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Queensland Rail's proof of concept for OpenPowerNet

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Queensland Rail's proof of concept for OpenPowerNet

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Queensland Rail is the Brisbane City network operator and conducted a prove of concept for the railway power supply simulation tool OpenPowerNet. OpenPowerNet runs in co-simulation with the railway operation simulator OpenTrack. The average total energy consumption deviation was with 6.1 % well in the accepted range and made Queensland Rail confident to order multiple licenses of the simulation tools.

QUEENSLAND RAIL – MACHBARKEITSSTUDIE FÜR OpenPowerNet
Queensland Rail veranlasste eine Machbarkeitsstudie für das Simulationsprogramm OpenPowerNet zur Bahnenergieversorgungsberechnung. OpenPowerNet läuft in einer Co-Simulation mit dem Betriebssimulator OpenTrack. Die Abweichung des durchschnittlichen Energieverbrauchs war mit 6,1 % deutlich im akzeptierten Bereich und veranlasste Queensland Rail mehrere Lizenzen der Simulationsprogramme zu bestellen.

ETUDE DE FAISABILITÉ DE QUEENSLAND RAIL POUR OpenPowerNet
Queensland Rail, l'opérateur du réseau ferré à Brisbane, a mené une étude de faisabilité pour le programme de simulation OpenPowerNet qui calcule l'alimentation électrique du réseau. OpenPowerNet fonctionne en co-simulation avec le simulateur d'exploitation OpenTrack. Avec 6,1 %, l'écart avec la consommation d'énergie moyenne était dans la fourchette acceptable. Ce résultat qui a incité Queensland Rail à commander plusieurs licences des programmes de simulation.

1 Queensland Rail

In 1976, construction commenced on an ambitious 25 kV AC system which would eventually provide electric suburban, interurban and freight services over the most extensive electrified system in Australia.

The first electric trains operated from Mitchelton to Darra in 1979. From this first service the system has been expanded with extensions and new lines to the network that exists today.

Today, Queensland Rail operates 201 3 car Electric Multiple Unit train sets on the City network, see Figure 1. The network covers the Brisbane suburban area with 145 stations. Services transported 55 million passengers in the 2010/2011 fiscal year.

The City network is radial. Through services from the North operate via the city centre to the Western, Southern and South Eastern suburbs and vice versa. The major stabling centre for City network services is on the northern city centre periphery at Mayne with limited outlying stabling areas towards the network extremities.

2 The simulation tool OpenPowerNet

The power supply performance software tool OpenPowerNet [1] was developed by the Institute for Railway Technology Dresden (IFB Dresden) to simulate rail network performance in conjunction with the OpenTrack [2] rail network simulator developed by OpenTrack Technology GmbH of Zurich Switzerland. Plateway Pty. Limited is the Australasian distributor of both products.

The operational simulation is done by OpenTrack in co-simulation with OpenPowerNet. OpenPowerNet has a retroactive effect to OpenTrack, see Figure 2.

OpenPowerNet is designed to calculate:
- electrical load flow of DC, 1 AC and 2 AC railway power supply systems
- electromagnetic coupling due to conductor arrangement and current [3]
- energy balance considering recovery and station as well as vehicle energy storages
- load analysis of equipment
- touch voltage
- electromagnetic field
- short circuit currents

3 Proof of Concept Setup

The proof of concept was designed to validate the simulation software OpenPowerNet and to verify the model configuration. The test was conducted in close cooperation between Queensland Rail pro-

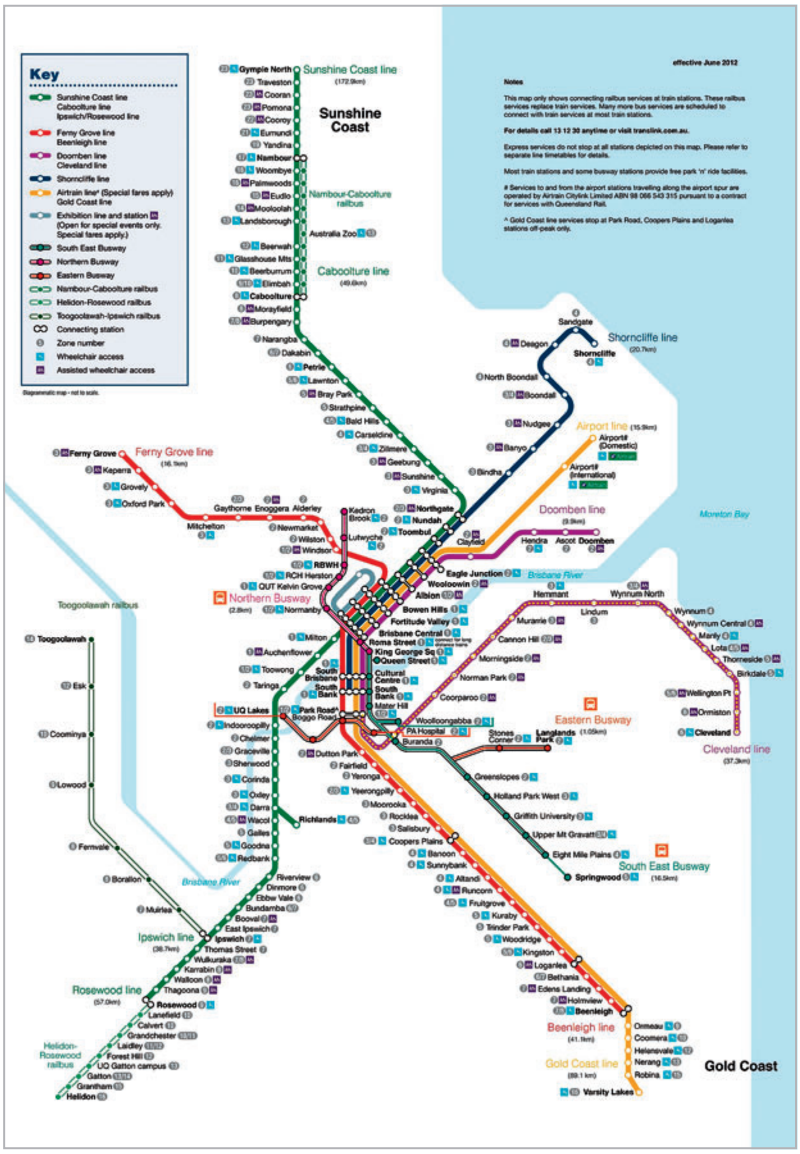

Figure 1:
Queensland Rail City network with Cleveland line, the simulation scope is marked with a yellow dotted line [4].

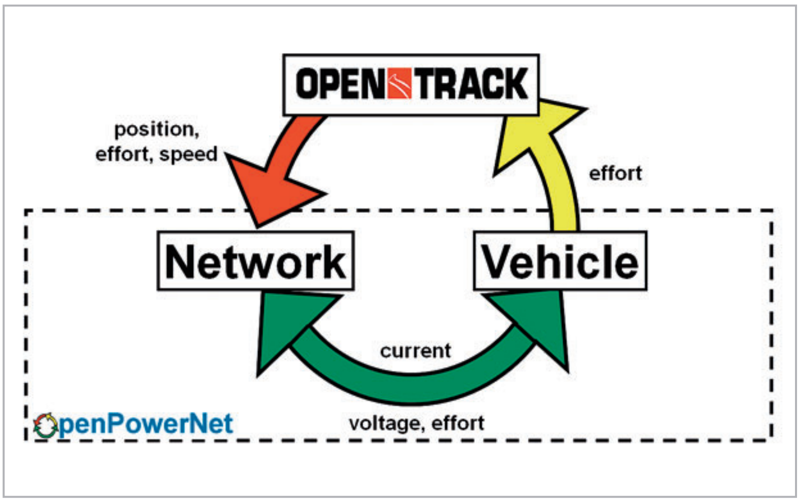

Figure 2:
The co-simulation of OpenTrack and OpenPowerNet.

viding input data and measurements, Plateway Ltd. creating the OpenTrack model and IFB Dresden preparing the OpenPowerNet model.

In the first step, the model would be verified by comparing single train runs to the simulation. A single train run has the advantage to have well defined and known measurement conditions.

The second step was to compare the measured energy consumption for 5 consecutive days of a 4 h morning peak period with the simulation. The pass fail criteria were defined by Queensland Rail as a maximum 10 % deviation between measurement and simulation. The simulation should be performed not knowing the measurements to have an impartial evaluation.

The Cleveland line was chosen, as this line is typical for Brisbane's commuter network. The test section was from Park Road to Cleveland. The line is feed from Lytton Junction transformer station. The station has two transformers, each feeding in separate directions, see Figure 3.

The traction power supply system is 1 AC 25 kV 50 Hz utilising 18 booster transformers to reduce stray currents. The total line length is 32 km with a 19 km double track section and an 11 km single track section.

4 Modelling

The first step was to assess the existing data and to compare this data as far as possible with the installation on site. For instance the existence and location of all booster transformers, connections from return wire to rails, signal locations and speed indicators.

After assessment the modelling was straight forward using the following main input parameter:

- track gradients, curves, line speed limit
- turnout location
- stations and platform
- traction effort
- maximum deceleration
- vehicle mass, length
- auxiliary power
- vehicle efficiency of the traction power system
- traction power and booster transformers
- resistance and cross section configuration layout of all conductors

The vehicle mass was considered particularly as the passenger load changes from station to station. Evaluation of the ridership proved a steady weight of passenger rise from Cleveland to Park Road, see Figure 4. This was modelled by trains having different payload. As the current OpenTrack version allows to change the payload at each station it would have been easier today.

As the timetable has a time reserve, especially at the single track section, this needed to be considered. An overall performance factor of 90% and a separate performance factor of 80% at the single line section considered the time reserve. The performance factor reduces the utilised traction power and maximum travel speed.

The modelling of the timetable includes 42 courses for each 4 h morning peak. As Queensland Rail has seven different vehicles types and the type allocation to courses varies every day it was necessary to prepare a separate timetable for each day.

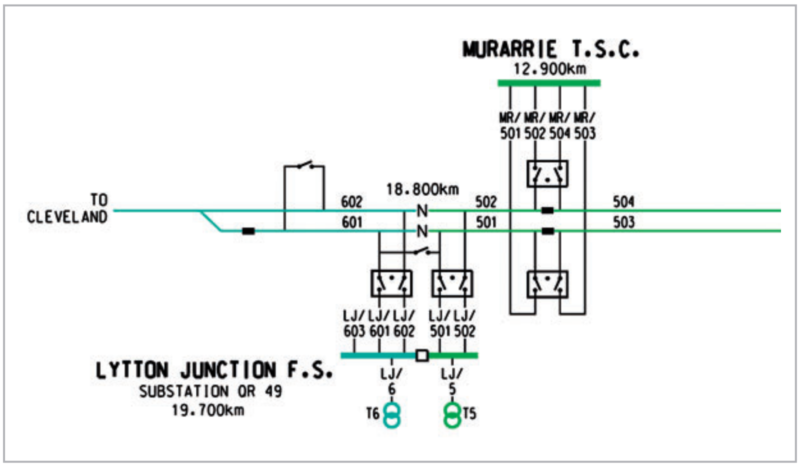

Figure 3:
Cleveland Line sectioning diagram.

5 Calibration

The calibration run took place early morning January 30th and January 31st 2012. The runs included express runs and all stations runs according to the timetable. Acceleration runs at both ends of the test section on both tracks were also carried out. All measurements were compared to simulations. Comparing the voltage drop during acceleration at the end of the lines allowed the verification of the electrical network model.

The measurements at the train were the basis to verify the total efficiency, maximum acceleration and auxiliary power consumption of the train. This was an important step as the existing vehicle data has been not very detailed. Figure 5 shows the very good congruence of the measured and simulated values. It also shows the significant influence of the driving behaviour as the congruence is only good where the measured and simulated speed respective acceleration is the same.

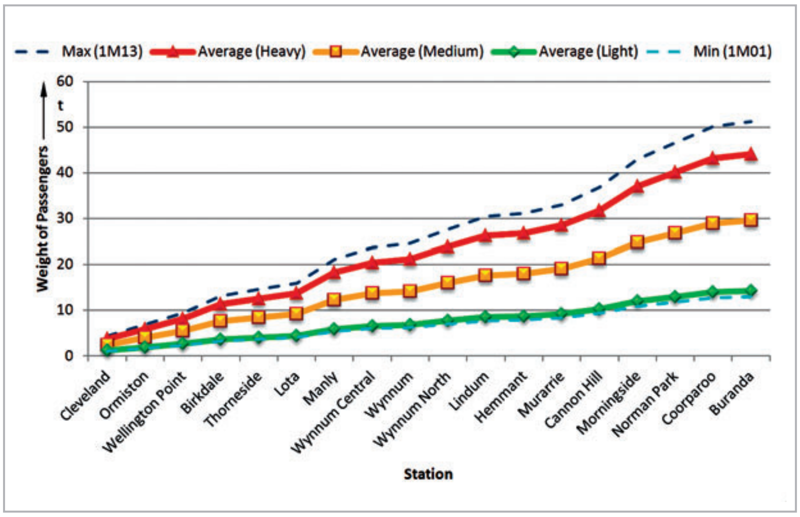

Figure 4:
Cumulative passenger weight of the Cleveland line.

6 Simulation and results

A simulation per day was done in about one hour plus half hour to run the automatic analysis. The consideration of timetable reserve and used performance factor gives a good congruence between planned and simulated timetable, see Figure 6.

Beside the consumed energy a number of other simulation results are available. These are minimum pantograph voltage, traction and booster transformer load, feeder load etc., see Figure 7 to Figure 10.

The total energy consumption per day has been presented to Queensland Rail and compared to the measurements. These results showed that OpenPowerNet was able to simulate the actual energy consumption within the required accuracy of 10% for the 5 day average as well as for each individual day, see Figure 11.

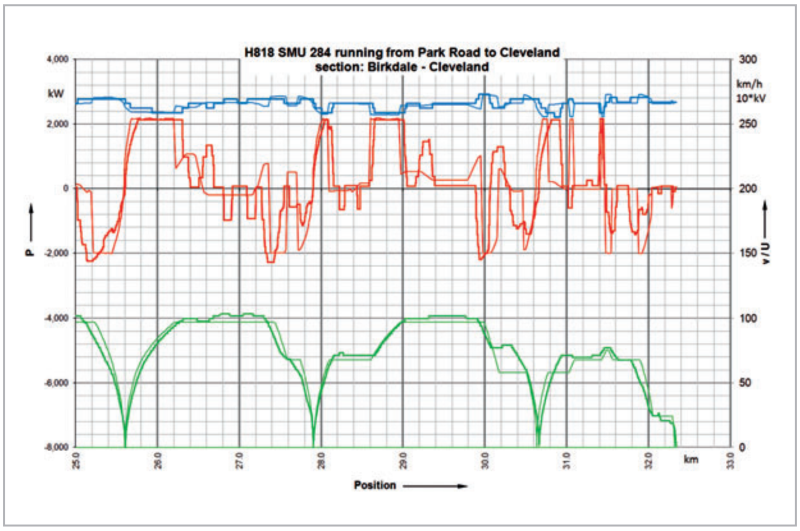

Figure 5:
Calibration run H818 from Park Road to Cleveland at section from Manly to Cleveland.

thick curves	*measurements*	red	*electrical power*
thin curves	*simulation*	green	*speed*
blue	*voltage*		

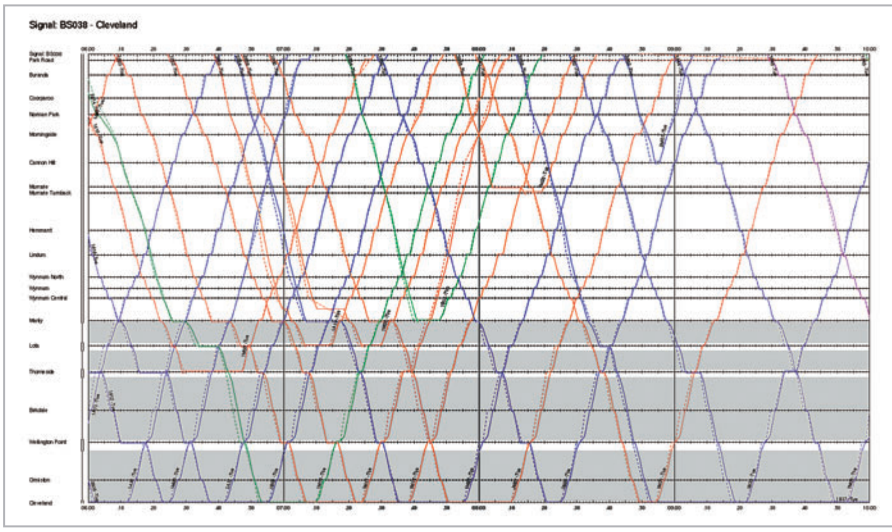

Figure 6:
The Tuesday morning peak timetable.
dashed *planned time*
solid *simulated time*
green *6 Car EMU 6 motor (no recovery)*
orange *6 Car EMU 8 motor (no recovery)*
blue *6 Car SMU/IMU (with recovery)*
pink *6 Car Hybrid EMU 6 & 8 motor (no recovery)*

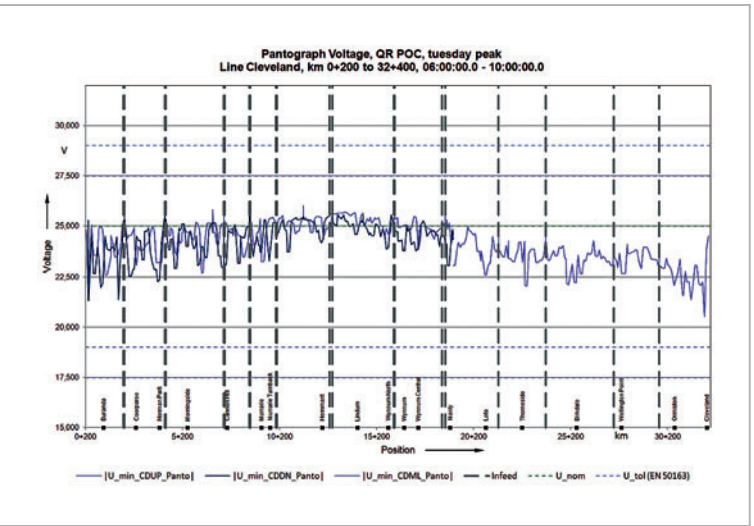

Figure 7:
Minimum pantograph voltage of the Tuesday morning peak from 6 am to 10 am at the Cleveland line.

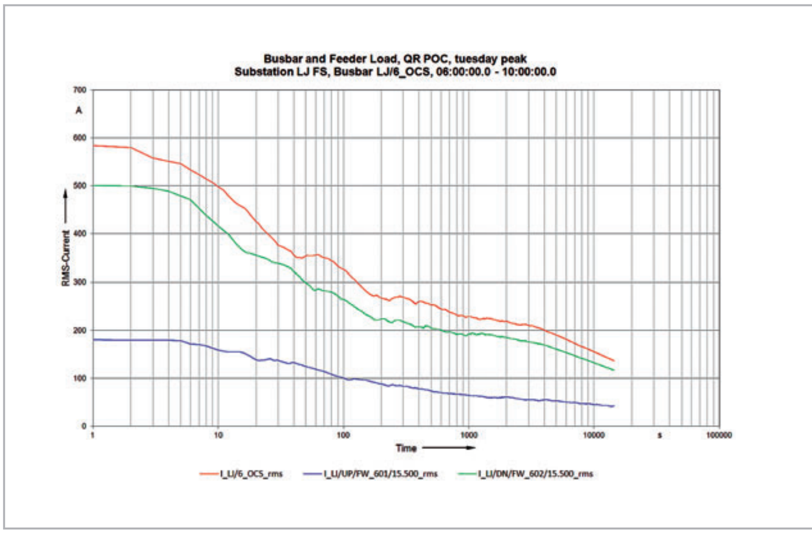

Figure 8:
Busbar and feeder load of the Lytton Junction substation as time rated load periods curve.

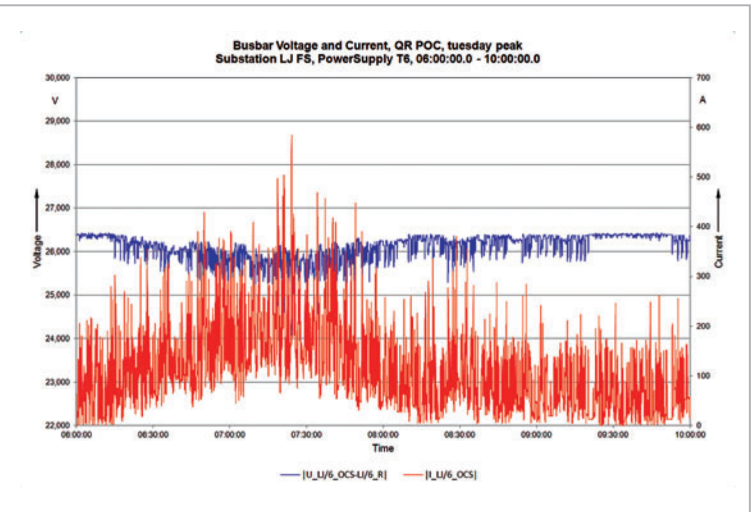

Figure 9:
The busbar voltage and current versus time of the Lytton Junction substation.

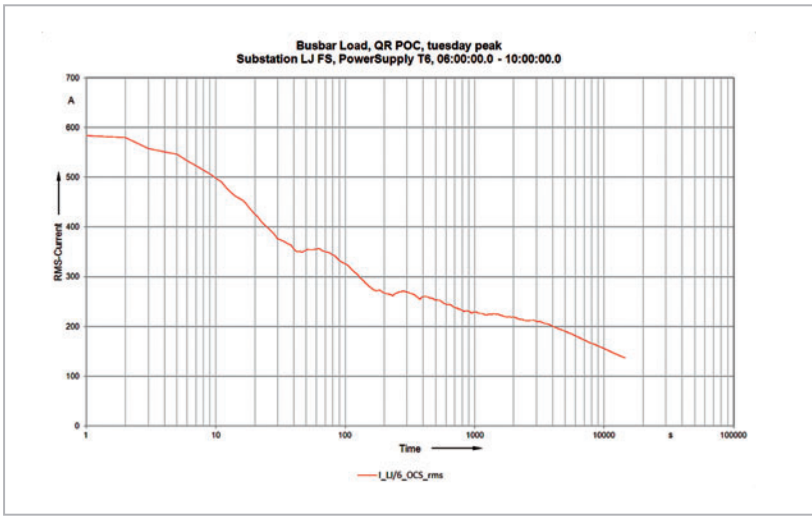

Figure 10:
The busbar current of the Lytton Junction feeder as time rated load periods curve.

After cross checking the measurements to the simulation a glitch in the model could be detected. It was then obvious that the auxiliary power consumption of the courses waiting at the terminus in Cleveland has been much lower than expected. According to the timetable there is always one train stabling in Cleveland. Additional simulations considered this effect and result in an even better congruence between the measurements and the simulations, see Figure 12.

References + Links

[1] http://www.openpowernet.de

[2] http://www.opentrack.ch

[3] *Lehmann, M.*; *Neumann, H.*: Network calculation with method of node potentials and consideration of electromagnetic coupling. Elektrische Bahnen 106 (2008), H. 8-9, S. 416–420.

[4] TRANSLink website: http://translink.com.au/resources/travel-information/network-information/maps/120618-busway-and-train-network.jpg

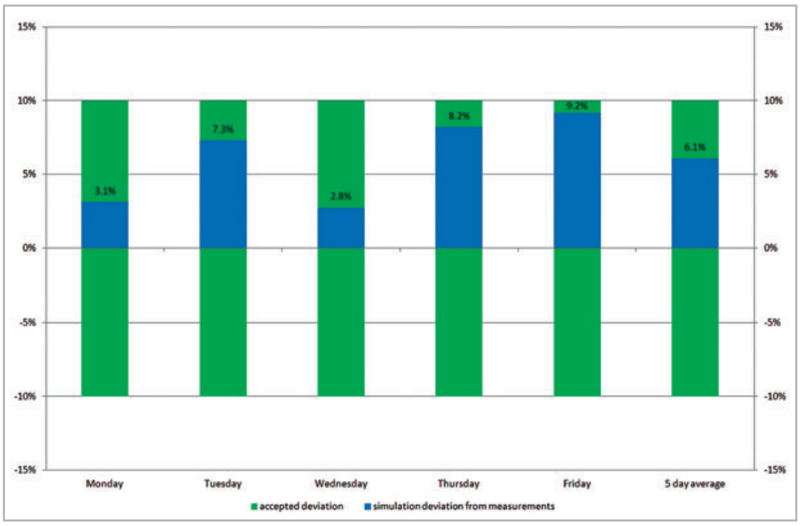

Figure 11:
Deviations of simulated energy consumption to measurements at Lytton Junction Feeding Station from 30.01.2012 to 03.02.2012 at morning peak 6 am to 10 am, Cleveland to Park Road for the proof of concept.

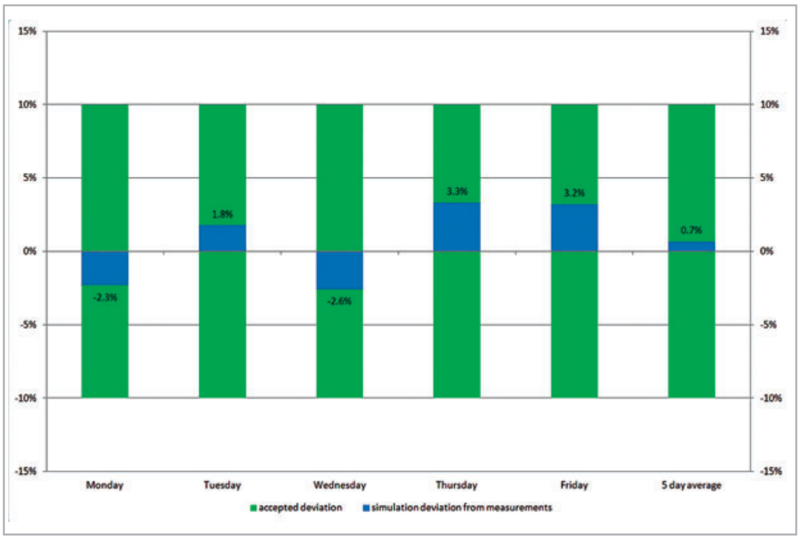

Figure 12:
Deviations of simulated energy consumption to measurements at Lytton Junction Feeding Station from 30.01.2012 to 03.02.2012 at morning peak 6 am to 10 am, Cleveland to Park Road considering the lower auxiliary power at Cleveland terminus.

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