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SUBSEA CONNECTIONS TO HIGH CAPACITY OFFSHORE WINDFARMS: ISSUES TO CONSIDER

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ABSTRACT

The AC subsea transmission options have been considered for a nominal 1GW offshore windfarm positioned 60km from subsea cable landing point. Incidence and cost of cable failures as well as ohmic and charging current losses have been assessed. Technological issues have been highlighted. The overall scheme costs were remarkably close. 400kV SC XLPE connection appeared to be slightly cheaper than the 132kV 3C XLPE solution if transfer capacity issues were ignored

KEYWORDS

Subsea Cable, Offshore Windfarms

INTRODUCTION

The scale of the UK offshore windfarm generating industry is increasing. By 2005, just over 200MW of shared capacity between 4 offshore UK windfarms had been installed. It is anticipated that by 2010 1GW of generated power shall be provided by 13 and a further 7GW by 15 windfarms. The plans are for the power in these large arrays to be collected at an offshore substation stepped up to a suitable voltage and transmitted via HV or EHV cables to the mainland substation. This discussion paper considers the AC options for these connections.

EXPORT CABLE OPTIONS

Offshore windfarms developed in the UK have up to now been at or below 100MW. The connection to the land network has been by way of 33kV and 132kV three core XLPE cables. In the planning stage are windfarms capable of generating 1GW or more. For these power transfer amounts the range of cable connection options can be expanded:

- 132kV 3C XLPE cables
- 220kV 3C XLPE cables
- 400kV 3C XLPE cables
- 220/275kV SC XLPE cables
- 400kV SC XLPE cables

Due to the windfarm size, the connection distances of up to 60km are under consideration. HVDC options as well as fluid filled options although viable have not been considered in this study.

ISSUES RELATING TO LARGE OFFSHORE WINDFARM CONNECTIONS

Project viability is dependent on the capital and operating costs as well as the projected revenues. Due to the vibrant oil and gas market as well as the subsea market, subsea cable prices have increased due to insufficient capacity in the market. This makes project budgeting even more complicated.

Export subsea power cables of 132kV and above sit at the cusp of a technological cross-road. The new polymer technology is not fully proven at voltages above 110kV. Fluid filled technology, although reliable, is unsuitable in most applications due to environmental concerns from cable fluid leaks.

Three core XLPE designs are preferred at up to 132kV [1], however the weight and diameter of the cables as well as complex jointing procedures have to be offset against the ease of single core manipulation and higher ohmic losses [2], [3]. There are potentially more suppliers of single core XLPE subsea cables as the laying up process is avoided.

Ratings of cables are always compromised by solid bonding on subsea projects. Windfarm locations are in most cases near to estuaries where high tidal water currents can lead to substantial sediment movement. Local scour can mean that seabed datum can move by several meters leaving cables exposed in deep water channels or buried underneath meters of sand with unfavourable thermal resistivity. Thermal rating sensitivities at pre contract stage as well as Distributive Temperature and Strain Sensing are necessary if such risks exist.

EXPORT CABLE CONSIDERATION

As large windfarms of between 500-1500MW are being considered, a nominal power of 1GW was chosen as an example. A 60km route with 1.5m burial and seabed thermal resistivity of 0.7 K.m/W.

The total loss figures favour the multiple three core HV cables or the large single core EHV cables. The charging current, although compensated from both ends, makes an appreciable difference to circuits with relatively low current carrying capability. The joint technology of subsea 3C EHV designs is also immature in comparison to land and fluid filled technologies. In our view the risk in single core technology is less as the pressure on keeping the outside diameter small is less than for three core designs. Lower dielectric screen stress can be employed and capacitance

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hence, the charging current of the cables can be reduced.

TABLE 1 Cable Types and Configurations

Voltage (kV)	132	220	400	275	400
Cable Type	3C	3C	3C	SC	SC
Per Cable Power Transfer	120	220	400	515	1000
No of cables (to transmit 1GW)	6	4	2	7*	4*
Charging current/km	3.5	7.4	11.8	10	16.8
Charging Current MW loss	2.1	15	74.2	18.4	56
Ohmic Cable loss in MW	5.8	5.7	5.8	17.6	19.3
Total Losses %	6.6	9.4	20	7	6.5

*Three phase circuits + 1 redundant phase

Reliable HVAC Subsea cable failure statistics are not in the public domain. CIGRE subsea statistics are mainly concerned with HVDC connections. Previously reported values are of limited use as the discrimination between cable types, internal or external fault, number of cores and whether the cable was buried or not is not explicit.

TABLE 2 Failure Statistics

Voltage (kV)	132	220	400	275	400
Cable Type	3C	3C	3C	SC	SC
Failure rate (failures/year)	0.25	0.46	0.67	0.15	0.22
Projected time between failures (years)	4.0	2.2	1.5	6.5	4.9
Projected number of repairs in 20 years	30	27	26	18	13
Estimated cost of repairs (M GPB)*	90.8	119	114	79.2	57.2
Ohmic Cable loss in MW	5.8	5.7	5.8	17.6	19.3
Total Losses %	6.6	9.4	20	7	6.5

*Revenue loss not factored in

Initial HV and EHV XLPE subsea systems failure rates could be based on single core land EHV XLPE cable systems. The quality of design and jointing would be at least of land systems. More onerous subsea cable handling could be offset by third party external fault probability.

Using figures such as described in the reference[4] with a single core cable failure rate of 0.024 failures/100km/yr and a joint failure rate of 0.01 per 100 components per year, the following failure statistics (table 2) can be generated. When XLPE cables are manufactured, production has to stop after a number of days (usually 10) for extruder clean down.

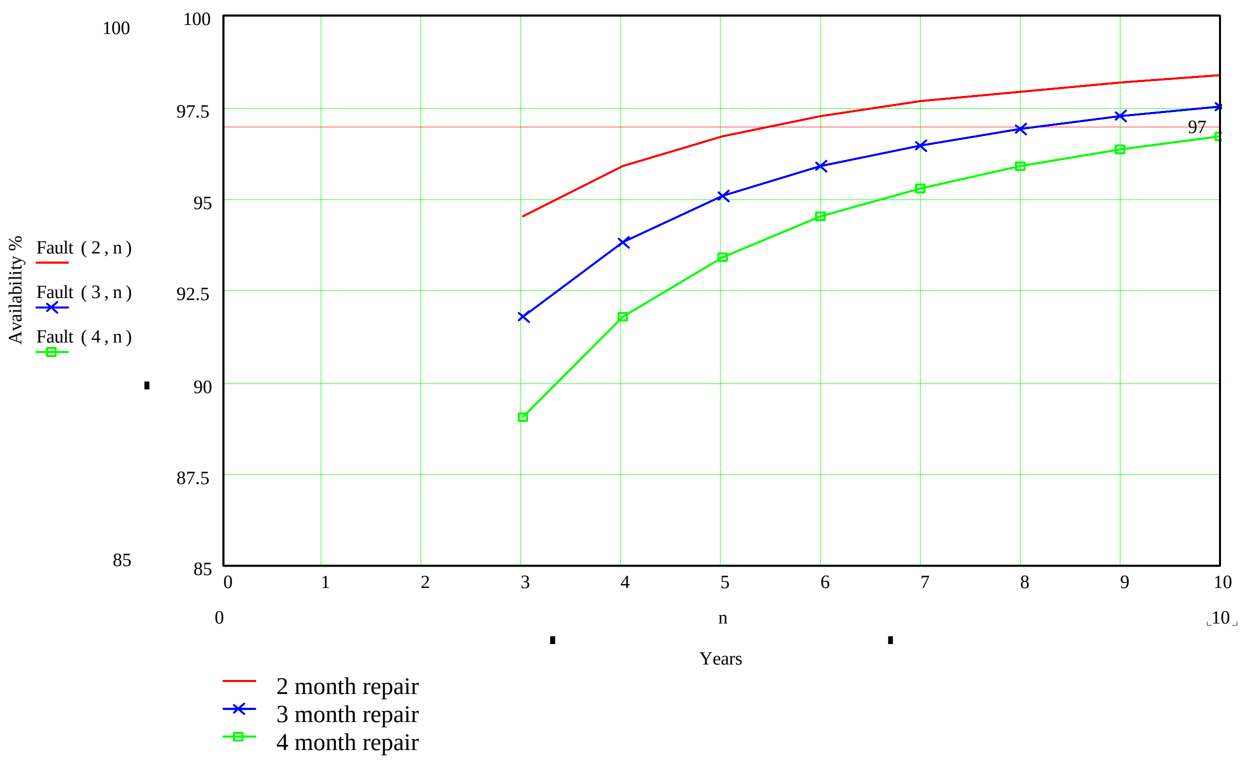

Figure 1 Effect of fault rate on Availability

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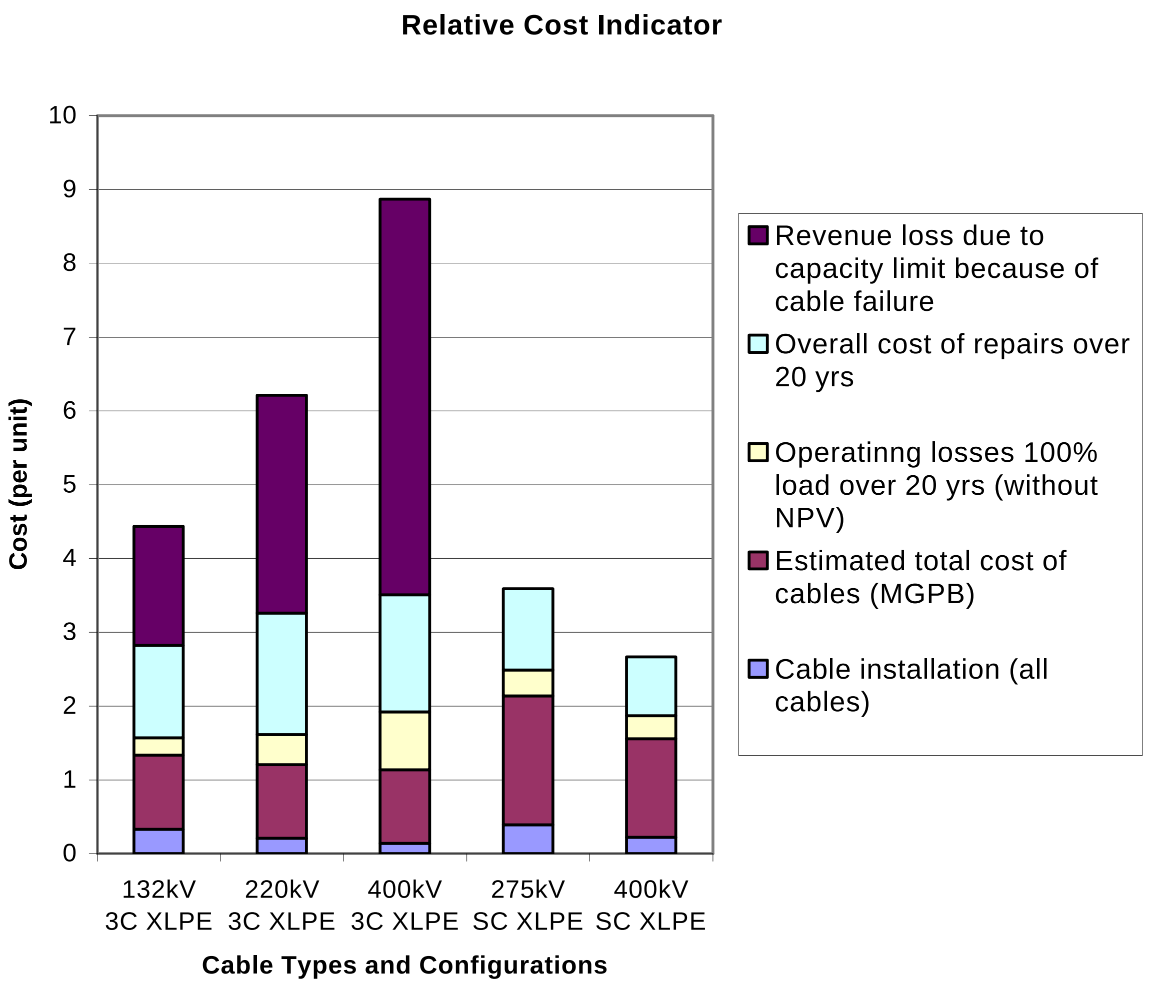

Figure 2 Estimated relative costs of schemes to transmit 1GW over 60km

Extrusion for EHV cables tends to be cure limited and therefore the larger the cable, the shorter the extrusion run and the more joints are required in the subsea cable [5].

The lower voltage solutions offer better redundancy as the majority of load can be carried by other cables. A redundant fourth phase conductor makes the Single Core approach attractive as after reconfiguration no loss of capacity is experienced.

Availability is an important stipulation which can make or break a project viability as can be seen in Figure 1. Either a fast reconfiguration for supply availability is required or redundancy by way of derating of circuits is necessary. If a single export cable is used and a fault develops every 5 years which takes 2 months to fix, availability shall never get over the 97.5% mark.

INSTALLATION AND REPAIR

Due to the buoyant oil and gas market as well as subsea cable market, suitable vessels for installation and repair are in short supply. Installation and fault repair costs are escalating.

The same can be said of production capacity for three core HV and EHV subsea cables with perhaps only 7 factories in the world capable of manufacturing three core 220kV designs weighing 112kg/m and a 250mm diameter.

The installation and cable prices are thus more about market conditions and less about base material costs (although the fluctuating price of copper cannot be ignored). Total cable weight has implications upon the installation method and costs. Cables above 5000T have to be laid in two campaigns and connected via an offshore joint as bigger cable laying vessels are not available.

All items in Figure 2 are used in the generation of CAPEX and OPEX models.

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TABLE 3 Cable Details

Voltage (kV)	132	220	400	275	400
Cable Type	3C	3C	3C	SC	SC
Outside Diameter (mm)	172	254	273	151	162
Weight (kg)	62	112	124	62.9	69.2
Bending Dia (m)	4.3	6.35	6.82	3.8	4.1
Weight of 60km of cable	3720	6720	7434	3774	4152

Even with estimates (Renewable Obligation Certificate value is taken as 40GPB/MWh), the resultant constraint on transfer capacity is noticable in Figure 2. The cost of reigning back generation as a result of export cable failures has to be factored in. It may be necessary to ovesize/derate cables slightly not to constrain the system. Investigation into the use of load factor to optimise generation may also be a way to extend capacity.

If a fault occurs during a bad weather period, it may be necessary to postpone the repair. Even interconnector cables with a well rehearsed Marine Disaster Recovery Programs take an appreciable amount of time to repair. A fault on the Cross Channel interconnector in 2003 was repaired in 83 days [6].

Environmental impact of the cable schemes depend on locality as well as cable and installation methods. If seabed movement or scour is a threat deeper burial and or protection measures will be necessary. Deeper burial also mitigates EMF effects which are more of a problem for single core cables.

Denser (cable volume per m/weight per m) cables have better seabed stability and tend to bury themselves in soft materials thus evading exposure.

CONCLUSION

The results of calculations indicate that 400kV SC XLPE cables (installed with a spare phase cable) are competitive against the 132kV 3C XLPE designs when the cost of installation, operational losses, future failure repairs and supply of cable are factored into the scheme.

The repair time has significant impact on revenues if remaining cables cannot fill the transmission rating gap.

Charging current at 60km even with compensation has significant effect on EHV cables with smaller conductor cross sections and therefore does not appear as attractive as single core options.

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