Technologies Overview

Technology description & application examples by currENT members

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Executive Summary

currENT is the key industry association representing innovative grid technology companies operating in Europe. Our members are taking Europe's power network to the next level – developing and supplying innovative technologies that optimise and maximise use of the existing grid.

currENT members provide three core solutions: Dynamic Line Rating, Modular Power Flow Control, and Superconductor Cable Systems. There are descriptions and application examples for each of these solutions in this deck.

currENT aims to generate greater awareness of these Grid Enhancing Technologies, and accelerate their implementation by working with the wider stakeholder ecosystem to develop future-proof regulatory and policy frameworks.

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Introduction to currENT

"Our Vision is a European power network that is the recognised world leader in enabling decarbonisation through the efficient use of modern grid technology"

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We supply solutions for a clean grid

Our members develop and supply innovative technologies that optimise and maximise the use of the existing power network, to:

- Enable the integration of an increasing share of renewables
- Enhance the mitigation of climate change in line with COP 21 and the European Green Deal
- Help TSOs, DSOs and governments meet their European and national energy and climate objectives, without compromising on security of supply or affordable customer bills
- Help TSOs and governments provide fast-to-deploy solutions when the detailed needs of the medium-term future are difficult to anticipate. In doing so they avoid stranded investments that customers ultimately shoulder through their bills.

SUPERNODE™ Ampacimon Smart solutions for a dynamic grid SMART WIRES LINEVISION

CURRENT Enabling Network Technology throughout Europe OTLM KNILL GRUPPE amsc HEIMDALL POWER GWP greenwood power

Our Objectives

currENT member companies are driven by a common goal – **to speed up the green energy transition**.

We want to see Renewables take up massively, climate change mitigated successfully, while security of supply is kept high and costs kept low. We see power networks at the core of, and as the basis for, a successful energy transition.

We achieve our common goal through the following actions:

1. **Generate awareness** – of new grid enhancing technologies, the opportunities and challenges, and increasing awareness of the benefits of new technology. We wish to bring new game changing solutions to the table.
2. **Move policy** – we contribute to future-proof regulatory frameworks that speed up the adoption of alternative proven solutions for the benefit of all Europeans.
3. **Enhance technology** – we introduce, and where needed, trial new technologies; learning from each other through European benchmarking.
4. **Engage** – in acting collectively through our association we stand up for the principles of transparency and stakeholder interaction.

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Dynamic Line Rating

Dynamic Line Rating technology represented by currENT

- currENT member companies are responsible for **80% of DLR monitoring in Europe**
- **Sensors** are placed locally to **monitor power lines** and **weather** conditions to increase transmission capacity on the grid
- currENT member companies share a common vision to optimize the grid

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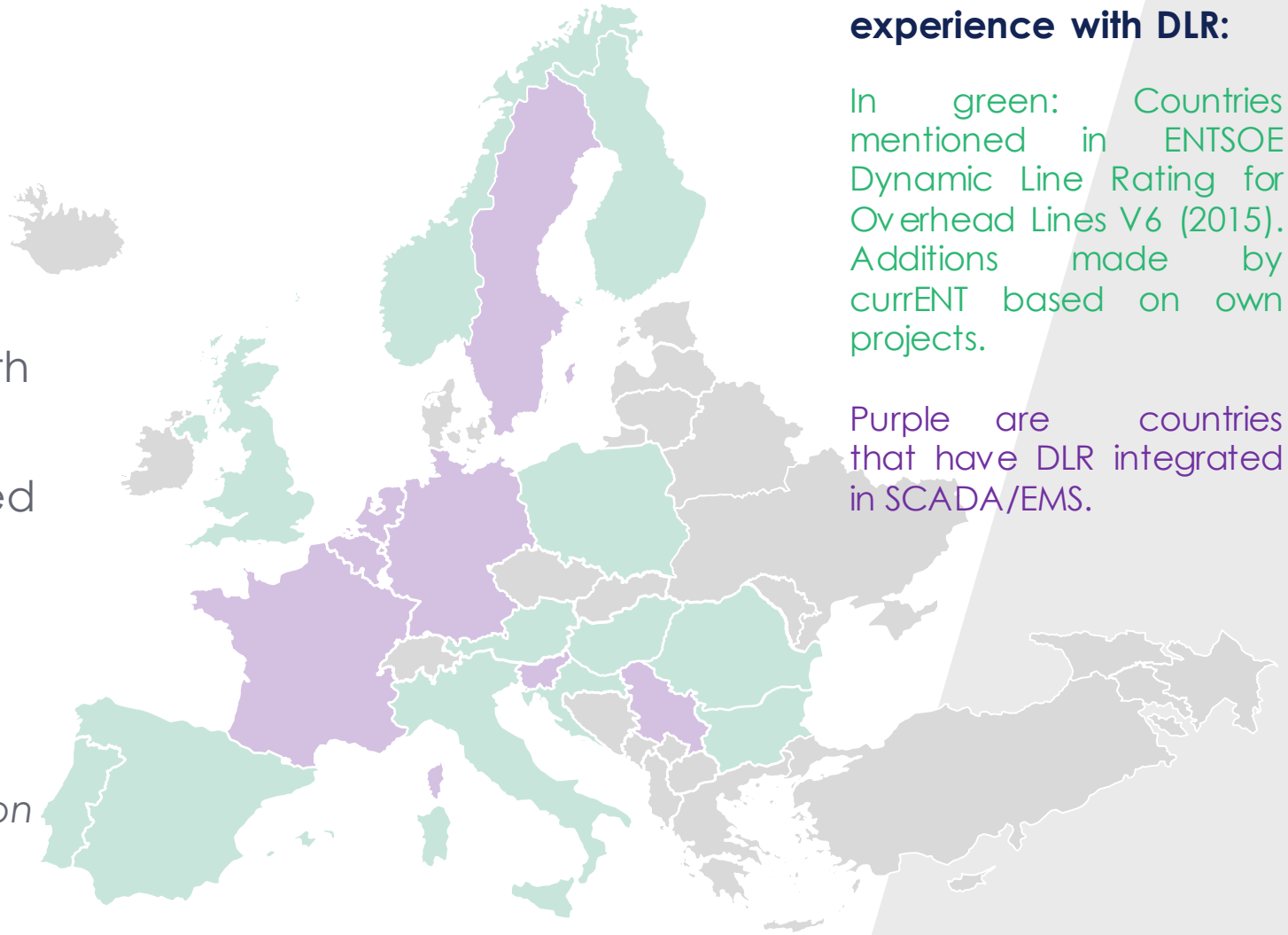
DLR adoption in Europe today

- **DLR is Proven**: Most countries in Europe have already deployed DLR
- **DLR is Expanding**: Most countries are done with pilots and are moving to deployments at scale
- **DLR is being Integrated**: Integrations with SCADA/EMS are increasing
- **DLR is a Market Factor**, and is being used for CACM and SCA processes
- **DLR Makes Economic Sense**, with clear business cases for:
  - ❑ *Cross Border trade capacity increase*
  - ❑ *Congestion management cost reduction*
  - ❑ *Faster renewables integration*



Colored countries have experience with DLR:

In green: Countries mentioned in ENTSOE Dynamic Line Rating for Overhead Lines V6 (2015). Additions made by currENT based on own projects.

Purple are countries that have DLR integrated in SCADA/EMS.

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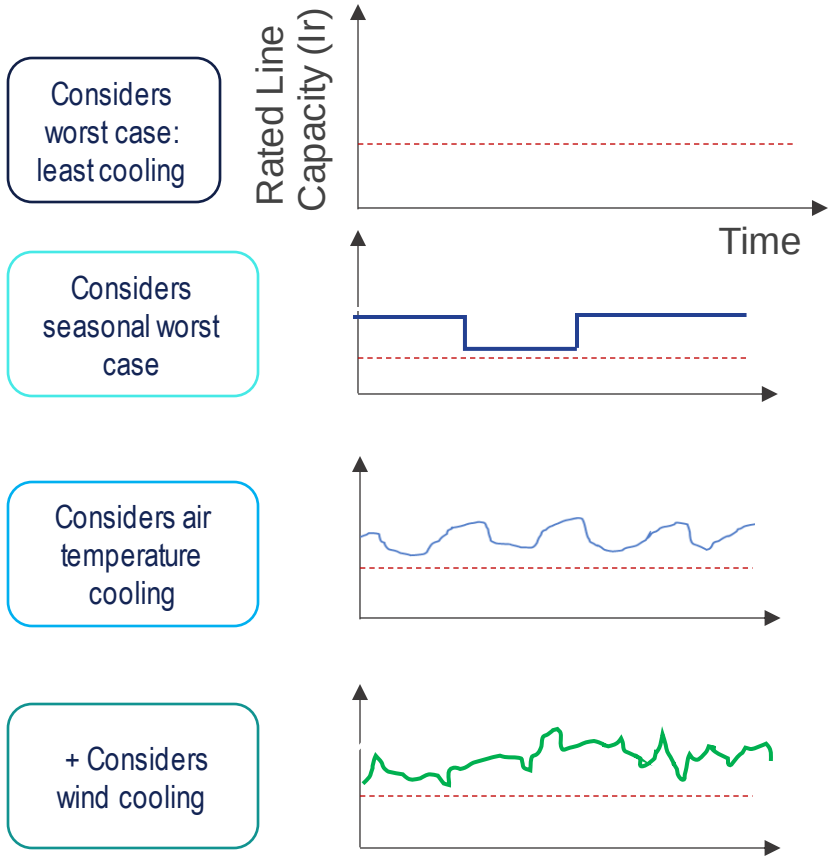
What is Dynamic Line Rating?

Types of line capacity rating



Static Line Rating (SLR)

Seasonally Adjusted Rating (SAR)

Ambient Adjusted Rating (AAR)

Dynamic Line Rating (DLR)

Full Benefit

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State of the art DLR system

What can be reasonably expected?

Fast and cost-effective transmission capacity increases to accommodate new renewable generation

Makes full use of wind and ambient cooling effects

At least 10-20% extra capacity is available 90% of the time

In some instances, twice the capacity available

Forecast line ratings with selectable confidence interval

Maximum sag and conductor temperature for safety never exceeded

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Applications and benefits

① Reduce congestion management costs

- Congestion management **costs range from 20-500EUR/MWh**
- Expensive measures used to address moderate (~10%) overloads.

Saved 500 kEUR redispatch costs in a day

② Economic dispatch cost reduction

- Making full use of **ambient cooling** effect, transmission lines can be used to **transport energy more efficiently**
- Maximum sag and conductor temperature for **safety** never exceeded

10-20% increase in acceptable infeed

③ Increase cross-border trade capacity

- **Short-term solution to boost market coupling capacity**.
- Small capacity increase in **high price split reap enormous returns in short time** frame.
- Cross border capacity benefits all citizens.

Saved 247 kEUR in 4 hours

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Applications and benefits

④ Reduce the need for remedial actions

- **Increasing need for remedial actions** to prevent overloading of lines (congestion) **in day-ahead and intraday timeframes** like topology change, PST tapping, redispatch, curtailment, load shedding.
- **DLR alleviates congestion thereby reducing this need.**

→ No need to reschedule maintenance outage

⑤ Accelerate renewables integration

- Generally **high loaded line** carrying **volatile infeed** from renewables.
- If forecast is wrong, it can very quickly deviate from expected loading.
- This needs remedial actions (actions to avoid (N-1) security issues).

→ 50% increase in hosting capacity, 15% less curtailment

⑥ Improve controllability of risk

- Visibility of real-time and forecast line capacity and flow allows grid operator to **manage more precisely overload risks**.
- Data statistics-based decisions can be made to inform asset management like outage planning and maintenance intervals.

→ Alerted overload risk in recent heat waves

⑦ Defer grid investment

- Increase in line capacity and visibility of use can be combined with power flow control.
- Such **grid operation-based solutions to tackle increased power flows can be counter-balanced with investment projects.**
- This gives flexibility in investment portfolio management.

→ Up to 15% saving on new CAPEX projects

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Modular Power Flow Control Solutions

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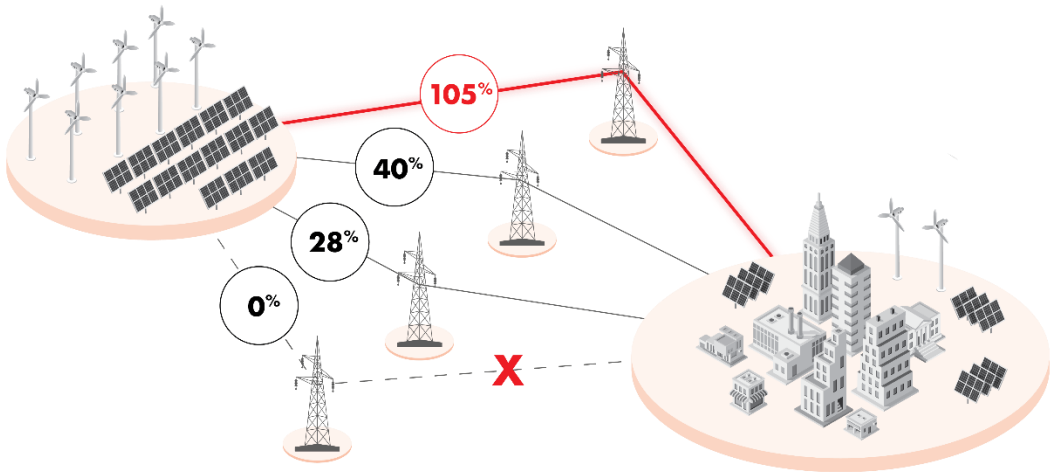
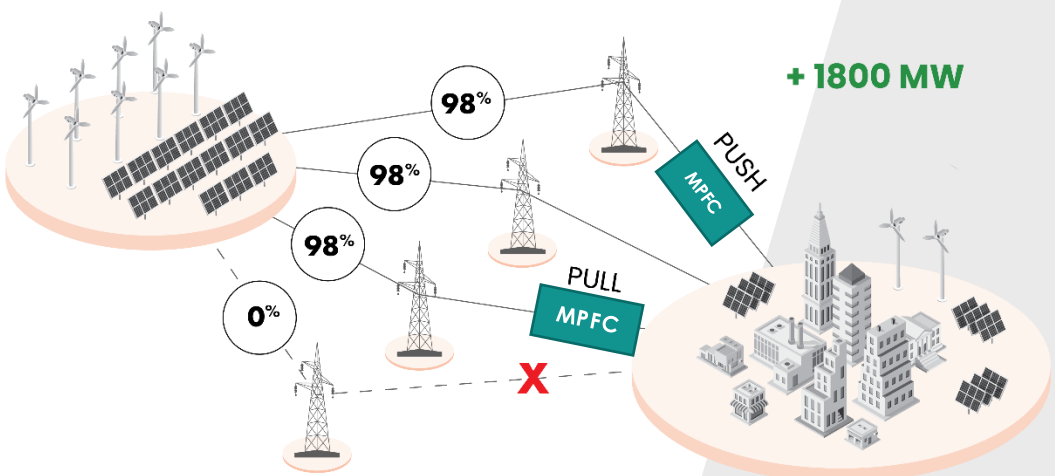
Modular Power Flow Control solutions can rebalance power flows across parallel lines to better utilise existing infrastructure

Before



After



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A Brief Introduction to SSSC Technology

- SmartValve™ uses a modular single-phase SSSC technology that employs Voltage-Sourced Converter (VSC) and Insulated-Gate Bipolar Transistors (IGBTs), both of which have been widely used for 20+ years in STATCOM, HVDC, and other applications such as variable speed wind power
- The first SSSC was implemented as part of a Unified Power Flow Controller (UPFC) power flow control project by American Electric Power (AEP) in 1998
- There have been several major subsequent SSSC applications including at the New York Power Authority and Red Eléctrica de España
- Previous SSSC installations required custom designs, series injection transformers, water cooling, circuit breaker bypass protection, and considerable substation space – all driving significant solution cost
- Smart Wires leverages a modular, transformerless approach, sealed forced air cooling, integrated fast-acting semiconductor switch bypass, and deployment flexibility to deliver greater solution value

Two ± 160 MVA VSCs at AEP Inez Substation. One of the VSCs can be operated in SSSC mode.

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SmartValve™ is the MPFC solution provided by Smart Wires

- **The SmartValve:** is a modular Static Synchronous Series Compensator (M-SSSC)
- **Power Electronics Technology:** that injects a controllable voltage (leading or lagging) in to a circuit, either manually or automated controls.
- **Main Application:** dynamic power flow control
- **Flexible Electrical Deployment:** Same unit can be used at any voltage in network; scaled or rescaled to meet the need
- **Flexible Physical Deployment:** Substations, on towers, or on mobile platforms, light and compact
- **Wider Use Cases:** solve small near-term and large long-term problems at any voltage level
- **Fast deployment:** 1 Year deployment possible from order to installation
- **High Security:** Combined capability offers naturally high reliability and redundancy
- **Lifetime:** 40 year plus

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SmartValve™ vs. Previous SSSC Solutions

Prior SSSC Installations	SmartValve
Custom-designed VSC for each installation	Built from standard, modular VSCs
Requires series injection transformer, adding significant cost	No injection transformer required, all operation is at line potential
Bespoke external water-cooling system, requiring maintenance and reliability risk	Self-contained cooling system integral to each device
Requires expensive circuit breaker for bypass protection	Bypass is achieved with fast-acting semiconductor switch
Consumes significant substation space	Can install inside substation, on a tower, outside in the ROW, or on mobile trailers.

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SmartValve Deployment Methods

Tower-based

Ground-based

Mobile Unit

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The Added Value of Modular Power Flow Control Solutions

Minimized Risk of Long Term Investment

Particularly important when considering future projects where need arises in a small number of scenarios and where there is uncertainty as to when the need will materialize.

Modularity and Scalability

The solution can be scaled up or down if the need materializes or changes in the future, particularly where a need is driven by new generation.

Redeployability

SmartValves are designed to be re-deployable to another area of the network if a greater need materializes.

Flexibility in Installation and Control

SmartValves can be installed on existing towers or within the substation environment. The substation deployment is designed to be as compact as possible.

Fast Delivery & Installation

SmartValve solutions can be installed in less time than traditional options. In many cases, this means that a solution can be installed in less than 1 year.

No Single Point of Failure

As the devices are modular, the failure of a single device as opposed to the entire solution such as a series reactor/PST means that the transmission owner has greater security with a SmartValve solution.

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Increase transfer capacity and renewable integration

QUICK

Deploys in **12 months**

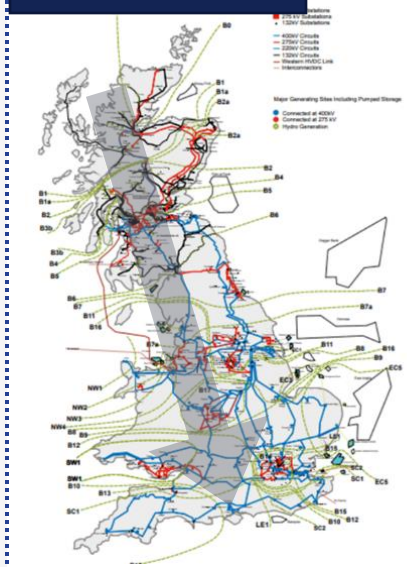
COST-EFFECTIVE

'No regrets' investment

FLEXIBLE

Expandable & **redeployable**

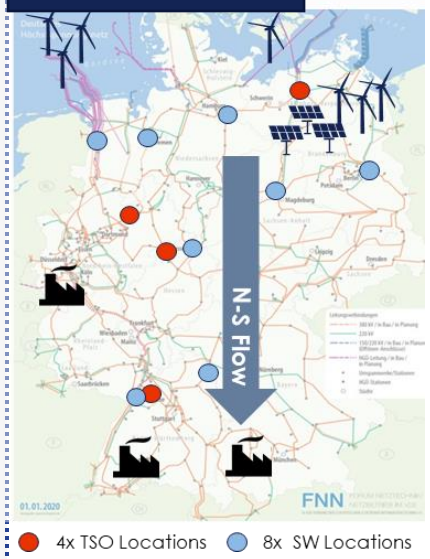
UK



+1.5 GW
of boundary capacity released

10s of GW
of incremental opportunity identified

GERMANY



€1.1 BN
per year congestion saving

4 x increase
In cost-benefit analysis compared to alternatives

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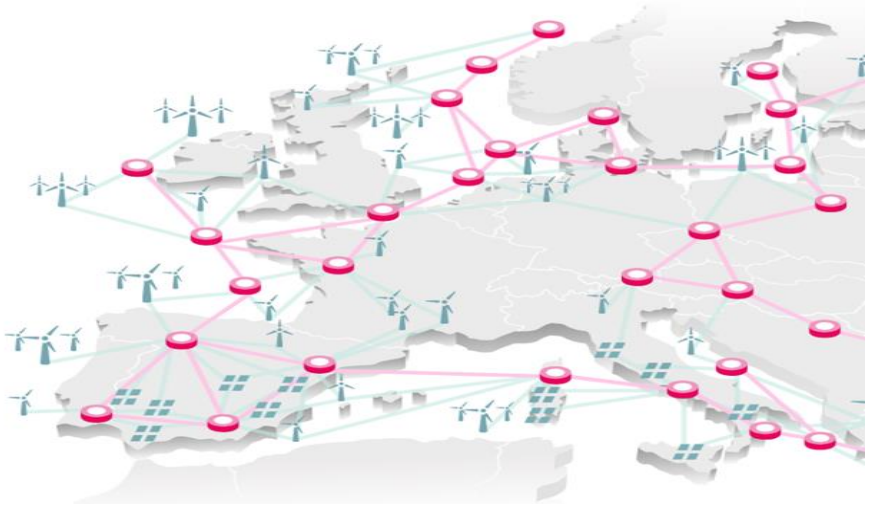
Superconductor Cable Systems

SuperNode

SuperNode addresses the need for more effective grid technology to achieve decarbonisation

Europe needs a Supergrid



- Europe needs to connect 2,000 GW of renewable resources by 2050 [1]
- SuperNode's transmission technology can be applied to offshore and terrestrial connections

Who are SuperNode?

- SuperNode is a cutting-edge global technology development company
- SuperNode designs superconductor-based power transmission products
- DNV GL statement of feasibility achieved in November 2020
- Founded by Mainstream RP and Dr. Eddie O'Connor in 2018
- Co-owned by Dr. Eddie O'Connor and AKER Horizons
- Chairman - Pat Cox, former President of the European Parliament

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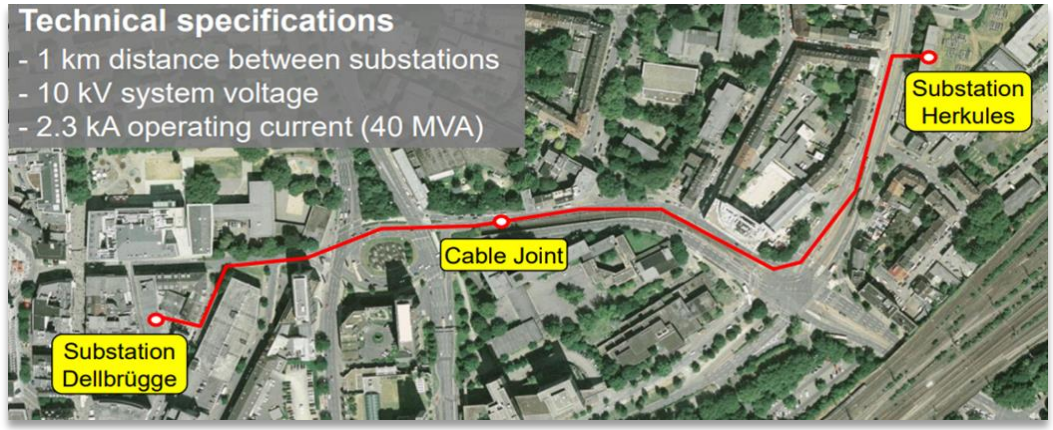
1. EU 2050 strategic vision "A clean planet for all" (1.5TECH scenario)

SuperNode

Superconductor cable systems in practice

Ampacity Installation, Essen, Germany[2]



Shingal Project, Seoul, S. Korea[3]

Active Superconductor Projects

Ampacity, Essen [40MVA, 10kV]	Operational since 2013
Horizon's 'Best Paths' Project [3.2GW, 320kV]	Demonstration project 2018
Shingal, Seoul [50MVA, 23kV]	Commercial since 2019
REG, Chicago	Under construction - Due 2021
Superlink, Munich (1st phase) [500MVA, 110kV]	Planned – Feasibility study phase

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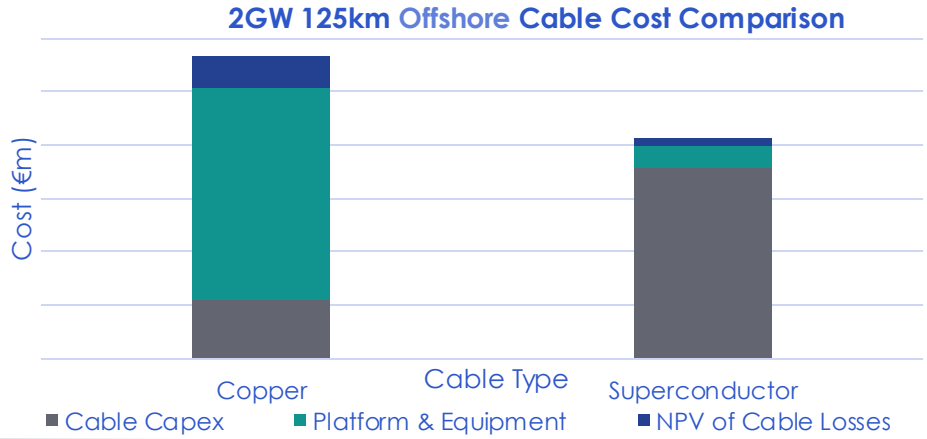
2. https://ieeexplore.ieee.org/document/6683508
3. https://iopscience.iop.org/article/10.1088/1361-6668/ab6ec3/meta

SuperNode

Significant market potential and technological disruptor for a decarbonized society

Superconductor Cable Technology

- SuperNode is developing superconducting cable systems for bulk power transfer
- SuperNode is developing technology in the areas of cryostats, cryogenics, materials, and transmission technology focused on direct current (DC) application

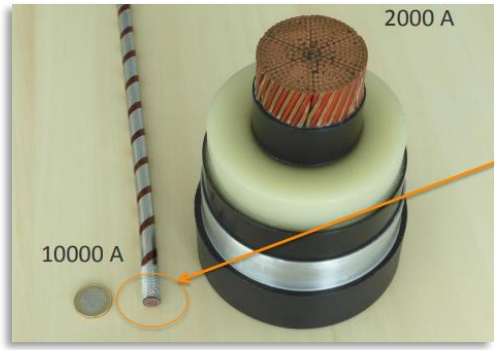


- ✓ Zero electrical losses
- ✓ Increased scalability of the overall connection system
- ✓ Significantly reduced environmental impact
- ✓ Many new potential superconductor applications

Market Potential

Offshore Power Transmission

- Smaller and more cost-efficient collector stations compared to conventional HVDC alternatives
- Connection of remote renewables to markets where demand is highest



Terrestrial Grid Connections

- Significantly smaller footprint and reduced environmental impact compared to lower capacity HVDC alternatives
- No heat leakage to surrounding soil and zero energy losses in transmission

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SuperNode

An expert perspective on superconductors

"By its very nature, renewable electricity will be cheaper than zero-carbon hydrogen (which is a vector that stores renewable electricity). In the view of the authors, this gives rise to possibly the most important conclusion from this study. Aside from energy efficiency, the most important and immediate priority for the EU in ensuring a cost-effective decarbonisation of its energy system must therefore be to identify and eliminate infrastructure and other bottlenecks that are likely to constrain the cost-effective production and use of renewable electricity moving forwards"

Florence School of Regulation: A. Piebalgs, fmr. European Commissioner for Energy, C. Jones, fmr. Head of Cabinet, DG Energy, European Commission, "*Cost-Effective Decarbonisation Study*" 2020

"In Best Paths, gigawatt-scale superconducting cables were investigated and shown to be technologically mature and cost-competitive for the transmission of large amounts of electricity. Thanks to their high efficiency, compact size, and reduced environmental impact, superconducting cables are likely to find higher public acceptance than overhead lines and conventional cables"

Best Paths, "*Advancing Superconducting links for very high-power transmission*" 2018

"Regarding HVDC cables, recurring to superconductivity technologies and namely High Temperature Cables (HTC) may be technically and economically convenient when the increase of transmission capacity need over a corridor requests the addition of more cables in parallel - It would be beneficial to develop HTC technologies for Superconducting Transmission Lines (STL) to explore its potential in situations where very high amounts of power need to be transmitted"
(…)
"to build the offshore energy production, and its connection to onshore consumption, an interconnected grid is needed"

European Commission, "*Clean Energy Transition – technologies and innovations. (CET-TIR)*" 2020

"Superconductors will do for electricity what fibre optic cables did for telecoms by replacing the twisted pair"

Pat Cox, SuperNode Chairman and former President of the European Parliament

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Sensors

Solution

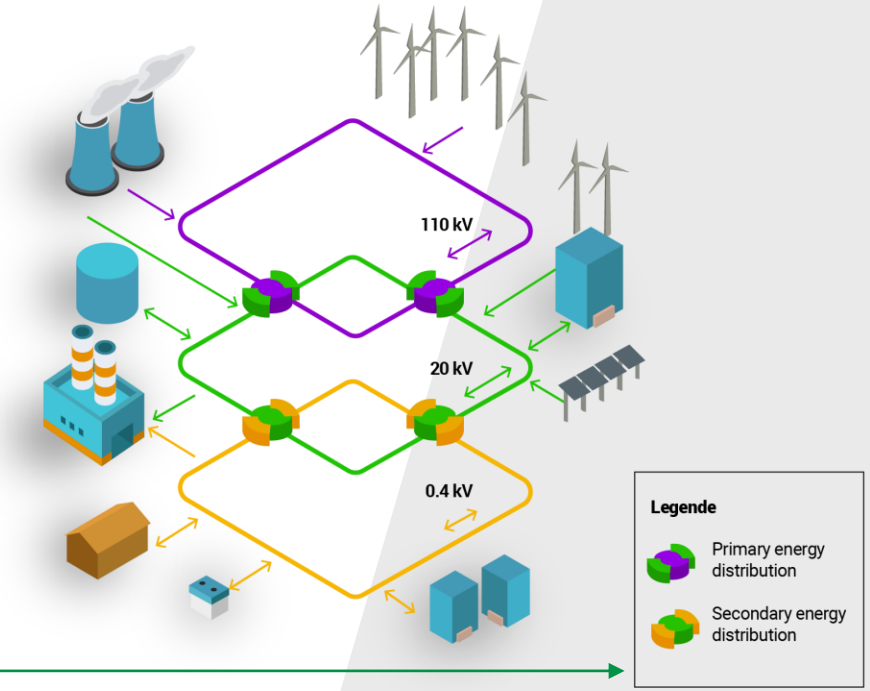
SMART DEVICES, WHICH CAN REGULATE THE GRID BASED ON THE LAW OF SUPPLY AND DEMAND!

One of the key components for making an effective and reliable smart grid working is the primary transducer, which transforms high voltage and high currents into smaller voltage signals, which measurement devices can handle.

GWP´s Products enable:

- High accuracy fault detection
- Monitoring
- Voltage level control
- Protection functions
- Acquisition of harmonics

Our sensors are located in conjunction points (primary or secondary energy distribution) of different voltage layers



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GWP-Technology

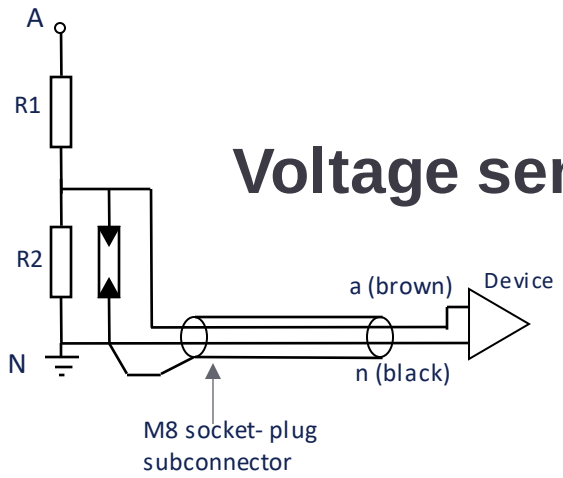
CORE TECHNOLOGY

The GWP technology consists of 2 basic principles.

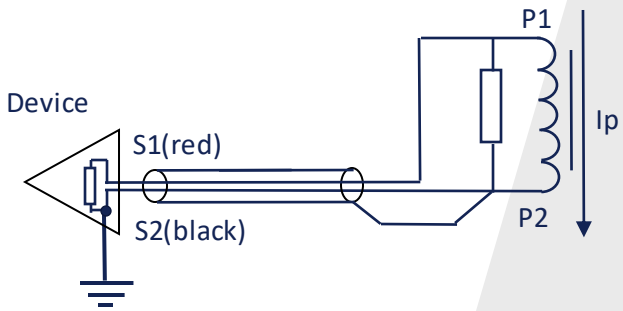
For the voltage sensor a mixed ohmic-capacitive divider and for the current sensor a inductive coil with shunt resistor

> “Both technologies have more advantages compared to other technical solutions on the market!“

Voltage sensor-principle



Current sensor-principle



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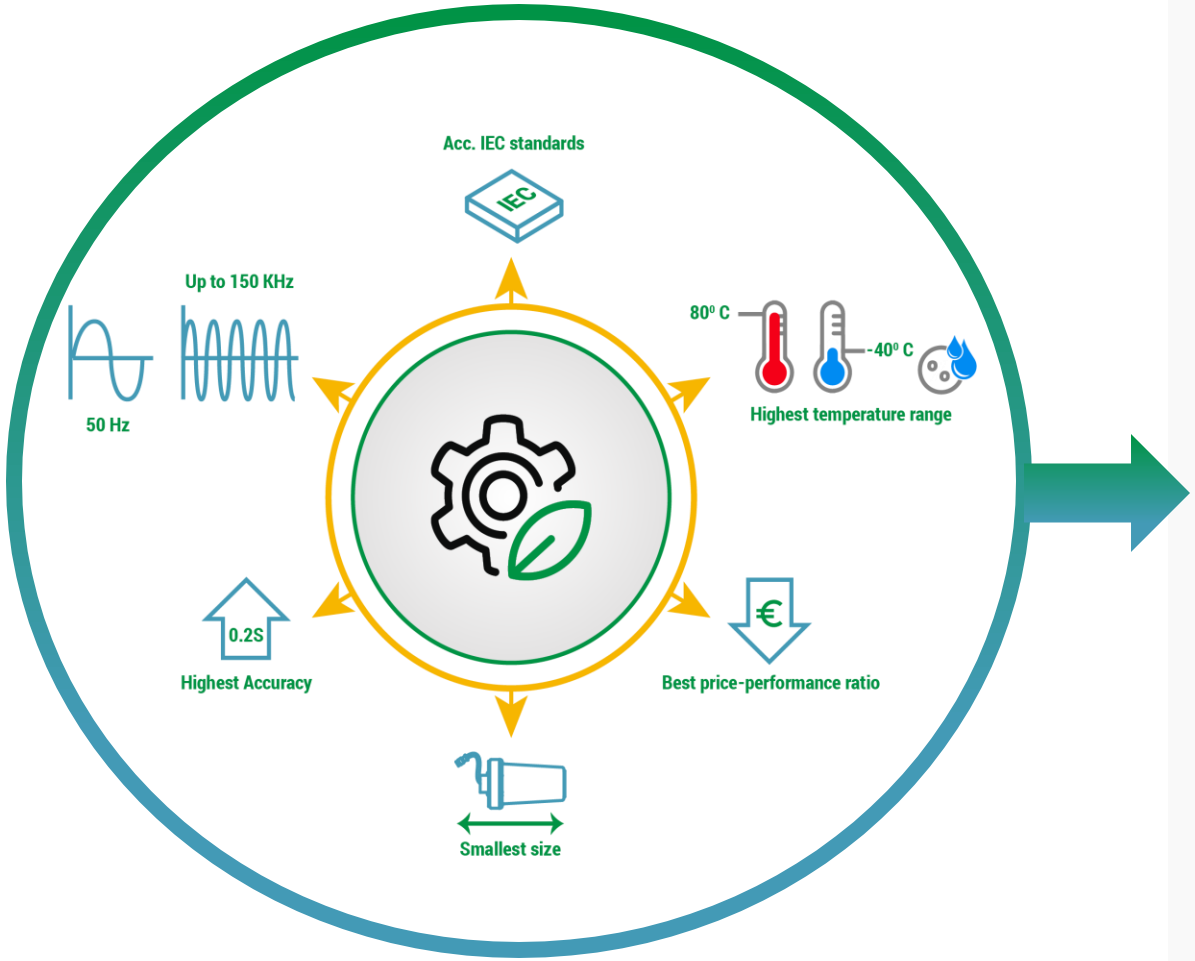
High-quality products



> “Technical superiority will be economic superiority!”

In order to maintain the technical lead over the competition, GWP is consistently applying for, and being awarded, mulitpe cutting edge sensor patents

3 patent granted - PCT treaty

3 patents declared - PCT treaty

3 patents currenty in draft stages

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GWP-Products

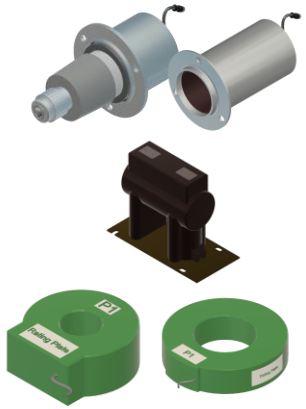
HIGH QUALITY PRODUCTS WITH AN ABSOLUTE CUSTOMER FOCUS

The products will be applied in the primary and secondary energy distribution layers, primarily on the medium voltage layer, but also on the low voltage level

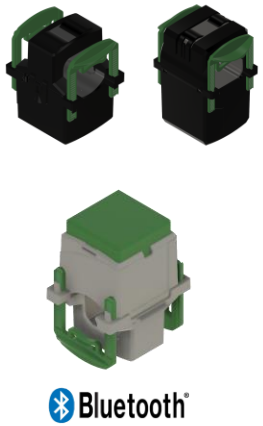
1st Product Range
Gas insulated switchgears

2nd Product Range
Air insulated switchgears

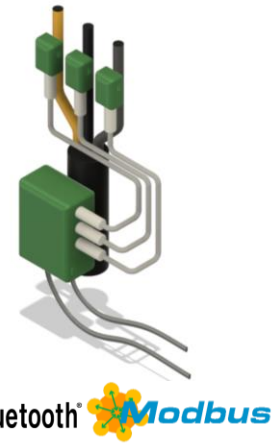
3rd Product Range
Primary Energy distribution



4th Product Range
Low voltage current sensors



5th Product Range
Temp. Sensors for medium voltage switchgears



6th Product Range
Sensor on a Chip SoC Solutions

7th Product Range
Infrastructure As a Service

IaaS

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Thank you

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