Multi-conductor Train Simulations for Electrification System
Design, Implement, Application

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Background

**Original MTS**
From 1970’s to 1990’s, MTS developed and written in Fortran by University of Birmingham, used for research and studies.

**DC MTS**
From 2000’s, Atkins got involved in further developing MTS with DC energy consumption calculation.

**DC&AC MTSAC**
From 2010’s, Atkins further developed MTS with detailed AC network modelling capability, and graphic user interface.
It is funded by Atkins and Knowledge Transfer Partnership (KTP).
AC (Classic) & DC Railways

400kV GRID

Grid Site

Feeder Station

Overhead Contact System

Train

SGT Y-B

Earth Wire

66/132kV GRID

Grid Site

Sub Station

Overhead Contact System

Train

1000V 3 phase

0.75/1.5/3 kV d.c.
AC Railways: typical feeding
AC Railway: Booster Transformer and RCs

Grid Site Sub Station
Track Side Feeder Station
Booster Transformer
Mid Point Connector
Overhead line

Steel Work Railway Fencing
Telecommunications Cables
Armour of Cables or Metal Pipes

Earthed Screening Conductor
AC railways: AT feeding arrangement

Grid Substation
Double Winding Transformer
Secondary 2x25 kV

400 kV 50Hz

Sub Station
Earth mat

Autotransformer
2x 25kV

200A
210A

10A
90A

20A
200A

10A
90A

20A
200A

10A
90A

20A
200A

10A
90A

20A
200A

10A
90A

20A
200A

10A
90A

20A
200A

10A
90A

-25 kV Auxiliary Feeder Wire

25kV Catenary and Contact Wire

-25 kV Auxiliary Feeder Wire

Return Earthed Bonded Running Rails
DC Traction Feeding Arrangement

33/11kV Supply

Power Transformer

Circuit Breaker Normally Closed

Rectifier Unit

Isolator Normally Open

Insulated Overlap or Sectioning Gap
AC Railway - MTS Modelling and Design

Twin track rail return

25kV 6kA Classic Railway Return Current Bonding Principles
AEW switched in OR out; Single OR Double Rail

Overhead Contact Wire

Return Conductor

Aerial Earth Wire

Rail Leakage and Masts Foundations

Track 1

Track 2

Overhead Contact Wire

~800m typical

~800m typical

~800m typical

OHL masts

OHL masts

OHL masts

Rail Leakage and Masts Foundations
AC Railway - MTS Modelling and Design

Twin track BT arrangement

25kV 6kA Classic Railway Return Current Bonding Principles
Single or Double Rail return

Overhead Contact Wire

Return Conductor

Track 1
Rail Leakage & Mast Foundations

~300m typical

OHL masts

Rail Leakage & Mast Foundations

Track 2

OHL masts

Return Conductor

Overhead Contact Wire

Communications cable (this may vary typically 1-10km)
Screening Conductor (same length as the OHE)

4 ohm-km

500m
AC Railway - MTS Modelling and Design

Twin track AT arrangement
Electrified DC Railway Issues

Protection for Civil Structures from Corrosion

• EN 50122-2 Railway Applications - Fixed Installations Electrical safety, earthing, and bonding- part 2
  • provisions against the effects of stray currents caused by d.c. traction systems;

• EN 50163 Protection against corrosion by stray current from direct current systems applications
Electrified AC&DC Railway Issues

Protection for Humans

Rail potentials Touch Accessible Potentials (AC&DC)
- EN 50122-1, IEC 62128-1 Railway applications — Fixed installations — Part 1: Protective provisions relating to electrical safety and earthing;
- EN 61140 Protection against electric shock — Common aspects for installation and equipment

Induced Voltages (AC)
- ITU-T Directive Vol VI Protection of telecommunications lines against harmful effects from electric power and electrified railway lines
- Danger, Damage and Disturbance.
- ITU-T Directive Vol II Protection of telecommunications lines against harmful effects from electric power and electrified railway lines; calculating induced voltage and currents in practical cases.
Rolling Stock Issues

Operational Requirements
• EN 50388 Railway applications. Power supply and rolling stock. Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability
• EN 50163 Railway applications – Supply voltages of traction systems

On Board Train Monitoring
• EN 50463-1 Railway Applications Energy measurement on board trains Part 1 General (GEL/9/X_11_0023 )
• EN 50463-2 Railway Applications Energy measurement on board trains Part 2 Energy measuring (GEL/9/X_11_0024 )
• EN 50463-3 Railway Applications Energy measurement on board trains Part 3 Data Handling (GEL/9/X_11_0025 )
• EN 50463-4 Railway Applications Energy measurement on board trains Part 4 Communication (GEL/9/X_11_0026 )
• EN 50463-5 Railway Applications Energy measurement on board trains Part 5 Conformity Assessment (GEL/9/X_11_0027 )
Aim and objectives

To develop Multi Trains Simulation (MTS) for electrification system.

The simulation involves:

- Trains
- Network
  - Train movement network
  - Signalling network
  - Power network
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Power network modelling

• Rolling Stock
  • Typical and future AC traction
  • Regenerative, Braking, Coasting

• Single Train in lumped conductor model

• Multi trains in lumped conductor model (other simulators)

• Trains in semi-lumped conduct model (MTS)

• Trains in multi-conduct model (MTS)
  • Bonding arrangement
  • BT arrangement
  • AT arrangement
MTS Design

- Operational
  - Selectable signalling systems and driving controllers;
  - Optimisation of energy consumption, carbon reduction, coasting etc;
  - Electrification System including regeneration,

- Post processing
  - Energy consumption analysis – including optimisation algorithms.
  - System losses;
  - Carbon Calculation of operating train timetable.
  - Human safety;
  - Rail and accessible potentials
  - Induction and Magnetic Fields;
  - Induced voltage calculation
  - Stray current and total charge

- Output display
  - GUI (graphic user interface)
Object Oriented Modelling Design

Top down
Object Oriented Operational Implementation

Bottom Up
AC Railway - MTS validation

**BT Arrangement**

- AAAB
- BABB

- BT1
- BT4: 1.6km

- BT2
- BT5: 4.8km

- BT3
- BT6: 8km

- AC
- BC: 9.6km

**Settings:**

- Rail Return + Booster Return
- Booster at 1.6km, 4.8km, 8km
- Rail-to-Rail bond spacing: 320m
- Cross bond spacing: 1220m
AC Railway - MTS Application

Modelling traction power system – from Wolverton to Rugby

82.632km 94.103km 101.369km 111.578km 118.336km 128.89km 132.6-133km 134.85km

Wolverton Patford Bridge Rugby
AC Railway - MTS Application

Train speed / line speed

Substation powers [kW]

Loss [kW]

Loss [%]
MTS applications 2012

- Induction Modelling for RR, Classic and AT arrangements
  - Atkins Design House

- Power Efficiency Modelling of RR, Classic and AT Arrangements
  - Atkins Internal design House
  - Network Rail
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Conclusion and Future development

MTS- Multi Train Simulator

- Multi-Conductor modelling
  - energy computation analysis, rail potential, induced voltage, EMC issue etc.
- Object oriented design
  - modelling update and development
- This work has been graded as an A ‘outstanding’ KTP project by the Technology Strategy Board (TSB).

Further Software development

- Simple GUI
  - for instant 2/4 track electrified railway modelling and research.
- Infrastructure Converters
  - Convert existing input files into MTS Format
- Electrification System Design for AC and DC systems
Thank You

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Plan Design Enable