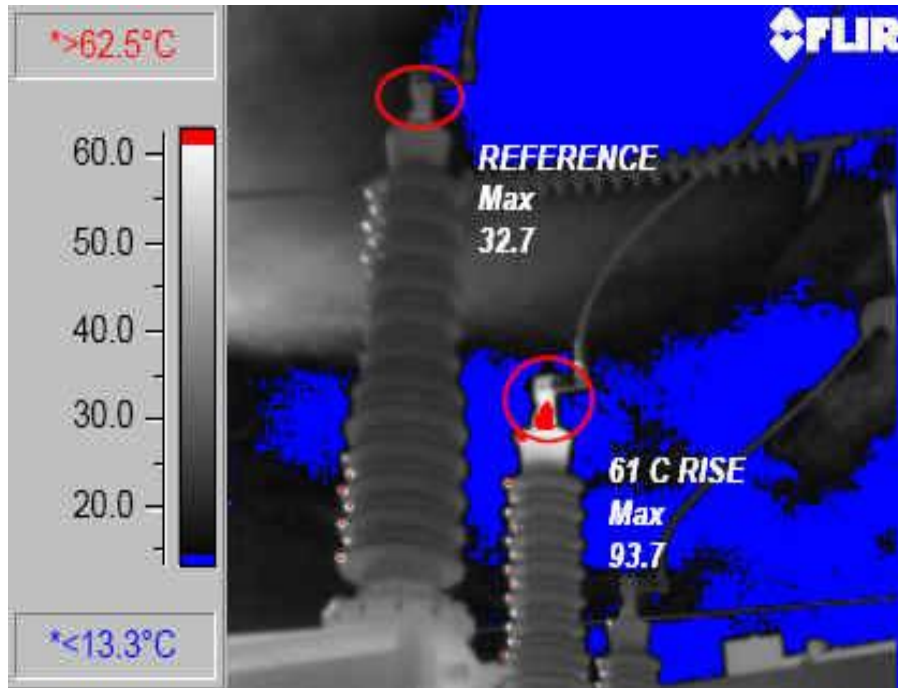
Thermal Stresses in Power Transformers

Thermal scans are very valuable



Thermal Scan Value

Example – Loose bushing terminal connection

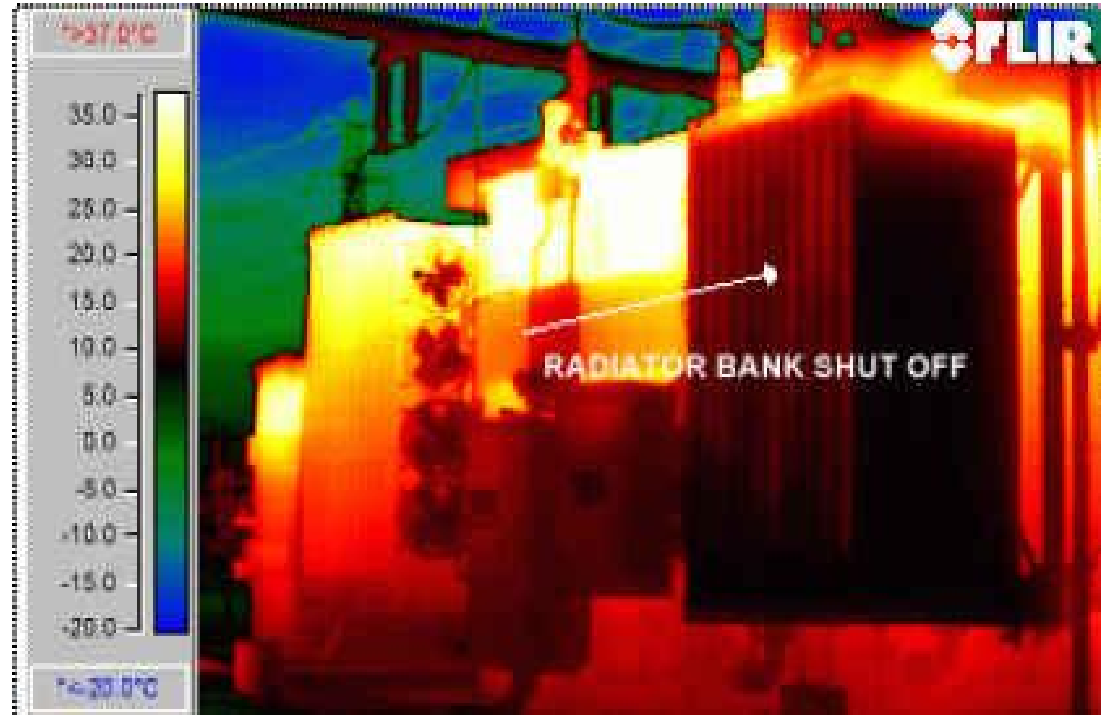


- § When there is a loose connection at the terminal from the bushing to the bus work, it will lead to overheating of the bushing top terminal when under load.
- § The thermograph will show the bushing terminal as hot, while the body of the porcelain will show normal temperatures.

Thermal Scan Value

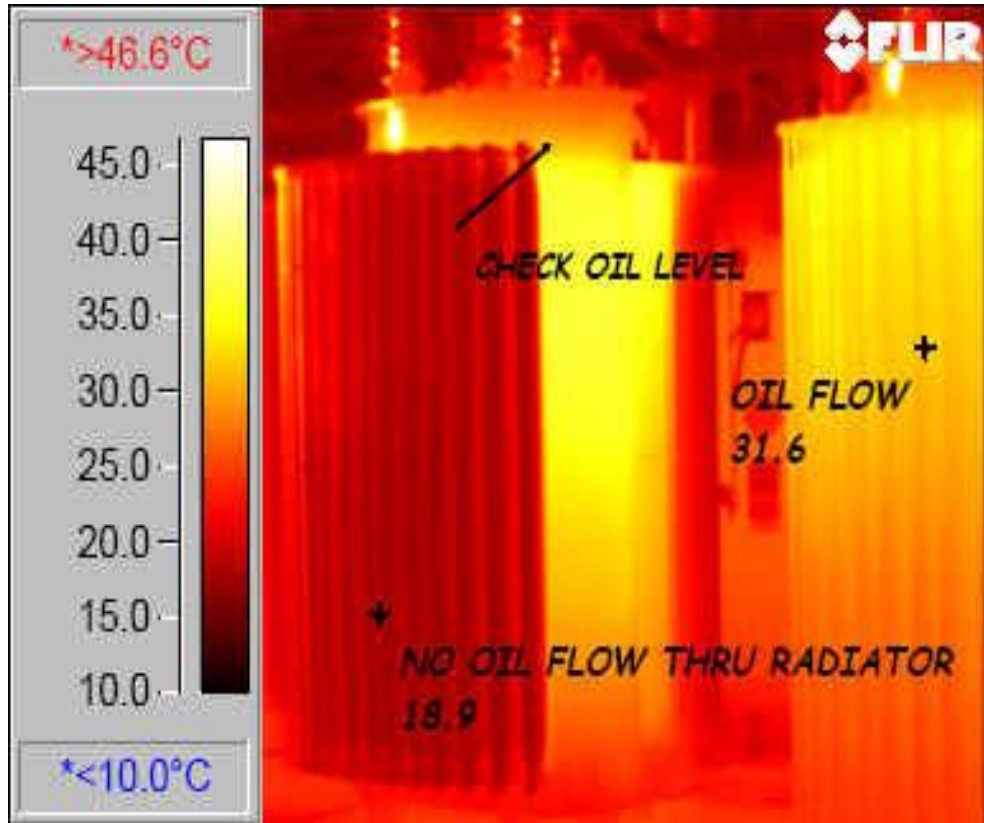
Example – Blocked oil flow in radiators

- § In case of a malfunction that stops or restricts the flow of oil through a radiator, this will show up on an infrared scan.
- § The image will reveal dim areas where the oil flow is restricted and brighter areas where normal oil flow is taking place



Thermal Scan Value

Example – Low oil Level in Transformer or Bushing



If a transformer (or especially a bushing) has a low oil level, a thermograph will show a dim image for the region without oil and a much brighter image in the areas with oil

Oil is the Life Blood of a Transformer

Maintenance/Oil Sampling Tips

- § When taking oil samples for moisture in oil, take sample when transformer temperature is over 60°C.
- § If the unit is a COPS or free breather, don't forget to check oxygen inhibitor content.
- § If unit is a COPS with breather, don't forget to check the bag for leaks.
- § If oil is degassed, establish a new baseline for Furan content.
- § Pumps should be replaced or refurbished every 10 years.
- § Don't forget to check condition of coolers. You can lose cooler efficiency which will accelerate transformer ageing.

Dissolved Gas Analysis









Advanced DGA Diagnosis

- § Close observation of dissolved gases in the oil and other oil properties provides the most valuable information about transformer health
- § ABB's Dissolved combustible Gas in oil Analysis tools takes the following into consideration:
 - § Gassing rates of increase for each key gas detected
 - § Historical trend of gassing
 - § Various ratios of key gases
 - § Estimated temperature of the hottest spot temperature
 - § Gas solubility depending on preservation system
 - § Concentration and ratios of carbon oxides
 - § Detailed design knowledge of the transformer, such as stray flux management, clamping and cooling system details.

CoreSense™

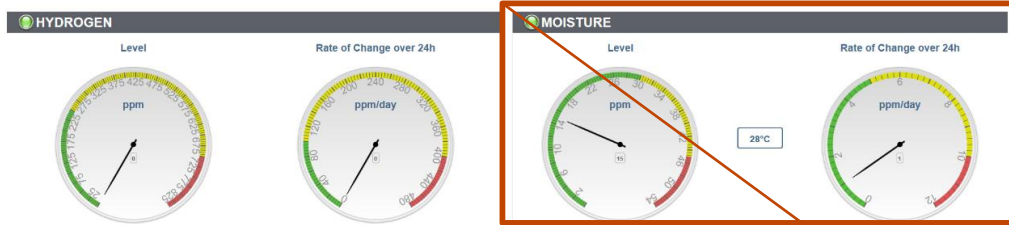
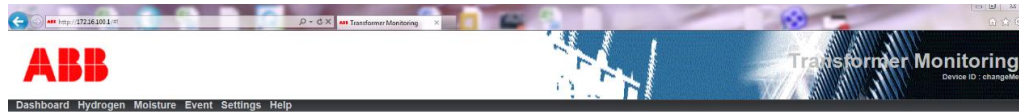
Product Overview

CoreSense™ is a transformer's first line of defense, it monitors the transformer status by observing Hydrogen and moisture levels. It features:

-  Continuous online monitoring
-  Easy installation - no maintenance
-  Oil movement by convection - no moving parts
-  Solid-state sensor - no membrane
-  Status at-a-glance with colored LED interface
-  One year data storage
-  User friendly web interface
-  Small investment to monitor the transformer's condition



CoreSense™ Web Interface Overview



SYSTEM EVENTS

| DATE | TYPE | DESCRIPTION |
|------------------------|---------|------------------------------|
| April 13, 2015 4:24 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:23 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:22 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:21 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:20 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:19 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:18 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:17 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:16 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:15 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:14 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:14 PM | Normal | System startup completed |
| April 13, 2015 4:13 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:12 PM | Warning | Hydrogen sensor is not ready |
| April 13, 2015 4:10 PM | Warning | Hydrogen sensor is not ready |



CoreSense Can connect your SCADA system and/or to a web interface that allows you to analyze Hydrogen and moisture trends and events of an equipped power transformer.

Why Test at Every Outage?

Every Test Establishes a Baseline for Comparison



Establishment of a trend is a key to prevent this kind of result

Advanced Diagnostic Testing Allows Determination of Condition Based Actions



For critical issues, state-of-the-art testing methods should be used to detect operating difficulties and pinpoint specific activities to speed restoration of service

§ **Materials and Oil Testing**

- § Metal in Oil Testing
- § CCD Testing for Sulfur contamination
- § Particle count
- § Oxidation Inhibitor Testing
- § Furanic Analysis
- § Degree of Polymerization Testing

§ **Advanced Diagnostics**

- § Advanced DGA
- § Acoustics
- § FRA Measurements
- § Dielectric Spectroscopy
- § Field Induced Testing
- § Recurrent Surge Testing

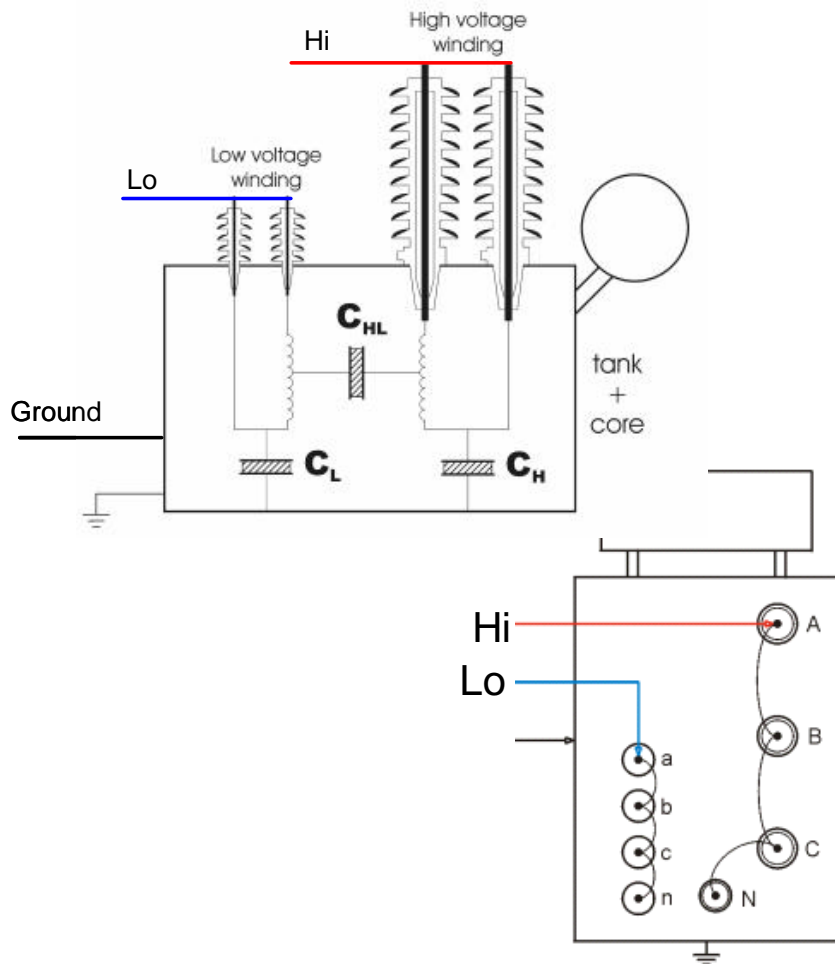
SFRA - Swept Frequency Response Analysis

Diagnostic Benefits

- § Frequency Response Analysis is a method of measuring the transfer function of the windings of a transformer
- § The SFRA is a plot of the swept frequency response of the transformer circuit
 - § This circuit is comprised of the inductance and capacitance characteristic of the transformer winding being measured
 - § One key use of the measurement is to compare a winding's response to either similar windings (other identical phases or other identical transformers) or to previous measurements of that winding
 - § The comparison can detect movement in the winding of the type experienced during transportation or an excessive through fault(s)
- § Changes in the transfer function reveal a wide range of failure modes, for example:
 - § Axial Winding Collapse
 - § Clamping Failure
 - § Hoop Buckling
 - § Shorted Turns



Dielectric Frequency Response Testing Power Factor at More Than 60 Hz



The DFR test is a series of power factor measurements at multiple frequencies.

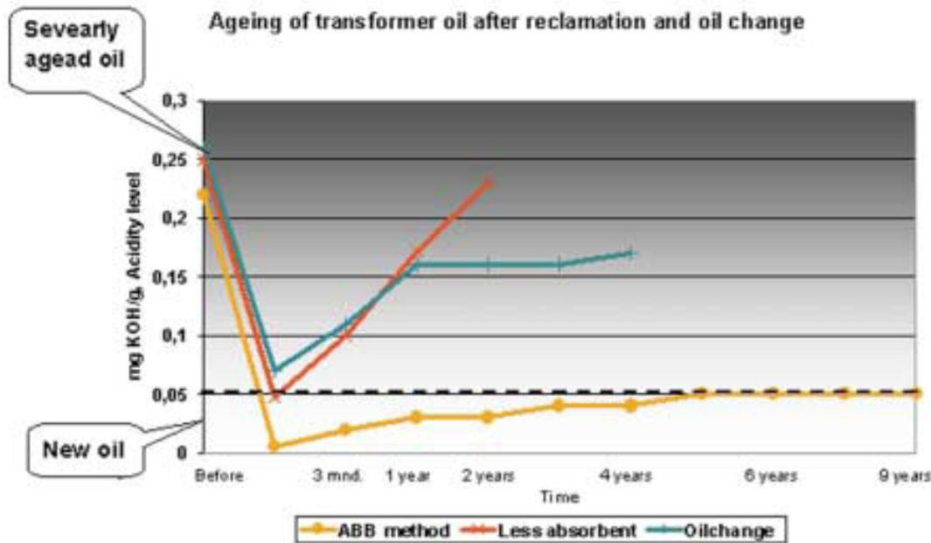
It provides more information about the dielectric behavior of the insulation system than a 60Hz test.

The method can be used to diagnose the following conditions:

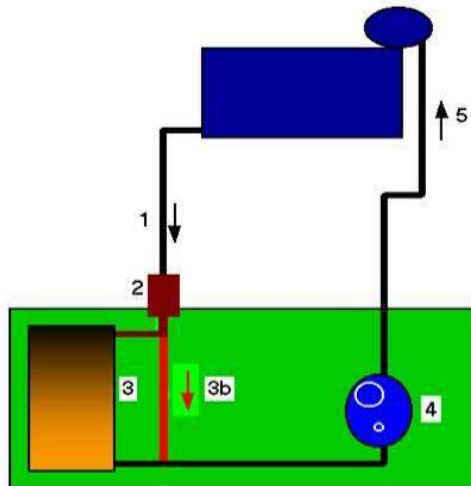
- § Moisture in the cellulose insulation
- § High oil conductivity due to aging or overheating of the oil
- § Chemical contamination of cellulose insulation
- § Carbon tracking in cellulose
- § High resistance in the magnetic core steel circuit

Solutions for Oil Purification

Reclaiming of Oil in Power Transformers



- § **Problem:** Oxidation of the oil-cellulose transformer insulation increases the aging of the insulation materials, consequently reducing the life expectancy and reliability of the transformer.
- § **Solution:** ABB's oil reclaiming process removes acids, sludge, and other degrading products from transformer oil.
- § **Value:** The aging rate of oil is lowered at an environmental advantage - instead of replacing a non-renewable resource, the oil is processed. This will also have a positive impact on the aging of the paper.



Case Study

Color before and after oil reclamation

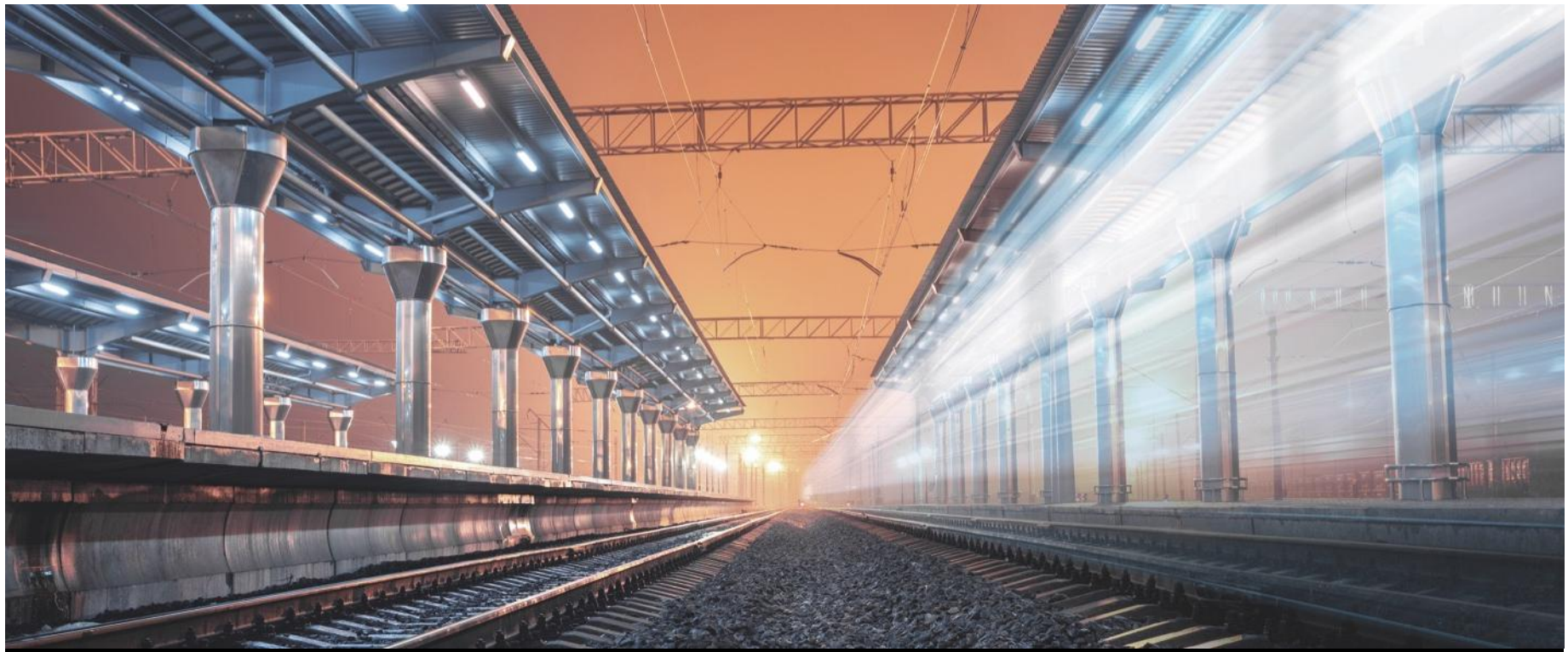


Transformer Condition Improvements

Reasons to consider a natural ester retrofill



- § Biodegradable and from renewable resources
 - § Potential regulatory relief on spill cleanup
 - § Vegetable-based oils produced from oil seed crops readily available
- § Natural ester fluids have a high fire point (above 300°C vs. 180°C for mineral oil)
 - § Increased fire safety and potential for lower insurance premiums
- § Natural ester fluids have a much greater ability to hold moisture
 - § Increased insulation system life and transformer overload capacity
- § Natural ester fluids exhibit excellent dielectric performance
 - § Dielectric constant is closer to cellulose lowering stresses in oil ducts
- § Overall, excellent alternative to petroleum products



Condition Monitoring & Asset Health Management

Proactive Rail Asset Management

Enterprise Software in Rail & Transport

Software solutions for the Transport industry

Network Control / "Electrical"

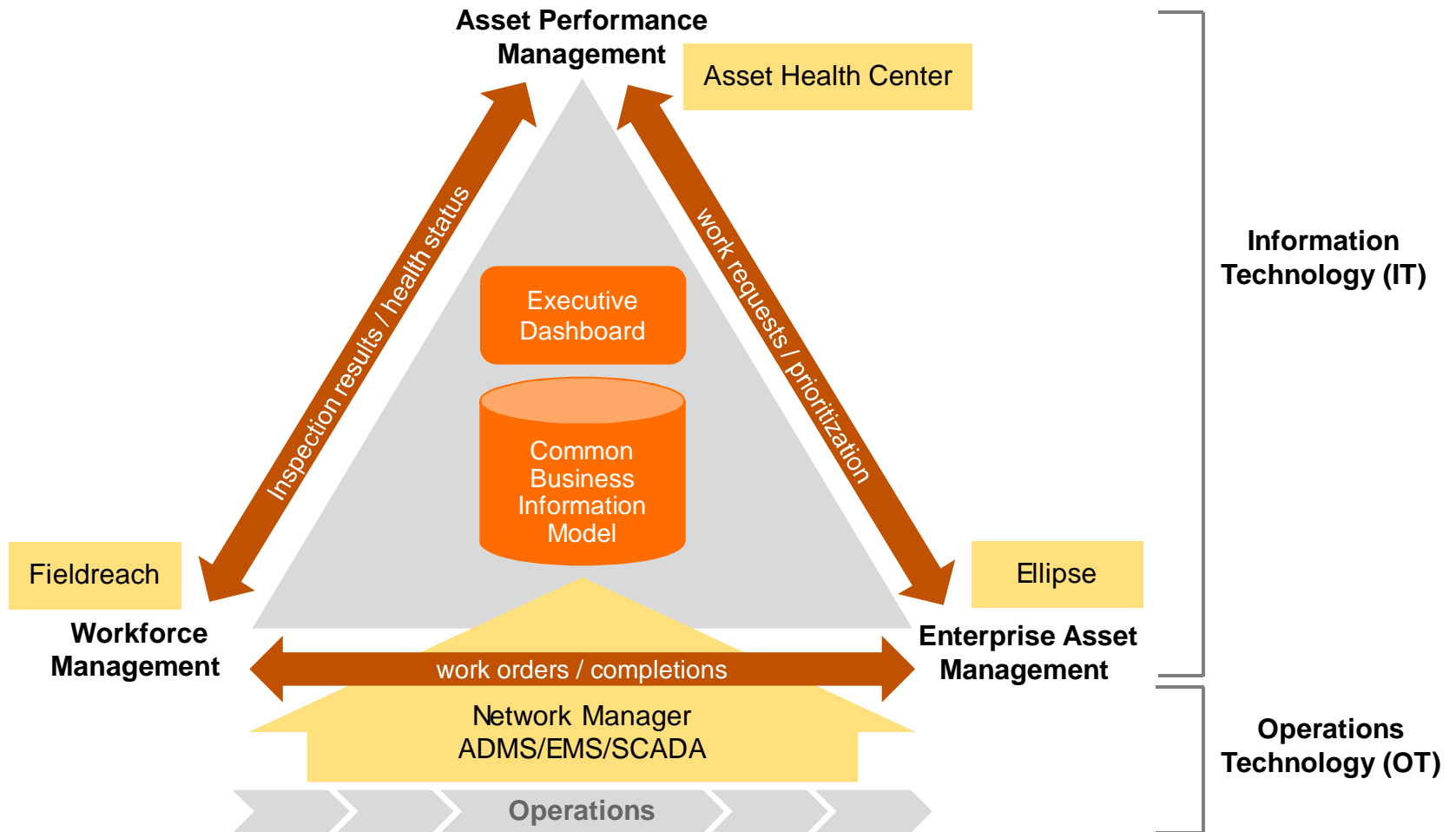
- § Control systems = SCADA DMS



Asset Management and Maintenance related

- § Enterprise Asset Management (EAM) = Ellipse, includes embedded ERP
- § Asset Performance Management (APM) = Asset Health Center
- § Mobile/Inspections = Fieldreach for Ellipse

ABB's Vision for Transport Asset Management IT & OT / Connected Asset Lifecycle Management (CALM)



The Ellipse solutions

Ellipse

Purpose-built EAM + ERP solution for asset-intensive organizations, ensuring critical assets deliver better business results



Ellipse Select

Packaged Ellipse: Preconfigured. Productized. Proven.

Fieldreach for Ellipse

Mobilizing work and asset business processes



Ellipse

EAM + ERP for asset-intensive organizations



ABB Ellipse – The EAM solution for Rail

- § Ellipse manages the entire asset lifecycle from design, capital works, construction, commissioning, operations & maintenance, and replacement
- § The Ellipse unique linear asset capabilities allow for world-class planning and execution of maintenance work along the asset corridor
- § Integration with other systems is flexible / SAP ERP certified adapters
- § Ellipse Select For Rail is the packaged version of Ellipse, with preconfigured business processes and out-of-the-box implementation methodology. It is the most economical deployment on the market and can be deployed in 3 months, ideal for midsize projects



ABB Asset Health Center

Prescriptive analytics for asset performance



1 Collect

Unified view of all asset data in proven analytics platform

2 Predict

Algorithms codify experience to predict and prioritize risk and prescribe actions

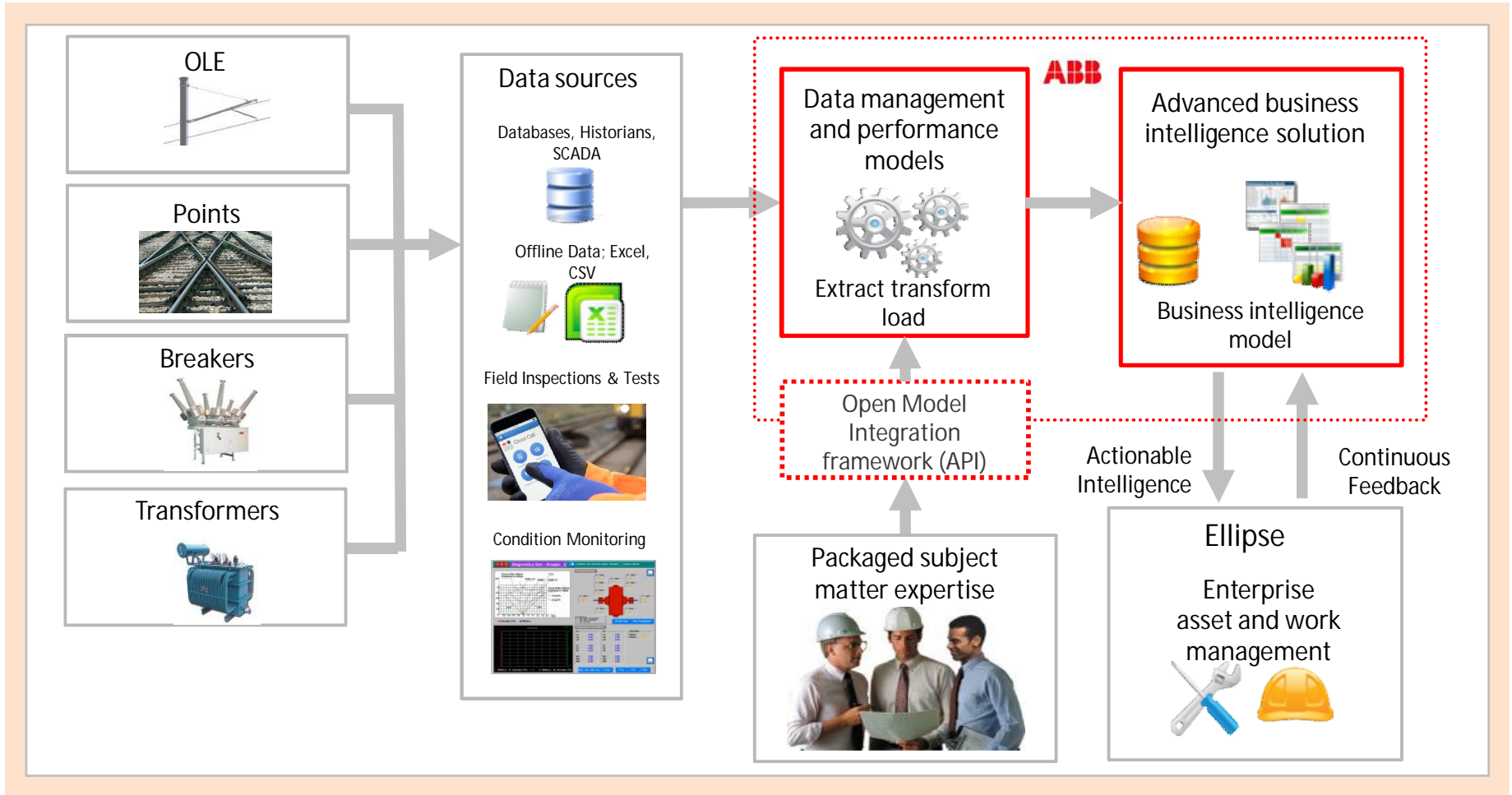
3 Review

Industry standard approaches help confirm analysis

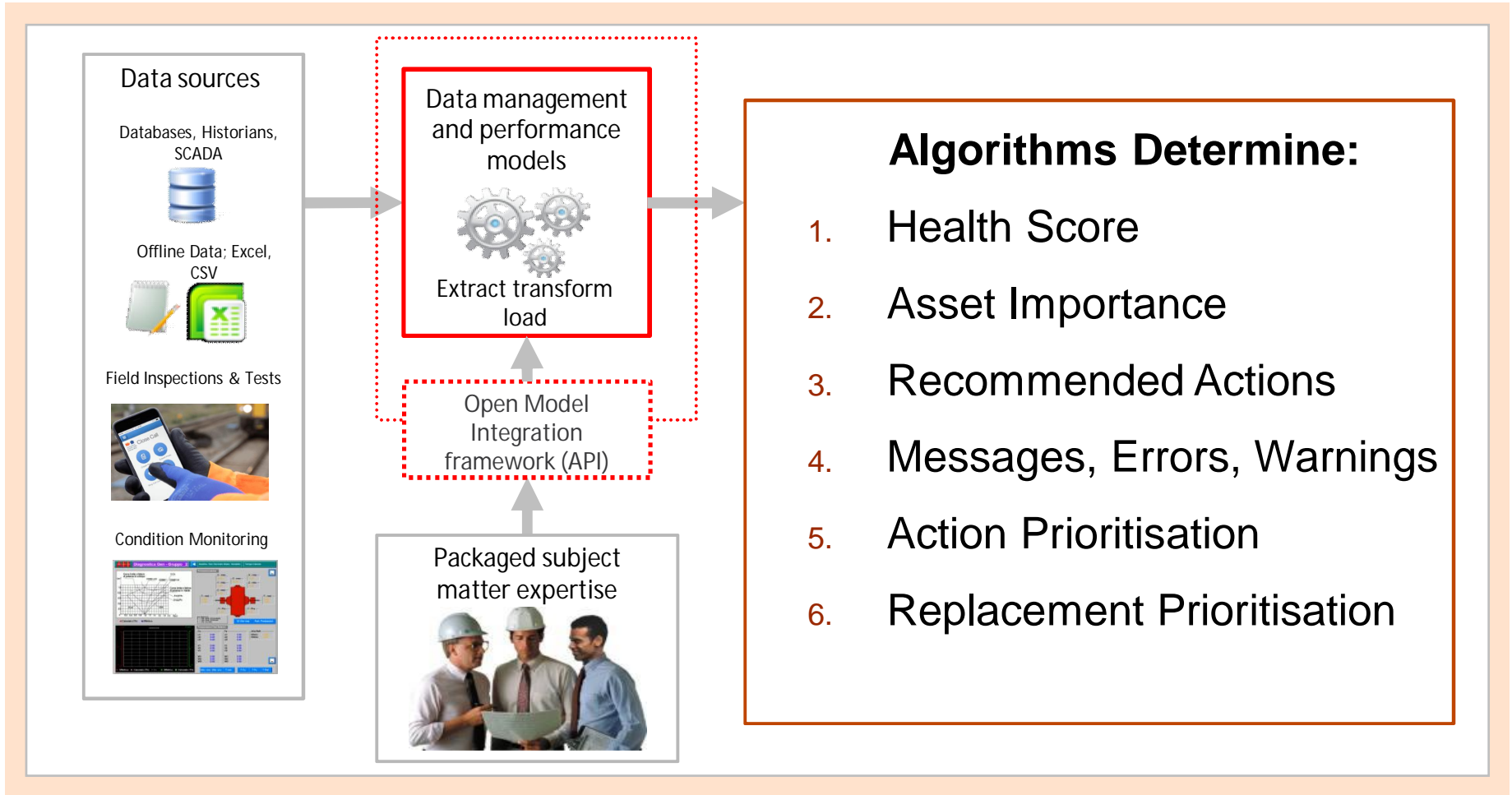
4 Act

Holistic asset performance management

Asset Health Center Prescriptive Analytics for Rail



Asset Health Center Performance Models



Models from ABB, Partners & Customers Leverage Subject-Matter Experts

§ Asset Performance Models for Rail

- § Transformers
- § Circuit Breakers & Switchgear
- § Backup Batteries (substations, crossings)



- § Capacitor Banks
- § Conductors
- § Underground Cables



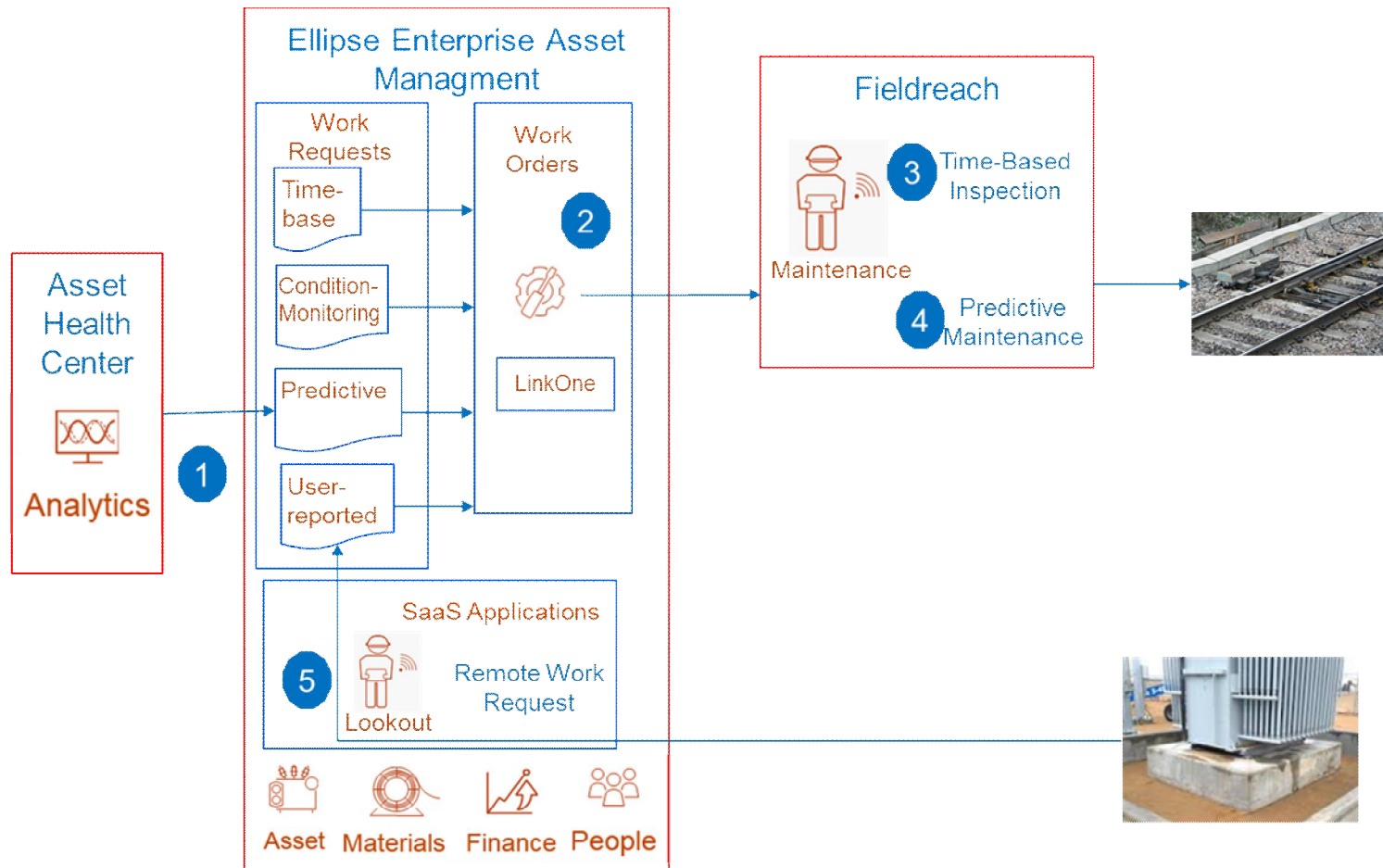
- § Switches (Points)
- § Overhead Line Equipment
- § Crossings



- § Overhead Line Equipment (Lines & Structures)
- § Third Rail

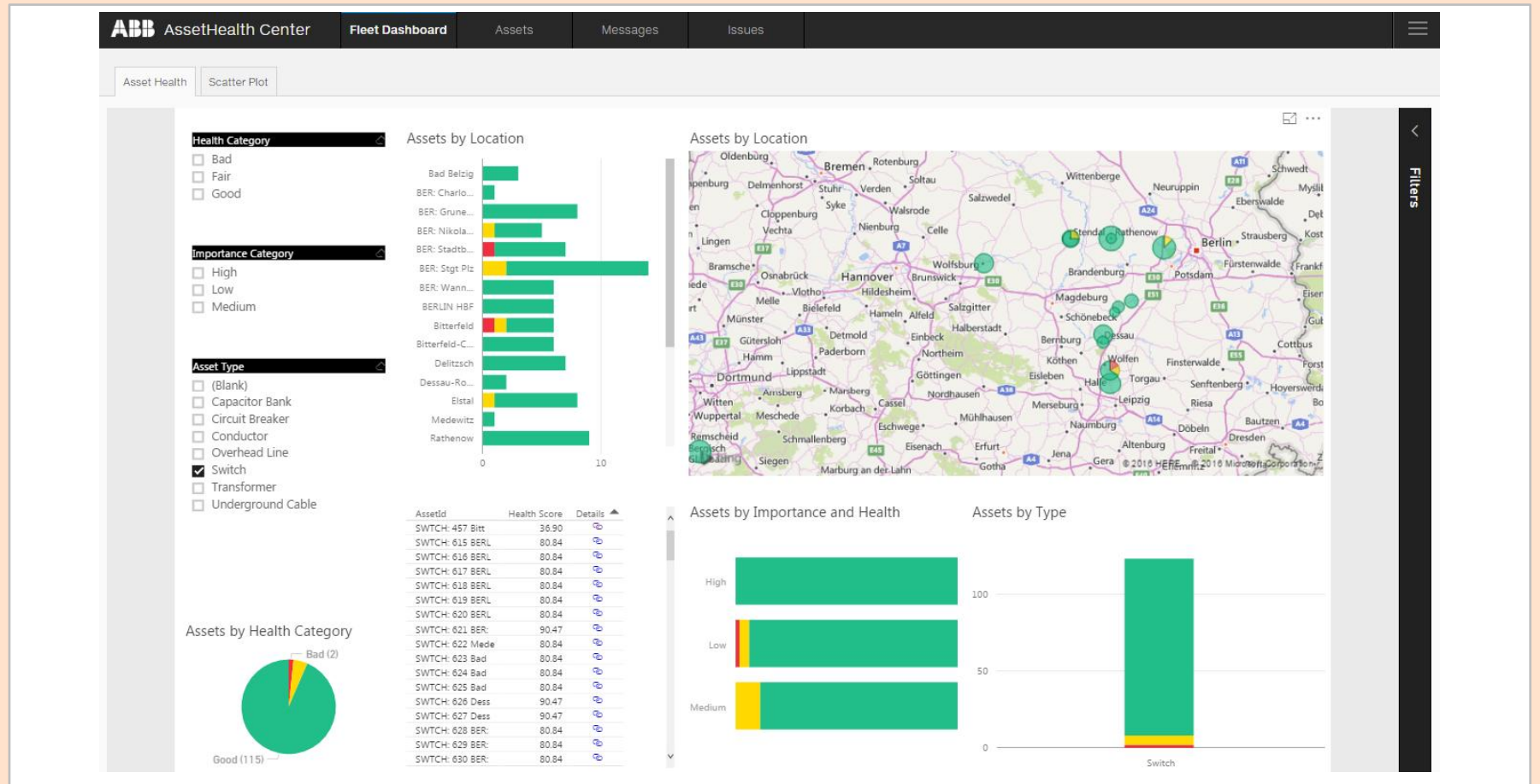


Proactive Rail Asset Maintenance Flow

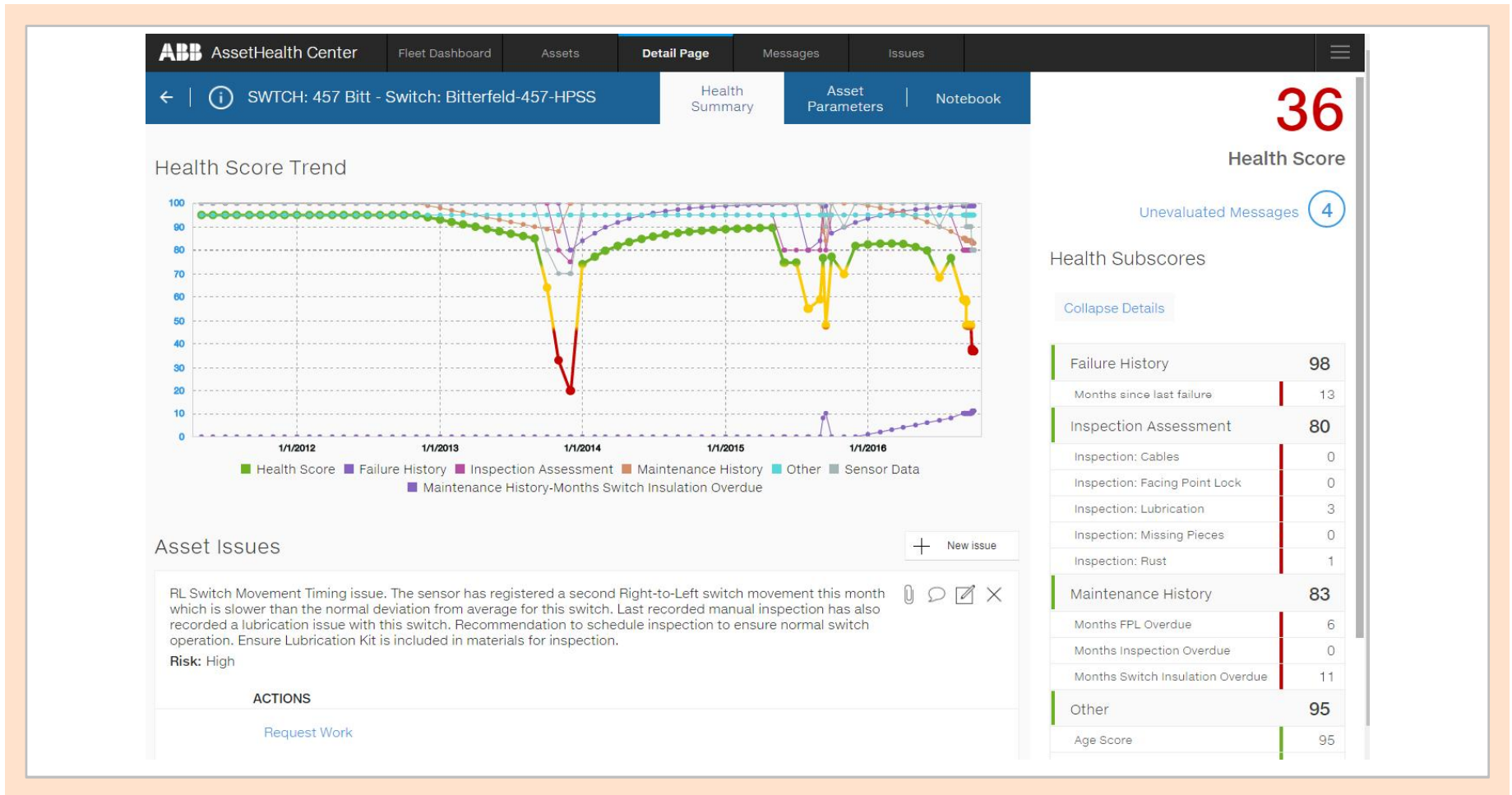


Rail Switch Analytics

Identify at-risk Switches



Detail View of one Rail Switch



Review Generated Messages

AHC Recommended Preventive Actions

The screenshot displays the ABB AssetHealth Center interface. At the top, there is a navigation bar with tabs for 'Fleet Dashboard', 'Assets', 'Messages', and 'Issues'. Below this is a search and filter section with fields for 'Search' (containing 'SWTCH: 457 Bitt'), 'Location' (set to 'All Locations'), 'Equipment Type' (set to 'All Types'), 'Importance' (set to 'All Importance'), and 'Health Score' (set to 'All Scores').

The main content area is titled 'Asset News / 5 items' and shows a list of messages for asset 'SWTCH: 457 Bitt'. The selected message is expanded to show details:

- Message Details**
- Asset: **SWTCH: 457 Bitt**
- Health Score: **36**
- Message Impact: **UNKNOWN**
- Date: **9/16/2015, 2:00:00 PM**
- Message: **RL Switch Movement Timing issue. The sensor has registered a second Right-to-Left switch movemen...**
- Description: **RL Switch Movement Timing issue. The sensor has registered a second Right-to-Left switch movement this month which is slower than the normal deviation from average for this switch. Last recorded manual inspection has also recorded a lubrication issue with this switch. Recommendation to schedule inspection to ensure normal switch operation. Ensure Lubrication Kit is included in materials for inspection.**

At the bottom of the message details, there are three buttons: '+ Track issue', 'Reminds', and 'Ignore'. The '+ Track issue' button is circled in orange.

Now a Work Request has been Created in Ellipse

The screenshot displays the ABB AssetHealth Center interface for a specific asset: SWITCH: 457 Bitt - Switch: Bitterfeld-457-HPSS. The main health score is 36, with 4 unevaluated messages. The health score trend graph shows a significant dip in early 2014, reaching a low of approximately 20. The asset issues section highlights a 'RL Switch Movement Timing issue' with a high risk level. The 'ACTIONS' section, circled in orange, shows a 'Requested' work request with a scheduled date and a unique number (000000003375).

Health Score Trend

Health Score: 36

Unevaluated Messages: 4

Health Subscores

| | |
|----------------------------------|----|
| Failure History | 98 |
| Months since last failure | 13 |
| Inspection Assessment | 80 |
| Inspection: Cables | 0 |
| Inspection: Facing Point Lock | 0 |
| Inspection: Lubrication | 3 |
| Inspection: Missing Pieces | 0 |
| Inspection: Rust | 1 |
| Maintenance History | 83 |
| Months FPL Overdue | 6 |
| Months Inspection Overdue | 0 |
| Months Switch Insulation Overdue | 11 |
| Other | 95 |
| Age Score | 95 |

Asset Issues

RL Switch Movement Timing issue. The sensor has registered a second Right-to-Left switch movement this month which is slower than the normal deviation from average for this switch. Last recorded manual inspection has also recorded a lubrication issue with this switch. Recommendation to schedule inspection to ensure normal switch operation. Ensure Lubrication Kit is included in materials for inspection.

Risk: High

ACTIONS

RL Switch Movement Timing issue. The sensor has registered a second Right-to-Left switch movement this month which is slower than the normal deviation from average for this switch. Last recorded manual inspection has also recorded a lubrication iss... [Show more](#)

Status: Requested
Scheduled date:
Number: 000000003375

Work Request Appears in Ellipse EAM

Ellipse 1 of 1 Quick Launch Power and productivity for a better world™ **ABB**

MSE541 - Update Work Request

Submit Refresh New Save As Delete Open New Search Navigate Actions

Work Request Id: 00000003375 **OPEN**

Description: RL Switch Movement Timing issue. The sensor has registered a second

Requester: **Work** | Map Location | Address | Assign | Estimate | Description | Service Level | Risk | History | Representatives | Document Link | Reference Codes | Alarms and Defects

Classification: A1 > INSPECTION
Activity:
User Status:
Equipment Reference: BITTERFELD457
Request Source:
Required By Date:
Raised By User: 0000000097 > Paul Walk
Raised Date: 09/15/2016

Request Type:
Priority:
Region: 0002 > 0002
Source Reference:
Required By Time: : :
Raised Time: 07: 47: 30

Create a Work Order

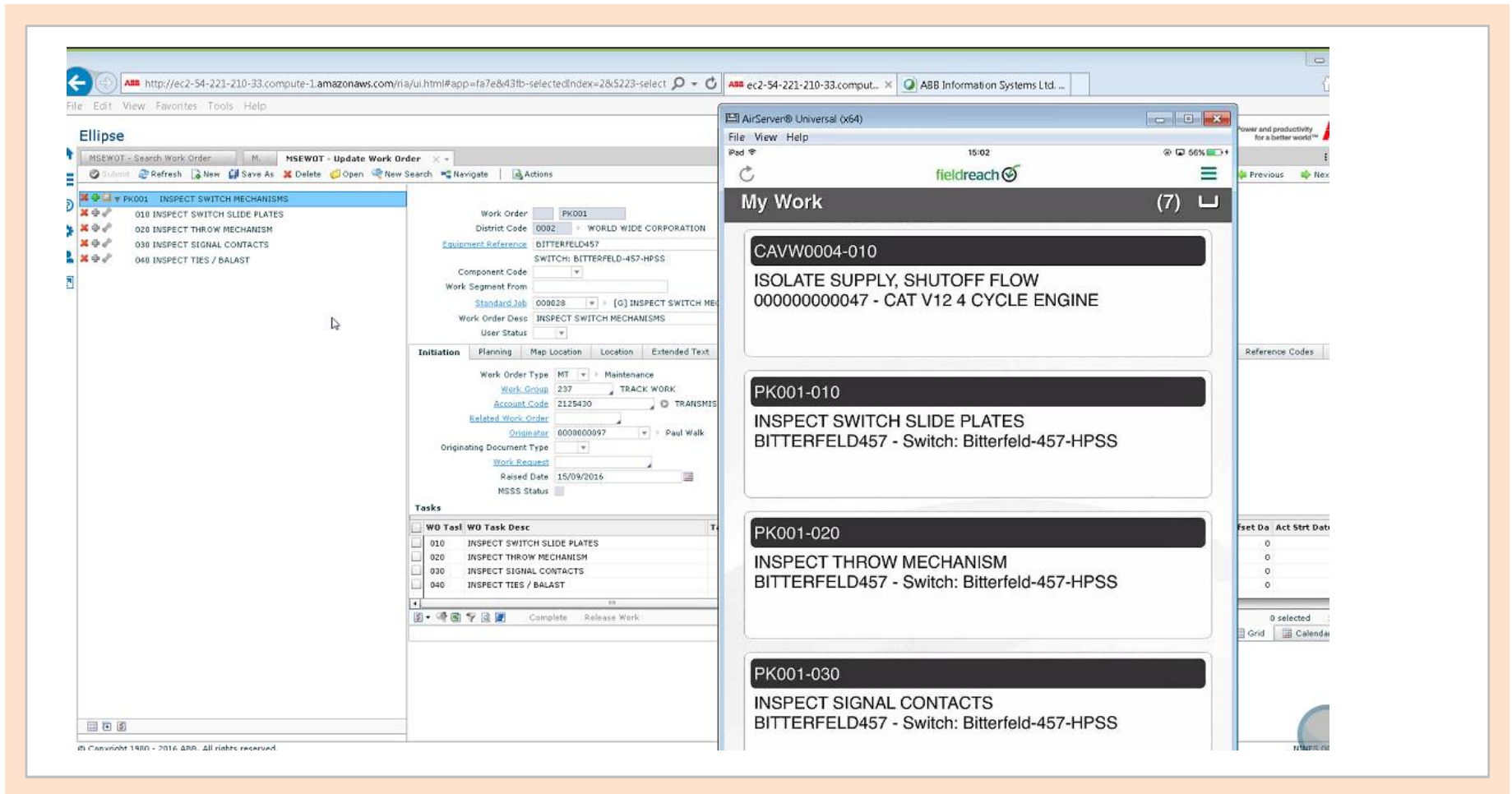
The screenshot displays the 'Ellipse' software interface for updating a work request. The window title is 'MSE541 - Update Work Request'. The top right corner features the ABB logo and the slogan 'Power and productivity for a better world™'. The interface includes a navigation bar with icons for home, menu, help, settings, and user profile. Below this is a toolbar with buttons for Submit, Refresh, New, Save As, Delete, Open, New Search, and Navigate, along with an Actions menu. The main content area shows a form for a work request with the following details:

- Work Request Id: 000000003375 (Status: OPEN)
- Description: RL Switch Movement Timing issue. The sensor has registered a second
- Classification: A1 (INSPECTION)
- Activity: [Empty]
- User Status: [Empty]
- Equipment Reference: BITTERFELD457 (SWITCH: BITTERFELD-457-HPSS)
- Request Source: [Empty]
- Required By Date: [Empty]
- Raised By User: 0000000097 (Paul Walk)
- Raised Date: 09/15/2016

An 'Actions' menu is open, listing various options. The 'Create Work Order' option is highlighted in blue. Other options include Cancel, Close, Contract, Create Appointment, Create Contract, Create Job Estimate, Create Project, Job Estimates, Update Work Activity Classification, Parent Work Orders, Projects, Reopen, Workflow, Work Orders, Batch Create From, and Work Request Hierarchy.

Mobile Access to Work

Receive Work and Document Completion in Fieldreach



Break: Resume at 3:00

Design considerations for safe and reliable operations in mass transportation

3:00– 3:45



AC electrification of Rail - design considerations

Bruce Warner, Electrification, ABB

3:45– 4:15



Electrification of buses – the infrastructure challenge

Daniel Simounet, Transportation, ABB

4:15– 4:45



Pan-Ontario electric bus demonstration project

Josipa Petrunic, CUTRIC



Bruce Warner

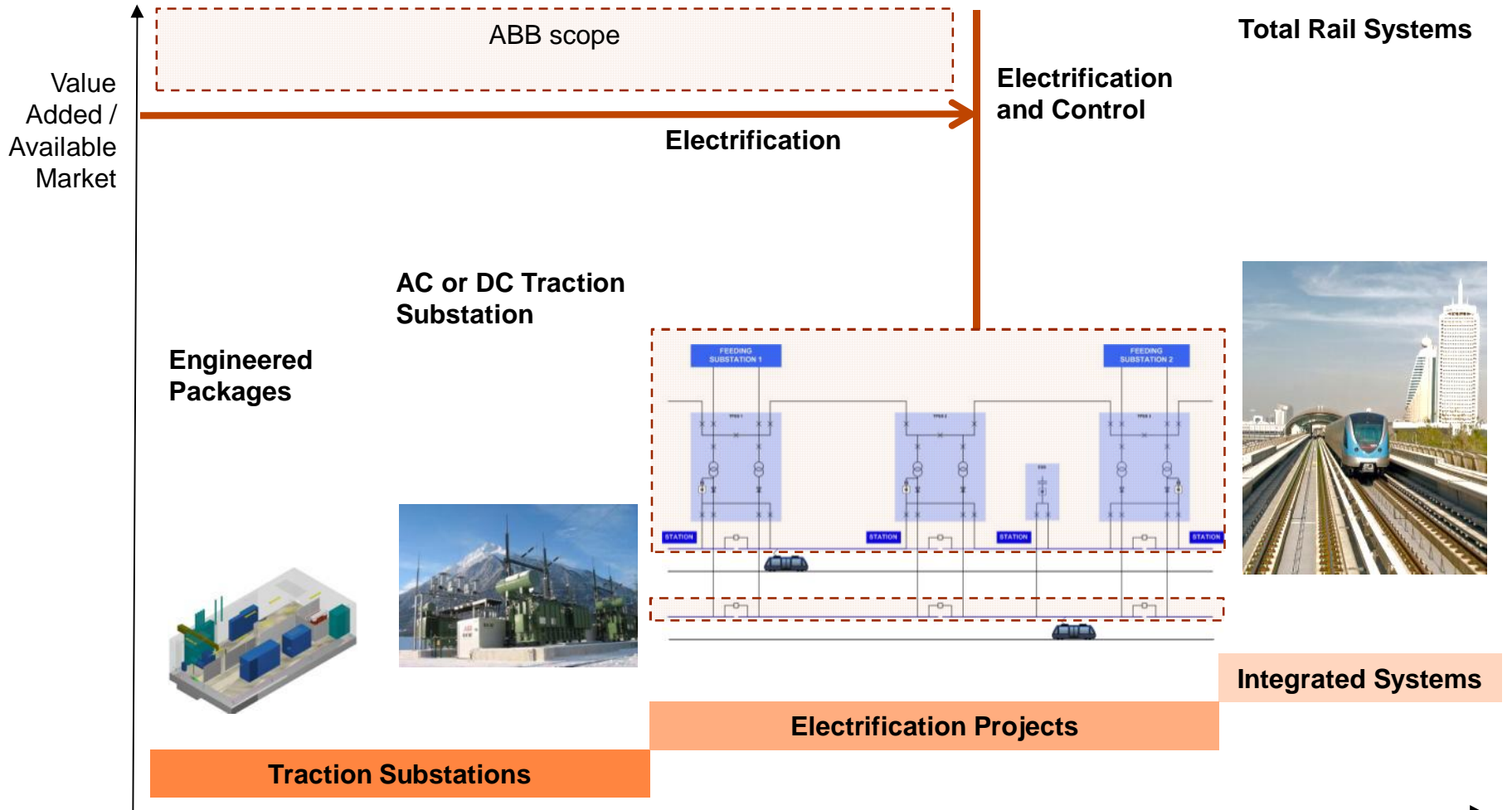
Rail and Transportation Expert Day AC Electrification

AC Electrification Contents

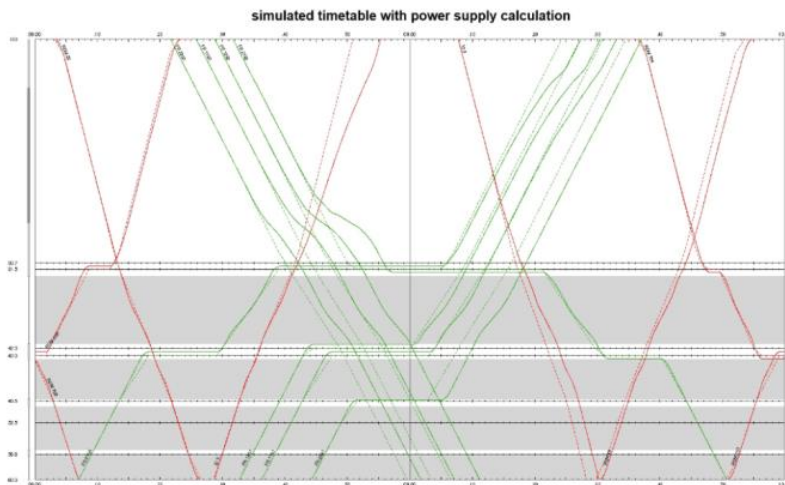
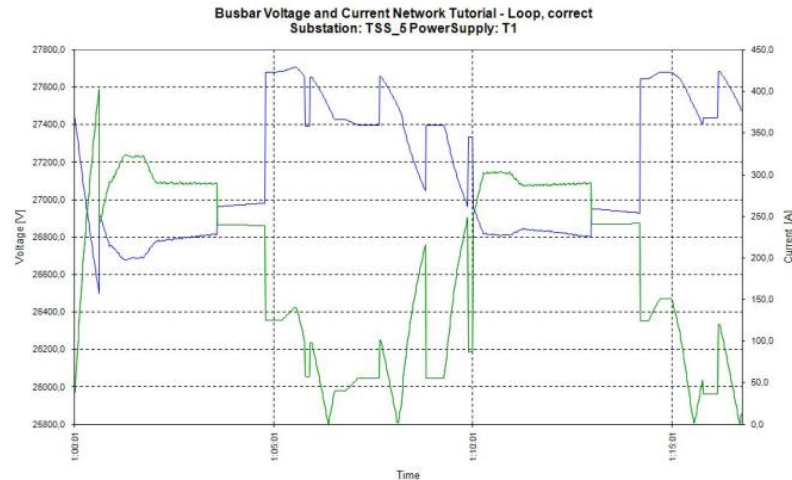
- § What ABB offers, at a systems level
- § An overview of AC electrification system
- § Considerations specific for AC rail systems
 - § Load balancing and power quality on the grid
 - § Switchgear
 - § Catenary protection
 - § Insulation Coordination
 - § Interfaces
- § Reference projects

AC Electrification

What ABB Offers

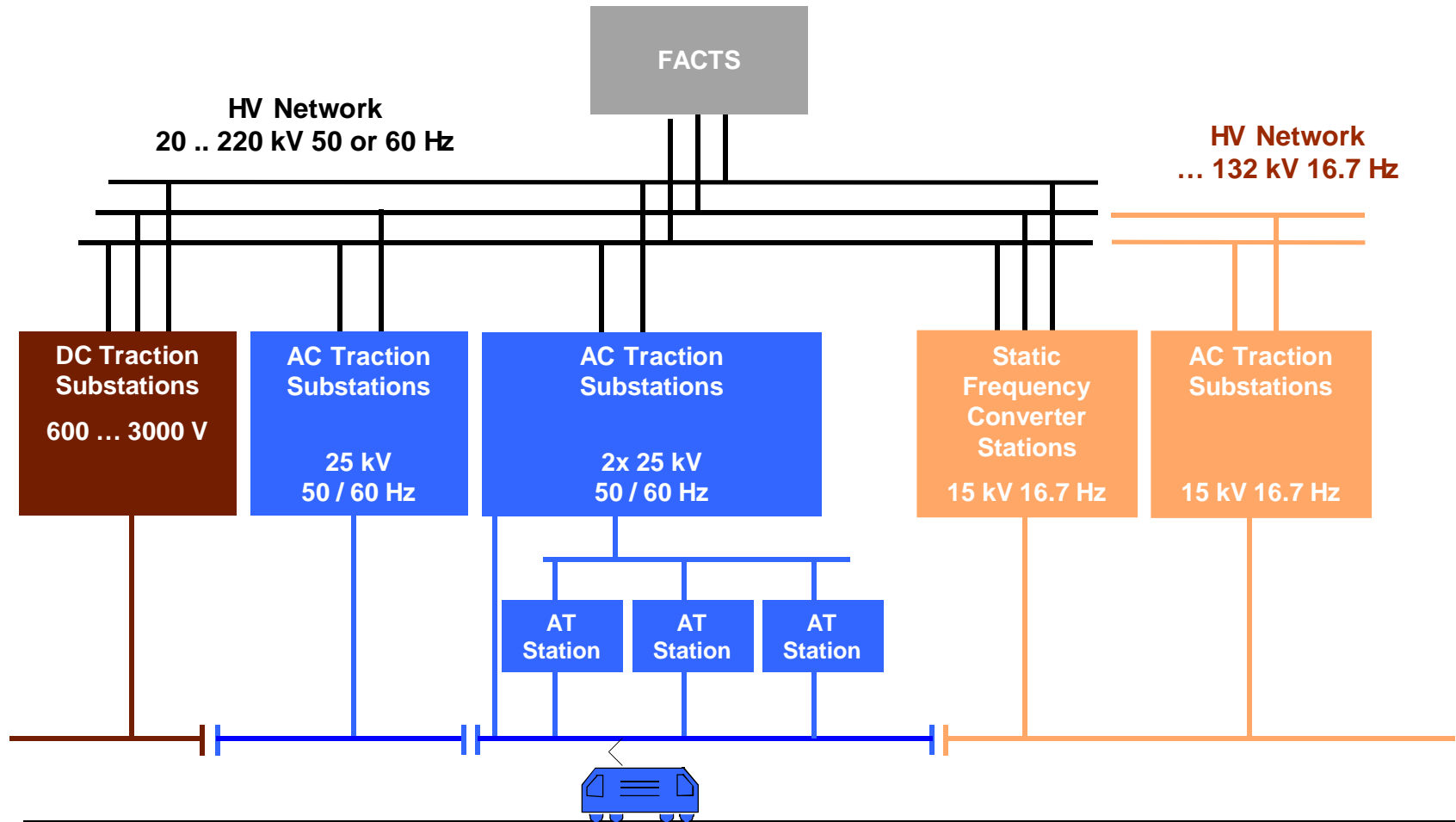


AC Electrification System Studies

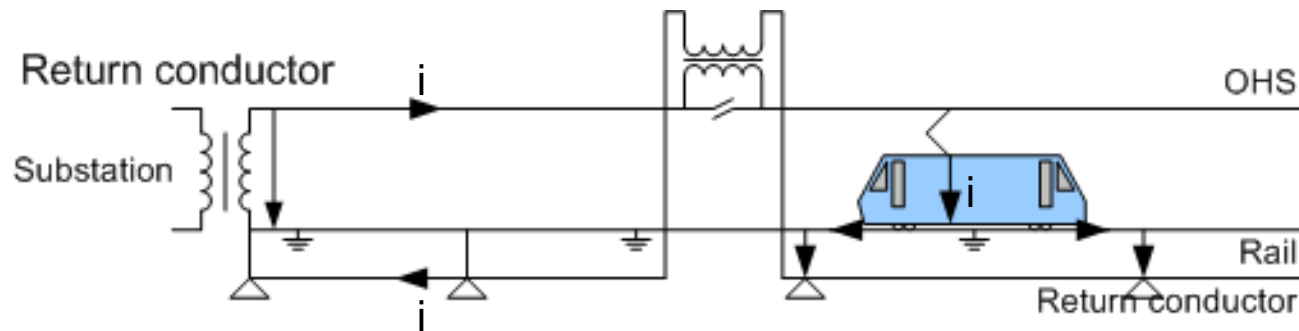
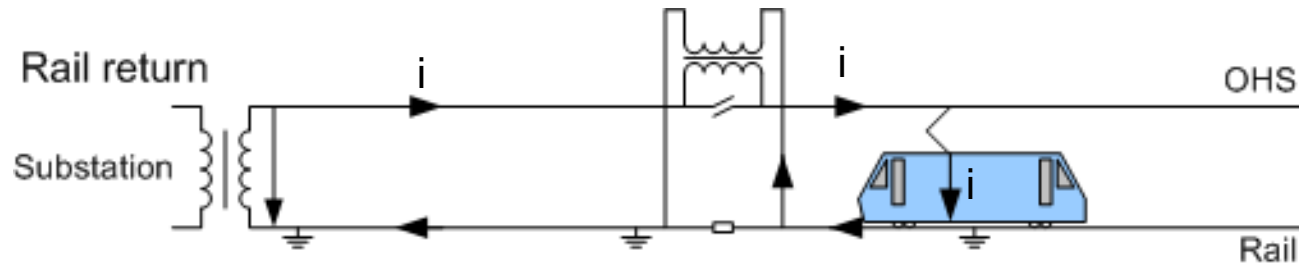


- § ABB is in a position to perform complete system studies, such as:
 - § Energy consumption analysis and prognosis
 - § Design and rating verification of the electrical installations
 - § EMC studies, Harmonics, etc..
- § Powerful software tools, such as DIGSILENT Power Factory, NEPLAN, PSSE, PSCAD, ATP, OpenTrack and OpenPowerNet are being used.
- § Railway specific studies based on OpenTrack and OpenPowerNet are performed by our consulting group

AC Electrification Feeding Schemes - General



AC Electrification Supply Booster Transformer



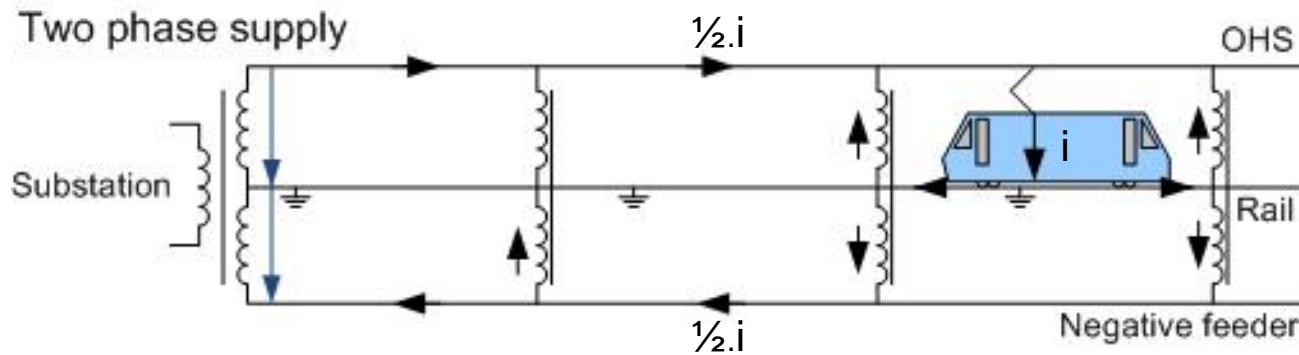
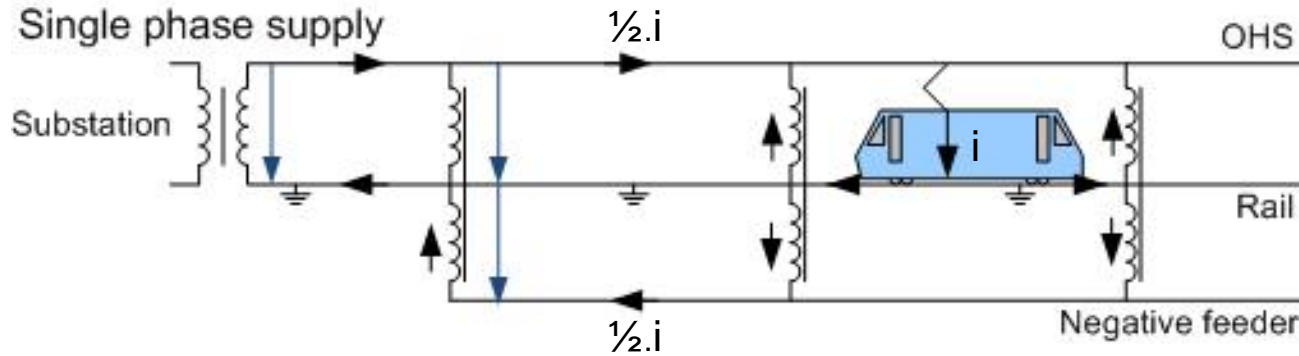
AC Electrification Supply Autotransformer with Return Conductor

Spacing between
feeder stations

1 x 25 kV system
: 60...80 km

2 x 25 kV system
: 120..140km

Spacing between
AT stations :
10...20 km



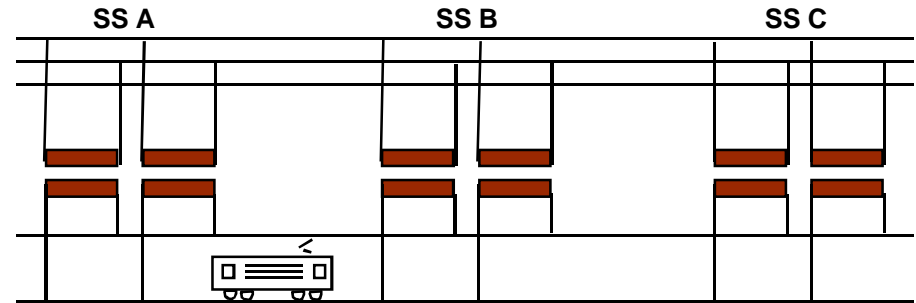
AC Electrification

Connection to the grid

Connections without settlement of unsymmetry

- Specific substation:**
- 1 ... 3 Transformers
 - 1 x operation rail 25 kV
- Specific track**
- no phase connectors necessary
 - good voltage position
- Specific HS-net**
- high unsymmetry

Typical user:

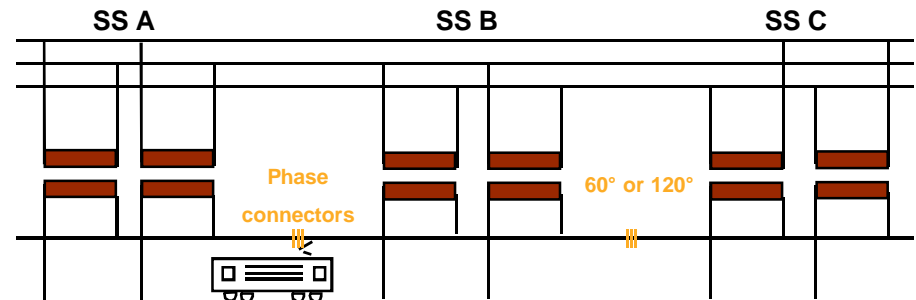


Connections with mediate settlement of the unsymmetry

- Specific substation:**
- 2... 3 Transformers
 - 1xoperation rail 25 kV
- Specific track:**
- phase connectors between SS necessary
 - good voltage position
- Specific HS-net**
- low unsymmetry

Typical user:

Spain, China
Czechia, Russia,
France, Hungary,
Grieece

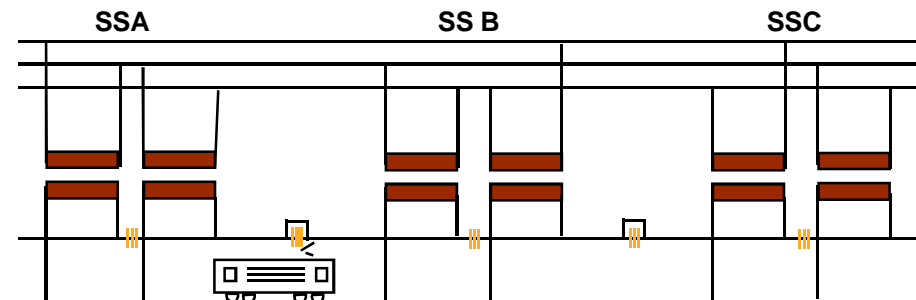


Connections with mediate and partially immediate settlement of the unsymmetry

- Specific substation:**
- 2... 3 Transformers
 - 2xoperation rail 25 kV
- Specific track:**
- phase connectors between SS necessary
 - good voltage position
- Specific HS-net**
- low unsymmetry

Typical user:

Netherlands, Russia,
France



AC Electrification SFC & Power Quality (FACTS)



§ Static Frequency Converter Stations

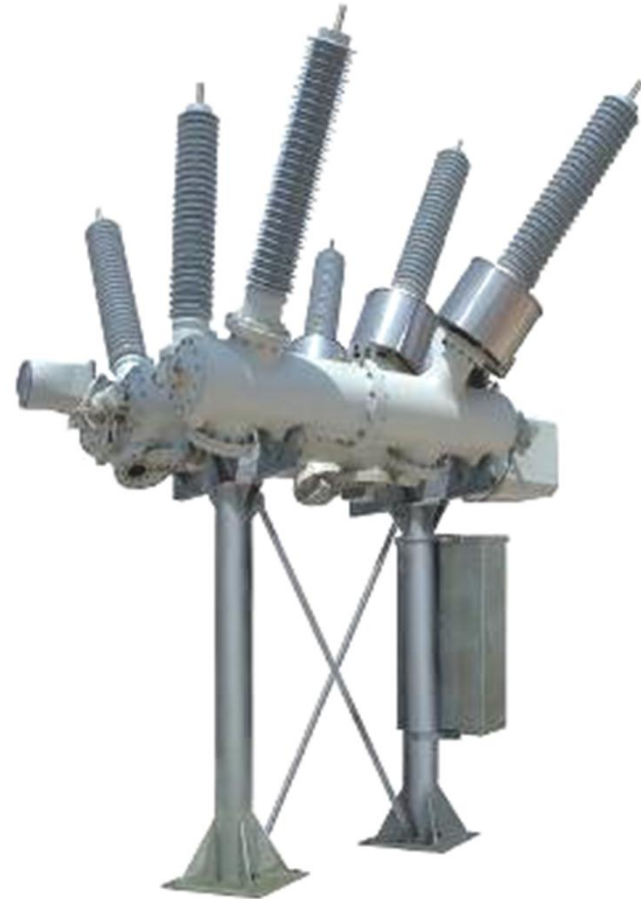
- § Turnkey frequency converter stations comprising
 - § Standardized converter modules
 - § HV and MV switchgear
 - § Protection and station control.



§ FACTS

- § Single-phase power takeoff from 3-phase grids creates unbalance which needs to be mitigated.
- § Static Var Compensation, SVC or SVC Light[®], is widely used for dynamic load balancing in conjunction with railway feeding.

AC Electrification HV Switchgear PASS

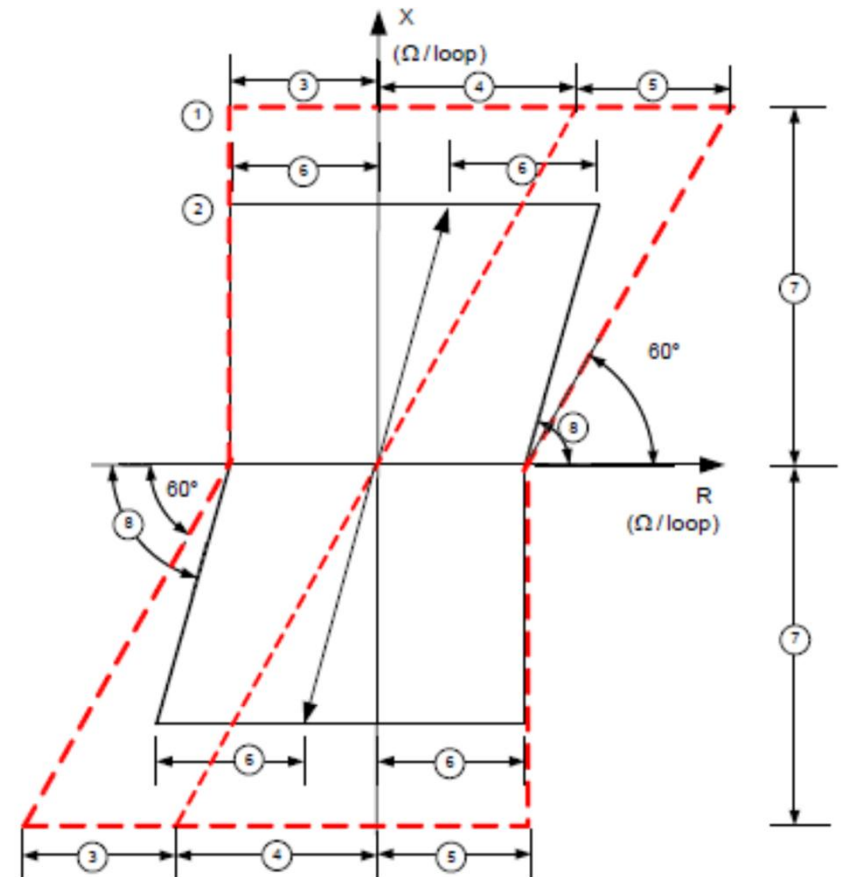


AC Electrification MV Switchgear

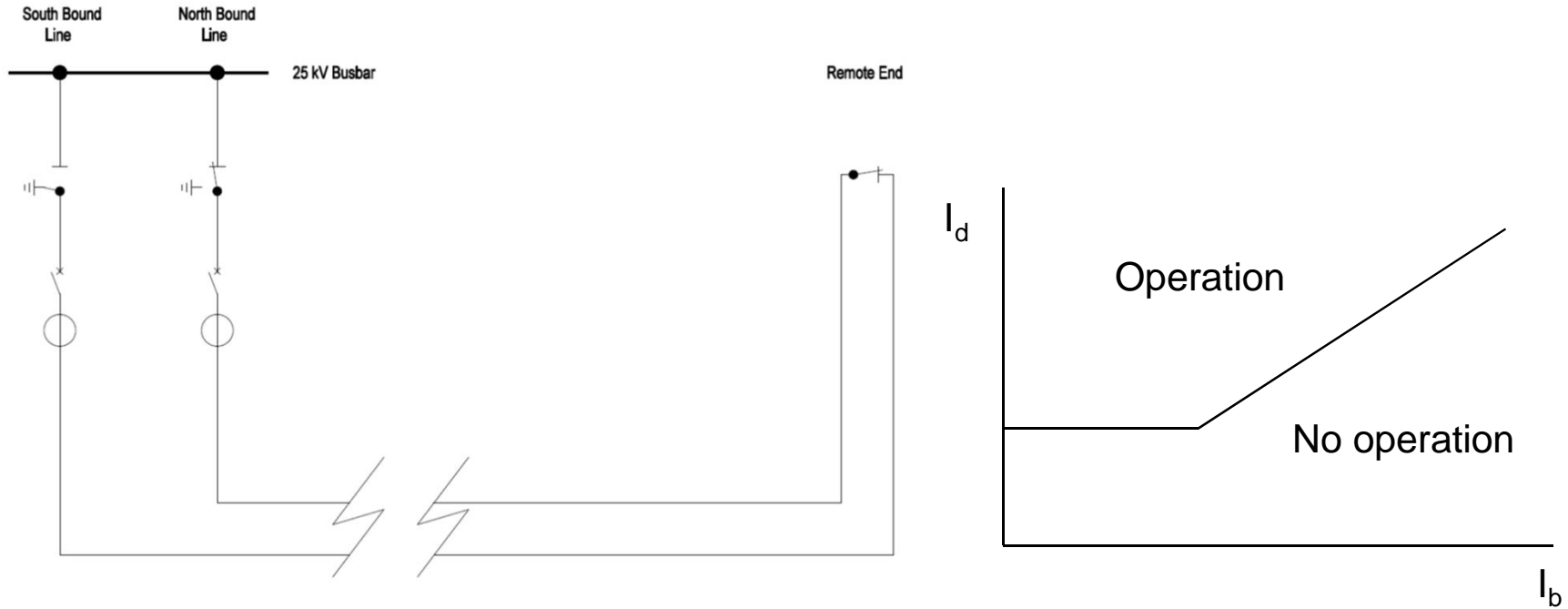
| | Primary Switchgear | Secondary Switchgear | Railway Switchgear | Compact Substation |
|-----|---|---|--|--|
| AIS |  UniGear-ZS1  UniGear-ZS8 |  UniSec |  UniGear R36/40  FSKII+ GSx II |  Compact Substation  SMOS Light |
| GIS |  ZX0  ZX2  ZX0.2 |  SafeRing  SafePlus |  ZX 1.5R |  Compact Substation |

AC Electrification Catenary Protection – Distance Protection

- § Main catenary protection.
- § Used in combination with auto-reclosure
- § Quadrilateral characteristics
- § High resistance faults
 - § di/dt
 - § Higher 3rd harmonic in load current so use as restraint
 - § Higher 2nd harmonic in inrush so also use as restraint



AC Electrification De-icing



§ Differential: $I_d = |I_C - I_F|$

§ Bias $I_b = \frac{|I_C + I_F|}{2}$

AC Electrification

MV Insulation coordination

According to reference standards, the insulation coordination is specified for three-phase systems in relation to phase-phase voltages.

For the railway applications, insulation is usually "approached" as the nearest equivalent in a three-phase system:

| Rated single-phase voltage | Equivalent three-phase voltage | Insulation levels according to IEC |
|--|--|--|
| 17.5 kV | $1.732 \times 17.5 \text{ kV} = 30 \text{ kV}$ | 24 kV (50 kV/ 125 KV BIL) 36 kV (70 kV/ 170 kV BIL) |
| 27.5 kV | $1.732 \times 27.5.5 \text{ kV} = 48 \text{ kV}$ | 36 kV (70 kV/ 170 kV BIL) 40.5 kV (95 kV/ 200 kV BIL) 52 kV (95 kV/ 250 kV) |
| <i>Note : EN 50124-1, table Z1 provides insulation parameters according to OV classification</i> | | |

AC Electrification Interfaces

HV Grid

- § More complicated
- § Grid code: Load balance, power factor, harmonics
- § Managed though FACTS

Catenary

- § Simple
- § Connection at the substation boundary

SCADA

- § Detailed but well known
- § Interface at substation RTU

Auxiliary supply

- § Galvanic separation between utility and railway usually required

Earthing/ Grounding

- § Must pay careful attention to segregation between railway and utility earthing systems.
- § Safety requirements as for utility substations

AC Electrification

Channel Tunnel Rail Link, United Kingdom

Customer: Electricité de France (EdF)

Year of commissioning: 2007



Customer needs

- § Experienced supplier to provide systems to feed the Channel Tunnel Rail Link, Phase II
- § Balancing large single-phase loads and enhancing the voltage profile along the track

ABB response

- § Turnkey delivery of the traction power supply package
- § Three 400 / 33 / 50 kV feeder substations and four 2 x 25 kV auto-transformer substations
- § Six 1-phase SVC's: 33 kV -5 to +40 MVar
- § One load balancer: 33 kV -84 to +168 MVar

Customer benefits

- § Optimized ABB system design ensures a reduced number of feeders and safeguards a symmetrical voltage with minimum disturbances

AC Electrification West Coast Mainline, United Kingdom

Customer: Network
Rail

Year of
commissioning: 2015



- § Principle Contractor on West Coast Main Line (WCML) – 25kV Containerised substation solution.
- § WCML is one of the most important intercity rail passenger route in the United Kingdom as well as the principal freight corridor, carrying around 43% of all UK rail freight traffic
- § The trains majority of trains are Virgin's 390 "Pendolino" trains for long-distance high-speed WCML services
- § To deliver a high-quality power to the line, all main feeder stations and autotransformers sites are equipped with primary 2x25 kV GIS ZX1.5 R type.
- § This represents more than 150 panels, 11 substations, for Phase 3B.

AC Electrification Gautrain, South Africa

Customer:
Gautrain Rapid
Rail Link

Year of
commissioning:
2008

ABB has been
selected by
Bombardier
Transportation to
design, install and
commission the
25 kV traction
power supply
system

Revenue
operation of the
new rapid transit
railway system is
planned to start in
2010



Rail

Customer need

- § Electrification of the 80 km mass rapid transit railway system in Gauteng Province

ABB's response

- § Turnkey delivery of the complete traction power supply system, comprising design, supply, installation, testing and commissioning of:
 - § one 88/2x25 kV feeder substation
 - § Five 2x25kV autotransformer substations based on pre-fabricated outdoor modules
 - § Supervisory control and data acquisition system

Customer benefits

- § Reduced overall project duration, short installation and commissioning

AC Electrification Wulkuraka, Australia

Customer:
Queensland Rail, Australia
Start of commercial
operation: 2015



Customer needs

- § Increased energy demand for the Brisbane Rosewood Line and for a new rolling stock maintenance depot nearby
- § Conversion of country's 3-phase 50 Hz grid to 1-phase 50 Hz railway grid without unbalance effects to the supplying grid

ABB response

- § Turnkey solution incorporating a 20 MVA static frequency converter
- § Transformers, switchgear, control and cooling systems
- § Design, engineering, installation, commissioning and civil works

Customer benefits

- § Stronger railway corridor performance
- § Higher power supply without fault current rating increase

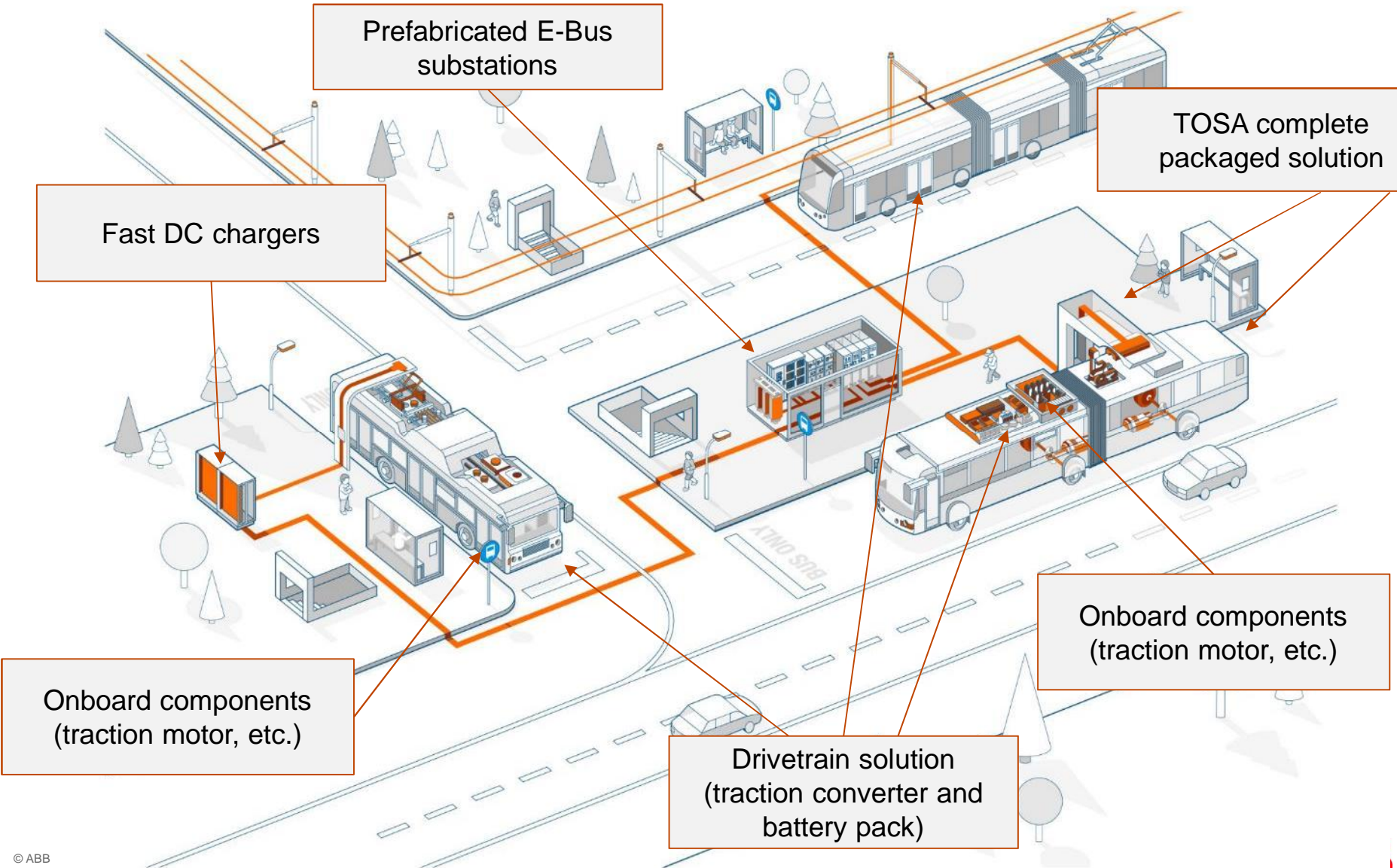


Daniel Simounet - October 2016

Electrification of buses The infrastructure challenge

Our E-Bus offering overview

Solutions for onboard and infrastructure applications



When Fast DC, when TOSA?

Fast chargers and complete solutions covering different city bus applications

Layover time on end stops



Onboard energy storage size



Commercial and technical feasibility / payoff

Fast DC approach



TOSA approach

Open industry standards are key to success ABB is working on global & EU standardization

Press release March 15 2016

Group of European electric bus manufacturers agrees on an open interface for charging

European bus manufacturers Irizar, Solaris, VDL and Volvo have agreed to ensure the interoperability of electric buses with charging infrastructure provided by ABB, Heliox and Siemens. The objective is to ensure an open interface between electric buses and charging infrastructure and to facilitate the introduction of electric bus systems in

§ In North America, ABB is involved within the EPRI Bus and Truck Charging Working Group and with SAE J3105 to help developing the standard for charging infrastructure system compatible with the needs of transit fleets.



Global leader in EV fast charging solutions

Proven technology in the field since 2010

ABB DC Charging infrastructure

Active since: 2010

Volume: > 3.000 DC fast chargers installed world wide, biggest installed base of all manufacturers

Regions: Europe, Americas, Africa, Asia, China, Pacific

Standards: CCS-1, CCS-2, GB/T, CHAdeMO, ISO 15118, IEC-61851-23, SAE J1772

Connectivity: Remote management and support, > 99,5% Uptime, global integration with payment systems, RFID, Smartphone, Creditcards and 3rd party IT systems.

Ebus charging experience: Coventry (UK) 2011, Offenback (DE) 2012, Geneva (CH) 2013, Luxembourg (2016), Namur (2016/2017)



Partner und Referenzen im Bereich DC Schnellladen



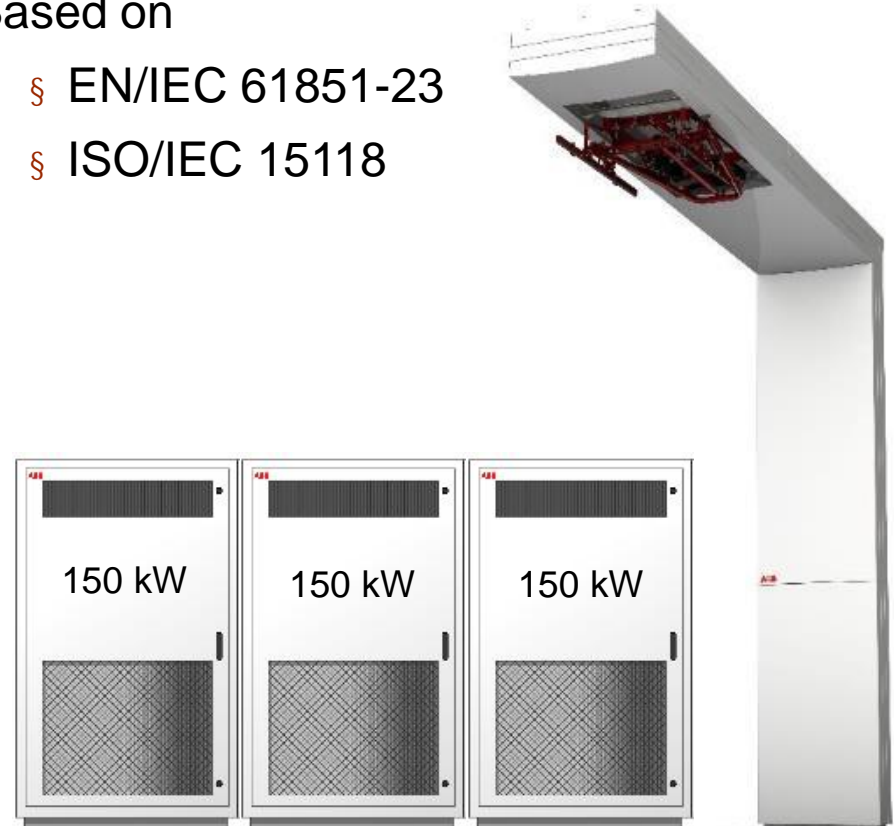
A practical fast charging solution for e-busses

Reliable, scalable, based on industry standards



- § Automated connection system
- § High power DC transfer to bus
- § Wireless communication to bus
- § Based on
 - § EN/IEC 61851-23
 - § ISO/IEC 15118

- § Industrial quality power cabinet
- § 150kW, 300kW & 450 kW modular
- § Redundancy per each 150kW module
- § 400-850 V_{DC} output
- § Galvanic isolation
- § Remote management



Example of installation proces

Volvo Gothenborg



Product portfolio

ABB offers complete solutions for eBus charging

High power platform

Depot charging CCS-2
50– 150kW



Opportunity charging
150 -450kW



Separate MV transformer station



Connectivity

Globally compliant server architecture



IT system integration

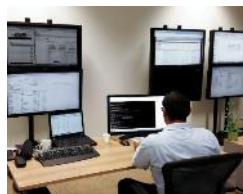
API platform
> 50 successful integrations

Web modules & statistics



Service

ABB global NOC support



> 250 trained local ABB experts



3rd party training for partners



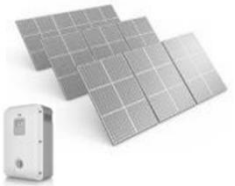
Our view - Three Keys to charging infrastructure



GRIDPOINT



- Demand response
- Distribution system management
- Using alternative energy sources



Grid-side

Integration platform (APIs)



Hectronic

- Fleet management
- Performance reporting
- System integration

Connected Services

OCPP

OCPP

Fleet Operation

API

Service API

Charger Management



BUS TELEMATICS



- Hardware and software checks
- Charge(r) remote support
- Charge(r) maintenance

When Fast DC, when TOSA?

Fast chargers and complete solutions covering different city bus applications

Layover time on end stops



Onboard energy storage size



Commercial and technical feasibility / payoff

Fast DC approach

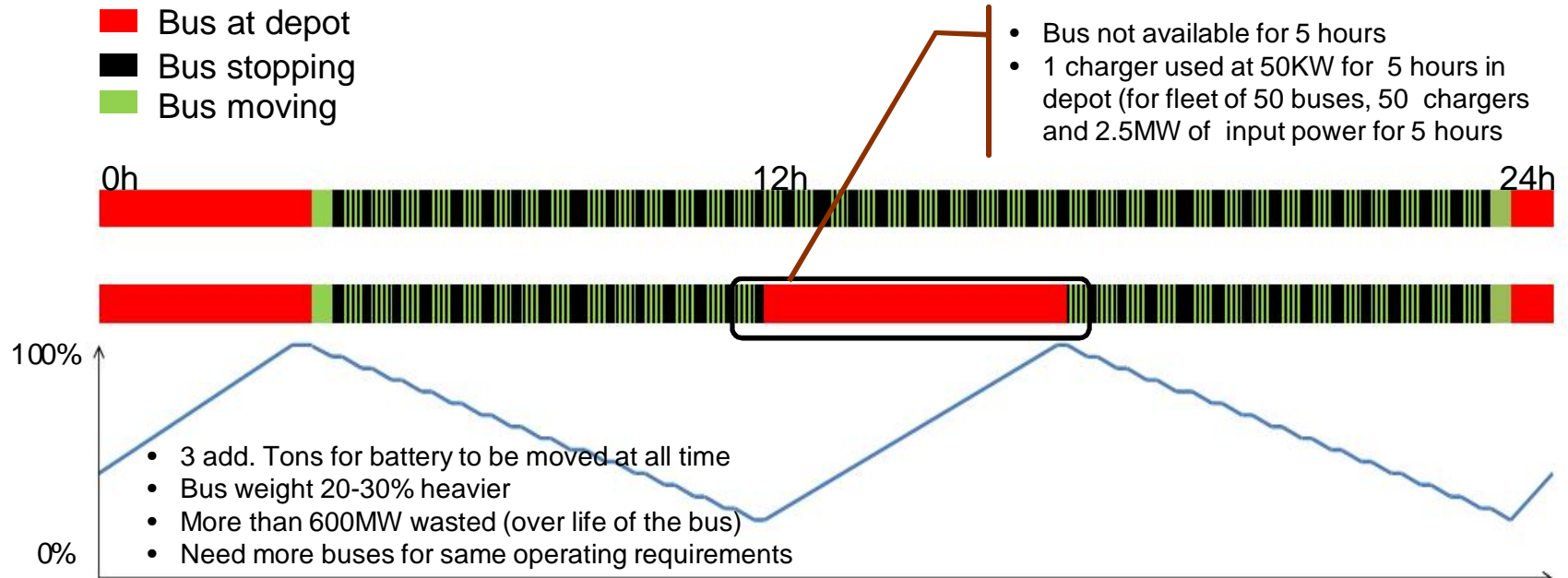


TOSA approach

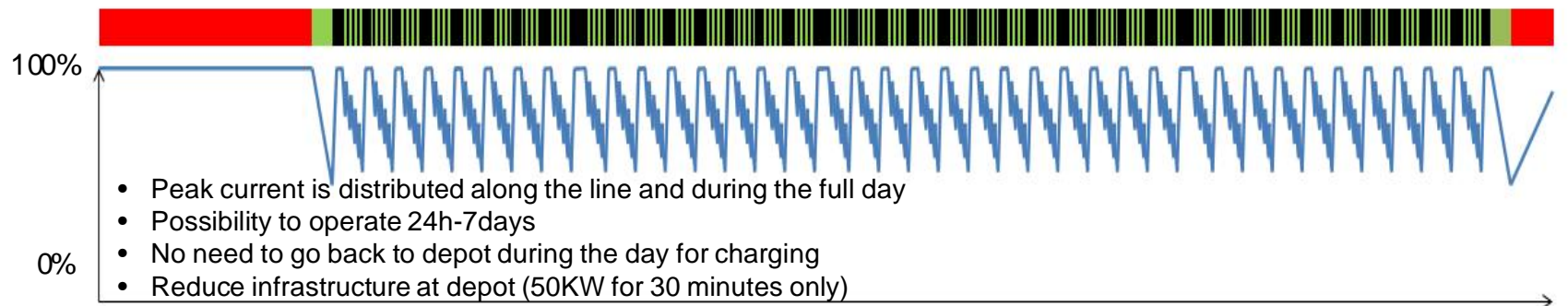
High density lines

Depot charging vs opp. charging

- Bus at depot
- Bus stopping
- Bus moving



Plugin charging at depot (300kwh) - battery energy level



Opportunity charging (40kwh) - battery energy level

Comparison of technologies

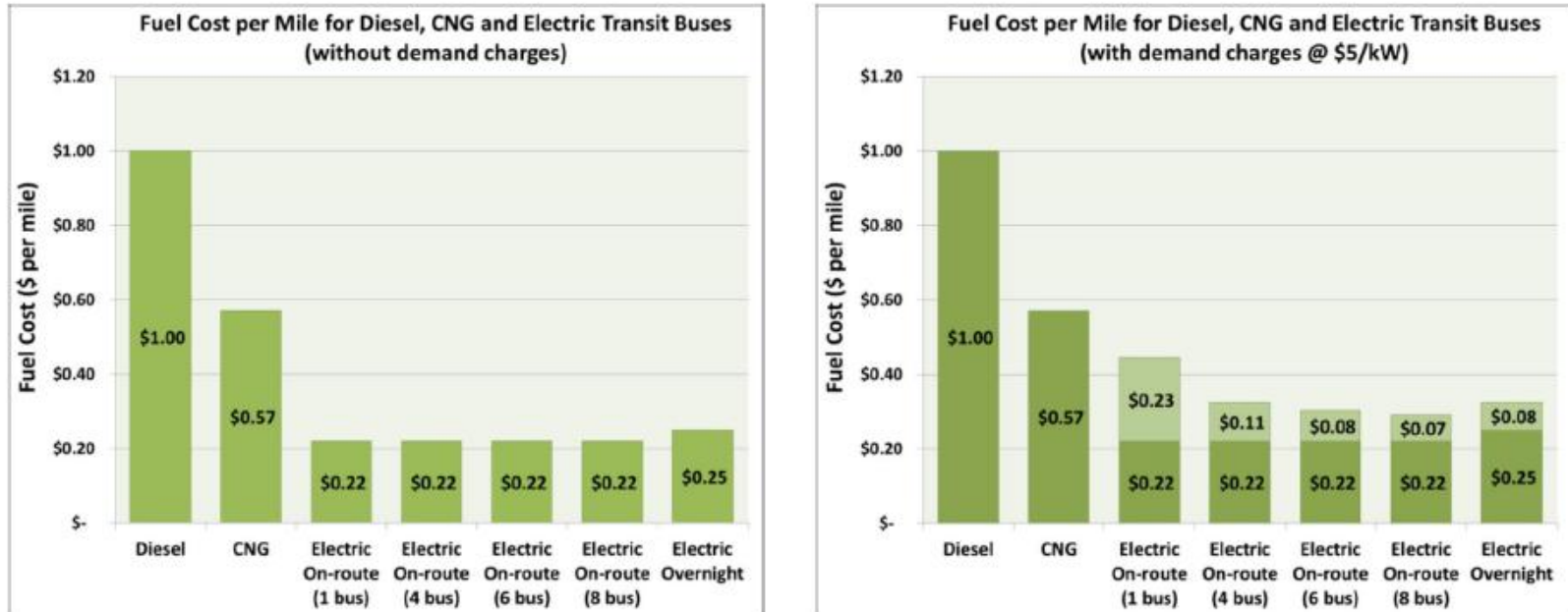


Figure ES-2: Fuel cost for diesel, CNG and electric buses with no and low demand charges

Critical factors:

- § High capacity & Energy efficient buses
- § Energy management solutions to reduce/eliminate peak demand charges

Source: Peak demand charges and electric transit buses - White paper – US Department of transportation Federal Transportation agency – prepared by Ted Bloch-Rubin, Jean-Baptiste Gallo & Jasna Tomić CALSTART – 8/14/2014

High capacity and start of operation May 2013



Flash Mobility
Clean City. Smart Bus



TOSA is a world premier in sustainable mobility
Doris Leuthard, Member of the Swiss Federal Council,
Head of the Department of Environment, Transport, Energy and
Communications



Equipment on board – Technology on the roof

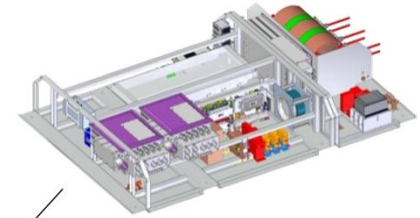
An answer to high-capacity requirement



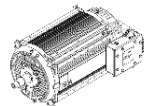
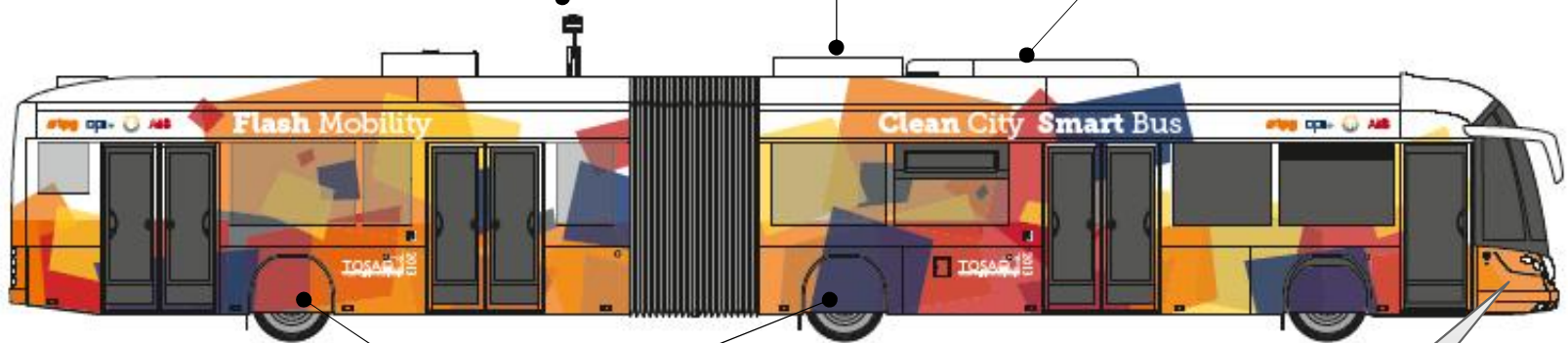
Entirely automatic energy transfer system



Water-cooled batteries pack



Water-cooled traction chain

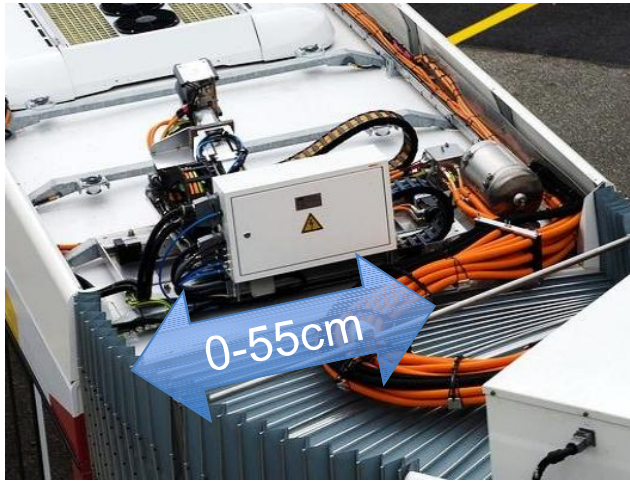


Two water-cooled motorized axis engine

I transport passengers and not batteries

Equipment on the roof

Energy Transfer System



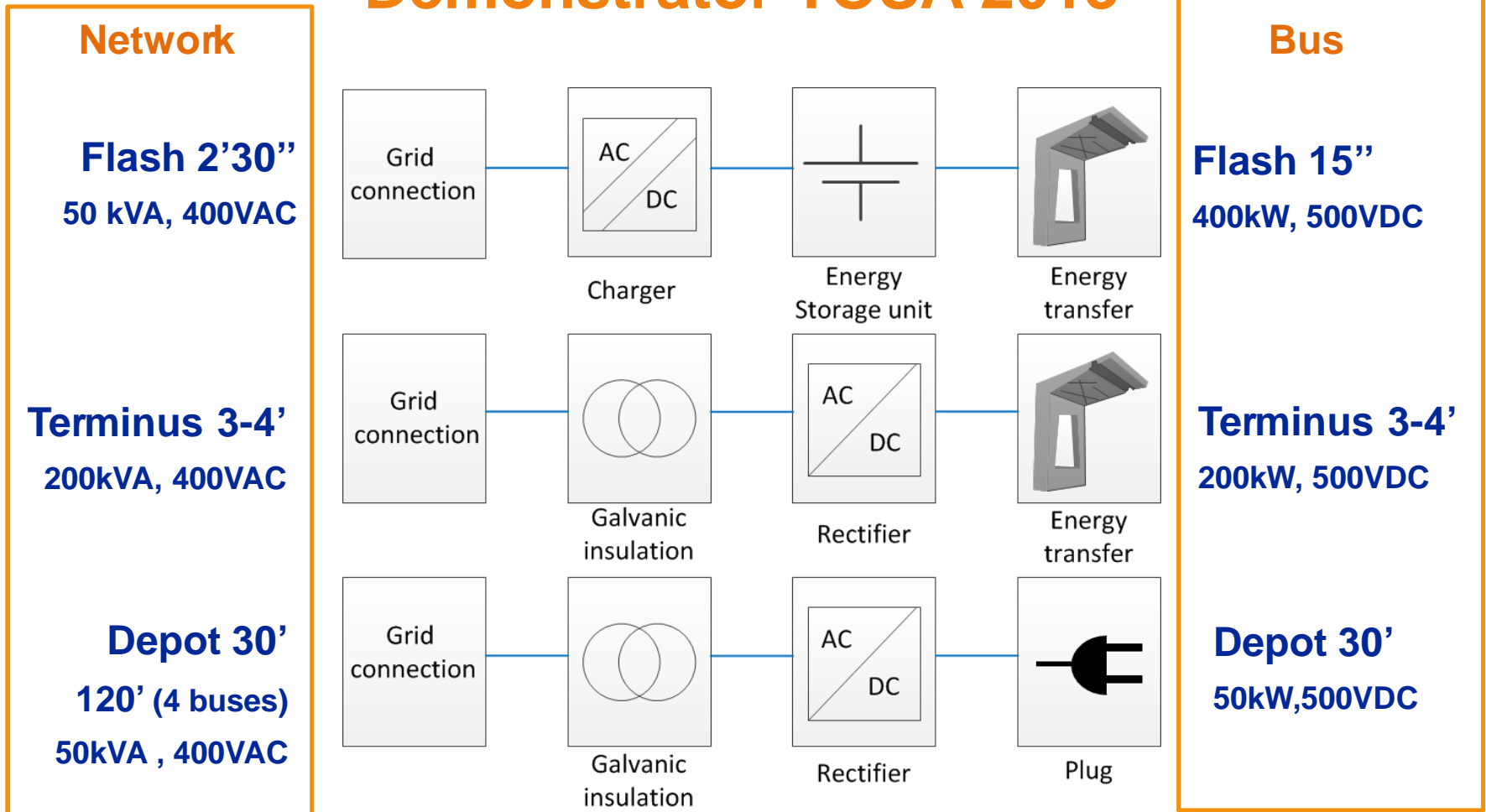
Entirely automatic energy transfer system

(no action from bus driver)

- § Connection with high capacity power in 1 sec
- § Compensation for distance to sidewalk: 0 to 55cm
- § Receptacle; length 3m to optimize approaching speed
- § High power and safe: Respecting RNI norms and directives (ICNIRP)
- § Energy efficiency less than 1% loss

Feeding stations Flash / Terminus / Depot

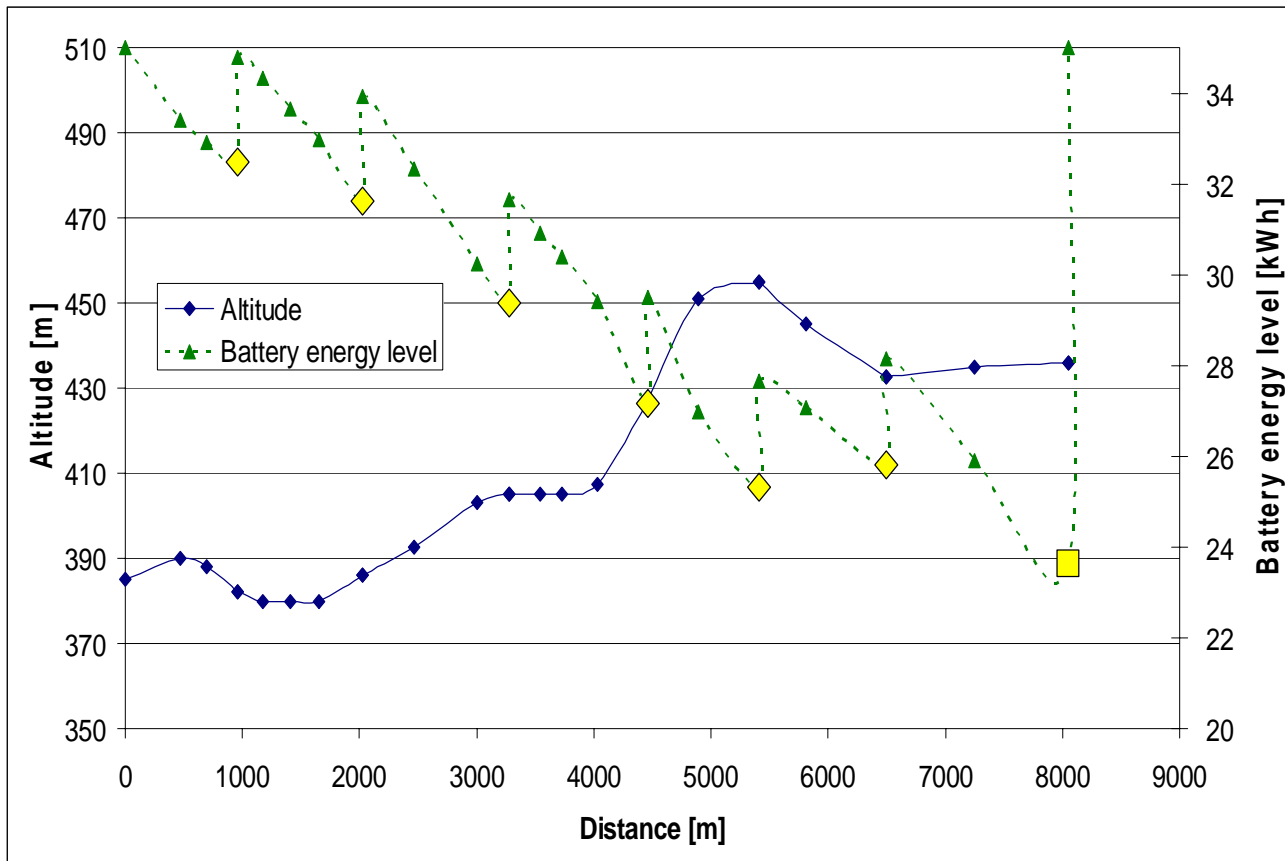
Demonstrator TOSA 2013



Principle - Intelligent energy management

100% electric

Goal: Reduce the energy storage on board
High energy efficiency and cost efficiency



First commercial order in Geneva, bus line 23

Press releases

+ Group press releases

+ Trade press releases

ABB wins 1st commercial order for breakthrough 15-second flash charging technology to enable CO2-free public transport in Geneva

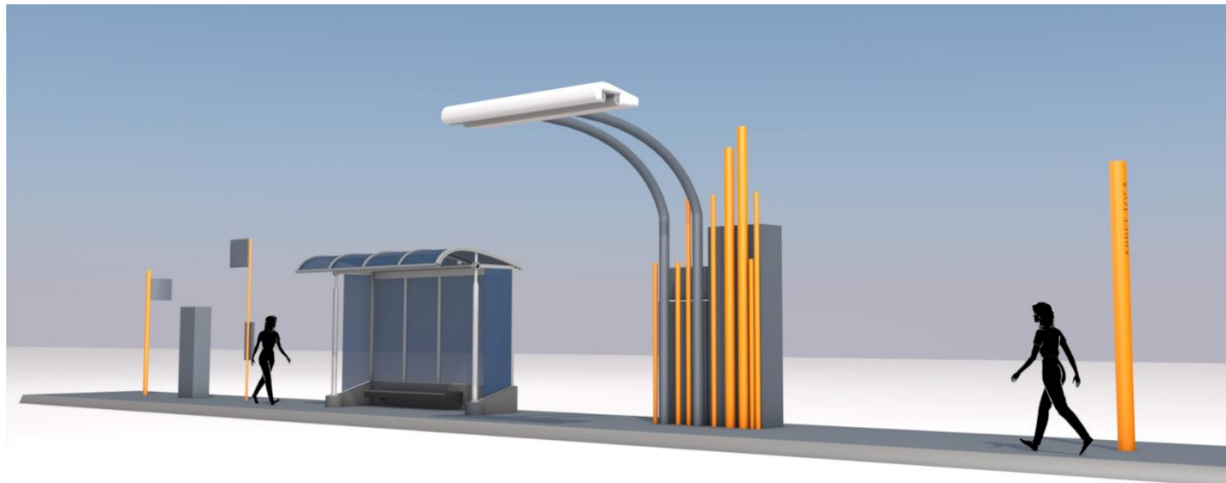
Revolutionary technology requires no overhead lines and offers silent and zero-emission mass transit solution as a viable alternative to diesel buses, providing a model for future urban transportation



TOSA bus

Zurich, Switzerland, July 15, 2016 – ABB has been awarded orders totaling more than \$16 million by Transports Publics Genevois (TPG), Geneva's public transport operator, and Swiss bus manufacturer HESS, to provide flash charging and on-board electric vehicle technology for 12 TOSA (Trolleybus Optimisation Système Alimentation) fully electric buses (e-buses) which will run on Line 23, connecting Geneva's airport with suburban Geneva. The e-buses can help save as much as 1,000 tons of carbon dioxide per year, when compared with existing diesel buses.

First commercial order in Geneva, bus line 23 Flash Feeding Station: first sketch



Technical progress vs. Demonstrator project

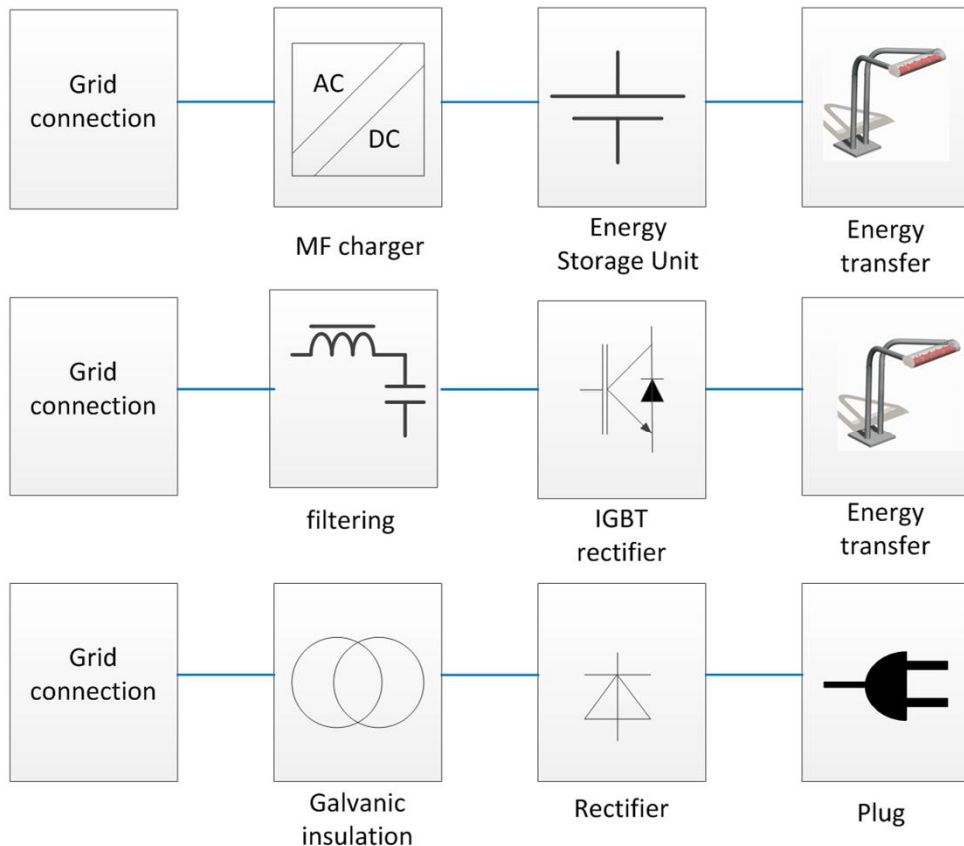
Flash / Terminus / Depot

Network

Flash 4'15''
55 kVA, 400VAC

Terminus 3-5'
436kVA, 400VAC

Depot 30'
120' (4 buses)
55kVA , 400VAC



Bus

Flash 20''
600kW, 600VDC

Terminus 3-5'
400kW, 600VDC

Depot 30'
50kW, 600VDC

High capacity Concept

133 to 182 passengers (at 5 pass/m²)



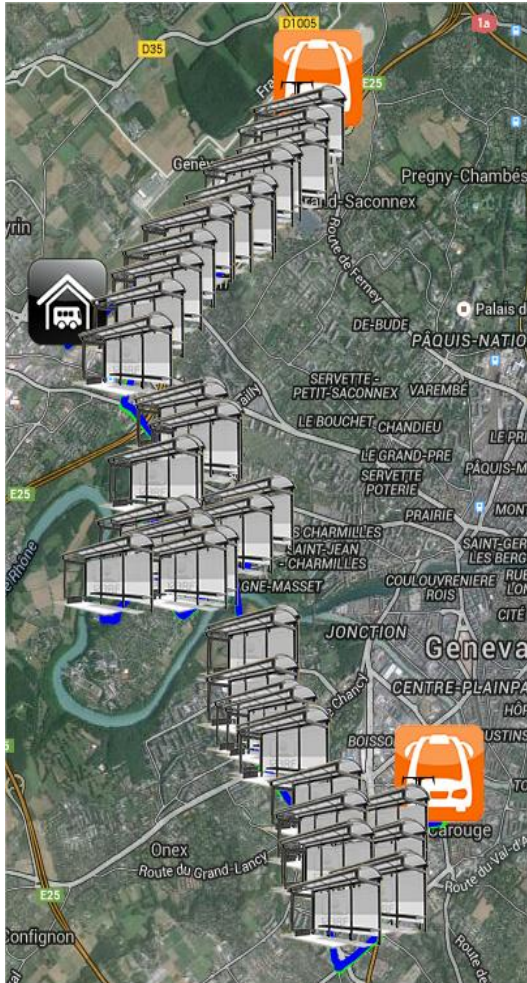
114 à 4 pass./m²
133 à 5 pass./m²
(17.5 m² + 44 assis)



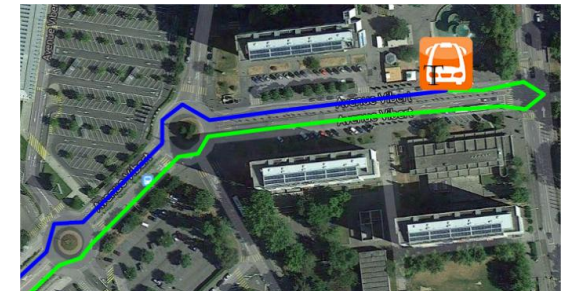
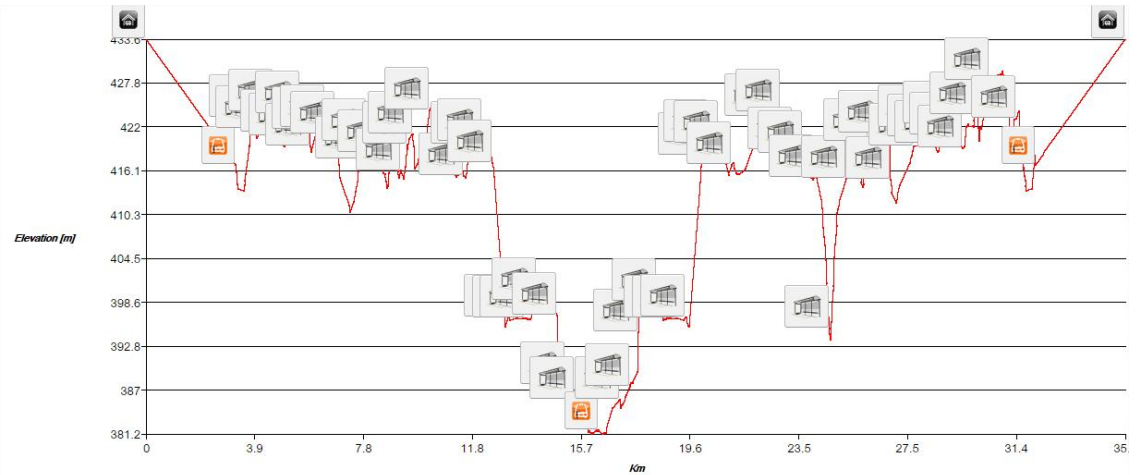
156 à 4 pass./m²
182 à 5 pass./m²
(25.1 m² + 56 assis)

I transport even more passengers and not batteries.

Line configurator



Allow to assess the energy needs of the route taking into account the elevation profile, number of stops and the commercial speed



Summary: TOSA, a complete packaged solution In-route flash charging for maximum bus capacity

An full electric bus systems designed according operation and total cost of ownership requirements

| | |
|---------------------------------|--|
| Timetable | high-power in-route charging at some bus stops and short layover time at terminalà same driving hours and speed as a diesel fleet |
| High-passenger capacity | All technology on the roof (all floor for passengers) for articulated and double-articulated buses. |
| Long-life battery | thanks to in-route charging principle, the high-power/low energy battery pack is used in its optimal operating range |
| Grid | Connection fee and energy cost optimized through embedded peak shaving functionality |
| Frequency and BRT | in-route charging (15') while passengers are disembarking-embarking at some bus stops and layover time compatible with high frequency lines (up to 4 000 pass./hours) |
| Light infrastr. at depot | Either free parking after fast (2-4mn) high power charging upon arrival or low-power (50kW) mutualized charging for four buses. |
| Homogenous fleet | TOSA bus configuration (e.g. battery size) is line independent. The line profile determine the required infrastructure. |

**Canadian Urban Transit Research & Innovation Consortium (CUTRIC)
Consortium de recherche et d'innovation en transport urbain au Canada (CRITUC)**

Dr. Josipa G Petronic, Executive Director & CEO
Josipa.Petronic@cutric-crituc.org
416-358-3206



CUTRIC Transportation Innovation Pillars

| | Descriptions (flexible) |
|---|--|
| 1. Alternative (low- and zero-emissions) propulsion systems & fueling systems | Battery electric propulsion Fuel cell electric propulsion Compressed/Liquefied/Renewable Natural Gas propulsion |
| 2. Light-weight materials and processes | Composites and hybrid structures Light-weight metals Biofibers Processes |
| 3. Autonomous, connected vehicle communications systems | Sensors, signals, control systems Artificial intelligence for networked, self-healing systems |
| 4. Cyber- & critical systems security | Securitization of component parts, critical systems Vehicles-to-X (V2X) communications |
| 5. Big Data & Analytics | Data driven analytic solutions for transportation and transit system optimization and networking Data driven analytic solutions for vehicle-to-grid communications Consumer applications (real-time mobile communications) |



Pan-Ontario Electric Bus Demonstration & Integration Trial

October 18th 2016

Project investors & stakeholders



Distributed charging: Electric bus technology options for transit

Nova Bus e-bus model

- 76 kWh battery
- Up to 20km one way (capacity for up to 40km one way at start-of-life)
- More than 25% Canadian content today

New Flyer e-bus model

- 200 kWh (modularly extended to 250 kWh)
- Capacity for up to 120 km one way at start-of-life
- Approximately 8% Canadian content today

Nova bus: electric bus solution

NOVABUS



Time to charge : 5 minutes



1
POSITIONING
EASY HOOK UP

2
CHARGING
QUICK SETUP

3
LEAVING
HAND FREE



- INVERTED PANTOGRAPH
- HIGH GROUND CLEARANCE
- OPEN STANDARD BY

ABB
SIEMENS



SAFETY / QUALITY / RELIABILITY

ZERO-EMISSION

CHARGING EFFICIENCY

FUEL EFFICIENCY

COST EFFICIENCY

TURN-KEY SOLUTION / SERVICE

New Flyer: electric bus solutions



- Leader in Heavy duty Transit Manufacturing since 1930
- Innovator since 1993 with Electric trolleys
- Launch of the Xcelsior XE40 Electric Bus in 2014
- Currently operating in Winnipeg and Chicago
- Pending orders for 2016-2017 totalling 31 XE40 buses

ABB Group: charging system solutions



ABB as a pioneer in EV fast charging solutions



ABB DC Charging infrastructure
 Active since: 2010
 Volume: > 3.000 DC fast chargers installed world wide, biggest installed base of all manufacturers
 Regions: Europe, Americas, Africa, Asia, China, Pacific
 Standards: CCS-1, CCS-2, GB/T, CHAdeMO, ISO 15118, IEC-61851-23, SAE J1772
 Connectivity: Remote management and support, > 99,5% Uptime, global integration with payment systems, RFID, Smartphone, Creditcards and 3rd party IT systems.
 Ebus charging experience: Conventry (UK) 2011, Offenback (DE) 2012, Geneva (CH) 2013, Luxembourg (2016), Namur (2016/2017)



ABB Group: charging system solutions



Objectives: accelerate adoption & enable localization ABB supports eBus projects/collaboration in Canada

- § Demonstration and deployment of a clean energy technology
- § Increase awareness and understanding of the implementation & use of eBus "on route" fast chargers at the city, PU & TA levels
- § Data gathering, analysis and sharing to develop local engineering expertise in an fast growing emerging market
- § Support actual standardization process of "on route" fast charger technology



- § Leverage of ABB expertise and footprint in Canada (50 offices, 4300 employees from coast to coast)
- § Prepare mass deployment of the technology across Canada to achieve a real environmental & economic impact




Siemens: charging system solutions

SIEMENS

Customer references for eBus charging

Gothenburg  Göteborg Energi



Stockholm  VATTENFALL



Vienna 



Montreal  NOVA BUS



Hamburg  HOCHBAHN



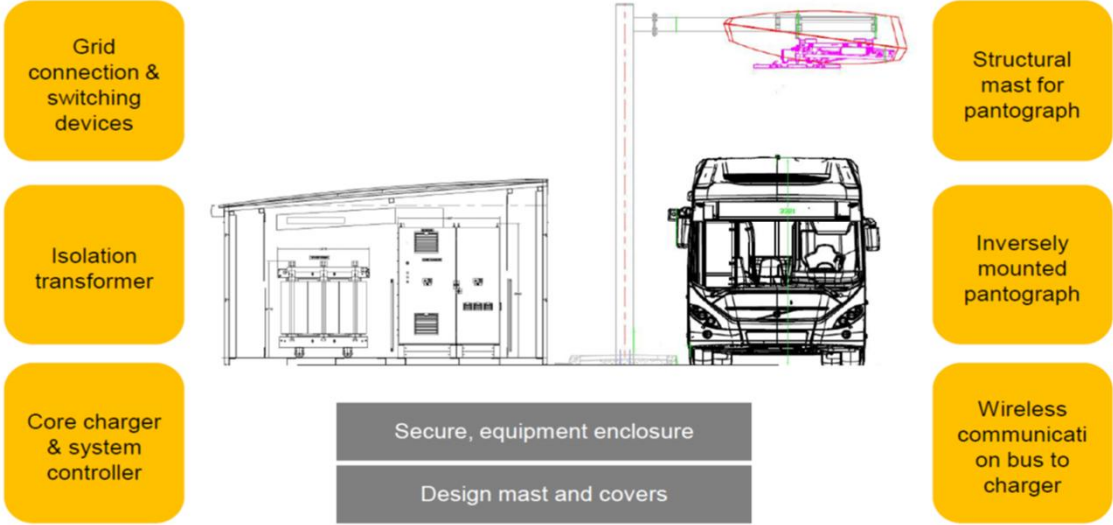
Restricted © Siemens AG 2015
Page 4 MO UT LRV

Charles halasz

Siemens: charging system solutions

SIEMENS

Siemens High Power Charger (HPC) – system view

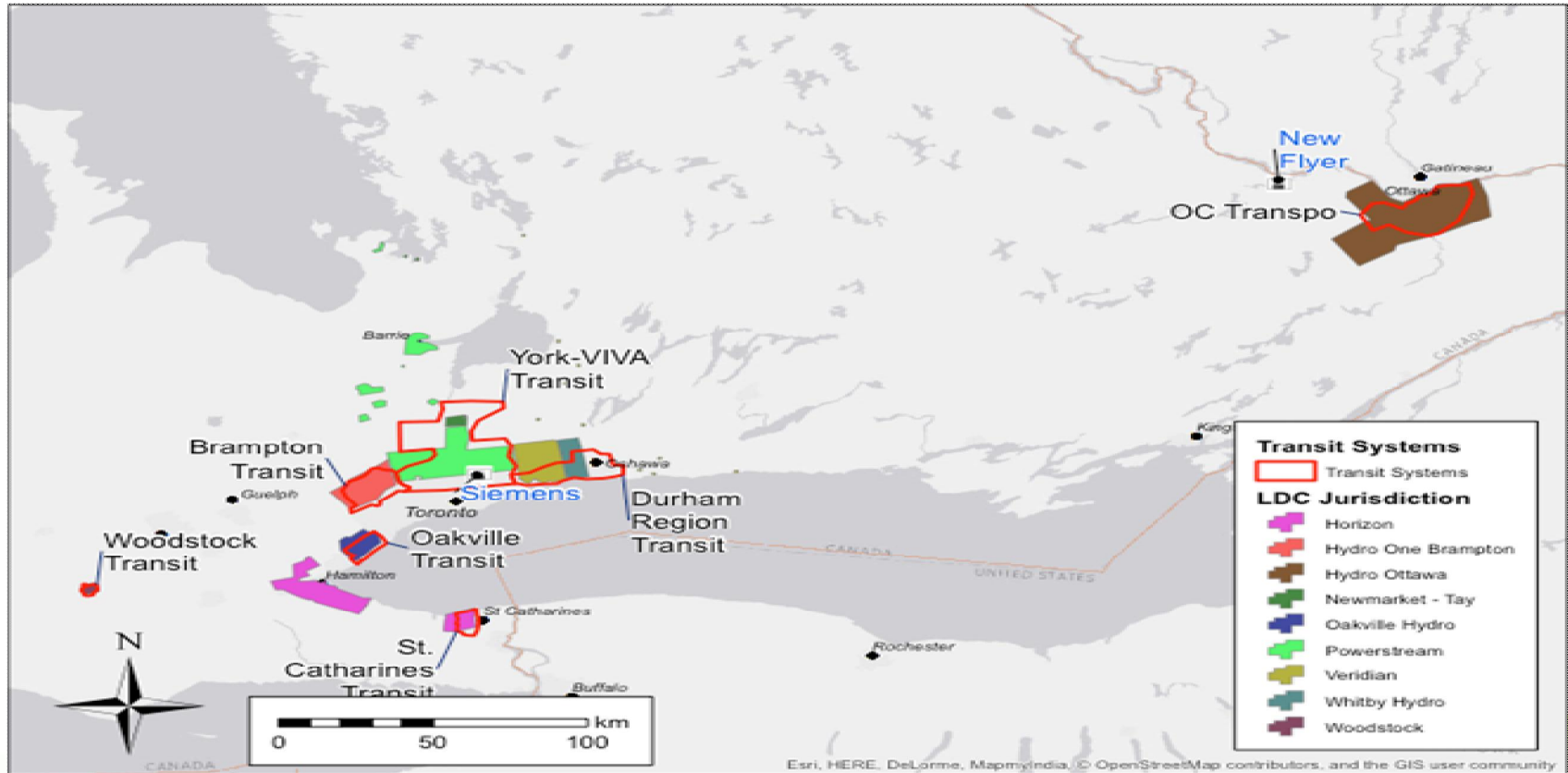


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<https://www.youtube.com/watch?v=0n3Lehz6faw=1.0>

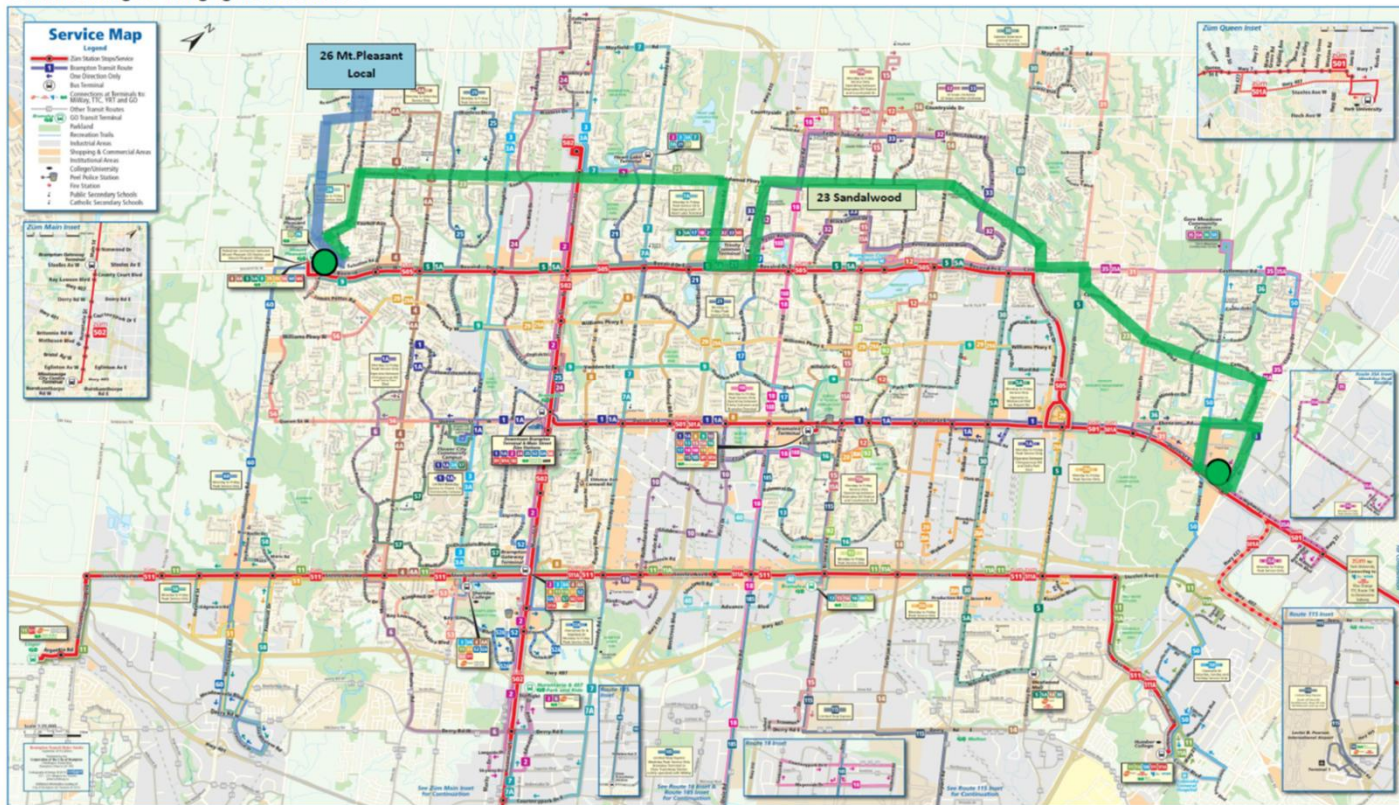
Charles halasz

LDC & Transit System dissonance

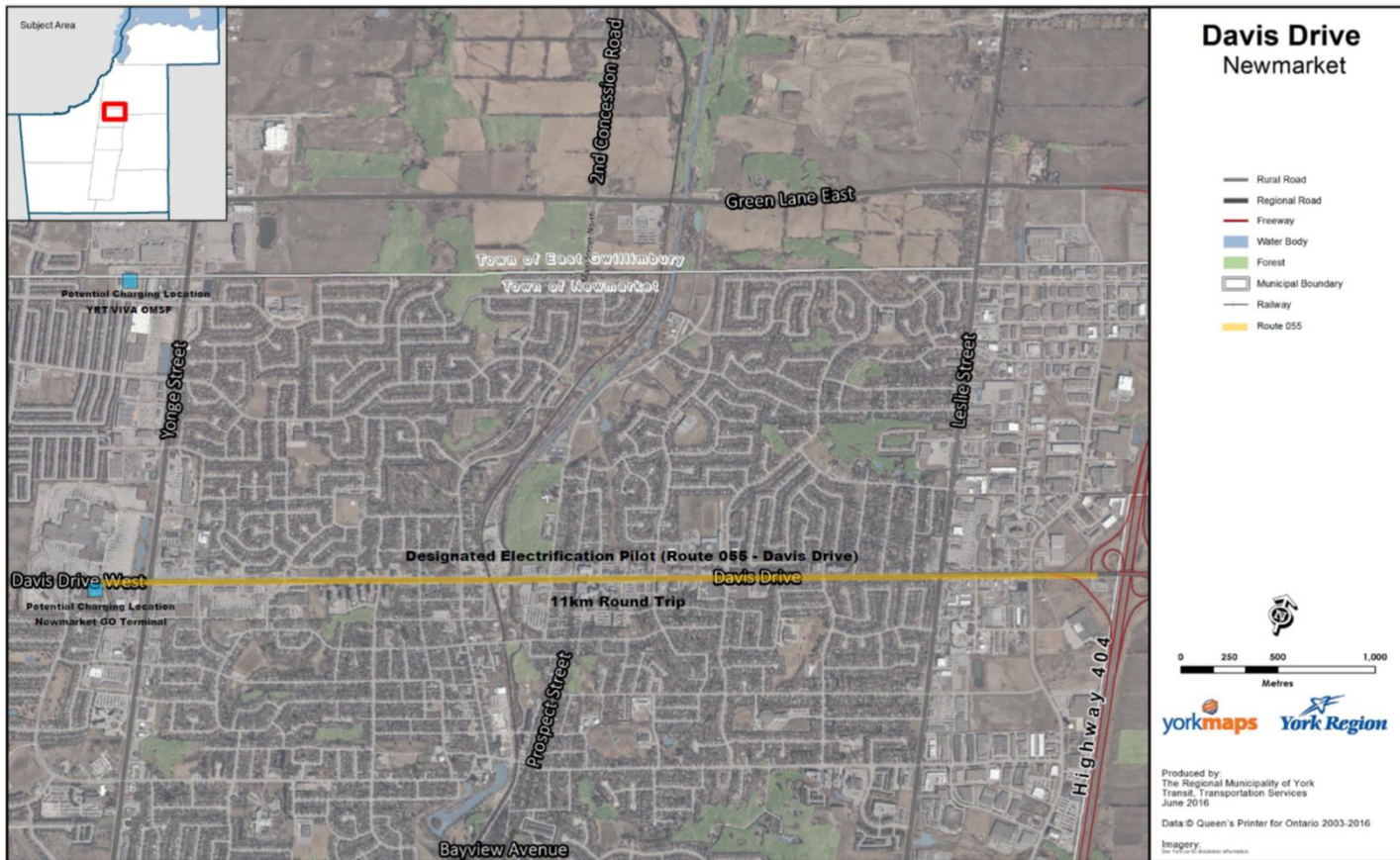


Brampton Transit: Routes 23 & 26

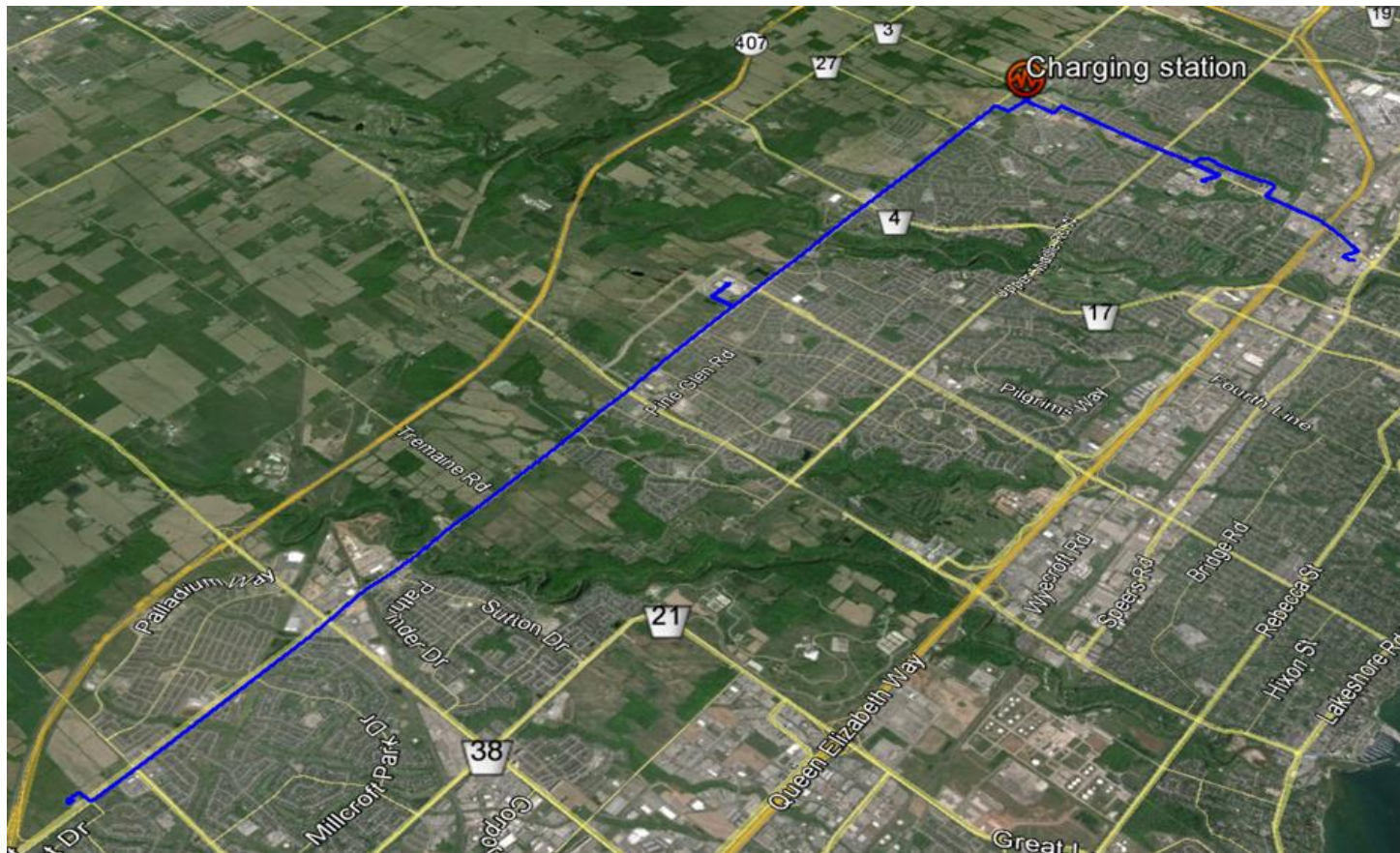
CUTRIC – Battery Electric Bus – Brampton Transit Demonstration Routes
Service Coverage & Charging Station Locations



York Region Transit: Route 55



Oakville Transit: Routes 1 & 5



St. Catharines Transit: Route 16

Route 16 – Brock - Glenridge

Outbound

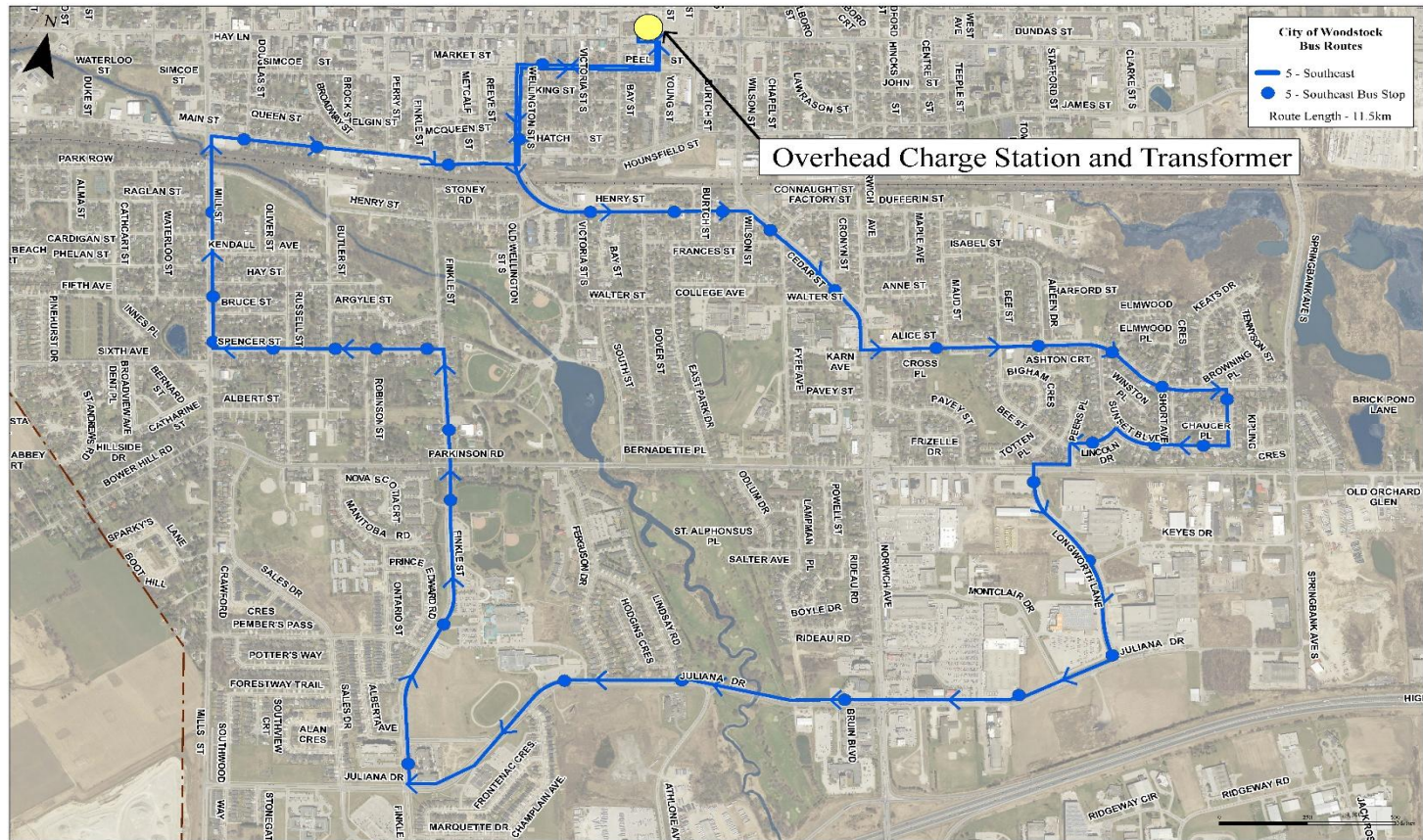


Inbound

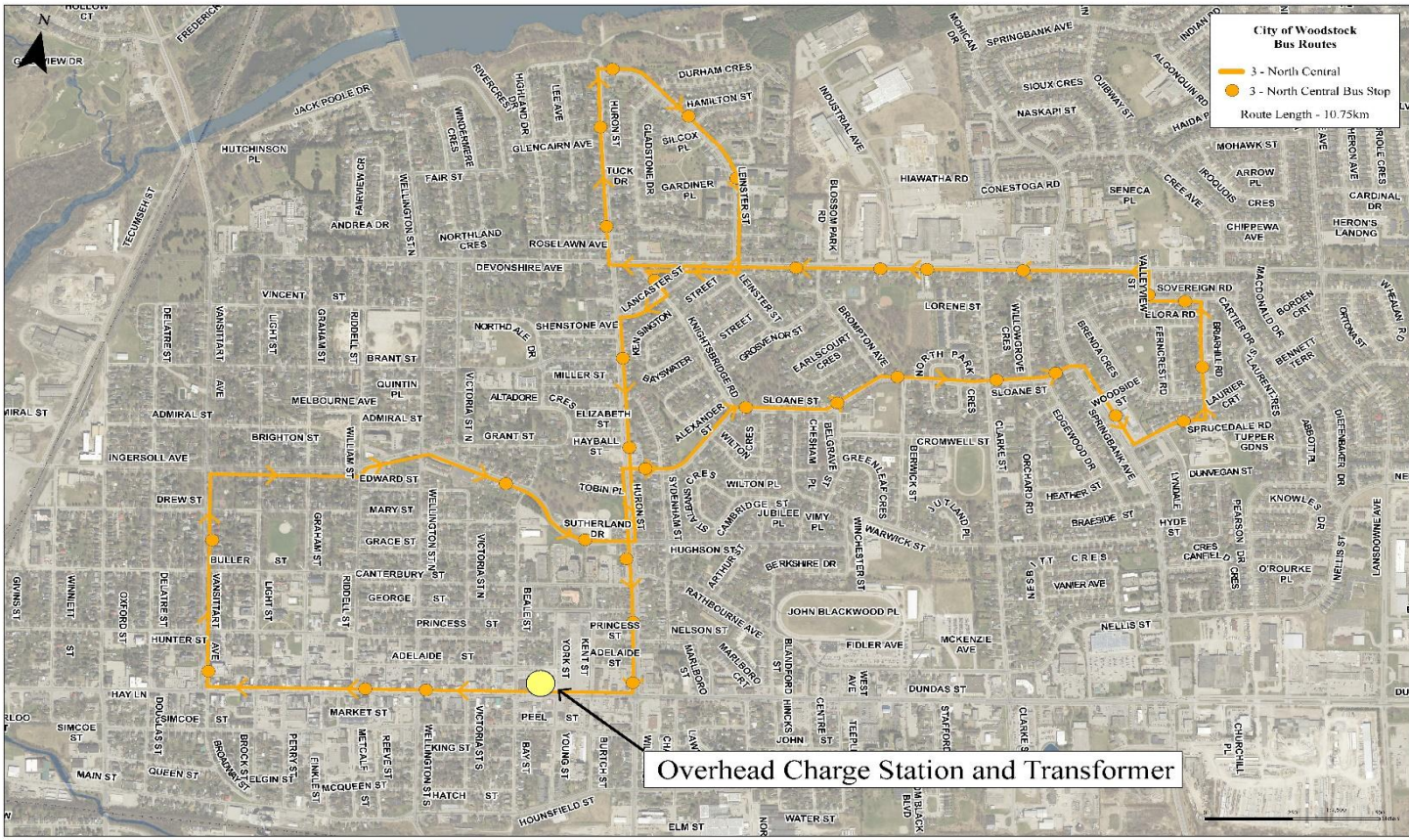


Mileage (round-trip – outbound & inbound) 13.34 km

Woodstock Transit: Routes 3 & 5



Woodstock Transit: Routes 3 & 5



Durham Region Transit: Routes 401 & 915



CUTRIC Modelling: ~12km route

Woodstock Route 3: 10.75 km + to garage

Woodstock Route 5: 11.47 km + to garage

- *Reasonable estimations for all six Woodstock Transit routes as currently designed.*
- *Potential exists for optimizing routes in Woodstock in the future*
 - *Based on demographic data (municipal) combined with real-time drive cycle and ridership data over the course of the trial period (2.5 years of data collection, Phase I)*

CUTRIC Modelling: ~12km route

1. Light-duty cycle (no stopping)
2. Medium-duty cycle (some stopping for scheduled stops and stop lights; some accessories turned on)
3. Heavy-duty cycle (significant stopping for lights, signs, pedestrians crossings, etc., and scheduled stops; full accessory load)

CUTRIC Modelling: ~12km route

Modelling assumptions

Price of diesel ~\$1.00/L

- Based on 10 years of historical price averaging
- Based on existing legislation which indicates diesel set to rise by 5% per annum starting January 1st 2017 due to Ontario's Cap and Trade carbon pricing mechanism.

Vehicle specifications

- Based on OEM data

Electricity pricing

- Based on IESO rates published online and utility modelling for >50kW systems

Bus Weight: ~20,000 Kg (40 ft. bus)

- Passenger loading: 77 passengers + 1 driver

CUTRIC Modelling Estimated Ranges: Woodstock Transit

Electricity costs as general service client:
energy + demand chargers.

Cost of electricity (IESO)

1. Monthly service charge: \$137.00 - \$200.00
2. Monthly demand charge: \$10.18/kW
3. Commodity charge: ~\$0.121/kWh

CUTRIC Modelling Estimated Ranges: ~12km route (NRC, OEM estimates, Woodstock stats)

| Usage | Light Duty (low estimate) | Heavy Duty (high estimate) |
|-------------------------------------|---------------------------|----------------------------|
| Total kWh used per route completion | 12 | 27 |
| kWh per kilometer | 1 | 2.25 |
| Δ SOC per lap (200 kWh) | 6% | 14% |
| Δ SOC per lap (76 kWh) | 16% | 36% |

| Charging | Light Duty | Heavy Duty |
|--|------------|------------|
| Endpoint charging @ 450kW @ 91% efficiency | | |
| Charging time on route per run | 2.1 mins | 4.1 mins |
| Uptime @ 450 kW | ~93% | ~86% |

CUTRIC Modelling Estimated Ranges: ~12km route (NRC, OEM estimates, Woodstock stats)

| Charging | Light Duty | Heavy Duty |
|---|-------------------|-------------------|
| Charging time on route per run | 2.1 mins | 4.1 mins |
| (1) Electricity service charge per year | \$1,644 - \$2,400 | \$1,644 - \$2,400 |
| (2) Electricity demand costs per year, per bus | ~\$7,000 | ~\$15,000 |
| (3) Electricity energy cost per year, per bus (9724 charging episodes/yr) | \$11,000 | \$25,000 |
| Total" electricity costs (estimated) per year, per bus | \$19,644 | \$41,644 |
| Diesel cost comparison (\$1/L) | \$20,240 | \$52,420 |

CUTRIC Modelling Estimated Ranges: ~12km route (NRC, OEM estimates, Woodstock stats)

| Woodstock Diesel (L) | CO2 Production | Cost @ \$12.15 per metric ton |
|--|---------------------|--|
| Based on new service schedule (August 1 st 2016) | | |
| Entire fleet (six routes) | | |
| <ul style="list-style-type: none"> • 641,784 kms per annum • 433,706 Litres diesel | | |
| 433,706 Litres diesel @ 2.68 kg CO2 / L | 1,162,333.23 kg CO2 | ~\$14,1221/year in potential carbon fees |

CUTRIC Modelling Estimated Ranges: Woodstock Transit CO2 Emissions, 2.68kg CO₂/L

| Route 3 or Route 5 | Light Duty (per bus) | Heavy Duty (per bus) |
|---------------------------------------|----------------------|----------------------|
| Fuel used per run (L) (per bus) | -2.8 | -8.2 |
| CO2 Reduction per year (kg) (per bus) | ~\$54,000 | ~\$155,000 |
| Carbon cost per year (per bus) | \$650 | \$1,900 |

Potential battery refurbishment comparison/maintenance

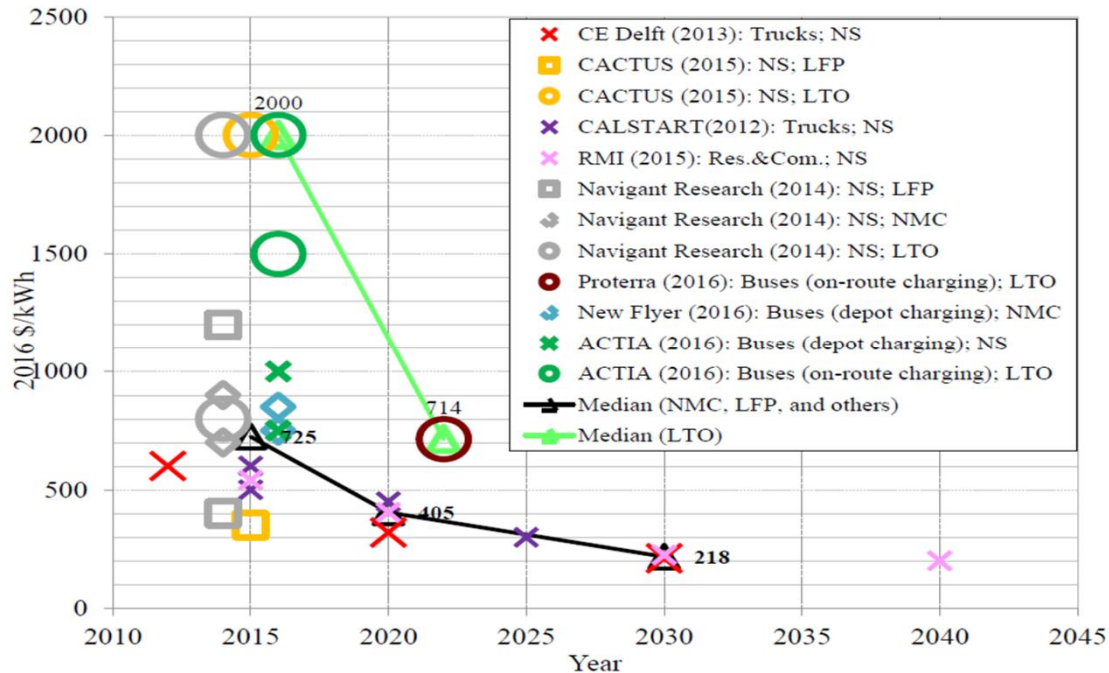
2016: \$400/kWh to \$2000/kWh (in packs, not cells)

| Nova Bus | | New Flyer | |
|---|---------------|--|---------------|
| <ul style="list-style-type: none"> • @ 7 yr time period estimated • Estimated 75% of battery life left at 7 years • 76 kWh battery • ~3 to 5 minute charge (kW) | | <ul style="list-style-type: none"> • @ 12 yr time period estimated • Estimated 80% of battery life left at 12 years • 200 kWh battery • ~5 to 7 minute charge (450 kW) | |
| Assumption \$400 kWh | \$30,400/pack | Assumption \$400 kWh | \$80,000/pack |

Advanced Clean Transit Battery Cost for Heavy-Duty Electric Vehicles (Discussion Draft) Revised August 22, 2016, California Air Resources Board

Potential battery refurbishment comparison

Figure 4: Battery Cost Estimates and Projections from Different Sources



Sources: CE Delft, 2013; CACTUS, 2015; CALSTART, 2012; RMI, 2015; Navigant Research, 2014; Proterra, 2016; New Flyer, 2016; ACTIA, 2016

CUTRIC Modelling Estimated Ranges: ~12km route (NRC, OEM estimates, Woodstock stats)

| Description of Cost (2 e-buses) | Light Duty | Heavy Duty |
|--|-------------------------------|----------------------------|
| Charging station (\$500,000K) per year (over 20 year lifecycle) | \$25,000 | \$25,000 |
| E-Bus" premium over diesel vehicle per year (over a 20 year lifecycle) | \$25,000 | \$25,000 |
| Total" electricity costs (estimated) per year, per bus | \$19,644 | \$41,644 |
| Potential battery refurbishment (@ year 12, over 20 year lifecycle) | -\$1,520-\$4,000 | -\$1,520-\$4,000 |
| Total (per year of operation) | -\$71,164/yr- -\$73,644/yr | -\$93,164/yr- -\$95,644 |

CUTRIC Modelling Estimated Ranges: ~12km route (NRC, OEM estimates, Woodstock stats)

| Description of Cost (2 diesel buses) | Light Duty | Heavy Duty |
|---|----------------------|----------------------|
| Diesel bus maintenance (7 yrs. old) <ul style="list-style-type: none"> • Parts and supplies • Oil costs | ~\$24,000 Unknown | ~\$66,000 Unknown |
| Engine & thermodynamic system refurbishment (\$100,000 @ year 12 to extend life to 20 years) <i>[*Not including oil]</i> | ~\$5,000 | ~\$5,000 |
| Diesel fuel costs (\$1/L) <i>[*Not including necessary \$ increase due to Cap and Trade in Ontario]</i> | ~\$20,245 | ~\$52,500 |
| Carbon pricing (potential) (\$12.15 per metric ton CO2) | \$650 | \$1,900 |
| Total (per year of operation) | ~\$49,895 | ~\$125,400 |

NRC Data Collection, Analysis & Project Management (2016-2019)



NRC's proposed contributions to CUTRIC electric bus project:

1. System integration
 - Modeling, simulation and optimization of charging station locations and route selection.
2. Project management
 - Development and execution of project management plan to ensure delivery of stated objectives.
3. Performance monitoring and reporting
 - Data collection, analysis and reporting to guide future phases of transit system electrification.

Phase II (2019-2021) & Phase III (2021-2023)

Phase II (2019-2021) [Earlier start is possible]

- Doubling the number of e-buses on existing (additional 20-27 e-buses) in existing (5) trial transit routes and LDC electricity jurisdictions.
- Doubling of the number of transit systems and utilities involved with a minimum of 4 e-buses per system across Ontario (e.g. Kingston Transit/Kingston Utilities, Belleville, Thunder Bay Transit, etc).
- Integrating BC Transit/BC Hydro/UBC as a British Columbia satellite trial location using similar/same metrics with BC government support.
- Integration of at least two community energy storage devices for local electric bus charging, peak shaving, renewable/intermittent daytime consumption optimization.

Phase II (2019-2021) & Phase III (2021-2023)

Phase III (2021-2023) [Earlier start is possible]

- Doubling the number of e-buses on existing (additional 20-27 e-buses) in existing (10) trial transit routes and LDC electricity jurisdictions.
- Doubling of the number of transit systems and utilities involved with a minimum of 4 e-buses across Ontario.
- Integrating Winnipeg Transit/Manitoba Hydro/University of Manitoba as a satellite trial location using similar/same metrics with Manitoba government support.
- Amelioration of “smart enabled” controls for vehicle-to-grid “state of charge” (SOC), vehicle-to-infrastructure “state of health” (SOH), and grid-to-vehicle GHG optimization communications.



Pan-Ontario Electric Bus Demonstration & Integration Trial Phase I

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