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Future Trends in Control and Protection

Daniel Otto - Siemens Energy Management
University of Manchester – March 2019

Overview

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- Future Trends in Protection and Control of Wind farms
- Future Trends in Protection and Control of HVDC Links
- Monitoring and Internet of Things (IoT)
- Process Bus Technology

Future Trends of Protection and Control in Wind farms

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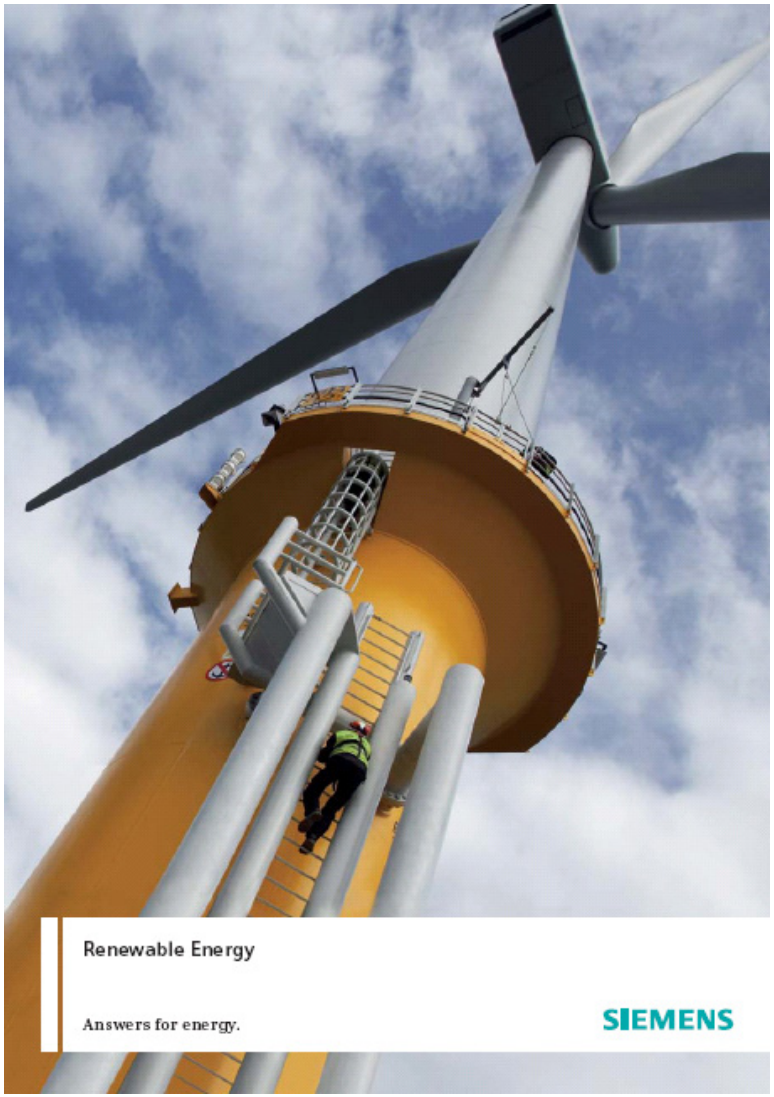

Changed generation mix by 2020 drives network changes

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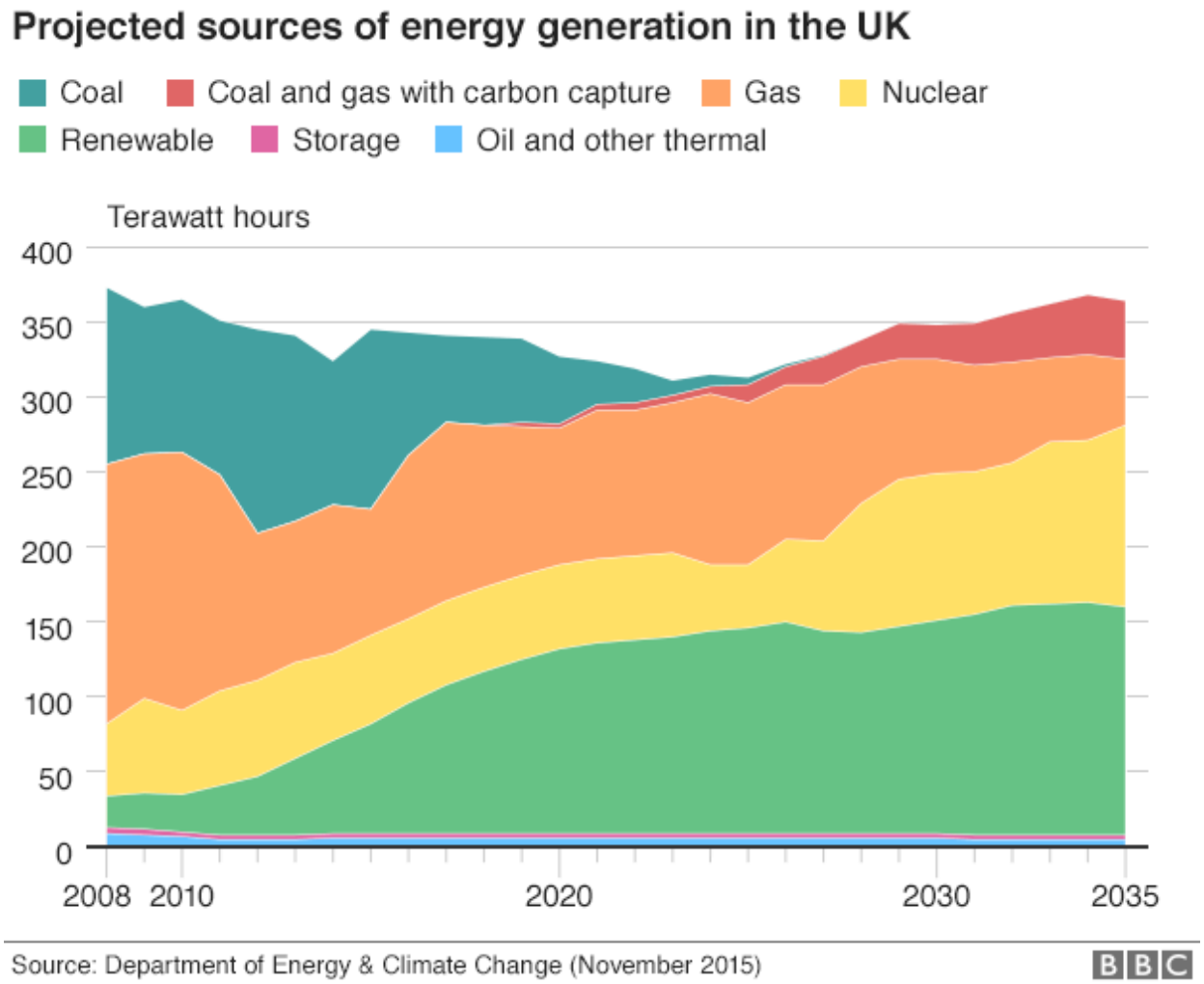

Source: http://www.bbc.co.uk/news/business-35722324

The UK's best resource is offshore

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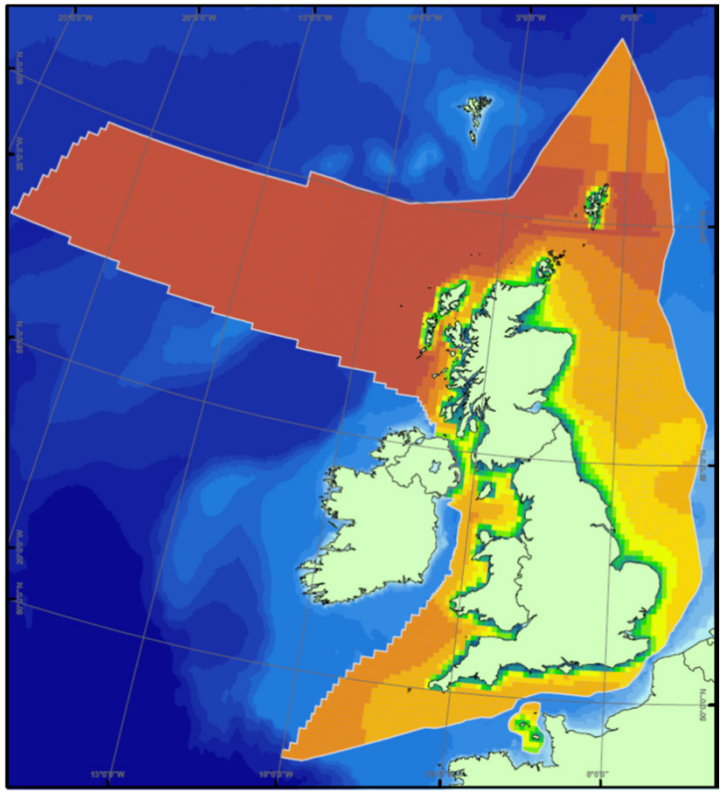

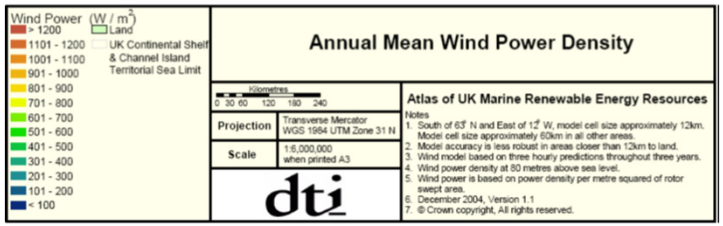

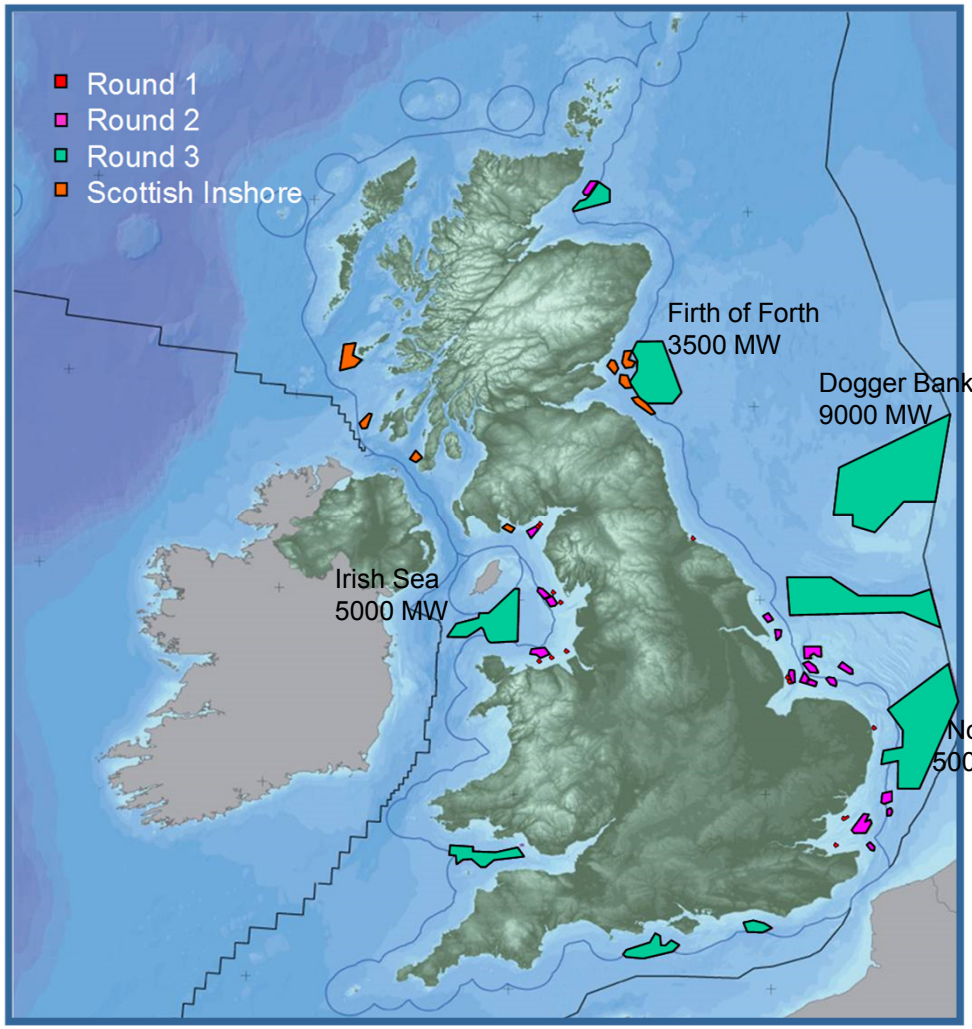

Offshore Windfarms (HVAC and HVDC)

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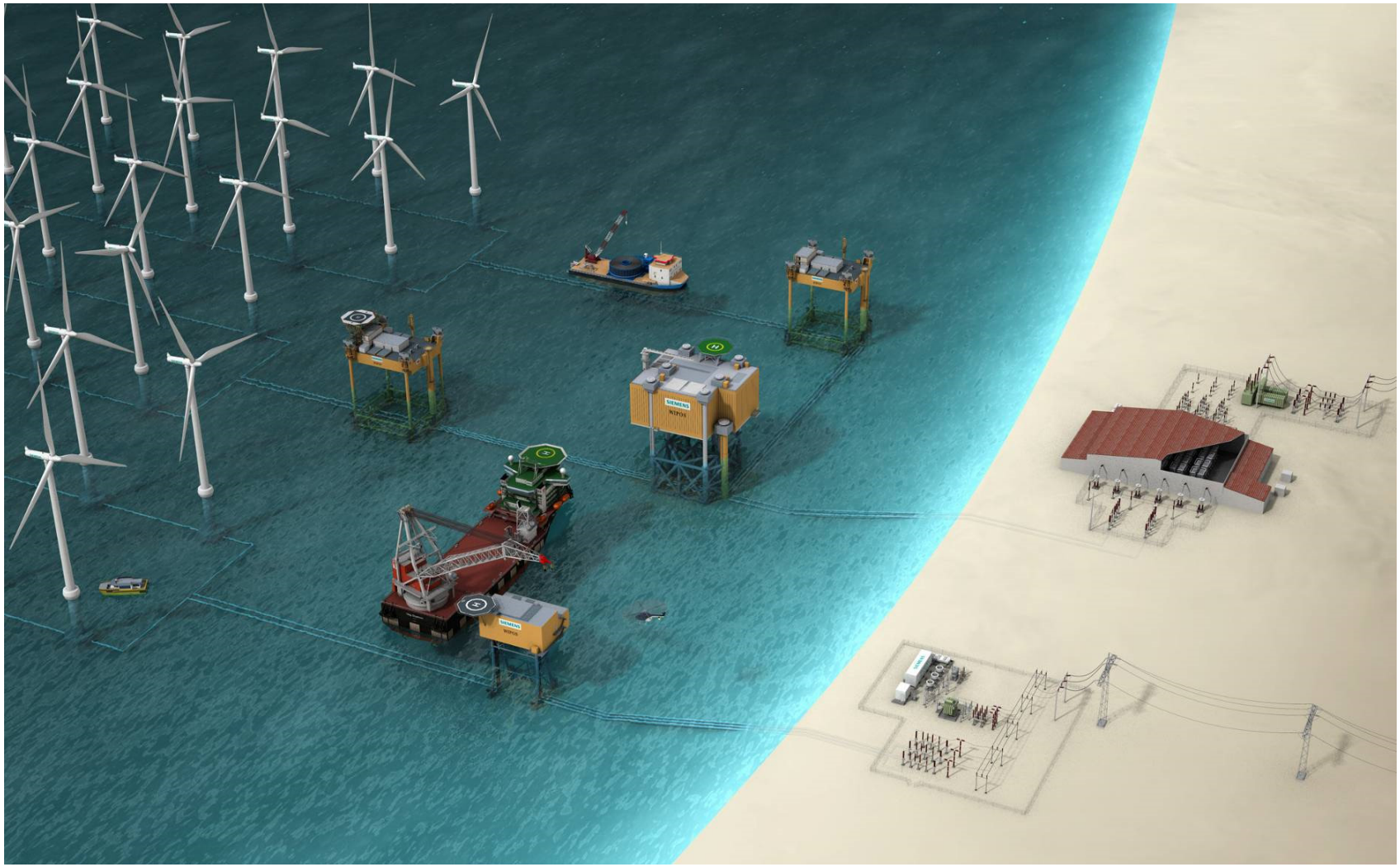

Offshore Windfarms - AC Connection
Close to shore

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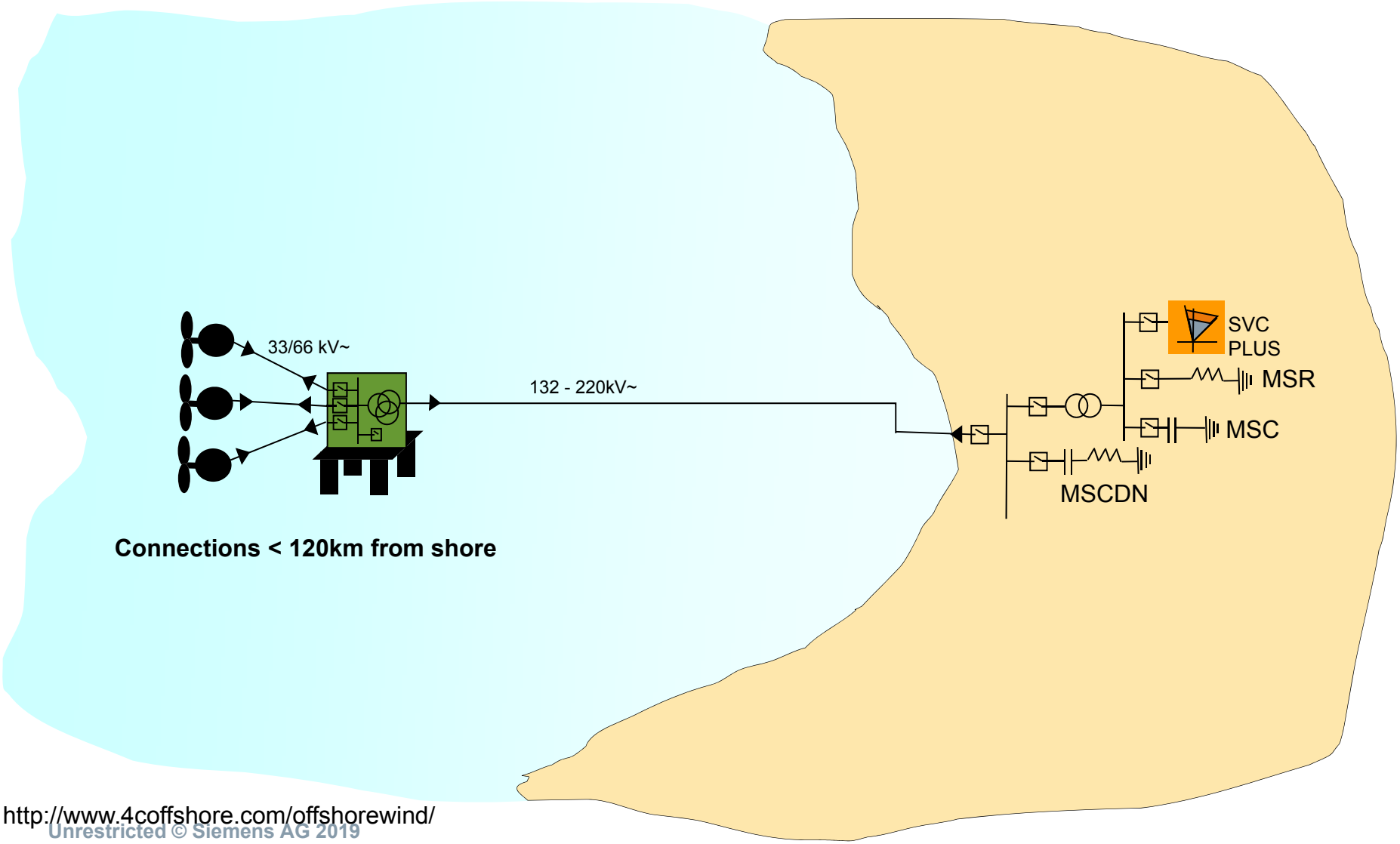

http://www.4coffshore.com/offshorewind/

Offshore Windfarms - AC Connection
Long distance from shore

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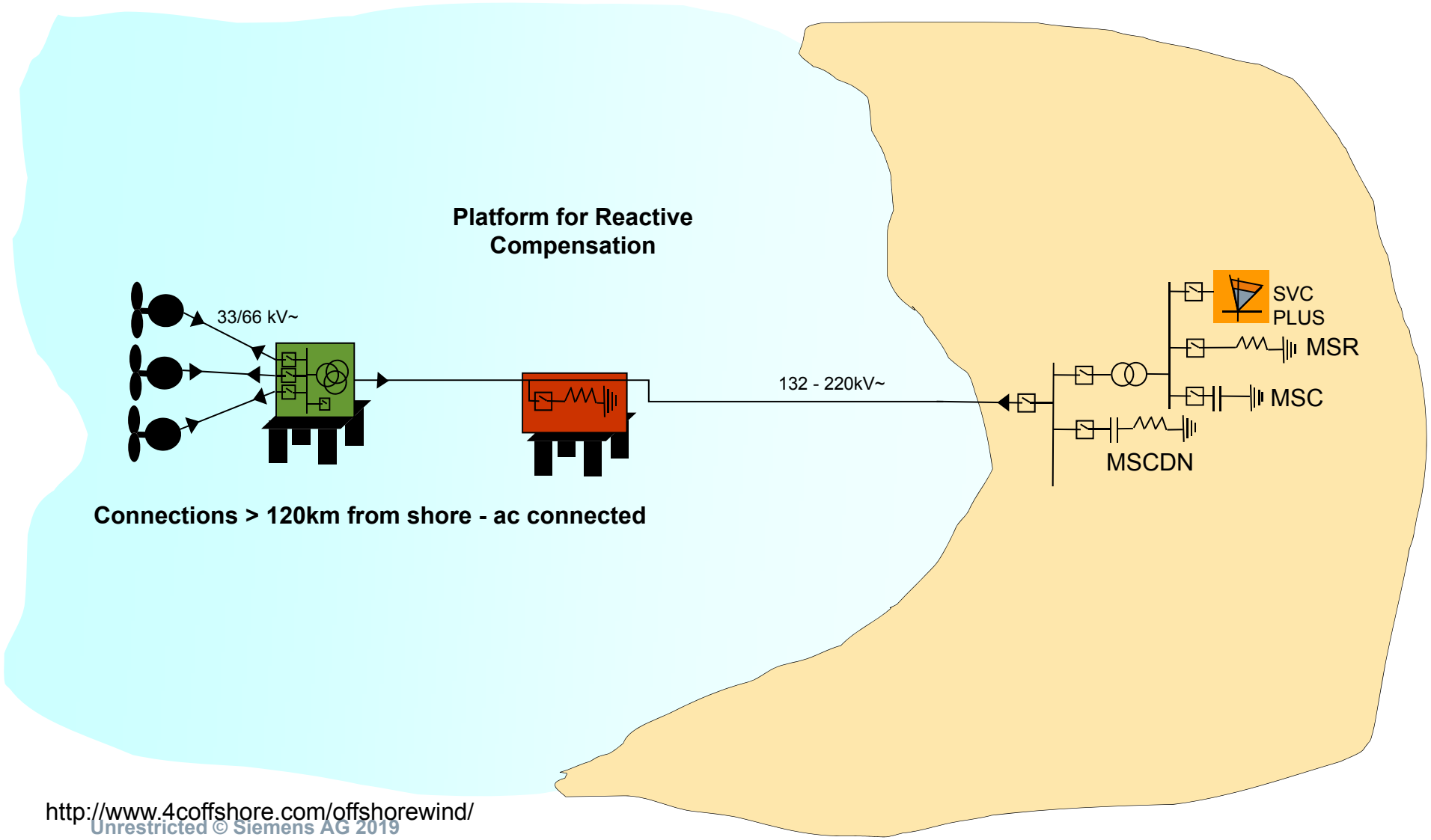

http://www.4coffshore.com/offshorewind/

Offshore Windfarms - DC Connection
Long distance from shore

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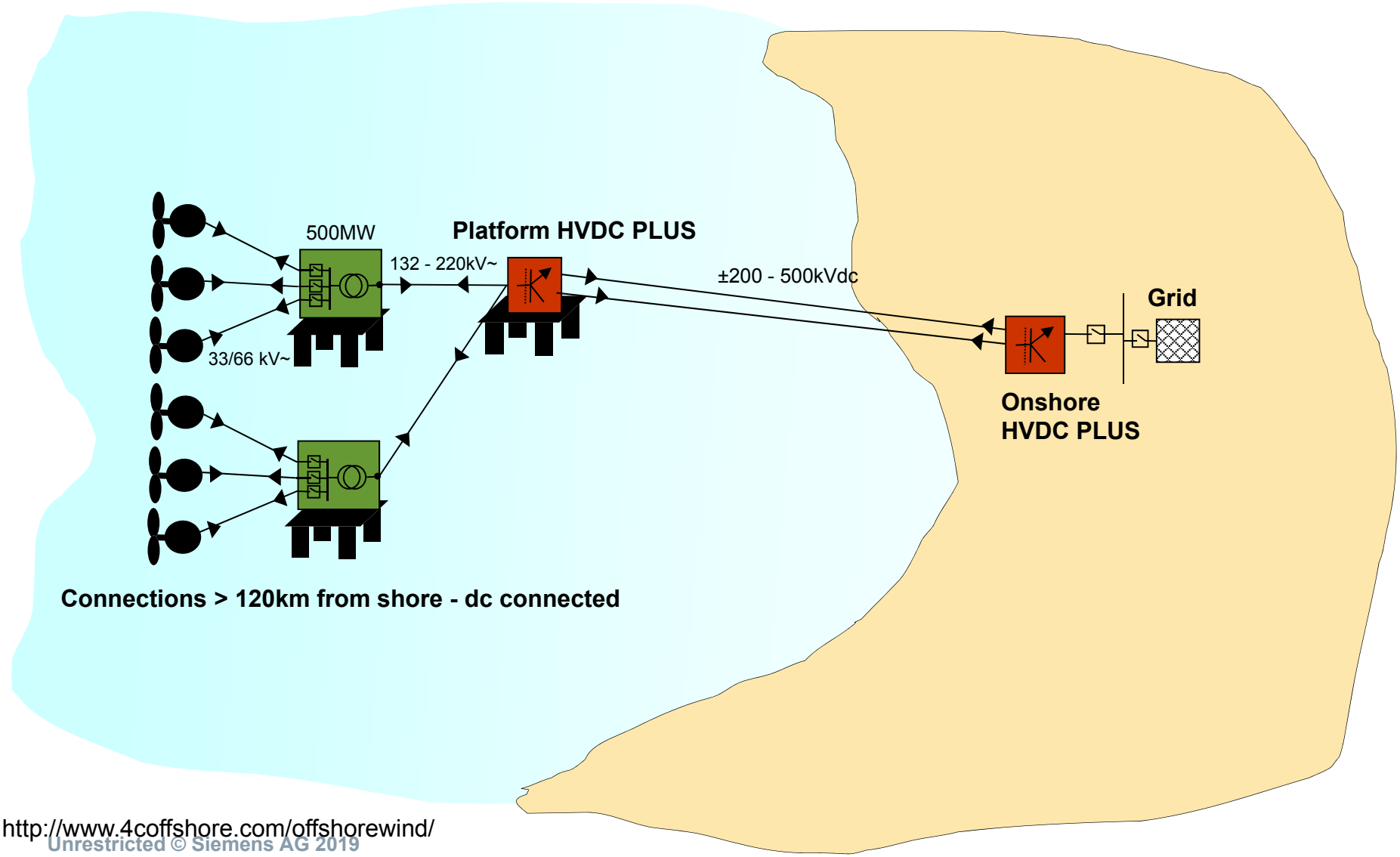

http://www.4coffshore.com/offshorewind/

Offshore Windfarms - DC Connection
Long distance from shore – UK projects

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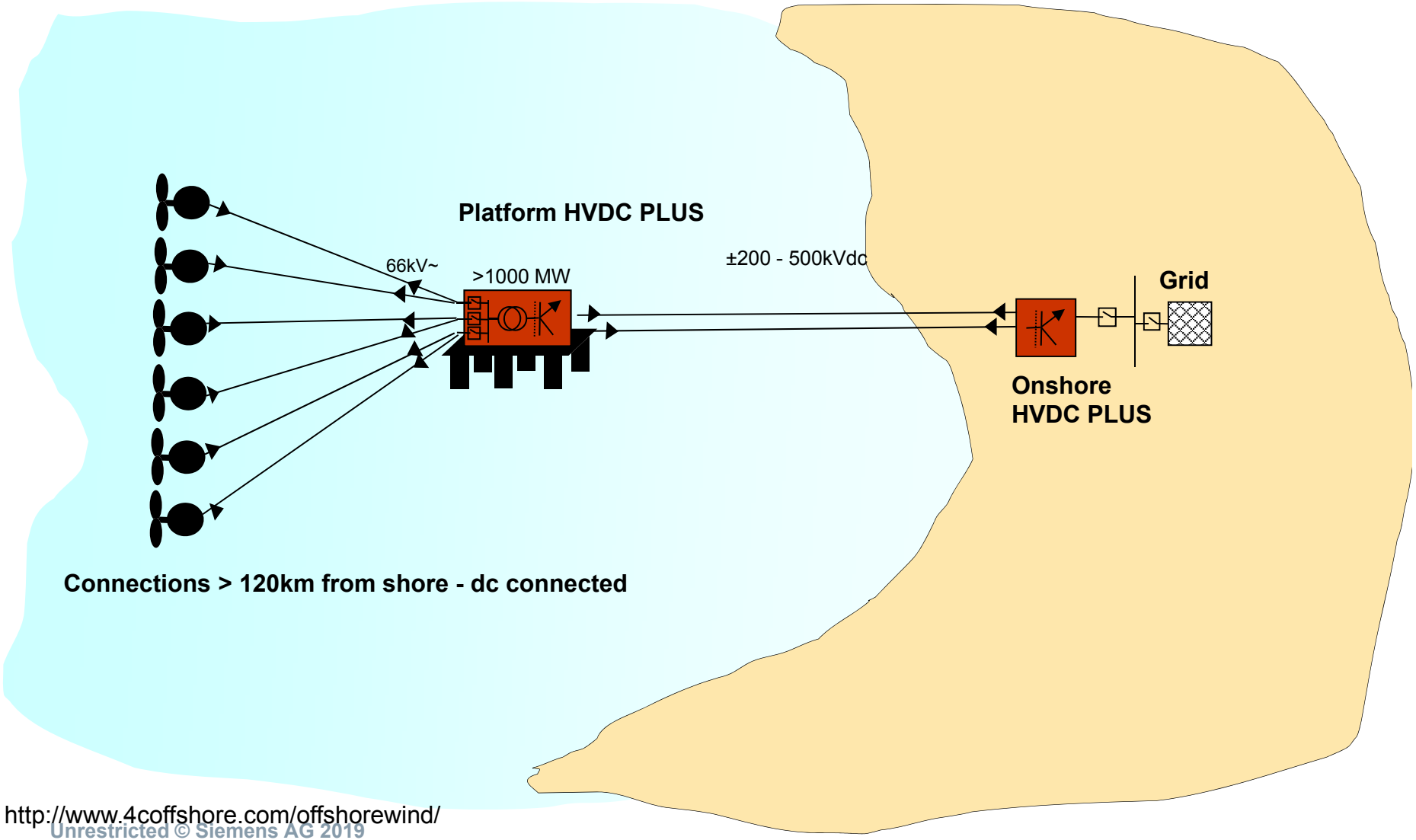

http://www.4coffshore.com/offshorewind/

Reference examples

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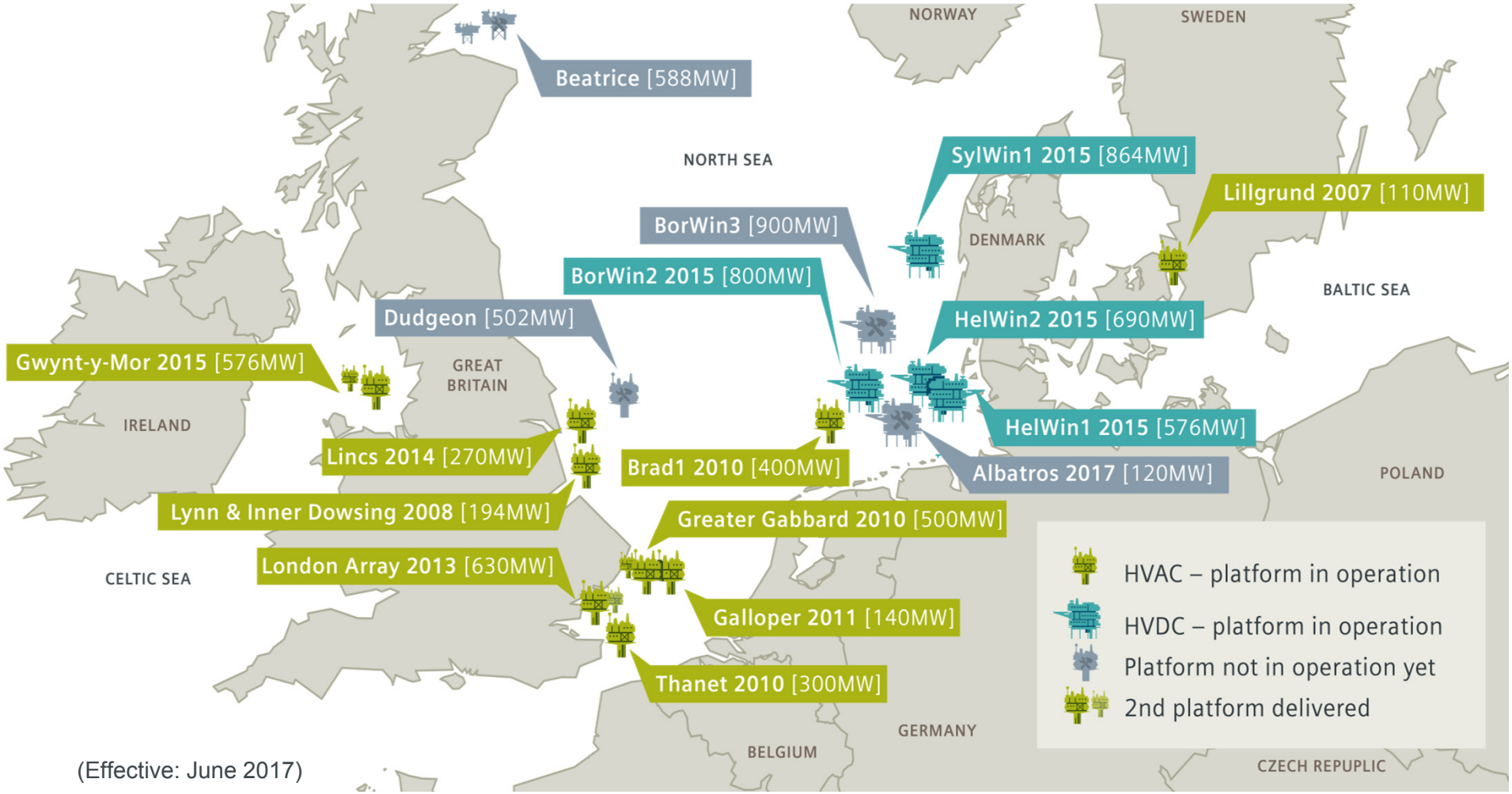

(Effective: June 2017)

Protection of Wind Farms

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Grid substation vs. Wind Farm substation:

General things to consider:

- Location
- Production cost
- Available space
- Voltage Level
  - Wind farms: 33/66kV main protection is Overcurrent & Earth fault
  - Grid system: 400kV main protection is Differential
- Customer has different requirements

Offshore Transformer Module

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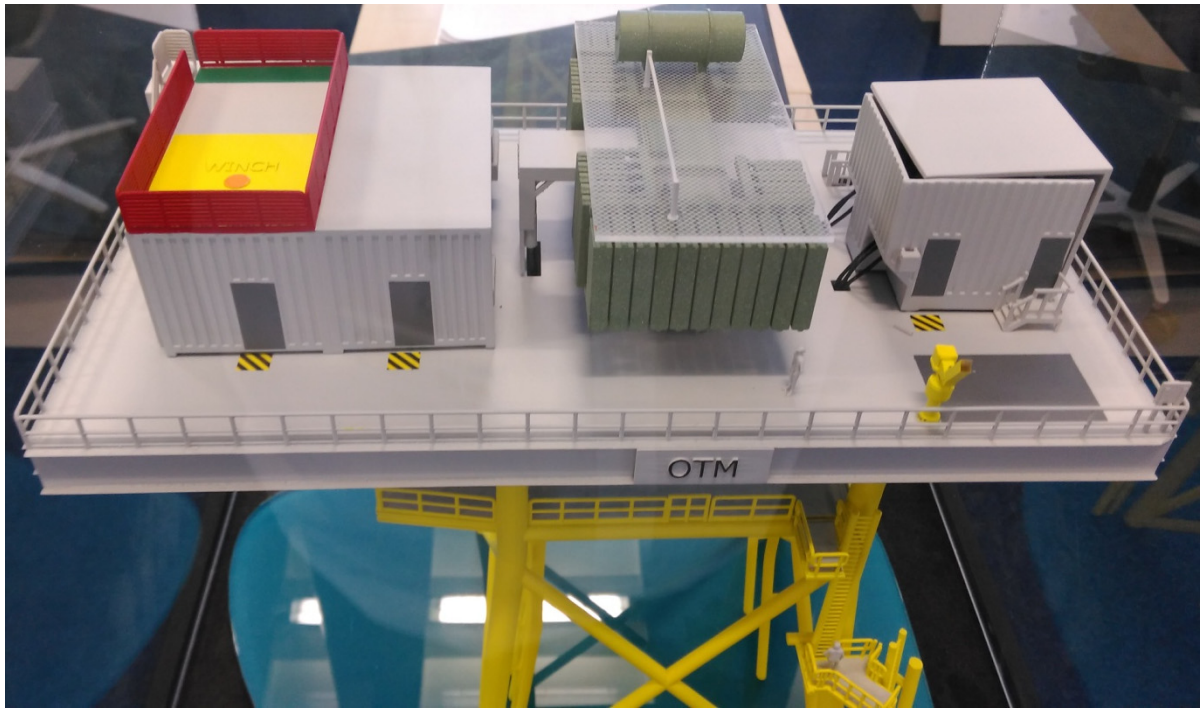
Offshore substations are expensive and funding has become difficult. Innovation is key to be able to build new Windfarm access solutions. Siemens has designed a more compact, less expensive solution:
The ‘Offshore Transformer Module’ or OTM®.



Offshore Transformer Module

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For the OTM®, the components are selected to reduce the size of the platform. Furthermore, non-essential devices will be removed or specific functions will be done at the Onshore substation. Examples are:
Beds, desks, workshop, etc.

<u>Example: Control & Protection Room:</u>
Previous Windfarm: 67 Turbines*6MW (402MW) – 200m^2
Power capability per m^2: 2.01 MW/m^2

OTM®: 42*7MW (294MW) – 48m^2
Power capability per m^2 : 6.12 MW/m^2

Similarly, space is also reduced for other parts of the platform.

Offshore Transformer Module

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Previously Protection and Control elements were separated, but are combined on the OTM® to reduce space requirements.

Source: http://electrical-engineering-portal.com/comparison-of-protection-relay-types

Different Protection approaches

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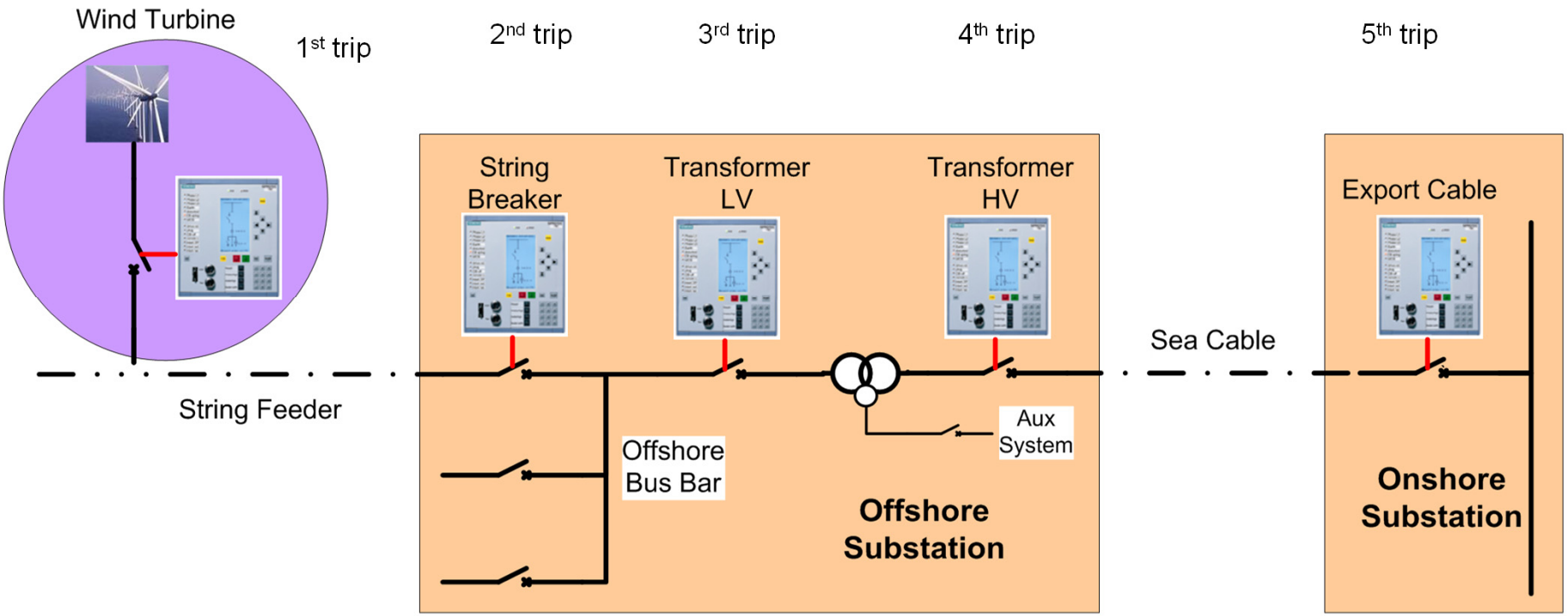
Overcurrent Protection:
Grid system: Graded on Distance Zone 3
Wind farms: Graded from turbine upwards

For turbine fault



Different Protection approaches

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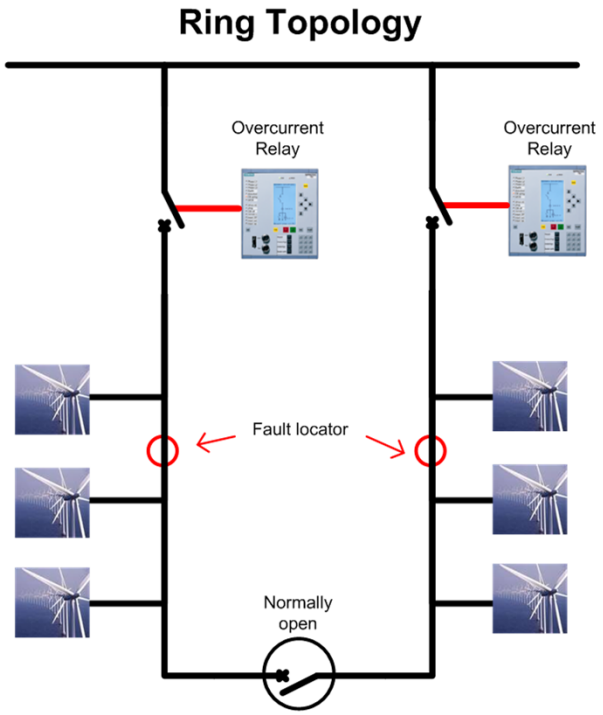
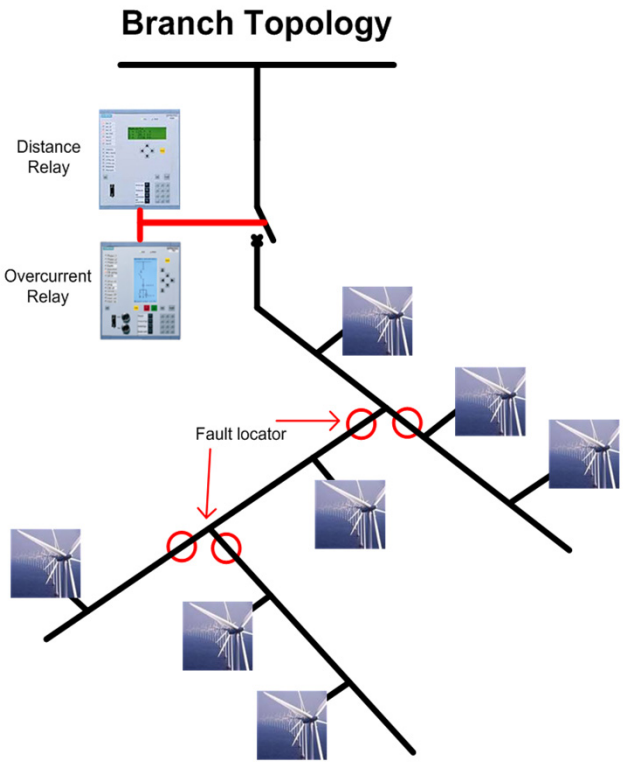
String Protection:
This does not exist within the Grid system. Ring Topology is used in Medium voltage applications. Originally a ring topology was used, but more wind farms are also planned with branched strings.





Control System vs. Control Centre

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Control Centre:

- Can initiate commands and receives indications
- No automation
- Commands can be send regardless of who is in control

Control System:

- Can initiate commands and received indications
- Automation for specific applications
- Command arbitration is done here

Control System vs. Control Centre

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Future Trends of Protection and Control of HVDC substations

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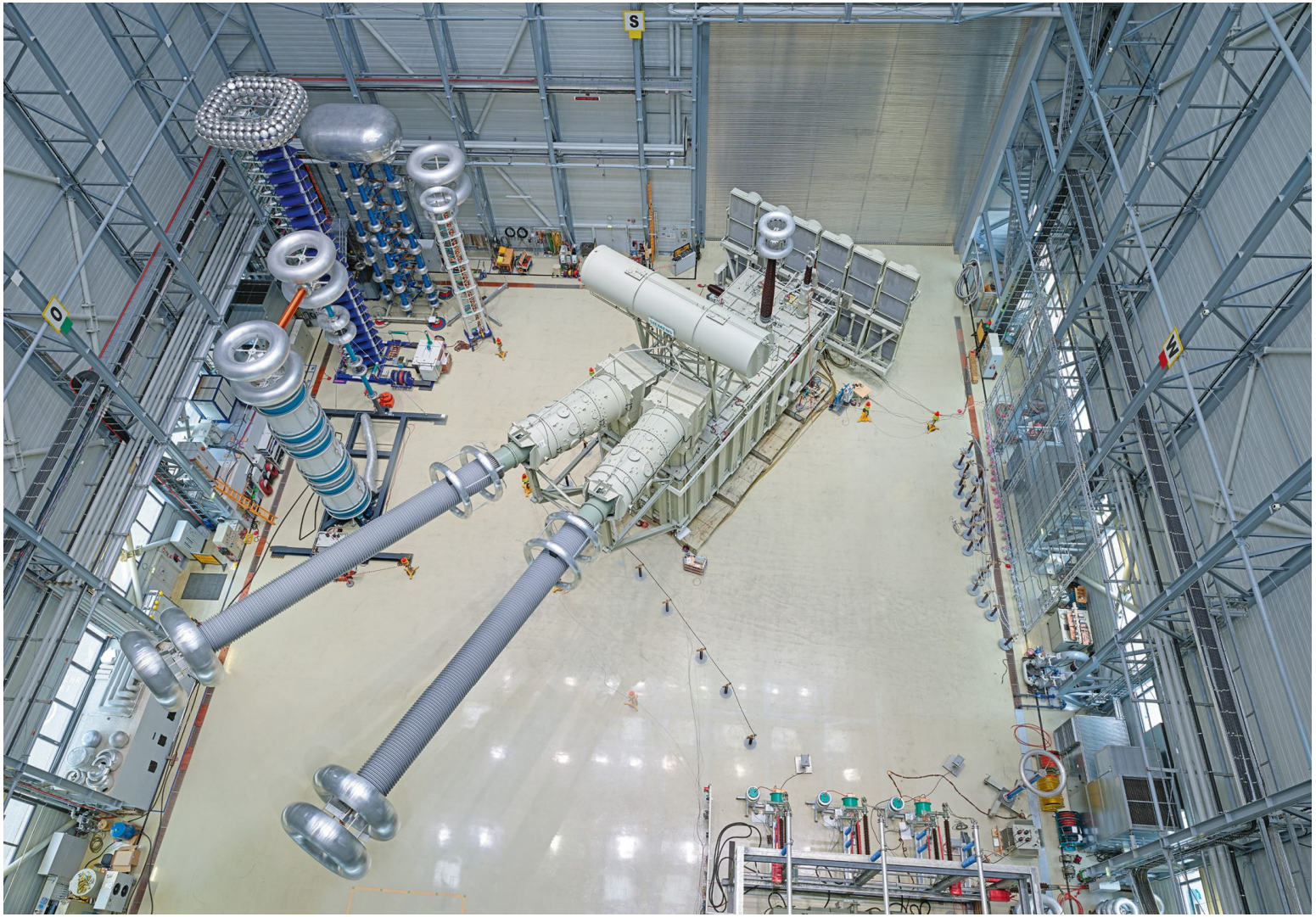

Hypothesis for number and voltage of export cables

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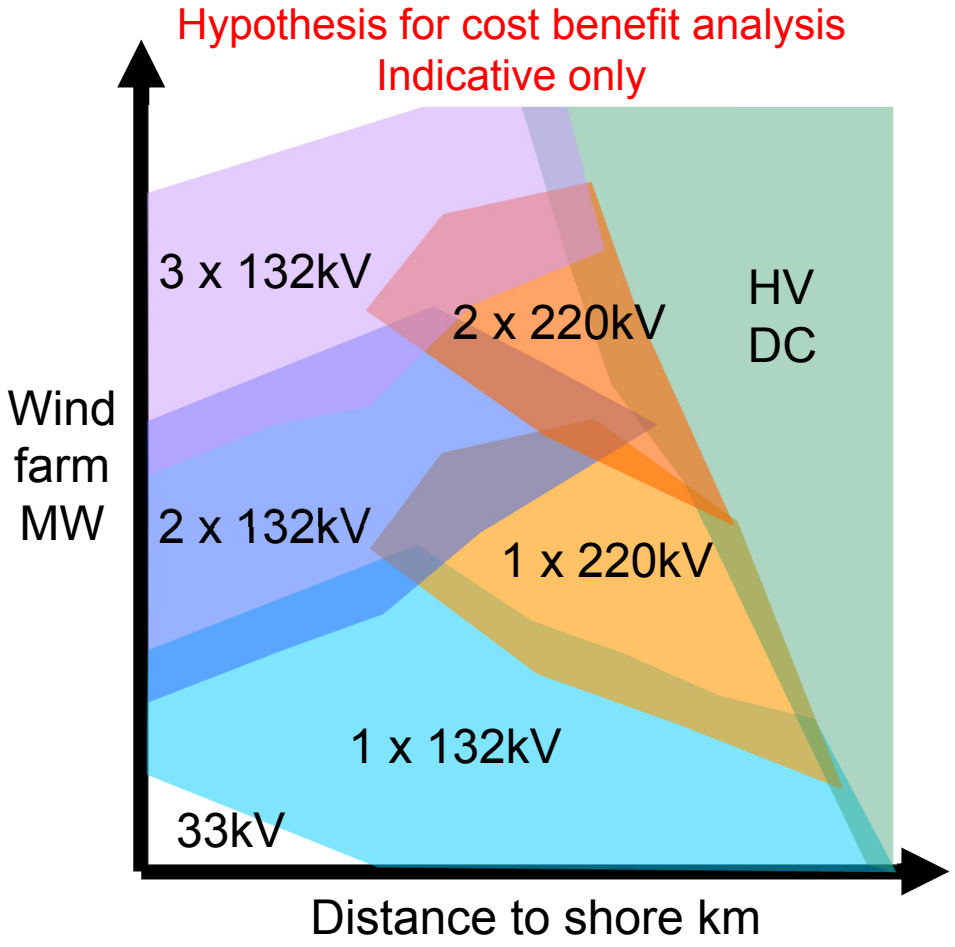

33kV, 132kV or 220kV? AC or DC?

Cable installation costs dominate
1 larger cheaper than 2 smaller cables
But capacity vs. cross section reduces with size

220kV wins simple cost benefit*

- Limited choice of manufacturer
- Cable and joints not yet proven
- Many more factors

132kV chosen on many older UK projects

- London Array long cable route
- reverted to 150kV

*CBA for SQSS
http://www.berr.gov.uk/files/file36032.pdf

HV DC transmission

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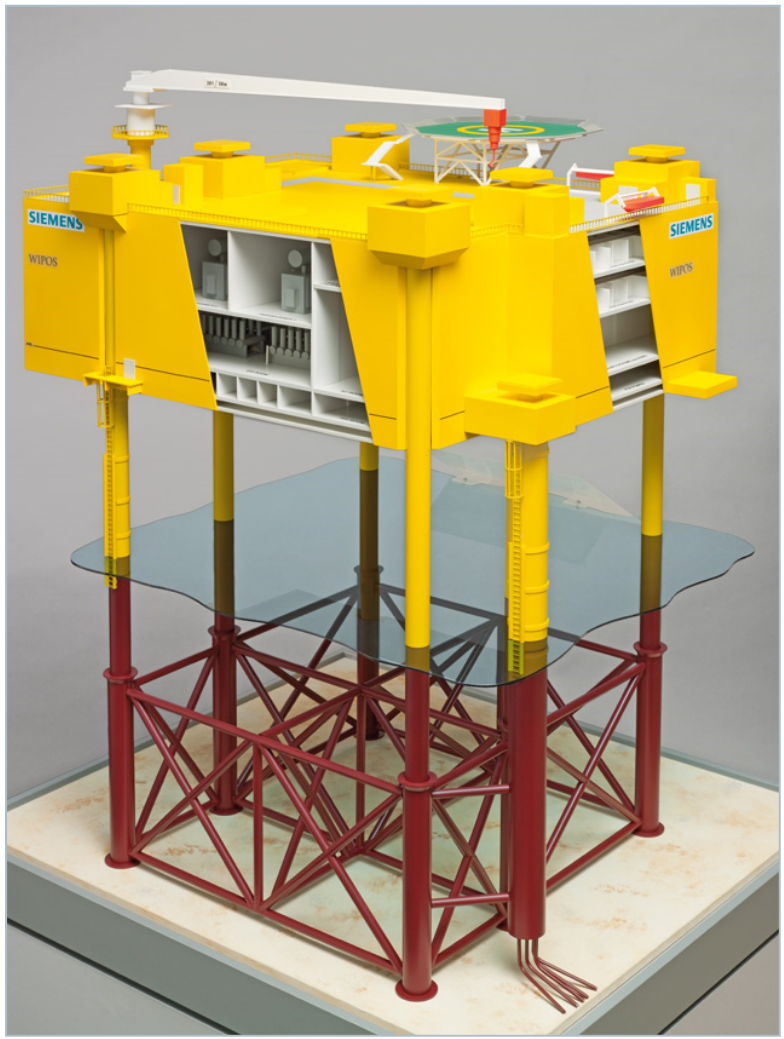
For distances >120km DC can become a better option

- Fewer cables
- Lower losses
- More controllable

Negligible losses in the DC circuit
Conversion losses per station:

- 0.75% CSC
- 1% MMC VSC

Topsides ≈10,000 tonnes
Crane limited to 11,000 tonnes
Heavier platforms needs to be self lifting



The EU and North African Supergrid

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Source: https://www.commonspace.scot/articles/2019/five-reasons-you-should-care-about-european-north-sea-super-grid

Current Developments in the North Sea

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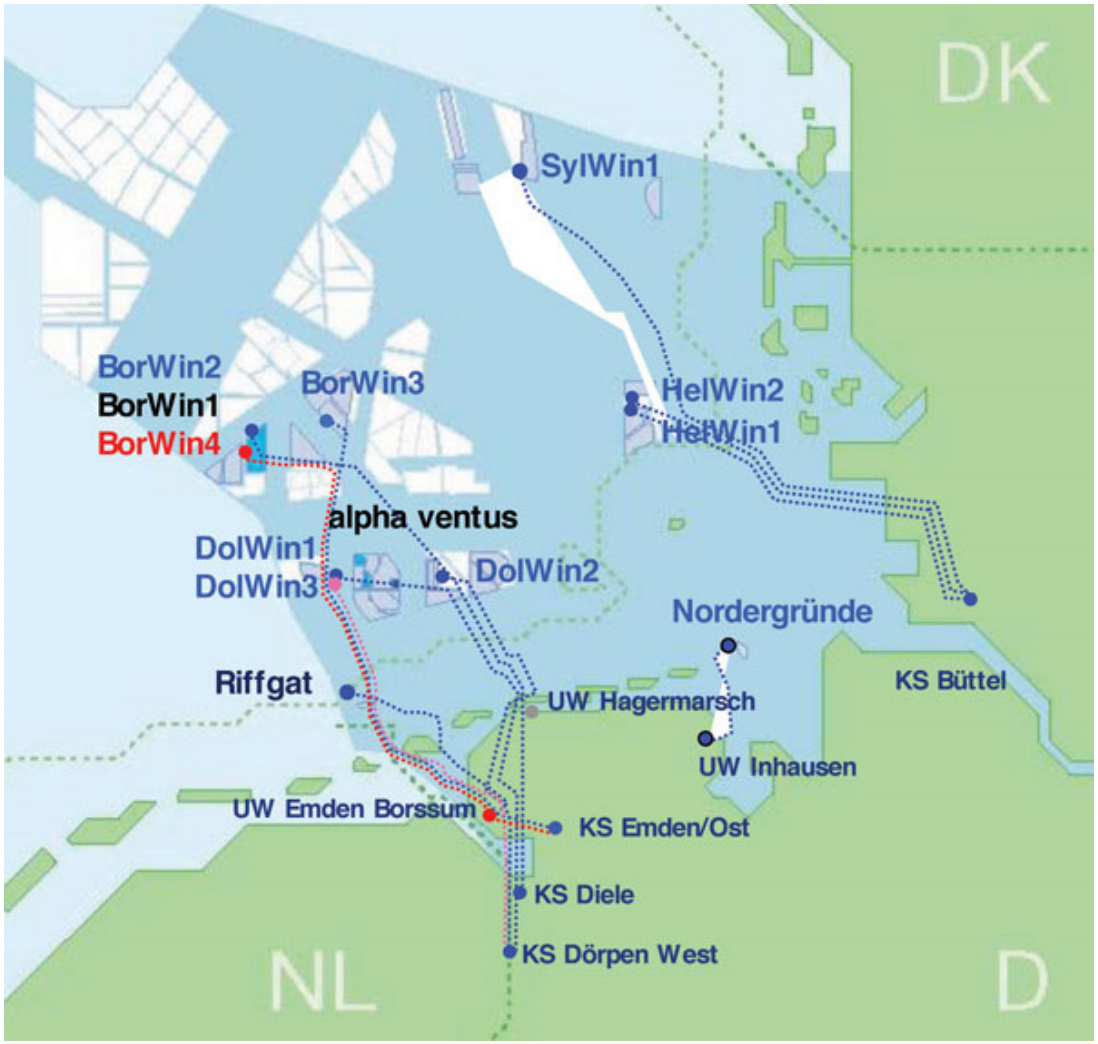
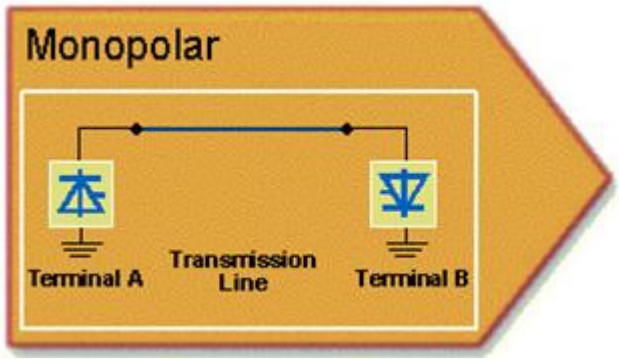
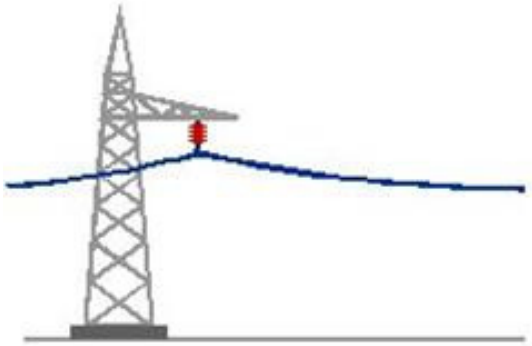


Source: http://www.modernpowersystems.com/features/featurenavigating-the-north-sea-learning-curve-4359059/featurenavigating-the-north-sea-learning-curve-4359059-458379.html

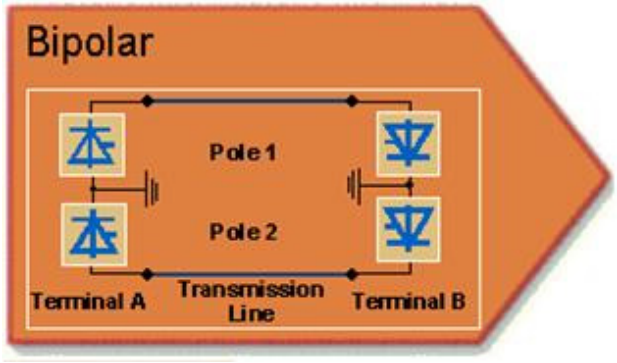
Monopolar and Bipolar HVDC





- One HV line for DC Current transmission
- Return path optionally via ground (in most cases not allowed anymore) or via return conductor
- Lower rating

Monopolar and Bipolar HVDC



- Two DC lines with +/- DC voltage level for transmission
- Higher Rating
- Can be used as monopolar in case of a fault on the converters or on the transmission line

Monopolar and Bipolar HVDC

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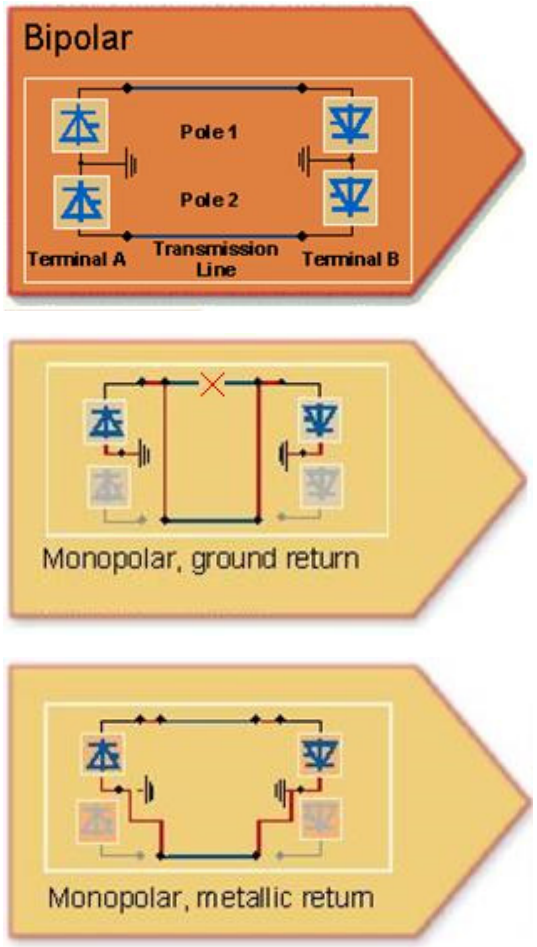
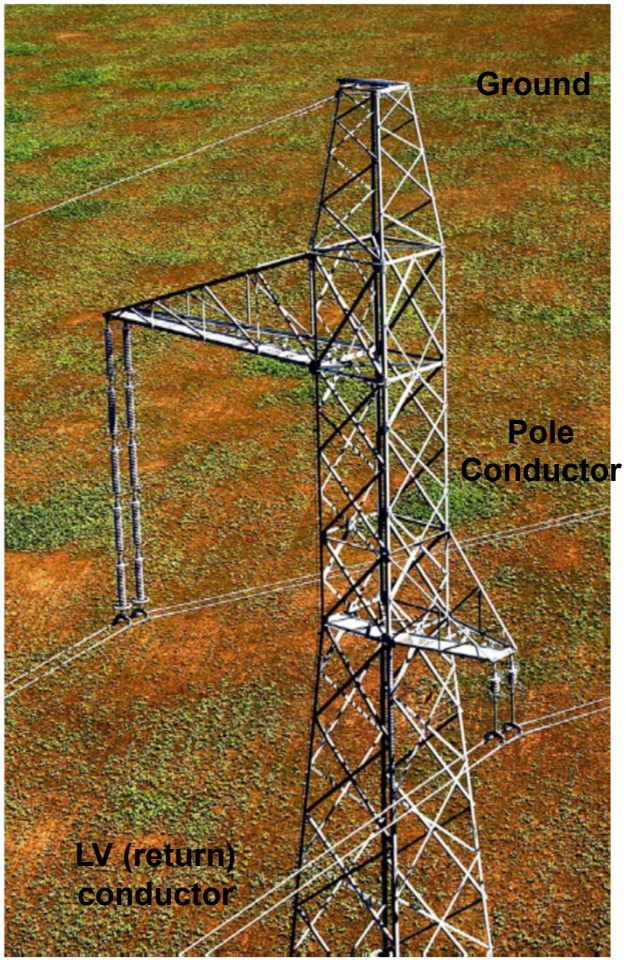
Normal Bipolar operation:

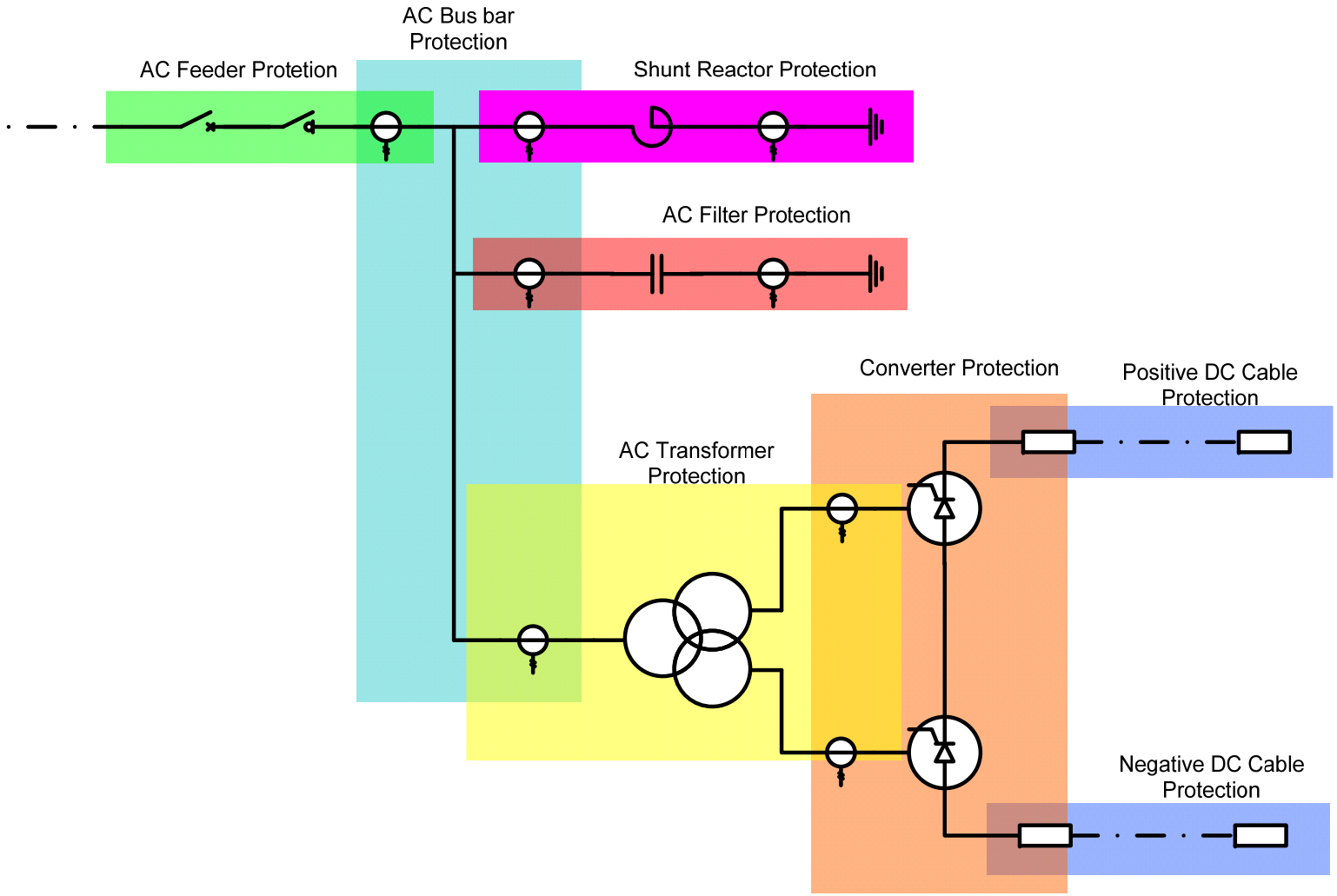
Monopolar operation in case of a fault in one DC line

Monopolar operation in case of a fault in one of the converters





Classical HVDC Protection (Current Source Converter)



HVDC Classic Converter Station

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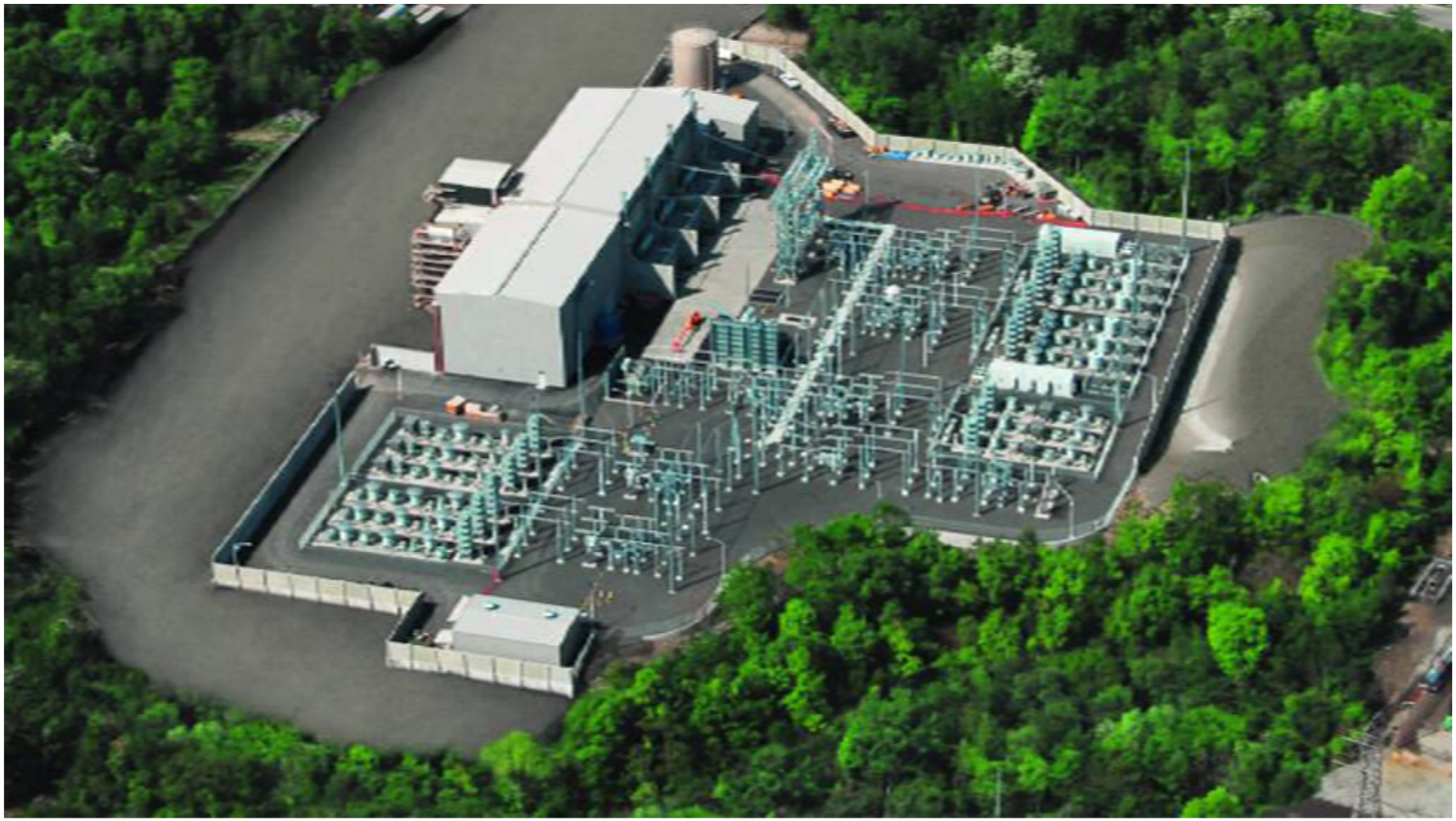

Neptune Project, New Jersey

HVDC Classic Converter Station

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Source: http://virtual.hunterston.eu/industry/converter.htm

Classical HVDC Protection

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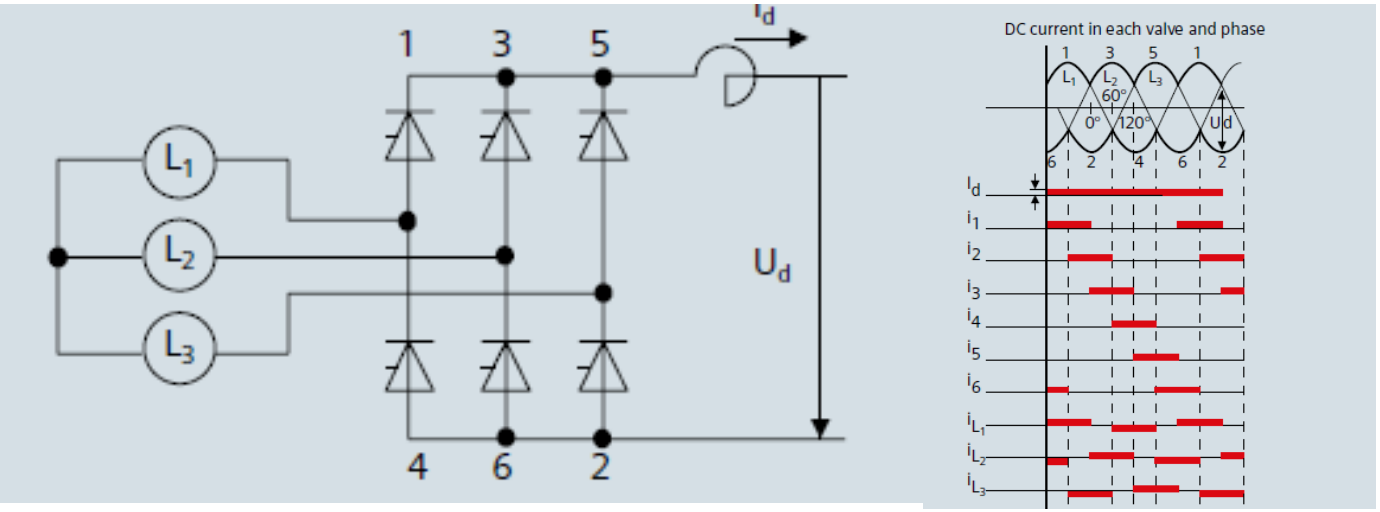
- Classical HVDC is Thyristor based
- 3 Winding Transformer needs to be used in order to achieve 30 degree phase shift.
- Reactive Power compensation and Harmonic Filters are required to confirm with Grid code.
- Protection for the above is split into different Zones
- Zones are build up from standard Protection Zone elements



HVDC Protection Systems (AC side)

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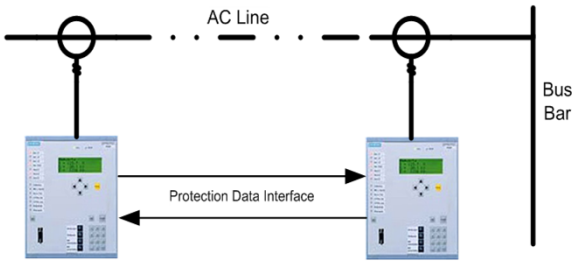
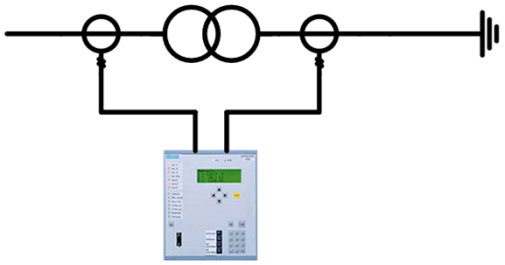
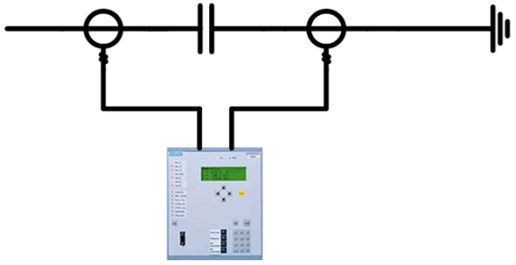
Line Differential Protection



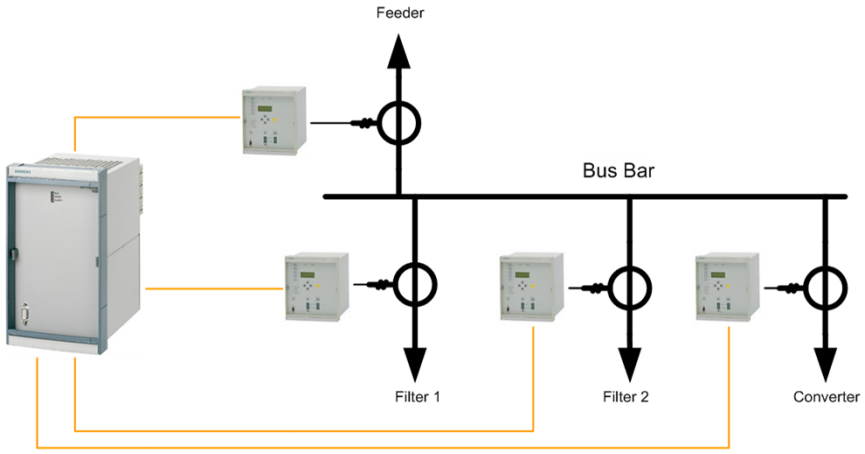
Transformer Differential Protection



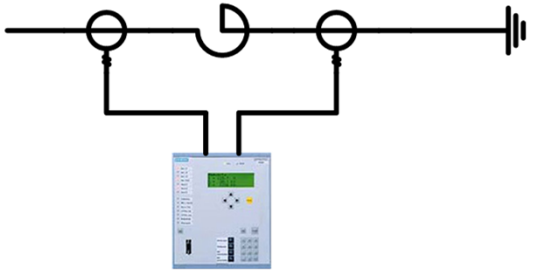
Filter Protection



Bus Bar Protection



Shunt Reactor Protection



DC Converter Measurement Locations

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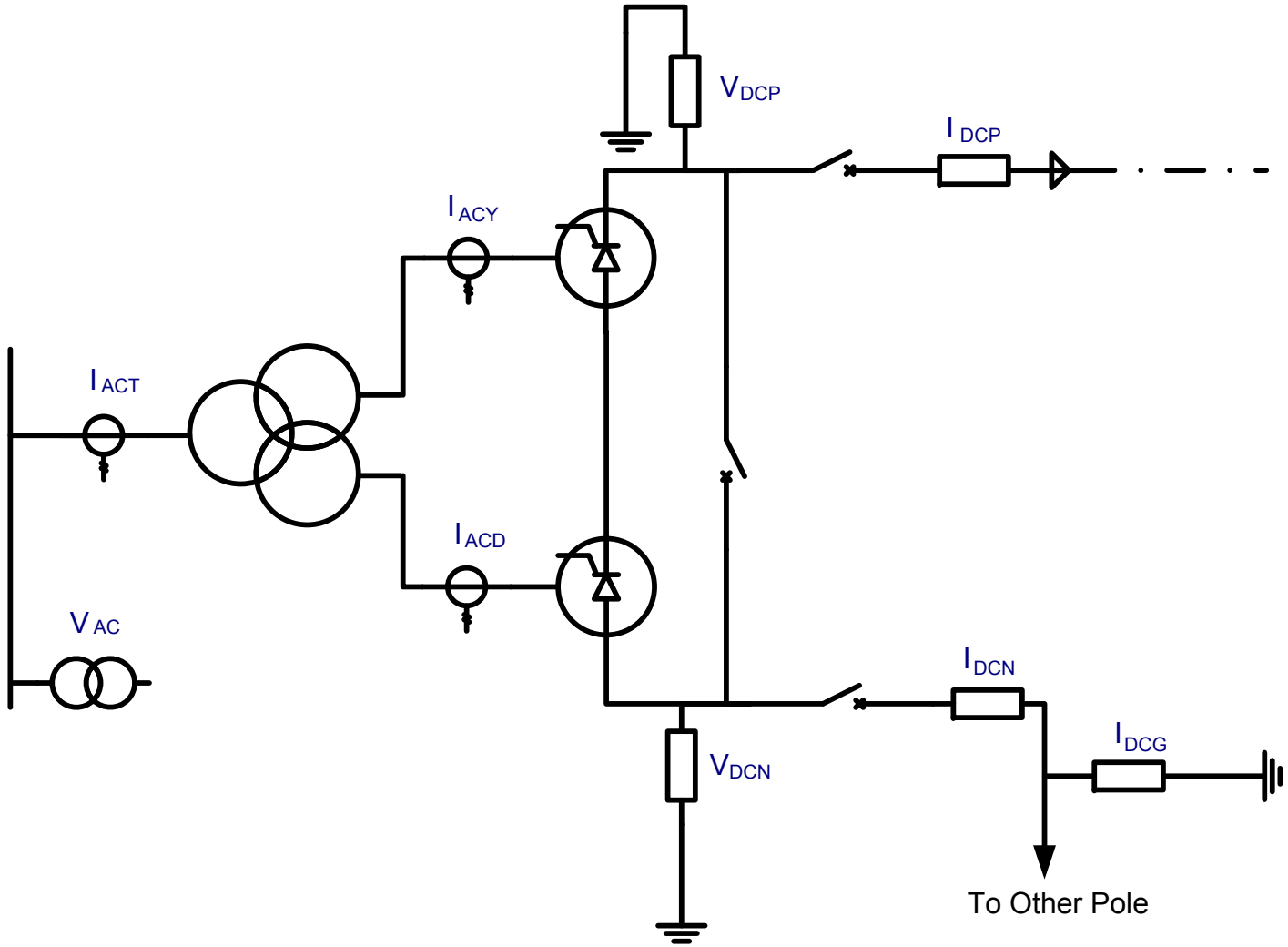

DC Measurement

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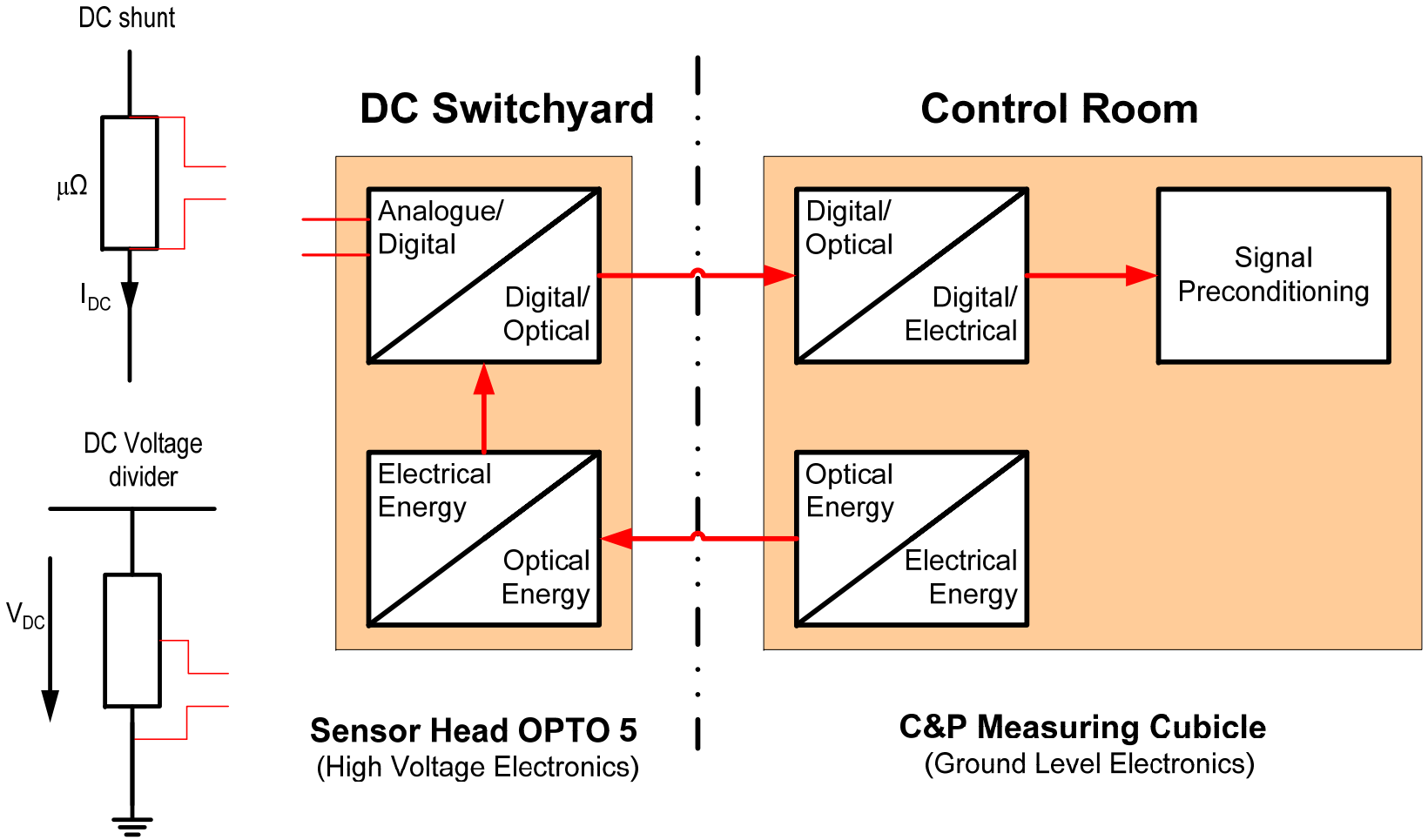

New Technology in HVDC (Voltage Source Converter)

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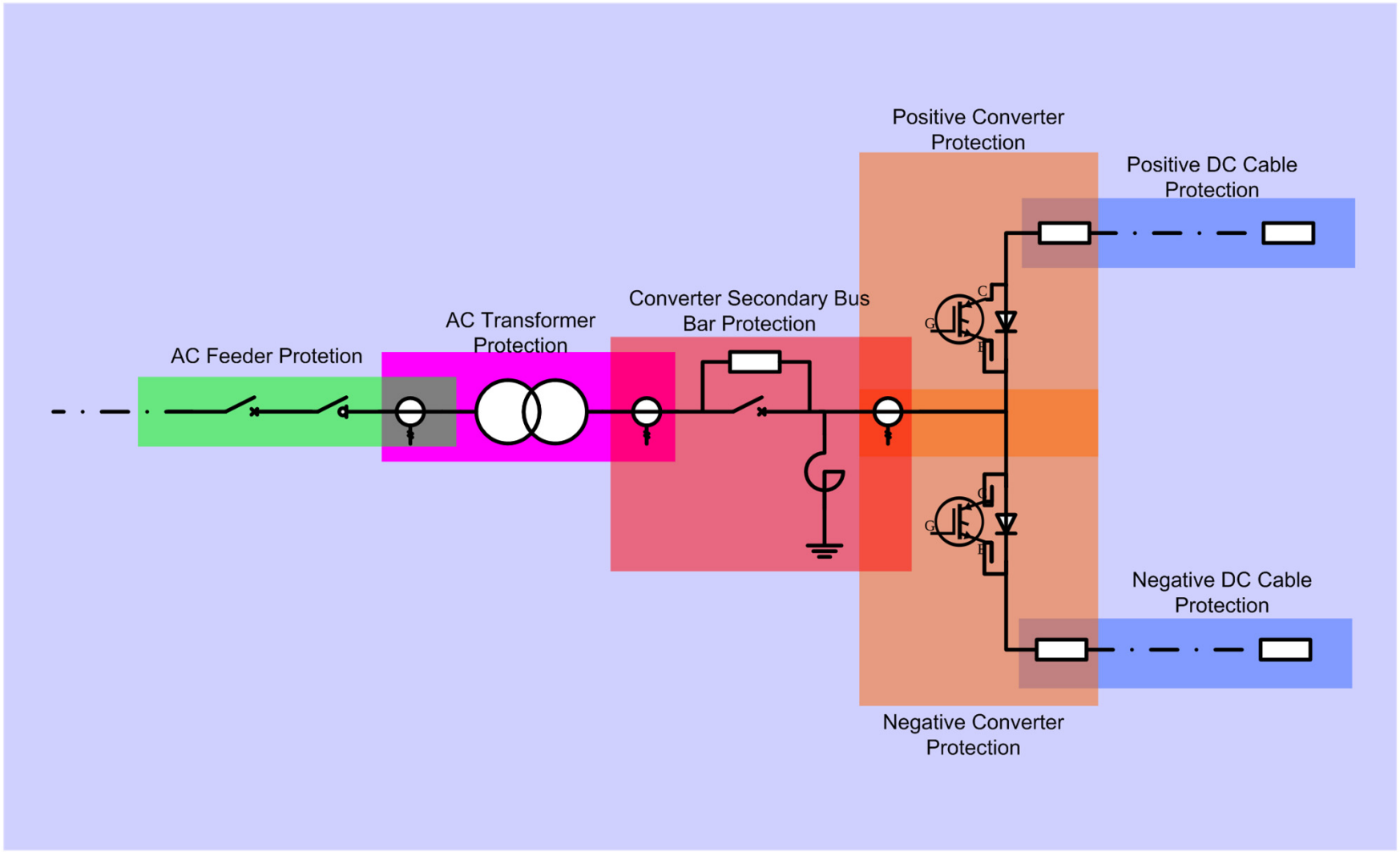

VSC HVDC converter station example

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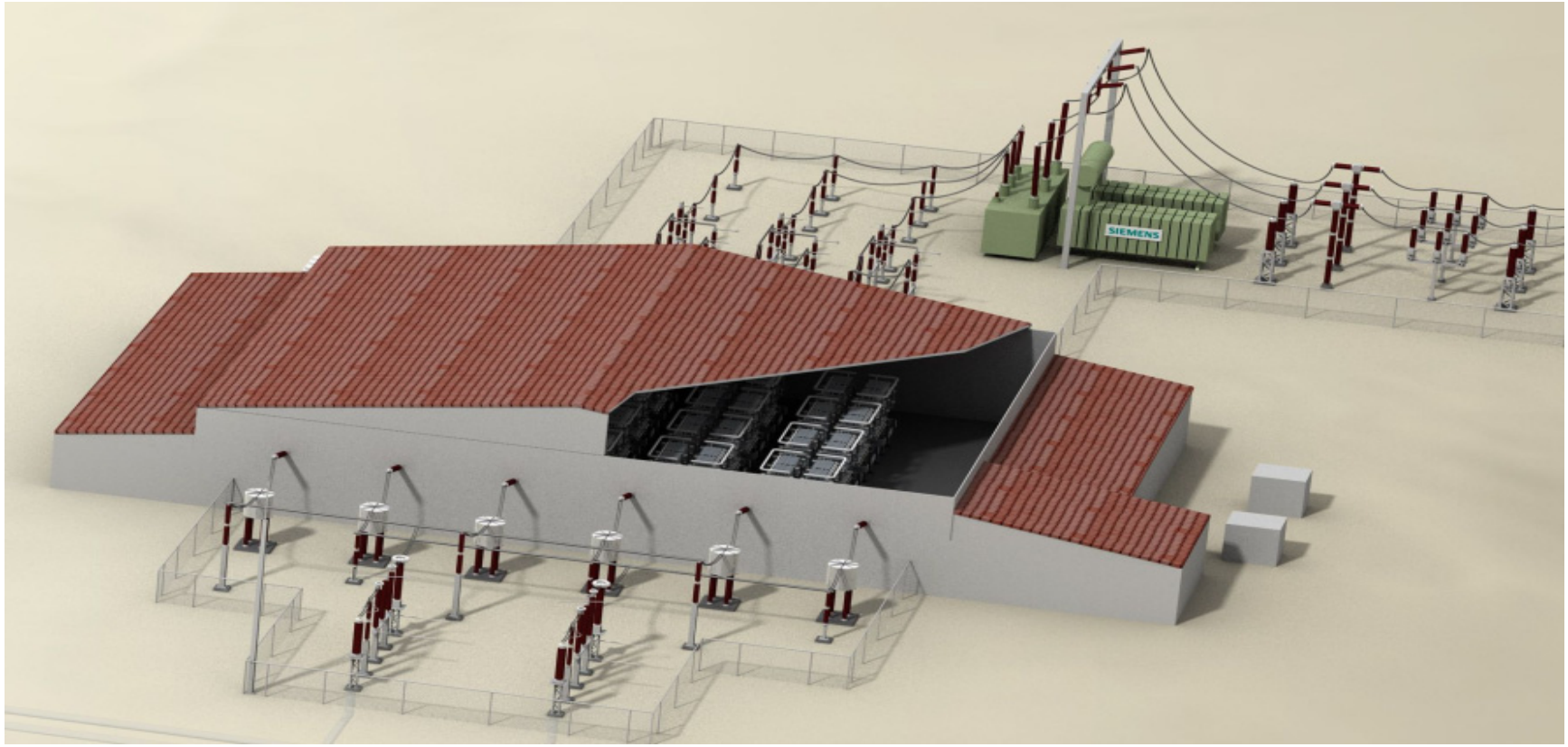

Advantages of VSC HVDC

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- Multi-terminal capable
- No filters are required to comply with Grid codes
- Only normal double wound transformer is required
- Less Space required on the substation
- Independent P and Q control can be achieved

However:

- Lower Rating than CSC
  - Western Link (CSC) rated at 2.2GW
  - Most UK VSC projects are around 1.4MW
- Switch-on resistor is required to start the converter
- Balancing Point needs to be established

Control System of HVDC

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- Grid System elements :
  - Control & Protection systems are separated
- HVDC system:
  - Control & Protection are integrated into one system

Monitoring and the Internet of Things (IoT)

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Every year, more and more assets are connected.

Increase Performance …

…powered by digital transformation

Build Digital Business …

…through development of applications & digital services

Differentiate in the Market …

…through new service and business models

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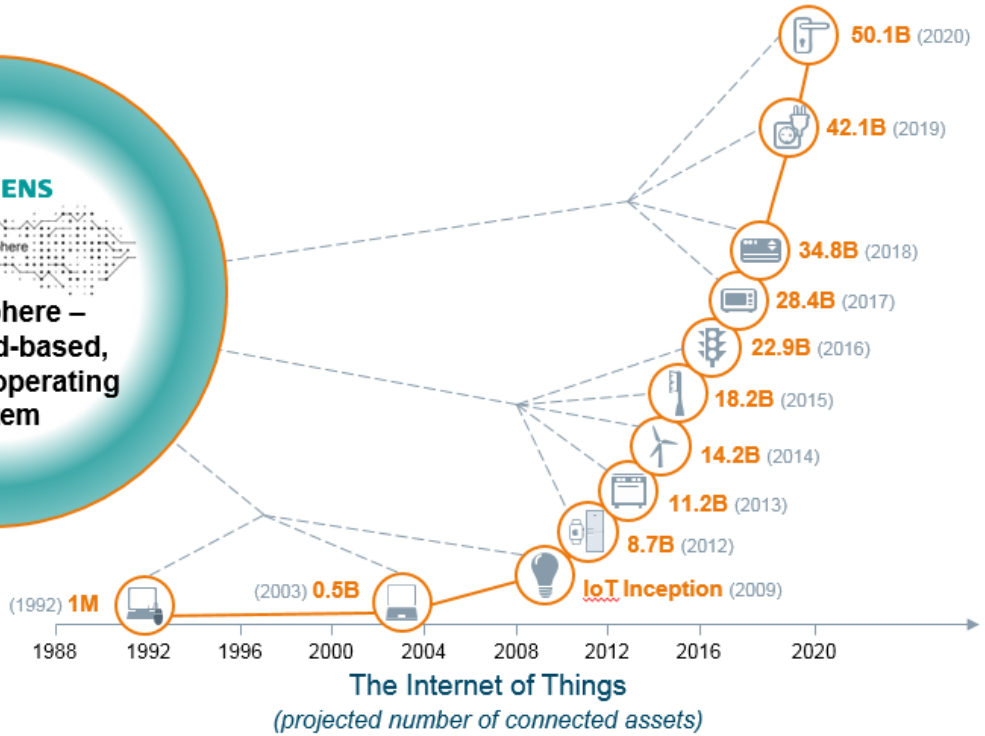
MindSphere
MindSphere – The cloud-based, open IoT operating system



Monitoring and the Internet of Things (IoT)

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Every piece of equipment has a wealth of data, which can be used to analyse its behaviour. This data can be used to create productive business results.

MindApps
- Use **apps from Siemens, partners or develop own** apps
- Gain **asset transparency** and **analytical insights**
- Subscription based **pricing model**

MindSphere
- Open interface for development of **customer specific apps**
- **Various cloud infrastructures: SAP, AtoS, Microsoft Azure** offered as public, private or on-premise (planned)

MindConnect
- **Open standards** for connectivity, e.g., OPC UA
- **Plug & play connection** of Siemens and 3rd party products
- **Secure** and **encrypted** data communication

Monitoring and the Internet of Things (IoT)

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Due to this change, there is a possibility for many other organisations to create growth within the Electricity Industry.

Monitoring and the Internet of Things (IoT)

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Examples:

Major soft drink producer

Machine monitoring

- **Affordable IoT solution** for **predictive maintenance** of 150 motors
- **Increased asset uptime** through accurate failure prediction
- Global **accessibility of data**

Major OEM for Honing Machines

Machine uptime and quality

- **The honing stones** must be replaced before either critical threshold values
- **Reduced downtime** and guaranteed quality
- **Differentiated** service offerings & revenue stream for OEM

Major international airport

Failure prediction for baggage carts

- Identification of all potential **failures in baggage trail**
- **On-time maintenance of defective baggage carts**
- Visualization of **system failures**

Monitoring and the Internet of Things (IoT)

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Also, in the Electrical Industry, the data can be used to give indication for required maintenance or replacement:
A few examples:

- Equipment Condition Monitoring – for example circuit breaker tripping performance
- GIS Gas Density Monitoring – identify leaks early
- Battery Monitoring – maintain or replace before batteries won't support the load
- Motor performance Monitoring – maintain or replace before equipment fails
- And much, much more….

In a lot of cases, the data is also combined with environmental aspects (location, weather, etc), which is not always is taken into consideration.

A live demo can be viewed here: https://siemens.mindsphere.io/live-demo

Process Bus Technology

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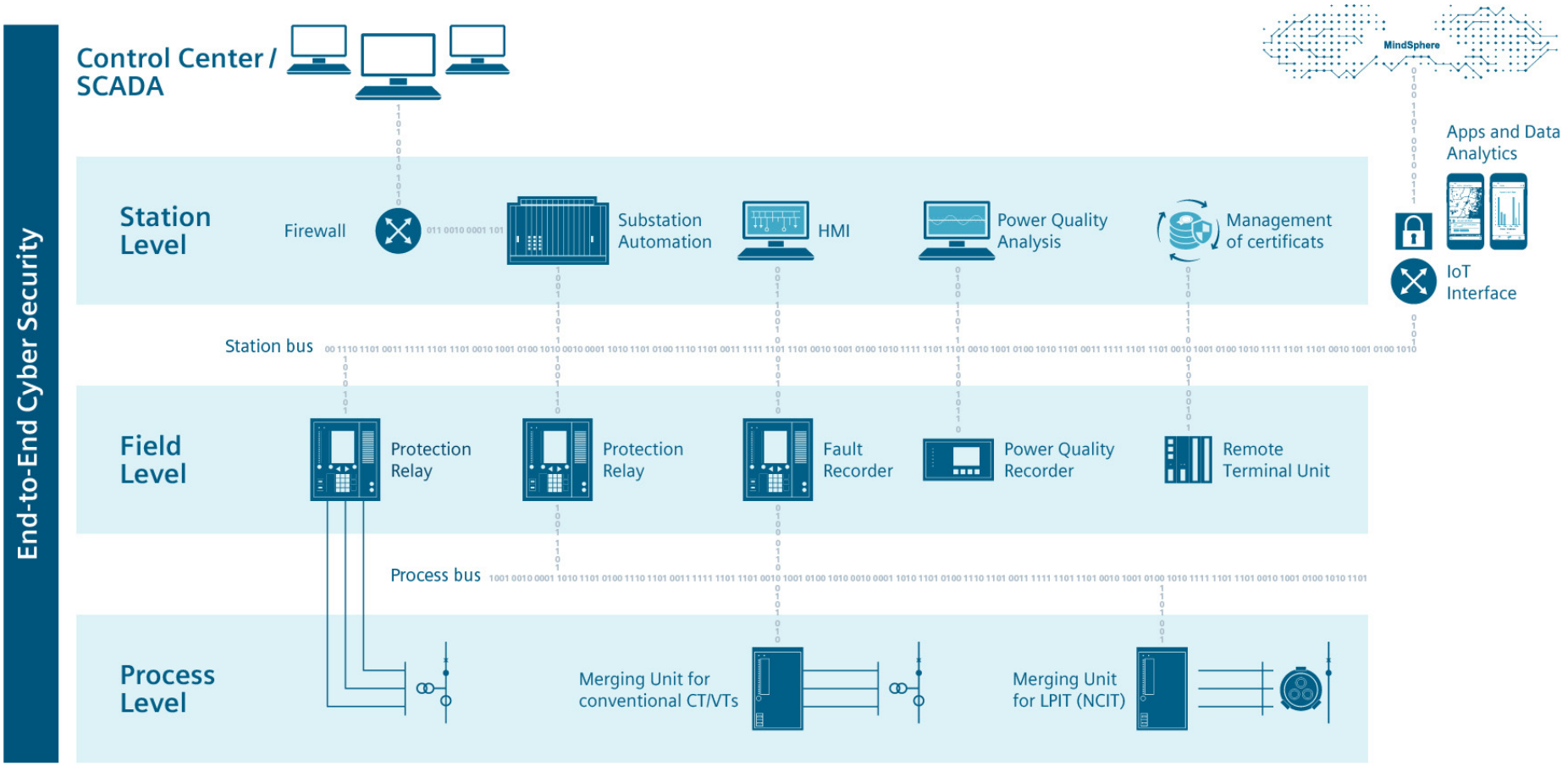

Process Bus Technology

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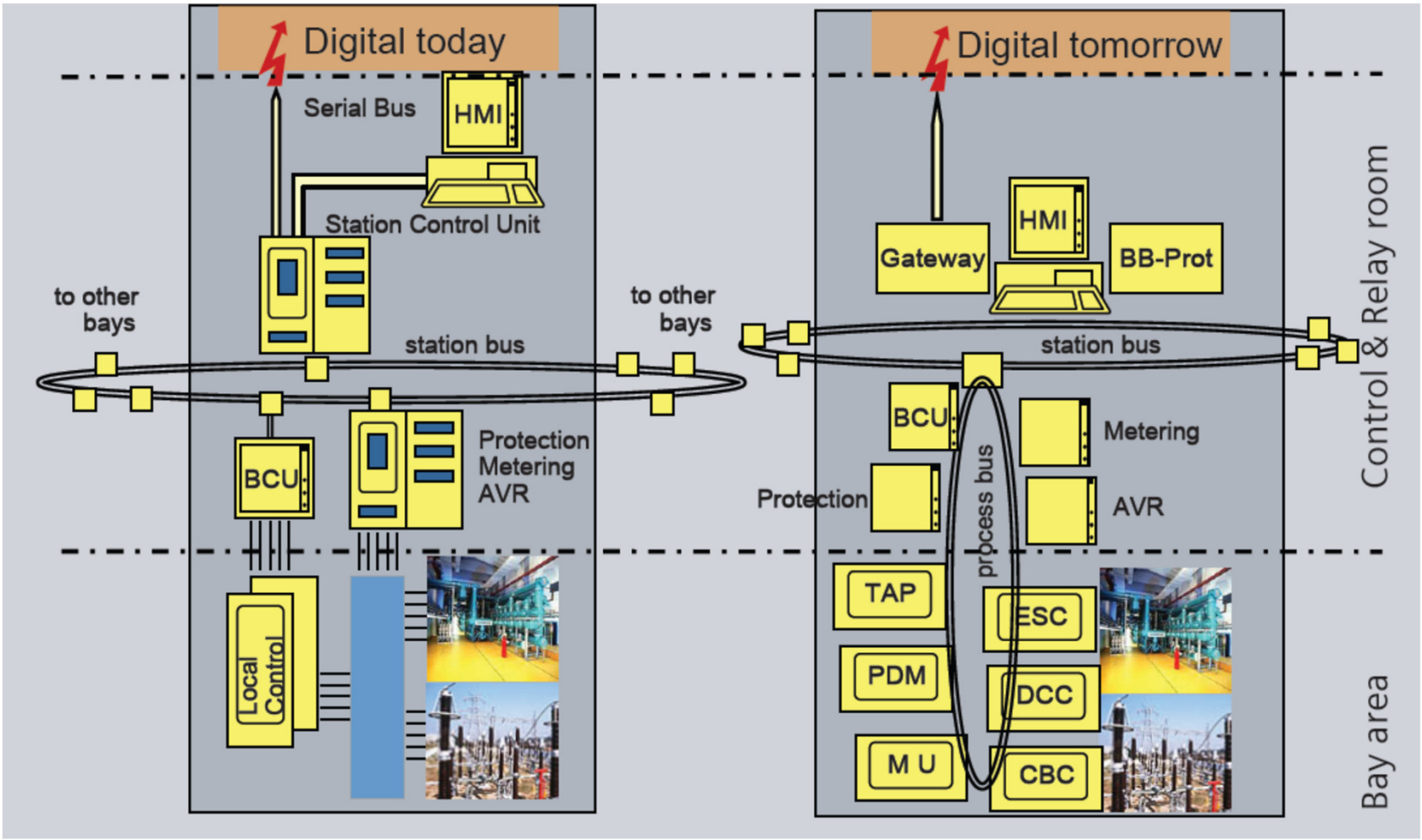

Process Bus Technology

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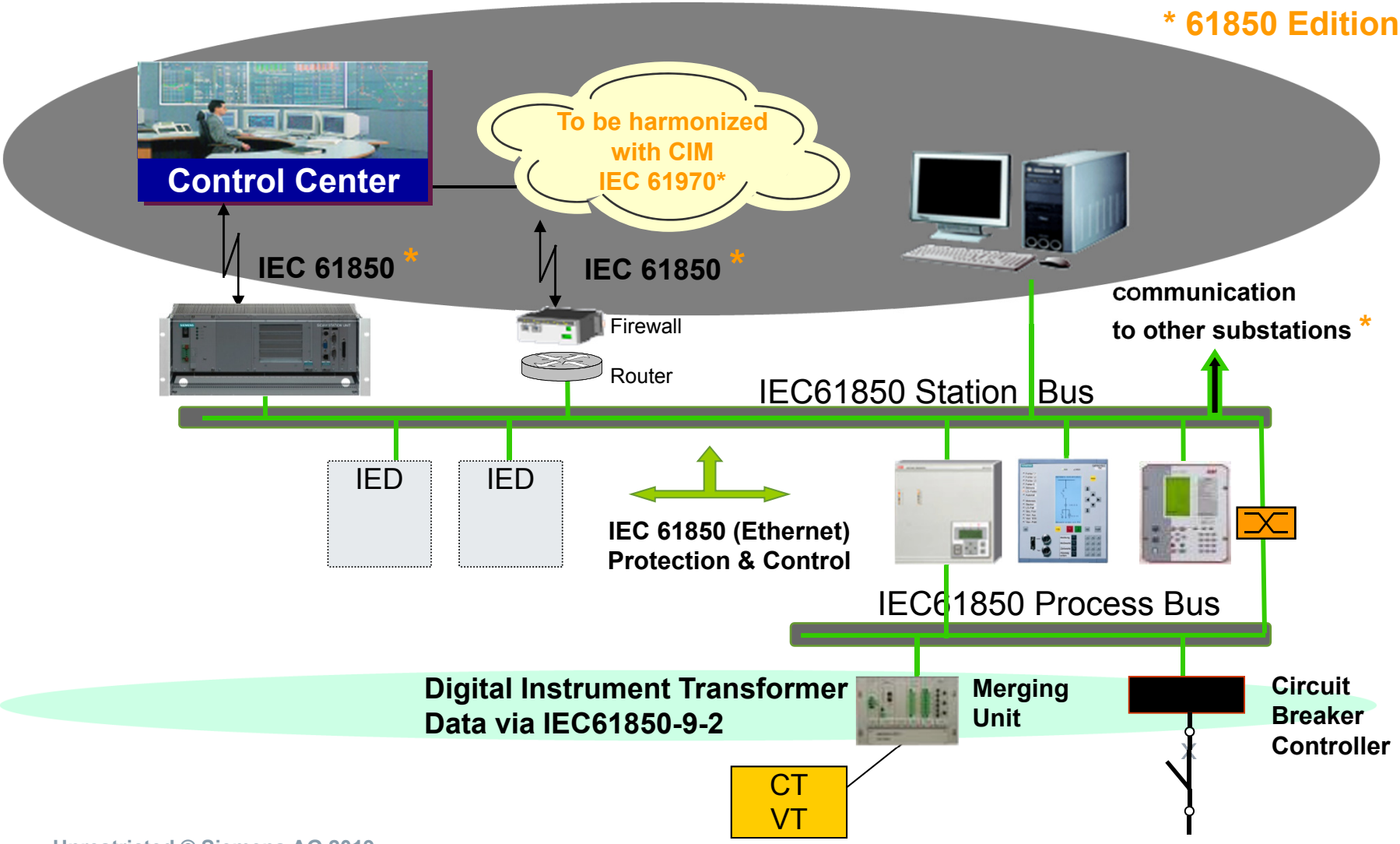

Process Bus Technology

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Benefits of the Process Bus Technology:

- Standardised communication interface on Ethernet
- Enables the use of Non Conventional Instrument transformers (NCITs)
- Save copper cables and other hardware structures
- Saves Engineering efforts
- Eases installation, maintenance and replacement
- It is the basis for intelligent switchgear and extended monitoring functions

Process Bus Technology

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Merging Unit (analogue):
Converts analogue voltages and currents into IEC 61850 compliant data stream.

Protection Devices:
Uses the current and voltage information from the data stream to evaluate the current state of the system. Send trip signals to Digital Merging Units

Merging Unit (digital):
Receives and transmits information from/to the protection device. Sends commands to the switchgear (including tripping)

Non-conventional Instrument transformers

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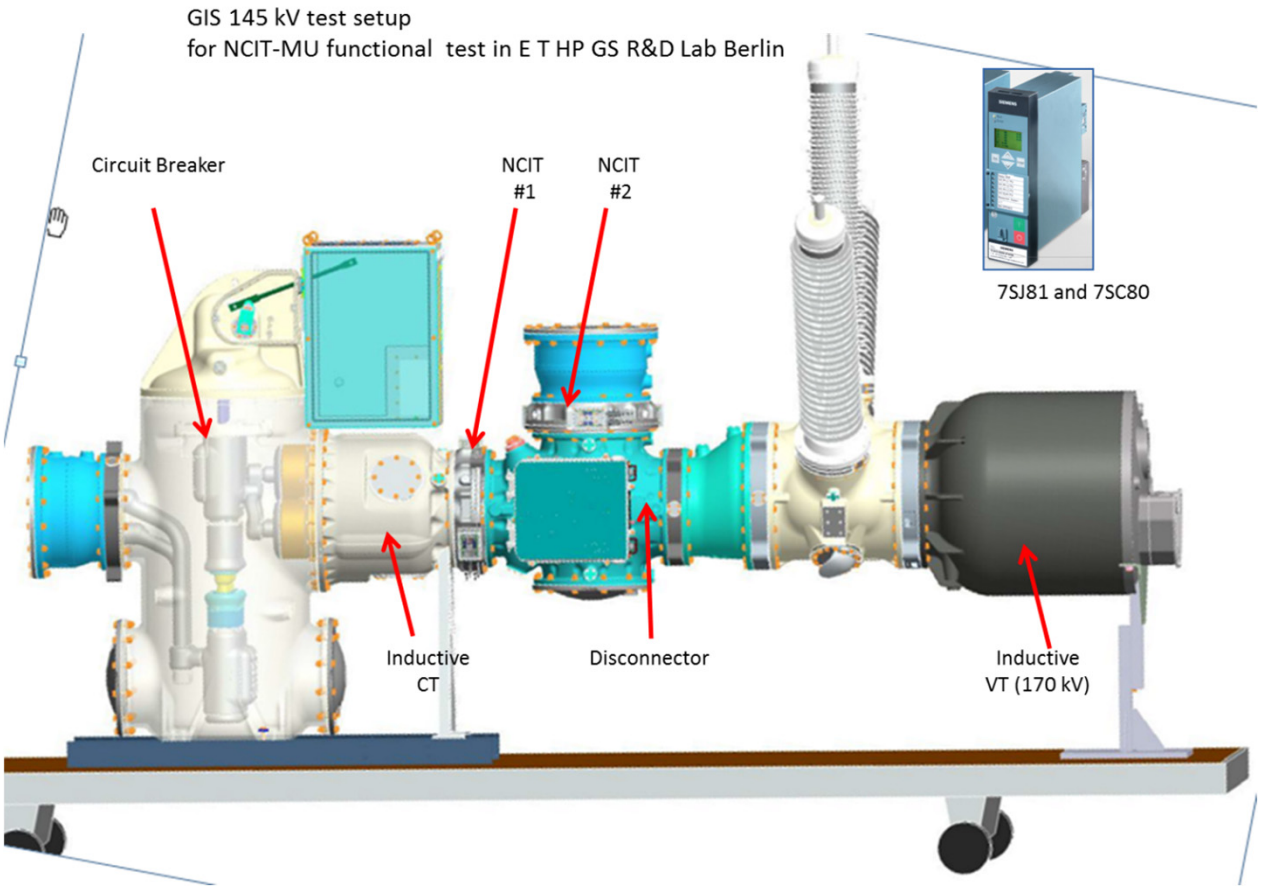
Test set for Rogowski coil and RCVDs



Non-conventional Instrument transformers

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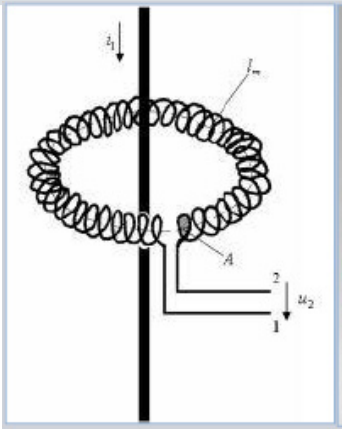
Characteristic	Inductive CT	Rogowski Coil
Saturation	Saturates with several times rated current	Does not saturate
Size and weight	Large and Heavy	Small and Light
Remanence	Remanence is possible	No remanence (no iron core)
Protection Schemes	Several CT cores required for different applications	One Rogowski coil can be used for different schemes
Safety	Open Secondary can generate dangerous voltages	Safe – open secondary voltage very small



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Research and Development Project „Intelligent Switchgear“ Station Nehden

R&D Project Configuration

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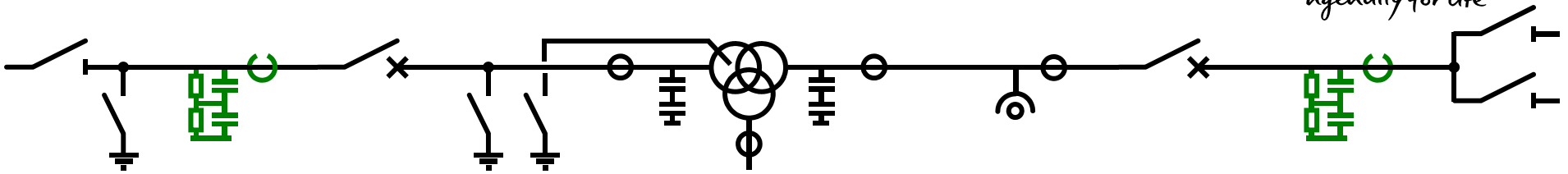

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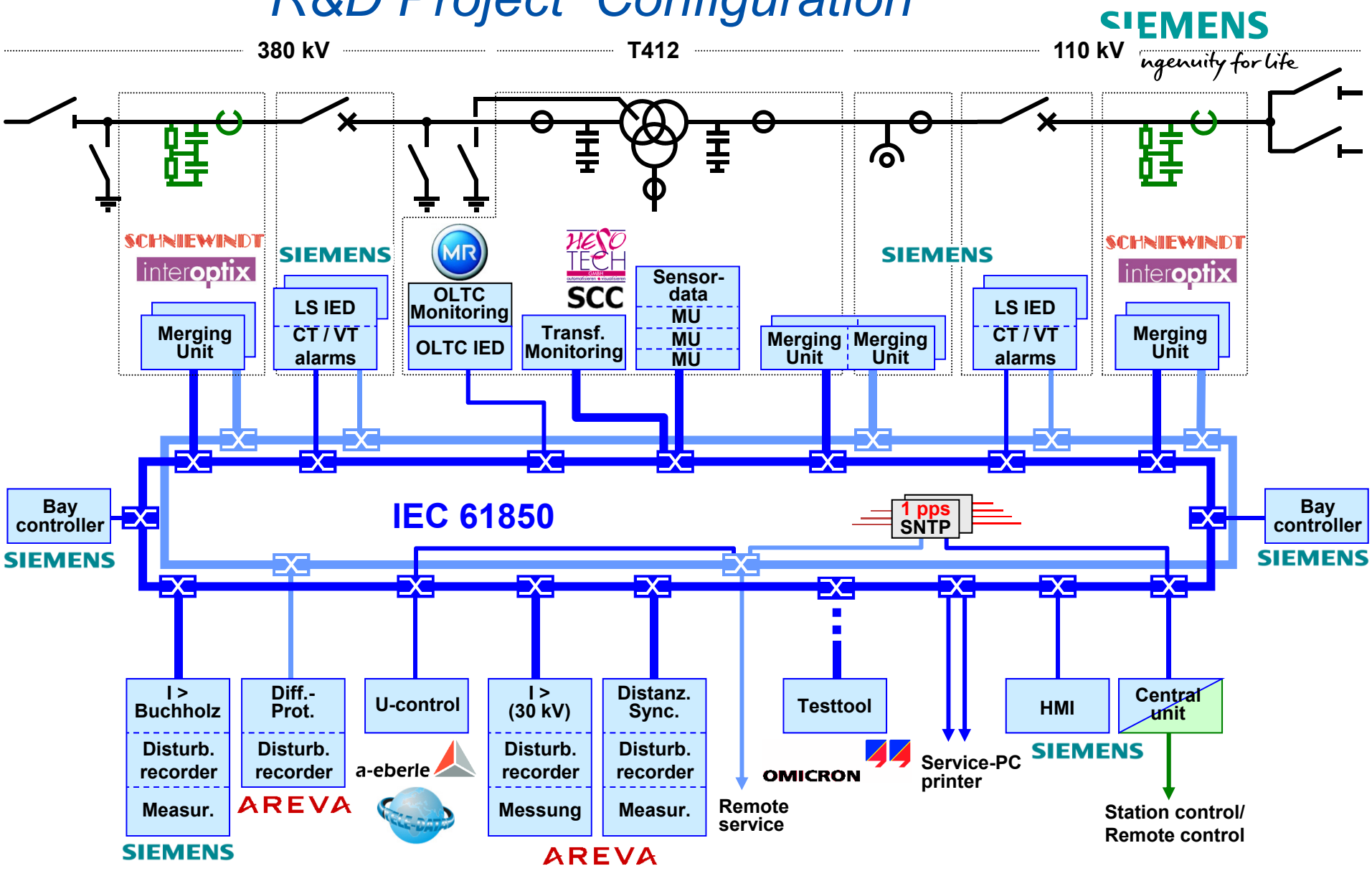
R&D Project Configuration



Process Bus Technology

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Current development status:

- Trials are in place all over the world to evaluate the technology
- Standards are defined to enable interoperability between manufacturers
- Trials have been done at the University of Manchester and around the world for Interoperability between different manufacturers
- Customer specifications are being developed to enable the use of Process Bus Technology
- Products are being developed and are also available on the market
- The idea of Process Bus Technology is already in use (GOOSE Tripping, even though it uses standard IEC 61850)

RSTP vs. Seamless Redundancy

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RSTP Redundancy:

- Only one link is active
- Needs time to reconfigure
- Messages are lost and need to be resend (not deterministic)

For Process Bus this is not good enough. For this applications seamless redundancy is necessary:

- Both Links are active all the time
- No reconfiguration time
- No messages are lost

There are 2 main seamless redundancy protocols:

- PRP – Parallel Redundancy Protocol
- HSR – High-availability Seamless Redundancy Protocol

Following slide shows both concepts working in parallel

PRP/HSR in Parallel and Ring Redundancy

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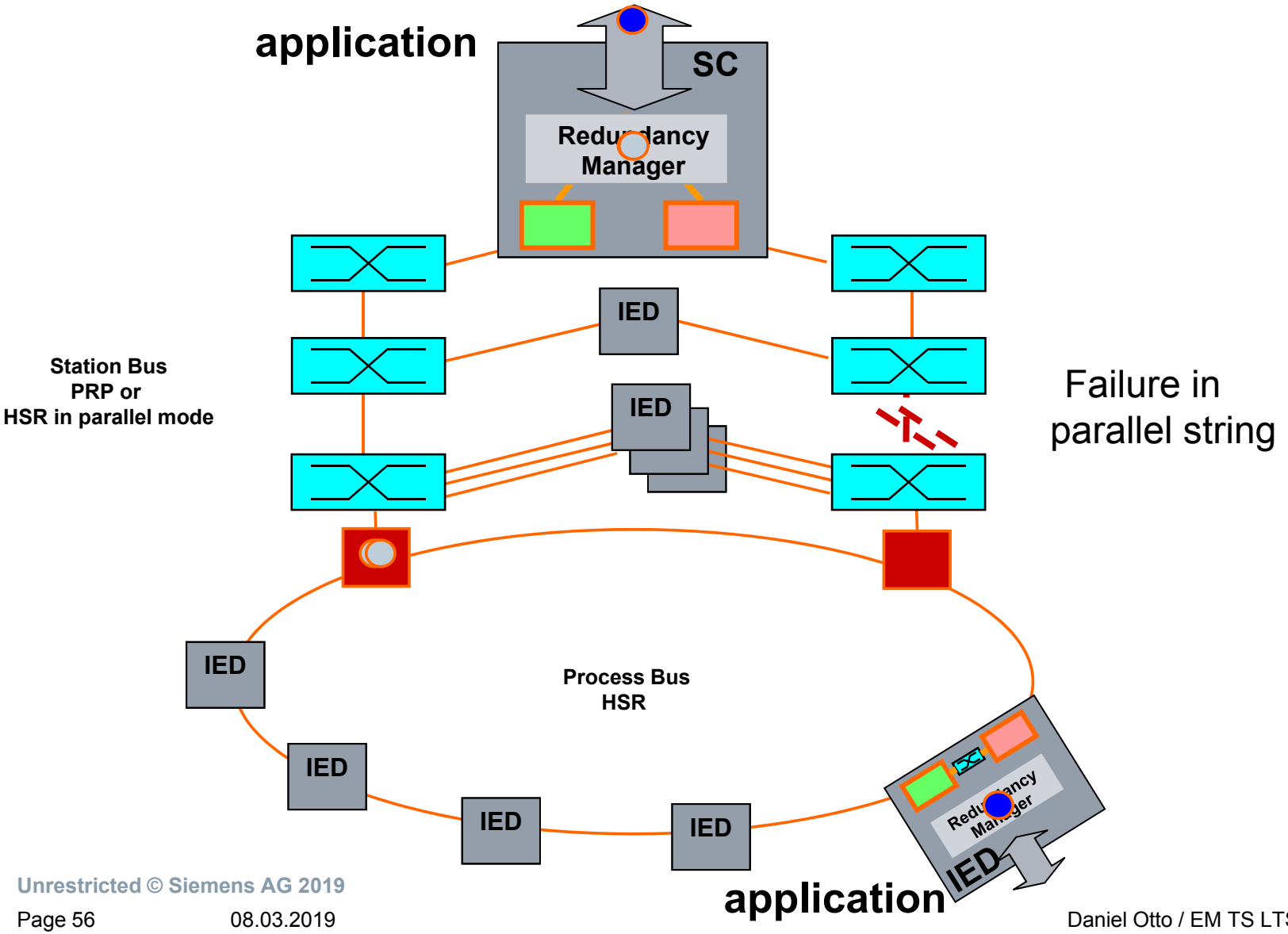

Process Bus

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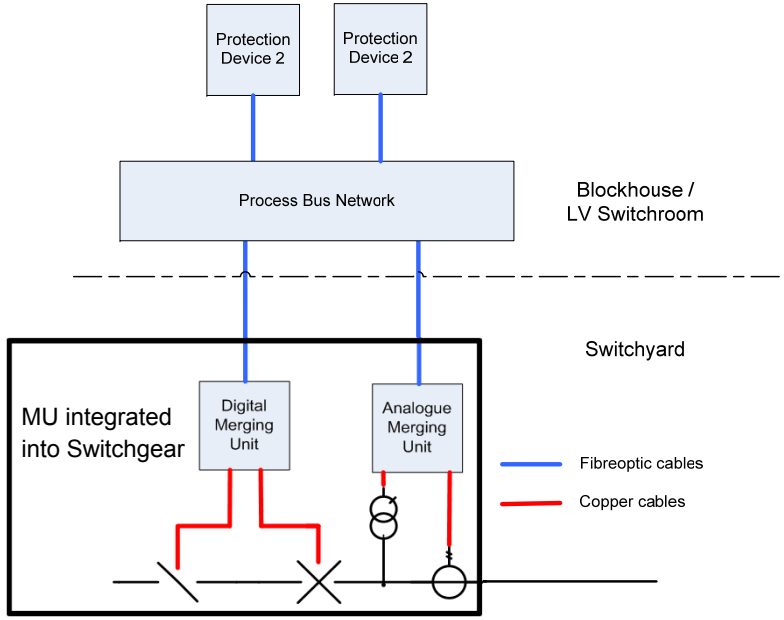
Future Prospect for Process Bus Technology:

- NCITs will be used to connect to the Merging Units
- Process Bus Technology will protect circuits, but localised in Control & Protection room (blockhouse)
- Merging Unit will be located outside in the switchyard or even integrated into the switchgear to achieve its full potential



Process Bus

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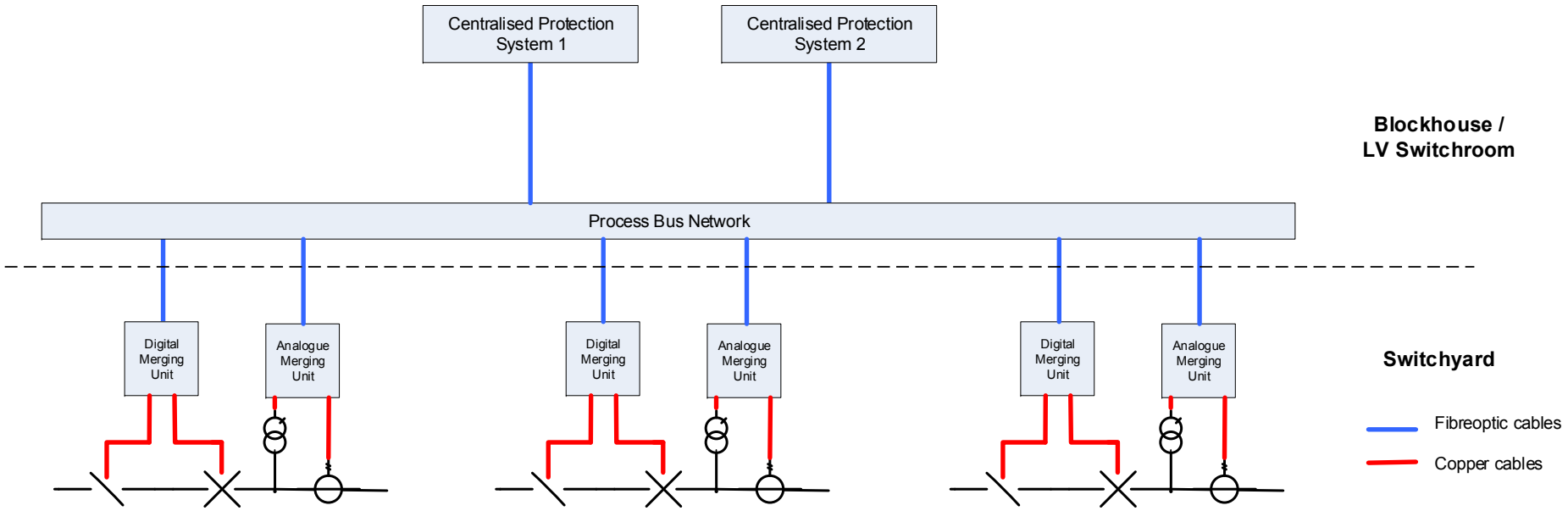
Future Prospect for Process Bus Technology – Centralise Protection:
Instead of having protection devices on a per bay basis, Process Bus Communication enables the use of a centralised protection system



Thank you.

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