Concept Design of AC and DC Traction Power Supply System (TPS)
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Head of Rail Electrification Engineering
(RE EN)

• More than 15 years of professional experience in project management of rail electrification projects world-wide

• More than 5 years experience in rail electrification engineering

• **Projects experiences:**
  – BTS Initial Line
  – MRTA Initial Blue Line
  – ARL Airport Rail Link
  – Singapore Down Town Line
  – Chennai Metro Line, India

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- **AC-DC Traction Power Supply VDO**
Introduction

Routing
- Contact line

Return circuit
- Track
Rail Electrification
Overview of traction power systems

High Voltage Grid (3 phase)

Medium Voltage

DC 750V, 1.5kV, 3kV

110 kV, 132 kV 16.7 Hz
Railway Power Network

AC 15kV 16.7 Hz

AC 25kV 50 Hz

High Voltage Grid

Central Traction Power Network or Medium Voltage

Traction Power Substations

Contact Line
Current Collector
Return Circuit

Urban Transport
Mainline

Mainline

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# Sitras TPS - Solutions for AC and DC Traction Power Supply

### Sitras traction power supply systems for every task
- DC substations
- AC substations
- Autotransformer stations
- Frequency converters
- Static Var Compensators
- Active balancers

### Voltage Frequency

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Frequency</th>
<th>DC</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>750 (600) V</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>1,500 V</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>3,000 V</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>15 kV</td>
<td>16.7 Hz</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>25 kV</td>
<td>50/60 Hz</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2x 25 kV</td>
<td>50/60 Hz</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

### Features
- Systems made of proven standard products from the power utility sector and special Sitras products
- Highly available systems
- Minimized life cycle costs

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*DC substation 750 V*  
*AC substation 25 kV*  
*Frequency converter 50/16.7 Hz*  
*Autotransformer station 2x 25 kV*

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Complexity of traction power supply

- Geographic requirements
  - Climate
  - Topography

- Requirements of power utilities
  - Systems interactions
  - Peak loads
  - Measurement and protection

- Transportation performance
  - Vehicles
  - Timetable

- Rail Automation
  - Signaling

- Standards
  - Local
  - International

- Electrical safety
  - Operators
  - Passengers / pedestrians
  - Protect. of installation

- Availability
  - Reliable power supply
  - Redundancy

- Economic efficiency (Lifecycle Costs)
  - Investment
  - Operation
  - Maintenance

- Energy saving

- Environmental compatibility
  - Electrical and magnetic fields
  - Noise emissions
  - Climate (CO₂)

- Line requirements
  - Stations
  - Technical buildings
  - Tunnels
  - Viaducts
  - Crossings

- Transportation performance
  - Vehicles
  - Timetable

- Rail Automation
  - Signaling
Sitras SIDYTRAC - The Powerful Simulation Tool

Multi-Train Simulation tool for

- AC Railways
- DC Railways
- Upstream 3-phase Energy Supplies
- Overhead Contract Lines and Return Circuit
- 3rd Rail Systems and Return Circuit
- 4th Rail Systems

Area of Application

<table>
<thead>
<tr>
<th>Area of Application</th>
<th>Simulation and Calculation</th>
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<tr>
<td>Overall System Design</td>
<td>Train Operations, Feeding Concepts, Network Design</td>
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<tr>
<td>Energy Demand</td>
<td>Dimension of Contact Lines, Cables, Transformers, SG</td>
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<tr>
<td>Safety and Protection</td>
<td>Rail Potentials, Stray Currents, Short Circuit, Relay Settings</td>
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<tr>
<td>Power Quality</td>
<td>Unbalance, Voltage Fluctuation, Resonance Behavior</td>
</tr>
<tr>
<td>Interference, EMC</td>
<td>Magnetic Fields, Interference with other Systems, Induced Voltages</td>
</tr>
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</table>

Sitras® Sidytrac

Energy Flow

Rail Potential

Harmonic Analysis

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DC- and AC- Traction Power Systems (TPS)
Principle differences Earthing and Bonding
Typical earthing measures for bridges and viaducts

- Pole
- earth wire
- pile
- earthing rebar

Section A - A
Typical Feeding for Conductor and Return Circuit

Direct Feeding

A direct connection to the rails and catenary is made via transformer secondary windings.

This has the disadvantage of large losses, high touch potentials and stray currents that interfere with telecommunications.
Power supply for AC railways
Return circuits via running rails

Return circuit via running rails

Substation

Catenary

Return circuit

1 AC 15 kV/16.7 Hz
1 AC 25 kV/50 (60) Hz
Current distribution at 50 Hz and 16,7 Hz

70%

30%

Return circuits via running rails with return wire

Substation

Return conductor

Catenary

Running Rails

Current distribution at 50 Hz (16,7 Hz)

40 % (38 %)

100 %

40 % (38 %)

20 % (24 %)
AC Traction Substation Main Equipment

Single-line diagram for typical single-phase system
Typical Feeding for Conductor and Return Circuit

Auto Transformer or Double phase Feeding (2x25 kV)

- To improve transmission properties, the 2x25 kV system is used for higher performance.

- Essentially providing a ‘boost’ to the voltage on the OCS and extending the reach of the substations.

- This type of feeding is characterized by additional auto-transformer and a return line at potential of 25 kV. This return line is often designated as a negative feeder.

- For this reason, 2-pole switchgear is required in the overhead line network.
AC Traction Substation Main Equipment

Single-line diagram for typical autotransformer system

High-voltage incoming panels 1+2

Traction transformers

Medium-voltage switchgear*

* Version with gas-insulated switchgear, type Sitras 8DA12

Return current busbar

Autotransformer feeder panel 1

Incoming panel 1

Autotransformer panels 2+3

Incoming panel 2

Autotransformer feeder panel 4
AC TP Feeding Concept for Main Line

Two phase connection

Two phase connection
AC Traction Substation Main Equipment

High-voltage switchgear

Outdoor type

Air-insulated

Indoor type (gas-insulated)
AC Traction Substation Main Equipment
Siemens MV Switchgear

Air-insulated medium-voltage switchgear *SITRAS® ASG25*

Gas-insulated medium-voltage switchgear *SITRAS® 8DA11/8DA12*
AC Traction Substation Main Equipment

MV Switchgear

**Sitrás 8DA11**
1-pole design for single-busbar systems

**Sitrás 8DA12**
2-pole design for autotransformer systems and single-busbar systems with testbar
AC Traction Substation Main Equipment

MV Switchgear

1. Low-voltage compartment
2. Numerical bay controller
3. Operating mechanism and interlock for three-position disconnector as well as mechanical switch position indication for three-position disconnector and circuit-breaker
4. Manometer for gas monitoring of feeder gas compartments
5. Circuit-breaker operating mechanism
6. Operating shaft for vacuum interrupters
7. Voltage detection system
8. Busbar housing
9. Busbar
10. Three-position disconnector
11. Gas-tight bushing between three-position disconnector and circuit breaker compartment
12. Circuit-breaker housing
13. Vacuum interrupter
14. Current transformer
15. Pole supporting plate
16. Panel connection
AC Traction Substation Main Equipment

Control and Protection

Hierarchy of operator control levels

- Central control room
  (remote control)
- Station control system
  (station control)
- Decentralized bay control system
  (local control)

Operator control levels and used hardware
Central control room

(remote control)
Normally, all substations, sectioning points, autotransformer stations, etc. are controlled and monitored from a central control room.

The SCADA system Vicos® RSC is used preferentially and runs on powerful standard personal computers. Due to the open and standardized interfaces, Sitras SCS-AC may be connected to all established SCADA systems.

The central control room is connected with Sitras SCS via remote link-up.
Airport Rail Link; Bangkok Thailand

MEA In-feed 69 kV 3 phases 50 Hz
Out-feed 25 kV 1 phase 50 Hz
Overhead Contact Line
Standard Gauge 1.435 m.
Length 28 km. 160 km/hr
8 Passenger Stations
1 Depot
1 Traction Substation
DC railways

Earthing and bonding

Voltage: 600 V, 750 V, 1500 V, 3 kV
Schematic diagramm

Contact line

Running rails

Return current

d.c. system

return circuit

structure earth

pole foundations
DC railways

Stray current path of tunnel systems
DC railways

Stray current path of viaducts

- Rückstrom / Return Current
- Fahrlleitung / Contact line
- Fahrschienen / Running rails
- Bauwerkserde / Structure Earth
- Streustrom / Stray Current

= Bereich der Streustromkorrosion
= Area of stray current corrosion
Δ = isoliert / insulated
Example of stray current corrosion in DC-Systems

Source: Elektrische Bahnen 1-2014 – modivied
Stray Currents

Detraction rate for metals per A and year

First rule of Faraday  \[ m = c \ I \ t \]

- Aluminium  2.90 kg  1.08 dm$^3$
- Lead  33.80 kg  3.00 dm$^3$
- Iron  9.13 kg  1.16 dm$^3$
- Copper  10.4 kg  1.17 dm$^3$
Stray Current Corrosion Examples
Example for a DC 750V Metro with conductor rail
DC Traction Power System Protection
General Requirements

Equipment Protection against:
- Short circuit currents
- Impermissible Overloads

Automatic Disconnection:
secure, fast, selective

Considering:
- Most unfavourable fault situation (= smallest short circuit current)
- Enlarged feeding sections
- Outage of Rectifier Substations
- Regenerating trains (bi-directional load flow)

Protection elements for a system without DC bus-feeder CB

MV-CB protects:
- Rectifier transformers
- Rectifier
- DC-busbar

DC-Line Feeder CB protects:
- all subsequent equipments of the traction power supply
- up to vehicles main CB

Source:
German recommendation VDV 520
DC traction power supply
Primary / Secondary Main Equipment

**Primary equipment**
- Medium-voltage switchgear
- Rectifier transformer
- Diode rectifier
- DC switchgear
- Voltage-limiting device
- Short Circuiting Device

**Secondary equipment**
- Station control system
- Remote control system (SCADA)
- Combined protective unit and controller
- Stray-current monitoring system
DC traction power supply
Rectifier transformer

Cast-resin transformer: GEAFOL®

Oil-insulated transformer: TUNORMA®, TUMETIC®
DC traction power supply
Diode rectifier

Diode rectifier Sitras® REC
Withdrawable diode rectifier Sitras® REC-W
DC traction power supply
DC switchgear

DC switchgear
Sitrás® DSG

Compact DC switchgear with integrated rectifier Sitrás® CSG
DC Switchgear (DSG Version 2)
DC traction power supply
Protective and control unit

Combined DC-protective unit and controller Sitras® PRO

Medium voltage AC-protective unit and controller Siprotec
DC traction power supply
Voltage-limiting device

Short-circuiting device Sitras® SCD

Compact short-circuiting device Sitras® SCD-C
Short Circuiting Device
Third Rail Overview

Introduction

Contact lines for Railways

- Overhead Contact Line
- Overhead Conductor Rail
- Conductor Rail

Single Wire Systems

Catenary Systems

Conductor Rail

Third rail

Fourth rail
2. Third Rail Overview

- 3rd rail
- Collector Shoe
2. Third Rail Overview

Collector Shoe

3rd rail
2. Third Rail Overview

Third Rail Contact

- **bottom contact**
- **side contact**
- **top contact**
Third Rail Overview

Type of Third Rail

- Steel conductor rails
- Aluminium-Stainless steel composite rail
Third Rail Overview

Third Rail Support
Third Rail Overview

Third Rail - Ramp

Left side

Right side

3rd rail - ramp
Running Rails Overview

Two Rails = 1 track

3rd rail = Track
Running Rails Overview

The direct fixation fastening

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1.4 Railway Gauges

1. Broad gauge: 1676, 1668, 1600, 1520 mm
2. Standard gauge: 1435 mm
3. Meter gauge: 1372, 1067, 1000 mm (Medium gauge)
4. Narrow gauge: 914, 762, 760, 610 mm
5. Minimum gauge: 381 mm
Running Rails Overview

IRJ (Insulated Rail Joints)

Figure 3: A typical IRJ showing rail, end post, insulation, joint bar and bolts.

Figure 4: Symmetrically suspended rail joint [10]

Figure 5: Unsymmetrically suspended IRJ
IRJ (Insulated Rail Joints)

Figure 13: IRJ Assembly of 6-Bolt.
Running Rails Overview

Train Type

Limit speed (km-hr)

350
250
200
160
96
1
16
32
50

ICE® 3
Velaro®

Combino®, Avenio®, S70, SD 160, Metros
Desiro®, Oceanside
Viaggio®, Intercity

average distance between stops (kms)
Thank You For Your Attention

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