


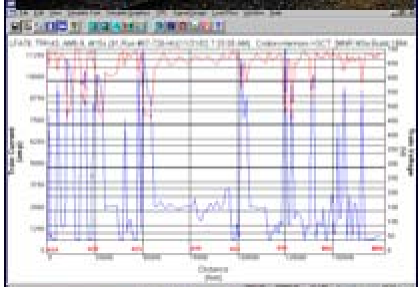


2nd International Conference on
Computer Modeling For Rail Operations

MODELING OF NEW RAILCARS AND SYSTEMS IMPACTS

Acela Express Regenerative Braking and Receptivity Field Testing and Modeling of M8 Vehicles

J Gordon Yu - SYSTRA

March 28-29, 2006
Philadelphia, USA

Acela Express Power Recording

Northeast Corridor – 3 Different Traction Power Supply Systems

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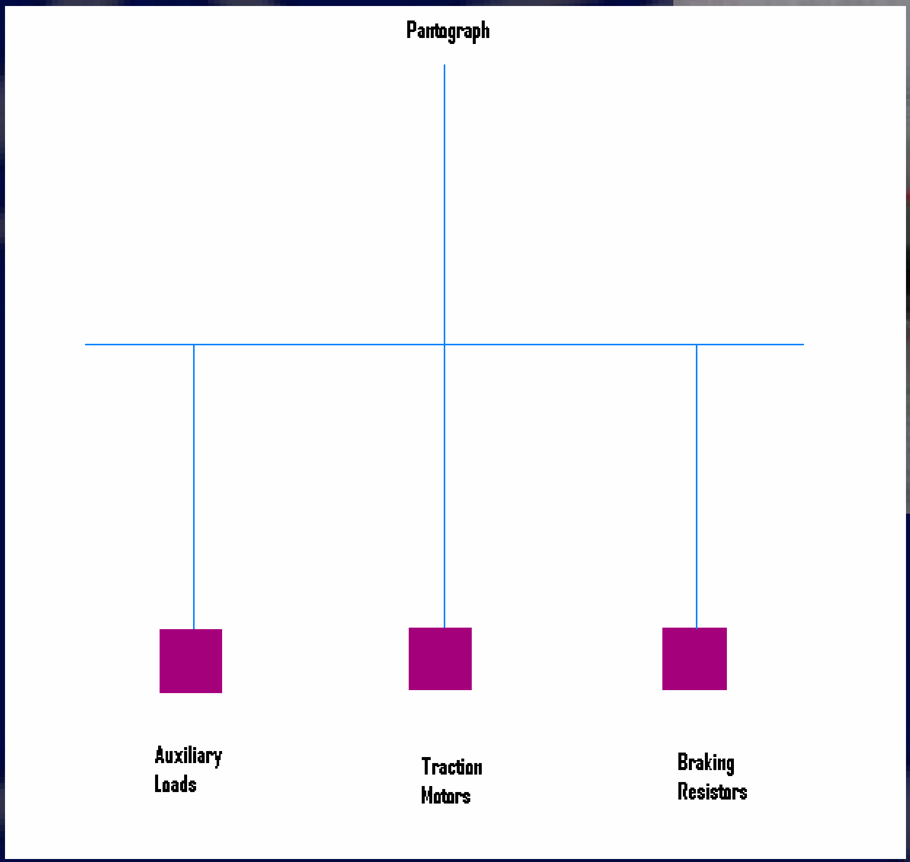
Acela Express Power Recording
Power Circuit Schematic Diagram



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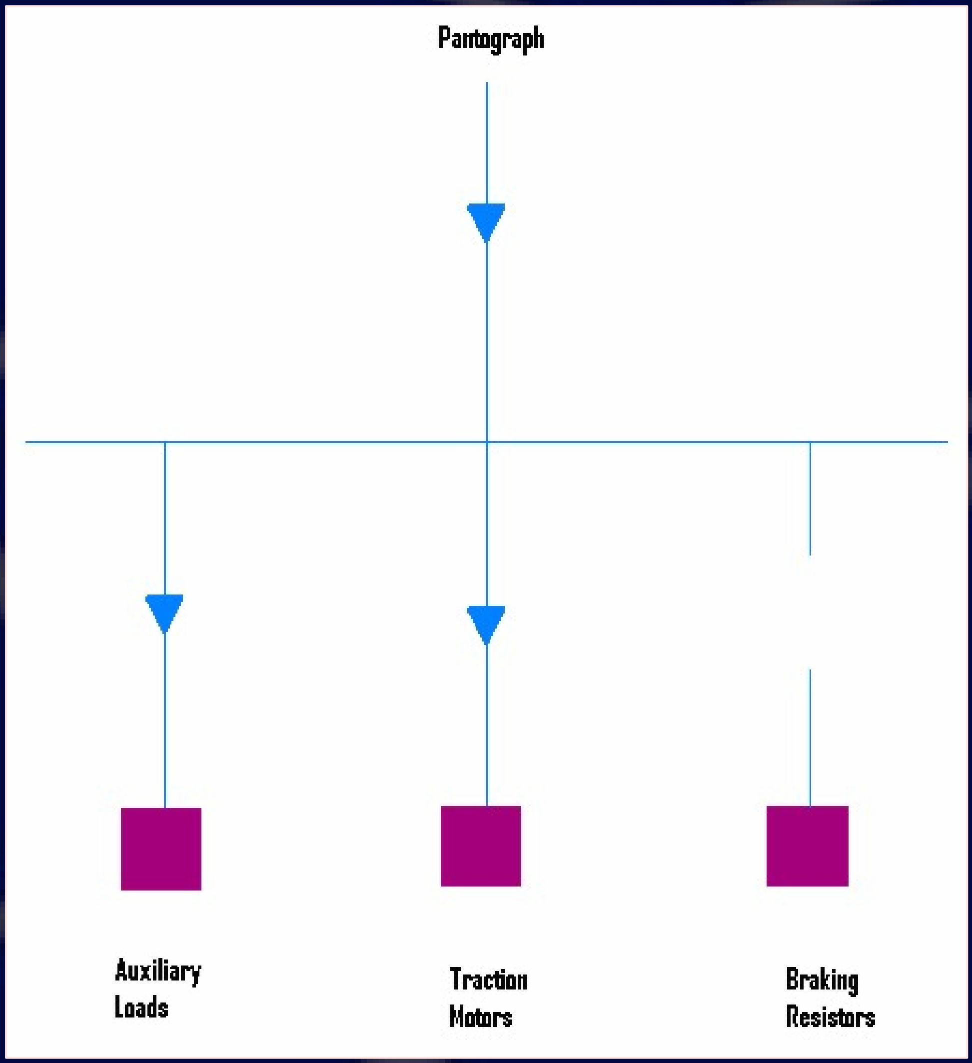
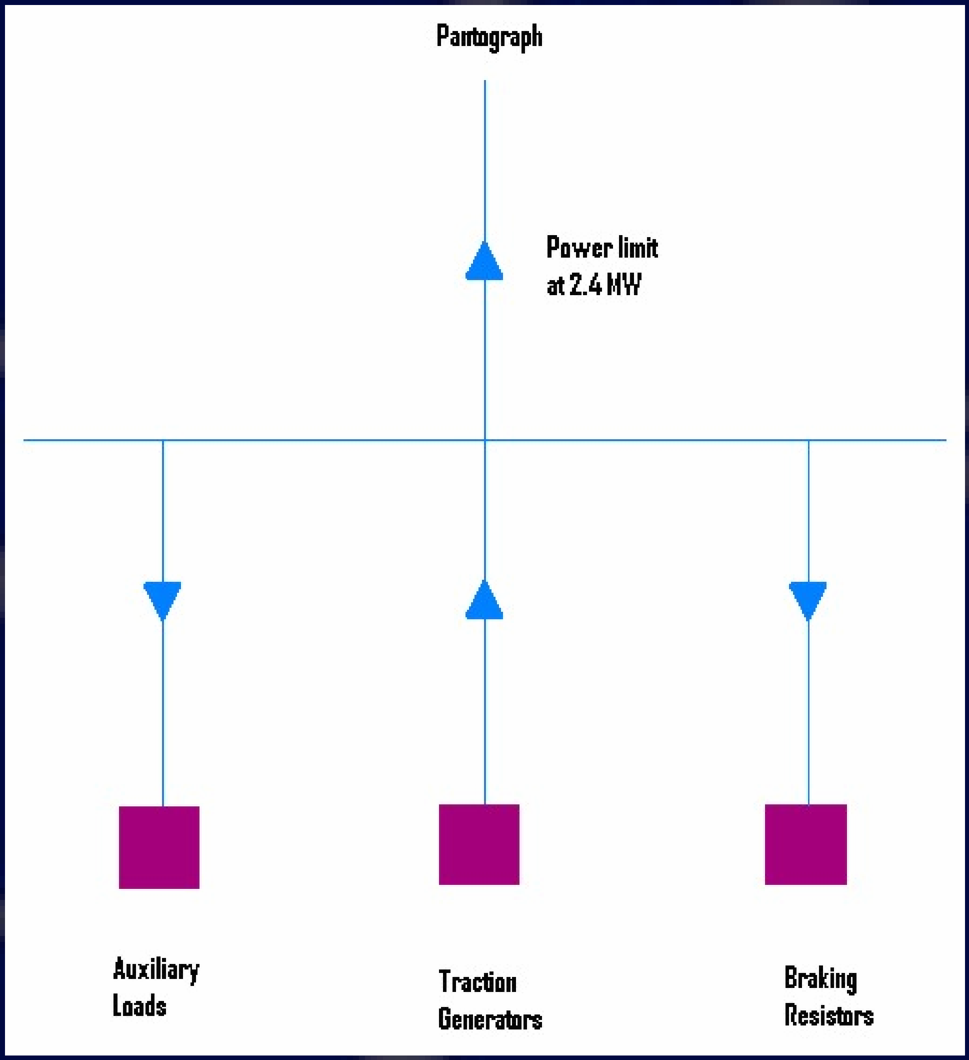
Acela Express Power Recording
Power Flow Diagram – Motoring Mode



Acela Express Power Recording
Power Flow Diagram – Regenerating Mode



Acela Express Power Recording
Objectives

- To assess how much power is fed back into the traction power system in 25Hz territory
  - How much regenerative braking energy is recovered
  - How receptive the traction power system is in absorbing the regenerated power and putting it to productive use

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Acela Express Power Recording
Test Conditions

- Two different train sets need to be recorded separately so that the results are representative of the full fleet
  - Train set #4
  - Train set #17
- The test train sets must be in normal service conditions
  - At least two full-week's data should be recorded from each train set

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Acela Express Power Recording
Recorded Parameters

Channel #	Parameters
1	Acceleration- mph/sec
2	HV Pantograph Voltage - Volts rms
3	HV Primary Current- Amps rms
4	Supply Frequency - Hz
5	HV Reactive Power - kVAr
6	Speed- mph
7	HV Real Power - kW

- Each channel needs a transducer to convert the desired parameter into voltage signal so that it can be recorded by the recorder.
- All connections must be non-invasive. They must not interfere with normal train operations.
- Current and power transducers need to be calibrated to 25 Hz to ensure accuracy.

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Acela Express Power Recording

Train Set #4 – Metering Equipment Being Installed In High Speed Shop

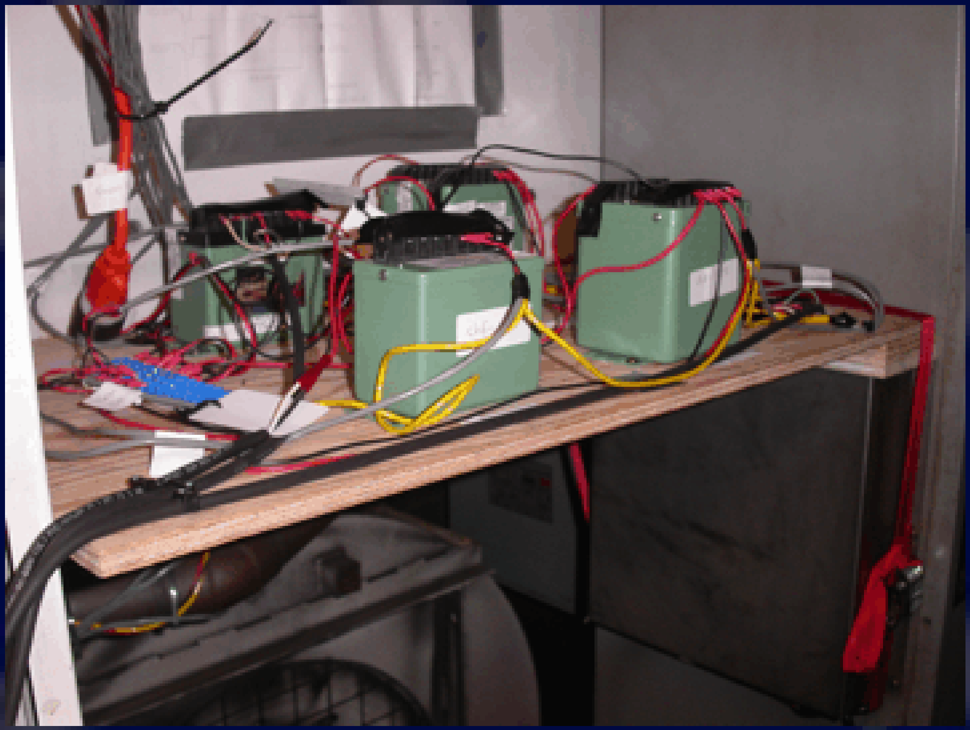
Acela Express Power Recording
Train Set #17 – Metering Equipment Being Installed Outside High Speed Shop

Acela Express Power Recording
Inside Of Power Car – Finding Spaces For Data Acquisition Equipment

Acela Express Power Recording

Inside Of Power Car – Installed Data Acquisition Equipment

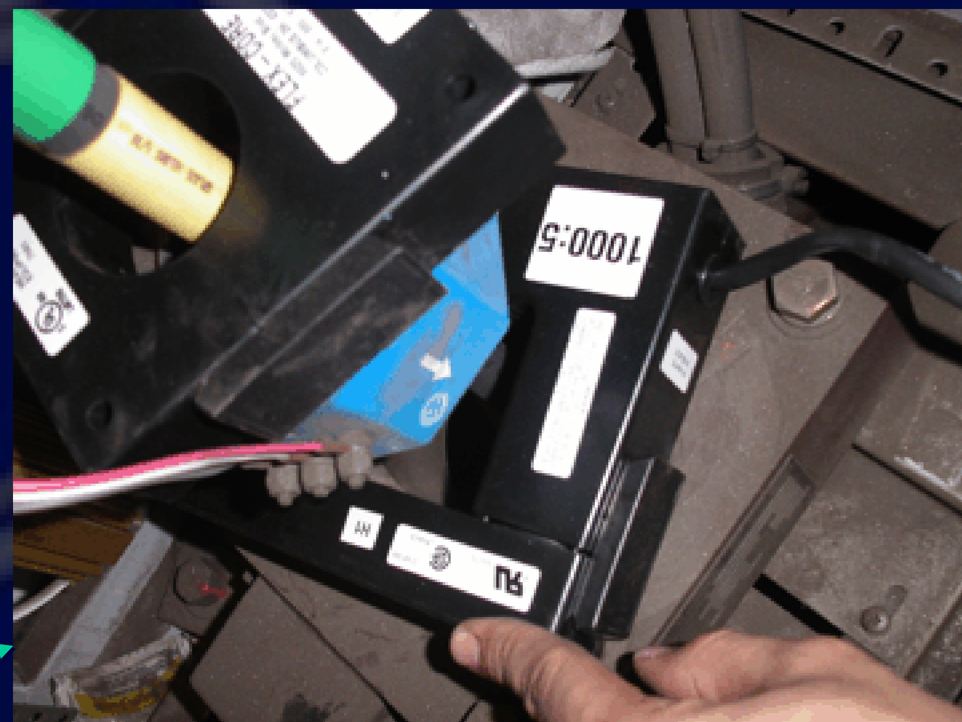
UPS & Recorder



Main Transducers

Acela Express Power Recording
Inside Of Power Car – Installed Data Acquisition Equipment

Wire Runs Between Transducers and Recorder Inside the Power Car



Hall-Effect Current Transducers Clamped on Return Conductor

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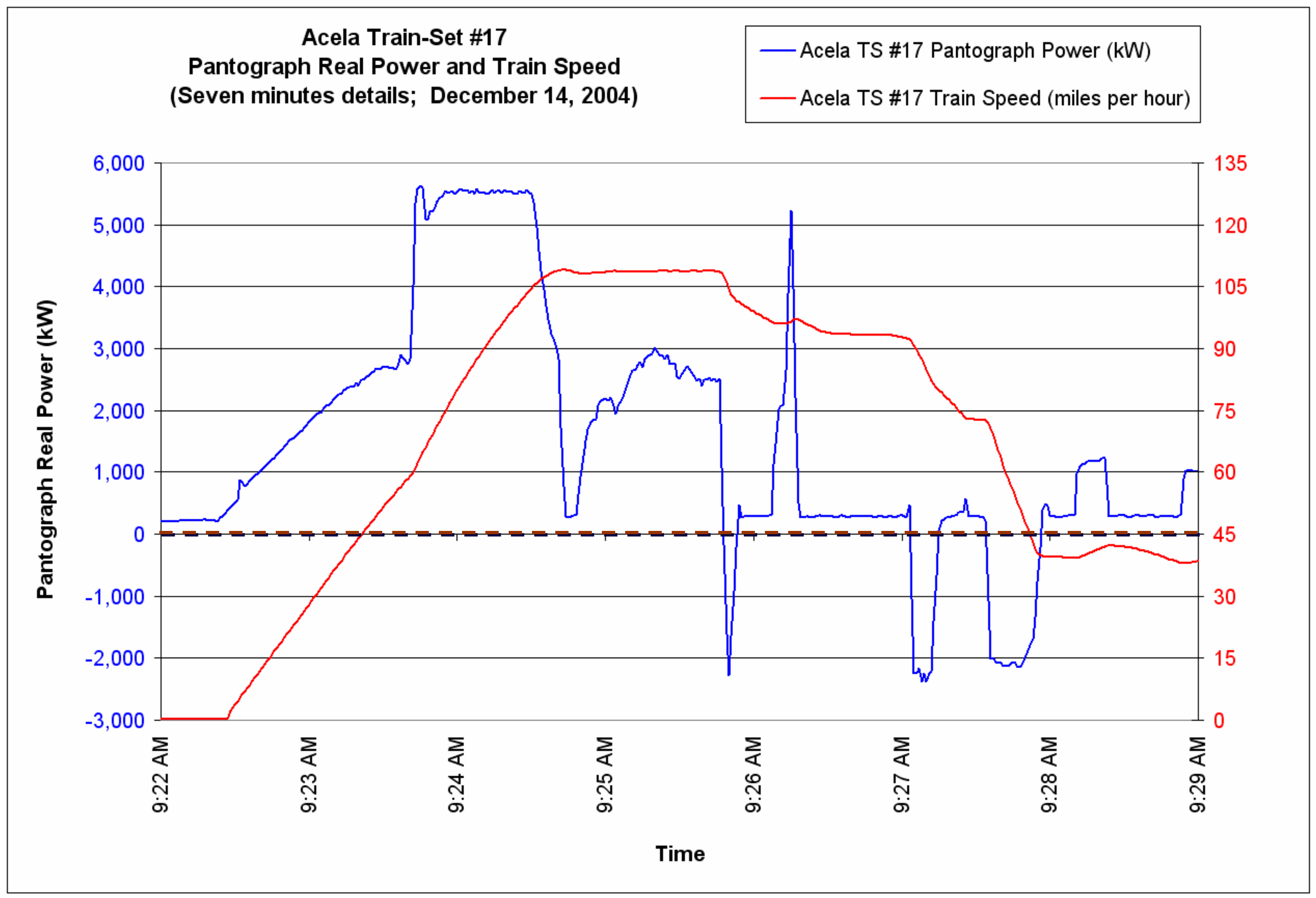
Acela Express Power Data Analysis
11 kV, 25 Hz Territory – Recorded Power and Train Speed



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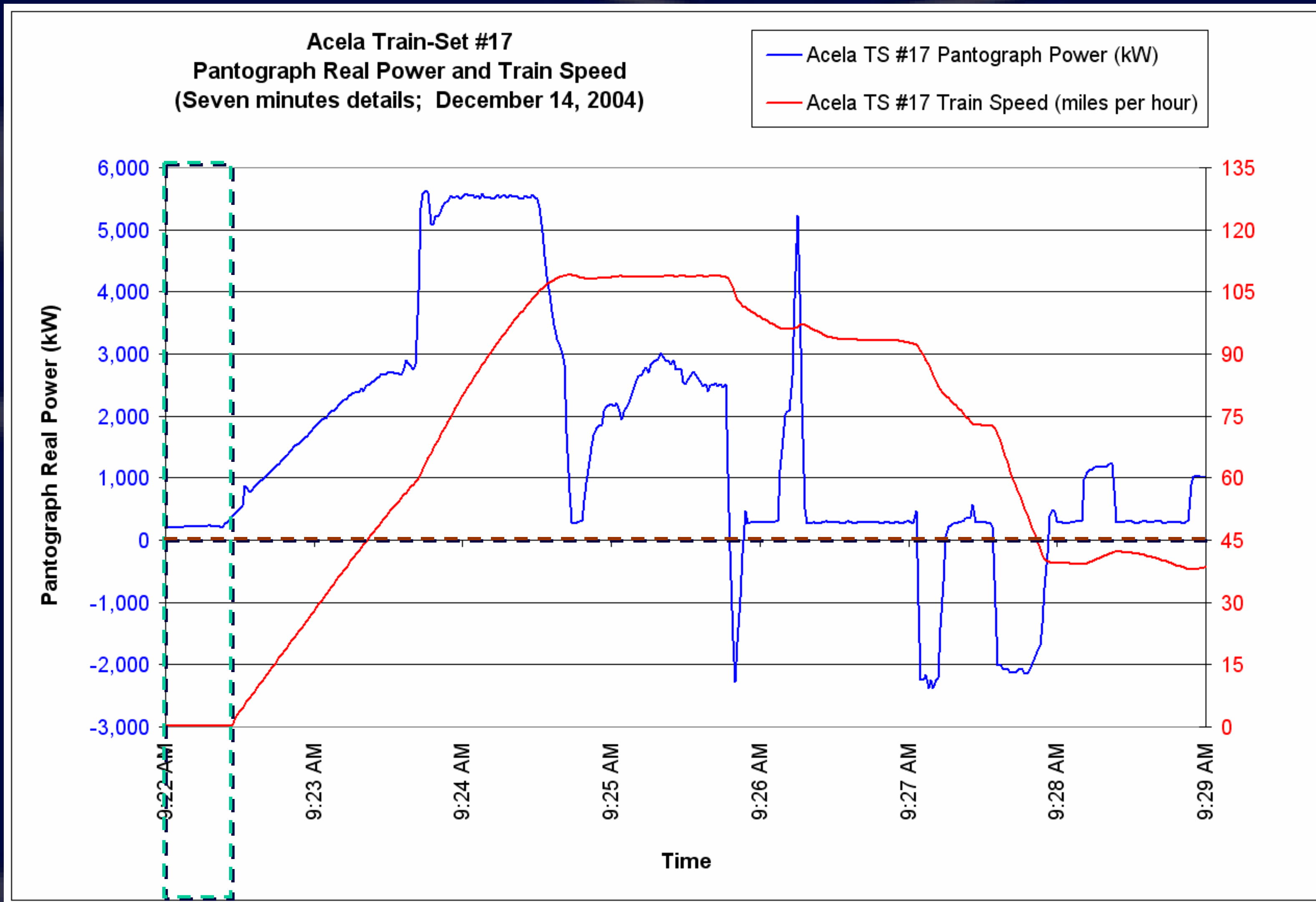
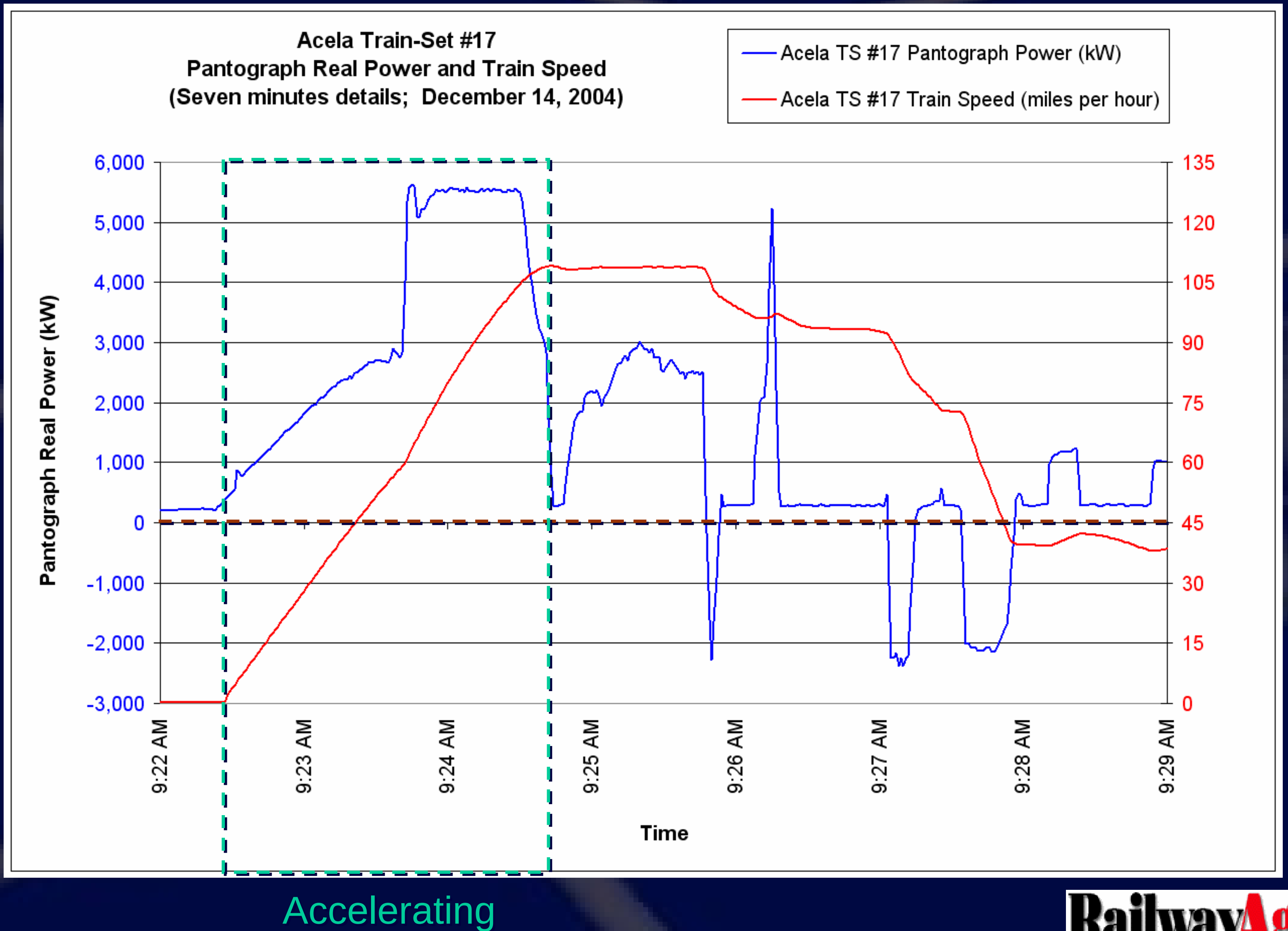
Acela Express Power Data Analysis
11 kV, 25 Hz Territory – Recorded Power and Train Speed



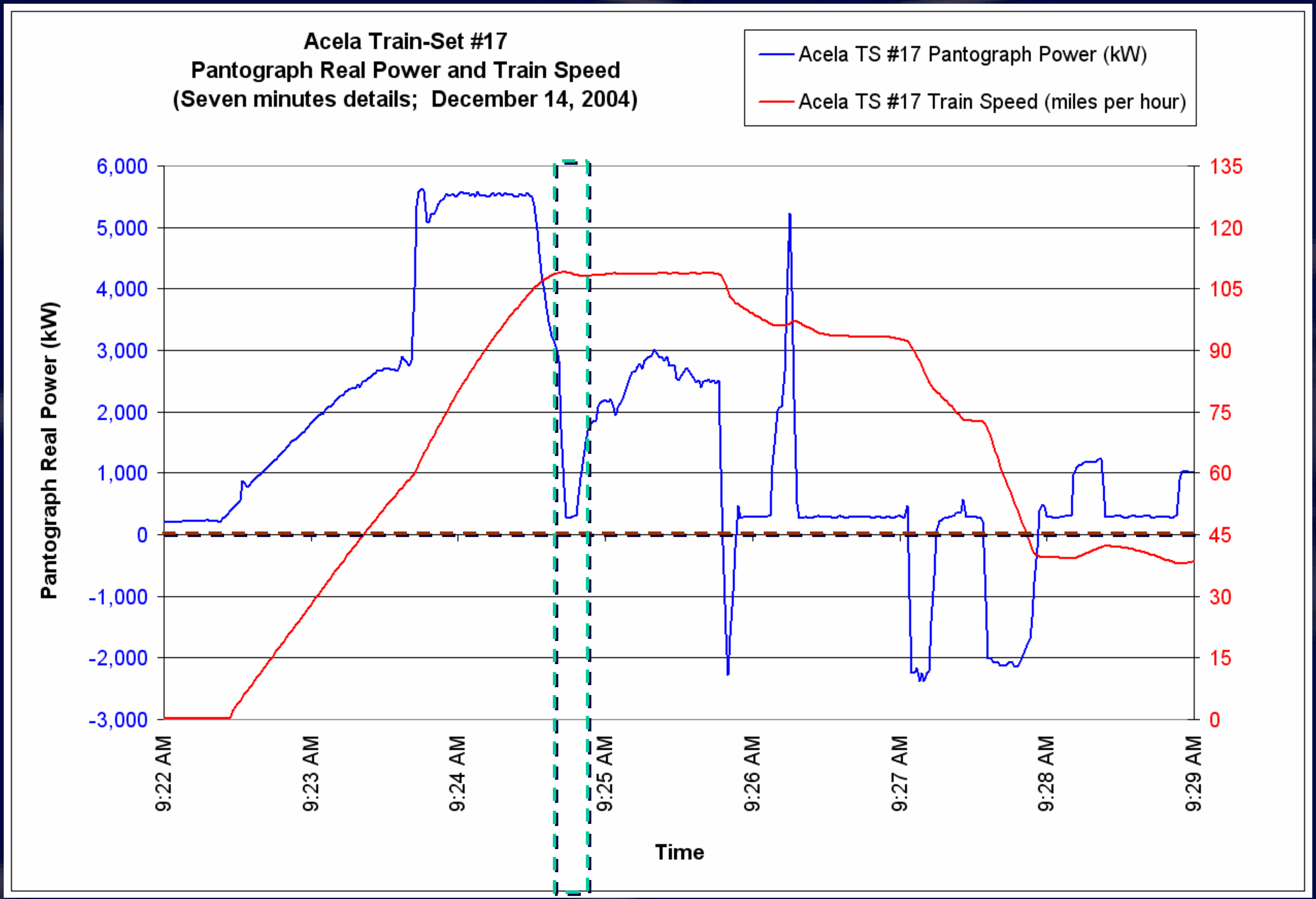
Stopped

Acela Express Power Data Analysis

11 kV, 25 Hz Territory – Recorded Power and Train Speed

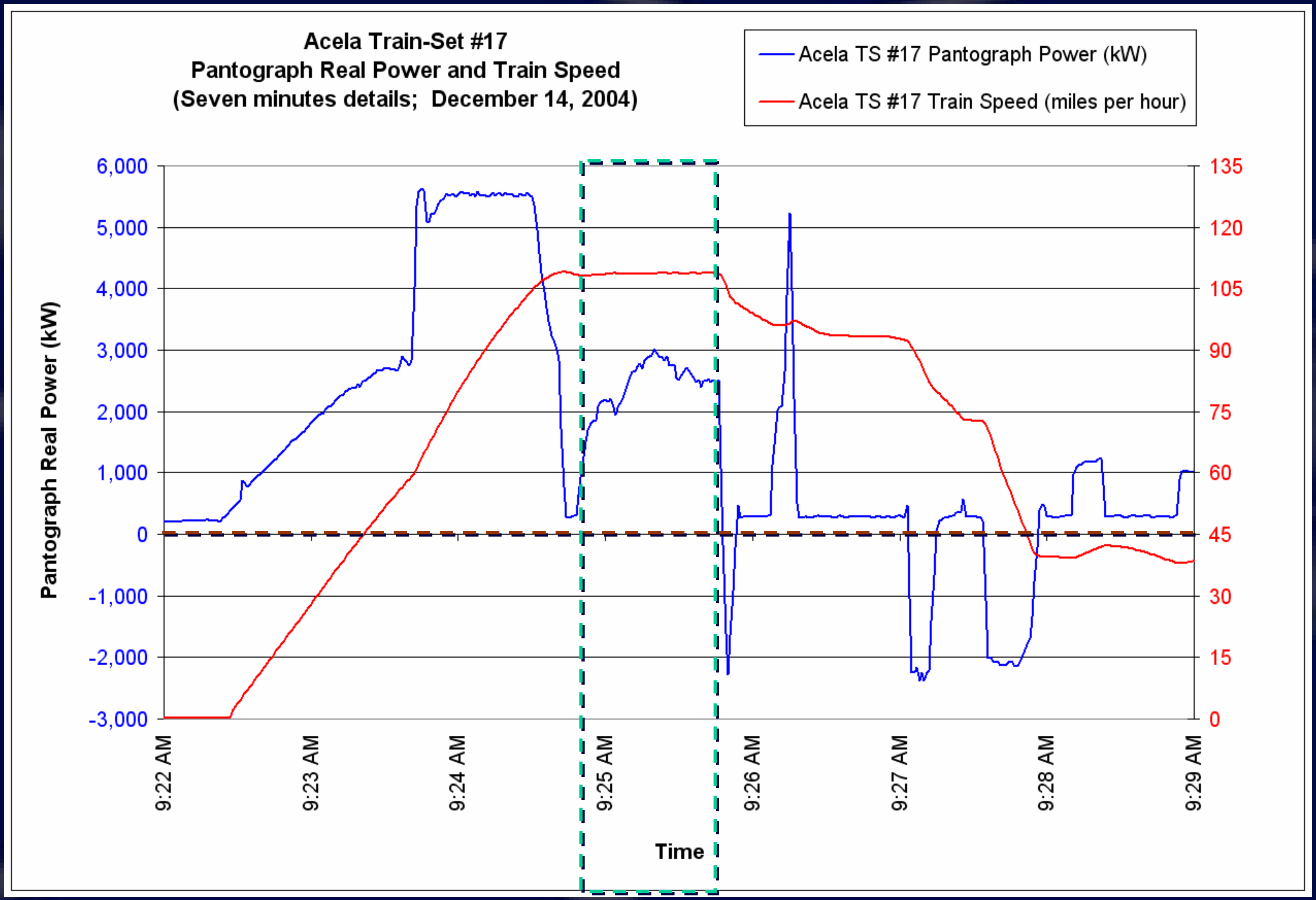


Acela Express Power Data Analysis
11 kV, 25 Hz Territory – Recorded Power and Train Speed



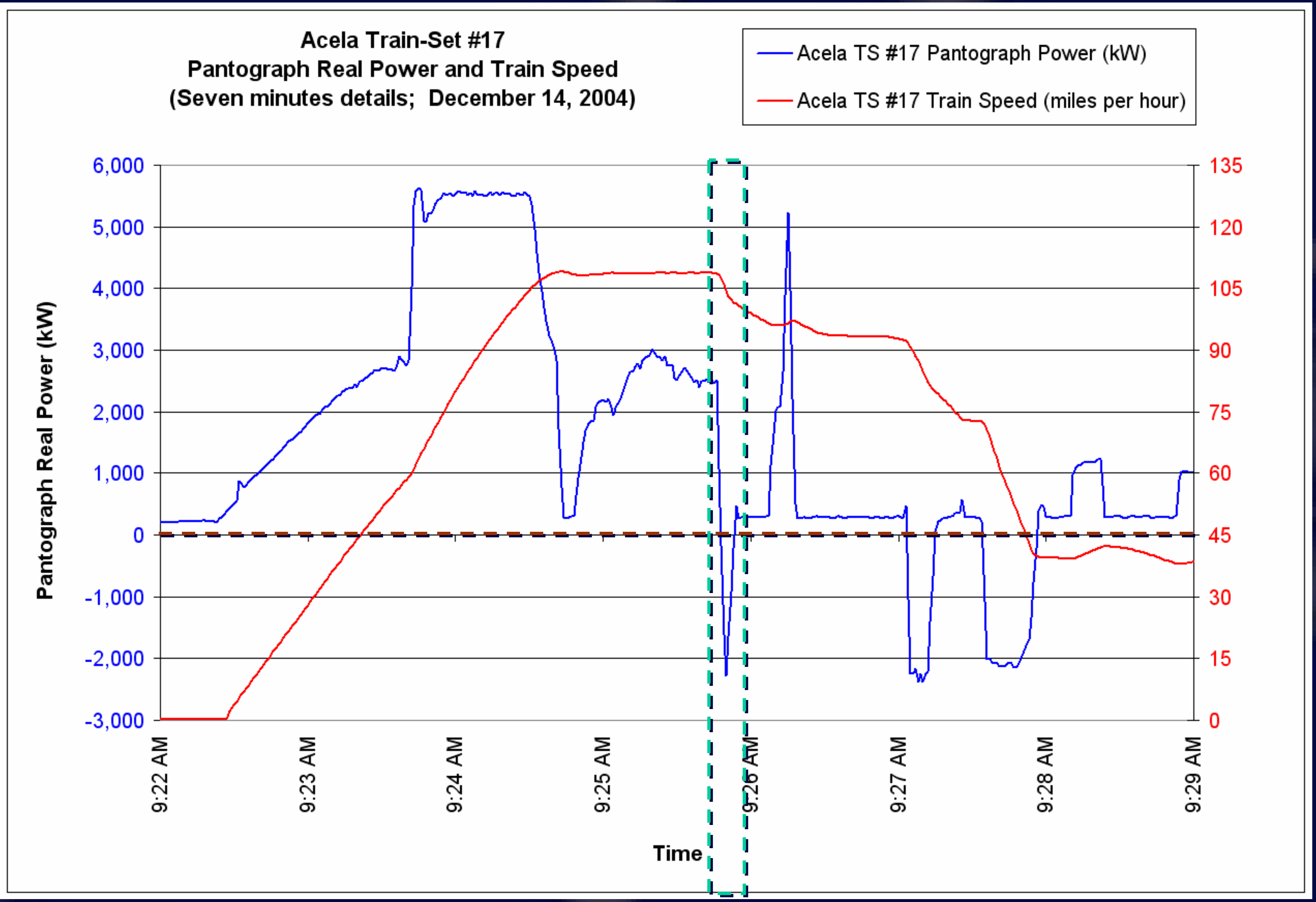
Coasting

Acela Express Power Data Analysis
11 kV, 25 Hz Territory – Recorded Power and Train Speed



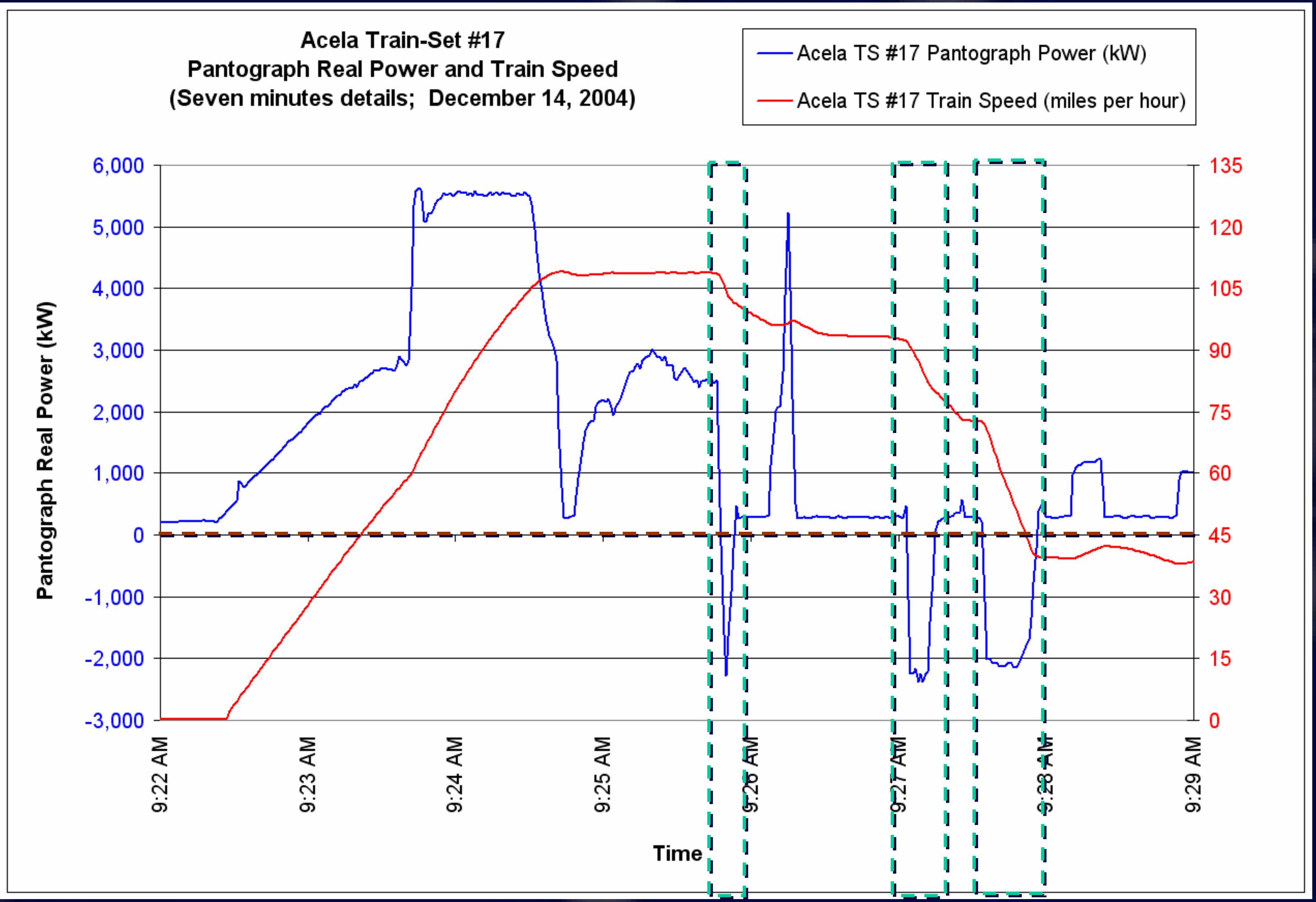
Maintaining Speed

Acela Express Power Data Analysis
11 kV, 25 Hz Territory – Recorded Power and Train Speed



Braking

Acela Express Power Data Analysis
11 kV, 25 Hz Territory – Recorded Power and Train Speed



Braking

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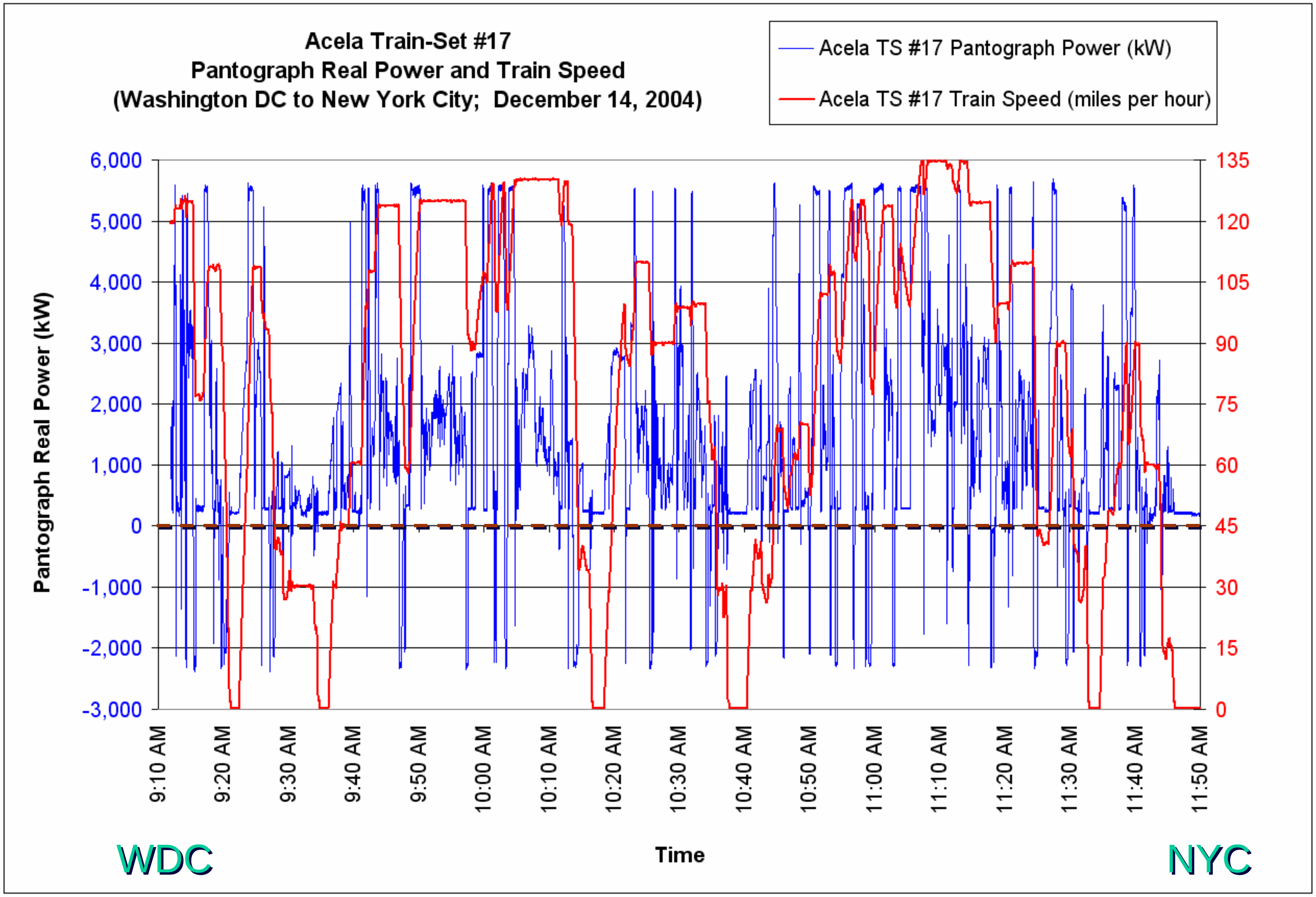
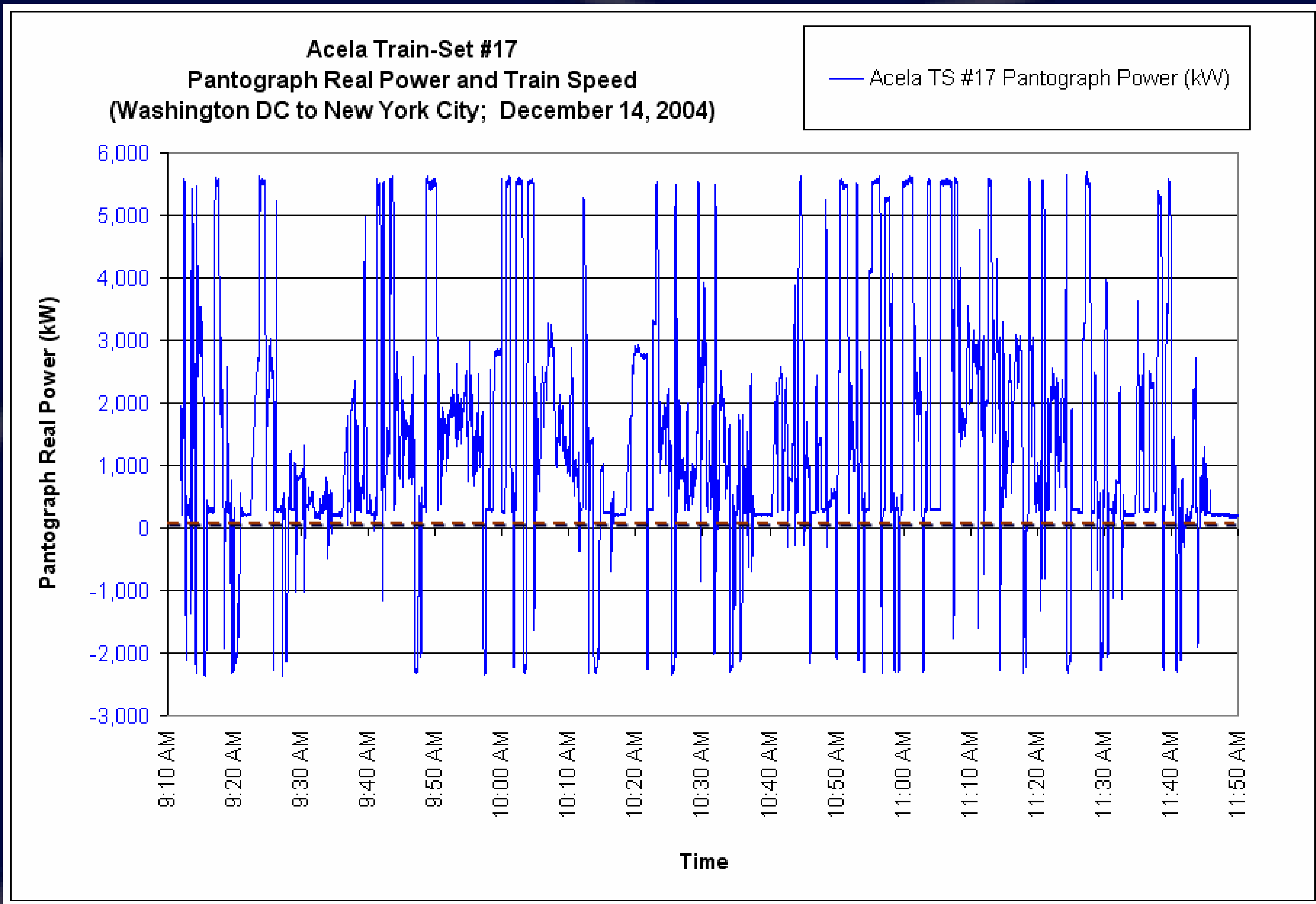
11 kV, 25 Hz Territory – Recorded Power and Train Speed

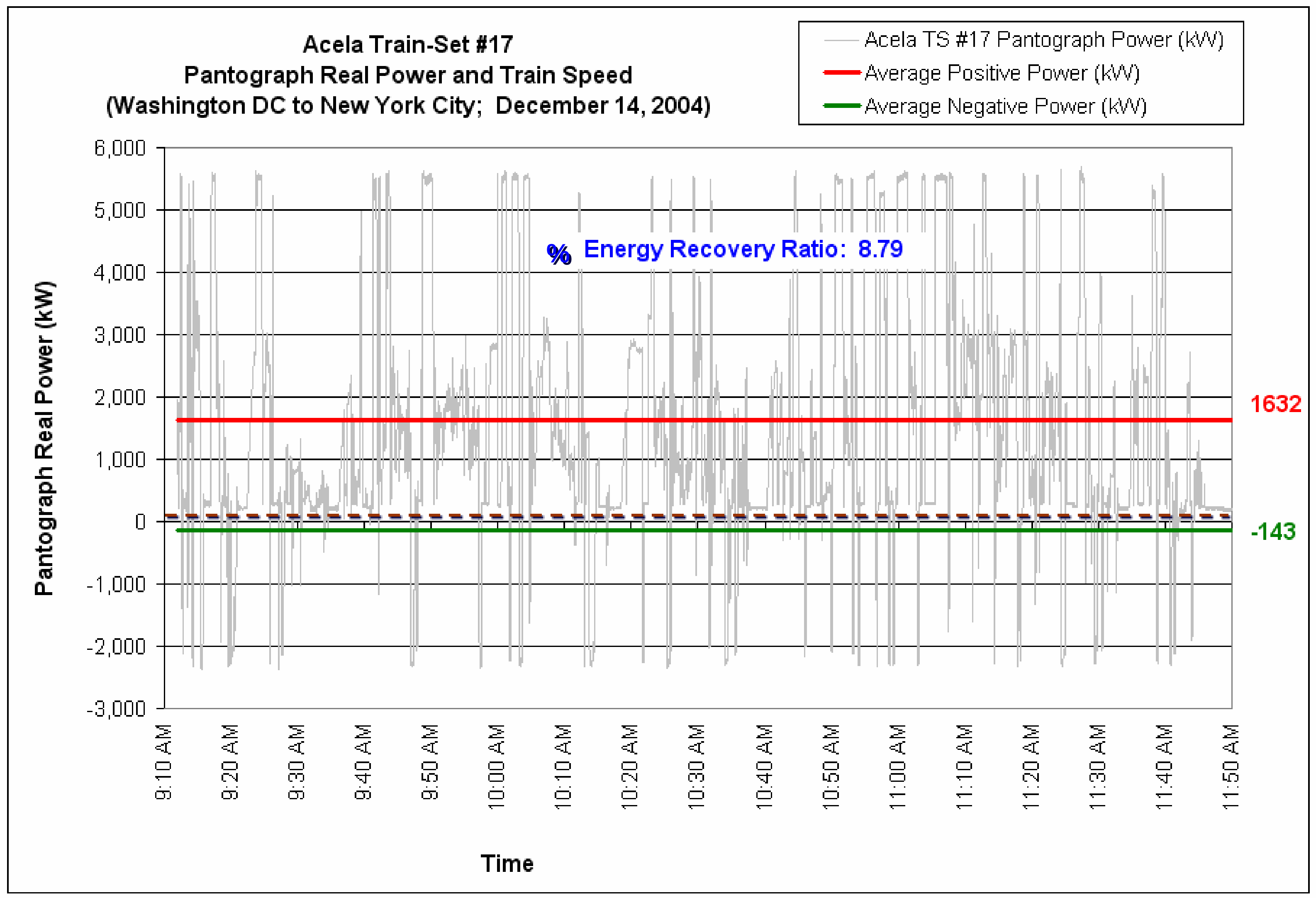


Acela Express Power Data Analysis

11 kV, 25 Hz Territory – Recorded Power



Acela Express Power Data Analysis
11 kV, 25 Hz Territory – Recorded Power



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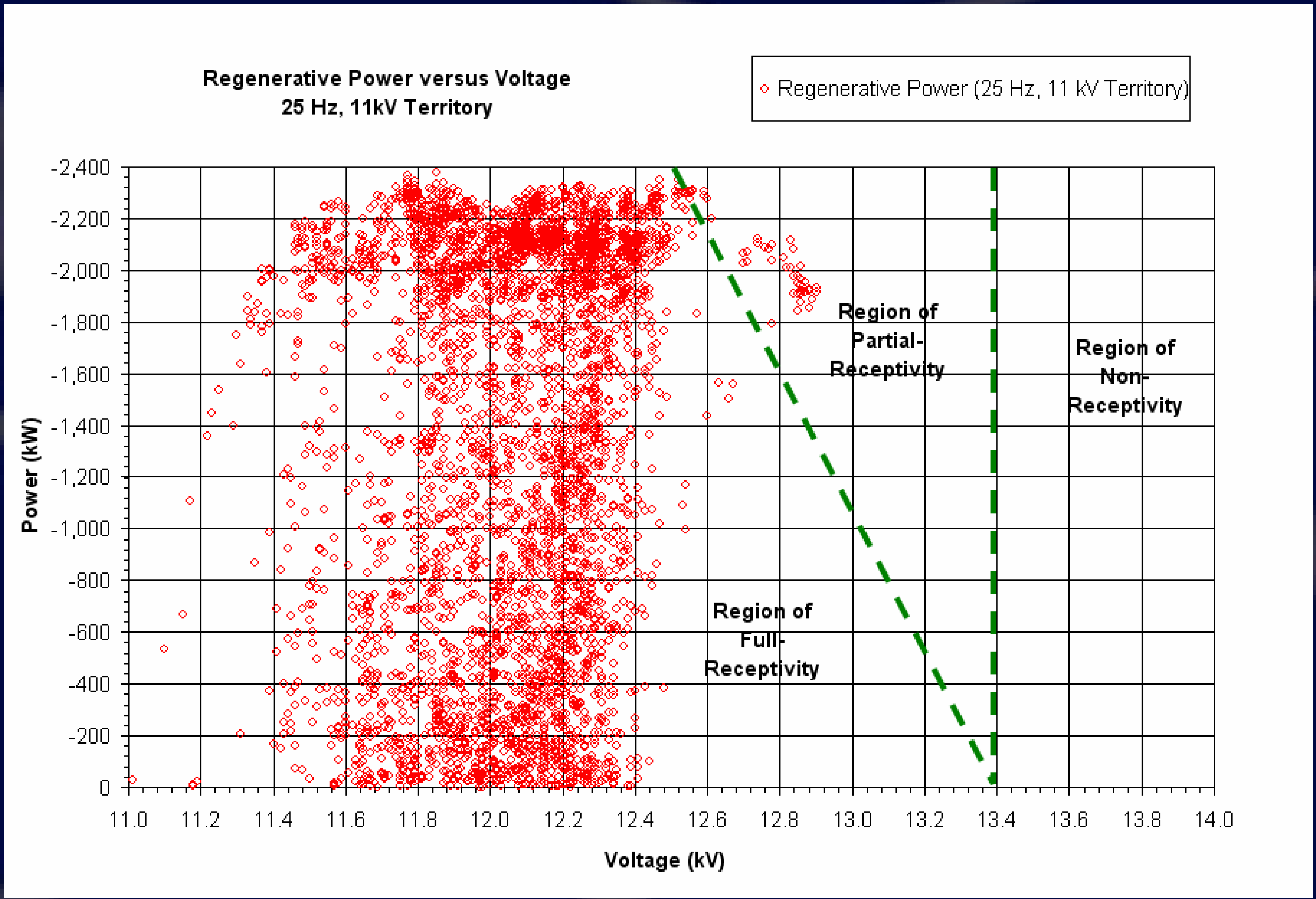
Acela Express Power Data Analysis
25 Hz, 11 kV Territory – High Receptivity Due to Lower Voltage Levels



Acela Express Power Data Analysis
Energy Recovery Ratio and System Receptivity in 25 Hz Territory

Summary of Test Data Analysis

	Train-set #4	Train-set #17
Potential Energy Recovery Ratio	7.66%	7.87%
Receptivity to Regenerative Braking Energy	99.92%	99.85%
Actual Measured Energy Recovery Ratio	7.65%	7.86%

- Consistency in recorded data between the two different train sets
- System-wide power demand and energy consumption simulation in 25 Hz territory
  - Energy recovery ratio and system receptivity derived from measured data are used as basic input parameters to the RAILSIM simulation model

Acela Express Power Data Analysis
Current Constraints And Future Opportunity

- Current status - Each Acela Express power car is capped at 2.4 MW in regenerated power feedback to the traction power supply system
  - Acela Express power cars are capable of delivering higher regenerated power
  - This 2.4 MW cap was imposed due to compatibility issues with the existing infrastructures and older rolling stock models
- Future opportunity – By removing the cap in power feedback to the traction power supply system, additional energy savings could be achieved
  - Requires complete retirement of the older rolling stock models that are the limiting factors for this cap in the traction power system;
  - A system-wide compatibility assessment needs to be performed, including the overhead contact system and its protection, as well as compatibility with all other rolling stock types that share the tracks with Acela Express.

Metro-North Railroad Traction Power System Study
Simulation of the Entire 13 kV AC Power System for New Haven Line

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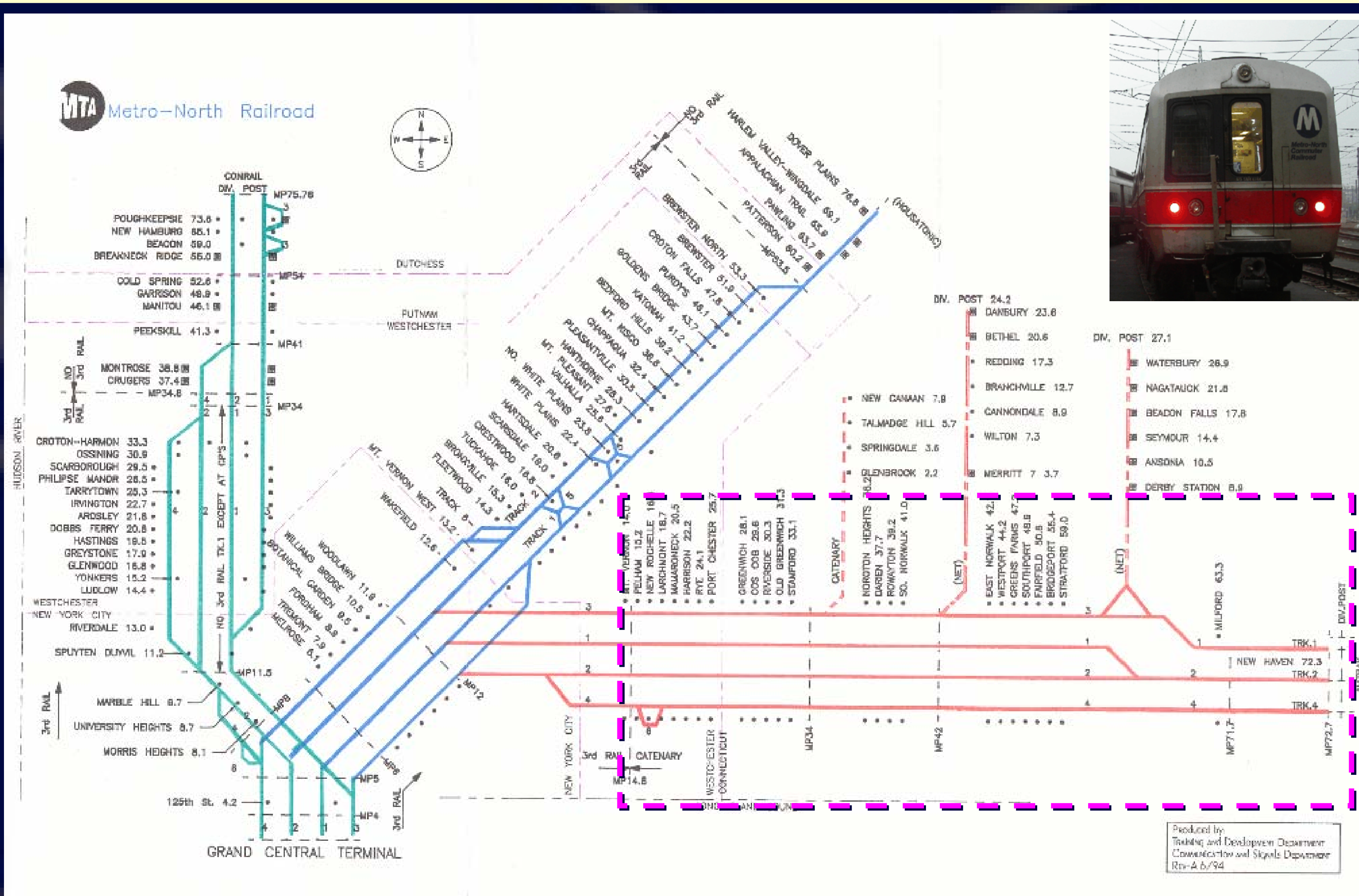
MTA Metro-North Railroad Network

Schematic Track Diagram



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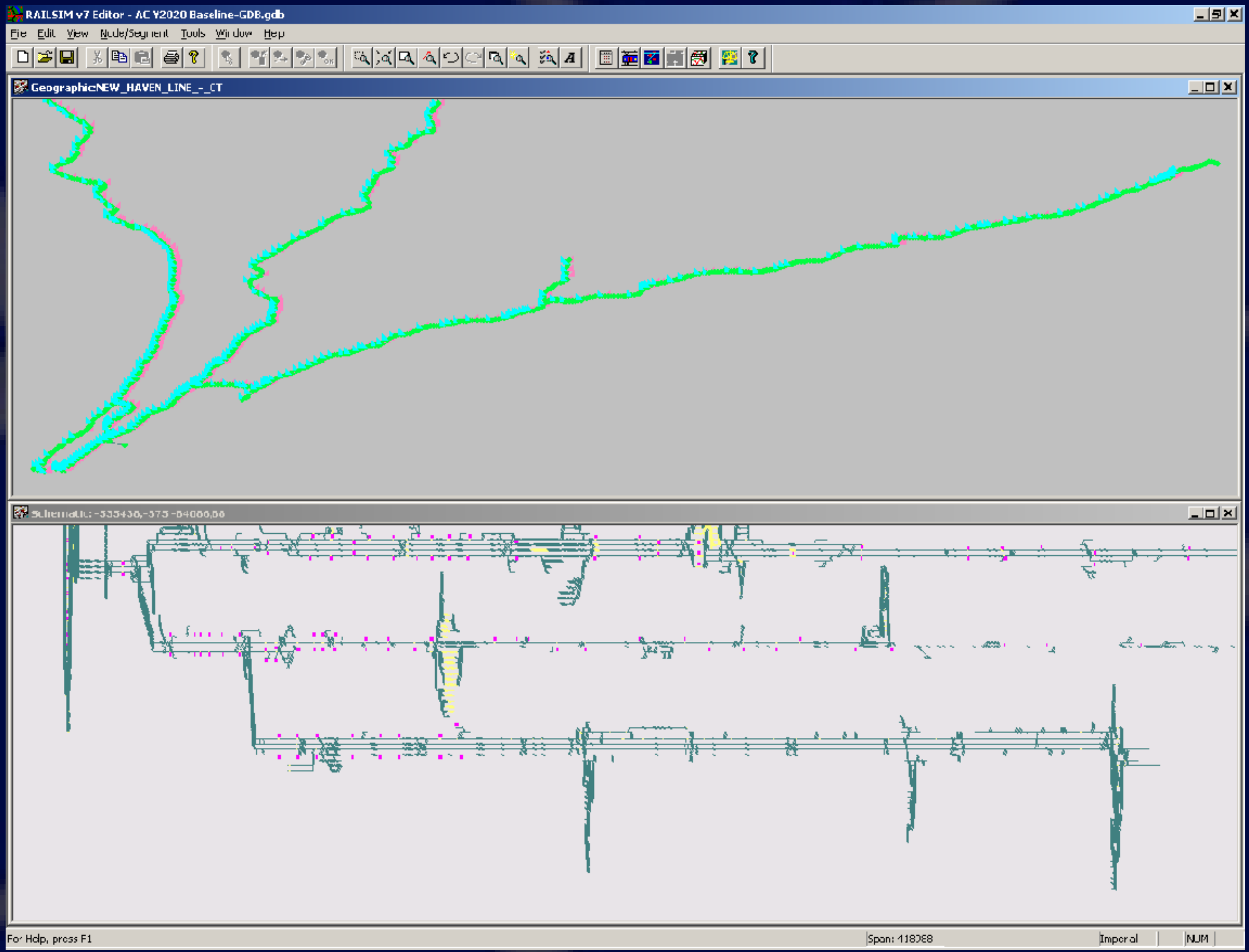
New Haven Line Power System Study:
Simulation of the Entire 13 kV AC Power System for New Haven Line

- +/-13 kV Auto-transformer fed system
- 4 supply substations 115kV/26kV
- 18 Auto-transformer substations 26kV/+13kV/-13kV
- 60 route miles between Pelham (New York) and New Haven, with an 8 mile branch from Stamford to New Canaan
- 250 track miles;
- Metro-North trains and Amtrak trains share the same tracks in this section of line
- Morning hours 4-9AM: 81 electric trains at present, increasing to 91 trains in Year 2020

Traction Power System Studies:
RAILSIM Infrastructure Database Development - Overview



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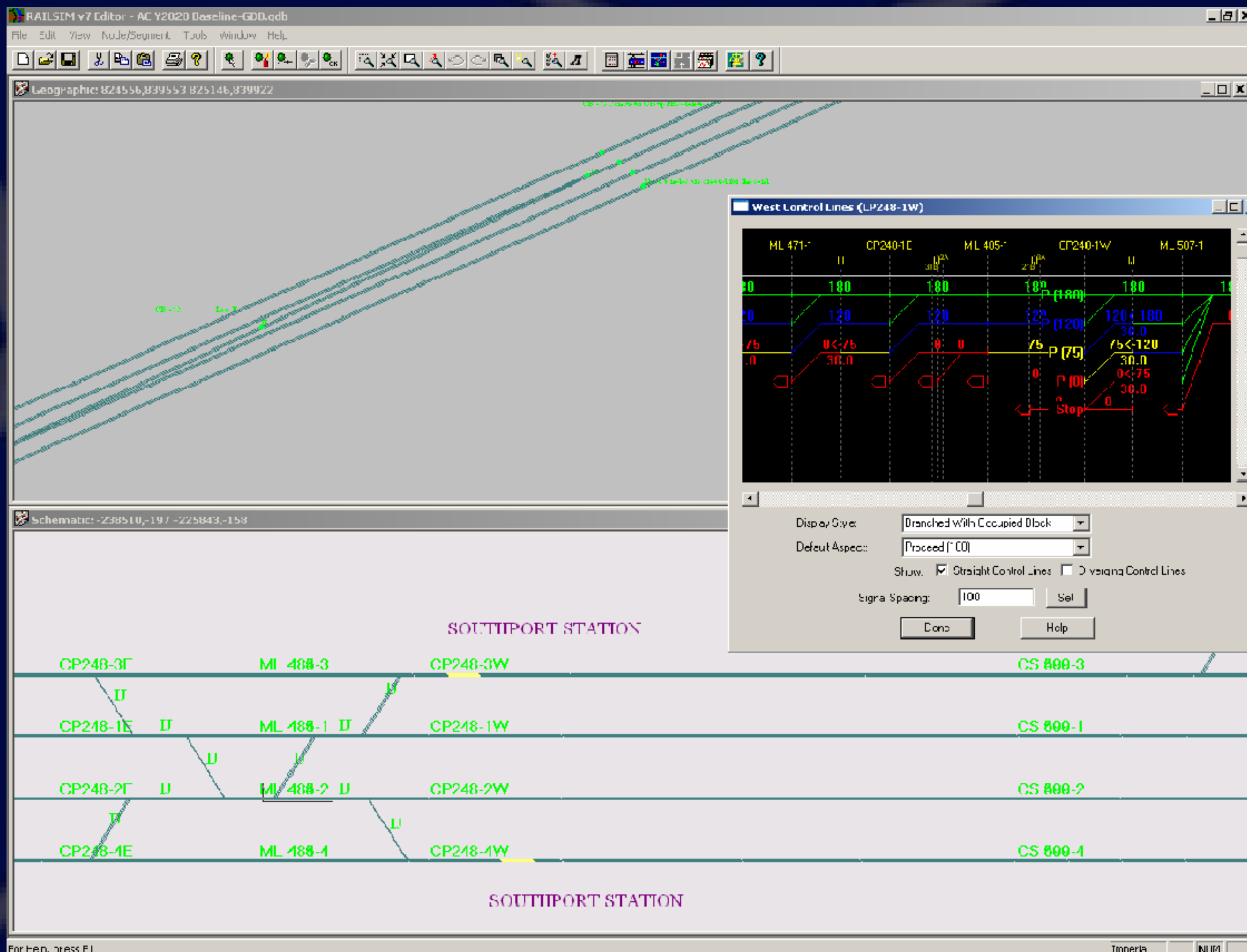
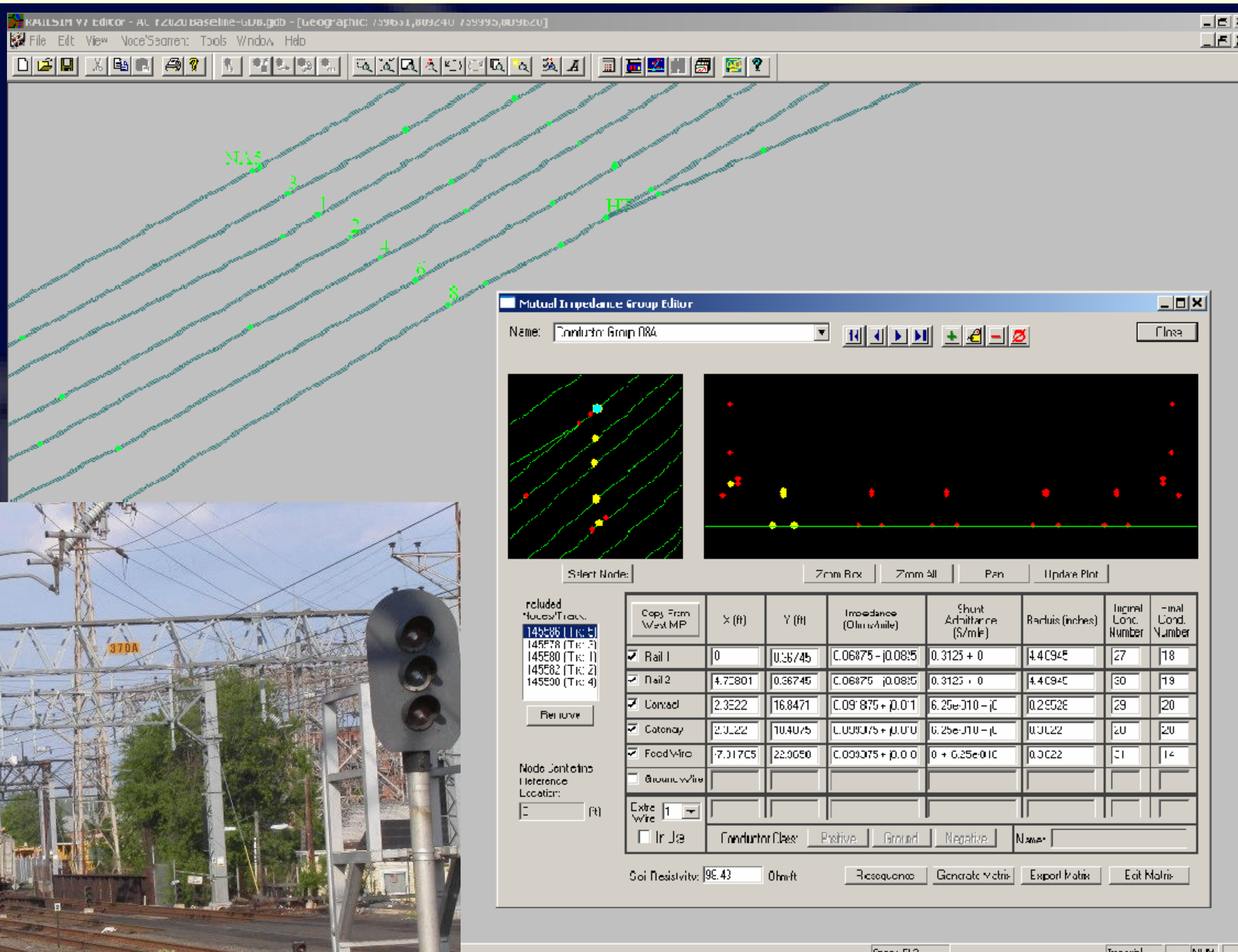
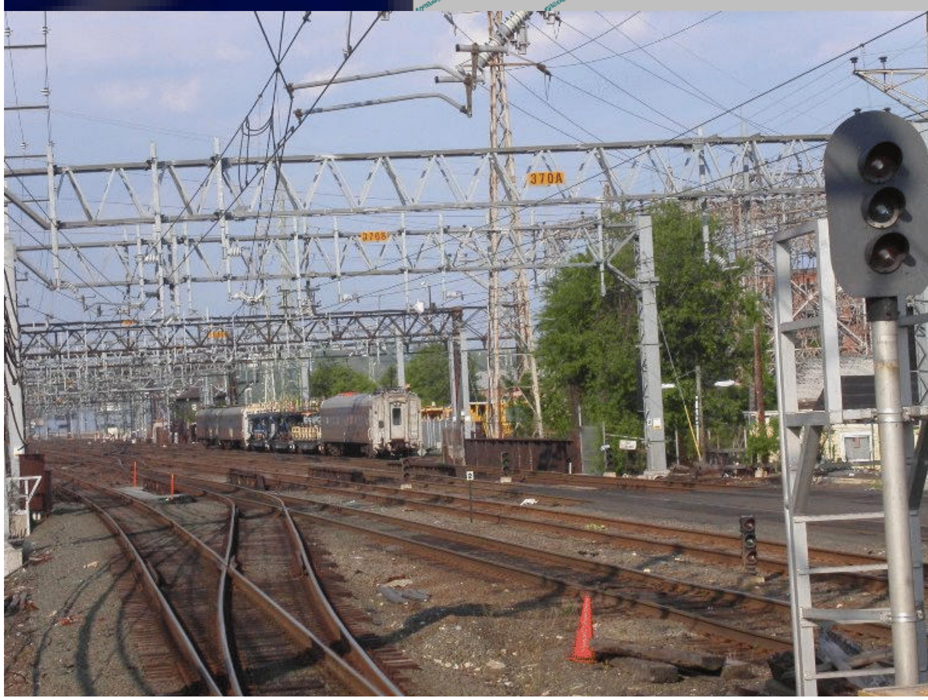
Traction Power System Studies:
RAILSIM Infrastructure Database Development - Detail



Traction Power System Studies:

Overhead Contact System – Modeled by RAILSIM Load Flow Analyzer



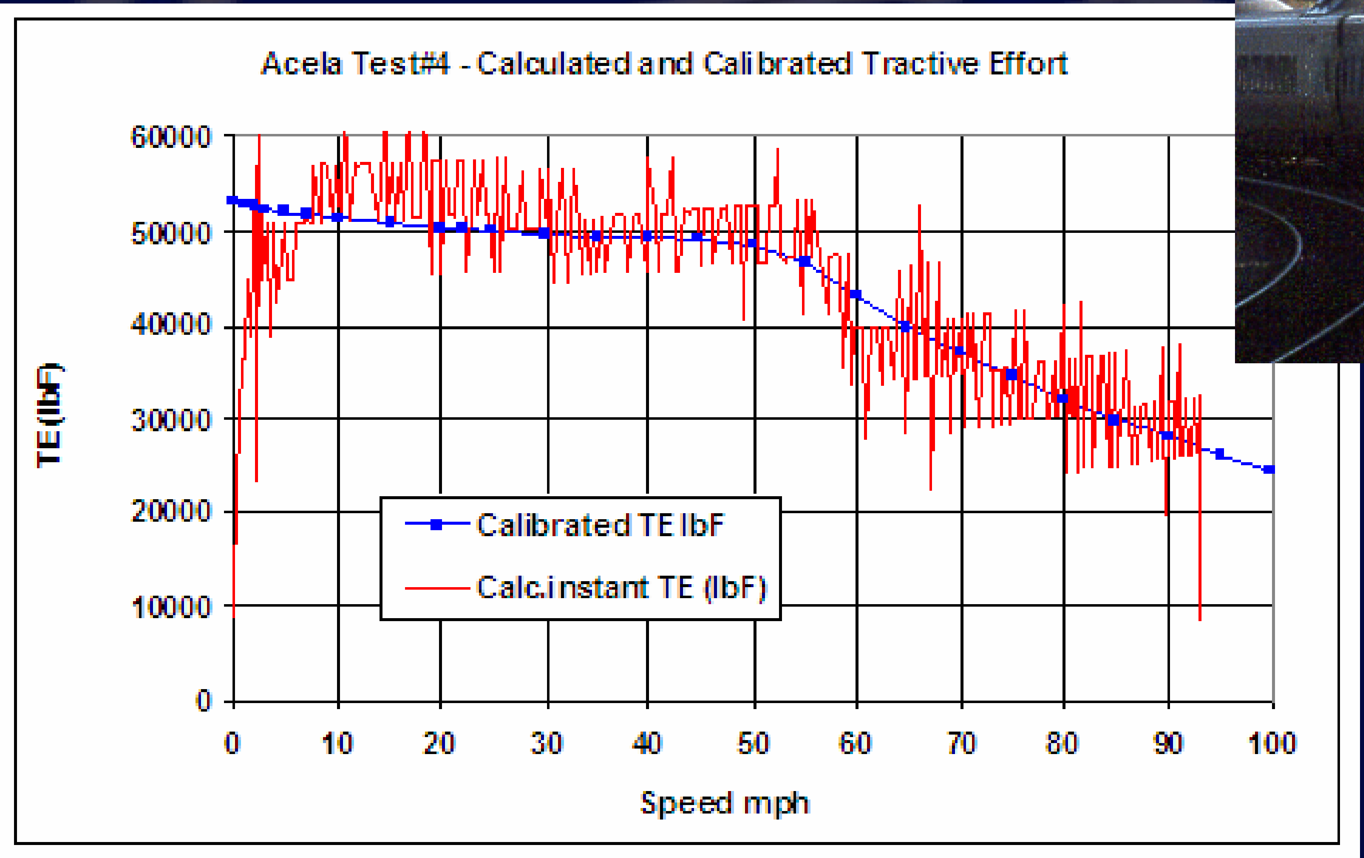


New Haven Line Power System Study: Practical Approach

- Obtained power system data through utility bills, field test and measurement for model calibration
- Obtained all rolling stock data through field test and measurement, including all Metro-North and Amtrak equipment
- Verified that the simulation model accurately represents the physical and electrical networks

New Haven Line Power System Study: Simulation Model Validation

- Rolling stock characteristic calibrations -within 5% of test values for each tested equipment



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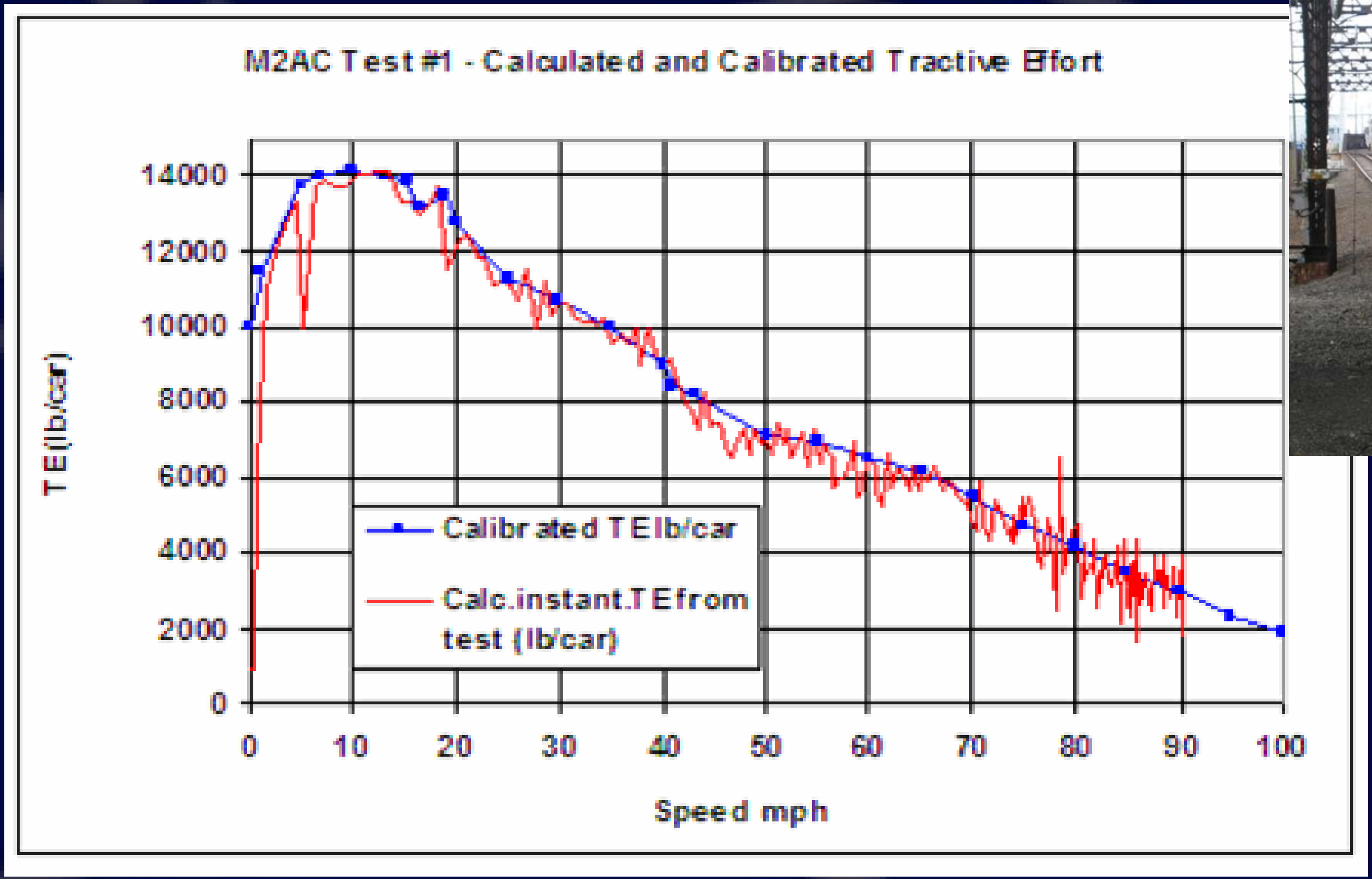
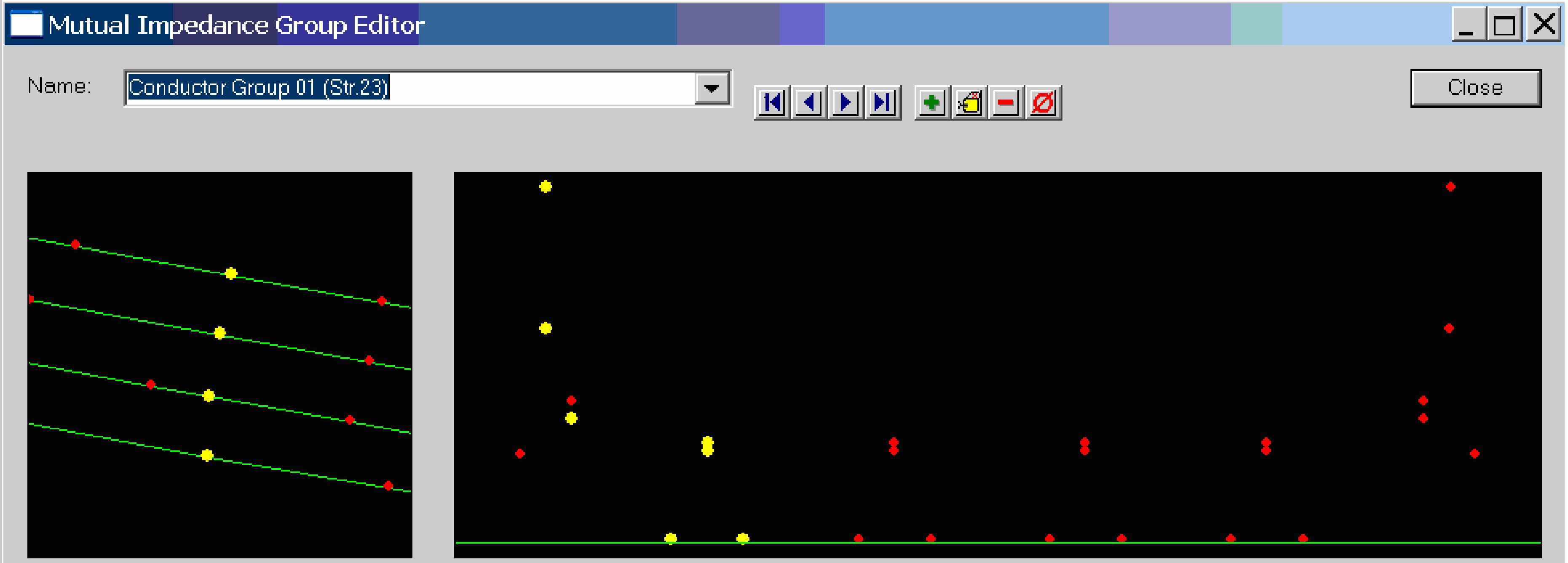
New Haven Line Power System Study: Simulation Model Validation

- M2 EMU has quite different characteristics from Acela Express



New Haven Line Power System Study: Simulation Model Validation

- Conductor loop impedance between overhead contact system and return rails - calculation within 2.2% of test values



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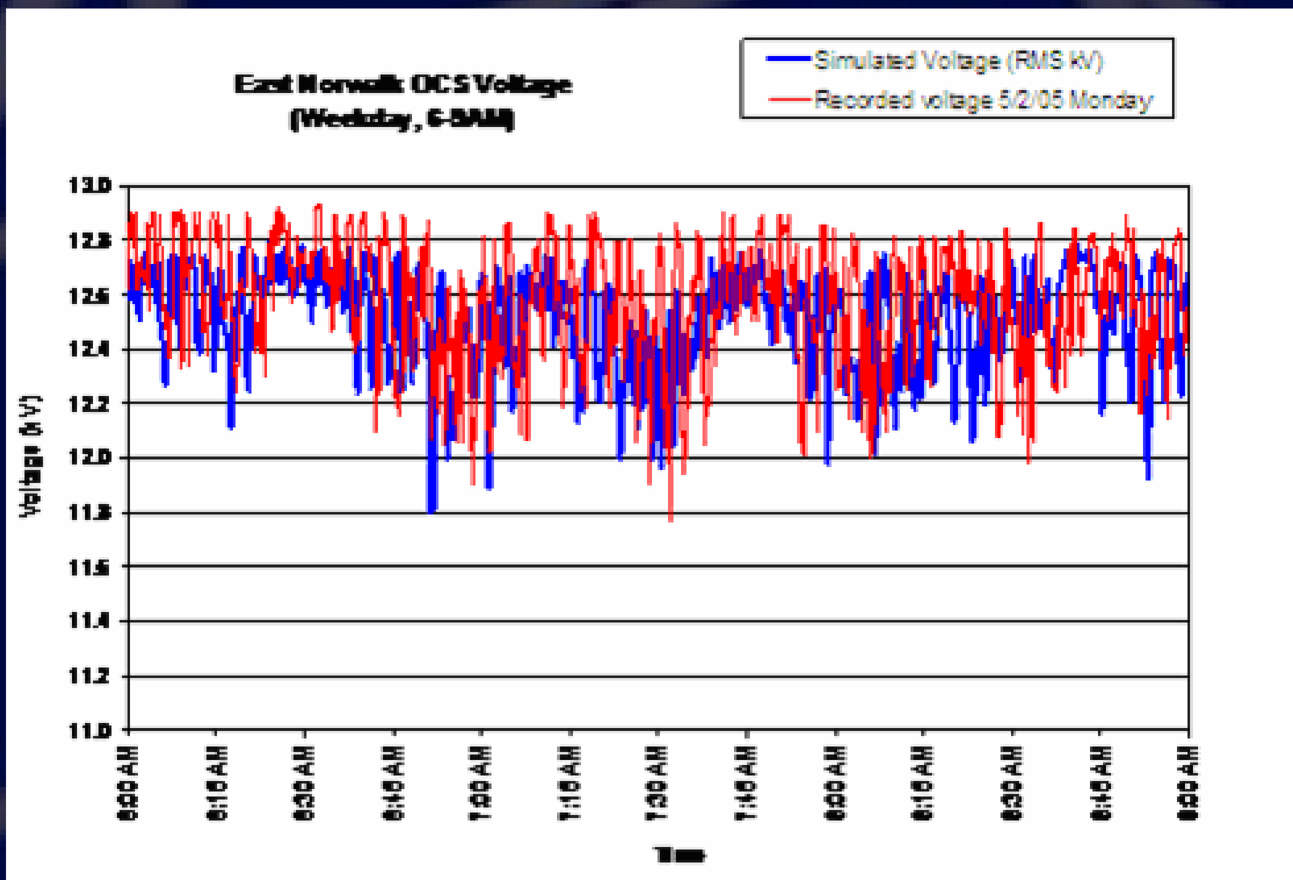
New Haven Line Power System Study: Simulation Model Validation

- Overall system power consumption
  - Simulation within 2.5% of utility billing data (with train coasting)
  - Simulation within 6.8% of utility billing data (without train coasting)

New Haven Line Power System Study: Simulation Model Validation

- Overhead contact system voltage levels (weekday 6-9AM average)
  - Simulation within 1% of measured values at East Norwalk
  - Simulation within 1% of measured values at Bridgeport



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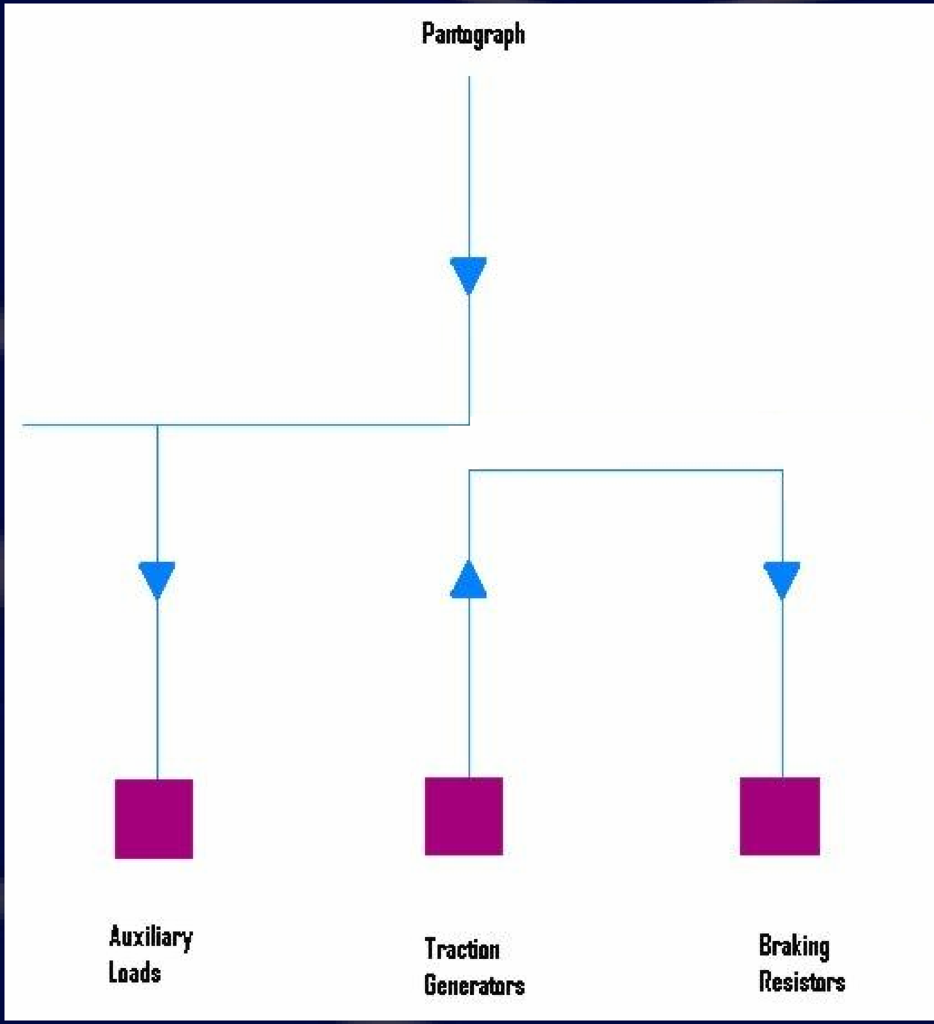
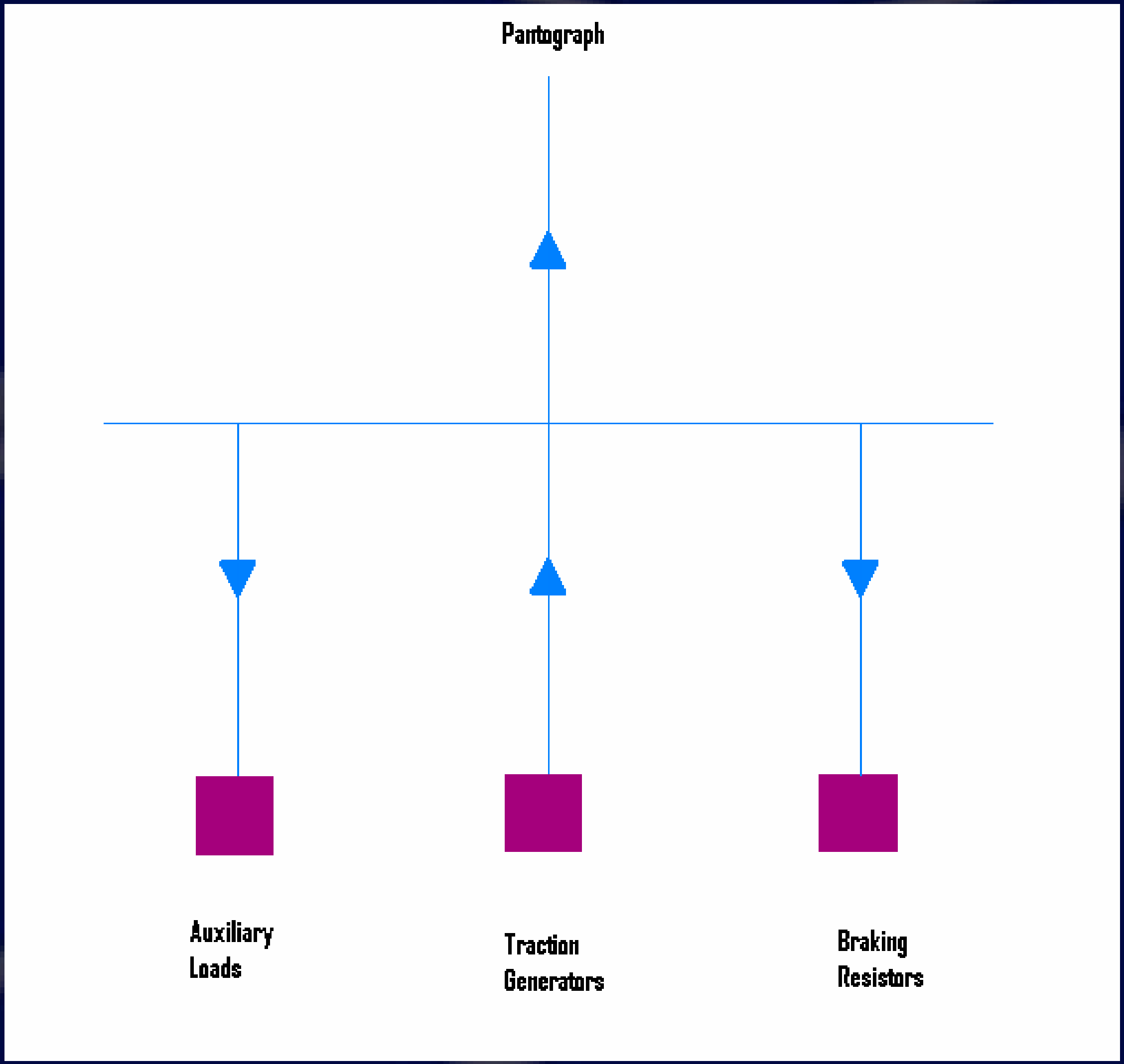
Metro-North Railroad New Vehicle Specification

- Metro-North Railroad / Connecticut Department of Transportation capital improvement for New Haven Line
  - Replacement of Existing M2 / M4 / M6 EMU's
  - New EMU's - M8 Specification For Purchase
- Energy efficiency is an important consideration
- Extensive RAILSIM simulation has been performed to assess the impact of M8 deployment

Metro-North Railroad Traction Power System Study
Existing EMU's (M2 / M4 /M6) – Braking power not utilized



Metro-North Railroad Traction Power System Study
New M8 Vehicle – Braking power to be fully utilized



Metro-North Railroad New Vehicle Specification
Simulated Energy Saving Due to Deployment of New Vehicles

Simulated system-wide power - weekday 6-9AM peak hours

- Both "Real" and "Reactive" powers are parameters used by the power supply company in its billing calculations

Year 2020 Simulated Real Power	Existing Fleet (M2/M4/M6 Trains)	All M8 Trains With Dynamic Braking	All M8 With Trains Regen Braking
System-Wide Average Power Demand (kW)	49,951	45,239	37,783
% Change	0.0%	-9.4%	-24.4%

Year 2020 Simulated Reactive Power	Existing Fleet (M2/M4/M6 Trains)	All M8 Trains With Dynamic / Regenerative Braking
System-Wide Average Power Demand (kVAr)	29,995	11,534
% Change	0.0%	-61.5%

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Metro-North Railroad New Vehicle Specification
Simulated Energy Saving Due to Deployment of New Vehicles

- Contributing factors of energy saving by M8 vehicles
  - Unity power factor of the M8 propulsion equipment
  - Capability of utilizing braking power to feed auxiliary load
  - Regenerative braking power feedback to the traction power supply system
- Staged energy saving strategy
  - With existing M2 / M4 / M6 EMU's still in operation, M8 maximum voltage needs to be capped at 13kV to ensure compatibility with existing equipments
  - After all existing M2 / M4 / M6 EMU's are phased out, M8 maximum voltage cap of 13kV can be increased to 15kV to achieve maximum energy saving

Conclusions

- Power measurement for Acela Express trains demonstrated that energy savings brought by this modern equipment are very real. It also pointed to future opportunities for maximizing the recovery of regenerated energy.
- Simulation results indicated that future M8 vehicles as specified for Metro-North Railroad and Connecticut Department of Transportation would bring significant energy savings on New Haven line, compared against existing vehicles.

Questions and Answers