Active Earth Fault Compensation and Railway Application of Medium Voltage Converters

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Medium Voltage 3-Level GTO Phase Module

Pulse frequency of the GTO: 150 Hz  (up to 250 Hz with derating)
⇒ 3 pulses per fundamental harmonic for the 50 Hz converter
⇒ 6 switching angles available for pulse pattern optimization

Traces of the output potentials of two phase modules of the 4QC and the resulting output voltage

\[ u_{AB} = v_A - v_B \]
Motivation of the Residual Current Compensation

Classical approach for power transmission grids

- Resonant grounded systems with arc-suppression coils (Petersen coil)
  - self extinguishing arcs in case of line to ground faults
  - power transmission not affected by earth faults

Problems

- Cable faults, harmonics, large grids with high damping
  - high currents at the fault location: danger to life, danger of fire

Solution

- Active compensation of residual currents with VSI feeding the neutral system of the transmission grid
Principle of the Residual Current Compensation

Target of RCC: \( I_F = 0 \)

\( \Rightarrow \) RCC needs to move potential of line 1 to earth potential ( \( U_{RCC} = U_{NE} = U \) )

\( \Rightarrow \) current of the RCC: \( I_{RCC} = U \times k - U \times (d + j \nu) \)
Residual Current Compensation for DB Energie (Borken)

- 18.500 km of 110 kV lines, 2AC 16.7 Hz (DB and ÖBB)
- Active power of 5.5 MW according to the damping of the grid
- Compensation of 3\(^{rd}\), 5\(^{th}\), 7\(^{th}\) Harmonic and 50 Hz components
- ALSPA VDM7000 medium voltage 3-level converter
Residual Current Compensation for DB Energie

- DC link capacitors, 33.3 Hz and 66.6 Hz filter circuits
- Four-quadrant converter (4QS) 2 phase modules
- 50 Hz transformer
- 50 Hz transformer
- Resistor with DC-chopper
- Rectifier
- 400 V 50 Hz
- 400 V 50 Hz
- 11 kV 16.7 Hz
- 16.7 Hz transformer
Residual Current Compensation for DB Energie Field Tests

Test conditions
- Island grid fed by two 55 MVA Generators:
- 500 km of overhead lines + simulation of 1400 km overhead lines by capacitors

Simulated faults
- Earth fault with low impedance
  - short circuit of 110 kV busbar to ground
- Earth fault with high impedance
  - tree contact
  - breaking of an overhead line
- Cable fault
Residual Current Compensation for DB Energie
Test Conditions
RCC - Measurement of High Impedance Fault (caused by tree)

1) $I_F$
2) $U_{12}$
3) $U_{10}$
4) $U_{20}$
5) $U_{NE}$

Tree contact

Fault detection

1.5 s
RCC - Measurement of Cable Fault

1) Before Fault
2) RCC off 690 ms
3) RCC on 2.75 s
4) RCC off 6.3 s
5) RCC on

- $I_F$
- $U_{12}$
- $U_{10}$
- $U_{20}$
- $U_{NE}$
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RCC - Field Tests

current measurement

intermitting arc
RCC - Compensation of Cable Fault
Residual Current Compensation - Highlights

- Proven method in medium voltage applications
- First high voltage application has passed realistic field tests and is ready for full operation
- Higher safety due to self-extinguishing arcs and low voltages at the fault location
- Increased availability of power supply due to fault clearing without power interruption
- Compensation of fault currents even in case of cable faults, high harmonics and a high damping in the grid
- Detection and location of faults
Concept of the standardized Static Frequency Converter (SFC)

Application of the 3 level GTO converter ALSPA VDM7000

ALSPA VDM7000
3 level GTO converter
for high power applications
(9…18 MVA)
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Block diagram of standardized SFC type BAUM

- **Four-quadrant converter (4QS)**: 2 phase modules
- **DC link capacitors**: 33.3 Hz filter circuits
- **15 kV resp. 110 kV 16.7 Hz**
- **20.5 kV bzw. 30 kV 50 Hz**

**Rated power at the single phase end:**
- 18.5 MVA resp. 15 MW \((\cos \phi = 0.81)\)

**Precharge and earthing system**

**Resistor with DC-chopper**

**400 V 50 Hz**

**Single phase transformer including filter circuit**
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Arrangement of the components in the modular container concept

(all components are designed for the transportation via rail and standard road haulage)
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Assembly of prefabricated modules of the back-to-back converter (BAUM) for railway applications within 4 days

1st. day prefabricated foundation of building and transformers with ready-made oil collecting pits.

2nd. day Erection of 16.7Hz transformer and 1. Container halve of converter room

3rd. and 4th. day Total view after assembling of SFC pilot type BAUM

Power part

16.7 Hz-Trafo

50 Hz-Trafo 16.7 Hz-Trafo
Pilot of Standard Converter  Type BAUM
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120 MW SFC Converter Substation for Berlin - Thyrow

Highlights
- standardized units
- pre-tested, portable
- compliance with local line requirements
- adjustable power factor
- high efficiency