Comparison of Stray Currents and Rail Voltage Profiles Between 750 VDC and 1500 VDC Power Supply Systems Using Simulation

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Plan

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- Modelling Stray Currents and Rail Voltages
- Basic Tests (Single line–single train)
- A Case Study: Üsküdar – Ümraniye Line
- Summary

Motivation

- ✓ Stray currents may have adverse effects on rail transit systems.
- ✓ ➔ CORROSION
- ✓ ➔ DECREASE IN EFFICIENCY
- ✓ Reducing the stray currents usually results in higher touch potentials.
- ✓ ➔ SAFETY PROBLEMS

Motivation (Earthing Strategies)

Earthing Strategies Used in Practical Systems

1. **Directly Connected Earth**
2. **Diode Earth**
3. **Totally Floating Earth**
4. **Earth with Rail Potential Control Devices (RPCD)**

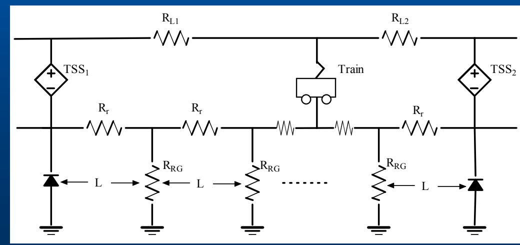
Motivation (Power Supply Systems)

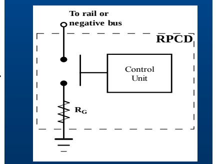
Effect of Different Power Supply Systems on Stray Currents and Rail Potentials

- When 1500V is used in power traction system instead of 750V, the current flowing in the return conductors will be smaller.
- **➔ Smaller Stray Currents**
- **➔ Smaller Rail Potentials**
- Use of 1500V instead of 750V usually means an increase between the substations.
- **➔ Higher Stray Currents**
- **➔ Higher Rail Potentials**

Modelling

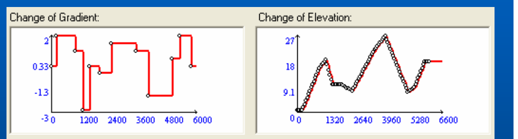
- **In computer simulations, conductivity between rails and the ground can be modelled by dividing the rails into small segments (called cells), and for each cell representing the conductivity by a resistance connected at a single point (R_{RG}).**

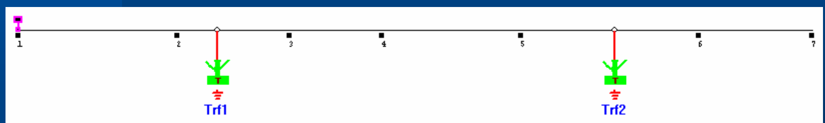




Basic Tests

- **Simulation Setup:**
  - **Single Line (6km)**
  - **Two Substations**
  - **Single Train**
  - **7 Passanger Stations**

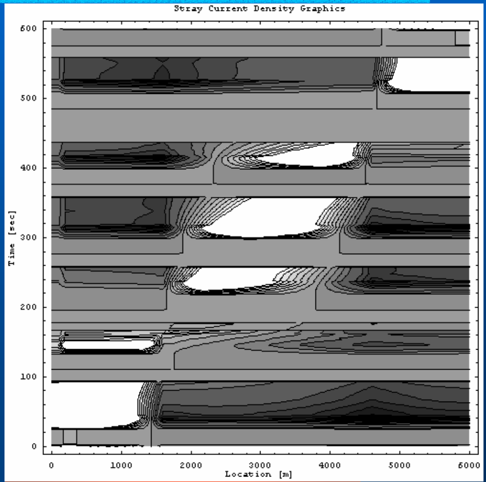




Tests Applied

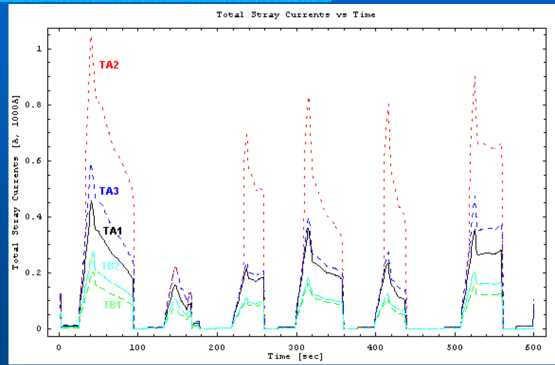
Earthing Strategy	750 VDC Sys.	1500 VDC Sys.
Directly Connected	*TA1*	*TB1*
Diode Earth	*TA2*	*TB2*
Floating Earth	*TA3*	*TB3*

Leakage current density plot



Leakage current density plot for the test run TA1 (Directly connected 750 VDC system). The whiter areas represent leakage from rail to the ground (stray currents), and darker areas represent leakage collection points.

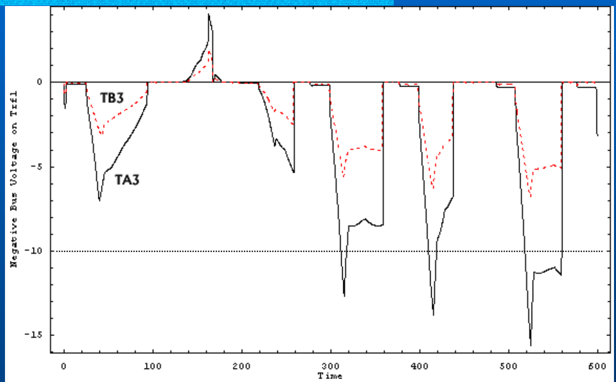
Total Stray Currents vs Time



Total stray currents (currents leaked from the whole line to the ground) vs. time
Connected Earth Tests (TA1 and TB1) are scaled by 10^{-3}

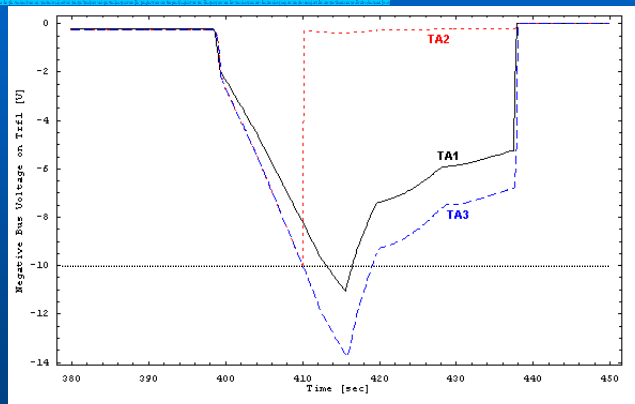
TB3 is exactly same as TB2 (Diode has never been triggered in 1500VDC).

Trigerring the Diode



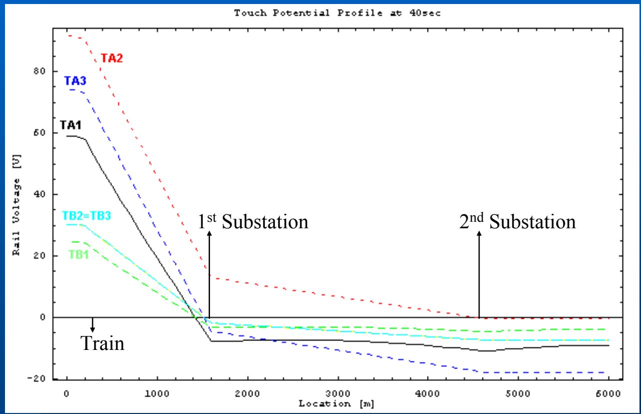
Voltage on negative bus of Trf1 for floating earth systems (TA3 and TB3).

Trigerring the Diode



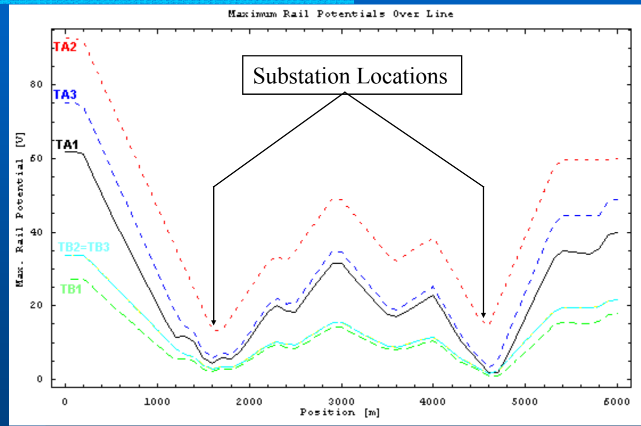
Voltage on negative bus of Trf1 for 750 VDC power supply systems (TA1, TA2 and TA3) between 380 and 450 seconds.

Rail Potential Profile



Train starts moving from the 1st passanger station.

Profile of maximum rail potentials



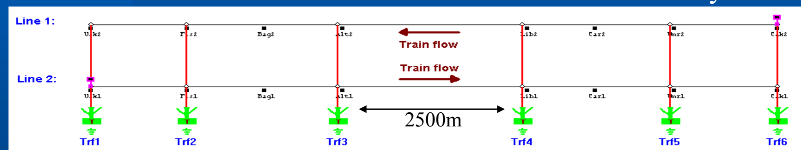
Maximum Rail Voltages

Earthing Strategy	750 VDC Sys.	1500 VDC Sys.
Directly Connected	*61.84V*	*27.35V*
Diode Earth	*93.01V*	*33.71V*
Floating Earth	*75.29V*	*33.71V*

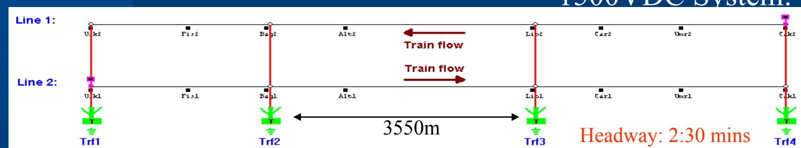
A Case Study: Üsküdar – Ümraniye Line

- Planned to be built by Istanbul Municipality.
  - Two parallel lines (9300m)
  - 8 passanger stations

750VDC System:

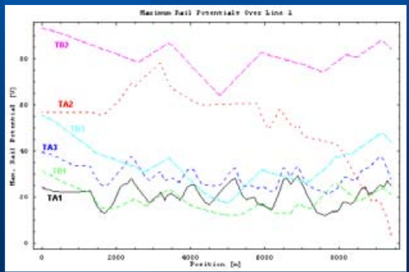


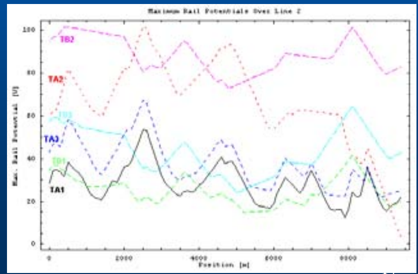
1500VDC System:



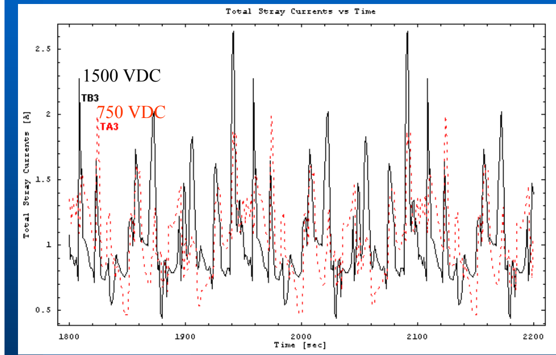
Maximum Rail Potentials

Earthing Strategy	750 VDC Sys.	1500 VDC Sys.
Directly Connected	*56.08 V*	*41.55 V*
Diode Earth	*104.08 V*	*103.04 V*
Floating Earth	*69.65 V*	*64.93 V*





Total Stray Currents vs Time



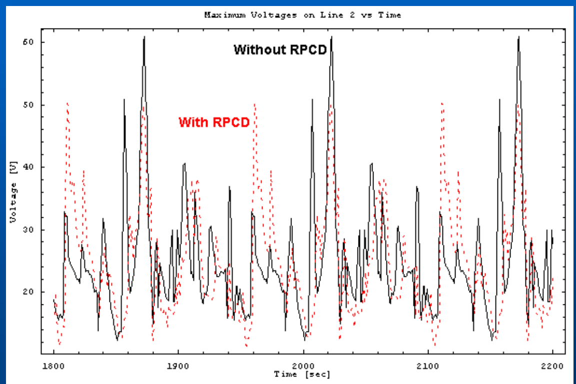
Average value:

1.01 A (for 1500 VDC Sys.)

1.02 A (for 750 VDC Sys.)

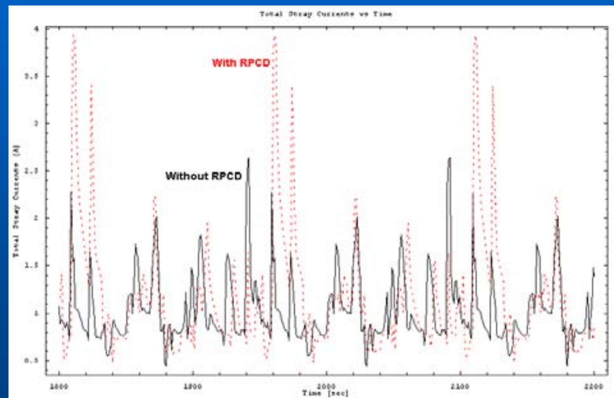
Total stray currents between 30:00 minutes and 36:40 minutes for floating earth strategies used in 750 VDC and 1500 VDC systems.

Use of RPCDs



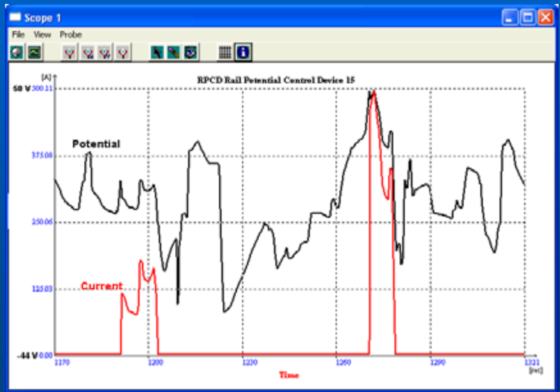
Maximum rail voltages on Line 2 vs. time for totally floating earth schemes for 1500 VDC power supply schemes with and without using RPCDs.

Use of RPCDs



Total stray currents vs. time for totally floating earth schemes for 1500 VDC power supply schemes with and without using RPCDs.

Use of RPCDs



Current and voltage observed on the RPCD device placed on a passenger station.

Summary

- **It has been shown by the help of simulation that the levels of rail potentials and stray currents are in favour of 1500 VDC systems even when the distances between the substations are chosen longer.**
- **Directly connected earth results in very high stray currents with reasonably low rail voltages, as already noted in literature.**
- **Floating earth, on the other hand, means low stray currents in exchange of a rise in rail voltages.**
- **Diode earth results in quite high rail voltages and stray currents in comparison to floating earth.**

Future Work

Possible future work includes the following:

1. The rail potentials and corresponding stray currents of the system might change considerably for different settings of the parameters of RPCDs.
2. Understanding the effects of regenerative braking systems on stray currents.

Thank you for listening!