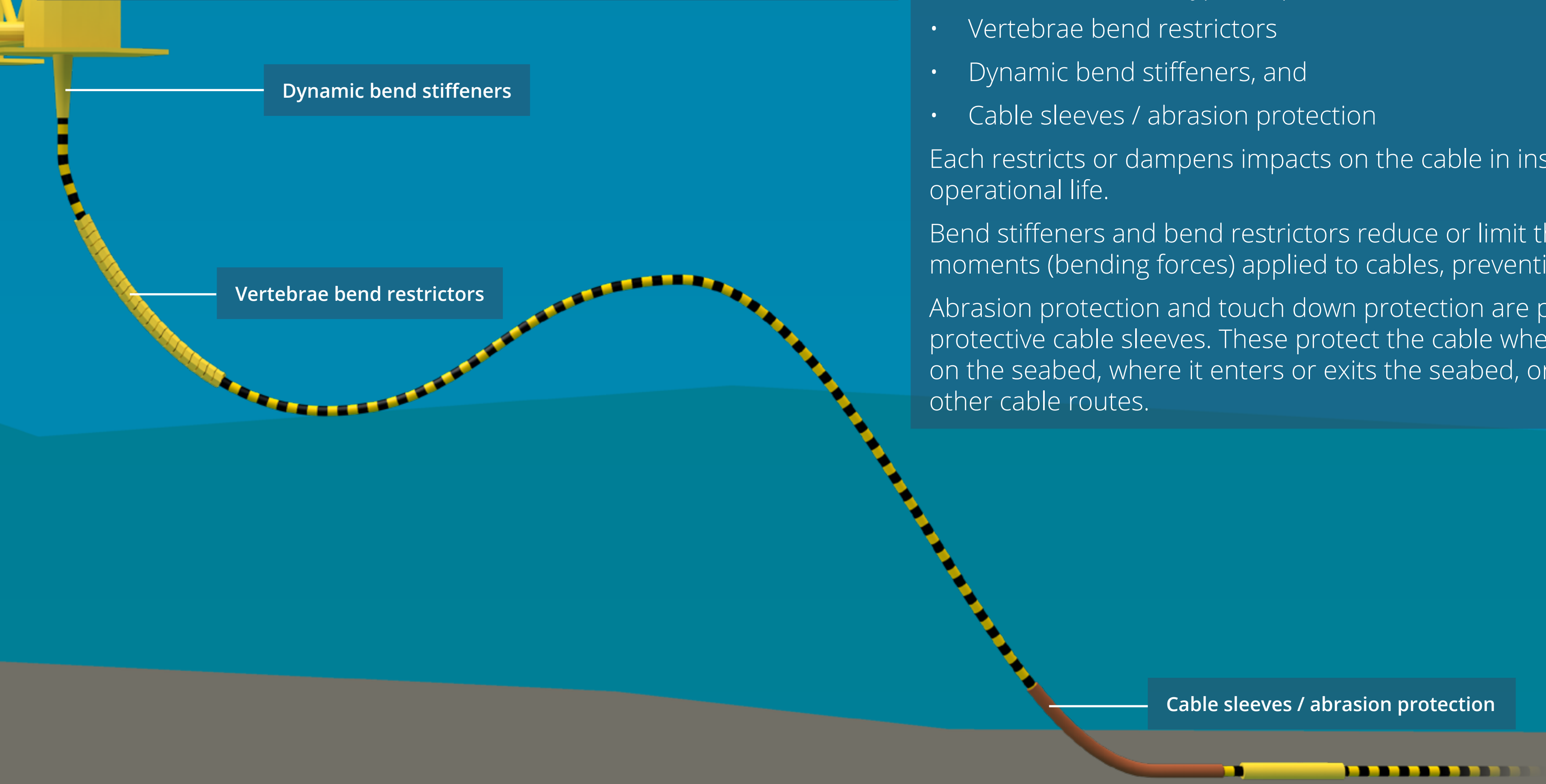
Fact sheet 3: **Cable protection systems**

What are cable protection systems?

Cable protection systems (CPS) help protect cables against impact, abrasion, fatigue, and damaging movement such as over-bending at vulnerable locations. This is particularly important for floating wind turbines which use dynamic cables to enable movement. CPS are needed to reduce costs involved with maintaining, repairing or replacing cables.



Overall description

CPS help to preserve the cables at vulnerable locations from wave and current action, including scour. For dynamic cables, this is typically where the cable enters and exits the floating substructure and the offshore substation, the touch down point on the seabed, and where the cable lies exposed on the seabed and cannot be buried.

There are three main types of protection:

- Vertebrae bend restrictors
- Dynamic bend stiffeners, and
- Cable sleeves / abrasion protection

Each restricts or dampens impacts on the cable in installation, or in operational life.

Bend stiffeners and bend restrictors reduce or limit the bending moments (bending forces) applied to cables, preventing over-bending.

Abrasion protection and touch down protection are provided by protective cable sleeves. These protect the cable where it lies exposed on the seabed, where it enters or exits the seabed, or where it crosses other cable routes.

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Cable protection systems: Main subcomponents

Vertabrae bend restrictors

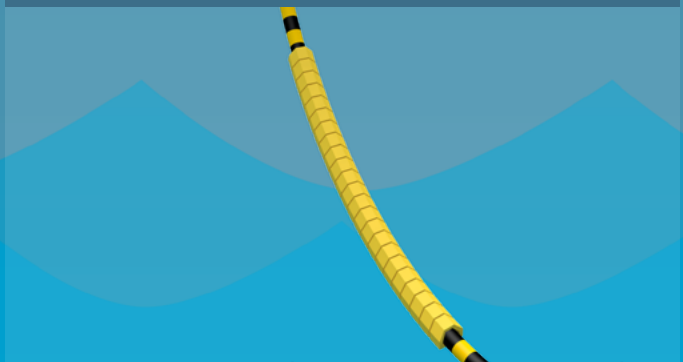
Description: Vertebrae bend restrictors (VBR) protect the bend radius of the cable, preventing fraying and damage. VBR are composed of multiple units of polymer discs fastened together to make up the total required length of protection. They are typically manufactured in two halves that are then fastened together round the cable. They work by physically limiting bending as vertebrae contact each other when the cable bends beyond a certain radius. When not at the bending limit, they do not dampen movement. VBR is typically used on static cables for fixed offshore wind to protect the cable during installation. However systems are also being developed to protect dynamic cables during their operation.

Sub-components: Polyurethane units, steel fasteners

Applicable standards: Empirical evidence of effectiveness in an offshore environment through a proven track record is required. Typically, FEA conducted and load tested pre-deployment. API 17L provides specifications for flexible pipe ancillary equipment.

Typical weights: Approximately 40-90 kg per unit.

Typical dimensions: Typical OD of 140 mm-400 mm or more. Lengths of the polyurethane units will vary but typically around 0.5 m or more. Overall length can be unlimited, but commonly used to achieve 90degree bend support for installation.



Dynamic bend stiffeners

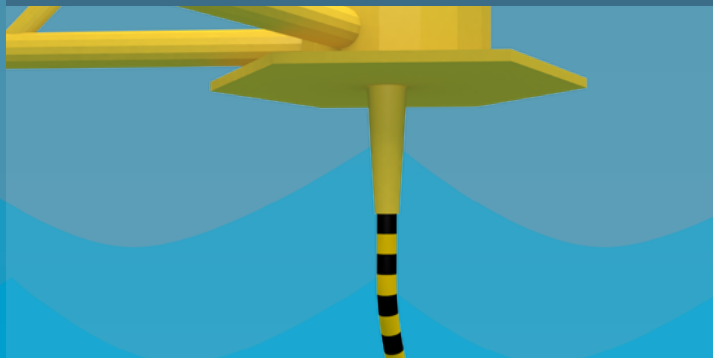
Description: Dynamic stiffeners are often used in floating wind projects to protect the cable at the point of connection to the floating substructure. They provide damping to the cable, minimising fatigue and wear at the highest risk critical points. Traditionally, these have been very large and costly to manufacture when sized above 5m. Their large size and weight also pose a logistical challenge. Some clients now offer 15m+ bend stiffeners. Their strength comes from the materials used in their construction, typically 60-90A shore hardness.

Sub-components: Polyurethane unit, steel bolts, stainless steel / carbon steel / super duplex insert acts as the interface with the flange.

Applicable standards: Empirical evidence of effectiveness in an offshore environment through a proven track record is required. Typically, FEA conducted. Tension angle plots are also common to demonstrate performance. API 17L provides specifications for flexible pipe ancillary equipment.

Typical weights: 0.5 - 8 tonnes

Typical dimensions: Conical sleeve approximately 2 - 15 m long. Due to complexity and cost when making 5m+ systems, suppliers have started to innovate with the solutions for this problem, see Subsea Energy Solutions SUB-FLEX system



Cable sleeves / abrasion protection

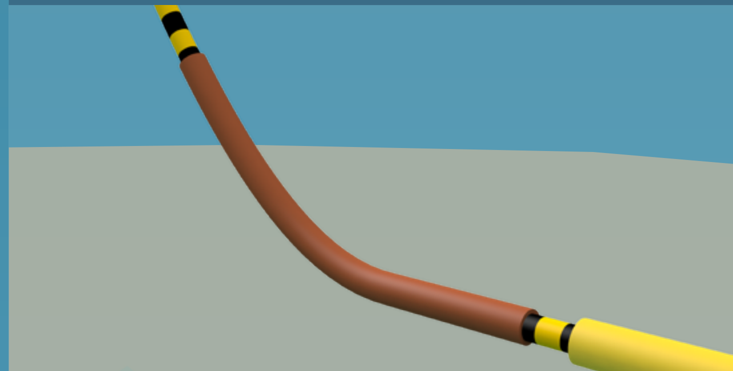
Description: Cable sleeves are used if cable burial is not feasible. They protect cables at the seabed from impact and abrasion. They are typically manufactured in two halves that are then fastened together or as a split single unit.

Sub-components: Polyurethane units, metallic or non-metallic straps to hold the units in place and closed.

Applicable standards: Empirical evidence of effectiveness in an offshore environment through a proven track record is required. API 17L provides specifications for flexible pipe ancillary equipment.

Typical weights: 40 – 80 kg per unit

Typical dimensions: Typical OD of 140 mm or more. 1.5 – 2 m length. Typical wall thickness is 25 mm.



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Cable protection systems: Manufacture

Typical manufacturing process

- All components are primarily made from gravity moulded polyurethane
- Manufacture of moulds for the various polyurethane components are sourced from specialist fabricators and are typically made of aluminium. CPS manufacturers generally compete with other industries for fabrication services, representing a potential manufacturing opportunity for new entrants.
- Polyurethane is gravity fed into the mould. Timing is key during the injection process to prevent the formation of air pockets and bubbles, which compromise the material properties of the component. Quality control is essential.
- The mould is then placed into an oven to cure the material.
- Once curing is complete, the mould is removed from the oven.
- Excess material is then removed from the component, which is then left to cool.
- Protection systems are then assembled.

Component materials

- Polyurethane 60A-90A (soft), 60D-90D (hard)
- For fasteners: Stainless steel, titanium.
- For straps: glass fibre composite or metallic options depending on environment and loading.

Manufacture facility requirements

Cable protection system manufacturing facilities require the following equipment:

- Polymer mixing and pouring equipment.
- Aluminium moulds
- Curing ovens (often the size limiting factor)
- Cutting equipment to remove excess material
- Lifting and handling equipment, and
- If in-house coating is desired, coating equipment.

Installation of Subsea Energy Solutions' Sub-VBRTM vertebrae system onto a cable at quayside.

Cast for polyurethane dynamic bend stiffener.

Cable protection systems: Design data

Component/Sub-component	Cost range	Material	Typical mass	Typical dimensions	Design considerations
Vertebrae and bend restrictors					
Vertebrae units	Approximately £1,300 - £1,800 per meter (depending on size)	Polyurethane	Approximately 70 kg per unit	Typically, OD of 140 mm or more	Neutrally buoyant units clamp, often produced in two parts to fit round cables
Fastening bolts	Approximately £120 per set	Stainless steel, titanium or glass fibre composite	Approximately 1 kg per unit	M12 - M20 bolts	Clamp must secure vertebrae to cables, while still allowing the cable to flex
Dynamic bend stiffeners					
Stiffener body	Approximately £10,000 per meter	Polyurethane 60A – 90A	0.5 - 8 tonnes	Conical sleeve approximately 5 - 15 m long	Damping aims to reduce fatigue and excessive bending on cables
Steel insert	Large range depending on size. £500 per unit to £5,000 per unit	Cast and fabricated steel	Large range, typically from tens of kilograms to tonnes	Varies depending on design and dimensions of stiffener	Steel insert that is moulded into stiffener body and used to bolt it to a substructure
Cable sleeves					
PU sleeve	Approximately £90 per meter	Polyurethane 60A – 90A	40 – 80 kg per unit	1.5 – 2 m length	Units deform to absorb impact during installation or lifetime operation
Fastening straps	Approximately £20 each. Typically, a single unit will use 3 – 4 straps	Metallic or glass fibre reinforced composite	0.3 kg each	Based on the OD of the system	Material selection based on loading conditions and environmental corrosion

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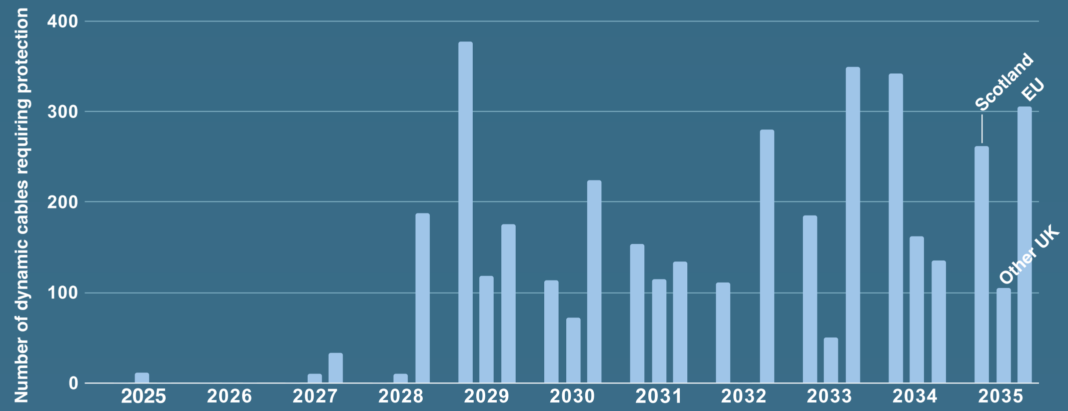
Cable protection systems: Market

Available market

For each floating turbine, and therefore dynamic array cable, two cable protection systems will be needed, one set for the exiting cable and one for entering cable in an array string. The market for VBR also includes protection of cables for fixed offshore wind. The exact specification of components within a system will vary dramatically based on the design, environmental conditions and site layouts. Fixed turbines may also use cable sleeves where seabed cables are exposed, but have not been included in the forecasts.



The table below shows forecast values for ScotWind and INTOG projects based on an 18 MW turbine capacity. Designs of cable protection systems for these projects are not confirmed, therefore we have assumed 50% of turbines will use VBR and 50% will use dynamic bend restrictors. In reality, a combination of both, or none is also possible. It was also assumed that all cables will use sleeves at touchdown. The exact choice of components is unknown.

Component	Assumption	Forecast for ScotWind / INTOG*	
		ScotWind	INTOG
Vertebrae bend restrictor system	2 units on on 50% of dynamic array cables (and therefore floating turbine). Up to 50 individual units could be strung together for one system, depending on requirements. Each unit comprises of 2 half sections and required bolts.	1,000 units	300 units
Dynamic bend stiffeners	2 units on on 50% of dynamic array cables (and therefore floating turbine).	1,000 units	300 units
Cable sleeve systems	2 on every dynamic array cables (and therefore floating turbine). Up to 50 individual units could be strung together for one system, depending on requirements. Each unit includes sleeves and required straps.	2,000 units	600 units

**this forecast is based on the entire ScotWind/INTOG capacity being installed. This number may decrease if projects are not taken forwards, or increase if projects increase their capacity.*

Route to market

- Suppliers must source polyurethane, typically in the form of thermoplastic polyurethane resin. Raw polyurethane must comply to specifications.
- Cable protection system suppliers themselves tend to use local suppliers for subcomponents such as fasteners.
- Generally, cable protection equipment is purchased by the cable supplier, which will offer a whole cables package, including protection, to a developer.
- In some cases, the cable installation contractor may purchase the cable protection to ensure no damage to the cable during installation.
- In some cases, more mature developers will directly purchase the cable protection systems.
- Incumbent suppliers include Balmoral, CRP Subsea, First Subsea, MacArtney, Subsea Energy Solutions, Supergrip, Tekmar (including Pipeshield), and WT Henley.

Accreditation / regulatory landscape

There is no industry standard for cable protection systems. In general, individual companies will be required to demonstrate their systems are suitable and provide empirical evidence of their effectiveness in an offshore environment through a proven track record.

Certification is often required, however, for the whole cable system, so the cable protection system supplier may be required to provide a design verification report to the certification body.

Cable protection systems: Costs

Typical costs / CAPEX requirements

- Cable protection systems cost approximately £7.5 million for a 450 MW floating offshore wind farm.
- This equates to 17,000 £/MW or approximately £250,000 for a 15 MW turbine's dynamic array cable.
- This is approximately 0.3 % of the total project cost.
- This cost is for the cable accessories work packages for a typical floating offshore windfarm as outlined in the cost assumptions. This will include all the components described above.
- This cost will vary significantly depending on what is included in the cable accessories package, environmental conditions, site layout and the foundation design used.
- Costs are sourced from **The Guide to a Floating Offshore Wind Farm**. See for more information and detail of all cost assumptions.

Potential user costs

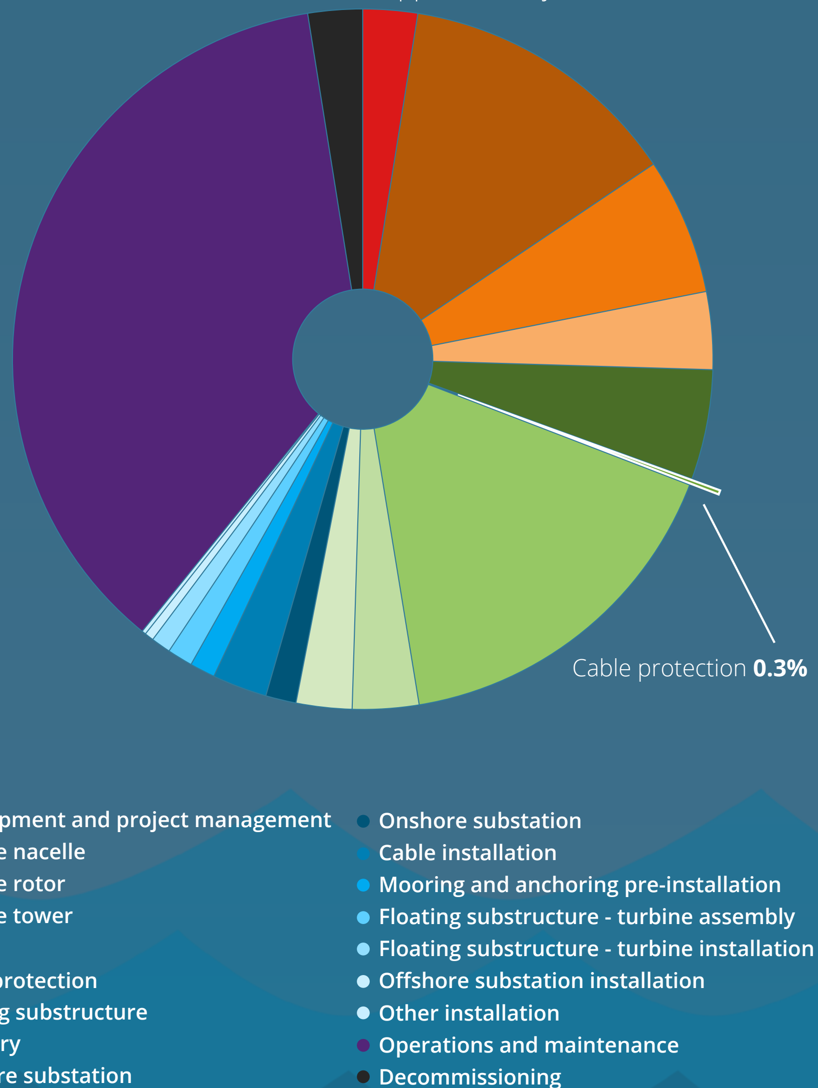
- Cable protection systems intended to minimise maintenance and incidents of breakage, ultimately reducing costs for the user.
- End user costs will come in the form of transportation and installation, however these tend to be minimal as CPS components are light and transportable. The exception would be dynamic bend stiffeners, which tend to be quite large and heavy and thus challenging to transport and install.

Support available

For further details on offshore wind supply chain assistance, information, and support programmes available, please contact Scottish Enterprise: **offshorewind@scotent.co.uk**

450 MW floating offshore wind farm lifetime costs

Lifetime 450 MW windfarm cost approximately £2,600 million.



Acknowledgements

Scottish Enterprise, Highlands and Islands Enterprise and South of Scotland Enterprise commissioned BVG Associates to produce a number of fact sheets on different aspects of floating offshore wind projects. They are intended to provide background information for companies wishing to enter the offshore wind supply chain. Other fact sheets are available including:

Fact sheet 1: Secondary steel

Fact sheet 2: Anchors and moorings

Fact sheet 4: Cables and accessories, and

Fact sheet 5: Corrosion protection

Thanks to First Subsea, Subsea Energy Systems and Tekmar for providing information used in this factsheet.

Further reading:

Guide to a Floating Offshore Wind Farm

The Guide to a Floating Offshore Windfarm provides more information on supply element of floating offshore wind projects. It has an overview of the important physical elements, lifecycle processes and costs of a floating offshore wind farm.

guidetofloatingoffshorewind.com

guidetofloatingoffshorewind.com/b-1-3-2-cable-protection

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