

Presentation to RTSA Wellington NZ

Phillip Imrie - Plateway

David Bond - KiwiRail





Corporate Background

Plateway Pty Ltd

Sydney Office

6/3 Sutherland Street

Clyde NSW 2142

Australia

Phone: +61 2 9637 5830

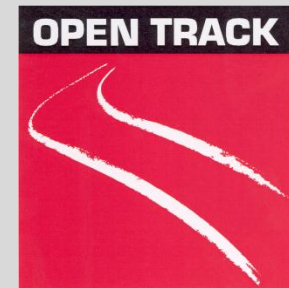
Fax: +61 2 9637 6350



Global and Local Partners

- Plateway works in close collaboration with several leading local and global partners
 - SMA and Partners Zurich
 - OpenTrack GmbH
 - Savannah Simulations
 - IFB Dresden
 - LIFT Trieste

sma+viriato



**SAVANNAH
SIMULATIONS**
the simulation company



Corporate Background

- Plateway has worked throughout Australia and New Zealand.
- Plateway's core business has grown from a railway infrastructure management capability focusing on process redesign.
- Plateway has since expanded to a much wider total rail systems capability.
- Clients include rail operators, network owners and increasingly, rail customers.

Why Simulate?

- Computer simulation allows a virtual reconstruction of complex systems both natural and man made.
- Takes into account the combined effect of all known variables and uncertainties.
- Very cheap means of obtaining experience.
- Unexpected problems and conflicts within a system can be detected and solved.

Why Simulate?

- Test Sensitivity of System Performance to inputs such as rollingstock, passenger patronage, freight volume, infrastructure configuration (track, signals), system reliability, access policy.
- Obtain stakeholder buy in.
- Communicate awareness of system drivers.
- Inputs to downstream processes.

Benefits of Simulation

- More control of modelling parameters.
- Reduces risk.
- Reduce project lengths.
- Visual representation which flowcharts and spreadsheets do not have.
- Reduce design errors in the preliminary stages.
- Can help decide project feasibility.
- All benefits can reduce costs.

Types of Computer Simulation

Simulation	Features
Dynamic simulations	Models changes in a system in response to a defined input signal.
Stochastic models	Uses random number generators to model chance or random events.
Discrete event simulation	Manages events in time- the computer simulates a queue of events in the order in which they occur.
Continuous dynamic simulation	Solves differential equations and uses the solution to change the simulation.

Source: Wikipedia

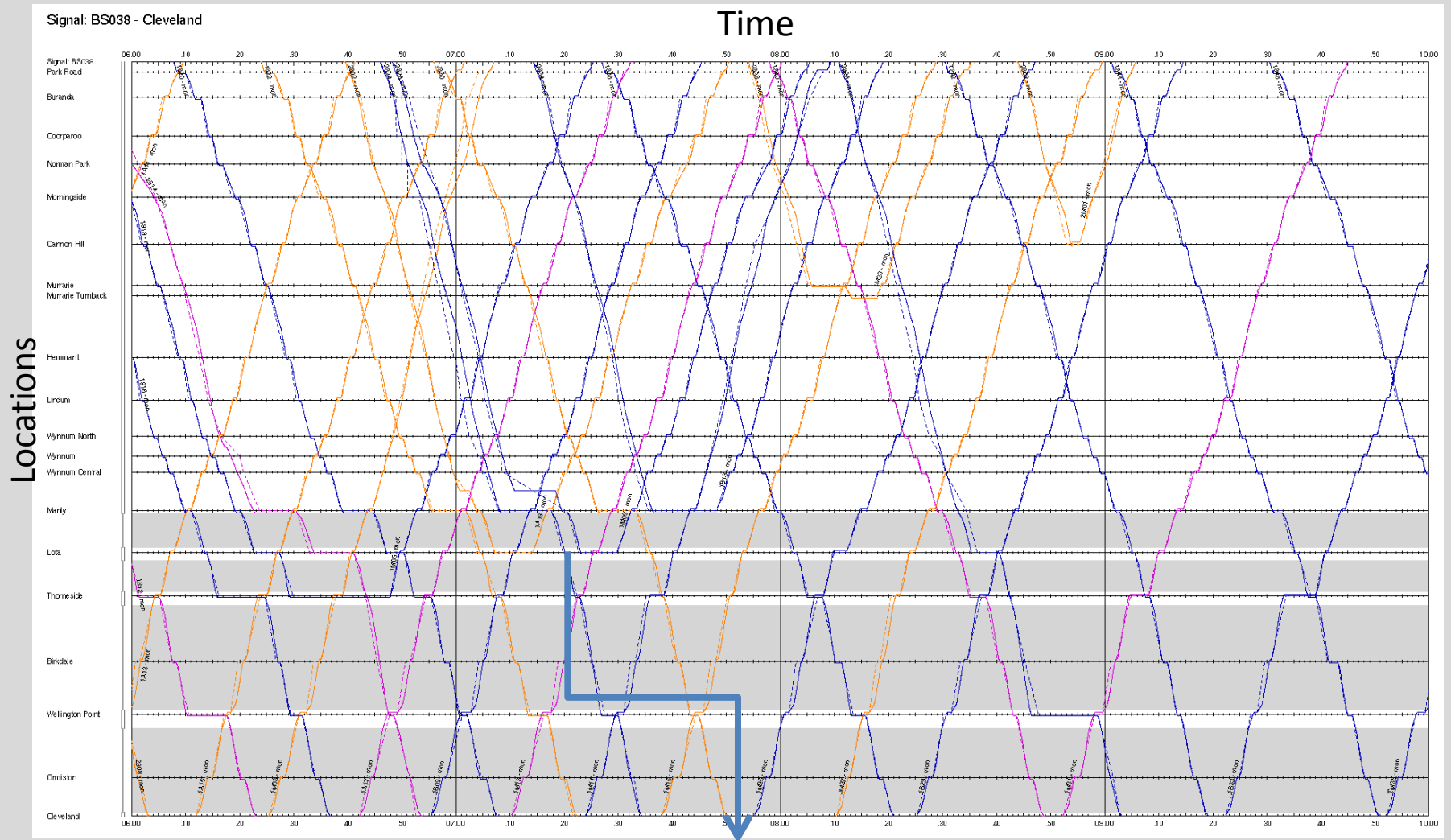
Dynamic Simulation

A dynamic simulation could be achieved by altering train arrival times to see which combinations may cause a problem.

Problems

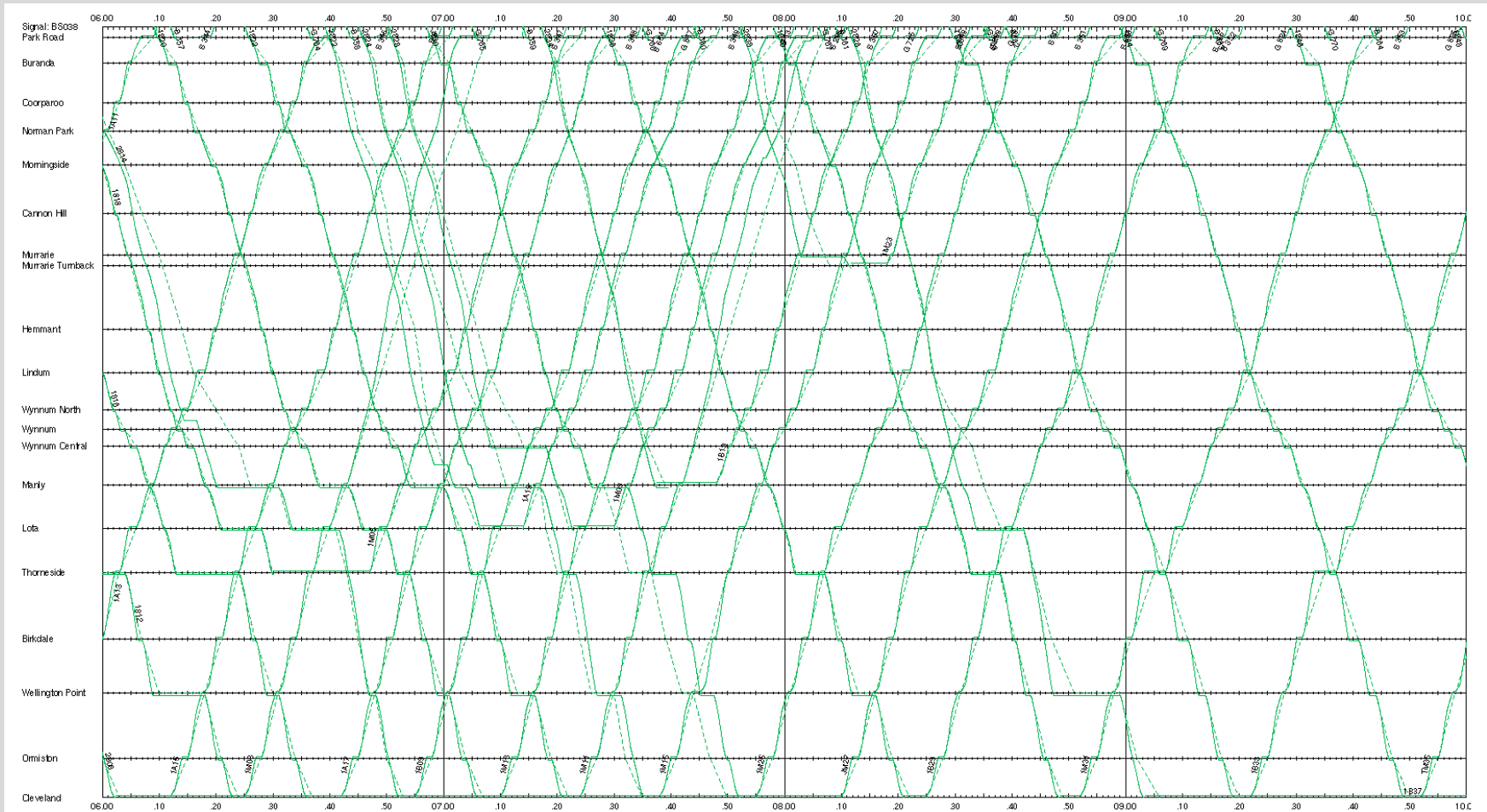
- There may be combinations that can either not occur or are extremely likely to occur in reality.

Reading Train Graphs

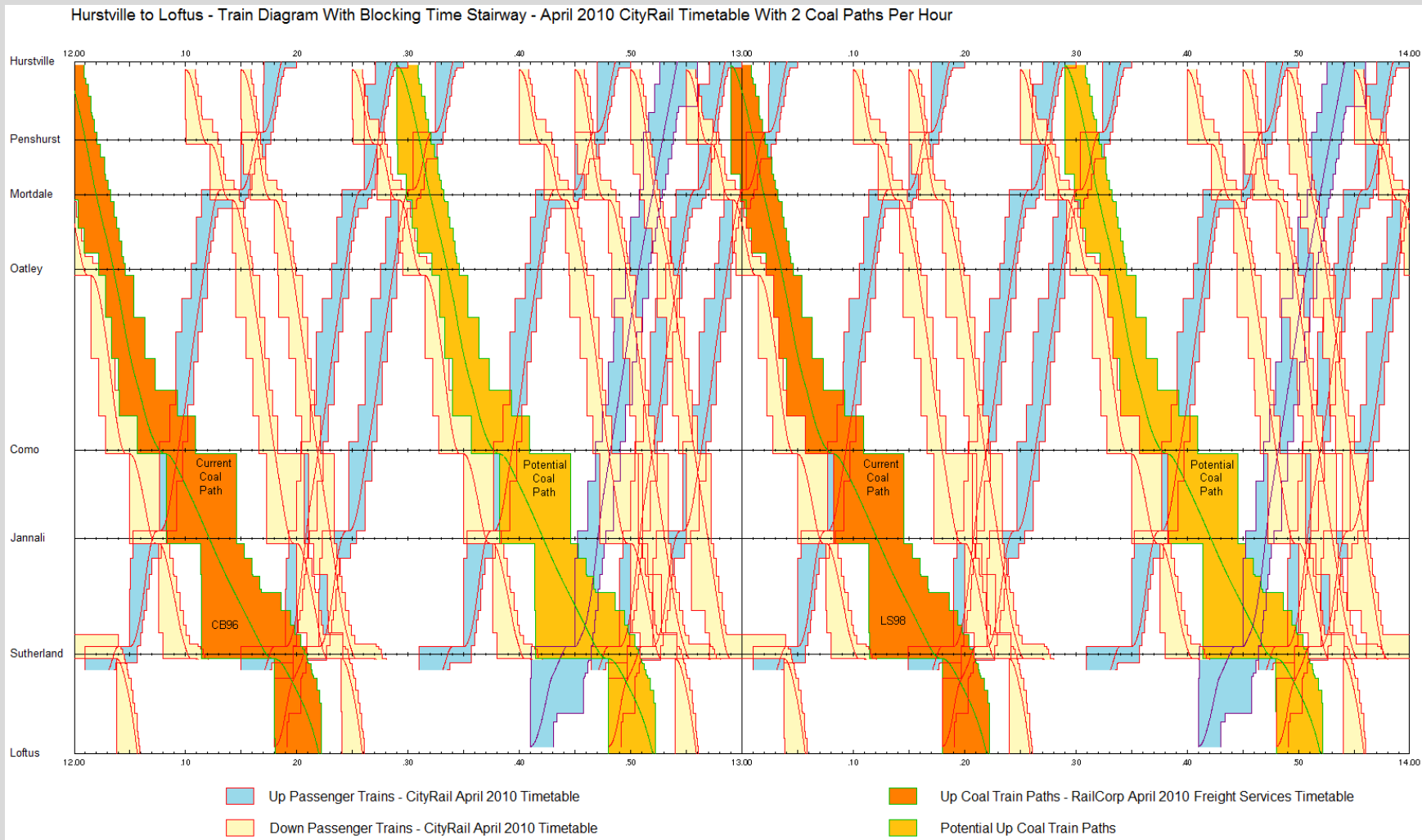


Slope of graph line shows train speed- the steeper the line the quicker the train

Dynamic Simulation



Dynamic Simulation



Could be achieved by describing train run times as a statistical distribution.

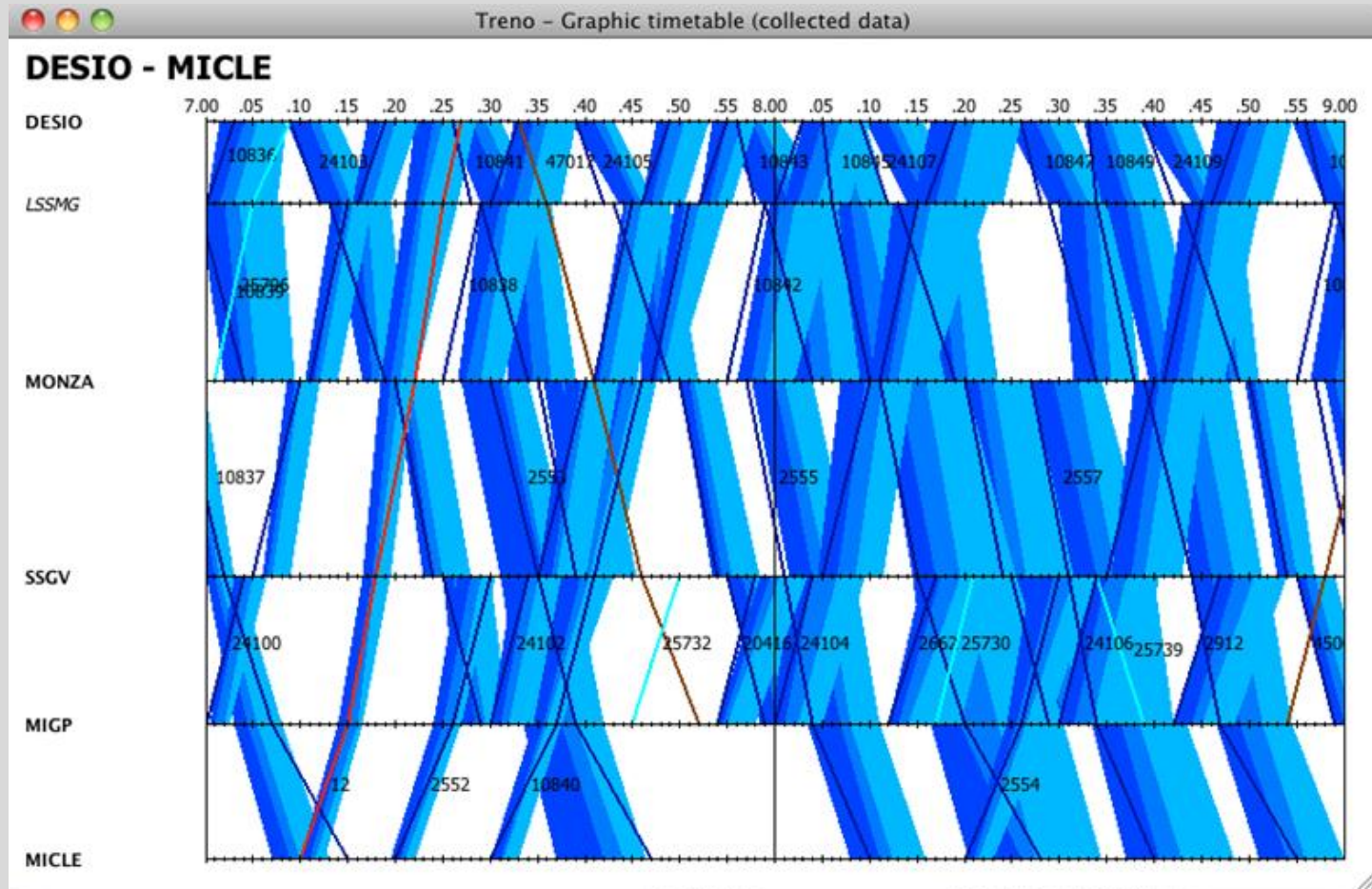
Problems

- The statistical distribution does not calculate actual train performance.
- Maybe incorrect relationships between cause and effect.
- Major problems if outliers are not analysed and treated correctly.

Benefits of Stochastic Models

- Modeling should be based on a range of outcomes.
- On time running is defined relative to that range i.e. about threading the train path through a series of nodes within an allowable band rather than an absolute value.
- Measure the expected reliability of a timetable change.

Stochastic models



Discrete Event Simulation

Discrete event simulations are generally based on the response of a service based system (say the operation of a bank) to a defined event such as a queue.

Problems

- The cause of queuing is not identified.

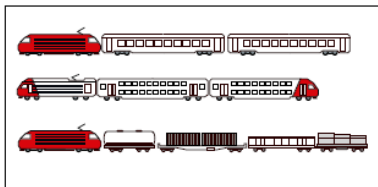
Uses equations which describe the physical processes involved to generate a simulation.

Problems

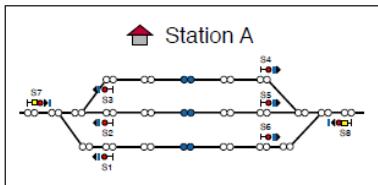
- Complicated code required which solves multiple ordinary differential equations. Requires a large amount of computing power.

OpenTrack Network Simulator

Input



Rolling Stock

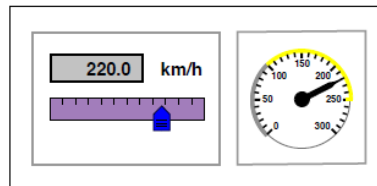


Infrastructure

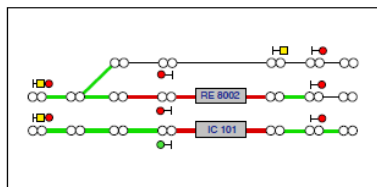
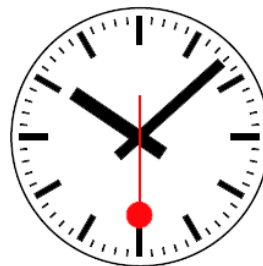
Course ID	Station	Arrival	Departure	Wait
IC 5000	IGG	HH:MM:SS	08:20:00	0
IC 5000	YPS	08:24:00	08:25:00	60
IC 5000	OBE	HH:MM:SS	08:31:00	30
IC 5000	AAT	HH:MM:SS	08:38:00	60
IC 5000	GRS	HH:MM:SS	HH:MM:SS	0
IC 5000	PEW	HH:MM:SS	HH:MM:SS	0
IC 5000	WED	08:55:00	HH:MM:SS	60

Timetable

Simulation

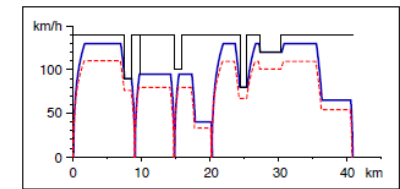


Interactivity

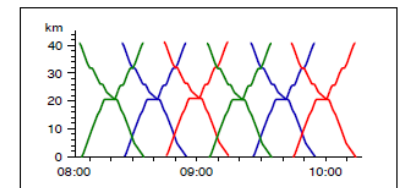


Animation

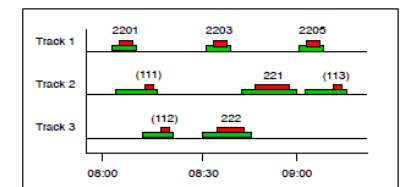
Output



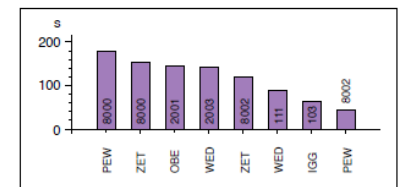
Diagrams



Train Graph



Occupations



Statistics

Railway/metro companies, railway administrations



Consultancies



Universities and research institutes



Railway supply industry / maglev industry



May 2012

- 248 OpenTrack licenses have been sold to 164 Companies and Institutes in 33 countries.

September 2010

- OpenTrack had issued 150 licences to 80 different holders within 22 countries.

OpenTrack Calculation Algorithm

The calculation engine in OpenTrack uses the equations of motion to calculate each train's acceleration, speed and position at a given point in time.

Force = mass x acceleration.

To move a train the power unit has to apply a net tractive effort to overcome the resisting forces.

So the acceleration becomes:

$$\text{Acceleration} = \frac{\text{Net tractive effort}}{\text{mass}}$$

OpenTrack Calculation Algorithm

The “resisting” forces considered in the OpenTrack calculation include:

- power unit losses
- rolling resistance
- the track gradient over the train length
- the track curvature over the train length



OpenTrack Input Data

To perform the calculation OpenTrack needs a reference set of data. This includes:

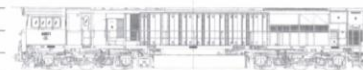
Traction unit characteristics including a speed vs. tractive effort curve.

Environmental conditions, how slippery the rail is.

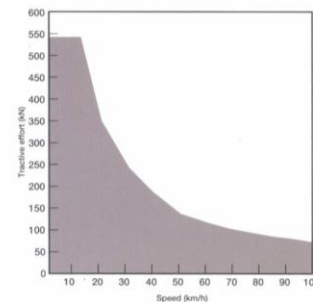
GT42CU ACe NARROW GAUGE

Diesel Electric Locomotive

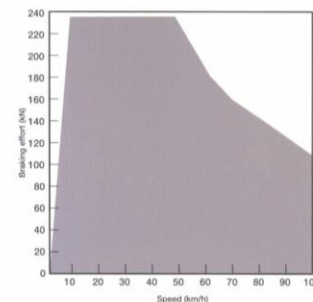
Model	GT42CU ACe
Power	2,424 kW gross 2,260 kW traction
Tractive effort - continuous	460 kN at 14.4 km/h
Rail gauge	1,067 mm
Mass	120 tonnes
Axleload	20 tonnes
Wheel arrangement	Co-Co
Maximum speed	100 km/h
Power per driving axle	377 kW
Gear ratio	90:17
Wheel diameter	1,031 mm
Fuel capacity	9,000 litres
Dimensions	
Length over headstocks	22,000 mm
Height over rail level	3,880 mm
Width over cab gutters	2,880 mm
Bogie wheelbase	3,800 mm
Engine	EMD 12N-710G3B-ES2
Main generator	TA12-QBE/CA7C
Traction motors	EMD A2916-8
Air compressor	Gardner Denver WLN9CE
Brakes - air	Combined electronic/distributed power
Brakes - dynamic	2,600 kW
Cooling system	2 x 1,321 mm speed AC motor driven fans
Drivers' controls	Island style dual position
Cab	Single, air conditioned, isolated
Special features	<ul style="list-style-type: none"> • MELCO AC traction system • EM2000 microprocessor control system • EMD Gen 2 FIRE screen based instrument displays • Isolated cab with island style consoles • Downer EDI Rail radial steering bogie • Electronic fuel injection • Split cooling system



Tractive effort - speed curve



Dynamic Braking effort - speed curve



BFLn-102, 31 October 2007

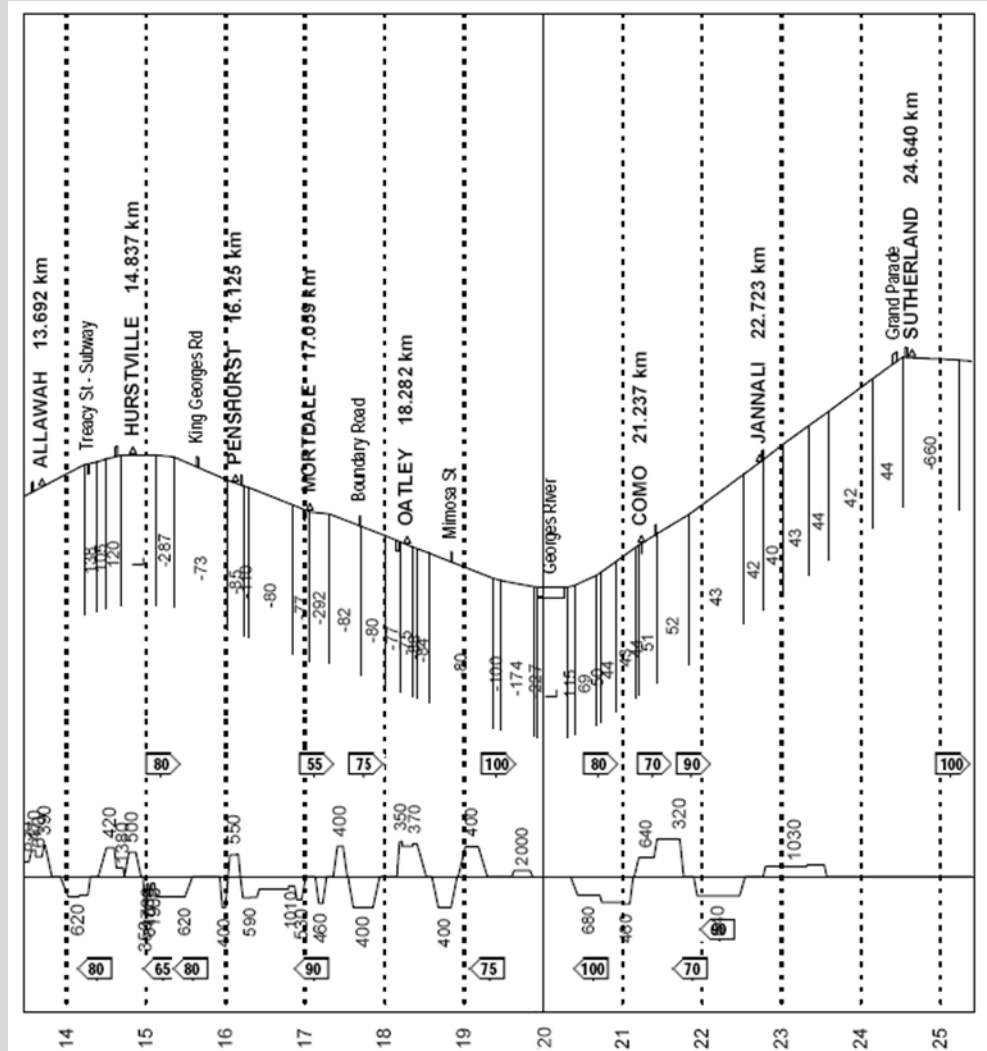
OpenTrack Input Data

Assumed train braking performance.

- Increasingly modern systems blend air and electric (dynamic) braking.
- Blending is computer controlled and dependent on environmental conditions as well as individual driving style.

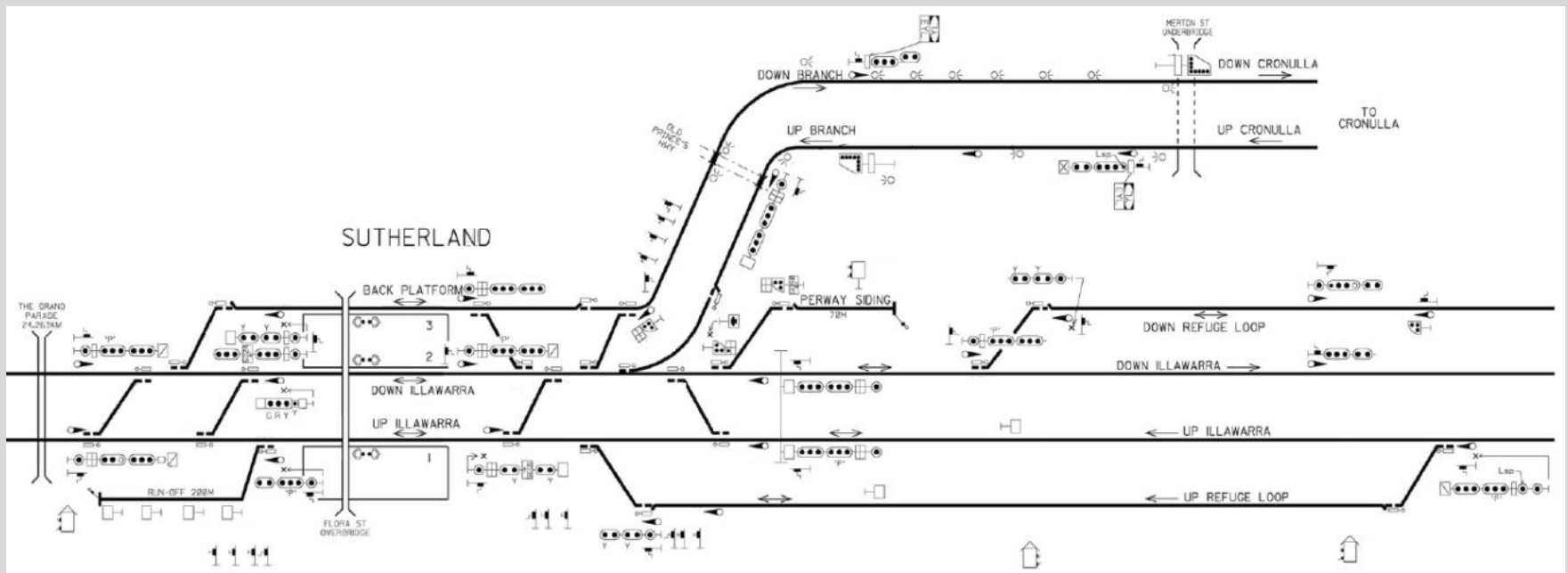
OpenTrack Input Data

- Railway curves, grades and line speeds.



OpenTrack Input Data

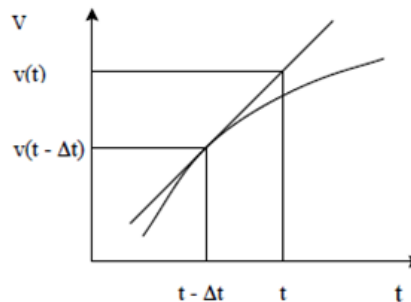
- Signaling layouts and interlocking functionality.



OpenTrack Calculation Algorithm

Once the net force available for traction has been calculated the computer applies differential calculus to the acceleration using the Euler method to calculate the speed of the train and then again to calculate the trains position.

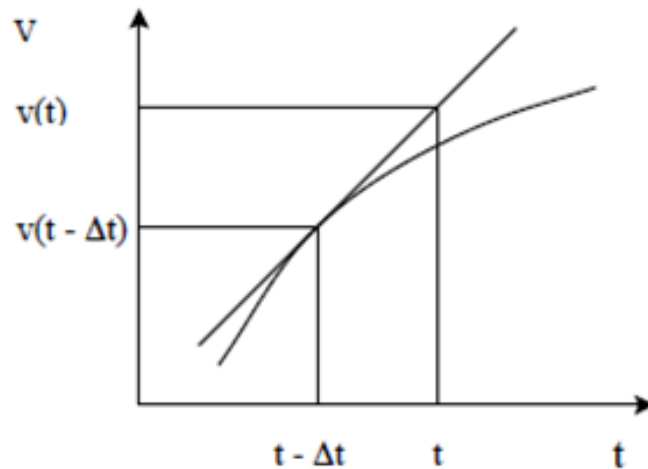
$$v(t) = v(t - \Delta t) + \Delta t \cdot \frac{dv}{dt}(t - \Delta t); v(t_0) = v_0$$



OpenTrack Calculation Algorithm

The Euler method is an approximation but **computers cannot solve differential equations.**

The accuracy of the approximation improves with decreasing the time interval used in the calculation.



OpenTrack Calculation Algorithm

- The acceleration and speed are also adjusted as a result of the signaling system inputs.
- Other defined “events” which are triggered by distance may include station stops, changes in train loading and direction.
- Once the computer has finished the calculations for each time interval the computer starts again for the next increment.
- The method uncorrected will generally produce the “best performance” possible. For use in practical applications this is always down rated.

Traction Power Supply Simulation

The basic electrical Ohms law relationship is a major factor in deciding the parameters for the chosen system.

Voltage (U) = current (I) x Impedance (Z)

The losses in the conductors can be given by $P = I^2 Z$

So the higher the voltage, the lower the current and the lower the system losses.

Traction Power Supply Simulation

In an AC system the impedance to the flow of current is a function of:

- The resistance.
- Magnetic coupling between the supply and return side conductors.
- Capacitive coupling is a component of impedance but not a major influence in traction supply systems. It does however generate interference.

Resistance to the flow of current is a function of:

- Conductor size.
- Conductor material.
- Conductor temperature.
- Conductor length - in a traction supply the distance of the train to the supply point.
- Component wear (of contact wire and rails)

Traction Power Supply Simulation

Why simulate the traction power supply?

- To determine the line voltage at the pantograph and the resulting impact on train performance.
- To determine the influence of the network structure on electrical load distribution.
- To size equipment such as cable, transformers, rectifiers
- Some energy suppliers have constraints on the ability of the network to cope with regenerated energy under different network switching conditions.

Traction Power Supply Simulation

The power supply system influences the resultant energy consumption and costs as well as train performance.

Simulation of these dynamic processes enables:

- Energy consumption analysis and prognosis.
- Design and rating verification of the electrical installations.
- Electromagnetic field studies.

Traction Power Supply Simulation

Energy consumption simulation for electrical railway systems is a factor of:

- Whether the train is powering or braking.
- The throttle setting and required traction power.
- The position of the trains within the network.
- The configuration and capability of the power supply system.

All of this information is needed at exactly the same time.

Older simulation products compromised on:

- the complexity of the rail operation (only able to simulate a small number of trains).
- the detail of traction unit performance under degraded line conditions and feedback into the simulation.
- the detail of the electrical network.

Traction Power Supply Simulation

Railway Operation Simulation

OPEN TRACK

Uses calculus to calculate the position, speed, acceleration and resulting power demand of every train in the network

“Co-Simulation”

ATM

Advanced Train Module

Locomotives adjust performance in response to available power supply



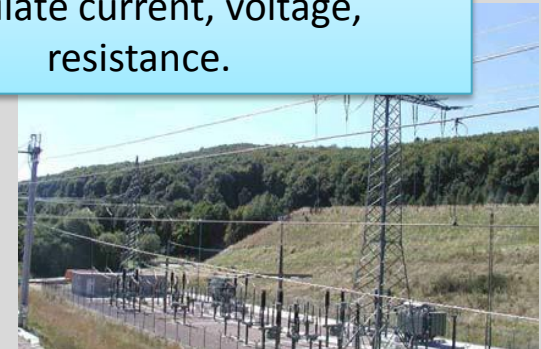
Propulsion Technology

Interaction



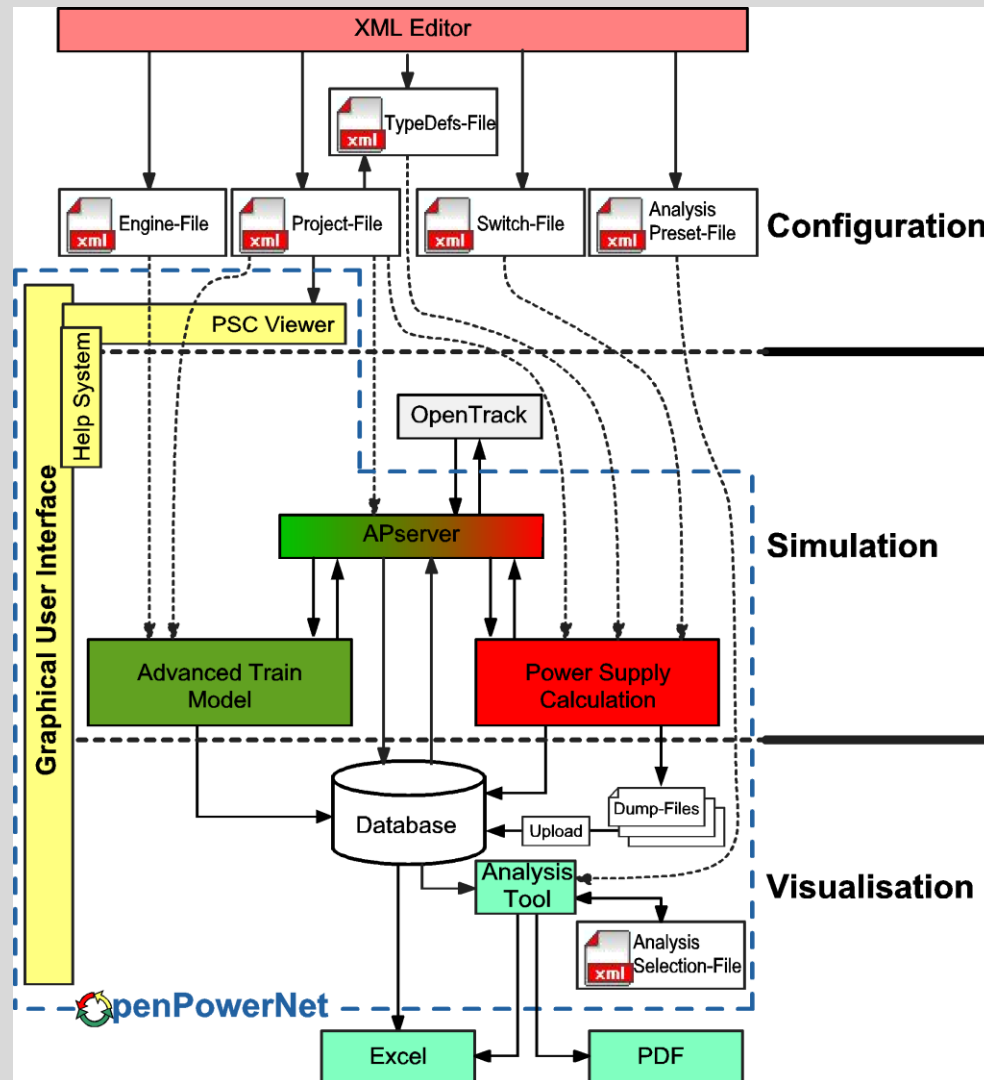
PSC Power Supply Calculation

Uses calculus to solve Ohm's Law to calculate current, voltage, resistance.



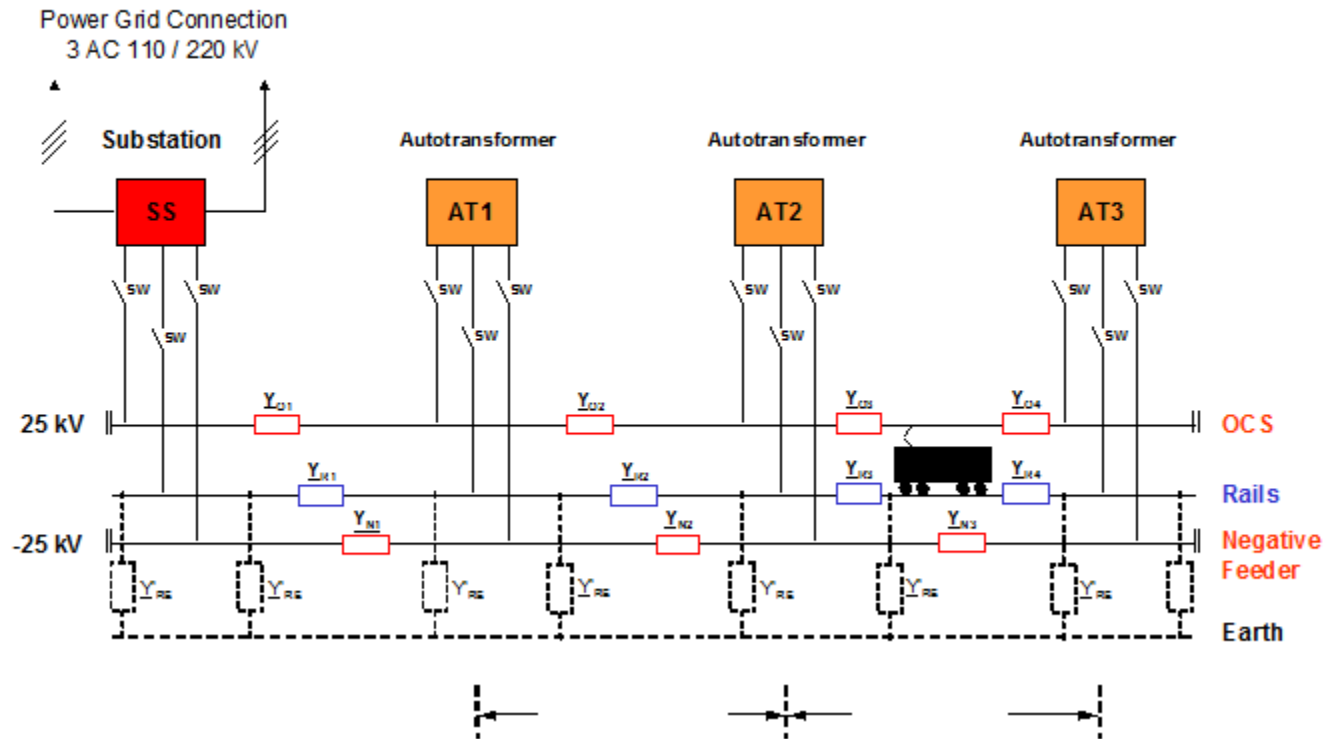
Power Supply System

Structure of OPN



Traction Power Supply Simulation

Power Supply Network Structure (2 AC 25 kV ~ 50 / 60 Hz)



Data Input

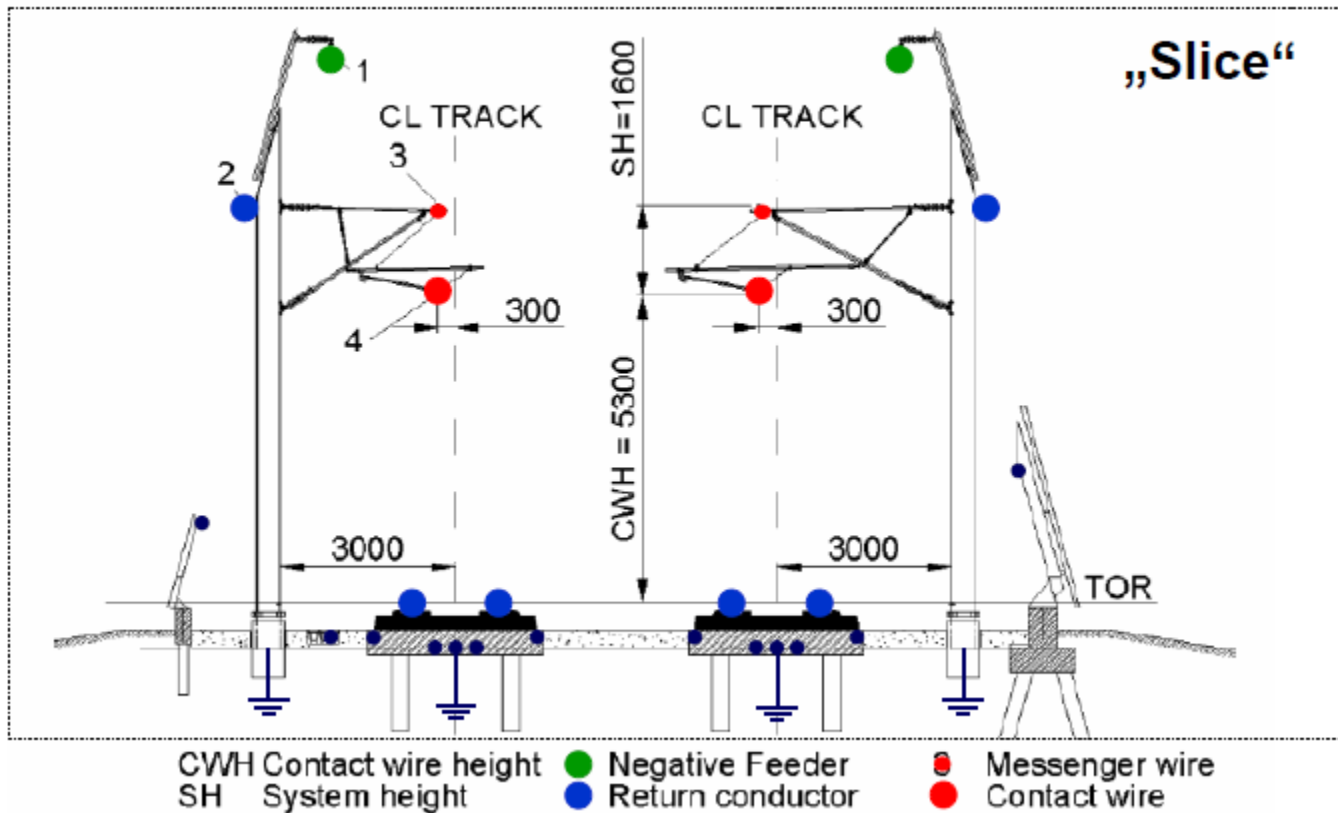
- Electrical network structure (feeding sections, feeding points, switch state) in congruence to the track topology.
- Electrical characteristics of the feeding power grid.
- Electrical characteristics of the substations.
- Electrical characteristics of the conductors (cables, Catenary wires, tracks, rails).
- Electrical characteristics rail-to-earth.

Data Input

- Modelling of additional power consumers (e.g. switch heaters).
- Loading capacity (conductors, converters, transformers).
- Protection settings.

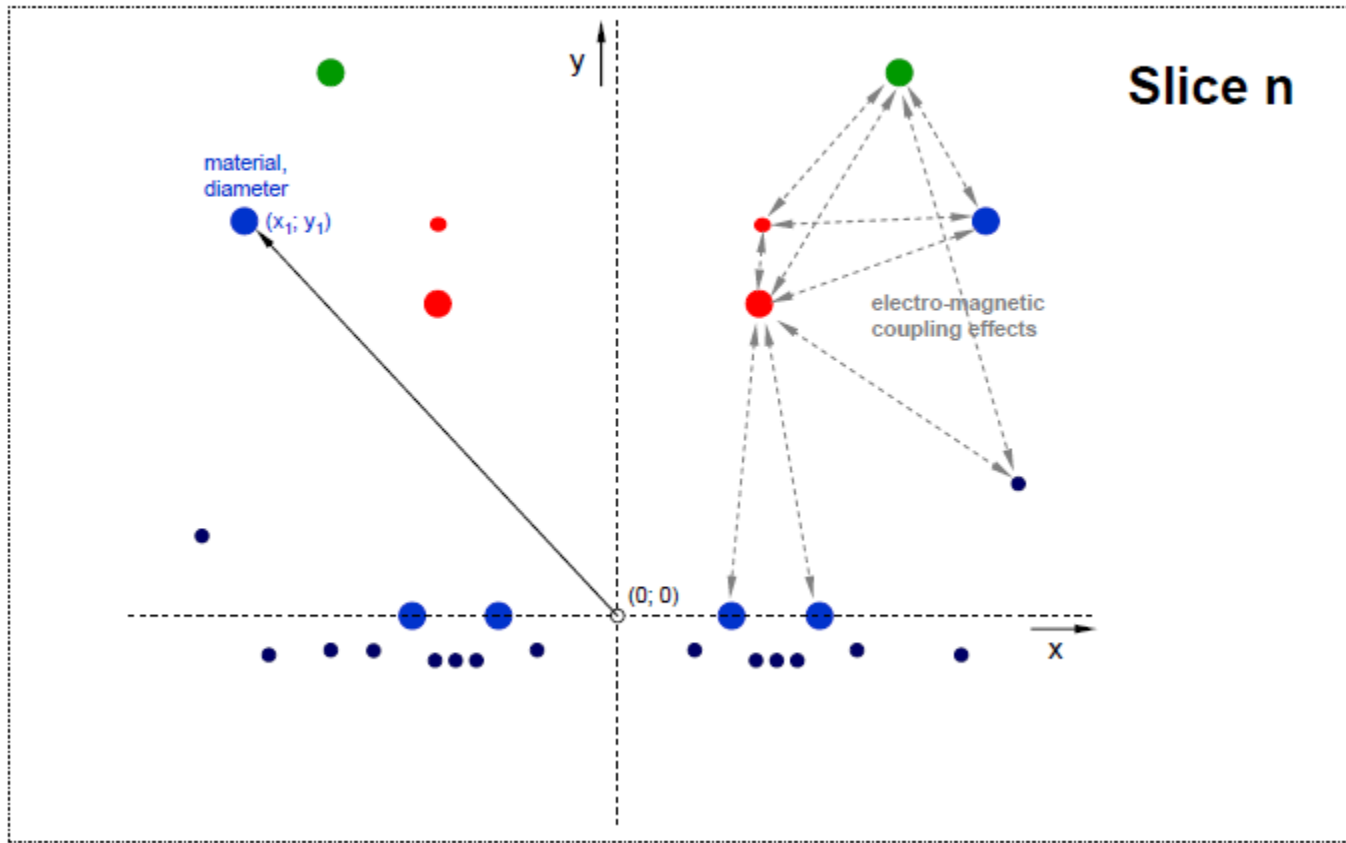
Traction Power Supply Simulation

Catenary Arrangement and Conductor Model



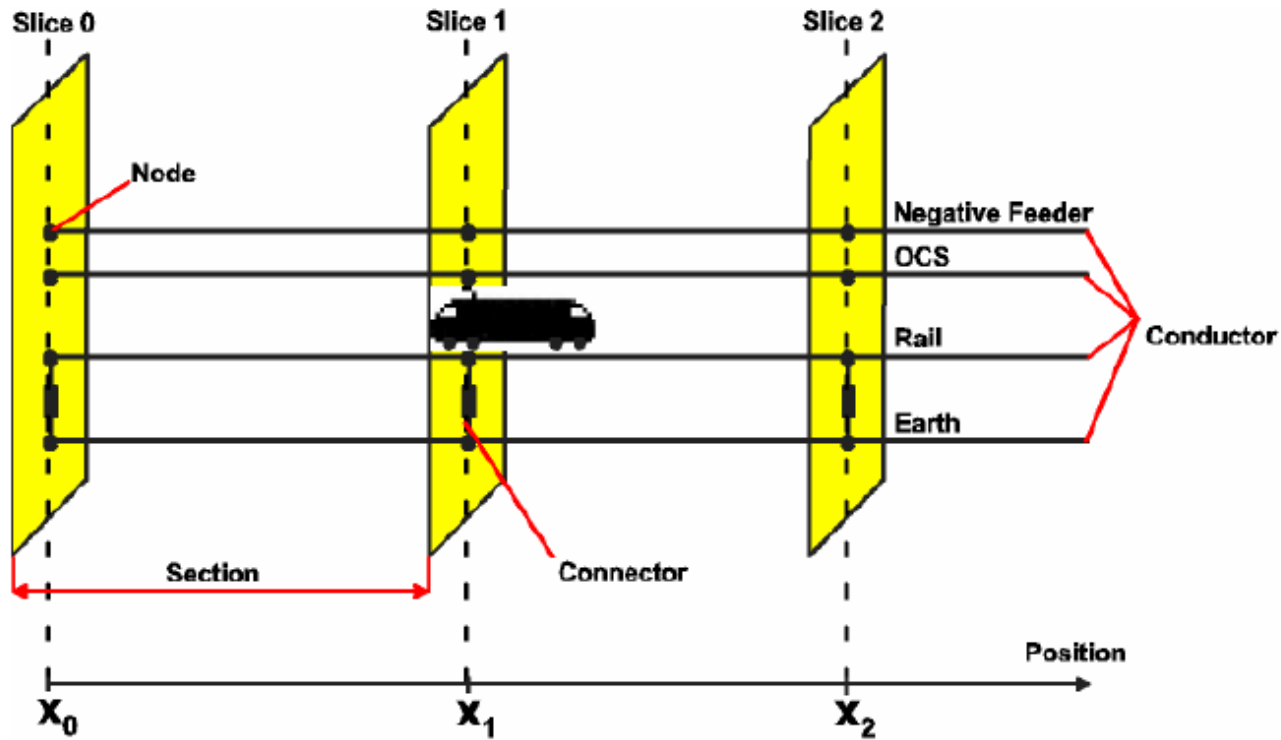
Traction Power Supply Simulation

Catenary Arrangement and Conductor Model



Traction Power Supply Simulation

Sequence of Slices



The logo for OpenPowerNet, featuring a circular arrow icon with red, yellow, and green segments, followed by the text "openPowerNet" in blue and "tool development" in black.

- Developed by IFB Dresden



to work with a commercial rail network simulator.

- Initial deployment on high speed network in the Netherlands
- Then used to simulate the operation of the Zurich tramways and trolley bus system.

 tool development



- License sold to the Fourth Railway Survey and Design Institute in China.
- Used for design verification for High Speed and Metro projects.



Cleveland Line Proof of Concept

- QR required comfort that the power supply simulation would produce data which could be used with confidence for future network design and analysis.
- Proof of Concept involved a series of instrumented single train runs and logging the performance of a traction sub station over five days and comparing the measured results with the simulated results.
- First time this has been done for a 25 kV AC urban rail network.

Cleveland Line Proof of Concept

- Measured voltage at each end and at Lytton Junction substation.
- The energy consumption was measured at the feeding location.

Cleveland Line Proof of Concept



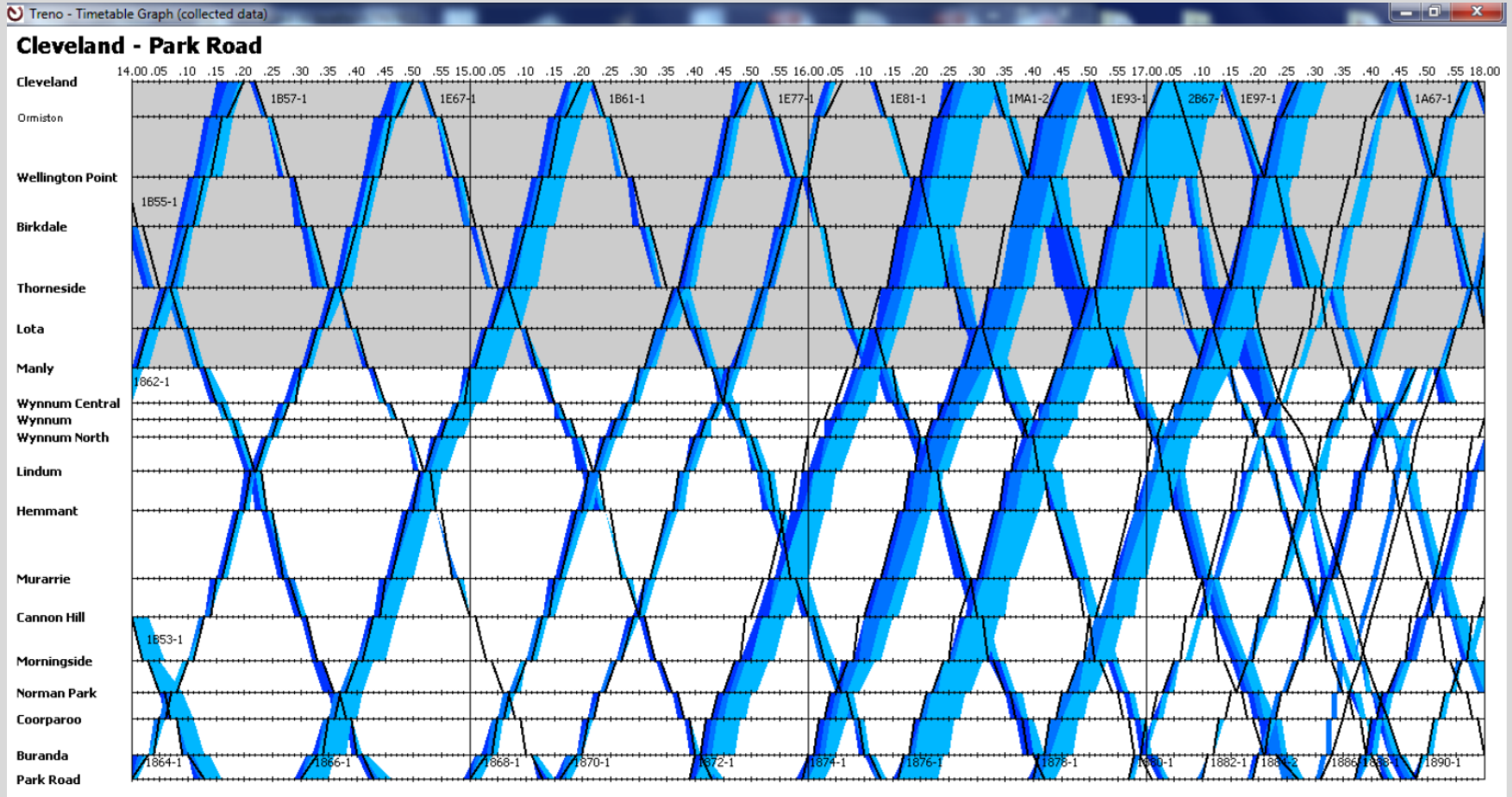
Source: <http://www.queenslandrail.com.au/NetworkServices/DownloadsandRailSystemMaps/SEQ/Pages/ClevelandLine.aspx>

- Part of the Brisbane suburban railway network.
- Runs east from Park Road station on the south of the river for 32 km to Cleveland.
- Line contains single and double sections.
- Fifteen peak hour services every weekday.

Potential Variables

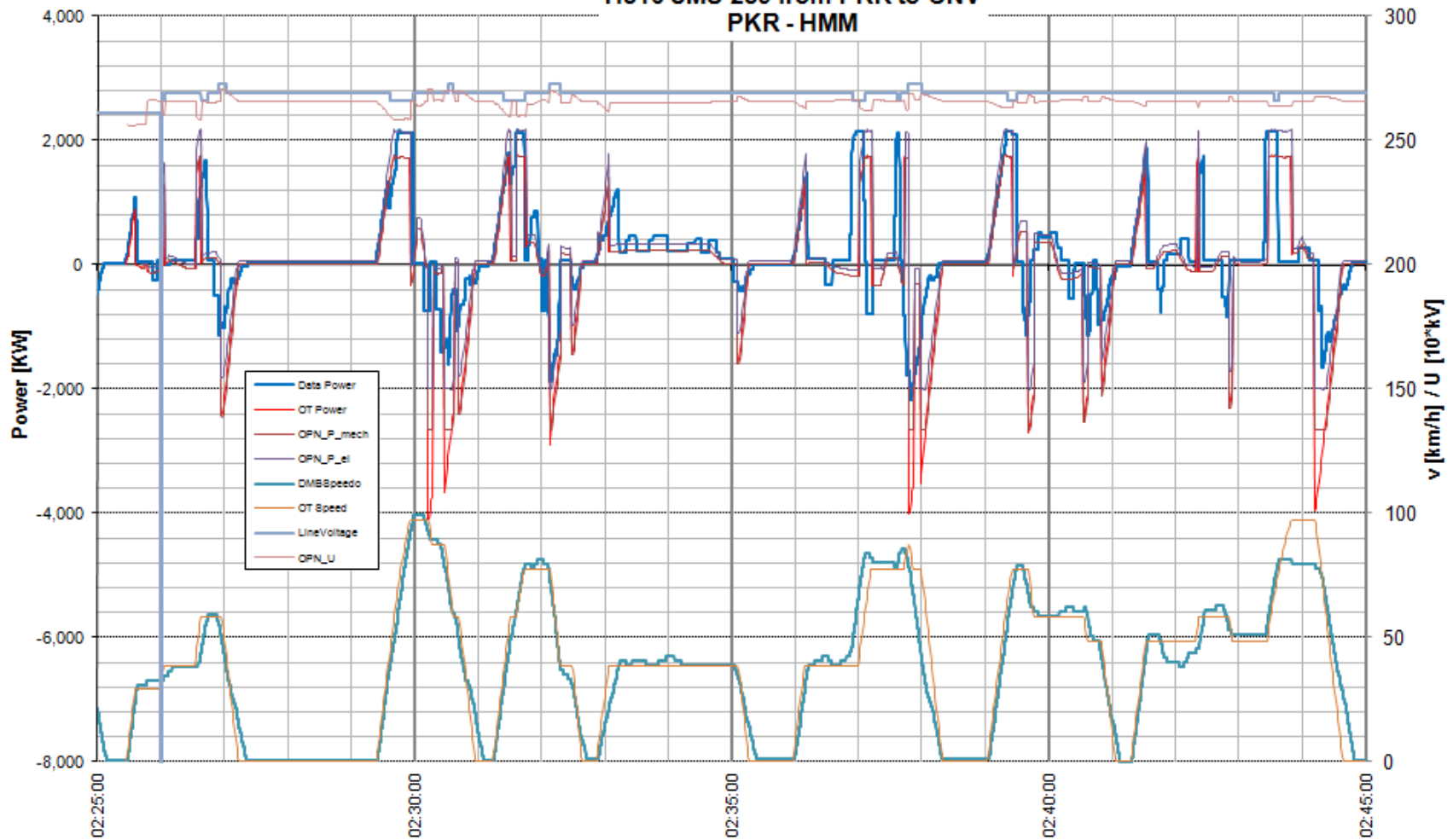
- Driving style.
- Interpretation of running rules and driver's instruction manual.
- Use of different rollingstock types each with different performance characteristics.
- Daily timetable variations.
- System feeding.

Cleveland Line Proof of Concept



Single Train Run Results

H816 SMU 289 from PKR to CNV
PKR - HMM



Single Train Run Results

Issues

- Sometimes the simulation output and measurement are calculating different things.
- The trains position had to be adjusted based on the AWS magnets as the traction / braking systems included controlled wheel slip which reduced odometer accuracy.
- The difficulty in simulating the blended braking is apparent.
- Even with a substantial performance derating, the simulation powers and brakes far harder than the human driver.

Cleveland Line Proof of Concept

- To enable the simulated and measured results to be compared the timetable had to be adjusted to account for actual train running.
- The global performance factor was adjusted to provide an average of how the trains were being driven.

Actual Timetable – Tue 31st Jan

Signal: BS038 - Cleveland

Signal: BS038

Park Road

Buranda

Coorparoo

Norman Park

Morningside

Cannon Hill

Murrarie

Murrarie Turnback

Hemmant

Lindum

Wynnum North

Wynnum

Wynnum Central

Murli

Lota

Thorne side

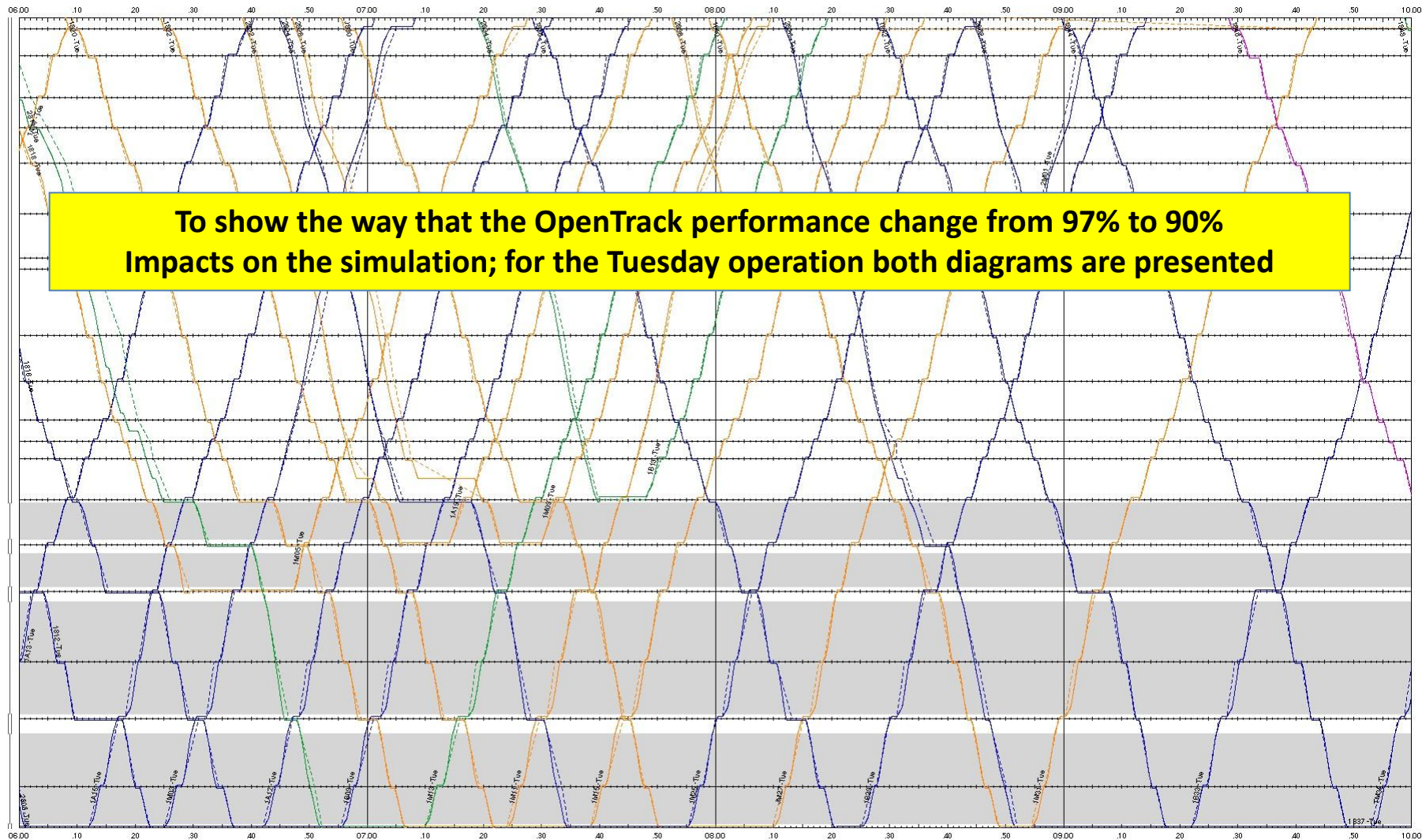
Birkdale

Wellington Point

Omission

Cleveland

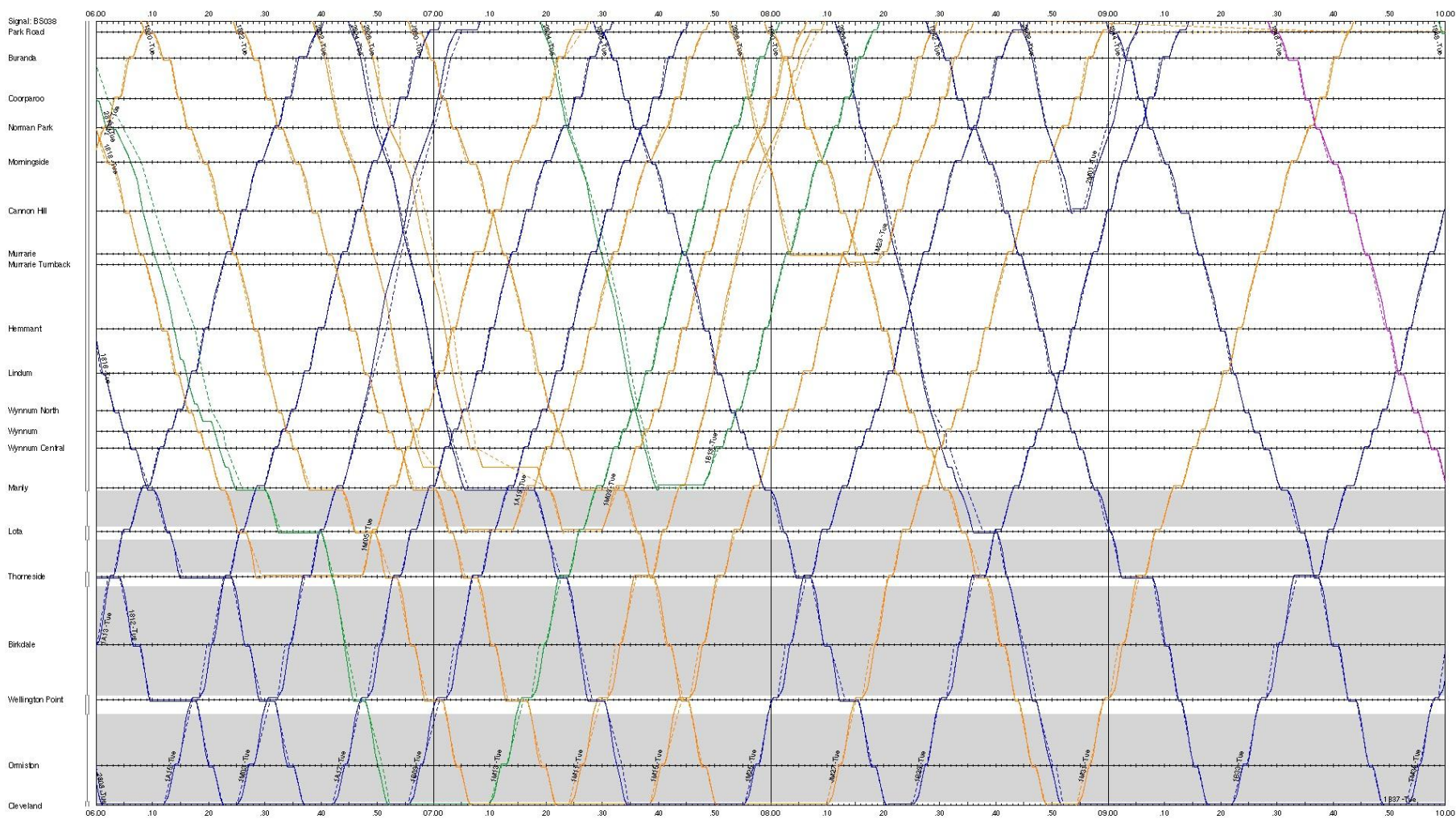
**To show the way that the OpenTrack performance change from 97% to 90%
Impacts on the simulation; for the Tuesday operation both diagrams are presented**



Actual Timetable – Tue 31st Jan

Performance Setting 97%

Signal: BS038 - Cleveland

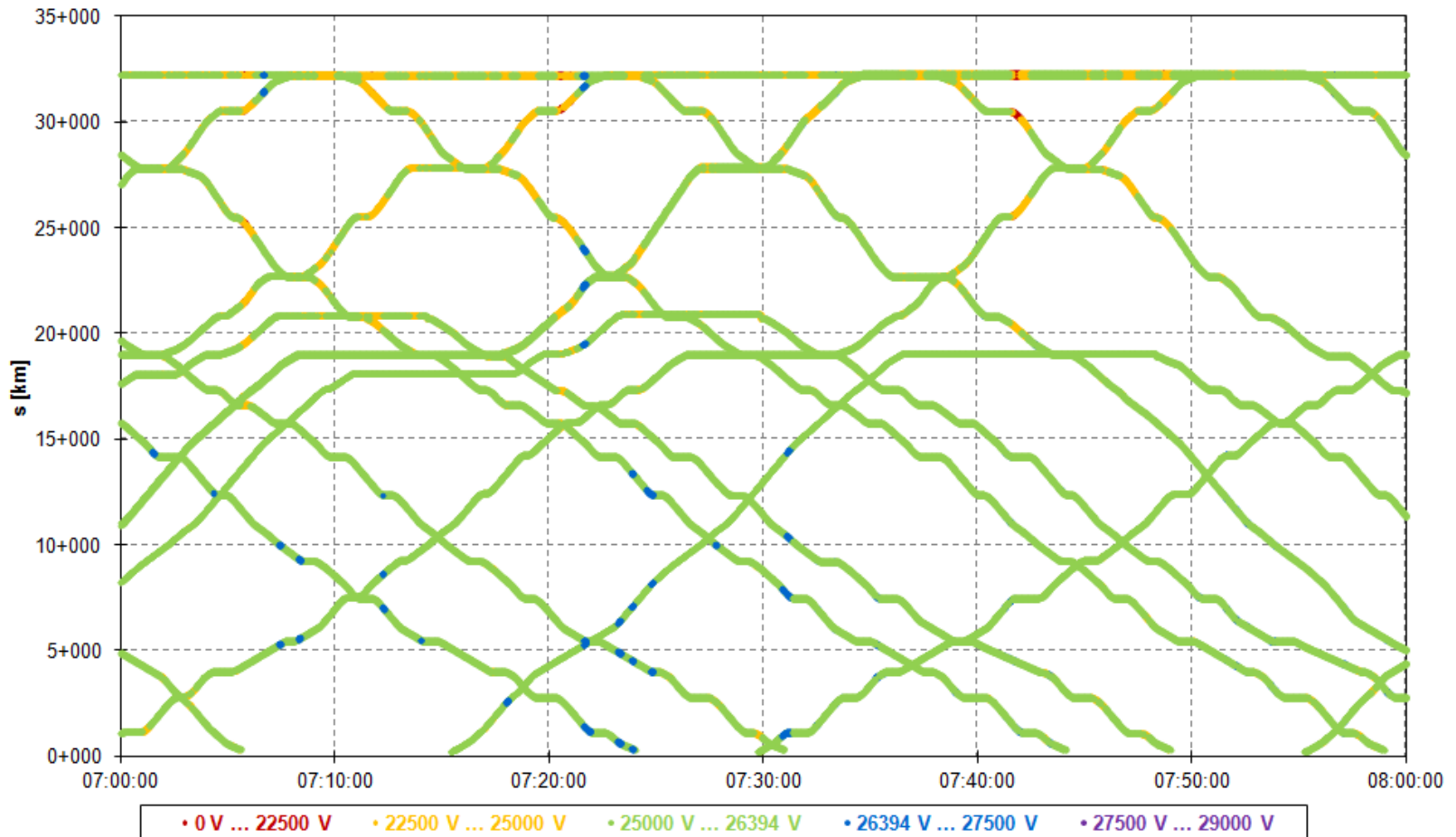


Performance Setting 90%

The graph displays the percentage of time spent in different states for various locations. The x-axis represents time from 06:00 to 10:00, and the y-axis represents the percentage from 0.00 to 100.00. The locations listed on the y-axis are: Signal, Buranda, Coorparoo, Norman Park, Morningside, Cannon Hill, Murrarie, Murrarie Tumbuck, Hemmant, Lindum, Wynnum North, Wynnum, Wynnum Central, Murrily, Lota, Thorneside, Birkdale, Wellington Point, Ormiston, and Cleveland. The graph shows multiple lines for each location, with labels such as 'top' and 'bottom' indicating the states. The lines are color-coded: blue for 'top' and orange for 'bottom'. The graph is divided into three main sections: a top section (Signal to Wynnum Central), a middle section (Murrily to Wellington Point), and a bottom section (Ormiston to Cleveland). The top section shows a high percentage of time spent in the 'top' state, while the middle and bottom sections show a high percentage of time spent in the 'bottom' state. The graph is a complex visualization of the data, with many lines and labels.

Network Simulation Results

**Train Graph with indicated Pantograph Voltage
monday peak (AdAd421Afe000)**



Results

- Extremely good correlation between single train simulations and measured values.
- The morning peak simulations were within the acceptance criteria.
- The results illustrated a very different electrical performance of assets at each end of the line.

For further details please see:

<http://www.openpowernet.de>

http://www.opentrack.ch/opentrack/opentrack_e/opentrack_e.html

<http://www.plateway.com.au/>