OCS-free Light Rail Vehicle Technology

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metro ligero
118
MTA
1 LA TRINIDAD
tranvia
5.5m
55 Bordet Station
3005
早稲田
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Porte d'Ivry
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LYNX

Light Rail Vehicle – LRV

Historically the application of the LRV to meet various operating environments was been achieved through a set of design criteria during initial planning such as;

- Vehicle Configuration - 70% or100% low floor
- Capacity- Total # passenger seats and standees
- Length – 20m to 32 m (65.6 to 104.9 ft)
- Width - 2.4 m or 2.65m (7.8 to 8.7 ft)
- Speed – 26 to 66 mph most common
- Minimum turning radius- 18m to 25m (59 to 82 ft)

Today the ability to provide an OCS-free LRV has resulted with **another new design choice** to be considered.

OCS – free Design Criteria Available

1. **On-Board**

   Storage Systems
   - Battery
   - Capacitors
     - Combination

   Create Energy
   - Flywheel
   - Generator
     - Diesel
     - Fuel cell

2. **Embedded Third Rail**
   - Electronic
   - Mechanical
   - Inductive

Overhead Contact System

OCS – (IEEE definition)

That part of the traction power system comprising the overhead conductors (or single contact wire), aerial feeders, OCS supports, foundations, balanceweights and other equipment and assemblies, that delivers electrical power to non-self powered electric vehicles.

Bilbao, Spain LRV

OCS versus OCS-free

With modern LRVs, the power distribution system provides Direct Current (DC) to the vehicle's power conversion equipment which, in turn, supplies Variable Voltage Variable Frequency (VVVF) power to the traction motors.

LRVs use Alternating Current (AC) as the power source, the AC power feeds a transformer and a DC link converts the AC power to DC power before being supplied to the traction inverter.

The major difference with OCS-free LRVs is in the equipment supplying energy to the on-board power conversion equipment.

CAF LRV Operating OCS-Free in Seville

OCS-Charged Systems

CAF ACR System

Construcciones y Auxiliar de Ferrocarriles, SA (CAF) has developed a rapid-charge, on-board energy storage system using supercapacitors, called ACR (Rapid Charge Accumulator). CAF's ACR *Freedrive system, which utilizes supercapacitors and batteries, allows the vehicles to operate OCS free for about 1.4 km. The supercapacitors are charged by the OCS at stations in 20 seconds.*

FreeDrive **Unit. Courtesy of CAF**

LRVs with on-board energy storage

- LRVs that create electrical energy

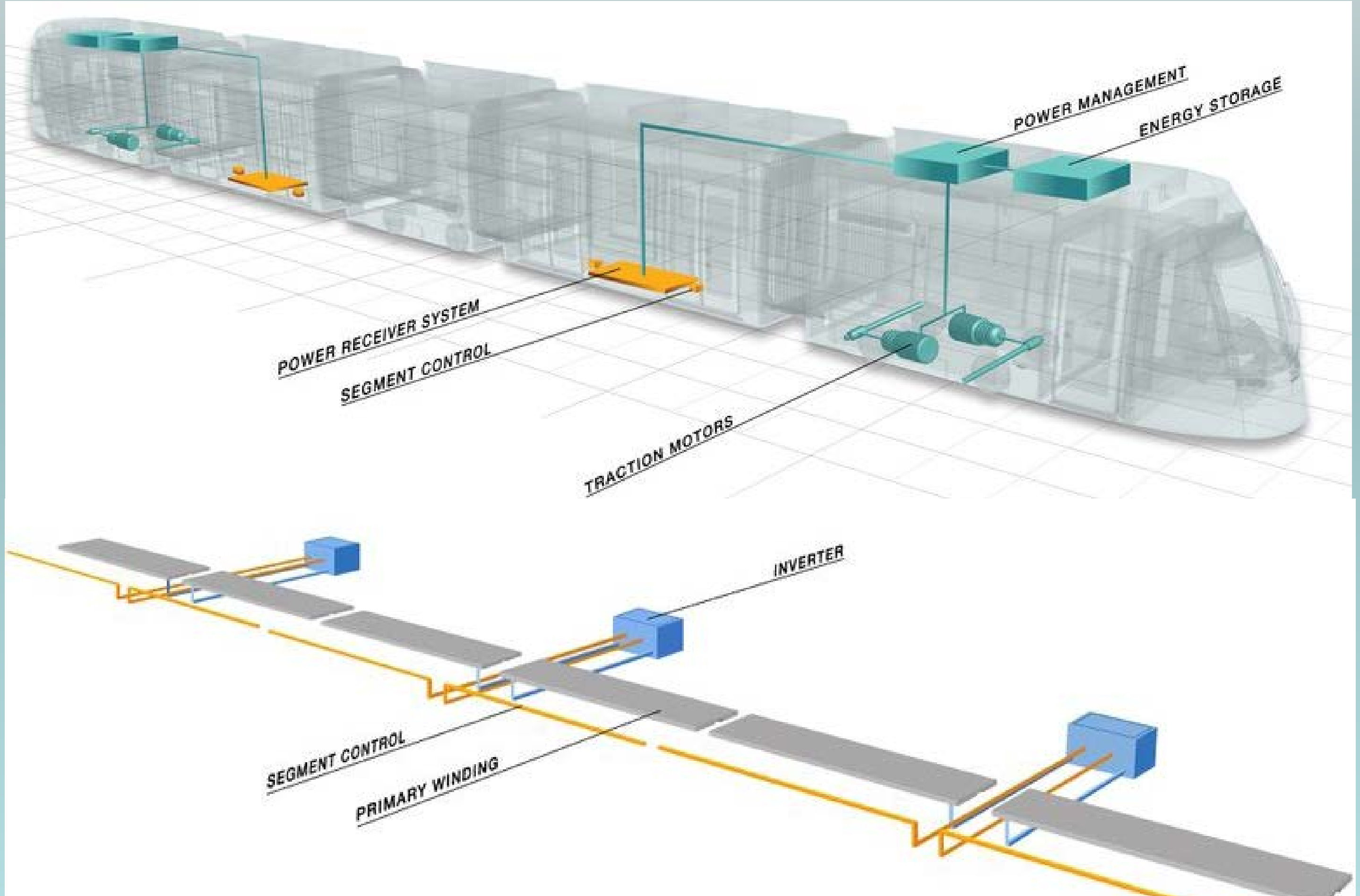
By using an onboard diesel-generator set or a fuel cell.

FEVE Hydrogen Fuel Cell Powered Vehicle. Courtesy Railway Gazette International

Citadis diesel hybrid tram-trains

LRVs with on-board energy storage

- LRVs that draw electrical energy inductively from a power source embedded in the ground.



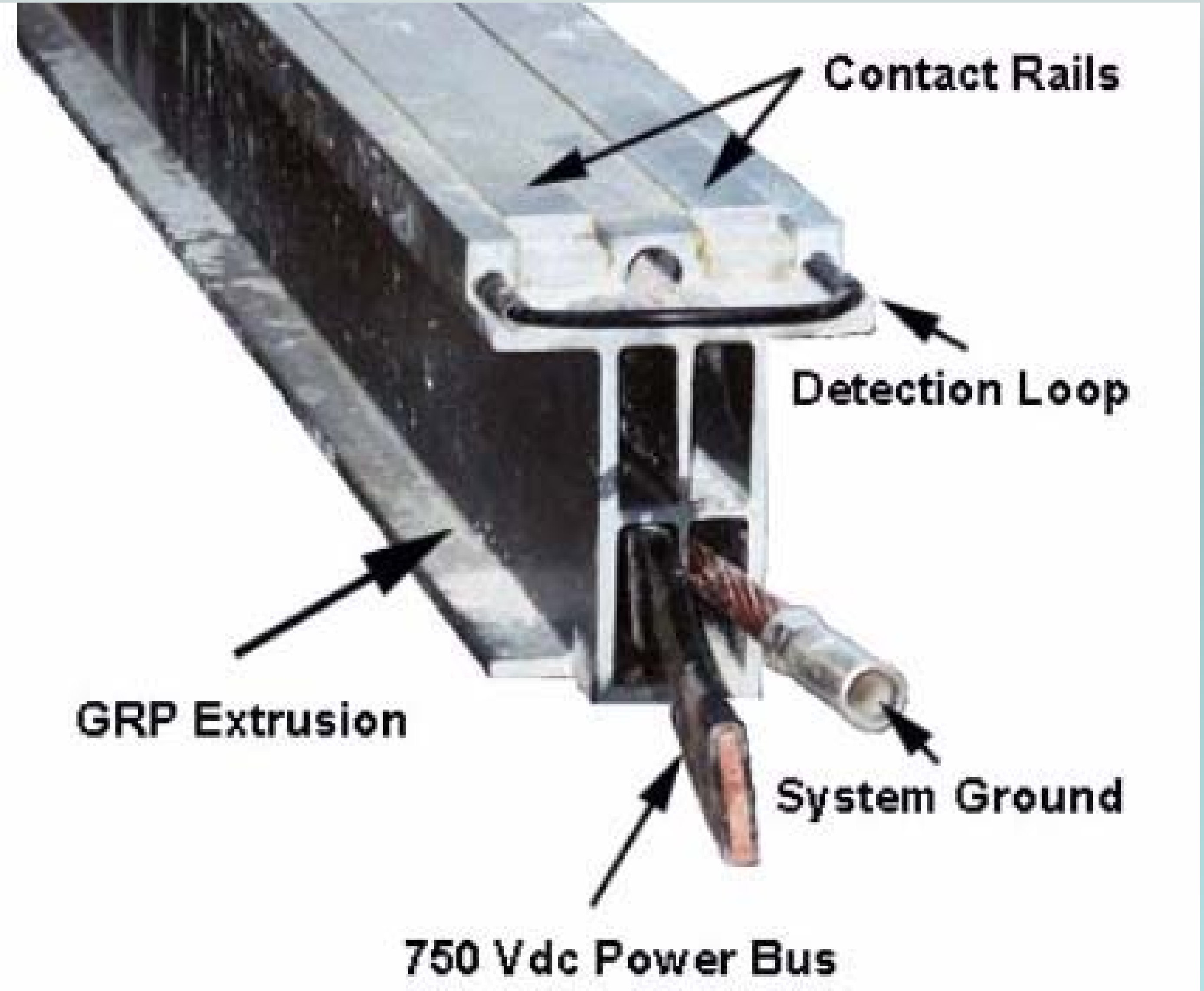
Bombardier PRIMOVE System

OCS –free technologies 2 major categories

2. **LRVs that draw electrical energy continually from a third rail embedded in the ground.**

- Electronically-Activated Third Rail - The Alstom APS (alimentation par le soleil – ground level power supply) system consists of short segments of conductor rail separated by insulated segments that are installed between the running rails along the length of the track.
- Mechanically-Activated Third Rail - The Ansaldo TramWave system consists of short segments of conductor rail installed between the running rails along the length of the track, each segment being individually connected to the electrical power supply.

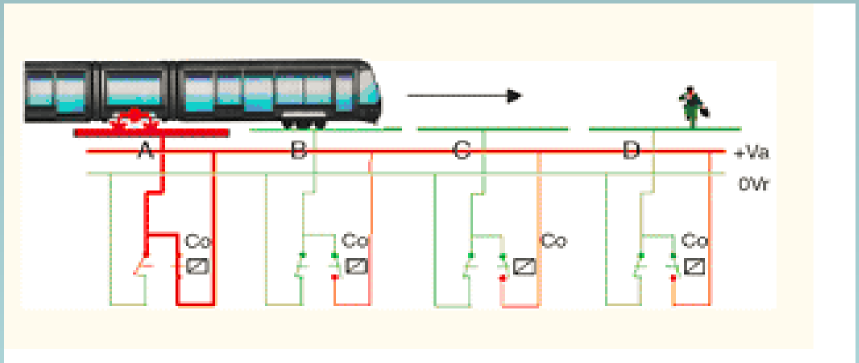
Embedded Third rail



EMBEDDED THIRD RAIL

Electronically-Activated Third Rail -

Currently solely represented by Alstom's APS system, and by the Alstom Citadis LRVs. The third rail system consists of short segments of conductor rail separated by insulated segments installed between the running rails. Each conductor rail is surrounded by a loop embedded in the track bed, and the loop receives a coded signal from the vehicle for power to be fed to the conductor rail from a "power box" embedded under the track. The conductor rail is only ever live when it is covered by the vehicle.



Live Third Rail Only Under the Vehicle. Courtesy of Alstom

Alstom Citadis Tram in Bordeaux. Photograph Courtesy of Peter Gugerell

EMBEDDED THIRD RAIL

Mechanically-Activated Third Rail -

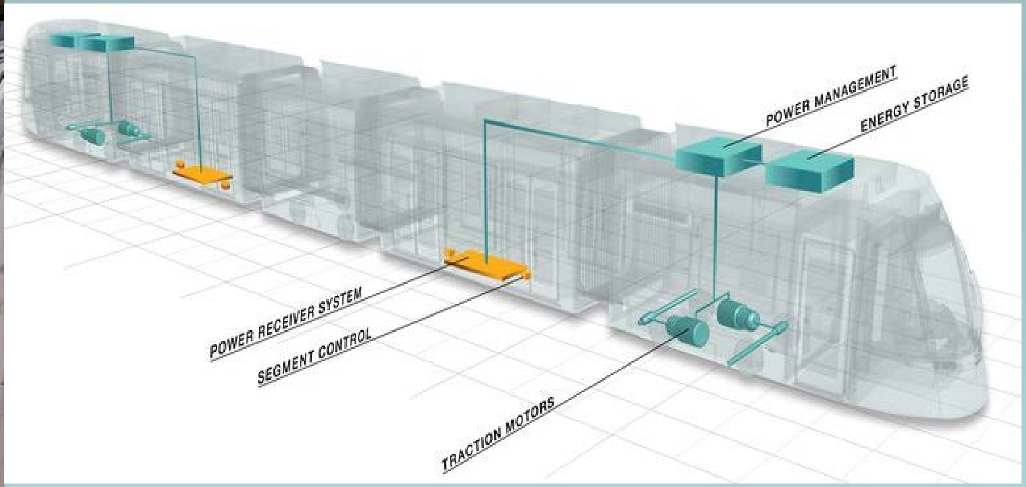
The Ansaldo *TramWave system functions similarly to the Alstom APS system, but operates on a mechanical rather than an electronic sectioning system. Powerful electro magnets on the vehicle lift a flexible conductor strip into contact with the lower surface of a live buss.*

Ansaldo TramWave Current Collector Shoe. Courtesy of Ansaldo STS

Ansaldo TramWave Third Rail Installation. Courtesy of Ansaldo STS

Inductively-Activated Third Rail

PRIMOVE is a contactless energy transfer technology developed by Bombardier. In 2010, Bombardier installed a demonstration PRIMOVE system for LRVs on an 800 m section of Line 3 to the Augsburg trade fair center.



Bombardier Primove System. Courtesy of Bombardier

Flywheel Energy Storage Systems

Since 2005, Alstom has been testing a Citadis LRV in Rotterdam with a CCM (Centre for Concepts in Mechatronics) flywheel system. Using the flywheel alone, the vehicle is capable of traveling for 2 km at speeds up to 50 km/h.

CCM Flywheel Package. Courtesy of CCM

CCM flywheel technology is currently being used in the development of a hybrid traction system as part of the ULEV-TAP 2 (Ultra Low Emission Vehicle Transport Advanced Propulsion) project sponsored by the European Commission. The system will be installed on a Siemens Avanto tram-train. The flywheel is designed to provide an output of 300 kW.

LRV with on board energy storage

OCS-Charged Systems -

LRVs draw electrical energy from an OCS at specific locations, such as when stopped at stations, to recharge the on-board energy storage system used to propel the vehicle. OCS-free LRVs frequently also incorporate energy storage equipment to receive and convert braking energy to be, in turn, used to propel the vehicle, thus saving energy.

OCS – alternative

- LRVs that draw electrical energy from an OCS at specific locations, such as when stopped at stations, to recharge the on-board energy storage system

Short Rigid OCS at Station Stops. Courtesy of CAF

Battery Storage Systems

Alstom- In Nice, France, the Alstom Citadis trams utilize battery power alone to cross the 500 m distance across the city's historical Place Masséna and Place Garibaldi squares. The roof-mounted SAFT Ni-MH batteries allow the trams to run for 1 km at 30 km/h.

Alstom Citadis Tram Crossing Place Masséna in Nice

Battery Storage Systems

Brookville Equipment Corporation

In February 2013, the Brookville Equipment Corporation of Brookville, Pennsylvania was awarded a $9.4m contract to supply two 70% low floor LRVs to DART for its downtown Union Station to Oak Cliff extension project. Brookville's Liberty Modern LRVs will utilize a battery energy storage system to power the cars OCS free over a 1.6 km section of track. The vehicles will have a maximum speed of 70 km/h.

Rendering of Brookville LRV for DART.
Courtesy of Brookville Equipment

Battery Storage Systems

Kawasaki - In 2007, Kawasaki introduced its prototype three-section low floor *SWIMO X LRV. The vehicle has a length of 15 m with a passenger boarding height of 330 mm. On battery power alone, the vehicle is capable of traveling over a distance of 10 km at a top speed of 40 km/h on a single five-minute charge.*

Kawasaki SWIMO. Courtesy of Kawasaki

In 2009, the next generation of *SWIMO was announced.*

Battery Storage Systems

Kinki Sharyo - In the United States, Kinki Sharyo has introduced its *ameriTRAM 100% low floor demonstrator LRV. Powered by its proprietary eBrid electro-hybrid Li-ion batteries, the vehicle can operate using the OCS or OCS free. The eBrid system charges the batteries and powers the auxiliary equipment when running on the OCS and also allows braking energy to be stored in the batteries. When running OCS free, eBrid uses battery power to propel the vehicle and to power the auxiliary equipment.*

Kinki Sharyo ameriTRAM. Courtesy of Kinki Sharyo

ameriTRAM is able to operate for 8 km on battery power alone and reported as fully compliant with ADA, Buy America, NFPA 130, and ASME RT-1.

Battery Storage Systems

Stadler

In 2011, a Munich Tramway S-class Stadler Variotram set a record for a battery powered tram by running 16 km on its battery, without the use of the OCS. The Li-ion battery weighed 380 kg. The test was carried out on one of four such vehicles ordered by Munich, and a further 10 vehicles have been ordered.

Diesel-Generator Systems

Alstom -Kassel, in Germany, is using 10 Alstom Regio Citadis diesel hybrid tram-trains. The vehicles have an acceleration of 1.1m/s2 and a top speed of 100 km/h.

Alstom Regio Citadis Tram-Train

However, it is to be seen whether or not this technology will increase in popularity, because the industry appears to be moving away from fossil fuel solutions.

Fuel Cells

In 2011, Spanish meter-gauge operator FEVE unveiled a prototype tram powered by two 12 kW hydrogen fuel cells that can carry up to 30 passengers at speeds up to 20 km/h. Constructed by Fenit Rail using a 14.3 m 1970s Series 3400 FEVE car. The fuel cells are supplied with hydrogen from a rack of 12 canisters. Energy produced during regenerative braking is stored in three supercapacitors or Li-ion batteries rated at 95 kW. The power conversion equipment was designed by CIDAUT.

FEVE Hydrogen Fuel Cell Powered Vehicle. Courtesy Railway Gazette International

PROS AND CONS OF THIRD RAIL AND ONBOARD ENERGY STORAGE SYSTEMS

- Based on an analysis of recent contract prices, it has been estimated that the onboard APS equipment can be expected to add between 8 to 15 % of the average selling price of LRVs over the past few years.
- Undoubtedly, the electrical power distribution system equipment on an OCS-free vehicle is more costly than that on a conventional LRV. Although little cost information is available, for the operators, any increased price of the vehicle must be balanced against the expected reduction in energy costs and any difference in maintenance and overhaul costs.

PRICE AND BUY AMERICA IMPACT

Today it is not at all apparent that any vehicle supplier or System supplier would invest in the manufacture of traction batteries in the USA. This, of course, only tends to make it more difficult for foreign suppliers to meet Buy America .requirements.

If the cost of the offshore electrical equipment cost increases the vehicle selling price by about 10%, foreign suppliers required to meet Buy America requirements must become more inventive to increase vehicle domestic content.

Interestingly though some vehicle manufacturers are committing to supply LRVs to US transit agencies that will meet Buy America requirements.

RELIABILITY

On-Board Vehicle -

On-board battery - Have the potential to be very reliable but lack to be service proven.

Supercapacitor technology, or a combination of supercapacitors and batteries, is now a fairly mature technology and it appears to have excellent reliability.

Flywheel energy storage technology is not yet sufficiently developed for LRV use, and its reliability in this environment is unknown.

Fuel cell technology is not in a sufficiently advance stage of development, and its reliability in a rail system environment is unknown.

Combustion energy technology is well proven and reliable.

RELIABILITY

Wayside Systems –

Third rail systems now appear to be a reliable technology, although it should be carefully assessed against the specific operating environment.

Induction power transfer system is also not service proven, and its reliability is unknown, although it has the potential to be very reliable.

MOVING FORWARD

Today there exists a considerable amount of technical information pertaining to OCS-free Systems for Transit Agencies to make the basic decisions such as the;

Type of System - Onboard energy storage vs. Wayside (Third rail / embedded induction power transfer) based.

Onboard energy storage – Battery, Capacitors, Flywheel, Generator, Diesel, Fuel cell

Third rail / embedded – *Electronic, mechanical activated or Inductive*

MOVING FORWARD

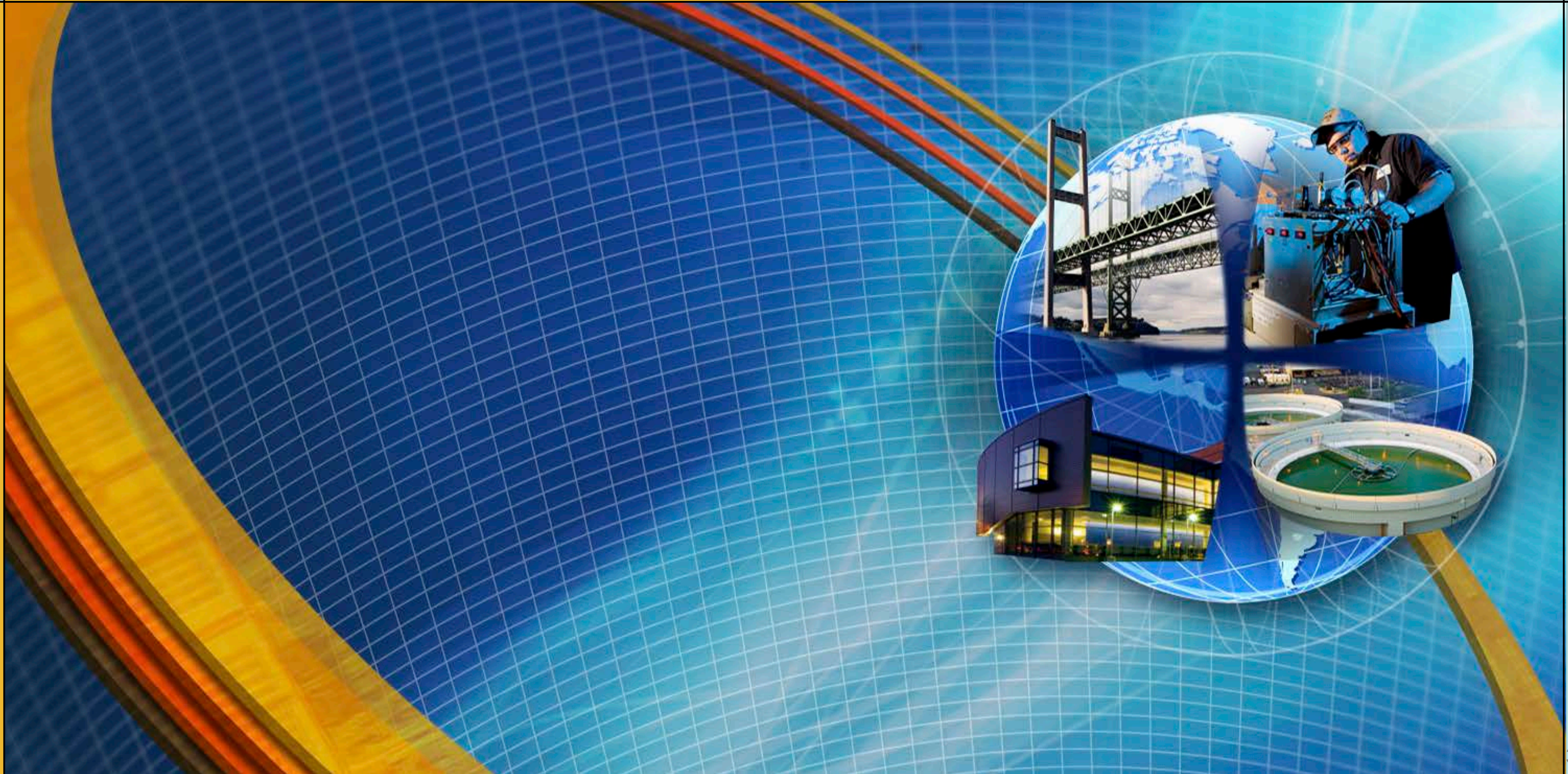
High expectations and benefits using OCS –free technology are apparent….

Decisions will need to be made with little;

- Historical reliability and maintenance data
- Total life costs or conflicting costing data differentials
- Fast moving technology improvement / gains in distance, speed, costs.

Transit Agencies must be prudent to carefully analysis their unique operations and rolling stock needs prior to committing to new technology.

Thank You !



Reference slides only

CURRENT PROPULSION TECHNOLOGY AND CONSTRAINTS

The vehicle propulsion system, that is the equipment downstream of the DC link, should be little different, if at all, to existing propulsion equipment. This is the reason that Siemens claims its Sitras equipment can easily be incorporated into older vehicles, including those of other manufacturers. Accordingly, whichever OCS-free technology is chosen, this should not affect the cost of the propulsion system.

- OCS-free technology directly affects the vehicle’s electrical power distribution system up to the DC link, however.

Flywheel Energy Storage Systems

Alstom and Williams Hybrid Power have joined forces to apply the Williams technology on Citadis LRVs, which will include testing the Williams combined magnetically loaded composite (MLC) flywheel, which is expected to provide fuel savings of about 15%.

Williams Hybrid Power Flywheel. Courtesy of Williams

Flywheel technology is far from mature, but it would appear to be a viable energy storage option in the not-too-distant future.

OCS-Charged Systems

Supercapacitor Energy Storage

Alstom

In July 2009, under the STEEM (Système de Tramway à Efficacité Energétique Maximisée) research and development project, Alstom and Paris transportation agency RATP carried out a trial of a supercapacitor-based on-board energy storage system on a low floor Citadis tram. The supercapacitors stored regenerated braking energy, but could also be recharged from the OCS in about 20 seconds during station stops. The system allows OCS free operation for about 400 m at 30 km/h. Energy savings on the order of 30% are estimated.

Diesel-Generator Systems

Vossloh- In 2012, Vossloh won an order to supply eight electro-diesel tram-trains for the network under development around Chemnitz, Germany. The tram-trains will operate from the existing network's 600 Vdc and 750 Vdc OCS, switching to diesel mode along regional lines. The vehicles have a top speed of 100 km/h.

Battery Storage Systems

Bombardier/CSR Nanjing Puzhen Rolling Stock Company

In April 2013, it was announced that Nanjing Puzhen Rolling Stock Company is to supply 15 OCS-free LRVs to Nanjing, the vehicles being designed and built under a technology licensing agreement with Bombardier.

The 100% low-floor vehicles will be based on Bombardier’s Flexity 2 platform and will be 32 m long and 2.650 m wide. Each vehicle will be equipped with two *Primove Li-ion batteries, which will be recharged using the OCS at station stops and the terminal.*

OCS-Charged Systems

Siemens Sitras MES and HES Systems

The Siemens Sitras MES (mobile energy storage) system utilizes supercapacitors to enable braking energy to be captured, and later released to propel the vehicle. The Sitras HES (hybrid energy storage) system combines the supercapacitors with a SAFT Ni-MH traction battery to store both braking energy and power drawn from the OCS to enable OCS-free operation

Siemens Sitras Energy Storage Unit and Traction Battery
Courtesy of Siemens

OCS-Charged Systems

Bombardier MITRAC

Bombardier's *MITRAC energy saving system utilizes supercapacitors to enable braking energy to be captured, and later released to propel the vehicle. This allows energy savings, but also allows OCS-free operation.*

Courtesy of Bombardier

Between 2003 and 2007, a Bombardier GTN6 LRV operated by Mannheim MVV was equipped with a *MITRAC energy saving unit and ran in normal revenue service. The MITRAC unit weighed 477 kg and had an output of 300 kW, and the trial demonstrated energy savings of up to 30%.*

OCS-Charged Systems

Siemens Sitras MES and HES Systems

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Siemens Sitras Energy Storage Unit and Traction Battery
Courtesy of Siemens

Battery Storage Systems

The use of batteries to propel rail vehicles is not new. As far back as 1958, British Rail operated a two-car train using lead acid batteries mounted on the underframes.

1958 British Rail Battery Powered Train

The trains ran successfully in revenue service for about four years, and completed over 100 miles per day at an average speed of 40 mph. The batteries were charged overnight, but received top up charges during operation.

Types of Rolling Stock

The European approach for passenger vehicles EN 12663 divides all vehicles into five structural design categories. These five categories are listed below, with an indication of the types of vehicle generally associated with each:

- Category P-I Coaches and locomotives;
- Category P-II Fixed units;
- Category P-III Underground rapid transit vehicles;
- Category P-IV Light duty metro and heavy duty trams
- Category P-V Tramway vehicles.