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Wired for success: selecting the ideal connectivity system for offshore wind farms

Words: Alexander Eigner, Global Head of Product Management, HV Solutions, TE Connectivity

As the global wind industry surges, technological advances are reshaping every stage of the supply chain. The need for connectivity innovation is especially evident in the offshore wind sector, where technology is scaling rapidly, making early decisions in wind farm design crucial. Developers often face the dilemma of choosing between two cabling systems: inner cone or outer cone.

Turbines today reach up to 16 MW, with 20 to 24 MW models on the horizon driving record energy outputs. For instance, the Hornsea 2 wind farm in the North Sea, now fully operational, produces 1.32 GW. Meanwhile, the Dogger Bank wind farm project[1], poised to become the UK's largest renewable energy source, will eventually supply 3.6 GW, enough to power six million homes.

Global offshore wind capacity, which reached 75 GW by the end of 2023, could exceed 250 GW by 2030, according to the Global Wind Energy Council (GWEC)[2]. But, this growth comes with technical challenges requiring engineering ingenuity.

Offshore operations are complex and costly, presenting risks at every stage. As the industry scales up, experts must ensure technological advancements address real-world challenges. One key development is the rising voltage levels in wind farms to support larger turbines. However, a reduction in suppliers for specific components is creating potential supply chain bottlenecks. Additionally, finding skilled installers may become a hurdle as the industry accelerates.

The offshore wind industry evolves rapidly, and even minor adjustments in project design can significantly impact performance and cost efficiency.

TE Raychem outer cone separable connectors up to 72.5 kV (left) and TE Raychem Dry Plug-In inner cone joint up to 145 kV (right) at 2024 WindEnergy Hamburg event

The road ahead presents challenges, and the offshore wind sector is ready to tackle them head-on.

Prototype of TE Raychem outer cone separable connector 145 kV at 2024 WindEnergy Hamburg event

A few years ago, research by the Carbon Trust[3] highlighted that shifting to 66 kV systems in offshore wind farms could reduce energy losses and cut project costs by up to 15%. This prompted the introduction of the first 66 kV cables in 2018, establishing a new industry standard evolving from 33 kV.

In response to the growing demand, TE Connectivity developed the TE Raychem RSTF 72.5 kV product line. Rigorously tested with leading global cabling suppliers, this solution is now operational across more than 500 turbines worldwide. Looking ahead, TE is developing products for 145 kV anticipating the industry shift as predicted by the Carbon Trust[4] with the first prototypes presented at WindEnergy 2024. Transitioning to 132 kV systems will bring even greater cost savings and support the industry's goal of scaling up to 250 GW by 2030.

Exploring cable accessory systems: inner cone versus outer cone

Early decisions in wind farm design, particularly around switchgear and transformers, are crucial. Cable systems depend heavily on these choices. Hence, when planning for offshore wind farm projects, developers typically choose between two systems for cable accessories: the inner cone or the outer cone system. Each has its own set of characteristics that impact flexibility, efficiency, and compatibility. It is important to understand the differences to make the best choice for a specific project.

The inner cone system is frequently used in the transition piece of wind turbines, and it has evolved rapidly in recent years. The outer cone is mostly used in the wind turbine itself.

Both technologies enable the connection of class five conductors, making them suitable for flexible tower cables or dropper cables.

But how do the inner cone and outer cone systems compare?

	Outer cone	Inner cone
Compatibility	EN 50673 standard	No standards
Installation	Flexibility of position	Straight connection only Cable requires bending space
Testing & commissioning	Not necessary to remove cables	Need to remove cables

1. Flexibility and compatibility

- The outer cone interface is standardised according to EN 50673, enabling customers to buy plugs and bushings from various manufacturers while ensuring compatibility. This system provides a lower total cost of ownership due to its smaller and standardised bushing, although it is limited to 72.5 kV.
- The inner cone system lack standardisation which can lead to compatibility issues between suppliers.

2. Design and installation

- The outer cone system provides more compact switchgear designs, which is critical for confined spaces like inside turbine towers. The cable preparation process is also simpler with the outer cone, as the cable can be fixed in its final position before the connector is attached.
- The inner cone system, by contrast, requires additional bending space during installation.

3. Testing and commissioning

Both inner and outer cone systems offer pre-installation and testing capabilities, which can save valuable time during offshore deployment.

- The outer cone system has a clear advantage during commissioning. It can be tested on-site without removing the cables, simplifying the process and accelerating deployment.
- The inner cone system often requires the complete removal of cables for testing, though the socket insulator can be pretested in the factory.

Early collaboration with switchgear manufacturers is essential to streamline the integration of these systems into turbines or transition pieces. Proactive planning helps avoid installation delays, ensuring projects stay on track.

Offshore versus onshore: different demands, different solutions

Offshore wind farms operate at significantly higher voltages than their onshore counterparts, adding complexity to project design. Offshore installations rely on inter-array cables (IAC) to connect turbines below ground, linking them to substations that feed power into the onshore grid via export cables.

This increased complexity has driven the development of new solutions to address unique offshore challenges. TE Connectivity has introduced innovations to handle the higher circulating currents and vibrations caused by offshore conditions. Our products are designed to integrate smoothly with cable compartments of switchgears and withstand the harsh offshore environment while maintaining peak performance.

The future of offshore wind: rising voltage and new standards

As wind turbine capacities grow, voltage levels in offshore wind farms will continue to rise significantly, with future projects soon to reach the 145 kV range. To support this growth, the industry is developing new standards, backed by CIGRE[5], to ensure the interchangeability of components from different manufacturers.

The demand for wind energy is intensifying as global targets for net zero emissions by 2030 approach. The industry is also venturing into new frontiers, with floating wind turbines poised to make a major impact. Small-scale floating wind projects are already in operation, and capacity is expected to surpass 1 GW in the coming years.

The road ahead presents challenges, and the offshore wind sector is ready to tackle them head-on. Through customer collaboration and innovation, TE is developing the technology needed to support offshore wind as it remains a key driver of the clean energy transition.

TE.com/wind

66 kV plug in system	Inner cone	Outer cone
Exchangeability		✓
Cross section limitation	✓	
Pluggable surge arrester		✓
Class 5 conductors	✓	✓
Angled connection		✓
Tool free connector installation	✓	✓
Voltage tap in insulator available (PD measurement)	✓	
Cable system testing without termination removal		✓
Covered by hard housing (touch-proof)	✓	

About the author

Alexander Eigner leads TE Connectivity's HV Solutions portfolio, bringing more than 21 years of experience in electrical power engineering, with a focus on high voltage engineering for the past 15 years.

With a background in the design and development of high voltage cable accessories, he holds several patents and has authored more than 20 technical papers.

Alexander is actively involved in working groups like Conseil International des Grands Réseaux Electriques (CIGRE), International Electrotechnical Commission (IEC), Deutsche Kommission Elektrotechnik (DKE), Verband der Elektrotechnik (VDE), and is a senior member of Institute of Electrical and Electronic Engineers (IEEE).

He holds both a Bachelor's degree and a Master's degree in Electrical Power Engineering from the Munich University of Applied Sciences in Germany.

Reference

[1] www.doggerbank.com/about

[2] Global Offshore Wind Report 2024 (GWEC)

[3] https://www.carbontrust.com/news-and-insights/news/carbon-trust-awards-funding-to-cut-offshore-wind-costs-by-up-to-ps100m-per-year

[4] https://www.carbontrust.com/news-and-insights/news/global-offshore-wind-industry-to-increase-voltage

[5] Conseil International des Grands Réseaux Électriques (International Council of Large Electric Systems)