AmpaCity Project
Advanced Superconducting Cable System
for Urban Power Supply

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Agenda

- AmpaCity Project Overview
- Techno-economical Study
- AmpaCity Installation
- HTS System Design
- AmpaCity Project Status
- Conclusions
AmpaCity Project Objectives

- Installation of 10 kV, 40 MVA (2.3 kA) HTS system in German city Essen
  - Project started in September 2011 with duration of 4.5 years
  - Commissioning before end of 2013
  - Demonstration period of at least 2 years
  - Funded by the German Federal Ministry of Economics and Technology

- Investigation of technical feasibility of HTS systems in distribution grids

- Comparison of investment between MV HTS and conventional HV systems

- Evaluation of operational advantages during demonstration period

- Assessment of further HTS system applications
Project Team and Responsibilities

- **RWE**
  - Specification of HTS system to be installed in distribution grid
  - Field test of HTS system connecting two substations

- **Nexans**
  - Development of HTS cable including type test of all components
  - Manufacturing of HTS cable system and HTS fault current limiter

- **KIT**
  - HTS tests and characterization
  - AC loss measurements and modeling (FEM 2D and 3D)
Ampacity project overview
New grid concept

introducing superconducting MV cables
Techno-economical study
3 solutions considered

Conventional 110 kV cable

Conventional 10 kV cables

Superconducting 10 kV cable
Future grid structure has been designed based on:
- Conventional 110 kV cables
- Superconducting 10 kV cables

Perquisites: same redundancy (n-1)
- Economic viability compared
Economic Study - Urban Grid with MV HTS Cables

Dispensable devices for new grid concept
- 12.1 km of 110 kV cable systems
- 12 x 110 kV cable switchgear
- 5 x 40 MVA, 110/10 kV transformers
- 5 x 110 kV transformer switchgear
- 5 x 10 kV transformer switchgear

Additionally required devices for new grid concept
- 23.4 km of 10 kV HTS cable system
- 16 x 10 kV cable switchgear
- 3 x 10 kV bus ties
Comparison of the 3 options based on NPV method

- Investment costs and operating costs (maintenance and losses)
- 40 years
- 2% yearly increase
- 6.5% interest rate
- 65 €/MWh

Real estate value represents additional benefit for the HTS technology.

Techno-economical study

Conclusion
Technical specification
- 1 km distance between substations
- 10 kV system voltage
- 2.3 kA operating current (40 MVA)
Ampacity project
Present electrical configuration

Substation Dellbrügge

Substation Herkules

10 kV

40 MVA

110 kV UGC

10 kV

40 MVA

110 kV UGC
Ampacity project

Configuration with supercond. system

Substation Dellbrügge

Substation Herkules

10 kV

110 kV UGC

10 kV HTS UGC

FCL

40 MVA

40 MVA

40 MVA

10 kV

110 kV
Substation Dellbrügge – Basement and 1st Floor
Substation Herkules – Front
Empty transformer box
Cable Design

Phase 1
Phase 2
Phase 3

Inner LN₂ Cooling
Former
Dielectric
Outer LN₂ Cooling
Screen
Cable Cryostat
Termination Design

Phase 1
Phase 2
Phase 3
Screen
Cooling Inlet
Measurement Connection
Cooling Outlet
Cable Connection
Termination Cryostat
## Fault Current Limiter Design

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>40 MVA</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>10 kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>2.3 kA</td>
</tr>
<tr>
<td>Lightning impulse withstand voltage</td>
<td>75 kV</td>
</tr>
<tr>
<td>Power frequency withstand voltage</td>
<td>28 kV</td>
</tr>
<tr>
<td>Prospective peak short circuit current</td>
<td>50 kA</td>
</tr>
<tr>
<td>Prospective short circuit current</td>
<td>20 kA</td>
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<tr>
<td>Limited peak short circuit current</td>
<td>&lt; 13 kA</td>
</tr>
<tr>
<td>Limited short circuit current</td>
<td>&lt; 5 kA</td>
</tr>
<tr>
<td>Limitation time</td>
<td>100 ms</td>
</tr>
</tbody>
</table>
> 4 kW cold power at 67 K
> Subcooled pressurized nitrogen
> Forced flow in closed circuit
> High availability and reliability
Pre-prototype cable

- Manufacturing of 100 m pre-prototype cable was completed in June 2012
- Installation of pre-prototype test setup (30 m cable loop with terminations) has been finished
- High voltage tests have been performed on pre-prototype test setup
- Bending test on 20 m pre-prototype cable has been carried out
- Cable sections from bending test have been dissected and inspected

Prototype cable

- Manufacturing of prototype cable was completed in October 2012
- Prototype cable was installed with joint and terminations in HV test lab
- Type test of prototype cable setup was successfully finished
Test Setup Pre-Prototype Cable
Type Test Setup Prototype Cable
Prototype Termination
Type Test Sequence Prototype Setup

- PD test at 20 kV (after 24 kV for 1 min)
- 20 Load cycles with 2.3 kA (3 phase)
- PD test at 20 kV (after 24 kV for 1 min)
- Lightning impulse test at ± 75 kV
- AC voltage withstand test at 30 kV (4 h)
AmpaCity – Cable Installation
AmpaCity – Fault Current Limiter Installation
AmpaCity – Status and Milestones

- Application for funding at the German Ministry of Economics and Technology (BMWI) - March 2011
- Project acceptance by BMWI with 43% funding on September 5th 2011
- Manufacturing of Prototype - Q3 and Q4 2012
- Successful type test beginning of 2013 – Start of cable system manufacturing
- Ground breaking ceremony in Essen on April 9th, 2013
- Installation of HTS System - Q3 and Q4 2013
- Commissioning - Q4 2013
- Grid operation - 2013 to 2015
- Analysis of grid operating experience and discussion of further implementation steps - early 2016
Superconductors have come out of laboratories and are now ready to be incorporated in power grids

Superconducting systems constitute attractive alternatives to conventional systems
- Reducing operating voltages
- Enabling new grid concepts
- Reducing the number of inner city transformer substations

The economical viability of superconducting systems is now achievable
Thank You For Your Attention