

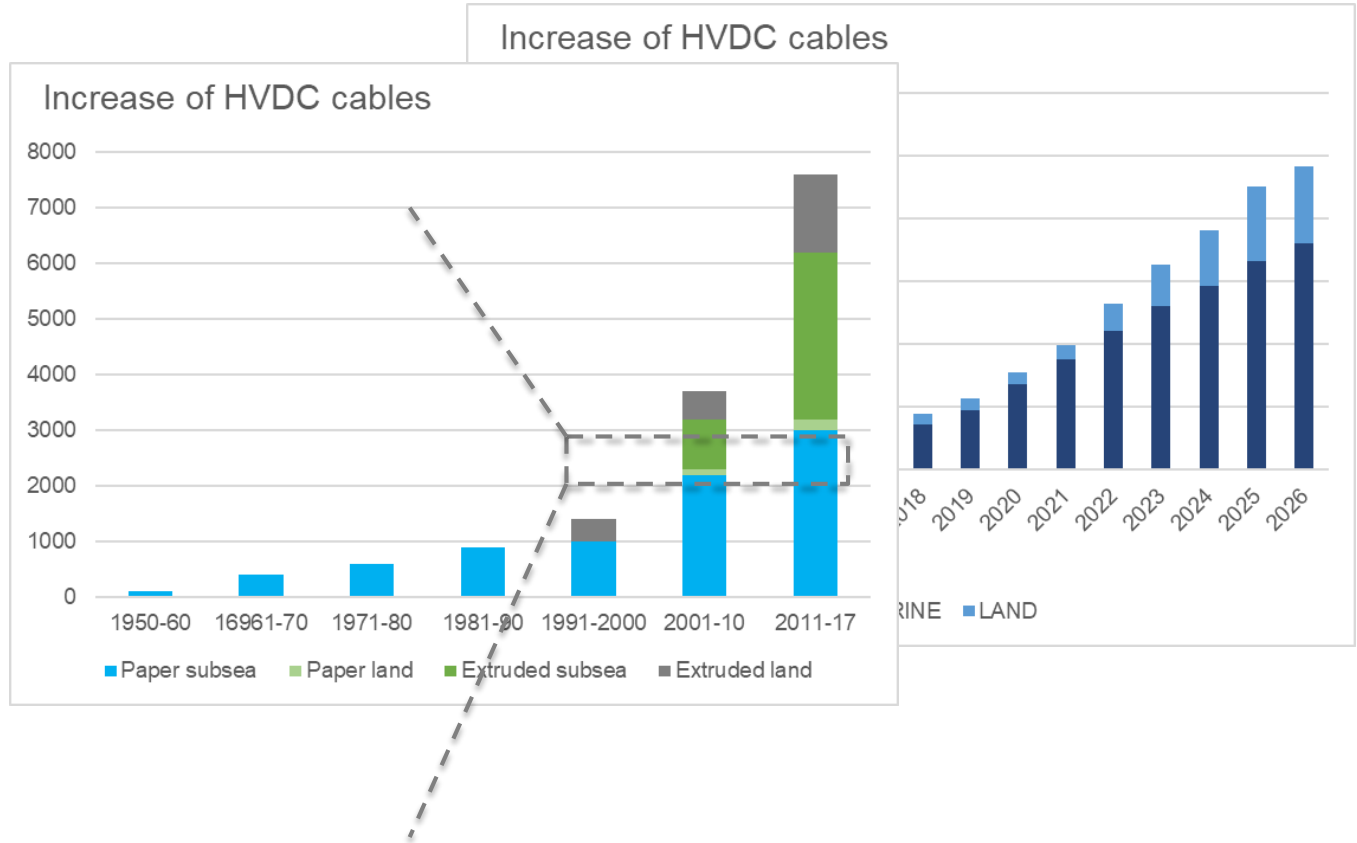
Submarine cable: industry progress

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27.06.2019
AGP21 TGED19, Versailles, France



HVDC FOR CABLE INTERCONNECTIONS

What will be required?



Sources: Forecast demand and manufacturing capacity for HVAC and HVDC underground and submarine cables, ENTSOE-E/Europacable
Electricity transmission of tomorrow underground and subsea cables in Europe, Europacable

Need for
fully
integrated
network
solutions



State-of-the-art cable designs for submarine interconnections

- 320kV extruded cables installed and in operation for distances up to 300km
- 400kV extruded cables recently introduced, potential up to 500km
- 525kV lapped cables installed and in operation for distances up to 700 km



Typically bundled with **optical cables**, to **combine energy and telecom transmission**: different types of system configurations (unrepeated, repeated with passive amplifiers, repeated with active amplifiers) depending on link length



New generation of cable laying vessels able to match with long installation campaign lengths, minimize number of joints and reduce installation time



Monitoring, preventive maintenance and readiness to repair – **integrated monitoring in the cable design**

HVDC FOR CABLE INTERCONNECTIONS

Extruded cables

- Completed **pre-qualification tests at 525kV** for land systems
 - XLPE** (commercial compound)
 - HPTE** (high performance thermoplastic elastomer)
- Large cross sections tested ($2500\text{mm}^2/3500\text{mm}^2$)
- Power up to **3GW**
- Now **moving to submarine**

Is the future of HVDC for thermoplastic materials?

- High operating temperature
- No by-products
- No space charges
- No degassing
- Fully recyclable

HPTE

- ±525 kV @ 90 °C



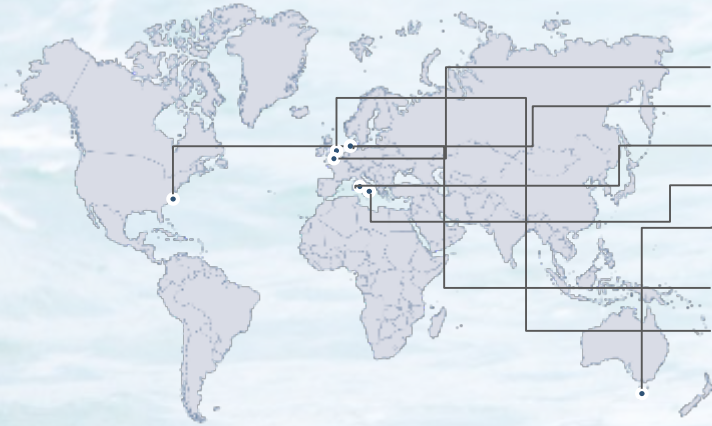
XLPE

- ±525 kV @ 70 °C



HVDC FOR CABLE INTERCONNECTIONS

Lapped cables



- NSN - UK/NO**
HVDC ± 515 kV 1800mm² Cu
- SKAGERRAK4 - DK**
HVDC ± 525 kV various sizes
- SAPEI - IT**
HVDC ± 500 kV various sizes
- ITALY GREECE - IT/GR**
HVDC + 400 kV 1250mm² Cu
- BASSLINK - AU**
HVDC + 400 kV 1250mm² Cu
- NEPTUNE - US**
HVDC + 500 kV 2100mm² Cu
- WESTERLINK - UK**
HVDC ± 600 kV various sizes



MANUFACTURING EXPERIENCE

>4000 km
of installed DC MI cables



INSTALLATION EXPERIENCE

7 interconnectors
above 400kV

Deepest installations
1650m (SAPEI)

Longest connections
740km (NSN)



SERVICE EXPERIENCE

20 years
operational experience
above 400kV (Italy-Greece)



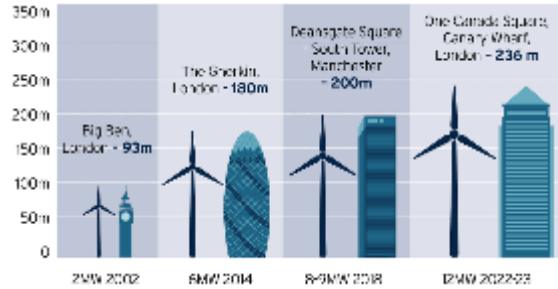
HIGHEST VOLTAGE

525kV
with MI

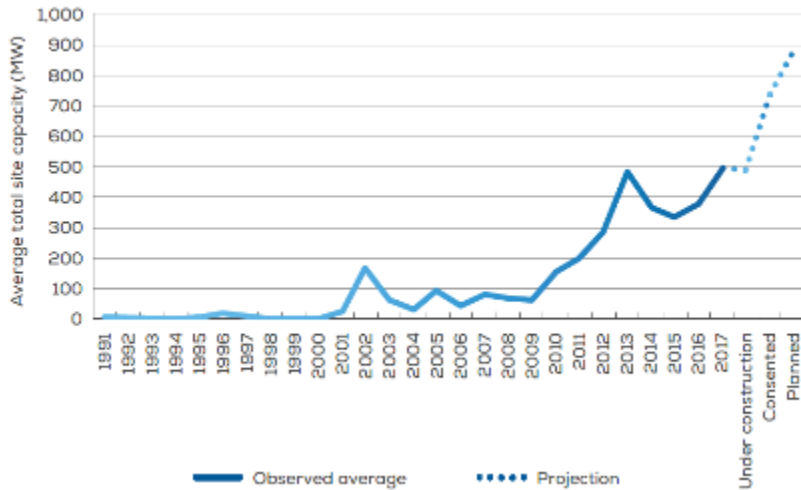
600kV
with MI PPL

HVDC FOR WINDFARMS

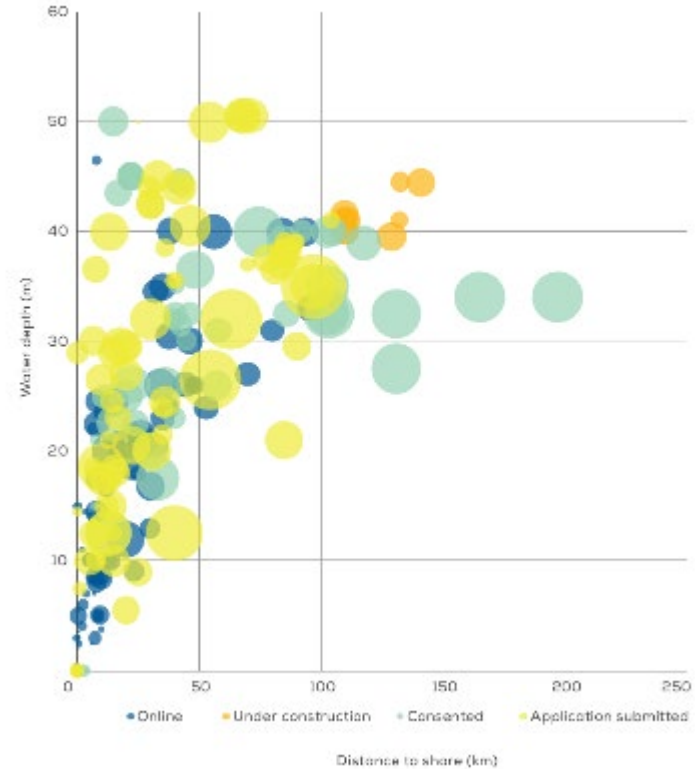
What will be required?



Average size of offshore wind farm projects (MW) commissioned per year



Average water depth and distance to shore of bottom-fixed offshore wind farms, organised by development status. The size of the bubble indicates the overall capacity of the site.



HVDC FOR WINDFARMS

Extruded cables

CONSOLIDATED CABLE DESIGN FOR SUBMARINE SECTION

Copper conductor
XLPE based insulation for 320kV
Lead sheathed
Single wire armoured (shallow waters)
Cross section transitions



CONSOLIDATED CABLE DESIGN FOR LAND SECTION

Aluminium conductor
XLPE based insulation for 320kV
Welded aluminium sheathed



... almost 10 years
service experience
at 320kV...

... what does it
mean translated
in numbers?

HVDC FOR WINDFARMS

Extruded cables



MANUFACTURING EXPERIENCE

>1600 km
of installed DC extruded submarine cables

>2500 km
of installed DC extruded land cables



INSTALLATION EXPERIENCE

11 projects
connecting HVDC offshore windfarms

>1000 joints
between offshore and onshore



POWER

900 MW highest rating for a DC extruded submarine cable

1200 MW new power requirement





Work for the future

1. Up to 2GW power for each windfarm connection

Requires qualifications up to 525kV and cross sections $>2500\text{mm}^2$

2. System solutions

System optimization since tendering phase, exploiting benefits of integrated supply&installation; closer interfaces with converter/platform suppliers

3. Hybrid solutions





New windfarm concepts; decreased installation corridors

4. Security of the power supply

System redundancy/backups, cable requirements in case of multiterminal systems, revision of insulation coordination requirements (CIGRE dedicated WGs)



AC SUBMARINE

CHARACTERISTICS	MV THREE CORE	HV THREE CORE	HV SINGLE CORE	
				
Insulation	EPR or XLPE	XLPE	XLPE	Self Contained Fluid Filled
Maximum voltage	72.5 kV	245 kV	420 kV	525 kV
Maximum power per circuit	90 MVA	400 MVA	1000÷1200 MVA	1200 MVA
Maximum length	Not limited by cable technology	Not limited by cable technology	Not limited by cable technology	~ 60 km due to hydraulic system limits

NOTE 1: Submarine cables may have different armouring design mainly depending on water depth

NOTE 2: rating depends on ambient and installation parameters

SUBMARINE AC TECHNOLOGY MILESTONS



60 kV Oil Filled

1949



60 kV 3C EPR

1972



First 525 kV Oil Filled

1984



150 kV EPR

2001



400 kV XLPE

2015

220 kV Oil Filled



1966

First 400 kV Oil Filled



1982

150 kV 3C XLPE



2000

230 kV XLPE



2006

230 kV 3C XLPE



2017

CHALLENGING TRENDS

✓ Deeper water



✓ Longer distance



✓ Higher power rating



✓ Higher efficiency



✓ Dynamic cables



WATER DEPTH > 3000 M

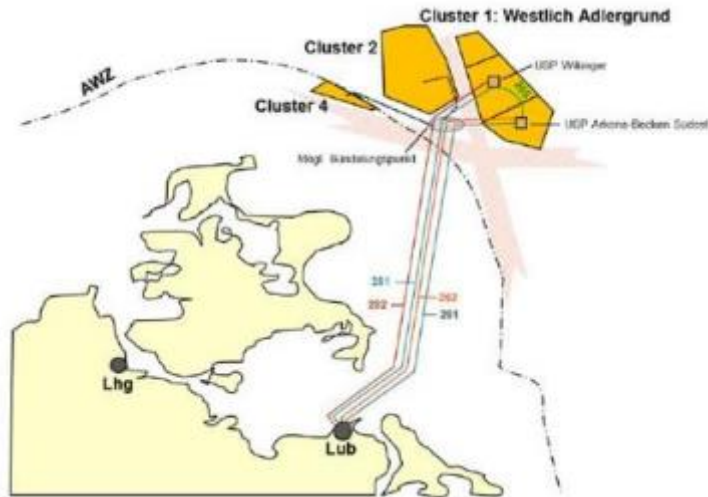
On going developments and tests confirm the feasibility of HV submarine power cables at water depth up to 3000 m and beyond.



50Hz – 220 kV Grid Connection Offshore Wind Park Cluster “Westlicher Adlergrund”

Main features

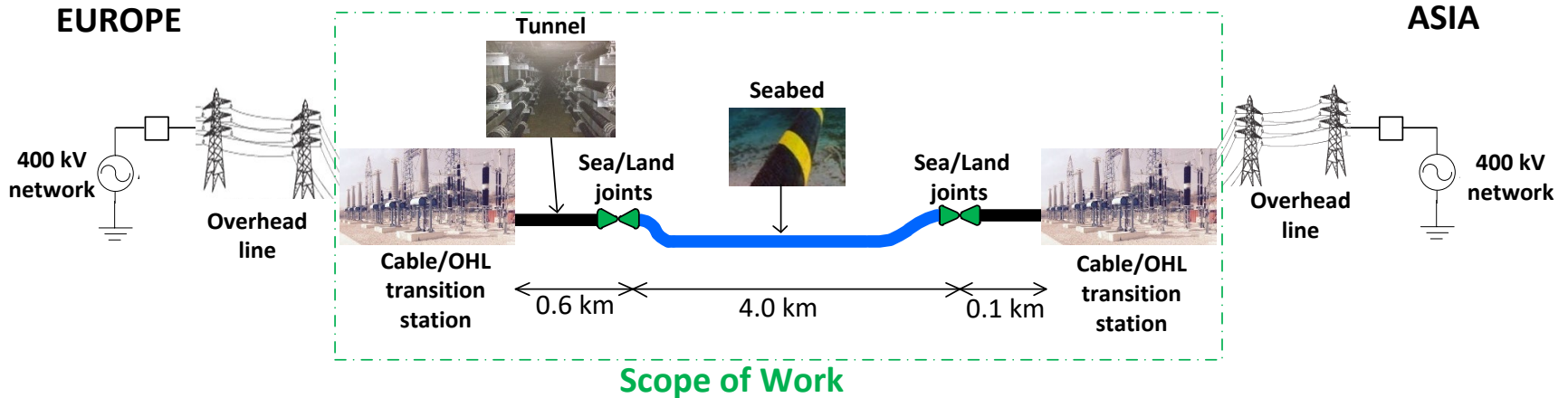
- ✓ Nos. 3 connections approx. 90 km long
- ✓ 300 MW per cable
- ✓ 3x1200 mm² Cu 220 kV XLPE



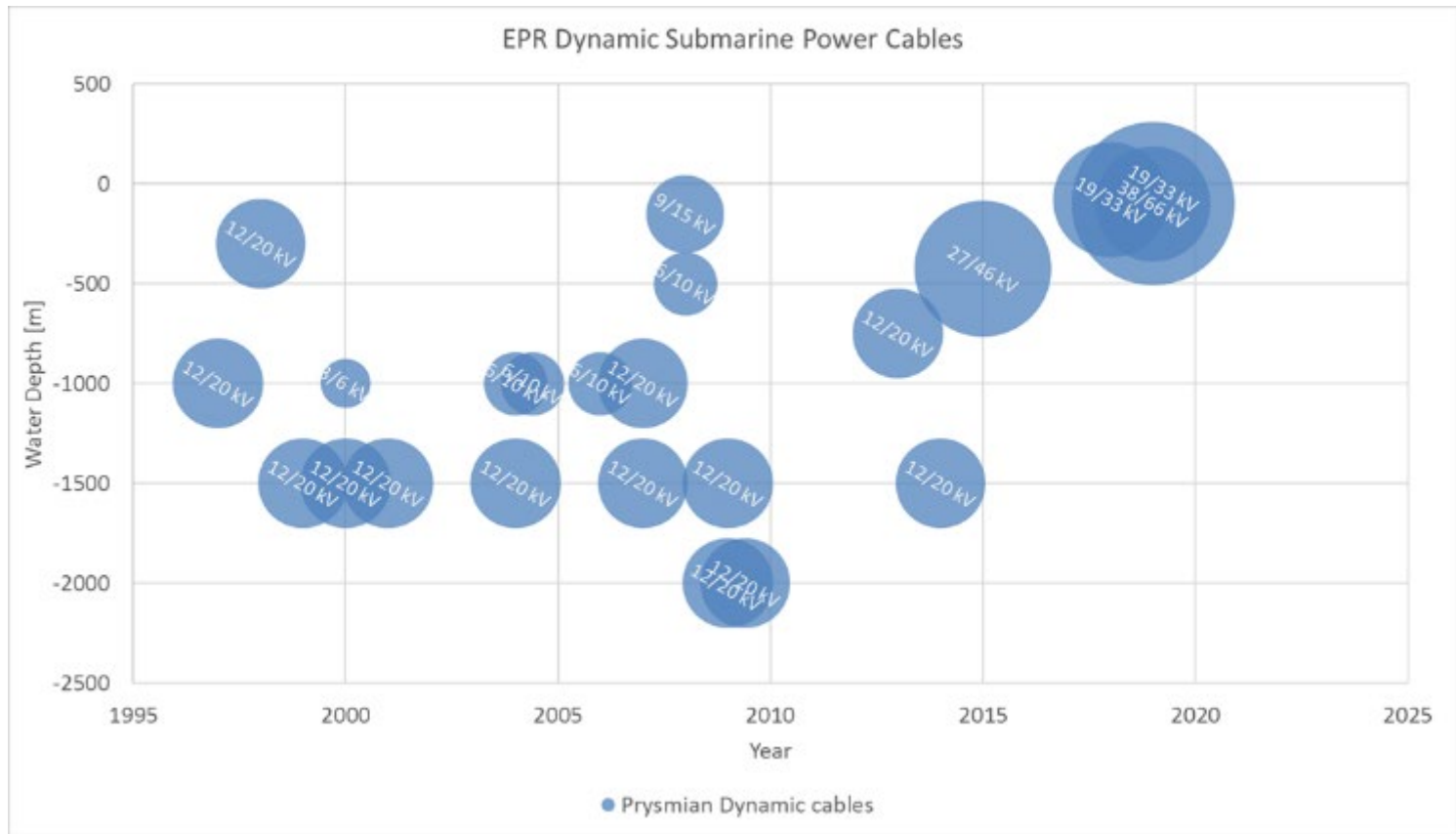
Dardanelles Strait (Turkey) 400 kV circuits

Main features

- ✓ N. 4 circuits. Each 4 km long
- ✓ 1000 MW per circuit
- ✓ 1600 mm² Cu 400 kV XLPE



PRYSMIAN DYNAMIC CABLES



SANTA YNEZ PROJECT

USA - California

- *Year of installation: 2015*
- *Power: 2 x 34 MW*
- *Cable: 3 core **EPR** insulated 46 kV*
 - *Able to withstand repetitive dynamic forces*
 - *Superior fatigue resistance & mechanical performance*
- *Overall Length: 44 km static cable + 4 km dynamic cable*
- *Completed full-size flex fatigue test*

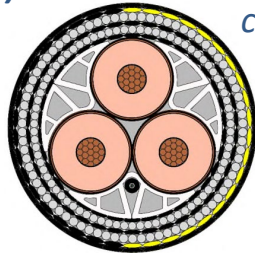


KINCARDINE PHASE I

- *Scotland – Kincardine*
- *Year of installation: 2018*
- *Power of 2MW (pilot)*
- *Water Depth: 80m*
- *Overall Length: 16km Static
+ 2km Dynamic (single
factory length)*

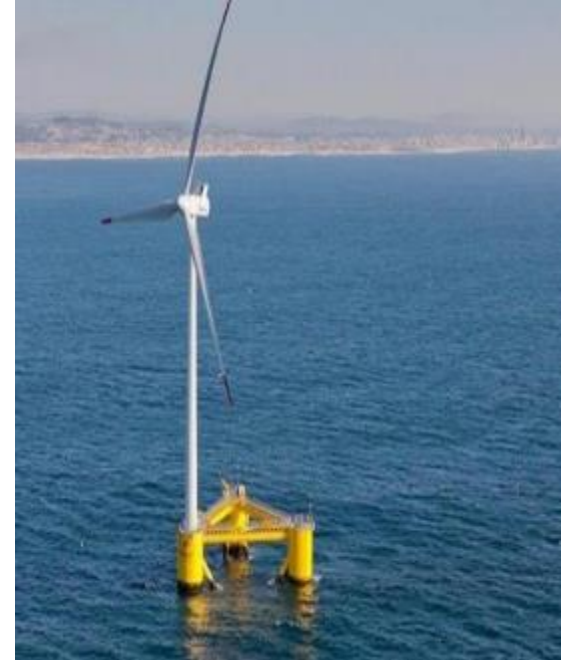
Cable Description (dynamic):

- *3x500mm² Cu*
- *19/33 kV EPR*
- *1x30 SM FOC*
- *DWA*



KINCARDINE PHASE II

- *Scotland – Kincardine*
- *Year of installation: 2020*
- *Power of 50MW (total)
5 WTG – 9,5MW each*
- *Water Depth: 80m*
- *Overall Length: 18km Static
+ 1km Dynamic (single factory
length) + 5 inter-array
dynamic
cables*



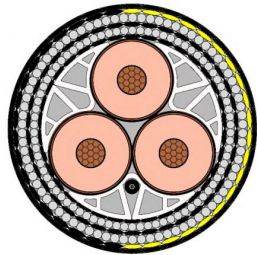
<https://www.windpoweroffshore.com/article/1497569/first-power-kincardine-floating-project>

PROVENCE GRAND LARGE (PGL)

- France, Provence
- Year of award 2019
- Power of 24MW (pilot)
- Water Depth: average 99m
- Length: 19 km of Static Export Cable and 3km of Submarine Dynamic Inter-Array Cables

Cable Description (dynamic):

- 3x150mm² Cu
- 38/66 kV EPR
- 1x48 SM FOC
- DWA



<https://www.sbmoffshore.com/wpcontent/uploads/2013/09/SBM-Offshore-wind-floater.jpg>

Thank you

