Sufficiently de-risked? Comprehending and mitigating the risks associated with offshore wind transmission

Devil in the Details:
Tail risks in offshore transmission

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PARADIGM CHANGE
CAPITAL PARTNERS

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Executive Summary

Offshore wind power is expected to play an increasingly important role in meeting EU decarbonisation targets. Offshore wind farms have significantly more potential in terms of project scale compared to onshore wind farms due to:

- substantially more favourable resource conditions;
- less spatial constraints; and
- easier consenting.

The sheer amount – over £440bn– of capital expected to be deployed in offshore wind power development across Europe by 2030 will require projects to attract non-utility investors. Simultaneously, the large size of individual projects make this particular type of asset ideal for institutional investors, who prefer to deploy sizeable funds into single projects.

As highlighted in our previous report[1], there is already evidence of institutional investor interest in offshore wind projects. However, given the limited experience with offshore wind power to date and the operating challenges it presents, institutional investors have traditionally invested in such assets under de-risking arrangements with energy utilities.

One such operational issue of note is a wind farm's ability to export its power to the onshore grid. A low probability, yet high impact, risk which has not been adequately addressed is that of offshore grid infrastructure. Serious faults in submarine cables can lead to:

- significant reduction in project IRR; and
- risk of insolvency if this happens in the early years of a levered project's life

The focus of this report is exploring the relationship between offshore wind power in the UK - the largest and most promising offshore wind market globally - and its associated transmission regime. We present the following key conclusions:

- the most efficient design of offshore grid is no transmission redundancy, implying that any grid unavailability leads to a commensurate reduction in offshore wind plant output;
- while the probability of a serious cable fault is very low, potential impact is severe;
- as wind farms are built further offshore, associated grid infrastructure risks are expected to become more acute;
- from a project perspective, different transmission technologies will experience varying levels of unavailability following a fault; and
- the UK's offshore transmission regime contains, to some extent, inherent risks, particularly surrounding incentives for efficient grid maintenance and repair.

The risks associated with each of these factors mean that offshore wind farms face a possibility of material business interruption. For this reason, it is important for prospective investors to carry out in-depth technical and contractual due diligence on the offshore grid infrastructure and ensure that there are appropriate risk mitigation measures in place to compensate for lost revenue due to transmission unavailability.

[1] *Going Green:* Institutional Investment in European Green Infrastructure, [November 2012, available at: http://www.paradigmchangecp.com/uploads/reports/Going_Green.pdf]

About PCCP

Paradigm Change Capital Partners is a leading investment advisor, with expertise in advising institutional investors on low carbon assets and designing specialised collective funding vehicles to access such investments. Our expertise encompasses:

- In-depth knowledge of low carbon value chain participants, from utilities, supply chain manufacturers to developers and independent power producers
- Understanding the individual needs and constraints of large investors such as pension funds, insurance companies, sovereign wealth funds, family offices, foundations and endowments
- Detailed know-how of terms and conditions, pricing and risks across various financial instruments and funding mechanisms
- Creating innovative risk-sharing partnerships and investment vehicles to access and unlock capital from traditional and unconventional sources

We work with clients through all stages of the investment lifecycle, providing:

Advisory

- Conducting educational workshops
- Strategic portfolio review
- In-depth technology/country analysis
- Best in class methodologies for accessing the most appropriate assets

Execution

- Access to high calibre investment opportunities, teams and projects, across technologies and geographies
- Structuring investment vehicles
- Monitoring financial and physical asset performance

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1. Introduction

To date, investors have relied heavily on their utility partners to manage risk in offshore wind generation. As utilities face increasing constraints in underwriting all risks however, it is prudent and potentially remunerative for investors to gain a better understanding themselves of the risks and rewards involved.

A risk that has been lightly integrated into the analysis so far has been the availability of offshore transmission infrastructure. As European countries have implemented various regimes governing offshore transmission, different risk profiles have emerged. The UK, which has one of the most vibrant offshore wind programs, has provisions for very high-level availability rates of transmission assets through its Offshore Transmission Owner (OFTO) regime.

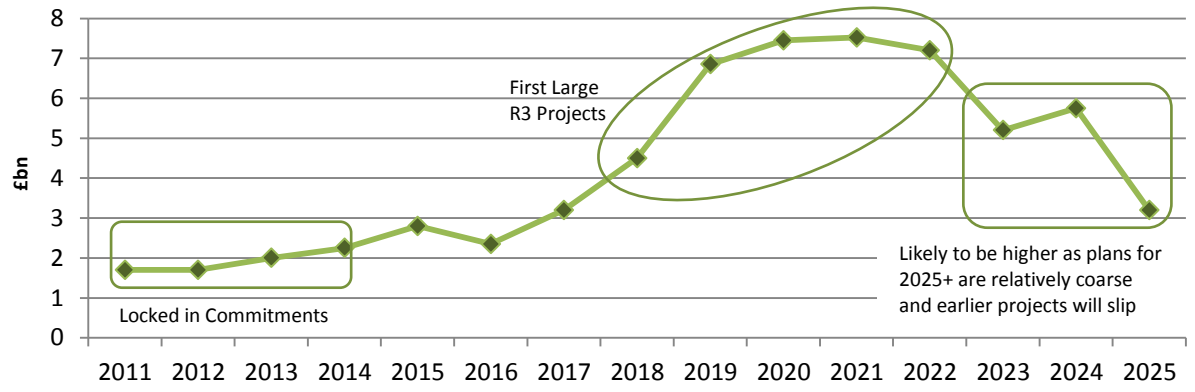
As this report explains however, the UK's OFTO regime exposes offshore wind farm investors to the low-probability, high-impact risk of offshore transmission line unavailability. The main arguments outlined in the report are as follows:

- Section 2 presents UK's offshore power outlook, the operating assets' business model and the OFTO regime itself. In addition, given these particular arrangements it evaluates the distribution of risk between an OFTO and a wind project owner with respect to grid infrastructure unavailability;
- Section 3 reviews technical characteristics of offshore grid infrastructure design and reliability, the implications of those on transmission availability and the ability to export electricity; and
- Section 4 summarises the risks and impacts, while suggesting remedies to address them

2. The UK's offshore wind and OFTO regime

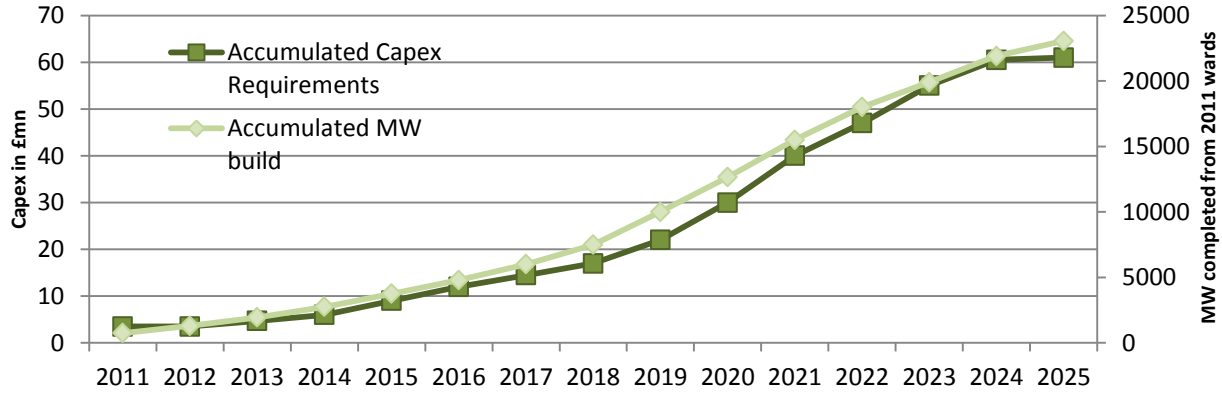
As shown in Figures 1 and 2, the financial investment needed to realise the UK's offshore wind targets is significant and as such, is expected to come from a multitude of investors with ranging risk considerations. To a large extent, energy utilities will continue to fund and lead asset development, with multilaterals and banks supplementing capital requirements, particularly during the development and construction phases. Institutional investors however, will play an increasingly important role in financing the operational stage, allowing construction finance to be efficiently recycled for further build out.

Figure 1: CAPEX estimate per year for offshore wind in the UK



Source: Crown Estate, "Report from the Financing Sub-group to the Offshore Wind Developers Forum", June 2011

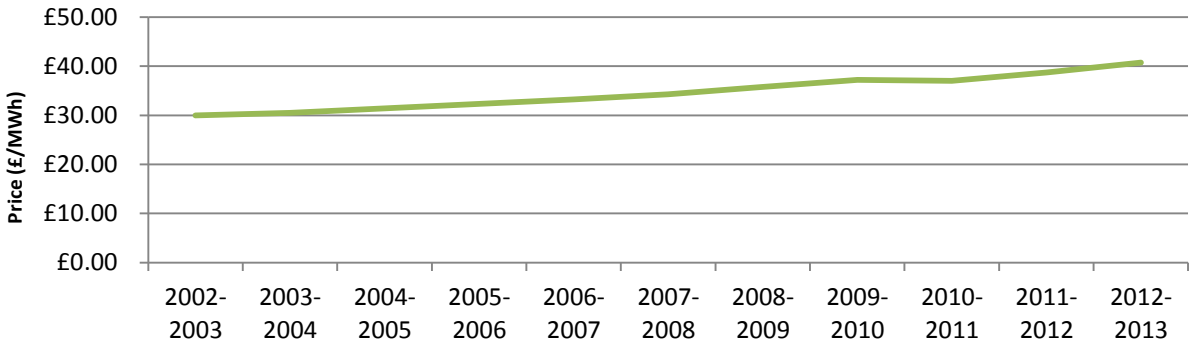
Figure 2: UK offshore wind cumulative MW and CAPEX



Source: Crown Estate, "Report from the Financing Sub-group to the Offshore Wi

The IRR of an equity investor involved in cradle to grave development, construction, ownership, and operation of an offshore wind farm is ranging from 12% to 18%

Figure 3: Historical ROC prices (£/MWh)



Source: PCCP analysis

Offshore wind business model in the UK

Offshore wind in the UK is financed in part through government subsidies called Renewable Obligation Certificates (ROCs) and the Levy Exemption Certificates (LECs). ROCs are expected to be replaced by Contracts for Difference (CfD)[2] Feed-in Tariff as part of the Electricity Market Reform that is currently underway. Through the current ROC regime, offshore wind receives two ROCs, the price of which is set periodically by government, as displayed in Figure 3. This is supplemented by the LECs which are issued for each unit (MWh) of electricity produced, in addition to the market electricity price.

Given the current revenue, which is on average close to £160/MWh, the IRR for an equity investor involved in cradle to grave development, construction, ownership, and operation of an offshore wind farm is in the range of 12–18%. In effect, the subsidy covers all costs of constructing and operating the offshore wind farm, including:

- infrastructure and grid connection costs;
- the cost of turbines and towers;
- foundations costs;
- licensing and planning costs; and
- labour and insurance for the above

Whereas turbine and tower costs need not vary according to the site, foundation costs depend on water depth and grid connection costs tend to vary with distance from shore. The latter can range from 10% of total wind farm costs for a project located 5km from shore to as much as 40% for a project located 200km from shore.

Interestingly, the cable connecting the offshore wind plant to the onshore grid is considered to be a 'local asset' rather than part of the onshore interconnected system. This means that in case of offshore cable downtime, the wind power generator is not compensated for lost revenue by the grid owner (in this case, the OFTO). This is in contrast to the UK onshore transmission access arrangements, where if a generator is constrained off (i.e. it cannot inject its power into the system due to unavailability of the transmission grid), it is compensated by the grid operator (National Grid). This highlights a stark discrepancy between offshore and onshore transmission regimes.

Offshore transmission regime in the UK

The UK's offshore transmission regime is based on third-party ownership. Under this arrangement, offshore transmission lines cannot be owned by the offshore wind power generator and must instead be owned by a third party, called the Offshore Transmission Owner (OFTO). This is

[2] The CfD revenue consists of two streams: the variable revenues from electricity sales in the wholesale market and a top-up or top-down payment calculated as the difference between the market wholesale price (the reference price) and a predetermined strike price.

mainly driven by the ownership unbundling directive of the EU's Third Energy Package, which requires the separation of energy network and energy production asset ownership.

For projects built or expected to be built by the generators, the transmission assets are auctioned to third-party investors after they are operational. These third parties then act as an OFTO and take on the operation and maintenance of the asset.

The OFTO annual revenue stream is calculated according to the Regulated Asset Base (RAB) model, which is paid by the offshore wind-generating companies through transmission tariffs, and guaranteed for twenty years.

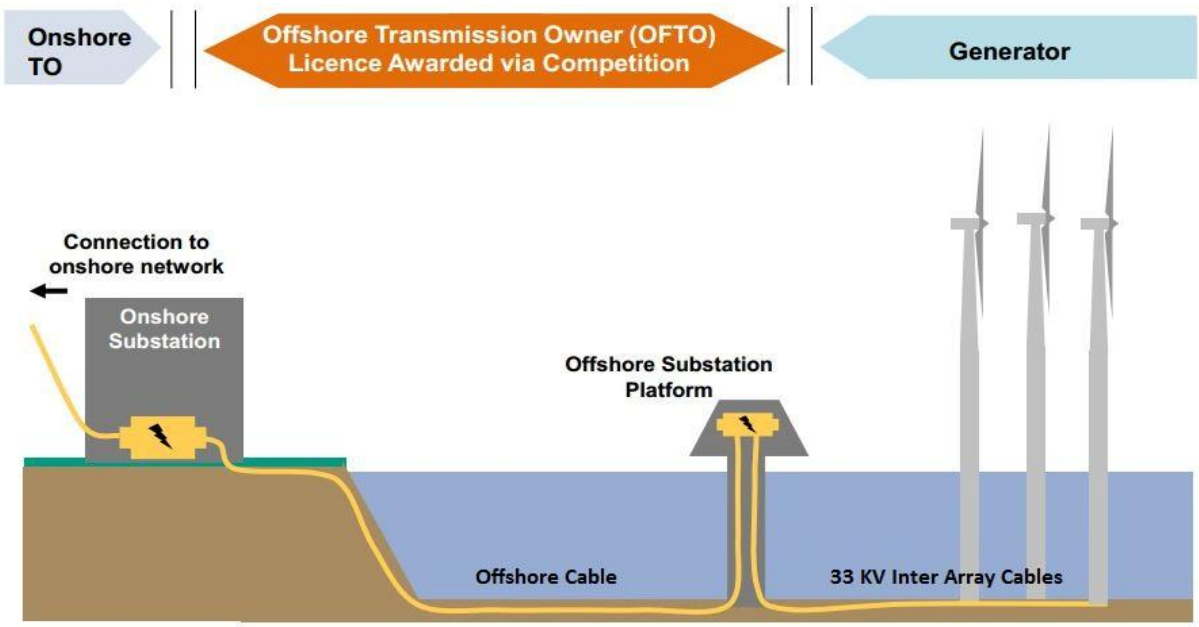
The revenue structure is dependent on availability of the facilities as opposed to being linked to usage. The rate of return is not regulated, but is determined through the auction process and is one of the elements which third-party bidders compete on. Going forward, there will also be an option for third-party OFTOs to build the assets.

Distribution of risk between an OFTO and an offshore wind project owner

While the revenues of the OFTO and the wind power generator depend on availability of the transmission assets, the risks to the two parties are asymmetric.

As OFTO revenue is guaranteed - with both costs and penalties capped - it is unlikely that an OFTO faces the risk of bankruptcy. In contrast, any downtime of the offshore transmission system has a disproportionately negative impact on revenues of the wind power generator. The structure of penalty caps mean that OFTOs are more incentivised to minimise the cost of repair, rather than minimising repair times (and the subsequent loss of revenue to the wind farm owner). As discussed in the next section, although the probability of this risk is small, when it does occur, the consequences are likely to be material.

Figure 4: Offshore transmission grid infrastructure assets



Source: Ofgem

3. Risk analysis of offshore transmission networks and assets

With over 60 projects currently in operation using subsea cables, there is substantial construction and operational experience in this area. While reliability and failure rates of offshore grid infrastructure have been established through several studies[i&ii], the impact of technical risks on offshore wind power generators has not been considered adequately in financial evaluations and risk analyses.

As we discuss in this section, offshore grid unavailability, especially in the early years of operation, can have serious implications for investors in an offshore wind project, particularly if appropriate mitigation measures are not in place.

Efficient design of offshore systems

As set out by SEDG Centre[iii], economically efficient offshore networks for wind energy should be designed with no redundancy. This seems to be validated by experience to date and as such, the practice of installing components with no redundancy is justified.

This means that all elements of the offshore network – the offshore platform, offshore cable connection, onshore network, and onshore substation - are sized to match the maximum capacity of the offshore wind farm.

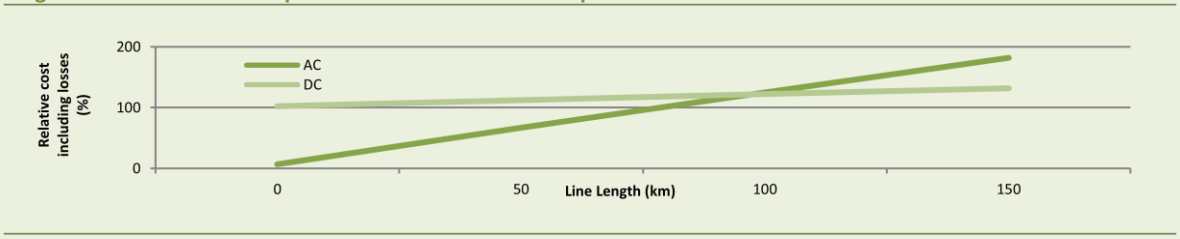
While this is all true on average, it does leave offshore wind generation investors vulnerable to unanticipated events which render the grid unavailable for longer than expected periods.

Causes for grid unavailability

Box 1: Cable technology and risk

There are two main offshore transmission technologies: alternating current (AC) and direct current (DC). The appropriate technology for an offshore wind farm depends mainly on distance of the project to shore, with AC being more efficient for shorter distances and DC more appropriate for wind farms located further offshore (i.e., more than 100km). To date, all offshore cables in the UK have been AC; however, there is considerable international experience with DC submarine cables to draw upon, albeit from interconnector projects, rather than from offshore wind connections.

Figure 5: Relative cost comparison of AC and DC with respect to distance to shore



Source: PCCP analysis

While no redundancy in offshore grid is optimal, the choice of transmission technology and its specific configuration can lead to varying impact on a farm's export capacity from a serious fault. In the case of AC systems, the exporting capacity following a serious cable fault will depend on:

- whether the system is connected to the transmission or distribution system;
- the cable configuration; and
- configuration of the onshore–offshore grid interface

In the case of DC technology, the key consideration is whether the system is comprised of one (monopole) or two (bipole) cables. In monopole systems, a serious cable fault would result in 100% export capacity loss, whereas in a bipole system, 50% of the power could still be exported using the remaining cable as a monopole.

Grid unavailability can be due to planned or unplanned activities.

Planned activities relate to annual maintenance that is likely to result in temporary reduction of available electricity export capacity. The duration of maintenance is dependent on the type of grid infrastructure in place.

Unplanned maintenance is caused by equipment failures and accidental damage. The former can be due to faulty equipment, incorrect operation (overloading), shoddy installation or where maintenance has not been carried out in accordance with the manufacturer's instructions, resulting in premature failure. Accidental damage may be caused by, amongst others, extreme weather-related events, anchoring and fishing activities.

Table 1: Planned and unplanned maintenance frequency and mean repair times

Failure Type	Lost Capacity for Component (%)	Outage Length (Hours)	Probability of Failure
Planned			
Transformer Maintenance - Minor	100%	12	Annual
Tap-changer Replacement	100%	48	7 years max
Circuit Breaker Maintenance	100%	1	Annual
Cover Maintenance	100%	72	Annual
Unplanned			
Transformer Failure - Minor	100%	720	0.011 per year
Circuit Breaker Failure	100%	720	0.025 per year
Cable Failure	100%	4320	Varies upon number of joints
Converter Failure	100%	720	0.12 per year

Source: Arup&TNEI, "OFTO Availability Incentive", October 2012

As presented in Table 1 below, the most severe fault is that of cable failure which can occur from any one of the previously outlined unplanned events. Such a failure can mean a loss of export capacity ranging from 50–100% depending on the grid infrastructure technology (please see Box 1). This is due to repair times, which can take up to six months and are dictated by weather conditions, vessel, repair crew and spare part availability. The outage lengths given in Table 1 are indicative and vary significantly in reality.

On the whole, cables have an extremely low probability of failure due to normal equipment degradation and are therefore most likely to fail as a result of mechanical damage. When such a serious cable fault does occur however, it can have serious implications for the wind farm investor.

Lost revenue quantification of an offshore wind farm following a major cable failure

In this section we use a back of the envelope calculation to quantify the effect that a cable

failure similar to that of the Moyle Interconnector (Box 2), would have had on the solvency of an offshore wind project.

The revenue model

To provide context, we present in Table 2 a summary of the main financing elements of a 500MW offshore wind farm. The annual revenue of such a wind farm, assuming a load factor[3] of 40% - typical for an offshore wind farm in the UK - would be approximately £280mn.

Table 2: 500MW offshore wind farm financial summary

Project cost (£mn)	1600
Average gearing ratio	0.65
Cost of debt (pre-tax)	0.075
OPEX (£mn/year)	48
Unit revenue (£/MWh)	160
Annual revenue (£mn/year)	280

Source: PCCP analysis

Based on these assumptions, the project IRR for an equity investor would be circa 17%.

Lost revenue due to cable failure

Assuming that an offshore cable experienced a series of faults similar to Moyle's (presented in Box 2), i.e. a 50% loss over a two year period, this would mean that the wind farm would only be able to export half of its produced power. On average, this would imply that its annual load factor would fall to 20% (supposing similar wind profiles during the on and off periods), which results in a revenue stream of £140mn per year as presented in Table 3.

Table 3: Load factor and annual revenue

Load factor	Annual revenue (£mn/year)
40%	280
20%	140
13%	93
10%	70

Source: PCCP analysis

Consequently, the project would experience combined lost revenue over the two years of approximately £280mn.

Impact to solvency and returns from lost revenue

The impact of such a loss varies significantly on whether the wind farm is levered or utilises pure equity for financing. In the instance where a wind plant has taken on the average debt load of 65% and the revenue loss occurred during the initial years of operation, the project would face a serious insolvency risk. Taking into account the annual OPEX, debt costs and assuming a 15 year loan tenor, it becomes evident that if such a loss occurred in the first three years of the project's operation, there would not be sufficient accumulated cash reserves within the project to cover the OPEX and debt costs.

Even if such losses were to occur in later years, they would decrease the generator's capacity to withstand wind resource shortfalls, and reduce the project IRR from c.17% to c.13%.

In the case of an unlevered project, the effect would be significantly less dramatic, with the estimated project IRR reducing from c13% to c.11%.

[3] The wind farm load factor is the ratio of the actual output of a power plant over a period of time and its potential output if it had operated at full nameplate capacity for the entire period.

project, should the appropriate mitigation measures not be in place.

In conclusion, although it is assumed that there is a very low probability that such a fault will occur, the impact when it does can be substantial and can affect the viability of the offshore wind

Box 2: The Moyle interconnector experience

The Moyle Interconnector, which has been in operation since 2001, consists of two separate (monopole) 250MW DC subsea cables. These run for 63 kilometres between Northern Ireland and Scotland.

In June 2011, one of the cables experienced a fault and was taken out of service, reducing the export capacity by half. Two months later the remaining cable also experienced a fault, making the interconnector completely unavailable.

After approximately five months, one of the poles was returned to service, followed by the second cable a month later. However, only four months after returning to operations, one of the poles experienced a further fault, which was unrelated to the earlier fault, and had to be taken out of service.

Due to these continued difficulties, it was deemed necessary for the interconnector to operate at just half its capacity for the foreseeable future.

The repair costs for this series of incidents were in the region of £30mn, not taking into account the lost revenue due to cable unavailability.

Moyle is an interconnector whose revenues (and costs) are borne by Irish rate payers. Had there been an offshore wind power generator involved in this operation, there is a considerable chance that these on-going issues would have led to it becoming insolvent.

4. Conclusion

Given the significant amount of offshore wind investment expected to take place going forward, offshore wind investors, even if they have entered de-risking arrangements, should be aware of the low-probability/high-impact risks associated with grid infrastructure and conduct proper technical due diligence. Future offshore wind projects are

expected to be larger and located further from shore, meaning that they may employ newer and potentially largely untested transmission technologies. This factor is expected to exacerbate the offshore transmission risks identified in this report.

Since repair of offshore equipment is time-consuming, expensive, and reduces availability of the wind farm, it is important to evaluate the reliability of grid design in detail. The following aspects in particular should be considered:

- evaluation of the grid EPC and O&M providers;
- incidence of any reported issues during the cabling process;
- the failure rate of installed individual components;
- operation, taking into account single-component level failure; and
- provisions in place, such as spare parts, to expedite repairs

In addition to grid infrastructure technical due diligence undertaken, it is also important to for an offshore wind operator to consider what kind of coverage he receives in case of business interruption due to transmission unavailability.

Mitigation measures minimising risks due to business interruption from grid unavailability might include:

- a cash reserve;
- contingent business interruption insurance[4]; and
- EPC, contractors and manufacturer warranties

It is highly possible that multiple insurance policies and warranties are in place. As a result insurance and warranty details including triggers, remedies, recourse and enforcement will need to be scrutinized and understood so as to ensure that all the contingencies are covered sufficiently.

Finally, there are currently a number of consultations underway evaluating the coordination and integration of onshore and offshore transmission arrangements in the UK. One of the possible options that could emerge from these consultations is the creation of some form of redundancy in an offshore transmission system by integrating it with the onshore grid. If this option emerges and becomes a reality, the associated risks of offshore grid infrastructure could be reduced to a very large extent.

[4] Third-party ownership of grid infrastructure in the UK implies that Contingent Business Interruption (CBI) insurance covering OFTO assets needs to be in place in order to shield the wind farm owner from any lost revenue due to cable unavailability. CBI insurance reimburses a company for lost profits and other possible transferred risks, such as necessary continuing expenses, that result from an insurable loss suffered by a related third party

5. References

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[ii] Eriksson, K.; Halvarsson, P.; Wensky, D. and Häusler, M (2003), System Approach On Designing An Offshore Windpower Grid Connection, ABB Utilities, Available at: http://www05.abb.com/global/scot/scot221.nsf/veritydisplay/34ec041beda66334c1256fda004c8cc0/$file/03mc0132%20rev.%2000.pdf

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