SCARLET

Superconducting CAbles foR sustainabLe Energy Transition

SCARLET – the European superconducting MVDC cable initiative

ZIEHL X, Berlin, 16.04.2026

Wolfgang Reiser on behalf of the Consortium

Partners: SINTEF, IASS Potsdam, WavEC, ELÚ, Alma Mater Studiorum, Absolut System, ESPCI Paris PSL, SuperGrid Institute, RSE, RINA, Supernode, Vision Electric Super Conductors, ASG Superconductors, Nexans

Funded by the European Union

SCARLET

Superconducting CAbles foR sustainabLe Energy Transition

Agenda

Project organisation
Survey Work Packages
High Temperature Superconducting (HTS) Cable
Superconducting cable in LH_2 for bi-energy distribution
Conclusions

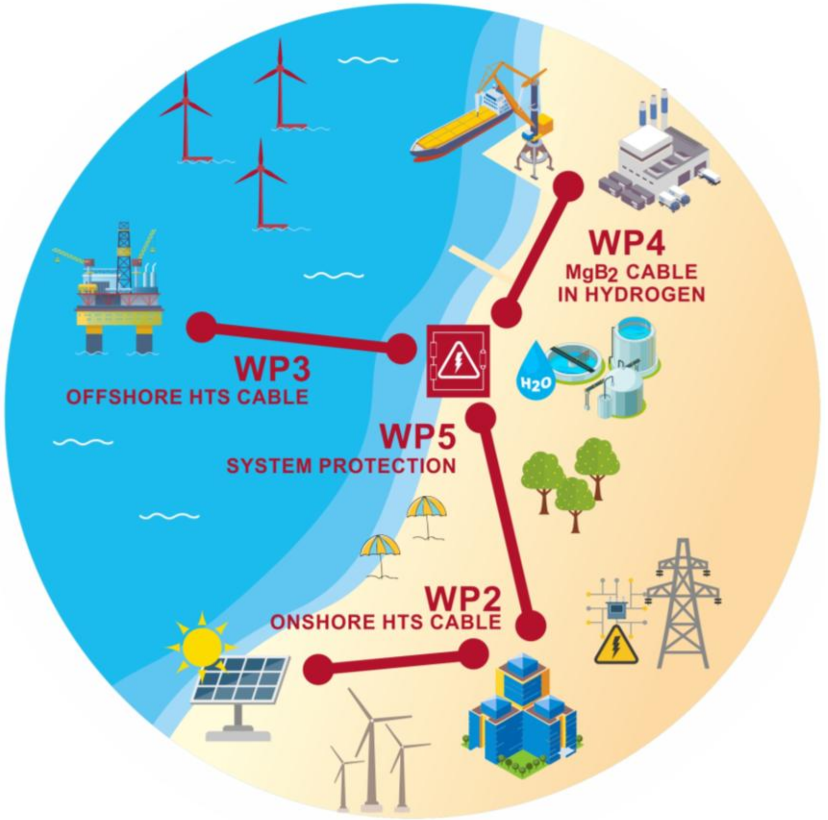
Project Organisation

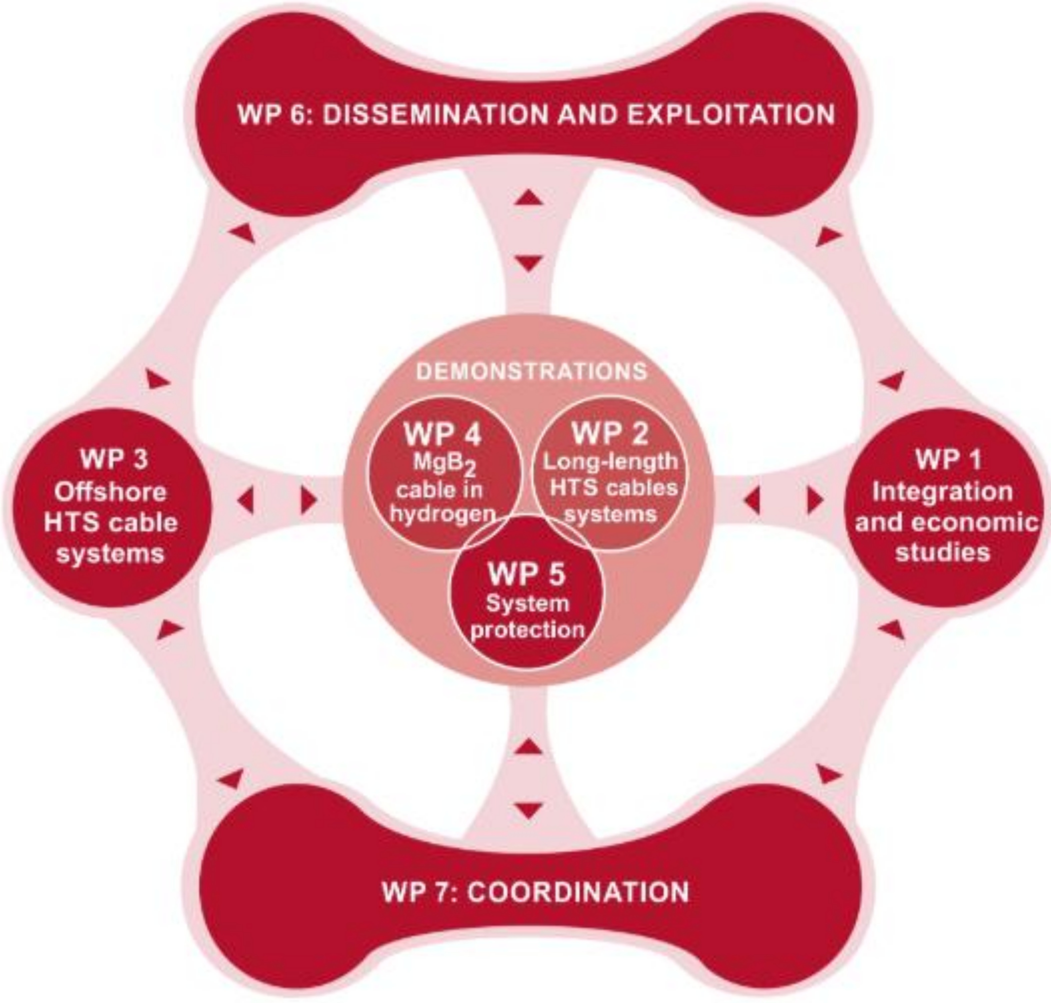
European Project SCARLET (2022-2027)

- **Goal:** develop and industrially manufacture superconducting cable systems at the gigawatt level, bringing them to the last qualification step before commercialization. Investigate the protection requirements of such transmission systems (incl. RSFCL module)
- Expertise from **15** industry and research organisations in the fields of material sciences, cryogenics, energy systems and electrical engineering

Project Organisation
Project structure

- 3 demonstration work packages
  - long-length onshore superconducting cable systems → WP2
  - Superconducting cables in liquid hydrogen → WP4
  - Resistive Superconducting Fault Current Limiter module → WP5

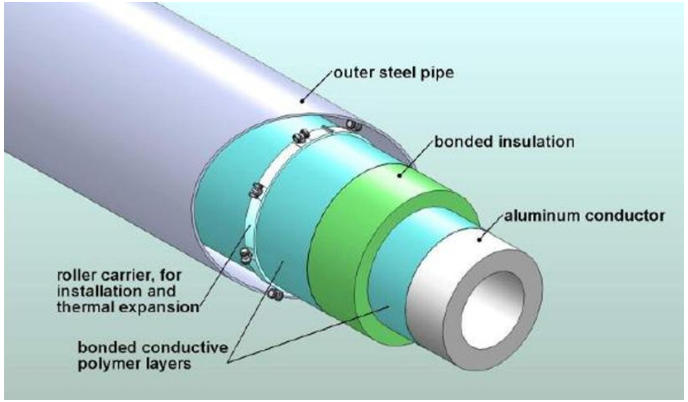




SCARLET
Superconducting CAbles foR sustainable Energy Transition

Side Request for Feasibility Study

- **ELPIPES** by Roger Faulkner
- Aluminium pipes with HV and HC in ground
- Result: Technical and commercial not relevant



Impact on System Architecture

Present Bulk electrical transmission practice

- **Bulk power transfer with offshore and onshore HVDC links**
  - Recent evolution of power transfer from typically 500 MW to 2 GW nowadays
  - the main bottle neck is the resistive cable that has a limited current transportation capability
  - As a consequence there was a recent switching from 320 kV DC to 525 kV DC as the new state of the art for the transmission voltage
  - Recently, bottleneck on cable production capacity and potential copper scarcity

- **What if we switch to a superconducting cable ?**
  - Current transportation capability could be more than 10 times higher than resistive cable
  - Increasing the current carrying capability also allows the operation at reduced voltage to transport the equivalent power
  - If reduced voltage could be applied, the impact on the size on many components and accessories would be highly significant

Impact on System Architecture

Why MVDC superconducting cable for bulk transmission ?

EFFICIENCY & ENVIRONMENT

- No electrical resistance = no joule losses and ~100% transport efficiency even on very long length
- DC voltage = no dielectric losses in cable insulation
- Low environmental footprint of cable system (no thermal impact in soil…)

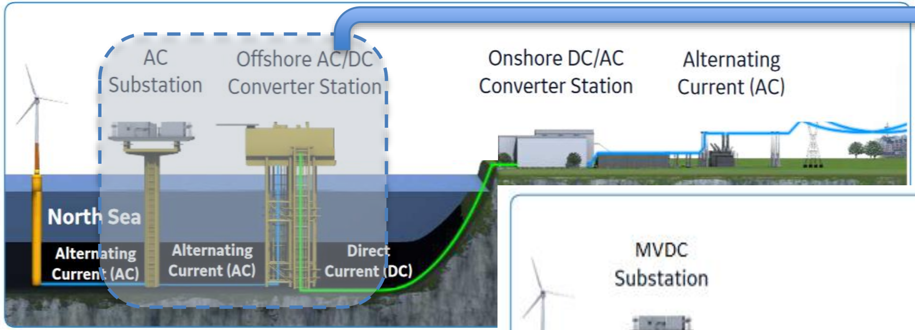
SIMPLIFICATION & COMPACTNESS

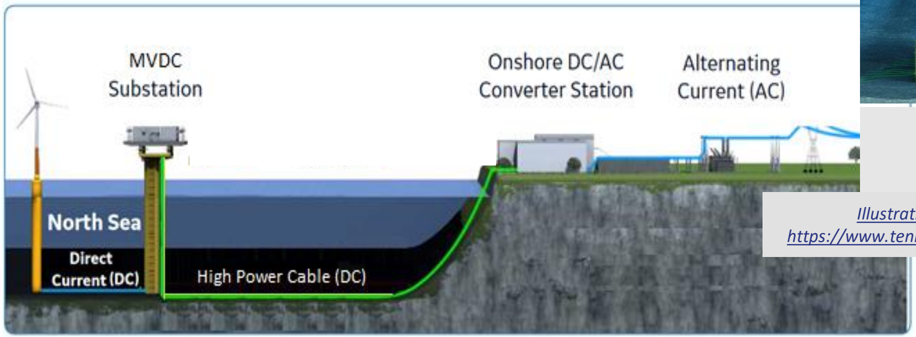
- Smaller – simpler platform required for offshore application
- High power transported using only medium voltage simplified the grid management (security, right of ways, permits…)
- Lower footprint and civil work even for very high powers

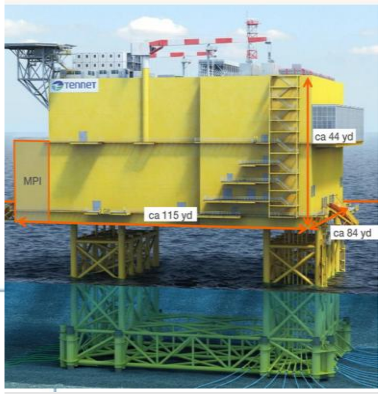
WP3: Impact on System Architecture

Application case: MVDC offshore wind power export

- The main incentive to switch from HVDC cable to MVDC superconducting cable is to suppress the offshore conversion platform



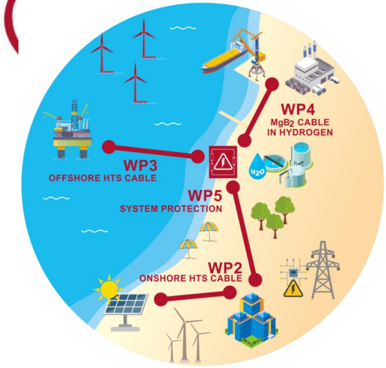




Dimensions:
~ 105 m x 77 m x 40 m

Illustration of a 2 GW 525 kVdc Platform from https://www.tennet.eu/about-tennet/innovations/2gw-program

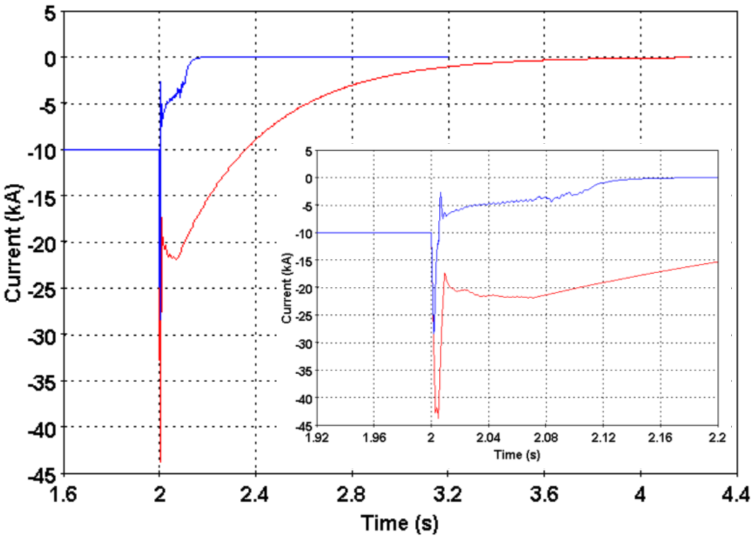
- **Conditions:**
  - MVDC transport voltage right at the windmill output
  - Feasibility of MVDC GW level converter
  - Fast protection in case of pole to pole fault



SCARLET
Superconducting CAbles foR sustainabLe Energy Transition

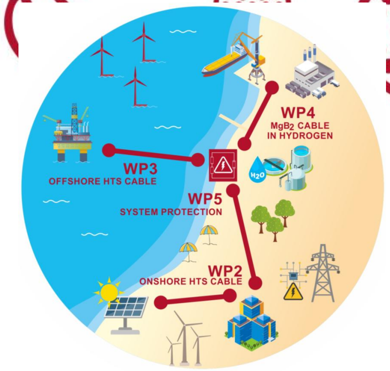
WP5: RSFCL demonstrator

- ❑ Based on 1 GW – ± 50 kVdc transmission system
  - ❑ Bushings 50 kVdc – 250 kV BIL – 10000 Adc
  - ❑ Pancakes:
    - ❑ Single 10.000 A module design
    - ❑ 4 pancakes built for the project will be stacked in series in the cryostat
- ❑ Pancake limitation performance to be demonstrated based on worst-case short-circuit simulation result of the transmission system



Prospective short circuit current
Limited short circuit current

SCARLET
Superconducting CAbles foR sustainable Energy Transition

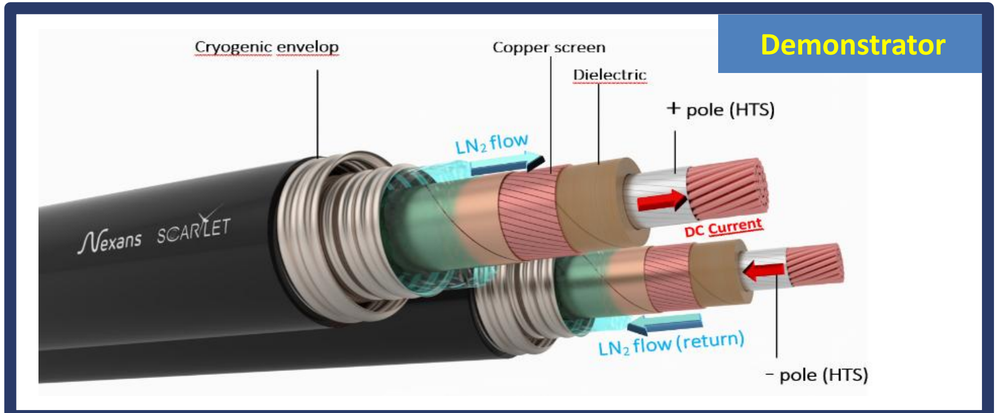


WP2: High Temperature Superconducting (HTS) Cable

- Detailed electrical designs are calculated for different cable structures for **1 and 2 GW**.
- The outer cable core diameter limits the length between cryo-coolers (thermo-hydraulic length).
- First results indicate **thermo-hydraulic lengths of 20-38 km** depending on the cryostat characteristics for a 220 mm outer diameter cryostat.

❑ **Demonstrator:** Type test of a +/- 100 kV, 10 kA cable with accessories.

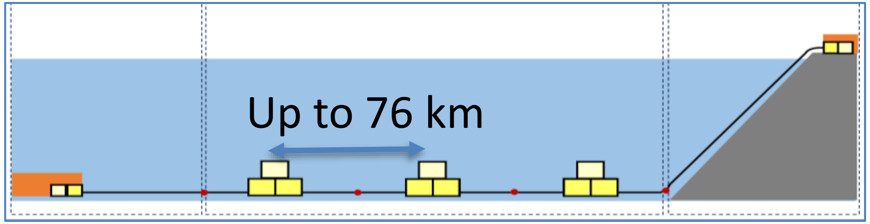
❑ **Offshore components:** Testing of mechanical reinforcement of the cryostat for high pressure



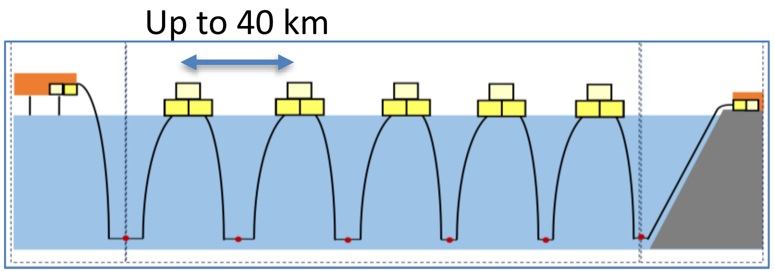
Chosen design

High Temperature Superconducting (HTS) Cable

- **Identification of offshore use cases corresponding to the variation of several parameters**
  - Cryostat size and max pressure
  - **floating** or **offshore** intermediate platform
  - Windfarm distance to shore: **100 and 250 km**
  - Exported power: **1 GW and 2 GW**

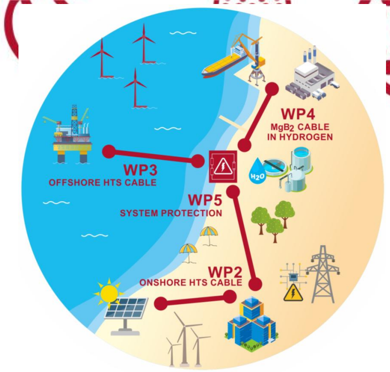


Submarine intermediate substation



Offshore intermediate substation

- **Rough techno-economical study to compare the scenarios:** type-test of a +/- 100 kV, 10 kA cable system
- **Selection of 3-4 uses cases for an in-depth analysis :** deeper study of components, risk assessment and environmental impact



SCARLET
Superconducting CAbles foR sustainabLe Energy Transition

WP4: Superconducting cable in liquid H_2 for bi-energy distribution

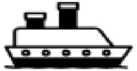
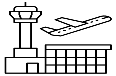
4 main goals and outputs of the bi-energy cable in SCARLET

- Investigate and select the best scenarios and most profitable business cases for such bi-energy systems
- Validate the existence and availability of the full supply chain
- Analyse and prepare the mandatory safety rules to be used to reassure the users - Hazard identification (HAZID) & Hazard in operation (HAZOP) methodologies
- Demonstrate by type and long-term testing of a 20 kA / 25 kV superconducting cable system designed and manufactured for operating in LH_2 in safe conditions

Superconducting cable in liquid H_2 for bi-energy distribution

Electricity and hydrogen: the next decarbonized energy vectors

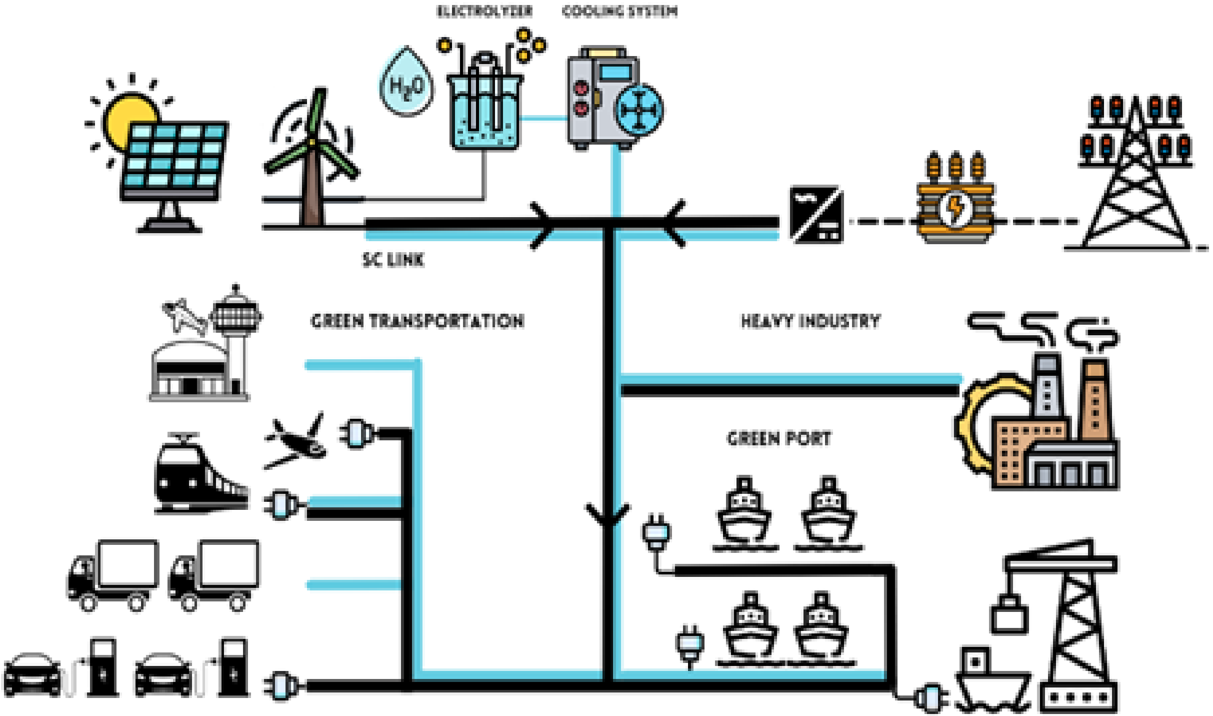
- H_2 can store the electrical power and be used as energy vector *(1 kg/h of H_2 can generate 33 kW)*
- But hydrogen and electricity also coexist in many scenarios

	H_2 needs	Electricity needs
	10 t/h in steel smelter for reduction reaction	50 to 200 MW
	15 t on board approx. 2-3 t/h for 2-5 ships in a port	50-200 MW per ship and port infrastructure (Green port)
	150 to 200 kg on board/train. For 20 trains 3t/d	10 MW per substation and railways station infrastructure
	80 kg/truck. For 0.3 t/h (100 truck) to 3 t/h (1000 truck)	100-200 kW per fast charge point ≈50 vehicles 10 MW
	Up to 9 t per aircraft for line airplane 10-30 t/h	Large range for electric aircraft from 50kW to 1 MW and airport infrastructure

A structured ecosystem economically viable for transportation and distribution is needed and studied in SCARLET

Superconducting cable in liquid H_2 for bi-energy distribution

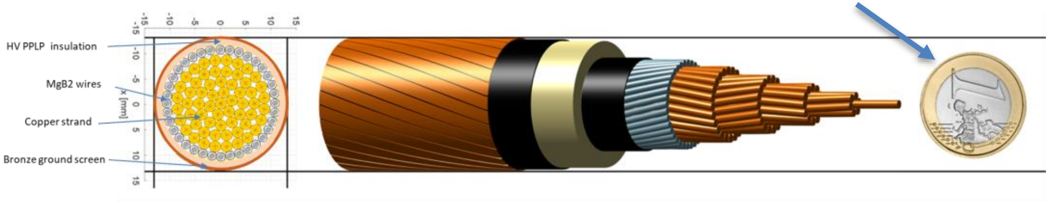
Our vision of the new bi-energy supply grid



Superconducting cable in liquid H_2 for bi-energy distribution

MVDC MgB_2 cable in SCARLET

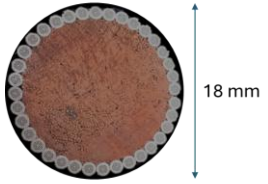
OD: 23,2 mm



Single-stage fault-tolerant cable design

20 kA at 25 K using 36 MgB_2 wires

- ❑ 300 m of very compact and fault-tolerant cable conductor
  - ✓ No degradation after cabling



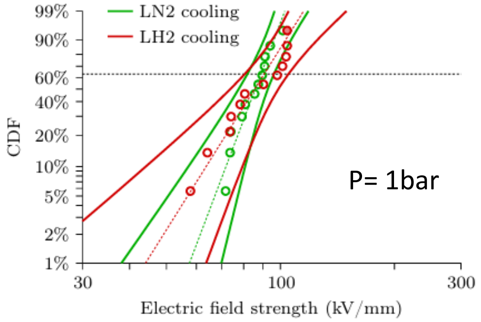
Cable conductor section

Superconducting cable in liquid H_2 for bi-energy distribution

HV insulation in LH_2

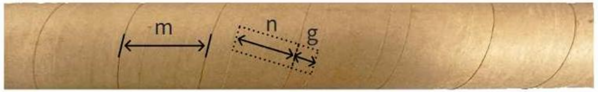
- ❑ Measurements performed at TU Dresden using a dedicated test bench
- ❑ Performances in LH_2 and LN_2 are similar
- ✓ LN_2 can be used to simulate tests conducted with LH_2

Voltage breakdown Weibull statistics in LN_2 and LH_2

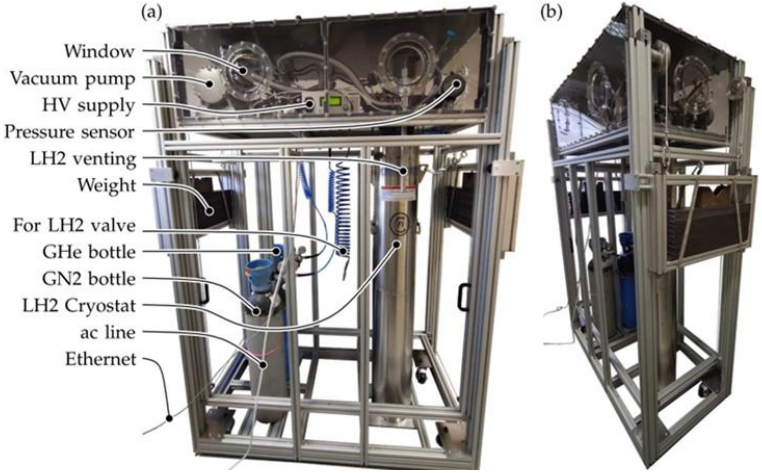


- ✓ Cable design validated in LH_2 with E_{max} =18 kV/mm

Representative samples insulated with PPLP



m=26 mm and n=20 mm



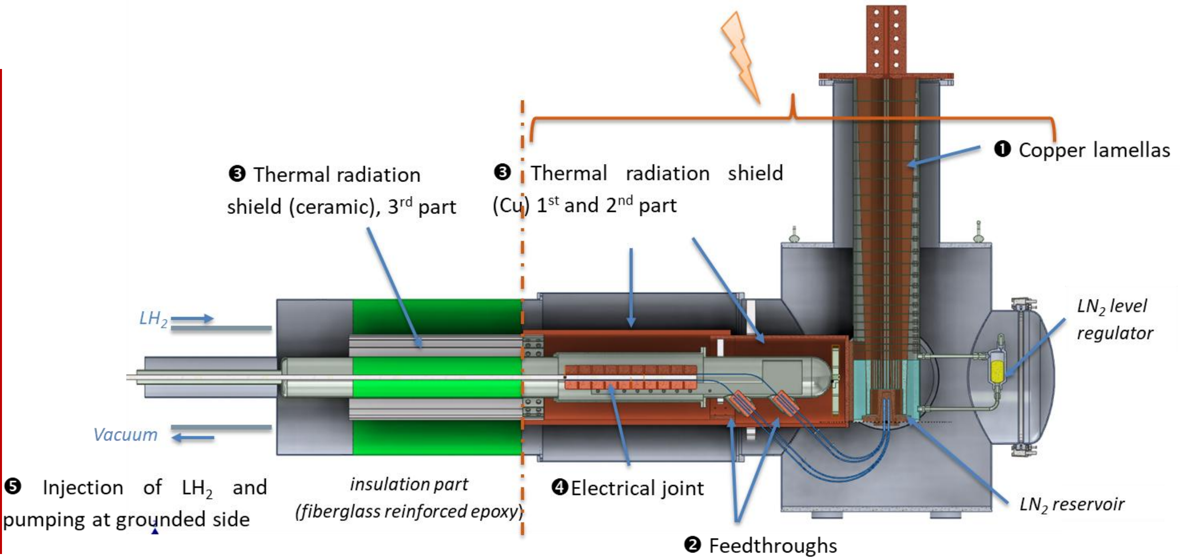
Innovative test bench for voltage breakdown in LH_2

Superconducting cable in liquid H_2 for bi-energy distribution

Termination design (25 kV, 20 kA → 1 GW)

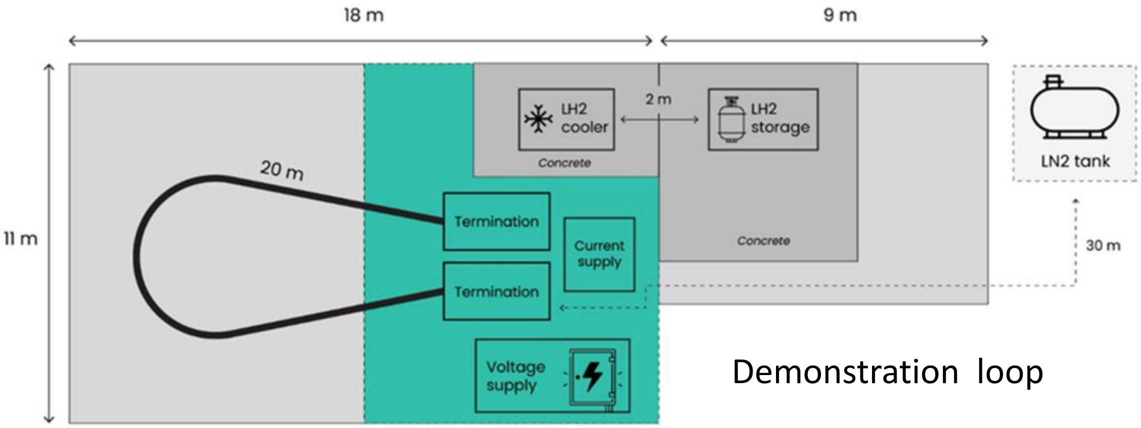
- Modular design concept with independent voltage and current management elements
  - ✓ Innovative thermal shield
  - ✓ Collaborative design

1 Upper current leads with copper lamellas
2 Special feedthroughs to ensure pressure-tight transition into LH_2 area
3 Three-part radiation shield from HV to ground
- Copper section near LN_2 reservoir
- Copper section in the joint area
- Ceramic section in the stress cone area for electrical insulation
4 Length of low-loss electrical joint between HTS stacks and MgB_2 cable
5 LH_2 coupling and vacuum pump moved to grounded side for simplicity

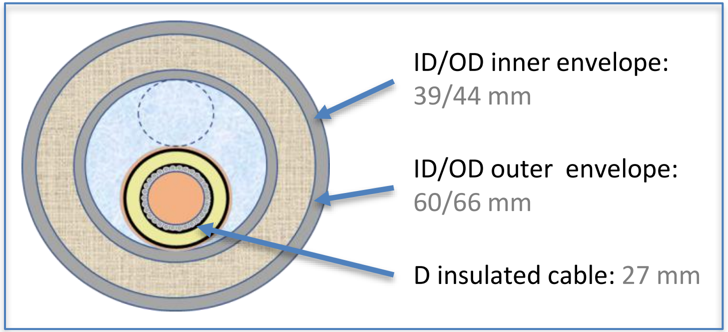


Demonstration loop of the MVDC MgB_2 cable in LH_2

SCARLET
Superconducting CAbles foR sustainabLe Energy Transition



Demonstration loop



Design for the demonstration cable

Next steps to type testing in SCARLET:

1. Manufacture and validate a single pole cable with two 20 kA-25 kV class **terminations** a robust **cooling machine**
2. Validate the defined **safety rules** for LH_2
3. Define MVDC testing procedure for superconducting DC cables and propose a **type test** to contribute to testing standardization within the CIGRÉ new group B1.101
4. Perform a **type test** followed by a **long-term test** (2 months)

Conclusions

- Design studies of the HTS and MgB_2 cables are concluded, and the cable assembly is ongoing
- Techno-economical analysis as well as environmental studies are ongoing based on realistic use cases
- Combined MgB_2 and LH_2 pipe use cases are identified starting with power level around 200 MW
- Success in promoting the topic at CIGRÉ level
  - Creation of a new WG B1.101, dedicated to HVDC SC cable testing
  - Information on SC cable will be presented in 2026 within B1 Tutorial at the Paris Session
- Topologies of converters and windmill conversion chain can be substituted to allow MVDC instead of HVDC transfer at GW level
- SC cable models can be combined with protection devices models and converter models to deeply assess the cable behaviour
- A 10 kADC RSFCL module is designed and underwent first successful tests

Contact information

Marte Gammelsaeter
Coordinator SCARLET project
marte.gammelsaeter@sintef.no

Dr. Adela Marian
Head of Communications
adela.marian@rifs-potsdam.de

Preparation of this presentation

Dr. Arnaud Allais – WP2
Coordinator HTS
arnaud.allais@nexans.com

Dr. Christian-Eric Bruzek – WP4
Coordinator bi-energy cable system
bruzek.christian-eric@as-g.it

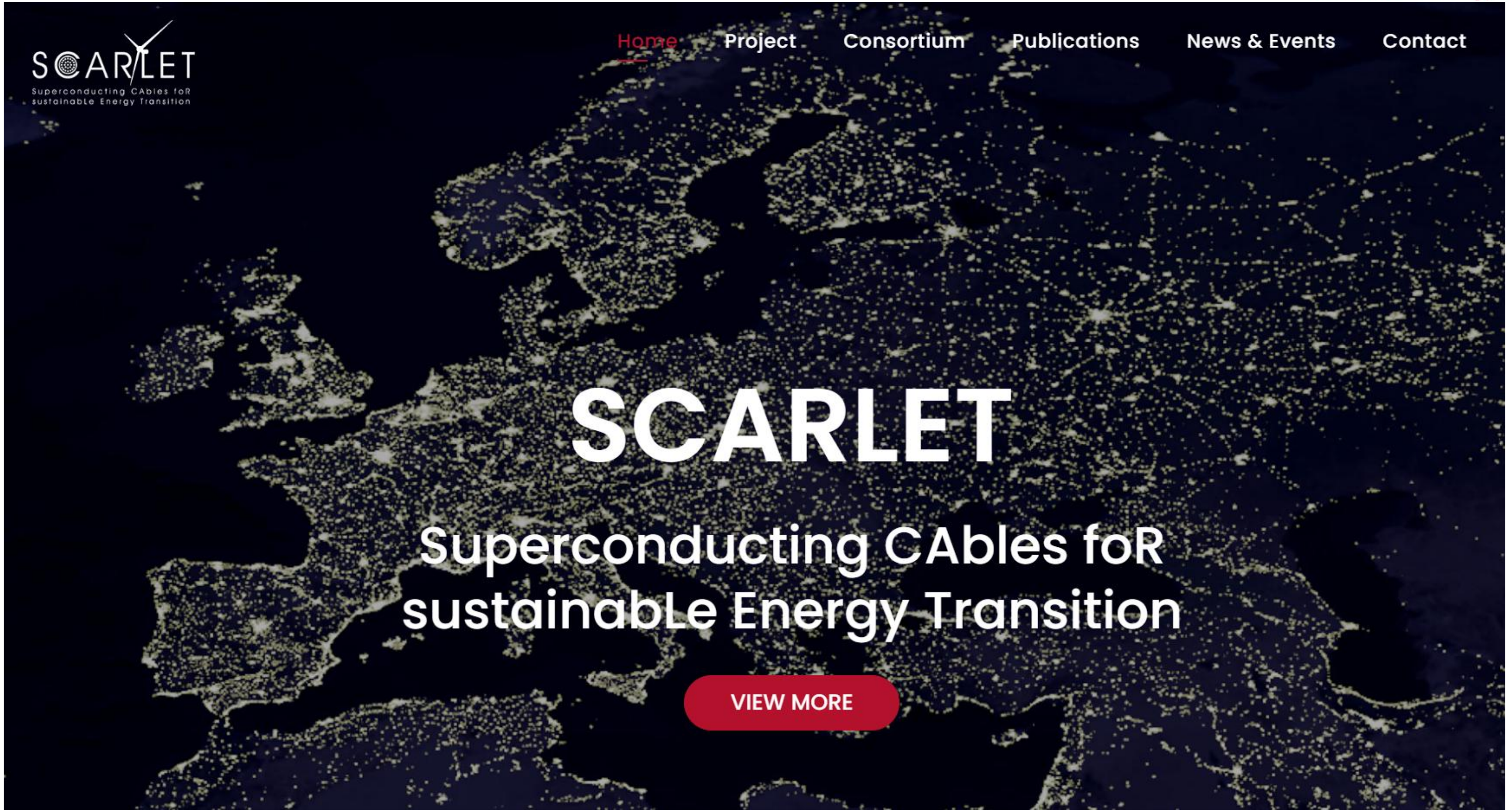
Christophe Creusot – WP5
Coordinator System & Protection
christophe.creusot@supergrid-institute.com

Follow us

https://scarlet-project.eu

https://www.linkedin.com/company/scarlet-project
https://zenodo.org/communities/101075602/records

SCARLET
Superconducting CAbles foR sustainabLe Energy Transition



Thank you for your Attention

SCARLET
Superconducting CAbles foR sustainabLe Energy Transition

Prof. Dr. Wolfgang Reiser
CEO
Vision Electric Super Conductors GmbH
www.vesc-superbar.de
info@vesc-superbar.de

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Funded by the European Union