From HTS Material Optimization to System Manufacturing – First Commercial FCLs from Nexans SuperConductors

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2011 MRS SPRING MEETING
April 25-29 - San Francisco, CA

Outline

- Introduction
- Material aspects of Bi-2212 (bulk and precursor)
- FCL systems
  - Function
  - System manufacturing
  - Projects realized and first field tests
- New projects in progress and new installation planned
- Conclusions

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Nexans SuperConductors
Materials – Components - Systems

From R&D to systems

Hoechst ZF Frankfurt Höchst and GBA Knapsack — 10‘1987

Hoechst Corporate Research & Technology — 01‘1995

HOECHST RESEARCH & TECHNOLOGY — 01‘1998

Aventis Research & Technologies — 05‘1998

ALCATEL — 10‘1999

Alcatel High Temperature Superconductors

Nexans — 10‘2000

Nexans SuperConductors

chemistry
physics
material sc.
electrical eng.
mechanical eng.

Nexans SuperConductors in new premises 2010

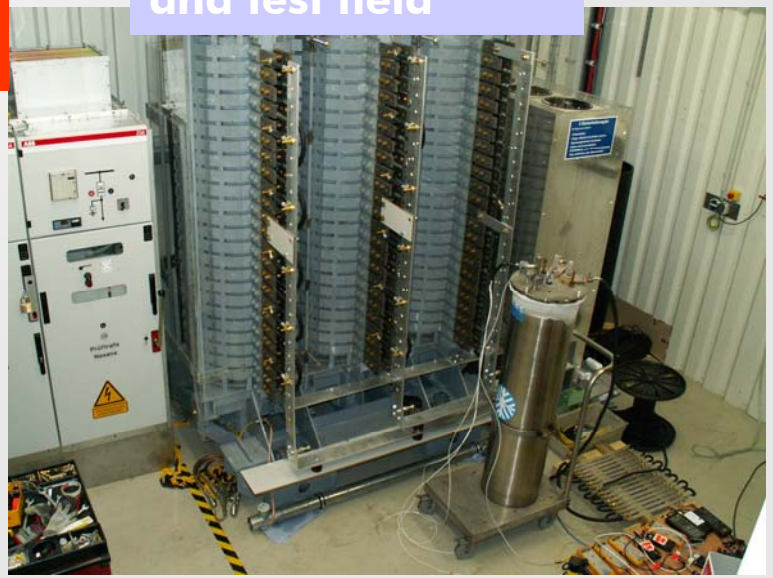
bldg. 2728

Office building and assembly hall

- **Assembly of Fault Current Limiter systems**
- **Building height allowing crane hook of 7 m**
- **Optimisation of the production**

Nexans SuperConductors
HTS system provider

Address remained unchanged:
Chemiepark Knapsack, D-50351 Hürth



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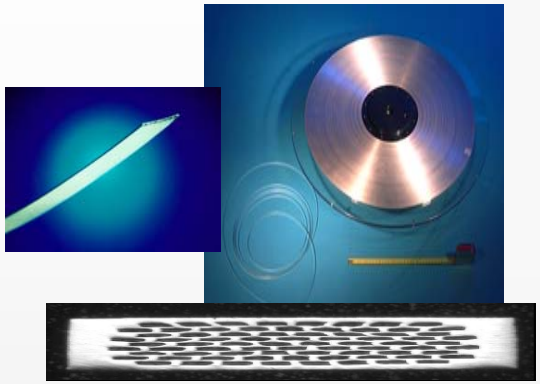
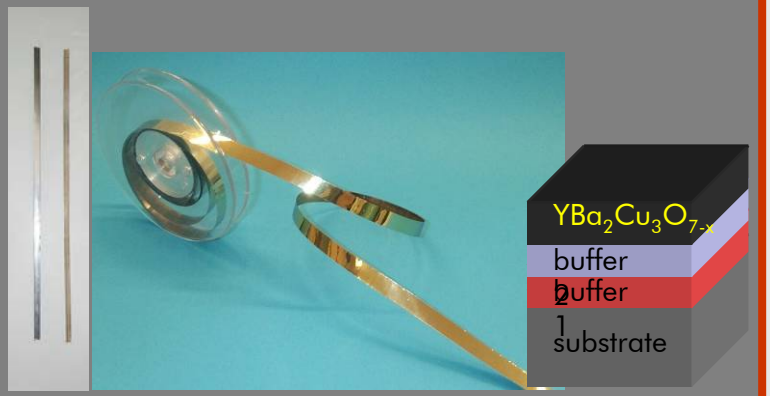
Materials and conductor types for industrial HTS applications



Bi-2212/ Bi-2223 tape
1st generation



Y-123 cc-tape
2nd generation

Systems realized

Bi-2212 bulk

Y-123 bulk

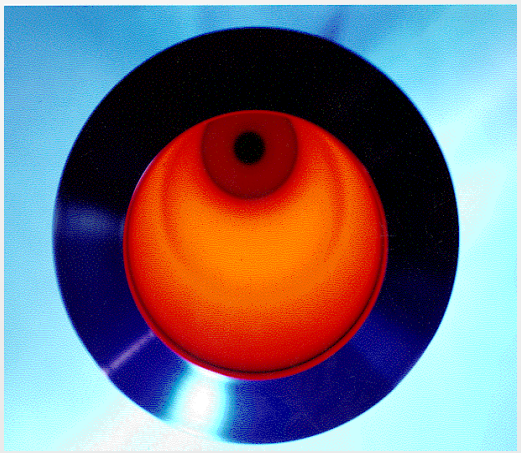
Production of HTS-bulk

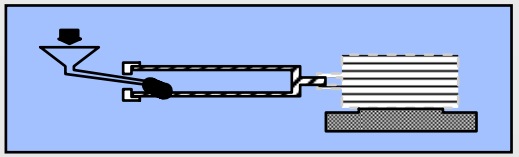
BSCCO-2212
Melt Cast Processing

Highly efficient and very flexible process

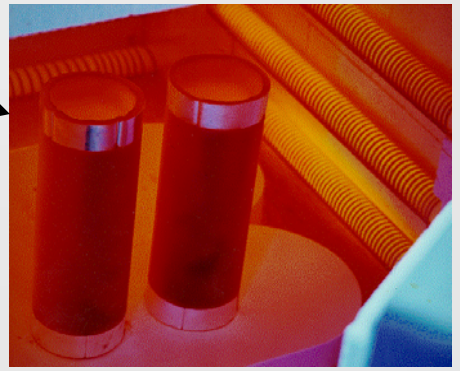
Melting

Mixing





Casting



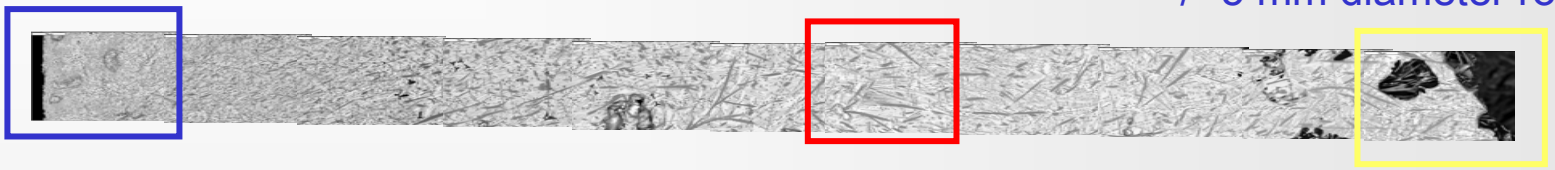
Annealing
Nexans SuperConductors

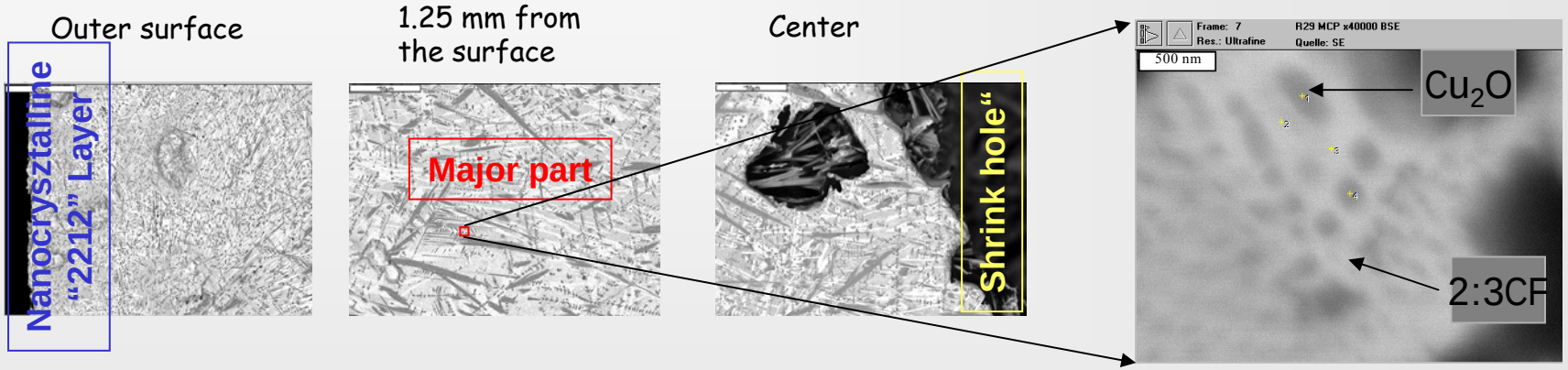
Microstructure of Melt Cast Processed BSCCO-2212

- Highly non-uniform **as-cast** microstructure

  (governed by directional solidification under conditions of thermal gradient)

/* 5 mm diameter rod */

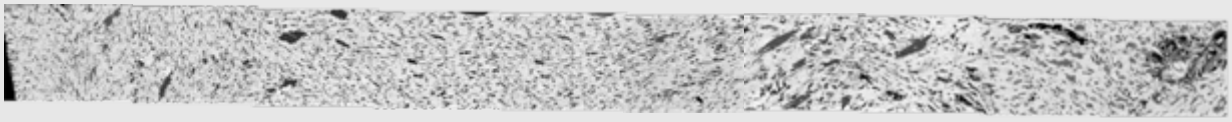




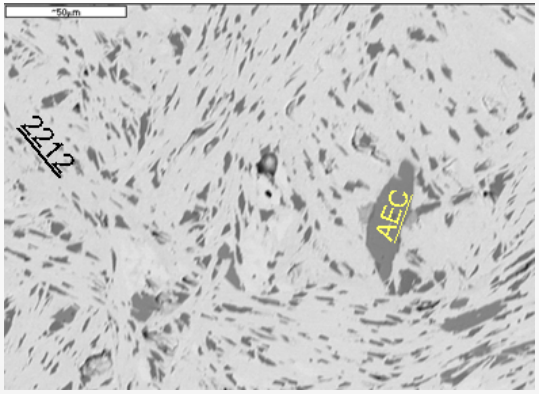
low melting eutectic

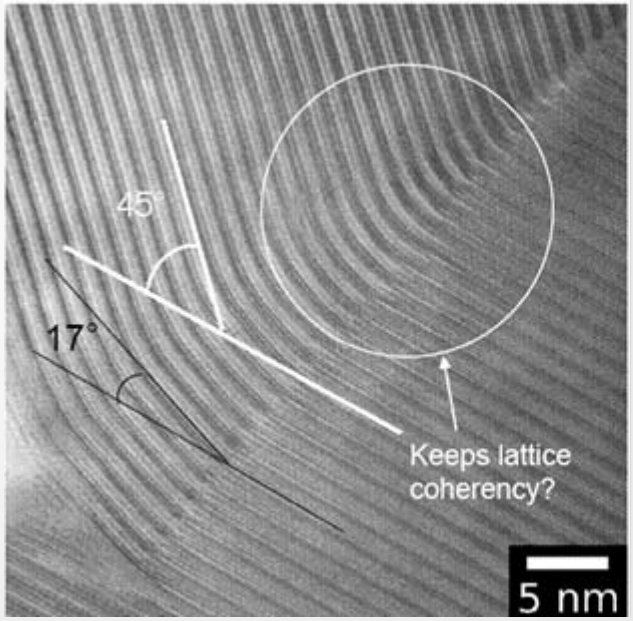
- Rather uniform **final** microstructure

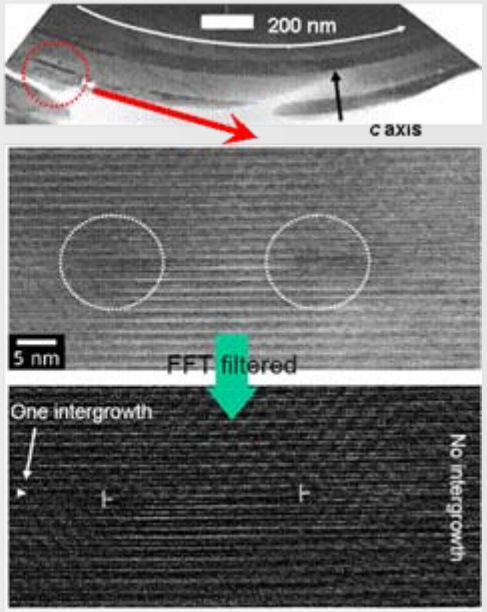
  (with rather good quality Bi-2212 phase)



Nanostructure adjusted for high Jc and Resistivity







No long-range texture

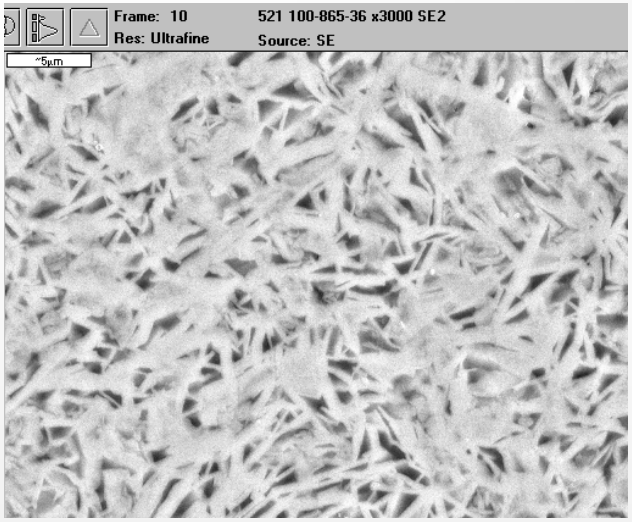
- J_c(77 K, sf) ~ 1 kA/cm^2
- J_c(4.2 K, sf) ~ 50 kA/cm^2

- High resistivity
  ρ(300 K) ~ 5 mΩ·cm

(Left) A high-angle GB with the tilt angle reduced from 45 to 17° due to lattice plane bending and (Right) a GB free bent grain (bending due to array of edge dislocations). TEM study by F. Kametani (NHMFL, Tallahassee) [compiled from D.C. Larbalestier et al, presentation at WAMSDOO 2008].

MCP Bulk BSCCO-2212 very suitable for FCL applications

Melt Cast Process for BSCCO-2212 precursor materials



M O Rikel, J Ehrenberg, J Bock (2006)
*__EP 1659104 B1__

Equilibrium precursor*

... designed for Partial Melt Processing of Ag-sheathed conductors

- same phase composition and particle size at RT and close to melting
- controlled particle size $d_{50} \sim 1–1.5\ \mu m$
- < 100 ppm C (in a granular material)
- sharpest melting transition

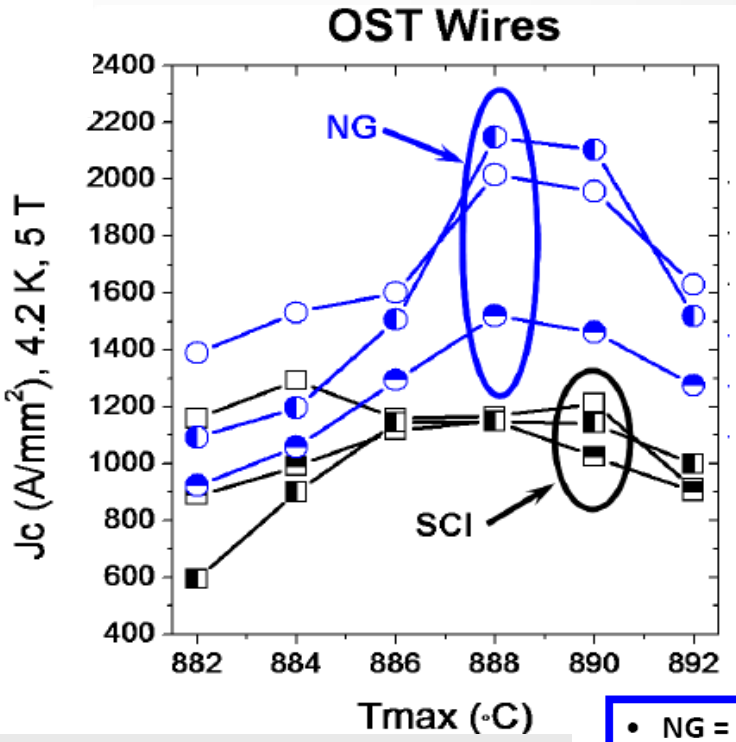
Standard cation stoichiometry:
Bi2.16(3)Sr1.94(3)Ca0.90(3)Cu2.00(3)
1 to 3 wt.% second phases

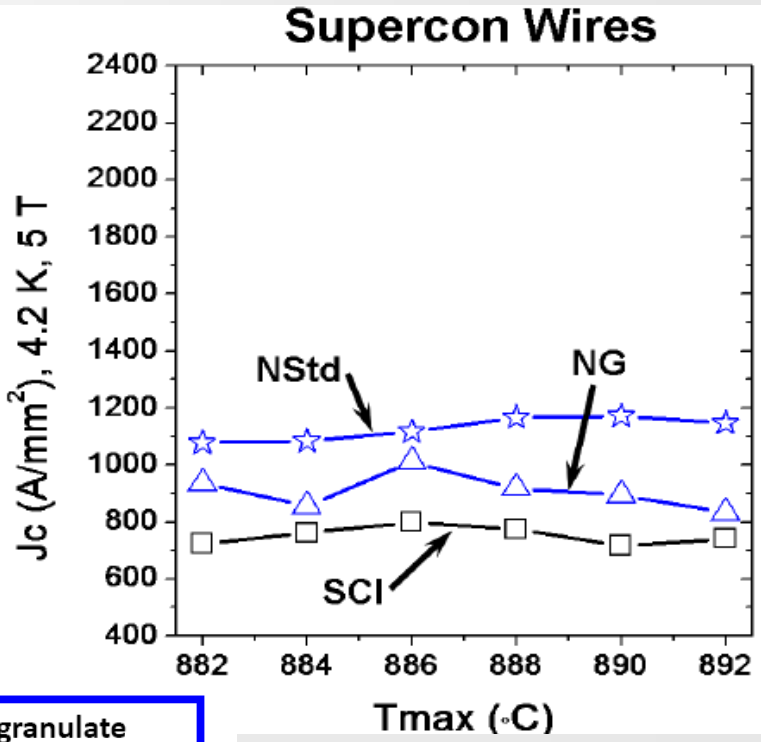
Highest reproduciblity

Evaluation of BSCCO-2212 precursors within VHFSMC

Optimization of various wires (2010)

J Jiang, E E Hellstrom, D C Larbalestier (ASC, NHFML),





- NG = Nexans granulate
- NStd = Nexans standard powder
- SCI = SCI Engineered Materials

Prototypes realized with BSCCO-2212 conductors

HTS High-Field Insert Magnets

K Marken, S. Heung, Z Melhem (OST), H Wejers (NHFML),

2003 (NHMFL,OST)
First **25T** SC Coil:
20 T with LTS +
5T with Bi2212

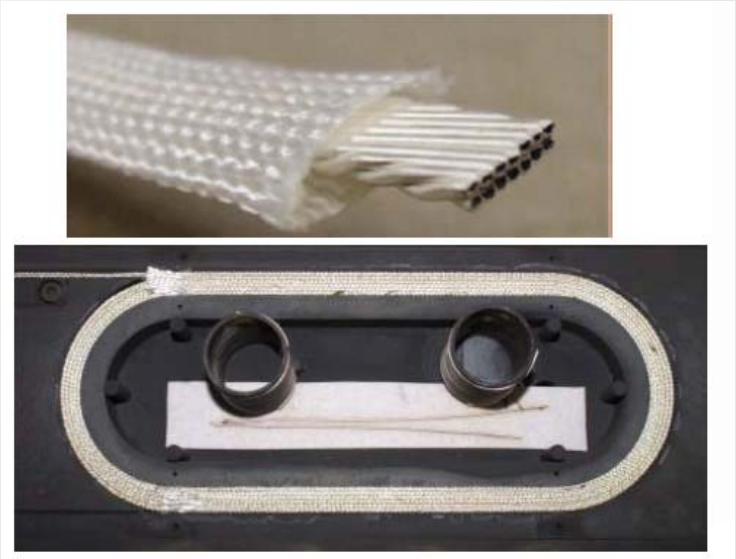
2008 (22 T), 2010 (22.5 T):
Latest Developments in High Filed Magnets:
22.5T = 20 T with LTS +
2.5 T with Bi2212

Dipole Magnet for VHFSMC

A Godeke (LBNL), Y. Huang (OST),

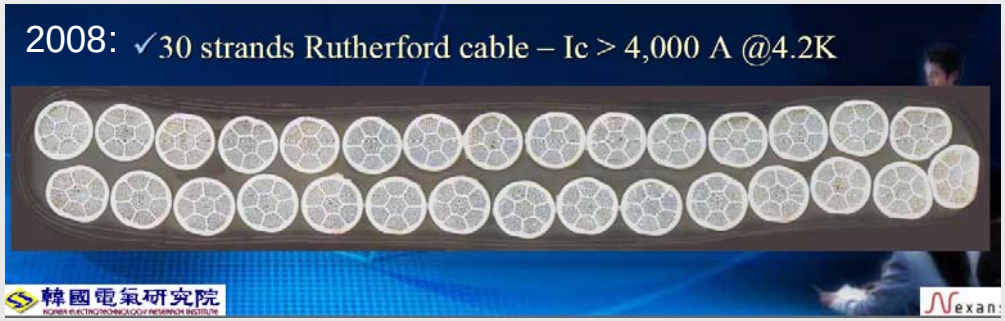
2009, 2010:
Dipole SC-08 Magnet with
Ic ~2600 A (4.2 K, sf)

Wind @ LBNL + React @ OST



Rutherford Cable

S C Kim (Nexans Korea), S-S Oh (KERI)



NSC Bi-2212 precursor inside

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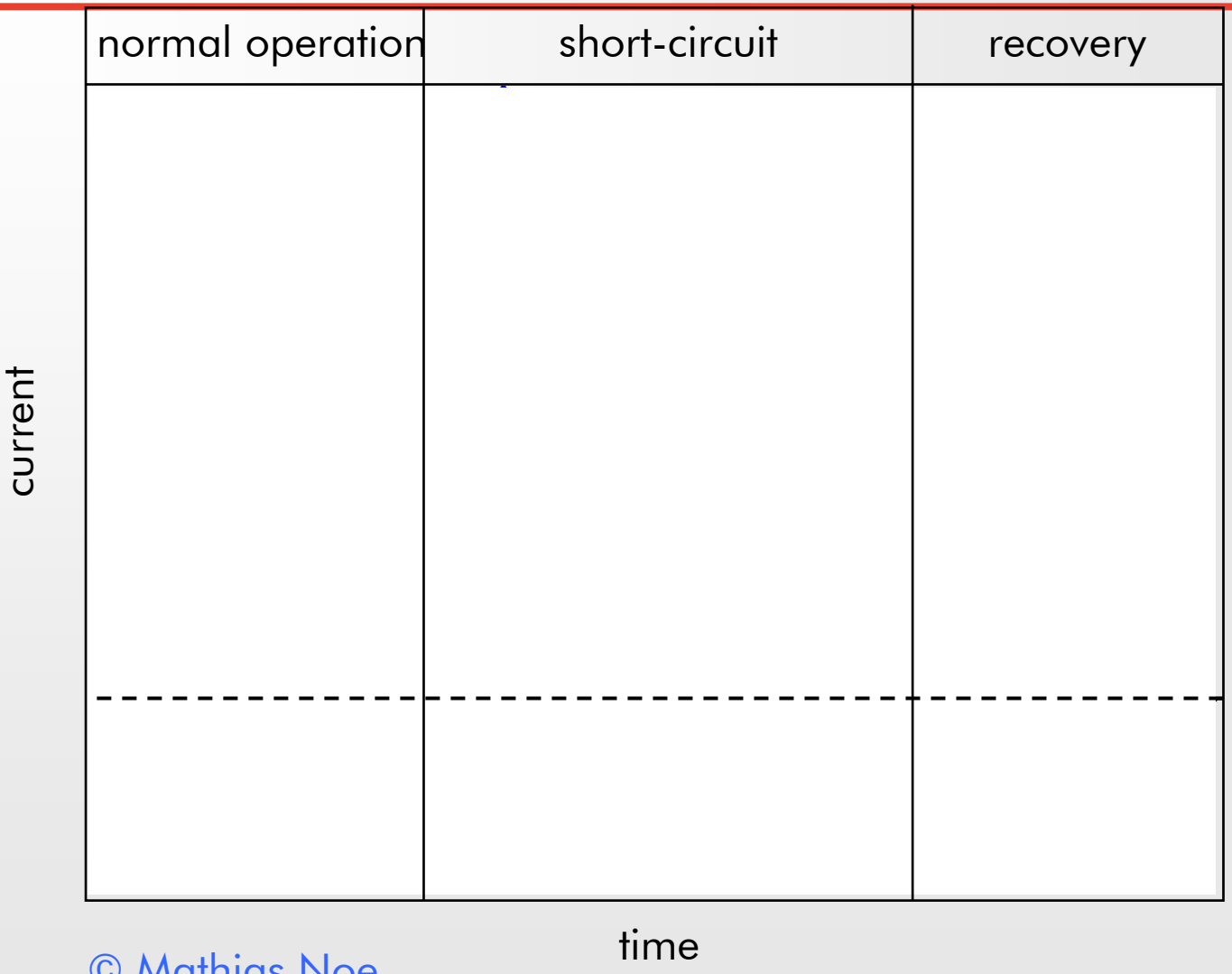
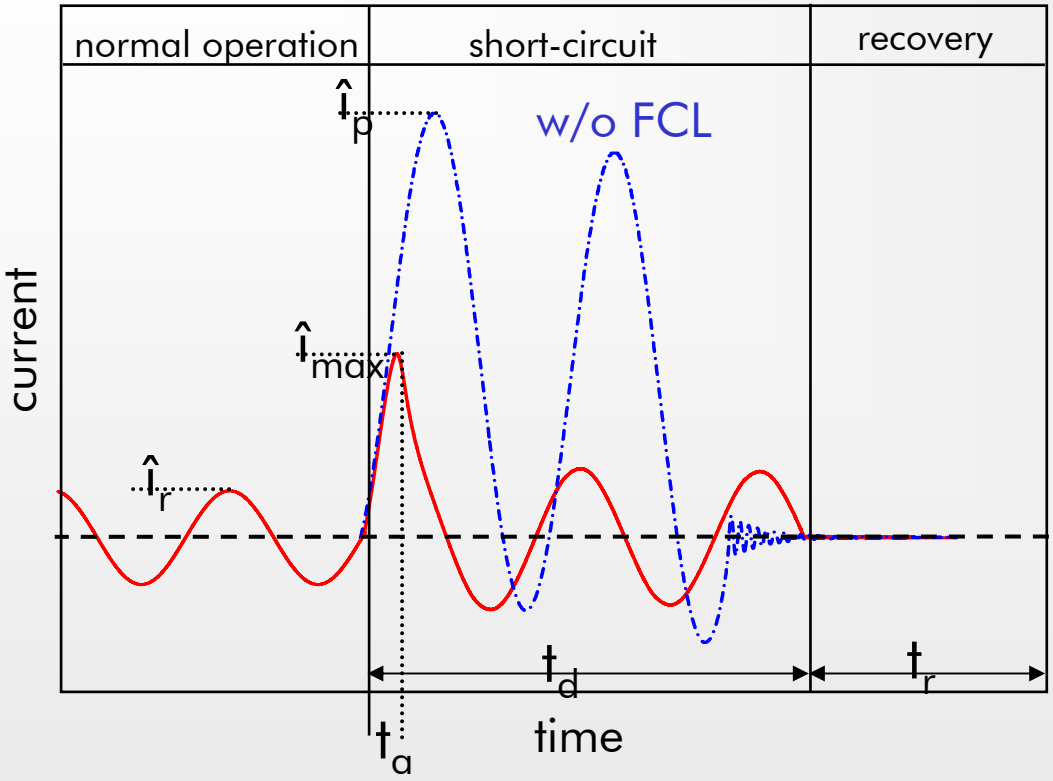
Function of the FCL



Operating behaviour of the FCL



- **ultrafast**
  reacts in 1-2 milliseconds
- **automatic**
  no external trigger necessary, self-recovering
- **wear-free**
  service only for cooling system

Superconductor Fault Current Limiters are intrinsically safe!

FCL systems
Commercial Projects

12-100 (ASL 1)
first commercial system
Field tested for ~8 months

12-800 (Vattenfall)
first system in a power station
Field tested Nov. 2009- Dec. 2010

12-400 (ASL 2)
second system for UK (bifilar)
Presently under installation

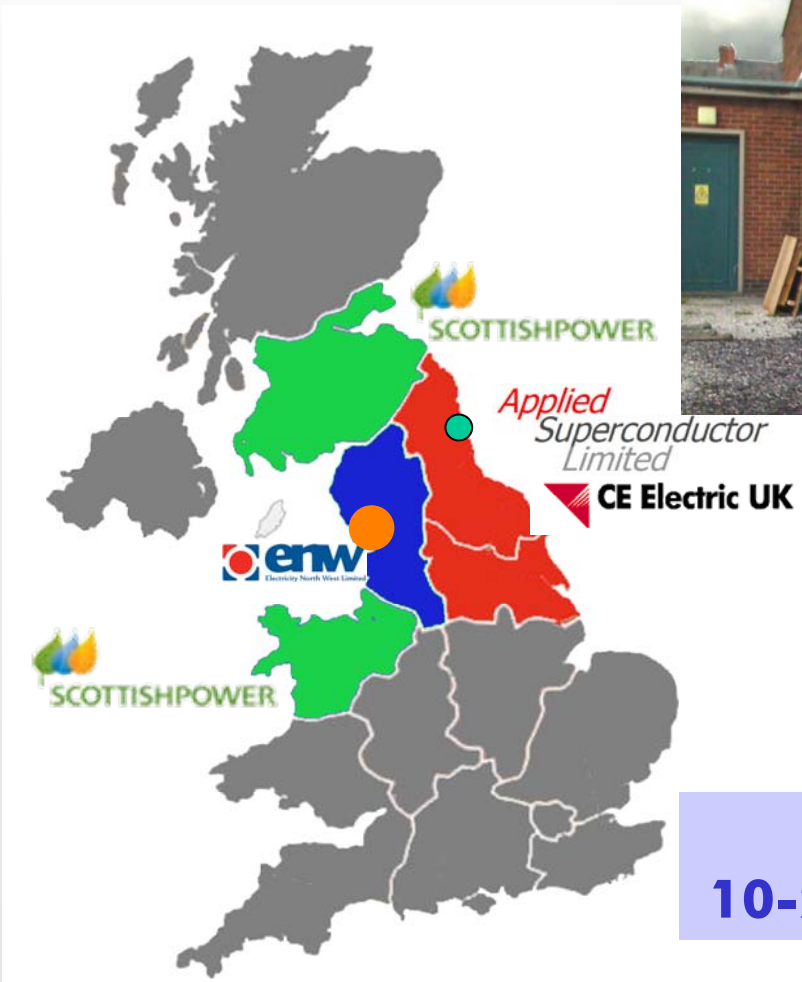
XX-YYY
XX: Voltage [kV]
YYY: Current [A]

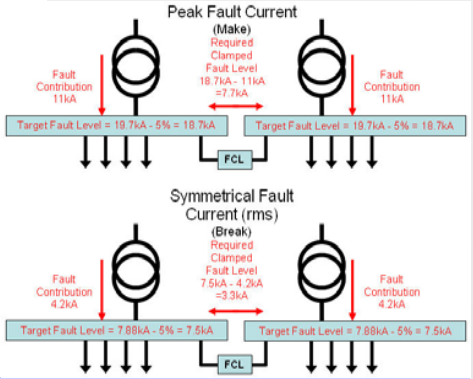
Project 1: 12-100 Realisation

- **first FCL-System realised by NSC**
- **first commercial system worldwide**

Project 1: 12-100 Field test

ASL, Newcastle
ENW, Bamber Bridge





Live on grid
10-2009 to 06-2010

Project 2: Vattenfall Brown Coal Power Plant

Block Q in Boxberg

VATTENFALL

Power to the consumer




Power to the consumer
Auxiliary Power

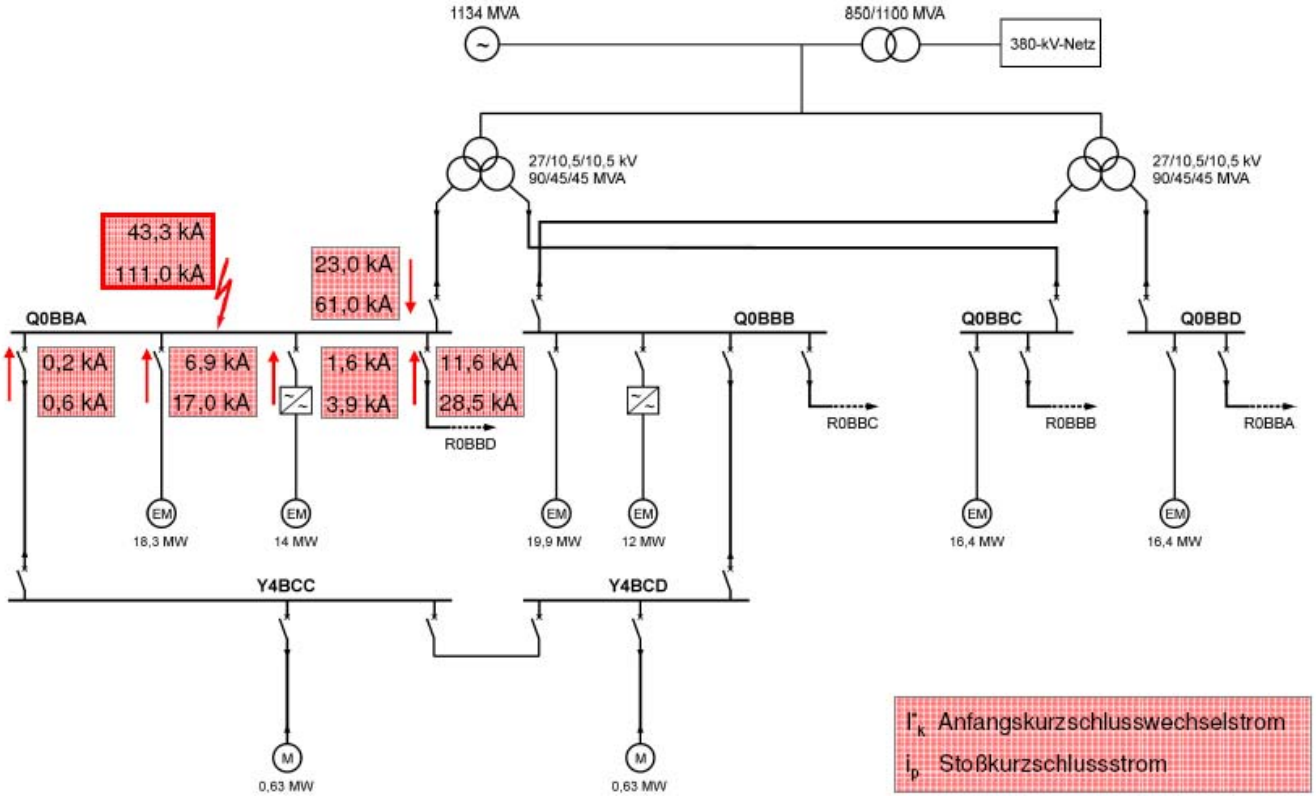




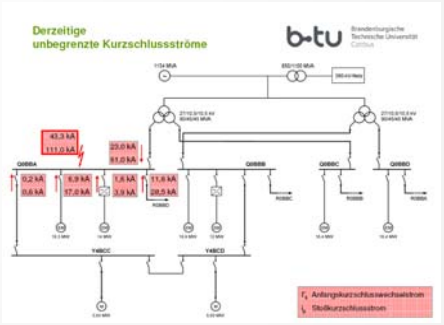

Auxiliary Power

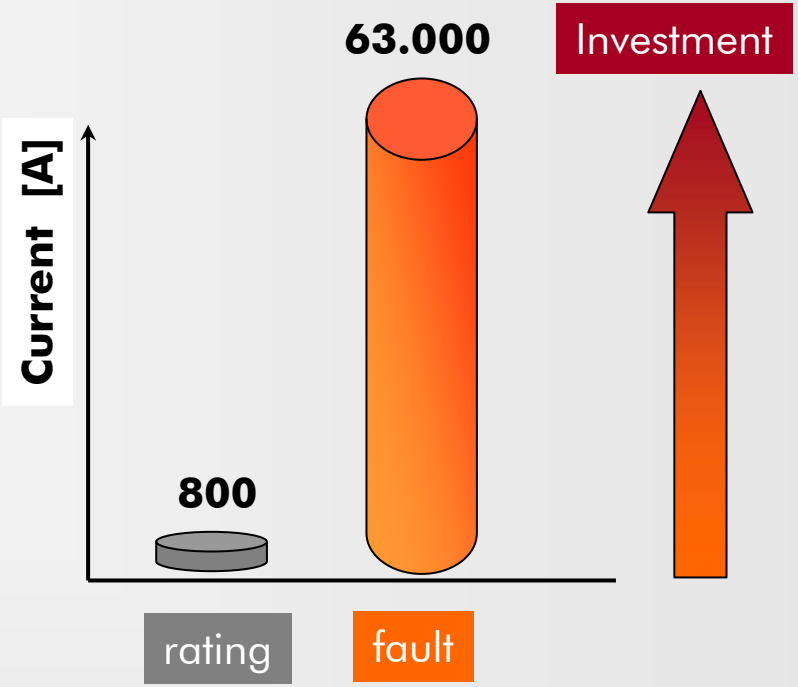
Not limited short circuit currents

Brandenburgische Technische Universität Cottbus



Auxiliary Power





High Short Circuit Currents

- **high mechanical and thermal forces**

No "fuses" on the MV power distribution level

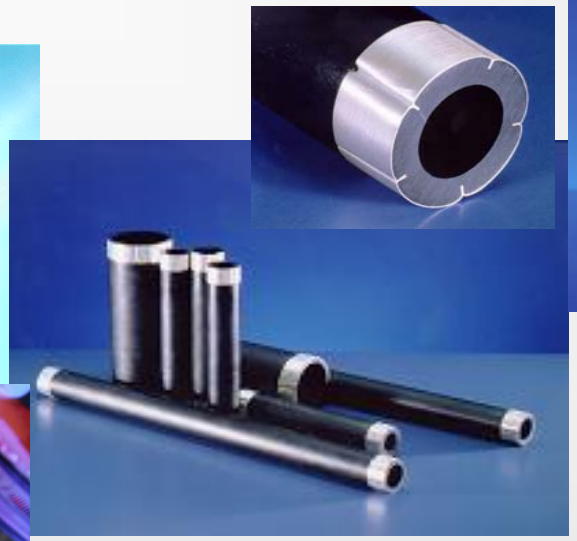
- **equipment and grid must be short-circuit proof**
- **high investment for equipment "oversizing"**

From metal oxide powder to HTS-components

Melt Cast Process
Nexans proprietary process

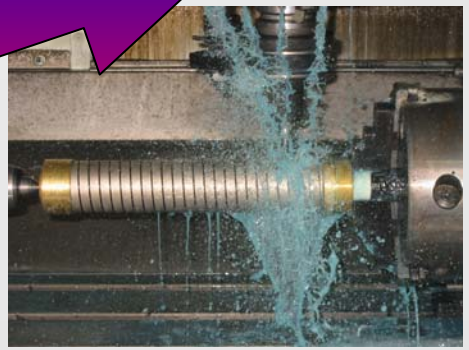
BiSrCaCuO

powder



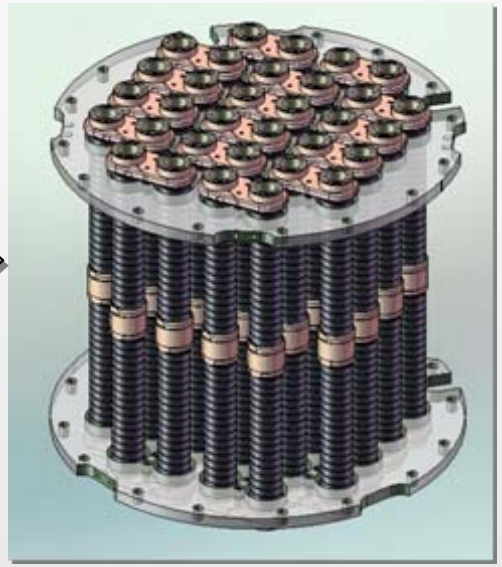
BSCCO-2212
tubes

Fault Current Limiter
Components



Basic design of the FCL

Connection for adaptation
- **Current** in parallel
- **Voltage** in series



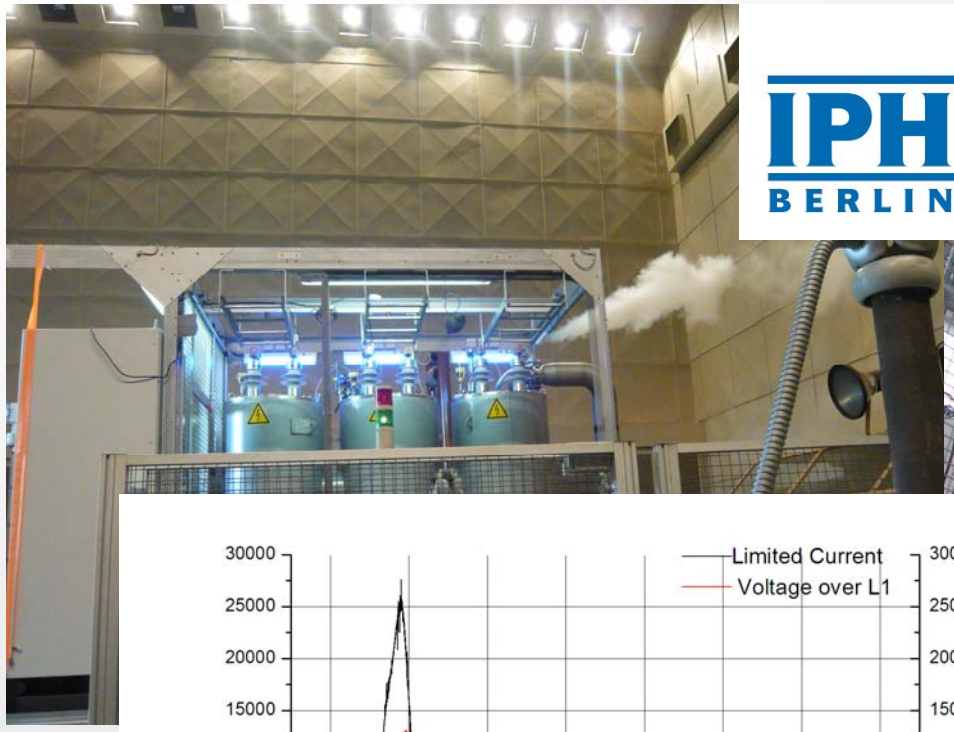
component **module** **set-up of a phase** **accomodation in a cryostat**

- **Fault Current Limiter connected in series with the grid**
- **Current and voltage adjustable by modular construction**

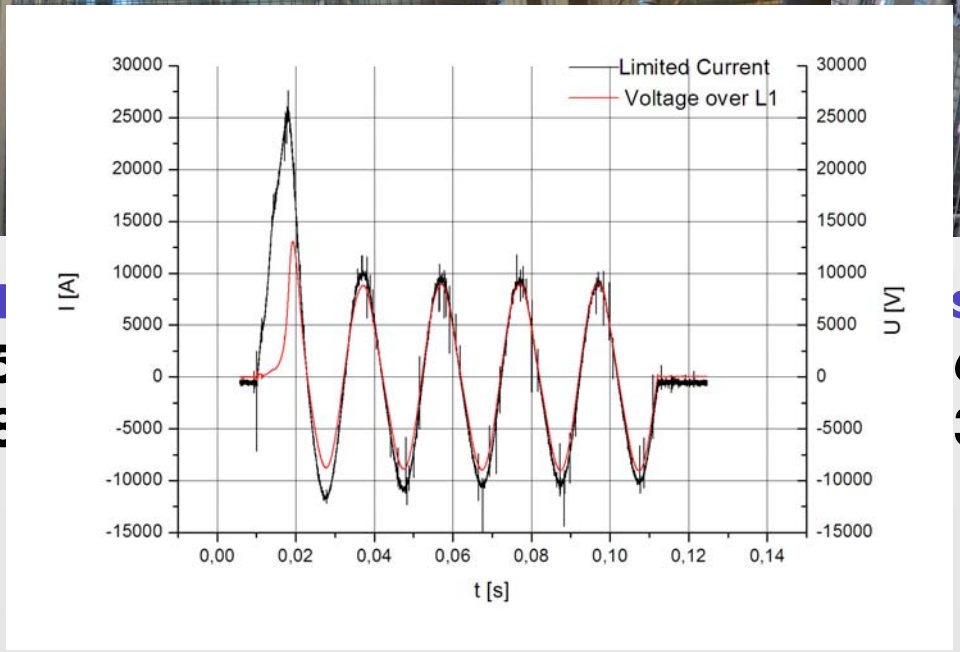
Realisation of the FCL

Nexans is mastering the full chain.

High voltage and high current testing of complete FCL-system



IPH BERLIN



Test sting scheme

- 75
- 28

63 kA (peak) maximum
3-phase full loads (4 shots)

Location
in Boxberg power plant

Standort im KW Boxberg

Standort:

Am Brecherturm Y 4UEF der Bekohlung für Block Q und R.

First FCL worldwide in a power plant

- Installation 10/ 2009
- Commissioning 02.11.2009
- End of field-test 12/ 2010

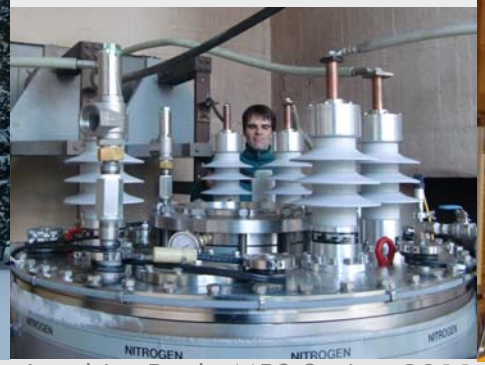
- second field-test starts IV/ 2011

- Significant savings for extension and new construction
- Improved safety for personnel and equipment

Project 3: 12-400 for ASL

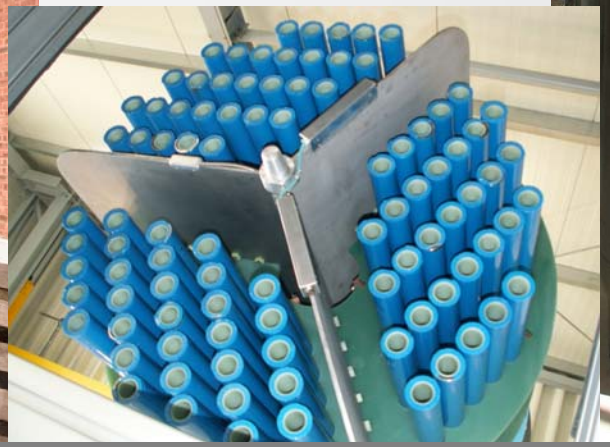
Customer has ordered second system!

Test at IPH



Project 3: 12-400 for ASL

Ainsworth Lane (Scottish Power)



In UK around 270 substations (MV up to 33 kV) are at or above max. rating

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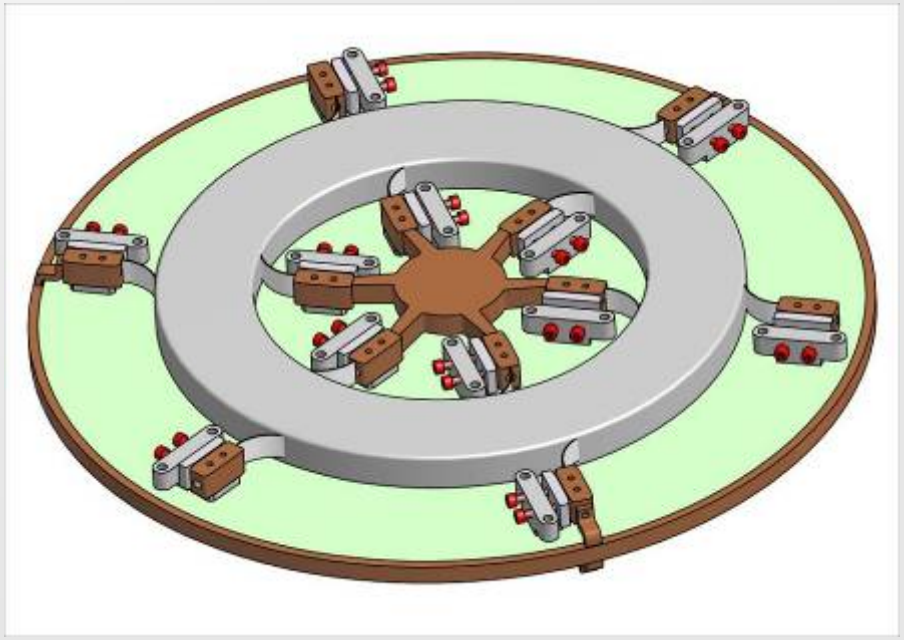
New developments: FCL systems based on cc-tape

12-600 (ENSYSTROB)
first MV system with cc-tape

This project has received funding
from German government under grant 03KP102A

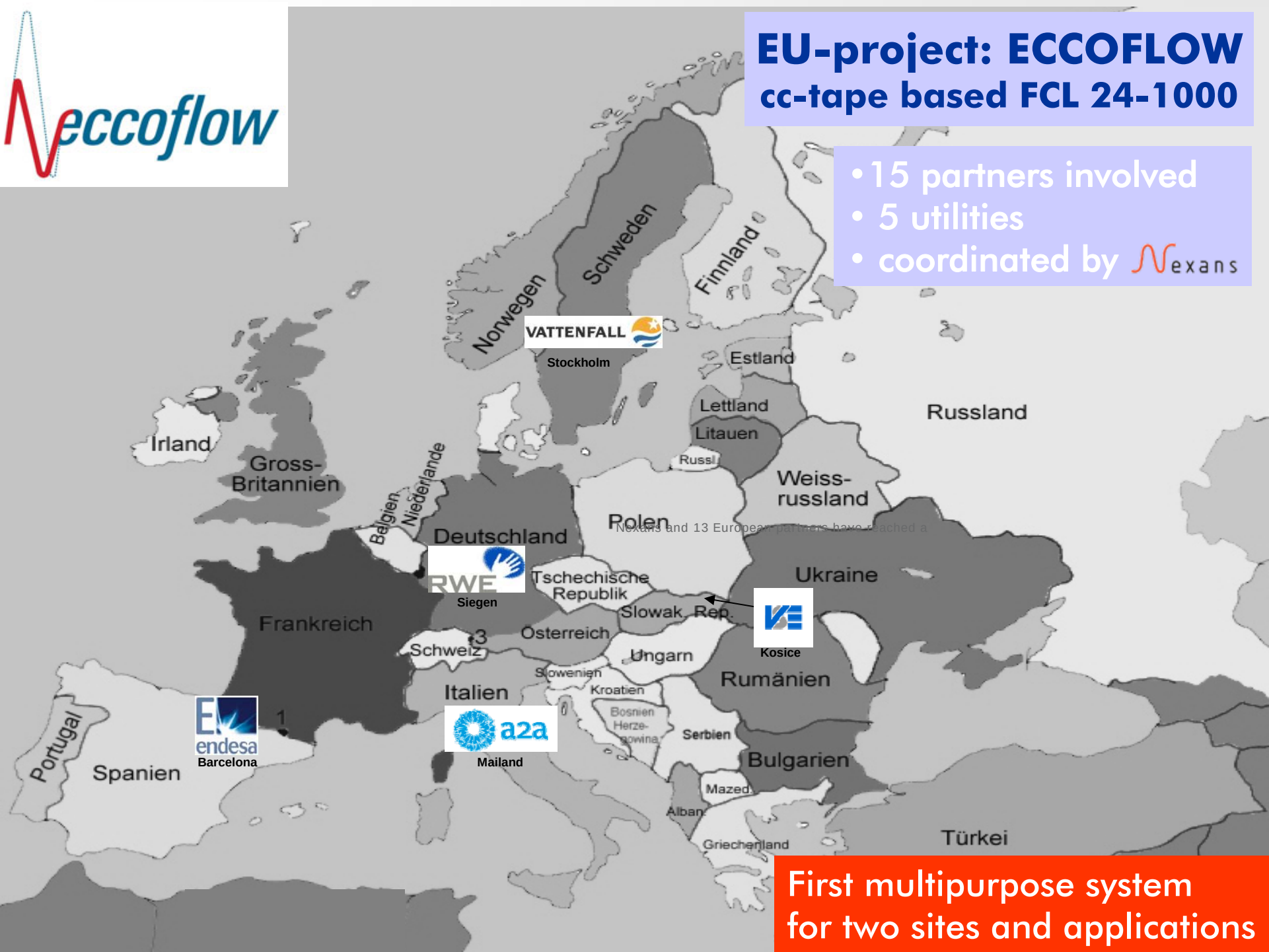


24-1000 (ECCOFLOW)
first system for
two different customers

This project has received funding
from the European Union
Seventh Framework Program (FP7/2007-2013)
under grant agreement No. 241285

EU-project: ECCOFLOW
cc-tape based FCL 24-1000

- 15 partners involved
- 5 utilities
- coordinated by Nexans

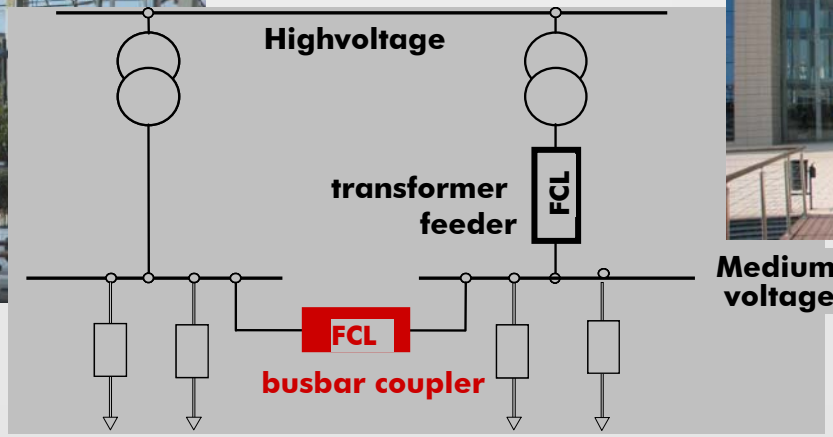


Nexans and 13 European partners have reached a

First multipurpose system
for two sites and applications

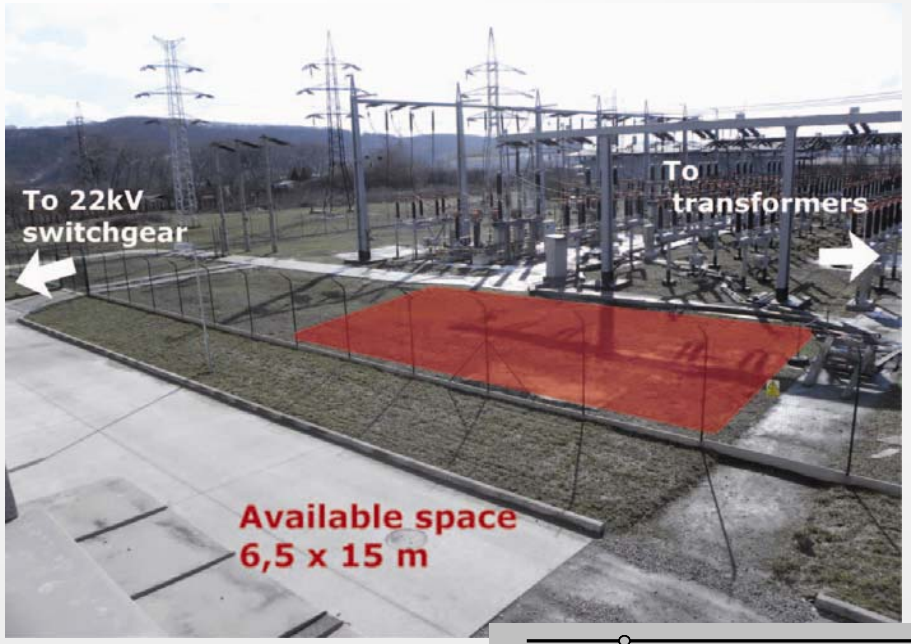
Project 24-1000 ECCOFLOW
1st site for installation

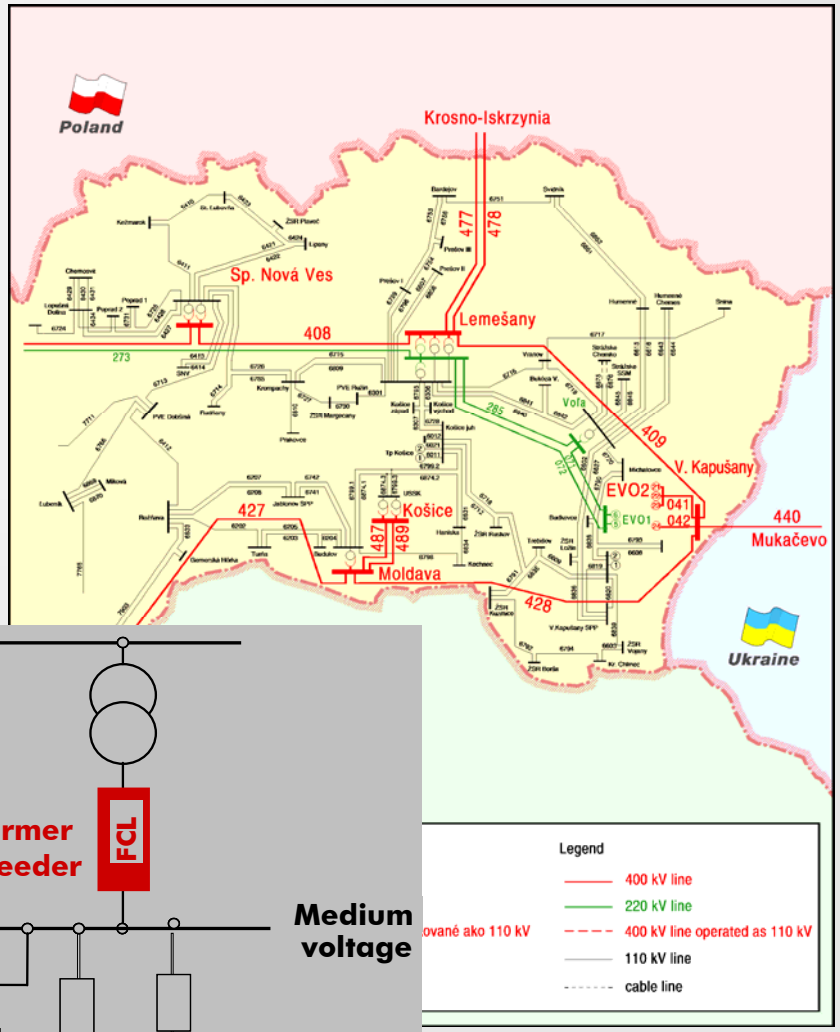
Palma de Mallorca



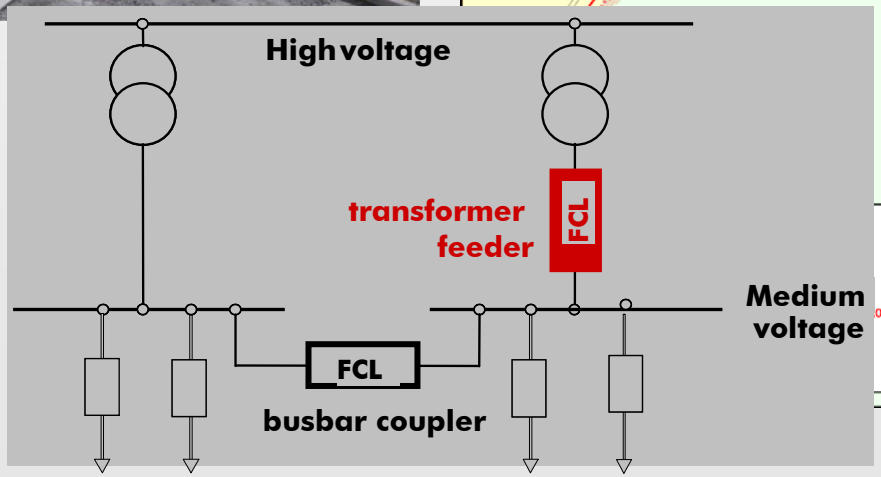
Juan de Dios

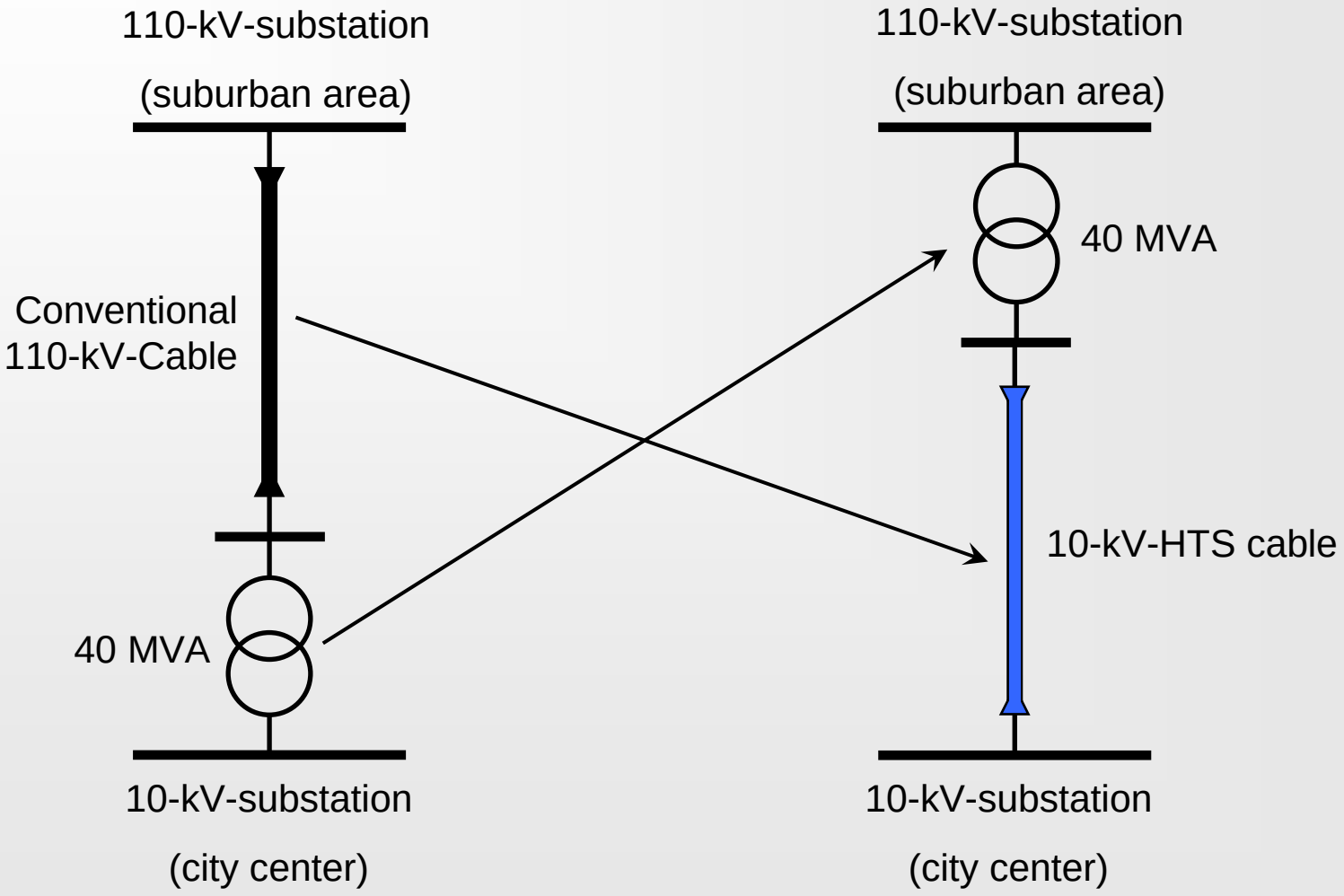
Project 24-1000 ECCOFLOW
2nd site for installation





VSE grid
Košice, Slovakia

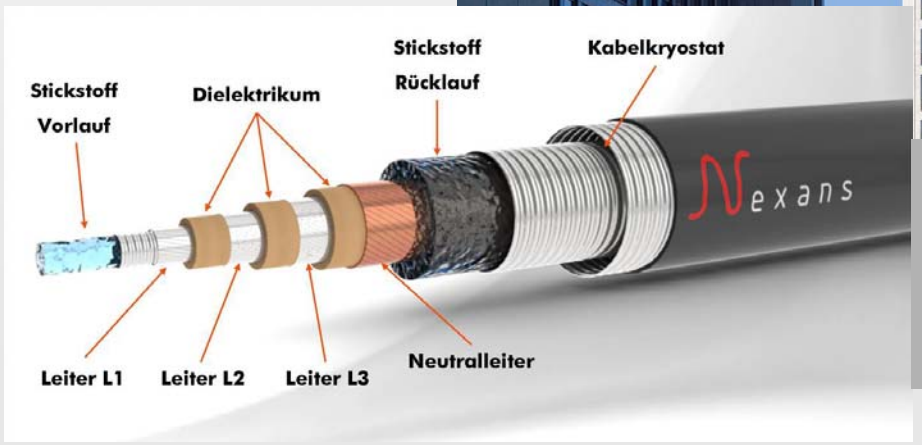




Supply of city center by MV HTS cable

SupraCity
Feasibility study

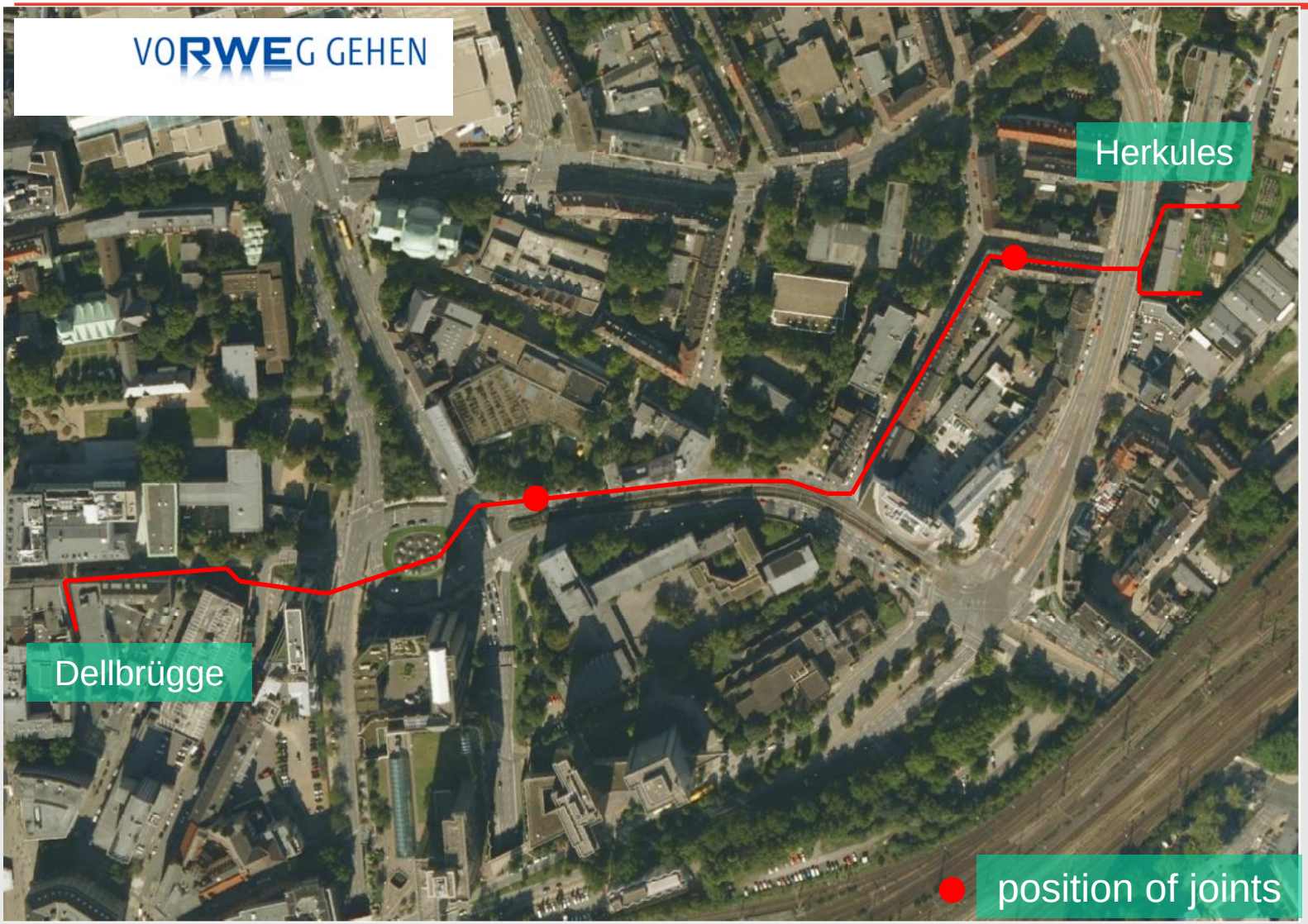
Karlsruhe Institute of Technology



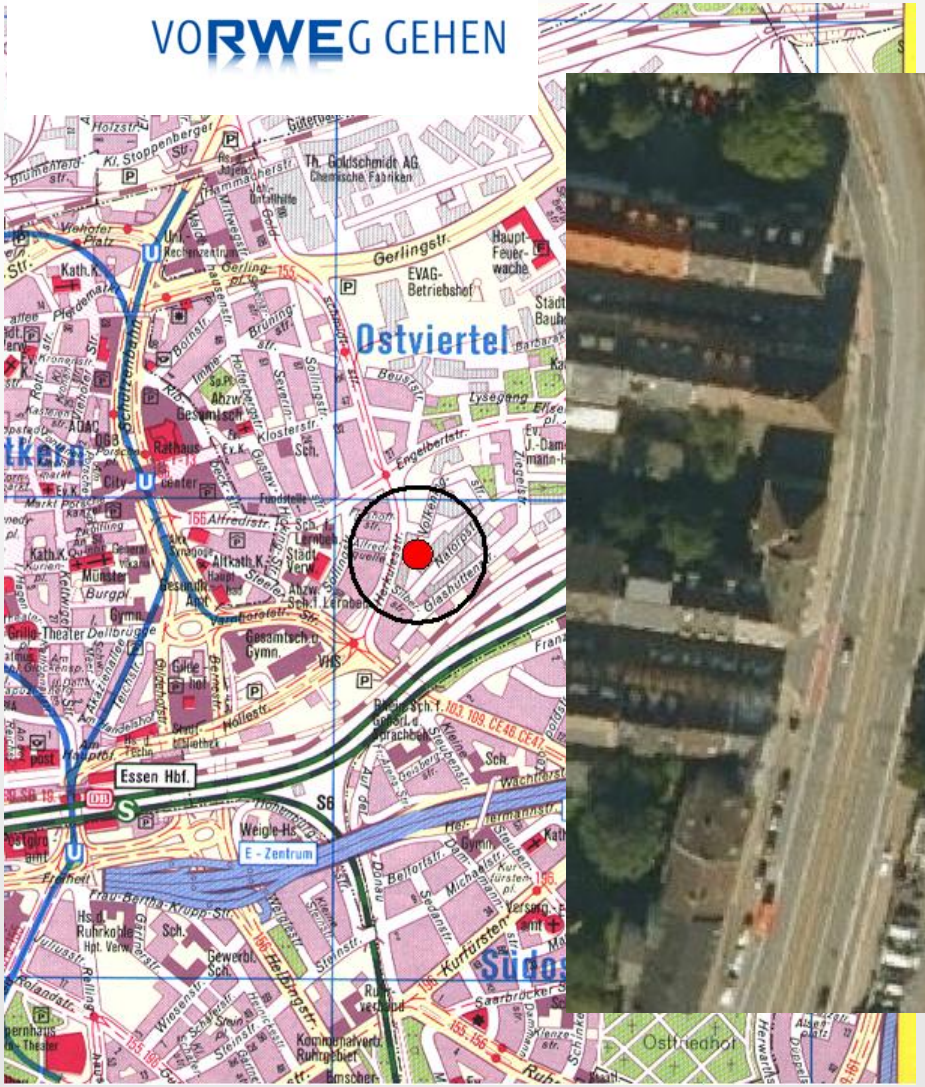
Possible start 06-2011

Study showed project is
- technically feasible
- economically reasonable

SupraCity
Center of Essen



SupraCity
First HTS cable with stand alone FCL



Conclusions

- **Full chain mastered from production of HTS material to final FCL system (for bulk)**
- **First commercial FCL systems realized (w/o any public funding)**
- **Successful grid operations also with the first HTS system in a power station worldwide**
- **Market entry with bulk already achieved**
- **New development projects started**
  - → **based on cc-tape**
  - → **multipurpose device**
  - → **new solutions for urban areas**

First FCL worldwide in a power plant

Power safety at its best

Thank you for listening!

Nexans SuperConductors