A new EC project: FASTGRID

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Cost effective FCL using advanced superconducting tapes for future HVDC grids

Started January 1st 2017 (42 months)
Introduction - context

HVDC supergrids

HVDC circuit breaker
SGRI (200 kV)
(7 x 7 m²)
Footprint & cost

Strong interest of R-SCFCL
Introduction - context

Cost of the Superconductor in a R-SCFCL:

\[
Cost_{SC} = \frac{C_{SC}}{E_{\text{lim}}} \cdot k_a \cdot I_a \cdot V_{SC} \cdot \text{Lim}
\]

⇒ Reduction of \( C_{SC} \)
- Material & Labor
- \( I_{c-w} \) Perf. & operating temp. => 65 K

⇒ Enhancement of \( E_{\text{lim}} \)
- Conductor design (shunt)
- Hot spot issue for low prospective faults
  - Homogeneity
  - NZPV
- New route

\[
T_{\text{max}} (\text{K})
\]

- 0.7 \( I_c \)
- 0.9 \( I_c \)

\[
T_{\text{max}} (\text{K})
\]

- 0.9 - \( \lambda \)
- 0.9 - 100 \( \lambda \)
FASTGRID deliveries

• **Advanced REBCO tape**
  - Low standard deviation in term of critical current over the tape length
  - Critical current higher than 1000 A/cm-w at 65 K (self-field)
  - Electric field higher than 100 V/m (50 ms)

• **Emerging REBCO tape**
  - Tape with enhanced propagation velocity (CFD concept)
  - Sapphire substrate REBCO tape with ultra high electric fields

• **Smart module of a HVDC apparatus**
  - Current and voltage in the range of 0.5/1 kA and 30/50 kV
  - New functionality such as quench detection through optical fiber
  - Extensive testing of the module in relevant operating conditions
Low standard deviation in term of $I_c$ over the tape length and high $I_c$

After optimization of process parameters:

- $I_C > 500A$
- $\Delta I_C < 5$

can be produced with high yield

Example:
- Ag thickness $I_{C-w} \approx 580 \text{ A/cm-w (77 K)}$
- $=> I_{C-w} > 1000 \text{ A/cm-w (65 K)}$
Conductor with high electric fields (> 100 V/m)

- A numerical model in COMSOL has been developed
- Various configurations of shunt tested in different scenarios (limitation, hot spot) with soldered or adhesive bonding
- Two architectures to test
  - CuproNickel shunt (Cu\textsubscript{60}Ni\textsubscript{40}) 150 µm - 300 µm
    - 5 µm solder PbSn
  - Hastelloy shunt 500 µm - 800 µm
    - 5 µm solder PbSn

Validations tests and first tests are undergoing
Conductor with high electric fields (> 100 V/m) – other approach

Original tape

Tape + shunt

Tape + 2x shunt

- High thermal capacity,
- Electrically insulating layer

FEM simulations, Comsol 5.2 model developed by EPM (Ch. Lacroix, F. Sirois)

Shunt properties:

C_p = 900 J/(kg.K) at 77 K
λ = 1 W/(m.K)

voltage pulse:

100-200 V/m

100 V/m

150 V/m
NZPV enhancement: Current Flow Diverter (CFD) concept

- Full 3D numerical simulations of 2G HTS CCs including the « Current flow diverter » (CFD) concept
- Types of shunt investigated:
  - Hastelloy, Stainless Steel, Composite, CuproNickel, etc.
  - Shunt thickness: 0 - 200 microns
- Calculations also realized for tapes based on a sapphire substrate

Quench simulation of a CFD-2G HTS CC with a 100-microns-thick Hastelloy shunt

The NZPV can be increased from 0.5 m/s to 15 m/s (x 30) using the CFD even with a thick shunt
CFD realization through Ink Jet Printing (IJP): customization of conductors

THEVA tapes are coated by IJP with amorphous Y$_2$O$_3$ layers tracks: CVD

Center of the tape

Surface temperature distribution

IJP insulating layer

IJP can be used to pattern customized tracks

THEVA CC (ISD)
OXO CC (CSD/ABAD)

IJP nanometric coatings of insulating layers customized

- IJP metalorganic precursors (~ 100 nm)
- High deposition speed (>20 m/h)
- Long lengths demonstrated (> 100 m)
- Low temperature annealing (T ~400-500 °C)
- SC performances CC stable
- Test of limitation properties underway
Thick YBCO layers can be grown after IJP deposition ($I_c > 220$ A/cm-w on LAO): implementation on sapphire substrates under way. 
Ultra high electric field tapes ($>1000$ V/m) expected.
Smart module of a HVDC apparatus

- Current and voltage in the range of 0.5/1 kA and 30/50 kV
- New functionality such as quench detection through optical fiber
- Extensive testing of the module in relevant operating conditions

- Preliminary Electro-thermal simulations on HTS tapes, show the feasibility of a system which can detect quickly and with good spatial resolution.
- Further investigations with Optical Fiber implementation in the model
  - Mesh issues and computational time.
- Study of feasibility for the integration
  - Which is the shunt? Which is the geometry? Is it feasible integrate a fiber in the shunt?
- Test samples with Optical Fiber integrated
Module

• Two studies are undergoing to validate the FCL design with pancake

Voltage breakdown

Positive Electrode 4-50 kV
Ground

Imposition of High voltage in DC in LN2 with or without bubbles

Dielectric studies of liquid Nitrogen at 77 K, 65 K with or without pressure
Impact on a Superconducting FCL
New testing tools

High-speed thermal imaging of quench propagation in HTS tapes using temperature-sensitive fluorescent films

0 ms  | 40 ms  | 60 ms  | 80 ms  | 100 ms
Reference | Heating starts | Quench starts | Normal area | Limit exceeded

Reference: 60 ms
Quench starts: 80 ms
Normal area: 100 ms
Limit exceeded: 100 ms

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Conclusions

H2020 FASTGRID project started January 1st 2017 with objective to reduce the cost of the REBCO tapes

• High $I_c$ tapes & operation at 65 K (1000 A/cm-w)
  • Hot spot issue to be carefully studied
• High Electric field under limitation (> 100 V/m)
  • High $I_c$ homogeneity (5 % already reached by THEVA)
  • Enhancement of NZPV
    • Current flow diverter (realization through Ink Jet Printing)
• New route: sapphire substrate based tapes
  • Successful short tapes
• 50 kV – 1 kA module
  • Quench detection and temperature through fiber glass
  • Works on electric insulation & winding configurations
• New investigation tools
  • High-speed thermal imaging using temperature-sensitive fluorescent films
Thank you!

http://fastgrid-h2020.eu