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Use of sea electrode systems in HVDC subsea cable systems

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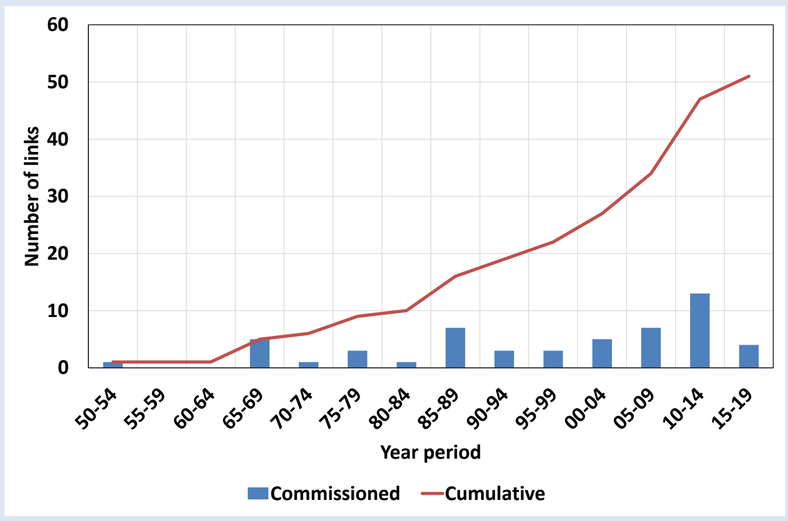
Introduction:

The first subsea HVDC link was installed in 1954. Since then approximately 50 HVDC subsea links have been commissioned, resulting in over 40 links operating today; others are in construction and many more in the planning phase.



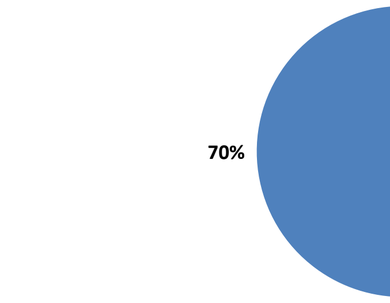
In recent years the number of HVDC subsea links in service has grown rapidly driven by factors including:

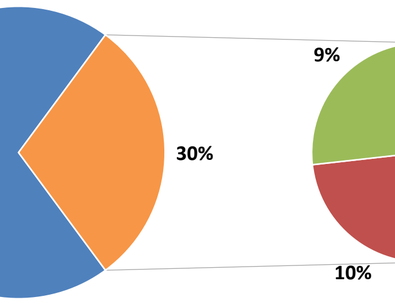
1. Liberalisation of the electricity market in Europe – electricity trading between countries has created an environment where the construction of inter-country HVDC subsea links has become economical.
2. Introduction of VSC convertor station technology and the rapid increase in maximum possible operating voltage.
3. Security of supply – subsea HVDC cables have also been installed to connect nearby islands to the mainland or interconnect groups of islands.

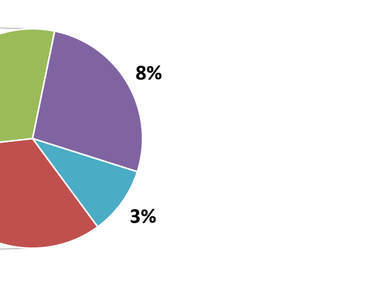
Return Path Options

Return path options for the DC current include bipole, metallic return, ground electrode or sea electrodes. Sea electrodes rely on the inherent electrical conductivity of the seawater to carry the return current: in reality a large proportion of the current flows deeply through the earth. There are three typical sea electrode installlation:

1. Shore – An array of electrodes is buried on land, often on the beach or a few metres back from the beach, and at a depth to ensure contact with salt water.
2. Pond – An electrode array is installed in a man-made harbour or lagoon. The individual sub-electrodes are either attached to the harbour wall or hung from a pontoon within the lagoon.
3. Marine – A long bare conductor (often in a ring configuration) or an electrode array installed on the seabed, typically a few kilometres offshore, and in water less than 20 m deep.





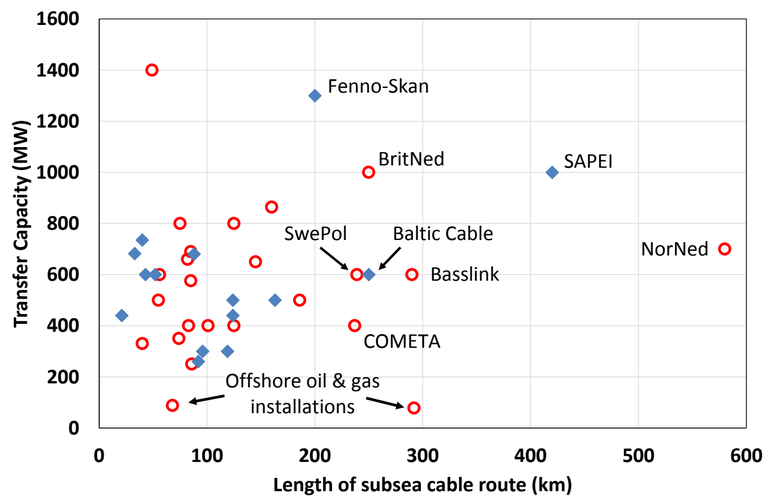


There are many competing factors to be considered when choosing whether or not to apply a sea electrode including environmental concerns, financial considerations, increased operational flexibility, location, operation and maintenance, and stray current issues.

Sea Electrode in Service

30% of existing HVDC subsea links have sea electrodes, with a roughly even split of marine, shore and pond electrode types. Sea electrodes are sometimes combined with land electrodes e.g. Inter-Island connection in New Zealand, if the convertor station is a long distance from the shore and the ground conditions suitable.

All Operating Subsea HVDC Links



It might be expected that longer links would be more likely to use sea electrodes (◆) than metallic returns (O) due to the cost savings of the simplified design. This proves not to be the case due to the complex balancing of competing factors that need to be considered during the design process. Basslink, NorNed and Swepol were all originally planned with sea electrodes but were changed due to objections.

Environmental Considerations

Environmental Impact Assessments are used evaluate the likely impact of electric and magnetic fields, and electrolysis products on organisms in the vicinity of the electrodes. Studies have been carried out before and after the installation and operation of sea electrodes: no detrimental impacts have been reported. The impact of stray currents on man-made structures also needs to be assessed.

	Basslink			Labrador Island Link		
	E-field	B-field	Electrolysis	E-field	B-field	Electrolysis
Algae	Yes ●	Yes ●	Yes ★	Yes ●	Yes ●	Yes ▲
Plankton	No –	No –	Yes ★	Yes ★	Yes ★	Yes ★
Invertebrates	Yes ●	Yes ●	Yes ▲	Yes ●	Yes ●	Yes ▲
Fish	Yes ●	Yes ●	Yes ★	Yes ●	Yes ★	Yes ▲
Bony fish	Yes ▲	Yes ★	Yes ★	Yes ▲	Yes ★	Yes ▲
Sharks/rays	Yes ★	Yes ■	No ■	Yes ▲	Yes ★	Yes ▲
Seals	Yes ▲	No –	Yes ▲	Yes ●	Yes ●	No –
Whales	Yes ▲	Yes ■	Yes ▲	Yes ▲	Yes ■	No –
Turtles	No –	No –	No –	No –	Yes ■	No –
Birds	N/A –	N/A –	Yes ▲	Yes ■	No –	No –

● Believed to be insensitive and/or no issue expected
▲ Believed to be sensitive but mitigated by proposed electrode design parameters. No change in behaviour expected
★ Believed to be sensitive and may alter behaviour close to the electrodes
■ Unknown level of sensitivity but no evidence to suggest a likely change in behaviour

Conclusions:

1. Sea electrodes provide a simple proven solution for the return current path having been used since the 1950s.
2. Of the approximately 40 HVDC subsea links in service today, 30% use sea electrodes under normal or emergency operation.
3. The engineering decision to adopt sea electrodes is complex and needs to weigh many elements including location, environmental impact, current capacity and financial factors (cost, flexibility, losses).
4. All the environmental impacts studies of HVDC subsea links with sea electrodes have found no significant effects on local organisms caused during installation or operation.
5. In the few cases where the original project design included a sea return but the final design used a metallic return, corrosion concerns to third party metallic structures has often driven this change.

The authors gratefully acknowledge the financial support of this work by the Research Councils UK, through the HubNet consortium, www.hubnet.org.uk (grant number: EP/I013636/1).