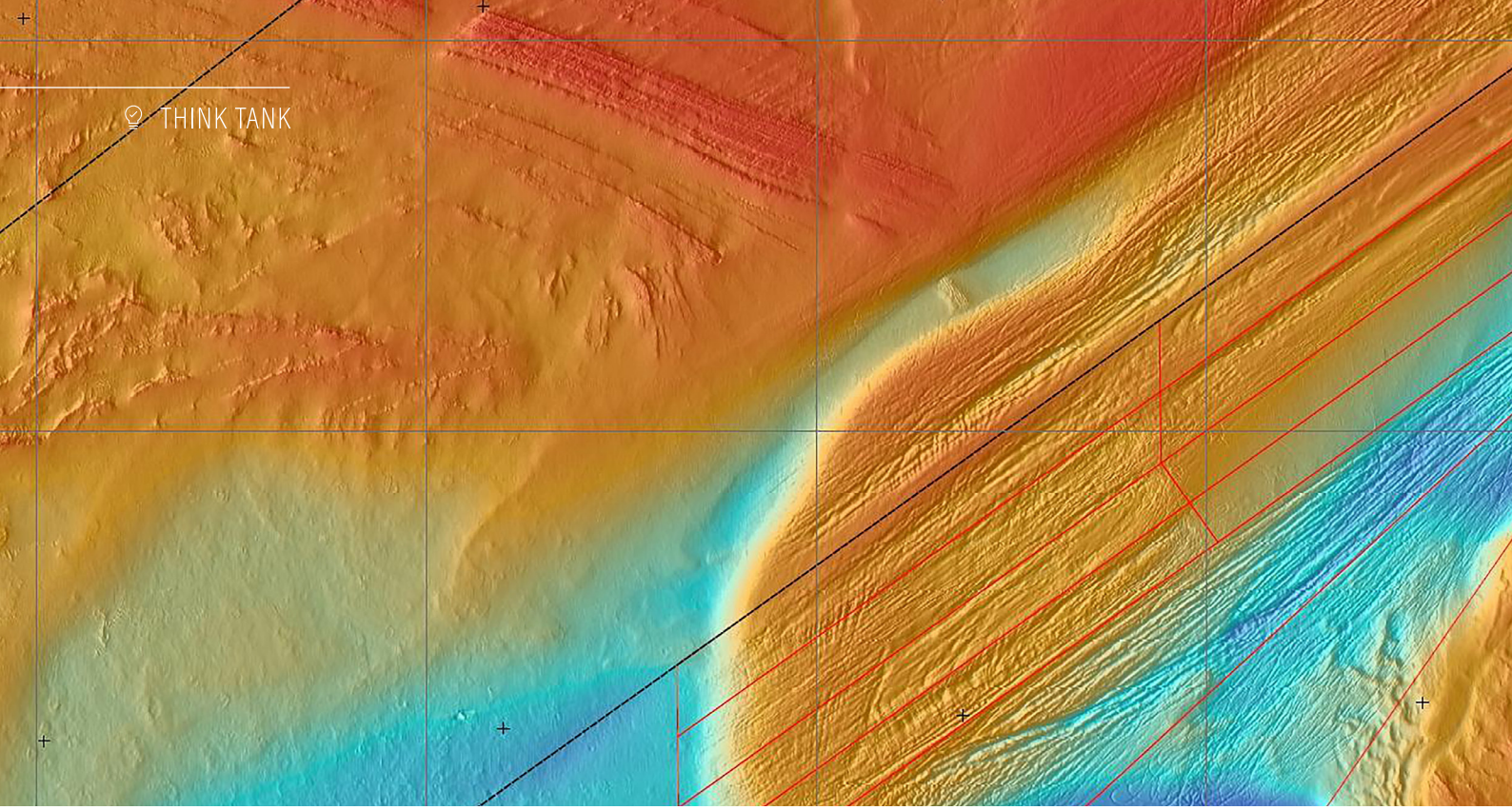

High-voltage direct current subsea interconnections: installation and reliability

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Subsea high-voltage direct current interconnectors are critical to the stability and flexibility of modern energy networks, but their installation and protection involve significant technical and commercial risks. This article examines the complex challenges facing developers and highlights how proactive, risk-based planning can reduce costly disruptions and improve long-term asset reliability.

The shift to low-carbon energy, wind, solar and nuclear continues to accelerate as nations phase out fossil fuels. But this transition is exposing capacity gaps in existing high-voltage grid infrastructure. Overland high-voltage expansion remains slow and often fraught with planning challenges.

In contrast, subsea high-voltage direct current (HVDC) interconnectors facilitate efficient national and bidirectional electricity transfer between countries. However, their strategic value also makes them a critical vulnerability: failure of a single HVDC link, particularly in the absence of a reactive backup, can destabilise an entire system. Unprotected assets also raise concerns around targeted disruption.

Deploying an HVDC subsea network requires specialised capabilities, including experienced marine crews and cable technicians, alongside a capital outlay that can approach £200 million. This covers installation vessels, protection equipment and shore-based logistics.

The risks are substantial: a single cable failure can incur interruption costs and repair bills ranging from £30 million to £100 million. Insurance typically follows LEG 1 to 3 wording, with increasing scrutiny on exclusions such as variance to agreed policy conditions for contractors' operations and sabotage, which are now often excluded from offshore energy project coverage. Settlements are usually negotiated and confidential. This makes comprehensive risk mitigation not just prudent, but essential.

Where risk management begins

Mitigating risk starts well before installation. Route engineering must account for both construction and long-term operational

threats. Strong planning disciplines can significantly lower failure rates.

This is where TGS | 4C Offshore plays a critical role. The team delivers subsea cable consultancy across planning, engineering and installation, with a focus on operational risk assessment and mitigation. Their work spans the full asset lifecycle from concept through decommissioning and has seen proven success in projects ranging in value from £750 million to £2.4 billion.

A risk-based approach ensures that decisions made in early development stages remain coherent and defendable throughout design, manufacture, commissioning and operation.

As interconnection projects increase, early-phase cable failures remain a recurring issue. A joint Lloyd's and Codan review of claims data revealed that more than 60% of total claim values originated from in-situ failures during early operation. Unsurprisingly, this has a chilling effect on investor and insurer confidence. TGS | 4C Offshore's analysis supports one conclusion: the industry standard must be raised.

Experts in risk and mitigation

Recurring risk factors are well documented. They can often be reduced through proficient supplier selection, as well as effective equipment and installation techniques. Engaging owners, developers, financiers and insurers early and committing to full transparency, creates an aligned project blueprint that reflects each stakeholder's requirements. Understanding individual exposures across the project timeline is key. Contractor incentives and commercial models reveal where risks may shift, both economically and operationally.

Lead times are another constraint. HVDC component manufacturing slots are already in high demand. Cable design, loading and marine transit logistics all affect timelines and cost. Without early intervention, these supply chain factors can erode the viability of a project schedule.

Risk planning must account for a range of issues, including seabed conditions such as rock, clay, sand dunes, gravel ripples, land slips and coastal metrology. It must also consider route obstructions like unexploded ordnance (UXO), boulders, debris and wrecks, as well as third-party utility crossings.

Cable protection is critical, particularly in terms of burial depth and safeguards against anchors, trawling and external impacts. The potential for damage during cable installation must be addressed, along with challenges related to landfall access in both marine and terrestrial environments.

Additionally, planners must factor in installation delays and their commercial consequences, manufacturing and loading logistics and the stability and mobility of both soil and seabed.

Challenging geologies, such as rock outcrops at landfall, require targeted mitigation strategies. Route optimisation depends on timely geophysical and geotechnical survey data. In boulder fields, mapping is critical. Burial and cutting trials are necessary to assess whether trenching is viable or rerouting is required. Hard rock types like flint may be impossible to trench and require alternate protective solutions. Additional Burial Assessment Studies (BAS) and field surveys help inform these strategies.

Offshore projects must also contend with persistent heavy swell and other metocean conditions. A robust study should capture wind, wave, tide and seasonal weather patterns to support design and scheduling. While environmental in nature, these factors are primarily treated as logistical and engineering constraints.

Installation risk and feasibility

Feasibility studies play a key role in identifying and mitigating risks. BAS work identifies both human and natural hazards and informs cable installation and protection planning. Where minimum burial depths are not achievable, the project must justify alternate protection methods such as rock dumps or mattresses. This is especially relevant for boulder fields, sand waves and shore approaches, where dynamic seabed conditions can shift risk over time.

Sediment mobility often increases near landfall, making burial conditions unstable. In such cases, rerouting to more stable terrain can reduce long-term maintenance needs.

Installation and protection decisions must weigh various factors, including site conditions such as depth, seabed morphology and hydrodynamics; cable specifications, including bundling and jointing requirements; and soil properties like the presence of bedrock, boulders and soil strength. These decisions must also account for the required burial depths and flexibility, as well as any regulatory and permitting limitations.

Choosing more robust burial approaches upfront may help avoid costly remedial work later.

Cable design must be tailored to the engineered route. Protection, heat dissipation, bending radius and soil thermal conductivity are interlinked with installation plans. Coordinated design and procurement, with tight collaboration between suppliers and contractors, supports smoother execution.

From plan to execution

Installation method statements and equipment specifications should align with schedules that minimise economic risk and support long-term reliability. The plan should include stakeholder engagement, from marine warranty surveyors to fishing interests, and address certification and permitting constraints. Contingency planning is key. That includes preparing for poor burial conditions and pre-emptively identifying zones where extra protection may be required.

A post-installation survey closes the loop. Verifying burial depth and soil conditions feeds back into the risk register and helps satisfy commitments to permitting authorities.

Conclusion: design, install, protect, repeat

HVDC subsea interconnectors operate reliably when engineering, commercial, and regulatory strands are integrated from day one. Overlooking route geology, metocean conditions, burial depth, or repair plans introduces failure risk, added cost and timeline slippage. Environmental compliance and marine habitat protection also play a growing role in project viability, especially in regulated waters.

TGS | 4C Offshore brings these strands together through a risk-led approach spanning the full asset lifecycle. With multidisciplinary technical insight, detailed risk analysis, and practical planning support, the team helps ensure projects are delivered with lower exposure and greater confidence for owners, investors, insurers and regulators alike.

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